Health Consultation

Selenium in Fish Tissue

BLACKFOOT, SALT AND BEAR RIVER WATERSHEDS

SOUTHEAST IDAHO

Prepared by
Idaho Department of Health and Welfare

AUGUST 28, 2013

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

HEALTH CONSULTATION

Selenium in Fish Tissue

BLACKFOOT, SALT AND BEAR RIVER WATERSHEDS

SOUTHEAST IDAHO

Prepared By:

Idaho Department of Health and Welfare
Division of Public Health
Bureau of Community and Environmental Health
Under a Cooperative Agreement with
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Contents

Foreword

This public health consultation was supported in part by funds from the Comprehensive Environmental Response, Compensation, and Liability Act through a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Department of Health and Human Services. It was completed in accordance with approved methodologies and procedures existing at the time the public health consultation was initiated. Editorial review was completed by the cooperative agreement partner.

The public health consultation is an approach used by the ATSDR and the Idaho Division of Public Health's Bureau of Community and Environmental Health (BCEH) to respond to requests from concerned residents for health information on hazardous substances in the environment. The public health consultation process evaluates environmental sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health.

For more information about ATSDR, contact their Information Center at: 1-800-232-4636 or visit the agency's Home Page: http://www.atsdr.cdc.gov.

Summary

INTRODUCTION

In Idaho, the Bureau of Community and Environmental Health (BCEH) serves the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent people from coming into contact with harmful substances.

The geological formation known as the Meade Peak Member of the Phosphoria contains naturally occurring selenium. This formation occupies Southeast Idaho, and adjacent areas of Wyoming, Montana, and Utah. Phosphorous rocks constitute the raw material for both fertilizer and food industries. Several phosphate mines, located in Southeast Idaho, have been processing phosphorous rock. This activity constitutes the major source of selenium contamination to the Blackfoot, Salt and Bear rivers. In 1996, environmental and human health concerns of selenium exposure were recognized arising from chronic selenosis found in horses pastured in the phosphate mining area in Southeast Idaho. In 1999, BCEH released two health consultations on health impacts. In 2003, BCEH issued a temporary fish advisory for East Mill Creek to protect children from consumption of Yellowstone cutthroat trout and Brook trout. The advisory was temporary due to a limited number of samples. Since 2003, more sampling has been completed in the area. In 2011, Agency for Toxic Substances and Disease Registry (ATSDR) received a petition request from the Greater Yellowstone Coalition (GYC). ATSDR and BCEH investigated the petition request and conducted this health consultation. BCEH reviewed the new data to determine if the levels of selenium found in trout species in the Blackfoot, Salt and Bear River watersheds pose a health risk.

CONCLUSION

BCEH concludes that eating trout harvested from the Blackfoot, Salt and Bear River watersheds is not expected to harm people's health.

BASIS FOR DECISION

The levels of selenium found in the fish are below levels of health concern and allow for a healthy fish consumption frequency as recommended by the United States Department of Agriculture and the Department of Human Health Services (8–12 ounces per week). Health risks from exposure to selenium are further reduced for the following reasons: selenium is a micro nutrient important for health, fish consumption would occur mostly during fishing season, the limited access, and the low

fishing pressure in some of the streams with relatively high selenium concentrations in fish.

NEXT STEPS

BCEH recommends that recreational fishermen targeting Spring Creek, Blackfoot River, Lower Dry Creek, Hoopes Springs, Sage Creek, and Crow Creek (downstream portion) follow eating guidelines outlined in this document. BCEH will communicate these findings to the GYC, the U.S. Environmental Protection Agency (EPA), the Idaho Department of Environmental Quality (IDEQ), and the Idaho Department of Fish and Game (IDFG) upon completion of this public health consultation. BCEH will remain in contact with EPA, IDEQ, and IDFG to evaluate new selenium fish data if more sampling is conducted in the future. BCEH will update information on its fish advisory web page to include more information on selenium in fish in Southeast Idaho streams.

FOR MORE INFORMATION

If you have concerns about your health, you should contact your health care provider. You can also contact BCEH at 1-208-334-5929 or email bceh@dhw.idaho.gov for information on selenium fish concentrations on the Blackfoot, Salt and Bear river watersheds.

Purpose and Statement of Issues

The Bureau of Community and Environmental Health (BCEH), Division of Public Health, Idaho Department of Health and Welfare (IDHW) has a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) to conduct public health assessments and consultations for hazardous waste sites in Idaho. This health consultation was developed under the cooperative agreement. The Greater Yellowstone Coalition (GYC), a conservation organization, petitioned ATSDR to evaluate selenium concentrations in fish tissue collected from streams impacted by phosphate mining in Southeast Idaho. As the cooperative agreement partner for ATSDR, BCEH performed the data analysis using results from GYC and monitoring data compiled by Idaho Department of Environmental Quality (IDEQ) and the U.S. Forest Service. This health consultation reviews fish tissue data from three watersheds (Blackfoot, Salt and Bear River) and eight years of sampling efforts (2003, 2005–2011). The purpose of this health consultation is to determine whether trout from these streams pose a health risk to those who eat them.

Background

Area of Study Description

The Blackfoot, Salt and Bear River watersheds are located in Southeast Idaho and cover approximately 2,000 square miles (ESRI, 2012). The area includes portions of Bonneville, Caribou, and Bear Lake counties with an estimated population of approximately 9,588. Population centers in the area include Soda Springs (3,058 inhabitants) and Montpelier (2,597 inhabitants) (US Census Bureau, 2010). The Blackfoot and Salt Rivers flow into the Snake River. The Bear River is the largest tributary to the Great Salt Lake in Utah (Bright, 1967). According to the U.S. Census, ethnic groups in the study area include 96% white, 4% Hispanic or Latino, and less than 1% American Indian, Asian, and/or African American (US Census Bureau, 2010). It is estimated that 52.2% of the homes within the study area are occupied only for seasonal, recreational or occasional use (US Census Bureau, 2010).

Sources of Contamination

Sources of contamination include active and historic phosphorus mining within the study area. The Meade Peak Member of the Phosphoria Formation is a geological formation containing large amounts of phosphorus that extends throughout Southeast Idaho and adjacent areas of Wyoming, Montana, and Utah (McKelvey, et al., 1959; McKelvey, Strobell, & Slaughter, 1986; Presser, Piper, Bird, Skorupa, & Hamilton, 2004). Over the last half of the 20th century, mining in Idaho has provided approximately 4.5% of the world's demand for phosphate, used mainly as a fertilizer (USDOI and USGS, 2000). The major phosphate mines in this region are open pit or contour strip operations that were developed near the surface of the Phosphoria Formation. Mining activities in the area are a major source of selenium in the streams (Appendix A, Figures 1–3). This region contains several mines currently or previously owned or operated by FMC Corporation, J.R. Simplot Company, Astaris, Nu-West Industries, Inc., Nu-West Mining, Inc. (Nu-West), Rhodia, Inc., and P4 Production LLC. Out of the 19 phosphate mining sites in Southeast Idaho, four are currently active (Dry Valley Mine, Enoch Valley Mine, Rasmussen Ridge Mine, and Smokey Canyon Mine) and two are categorized as existing mine operations

(Maybe Canyon Mine and Lanes Creek Mine) (McKelvey, Strobell, & Slaughter, 1986). However, according the Bureau of Land Management (BLM) Dry Valley Mine is active, but temporarily idle (BLM, 2012). Ten mining sites (Conda Mine, Woodall Mine, Gay Mine, Ballard Mine, Henry Mine, Enoch Valley Mine, Champ Mine, Maybe Canyon Mine, Mountain Fuels Mine, and Smoky Canyon Mine) comprise areas where IDEQ has started site investigations for future clean up (IDEQ, 2012). In the Georgetown industrial site cleanup has been completed (IDEQ, 2012).

The soils in the area contain selenium that is dispersed throughout the phosphate deposits. The highest concentration is found in a waste shale zone between two major phosphate-ore zones of the Meade Peak Member (McKelvey, Strobell, & Slaughter, 1986). Selenium exists in many forms. The most common forms of selenium in water bodies are selenate and selenite. Biological activity can also generate small amounts of organic selenium compounds in water. Fine particulate organic matter composed of living and dead organisms may contain organic and inorganic selenium. Selenium present in the streams from waste-water discharge or from sediments has the potential to be incorporated into aquatic organisms and bioconcentrated in the food chain. The primary route of human exposure to selenium is through eating food, such as fish. Fishermen who regularly eat fish containing high concentrations of selenium may consume above average levels of selenium (ATSDR, 2003).

Past Health Concerns

The toxic effects of selenium in Southeast Idaho became evident in 1996 when several horses pastured downstream from a historic mine in the Southeast Idaho Phosphate Mining Resource Area (Resource Area) were diagnosed with chronic selenosis characterized by erosions of long bones, emaciation, hoof lesions, and loss of mane and tail hair (MW, 1999). In 1997, another group of horses pastured in a different location in the Resource Area were also diagnosed with chronic selenosis. These events, along with a number of sheep deaths, prompted public and agency concern about potential releases of selenium to the environment from mining activities and the possible impact on human health.

BCEH completed several health consultations in the past that focused on the Resource Area. A health consultation to evaluate selenium contamination in the groundwater (BCEH, 2001) found that selenium levels were too low to cause harm to children or adults drinking the water. Another health consultation completed in the same year evaluated selenium contamination in beef, elk, sheep, and fish in the Resource Area (BCEH, 2001). In this health consultation, the selenium levels found in elk and beef were too low to cause harm to hunters and their families who followed meal recommendations. In 2003, BCEH assessed selenium contamination in fish in streams of the upper Blackfoot River watershed (BCEH, 2003). Selenium was found at levels high enough in Cutthroat trout from East Mill Creek to cause possible harm to children. In a 2006 public health assessment, BCEH revisited the previous conclusions and recommendations, reviewed environmental and biological data, reviewed community health concerns, and conducted a cancer incidence analysis for the Resource Area (ATSDR, 2006). This review had no new recommendations and the cancer analysis found that the incidence rate of cancers in the area was similar or lower compared to other regions of the state. The last public health consultation, published in 2007, reviewed selenium in elk and health impacts on hunters and their families (ATSDR, 2007). In the latter publication, selenium levels in elk muscle were too low to cause harm to the hunters and others who eat the meat. However; higher levels of selenium in elk liver were found and it was recommended that the number of elk liver meals should be limited.

In the 2003 public health consultation that investigated fish data, BCEH communicated with IDEQ and gained access to earlier studies conducted by IDEQ and mining company contractors Montgomery & Watson and Tetra Tech Inc. These studies revealed selenium fish tissue concentrations above 2 milligrams per kilogram (mg/kg) wet weight. At the request of IDEQ, BCEH reviewed available information on selenium fish tissue concentrations and issued a temporary fish advisory to limit children's consumption of trout from East Mill Creek, a tributary to the Blackfoot River. The temporary advisory relied on a very limited number of samples (2 Yellowstone cutthroat trout and 1 Brook trout) (BCEH, 2003).

Discussion

Pathway Analysis
To determine whether people are, were, or could be exposed in the future to selenium in fish, the environmental and human components that lead to exposure were evaluated. Selenium present in these streams comes from natural sources and waste disposal from mining activities. Fish in the streams take up selenium through the food chain and in turn are eaten by fishermen and their families. Thus, there is a complete pathway because people are being exposed to selenium when they eat fish from these streams. While there may be other exposure pathways, this health consultation only discusses the fish ingestion pathway.

Selenium Fish Tissue Data–Methods
The data used in this health consultation come from several sources: GYC, IDEQ (GEI Consultants Inc. and Formation Environmental), and the U.S. Forest Service. The fish data were collected every year from 2003 to 2011 with the exception of 2004 when no fish were collected. A total of 29 streams in the Blackfoot, Salt and Bear River watersheds were sampled (Appendix A, Figures 1–3). Fish species sampled belong to four families: Salmonidae (Brown trout, Yellowstone cutthroat trout, Brook trout, Rainbow trout, and Mountain whitefish); Cyprynidae (Longnose dace, Speckled dace, Utah chub); Cottidae (Molted sculpin, Paiute sculpin); and Catostomidae (Utah sucker).

In this public health consultation, BCEH analyzed only data from trout species: Brown trout, Yellowstone cutthroat trout, Brook trout, and Rainbow trout, which are commonly harvested and consumed from these streams. The length of the fish collected ranged from approximately two to 18 inches. The majority of fish sampled were small, with an average size of 5 inches (127 millimeters [mm]) for the Blackfoot River, 6 inches (152 mm) for the Salt River, and 4 inches (102 mm) for the Bear River. According to the Idaho Department of Fish and Game (IDFG) the primary reason for collecting small fish is because small fish tend to remain in a small area of the stream whereas larger fish migrate longer distances. If assessing selenium levels using fish, it is better to use young fish which are likely to have selenium values more representative of the area of the stream where they are captured. Also, IDFG fishing rules do not have any size restriction for fish on the Bear River or Crow Creek where fish may be impacted by selenium and fish consumption by humans is a potential (David Teuscher, IDFG, personal communication,

February 11, 2013). To determine the relationship between fish size and selenium levels, BCEH ran a linear regression analyses (see Appendix B and Results section for details).
A total of 1,581 individual whole-body selenium (wet weight) values were used for the calculations. All the data sources provided to BCEH had selenium concentrations expressed as whole-body. Only the GYC data provided two measurements of selenium concentrations for most of the samples (i.e., fillet and whole-body). BCEH used GYC data to determine if whole-body values differ from fillet values. A linear regression analysis was completed (see Appendix C and Uncertainties section for details). Individual values missing either fish species names or sampling locations were excluded from the data analysis. Sampling took place in different months for the three watersheds. In the Blackfoot watershed sampling took place in April, June, July and September of 2005; July of 2006; September and October of 2007, 2008, and 2009; July of 2010, and February of 2011. Sampling in the Salt River took place in August 2003; July 2005; January, July, August and September of 2006; May, August and September of 2007; May, June and September of 2008; September of 2009; July, August, and September of 2010; and February and August of 2011. Bear River was sampled in October of 2007. Fish were sampled using backpack electrofishing equipment. All tissue samples were kept on ice in the field until they were frozen at -20°C. Frozen samples were sent for laboratory analysis. Whole body and fillet samples were analyzed for total selenium. Values reported in dry weight were transformed to wet weight using the following formula:

$$Selenium\ wet\ weight\ (mg/kg) = Dry\ weight\ (mg/kg)[1 - \%\ Moisture\ Content/100]$$

If not provided in the data sets, the moisture content was assumed to be 75% (Hamilton, 2004). For this consultation, BCEH relied on the data provided by GYC and other agencies and assumed adequate quality assurance/quality control procedures were followed with regard to data collection, chain-of custody, laboratory procedures, and data reporting.

Screening Value Calculation

To determine which streams in the area had levels of selenium in fish that may pose a health risk to those who consume fish from the streams, BCEH developed a screening value. Since children are considered a sensitive population in most environmental health exposures, BCEH used values for children in the screening formula. The screening value calculation is found in Appendix D. The formula also incorporates the amount of selenium considered to be the average dietary daily intake for children 3–5 years old (US DHHS, 2002), an exposure frequency of 104 days/year (BCEH, 2011), which corresponds to eating fish 2 days per week, a weekly intake of 4.5 ounces (oz.) or 0.127 kg for one year, and a body weight of 20 kg (McDowell, Fryar, & Ogden, 2008). On a daily basis this equates to eating 0.018 kg each day. The screening value is simply a tool that eliminates from further investigation the streams that are not likely to pose a health risk to children who on average eat 4.5 oz. per week of fish from that stream on an annual basis. Streams where the geometric mean selenium concentrations in fish are greater than the screening value are discussed in the Results section.

ATSDR defines a Minimal Risk Level (MRL) as an estimate of daily human exposure to a substance that is likely to be without appreciable risk of adverse, non-carcinogenic effects over a specified duration of exposure. The chronic oral MRL derived by ATSDR for selenium is 0.005 milligrams per kilogram of body weight per day (mg/kg/day), which is the same as the

Environmental Protection Agency (EPA)'s Reference Dose (RfD) value. BCEH used the ATSDR selenium oral MRL of 0.005 mg/kg/day to calculate the amount of fish that can be safely eaten on a regular basis without any adverse health effects. Details on the formula used for the calculation of the screening value are in Appendix D.

For streams where the screening value was exceeded, BCEH calculated the maximum allowable fish consumption per week for children, adult females and adult males (See Appendix G). The maximum allowable fish consumption formula allows BCEH to determine the maximum number of fish meals that can be eaten without exceeding a health-based standard, such as the MRL (See Appendix D). Streams where the geometric mean concentrations of selenium in fish does not allow for the recommended fish meals per week are considered to be streams where a fish advisory may be needed. BCEH does not currently have access to any data concerning "subsistence fishing," particularly in the streams neighboring the Shoshone-Bannock Tribes. Thus, "subsistence fishing" scenario analysis was not included in this health consultation and will be evaluated in a separate health consultation after the appropriate information is obtained.

Results

Size and Tissue Concentration
Linear regression analyses showed weak linear relationship between selenium tissue concentrations and fish length for the different species of fish sampled at the site. Figures showing two examples of these weak relationships are in Appendix B (Figures B1 and B2). For example the Brook trout with the highest selenium concentration of 9.3 mg/kg had a length of approximately 6 inches (152 mm), which is slightly above the average size of 5 inches (127 mm) for the Blackfoot River. The largest Brook trout caught from the Blackfoot River measured 11 inches (279 mm) and had a selenium concentration of 2.5 mg/kg. Unlike other contaminants (e.g., mercury) selenium tissue concentrations in fresh water fish do not appear to be related to age or size (MassDEP, 2006; Golder, 2005).

Fish Tissue Concentration Analysis
BCEH calculated the geometric mean selenium fish tissue concentrations for trout species sampled in the Blackfoot, Salt and Bear River watersheds (Appendix E, Tables E1–E3). Geometric mean values of whole-body fish selenium concentrations (wet weight) for each stream were compared to the calculated selenium screening value of 2.6 mg/kg (Table 1 and Appendix D). None of the values exceed the screening values in Bear River tributaries (Appendix E3). Four of the 17 streams sampled in the Blackfoot River watershed and three of the 15 streams sampled in the Salt River watershed exceed the screening value of 2.6 mg/kg (Table 1). For those streams where the screening value was exceeded, a dose was calculated to determine if the amount of selenium that would be consumed is above health-based standards. Table 2 shows dose calculations for men, women, and children, using an exposure scenario of 8 oz. per week for adults and 4.5 oz. per week for children for the different types of fish caught from the Blackfoot and Salt River watersheds (See Appendix F for dose calculation details). The maximum allowable fish meals for men, women and children are provided in Appendix G.

Blackfoot River and Tributaries Analysis

Geometric mean concentrations in the Blackfoot ranged from 2.81 mg/kg in Lower Dry Valley Creek to 4.26 mg/kg in Spring Creek. The only fish captured during sampling in East Mill Creek had a selenium concentration level of 9.3 mg/kg (Table 1). This Brook trout from East Mill Creek had a concentration 3.5 times higher than the screening value (Table 1). Yellowstone cutthroat from Lower Dry Valley Creek had geometric mean concentrations slightly higher than the screening value (Table 1).

Accessibility, Fishing Pressure and Dose Comparisons

East Mill Creek

East Mill Creek has good accessibility for anglers and based on the fish tissue concentration found in Brook trout from East Mill Creek the dose calculations (See Appendix F) for men (0.0038 mg/kg/day) and women (0.0043 mg/kg/day) are below the MRL of 0.005 mg/kg /day. The estimated dose for children (0.0083 mg/kg/day) slightly exceeded the MRL (Table 2 and Appendix F). However; East Milk Creek lacks sufficient fish to provide fishermen and their families enough fish to cause harmful health effects if eaten. In fact, GYC attempted to collect fish from East Mill Creek every year from 2005 until 2011, with the exception of 2009, and only one Brook trout was captured in 2007 (Marv Hoyt, GYC, personal communication, GYC, August 13, 2012). Low numbers of fish in East Mill Creek exists most likely because the elevated total selenium concentration in water (0.43 mg/L) is higher than the acute aquatic life criterion of 0.02 mg/L and the chronic aquatic life criterion of 0.005 mg/L (IDEQ, 2007).

Spring Creek

In Spring Creek the total selenium concentration in water (0.026 mg/L) exceeds the acute aquatic life criterion of 0.02 mg/L and the chronic aquatic life criterion of 0.005 mg/L (IDEQ, 2007). IDFG angler's survey does not specifically mention this creek as a common destination for anglers (Grunder, McArthur, Clark, & Moore, 2008), but it is accessible. All the dose calculations for consumption of Yellowstone cutthroat and Brook trout were below the MRL of 0.005 mg/kg/day (Table 2). Consequently, BCEH does not expect fishermen and their families to be harmed from eating fish from Spring Creek.

Blackfoot

According to the IDFG 2003 economic survey, the Blackfoot River is a common destination for anglers (Grunder, McArthur, Clark, & Moore, 2008). Dose calculations for the consumption of Brook trout and Yellowstone cutthroat are lower than the MRL of 0.005 mg/kg/day (Table 2). Thus, BCEH does not expect exposure to selenium in fish from the Blackfoot River to result in adverse health effects.

Lower Dry Valley Creek

Lower Dry Valley Creek has good accessibility and variable flows, but the IDFG angler's survey does not mention this stream as a common destination for anglers (Grunder, McArthur, Clark, & Moore, 2008). The dose calculations presented in Table 2 show values below the MRL of 0.005 mg/kg/day. Therefore, BCEH does not expect exposure to selenium in fish from the Lower Dry Valley Creek to result in adverse health effects.

Table 1. Summary Fish Selenium Concentration Data (2003, 2005–2011) that exceeded the selenium screening value in the Blackfoot River and Salt River Watersheds

River watershed	Waterbody name	Fish type	Number of Samples	Min (mg/kg)	Max (mg/kg)	Geometric mean (mg/kg)	Screening Value (mg/kg)
Blackfoot	East Mill Creek	BRK	1	9.30	9.30	NA	2.6[a]
	Spring Creek	YCT	10	1.73	5.50	4.26	
	Blackfoot River	BRK	1	3.50	3.50	NA	
	Spring Creek	BRK	23	1.79	5.50	3.32	
	Blackfoot River	YCT	40	1.82	5.00	3.02	
	Lower Dry Valley Creek	YCT	7	1.68	4.50	2.81	
Salt	Hoopes Spring	BRN	58	2.98	9.73	5.37	
	Hoopes Spring	YCT	8	2.71	7.83	5.28	
	Sage Creek	BRN	167	1.55	8.80	4.27	
	Crow Creek (downstream portion	YCT	26	1.88	6.82	3.20	
	Crow Creek (downstream portion)	BRN	103	1.33	5.80	2.97	

a = Screening value calculations available in Appendix D
BRK = Brook trout; BRN = Brown trout; YCT = Yellowstone cutthroat trout
Min = Minimum; Max = Maximum; mg/kg = milligram per kilogram
NA = not applicable because only one sample is available.

Salt River and Tributaries Analysis

Geometric mean fish tissue concentrations in the Salt River ranged from 2.97 mg/L in the downstream portion of Crow Creek to 5.37 mg/L in Hoopes Springs (Table 1). Brown trout from Hoopes Spring had geometric mean concentrations 2 times higher than the screening value (Table 1). Brown trout from Crow Creek (downstream portion) had geometric mean concentrations slightly higher than the screening value (Table 1). However, at these levels most of the streams still allow recommended values of consumption of 8 oz. per week for adults and 4.5 oz. per week for children (Appendix G).

Table 2. Summary Dose calculations in the Blackfoot River and Salt River Watersheds and comparison value

River watershed	Waterbody name	Fish type	Geometric mean (mg/kg)	Dose Calculation (mg/kg/day)			Comparison Value (mg/kg/day)
				Children	Women	Men	
Blackfoot	East Mill Creek	BRK	9.30	0.0084	0.0043	0.0038	0.005[b]
	Spring Creek	YCT	4.26	0.0038	0.0020	0.0017	
	Blackfoot River	BRK	3.50	0.0032	0.0016	0.0014	
	Spring Creek	BRK	3.32	0.0030	0.0015	0.0013	
	Blackfoot River	YCT	3.02	0.0027	0.0014	0.0012	
	Lower Dry Valley Creek	YCT	2.81	0.0025	0.0013	0.0011	
Salt	Hoopes Spring	BRN	5.37	0.0048	0.0025	0.0022	
	Hoopes Spring	YCT	5.28	0.0048	0.0024	0.0021	
	Sage Creek	BRN	4.27	0.0038	0.0020	0.0017	
	Crow Creek (downstream portion	YCT	3.20	0.0029	0.0015	0.0013	
	Crow Creek (downstream portion)	BRN	2.97	0.0027	0.0014	0.0012	

a = Estimated exposure dose calculations available in Appendix F; b = MRL value
BRK = Brook trout; BRN = Brown trout; YCT = Yellowstone cutthroat trout

Accessibility, Fishing Pressure and Dose Comparisons

Hoopes Spring

Observations from a BCEH site visit (July 10, 2012) found very limited access to Hoopes Spring. The private access road leading to Hoopes Spring has been recently closed by property owners and mining company operations in the area. Records from IDFG concerning fishing pressure (i.e., total number of angler-days spent fishing over a specified period) do not explicitly mention Hoopes Spring (Grunder, McArthur, Clark, & Moore, 2008), but observations from BCEH site visit (July 10, 2012) showed limited access to Hoopes Spring. All dose calculations for fish caught from Hoopes Spring are at or below the MRL of 0.005 mg/kg/day (Table 2). Thus, BCEH does not expect fishermen and their families to be exposed to selenium contaminated fish from Hoopes Spring.

Sage Creek
Observations from a BCEH site visit (July 10, 2012) demonstrate limited access to Sage Creek, which is located along the same private road as Hoopes Spring Creek that has been recently closed by property owners and mining company operations in the area. Also, results from the IDFG 2003 fishing pressure survey do not explicitly mention Sage Creek (Grunder, McArthur, Clark, & Moore, 2008). All dose calculations for fish caught from Sage Creek are below the MRL of 0.005 mg/kg/day (Table 2). Thus, BCEH does not expect fishermen and their families to be exposed to selenium contaminated fish from Sage Creek.

Crow Creek (Downstream portion)
The downstream portion of Crow Creek is designated as the section of the creek that is downstream of its confluence with Sage Creek. The IDFG 2003 survey does not specifically mention this stream as high in fishing pressure, but observations from a BCEH site visit (July 10, 2012) suggest good accessibility. All dose calculations for fish caught from Crow Creek (downstream portion) are below the MRL of 0.005 mg/kg/day. Therefore, BCEH does not expect to see adverse health effects in anglers and their families eating fish from the downstream portion of Crow Creek.

Fish Consumption Recommendations
Serving size recommendations for fish consumption in the United States vary among agencies. The EPA (US EPA, 2004) and the California Environmental Protection Agency (California Environmental Protection Agency, 2008) suggest using an 8-ounce serving size per week for adults. The American Heart Association suggests eating fish (particularly fatty fish) at least two times (two servings) a week. The American Heart Association defines a serving as 3.5 oz. cooked or about ¾ cup of flaked fish (AHA, 2006). The United States Department of Agriculture and the Department of Human Health Services recommend consuming 8 to 12 oz. of seafood per week from a variety of seafood types which include fish (USDA, 2010). Eating 8 oz. is equal to eating 0.23 kg/week, which is within the mean range of 20–70 grams per day (0.14–0.49 kg/week) from relevant studies on freshwater recreational fish intake in the United States cited in the 2011 EPA exposure factors handbook (US EPA, 2011).

BCEH adopted the serving size and meal frequency to match current Idaho Fish Consumption Advisory Project (IFCAP) protocol. The IFCAP is comprised of members of state and federal agencies including Idaho Division of Public Health, IDEQ, EPA, Idaho Department of Fish and Game (IDFG), Idaho State Department of Agriculture, and United States Geological Survey. The goal of IFCAP is to protect the public from adverse health risks associated with consuming contaminated fish from Idaho waters (BCEH, 2011). IFCAP's risk assessment procedures use 8 oz. per week for adults (0.23 kg/week or 0.0324 kg/day) and 4.5 oz. per week (0.12 kg/week or 0.018 kg/day) for children in its calculations to determine if fish advisories are needed.

Tiered Approach
The population at risk for this health consultation constitutes people eating fish caught from selenium contaminated streams in Southeast Idaho. For the re-evaluation of the current temporary fish advisory in East Mill Creek and evaluation of prospective fish advisories in the Blackfoot, Salt and Bear River watersheds, BCEH considered the following aspects in the exposure analysis:

1) IFCAP's protocol suggests issuing fish advisories when at least 8 oz. per week for adults and 4.5 oz. per week for children cannot be eaten without consuming a dose of a contaminant that exceeds a health-based screening level, such as a MRL (BCEH, 2011).
2) Selenium tissue concentrations above the screening value.
3) Accessibility of the stream to fishermen.
4) Fishing pressure in the streams as reported by IDFG (Grunder, McArthur, Clark, & Moore, 2008).

The way this tiered approach was used was if all the aspects apply then a fish advisory is guaranteed.

Public Health Implications

Selenium in Human body

What happens after selenium enters the human body and how can it be measured?
Selenium is a trace mineral that is essential to good health in humans and animals, but it is required only in small amounts (Micke, Schomburg, Buentze, Kisters, & Muecke, 2009; Thomson C, 2004). Ingestion of organic and inorganic forms of selenium from the diet is the primary exposure route for the general population (ATSDR, 2003). According to the ATSDR toxicological profile for selenium, selenium bioavailability from fish may be lower compared to other foods (ATSDR, 2003). Once selenium enters the human body, it is absorbed by the gastrointestinal system, and leaves the body via urine, and to a lesser extent through feces and breath, usually within 24 hours (ATSDR, 2003). However, if selenium concentrations are higher than dietary needs and exposure occurs over a long time, it can build up in the human body. The amount of selenium that builds up in the body depends on several factors, such as the type of selenium, solubility, time of exposure, and the sensitivity and health habits of the people exposed. Selenium can build up in kidneys, lungs, heart, testes, blood, nails, and hair. Most common methods to detect recent high levels of selenium exposure include tests in blood and urine. Selenium can also be detected in feces, hair, and nails of exposed individuals (ATSDR, 2003).

What are some of the benefits of Selenium?
Selenium is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes. The antioxidant properties of selenoproteins help prevent cellular damage from free radicals. Free radicals are natural by-products of oxygen metabolism that may contribute to the development of chronic diseases such as cancer and heart disease (Thomson C, 2004; Combs & Gray, 1988). Selenoproteins help regulate thyroid function and play a role in the immune system (McKenzie, Rafferty, & GJ, 1998; Levander, 1997; Arthur, 1991; Corvilain, et al., 1993). Selenium may inhibit the human immunodeficiency virus (HIV) progression to acquired immunodeficiency syndrome (AIDS) (Rayman, 2000). The decline of selenium levels over time as the natural result of aging may contribute to cognitive reduction and other declines in neuropsychological functions among the elderly (Akbaraly, et al., 2007).

What are dietary recommended levels of selenium?

Several recommendations for daily intake of selenium exist to avoid selenium deficiency. The National Academies' Institute of Medicine (IOM) recommends that adult males and females should ingest 0.055 milligrams/day (mg/day) [approximately 0.0008 milligrams per kilogram per day (mg/kg/day)] (IOM, 2000). The National Academy of Sciences recommends a selenium intake of 0.065 mg/day for pregnant women and 0.075 mg/day for breast feeding mothers (NAS, 1989). According to the EPA, selenium requirements for infants and children vary according to age and these populations demonstrate an increased requirement per unit weight relative to adults. For infants, the selenium requirement is 0.00167 mg/kg, and for children the requirement ranges from 0.00107-0.00153 mg/kg (US EPA, 2012). The current IOM Tolerable Upper Intake Level (UL) of 0.4 mg/day (approximately 0.0057 mg/kg/day) is considered the maximum intake of selenium that an adult could ingest daily without suffering any adverse effects (IOM, 2000). When this recommended dietary intake is exceeded, selenium compounds can be harmful to human health. The negative effects of excess selenium in the diet depend on the amount of selenium consumed and the frequency of consumption (MacFarquhar J, 2010). Studies show that the average daily intake of 0.114 mg/day by the U.S. population is well below the IOM's UL (US DHHS, 2002). When comparing the IOM's UL of 0.4 mg/day (approximately 0.0057 mg/kg/day) to the calculated exposure doses for the streams, no weekly consumption of fish (8 oz. for adults and 4.5 oz. for children) would put fish consumers at risk with the exception of East Mill Creek. However, this stream does not support sufficient fish populations to allow for consumption by children that would exceed the UL.

What are the toxic effects of oral exposure to selenium?

Acute oral exposure to high levels of selenium (e.g., several thousand times higher than the normal daily intake) includes nausea, vomiting, diarrhea, and cardiovascular symptoms such as tachycardia (ATSDR, 2003). Other symptoms of acute toxicity from dietary supplements reported in the literature include nail and hair changes (including hair loss) and fatigue (MacFarquhar J, 2010). Chronic oral intake of selenium (10–20 times more than the normal levels) can produce selenosis, skin discoloration, skin lesions, brittle hair and nails, morphological alterations in finger nails, mottled tooth enamel, prevalence of chronic arthritis, and nervous system disorders (ATSDR, 2003). The EPA and the International Agency for Research on Cancer (IARC) have classified selenium compounds as not carcinogenic to humans because of inadequate evidence of carcinogenicity in humans or animals (IARC, 1975). Therefore, it is not likely that selenium causes cancer. In fact, doses lower than the normal selenium in diet might increase the risk of cancer (ATSDR, 2003). Other health effects of selenium that have not been fully studied include diabetes and cardiometabolic perturbations (Steinbrenner, Speckmann, Pinto, & H, 2011; Stranges, Navas-Acien, Rayman, & Guallar, 2010).

What epidemiological studies are available?

Yang et al. (Yang, Wang, Zhou, & Sun, 1983) investigated health effects from a selenium-rich diet in China. Morbidity was 49% among 248 inhabitants of five villages with a daily intake of about 5,000 micrograms (µg) selenium. The daily intake among those with clinical signs of selenosis was estimated at an average of 4,990 µg selenium (range: 3,200–6,690 µg). In a follow up to their earlier work, Yang et al (Yang, et al., 1989a; Yang, et al., 1989b) studied a population of about 400 individuals in China exposed to selenium by eating selenium-rich crops and inhaling selenium vapors from domestic heating and cooking with mineral coal. Geographical areas of exposure were classified into low, medium and high according to selenium levels in the soil and food supply. Daily average selenium intakes, based on lifetime exposure, were calculated for adult males and females in the low, medium and high areas and corresponded to 70, 195 and 1,438 µg/day for adult males and 62, 198 and 1,238 µg/day for adult females. Results from Yang et al. 1989 were used to derive the EPA oral RfD of 0.005 mg/kg/day. No fish consumption from streams in this study would place adults or children in excess of the RfD or MRL of 0.005 mg/kg/day with the exception of children eating fish from East Mill Creek. Again, the probability of catching enough fish from East Mill Creek to represent a health risk is very low.

Hansen et al. (Hansen, Deutch, Pedersen, & HS, 2004) report a lack of signs of selenosis in three Greenlandic population groups, 222 men and women aged 18–54, exposed to selenium through traditional diet (whale skin, seal meat, fish, birds, mammals, and berries) and imported food items (meat products, cereal, bread, milk, fruit, and vegetables). High selenium intake was associated with the local traditional diet particularly whale skin and seal meat. Lemire et al. (Lemire, et al., 2012) also found an absence of selenosis in a recent study in the Lower Tapajos River region of Brazil. He studied 448 participants aged 15–87 exposed to selenium in their diet (Brazil nuts, chicken, game meat, and certain fish species). Forty-five percent of the participants who had the highest selenium concentrations in whole blood and plasma reported subsistence fishing. Low concentrations of selenium in drinking water sources existed in communities exposed, and no industrial sources of selenium were identified around these communities. No dermal, breath-related signs, gastrointestinal or motor sensory disorders were associated with selenium exposure at those levels (Lemire, et al., 2012).

Uncertainties and Limitations

- Fish selenium concentrations used for this health consultation may not be representative of the levels of contaminants in a particular site because of migration patterns of fish in the different streams present in the Blackfoot, Salt, and Bear River watersheds. It is known that some trout species may migrate along a stream that has different selenium water concentrations. For example fish may migrate from upstream (area of elevated water selenium concentration) to downstream (area of low water selenium concentration) and vice versa during spawning season. However, it appears that there is not a positive relationship between selenium concentrations and fish size as it is expected in other contaminants such as mercury. While it is not known if there are temporal or seasonal variations in selenium levels in waters and fish in the area, since most of the sampling was completed in the months when fishing takes place, it is expected that the selenium levels reported in this document are representative of the levels of selenium in fish harvested in the area.

- The existence of subsistence fishing in SE Idaho is unknown. The Shoshone-Bannock Tribes, located on the Fort Hall Reservation in Southeastern Idaho (between the cities of Pocatello, American Falls, and Blackfoot) and EPA are currently working on a future study that will provide better estimates of fish consumption among tribal members including subsistence fishing consumption rates.

- Exposure scenarios for the calculation of the maximum allowable fish consumption considered children as a potentially sensitive population. However, there is some uncertainty regarding how often young children actually consume fish from these streams and if children are more susceptible to selenium. These assumptions are conservative since they consider weekly fish meals throughout the year and may not truly represent exposure risk to those eating fish caught in the area due to its very isolated location. Also, selenium bioavailability from fish maybe lower compared to other foods.

- For this health consultation, BCEH combined several data sets during this process and two assumptions were made: 1) Selenium concentrations do not differ between fillets and whole body. Using data provided by GYC, BCEH ran a linear regression analysis to compare whole-body (n=65) and fillet (n=65) selenium concentrations (dry weight) of fish from the Blackfoot streams. Although existing literature cited in the ATSDR selenium toxicological profile (ATSDR, 2003) indicates that selenium concentrates in visceral tissue (25–35 mg/kg wet weight) would be greater than in skeletal muscle (6–11 mg/kg wet weight) in fish, results of site-specific data analysis showed similar results for whole-body and fillet selenium concentrations ($R^2 = 0.9$) (Appendix C). Because all other data sets reported selenium values as whole-body selenium concentrations, BCEH used whole-body selenium concentrations and assumed these concentrations are similar to selenium concentrations in fillets, the part of the fish usually eaten. 2) Moisture content of fish without a reported moisture value was set at 75% moisture. BCEH used a conservative number of 75% moisture content which could overestimate the selenium content in fish.

- The selenium MRL used for the derivation of the selenium screening values dates from 1991. To account for sensitive individuals, ATSDR applied a three-fold uncertainty factor to derive the selenium MRL. Little information has been published since 1991 to determine human health effects to sensitive populations (i.e., children and pregnant women) and the general population. Although screening values developed in this health consultation followed best up-to-date scientific information, this does not necessarily imply that these values are absolutely safe for every single individual in each population group.

- Selenium behavior and toxic effects in the freshwater environment are not fully understood.

- Similar to exposure to other contaminants, selenium's toxic effects depend on a wide variety of factors such as smoking, alcohol consumption, ethnicity, and economic status which were not considered in this health consultation.

Community Health Concerns

In their petition letter the GYC highlights:

- Numerous Idahoans are exposed to selenium through fish, particularly trout, consumption from Blackfoot and Salt River watersheds.

- Those consuming fish in the area include the very young, pregnant women and the elderly.

The following are responses to GYC health concerns:

1) Numerous Idahoans are exposed to selenium through fish, particularly trout, consumption from Blackfoot and Salt River watersheds.

BCEH agrees that people are being exposed to selenium through eating trout from the Blackfoot and Salt River watersheds. However, after a thorough review of all the selenium fish data provided and using a tiered approach (see Tiered Approach section), BCEH has determined that the selenium concentrations (whole-body wet weight) in fish found in tributaries to the Blackfoot and Salt River watersheds are not expected to harm people's health because the amount of the contaminants are below levels of health concern. The maximum allowable fish consumption from Spring Creek, Blackfoot River, Lower Dry Creek, Hoopes Springs, Sage Creek, and Crow Creek (downstream portion) are included in Appendix G.

2) Those consuming fish in the area include very young, pregnant women and elderly.

A literature review revealed a lack of categorical evidence of negative health effects from selenium exposure through fish consumption to children, pregnant woman and the elderly. On the contrary, it appears that selenium is an important micronutrient, particularly for pregnant women and children (See Selenium in Human Body section). A study in China on children aged 3–12 years chronically exposed to selenium in their diet showed significantly higher intake of selenium than the adults, but an increase in blood levels of selenium appeared only in the children aged 7–12. Analysis of the incidence of selenosis in different age groups showed 97% of cases corresponded to individuals older than 18 years, and no cases of selenosis were observed in children below 12 years of age (ATSDR, 2003). The majority of the studies available for pregnant women and their young children correspond to exposure to selenium from a seafood diet. None of these studies showed health effects on newborn babies or their mothers. Umbilical cord blood and hair of 131 Swedish women aged 20–40 years was analyzed to find the influence of an average consumption of seafood of 25 g/day (range 0–110 g/day). Björnberg found a lack of significant association between selenium concentration in cord blood and seafood consumption (Björnberg K. , et al., 2003). A similar study in Sweden of women aged 19–45 with high fish consumption (median consumption rate = 4 times/week) found blood median serum selenium concentration of 70 µg/L (Björnberg K. , Vahter, Petersson-Grawé, & Berglunda, 2005), which is within the IOM's recommended value (IOM, 2000). In Western Greenland, 136 mothers and their newborn babies were analyzed for selenium plasma concentrations. Results of this study showed weak correlation ($R^2 = 0.29$) between mother and child selenium plasma concentrations (Bjerregaarda & Hansen, 2000). A 2000 study found that selenium is needed for adequate function of the immune system and may reduce the risk of miscarriage (Rayman, 2000).

A couple of recent studies evaluated the effects of the simultaneous effects of mercury and selenium from freshwater fish consumption. Hair samples of 50 women aged 17–46 from Qiandao Hu fishing village in Eastern China were analyzed for selenium and mercury concentrations (Fang, Aronson, & Campbell, 2012). Although fish selenium concentrations in some fish were 0.5 mg/kg wet weight, hair selenium average concentration in women was 1.0 micrograms/gram (µg/g), which is below the average value found in the Yang study (3.7 µg/g) with no signs of selenosis (Yang, Wang, Zhou, & Sun, 1983). Another study focused on the combined effects of selenium and mercury to pregnant women and their young children. Selenium concentrations in hair of pregnant and non-pregnant women aged 13–45 eating mercury and selenium contaminated fish (13–15 meals/week) from the Tapajós River in Brazil showed significantly lower ($p < 0.001$) concentrations of selenium in pregnant women compared to non-pregnant women (Pinheiro, et al., 2006). The geometric means of selenium concentrations in pregnant (0.6 µg/g) and non-pregnant women (2.6 µg/g) were below the mean value of 3.7 µg/g reported by Yang et al. (Yang, Wang, Zhou, & Sun, 1983) for exposures to high selenium levels with no signs of selenosis. Authors speculate that the low concentrations of selenium in pregnant women may be due to high mineral consumption by the fetus to satisfy metabolism requirements. Results from this study are inconclusive and, thus, additional studies are needed to demonstrate the effects of selenium from fresh water fish consumers on the developing fetus.

The decline of selenium levels over time associated with cognitive reduction was studied in a cohort of 1,389 subjects of an elderly French community aged 60–71 (Akbaraly, et al., 2007). Authors demonstrated that selenium status decreases with age, which may contribute to declines in neuropsychological functions among the elderly. Recent studies in Brazilian populations suggest a positive association between selenium status and motor performance, and visual acuity in fish consumers and lower prevalence of age-related cataracts among those with elevated selenium (Lemire, et al., 2011; Fillion, et al., 2011; Lemire, et al., 2010). A nine-year cognitive study showed the benefits of selenium intake (i.e., brain function) through fish consumption in the elderly population in a study in France (Berr, et al., 2009). Another study revealed confounding factors such as socioeconomic status, dietary habits, depression, and vascular risk factors may interfere in the relationship between fish consumption and risk of dementia (Barberger-Gateau, et al., 2005). This information provides lines of evidence to hypothesize that selenium may play an important role for brain function in the elderly; however, lack of quantitative studies (i.e., concentration of selenium in fish diet) prevent BCEH from making definitive conclusions regarding the positive or negative effects of selenium on the elderly.

Children's Health Considerations

ATSDR and BCEH recognize that children may be more sensitive to contaminant exposures than adults. This sensitivity is a result of several factors: 1) children may have greater exposures to environmental toxicants than adults because pound for pound of body weight, children drink more water, eat more food, and breathe more air than adults; 2) children play outdoors close to the ground, increasing their exposure to toxicants in dust, soil, water, and air; 3) children have a tendency to put their hands in their mouths while playing, thereby exposing them to potentially contaminated soil particles at higher rates than adults; 4) children are shorter than adults, meaning that they can breathe dust, soil, and any vapors close to the ground; and 5) children grow and develop rapidly; they can sustain permanent damage if toxic exposures occur during critical growth stages.

Conclusions

BCEH concludes that people who eat trout from Blackfoot, Salt and Bear River watersheds at the nationally recommended rates of two meals per week will not be harmed from selenium exposure. Based upon the selenium data provided, site visit observations, and literature review, BCEH finds that although a few tributaries to the Blackfoot and Salt River watersheds exceeded the screening value of 2.6 mg/kg, all the fish sampled from these streams have concentrations that allow eating fish at a recommended level (i.e., 8 oz./week for adults and 4.5 oz./week for children).

Recommendations

- Future sampling should focus on collecting fish that are of a consumable size. Data for this report are based on small fish which may not be typical of the fish normally harvested for human consumption.

- BCEH suggests that fishermen and local residents targeting the Blackfoot and Salt rivers and its tributaries to follow IFCAP's suggestions for fish consumption in Idaho (8 oz. per week for adults and 4.5 oz. per week for children). BCEH maintains a list of various fish advisories found within the state and the recommended number of meals per month; more details can be found at: http://www.healthandwelfare.idaho.gov/Health/EnvironmentalHealth/FishAdvisories/tabid/180/Default.aspx.

- BCEH recommends that recreational fishermen and the community in general targeting Spring Creek, Blackfoot River, Lower Dry Creek, Hoopes Springs, Sage Creek, and Crow Creek downstream follow the eating guidelines outlined in Appendix G.

- BCEH will ask IFCAP to consider the cancellation of the temporary fish advisory for East Mill Creek because of the lack of catchable fish in this stream. During the last several attempts to collect fish, no fish have been collected. Therefore, it is unlikely that there are sufficient quantities of fish to be harmful to fishermen and their families.

Public Health Action Plan

Actions planned

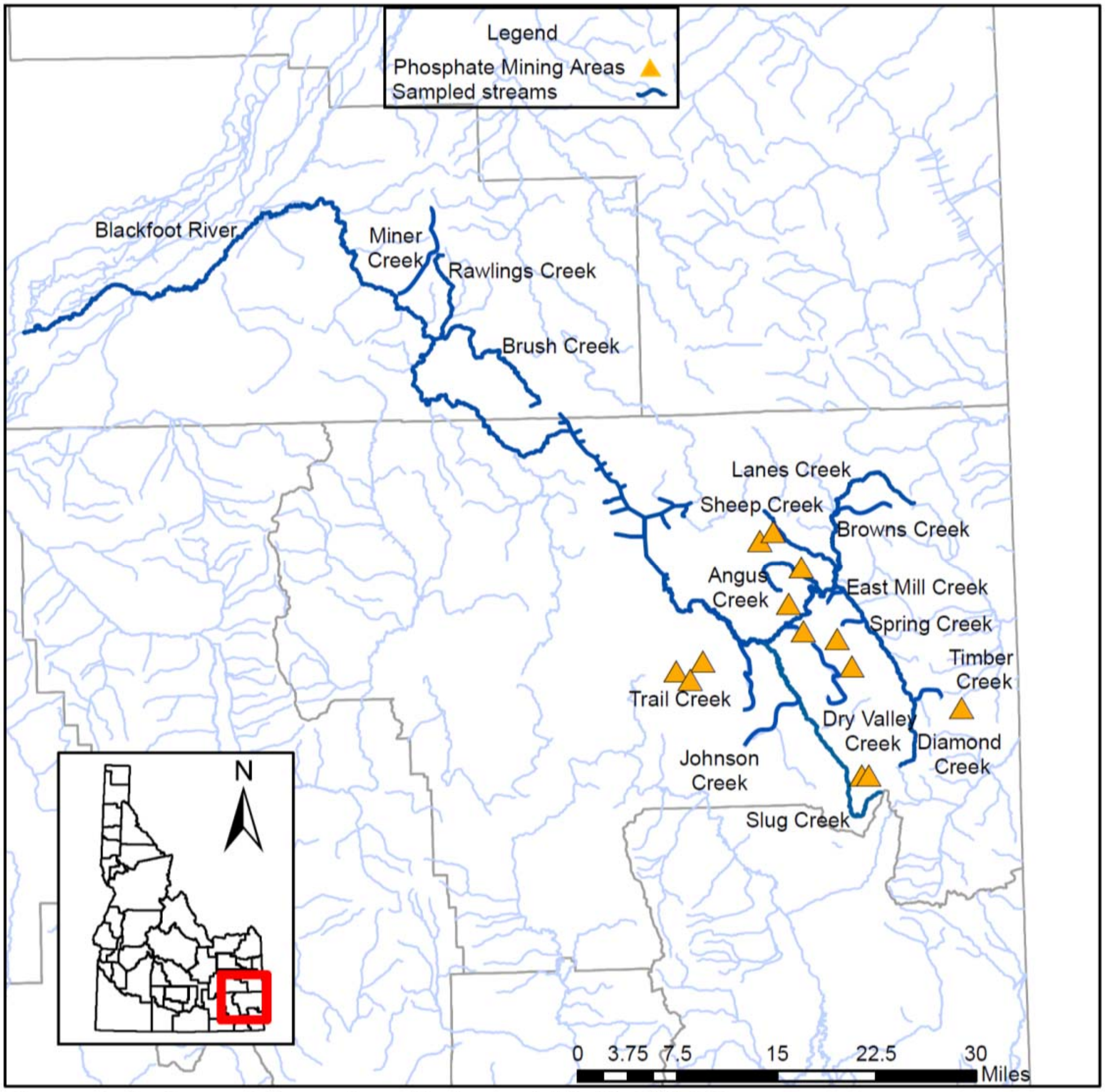
- BCEH will communicate these findings with the GYC, EPA, IDFG and IDEQ upon completion of this health consultation.

- BCEH will remain in contact with EPA, IDFG and IDEQ and will evaluate new selenium fish data if more sampling is conducted in the future in the Blackfoot, Salt and Bear River watersheds. BCEH will update information on its fish advisory web page to include more information on selenium in fish in Southeast Idaho streams.

- BCEH will remain in contact with EPA, IDFG and the Shoshone-Bannock Tribes and collaborate in their efforts to determine the existence of “subsistence fishing” in Southeast Idaho.

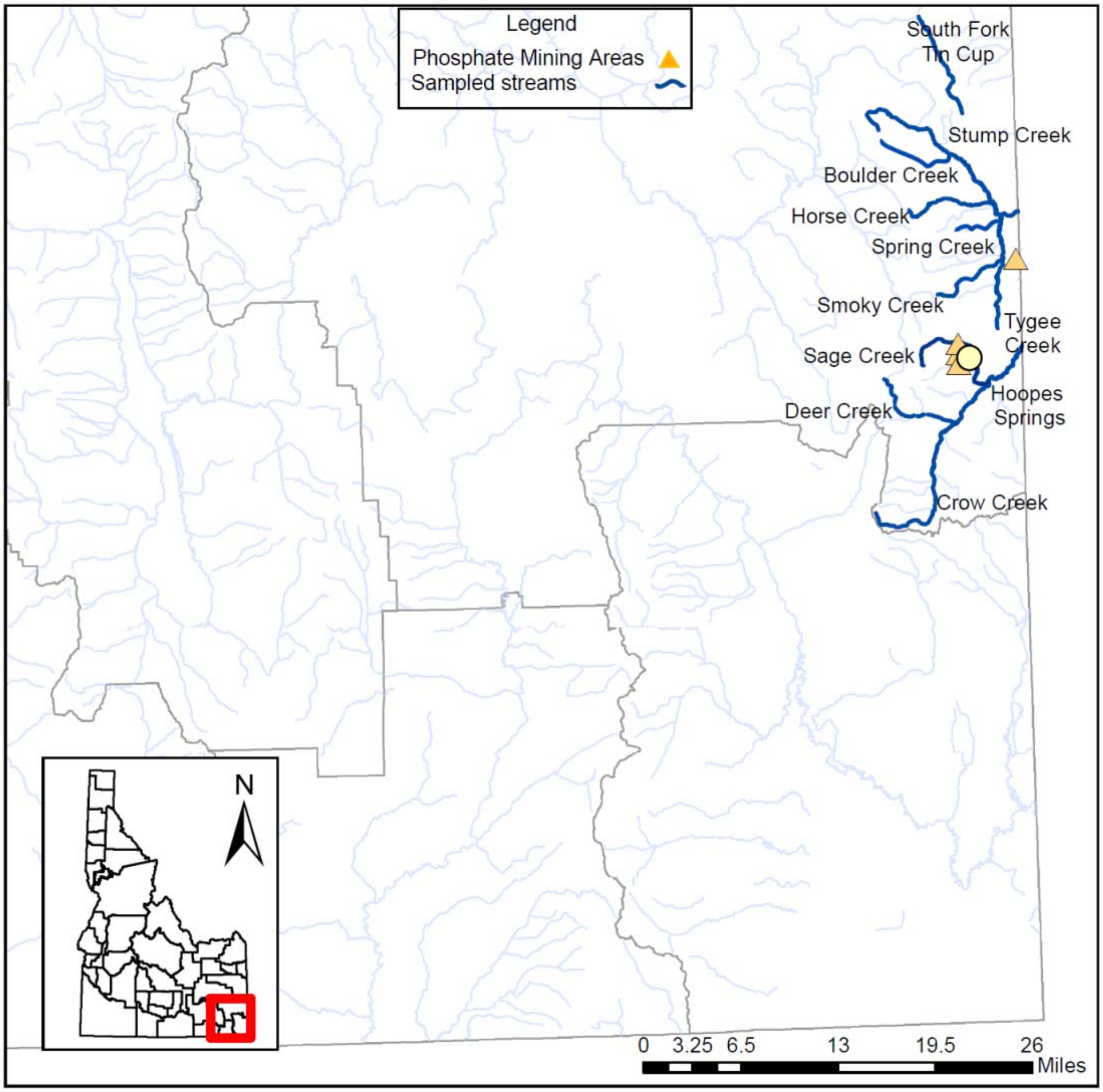
Appendix A: Maps of the Study Area

Figure 1: Blackfoot River's tributaries sampled and potential sources of contamination



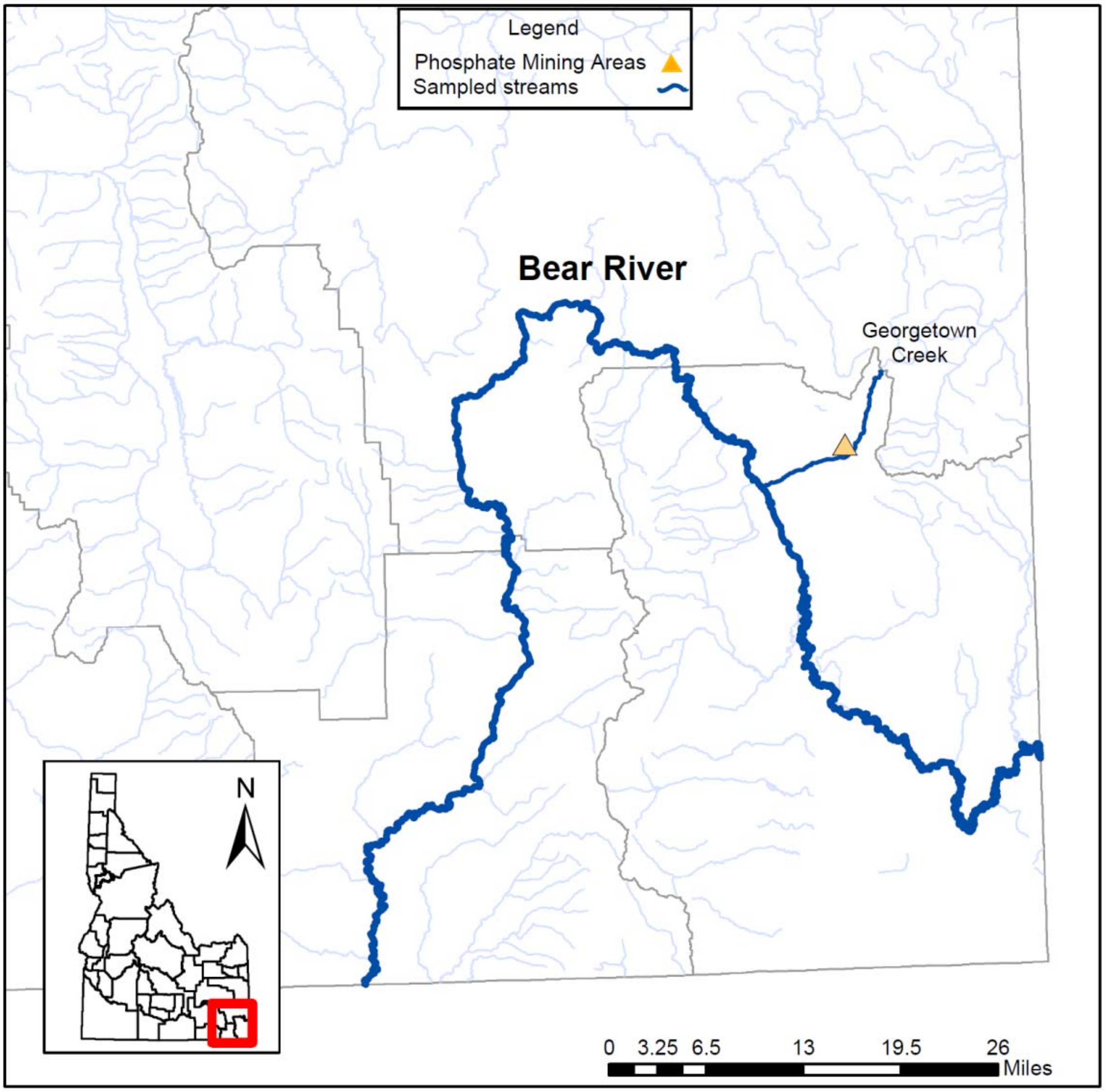
Map created by Bureau of Community and Environmental Health, 3/15/2013

Figure 2: Salt River's tributaries sampled and potential sources of contamination



Map created by Bureau of Community and Environmental Health, 3/15/2013

Figure 3: Bear River's tributaries sampled and potential source of contamination



Map created by Bureau of Community and Environmental Health, 3/15/2012

Appendix B: Linear Regression Analysis Selenium Concentration versus Size

Figure B1: Linear regression analysis selenium concentrations in Brook Trout versus size using GYC data

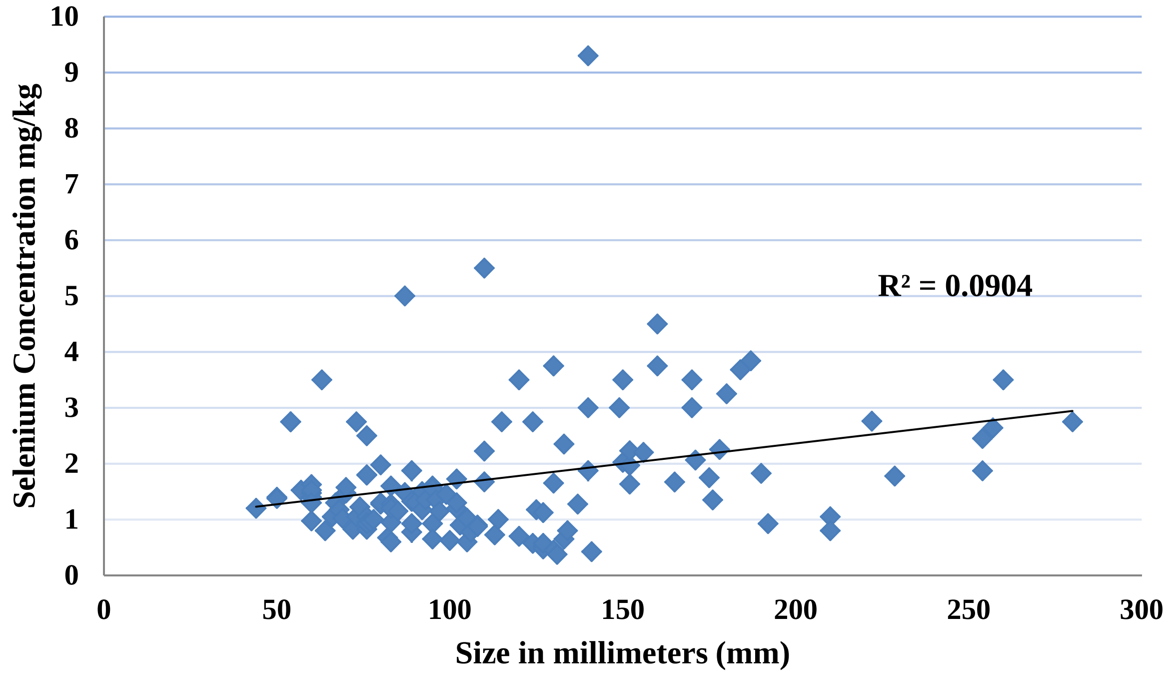
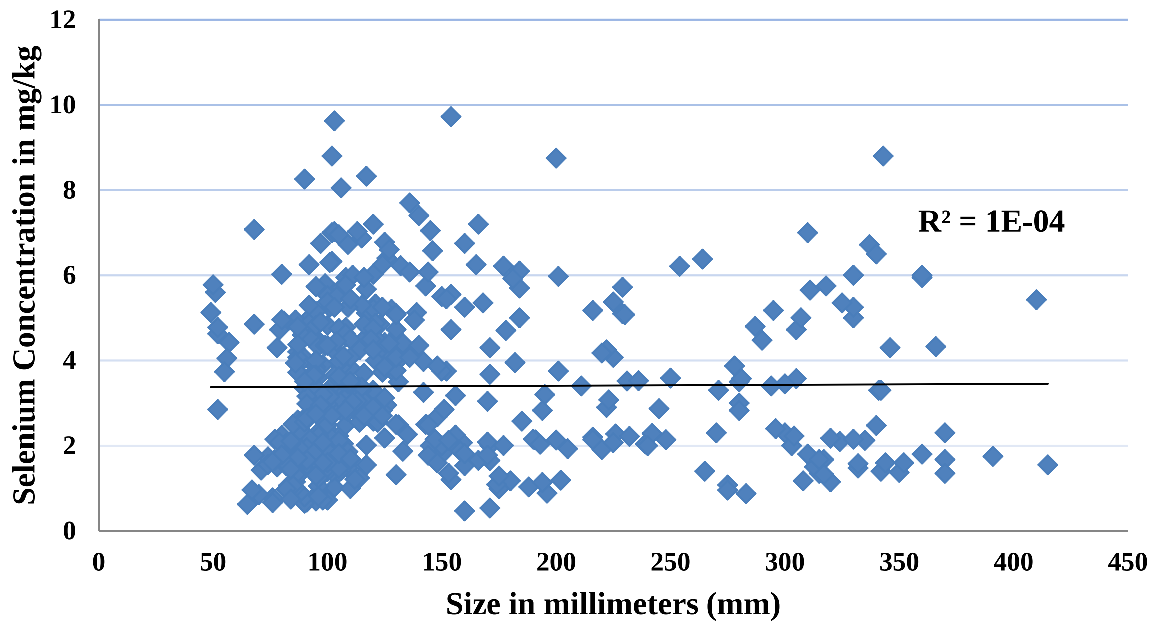


Figure B2: Linear regression analysis selenium concentrations in Brown Trout versus size using GYC data



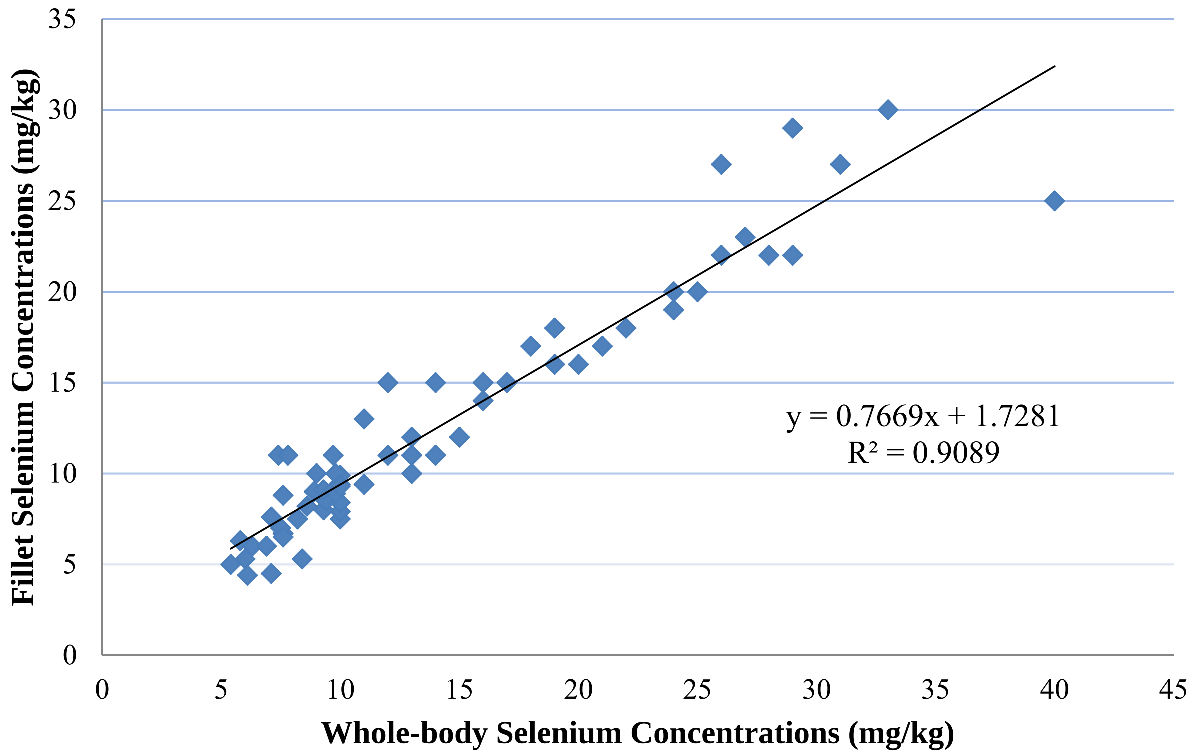
Appendix C: Linear Regression Analysis Whole-body versus Fillet Selenium Concentration

Table C1: Whole-body and fillet Selenium Data (dry weight) provided by Greater Yellowstone Coalition (2011 sampling efforts)

Sampling Site	Selenium concentration dry weight milligram/kilogram (mg/kg)	
	Whole-body	Fillets
GYC-1 A	10	9.9
GYC-1 B	7.4	11
GYC-1 C	11	13
GYC-1 D	9	10
GYC-1 E	9.8	10
GYC-1 F	12	15
GYC-1 G	7.8	11
GYC-1 H	7.6	6.7
GYC-1 J	12	11
GYC-3 A	6	5.3
GYC-3 B	6.3	6
GYC-3 C	5.8	6.3
GYC-3 D	6.1	4.4
GYC-3 E	5.4	5
GYC-3 F	6.9	6
GYC-3 G	7.1	4.5
GYC-5 A	9.3	8
GYC-5 B	13	10
GYC-5 C	8.9	9
GYC-5 D	10	7.5
GYC-5 E	10	7.9
GYC-5 F	9.4	8.5
GYC-5 G	9.3	9.1
GYC-5 H	9.7	9.1
GYC-5 I	7.5	7
GYC-6 A	25	20
GYC-6 B	40	25
GYC-6 C	28	22
GYC-6 D	29	22
GYC-6 E	24	19
GYC-6 F	27	23
GYC-6 G	26	27
GYC-6 H	29	29
GYC-6 I	33	30

Sampling Site	**Selenium concentration dry weight milligram/kilogram (mg/kg)**	
	Whole-body	**Fillets**
GYC-6 J	13	11
GYC-7 A	19	16
GYC-7 B	24	20
GYC-7 C	20	16
GYC-7 D	21	17
GYC-7 E	18	17
GYC-7 F	19	18
GYC-7 G	22	18
GYC-7 H	26	22
GYC-7 I	31	27
GYC-7 J	10	8.4
GYC-23I	8.6	8.2
GYC-23J	7.6	6.5
GYC-25 A	16	14
GYC-25B	16	15
GYC-25 C	14	11
GYC-26 A	17	15
GYC-26 B	8.4	5.3
GYC-26 C	15	12
GYC-26 D	13	11
GYC-26 E	10	9.4
GYC-26 F	14	11
GYC-26 G	13	12
GYC-26 H	14	15
GYC-26 I	11	9.4
GYC-28 B	8.2	7.5
GYC-28 C	9.8	8.9
GYC-28 D	9.7	11
GYC-28 E	7.6	8.8
GYC-28 G	10	9.3
GYC-28 J	7.1	7.6

Figure C1: Linear Regression Analysis Whole-body Selenium concentrations versus Fillet Selenium Concentration (dry weight) using data from Table C1



Appendix D: Formulas for Screening Value and Maximum Allowable Fish Consumption

Formula for Selenium Screening Value

$$\text{SV} = \frac{MRL \times BW \times RSC \times AT}{EF \times ED \times IR}$$

Where:
SV = Screening value in mg/kg selenium (wet weight)
MRL = Minimum Risk Level (0.005 mg/kg of body weight/day for selenium)
BW = Body weight (kg) (20 kg for a child)
RSC = Relative Source Contribution [Average selenium daily intake, 79 µg/day for children (ages 3-5) as percent of the upper tolerable intake level of 150 µg/day] (US DHHS, 2002)
AT = Averaging Time (Number of days in one year = 365)
EF = Exposure frequency = 104 meals. This equates to eating fish 2 days per week over the course of one year.
ED = Exposure Duration (1 year)
IR = Ingestion Rate [Children's meal size = 2.25 oz. (0.063kg) uncooked]

$$SV = \frac{0.005 \times 20 \times 0.47 \times 365}{104 \times 1 \times 0.063}$$

$$SV = 2.6 \text{ mg/kg}$$

Formula for Calculation of Maximum Allowable Fish Consumption

$$\text{CR} = \frac{\text{MRL x BW}}{\text{Contaminant Concentration}}$$

Where:
CR = Maximum allowable fish consumption rate (kg/day)
MRL = Minimum risk level (0.005 mg/kg/day for selenium)
BW = Body weight (kg)
Contaminant Concentration = Fish tissue selenium concentration wet weight (mg/kg)

Appendix E: Tables Whole-Body Selenium Concentrations in Blackfoot, Salt and Bear River Watersheds

Table E1: Whole-body Fish Selenium Concentration Data (2003, 2005–2011) in the Blackfoot River Watershed

Stream Name or River/ (Type of fish)	Number of Samples	Min (mg/kg)	Max (mg/kg)	Average (mg/kg)	Median (mg/kg)	Geometric mean (mg/kg)
East Mill (BRK)	1	9.30	9.30	9.30	9.30	9.30
Spring (YCT)	10	1.73	5.50	4.45	4.63	4.26
Blackfoot (BRK)	1	3.50	3.50	3.50	3.50	3.50
Spring (BRK)	23	1.79	5.50	3.42	3.50	3.32
Blackfoot (YCT)	40	1.82	5.00	3.12	3.00	3.02
Lower Dry Valley (YCT)	7	1.68	4.50	3.02	3.00	2.81
Blackfoot (RBT)	5	1.85	3.03	2.38	2.20	2.34
Angus (BRK)	6	1.78	2.76	2.25	2.24	2.22
Angus (YCT)	87	0.68	5.25	2.06	1.90	1.90
Diamond (YCT)	53	0.82	3.25	1.75	1.65	1.67
Sheep Creek (BRK)	12	1.15	2.06	1.53	1.49	1.51
Sheep Creek (YCT)	38	0.51	2.75	1.56	1.51	1.50
Lanes Creek (YCT)	10	0.72	3.62	1.67	1.39	1.45
Unnamed Tributary (YCT)	10	0.69	3.06	1.57	1.37	1.39
Slug (BRK)	45	0.60	3.00	1.41	1.38	1.31
Diamond (BRK)	17	0.83	2.23	1.31	1.28	1.27
Johnson (BRK)	10	0.80	1.35	1.04	1.03	1.03
Rawlins (YCT)	15	0.75	1.43	1.02	0.95	1.00
Trail Creek (BRK)	3	0.60	1.65	1.07	0.96	0.98
Timber Creek (YTC)	21	0.51	1.85	0.98	0.70	0.89
Miner (YCT)	15	0.75	1.00	0.89	0.90	0.89
Browns (YCT)	10	0.70	1.10	0.85	0.79	0.84
Brush (YCT)	15	0.38	1.30	0.65	0.60	0.62

BRK = Brook trout; YCT = Yellowstone cutthroat trout; RBT = Rainbow trout
milligram/kilogram = mg/kg
Min = Minimum
Max = Maximum

Table E2: Whole-body Fish Selenium Concentration Data (2003, 2005–2011) in the Salt River Watershed

Stream	Number of Samples	Min (mg/kg)	Max (mg/kg)	Average (mg/kg)	Median (mg/kg)	Geometric mean (mg/kg)
Hoopes Spring (BRN)	58	2.98	9.73	5.57	5.43	5.37
Hoopes Spring (YCT)	8	2.71	7.83	5.50	5.51	5.28
Sage (BRN)	167	1.55	8.80	4.50	4.48	4.27
Crow Downstream (YCT)	26	1.88	6.82	3.43	2.97	3.20
Crow Downstream (BRN)	103	1.33	5.80	3.12	3.05	2.97
Sage (YCT)	86	0.55	7.26	2.69	1.33	1.93
Horse (BRN)	11	1.29	2.15	1.77	1.78	1.75
Crow Upstream (YCT)	109	0.05	6.43	1.94	1.70	1.71
Deer Creek (YCT)	190	0.03	6.32	2.03	1.97	1.68
Smoky (YCT)	35	1.04	2.43	1.71	1.75	1.67
Crow Upstream (BRN)	139	0.65	5.25	1.72	1.66	1.61
Crow Downstream (BRK)	1	1.58	1.58	1.58	1.58	1.58
Smoky (BRK)	10	1.10	2.04	1.54	1.51	1.52
Tygee (YTC)	7	0.61	2.07	1.20	1.21	1.13
Horse (YCT)	23	0.57	1.88	0.97	0.98	0.94
Stump (BRN)	3	0.535	1.08	0.86	0.96	0.82
Spring (BRN)	10	0.47	1.06	0.77	0.74	0.75
Stump (YCT)	21	0.355	1.98	0.85	0.63	0.74
SF Tin Cup (YCT)	31	0.45	2.29	0.80	0.65	0.72
Spring (YCT)	44	0.19	1.10	0.67	0.71	0.63
Boulder (BRK)	15	0	1.08	0.52	0.45	0.49

BRN = Brown trout; BRK = Brook trout; YCT= Yellowstone cutthroat trout
milligram/kilogram = mg/kg
Min = Minimum
Max = Maximum

Table E3: Whole-body Fish Selenium Concentration Data (2003, 2005–2011) in the Bear River Watershed

Stream	Number of Samples	Min (mg/kg)	Max (mg/kg)	Average (mg/kg)	Median (mg/kg)	Geometric mean (mg/kg)
Georgetown (BRK)	12	1.48	3.25	2.35	2.21	2.28
Georgetown (RBT)	3	1.75	2.50	2.04	1.88	2.02
Left Hand Fork Georgetown (BRK)	15	0.90	1.65	1.25	1.28	1.23

BRK = Brook trout; RBT = Rainbow trout
milligram/kilogram = mg/kg; Min = Minimum; Max = Maximum

Appendix F: Estimated Exposure Dose Calculations

$$D = \frac{C\ x\ IR\ x\ BF\ xEF}{BW}$$

D = Dose in milligram per kilogram of body weight per day (mg/kg/day)
C = Contaminant concentration in milligrams per kilogram (mg/kg)
IR = Ingestion rate in fish meals consumed over a period of time (kg). IR was calculated using an average consumption of 8 oz. (0.227 kg) per week for adults and 4.5 oz. (0.127 kg) per week for children. This yields a daily consumption rate of 0.0324 kg for adults and 0.018kg for children.
BF = Bioavailability Factor (default used 1) (unitless)
EF = Exposure Factor in days per year exposed/365 (unitless)
BW = Body Weight: 70 kg (adult female), 80 (adult male), 20 (child) (McDowell, Fryar, & Ogden, 2008)

East Mill Creek

Selenium concentration in Brook trout (9.30 mg/kg)

Adult Female

$$\text{Dose (mg/kg/day)} = \frac{\text{C (mg/kg) x IR (kg of fish per day) x BF x EF}}{\text{BW (kg)}}$$

$$= \frac{9.30 \times 0.0324 \times 1.0 \times 1.0}{70}$$

$$= 4.3 \times 10^{-3} \text{ mg/kg/day (Exposure Dose)}$$

Adult Male

$$\text{Dose (mg/kg/day)} = \frac{\text{C (mg/kg) x IR (kg fish per day) x BF x EF}}{\text{BW (kg)}}$$

$$= \frac{9.30 \times 0.0324 \times 1.0 \times 1.0}{80}$$

$$= 3.8 \times 10^{-3} \text{ mg/kg/day (Exposure Dose)}$$

Children

$$\text{Dose (mg/kg/day)} = \frac{\text{C (mg/kg) x IR (kg fish per day) x BF x EF}}{\text{BW (kg)}}$$

$$= \frac{9.30 \times 0.018 \times 1.0 \times 1.0}{20}$$

$$= 8.4 \times 10^{-3} \text{ mg/kg/day (Exposure Dose)}$$

Appendix G: Recommended Maximum Allowable Weekly Fish Consumption in the Blackfoot River, Salt River and Bear Tributaries

Table G1: Recommended Maximum Allowable Weekly Fish Consumption in the Blackfoot River and Salt River watersheds

Watershed	Stream name/ Fish type	Geometric mean Whole-body Selenium concentration (wet weight) (mg/kg)	Maximum Allowable Weekly Fish Consumption[1]		
			Men	Women	Children
			4 oz. meal	4 oz. meal	2.5 oz. meal
Blackfoot	Spring (YCT)	4.26	6	5	3
Blackfoot	Blackfoot (YCT)	3.02	8	7	4
Blackfoot	Blackfoot (BRK)	3.50	7	6	3
Blackfoot	Lower Dry Valley (YCT)	2.81	9	8	4
Salt	Hoopes Spring (BRN)	5.37	5	4	2
Salt	Hoopes Spring (YCT)	5.28	5	4	2
Salt	Sage (BRN)	4.27	6	5	3
Salt	Crow Creek (downstream portion) (BRN)	2.97	8	7	4
Salt	Crow Creek (downstream portion) (YCT)	3.20	8	7	3
Bear	Georgetown (BRK)	2.28	11	10	5
	Georgetown (RBT)	2.02	12	11	5
	Left Hand of Georgetown	1.23	20	18	9

BRK = Brook trout   YCT = Yellowstone cutthroat   1 = Consumption based on 4 oz. (0.1 kg) meal size
BRN = Brown trout   milligram/kilogram = mg/kg   4 oz. – Men and women; 2.25 oz. - Children

Report Preparation

This public health consultation was prepared by the Idaho Department of Health and Welfare under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, and procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

Authors
Norka E. Paden, Ph.D., Idaho Division of Public Health
Health Assessor

Jim Vannoy, MPH, Idaho Division of Public Health
Program Manager

State Reviewers
Kara Stevens, BS, Idaho Division of Health
Acting Bureau Chief

Jeffrey E. Fromm, PhD., Idaho Department of Environmental Quality
Technical Services

ATSDR Reviewers

Division of Community Health Investigations

Audra Henry, Technical Project Officer
Carol Hossom, Environmental Health Scientist
Sven Rodenbeck, Acting Western Branch Chief
Tina Forrester, Acting Division Director

References

AHA. (2006). *American Heart Association Learn and Live.* Retrieved August 7, 2012, from Fish and omega-3 fatty acids: http://www.heart.org/HEARTORG/GettingHealthy/NutritionCenter/HealthyDietGoals/Fish-and-Omega-3-Fatty-Acids_UCM_303248_Article.jsp

Akbaraly, N., Hininger-Favier, I., Carrière, I., Arnaud, J., Gourlet, V., Roussel, A., & Berr, C. (2007). Plasma Selenium Over Time and Cognitive Decline in the Elderly. *Epidemiology, 18*(1), 52-58.

Arthur, J. (1991). The role of selenium in thyroid hormone metabolism. *Canadian Journal of Physiology and Pharmacology, 69*(11), 1648-1652.

ATSDR. (2003). *Toxicological Profile for Selenium.* Atlanta: US Department of Health and Human Services.

ATSDR. (2006). *Public Health Consultation for Southeast Idaho Phosphate Mining Resource Area, Bannock, Bear lake, Bingham, and Caribou Counties.* Atlanta: US Department of Health and Human Services.

ATSDR. (2007). *Evaluation of Selenium in Elk In the Southeast Idaho Phosphate Resource Area.* Atlanta.

Barberger-Gateau, P., Jutand, M.-A., Letenneur, L., Larrieu, S., Tavernie, B., & Berr, C. (2005). Correlates of regular fish consumption in French elderly community dwellers: data from the Three-City study. *European Journal of Clinical Nutrition, 59*(7), 817-825.

BCEH. (2001). *Health consultation: evaluation of selenium in beef, elk, sheep, and fish in the southeast Idaho phosphate resource area.* Boise: Idaho Department of Health and Welfare.

BCEH. (2001). *Health consultation: evaluation of selenium in groundwater in the southeast Idaho phosphate resource area.* Boise: Idaho Department of Health and Welfare.

BCEH. (2003). *Health consultation: selenium in fish in streams of the upper Blackfoot River watershed, southeast Idaho selenium project.* Boise: Idaho Department of Health and Welfare.

BCEH. (2011). *Idaho Fish Consumption Advisory Project Protocol.* Boise: Idaho Department of Health and Welfare.

Berr, C., Akbaraly, T., Arnaud, J., Hininger, I., Roussel, A., & Barberger-Gateau, P. (2009). Increased selenium intake in elderly high fish consumers may account for health benefits previously ascribed to omega-3 fatty acids. *13*(1), 14-18.

Bjerregaarda, P., & Hansen, J. (2000). Organochlorines and heavy metals in pregnant women from the Disko Bay area in Greenland. *Science of the Total Environment, 245*, 195-202.

Björnberg, K., Vahter, M., Petersson-Grawé, K., & Berglunda, M. (2005). Methyl mercury exposure in Swedish women with high fish consumption. *Science of the Total Environment*(341), 45– 52.

Björnberg, K., Vahter, M., Petersson-Grawé, K., Glynn, A., Cnattingius, S., Darneud, P., Berglunda, M. (2003). Methyl Mercury and Inorganic Mercury in Sweden Pregnant Women and Cord Blood: Influence of Fish Consumption. *Environmental Health Perspectives, 111*(4), 637-641.

BLM. (2012, November 11). *US Department of Interior, Bureau of Land Manament*. Retrieved from Minerals Phosphate Mining: http://www.blm.gov/id/st/en/Districts-Idaho/IFD/pocatello/Phosphate.html

Bright, R. (1967). Late-Pleistocene Statigraphy in Thatcher Basin, southeast Idaho. *Tebiwa, Journal of the Idaho State University, 67-7*(10), 1-7.
California Environmental Protection Agency. (2008). *Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California sport fish: chlordane, DDT, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene.*
Combs, G. J., & Gray, W. (1988). Chemopreventive agents: Selenium. *Pharmacology and Therapeutics, 79*(3), 179-192.
Corvilain, B., Contempre, B., Longombe, A., Goyens, P., Gervy-Decoster, C., Lamy, F., Dumont, J. (1993). Selenium and the thyroid: How the relationship was established. *American Journal of Clinical Nutrition, 57*(2), 244S-248S.
ESRI. (2012, June 12). Community Analyst software. Redlands, California, USA: ESRI.
Fang, T., Aronson, K., & Campbell, L. (2012). Freshwater Fish–Consumption Relations With Total Hair Mercury and Selenium Among Women in Eastern China. *Archives of Environmental Contamination and Toxicology, 62*(2), 323-332.
Fillion, M., Lemire, M., Philibert, A., Frenette, B., Weiler, H., & DeGuire, J. (2011). Visual acuity in fish-consumers of the Brazilian Amazon: risks and benefits from local diet. *Health Nutrition, 14*(12), 2236-2244.
Golder. (2005). *Keylake Operations Compresensive Environmental Effects Monotoring Program Interpretative Report.* Saskatoon, Canada: Golder Associates Ltd.
Grunder, S., McArthur, T., Clark, S., & Moore, V. (2008). *2003 Economic Survey Report.* Pocatello: Idaho Department of Fish and Game.
Hamilton, S. B. (2004). Selenium in water, sediment, plants, invertebrates, and fish in the Blackfoot River drainage. *Water, Air, and Soil Pollution, 159*(3-34).
Hansen, J., Deutch, B., Pedersen, & HS. (2004). Selenium status in Greenland Inuit. *Science of the Total Environment, 331*, 207-214.
IARC. (1975). *Monographs on the evaluation of carcinogenic risks to humans: Selenium and selenium compounds.* Lyon, France: World Health Organization.
IDEQ. (2007). *Selenium Project Idaho Phosphate Mining Area. Water Quality Sampling for Metals-Blackfoot River and Tributaries (HUC 17040207), Selected Bear River Tributaries (HUC 16010201), and Selected Salt River Tributaries (HUC 17040105).* Pocatello.
IDEQ. (2012). *Update: Phosphate Mine Investigations and Clean Up in South East Idaho.* Pocatello: South East Idaho Project.
IDFG. (2013, February 11). Personal Communication with David Teuscher.
IOM. (2000). *Dietary reference intakes for vitamin C, vitamin E.* Washington D.C.: National Academy Press.
Lemire, M., Fillion, M., Frenette, B., Passos, C., Guimarães, J., & Barbosa, F. (2011). Selenium from dietary sources and motor functions in the Brazilian Amazon. *Neurotoxicology, 32*(6), 944-953.
Lemire, M., M, F., Frenette, B., Mayer, A., Philibert, A., & CJ, P. (2010). Selenium and mercury in the Brazilian Amazon: opposing influences on age-related cataracts. *Environmental Health Perspectives, 118*(11), 1584–1589.
Lemire, M., Philibert, A., Fillion, M., Passos, C., Guimarães, J., Barbosa, F., & Mergler, D. (2012). No evidence of Selenosis from a Selenium-rich diet in the Brazilian Amazon. *Environment International, 40*, 128-136.

Levander, O. (1997). Nutrition and newly emerging viral diseases: An overview. *Journal of Nutrition, 127*, 948S-950S.
MacFarquhar J, B. D. (2010). Acute Selenium Toxicity Associated With a Dietary Supplement. *Archives of Internal Medicine, 170*(3), 256-261.
MassDEP. (2006). *Massachusetts Mercury Studies: Investigations of Seasonal and Other Sources of Variation.* Boston: Massachusettts Environmental Protection.
McDowell, M., Fryar, C., & Ogden, C. F. (2008). *Anthropometric Reference Data for Children and Adults, 2003-2006.* Centers for Disease Control and Prevention.
McKelvey, V., Strobell, J., & Slaughter, A. (1986). The Vanadiferous Zone of the Phosphoria formation in western Wyoming and Southeastern Idaho. *Professional Paper 1465.* Denver: US Geological Survey.
McKelvey, V., Williams, J., Sheldon, P., Cressman, E., Cheney, T., & Swanson, R. (1959). The Phosphoria, Park City, and Shedhorn Formations in the western phosphate fields. *Professional paper 131-A.* Denver: US Geological Service.
McKenzie, R., Rafferty, T., & GJ, B. (1998). Selenium: an essential element for immune function. *Immunology Today, 19*(8), 342-345.
Micke O, S. L. (2009). Selenium in oncology: from chemistry to clinics. *Molecules, 14*(3945-3988).
Micke, O., Schomburg, L., Buentze, l. J., Kisters, K., & Muecke, R. (2009). Selenium in Oncology: From Chemistry to Clinics. *MOlecules, 14*(10), 3975-3988.
MW. (1999). Responses to Comments on the Draft 1998 Regional Investigation Report - Southeast Idaho Phosphate Resource Area Selenium Project. *cited in: BCEH 2006. Southeast Idaho Phosphate Mining Resource Area Bannock, Bear Lake, Bingham, and Caribou Counties, Idaho*. Soda Springs.
NAS. (1989). *Recomended Dietary Alloances, 10th ed.* Washington DC: National Academy Press.
Pinheiro, M., Mölle, R., Sarkis, J., Vieira, J., Oikawa, T., Gomes, M., Silveira, L. (2006). Mercury and selenium concentrations in hair samples of women in fertile age from Amazon riverside communities. *349*, 284-288.
Presser, T., Piper, D., Bird, K., Skorupa, J., & Hamilton, S. D. (2004). The Phosphoria Formation: a model for forecasting global selenium sources to the environment. In J. Hein, *Life Cycle of the Phosphoria Formation: From Deposition to Post-Mining Environment* (pp. 299-315). Amsterdam, The Netherlands: Elsevier.
Rayman, M. (2000). The Importance of Selenium in Human Health. *Lancet, 356*(9225), 233-241.
Steinbrenner, H., Speckmann, B., Pinto, A., & H, S. (2011). High selenium intake and increased diabetes risk: experimental evidence for interplay between selenium and carbohydrate metabolism. *Journal of Clinical Biochemistry and Nutrition, 48*(1), 40-45.
Stranges, S., Navas-Acien, A., Rayman, M., & Guallar, E. (2010). Selenium status and cardiometabolic health: state of the evidence. *Nutrition Metabolism and Cardiovascular Disease, 20*(10), 754–760.
Thomson C. (2004). Assessment of requirements for selenium and adequacy of selenium status: a review. *European Journal of Clinical Nutrition, 58*(3), pp. 391-402.
US Census Bureau. (2010). *US Census of Population and Housing.* (US Census Bureau) Retrieved May 24, 2010, from US Department of Commerce.

US DHHS. (1997). *National Health and Nutrition Examination Survey (NHANES), III 1988-1994.* US Department of Health and Human Services, Centers for Disease Control Prevention (CDC).

US DHHS. (2002). *Dietary intake of macronutrients, micronutrients, and other dietary constituents: United States, 1988-94. Data from the National Health Examination Survey, the National Health and Nutrition Examination.* Haysville, Maryland: US Department of Health and Human Services.

US EPA. (2004). *Water Outreach & Community.* Retrieved July 18, 2012, from Technical Memorandum. Origin of 1 meal/week noncommercial fish consumption rate in National Advisory for Mercury: http://water.epa.gov/scitech/swguidance/fishshellfish/outreach/advice_index.cfm

US EPA. (2011). *Exposure Factors Handbook 2011 Edition.* Washington DC: National Center for Environmental Assessment, Office of Research and Development.

US EPA. (2012, August). *Integrated Risk Information System*. (EPA) Retrieved October 12, 2012, from Selenium and Compounds (CASRN 7782-49-2): http://www.epa.gov/iris/subst/0472.htm

USDA. (2010). *Dietary Guidelines for Americans.* US Department of Health and Human Sciences.

USDOI and USGS. (2000). *Minerals year book, metals and minerals Vol I.* Washington DC: US Government Printing Office.

Yang, G., Wang, S., Zhou, R., & Sun, S. (1983). Endemic selenium intoxication of humans in China. *American Journal Of Clinical Nutrition, 37*, 872-881.

Yang, G., Yin, S., Zhou, R., Gu, L., Yan, B., Liu, Y., & Liu, Y. (1989b). Studies of safe maximal daily dietary Se-intake in a seleniferous area in China Part II: Relation between Se-intake and the manifestation of clinical signs and certain biochemical alterations in blood urine. *Journal of Trace Elements Electrolytes in Health and Disease, 3*, 123-130.

Yang, G., Zhou, R., Yin, S., Gu, L., Yan, B., & Liu, Y. (1989a). Studies of safe maximal daily selenium intake in a seleniferous area in China Part I. *Journal of Trace Elements and Electrolites in Health and Disease*, 77-87.

Selected Glossary

Acute
Exposure occurring for less than 14 days.

Acute Aquatic Life Criterion
The EPA national water quality criteria recommendation for the highest instream concentration of a toxicant or an effluent to which all organisms can be exposed for a brief period of time without causing an adverse acute effect.

Agency for Toxic Substances and Disease Registry (ATSDR)
The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.

Angler
Person using a fishing pole or rod and reel to catch fish.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time (more than 1 year).

Chronic Aquatic Life Criterion
The EPA national water quality criteria recommendation for the highest instream concentration of a toxicant or an effluent to which organisms can be exposed indefinitely without causing unacceptable effect.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dose
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An “exposure dose” is how much of a substance is encountered in the environment. An “absorbed dose” is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dry weight
The amount of the chemical found in subsequent analysis is then expressed as weight of chemical divided by weight of the dried material which once contained it.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute**], of intermediate duration [**intermediate**], or long-term [**chronic**].

Fishing Pressure
Total number of angler-days spent fishing over a specified period.

Ingestion rate
The amount of an environmental medium which could be ingested typically on a daily basis. Units are in milligram per kilogram of soil per day for this study.

MRL
Minimal Risk Level is as an estimate of daily human exposure to a substance that is likely to be without appreciable risk of adverse, non-carcinogenic effects over a specified duration of exposure.

Media
Soil, water, air, plants, animals, or any other part of the environment that can contain contaminants.

Oral Reference Dose (RfD)
An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.

Phosphoria Formation
It is located in the western United States. The formation is a phosphorite and an important resource of phosphorus.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing (**inhalation)**, eating or drinking (**ingestion**), or contact with the skin (**dermal contact**).

Subsistence fishing
Fishing for personal consumption or traditional/ceremonial purposes.

Watershed
The area drained by a river system.

Wet weight
The amount of the chemical found in subsequent analysis is expressed as the weight of chemical divided by the total weight, including any water present, of the material which once contained it.