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Fish Consumption, Exposure to Dioxin, and Health Risk Assessments

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Human health issues have become the focus of much of the environmental debate that continues to occur daily in the U.S. In Maine, dioxin, a by-product of the kraft paper making process, has gathered its share of attention in recent months. In the following article, University of Maine resource economist Kevin Boyle discusses the difficulties associated with assessing human health risks relative to the consumption of fish tissue potentially contaminated with dioxin. He cautions state regulators to avoid overestimating the potential risks associated with human exposure to toxic substances such as dioxin. [The April 1995 issue of MPR will include a another perspective on the dioxin question.]

By Kevin J. Boyle

Introduction

Promulgating regulations for emissions of hazardous substances is a complicated and difficult process. Assessments of human health risks require scientific investigations to identify toxicity, pathways of exposure, and subsequent threats to human health. The imperfect and imprecise nature of scientific information further complicates the regulation process by making it difficult for members of the public to assess risks. The Maine Board of Environmental Protection's (BEP) rule-making hearing in fall 1992 on dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) in waste-water emissions from Maine paper mills using the kraft paper-making process is an example. (Kraft mills use chlorine in the bleaching process and dioxin is a by-product of this production.)

The BEP public hearing, while allowing ample opportunities for the presentation of scientific data and comment by the public, may be prone to the major problem involved in risk assessments -- the predisposition of the public to overestimate the likelihood of low probability events. The BEP was confronted with a substantial amount of technical information that was often contradictory. As a citizen board, the BEP is as likely to overestimate risks associated with human exposure to dioxin as is any member of the public.

The purpose of this article is not to debate the toxicity of dioxin, but to focus on human consumption of fish tissue that is potentially contaminated with dioxin, a major pathway of human exposure, and the foibles of human decision making when evaluating risks.[1] The discussion is intended to provide a flavor of the risk assessment process in the hearing based on my perceptions, and to link the process used in the hearing to the risk assessment literature.

Rule-making process

My characterization of the rule-making process is diagramed in Figure 1. The Maine Department of Environmental Protection has responsibility for water quality protection in Maine. The Commissioner of the Department of Environmental Protection proposed a dioxin rule for

consideration by the BEP. This recommendation was based on staff recommendations, which adhere to general U.S. Environmental Protection Agency guidelines, and input was provided by the state agencies responsible for protecting human health (the Department of Human Services) and managing inland fisheries (the Department of Inland Fisheries and Wildlife).

The proposed rule was based on the following risk assessment equation (Frakes, 1990):

WQC = (AR/CPF)(WAP/FC)(1/B)
Where:
WQC=Water Quality Criterion,
AR=Acceptable Risk,
CPF= Cancer Potency Factor,
WAP=Weight of an Average Person,
FC= Fish Consumption, and
B=Bioaccumulation of dioxin in fish tissue.

The proposed water quality criterion was 0.5 parts per quadrillion (ppq), measured in picograms per liter. This is known as an "end of pipe" standard for wastewater emissions by kraft mills. The proposed rule of 0.5 ppq was based on a fish consumption rate of 6.5 grams per day per person (g/d/p).

The BEP held hearings on the proposed regulation, where the kraft mills acted collectively to provide technical data to support the proposed regulation. The Natural Resources Council of Maine, acting as a public intervenor, presented experts to argue for a stricter regulation. The Penobscot Nation testified as an intervenor for a stricter regulation to protect their sustenance fishing rights on the Penobscot River, one of the rivers with a kraft mill.

The values of the acceptable risk, cancer potency factor, and fish consumption variables were controversial in the hearings. The alternative rule advocated by the Natural Resources Council of Maine was 0.01 ppq, based on a lower acceptable risk (10^{-6} versus 10^{-5}), higher cancer potency factor and higher fish consumption rate (32.4 g/d/p versus 6.5 g/d/p). (An acceptable risk of 10^{-5} equates to one cancer case from exposure to dioxin in tainted fish tissue per 100,000 people.)

While the acceptable risk and cancer potency factor are of political and scientific concern, this paper focuses on fish consumption. The BEP hearings and decision did not revolve entirely on arguments about the appropriate fish consumption rate. Fish consumption is the facet of the hearings with which I have direct experience and knowledge. I will argue, however, that the fish consumption debate had the potential to have a potent effect on the BEP's perceptions of human health risks associated with dioxin in waste-water emissions.

Consumption of freshwater fish

Ideally, estimated fish consumption should represent consumption of fish taken from sections of Maine rivers below kraft mills. These data would be collected by surveying anglers, rather than consumers, because the origin of the fish is important for the risk assessment. For example, Maine's lakes and ponds, and the vast majority of rivers in Maine, are unaffected by dioxin

emissions from kraft mills. Consumption of fish from waters that are not potential recipients of waste-water emissions containing dioxin should not be included in the fish consumption rate used in the equation. Surveying anglers allows identification of waters where fish are caught, while surveying fish consumers obscures this information.

Fish consumption data specific to Maine were provided from a survey of licensed resident anglers, which was funded by the kraft mills (Ebert et al. 1993). Prior to the industry study, data on freshwater fish consumption were not available for Maine. The Maine Department of Inland Fisheries and Wildlife is responsible for managing inland fisheries, but their concern is with annual harvest rates for specific waters, not the disposition of fish once they are harvested. Collection of fish consumption data falls between the jurisdictional mandates of the departments of Inland Fisheries and Wildlife, Environmental Protection, and Human Services.

Developing the ideal consumption estimate proved problematic for two reasons. Maine fishing licenses provide the only basis from which sample estimates can be extrapolated to a known population. But the licenses, which are required to fish Maine's inland waters, are not specific to individual waters. Licensed anglers can fish any water open to sport fishing, while adhering to regulations on open seasons, gear restrictions, and harvest restrictions. Thus, it is not possible to identify anglers who may fish mainstem sections of rivers below kraft mills .

An added complication is that inland fishing effort in Maine is concentrated on lakes, ponds, streams, brooks and the head waters of major rivers, not the mainstems of major rivers where kraft mills are located. In order to survey licensed anglers who fish the mainstems of the St. Croix, Penobscot, Kennebec, Androscoggin and Presumpscott Rivers below kraft mills, a sample in excess of 100,000 anglers might be required. Using a cost of $15 per observation for a mail survey, the data collection effort alone would cost $1.5 million. A sample of 100,000 exceeds all survey efforts of which I am familiar, except the U.S. Census. Such a survey effort, if applied in all risk assessments, would essentially grid lock the rule-making process.

An alternative approach could be on-site river surveys below kraft mills. The sample could be drawn throughout the six-month open water fishing season and would cover each of the five rivers with kraft mills. Rivers below kraft mills are not open to ice fishing. Therefore, anglers can only legally fish these waters during the open water season, April 1 through September 30. The on-site sample size would be much less than 100,000 anglers, and the cost would be considerably less than $1.5 million. But an on-site survey creates great problems in extrapolating sample estimates to an unknown population. Given the multitude of access points to any river, there is no way to insure that all access points would be represented in the sample. In the rulemaking process, there would be no way to know whether estimated consumption was overestimated or underestimated, and there would be no assurance that highly exposed individuals would be included in the data. Regulations of hazardous substances are often promulgated to protect the most highly exposed individuals and the desire is to have a sample that would include individuals who consume large amounts of fish caught from sections of Maine rivers downstream from kraft mills.

The consultants for the industry (who include the author) decided to use a sample of licensed resident anglers and to survey anglers about all of their fishing on flowing water bodies (rivers,

streams and brooks), which overestimates the average fish consumption rate from any single river. Resident anglers were surveyed because they are more likely to fish Maine's flowing waters than nonresidents (77 percent versus 49 percent), and their participation is more extensive (13 versus seven days of effort per year). This approach might be criticized because the smaller sample might miss an individual who fishes extensively and intensively on a mainstem river downstream from a kraft mill. Although the mean fish consumption is overestimated, an individual in the upper tail of the consumption distribution might be omitted. On the other hand, streams, brooks and head waters of major rivers are fished more extensively and intensively in Maine than mainstems of major rivers. (Unpublished data collected by the Department of Inland Fisheries and Wildlife and the author.) Consequently, anglers who fish brooks, streams and head waters of rivers are much more likely to constitute the upper tail of the fish consumption distribution and would be included in the sample. The strategy of surveying anglers about consumption of fish from all flowing waters definitely overestimates the average consumption from any single river section downstream from a kraft mill, and is very likely to overestimate the upper tail of the fish consumption distribution. In turn, the consumption level of highly exposed individuals would be contained within the estimated distribution of fish consumption.

The decision to survey anglers regarding all of their fishing effort on flowing waters is illustrative of the imperfections in technical data used in risk assessments. The method of treating this specific imperfection explicitly overestimates the entire fish consumption distribution. The survey data also contain inherent imprecision; i.e., when individuals are asked to recall factual data, a recall bias enters as the recall period lengthens. In particular, Westat (1989) found that anglers tend to overreport their activity as the recall period is lengthened (see also Chu et al. 1992). Overreporting can be due to the proverbial "big fish story" and a blurring of events in the respondents' minds, e.g., including consumption of fish caught on standing waters (lakes and ponds).

The survey of licensed anglers was conducted in the fall of 1990, and anglers were asked about all of their open water fishing effort during 1990. Open water fishing begins April 1 for rivers, brooks, and streams and closes September 30. Surveys were mailed to anglers in mid-October. The recall periods were five months for anglers who only fished in the beginning of the season and less than a month for anglers who only fished at the end of the season. The heaviest fishing effort in Maine is concentrated in the late spring and summer so the recall period for most respondents was two to four months. Results from the Westat (1989) study suggest that three month recall will reduce the over-reporting bias relative to annual recall, but will not completely remove recall bias from survey data.

Recall bias, if present in the fish consumption data, will occur throughout the estimated distribution, thereby leading to overestimates of the mean and upper percentiles of the distribution. Westat (1989) found that overreporting was most profound among activities with frequent participation. Thus, overreporting of fish consumption is likely to be most prevalent among avid anglers, skewing the entire distribution of fish consumption to the right.

Estimated consumption

Surveys were sent to a random sample of licensed resident anglers (ChemRisk 1992 and Ebert et al. 1994). Seventy percent of the surveys with addresses deliverable by the U.S. Postal Service were completed and returned to the researchers (a total of 1,612 surveys). For anglers who reported consuming fish caught from flowing waters, the median consumption rate was 1 gram per day per person (g/d/p), with a mean of 3.7 g/d/p and a 95th percentile of 12 g/d/p. Estimates are based on the assumption that the angler shares fish equally with other members of the household who eat freshwater fish. If, however, it is assumed that anglers consume all of the fish they catch, the median increases to 5 g/d/p and the mean increases to 15 g/d/p. The survey data, however, indicate that anglers do share their catches with other members of their households.

Fish consumption debate

The alternative fish consumption rate of 32.4 g/d/p was originally recommended by the Department of Human Services (Frakes 1990). (Fish consumption data for Maine were not available when Frakes wrote his report.) In the absence of regional fish consumption data, the U.S. Environmental Protection Agency recommends using a rate of 30 g/d/p for sport-caught fish (USEPA 1989b). The recommended number is an average of medians from studies of sport fishing in Commencement Bay in Washington (Pierce et al. 1981) and in the Los Angeles area (Puffer et al. 1983). The respective median consumption rates are 23 g/d/p and 37 g/d/p. Based on these medians, Frakes asserted that "a consumption rate of one fish meal (1/2 pound) of sport fish per week (32.4 g/d/p) (will) protect the majority of Maine fishermen and their families" (p. 20). In as much as Frakes made no mention of highly exposed individuals and referred only to the majority, he recommended a protection level slightly above what he presumed to be the 50th percentile of consumption of fish taken from waters downstream of kraft mills.

When compared to the data on freshwater fish consumption from all flowing waters in Maine from the Ebert (1993) study, the consumption rate of 6.5 g/d/p in the proposed rule represents the 92nd percentile of the fish consumption distribution. Given the built-in overestimation in the consumption data for Maine (consumption for all flowing waters and recall bias), it is very likely that 6.5 g/d/p is actually at or above the 99th percentile of fish taken and consumed from rivers below kraft mills. Thus, the proposed rule, with a consumption rate of 6.5 g/d/p, in all likelihood, would protect the most highly exposed individuals. Applying Frakes criteria to protect "the majority of Maine fishermen and their families" would imply a consumption rate of a little over 1 g/d/p (the median consumption rate). The consumption rate of 6.5 g/d/p supported by the kraft mills is based on a more conservative premise of protecting highly exposed individuals.

The debate between 6.5 g/d/p and 32.4 g/d/p may appear subtle, but the practical implications of these two consumption rates for kraft mills are substantial. The 6.5 g/d/p rate and the levels of the other variables in the risk assessment equation lead to a 0.5 ppq regulation, requiring kraft mills to continue to enhance their investments to reduce dioxin emissions. In contrast, the 32.4 g/d/p consumption rate and associated levels of the other variables in the risk assessment equation lead to a regulation of 0.01 ppq, which is purported to be below what is detectable with current technology. Adherence to a 0.01 ppq regulation would require kraft mills to stop using chlorine in their production process, thereby removing all dioxin.

Risk assessment issues

People apply subjective perceptions of probabilities when making decisions about risks, particularly human health risks. In a landmark study, Lichtenstein et al. (1978) found that "people do not have accurate knowledge of the risks they face" when evaluating "situations for which good estimates of true frequency exist" (p. 577). Lichtenstein investigated health risks and found people overestimate the likelihood of rare events, and also found that drama and vividness unduly influence overestimation of subjective perceptions of risks. These researchers state that "experts who guide and influence policies should be aware that when they rely on their own experience, memory, and common sense, they, too, may be susceptible to bias" (p. 577).

The Lichtenstein results are supported by recent research I conducted of resident moose hunters in Maine. A total of 900 permits are issued to hunt moose each year, and 1.3 percent of the applicants for a permit are actually selected in the lottery. The lottery has been an annual event since the early 1980s, and substantial information is present on the lottery each fall by the mass media. I surveyed individuals who participated in the hunt and found their subjective perception of the probability of being selected in the lottery is 16.2 percent (on average), more than an order of magnitude greater than the actual probability. We also surveyed hunters who applied for a permit and were not selected. These individuals reported an average subjective probability of 18.6 percent. Thus, overestimation of uncertain events even occurs when the parameters of the choice are relatively well known, the likelihood is not a small fraction of one percent, and human health concerns are not involved.

The concerns raised by the Lichtenstein study are problematic for citizen boards such as the BEP. Board members, like any other member of the public, are susceptible to overestimating the likelihood of rare events. Testimony before the board is often choreographed to be dramatic and vivid, exacerbating the tendency toward overestimation. In addition, BEP members are not necessarily experts on the technical information they must consider when making regulation decisions. BEP members are, however, well intentioned public servants who are presented with massive amounts of technical information that is often contradictory. If the BEP finds itself mired in the morass of technical information and becomes confused, or does not have time to fully consider the information, it is likely that members will resort to their own experience and common sense when voting on regulations.

The predisposition to overestimate risks can be exacerbated by the media. On February 18, 1993 the Bangor Daily News dedicated a page of the editorial section to two opposing views on the dioxin debate. The editors also placed a cartoon at the top of the page, with dioxin leaking from a barrel at the top of the state. The barrel from which the dioxin was leaking was nearly one-fifth the size of Maine and was leaking dioxin into the St. John river and flowing throughout the major rivers of the state. This cartoon portrayed a number of fallacies: dioxin is not stored in metal drums; the quantity of dioxin emission is not sufficient to cover one fifth of Maine; kraft mills are not located on the St. John, Allagash, Aroostook, East Branch of the Penobscot, Piscataquis, Narraguagus and Saco Rivers; and kraft mills are not located on the upper reaches of the Penobscot and Kennebec Rivers. The cartoon was vivid and dramatic, exactly the type of information that leads to overestimation of low probability events. Although many people

recognize cartoons are distorted (e.g., the large barrel of dioxin in relation to the size of the state), most of the information in the cartoon was incorrect, not exaggerated.

The fish consumption debate

The fish consumption arguments in the dioxin case illustrate the potential to substitute intuitive reasoning for objective information. Specifically, the Natural Resources Council argued, based on Frakes report, that one fish meal per week is a reasonable consumption estimate. Logical intuition can lead one to conclude that many people fish, many people catch fish, many people eat fish, and many people eat a lot of fish, so there must be someone who eats a very large amount of fish taken from Maine rivers below a kraft mill. This logic is appealing and leads to a perception of extensive human exposure and perhaps subjective overestimation of risks from consuming freshwater fish caught in Maine.

While 1/2 pound of fish per week seems reasonable at face value, consideration of the larger context is required. The consumption rate of 32.4 g/d/p, or 1/2 pound per week, converts to 87 pounds of whole fish per year. This consumption rate takes into consideration that only 30 percent of a whole fish is edible (USEPA 1989a). An angler would have to catch and consume 324 brook trout, or 86 smallmouth bass, the most popular coldwater and warmwater species, from flowing waters to sustain consumption of 1/2 pound per week (Boyle et al. 1989). Because the angler's catch is shared with others, the actual harvest would have to exceed these numbers. An angler would have to catch and personally consume an average of about two brook trout per day, or catch and consume one smallmouth bass every other day, throughout the open water season to consume 87 pounds of whole fish from flowing water (two fish meals per week during the open water season). In contrast, the 6.5 g/d/p consumption rate converts to 17.4 pounds of whole fish per year (65 brook trout or 17 smallmouth bass), less than one fish meal every other week from flowing waters.

The Department of Inland Fisheries and Wildlife estimated that the average angler caught 3.1 fish from all flowing waters during the 1983 open water season and kept 1.9 fish (Fenderson 1985). Again, because the data are for all flowing waters, the figures substantially exceed catch data for river segments below kraft mills. Seventy-four percent of all fish kept from flowing waters were brook trout and three percent were smallmouth bass. The only other species with a higher harvest than smallmouth bass was white perch (10 percent of the total harvest from flowing waters). Sixty-five brook trout (associated with the 6.5 g/p/d consumption rate) exceeds the 99th percentile of the Department of Inland Fisheries and Wildlife's harvest data for all flowing waters. The factual data on exposure, and corroboration with data from the Department of Inland Fisheries and Wildlife, simply does not support the assertion, nor perception, of substantial exposure.

The risk assessment dilemma

If the public has difficulty assessing risks, and the BEP is a citizen board that is subject to the same problems, is there a better way to make decisions about risks? Some people have advocated experts should not only conduct risk assessments, but also make decisions about management of

risks. But Lichtenstein (1978) argues that experts can also be prone to subjective perceptions of risk that are incompatible with the true likelihood of the actual events.

In a study of public risks, Lindell and Earle (1983) surveyed environmentalists, urban residents, people who live in communities with hazardous waste facilities, science writers, nuclear engineers and chemical engineers about their willingness to live and work within 10 miles of various types of power plants and hazardous waste facilities. They found 88 percent of nuclear engineers, 61 percent of chemical engineers and 22 percent of urban residents were willing to live within a 10 mile radius of a nuclear power plant. When a coal-fired power plant was considered, 48 percent of nuclear engineers, 84 percent of chemical engineers and 56 percent of urban residents were willing to live within 10 miles of such a facility.

Two key findings arise from the Lindell and Earle study. Experts, as might be expected, are more confident about risks in their own area of expertise than they are for alternative technologies. The public (urban residents in the study) were less confident about risks than were experts for each technology. But moving to an expert-dominated decision framework is unacceptable because experts, when evaluating risks outside their area of expertise, appear to be subject to the same foibles of applying subjective perceptions of risk as are encountered for the public at large. Risk assessments are personal decisions based on the extent to which individuals are willing to accept exposure to health risks. Experts, by the nature of their professions, represent self-selected groups who are willing to accept higher degrees of exposure to certain risks than are other groups within society.

Associated issues

To my knowledge, the "acceptable risk" variable in the proposed rule and the alternative proposal supported by the Natural Resources Council of Maine are not based on any survey of consumers of fish from Maine's rivers, licensed anglers or residents of Maine. A question arises as to what risk consumers of freshwater fish and Maine residents are willing to accept. The rule-making process does allow one balance for this concern. The BEP, as trustees to protect public health, provide their own assessment of acceptable risk when making individual decisions of how to vote on the proposed regulation.

A second issue involves regulation of choice versus nonchoice exposure to risks. Anglers have ample opportunities to fish inland waters in Maine that are free of dioxin and other contaminants. The mainstem sections of rivers below kraft mills comprise less than one percent of all flowing waters in Maine. Exposure to dioxin through consumption of sport-caught fish, therefore, is a choice of the angler/consumer. In contrast, exposure to hazardous substances in the work place may not be viewed as a choice, because individuals may not have opportunities to switch to alternative jobs. The question for decision makers is how much effort should be involved in regulating choice versus nonchoice exposures to hazardous substances.

Regulation of low probability risks can be extremely costly (e.g., forcing kraft mills to stop using chlorine to bleach paper) and a question that should be asked is at what point do the costs of protection become excessive. In the case of nonchoice exposure in the work place, protecting the most highly exposed individuals may make perfect sense. However, when exposure is choice-

based, as with consumption of fish from sections of rivers below kraft mills, the question is whether public education (e.g., fish consumption advisories) is warranted as a less costly step to ensure scarce resources are available to address nonchoice risks.

The third problem arises because the U.S. Environmental Protection Agency allows states to implement state-level dioxin regulations. This policy has two complications. Two states may share a border, with a river from one state flowing into the other state, e.g., the Androscoggin River flowing from New Hampshire to Maine. New Hampshire has a kraft mill in Berlin and the dioxin regulation there is 1.0 picogram per liter, while the proposed regulation for Maine was 0.5 picograms per liter. The protection level for the Androscoggin River in Maine is stricter than allowable upstream waste-water emissions in New Hampshire. In addition, when kraft mills in other states do not have to comply with regulations that are as strict as Maine's, all other factors being equal, Maine kraft mills are placed at a competitive disadvantage. Some mills may close and others may reduce production. Even within a single company, a Maine mill might be closed or have production reduced while production is increased at a mill in another state with a less stringent dioxin regulation.

There may be hope for Maine and New Hampshire to negotiate a common dioxin regulation to solve the transboundary pollution problem. It is unrealistic, and perhaps inappropriate, to expect Maine to negotiate equivalent dioxin regulations with all other states that have kraft mills. This is an area where guidance from the U.S. Environmental Protection Agency is warranted to avoid either mills in some states being unduly penalized to protect public health or public health being unduly exposed to risk to protect the competitiveness of some mills.

Summary

The BEP deferred a decision on the proposed dioxin regulation pending the U.S. Environmental Protection Agency's review of the toxicity of dioxin. Their deferment could be viewed as an indication that the BEP is open to additional information that may help them to understand the risks associated with human exposure to dioxin. A more skeptical perspective would view the delay as removing the BEP from the "hot seat" by not making a decision; no one clearly loses and no one clearly wins.

The BEP hearing process presents a unique opportunity for managing risks. The BEP, as a citizen board, insures that a small, self-selected group of experts does not impose its preferences on society as a whole. Simultaneously, the experts through their testimony are able to educate the BEP about the risks associated with approving, approving with modification, or rejecting a proposed regulation. The success of the public hearing process depends on the ability of the BEP to avoid overestimating the risks associated with human exposure to toxic substances. To fulfill its mission, the BEP must understand both risk assessment and also the tactics that are used by various parties when testifying to influence the BEP's subjective perceptions of risks. The education effort that Lichtenstein advocates to help the "citizenry to make reasonable public-policy decisions about societal risks" (p. 577) could be applied to the BEP, albeit on a less grand scale than educating the public at large.

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Endnote

1. Information was recently presented that dioxin bioaccumulates in the liver of lobsters. Since I do not have direct access to this data, I will not discuss this exposure pathway.

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