COMMONWEALTH of VIRGINIA
Department of Health
KAREN REMLEY, MD, MBA, FAAP
STATE HEALTH COMMISSIONER
P O BOX 2448
RICHMOND, VA 23218
TTY 7-1-1 OR
1-800-828-1120

VIRGINIA DEPARTMENT OF HEALTH GUIDELINE FOR ISSUANCE OF FISH-EATING ADVISORY DUE TO CONTAMINATION OF FISH WITH MERCURY (REVISED 2012)

Pursuant to § 32.1-248.01, Code of Virginia, the Virginia Department of Health (VDH) "...shall develop a written policy, which shall be revised annually, that identifies the criteria and levels of concern for certain toxic substances that the Department will use in determining whether to issue a fish consumption advisory..." VDH currently maintains fish consumption guidelines for five fish contaminants, including dioxin, kepone, mercury, polychlorinated biphenyls, and polybrominated diphyenyl ethers. Mercury was included in the initial guidelines developed in 2000 because mercury persist in the environment, bioaccumulate in the food chain, affects the nervous system, and can permanently damage the brain, kidneys, and developing fetus at high exposure levels. VDH has recently revised its guidelines for calculating the concentration of mercury in fish for issuance of consumption advisories. The new guidelines will become effective November 1, 2012.

Rationale for the Revision of Guidelines

Previous mercury guidelines drafted in 2000 for consumption of fish were developed pursuant to § 32.1-248.01, Code of Virginia. At that time, VDH derived acceptable intake values of a contaminant in fish based upon several factors and assumptions from regulatory and non-regulatory state and federal agencies, including the Food and Drug Administration and the Environmental Protection Agency (EPA). The EPA recently released new factors and assumptions related to human behavior and characteristics that can be used to determine an individual's exposure to a contaminant. Exposure factors to consider include length of exposure, frequency of exposure, and population characteristics such as body weight, and amount of fish consumed during a meal. Depending upon these assumptions, one could derive several values, which fall within an extremely wide range differing by several orders of magnitude. For this reason, several states and federal government agencies differ in what they consider acceptable intake values.

After reviewing the updated factors and assumptions recommended by EPA, the only updated factor adopted by VDH for calculating the acceptable concentration of mercury in fish for consumption was the average adult body weight. VDH will now use 80 kg for the average adult body weight, whereas 70 kg was used previously.

Characteristics of Mercury

Mercury is a naturally occurring metal which is widespread and persistent in the environment. It exists in three forms: elemental or metallic mercury, inorganic mercury, and organic mercury.

Elemental mercury is a silver-white liquid at room temperature that vaporizes readily when heated. Inorganic mercury compounds occur when mercury combines with elements such as chlorine, sulfur, or oxygen. Most inorganic compounds are powders or crystals. Organic mercury compounds occur when mercury combines with carbon. One organic form of mercury, methylmercury, is produced when a carbon and three hydrogen molecules are attached to the elemental mercury. Methylmercury is of particular concern because it can accumulate up the food chain in aquatic systems and lead to high concentrations in predatory fish which may be caught and eaten.

Uses of Mercury

Elemental mercury is used in thermometers, thermostats, switches, barometers, batteries, dental amalgam, and other products. Inorganic mercury compounds are commonly used in electrical equipment (e.g., switches and lamps), and in medicinal and skin care products, such as antiseptic creams and ointments. Organic mercury compounds are used in industry as pigments in paints and as fungicides.

Sources of Mercury in the Environment

Mercury is released to the environment by both natural sources and human activities. Most of the mercury in air, water, and soil is inorganic mercury. This inorganic mercury can enter the air from deposits of ore that contain mercury, from burning fuels or garbage, and from emissions by factories that use mercury. Inorganic mercury may also enter water or soil from rocks that contain mercury, releases of water containing mercury from factories or water treatment facilities, and the disposal of wastes. Organic compounds of mercury may be released in the soil through the use of mercury-containing fungicides. Metallic mercury can evaporate easily into the air and be carried a long distance before returning to water or soil in rain or snow. Once mercury enters lakes, rivers, or oceans in any form, it is converted to methylmercury by microorganisms (bacteria and fungi) or by chemical reactions.

Fish absorb methylmercury directly from water and from eating smaller aquatic organisms that contain methylmercury. Although virtually all fish species contain at least trace amounts of methylmercury, larger predatory fish species have the highest concentrations. Methylmercury is tightly bound to proteins in all fish tissue, including muscle. There is no method of cooking or cleaning fish which will reduce the amount of mercury in a meal. Since almost all of the mercury in fish is in the form of methylmercury, the fish-eating advisory guideline is based on methylmercury.

Toxicity of Mercury

Evidence from human and animal studies indicates that the nervous system is sensitive to all forms of mercury. Exposure to high levels of all forms of mercury can permanently damage the brain, kidney, and developing fetus. Methylmercury is more harmful because more mercury in this form reaches the brain. Methylmercury is rapidly absorbed from the gastrointestinal tract (about 95%) and readily enters the adult and fetal brain where it accumulates and slowly converts to inorganic mercury. The exact mechanism by which mercury causes neurotoxic effects is not known, and data are not avail-available on how exposure to other forms of mercury affects methylmercury toxicity.

Acute high-dose exposure to methylmercury can result in adverse effects in several organ systems throughout the life span of humans and animals. Extensive data exist on the effects of methylmercury on the development of the brain in humans and animals. The most severe effects reported in humans were seen following high-dose acute poisoning episodes in Japan and Iraq. The outbreak of neurological dis- orders in Japan in the 1950s was attributed to the consumption of fish

contaminated with methylmercury. Industrial waste containing inorganic mercury had been discharged into Minimata Bay and was converted by microorganisms into methylmercury. This resulted in contamination of fish, a major food source to the surrounding population. In this incident 700 people died and approximately 9,000 suffered severe health effects. A similar epidemic of neurological disorders occurred in Iraq in 1971 as a result of con- sumption of contaminated food. In this case, flour was ground from grain treated with methylmercury fungicide. This incident affected more than 6,000 people. The health effects on brain functioning included irritability, mental retardation, shyness, tremors, cerebral palsy, deafness, and blindness in individuals who were exposed in utero, and sensory and motor impairment in exposed adults.

Chronic, low-dose prenatal methylmercury exposure from maternal consumption of fish has been associated with more subtle endpoints of neurotoxicity in children. Results from the three large epidemiological studies (the Faroe Islands, Seychelles Islands, and New Zealand studies) have added substantially to the body of knowledge on brain development following long-term exposure to small amounts of methylmercury. The Faroe Islands study reported associations between low-dose prenatal methylmercury exposure and children's performance on standardized neurobehavioral tests, particularly on the tests of attention, fine motor functions, confrontational naming, visual-spatial abilities (e.g., drawing), and verbal memory. The Seychelles Islands study did not report such associations. The New Zealand study also observed associations, as did the large pilot study conducted in the Faroe Islands.

There is evidence in humans and animals that exposure to methylmercury can have adverse effects on the developing and adult cardiovascular system (blood pressure regulation, heart rate variability, and heart disease). There is also evidence in animals that the immune and reproductive systems are sensitive targets for methylmercury. In 2000, the National Academy of Sciences (NAS) recommended a methylmercury reference dose (RfD) of 0.0001 milligrams per kilograms per day (mg/kg/day). The RfD is an estimate of a daily exposure to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Derivation of Acceptable Concentration of Methylmercury in Fish

The formula for calculating an acceptable concentration, corresponding to a recommended two meals per month of methylmercury in edible fish tissue, for protecting fish consumers from non-cancer health effects is as follows:

$$C = \frac{RfD \times BW \times T}{MS \times NM}$$

Where:

C = acceptable concentration of methylmercury in edible portions of fish in milligrams per kilograms (mg/kg).

RfD = reference dose (RfD) for methylmercury in milligrams per kilogram per day (0.0001 mg/kg/day).

BW = consumer adult body weight in kilograms (80 kg).

T = time period 30 days (days/month).

MS = average fish meal size of 8 ounces (oz) or 0.227 kg.

NM = number of allowable meals per month (2 meals/month).

Substituting for assumptions in the above equation, an acceptable methylmercury concentration of 0.5 mg/kg or 0.5 ppm in edible fish tissue was calculated:

$$C = \frac{0.0001 \text{ mg/kg/day} \times 80 \text{ kg} \times 30 \text{ day/month}}{0.227 \text{ kg/meal} \times 2 \text{ meals/month}}$$

$$= 0.528 \text{ mg/kg} \approx 0.5 \text{ mg/kg} = 0.5 \text{ ppm}$$

Various assumptions used in deriving the acceptable concentration are described as follows:

Concentration (C)

Acceptable concentration of methylmercury (mg/kg) in edible portions of fish tissue.

Reference Dose (RfD)

The RfD is an estimate of a daily exposure to the human population (including sensitive subpopulations) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Body Weight (BW)

The average adult body weight is widely accepted by many regulatory agencies for risk assessment and establishing guidelines and standards for chemical exposure. The current average adult body weight is 80 kg.

Time (T)

Time period (30 day/month) was used to calculate fish meal consumption limits in a 30-day period as a function of meal size.

Meal Size (MS)

Meal size is defined as the amount of fish (in kilograms) consumed at one meal. An 8-oz (0.227 kg) meal size was assumed.

Number of Meals (NM)

Number of meals consumption limit is expressed as the maximum allowable fish meals in a 30-day time period (meals/month). These are based on the total dose allowable over a 1-month period (based on the RfD).

Conclusion

Based on the above calculation, VDH would use 0.5 mg/kg or 0.5 ppm of methylmercury in fish as the trigger level for the issuance of a fish-eating advisory. VDH will use a four-tiered approach when issuing a fish-eating advisory.

- Average fish tissue concentrations ranging from non-detectable to below 0.5 ppm will not warrant issuance of a fish-eating advisory.
- When the average concentrations in fish range from 0.5 ppm to below 1 ppm, VDH recommends limiting consumption of contaminated species to two, 8-oz meals per month.

- When the average concentration in fish range from 1 ppm to below 2.0 ppm, VDH recommends limiting consumption of contaminated species to one, 8-oz meal per month.
- When the average concentrations in fish equal or exceed 2.0 ppm, VDH recommends that contaminated fish should not be consumed.

VDH also recommends that pregnant women, nursing mothers, and young children should not consume fish contaminated with methylmercury at concentrations above 0.5 ppm.

Prepared by: Dwight D. Flammia, Ph.D.
State Public Health Toxicologist
Division of Environmental Epidemiology
Virginia Department of Health
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Approved by: /S/
Karen Remley, M.D., M.B.A., F.A.A.P.
State Health Commissioner

Approved by: /S/
Maureen E. Dempsey, M.D., F.A.A.P.
Chief Deputy for Public Health

Approved by: /S/
David H. Trump, M.D., M.P.H., M.P.A.
Director, Office of Epidemiology

Approved by: /S/
Rebecca LePrell, M.P.H.
Director, Division of Environmental Epidemiology