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POTENTIAL RADIOLOGICAL IMPACT OF A CONCEPTUAL HANFORD NUCLEAR ENERGY CENTER

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DISCLAIMER

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ABSTRACT

The potential radiological impact of the siting of 20 light-water reactors and associated nuclear fuel cycle facilities on the Hanford reservation was evaluated by calculating the potential radiation doses received by individuals and populations in the vicinity of the reservation. The largest contributor to the potential radiation doses, to both the individual and the 50-mile population, were the effluents from the conceptual 1500 MT/yr fuel reprocessing plant. The effluents from the 20 reactors combined was the second largest contributor. The radiation dose contributions from the 300 MT/yr mixed oxide fuel fabrication plant were insignificant. The highest organ dose from all facilities combined was 24 mrem/yr to the child thyroid; followed by 8 mrem/yr to the adult thyroid. The radiation doses met proposed EPA guidelines. The 50-year collective dose commitment to the population within 50 miles was about 50 man-rem for most organs of reference, while the estimate for bone was 70 man-rem.

With the exception of ^{85}Kr, the release rates of radionuclides were also within the EPA guidelines. Removal of about 90% of the 4×10^5 Ci/yr per gigawatt-year of electricity of ^{85}Kr from the fuel reprocessing plant gaseous effluents would be required for compliance with the EPA guidelines.

POTENTIAL RADIOLOGICAL IMPACT OF A CONCEPTUAL HANFORD NUCLEAR ENERGY CENTER

INTRODUCTION

This report briefly discusses the potential radiological impact of a conceptual Hanford Nuclear Energy Center (HNEC) on the environment. It was prepared as one part of a detailed study sponsored by the Department of Energy. A description of the HNEC concept and its overall impact/benefit considerations is contained in Report PNL-2640 (0)

The discussion addresses, in a generic sense, the routine release rates of radionuclides from nuclear power plants and associated fuel cycle facilities at such an HNEC. The radiation doses resulting from such releases are summarized briefly, but details of the dose calculations are not presented. Further analysis of the potential radiological impact would have to be undertaken once specific sites and plant designs are chosen. Depending upon the actual plant characteristics, the radiological impact could be different than derived here for the generic site, but in all probability the net impact would not be significantly greater because of the conservative assumptions employed.

All industrial plants handling radionuclides have radioactive waste (radwaste) systems that treat the waste streams containing radionuclides. These systems are referred to as the liquid, gas, or solid radwaste systems in accordance with the physical form of the waste streams being treated. The purpose of the radwaste systems is to minimize release of radionuclides to the environment and the consequent radiation dose to the general public.

The radwaste systems can be designed for all degrees of treatment from essentially zero up to very sophisticated systems which result in virtually no release of radionuclides to the environment. The costs for operating these systems also have a broad range from a low value for minimal treatment up to high values for sophisticated treatment.

STANDARDS AND GUIDES

The NRC has a general policy that the radiation dose received by the general public shall be "as low as practicable" which is defined as "as low as is practicably achievable taking into account the state of technology and the economics of improvement in relations to benefits to the public health and safety and in relation to the utilization of atomic energy in the public interest."[1] This has been translated into design guides, in Appendix I to 10 CFR 50,[2] which defines the term "as low as practicable" in relation to radiation doses that the general public might receive as a result of radionuclide releases from nuclear power plants. Such design guides have not been issued for fuel cycle facilities by the USNRC but only for Light Water Reactor (LWR) power plants. New terminology, "as low as reasonably achievable" (ALARA) has since been adopted by the NRC.

Recently the EPA recommended radiation protection standards for limiting the exposure of the public from uranium fuel cycle operations.[3] These standards are summarized below.

(a) The annual dose equivalent to any member of the general public from effluents or radiation from uranium fuel cycle operations shall not exceed 75 millirem to the thyroid and 25 millirem to any other organ (excluding skin and cornea).

(b) The total quantity of radioactive material discharged to the environment per gigawatt-year of electricity generated shall contain less than 50,000 curies of krypton-85, 5 millicuries of iodine-129, and 0.5 millicurie combined of plutonium-239 and other alpha-emitting transuranic radionuclides with half-lives greater than one year.

The effective date for these standards is December 1, 1979 for all operations except milling of uranium ore, for which the effective date is December, 1980. The EPA has examined the previously promulgated NRC Guidelines for individual light-water-cooled power reactors as contained in Appendix I to 10CFR50.[2] They concluded that existing reactors licensed

under the Appendix I Guides by NRC would have no difficulty complying with the new EPA standards even at sites with up to 5 LWRs, or at multiple sites each with one or two LWRs provided the sites were spaced at least 10 miles apart.

EXPOSURE PATHWAYS

Each of the several types of nuclear facilities expected to be located within an HNEC will routinely release radioactive gases, liquids, and/or solids to the environment and must meet the ALARA guidelines and the EPA standards for total impact. In a general way, the total impact of the facilities is the sum of the impacts caused by each facility. However, the individuals receiving the highest doses will not necessarily be identical for each geographically-separated facility and the doses to the maximum individual will not necessarily be completely additive, especially in the instance of gaseous effluents.

The radiation dose received by the general public, as a result of radionuclide release from a plant, depends primarily on the design of the radwaste systems, the distance between the plant and the nearest members of the general public, and the pathways for radionuclide travel to the public.

The composition of the radioactive effluents affects the organs which might receive the highest radiation doses as well as the pathways of exposure. At a fuel fabrication plant where actinide elements are released to the atmosphere, inhalation is the principal pathway and the lung, bone and liver are the organs receiving the highest exposure.

At nuclear power reactors and fuel reprocessing plants where tritium and mixed fission product radionuclides are released, ingestion of milk and produce are the pathways of interest and the thyroid (particularly of infants) is the organ of interest.

Several mathematical models developed for calculating radiation doses to man and other biota from radioactive materials released to the environs have been reported in detail in the literature. Some of these models were specifically designed to treat accidental or acute releases[4,5] although they can be applied with modifications to chronic releases.[6,7] Other models were designed to calculate radiation doses in a large region of the

United States from chronic releases.[8,9] Applications of these models to the estimation of radiological impact of nuclear facilities for inclusion in the Environmental Reports required by the National Environmental Policy Act (NEPA) have also been discussed in the literature.[10,11] In addition, they have been applied to the analysis of the radiological impact of large nuclear energy centers for an NRC study.[12,13,14] Application of the results from these studies to the HNEC can be made by replacing the generic environmental conditions assumed in them with the specific conditions in existance at Hanford. The following discussions of the radiological impact of the various types of nuclear facilities at an HNEC are based upon such an application.

FUEL FABRICATION PLANT

In an NEC fuel fabrication facilities might be required for both uranium and plutonium LWR fuels.

In the uranium plant, uranium is received as either the hexafluoride or oxide powder. It is converted to the oxide, formed into pellets, sintered, etc., and then placed in zirconium tubes. The tubes are sealed and then assembled into finished assemblies. The plant ventilation system employs adequate safeguards to prevent the release of significant amounts of particulate matter. The radiological impact of a uranium fuel fabrication plant would be much less than that of the mixed oxide (plutonium fuel fabrication) plant discussed below.

A safeguarded plutonium fabrication plant would have several additional steps in the process. Typically plutonium-bearing materials may have to be converted to an oxide, blended with uranium oxide and then formed into pellets. The pellets, after further treatment, would be placed in tubes and welded closed. Up to this point all operations have taken place in shielded glove boxes because of the potentially highly radioactive nature of the safeguarded plutonium. The remainder of the process parallels the uranium assembly line equipment, so that both plants do not require significant controlled access or low population zones surrounding them.

The potential environmental impact of a 300 MT/yr mixed oxide fuel fabrication (MOX) plant was addressed in document NUREG-0001-ES.[14] This size plant could provide the plutonium fuel for about 40 LWR power reactors. A safeguarded plant would probably not be significantly different. The release rates of transuranium nuclides from the postulated MOX plant given in Reference (12) are reproduced in Table 1.

TABLE 1. Estimated Release Rates of Radionuclides to the Atmosphere from a 300-MT/yr MOX Plant (12)

Nuclide	wt %	mg/yr	Ci/mg	Ci/yr[b]
^{238}Pu	2.0	7.6E-2	1.7E-2	1.3E-3
^{239}Pu	45.5	1.7E+0	6.1E-5	1.0E-4
^{240}Pu	25.0	9.5E-1	2.3E-4	2.2E-4
^{241}Pu	15.5	5.9E-1	9.9E-2	5.8E-2
^{242}Pu	12.0	4.6E-1	3.9E-6	1.8E-6
^{241}Am	--	2.6E-2[a]	3.4E-3	9.0E-5
TOTAL	100%	3.8 mg	--	5.8E-2 1.7E-3

[a] Assuming a 1-year delay between reprocessing plant and fuel fabrication plant.

[b] Released from roof vents.

Siting such a plant on the 200 Area plateau in an HNEC increases the site boundary distance to nearly 20 miles. The maximum individual would probably be located in the direction of the prevailing wind (SE) where the annual average atmospheric dilution factor is $2.1X10^{-8}$ sec/m^3.[15] The radiation doses to the maximum individual were calculated using this dilution factor and the release rates in Table 1. The results are summarized in Table 2. Also included in Table 2 are the radiation doses to the population (290,000 persons) within 50 miles of the plant site using a population weighted average atmospheric dilution factor of $8.0X10^{-9}$ sec/m^3.

The principal pathway of exposure is inhalation, with negligible contribution from external exposure or food consumption. The doses in Table 2 are certainly well below the EPA standards or any potential ALARA criteria for fuel fabrication plants. In addition, the projected release rate of less than 2 millicuries of long lived alpha emitters amounts to about 0.05 millicuries per gigawatt year of electricity generated or about 10% of the EPA standard for such releases.

TABLE 2. Estimated Radiation Doses to a Maximum Individual and the Population Within 50 miles of a 300 MT/yr MOX Plant at an HNEC Site

Organ	First-Year Dose	Fifty-Year Dose Commitment
	Maximum Individual (millirem)	
Total Body	4 E-6	1 E-3
Bone	2 E-4	4 E-2
GI-LLI	6 E-6	6 E-6
Liver	2 E-5	4 E-3
Lung	8 E-4	1 E-3
Thyroid	5 E-7	5 E-7
	Population (man-rem)	
Total Body	4 E-4	0.1
Bone	2 E-2	4.3
GI-LLI	4 E-4	4 E-4
Liver	2 E-3	0.4
Lung	8 E-2	0.2
Thyroid	4 E-5	4 E-5

FUEL REPROCESSING PLANT

If fuel reprocessing were undertaken at a HNEC, then a plant of 1500 MT/yr capacity would be sufficient for reprocessing the fuel discharged from about 40 operating light-water reactors. The radwaste system postulated in Reference 12 assumed DF's of only 20 and 40 for ^{129}I and ^{131}I respectively. By the time an FRP were constructed at the HNEC, DF of 500 and 1000 for ^{129}I and ^{131}I, respectively, would be more realistic. Therefore the release rates of these 2 nuclides to the air from the FRP stack were assumed to be 1/25 of those given in reference (12). The rad-waste system DF's for the other nuclides were assumed to be the same. The revised list of release rates is given in Table 3.

Siting this FRP at the 200 Area plateau of the Hanford project and utilizing a 60-meter (200') stack would provide an annual average atmospheric dilution factor of $4X10^{-9}$ sec/m^3 at the location of the maximum individual (20 miles SE).[15] The population-weighted average dilution factor for the 50-mile population (290,000 persons) would be $1.5X10^{-9}$ sec/m^3. Combining these factors, the release rates of Table 3 and the radiation dose calculation models and parameters normally utilized for the Hanford Project[15] yields the radiation doses summarized in Table 4.

The radiation doses in Table 4 are about 20% of the EPA Standards of 75 mrem/yr to the thyroid and 25 mrem/yr to any other organ. They also should be below any future ALARA guidelines that might be promulgated by the NRC for fuels reprocessing plants.

Table 5 lists the release rates of ^{85}Kr, ^{129}I and long-lived alpha emitters in units of Ci per gigawatt-year of electricity generated. These values were obtained by dividing the corresponding values in Table 3 by the 40 gigawatt equivalent represented by the FRP. Also listed in Table 5 are the EPA standards for release of these radioactive materials.

TABLE 3. Estimated Release Rates of Radionuclides from a 1500 MT/yr LWR-Pu Fuels Reprocessing Plant [12]

Nuclide	Ci/yr	Nuclide	Ci/yr
^{3}H	1.2E+6	^{134}Cs	6.0E-1
^{14}C	7.0E+2	^{137}Cs	5.1E-1
^{85}Kr	1.4E+7	^{141}Ce	1.3E-1
^{89}Sr	2.3E-1	^{144}Ce	2.2E+0
^{90}Sr	2.0E-1	^{147}Pm	3.0E-1
^{90}Y	2.0E-1	^{154}Eu	2.3E-2
^{91}Y	3.9E-1	^{155}Eu	2.2E-2
^{95}Zr	7.2E-1	^{238}Pu	7.5E-2
^{95}Nb	1.4E+0	^{239}Pu	3.6E-3
^{103}Ru	1.1E-1	^{240}Pu	7.5E-3
^{106}Ru	7.5E-1	^{241}Pu	2.2E+0
^{110m}Ag	1.0E-2	^{242}Pu	6.0E-5
^{125}Sb	2.9E-2	^{241}Am	2.2E-3
^{127}Te	1.9E-2	^{243}Am	6.3E-4
^{129m}Te	6.6E-3	^{242}Cm	2.8E-1
^{129}I(a)	1.2E-1	^{244}Cm	1.5E-1
^{131}I(a)	1.4E+0		

(a) These are 1/25 of the values given in Reference 12; see text.

TABLE 4. Estimated Radiation Doses to a Maximum Individual and the Population Within 50 Miles of a 1500 MT/yr FRP at an HNEC Site

Organ	First-Year Dose	Fifty-Year Dose Commitment
	Maximum Individual (millirem)	
Total Body	4.9	5.1
Bone	0.2	0.6
GI-LLI	4.9	5.1
Thyroid (adult)	5.1(a)	5.3
Thyroid (infant)	13.(a)	--
	Population (man-rem)	
Total Body	410	430
Bone	13	32
GI-LLI	410	430
Thyroid	430	450

(a) 95% of this dose is from ^{3}H

TABLE 5. Comparison of Release Rates of ^{85}Kr, ^{129}I and Long-Lived Alpha Emitters from a 1500 MT/yr FRP with EPA Standard

(Curies per Gigawatt-Year Electricity)

Radioactive Material	Estimated Release Rate	EPA Standard(3)
^{85}Kr	4E+5	5E+4
^{129}I	3E-3	5E-3
Lived-lived* Alpha Emitters	6E-3	5E-4

* Includes all TRU nuclides from Table 3 except Pu-241 and Cm-242.

It can be seen from Table 5 that release rates of ^{85}Kr and long-lived alpha emitters are each about a factor of 10 above the EPA standard. Improvement by a factor of 10-20 in the filtration efficiency of the particulate rad-waste system over that employed in deriving the releases in Table 3 should be feasible. The values that were used in the NECSS-75 study for filter efficiency were conservatively low.[14] Even if an extra bank of high-efficiency particle filters were required, they can be added at a small incremental cost.

The ^{85}Kr release rate however cannot be significantly lowered without the installation of a system for collection and storage of krypton. Such a system was proposed for the Nuclear Fuel Recovery and Recycling Center planned by EXXON Nuclear Co., Inc. for the Oak Ridge, TN area[16]. The projected overall ^{85}Kr recovery of that system was 95%, which would be sufficient for the postulated FRP.

NUCLEAR POWER REACTORS

Operation of a nuclear power reactor creates radioisotopes in the fuel elements, the fuel element cladding and end supports, the structural materials, and the coolant. Most of these radioisotopes are immobile because they are either encased in the fuel elements or are part of the permanent equipment. However, small amounts are created in or enter the coolant and travel throughout the coolant and the associated purification and waste systems. Small amounts also escape into other parts of the reactor building and eventually are transported to the radiation waste systems for appropriate treatment, storage and/or release to the environment.

Estimated release rates of radionuclides with liquid and gaseous effluents from BWR and PWR nuclear power reactors were given in reports of the NECSS-75 Study.[13, 14] Guidance on the specific radionuclide content of liquid and gaseous wastes versus radwaste system complexity at LWRs can be found in WASH-1258.[1]

Table 6 lists the estimated release rates of radionuclides with the liquid effluents from a 20-reactor HNEC. These values include the total contribution from 7 BWRs and 13 PWRs.

Assuming that the entire annual release of radionuclides given in Table 6 is mixed into the average annual flow rate of the Columbia River (120,000 cfs) the radiation doses to a maximum individual and the 50-mile population[a] were calculated. The results are summarized in Table 7.

The doses in Table 7 include the conservative assumption that all 20 reactors were on line simultaneously for 30 years, during which time the released radionuclides were accumulating in river sediments and irrigated farmland, prior to initiation of the radiation exposure period.

Even though the NRC ALARA guidelines were not designed for large nuclear energy centers, the doses in Table 7 are below the guidelines

(a) Different numbers of persons are engaged in swimming, boating and fishing than consume water or eat irrigated produce (see Reference 15). It was conservatively estimated here that in the future as many as 20,000 persons could be ingesting irrigated farm products instead of the 2,000 persons quoted in Reference 15.

TABLE 6. Estimated Release Rates of Radionuclides with Liquid Effluents from a 20-Reactor HNEC(a)

Nuclide	Ci/yr	Nuclide	Ci/yr
H-3	5.6E+3	Mo-99	0.84
Na-24	4.7E-3	Tc-99m	0.77
P-33	1.8E-3	I-131	1.8
Cr-51	1.0E-3	I-132	3.2E-2
Mn-56	1.1E-3	I-133	0.62
Fe-55	4.6E-2	Cs-134	5.9E-2
Fe-59	1.4E-2	Cs-137	4.2E-2
Co-58	8.7E-2	Ba-140	8.4E-2
Co-60	1.0E-2	Ce-141	2.2E-3
Sr-89	7.0E-2	Ce-143	1.2E-2
Sr-90	4.2E-3	Ce-144	5.0E-4
Y-90	0.12	W-187	2.0E-2
Sr-91	2.5E-2		
Y-91	3.2	TOTAL, Less ^{3}H	7.8

(a) Total release to the Columbia River from 7 BWRs and 13 PWRs based on the release rates given in Reference 13.

TABLE 7. Estimated Radiation Doses to a Maximum Individual and the Population Within 50 Miles from the Liquid Effluents from 20 Operating Reactors at HNEC[a]

Organ	First-Year Dose	Fifty-Year Dose Commitment
	Maximum Individual (millirem)	
Total Body	0.02	0.03
Bone	0.004	0.03
GI-LLI	0.02	0.02
Thyroid (Adult)	0.06	0.07
Thyroid (infant)	0.3	--
	Population (man-rem)	
Total Body	0.3	0.3
Bone	0.02	0.3
GI-LLI	0.3	0.3
Thyroid	1.2	1.3

(a) Includes contributions from external exposure to contaminated water and sediment and internal doses from ingestion of water, fish and irrigated farm products, conservatively assuming 30 years of accumulation of radionuclides in the environment from simultaneous operation of all 20 reactors prior to the first year of the dose period.

for liquid effluents of 3 mrem annual dose commitment to the total body and 10 mrem annual dose commitment to any organ from each LWR. They are also well below the proposed EPA standards of 75 mrem to the thyroid and 25 mrem to other organs per gigawatt-year of electricity generated, since the 20 reactors would generate a combined total of about 25 GWe-yr per year of operation.

Table 8 summarizes the estimated releases of radionuclides with gaseous effluents from 7 BWRs and 13 PWRs at the postulated HNEC. The release rates are based on data from the NECSS-75 Nuclear Energy Study.[13]

The radiation doses from the releases listed in Table 8 were conservatively estimated by assuming one-half of the release occurred at the site of WPPSS reactors 1, 2 and 4, and the other one-half occurred at the site of the 100-N reactor. Appropriate meteorology for vent releases and population distributions were readily available for these two locations.[15, 17, 18] It was also assumed that sufficient food was grown locally to provide for all of the 2×10^5 persons residing within 50 miles of either site. As was done for the liquid release, it was assumed that all 20 reactors had operated simultaneously for 30 years prior to the beginning of the dose period. The resulting doses are summarized in Table 9.

The principal pathway for all the doses listed in Table 9 is ingestion of foods contaminated with ^{3}H, ^{14}C, ^{131}I and ^{133}I. The principal contributor to total-body dose was ^{3}H with a small contribution from ^{14}C. As before, the doses are well below the EPA standard of 75 mrem/yr to the thyroid and 25 mrem to other organs. The thyroid dose to the infant amounts to only about 0.5 mrem per gigawatt-year of electricity generated. The ^{85}Kr release is about 950 Ci per Gwe-yr compared to the EPA standard of 50,000 Ci per GWe-yr.

The doses listed in Table 9 do not exceed the ALARA guidelines specified for gaseous releases from each LWR at a site; viz., 5 mrem/yr to the total body and 15 mrem/yr to any organ (from radioiodine and particulates).

TABLE 8. Estimated Release Rates of Radionuclides with Gaseous Effluents from a 20-Reactor HNEC[a]

Nuclide	Total Ci/yr
H-3	15,000
C-14	170
Kr-83m	90
Kr-85m	1,100
Kr-85	19,000
Kr-87	390
Kr-88	680
Kr-89	1,300
Xe-131m	1,300
Xe-133m	380
Xe-133	63,000
Xe-135m	440
Xe-135	4,000
Xe-137	2,200
Xe-138	1,800
I-131	1.2
I-133	0.82
TOTAL	110,000

(a) Total released from 7 BWRs and 13 PWRs with a combined capacity of 25,000 GWe.

TABLE 9. Estimated Radiation Doses to a Maximum Individual and the Population Within 50 Miles from the Gaseous Effluents from 20 Operating Reactors at an HNEC(a)

Organ	First-Year Dose	Fifty-Year Dose Commitment
	Maximum Individual (millirem)	
Total Body	1.5	1.5
Bone	0.9	1.1
GI-LLI	1.5	1.5
Thyroid (adult)	2.7	2.8
Thyroid (infant)	11.	--
	Population (man-rem)	
Total Body	53.	55.
Bone	28.	32.
GI-LLI	53.	55.
Thyroid (adult)	84.	87.

(a) Includes contributions from external exposure to airborne and deposited radionuclides and internal dose from inhalation and ingestion of produce, meat, milk, and eggs. Conservatively assuming 30 years of accumulation of radionuclides in the environment from simultaneous operation of all 20 reactors, prior to the first year of the dose period.

WASTE MANAGEMENT FACILITIES

Waste Management includes disposal of low-level solid wastes from all the nuclear fuel cycle facilities and either storage of spent reactor fuel elements or, if reprocessing and MOX fuel fabrication is undertaken, storage, solidification and ultimate disposal of high-level liquid waste. In addition, an incinerator for alpha wastes generated at the FRP and/or MOX would be required if these facilities were operated.

Low-level wastes from DOE facilities have been buried at the Hanford site for three decades and commercial low-level wastes for one decade. No indication of any offsite radiation exposure to man has been found from either of these operations, and none is expected in the future from any waste burial operations associated with the HNEC.

Also, an alpha waste incinerator has been operated on the Hanford site with no off-site radiological impact. Based on this experience, the annual quantity of actinides potentially released from incineration of the wastes from a 300 MT/yr MOX plant and from a 1500 MT/yr FRP would be about 0.053 mg/yr and 0.023 mg/yr, respectively.[12] Thus a total of 0.076 mg/yr of radioactive material is expected to be released. This is 2% of the release rate estimated for the MOX plant (Table 1). The composition of this material can be assumed to be similar to that given in Table 1, since most of the wastes would come from the MOX plant. Therefore, the offsite radiation doses from operation of an alpha waste incinerator would be about 2% of the doses from the MOX plant given in Table 2. The resultant doses are vanishingly small by any standard.

Waste management facilities were discussed in ORNL-4451[19] and it was concluded that with proper design and siting any environmental radiological impact of such facilities would be minimal. Interim storage of high-level liquid wastes does not normally result in release of radioactive

materials to the surface waters. Acceptably small releases of radionuclides to the atmosphere will occur routinely, and accidental leaks could release liquid material to the ground. For these reasons, careful design and judicious siting of high-level liquid waste storage facilities must be accomplished. Siting of these facilities within a nuclear center where the distance to the nearest population is relatively large would normally result in extremely low radiation doses to the offsite population.

Solidification of liquid wastes from the postulated HNEC reprocessing plant after a brief (3 to 5 yr) storage period would normally be done at the site of the FRP for economic and safety reasons. Properly encapsulated solidified wastes could be stored at an interim retrievable storage facility if necessary prior to shipment to an ultimate disposal site. It is also possible that the ultimate storage site might be on the Hanford reservation, eliminating the need for offsite shipment.

Neither the storage nor the solidification itself should impose an unacceptable environmental impact. According to the data provided in Reference 12, the release rates of radionuclides during the HLW solidification process are, with few exceptions, less than 1% of the release rates expected during reprocessing of spent fuel. The exceptions include ^{3}H, ^{14}C, and ^{85}Kr for which the release rates during solidification are essentially zero. Hence, the radiation doses to the maximum individual and the population offsite resulting from solidification, would be a small fraction of those previously calculated for the releases from the FRP. This is especially true since ^{3}H, which is one of the principal contributors to offsite doses from the FRP, was assumed to be all released during reprocessing operations.

The radiological impact of the ultimate disposal of either encapsulated HLW or spent fuel elements is the subject of a generic environmental impact statement being prepared by PNL for DOE. This statement is now

nearing completion. The decision on exactly where and how solidified HLW or spent fuel would be disposed has not yet been made. But it appears that barring improbable accidents or a major natural catastrophe, no significant radiation doses from waste management operations or long-term storage of these radioactive materials is foreseen. Therefore, it is not expected that any of the waste management activities would lead to off-site radiation doses, which would be significant compared to either the existing NRC guides or the EPA Standards.

OVERALL RADIOLOGICAL IMPACT

Primary radiological safety advantages of siting all of the fuel cycle facilities at a nuclear power center include elimination of transportation over public highways of highly radioactive materials between the several process stages, and the increased distance between the facilities and the site boundary.

The disadvantages include the larger quantities of radionuclides discharged to air and water at one site compared to isolated facilities. There does not seem to be any insurmountable problems with the combined releases of 95,000 Ci of noble gases, 15,000 Ci of tritium, 200 Ci of ^{14}C, and 2 Ci of radioiodine to the atmosphere from 20 reactors, since the facilities would be well separated from each other and from the general public. Neither does the discharge of some 6,000 Ci/yr of tritium and less than 10 Ci/yr of other fission and activation products to one body of water from 20 operating reactors seem to present any environmental impact problems. The estimated total radiation doses and release rates were all below those specified in the NRC guidelines for LWRs, and in the EPA fuel cycle standards.

Radiation doses from the postulated 1500 MT/yr fuels reprocessing plant are also well below the NRC and EPA standards. However, the release rates of ^{85}Kr and long-lived alpha emitting radionuclides from the FRP are about an order of magnitude higher than the EPA standards for these two sources. State-of-the-art radioactive waste systems can be installed to lower these releases to acceptable values.

The contribution to the total offsite doses from a 300 MT/yr MOX plant, an alpha waste incinerator and other waste management facilities which might be sited at the HNEC are negligible compared to those from the reactors and the FRP.

The estimated total combined radiation doses to the maximum individual and the population within 50 miles of all postulated HNEC facilities are summarized in Table 10.

In view of the small off-site radiation doses listed in Table 10, it is apparent that no significant doses to construction workers or operating personnel should be present from routine releases of radionuclides from an HNEC. This is especially true since the majority of the off-site doses arise from locally grown foods, rather than external exposure or inhalation.

In summary, it appears that there are no insurmountable ~~environmental~~ radiological impacts expected from the siting of 25 GWe of operating LWRs along the Columbia River plus associated fuel cycle facilities sited near the 200 Areas plateau within the Hanford Project. Continued monitoring of the environment and radiation exposure pathways as the power reactors and fuel cycle facilities are added would test this conclusion and provide data to modify the dose estimates prior to completion of each new construction phase.

TABLE 10. Estimated Total Radiation Doses and Dose Commitments to a Maximum Individual and the Population Within 50 Miles from Operation of an HNEC

Organ	First-Year Dose				Fifty-Year Dose Commitment			
	MOX(a)	FRP(b)	Reactors(c)	Total(d)	MOX	FRP	Reactors	Total
Maximum Individual(mrem)								
Total Body	4E-6	4.9	1.5	6.4	1E-3	5.1	1.5	6.6
Bone	2E-4	0.2	0.9	1.1	4E-2	0.6	1.1	1.7
GI-LLI	6E-6	4.9	1.5	6.4	6E-6	5.1	1.5	6.6
Lung	8E-4	4.9	1.5	6.4	1E-3	5.1	1.5	6.6
Thyroid (adult)	5E-7	5.1	2.7	7.8	5E-7	5.3	2.8	8.1
Thyroid (infant)	--	13.	11.	24.	--	--	--	--
Population(man-rem)								
Total Body	4E-4	410	53	460	0.1	430	55	490
Bone	2E-2	13	28	41	4.3	32	32	68
GI-LLI	4E-4	410	53	460	4E-4	430	55	490
Lung	8E-2	410	53	460	0.2	430	55	490
Thyroid	4E-5	430	85	520	4E-5	450	88	540

(a) A 300 MT/yr MOX fuel fabrication plant

(b) A 1500 MT/yr fuel reprocessing plant

(c) 7 BWRs and 13 PWRs with total capacity of 25 GWe.

(d) Doses from other waste management facilities not listed are negligible.

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