HEALTH CONSULTATION

LOWER WATTS BAR RESERVOIR OPERABLE UNIT
U.S. DOE OAK RIDGE RESERVATION
OAK RIDGE, TENNESSEE

STATEMENT OF ISSUES

In March 1995, the U.S. Department of Energy (DOE) released a proposed plan for addressing contaminants in the Lower Watts Bar Reservoir. The plan presented the potential risk posed by contaminants and their preferred remedial action alternative. In the September 1995 Record of Decision for the Lower Watts Bar Reservoir, DOE selected the remedial action for the Lower Watts Bar Reservoir. The U.S. Environmental Protection Agency and the Tennessee Department of Environment and Conservation concur with the selected remedial action.

Some local residents were concerned whether DOE's remedial action will sufficiently protect the public health. These residents have asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health risk from the Lower Watts Bar Reservoir contamination and provide an independent opinion on whether the DOE's selected remedial actions are adequately protective of public health.

Consequently, we evaluated data on environmental sample analyses from the 1980's and 1990's and used worst case exposure scenarios to determine if current chemical and radiological contaminants levels could pose a health risk to residents of the area.

Our findings are as follows:

1. Polychlorinated biphenyls (PCBs) in Lower Watts Bar Reservoir fish are the only contaminants of public health concern. Frequent and long-term consumption of fish from the reservoir is not advisable because it poses a moderate increase in risk of cancer in adults and could possibly cause developmental effects in infants whose mother consumed reservoir fish regularly during pregnancy or while nursing. Turtles in the reservoir may also contain levels of PCBs that are of public health concern.

2. Current levels of chemical and radiological contaminants in the Lower Watts Bar Reservoir surface water and sediment do not pose a public health hazard. The reservoir is safe for swimming, skiing, boating, and other recreational purposes. The drinking water from the municipal water systems along the reservoir is safe to drink.

3. DOE's selected remedial action is protective of public health.

We recommend the following:

1. Continue the Lower Watts Bar Reservoir fish advisory. *Follow the precautions in the fish advisory to minimize exposure to PCBs in reservoir fish and reduce the cancer risk associated with PCB exposure. Also, pregnant women and nursing mothers should avoid eating all reservoir fish.*

2. ATSDR will work with the State of Tennessee to implement a community health education program on the Lower Watts Bar Reservoir fish advisory and the health effects of PCB exposure.

3. Evaluate the health risk from consumption of turtles in the Lower Watts Bar Reservoir by determining area residents' turtle consumption patterns and analyzing PCB levels in edible portions of turtles.

4. For the sake of caution and to prevent unnecessary exposure to workers and the public, do not disturb, remove, or dispose of sediment in the reservoir without careful review of sediment sampling data for the specific area where sediment-disturbing activities will take place. A interagency working group is reviewing sediment disturbing activities through the Watts Bar Reservoir Permit Coordination established by the interagency agreement (IAG) among DOE, Tennessee Department of Environment and Conservation, U.S. Environmental Protection Agency, Tennessee Valley Authority, and the U.S. Army Corps of Engineers.

5. Continue to sample drinking water from the municipal water system periodically. In addition, DOE should notify municipal water systems and monitor municipal water intakes when there is any significant increase in releases of contaminants from the Oak Ridge Reservation into tributaries of the Clinch River.

This health consultation is based on data and information made available to ATSDR. These conclusions and recommendations are based on the most recent levels of contaminants in the surface water, sediment, and wildlife and assumes the levels of contaminants released from the Oak Ridge Reservation will not substantially change. If additional information is received, ATSDR will evaluate it. The analysis of additional data could alter the conclusions and recommendations presented here.

BACKGROUND

In March 1995 DOE released the *Proposed Plan for Lower Watts Bar Reservoir*. The plan presented DOE's proposal for addressing contaminants in the Lower Watts Bar Reservoir and a summary of results of DOE's risk assessment conducted as part of the remedial investigation (DOE's December 1994 *Remedial Investigation Report for the Lower Watts Bar Reservoir*) [1]. The 1994 risk assessment evaluated the possible current and future risks to human health posed by the current levels of contaminants in the Lower Watts Bar Reservoir. The 1994 risk assessment indicated unacceptable risk to human health would result from consumption of certain species of fish from Lower Watts Bar Reservoir and the transfer of sediment from the deeper areas of the reservoir to areas on land where crops are grown [1,2]. DOE's preferred remedial action alternative includes maintaining fish consumption advisories; monitoring of water, sediment, and biota EXIT; and implementation of existing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediments [1]. In the September 1995 Record of Decision for the Lower Watts Bar Reservoir DOE selected the proposed remedial alternative as the remedial action for the Lower Watts Bar Reservoir in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Superfund Amendments and Reauthorization Act (SARA), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the Federal Facilities Agreement (FFA) between DOE, U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation [3]. The EPA and Tennessee Department of Environment and Conservations concurred with the selected remedial action [3].

At the request of residents in the vicinity of DOE's Oak Ridge Reservation and the Lower Watts Bar Reservoir, ATSDR evaluated the public health implications of chemical and radiological contaminants in the reservoir and the effectiveness of DOE's proposed remedial action for protecting public health. We evaluated Lower Watts Bar Reservoir studies performed by the DOE, the Tennessee Valley Authority (TVA), and their consultants during the 1980's and 1990's. These studies included analyses of sediment, surface water, and wildlife (primarily fish) samples. We also reviewed TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar Nuclear Plant. These studies indicate waterborne contaminants (radionuclides, metals, and organic compounds) have been released from the Oak Ridge Reservation and transported down East Fork Poplar Creek, Poplar Creek, and White Oak Creek to the Clinch River over the past fifty years. The Lower Watts Bar Reservoir is located downstream from the Oak Ridge Reservation and extends from the junction of the Clinch River and the Tennessee River to the Watts Bar Dam [1]. Waterborne contaminants from Oak Ridge Reservation can be found in the reservoir dissolved in the water, bound to particulates suspended in the water, or bound to particulates settled out in the sediment [4].

DISCUSSION

We analyzed Lower Watts Bar Reservoir environmental data for each media (i.e., surface water, sediment, animal and plant life) using worst case exposure scenarios. These worst case scenarios assumed the most sensitive population (e.g., young childern and older adults) exposed to the highest concentration of each contaminant in each media by the most probable exposure routes (e.g., ingestion, inhalation, dermal contact, and external radiation exposure). Our evaluation using worst case scenarios indicates only polychlorinated biphenyls (PCBs) in the reservoir fish are of potential public health concern. Other contaminants in the surface water, sediment, and fish are currently not at levels of public health concern. We subsequently evaluated PCBs in the fish using a more realistic scenario and concluded that PCBs concentrations in fish are at levels that are of public health concern.

I. Reservoir Fish and Other Wildlife

Levels of PCBs in reservoir fish are a public health concern. The fish consumption advisory should remain in effect for the Lower Watts Bar Reservoir. Frequent and long-term ingestion of reservoir fish with these levels of PCB contamination can moderately increase the risk of cancer in adults and possibly cause developmental effects in infants whose mothers consumed fish regularly during pregnancy or while nursing. Turtles in

the reservoir may also contain levels of PCBs that are of public health concern. Health risk from consumption of turtles should be determined for the Lower Watts Bar Reservoir

Polychlorinated Biphenyls (PCBs)

PCBs are a group of organic compounds (209 individual compounds) that were widely used from the 1930s through the mid-1970s as coolants and lubricants in transformers, capacitors, other electrical devices (e.g., fluorescent lighting fixtures) and appliances (e.g., television sets, refrigerators), microscope oil, and hydraulic fluids [5]. The manufacture of PCBs ceased in the United States in 1977. In the past, PCBs entered the environment during their manufacture and use. PCBs are pervasive and very persistent environmental pollutants that can remain in water and soil for years [5]. Today, PCBs continue to enter the environment and are widely distributed in small amounts in almost all outdoor air, indoor air, soil surfaces, and surface water [5]. PCBs are also found in body tissue and fluids of the general population [5].

The DOE Oak Ridge Reservation used PCBs in the Y-12 Plant machining operation cutting oils and the K-25 Site (formerly the Oak Ridge Gaseous Diffusion Plant) transformers until their ban in 1977 [2]. The PCB contaminated cutting oils were released, via runoff and seepage from the Y-12 Plant into the East Fork Poplar Creek and Bear Creek [2]. PCBs released from K-25 transformers may have migrated to Poplar Creek [2]. These three creeks are tributaries to the Clinch River. However, the extent to which the DOE Oak Ridge Reservation contributed PCBs to the Lower Watts Bar Reservoir has not been quantified [2].

PCB Bioaccumulation In Fish And Other Wildlife

A major concern with PCBs is bioaccumulation in wildlife and exposure to humans through the food chain. Wildlife contamination with PCBs is a consequence of fish and other wildlife accumulating trace levels of PCBs found in water, in their food, and in surface sediment [5]. PCBs concentrate primarily in the fat, but also in muscle (i.e., fish fillet). PCB levels in fish can reach levels hundreds of thousands of times higher than levels in water [5]. Therefore, even though levels of PCBs in the Lower Watts Bar Reservoir surface water and surface sediment were very low (below the equipment detection limits of 0.003 parts per million (ppm) and 0.1 ppm, respectively), PCBs were found at higher levels in fish [2].

Studies have reported that turtles also accumulate PCBs. Turtles in PCB contaminated ponds have been reported to concentrate PCBs in muscle at levels over 6 times greater than the average PCB levels in whole fish [6].

PCB Levels In Lower Watts Bar Reservoir Wildlife

Fish fillet samples from the Lower Watts Bar Reservoir contain elevated levels of PCBs. The mean PCB levels range from 0.3 to 1.2 ppm (or milligram per kilogram [mg/kg]) in different fish species collected from different areas of the Lower Watts Bar Reservoir [7]. These mean PCB levels in reservoir fish (fillet) are greater than the range of mean PCB levels (i.e., 0.05 to 0.26 ppm) in fish collected from different areas of Norris Lake (Clinch River and Powell River above Norris Dam) [7].

Other wildlife, including turtles, were not analyzed for PCBs. However, turtles in the reservoir are likely to have greater concentrations of PCBs.

Human Exposure to PCB

Fish consumption is a major source for PCB exposure by the general population. Human exposure can be determined by detecting PCBs in the blood, adipose (fat) tissue, and breast milk [8]. Almost everyone has had some exposure to PCBs. However, the consumption of contaminated sport fish increases the level of exposure to PCBs [5]. Studies indicate PCB exposure will be higher for people consuming sport fish than people who eat commercially marketed fish [9,10]. Concentrations of PCBs in sport fish can be at least an order of magnitude higher than nonsport fish, and people consuming sport fish eat fish more frequently than people who consume market fish [5]. Studies have shown people who regularly eat fish have PCB blood levels 2.5 times higher than people who occasionally eat fish [9].

In addition, women consuming fish contaminated with PCBs can expose fetuses during pregnancy or infants while nursing. PCBs cross the placenta and enter the fetus [10]. Also, breast milk can accumulate high concentrations of PCBs [10, 11]. Breast-fed infants of mothers who consume large amounts of contaminated fish are generally exposed to higher concentrations of PCBs. [12]. A resent study estimated that 95 to 98 percent of PCBs in breast milk were absorbed by a 19 week-old nursing infant [5].

We did not find information on consumption rates of turtles by the general population. However, with the potential for high levels of PCBs in turtles, frequent consumption of turtle fat and muscle is likely to result in higher PCB exposures than from consumption of fish fillets.

Fish Consumption Exposure Scenarios and Estimated Exposure Doses

We evaluated the health risk posed by Lower Watts Bar Reservoir fish using realistic exposure scenarios. Our analyses indicated PCB levels in reservoir fish are a public health concern.

In our realistic exposure scenario analysis we used maximum mean PCB concentrations (0.5 to 1.2 ppm) for each fish species in different areas of the reservoir and two exposure scenarios: one which assumes an adult (70 kilograms) consumes one fish meal (8 ounces or 0.5 pounds of sport fish) a week (52 meals per year) for 30 years, and the other assumes one fish meal a month (12 meals per year) for 30 years. We estimated ranges of PCB exposure doses from 0.099 to 0.24 micrograms of PCBs per kilogram of human body weight every day (ug/kg/day) for the one fish meal a week scenario and 0.023 to 0.055 ug/kg/day for the one fish meal a month scenario. To determine if these estimated exposure doses pose

a health hazard, we estimated cancer risk, based upon animal studies, and examined non-cancer effects observed in recent human and animal studies [17,23].

We were not able to estimate PCB exposure doses from the consumption of turtles without analysis of PCBs levels in turtles and the consumption rate of turtle by the general population.

Cancer Risk

Frequent and long-term ingestion of reservoir fish could result in PCB doses over a lifetime that can moderately increase the risk of cancer in adults. Our analysis supports the fish advisory for the Lower Watts Bar Reservoir. If precautions in the fish advisory are followed, exposure to PCBs in reservoir fish will be minimized and cancer risk associated with PCB exposure will be greatly reduced.

The potential cancer risk from PCBs in reservoir fish is based on many human exposure assumptions regarding the consumption of reservoir fish and many toxicological assumptions based on the results of carcinogenic animal studies. We cannot predict with certainty the probability of getting cancer from eating PCB contaminated fish. Currently, one in every three people in the United States will get cancer, primarily due to smoking, diet, and hereditary risk factors [13]. However, our analyses indicates the risk of cancer can increase with an increase in consumption of reservoir fish. At worst, we estimate that approximately one additional cancer case may develop in 1,000 people eating one fish meal a week for 30 years and three additional cancer cases may develop in 10,000 people eating one fish meal a month for 30 years. Our analysis supports the current fish advisory for the Lower Watts Bar Reservoir. Following the fish advisory will minimize exposure to PCBs in reservoir fish and reduce the cancer risk associated with PCB exposure.

Because no data is available for turtles in the reservoir, we were not able to estimate the cancer risk from consumption of turtles. However, since turtles are likely to contain much higher concentrations of PCBs than fish fillets, frequent consumption of turtles is likely to result in a higher cancer risk.

Carcinogenicity of PCBs:

In the absence of compelling data to the contrary, ATSDR presumes PCBs pose a carcinogenic risk to humans since PCBs have been shown to cause cancer to animals [14,17]. Our analysis and conclusions presented above are based on this presumption. However, the evidence for carcinogenicity in humans is inconclusive [5].

In addition, the U.S. Environmental Protection Agency (EPA) has classified PCBs as a probable human carcinogen and the International Agency for Research on Cancer (IARC) has classified PCBs as probably carcinogenic to humans [5, 15]. This category, probable human carcinogen, is based on a weight-of-evidence classification of animal and human studies and it means there is insufficient evidence of human carcinogenicity and sufficient evidence of animal carcinogenicity from exposure to PCBs [15]. Evidence of cancer from occupational epidemiological studies is inconclusive and inadequate to determine the human carcinogenicity of PCBs with any reasonable degree of confidence [5,17]. Study limitations and inconsistent findings among occupational studies contribute to the inconclusive results [5,17].

Animal studies show that elevated doses of PCBs are clearly carcinogenic to rats [5,16]. These studies reported an increased incidence of both benign and malignant liver tumors in rats chronically fed large doses (i.e., 3,450 to 5,000 ug/kg/day Aroclor 1260) of PCBs over their lifetime (i.e., 21 to 24 months) [16]. Our maximum estimated chronic PCB exposure dose of 0.24 ug/kg/day from ingesting one reservoir fish meal a week is over 14,000 times *less than* these very high doses of PCBs that resulted in tumors.

Non-Cancer Risk

Frequent consumption of reservoir fish by women during pregnancy or while nursing may increase the risk of adverse developmental effects in their child. We believes these health effects are unlikely; however, as a precautionary public health stand, pregnant women and nursing mothers should avoid eating all reservoir fish.

Studies of both humans and animals have shown that fetuses and breast fed infants can be exposed to high concentrations of PCBs during pregnancy and while nursing if the mother consumes PCB contaminated fish [10,11,12]. The hypothesis that chronic low level ingestion of PCBs by females is associated with lower birth weight and neurobehavioral deficits in infants has been examined in a number of studies [18,19,20,21,22,23]. However, evidence from human studies suggesting that PCBs represent a developmental hazard is inconclusive and results of monkey studies are insufficient to establish an exposure-effect relationship [5,19]. Even though there are limitations in human studies, insufficient dose-response results in animal studies, and uncertainty in our maximum estimated chronic PCB exposure dose, we have taken a precautionary public health stand that women should not eat reservoir fish during pregnancy and while nursing. We have taken this precautionary public health stand to minimize PCB exposure to at risk groups such as fetuses and infants, and reduce their potential for neurodevelopmental delays.

We assume that ingestion of reservoir fish by pregnant women and nursing mothers may result in exposure doses that cause adverse neurobehavioral effects in infants. Our maximum estimated chronic PCB exposure dose of 0.24 ug/kg/day from ingesting one reservoir fish meal a week is approximately 29 times *less than* the chronic no-observed-adverse-effect level (NOAEL)[(1)] of 7 ug/kg/day and 125 times *less than* the chronic lowest-observed-adverse-effect level (LOAEL)[(2)] of 30 ug/kg/day observed in monkeys [23]. Even though our maximum estimated chronic exposure dose is *less than* the chronic NOAEL and LOAEL for developmental effects in the offspring of monkeys, we have taken this precautionary stand for pregnant women and nursing mothers because of the special vulnerability of developing fetuses and infants. Further, we take a

conservative stand when generalizing from animal data for the following reasons:

1. Monkey data may not be directly applicable to humans (humans may be more sensitive).

2. Individuals may have different responses (some humans are likely to be more sensitive than the average).

Human Studies on Developmental Effects:

Human epidemiologic studies suggest maternal exposure to PCBs leads to adverse developmental effects in children; however, the results of these studies are difficult to evaluate and the clinical significance is difficult to assess [18,19]. Results from two studies have suggested that low birth weight and neurodevelopmental effects (e.g., motor deficits at birth, impaired psychomotor development during the first year of life, impaired visual recognition memory at 7 months of age, and deficits in short-term memory at 4 years of age) correlate with fetal PCB exposure from placental passage of PCBs or infant exposure to PCBs in maternal milk [20]. However, these human studies had serious limitations in their design and methods that affect the validity of the results [5,19]. Thus, there evidence suggesting PCBs represent a developmental hazard to human health is inconclusive and there clinical significance is limited [5]. Consequently, results of animal studies have been used as the basis of LOAELs and NOAELs.

Animal Studies on Developmental Effects:

Animal studies, particularly in monkeys, support the human studies and suggest PCBs represent a developmental hazard [21]. The most sensitive developmental endpoint appears to be neurobehavioral function [5]. However, results from animal studies are insufficient to establish a causal relationship between low exposure and effect.

Two separate monkey studies provide the basis for our health thresholds for developmental effects in offspring. Both studies of female monkeys have been used to define the NOAEL of 7 ug/kg/day for chronic exposure to PCBs [22,23]. This chronic NOAEL is the amount of PCBs female monkeys ingested for 18 months during gestation and lactation without any adverse developmental effects in offspring. These female monkeys fed 7 ug/kg/day PCBs had offspring that were not impaired in ability to learn simple problems [5,22,23,29].

One of these monkey studies has been used to define a LOAEL of 30 ug/kg/day for chronic exposure of PCBs [22]. The chronic LOAEL is the smallest dose of PCBs female monkeys ingested for 18 months during gestation and lactation that produced adverse developmental effects in offspring. However, these exposed female monkeys experienced uncomplicated pregnancies and carried their infants to term [5]. The significant neurobehavioral deficits observed in the offspring of monkeys exposed to 30 ug/kg/day PCBs was a *lower* birth weight and possible *impaired* ability to perform a spatial position discrimination problem at age 14 months but no significant deficits at age 4-6 years [22]. In the another study, offspring of monkeys exposed to 80 ug/kg/day PCBs had a significant *impairment* in performance on the spatial learning and memory task at age 4-6 years [23].

Although we are suggesting that pregnant women and nursing mothers not eat reservoir fish, the evidence that PCBs causes developmental defects is difficult to evaluate and inconclusive. First, the human studies have limitations and their clinical significance is difficult to assess [5]. Second, results of low PCB exposure dose studies in monkeys are conflicting and insufficient for establishing a low exposure-effect relationship because of inconsistencies in the outcome of these neurobehavioral tests [29]. For example, at the age of 14 months, offspring of monkeys exposed to 30 ug/kg/day had an *impaired* ability to perform a spatial position discrimination problem, but were actually *better* at learning the shape discrimination problem [29]. In the same study, at age 4-6 years, offspring of the two exposed monkey groups (i.e., low dose - 8 ug/kg/day, high dose - 30 ug/kg/day) did not have any significant impairment of performance for on the spatial learning and memory task when compared to the control group [29]. There is evidence suggesting that the observed neurobehavioral deficits may be related to decreased levels of the neurotransmitter dopamine, which has been observed in monkeys exposed to PCBs [30].

Other serious developmental effects were seen in offspring in monkeys exposed at a higher dose of PCBs. Female monkeys fed 100 ug/kg/day PCBs for 15 months resulted in dose-related early abortions and offspring with lower birth weights and PCB intoxication (i.e., facial acne, swollen eyelids, loss of eyelashes, and hyperpigmentation of skin) [31]. However, our maximum estimated chronic PCB exposure dose of 0.24 ug/kg/day for ingestion of reservoir fish is 400 times *less than* this dose of 100 ug/kg/day. We are confident that these other serious developmental effects are not likely to occur.

Immune response is another potential sensitive toxicological endpoint. A LOAEL of 5 ug/kg/day PCBs has been established from a PCB dose that was shown to decrease IgG and IgM antibody response in monkeys following an injection of sheep red blood cells [28]. However, we have not based our evaluation of PCBs in Lower Watts Bar Reservoir fish on this potential toxicological endpoint because only one animal study has observed a reduced antibody response in monkeys exposed to low PCB levels and the clinical significance of lowered antibody responses to the injection of a specific antigen is unknown [5] Therefore, additional studies are necessary to determine if immunological effects are a critical target for low PCBs exposures and the significance of these immunological effects (5).

Metals and Organic Compounds In Fish

We evaluated the maximum level of each metal and organic compound detected in Lower Watts Bar Reservoir fish using the worst case scenario previously mentioned. We believe these contaminants pose no apparent increased risk of adverse health effects beyond that of the PCBs.

Radionuclides In Fish

The majority of the fish sampling for radioactive contaminants was done in the Clinch River near the Oak Ridge Reservation and not in Lower Watts Bar Reservoir. However, radiological data were reviewed from three sample sites in or downstream from Lower Watts Bar Reservoir: Mid Watts Bar Reservoir (Tennessee River Mile 557.0), Lower Watts Bar Reservoir north of the dam (Tennessee River Mile 530.5), and Upper Chickamaugua Reservoir (Tennessee River Mile 518.0). At these three locations channel catfish were sampled for cesium-137 (Cs-137), cobalt-60 (Co-60), and strontium-90 (Sr-90), and bluegill, sunfish, and largemouth bass were sampled for Cs-137 and Co-60 [37]. These results were compared to the results reported by TVA for the same type of fish in their Annual Radiological Environmental Monitoring Report [33], and the results were similar.

In order to evaluate the potential radiological exposure from fish, we used the maximum concentration of each radioactive contaminant in fish and a worst case scenario that assumes adults and children consume two 8-ounce fish meals a week (i.e., 104 meals a year). In the case of SR-90, we assumed that the meal could include some bone; however, with other radioactive contaminants we assumed that the meals consisted of fish fillets. The level of potential radiological exposure (i.e., less than 6 millirem per year (mrem/yr) or 0.06 millisieverts per year (mSv/yr[(3)]) from the three primary radioactive contaminants in reservoir fish is not a public health concern.

Limited sampling of other animal and plant life (e.g., clams, other fish, cattle, and vegetation) for radioactive contaminants was conducted in or near the Lower Watts Bar Reservoir and the results indicate radioactive contaminants are not a public health concern [33].

II. Reservoir Surface Water

Current levels of chemical and radiological contaminants in the Lower Watts Bar Reservoir surface water are not a public health concern. The reservoir is safe for swimming, skiing, boating, and other recreational purposes. Drinking water from the municipal water systems which draw surface water from tributary embayments of the reservoir and the Tennessee River is safe to drink.

Metals and Organic Compounds

We evaluated the levels of metal contaminants detected in the reservoir surface water using a worst case scenario that assumes a child would daily ingest a liter of unfiltered reservoir water containing the maximum level of each metal [2,7]. Organic contaminants were not detected in the water above detection limits [2,7]. We believe levels of chemicals in the reservoir surface water are not a public health concern and the reservoir is safe for swimming, skiing, boating, and other recreational purposes.

The Rockwood and Spring City municipal water system intakes draw surface water from the Piney River and King Creek tributary embayments of the Lower Watts Bar Reservoir and the Kingston municipal water system intake is in the Tennessee River upstream of the Clinch River and Lower Watts Bar Reservoir. These water intakes could be impacted only during reverse flow conditions. In addition, these municipal water systems are required to meet the Tennessee Department of Environment and Conservation domestic water supply standards which ensure the drinking water is safe for public consumption.

Radionuclides

Composite and grab surface water samples collected from the municipal water intake and the reservoir were analyzed for radionuclides [32,34,35]. These surface water data were compared to EPA's drinking water standards and were well below the current and proposed limits [36,37]. In addition, maximum concentrations for each radioactive contaminant were evaluated using worst case exposure scenarios. These scenarios evaluated radiation exposures to children, approximately 10 years old, who may drink and shower with unfiltered water from the reservoir and swim in the reservoir daily. This conservative scenario was selected because it uses the most sensitive population (i.e., 10 years old) who might be exposed through the most likely pathways.

The total radiation dose to a child from waterborne radioactive contaminants would be less than 1 mrem/yr (0.01 mSv/yr), which is not a health concern. In contrast, a total average radiation dose of approximately 100 mrem/yr (1.0 mSv/yr) is received by members of the U.S. population by naturally-occurring sources, not including radon gas [38].

III. Reservoir Sediment

Current levels of chemical and radioactive contaminants in the reservoir sediment do not and will not pose a public health problem. For the sake of caution and to prevent unnecessary exposure to workers and the public, sediment should not be disturbed without thorough review of sediment sampling data in the specific area where sediment-disturbing activities will take place.

Many sediment studies of chemical and radioactive contaminants have been conducted in the Clinch River and Lower Watts Reservoir; these studies detected predominantly Cs-138 and mercury [2,7]. Annual radiological surveys of the sediment in the Clinch River and the Tennessee Rivers began as early as 1951 to detect radioisotopes released from the Oak Ridge Reservation [2]. In the past ten years, the predominant radioactive contaminants released to Clinch River tributaries and eventually to the Lower Watts Bar Reservoir have been Cs-137, Sr-90, Co-60, and hydrogen-3 (H-3, tritium) [4,33,35,39,40,41,42,43,44]. Cs-137 binds to fine-particle sediment such as silt and clay. Sr-90 and Co-60 also appear in the sediments of Lower Watts Bar Reservoir but in lower concentrations than Cs-137. Most of the other radionuclides appear to remain waterborne, are diluted with water from the Tennessee River and other tributaries, and pass downstream [4,32].

Although the main radioactive contaminants found in the sediments of Lower Watts Bar Reservoir are Cs-137, Sr-90, and Co-60, several other radioisotopes were detected in lower concentrations [4,32,34,45,46]. Our evaluation considered all reported radioactive contaminants to estimate radiological exposures and potential health effects.

Sediments In Shallow Areas

We evaluated surface sediments in shallow areas of the reservoir using maximum concentrations of contaminants and worst case scenarios. These scenarios assume children would be exposed to radionuclides in surface sediments while swimming or fishing in the reservoir and to radionuclides in soil if surface sediments were dredged and used for surface soil at residential properties. We determined that the maximum chemical and radioactive contaminant concentrations reported in the recent surface sediments data (mercury, Co-60, Sr-89/90 and Cs-137) would not present a public health hazard [2,7]. The estimated dose from radioactive contaminants was less than 15 mrem/yr or 0.15 mSv/yr.

Sediments In Deep Channels

People are not being directly exposed to the highest concentrations of chemical and radioactive contaminants in the subsurface sediments because these deposits are found in deep channels where contaminants are covered by 40 to 80 centimeters of sediment and several meters of water [2,7]. We evaluated the potential exposure a child might receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties. This scenario includes ingestion, inhalation, external, and dermal contact exposure routes. The potential radiation dose to individuals living on these properties would be less than 20 mrem/yr or 0.2 mSv/yr and would not pose a public health concern. The potential exposure to chemicals, and mercury in particular, also would not pose a public health concern.

Sediment Removal

We believe that any efforts to remove the contaminated sediment could increase the levels of contaminants in the surface water by desorption or resuspension of particulates and could increase exposure to workers and the public. Concentrations of contaminants detected in the near-shore sediment and the deep channel sediment are not of public health concern. Therefore, no exposure of health concern is anticipated if subsurface sediments remain in place, and we agree with the DOE's recommendation to leave the deep channel contaminated sediments in place. However, for the sake of caution and to prevent unnecessary exposure to workers and the public, sediments should not be disturbed, removed, or disposed of without prior review of sediment disturbing activities and sediment sampling data in the specific area where sediment-disturbing activities will take place. Sediment disturbing activities are reviewed through the Watts Bar Reservoir Permit Coordination by the working group established by the interagency agreement among DOE, Tennessee Department of Environment and Conservation, U.S. Environmental Protection Agency, Tennessee Valley Authority, and the U.S. Army Corps of Engineers.

CONCLUSIONS

1. The levels of polychlorinated biphenyls (PCBs) in the Lower Watts Bar Reservoir fish pose a public health concern. Frequent and long-term ingestion of fish from the reservoir poses a moderately increased risk of cancer in adults and increases the possibility of developmental effects in infants whose mothers consume fish regularly during gestation and while nursing. Turtles in the reservoir may also contain levels of PCBs that are of public health concern.

2. Current levels of contaminants in the reservoir surface water and sediment are not a public health concern. The reservoir is safe for swimming, skiing, boating, and other recreational purposes. Drinking water from the municipal water systems, which draw surface water from tributary embayments of the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir, is safe to drink.

3. DOE's selected remedial action, which includes maintaining the fish consumption advisories, continuing environmental monitoring, and implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment, is protective of public health.

These conclusions are based on current levels of contaminants in the water, sediment, and wildlife. If levels of contaminants released from the Oak Ridge Reservation substantially change or ATSDR becomes aware of new information, we will evaluate the new information and make appropriate recommendations.

RECOMMENDATIONS

1. The Lower Watts Bar Reservoir fish advisory should remain in effect. Follow the precautions in the fish advisory to minimize exposure to PCBs in reservoir fish and reduce the cancer risk associated with PCB exposure. Pregnant women and nursing mothers should avoid eating all reservoir fish.

2. ATSDR will work with the State of Tennessee to implement a community health education program on the Lower Watts Bar Reservoir fish advisory and health effects of PCB exposure.

3. Evaluate the health risk from consumption of turtles in the Lower Watts Bar Reservoir by determining turtles consumption patterns of area residents and analyzing PCB levels in the edible portion of turtles.

4. The surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.

5. Drinking water from municipal water system should continue to be sampled at regular intervals. DOE should notify municipal water systems and monitor surface water intakes when there is any significant increase in the release of contaminants from the Oak Ridge Reservation into tributaries of the Clinch River.

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REFERENCES

1. U.S. Department of Energy. *Proposed Plan for Lower Watts Bar Reservoir*. DOE/OR-01-1294&D5. Oak Ridge, Tennessee: U.S. Department of Energy, March 1995.

2. U.S. Department of Energy. *Remedial Investigation/Feasibility Study Report for Lower Watts Bar Reservoir Operable Unit*. DOE/OR/01-1282&D2, ORNL/ER-244&D2. Oak Ridge, Tennessee: Oak Ridge National Laboratory and Jacobs Engineering Group, Inc, December 1994; Contract Number DE-AC05-84OR21400.

3. U.S. Department of Energy. *Record of Decision for the Lower Watts Bar Reservoir*. DOE/OR/02-1373&D2. Oak Ridge, Tennessee: Jacobs

Engineering Group, Inc., July 1995.

4. Olsen CR, et al. *Transport and Accumulation of Cesium-137 and Mercury in the Clinch River and Watts Bar Reservoir System*. ORNL/ER-7. Oak Ridge, Tennessee: Oak Ridge National Laboratory, March 1990 (Draft), June 1992 (Final).

5. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

6. Olafsson et al.1983, Stone et al. 1980, Bryan et al. 1987a. Cited by: Meyers-Schone, L., Walton, B. T. *Comparison of Two Freshwater Turtle Species As Monitors of Environmental Contamination*. ORNL/TM-11460. Oak Ridge, Tennessee: Oak Ridge National Laboratory, April 1990.

7. U.S. Department of Energy. Electronic Data Package of the Remedial Investigation/ Feasibility Study Report for Lower Watts Bar Reservoir Operable Unit, DOE/OR/01-1282&D2. Oak Ridge, Tennessee: Oak Ridge National Laboratory and Jacobs Engineering Group, Inc, November 1994.

8. U.S. Environmental Protection Agency, 1986b; Jensen 1987; Ouw et al. 1976; Schecter et al. 1991. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

9. Humphrey 1988. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

10. Fiore et al.1989. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

11. Jacobson et al. 1984b; Ando et al. 1985; Jensen. 1987. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

12. U.S. EPA 1985b. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

13. American Cancer Society. *Cancer Facts and Figures - 1993*. Atlanta, Georgia: ACS, Inc. 1993.

14. Agency for Toxic Substances and Disease Registry. Cancer Policy Framework. Atlanta, Georgia: ATSDR, January 1993.

15. IRIS 1992. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

16. Norback 1985; Kimbrough et al. 1975. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

17. Brown 1987; Brown and Jones 1981; Bertazzi et al. 1987; Gustavsson et al. 1986; Shalat et al. 1989; Bahn et al. 1976,1977; Lawrence 1977; NIOSH 1977; Davidorf and Knupp 1979; Sinks et al. 1991. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

18. Fein et al. 1984a, 1984b; Jacobson 1985; Jacobson et al. 1984a, 1990a, 1990b; Rogan et al. 1986; Gladen et al. 1988; Gladen and Rogan 1991. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16. 19.

19. Paneth 1991. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

20. Fein et al. 1984a; Rogan et al. 1986. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

21. Barsotti and Van Miller 1984; Allen et al. 1980; Allen and Barsotti 1976; Levin et al. 1988; Schantz et al. 1989. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016).

Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

22. Schantz et al. 1989. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

23. Levin et al. 1988; Schantz et al. 1989. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16.

24. Svensson et al.1984. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated Biphenyls (Update). Atlanta: ATSDR, August 1995; Research Triangle Institute.

25. Loose et al. 1979a, 1979b. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated Biphenyls (Update). Atlanta: ATSDR, August 1995; Research Triangle Institute.

26. Street and Sharma 1975. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated Biphenyls (Update). Atlanta: ATSDR, August 1995; Research Triangle Institute.

27. Vos and de Roij, 1972. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated Biphenyls (Update). Atlanta: ATSDR, August 1995; Research Triangle Institute.

28. Tryphonas et al. 1989. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Polychlorinated Biphenyls (Update). Atlanta: ATSDR, August 1995; Research Triangle Institute.

29. Great Lakes Sport Fish Advisory Task Force. *Protocol for a Uniform Great Lakes Sports Fish Consumption Advisory*. Wisconsin: Wisconsin Department of Natural Resources and Wisconsin Department of Health and Social Services, September 1993.

30. Seegal et al. 1990; Schantz et al. 1991. Cited by: Great Lakes Sport Fish Advisory Task Force. *Protocol for a Uniform Great Lakes Sports Fish Consumption Advisory.* Wisconsin: Wisconsin Department of Natural Resources and Wisconsin Department of Health and Social Services, September 1993.

31. Bowman et al. 1978; Allen et al. 1980; Allen and Barsotti 1976. Cited by: Agency for Toxic Substances and Disease Registry. Toxicological Profile for Selected PCBs (Aroclor -1260, -1254, -1248, -1242, -1232, -1221, and -1016). Atlanta: ATSDR, April 1993; DHHS publication no. ATSDR/TP-92/16

32. Cook et al. 1992. *Phase 1 Data Summary Report for the Clinch River Remedial Investigation: Health Risk and Ecological Risk Screening Assessment.* ORNL/ER-155. Oak Ridge, Tennessee: Oak Ridge National Laboratory. December 1992.

33. Tennessee Valley Authority. *Annual Radiological Environmental Monitoring Report, Watts Bar Nuclear Plant Data Supplement 1993*. TVA, April 1994.

34. Tennessee Valley Authority. *Results of Sediment and Water Sampling for Inorganic, Organic and Radionuclide Analysis at Recreation Areas and Water Intakes - Norris, Melton Hill, and Watts Bar Lakes - Data Report.* TVA, October 1991.

35. Oak Ridge National Laboratory. *Oak Ridge Reservation Environmental Report for 1992, Vol.1 and 2.* ES/ESH-31/V2. Oak Ridge, Tennessee: Oak Ridge National Laboratory, September 1993.

36. Code of Federal Regulations. National Primary Drinking Water regulations. Title 40 CFR Part 141 and 142, Section 15 and 16. 40 FR 59570, December 24, 1975.

37. Code of Federal Regulations. Proposed rule for 40 CFR 141 and 142. 56 FR 33050, July 18, 1991.

38. Committee on the Biological Effects of Ionizing Radiation (BEIR V), Board on Radiation Effects Research, Commission on Life Sciences, National Research Council. *Health Effects of Exposure to Low Levels of Ionizing Radiation.* National Academy Press, Washington, D.C. 1990.

39. Martin Marietta Energy Systems, Inc. *Environmental Surveillance of the U.S. Department of Energy Oak Ridge Reservation and Surrounding Environs During 1986, Vol.2: Data Presentation.* ES/ESH-1/V2. Oak Ridge, Tennessee: Martin Marietta Energy Systems, Inc., April 1987.

40. Union Carbide Corporation. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year

1982. May 1, 1983.

41. Martin Marietta Energy Systems, Inc. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984. August 1985.

42. Oak Ridge National Laboratory. *Oak Ridge Reservation Environmental Report for 1988, Vol. 2. Data Presentation.* ES/ESH-8/V2. Oak Ridge, Tennessee: Oak Ridge National Laboratory, May 1989.

43. Oak Ridge National Laboratory. *Oak Ridge Reservation Environmental Report for 1989, Vol. 2. Data Presentation.* ES/ESH-13/V2. Oak Ridge, Tennessee: Oak Ridge National Laboratory, October 1990.

44. Oak Ridge National Laboratory. *Oak Ridge Reservation Environmental Report for 1990, Vol. 2. Data Presentation.* ES/ESH-18/V2. Oak Ridge, Tennessee: Oak Ridge National Laboratory, September 1991.

45. Oakes, T. W. et al. *Technical Background Information for the Environmental and Safety Report, Vol.5: The 1977 Clinch River Sediment Survey - Data Presentation.* ORNL-5878. Oak Ridge, Tennessee: Oak Ridge National Laboratory, November 1982.

46. Levine DA, Hargrove WW, Campbell KR, Wood MA, Rash CD. *Data Summary for the Near-Shore Sediment Characterization Task of the Clinch River Environmental Restoration Program.* ORNL/ER-264. Oak Ridge, Tennessee: Oak Ridge National Laboratory, October 1994.

47. U.S. Department of Energy. *Remedial Investigation/Feasibility Study Report for Lower Watts Bar Reservoir Operable Unit*. DOE/OR/01-1282&D2, ORNL/ER-244& D1. Oak Ridge, Tennessee: Oak Ridge National Laboratory and Jacobs Engineering Group, Inc, August 1994; Contract Number DE-AC05-84OR21400.

ADDITIONAL DOCUMENTS REVIEWED

1. Tennessee Valley Authority. *Instream Contaminant Study - Task 4, Fish Sampling and Analysis.* TVA, April 1985.

2. Tennessee Valley Authority. *Instream Contaminant Study - Task 5, Summary Report*. TVA, January 1986.

3. Hoffman FO, Blaylock BG, Frank MC, Hook LA, Etnier EL, Talmadge SS. *Preliminary Screening of Contaminants in the Off-Site Surface Water Environment Downstream of the U.S. Department of Energy Oak Ridge Reservation.* ORNL/ER-9. Oak Ridge, Tennessee: Oak Ridge National Laboratory, November 1991.

4. Suter GW,II. *Screening Level Risk Assessment for Off-Site Ecological Effects in Surface Waters Downstream from the U.S. Department of Energy Oak Ridge Reservation.* ORNL/ER-8. Oak Ridge, Tennessee: Oak Ridge National Laboratory, May 1991.

5. Blaylock, B.G. et al. *The Utility of Existing Data for Conducting a CERCLA Baseline Risk Assessment for Lower Watts Bar Reservoir*. ORNL/ER-XXX. Oak Ridge, Tennessee: Oak Ridge National Laboratory, September 1993.

6. International Commission on Radiological Protection. ICRP Publication 30, Limits for Intakes of Radionuclides by Workers. New York:Pergamon Press, July 1978.

7. International Commission on Radiological Protection. ICRP Publications 56 and 67, Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1 and Part 2. New York:Pergamon Press, April 1990 and April 1993.

8. International Commission on Radiological Protection. ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection. New York:Pergamon Press, November 1990.

9. International Commission on Radiological Protection. ICRP Publication 61, Annual Limits on Intake of Radionuclides by Workers Based on the 1990 Recommendations. New York:Pergamon Press, November 1990.

10. Shleien B. The Health Physics and Radiological Health Handbook. Silver Spring: Scinta Inc, 1992.

11. Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual. Chelsea: Lewis Publishers, 1992.

1. No-observed-adverse-effect level (NOAEL) is the PCB dose (ug/kg/day - micrograms of PCBs for every kilogram of body weight per day) female monkeys ingested for over a year during gestation and lactation without any adverse developmental effects in offspring.

2. Lowest-observed-adverse-effect level (LOAEL) is the smallest PCB dose (ug/kg/day - micrograms of PCBs for every kilogram of body weight everyday) female monkeys ingested for over one year during gestation and lactation that produced developmental effects in offspring.
3. A millirem and a millisievert are units used to express dose equivalent (absorbed dose multiplied by a quality factor). One millirem is equivalent to 0.01 millisievert.

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