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MONITORING FISH, WILDLIFE, RADIONUCLIDES AND CHEMICALS AT HANFORD, WASHINGTON

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MONITORING FISH, WILDLIFE, RADIONUCLIDES AND CHEMICALS AT HANFORD, WASHINGTON

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Abstract: Concern about the effects of potential releases from nuclear and non-nuclear activities on the U.S. Department of Energy's Hanford Site in southeastern Washington has evolved over four decades into a comprehensive environmental monitoring and surveillance program. The program includes field sampling, and chemical and physical analyses of air, surface and ground water, fish, wildlife, soil, foodstuffs, and natural vegetation. In addition to monitoring radioactivity in fish and wildlife, population numbers of key species are determined, usually during the breeding season. Data from monitoring efforts are used to assess the environmental impacts of Hanford operations and calculate the overall radiological dose to humans onsite, at the Site perimeter, or residing in nearby communities.

Chinook salmon (Oncorhynchus tshawytscha) spawning in the Columbia River at Hanford has increased in recent years with a concomitant increase in winter nesting activity of bald eagles (Haliaeetus leucocephalus). An elk (Cervus elaphus) herd, established by immigration in 1972, is also increasing. Nesting Canada goose (Branta canadensis) and great blue heron (Ardea herodias), and various other animals, e.g., mule deer (Odocoileus hemionus) and coyotes (Canis latrans) are common. Measured exposure to penetrating radiation and calculated radiation doses to the public are well below applicable regulatory limits.

Key Words: environmental monitoring, radionuclides, chemicals, fish, wildlife.

The U.S. Department of Energy's (DOE) Hanford Site occupies a land area of about 1,450 km^2 (560 mi^2) in semi-arid southeastern Washington (Fig. 1). The Columbia River flows through the Site and forms part of its eastern boundary. The southwestern portion of the Site includes the southern terminus of the Rattlesnake Hills with elevations exceeding 1000 m. Both unconfined and confined aquifers lie beneath the Site.

Nuclear and non-nuclear industrial and research activities have been conducted at Hanford since 1943. The most environmentally significant activities have involved the production of nuclear materials and the chemical processing and waste management associated with the major product, plutonium. Byproduct wastes have included gamma, beta, and alpha-emitting radionuclides, and various nonradioactive chemicals in gaseous, liquid and solid forms.

There are currently four major DOE operations areas on the Hanford Site (Fig. 1). The 100 Areas located along the Columbia River include the dual-purpose N Reactor that produced plutonium for national defense and steam for the Hanford Generating Project (HGP), operated by the Washington Public Power Supply System (WPPSS), and eight, now deactivated single-purpose, plutonium production reactors. The plutonium uranium extraction (PUREX) plant (reactor fuel reprocessing), plutonium finishing plant (Z Plant), and waste-disposal facilities are located in the 200 Areas on a plateau (elevation 229 m) about 11.3 km west of the Columbia River. The 300 Area, located just north of

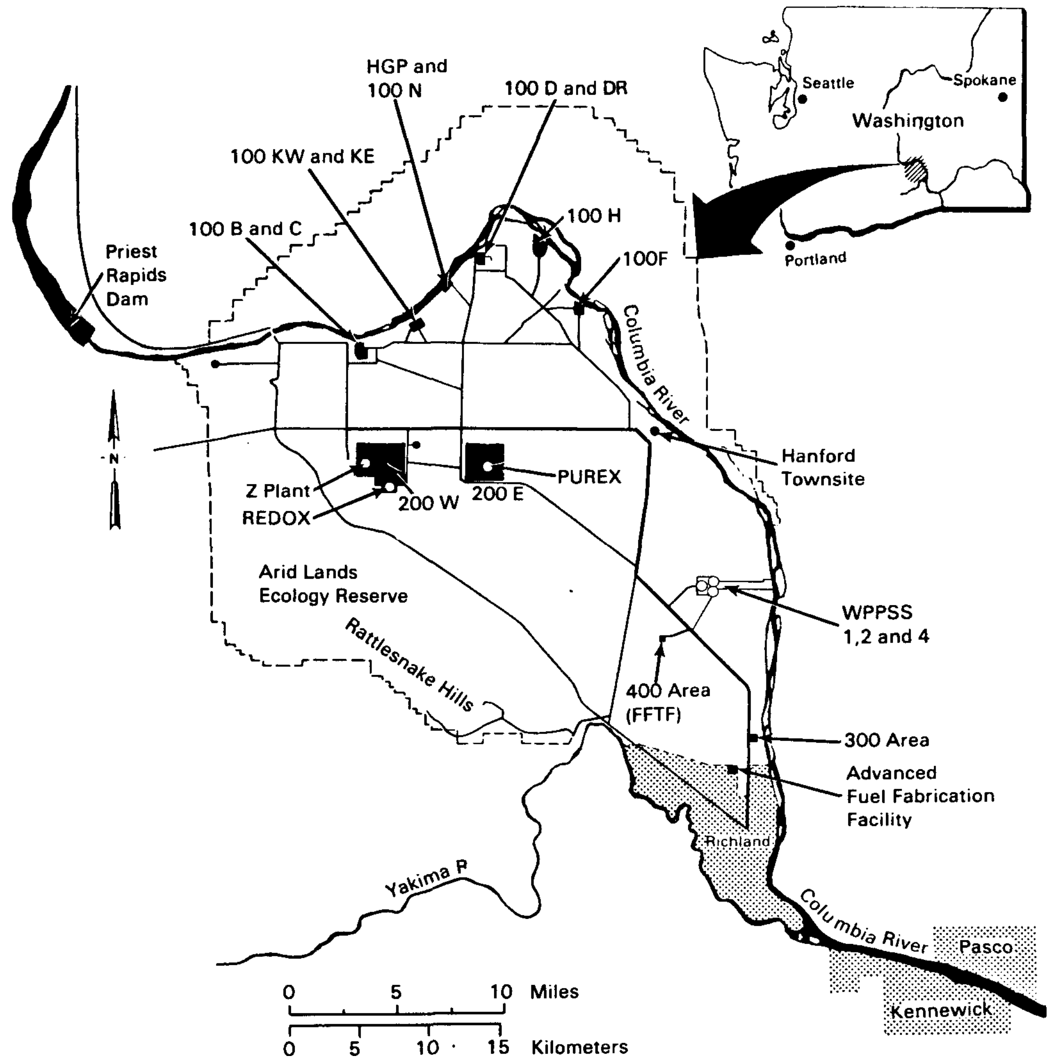

Fig. 1. The Hanford Site. HGP = Hanford Generating Project; REDOX = reduction-oxidation; PUREX = plutonium uranium extraction; WPPSS = Washington Public Power Supply System; FFTF = Fast Flux Test Facility.

Richland, Washington contains the uranium fuel manufacturing facilities in support of N Reactor, and research and development laboratories. The Fast Flux Test Facility (FFTF), which has operated intermittently since 1981 to test new fuels and materials for future breeder reactor technology, is located in the 400 Area. Nongovernment facilities within Hanford Site boundaries include HGP, the WPPSS nuclear plant (WNP) sites, WNP-1, WNP-2 and WNP-4, including one commercial reactor (WNP-2) that achieved full operation status in the fall of 1984, and a commercial low-level radioactive-waste burial site near the 200 Areas, operated by U.S. Ecology. The Advanced Nuclear Fuels Corp. (formerly Exxon) fuel fabrication facility is immediately adjacent to, but not located on Hanford Site property.

Environmental monitoring at Hanford has been ongoing for 43 years. The program is conducted to assess potential impacts to individuals and populations that may be exposed to radionuclides, ionizing radiation and hazardous chemicals. Environmental monitoring currently includes air, ground and surface water, fish, wildlife, soil, vegetation, and foodstuffs (fruits, vegetables, milk). Fish and wildlife are monitored for radioactivity and to determine the population status of key species.

LAND USE, WILDLIFE AND FISHERIES

The Columbia River above and below the Hanford Reach and much of the adjacent land have experienced extensive environmental change over the last four decades due to construction of hydroelectric dams and increased irrigation (Rickard and Watson 1985). Land surrounding the Hanford Site is primarily used for agriculture and livestock grazing. Agricultural lands are found north and east of the Columbia River and south of the Yakima River. These areas contain orchards, vineyards irrigated fields of alfalfa, various vegetable crops, and dry land fields of wheat and other cereals.

The Hanford site provides facility siting areas, a large population-free safety and security zone, and serves as an outdoor laboratory for ecological research. The Site consists mostly of undeveloped land that supports stands of native vegetation and a few exotic species (e.g., cheatgrass, Russian thistle, and tumble mustard), is free from agricultural practices, and has been essentially free from livestock grazing and hunting for 45 years. Thus, the Site serves as a refuge for migratory waterfowl, elk (Cervus elaphus), mule deer (Odocoileus hemionus), coyote (Canis latrans) and other plants and animals. Restricted land use has favored native wildlife that frequent riverine habitats, for example, mule deer, Canada goose (Branta canadensis), and great blue heron (Ardea herodias).

Use of the Hanford Site as an outdoor laboratory for ecological research and to preserve the diversity of native plants and animals predates 1952 (Vaughan and Rickard, 1977). In 1977, the Hanford Site was designated as a National Environmental Research Park (Rickard et al., 1982). About 259 km^2 of land on the northeast slope of Rattlesnake Hills is designated as the Arid Lands Ecology Reserve (Fig. 1). This area supports large expanses of native shrub-steppe (sagebrush-grass) plant and animal communities, some of which are in relatively undisturbed condition. The Hanford Site north of the Columbia River is shared between a state wildlife management area and a federal wildlife refuge.

Flow of the Columbia River through the Hanford Site is regulated daily according to electric power demands. Although the river was once closed to public access, public use for recreational and barge traffic is again practical. The Columbia River at Hanford supports up to 48 species of fish (Gray and Dauble, 1977). The physical and chemical characteristics of the Hanford Reach and the river's use by anadromous salmonids were recently reviewed and summarized (Becker, 1985). The Hanford Reach serves as a migration route for upriver runs of Chinook (Oncorhynchus tshawytscha), coho (O. kisutch) and sockeye (O. nerka) salmon, and steelhead trout (Salmo gairdneri). It also supports the last remaining mainstem spawning habitat for fall chinook salmon. The salmon population is maintained by a combination of natural spawning, artificial propagation and regulated commercial and sport harvest of returning adults.

Based on redd (nest) counts from the air, fall chinook salmon spawning in the Hanford Reach of the mainstem Columbia River has increased dramatically since 1980 (Fig. 2). Recent observations by divers (Swan et al., 1988) showed salmon redds at depths (4.6 - 9.1 m) below those visible by boat or aircraft and suggests that salmon spawning in the Hanford Reach may be even greater than previously estimated. The increase in salmon spawning has

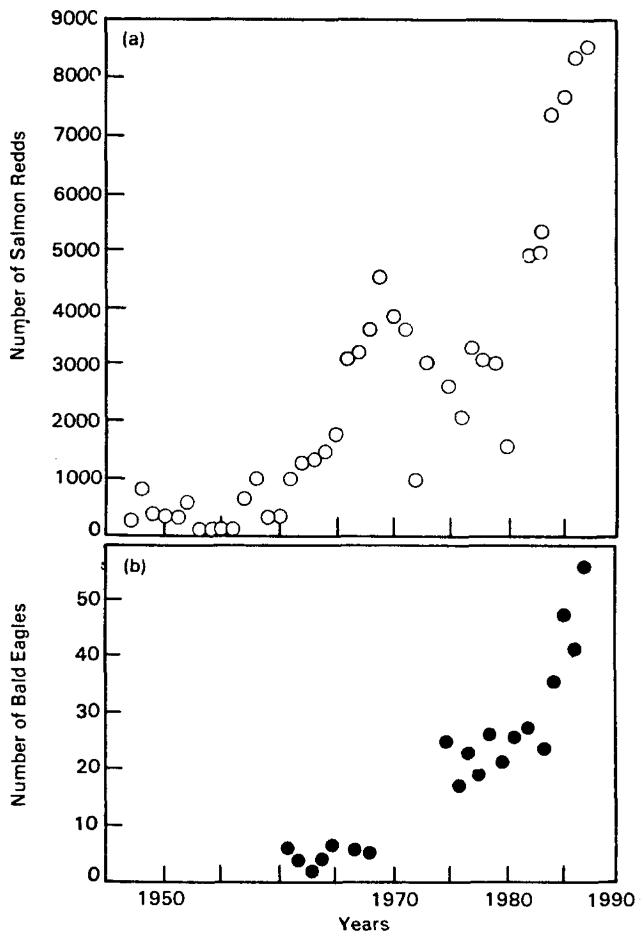

Fig. 2. Numbers of (a) salmon redds (nests) and (b) wintering bald eagles (there were no counts from 1969-1974) at Hanford (adapted and updated from Rickard and Watson, 1985).

attracted increasing numbers of wintering bald eagles (Haliaeetus leucocephalus) (Fig. 2). The bald eagle is listed by the U.S. Fish and Wildlife Service as "threatened" in the state of Washington (Rickard and Watson, 1985).

The sparsely vegetated islands in the Columbia River have historically been used as nesting habitat for great basin Canada goose (Hanson and Eberhardt, 1971; Fitzner and Rickard, 1983). From the mid-1950s to the mid-1970s the number of goose nests declined from about 250-300 to about 100 annually (Fig. 3). From the late 1970s to the present, the number of nests has increased and appears to have stabilized at about 150-200. Initially, closure of the Hanford Reach was beneficial to the geese by providing freedom from human intrusion. However, the coyote, a natural goose predator, also benefited, and is believed to be the major cause of the decline in numbers of goose nests into the mid-1970s.

Initially, there were no nesting great blue heron on the Hanford Site. However, there are now three active colonies consisting of about 35-40 birds each, and herons are present year round.

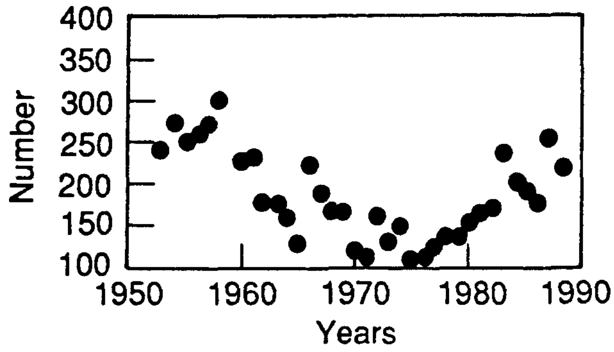

Fig. 3. Numbers of Canada Goose Nests on Islands in Hanford Reach of the Columbia River, 1953-1988 (Adapted and Updated from Fitzner and Rickard, 1983).

Elk first arrived on the Hanford Site in 1972 (Rickard et al., 1977). From a small founding population, the herd size grew to about 80 animals in 1988 (Fig. 4). The rapid increase in elk is attributed to the lack of predation or human disturbance during calving, absence of onsite hunting, and the lack of competition from sheep and cattle for available forage.

The mule deer population at Hanford is estimated at several hundred animals and appears stable even in the absence of onsite hunting. Coyote predation on fawns is believed to be an important factor that maintains a stable deer population (Steigers and Flinders, 1980).

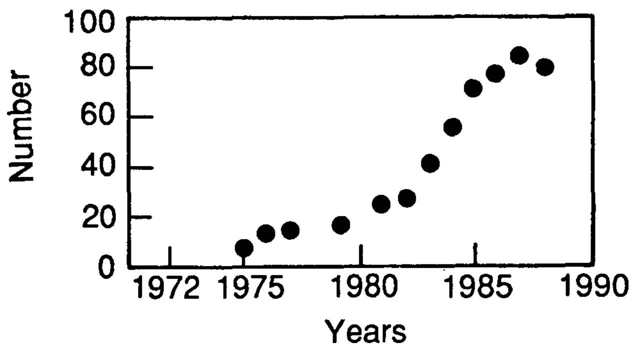

Fig. 4. Estimated numbers of Elk at Hanford, 1974 to 1988.

RADIOLOGICAL TRANSPORT

Air

Potential airborne transport of stack releases containing radionuclides from Hanford facilities offers a direct pathway for human exposure. Thus, air is sampled continuously for airborne particulates and analyzed for radionuclides at 50 locations onsite, at the Site perimeter, and in nearby and distant cities (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988). At selected locations, gases and vapors are also collected and analyzed. Many of the longer-lived radionuclides released at Hanford are also present in atmospheric fallout that resulted from nuclear weapons testing in the 1950's and 1960's or from nuclear accidents that occurred elsewhere. In May and June, 1986, air samples collected onsite as well as those for distant locations showed increases in several long- and short-lived radionuclides (e.g., ^{137}Cs, ^{131}I, ^{103}Ru) resulting from the reactor accident at Chernobyl, April, 1986, in western Russia. However, even then, no sample exceeded 0.17% of the applicable DOE derived concentration guide (DCG) for areas permanently occupied by the public.

Ground Water

The shallow unconfined (water-table) aquifer has been affected by waste-water disposal practices at Hanford more than the deeper, confined aquifers. Discharge of water from various industrial processes has created ground-water mounds near each of the major waste-water disposal facilities in the 200 Areas, and in the 100 and 300 Areas (Fig. 1). Discharge to ground water in the 200 Areas may contribute ten times more water annually to the unconfined aquifer than natural input from precipitation and irrigation (Graham et al., 1981). These ground-water mounds have altered local flow patterns in the aquifer, which are generally from west to east.

Ground water, primarily from the unconfined aquifer, is currently sampled from over 560 wells (Jaquish and Mitchell, 1988). Tritium (^3H) occurs at relatively high levels in the unconfined aquifer, is one of the most mobile radionuclides, and thus, reflects the extent of ground-water contamination from onsite operations. Many liquid wastes discharged to the ground at Hanford have contained ^3H. The PUREX facility is currently the main source for ^3H-containing wastes (DOE, 1983). Tritium from releases prior to 1983 that passed downward through the vadose (unsaturated) zone to the unconfined aquifer continues to move with ground-water flow toward the Columbia River. Tritium concentrations in Hanford ground water range from less than 300 pCi/L to over 2,000,000 pCi/L near or within the 200 Areas (PNL, 1987; Jaquish and Mitchell, 1988).

Ground water from the unconfined aquifer enters the river through subsurface flow and springs that emanate from the riverbank. McCormack and Carlile (1984) identified 115 springs along a 41-mile stretch of river. Tritium concentrations in wells near the springs ranged from 19,000 to 250,000 pCi/L and averaged 176,000 pCi/L in 1985 (Price, 1986). Although the distribution of ^3H and other nuclide concentrations in springs generally reflected those in nearby ground-water wells, the magnitude was generally less in springs due to mixing of ground and surface water. Tritium concentrations in the river were generally less than those in springs. It is noteworthy that ^3H also occurs naturally in the Columbia River upstream from Hanford. Once discharges from springs are mixed with the river a short distance downstream, ^3H from the springs cannot be detected. Concentrations of ^3H upstream from Hanford and at Richland are similar. Tritium concentrations in springs were less than 4% of the DOE DCG (2,000,000 pCi/L). Tritium concentrations in the river were less than 0.5% of the DCG and less than half the regulatory limit for drinking water (20,000 pCi/L; EPA, 1976).

Surface Water

Columbia River water is used for drinking at downstream cities, for crop irrigation and for recreational activities (fishing, hunting, boating, water-skiing, swimming). Thus, it constitutes the primary environmental pathway to people for radioactivity in liquid effluents. Radionuclides can be delivered to human foodstuffs through crops irrigated with river water, and cow's milk through irrigated alfalfa and other cattle forage. Although radionuclides associated with Hanford operations, world wide fallout, and natural phenomena continue to be found in small but measurable quantities in the Columbia River, concentrations are below Washington State and Environmental Protection Agency (EPA) drinking water standards.

Deep sediments in downstream reservoirs still contain low concentrations of some long-lived radionuclides (Nelson and Haushild, 1970; Haushild et al., 1975; Robertson and Fix, 1977; Sula, 1980; Beasley et al., 1981). Trace amounts of ^{239}Pu, ^{60}Co, ^{137}Cs, and ^{152}Eu persist in sediments accumulated above the first downstream dam (McNary). In 1977, between 20 and 25% of the integrated plutonium inventories ($^{239,\ 240,\ 241}$Pu) in Lake Wallula sediments, 100 km downstream, were believed to originate from the 1944 through 1971 releases at Hanford (Beasley et al., 1981). However, only ^{239}Pu was believed to reflect earlier reactor operations. Further, this ^{239}Pu was derived from ^{239}Np (produced by neutron capture in natural uranium followed by decay to ^{239}Np) an abundant isotope in Columbia River water during the years of reactor operations. Thus, plutonium was apparently never actually released to the river from reactor operations.

Fish and Wildlife

Fish are collected at various locations along the Columbia River and boneless fillets are analyzed for ^{60}Co, ^{90}Sr, and ^{137}Cs. Carcasses are analyzed to estimate ^{90}Sr in bone. Following shutdown of the last single-purpose, once-through cooling reactor and installation of improved liquid effluent control systems at N Reactor, short-lived radionuclides (including the biologically important ^{32}P and ^{65}Zn) essentially disappeared from the river (Cushing et al., 1981) through radioactive decay. Radionuclide concentrations in fish collected from the Hanford Reach of the Columbia River are similar to those in fish from upstream locations.

Wildlife have access to several onsite waste-water ponds and ditches that contain low levels of radionuclides and, thus, provide a potential biological pathway for dispersal of contaminants accumulated in water and sediments (Cadwell et al., 1979; Rickard et al., 1981; Rickard and Price, 1984). Samples from these areas help estimate the dose to Hanford fauna and the potential dose impact to humans if onsite game animals were consumed.

Deer (Odocoileus sp.), ring-necked pheasants (Phasianus colchicus), mallard ducks (Anas platyrhynchus), Nuttall cottontail rabbits (Sylvilagus nuttallii) and black-tailed jack rabbits (Lepus californicus) are collected and tissues are analyzed for ^{60}Co and ^{137}Cs (muscle), $^{239,\ 240}$Pu (liver) and ^{90}Sr (bone). The dose that could be received by consuming wildlife at the maximum radionuclide concentrations measured in 1985-1987 was below applicable DOE standards (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988).

Soil and Vegetation

Airborne radionuclides are eventually deposited on vegetation or soil. Samples of surface soil and rangeland vegetation (sagebrush) are currently collected at 15 onsite and 23 site perimeter and offsite locations (Jaquish and Mitchell, 1988). Samples are collected from nonagricultural, undisturbed sites so that natural deposition and buildup processes are represented. Sampling and analyses in 1985 through 1987 showed no radionuclide buildup offsite that could be attributed to Hanford operations (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988).

Foodstuffs

The most direct way for deposited radionuclides to enter the foodchain is through consumption of leafy vegetables. Samples of alfalfa and several foodstuffs, including milk, vegetables, fruit, beef, chickens, eggs, and wheat, are collected from several locations, primarily downwind (i.e., south and east) of the Site. Samples are also collected from upwind and somewhat distant locations to provide information on radiation levels attributable to worldwide fallout. Foodstuffs from the Riverview Area (across the river and southeast) are irrigated with Columbia River water withdrawn downstream of the Site. Although low levels of ^{3}H, ^{90}Sr, ^{129}I, and ^{137}Cs have been found in some foodstuffs, concentrations in samples collected near Hanford are similar to those in samples collected away from the Site. Elevated levels of ^{131}I were detected in milk samples after the Chernobyl accident. Because there are no radionuclide concentration limits for foodstuffs, impacts are assessed by predicting radiation dose from food consumption (see below, Overall Radiological Impact from Hanford Operations).

Penetrating Radiation

Penetrating radiation (primarily gamma rays) is measured in the Hanford environs with thermoluminescent dosimeters to estimate dose rates from external radiation sources. Radiation surveys are conducted at numerous onsite locations including roads, railroads, and retired waste-disposal sites located outside of operating areas. Onsite and offsite measurements and survey results for 1985-1987 were similar and comparable to past years. Dose rates near some operating facilities were only slightly higher than natural background rates.

Overall Impact from Hanford Operations

Beginning in 1974 the evaluation of radiation doses has included assessment of the maximum external dose rate at a location accessible to the general public, doses to a hypothetical maximally exposed individual, and doses to the population within 80 km of the Site. Based on these assessments, potential radiation doses to the public from Hanford operations have been consistently below applicable standards and substantially less than doses normally received from common sources of background radiation. The calculated 50-year whole-body cumulative dose received by the maximally exposed individual ranged from 0.5 to 3 mrem during the years 1981 through 1986 (PNL, 1987). The maximally exposed individual is a hypothetical person who receives the maximum calculated radiation dose when worst case assumptions are used concerning location, inhalation of radioactive emissions, consumption of contaminated food and water, and direct exposure to contaminants. Expressed as effective dose equivalents, the calculated dose received by a hypothetical maximally exposed individual was 0.1, 0.09 and 0.05 mrem respectively, in 1985, 1986 and 1987. The average percapita whole-body cumulative (effective) dose for 1985, 1986, and 1987 based on the human population of 340,000 within 80 km of the Site, was 0.02, 0.03 and 0.01 mrem annually, respectively (Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988). These estimates and the measured Hanford area background radiation can be compared to and are considerably less than doses from other routinely encountered sources of radiation, such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural internal body radioactivity, worldwide fallout, and consumer products (Fig. 5).

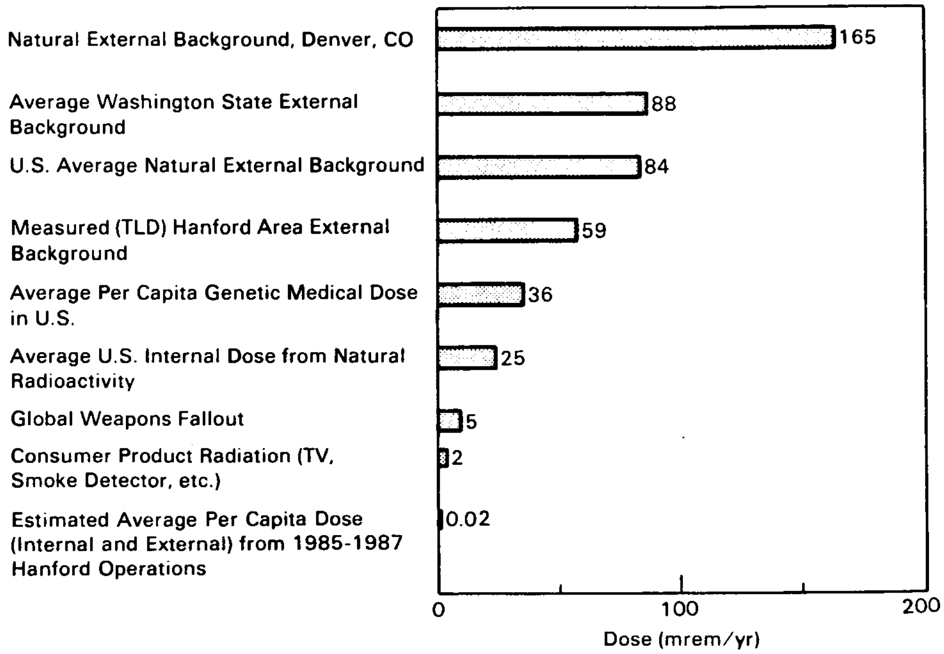

Fig. 5. Annual radiation doses from various sources: external background, Denver, Colorado, Washington State and U.S. average from Oakley (1972). Genetic medical dose, U.S. internal dose, weapons fallout and consumer product radiation from Klement, et al. (1972; adapted from Price, 1986; PNL, 1987; Jaquish and Mitchell, 1988); TLD = thermoluminescent dosimeter, does not include neutron component; mrem/yr = millirem per year.

NONRADIOLOGICAL TRANSPORT

Air Quality

Nitrogen oxides (NO_x) are routinely released onsite from fossil-fueled steam and chemical processing facilities, most notably the PUREX plant. Nitrogen dioxide is sampled at eight onsite and one offsite locations by the Hanford Environmental Health Foundation (HEHF). Nitrogen dioxide concentrations measured in 1984-1987 were well below federal (EPA) and local (Washington State) ambient air quality standards (Price 1986, PNL, 1987; Jaquish and Mitchell, 1988).

Ground Water

In 1987, over 3000 ground-water samples were collected and analyzed for inorganic constituents, and over 290 wells were monitored for potentially hazardous materials including pesticides, herbicides, and total organic halogen (Jaquish and Mitchell, 1988). In addition, well samples were analyzed by HEHF for water quality. Detected constituents included several metals, anions, coliform bacteria, radionuclides, and total organic carbon. Many of these constituents are expected in natural ground water. Chromium, cyanide, fluoride, and carbon tetrachloride were found in wells not used for drinking water near operating areas.

Columbia River

Nonradioactive waste water is discharged at eight locations along the Hanford reach of the Columbia River. Discharges consist of backwash from water intake screens, cooling water, water storage tank overflow, and fish laboratory waste water. Effluents from each outfall are monitored by the operating contractors. The Columbia River is also monitored by the United States Geological Survey, upstream and downstream of the Site, to verify compliance with Class A (WSDOE, 1977) water-quality requirements. In addition, numerous studies have evaluated, and in most cases resolved, the environmental issues associated with water intake and thermal discharge structures at Hanford (Page et al., 1977; WPPSS, 1978; Gray et al., 1979, 1986; DOE, 1982; Neitzel et al., 1982).

SUMMARY

The Pacific Northwest Laboratory (PNL) conducts an environmental monitoring program to assess potential effects of Hanford Operations on the local environs, onsite workers, and the offsite public. Monitoring for radiological emissions at Hanford has been ongoing for over 40 years and includes air, ground and surface water, fish and wildlife, soil, vegetation, and foodstuffs. Measured and calculated radiation doses to the public have been consistently below applicable regulatory limits. Monitoring of fish and wildlife is a significant component of the overall program. The Hanford Site now serves as a refuge for key fish and wildlife species.

ACKNOWLEDGMENTS

Environmental monitoring at Hanford reflects the cooperative efforts of numerous individuals representing the staffs of DOE, PNL, HEHF, and other contractor, state and federal organizations. Environmental monitoring has been conducted by PNL since 1965, and is supported by DOE under Contract DE-AC06-76RLO 1830 with Battelle Memorial Institute.

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