HW-SA-2748

ABSTRACT

EVALUATION OF DISCHARGING RADIOACTIVE WASTES INTO FRESH WATER STREAMS

by

R. B. Hall and R. H. Wilson
Environmental Studies and Evaluation
Radiation Protection Operation
Hanford Laboratories Operation*

Radioactive waste releases are evaluated against national standards for radiation dose to people. One of several sources of potential radiation exposure results from waste releases to fresh water streams. The principal mechanisms of exposure are through drinking water, fish, irrigated crops, and recreational use of streams for swimming and boating. Below the Hanford reactors, each potential source is measured and its contribution to total exposure evaluated to assure that this exposure remains below established limits.

* Work performed under Contract No. AT(45-1)-1350 between the Atomic Energy Commission and General Electric Company.

INTRODUCTION

Radioactive wastes represent a comparatively recent problem in the area of liquid effluent management. Consequently, the propriety of releasing such wastes into the public domain is sometimes questioned by those who are not thoroughly familiar with the high degree of reliability with which the potential effects of the releases can be evaluated. Although radioactive effluent problems have existed for less than a decade, the technology for monitoring the releases and standards against which environmental conditions can be appraised are much better developed than for virtually any other type of waste.

Since the first recognition that large doses of ionizing radiation were harmful some sixty years ago, a continuing research effort has been aimed at identifying the kinds of effects, developing an understanding of how they are produced, and relating effects to the quantity of radiation involved. Extensive experience in the use of X-rays and other types of radiation by the medical profession has added immensely to the fund of knowledge, and the entire program has been accelerated greatly since the advent of the atomic age and the wide use of radioisotopes in research laboratories and industry. Over thirty years ago the National Committee on Radiation Protection and Measurement (NCRP) issued recommendations applicable to persons working with sources of radiation. These recommendations have been updated on several occasions as the rapidly accumulating fund of knowledge permitted refinements.[1] Quite recently, a new authoritative group, the Federal Radiation Council has contributed its guidance.[2, 3]

The recommendations of the NCRP and the FRC applicable to radiation workers fix maximum exposures at levels which are not expected to result in any discernable biological effects even if continued throughout the life of an individual. Since all radiation is considered to be additive in ultimately producing some effect, it is not possible to state categorically that there is a zero probability that some few individuals out of many thousands will not be slightly affected at some time during their life. The odds in favor of the appearance of even small effects are so low, however, that the risk is considered negligible.

Subsequent to the development of standards for exposure of radiation workers, the NCRP issued recommendations applicable to persons living in the neighborhood of atomic energy plants and other areas where radiation sources are controlled. Similarly, the FRC has issued radiation protection guides for the general public. For the most part, the recommendations for the public are on the order of one-tenth of those applicable to radiation workers. It is against the conservative standards for the general public that radiation exposures occasioned by the release of radioactive effluents are evaluated. In spite of their very low levels, it is practical to measure such exposures quite accurately with the sophisticated electronic equipment now available.

EVALUATION OF RADIATION EXPOSURE

Every individual receives radiation exposure from a number of different sources. Some of these are referred to as "natural background" because they have always existed in nature and are quite independent of the artificial sources added by man. Included in the background are the natural radioisotopes of potassium, carbon, and radium, and the exposure which results from cosmic rays. The natural background is excluded from consideration in the evaluation of exposure from man-made sources. Radiation administered by doctors and dentists, termed "medical exposure", is also excluded from consideration. People should recognize, however, that the radiation dose which they receive from medical exposure quite often exceeds by a substantial margin the amount which is specified in standards for non-medical sources.

Another source which is widely publicized at this time is fallout from weapons testing. Many of the radioisotopes in fallout are identical with ones which enter the environment with effluents from atomic energy plants and can not be distinguished from them except by variations in quantities. At this time it is not entirely clear whether or not the radiation dose from fallout should be included in the evaluation of exposure resulting from an atomic energy plant. The body, of course, does not distinguish between the two sources.

Effluents from atomic energy plants may contain a number of different kinds of radioisotopes. In the case of liquid effluents discharged to streams, these isotopes can constitute small sources of exposure to people who use the stream for swimming or boating, who drink the water, who eat fish or waterfowl which have accumulated the radioisotopes from the water, or who eat farm produce which comes from fields irrigated with water from the stream. Some few people may have dietary and recreational habits which embrace all of these potential sources, and in this event the several small doses must be added together to obtain the total. More likely an individual will receive exposure from only one or two of these sources, and a great many people will not come in contact with the radioactive material at all, even though they live in the near vicinity.

Not all of the radioisotopes which are taken into the body with food or water behave in the same manner. Many will pass through the gastro-intestinal tract with very little assimilation. Others will be readily assimilated and circulate in the blood throughout the body. Some will be deposited in the bone, others will accumulate preferentially in other organs and remain for a few days or months before being eliminated along with other natural body wastes. The amount of radiation exposure received by various parts of the body will, therefore, depend upon the kinds of radioisotopes taken in, the intensity of the radiation which they emit, and the length of time they remain in the body. For this reason, a separate limit has been established for each different isotope, and in summing the contributions from several isotopes, one must consider the particular body organ most involved. This complicates the task of evaluating the over-all exposure, but satisfactory estimates can be obtained in a relatively straightforward manner once the various radioisotopes present have been identified.

The limits for a few radioisotopes where the source is considered to be drinking water are listed in Table 1. For comparison, the conventional limits for the non-radioactive form of these same elements are also included.(4) Obviously it would be impractical by ordinary chemical procedures to measure the very small quantities of the radionuclides if present at the permissible level, nor could the radioisotopes be distinguished from the non-radioactive isotopes of the same element. With the use of radiochemical techniques, however, small fractions of the permissible concentrations can easily be measured.

Because the standards established for radioactive materials are set at levels which are not expected to cause any significant effect even if the radiation dose was cumulative throughout the life of an individual, substantial short term variations in the rate at which the exposure is received are unimportant. For this reason there should be no concern if off-standard conditions should exist for a few day's or few week's time. A specific part of the recommendations of both the NCRP and FRC is that exposures can be averaged over the period of one year.

TABLE 1

QUANTITATIVE COMPARISON OF DRINKING WATER LIMITS - USPHS DRINKING WATER STANDARDS (DWS) vs NBS HANDBOOK 69 LIMITS (MPC) FOR RADIOISOTOPES IN WATER

Chemical Constituent	Comparison of Values (mg/l) DWS (1)	MPC	Radioactive Form Nuclide	MPC (uc/cc) (2)
Arsenic	5×10^{-2}	1×10^{-12}	As^{76}	2×10^{-5}
Barium	1×10^{0}	4×10^{-11}	Ba^{140}	3×10^{-5}
Cadmium	1×10^{-2}	6×10^{-12}	Cd^{115}	3×10^{-5}
Chromium (Cr^{+6})	5×10^{-2}	2×10^{-9}	Cr^{51}	2×10^{-3}
Lead	5×10^{-2}	1×10^{-10}	Pb^{210}	1×10^{-7}
Selenium	1×10^{-2}	2×10^{-9}	Se^{75}	3×10^{-4}
Silver	5×10^{-2}	6×10^{-10}	Ag^{110m}	3×10^{-5}

(1) Grounds for rejection of the supply.

(2) Based on one-tenth of the maximum permissible limit for continuous exposure to persons occupationally exposed - NBS Handbook 69.

THE SURVEILLANCE PROGRAM AT HANFORD

Although the great bulk of the radioactive waste generated by the Hanford plant is stored in underground tanks or "fixed" in the soil above the water table, relatively small quantities of radioactive materials do enter the environment with stack gases and the spent cooling water from the reactors.[5] Evaluation of the potential exposure in the environs of the plant which results from these effluents is an important part of the over-all radiation protection program at Hanford. This paper is confined to those aspects associated with the presence of the reactor effluent in the Columbia River.

A part of the surveillance program involves an audit of the amount of radioactive material released with the reactor effluent. This requires identification of all of the significant radioisotopes present and measurement of their concentrations in the effluents from each of the eight reactors. This data provides information on what materials may be expected in the river and fluctuations in amounts, but it does not provide the best basis for evaluation of exposure to people outside the project.

A more extensive part of the surveillance program involves the identification of all important sources of radiation exposure to people living outside the project and a system of samples and measurements to provide adequate estimates of the radiation dose which might accrue from each of these sources. This evaluation must take into account the many uses which are made of the Columbia River and the recreational and dietary habits of the people.

Figure 1 is a map of the area in the vicinity of the Hanford plant and is provided for general orientation.

The region is semiarid with mild winters but rather warm summers. The Columbia River flows east and south through the reservation. The reactors, where the radioactive wastes originate, are situated on the south bank of the river toward the north of the project. The first point of public access to the river below the reactors is at Ringold, where there is some sports fishing and where a small amount of water is pumped from the river to irrigate about 500 acres of farm land. Water is also pumped from the river to irrigate about 3000 acres just north of Pasco. Both the cities of Pasco and Kennewick use water from the Columbia for municipal supplies and Richland will do likewise next year. Sports fishing for steelhead, bass, and other spiny-rays, whitefish, sturgeon, and some other species is popular at several locations in the Tri-City area and in the reservoir

FIGURE 1

HANFORD PROJECT AND VICINITY

behind McNary Dam. Waterfowl which nest in the area or migrate through the region are available to hunters at the McNary Game Range and in the surrounding territory.

The water monitoring program may be divided into three parts; (1) raw river water, (2) sanitary water, and (3) measurement of the direct radiation dose from the river water.

1. Raw River Water - There are six locations along the river where raw river water is collected routinely for analysis: Vernita Ferry, Hanford, 300 Area, Richland, Pasco, and Vancouver. Samples are collected by dipping water from the riverbank except at the 300 Area, Pasco, and Vancouver. At the 300 Area, water is pumped to a building on the shore where the activity is continuously monitored and samples obtained. At Pasco the raw water is collected at the pumping station for the city water supply, and at Vancouver the Public Health Service collects samples for us from the middle of the river at the Interstate Bridge. Figure 1 shows the geographical location for these sampling points. Sample volume and frequency are dependent upon the analyses desired from a particular location. Table 2 shows the frequency of collection at the six sampling sites and the analyses performed.

The samples from Vernita Ferry, upstream from the plant, provides information on the natural and fallout activity in the river. Hanford is the first convenient sampling point downstream of all the reactors. Although the radioactive material is not yet uniformly distributed across the river at this point, surveys have shown that samples obtained at the shoreline are nearly representative of the average conditions throughout the cross section of the river.

The primary river monitoring point is at the 300 Area, just before the water leaves the project. A continuous measurement at this point provides

TABLE 2

RIVER AND SANITARY WATER SAMPLES TYPE AND FREQUENCY OF ANALYSES

Sampling Location	Total Beta	Total Alpha	Type of Analyses U	Type of Analyses Sr^{90}	Isotopic* Analysis	Integrated** Analysis
River Water						
Vernita Ferry	Biwkly	Biwkly	Biwkly	Biwkly	-	-
Hanford	Biwkly	Biwkly	Biwkly	-	Biwkly	-
300 Area	Daily	Wkly	Wkly	-	Wkly	Wkly
Richland	Wkly	-	-	-	Qtrly	-
Pasco	Wkly	-	-	-	Biwkly	Wkly
Vancouver	Biwkly	-	-	-	Biwkly	-
Sanitary Water						
Pasco	Daily	-	-	-	Wkly	-
Kennewick	Daily	-	-	-	Mo.	-

* Isotopic Analysis - As^{76}, Np^{239}, RE+Y, Na^{24}, Cu^{64}, Ga^{72}, I^{131}, P^{32}, Zn^{65}, Cr^{51}, Zn^{69}, Sc^{46}, Mn^{56}, Sr^{89} and 90.

** Integrated Analysis - P^{32}, Sr^{89} and 90, I^{131}, Ba^{140}.

immediate information on all fluctuations in the level of activity in the water. The monitoring instrument is also equipped with alarm circuits which will signal a warning if the level of radioactivity approaches a hazardous amount. Grab samples are also taken at this point each week and analyzed for some 17 radioisotopes. A continuous sample of the river water is also collected at this point. It is picked up weekly and analyzed for five of the longer lived radionuclides.

In order to obtain background information for the time when Richland will begin using Columbia River water, river samples are taken occasionally at the site of the future pumping plant. The intakes of the Pasco and Kennewick water plants are on opposite sides of the river and, as a matter of convenience, the river water sample for this area is taken at the Pasco water plant intake.

Downriver from Pasco, the concentration of radioactive materials in the Columbia River continues to diminish through radioactive decay and because of dilution by the Snake and other tributaries. However, a small fraction of the radioisotopes introduced into the river at Hanford are still detectable at the mouth of the river. Samples taken from the Portland-Vancouver Bridge provide information on the residual at this point and a reasonable estimate of the quantity discharged to the ocean. Analysis of samples collected below Vancouver is greatly complicated by the presence of salt water.

2. Sanitary Water - Water used for human consumption is sampled routinely at Pasco and Kennewick since the original source is the Columbia. When the new Richland plant is placed in service, frequent sampling of treated water will be initiated. The frequency of sanitary water samples collected and the analyses performed are also listed in Table 2.

3. Direct Exposure - Radiation exposure can be received directly from the water by those who swim in the river or ride in boats. This small dose can be measured directly and such measurements are made at Vernita Ferry, Hanford, 300 Area, Richland Marina Dock, Columbia Park Marina Dock, and the Pasco Pump House. In this case small ionization chambers of the type worn by workers within the plant are placed in sealed plastic bottles and submerged two to five feet in the water. These chambers are exchanged weekly and the accumulated dose read out on instruments in the laboratory. Figure 1 shows the locations where these dose measurements are made.

4. Foodstuffs - Several measurements of activity in various foodstuffs are also made. The most important of these measurements are made on fish and waterfowl. However, measurements are also made on samples of miscellaneous produce from the irrigated farms. The radioactivity of farm produce is more closely associated with air-borne radioactive materials, including fallout from weapons testing, than with the river, but some samples from the Ringold and Riverland areas contain detectable amounts of isotopes which could only have come from the river.

Fish which live for long periods of time in the Columbia downriver from the reactors gradually accumulate a few of the radioisotopes present in the water. The most important source of the radioisotopes to the fish is actually the food organisms which the fish eat. For this reason, the salmon which return to the river from the sea are not affected. On the other hand, non-migratory fish caught by local sportsmen do constitute a source of radioisotopes for the people who eat them and thus the sampling and analysis of such fish is a necessary part of the over-all surveillance program.

Fish are collected each month from five general locations along the river. These locations are Priest Rapids, which is upstream from the project, at Hanford, which is just downriver from the reactors but not accessible to public, and at Ringold-Richland, Burbank, and McNary Dam which are popular fishing sites. Sampling is concentrated on those species of fish which are caught in greatest numbers by the sportsmen. These include whitefish, bass, crappie and other "pan fish", and occasionally steelhead, catfish, sturgeon, trout, and salmon. Scrap fish, such as suckers, squawfish, and minnows are also sampled routinely since they are relatively easy to obtain. An attempt is made to collect at least five specimens of the most abundant species at each location each month throughout the year. Fishing is not always good enough to obtain the desired number of fish, however. Gill nets are effective in capturing many of the scrap fish, but the standard technique of hook and line is more productive for whitefish and some of the spiny-rays.

Ducks and geese which remain in the Hanford area long enough to feed on food available to them in the river, also accumulate some radioactive isotopes. With rare exceptions, the level of activity in the waterfowl is lower than in the fish and most of the birds on migratory flights through the project do not pick up detectable amounts of radioisotopes from the river.

Waterfowl are sampled monthly during the regular hunting season from two general sections of the river. One section designated as "upper river", extends from the upstream plant boundary to Hanford, and the other, designated as "lower river", extends from Hanford to Richland. Attempts are made to obtain samples of river ducks, diving ducks, mergansers and coots. Lesser Canadian geese are also collected in the "lower river" region when available. Generally four to ten ducks from each group constitute a sample.

The samples collected by our own personnel are augmented by donations from a number of local sportsmen. The donations consist of the heads of ducks killed in this region of the state and include a sufficient amount of muscle tissue for analytical needs.

EVALUATION OF TOTAL EXPOSURE

In order to calculate the radiation exposures received by people from the several sources, the data on isotope concentrations obtained from the surveillance program must be combined with estimates of the daily intake of water and various foods. Standard reference values are available for water and the common foods, but local estimates must be used for the fish and waterfowl. The results of these calculations, together with the surveillance data, are reported routinely to the Atomic Energy Commission and to other federal, state, and local agencies concerned with radiological safety.[6, 7, 8] These reports are unclassified and are available to the public.

As an example of the type of end product which results from a comprehensive evaluation program, the total body dose calculated for persons living in the neighborhood of the Hanford plant during 1961 is described here. Similar evaluations have been made for the dose to the gastro-intestinal tract and bone.

In Figure 2 the magnitude of the radiation dose received from a variety of sources is related to the number of persons who may receive exposure from these sources. The natural background is included on the figure for comparative purposes. It should be remembered, however, that the exposure from natural background, which everyone receives, and medical exposure is excluded from the appraisal against the standards. Included in the summation, however, is the exposure which results from air-borne materials

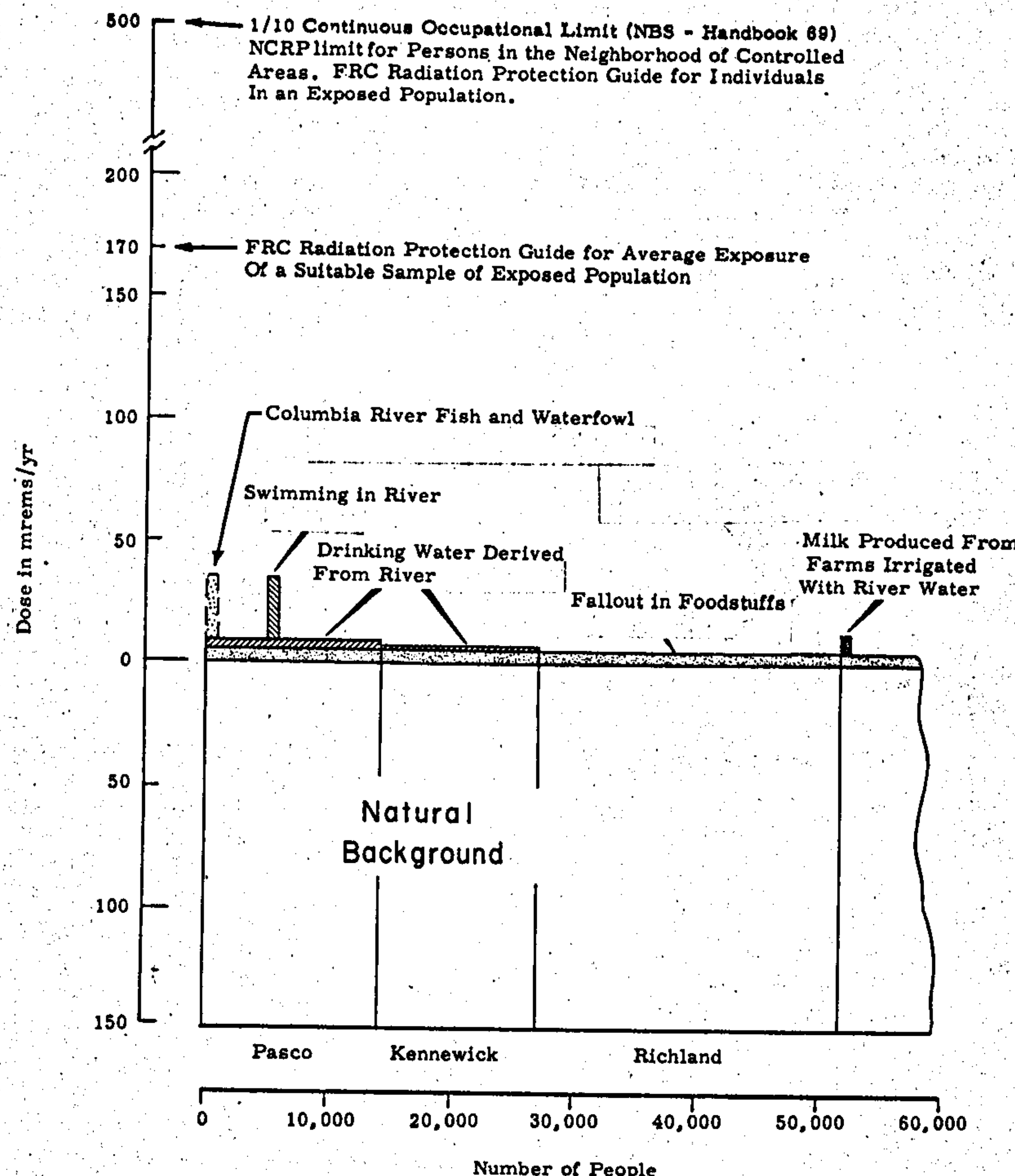

FIGURE 2

Calculated Dose to Total Body, 1961

(principally world-wide fallout) since these contribute a significant part of the exposure from environmental sources. The estimate of dose attributable to fallout shown here is based on the local surveillance information. A similar result would be obtained from data published by the U. S. Public Health Service for their nation wide surveillance program.[9, 10] Essentially everyone in the northern hemisphere receives an annual dose of this magnitude in addition to natural background.

Quite small doses for the total body are received from the drinking water supplied to residents of Pasco and Kennewick. Because of the particular kinds of radioisotopes present in the water, the dose to the gastrointestinal tract is higher than for the body as a whole but still amounts to only about five per cent of the appropriate limit. Richland residents do not, at this time, receive a dose contribution from their drinking water.

The dose which can result from eating local fish and waterfowl can be greater than that which accrues from other radioisotopes in the environment but is substantially less than that from natural background. The number of persons who eat local fish caught from the Columbia is quite small and adding the dose from this source to that received from other sources by the people of Pasco tends to maximize the combined exposure. The principal isotope found in fish and waterfowl is radiophosphorus which deposits in the bone. In this case, exposure to the bone is more significant than to the body as a whole and some few people who eat unusually large amounts of fish may acquire about 30 per cent of the appropriate limit.

The direct exposure which one may receive while swimming in boats results principally from a very short lived isotope of sodium (Na^{24}). In this case the total body is a more important receptor of the radiation than any of the body organs. The estimated dose of about 25 millirems per year from this source is about 15 per cent of the FRC limit.

The amount of milk and produce supplied by the local farms irrigated with Columbia River water is very small in relation to that consumed by the urban population of the Tri-Cities. It is, therefore, an insignificant source of exposure to people other than the families living on the farms and subsisting largely on their own produce. Here again the actual exposure received is but a small fraction of the limit.

CONCLUSION

Although people are exposed to ionizing radiation from a large number of sources in the environment, it is quite feasible to identify the ones which are of greatest importance and to relate certain portions to individual plant effluents. Further, there is available to the evaluator a rather complete set of standards to which exposure conditions in the environment may be compared. The existence of such standards, together with an advanced technology for detection and measurement of radioactive materials, provides the plant operator with a comparatively precise knowledge of the status of his waste disposal operations in relation to acceptable conditions in the environs. Such knowledge is a most valuable asset in focusing attention on the most significant sources of exposure which result in the environs and on plant processes which may contribute most to the exposure.

References

1. National Committee on Radiation Protection, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure", U. S. Department of Commerce, National Bureau of Standards, Handbook 69, (June 5, 1959).

2. Federal Radiation Council, "Radiation Protection Guidance for Federal Agencies (Report No.1)", Federal Register, Doc. 60-4539, Washington, D. C., (May 18, 1960).

3. Federal Radiation Council, "Radiation Protection for Federal Agencies (Report No. 2)", Federal Register, Doc. 61-9204, Washington, D. C., (September 26, 1961).

4. U. S. Department of Health, Education, and Welfare, Public Health Service, "Drinking Water Standards", Code of Federal Regulations - Title 42 - Part 72, Federal Register, Doc. 62-2191, Washington, D. C., (March 5, 1962).

5. Foster, R. F., R. L. Junkins, and C. E. Linderoth, "Waste Control at the Hanford Plutonium Production Plant", Journal Water Pollution Control Federation, May 1961.

6. Environmental Studies and Evaluation Staff, Hanford Laboratories, "Evaluation of Radiological Conditions in the Vicinity of Hanford for 1961", U.S. A.E.C., Doc. HW-71999, (1962).

7. Environmental Studies and Evaluation Staff, Hanford Laboratories, "Evaluation of Radiological Conditions in the Vicinity of Hanford, January - March, 1962", U.S. A.E.C., Doc. HW-73366, (April 23, 1962).

8. Environmental Studies and Evaluation Staff, Hanford Laboratories, "Evaluation of Radiological Conditions in the Vicinity of Hanford, April - June, 1962", U.S. A.E.C., Doc. HW-74398, (July 23, 1962).

9. U. S. Department of Health, Education, and Welfare, Public Health Service, "Radiological Health Data", issued monthly.

10. Federal Radiation Council, "Health Implications of Fallout From Nuclear Weapons Testing Through 1961", U. S. Government Printing Office, (May, 1962).