DEVELOPMENT OF A PLAN FOR FISH TISSUE MONITORING AND ISSUANCE OF CONSUMPTION ADVISORIES

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Abstract. The Georgia Department of Natural Resources (DNR) formed a committee of advisors to develop guidelines for monitoring fish tissue contamination and issuing fish consumption advisories due to the growing concern regarding toxic contamination of aquatic biota and the increasing amount of information pertaining to toxicity of chemicals and risk assessment. The guidelines developed by the Fish Tissue Advisory Committee (FTAC) are for a systematic monitoring plan for rivers and lakes.

The monitoring strategy consists of two tiers of studies. Primary studies are designed to provide sufficient information on fish tissue contamination of two target species, largemouth bass and catfish, for issuance of fish consumption advisories. Secondary studies will be utilized to provide additional information on geographic extent and/or other species in affected areas. Analyses will be conducted on composites of fillet tissue from a minimum of five fish per species per site. Multiple sites within a waterbody are recommended with specific numbers dependent upon lake size or river reach, lenght or number of tributaries, known or suspected contaminant inputs, and available historical data. Quantitative risk assessment methodologies incorporating U.S. EPA's potency factors for carcinogens and reference doses for toxics will be utilized to evaluate the data for human health concerns. Fish consumption advisories will be issued for all waterbodies sampled and will be written in a readily understandable manner. The strategy calls for evaluation of toxic contamination of fish tissue in relation to number of fish meals which may be eaten over a given period of time. Advisory information will then be generated for a particular water body and species/size of fish, ranging from "unlimited consumption" to "don't eat" with several intermediate recommendations for specific numbers of allowable meals per week or month.

INTRODUCTION

Contamination of fish with toxic chemicals is important to the citizens of Georgia. Contamination of lakes, rivers, and streams, has occurred as a result of urbanization, industrialization, and intensive agricultural practices.

Contamination of surface waters with even low environmental concentrations of toxic chemicals is problematic. Many toxic chemicals are relatively resistant to natural degradation and are, therefore, extremely persistent. Fish accumulate toxic chemicals directly from the water and through their diet, and contaminant residues may ultimately reach concentrations hundreds or thousands of times above those measured in the water, sediment and food. Monitoring fish tissue contamination serves as an early indicator of water quality problems and of toxic chemicals in fish that may be harmful to consumers or the environment, so that the state can take appropriate action.

To address these issues, DNR formed the Fish Tissue Advisory Committee (FTAC) which is responsible for providing guidelines for: 1) a comprehensive fish tissue sampling and analysis plan, and 2) the development and issuance of improved fish consumption advisories. Committe members included: R. Manning, Georgia Environmental Protection Division; C. Coomer, Georgia Game & Fish Division; J. Crellin, Agency for Toxic Substances and Disease Research; R. Reinert, University of Georgia; J. Stober, U.S. Environmental Protection Agency; and P. Winger, U.S. Fish & Wildlife Service.

PRIMARY STUDIES

The objective of the primary study is to identify waterbodies where fish are unsafe to eat, while providing sufficient data to issue specific consumption advice for at least two important target species of fish.

Target Species. Target species recommended for the primary study are one bottom-feeding species (catfish preferred, carp secondary choice), and one predator species (largemouth bass preferred). Target species were chosen to meet several criteria. The target species are known to accumulate high concentrations of target contaminants in their tissues (i.e., a plausible worst-case exposure situation). They normally populate most of the freshwater systems in Georgia, and are routinely caught and consumed by anglers. Also the target species are non-migratory, pollutant-tolerant, easily identified, abundant and easy to collect, and of sufficient size to provide adequate tissue samples for analyses of toxicants.

Target Contaminants. A list of target contaminants and detection limits was developed, including 13 metals and 30 organic pesticides/PCBs. Dioxins and dibenzofurans were not included on the list. Currently, dioxins/dibenzofurans are monitored in fish tissue (whole fish and fillets) in the vicinity of five bleached kraft pulp mills in Georgia. The studies are conducted yearly by a private consulting firm following a study protocol that was approved by DNR. The data collected by this program should be evaluated in a manner consistent with the evaluation of the other data collected through the State's monitoring programs. The list of target contaminants and detection limits is provisional because new chemicals may be identified that require monitoring and new technologies may lower detection limits.

Sampling Sites and Timing. Sampling sites should be chosen to target areas suspected of contamination. Selection criteria have been recommended by U.S. EPA (U.S. EPA, 1986a). These include the presence of municipal or industrial discharges and facilities, RCRA or CERCLA sites, the presence of intensive agricultural activities, and intensive urban land development. Species and numbers of fish present, and fishing pressure should also be considered.

FTAC reviewed a list of 27 lakes listed in the 1990 Lake Monitoring Project by EPD ranging in size from 600 to 70,000 acres. For the primary study, a minimum of three separate sites should be chosen to provide adequate coverage of the larger lakes. Particular attention should be given to choice of sampling locations in the larger lakes that may have more than one major tributary source and where contaminant concentration gradients occur. More than three sites may be needed in larger lakes to adequately define geographic extent of contaminant problems.

Sampling should be conducted on a yearly basis in late summer through fall. Collection of samples during this period avoids the spawning season of the target species, and ensures that lipid content of fish is relatively high and constant. Another factor which may facilitate fall sampling is that water levels are often lower which may make collection easier.

Composite Samples. Compositing edible fillets from several individuals prior to analysis provides information on average contaminant concentrations from a large number of fish with a limited number of analyses. The variability among contaminant concentrations in individual fish is lost by compositing. However, an accurate estimate of individual variation is not necessary to meet the objective of the primary study. Therefore, composite samples are recommended to reduce cost of analysis.

Composites should contain tissue from five fish of a given target species. Tissue from different species of fish should never be mixed to produce a composite. An edible fillet is defined as the fillet portion of the fish including the bellyflap. For scaled fish, fillets should be scaled but left with the skin on. For fish without scales, the skin should be removed from the fillet.

Fish collected from a given site should be of a size that is representative of what fishermen actually catch. All fish collected should also be of a legally harvestable size. Ideally, the smallest fish in a composite should be at least 75% of the size of the largest fish. Composites should be prepared with five fish of a similar size and length representative of the three most prevalent size classes (i.e., small, medium, and large). This type of sampling effort and grouping of fish based on size (length) will allow development of advisory information based on specific size classes of fish.

Because fish collected at a sampling station will be grouped into composites based on size (length), replication of composites at each site will not be achieved. However, in most instances composites will be collected from multiple sites within waterbodies to adequately evaluate fish tissue contamination. Therefore, samples of the same size class from different stations within a waterbody can be treated as replicates, unless there are differences in contaminant concentrations related to sampling area.

SECONDARY STUDIES

Advisories Based on Action Levels. The objective of the secondary study is to provide information regarding additional fish species and/or geographic extent of contamination for waterbodies where the primary study indicated that contamination of the target species was significant. Target species for the secondary study should be chosen based on site- specific information related to fish populations and fishing preferences of the local anglers and might include crappie; bream (bluegill, redear, shellcracker); white, striped, and hybrid bass; and brook, brown, and rainbow trout.

The same general study design should be used regarding sampling times, sample type, fish size, and sample analysis as in the primary study. Site specific information should be utilized in selection of sampling numbers and locations, and numbers of sample replicates per site to best meet the objective of the secondary study.

DATA ANALYSIS AND ADVISORIES

In the past, DNR has based fish consumption advisories on FDA action levels or tolerances which have been set for mercury, approximately 12 pesticides or related degradation products, and PCBs. Even though many states still use FDA's action levels as the basis for issuing fish consumption advisories, this method is increasingly criticized. In recent years, interest in the use of risk assessment methods which allow estimation of the risk resulting from consumption of contaminated fish has increased. With these methods, a quantitative value for risk from consumption of fish containing carcinogens is calculated (U.S. EPA, 1989a). It should be emphasized that calculations of risk are only estimates; the actual risk cannot be determined.

Currently, probability is not used to express the potential for noncarcinogenic toxicity. Instead, the potential for noncarcinogenic toxic effects are evaluated by comparing an exposure level for a specified time period with a reference dose or RfD (i.e., a level of exposure below which it is unlikely that even sensitive populations will experience any adverse health effect). If this ratio, referred to as a hazard quotient, exceeds unity there may be concern for potential noncancer effects (U.S. EPA, 1989b).

Calculating Action Levels: Allowable Tissue Concentrations. Accurate estimates of fish consumption (intake) are needed to estimate potential toxicity or carcinogenicity of contaminated fish tissue. The generalized formula for calculating intake from fish consumption is as follows:

Intake (mg/kg/day) = (CF x IR x FI x EF x ED)/(BW x AT)

where CF = contaminant concentration in fish (mg/kg), IR = ingestion rate (kg/meal), FI = fraction ingested from contaminated source (unitless), EF = exposure frequency (meals/year), ED = exposure duration (years), BW = body weight (kg), and AT = averaging time (period over which exposure is averaged in days).

Utilizing this methodology, U.S. EPA has calculated "fish tissue concentrations" for numerous chemicals (U.S. EPA, 1991). The values are calculated using standard inputs of 6.5 g/day consumption, 365 day/year exposure frequency, 70 years exposure duration, 70 kg bw, and 70 years x 365 days/year averaging time. For chemicals which are carcinogenic, U.S. EPA utilizes a risk value of 1×10^{-6} in calculating the fish tissue concentration, and for chemicals which result in noncancer toxicity, U.S. EPA uses the RfD. These values indicate "how much of a given contaminant fish tissue may contain, without risk of excess lifetime cancer exceeding 1 in a million, or any likelihood of noncancer toxicity occurring, as long as the exposure assumptions are appropriate."

Model for Advisories Based on Meals-Per-Week

The State should develop a strategy whereby advisories not only convey information that is readily understandable, but also stress the importance of the relationship between consumption or exposure and the ultimate toxic or carcinogenic endpoints of concern.

Proposed Model. Dourson and Clark (1990) proposed a method to improve the credibility of fish consumption advisories and make the information more useful for the fisherman. The proposed model accounts for the amount of fish consumed by making fish consumption the dependent variable and recommends that, where consumption should be limited, advisory information be released as number of fish meals allowed per month or week.

The steps required for evaluation of data with the Dourson and Clark (1990) model include the calculation of fish intake from the appropriate RfDs for noncancer toxicity or potency factors for cancer. Equations for these calculations are shown in Table 1. The second step is to estimate the amount of fish consumed per meal. Dourson and Clark (1990) determined that a difference of approximately twofold (i.e., ¼ to ½ lb) exists in the sizes of individual fish meals (U.S. EPA, 1988). The authors concluded that this range of meal size and the frequency of fish meals eaten over a given period follows a logarithmic scale. That is, the consumption of 3 to 10 g of fish per day is in the range of eating one ¼- to ½-lb fish meal per month: the consumption of 10 to 30 g/day is in the range of eating one ¼- to ½-lb meal per week: the consumption of 30 to 100 g/day is in the range of eating three ¼- to ½-lb meals per week: the consumption of 100 to 300 g/day is in the range of eating one ¼- to ½-lb meal per day. The fish consumption advisory proposed by Dourson and Clark (1990) is developed from a direct comparison of calculated fish intake values to the estimated amount of fish consumed per meal and meal frequency.

Model Assumptions. Management decisions must be made concerning appropriate inputs for the basic model parameters. For analyses of carcinogenic compounds, an appropriate risk level, a standard body weight, and an exposure duration must be chosen. For analyses of noncarcinogen toxicity, only body weight and exposure duration must be chosen. FTAC recommends that a risk level of 10^{-4} be used in the model for analysis of carcinogens. In any risk assessment, managers must determine what level of risk is "acceptable" to both individuals and the regulatory agency. Even though an acceptable risk level has not been strictly defined by any regulatory agency, risks acceptable to different U.S. regulatory agencies have ranged as high as 10^{-3} to 10^{-2} in situations where the exposed population was small (Travis, *et al.*, 1987). However, for exposures of the entire U.S. population, 10^{-6} has been the most widely accepted risk level (U.S. EPA, 1989a).

By convention, 70 years (or lifetime) has been utilized most frequently as an exposure duration. However, 30 years is the national upper-bound time (90th percentile) at one residence and 9 years is the national median time (50th percentile) at one residence (U.S. EPA, 1989c). FTAC recommends using 30 years as the exposure duration in the model to calculate fish intake.

FTAC recommends that 70 kg be utilized in calculations as the standard body weight for an adult (U.S. EPA, 1989c). In areas where contamination results in a restriction advisory of less than one meal per weak, a general statement that "fish consumption by small children and nursing women (or women of child bearing age) should be severely restricted" should be added to the advisory.

Model Advantages. The advantages of this model are numerous. It allows the release of a gradient of recommendations ranging from unlimited consumption to complete restriction with intermediate recommendations based on fish meals per week or month. This type of information should be easier to interpret and will stress the important principle that degree of health risk is based on contaminant concentration and quantity consumed (i.e., the dose makes the poison).

Another advantage of this method is that it enables one to conduct risk assessments for mixtures (i.e., assessments when more than one chemical is present in fish tissue) for either toxics or carcinogens with similar organ effects. The model treats toxic or carcinogenic effects as additive, which is the currently accepted practice in risk assessment (U.S. EPA, 1986b). However, when fish tissue contains contaminants that cause both noncancer and cancer toxicity, separate fish intakes would need to be calculated for both endpoints because current theoretical methods do not exist to combine risks from both (U.S. EPA, 1986b).

Additionally, recommendations are based on how much fish people should be able to "safely" eat. Theoretical risk calculations, cancer potency factors, RfDs, or toxic versus carcinogenic classification systems need not be explicitly addressed. All of these are technical, complex concepts that are difficult to explain and place in the proper perspective for the general public, and may only serve to confuse the issue of how much fish should be consumed.

SUMMARY

The goal of this program, as envisioned by FTAC, is to provide information from primary studies on Georgia's major lakes and river reaches within five years. In addition to primary studies, a portion of the resources and effort devoted to fish tissue monitoring should be allocated for secondary studies on important fisheries where a significant contaminant problem was identified by the primary study. As data are generated for fish consumption advisories each year, new advisories should be issued and existing advisories reissued or updated in a systematic and consistent manner. The advisories should be designed to present readily understandable information based on numbers of allowable fish meals per month or week. This program should ultimately result in the release of advisory recommendations based on fish tissue consumption for all important fresh water lakes and rivers in Georgia.

Table 1. Calculation of Risk Specific Dose

$$\text{Intake (kg/day)} = [\text{RfD (mg/kg-day)} \times \text{bw (kg)}] / \text{E(mg/kg)}$$

$$TC/RfD_m = E_1/RfD_1 + E_2/RfD_2 + \ldots + E_i/RfD_i$$

Therefore: $$RfD_m = TC/(\Sigma E_i/RfD_i)$$

$$\text{RSD (mg/kg-day)} = \text{risk (unitless)}/\text{SF (mg/kg-day)}^{-1}$$

Where:
RfD = reference dose.
RSD = risk specific dose.
SF = cancer slope or potency factor.
RfD_m = RfD for mixtures.
RSD_m = risk specific dose for mixtures.
E = fish contaminant concentration.
TC = total contaminant concentration.

Note: Equations 1 through 3 are for calculation of fish intake for noncancer toxicity. For calcualtion of fish intake for carcinogenic effects, substitute RSD for RfD in equations 1 through 3.

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