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CONTAMINATION OF THE NORTHERN OCEANS FROM RELEASES OF RADIOACTIVITY FROM THE FORMER SOVIET UNION

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(No figures or tables)

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During the Cold War the handling of Soviet military nuclear wastes was a classified topic – kept secret to hide the status and readiness of Soviet military forces. Following the end of the Cold War information about the handling of nuclear wastes by agencies of the Former Soviet Union (FSU) became available[1]. The US Government response to the disclosure of disposal of radioactive wastes into the Arctic Ocean and into rivers that drain into the Arctic Ocean was the funding of the Arctic Nuclear Waste Assessment Program (ANWAP) in the Office of Naval Research (ONR). Projects were funded by ANWAP to study the behavior, transport, and fate of radionuclides in the Arctic Ocean. One of the research teams, the Risk Assessment Integration Group (RAIG) assessed the potential risks to humans and to the environment, particularly in the US Alaskan Arctic[2].

The RAIG consisted of scientists from Lawrence Livermore National Laboratory (California), Pacific Northwest National Laboratory (Washington), Sandia National Laboratories (New Mexico), the Alaskan North Slope Borough, the Department of Environmental Conservation (Alaska), and the Office of Naval Research (District of Columbia).

The FSU disposed of 16 nuclear reactors from submarines and an icebreaker in the Kara Sea near the island of Novaya Zemlya - six of the nuclear reactors contained spent nuclear fuel (SNF). The FSU also disposed of solid and liquid wastes in the Sea of Japan, lost a ^{90}Sr-powered radioisotope thermoelectric generator (RTG) in the Sea of Okhotsk, and disposed of liquid wastes at several sites in the Pacific Ocean, east of the Kamchatka Peninsula. In addition to these known sources, the RAIG evaluated FSU waste disposal practices at inland weapons development sites that have contaminated major rivers flowing into the Arctic Ocean. These sources were evaluated for the potential for release to the environment and for transport and impact to Alaskan ecosystems and peoples through a variety of scenarios, including a worst-case total instantaneous and simultaneous release of the sources under investigation.

The objective of the RAIG effort was to develop and apply a marine radiological assessment methodology that specifically addressed (1) the principal sources of nuclear wastes from the FSU that could affect the Arctic Ocean; (2) the transport of key radionuclides in the Arctic Ocean; (3) bioaccumulation of those key radionuclides in marine species; (4) human dietary exposures via the consumption of fish and marine mammals; and (5) absorbed doses and associated risks for marine ecosystems and exposed human populations, with a principal emphasis on Alaskans relying on seafoods as important dietary items.

This was a prospective assessment, not undertaken to address any specific, observed human health or ecological problem in Alaska, but rather to evaluate the potential impacts from the

FSU's improper disposal of nuclear materials.

The RAIG risk assessment reached out to the native community in Alaska soliciting their input. Native health associations, scientists and community leaders particularly knowledgeable about resources and dietary practices in north and northwestern Alaska were involved in the project. Representatives of the RAIG traveled to Anchorage, Barrow, Kotzebue and Nome, Alaska to discuss the elements, purpose and goals of the risk assessment and to ensure that the RAIG risk assessment reflected local knowledge and interests.

The ANWAP risk assessment addressed the following FSU wastes, media, and receptors:

- Dumped nuclear submarines and an icebreaker in the Kara Sea: *Marine pathways*
- Solid reactor parts in the Sea of Japan and the Pacific Ocean: *Marine pathways*
- Thermoelectric generator in the Sea of Okhotsk: *Marine pathways*
- Currently known aqueous wastes in Mayak Reservoir and Asamov Marshes: *Riverine to marine pathways*
- Alaska as the receptor

The ANWAP risk assessment did NOT address the following wastes, media, and receptors:

- Radioactive sources in Alaska (except to add perspective to the FSU source term)
- Radioactive wastes associated with FSU naval military operations and decommissioning
- Nonaqueous source terms from FSU production reactor and spent fuel reprocessing facilities
- Atmospheric, terrestrial and nonaqueous pathways
- Dose calculations for any circumpolar locality other than Alaska

The first activity of the risk assessment was to characterize radionuclide sources in the Arctic seas - both marine and riverine. To place the sources into perspective ANWAP characterized existing fallout levels of key radionuclides, wastes from Chernobyl and from European fuel-reprocessing facilities, and naturally-occurring radioactivity. Except for very localized instances in the Kara Sea near dumped reactors and nuclear testing sites, existing fallout levels and the fuel reprocessing source terms now dominate in the Arctic[3].

Screening analysis by the RAIG indicates that the radionuclides that result in over 95% of the potential human and ecological risks are ^{137}Cs, ^{239}Pu, ^{241}Am, and ^{90}Sr. The primary risks from the submarine reactor cores in the Kara Sea arise from ^{137}Cs, and the primary potential risks from the land-based sources arise from ^{90}Sr. However, the dominant source of ^{137}Cs in the Arctic Ocean is the reprocessing facility at Sellafield (9,000 TBq through 1992), whereas worldwide fallout is the primary source of ^{90}Sr. It is estimated that about 20 TBq of ^{239}Pu released from Sellafield reached the Arctic Ocean through 1992.

Two release scenarios were considered for the dumped submarines and icebreaker in the Kara Sea: (1) a worst-case condition where all materials are released instantaneously, and (2) a time-varying, best-estimate case in which the radionuclides are released as the SNF corrodes. Both scenarios were based on results of the International Arctic Seas Assessment Program (IASAP)[4], sponsored by the International Atomic Energy Agency (IAEA). In the worst case about $4.7(10^6)$ GBq are released instantaneously. In the best-estimate case, the maximum Kara Sea release occurs in about the year 2050, after seawater enters unprotected reactor compartments. The total annual release never rises above 1300 GBq/yr. The rate drops from 1000 GBq/yr in the year 2100 to 1 GBq/yr in the year 3000. These two scenarios limit the potential impacts.

In the Sea of Japan and in the Pacific Ocean, East coast of Kamchatka a worst-case assumption was taken that the dumped objects are unenclosed and subject to corrosion at a rate of 0.05 mm/yr. Sedimentation cover is assumed to occur within 1000 years. The total release rate in the Sea of Japan begins at about 1 GBq/yr beyond the year 4000; and in the Pacific Ocean releases start below 0.01 GBq/yr over 1000 years, and fall to 10^{-9} GBq/yr.

In the Sea of Okhotsk we assumed $11(10)^6$ GBq of ^{90}Sr in the RTG. The RAIG assumed that since the RTG is hermetically sealed and solidly constructed, the radionuclides will decay before release.

In the West Siberian Basin four scenarios were considered: (1) baseline release based on historical records, (2) Mayak reservoir failure releasing all ^{90}Sr within one year, (3) Mayak reservoirs releasing radioactivity to near-surface groundwater under worst-case conditions, and (4) remobilization of ^{90}Sr from the Asamov Marshes, with a one-year release period. The upper bound for the current baseline release from global fallout plus past releases from the land-based facilities is $40(10)^3$ GBq/yr of ^{90}Sr. All other scenarios result in a flux rate of about $1.4(10)^6$ GBq /yr for only one year.

The RAIG radiological risk assessment used actual measurements of radionuclides in biota as well as bioconcentration factors (BCF) to extrapolate radionuclide concentrations in seawater with expected biota levels over time. The BCF values are summarized in an IAEA document[5]. The BCFs were used to predict uptake of Arctic contaminants in important dietary species for man as well as those that are an important part of food chains leading to man.

The RAIG evaluated radionuclide levels in Alaskan coastal waters and sediments and in selected marine mammals, fishes, and other biota, and found the levels to be below levels of concern for bioeffects. Predicted concentrations of radionuclides from FSU sources are not expected to affect survival of populations of marine mammals, fishes, and other biota, especially those of human dietary importance in Alaska. The predicted doses are so low in all cases as to make it very unlikely that any loss of endangered species or any significant ecological impacts will occur in areas away from the FSU nuclear waste disposal sites.

The RAIG, using data on subsistence diets, focused on people in north and northwestern Alaskan coastal communities whose diet includes fish and marine mammals from the Arctic Ocean. The RAIG estimated peak radiation doses for individuals living in different communities with varying diets. The largest doses to Alaskans in coastal communities who consume subsistence seafoods come from naturally-occurring ^{210}Po, followed by ^{137}Cs and ^{90}Sr from global fallout. The highest predicted doses from FSU sources result from the instantaneous release of radionuclides from reactors dumped in the Kara Sea, but those doses are well below background levels. The predicted acute and chronic discharges from the Ob and/or Yenisey rivers yield doses similar to the Kara Sea sources. Therefore, the RAIG concluded that there is no indication that FSU dumping activities caused elevated concentrations of radionuclides in Alaskan waters.

The potential human health risks associated with ingesting Alaskan seafoods containing radionuclides from FSU releases are extremely low and pose no threat to human health. Therefore, Alaskan communities need not alter any of their dietary habits associated with subsistence foods obtained from Alaskan waters because of radionuclide releases from the FSU.

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