Idaho Fish Consumption Rate and Human Health Water Quality Criteria—Discussion Paper #7

Risk Management and
Protection of Human Health

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Introduction

An important function of ambient water quality criteria is to manage the risk associated with chemicals that are released into the environment through human activity in such a way that human health is protected. This paper will consider the nature of risk and how risk is determined to be acceptable, or not.

What does health protectiveness mean in the context of ambient water quality criteria? Does it mean prevention of exposure? Does it mean prevention of excessive risk? It is not possible to eliminate exposure to chemicals in our environment. Industrial processes lead to the discharge of chemicals into water bodies, and municipalities also unavoidably discharge chemicals. If it is unreasonable to expect that discharges can be reduced to zero, then the goal must be to limit the release of those chemicals that have the potential to adversely impact human health so that exposure, and the potential for adverse effects (risk) is reduced as much as feasible. To understand how chemical exposure is related to risk, it is helpful to consider separately chemicals that can cause cancer (carcinogens) and chemicals that are associated with other kinds of adverse health effects (noncarcinogens). The latter category will be addressed first.

Health Risk from Exposure to Noncarcinogenic Chemicals

For each noncarcinogenic chemical that has a human health criterion, there is a level of exposure, called the reference dose (RfD), that is considered to be without risk of adverse health effects for prolonged exposure. The following is the US Environmental Protection Agency (EPA) definition of reference dose:

> An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. (EPA 2014)

There are several things to note in this definition. One is that there is uncertainty in the dose estimate and that uncertainty factors have been used in an attempt to address this uncertainty. The effect of the uncertainty factors is to lower the RfD so that risk is not underestimated. Another point is that any human population has sensitive subgroups because individuals can have different responses to chemicals based on a number of factors, including age, genetic differences, gender, nutritional status, and various diseases. Because individuals differ in their innate sensitivity, and therefore their risks are variable with a given exposure, it is necessary to build conservatism into the RfD to reduce the likelihood of sensitive individuals having unacceptable risk. Some individuals will necessarily have higher risks than others at any concentration above the RfD because of these innate differences in sensitivity.

Relative Source Contribution

Because individuals are exposed to chemicals from multiple sources through various media (e.g., air, water, food, soil), the human health equation for noncarcinogens incorporates a term called the relative source contribution (RSC). The RSC accounts for non-surface water or fish contributions to exposure so that the acceptable exposure (RfD) is not exceeded when water-based exposure is added. The RSC can be expressed as a chemical-specific percentage. However, because available information is insufficient to quantify exposure contributions from all other

sources, regulators typically use a default value of 20% for all chemicals. What this means is that only 20% of the RfD is allowed to come from surface water and fish ingestion. The default RSC may be very conservative (protective) for some chemicals (in that it overestimates total exposure) and less so for other chemicals.

Other media that may contribute to exposure include air, drinking water, soil, and food other than fish. If the fish consumption rate (FCR) surveys indicate significantly greater fish consumption in Idaho than assumed previously, the contribution from fish may represent a larger percentage of total exposure than 20%. Total exposure will necessarily be greater than 20% if a constant caloric intake is assumed. For example, if fish consumption increased by an order of magnitude, it is not reasonable to assume that it still represents 20% of total exposure.

The Florida Department of Environmental Protection (FDEP) has developed RSC values for noncarcinogenic chemicals lacking recommended RSC values developed by EPA (FDEP 2014). Literature searches were performed for each major source of each chemical; these searches yielded information from the World Health Organization, the Agency for Toxic Substances and Disease Registry, the Centers for Disease Control and Prevention, EPA, and others. Where adequate data were available, the FDEP developed a number of chemical-specific RSCs between 0.2 and 0.81. (i.e.,20% and 80%). FDEP's analysis suggests that the default RSC of 20% may result in lower criteria than necessary for a number of chemicals. Idaho could potentially develop chemical-specific RSC values following a similar process, but this process would require a significant level of effort.

Health Risk from Exposure to Carcinogens

EPA considers that there is some risk with even the lowest exposure to carcinogens (i.e., there is no threshold exposure below which risk is zero). This assumption is in contrast to the approach with noncarcinogens, in which exposure at levels below the RfD is assumed to be safe. To establish regulatory criteria for carcinogens, the level of acceptable risk must be determined.

Chronic exposure to carcinogenic chemicals is associated with an increased likelihood of developing cancer at some point in an individual's lifetime. This likelihood is sometimes referred to as the incremental excess lifetime cancer risk. That increased likelihood is expressed as a probability, such as one in one thousand, expressed as 1×10^{-3}, or one in one million (1×10^{-6}) risk above the "background" risk of developing cancer. According to the American Cancer Society (2014), the lifetime risk of developing cancer from all causes in the United States is currently greater than one in three for females (37.81%) and almost one in two (44.31%) for males. Among causes, hereditary factors account for 20–25% of cancer cases, tobacco for 30%, and the combination of poor nutrition, physical inactivity, and obesity for 35%. Relatively small percentages are thought to be caused by exposure to carcinogenic agents: 4% from occupational exposures and 2% from environmental pollutants (man-made and naturally occurring).

Acceptable Risk

Because exposure to surface water or any other media cannot be risk-free, the challenge is to find some level of risk that most people will find acceptable. The risk that society considers acceptable is the basis for setting many environmental standards and clean-up levels. The

following is a partial list of potential criteria for considering risk to be acceptable (adapted from Hunter and Fewtrell 2001):

- It falls below an arbitrarily defined probability.
- It falls below a level that is already tolerated.
- It falls below an arbitrarily defined attributable fraction of total disease burden in the community.
- The cost of reducing the risk would exceed the costs saved.
- The cost of reducing the risk would be better spent on other public health problems.
- The general public says it is acceptable.
- Public health professionals say it is acceptable.
- Politicians say it is acceptable.

Not all of the above are based solely on health risk; some clearly involve cost-benefit analysis.

For exposure to noncarcinogens, the situation is fairly straightforward. Risk (the term "hazard" refers to the likelihood of adverse health effects other than cancer) is considered acceptable if exposure to a chemical is lower than the RfD. The ratio of the estimated exposure to the RfD is called the hazard quotient (HQ). The HQ is the level of exposure to one or more chemicals from significant exposure pathways in a given medium below which it is unlikely for even sensitive populations to experience adverse health effects. If the HQ equals one or less, adverse health effects are not expected. As the HQ increases above one, confidence decreases that adverse health effects will not occur. Regulatory programs typically consider HQs of one or less to be acceptable.

For exposure to carcinogens, the risk-based point of departure for many environmental regulations is an arbitrarily defined probability of cancer. This point of departure is typically an excess risk of one in one million, or 1×10^{-6}. Risks at this level or lower are regarded as acceptable. Higher risks may or may not be considered acceptable, depending on the regulatory program involved. How did this particular risk level come to be identified by many as the upper limit of acceptable risk?

Origin of 1×10^{-6} as Acceptable Risk

It is surprisingly difficult to pin down the origin of 1×10^{-6} as a criterion of acceptable risk (Kelly and Cardon 1991). The concept of 10^{-6} was originally developed by the US Food and Drug Administration as a screening level of "essentially zero," or *de minimus* risk—in other words, a level of risk considered below regulatory concern.

The Federal Food, Drug, and Cosmetics Act of 1938 required manufacturers to prove their products were safe before they could sell them. The act was amended to include a series of laws addressing food additives in 1958 and color additives in 1960. The Food Additives Amendment of 1958 established the designation of "generally recognized as safe," which refers to chemicals that can be used as food additives without further evaluation because they have long been used and are generally accepted for use. New chemicals require testing. The Delaney Clause is a provision in the amendment that prohibits human food additives found to induce cancer in animals. Therefore, the testing of new chemicals must evaluate their potential to cause cancer.

The Delaney Clause was modified in 1962 to permit the US Food and Drug Administration (FDA) to approve the use of carcinogenic compounds in food-producing animals if those chemicals are not passed on to humans. The modification, called the Diethylstilbesterol (DES) Proviso, was named for a hormone approved in 1954 to promote growth in cattle and sheep. It was also thought to prevent miscarriages in women but was later linked to vaginal tumors in the daughters of women who were treated by the drug during pregnancy. Under the DES Proviso, the FDA could approve a carcinogen for use in food animals if the residue remaining in edible tissues was so low that it presented insignificant risk to consumers. (The use of DES was banned in animals and people in the 1970s, but the DES Proviso is still in effect.)

A regulatory concern at the time was that existing analytical methods were not sensitive enough to measure concentrations in foods that were very low but still unsafe. The development of methods with lower detection limits led to a 1987 regulation called the sensitivity-of-method procedures. The regulation defines an insignificant risk of cancer as a one in one million (1×10^{-6}) increase in risk and specifies how to measure the residue concentration. In adopting a threshold of safety, the FDA cited Mantel and Bryan (1961) who observed that, in defining the parameters of safety testing, it is first necessary to define “safety.” For purposes of discussion, they had assumed “safe” to be equal to 1 chance in 100,000,000 of developing cancer. Mantel was asked how they had arrived at this figure and he replied “We just pulled it out of a hat” (Kelly and Cardon 1991). Apparently they picked it simply as an example of a risk level that most people would consider to be the same as zero. The FDA initially adopted this probability in their Federal Register notice of the draft regulation but changed it to 1 in 1,000,000 by the time the final rule was issued; thus, 1×10^{-6} became the “lifetime risk that is essentially zero.” Below this level there would be no regulatory concern regarding the safety of residues of carcinogenic animal drugs in food for humans.

At some point, a level of risk that was considered to be “essentially zero” has come to be identified for many as a maximum level of acceptable risk. Given that a complete absence of risk is impossible and that 1×10^{-6} is an arbitrarily chosen risk level, it is reasonable to expect that different risk levels may be considered acceptable in different situations, for a variety of reasons.

Regulatory Interpretations of Acceptable Risk

The National Oil and Hazardous Substances Pollution Contingency Plan provides guidelines and procedures for the Superfund program. According to the plan, EPA's risk reduction goal is to reduce the threat from carcinogenic contaminants such that, for any medium, the excess risk of cancer to an individual exposed over a lifetime generally falls within a range from 10^{-6} to 10^{-4}. EPA's preference, all things being equal, is to select remedies that are at the more protective end of the risk range. Thus, the point of departure for developing site-specific media clean-up standards should generally be 10^{-6}. For noncarcinogens, the HQ should generally not exceed one.

It appears then that a range of risks can be considered acceptable, but there is a bias toward being more protective (i.e., cleaning up contamination to lower concentrations so that risk is lower). However, the following is taken from guidance on Superfund remedy selection. It suggests that remedial decisions are often made at the upper (less protective) end of the risk range, and that even the upper end of that range is not necessarily fixed. A number of criteria in addition to protectiveness, such as implementability and cost, are used in the analysis of remedial

alternatives. A selected alternative must be protective, but that does not mean that it must have the lowest risk of available alternatives.

> In the absence of ARARs [applicable or relevant and appropriate requirements], remedies should reduce the risks from carcinogenic contaminants such that the excess cumulative individual lifetime cancer risk for site-related exposures falls between 10^{-4} and 10^{-6}. The Agency has expressed a preference for cleanups achieving the more protective end of the risk range (i.e., 10^{-6}). (NOTE: The upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions.) For non-carcinogens, remedies generally should reduce contaminant concentrations such that exposed populations or sensitive sub-populations will not experience adverse effects during all or part of a lifetime, incorporating an adequate margin of safety (i.e., a hazard index at or below one). (EPA 1997)

The risk range provides flexibility in Superfund remedial decision-making. Underlying its creation and use is the understanding that a range of residual risks following remediation of a site can be considered health-protective.

A similar flexibility is indicated in Clean Water Act guidance. The following discussion from EPA (2000) is particularly relevant to the current task of defining a level of protectiveness:

> For deriving 304(a) criteria or promulgating water quality criteria for States and Tribes under Section 303(c) based on the 2000 Human Health Methodology, EPA intends to use the 10^{-6} risk level, which the Agency believes reflects an appropriate risk for the general population. EPA's program office guidance and regulatory actions have evolved in recent years to target a 10^{-6} risk level as an appropriate risk for the general population. EPA has recently reviewed the policies and regulatory language of other Agency mandates (e.g., the Clean Air Act Amendments of 1990, the Food Quality Protection Act) and believes the target of a 10^{-6} risk level is consistent with Agency-wide practice.
>
> EPA believes that both 10^{-6} and 10^{-5} may be acceptable for the general population and that highly exposed populations should not exceed a 10^{-4} risk level. States or Tribes that have adopted standards based on criteria at the 10^{-5} risk level can continue to do so, if the highly exposed groups would at least be protected at the 10^{-4} risk level. However, EPA is not automatically assuming that 10^{-5} will protect "the highest consumers" at the 10^{-4} risk level. Nor is EPA advocating that States and Tribes automatically set criteria based on assumptions for highly exposed population groups at the 10^{-4} risk level. The Agency is simply endeavoring to add that a specific determination should be made to ensure that highly exposed groups do not exceed a 10^{-4} risk level. EPA understands that fish consumption rates vary considerably, especially among subsistence populations, and it is such great variation among these population groups that may make either 10^{-6} or 10^{-5} protective of those groups at a 10^{-4} risk level.
>
> Therefore, depending on the consumption patterns in a given State or Tribal jurisdiction, a 10^{-6} or 10^{-5} risk level could be appropriate. In cases where fish consumption among highly exposed population groups is of a magnitude that a 10^{-4} risk level would be exceeded, a more protective risk level should be chosen. Such determinations should be made by the State or Tribal authorities and are subject to EPA's review and approval or disapproval under Section 303(c) of the CWA.
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> Adoption of a 10^{-6} or 10^{-5} risk level, both of which States and authorized Tribes have chosen in adopting water quality standards to date, represents a generally acceptable risk management decision, and EPA intends to continue providing this flexibility to States and Tribes. EPA believes that such State or Tribal decisions are consistent with Section 303(c) if the State or authorized Tribe has identified the most highly exposed subpopulation, has demonstrated that the chosen risk level is adequately protective of the most highly exposed subpopulation, and has completed all necessary public participation. States and authorized Tribes also have flexibility in how they demonstrate this protectiveness and obtain such information. A State or authorized Tribe may use existing information as well as collect new information in making this determination. In addition, if a State or authorized Tribe does not believe that the 10^{-6} risk level adequately

> protects the exposed subpopulations, water quality criteria based on a more stringent risk level may be adopted. This discretion includes combining the 10^{-6} risk level with fish consumption rates for highly exposed population groups.
>
> It is important to understand that criteria for carcinogens are based on chosen risk levels that inherently reflect, in part, the exposure parameters used to derive those values. Therefore, changing the exposure parameters also changes the risk. Specifically, the incremental cancer risk levels are relative, meaning that any given criterion associated with a particular cancer risk level is also associated with specific exposure parameter assumptions (e.g., intake rates, body weights). When these exposure parameter values change, so does the relative risk. For a criterion derived on the basis of a cancer risk level of 10^{-6}, individuals consuming up to 10 times the assumed fish intake rate would not exceed a 10^{-5} risk level. Similarly, individuals consuming up to 100 times the assumed rate would not exceed a 10^{-4} risk level. Thus, for a criterion based on EPA's default fish intake rate (17.5 g/day) and a risk level of 10^{-6}, those consuming a pound per day (i.e., 454 grams/day) would potentially experience between a 10^{-5} and a 10^{-4} risk level (closer to a 10^{-5} risk level). (Note: Fish consumers of up to 1,750 g/day would not exceed the 10^{-4} risk level.) If a criterion were based on high-end intake rates and the relative risk of 10^{-6}, then an average fish consumer would be protected at a cancer risk level of approximately 10^{-8}. The point is that the risks for different population groups are not the same. (EPA 2000)

Thus, it appears that EPA considers a range of 10^{-6} to 10^{-5} to be appropriate for state water quality criteria, as long as highly exposed subpopulations do not exceed a risk level of 10^{-4}. The reference to the criterion being "based on high-end intake rates" in the previous paragraph relates to the population statistic on which the criterion FCR is based, in this case, an upper percentile of the FCR distribution. Alternatively, we could choose to base the criterion on the mean FCR. If we make the simplifying assumption, for explanatory purposes, of a normally distributed FCR, half of the population would have higher risk and half would have lower risk. If instead we based the criterion on an upper percentile of the FCR distribution (e.g., the 90th percentile), the majority of individuals in the population would have lower risk at the criterion, while a small percentage would have higher risk because of higher consumption. As the discussion in EPA (2000) indicates, individuals will always have different risk levels regardless of the FCR distribution statistic on which we choose to base the criterion.

Several decisions must be made that ultimately affect the criteria: (1) the percentile of the FCR distribution (e.g., 50th, 90th, 95th) on which to base the criteria, (2) the risk level on which to base those criteria (e.g., 10^{-6} or 10^{-5}), and (3) the highest acceptable risk for a subpopulation or individual (10^{-4} or some other risk level). If an upper percentile of the FCR distribution is used (e.g., 90th percentile) with a criteria risk level of 10^{-5}, more individuals will exceed 10^{-5} risk than if a criteria risk level of 10^{-6} is selected. High-consuming subpopulations should be protected if the 99th percentile FCR does not result in risk exceeding 10^{-4}. However, it is still possible for an individual to have higher risk if that individual has a very high FCR.

It is helpful to put the relative individual risks in perspective, as the excerpt from EPA (2000) does above. For another hypothetical example, assume a state decides to base criteria on an FCR of 175 grams (g) per day—because the survey results indicate that value is the 90th percentile of the state's overall FCR distribution—and on a risk level at this FCR of 1×10^{-6} (or for noncarcinogens an HQ of 1). An individual who consumes 175 g/day would have 1×10^{-6} risk from each carcinogen present in the consumed fish, and at an HQ of 1 for each noncarcinogen, that individual should not experience adverse noncancer health effects. If a member of a higher fish consuming subpopulation consumes 205 g/day, that individual would have a 1.17×10^{-6} risk from that carcinogen (205/175 = 1.17). This risk is higher, but not significantly so. EPA

convention for reporting risk is to use one significant figure, because of the overall uncertainty in any risk estimate, so both risks would be considered 1×10^{-6}. The noncancer HQ would be greater than one, but by a small margin. These risk levels address exposure to individual chemicals only. Exposure may occur to multiple chemicals; the following section addresses the implications of this situation.

Cumulative Risk

Some regulatory programs, such as Superfund, address cumulative risk from exposure to multiple contaminants, and the acceptable risk range applies to this total risk. Water quality criteria do not address cumulative risk. If criteria for carcinogens are based on a risk of 1×10^{-6}, and if an individual is exposed to multiple carcinogens at their criteria concentrations, the total cancer risk experienced by that individual will be greater than 1×10^{-6}. The same is true for noncarcinogens, if they have the same target organs or similar mechanisms of toxicity. If exposure occurs to two chemicals, each at a concentration equal to an HQ of one, the actual HQ will be greater than one. This situation presents an argument for conservatism in setting criteria, favoring lower risk levels.

Other factors also favor conservatism in setting criteria. Many waterborne chemical exposures are not addressed by criteria. Some chemicals that have the potential to interfere with normal functioning of the endocrine system, including pharmaceuticals and personal care products, do not have criteria. In addition, many chemicals reach waterways by means of nonpoint sources (e.g., agricultural run-off) rather than through permitted discharges. Many of these chemicals have the potential to contribute to cumulative risk from consumption of water and fish.

Voluntary versus Involuntary Risk

We all experience numerous risks in everyday life. One way these can be categorized is by whether they are voluntary or involuntary risks. Examples of voluntary risks are those associated with driving, skiing, and tobacco use. Involuntary risks include exposure to pollutants in air or drinking water. It is well known that society generally tolerates voluntary risks more than involuntary ones (Star 1969).

The amount of contaminants in fish to which we are exposed is a function of the amount of fish we consume. There are risks associated with eating fish, as well as health benefits. Beyond a certain level of fish consumption, the risks become more significant, and given the availability of other healthy food choices, consuming large amounts of fish must be considered a voluntary risk. In some cases, the voluntary nature of fish ingestion risk is tempered by financial need or cultural factors. For subsistence fishers, it is a way to obtain a high quality protein source inexpensively. Native American cultural identity with fish harvest and consumption also casts the voluntary nature of the risk in a somewhat different light. Still, fish consumption is a voluntary behavior. While we do not have a choice regarding breathing air or drinking water, we do have choices in food consumption, albeit culturally constrained.

If a risk is voluntary, the question of individual responsibility arises. When voluntary behaviors lead to risk, to what extent is it the responsibility of the government to reduce that risk? When

regulatory efforts have reduced the risk associated with fish consumption to the extent possible, individual responsibility still plays a role in managing risk associated with fish consumption.

As Low as Reasonably Achievable (ALARA)

In the nuclear industry, there is a radiation safety principle called ALARA, which stands for "as low as reasonably achievable." ALARA means minimizing radiation doses and releases of radioactive materials by employing all reasonable methods. In addition to being a sound safety principle, it is a regulatory requirement for all radiation safety programs. The ALARA definition from the Nuclear Regulatory Commission is as follows:

> ALARA means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. (10 CFR 20.1003)

The concept of ALARA has some significance to the development of water quality criteria. Most would agree that risk from exposure to pollutants should be minimized, but the question then becomes how much risk reduction is reasonable. In other words, there may be a point at which lowering criteria further imposes insurmountable implementation challenges. For criteria to function as intended there are limits to what is reasonably achievable in lowering risk. The challenge is to be as health protective as possible without going beyond those limits and to consider reducing exposure through other means, such as fish consumption advisories and direct toxics reduction efforts (e.g., reducing use of toxic chemicals and switching to less-toxic alternatives, where possible).

Conclusions

A number of decisions must be made in revising the Idaho human health water quality criteria; some of these are data-based, and some are policy-based. The policy decisions include the risk level on which to base criteria for carcinogens and the percentile of the FCR distribution (provided by the ongoing surveys) to associate with that risk level. It must be accepted that population risk is different than individual risk, and that any subpopulation or individuals with higher fish consumption will necessarily experience greater risk. Acknowledging that different people can have different positions on what is acceptable risk, what is reasonable, and what is achievable, the challenge is to develop "reasonably achievable" criteria that are protective for the general population and for high-consuming subpopulations, whose risk will be greater, but still acceptable.

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