Chapter 4 - EXPOSURE TO MERCURY

A. Introduction

Nationally, the most important source of exposure to any mercury compound is the consumption of fish. Certain populations may have occupational exposures and in certain areas of NJ consumption of water from private wells can be a significant source of mercury exposure (see Volume II Chapter 7). The extent of exposure to mercury from cultural uses is not known and such practices appear to be limited to specific communities. There has been a long history of occupational exposure to mercury, but nationally most significant occupational exposures have ended. While dental amalgams may be a significant source of exposure on an individual bases, the health implications of such exposures are unclear. This chapter therefore will largely emphasize exposure to methylmercury from fish consumption.

B. Mercury in Fish

1. Introduction

Mercury in fish was already recognized as a public health and ecological problem in the 1960's. It was commonly assumed that local point sources (industrial effluent, utility emissions, fungicide applications) were the main sources, and many studies focused on waters with nearby point source contamination. By the early 1980's there was convincing evidence of mercury contamination of water bodies remote from point sources of mercury emissions or effluent, calling attention to regional and global atmospheric deposition as the source of elevated mercury levels.

There is a huge amount of literature on mercury levels in fish from Eurasia and North America, much of it in peer reviewed journals but even more in the gray literature (e.g., agency reports; see references in Johnston et al. 1991) and more recently in unpublished data bases. The Concentration Factor (CF) (for higher trophic level fish vs. water) can be in the range of 10^5-10^6 (USEPA 1997e). The typical assumption is a one million-fold CF.

MeHg bioamplifies through aquatic food chains, and consumption of fish is the most important pathway for human exposure to MeHg. Most of the literature on Hg in fish reports only total Hg, but in most cases where the proportion of MeHg/total Hg has been measured in fish, MeHg comprises 90% or more of the total Hg. Most fish eaten by most people in the United States are purchased in supermarkets or fish stores (commercial fish), but recreational fishing is extremely popular and many anglers consume at least some of the fish they catch. A small percentage of the population relies on self-caught fish for a significant portion of their diet (subsistence fishing). The distinction between recreational and subsistence fishing is sometimes blurred (Burger et al. 2001b).

Gold mining practices throughout the developing world have resulted in increased exposure to elemental mercury (primarily occupational) and to methylmercury (e.g. de Jesus et al. 2001) in fish. Many South American tribes live along waterways and fish play important roles in their diets. Predatory fish have higher mercury levels than omnivorous or herbivorous species (Lacerda et al. 1994). In Rondonia, Brazil, sediment mercury levels were as high as 20 ppm, and levels in fish were up to 2.7 ppm (Pfeiffer et al. 1989). In French Guiana, 57% of tribal members had hair levels above 10 ppm and 14.5% of the fish exceeded 0.5 mg/kg. Amazonian Indians in two villages along the Rio Tapajos averaged about 25 ppm mercury in hair (maximum 151 ppm), while the average level in fish was 0.69

ppm (Malm et al. 1995). Even in North America where Indian tribes consume large quantities of fish, they may exceed tolerable daily intake levels (Marien and Patrick 2001).

2. Factors Influencing Mercury Levels in Fish

Factors influencing mercury levels can be divided into exogenous (characteristics of the waterbody) and endogenous (characteristic of the individuals or species). Exogenous factors include pH, sulfur and organic matter (e.g., dissolved organic carbon). Endogenous factors include species, habitat and food preferences, metabolic rate, age, growth rate, size, mass, and diet, (Jackson 1991).

Many studies have shown that concentrations of Hg in fish tend to be higher at low pH (Grieb et al. 1990; Cope et al. 1990), although acidity explained only a small portion of the Hg variability in some Russian lakes (Haines et al. 1995) and a high amount of variability (r = -0.93) in others (Haines et al. 1992). Yellow Perch had higher mercury levels in Wisconsin lakes with lower pH, and the Hg in Walleyes was positively correlated across lakes with the Hg in perch, their favored prey (Cope et al. 1990). Organic matter experimentally increases mercury accumulation in Yellow Perch (Johnston et al. 1991).

The mechanism(s) of the interaction---presumably an influence on uptake more than on methylation per se (Miller and Akagi, 1979) ---is still not clear at this time. At low pH, the formation of the MeHgCl rather than the MeHgOH is favored and this species is more readily absorbed by plankton. Acid Neutralizing Capacity of different lakes was also negatively correlated with Hg in Yellow Perch muscle from those lakes (Grieb et al. 1990).

Numerous studies have shown that within a species the larger, longer, and older fish have higher concentrations of mercury. However, the relationship varies among species. Faster growing species tend to have a flatter relationship due to a faster assimilation into tissue than accumulation of mercury (Huckabee et al. 1979).

Bache et al. (1971) characterized the increasing total Hg and MeHg in Lake Trout as a function of age. Mercury is positively correlated with age, length, weight of Yellow Perch (Grieb et al. 1990), but it increased more strongly with age in Northern Pike, White Sucker and Largemouth Bass (Grieb et al. 1990). Hg in liver and muscle but not gill tissue was positively correlated with fish size in Largemouth Bass (Jagoe et al. 1996).

3. Levels of Mercury in Commercial Fish

In the early 1970's a comprehensive database of mercury levels in 204 species of commercial finfish, mollusks, and crustaceans landed in the US was established by the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration, US Department of Commerce based on sampling of species intended for human consumption (Hall et al. 1978). Fish landed in foreign ports and transported to the US market were not represented. The number of individual fish sampled varied by species, but most species were represented by more than 10 samples. Total mercury concentrations were reported in range categories. In muscle tissue (the most commonly consumed part of fish) the highest observed Hg concentration was in the 4-5 ppm range. In finfish liver however, the highest observed mercury concentration was in the 10-20 ppm range. Of the catch intended for human consumption, 48% had mercury concentrations below 0.1 ppm, 41% had concentrations of 0.1-0.2 ppm and 11% had concentrations greater than 0.2 ppm. Tuna, the most commonly consumed fish, (muscle of various species) had concentrations ranging from 0.1 to 0.4 ppm.

Shrimp (various species) had concentrations ranging from less than 0.1 ppm to 0.2 ppm. Salmon (muscle of various species) had concentrations less than 0.1 ppm. Flounder (muscle of various species) had concentrations ranging from less than 0.1 ppm to 0.2 ppm (Hall et al.1978).

The overall average concentration (weighting the concentration mid-point for each concentration category by the percentage of the total catch intended for human consumption represented by that category) was 0.11 ppm. Among those species with the most highly elevated mercury levels, shark (muscle of various species) had concentrations ranging from 0.5 to 2.0 ppm and tilefish was in the range of 1.0-2.0 ppm. No data were reported for swordfish, a species which typically has high mercury concentrations. All of the above results are for total mercury and it is reasonable to assume that about least 90% of the amount was MeHg.

No comprehensive study of mercury in commercial fish has been reported since the NMFS study of the 1970's. This is a serious problem since there have been significant changes in fisheries due to overfishing. Fishing grounds have shifted, the species composition has changed, and the average sizes of fish are smaller. At the same time industrial point source releases have been reduced while air emissions from utilities have increased. Thus, the levels today could be different from levels of the 1970's. The USFDA did report on methylmercury concentrations in a smaller scale sampling of selected species (USFDA 1992). These samples did not represent the overall catch intended for human consumption, and many species are represented by a small number of individuals. However, this database does contain results from 99 samples of Swordfish revealing a mean MeHg concentration of 0.93 ppm. When the NMFS and FDA databases are compared for the 15 species for which at least three samples were reported in each database, the mercury concentrations in the FDA database are lower than that reported in the NMFS database for all but two species (shrimp and oysters). The mean ratio (FDA/NMFS) is 0.66 and the difference is statistically significant. There are several possible explanations for this difference. They include: data from 1970 was for total mercury and 1992 data was for methylmercury; species misclassification; reduction in average size of fish within a species; inter-laboratory variability; improvement in analytic technique with lowering of detection levels; and actual decline in mercury pollution.

Although all of these factors may contribute to the apparent decline, one of the most important differences is that in the approximately 20 years separating these databases, there has been widespread commercial over-fishing which has resulted in the landing of smaller and younger fish. For any given species, smaller fish tend to have lower Hg concentrations than larger ones.

In 1991, the USFDA conducted a survey of mercury levels in canned tuna from 18 FDA districts throughout the US (Yess 1993). Samples from 220 cans representing a selection of packing liquids, styles (e.g., chunk light, solid white, etc.), and can sizes were analyzed for MeHg. Although no formal statistical procedure was followed, the data appear to roughly reflect the availability and prevalence of the various choices. The mean MeHg concentration was 0.17 ppm (ranging from below 0.1 up to 0.75 ppm, with a 90th percentile concentration of 0.42 ppm). Of the various styles, chunk white had the highest average concentration (0.31 ppm), while chunk and chunk light had the lowest (0.10 ppm).

Given the existence of only two incomplete data bases and the lack of any systematic program for fish surveillance, the Task Force concludes that there is a serious lack of current

data on Hg levels in commercial fish nationally and locally. Accurate characterization of exposure and risk from MeHg intake, as well as appropriate consumption guidance, requires the systematic and regular collection of such data.

4. Levels of Mercury in Non-Commercial Fish

Fishing is one of the most popular outdoor recreational activities in the United States. The number of licensed fishermen in NJ is approximately 250,000, and since salt water fishermen need no license, it is conservative to estimate that 15% of the NJ population fish at least occasionally. Not only do fishermen eat more fish more often than the average member of the general public, but they often eat species that are usually not available commercially. Since this subset of the population consumes so much fish, it is likely to be at higher risk from any contaminants in the fish. Hence it is important to document mercury levels in sport fish. Subsistence fishermen likewise consume large amounts of fish, mostly species that are not commercially available. Even people who do not fish may receive and consume fish from friends and family members.

There are many papers and reports on Hg levels in fish. Studies differ widely in the number of water bodies, the number of species, and the number of individuals sampled. Many studies, particularly early studies, relied on pooled samples to provide cost-efficient statistical validity, at the expense of fully characterizing the statistical distribution of mercury in the sample. More recent studies have been more likely to analyze individual fish, as the instrumentation has improved.

Studies focused on risk to humans usually analyzed muscle or edible fillets. Research focused on risks to the fish themselves frequently analyzed liver, and sometimes kidneys, gills, or other tissue. Less frequently, whole fish would be analyzed to provide information on the accumulation of mercury up the food chain. Usually only small fish at lower trophic levels would be analyzed in their entirety.

Studies differ also in the parameters reported: arithmetic mean, geometric mean, median with or without percentiles, range and some studies report on a dry weight rather than wet weight basis. One of the most useful values, however, is seldom reported---the percent of fish of each species (and perhaps of each size or age class) that exceed specific mercury criteria (usually 0.5 or 1 ppm). The likelihood of excess exposure can be influenced by the proportion of fish exceeding the criterion, and the likelihood that such fish would be caught and eaten. If only 1 percent of fish exceed a level, one can be confident that the next fish meal will comprise low mercury fish.

For example, Gerstenberger et al. (1993) report the number of Walleye in the ranges of 0.5 to 0.74, 0.75-1.00 and greater than 1.00 ppm. Of 83 fish in 34 Wisconsin lakes, the grand mean mercury was 0.52 ppm, with individual lake means ranging from 0.29 to 1.0 ppm. In the lake with the highest mercury, two of three fish exceeded 1 ppm and, overall, 47% of the fish exceeded 0.5 ppm and 7% exceeded 1.0 ppm.

In 1984 and 1985, US Fish and Wildlife Service (USFWS) identified mercury concentrations in predatory fish species (e.g., trout, Walleye, Largemouth Bass) that were at nearly twice the level in bottom dwelling species (e.g., carp, catfish and suckers). EPA's National Study of Chemical Residues in Fish (NSCRF) study found the mean mercury concentration in bottom feeding fish species to be generally lower than the concentrations found in top level predatory species. In addition, the study revealed that the majority of the higher mercury concentrations

identified were in fish collected from the northeastern states. A 1998 NESCAUM report on mercury concentration in fish collected from northeastern states and eastern Canadian provinces found that the top level sport fish species, such as Walleye, Chain Pickerel, Largemouth Bass and Smallmouth Bass typically exhibited the highest mercury concentrations. Highest mercury concentrations were identified in a Largemouth Bass (8.94 ppm) and Smallmouth Bass (5.0 ppm).

The EPA's 2001 report, National Listing of Fish and Wildlife Advisories collected from 43 states provides a national mean mercury concentration for several predator and bottom feeding fish species. The national mean mercury concentrations for walleye, Largemouth Bass, Smallmouth Bass and Brown Trout are 0.52, 0.46, 0.34 and 0.14 ppm (wet weight) and 0.11, 0.11, and 0.09 ppm (wet weight) for Carp, White Sucker and Channel Catfish respectively.

In 1993, the US EPA, Office of Water generated a National Fish Tissue Data Repository (NFTDR). The NFTDR stores fish and shellfish tissue contaminants data submitted by state and federal agencies to EPA's Ocean Data Evaluation System (ODES). This system provides a means of retrieving, downloading and analyzing data stored from this system. Data for non-commercial fish species are available for every state. Table 2.4 summarizes mercury contaminant data for several popular freshwater gamefish species.

In January 2001, EPA released a new surface water criterion value for methylmercury. Whereas traditionally surface water criteria are based on analytic measurements of contaminants in water, this new criterion is based on the concentration of MeHg in fish tissue, due to the strong bioaccumulative tendency of MeHg in aquatic ecosystems. As a general rule of thumb, the ratio of MeHg in fish to MeHg in the same water column is about 1 million to 1. This criterion value of 0.3 μg/g (ppm wet

weight) is intended to protect human health. EPA expects the criterion to be used as guidance by states in updating water quality standards and in issuing fish and shellfish consumption advisories.

Table 2.4. Mercury Concentrations in Selected Fish (EPA/NFTDR 1993).

Species	State	Samp.	Range	Mean	Highest Lake
Chain Pickerel	North Carolina	50	0.02-1.90	0.5	White Marsh Lake
	Vermont	2	0.35-0.65	0.5	Lake Groton
	New Hampshire	22	0.13-0.84	0.38	Conway Lake
	Arkansas	1	-	1.17	Big Johnson Lake
	South Carolina	1	-	0.76	Flat Rock Pond
	Alabama	1	-	0.59	Little Escambia Creek
	Rhode Island	15	0.01-0.88	0.49	Yawgoo Pond
Largemouth Bass	Minnesota	17	.09-1.40	0.46	Orchard Lake & Pelican Lake
	Mississippi	1	-	1.21	Leaf River
Bluegill Sunfish	Wisconsin	205	0.02-0.58	0.13	Waccaman River
	Oregon	23	0.01-1.13	0.35	Cottage Grove Res.
	Kentucky	18	0.14-0.50	0.28	West Kentucky Lake
	Georgia	3	0.30-0.80	0.53	Satilla River
Yellow Bullhead	Maryland	1	-	0.11	
	Wisconsin	7	0.02-0.20	0.09	Henry Lake
	Arizona	6	0.34-0.89	0.52	Pena Blanca Lake

	South Carolina	2	0.44-0.49	0.47	Four Hole Swamp
	Ohio	7	0.06-0.41	0.23	Tuscarawas River
	Massachusetts	17	0.25-0.58	0.36	Upper Naukeg Pond
	Michigan	8	0.42-0.90	0.62	Selkirk Lake
	Minnesota	10	0.09-0.63	0.26	Bush Lake
Brown Bullhead	North Carolina	35	0.02-0.49	0.12	Big Creek
	New Hampshire	22	0.05-0.59	0.18	Monomomac Lake
	South Carolina	4	0.25-0.26	0.25	Langley Lake
	Ohio	4	0.03-0.12	0.07	Pine Creek
	Georgia	2	0.10-0.10	0.1	Ocmulgee Lake
	Oregon	8	0.45-0.71	0.56	Cottage Grove Res.
	New York	6	0.01-0.18	0.07	Moreau Lake
	Massachussetts	168	0.04-0.53	0.14	Wampanoaq Pond
	Michigan	27	0.05-0.67	0.24	Sisters Lake
	Rhode Island	12	0.04-0.31	0.1	Tioque Lake
	Minnesota	5	0.02-0.08	0.05	Winnibioshih Lake

Data on individual specimens, skin-on fillet, except for samples of bullhead (skin-off fillet)
Data reported in µg/g (parts per million) wet weight concentrations

5. Patterns of Fish Consumption and Advisories

The greatest number of fish consumption advisories issued by state agencies throughout the country are for mercury in recreational species of fish. EPA reports that almost 79 % of all the fish contaminant advisories issued were at least partly due to mercury and that the number of states issuing mercury-related advisories has steadily increased in recent years. In 1993, a total of 899 mercury advisories had been issued by 27 states. In 2000, a total of 2,242 fish consumption advisories for mercury were issued by 47 states. The increase in mercury advisories is largely attributed to an increased awareness of mercury impacts in the aquatic environment and an increase in fish monitoring programs throughout the states.

The amount of fish that people consume varies greatly from place to place and time to time. Fish consumption has increased in the United States over the past 50 years (Anderson and Rice 1993), partly due to health education messages and partly due to the increased availability of fresh and frozen fish in markets. In some countries (e.g., Japan, Seychelles) and some regions (Amazonian rivers), fish consumption rates are much higher on average than in the United States, however, even in the United States some people consume great quantities of fish (e.g., Burger et al. 1998). In a South Carolina study, for example, black fishermen averaged more than twice the fish consumption of white fishermen along the same river stretch (Burger et al. 2001). Understanding the statistical distribution of fish consumption is therefore important for risk assessment, regardless of whether the fish consumption is influenced by ethnicity, health considerations, or personal preferences.

Data on fish consumption patterns in NJ are provided in Chapter 9, Section B. These include stratified studies of New Jerseyans, a study of pregnant women, and several interview studies of fisherfolk.

Attempts to estimate fish consumption are subject to uncertainties (see discussion in Jacobs et al. 1998). Price et al. (1994) argued that "creel surveys" oversample frequent anglers and therefore overestimate the average fish consumption. They argued that instead of the EPA Guidance value of 30 g/day for anglers, a value of 2 g/day was more representative. Using

random-digit dialing, Stern et al. (1996) estimated that New Jerseyans had a mean fish consumption of 50 g/day and Burger et al. (1998) found a similar value (51 g/day) for fisherfolk in the NY-NJ Harbor.

Indeed, based on extensive interviews of fishermen along the Savannah River in South Carolina, Burger et al. (1999) reported that the EPA's criterion of 19 kg/year for recreational fishers was inadequate for estimating risk to high end consumers. They reported that fish consumption was 17.6 kg/year, but about half of the black fishers and about 30% of whites exceeded 19 kg/year, and 25% of blacks and 5% of whites exceeded the EPA's "subsistence" criterion of 50 kg/year with a maximum of over 100 kg/year. Median consumption rates were 51.8 and 35.2 g/day for black males and females, and 18.8 and 12.8 g/day for white males and females (Burger et al. 2001). The Hazard Quotient for mercury effects exceeded one for black males eating Bowfin and Largemouth Bass (median consumption) or most species (75th percentile of 131 g/day) consumption. White males consuming Bowfin and Bass at the 75th percentile (53.4 g/day) also exceeded an HQ of 1.0 (Burger et al. 2001).

6. Summary and Conclusions: Mercury in Fish

Nationwide, it appears that nearly all adults and most children eat at least some fish. The average fish consumer eats 1-3 fish meals per week (including canned tuna), but a significant fraction of the population eats five or more meals per week. The consumption by women of childbearing age is generally comparable to or lower than that of the general population. The frequency of consumption appears to have increased significantly since the 1970's, although lack of comparability of survey methods makes precise comparisons to recent trends difficult. Tuna and shrimp account for about half of the total fish consumption.

Based on data from the early 1970's, the average Hg concentration in muscle tissue in commercial fish in the US intended for human consumption was 0.11 ppm, and the most commonly consumed species generally had levels in the 0.1-0.2 ppm range. Tuna are generally in the range of 0.1-0.4 ppm. Higher trophic level fish often exceed 1 ppm. More recent data suggest that mercury levels in commercial fish may have declined over the past 20 years, perhaps reflecting reductions in industrial uses and releases of mercury or changes in size of fish harvested. Nonetheless, elevated levels of mercury are still found in commercial fish, commonly exceeding 1.0 ppm. The lack of regular and systematic sampling of commercial fish is a serious impediment to assessing and communicating the risk to fish consumers.

Mercury has been shown to enter the aquatic food chain very rapidly, and is readily bioaccumulated to elevated levels in many recreational sport fish. Fish at the top of the food chain, which are typically gamefish species, can bioaccumulate mercury to levels a million times greater than the mercury found in the surrounding water.

C. Other Sources of Exposure

1. Occupational Exposures to Mercury

A special exposure pathway involves occupational exposure, primarily through inhalation of elemental mercury. Mercury has had many industrial uses, for example in thermometers and electronic equipment, in batteries, as a liquid seal in vacuum pumps and gas regulators, as pigments, in amalgamation, and in biocides. Biocidal uses include common antiseptic

agents, vaccine preservatives, anti-fouling paint, and fungicides (particularly for seed dressings). Many of these uses have been greatly curtailed.

The main occupations in which exposure has been documented include mining, smelting, precious metal extraction by amalgamation, instrument manufacture, gilding using gold-mercury amalgam, manufacture of drugs and health products containing mercury, felting of fur, finger-printing with a mercury-chalk mixture, and dental work. The Renaissance alchemist and one of the fathers of toxicology, Paracelsus, described mercury poisoning in miners of quicksilver (liquid elemental mercury) in Idria, Yugoslavia in the 1550s (Hunter 1974). Ramazzini, the father of occupational medicine, wrote: "It is from mercury mines that there issues the most cruel bane of all that deals death and destruction to miners." (Ramazzini 1713). Ramazzini (1713) described the maladies of gilders exposed to mercury, "Very few of them reach old age, and even when they do not die young their health is so terribly undermined that they pray for death".

The biocidal properties of mercury were commonly exploited in anti-fouling paints for ship bottoms, but, except for naval vessels, this use has been replaced mainly by tributyltin, which is itself highly toxic to aquatic organisms. Mercury biocides are organic compounds that pose a risk to production workers and applicators. Mercury mining has caused frank mercury poisoning among miners. The fabrication, use, and disposal of mercurial products is also an important source of exposure. Dentists and technicians are highly exposed to mercury used in amalgam fillings which continue to be in widespread use as a dental restorative, although an increasing number of dentists are using other materials. Fulminate of mercury has been important as an explosive. Use of mercury in manufacturing thermometers has frequently been a source of elevated exposure. Mercury was most familiar as the indicator liquid in thermometers and barometers. Mercury vapor lamps, mercury switches, and mercury batteries were also widely manufactured and installed. Now spills of mercury from thermometer breakage or during replacement of gas meters have become a commonly recognized residential source of elemental mercury exposure. Mercury sulfide has been widely used as a red pigment, and mercurials were added to paints to cut down on mold.

The potent toxic properties of mercury resulted in several different medicinal uses. Physicians treated syphilis by rubbing liquid mercury into the skin of patients. The efficacy was dubious but the toxicity was certain, and the doctors suffered from the repeated exposure to mercury (Ramazzini, 1713). Likewise Ramazzini (1713) described the plight of mirror makers who learn "how malignant is mercury….Those who make mirrors become palsied and asthmatic from handling mercury….gazing with reluctance and scowling at the reflection of their own sufferings in their mirrors and cursing the trade they have adopted".

Alice Hamilton (1925), the founder of modern occupational medicine, described mercury poisoning in New Almaden, California, including sore mouth and gums, nervousness, irritability, insomnia and depression. During extraction of mercury from ore, workers experienced severe gum disease and loss of teeth, as well as the characteristic tremor. The Mad Hatter syndrome, made famous in Lewis Caroll's "Alice in Wonderland", was a manifestation of the mercury used as a corrosive in the manufacture of felt hats (Hunter 1974).

Although the vast majority of occupational exposure involves elemental or inorganic mercury, there is and has been significant exposure to organic forms, particularly in the manufacture, fabrication, and application of mercurial fungicides and additives to anti-fouling marine paints. Organomercurials have had many biocidal uses, particularly as

fungicides in agriculture. They have been used as antiseptics (e.g., mercurochrome, merthiolate) and as a preservative for vaccines and pharmaceuticals. These latter uses have been reduced. These compounds are highly toxic by the dermal route as well as by inhalation and incidental ingestion. Hunter (1974) describes many scenarios of death and morbidity in workers exposed to organomercurials during manufacture, storage, or application.

The widely accepted standard of 50 $\mu g/m^3$ in workplace air is intended to protect workers exposed for a 40-hour work week over a 40-year working lifetime. The National Institute for Occupational Safety and Health recommended a standard of 25 $\mu g/m^3$, and the American Conference of Governmental Industrial Hygienists (ACGIH) lowered its TLV to 25 $\mu g/m^3$. In the past, workplace levels have been reported to be much higher, and Bidstrup et al. (1951) reported levels of 1700 $\mu g/m^3$.

The newest group of exposed workers are those involved in the cleanup of mercury spills, the recycling of mercury products, and the remediation of hazardous waste sites containing mercury. Ideally, modern protective methods and industrial hygiene will prevent any significant exposure to such groups. However, in some cases huge quantities of mercury are encountered, such as the 260,000 pounds of mercury recently retrieved from the Holtra Chem chloralkalai plant which closed in Maine in 2000.

In the United States, most of the above mentioned uses ended long ago, while others such as the use of mercury in gas regulators, thermostats, and thermometers is just now being phased out. Mercury continues to be used in fluorescent and mercury vapor lamps. Mercury in batteries was greatly reduced during the 1990's. Increased awareness of the potential for exposure and health effects appears to be resulting in a decrease in exposure through industrial hygiene controls (ATSDR 1999a).

2. Dental Amalgams

Dental amalgams continue to be the most commonly used restorative material in dentistry in the United States. They typically contain about 50% elemental Hg (Hg^0) by weight (USEPA, 1997b). There is a lively controversy regarding the possible importance of dental amalgams as a source of mercury in people, and whether this source, measured in μg/day, is sufficient to prevent various diseases in sensitive individuals. The Task Force was not charged with investigating this controversy but applauds efforts to reduce this use and encourages the use of suitable substitute materials and preventive measures. Moreover, insurance policies that do not adequately pay for alternative restoratives create an unfortunate incentive for continued use of mercury and should be changed.

The use of mercury in dentistry continues to be a potential hazard for dental personnel, and the release of mercury from dental offices into the environment is covered extensively in Volume III of this report.

3. Thimerosal in Vaccines

The organomercurial, Thimerosal, commonly used as an antiseptic (merthiolate) has been used for decades to stabilize vaccines. Recent concern over whether the dose of organic mercury from vaccines might cause neurological conditions (for example, autism) in some sensitive individuals receiving vaccines in the neonatal period (particularly low birth weight premature infants), has led the Food and Drug Administration to require the elimination of Thimerosal as a preservative in biologics intended for infants. The Task Force did not

independently investigate this issue since the decision had already been reached by the FDA. Calculations indicated that the total amount of mercury that could be re-circulated into the environment by this route was negligible.

D. Recommendations

Expand and institutionalize routine monitoring for mercury in fish from NJ waters through State-level programs (From Recommendation "G" in Volume 1).

Actively encourage the federal government to initiate and maintain comprehensive monitoring and surveillance for mercury in commercial fish and to require that information regarding the mercury content of fish be made readily available. If the federal government does not initiate nation-wide evaluation of commercial fish, NJ should, with other states in the region, monitor mercury in commercial fish (From Recommendation "H" in Volume 1).

The federal government should re-instate and expand a comprehensive monitoring and surveillance program for mercury and other important contaminants (e.g., PCBs) with a statistically appropriate sampling strategy covering all of the commonly consumed fish sold in the United States, including documentation of the origin and sizes of the fish analyzed. The results of federal monitoring and surveillance programs for commercial fish should be provided to the public and to regulatory agencies in a comprehensive and timely fashion.

Research is needed to identify factors contributing to mercury concentrations in various species of fish representing diverse geographic regions and ecosystems, and linking such levels to the various known sources of natural and anthropogenic mercury.

A comprehensive database on taxonomic, spatial, and temporal trends in mercury (and other pollutant) concentrations in fish, should be established to provide an indicator of the success of current and future control measures and to identify new or expanding sources of mercury.

Studies of pollutant concentrations in fish should include mercury as well as organochlorines, as a substantial portion of the expense lies in the sampling, collecting, and specimen preparation.

Address critical information gaps concerning the quantities and chemical species of mercury emissions and releases, the fate and transport of mercury in the environment, and the exposure pathways. To accomplish this, NJ should:

- **Identify demographic characteristics and exposure patterns of population groups in NJ that consume large quantities of fish. (From Recommendation "M.4." in Volume 1).**

Systematic data collection on the patterns and trends in fish consumption should be established on a national level to provide important data on the species consumed, amount consumed, types of food preparation, as well as identifying the most highly exposed subgroups. Data should be collected and reported in a form that can be desegregated on a state-by-state basis. This survey should oversample high end consumers and should be repeated at least every 10 years to capture trends due to new information and changing demography.