PNL-10072

712508

Reprinted from

NUCLEAR SAFETY

A TECHNICAL PROGRESS REVIEW
prepared in cooperation with
Nuclear Safety Information Center,
Oak Ridge National Laboratory
for Division of Technical Information, USAEC,

REPOSITORY PNL
COLLECTION 65 Zinc Study
BOX No. J Soldat
FOLDER N/A

1082122

Consequences of Activity Release

Edited by K. E. Cowser

A Survey of Environmental Dose Evaluations

By J. F. Honstead*

Abstract: Environmental dose calculations are used as a basis for evaluating environmental surveillance data. Dose evaluations are consistent with the recommendations of the Federal Radiation Council (FRC) and the International Commission on Radiological Protection but are not now required by the regulations governing the operation of nuclear facilities. This means of judging the radiological condition of an environment is most helpful to those sites releasing complex mixtures of radionuclides and having a multitude of possible pathways back to man. Hanford is the only U. S. site at which regular annual dose evaluations are published. A detailed study of the dietary pathways originating with Clinch River water is used at Oak Ridge National Laboratory as a means of assessing dose-level changes.

The following benefits might be derived from dose evaluations at more U. S. sites: (1) demonstration of the FRC range appropriate for each site, (2) optimization of the scope of environmental monitoring programs, (3) assurance that any environmental reconcentration processes will be detected, and (4) ready accommodation of new sources of exposure in the environment.

The techniques employed in monitoring the environment of a nuclear installation and interpreting the monitoring data are largely determined by the objectives of the environmental surveillance program. It is very important that these objectives be clearly defined before an environmental surveillance program is designed. Usually a variety of purposes can be identified for monitoring the environment, with one or two objectives being of overriding importance.

The environmental surveillance program is sometimes tied to the regulatory climate in which the facility operates. In other cases the environmental program may be a final step in the control of radioactive effluents. Some objectives are efficiently fulfilled by a program involving the evaluation of doses received by people living in the neighborhood of the facility. This summary reviews the status of environmental dose evaluation at some U. S. sites and reports some of the techniques employed.

The publication of Federal Radiation Council (FRC) Report No. 1 in May 1960 gave emphasis to the application of dose calculations for the evaluation of environmental monitoring data.[1] The FRC was formed under Public Law 86-373 in 1959 to "... advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in the establishment and execution of programs of cooperation with States . . . ." The first report of this Council provided Radiation Protection Guides for both individual members of the population and the population average for those people living in the vicinity of a nuclear installation.[2] The guides are based on the dose received by such people as a result of the nuclear facility itself and exclusive of other environmental and medical exposure. The FRC Report No. 1 introduces the term "radioactivity concentration guide," which is that concentration of radioactivity in the environment resulting in an organ dose equal to the "radiation protection guide." This definition permits a distinct step forward from the more naive term "maximum permissible concentration" (MPC). The MPC's recommended by both the National Committee on Radiation Protection (NCRP)[3] and the International Commission on Radiological Protection (ICRP)[4] are limited to drinking water and air, whereas the radioactivity concentration guides recognize other exposure pathways. The uncertainties involved in determining the amount of internally

*J. F. Honstead has been associated with radiation-protection work since 1950, when he began working for the General Electric Company at Hanford. In addition to environmental research and radiological engineering work, he has supervised research studies in geophysical and geochemical fields at Hanford. In 1962 Mr. Honstead began a 2-year assignment with the International Atomic Energy Agency in Vienna, Austria, as a senior officer in the Division of Health, Safety, and Waste Disposal. Upon returning to Hanford he worked as a research associate in studies of the mechanisms of environmental exposure and is currently Manager of Environmental Studies Section. He is now affiliated with the Pacific Northwest Laboratory of Battelle Memorial Institute, which replaced the General Electric Company as operator of the Hanford research laboratory.

1082122 A

deposited radioactive material from various pathways were clearly recognized by the FRC, and for this reason the staff report avoided specific numerical recommendations for radioactivity concentration guides. Instead, installations were invited to perform the necessary exercises to establish their own concentration guides on the basis of the situation in which they operated.

The second staff report of the FRC was issued[5] in September 1961. This report introduces the concept of graded action guides defined in terms of ranges representing fractional approaches to radiation-protection guides.[6] Range I is defined as follows:

> Intakes falling into this range would not under normal conditions be expected to result in any appreciable number of individuals in the population reaching a large fraction of the RPG [radiation protection guide]. Therefore, if calculations based upon a knowledge of the sources of release of radioactive materials to the environment indicate that intakes of the population are in this range the only action required is surveillance adequate to provide reasonable confirmation of calculations.

Range II is defined as:

> Intakes falling into this range would be expected to result in average exposures to population groups not exceeding the RPG. Therefore such intakes call for active surveillance and routine control.

The report proceeds to define the surveillance program that would be appropriate to effect the control in Range II and then defines Range III as follows:

> Intakes within this range would be presumed to result in exposures exceeding the RPG if continued for a sufficient period of time. However, transient rates of intake within this range could occur without the population group exceeding the RPG if the circumstances were such that the annual average intake fell within Range II or lower. Therefore, any intake within this range must be evaluated from the point of view of the RPG and if necessary, appropriate positive control measures instituted.

From the publications of the FRC, it is clear that nuclear installations should be in a position to evaluate the environmental consequences of their operation in terms of exposure to the local population. In some cases this should be a dose estimate, whereas in other cases it may be a comparison with radioactivity concentration guides. AEC installations are provided with regulations governing their environmental safeguards in AEC Manual Chapter 0524. Installations operating under license issued by the AEC or, in the case of agreement states, under state license, are regulated[7] by Title 10, *Code of Federal Regulations*, Part 20 (10 CFR 20) or the appropriate state regulation based on this federal code. These regulations provide tables of concentration values for air and water equivalent to MPC's.

Exposure Pathways

The dose received by people in the neighborhood of a nuclear facility may reach them by a variety of pathways. The identification of pathways and their evaluation in terms that permit their effects to be summed represents the technical process of environmental dose evaluation. It is, of course, necessary to identify critical organs, as well as to evaluate total body doses. In some cases the pathway represents the direct exposure of people to radioactivity in the air or surrounding environment. For example, the movement of a cloud of radioactive gas will result in the direct irradiation of people in its path, as well as lung irradiation from breathing the radioactive material. When the radioactivity is transported by water, a direct radiation dose may be received by people as a result of an accumulation of radioactive debris on exposed surfaces near or in the stream. For example, the doses received by swimmers submerged in the water, water skiers and boaters on the water, and fishermen standing at the edge of the stream should be considered. Clearly, part of the technical investigation of the exposure received from these pathways involves a study of the habits of the population.[8] The length of time that can be reasonably ascribed to such exposure for the average member of the population and for the critical population group must be estimated.

Of additional interest is the radiation dose that may be accumulated by segments of the population as a result of the ingestion of radioactivity in foodstuffs. The procedure for evaluating the internal dose contribution requires data from a statistically valid monitoring program to determine the seasonal concentration of radionuclides in the foodstuffs contributing to each pathway. This normally involves selecting and applying a sampling routine, together with the proper analyses of samples for radionuclides. Knowledge of the seasonal changes of radioactivity levels in samples of foodstuffs represents only the beginning in this evaluation, however. It is necessary either to estimate or to measure the consumption levels of each of the foodstuffs of interest by members of the population and to obtain by some means a consumption distribution pattern. Next, by applying the calculation techniques described in the ICRP Committee II Report[4] and elsewhere, it is possible to estimate the organ burdens and the resulting organ dose. It then becomes possible to sum the dose received by each organ from each pathway and each radionuclide.

In this technique the greatest source of uncertainty is generally the middle step, the estimate of consumption levels of various segments of the population. Techniques for adequately sampling and analyzing radioactivity in the environment are well established. Likewise, the methods for determining the resulting body burdens from the consumption of various radionuclides are widely accepted, and studies of the metabolism of specific materials will continue to improve these methods. The intervening

1082123

step, however, that of eliciting consumption data which may be statistically valid, has not been widely studied. Most investigations of dietary levels have been aimed at determining broad population averages. These averages may be helpful in the dose evaluation problem, but the consumption level distribution within the population is also needed.[9] Special dietary investigations are particularly important where a pathway involves a specific limited source of foodstuffs. For example, a pathway for radioiodine may be milk from a limited number of dairies. It becomes necessary to identify the consumption of milk from a specific source in such a case.

Ultimately, the organ dose received through all dietary and environmental pathways must be summed. In this way the prominent pathways, those contributing most significantly, are identified. In general, this permits limiting the materials that must be sampled and analyzed to only those affecting the prominent pathways. In response to the recommendation of the ICRP, it is desirable to calculate the average dose from both external and internal sources for the population living in the vicinity of the plant, as well as the maximum dose to an individual in the population. It is not necessary to seek out and identify the "maximum individual," but it is necessary to discover that critical population group whose particular diet and recreational habits maximize their exposure to radioactivity in the environment.[10] The calculated average dose for this critical population group is referred to as the "estimated dose to the maximum individual."

Radioactivity Concentration Guides and Maximum Permissible Concentrations

At first glance the radioactivity concentration guides advanced by the FRC seem little different from the maximum permissible concentrations defined by the ICRP and NCRP. In both these expressions a numerical value is developed that relates environmental concentration to the basic standard of dose. The convenience of having numerical concentration standards tabulated and published by an authoritative commission has led to wide application of MPC's. Two MPC's are normally quoted: MPC_w, which is the maximum permissible concentration for drinking water; and MPC_a, which is the maximum permissible concentration for air. Both these values are based on radioactivity ingestion by a "standard man" and the resulting dose received by this hypothetical individual. The air inhalation and water consumption rates of other members of the population are to some extent related to their body size, and thus the standard-man concept has some built-in compensations. However, it is generally recognized that the application of MPC's based on the standard-man calculations contain uncertainties that should be examined before wide application to the general public. There is a distinct risk in using MPC's outside of the limited application for which they were designed.

There are no published values for radioactivity concentration guides. These concentrations are derived from a study of all the pathways whereby radioactivity in the environment may expose members of the population. The appropriate concentration guide is that concentration which restricts the resulting dose to the appropriate limit when all pathways are summed. Each environmental circumstance must thus be examined and concentration guides developed for each installation.

It may be appropriate to look at a few examples of radionuclides in the environment to compare radioactivity concentration guides and maximum permissible concentrations. There is some tendency to view MPC's as a "conservative" guide against which environmental contamination may be compared. One hears such phrases as, "Of course, nobody actually drinks the water from that stream, but if they did the radioactivity concentration is only a small fraction of the MPC." The following examples are deliberately chosen to illustrate the fact that other pathways may be more restrictive than air or drinking water. In these cases the MPC's may be a very unconservative measure of the environmental situation.

Suppose the radionuclide being discharged to a stream was ^{32}P, which has an MPC for drinking water of 2×10^{-5} μc/ml. If the river activity were maintained at this level and fish were caught from the stream, on the average it would require less than 4 g of fish flesh per week to provide a standard man with the same dose he would get from drinking the water. This estimate is based on an assumed concentration factor for fish[11] of 4000. Actual values ranging from 1000 to 10,000 have been reported.[12,13] Further, suppose that ^{65}Zn was being discharged to the sea and that the ^{65}Zn MPC_w (1×10^{-4} μc/ml) was the guide for limiting seawater contamination. If the seawater were maintained at its MPC_w for an extended length of time and oysters were harvested from it, it would require less than 1 g of oyster flesh per week to provide a standard man with the same dose he would obtain if he were to drink the water. This calculation is based on the oyster concentration factor for ^{65}Zn of 17,000 to 40,000 reported in the literature.[14,15] If the facility were discharging ^{106}Ru to the sea rather than ^{65}Zn, the pathway of concern could become seaweed. In parts of Britain, seaweed is consumed in rather large amounts.[16,17] If seawater were maintained at the MPC_w for ^{106}Ru, 1×10^{-5} μc/cm^3, with the reported concentration factor[15,18] of 2000, a standard man would need to eat only 7.7 g of seaweed per week in order to obtain the same dose he would obtain from drinking water at the MPC_w. Consider the situation of a pasture near a nuclear facility discharging radioiodine to the atmosphere. If the discharge were

1082123 A

such that the ^{131}I concentration in the air over the pasture grass was maintained at its MPC_a, 1×10^{-10} $\mu c/cm^3$, a standard man would have to drink only 40 ml of milk per day from cows grazing on that pasture to get the thyroid dose of 1.5 rems per year recommended as a limit by the FRC. A small child with a 2-g thyroid would need to drink only 4 ml of milk per day to get the same dose.[19,20]

The standard against which environmental situations are evaluated should be related as directly as possible to the basic standard of dose. This is the essence of the radioactivity-concentration-guide concept. In the instances cited above, the tabulated values of MPC may be useful as appropriate guides, but they clearly are not conservative measures of the dose resulting to the local population. Four examples have been cited here that have been investigated and documented in which other pathways are more significant than drinking water or breathing air. One justification for increased use of the radioactivity-concentration-guide technique is the wider study of pathways that would result. Such a study could well reveal other situations of this kind. It is known that the four means described above of concentrating radionuclides in an environmental pathway exist, but there is no assurance that there are not others which have remained undetected.

Environmental Dose Estimates

In practice, most U. S. nuclear installations do not routinely evaluate environmental dose. Most of these installations release such a small amount of radioactivity to the environment that the labor of making detailed dose estimates does not seem justified. In these instances the facilities would fall well within Range I of the FRC scale for evaluating environmental situations. There are a few installations where scientific calculations are currently being made to evaluate dose and others where studies are being performed that have a bearing on dose estimates.

If the amount and complexity of radioactivity in the environment warrants regular detailed dose evaluations, the evaluations may be made either through annual estimates of dose or by a single investigation followed by annual comparisons against this standard. The first approach is used at Hanford, where yearly dose estimates are performed and reported. The second approach is used at Oak Ridge, where annual environmental data are compared with the results of the Clinch River study,[21] which was a detailed analysis.

The guide followed by a nuclear installation concerning environmental surveillance requirements limits attention to the dose contribution from that site. There are, however, other dose contributions in the environment which may be larger than that originating at the nuclear site. For example, all sites receive a dose contribution from radioactive fallout from nuclear weapons tests. In addition, there is always a natural background contribution. The natural background and fallout contributions can seriously interfere with an environmental surveillance program when the amount of radioactivity released by a site is extremely small.[22] Some helpful information is regularly provided by federal agencies responsible for evaluating the significance of fallout dose.

A study is in progress at the Health and Safety Laboratory of the AEC in New York City to assess the radiation doses to bone from ^{90}Sr fallout. Workers there have utilized the results of systematic measurements of ^{90}Sr fallout rates and cumulative deposit, contamination levels of foods, and the skeletal ^{90}Sr concentrations of people in these studies. From results obtained over a 10-year period, they have constructed models to predict both the distribution of fallout with time and the resulting radioactive contamination of diets. From diet studies and the ^{90}Sr levels in foods, they calculate the strontium concentration in bone and compare the calculated concentrations with measured values. Radiation dose rates from known concentrations in bone can then be calculated for specific bone tissue. Total doses are calculated by integrating the dose rates over time. They estimate that the average 70-year dose to mineral bone of New York City residents from atmospheric nuclear tests conducted to date is about 170 mrads. The maximum 70-year dose will probably be received by persons born in 1963 and is expected to be about 400 mrads. They estimate that these doses are fairly typical for people living in the north temperate zone and having a western type of diet.[23]

The U. S. Public Health Service regularly publishes data on fallout concentrations in *Radiological Health and Data Reports*. The data are provided by various federal and state agencies collecting information pertinent to the evaluation of fallout. For example, a bovine thyroid network is operated by the National Center for Radiological Health in conjunction with the U. S. Department of Agriculture. The network consists of broad collection areas often located near large nuclear facilities but also covering geographical areas throughout the United States. The network is considered to be basically an alert surveillance operation for ^{131}I. High levels of ^{131}I observed in the past few years usually correspond to foreign nuclear tests. For example, Fig. 1 shows the data obtained during May and June 1966 following an announced foreign nuclear test.[24] The curve shows the bovine thyroid concentration measured in Region IV (Georgia, Mississippi, and South Carolina) together with ^{131}I concentrations in milk samples from the same region. Thus these data reveal two steps in the grass–cow–milk–man pathway by which ^{131}I may contribute to human exposure. This particular

1082124

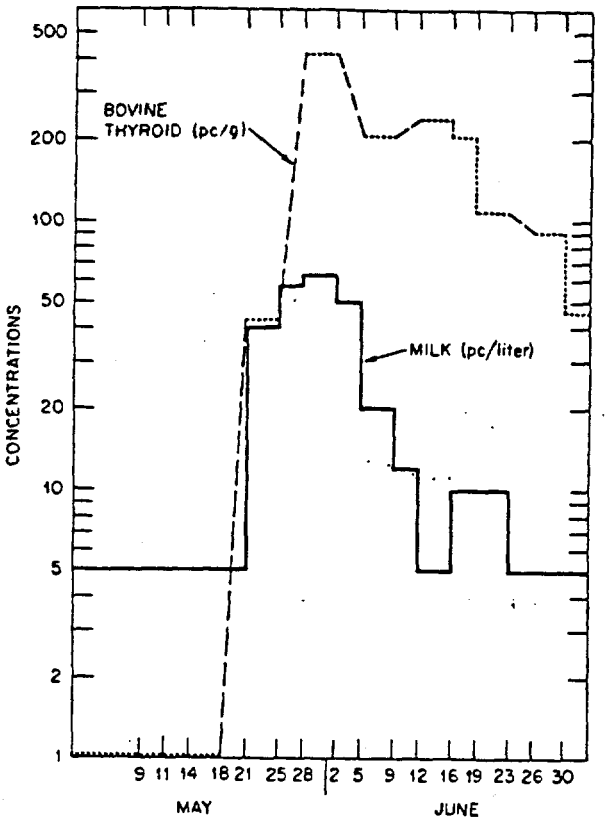

Fig. 1 Average ^{131}I concentrations in bovine thyroids and milk for Region IV (Georgia, Mississippi, and South Carolina) from May 9 to June 30, 1966. The concentration peak is estimated to have provided 18 mrems to a standard man's 20-g thyroid.[24] These data are part of the U. S. Public Health Service study of fallout from nuclear tests.

milk concentration pattern is estimated to provide a thyroid dose of 18 mrems to the 20-g thyroid of a standard man.

The National Center for Radiological Health also gives consideration to exposure and resultant dose from the expanding nuclear power industry caused by overlapping and interaction of exposure from several nuclear facilities in close proximity. The desire is to develop procedures for evaluating cumulative exposures to some critical population that would fall in the sphere of influence of more than one source of radioactivity. A preliminary publication of this kind[25] provides information concerning the dose estimated from exposure to ^{85}Kr as the nuclear industry expands. This analysis estimates that the annual dose from ^{85}Kr will build up to 30 to 100 mrads by the year 2060.

Environmental Surveillance Studies

A recent analysis of environmental dose resulting from radioactive waste disposal at various installations was provided by Ophel.[26] He reported environmental surveillance data for four American locations and one Canadian location in terms of dose. In studies of this kind, it becomes necessary to make very preliminary estimates of consumption levels for those environmental situations for which dietary survey data are not provided, and only an upper limit can be set on the environmental dose. The following sections summarize some of the environmental surveillance programs in the United States with regard to their evaluations of dose.

OAK RIDGE NATIONAL LABORATORY

A detailed study was made by the Clinch River Study Steering Committee to investigate the pathways whereby radionuclides discharged to White Oak Creek from the Oak Ridge facility could cause exposure of the downstream population. A comprehensive report of this study was issued in April 1967 by Struxness and his associates.[21] The Committee found that the radionuclides of principal concern at this site were generally long-lived fission products. Their study included evaluation of consumption levels of various foodstuffs through which these radionuclides reach people. Figure 2 is a family of curves taken from this report which illustrate the estimated annual dose received by various population groups as a result of ^{90}Sr concentrations in the Clinch River. The influence of age of the individual evaluated is clearly depicted. The importance of knowing the makeup of the affected population can be assessed by comparing the dose curve of a standard man with that of a 14-year-old boy. From this detailed study it is possible to evaluate the environmental situation by comparing surveillance data with those used in the Clinch River study. For this reason, ORNL does not reproduce an annual dose evaluation.

This procedure is satisfactory because of the relative simplicity of the isotopic mixture that needs to be considered. If the mixture of radionuclides changes in an important way from year to year, evaluation by direct comparison is inappropriate. In 1966 the gaseous and liquid waste released from ORNL was such that the concentration of radioactive materials in the environs was well below maximum levels recommended by the NCRP and FRC. For example, the average concentration of radioactive materials in the atmosphere at the X-10 site was less than 1% of the maximum permissible for persons residing in the neighborhood of an atomic energy installation, and the concentration was even lower at the perimeter of the controlled area. The calculated average concentration of radioactive materials in the Clinch River at the point of entry of White Oak Creek was less than 2% of the maximum permissible for persons residing in the neighborhood of an atomic energy installation.[27]

1082125

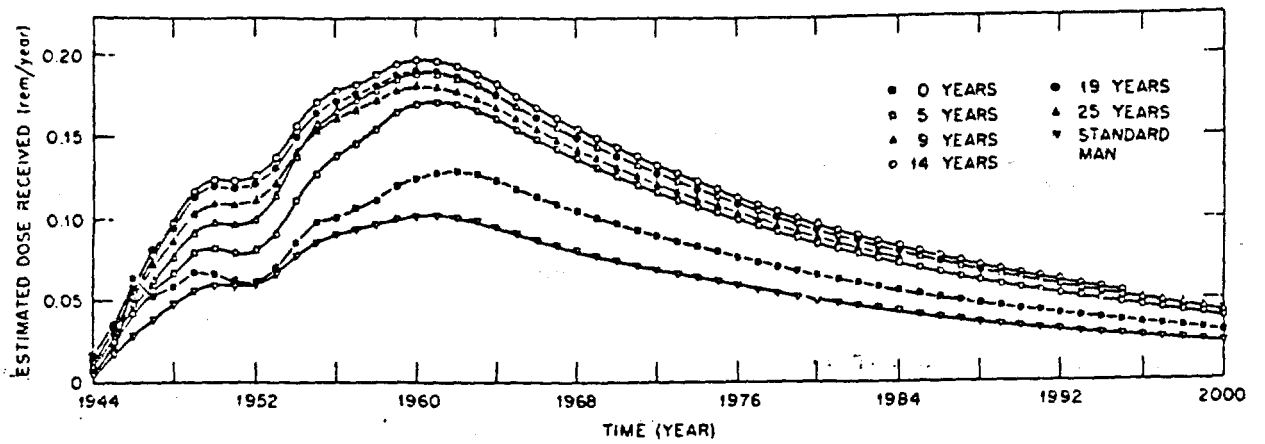

Fig. 2 Estimated dose received by skeleton of males from drinking Clinch River water and consuming contaminated fish. These calculations were made as part of the ORNL Clinch River study.

ARGONNE NATIONAL LABORATORY

The amount of radioactive material discharged to the environment from Argonne National Laboratory is normally very small. It is largely limited to effluent discharged to Saw Mill Creek, which runs through the Argonne grounds and enters the Des Plaines River about 500 yards downstream from the waste-water discharge.[28] In 1964 the radionuclide that contributed the most radioactivity to this creek was tritium. During the first 6 months of 1967, the average concentration of tritium in this creek represented 0.8% of the appropriate MPC, and the maximum concentration observed was 15% of the MPC.[29]

Other radionuclides monitored in this environment included ^{58}Co which had a maximum concentration representing 0.20% of the MPC and ^{90}Sr which had a maximum concentration representing 0.8% of the MPC. The ^{90}Sr was almost entirely from fallout. Argonne does not evaluate population dose as part of its surveillance program.

HANFORD

Radioactivity enters the environment from Hanford by way of the atmosphere from chemical-separations-plant and reactor stacks and by way of the Columbia River, which receives reactor cooling-water discharge. Hanford publishes an annual evaluation of radiological conditions which gives an annual dose estimate. The dose to a typical Richland resident is estimated and is identified as the average dose received by a suitable sample of the local population. The dose received by a "maximum individual" is also estimated in which the combined contribution of various pathways is maximized in a realistic way by assuming extreme dietary and recreational habits. Figures 3 and 4 show the environmental dose estimates for 1966. Doses are reported for those four organs for which the estimated doses most closely

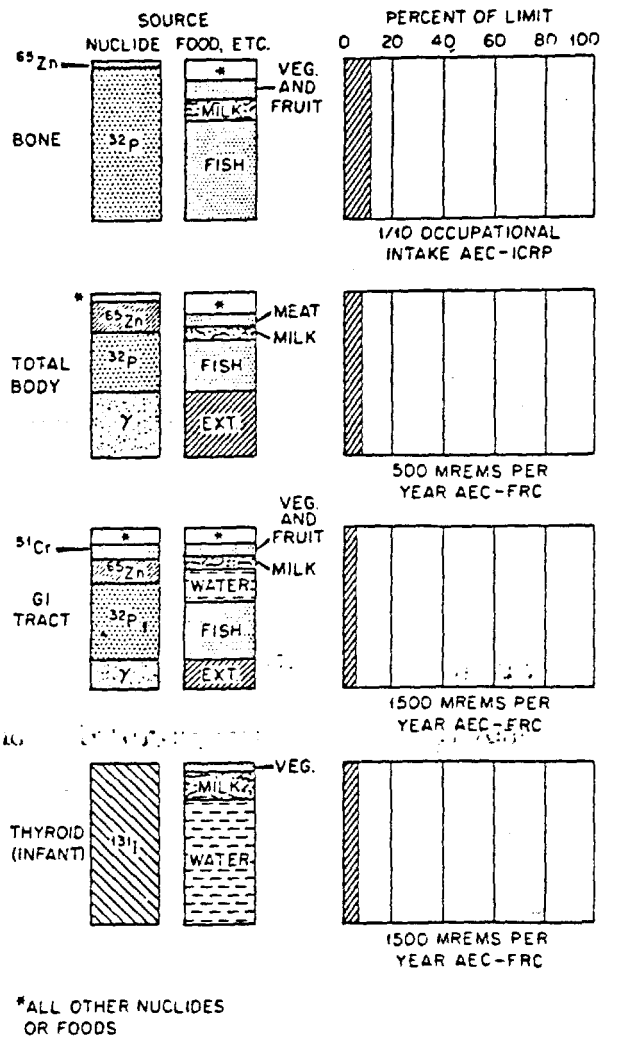

Fig. 3 Estimated dose to maximum individual at Hanford in 1966.

1082126

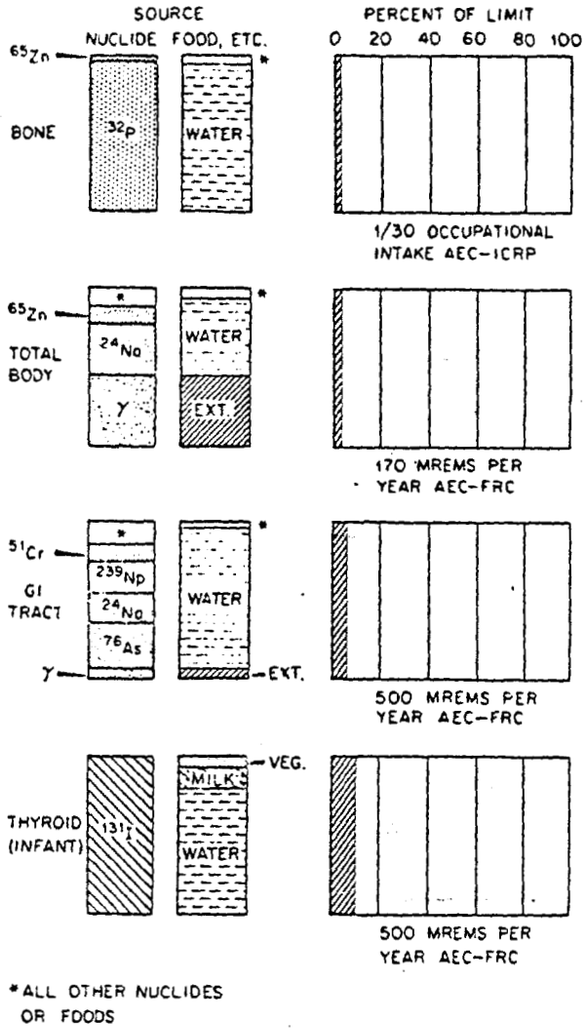

Fig. 4 Estimated dose to typical Richland, Wash., resident in 1966.

approach the appropriate limit. Most of the dose received by people as a result of Hanford's operation reached them by way of the Columbia River, although some thyroid dose was received as a result of airborne ^{131}I.

The consumption levels on which these doses are based are estimates, and studies are under way at Hanford to improve them. Figure 5 shows the diet questionnaire requested of adults given whole-body counts at Hanford. Several thousand estimated consumption levels have been obtained in this way and are entered in a computer program. Currently, a study is under way to determine the average annual dose that would be calculated if the 1966 environmental contamination levels were applied to each individual diet estimate. This is largely a study of plant employees, since most of the whole-body counting data are obtained from those working for various Hanford contractors.

A research program is under way to extend these data to children. For this purpose, the local elementary schools are contacted and a cooperative program is arranged in which children are asked to provide dietary information and are given whole-body measurements. Figure 6 shows the diet record card these children are asked to complete. They keep a 7-day record of pertinent foodstuffs for this purpose. Later, a mobile whole-body counter, shown in Fig. 7, visits each school and the children are measured. Correlations between body burdens of radionuclides and consumption levels of various foodstuffs help to identify important pathways.

The Hanford surveillance program is appropriately directed to dose evaluation because of the complexity of the pathways involved and the variable mixture of radionuclides that cannot be adequately evaluated by other means. The site is currently near the lower bound of Range II as defined by the FRC. In 1966 the estimated average dose to the population in the vicinity of the Hanford plant was 9% of the limit for an infant's thyroid, 7% of the limit for the GI tract, 2% of the limit for whole-body exposure, and 0.8% of the limit for bone. In the case of the maximum individual, who was assumed to eat 200 meals per year of fish caught in the Columbia River, the radionuclides and resulting doses were somewhat different. Estimates revealed that the maximum individual probably received 10% of the appropriate limit to bone, 7% of the whole-body limit, 6% of the infant thyroid limit, and 5% of the GI tract limit. Some of these values are very sensitive to the consumption levels estimated for specific foods.[30]

NATIONAL REACTOR TESTING STATION

The environmental surveillance problem at the National Reactor Testing Station (NRTS) involves seeking very low levels of radionuclides in a large environmental area. The concentrations resulting from the operation of the facility tend to be masked by fallout. As a result, a regular evaluation of dose is not made. A research program is under way at NRTS to study the atmospheric release of fission products from reactors. In particular, the behavior of ^{131}I released from reactors has been studied under very realistic conditions.

The study of the behavior of radioiodine in the environment was initiated to provide better understanding of the behavior of ^{131}I under the conditions of an emergency release. The study is referred to as the "Controlled Environmental Radioiodine Test" and was established at NRTS in 1963. The primary objective is to study the kinetic behavior of radioiodine as it moves through the air–grass–cow–milk–human chain. In these studies they are defining and quantitating the meteorological, physical, chemical,

1082127

BATTELLE-NORTHWEST
RICHLAND, WASHINGTON

THE INFLUENCE OF DIET ON RADIOACTIVITY IN PEOPLE

THIS QUESTIONNAIRE IS TO OBTAIN DIET INFORMATION TO SUPPLEMENT YOUR WHOLE-BODY COUNTING RESULTS. THE DATA ARE OF REAL SCIENTIFIC VALUE TO HELP US UNDERSTAND THE WAY PEOPLE TAKE UP RADIOACTIVITY FROM THEIR FOOD, AND HOW LONG IT IS RETAINED IN THEIR BODIES. WE CAN DO THIS BY RELATING THE MINUTE AMOUNTS OF RADIOACTIVITY MEASURED BY THE WHOLE-BODY COUNTER TO INDIVIDUAL DIETS. WHEN A LARGE NUMBER OF THESE RELATIONSHIPS ARE OBTAINED WE CAN DETERMINE SIGNIFICANT AVERAGES. EVEN THOUGH IT IS NOT POSSIBLE TO PROVIDE PRECISE ANSWERS, WE APPRECIATE YOUR GIVING THE BEST ESTIMATES YOU CAN TO THE FOLLOWING QUESTIONS. TRY TO AVERAGE YOUR DIET THROUGHOUT THE YEAR WITHOUT BEING UNDULY INFLUENCED BY RECENT SEASONAL FACTORS. IT MAY HELP YOU TO UNDERSTAND THE QUESTIONS IF YOU REMEMBER THAT WE SIMPLY WANT TO FIND OUT YOUR AVERAGE CONSUMPTION RATE OF CERTAIN FOODSTUFFS AND WHERE THESE FOODS WERE PRODUCED.

NAME	SOC. SEC. NO.	DATE
HOME ADDRESS	PAYROLL NO.	OCCUPATION

AGE	HEIGHT	WEIGHT	SEX ☐M ☐F	EMPLOYED BY	BLDG.	AREA

1 RESIDENCE HISTORY

I HAVE LIVED IN MY PRESENT COMMUNITY FOR _____ YEARS.

BEFORE THAT I LIVED IN _____ CITY

FOR _____ YEARS.

2 DRINKING WATER

WHAT IS THE SOURCE OF DRINKING WATER IN YOUR HOME?
☐ WELL ☐ MUNICIPAL SYSTEM

HOW MANY GLASSES OF WATER DO YOU DRINK PER DAY?
_____ GLASSES

ON A WORK DAY HOW MUCH OF THIS WATER DO YOU DRINK WHILE AT WORK?
☐ LITTLE ☐ SOME ☐ MOST OF IT

3 OTHER LIQUIDS

HOW MANY CUPS OF BEVERAGE MADE FROM TAP WATER (COFFEE, TEA, SOUP, KOOL-AID, ETC.) DO YOU DRINK PER DAY?
_____ CUPS

HOW MUCH OTHER LIQUID DO YOU DRINK (BOTTLED SOFT DRINKS, JUICE, BEER, ETC.)?
_____ GLASSES

4 MILK

HOW MANY GLASSES OF FRESH MILK DO YOU DRINK PER DAY?
_____ GLASSES

WHAT IS THE SOURCE OF YOUR FRESH MILK?
☐ COMMERCIAL ☐ LOCAL FARMS

WHICH BRAND OF COMMERCIAL MILK DO YOU USUALLY DRINK?
_____
(DO NOT INCLUDE CANNED OR POWDERED MILK)

5 MEAT

FOR HOW MANY MEALS A WEEK DO YOU EAT FRESH MEAT (OTHER THAN CANNED OR CURED)?
(DO NOT INCLUDE PREPARED MEATS SUCH AS WEINERS, LUNCH MEAT, AND TV DINNERS)
_____ MEALS

HOW MUCH OF THIS FRESH MEAT IS BEEF? ☐ NONE ☐ LITTLE ☐ MOST ☐ ALL OF IT

WHERE DO YOU OBTAIN YOUR FRESH BEEF? ☐ MEAT MARKET ☐ LOCAL FARMS

6 FRESH VEGETABLES

FOR HOW MANY MEALS A WEEK DO YOU EAT FRESH VEGETABLES (OTHER THAN CANNED OR COMMERCIALLY FROZEN? _____ MEALS

FRESH FRUIT? _____ TIMES

WHERE DO YOU OBTAIN MOST OF YOUR FRESH VEGETABLES?
☐ GROCERY ☐ LOCAL FARMS

WHERE DO YOU OBTAIN MOST OF YOUR FRESH FRUIT?
☐ GROCERY ☐ LOCAL FARMS

7 SEAFOOD

ABOUT HOW MANY TIMES A YEAR DO YOU EAT THE FOLLOWING SEAFOODS?

FRESH OYSTERS _____ TIMES

FRESH CRAB _____ TIMES

FRESH CLAMS _____ TIMES

(DO NOT INCLUDE FISH OR CANNED OR COMMERCIALLY FROZEN SEAFOOD. INCLUDE ONLY THAT FROM NEARBY PACIFIC SOURCES.)

8 GAME BIRDS

HOW MANY TIMES A YEAR DO YOU EAT THE FOLLOWING GAME BIRDS?

DUCK _____ TIMES

GOOSE _____ TIMES

PHEASANT _____ TIMES

QUAIL _____ TIMES

CHUKKAR OR GROUSE _____ TIMES

9 COLUMBIA RIVER FISH

HOW MANY TIMES A YEAR DO YOU EAT FISH CAUGHT IN THE COLUMBIA RIVER BELOW HANFORD (OTHER THAN COMMERCIAL FISH?)

ABOUT _____ TIMES

WHAT KINDS OF FISH WERE THEY?

	MOST	SOME	NONE		MOST	SOME	NONE
SALMON				STEELHEAD			
STURGEON				WHITEFISH			
BASS				CRAPPIE			
TROUT				PERCH			
CATFISH				OTHER			

FOR SECTION USE ONLY

IDENTIFICATION CODE _____

A	B	C	D	E	F	G	H

NA-24 _____
ZN-65 _____
CS-137 _____
K-40 _____

10 OTHER QUESTIONS

WHEN WAS THE LAST TIME YOU ATE SEAFOOD (OTHER THAN FISH) AS THE PRINCIPAL PART OF A MEAL? _____

WHICH SEAFOOD WAS IT? _____

WHEN WAS THE LAST TIME YOU ATE FISH FROM THE COLUMBIA RIVER? _____

WHEN YOU OBTAIN SEA FOOD OR LOCAL FISH DO YOU USUALLY PRESERVE IT BY FREEZING? ☐ YES ☐ NO SMOKING? ☐ YES ☐ NO CANNING? ☐ YES ☐ NO

RB-1200-108 (10-65)

Fig. 5 Diet questionnaire given to each person counted in Hanford's whole-body counter.

1082128

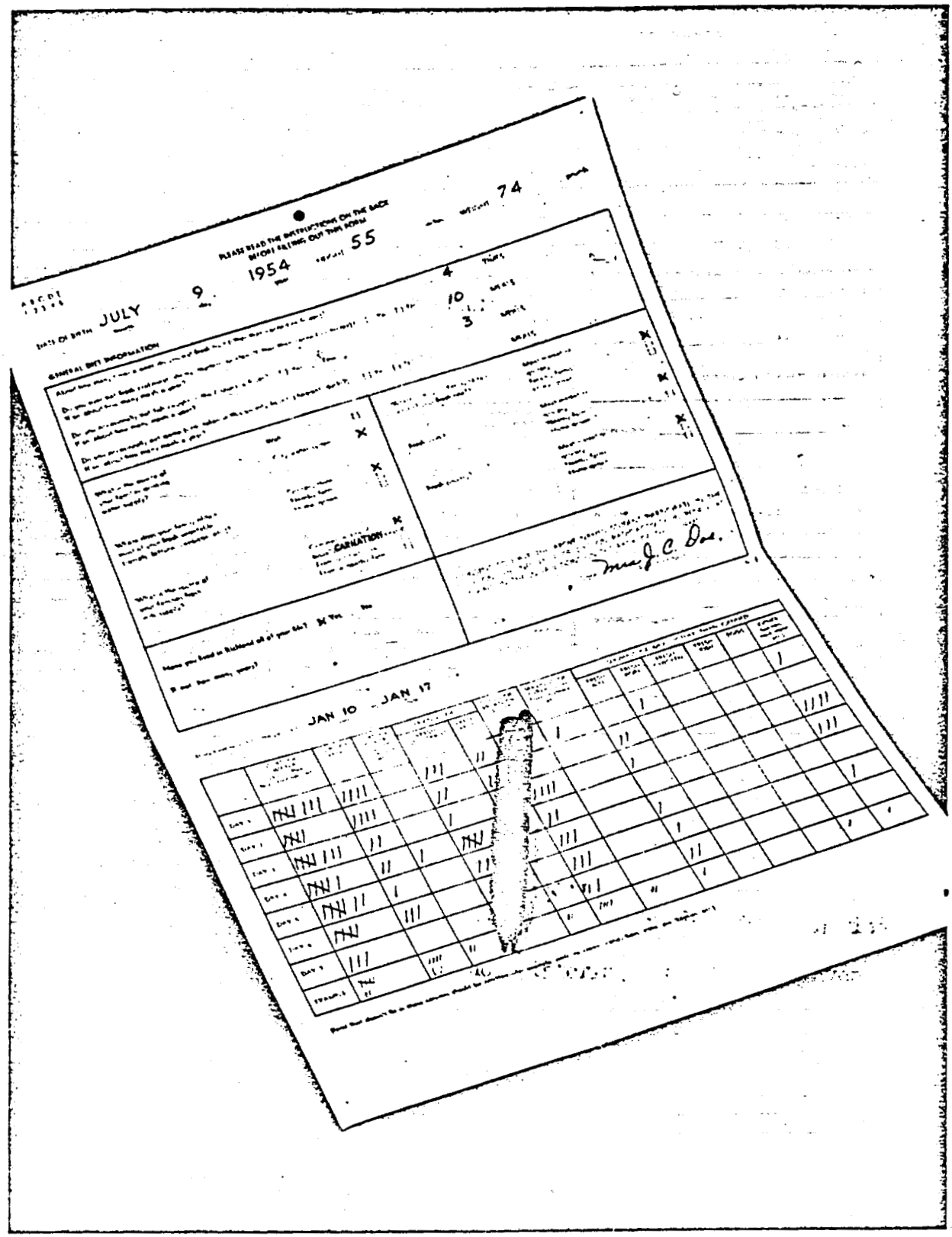

Fig. 6 Record form for children in schoolrooms. Consumption is recorded for 7 days.

1082129

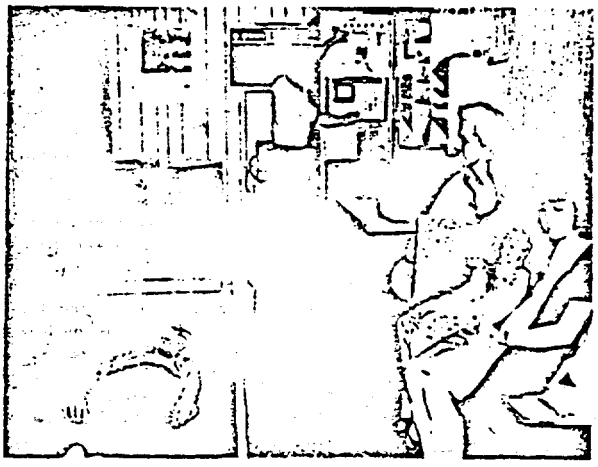

Fig. 7 Shadow-shield whole-body counter mounted in a track that may be moved to various schools to permit measurement of radioactivity body burdens in children.

and physiological variables that control the kinetics of ^{131}I in its movement through the environment. They are using the results of the studies to develop mathematical models that will allow realistic population dose evaluations for any kind of ^{131}I release. Their experimental facilities include a 17-acre dairy farm on which a herd of registered Holstein dairy cows is maintained during the summer. The remote location of the farm makes it ideal for use in releasing known quantities of radioiodine to the atmosphere during meteorological conditions in which the radioactive cloud passes over the pasture. A fraction of ^{131}I deposits on the grass and begins its movement through the food chain. Some experiments have included human volunteers who breathed the radioactive cloud as it passed over the pasture and drank milk produced from the contaminated pasture grass. The principal results that have emerged to date from this study include the following:[31]

1. The deposition velocity of ^{131}I is directly proportional to wind speed.
2. The concentration of ^{131}I in air during a continuous release is inversely proportional to wind speed, so the total relative quantity of ^{131}I deposited in a given area is independent of wind speed.
3. The fraction of ingested radioiodine taken up by the thyroids of the volunteers was 0.19 ± 0.04.

SAVANNAH RIVER LABORATORY

The radionuclides reaching the environment from Savannah River's installations represent a simple problem in dose evaluation for the most part because the radionuclide mixture is relatively constant and includes only a very few nuclides. The environmental dose is not actually reported on an annual basis, but the extent to which the dose contributes to environmental contamination is evident from a report on the effects of the Savannah River Plant[32] for the first half of 1967. The bulk of the radioactivity detected in the environs is tritium, which did not exceed 1.1% of the MPC in atmospheric samples at the plant perimeter and at 25-mile stations. In the Savannah River, tritium and ^{51}Cr concentrations averaged 1.2 and 0.001% of the MPC, respectively.

The Savannah River Laboratory (SRL) has adopted a comprehensive list of guides for the release of radioactive materials that is based on dose to the environmental population. These guides can be implemented at Savannah River because the site has the ability to control the release of radioactive materials at the source through the use of ion exchange, concentration by evaporation and storage, and use of seepage basins. These dose-related guides perform some of the same functions as annual dose evaluations. The MPC's utilized at Savannah River are derived from ICRP recommendations or daily intake guides established by the FRC. In those cases where ICRP recommendations are used, the occupational MPC for a 168-hr week is reduced to a level that would limit the dose to a value less than the maximum recommended by the FRC for the general population. Health physicists at the Savannah River installation do make periodic calculations of dose to the public based on analysis of air, river water, and fish, but these calculations are not published. Since SRL's adoption of very conservative release guides, the calculations of dose are made for the information of SRL's own health physicists to assure that releases are not contributing any significant exposure to the public.[33]

Conclusions

At the present time, only a limited number of U. S. nuclear installations feel constrained to evaluate environmental dose on an annual basis. As the nuclear industry grows, it is probably going to be necessary to extend the determination of environmental dose to other sites. In those cases where operations of more than one installation impinge on the same environment, the use of dose as a parameter for evaluation will become of great importance. The primary advantage of dose evaluations is the ability they provide to sum the contributions of a variety of radionuclides and a variety of pathways. The following benefits may be derived from the adoption of environmental dose as a surveillance evaluation parameter:

1. Through an exhaustive evaluation of dose, it is possible to demonstrate the range in which a given installation should be placed according to the FRC's definition. Knowledge of the range permits the adoption of the corresponding action guides proposed by FRC and the surveillance requirements recommended by the FRC.

1082130

2. Through performing the exercise of estimating environmental dose, it becomes evident which of the available pathways are of greatest significance; this permits optimization of the monitoring program.

3. The development of increased interest in studies leading to dose evaluation will give added assurance that those environmental pathways which contain mechanisms for concentrating radionuclides are being detected.

4. In a period of rapid growth of the nuclear industry, the possibility of a population becoming exposed to radionuclides from a multitude of sources is increased. An environmental surveillance discipline based on dose evaluations permits easy accommodation of new sources of exposure in the environment.

References

1. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 1, Superintendent of Documents, U. S. Government Printing Office, Washington, May 13, 1960.
2. W. S. Snyder, First Report of the Federal Radiation Council, *Nucl. Safety*, 2(2): 6-7 (December 1960).
3. U. S. National Committee on Radiation Protection and Measurements, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure*, National Bureau of Standards Handbook 69, Superintendent of Documents, U. S. Government Printing Office, Washington, June 5, 1959.
4. International Commission on Radiological Protection, *Recommendations of the International Commission on Radiological Protection*, ICRP Publications 2 and 6, Pergamon Press, Inc., 1959 and 1964.
5. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 2, Superintendent of Documents, U. S. Government Printing Office, Washington, September 1961.
6. W. S. Snyder, Second Report of the Federal Radiation Council, *Nucl. Safety*, 3(3): 1-4 (March 1962).
7. USAEC Rules and Regulations, *Code of Federal Regulations*, Title 10, Part 20, Standards for Protection Against Radiation, 1960, revised 1967.
8. R. F. Foster and J. K. Soldat, Evaluation of the Exposure Resulting from the Disposal of Radioactive Wastes into the Columbia River, in *Disposal of Radioactive Waste into Seas, Oceans, and Surface Waters*, Symposium Proceedings, Vienna, 1966, pp. 683-696, International Atomic Energy Agency, Vienna, 1966 (STI/PUB/126).
9. R. C. Steinkamp et al., Diet Model for Measuring Radioactivity Exposure Through Food—Pilot Study, *Radiol. Health Data*, 8(10): 565-573 (October 1967).
10. International Commission on Radiological Protection, *Principles of Environmental Monitoring Related to the Handling of Radioactive Materials*, ICRP Publication 7, Pergamon Press, Inc., 1965.
11. R. F. Foster and D. McConnon, Relationships Between the Concentration of Radionuclides in Columbia River Water and Fish, USAEC Report HW-SA-2688, Hanford Atomic Products Operation, presented at the Third Seminar on Biological Problems in Water Pollution, Cincinnati, Ohio, August 1962.
12. J. J. Davis et al., Radioactive Materials in Aquatic and Terrestrial Organisms Exposed to Reactor Effluent Water, in *Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958*, Vol. 18, pp. 423-428, United Nations, New York, 1958.
13. *Radioactive Waste Disposal into the Sea*, Safety Series No. 5, International Atomic Energy Agency, Vienna, 1961 (STI/PUB/14).
14. W. A. Chipman, T. R. Rise, and T. J. Price, Uptake and Accumulation of Radioactive Zinc by Marine Plankton, Fish, and Shellfish, *U. S. Fish Wildlife Serv., Fishery Bull.*, Vol. 135, pp. 279-292, 1958.
15. E. Wallauschek and J. Luetzen, Study of Problems Relating to Radioactive Waste Disposal into the North Sea. II. General Survey on Radioactivity in Sea Water and Marine Organisms, USAEC file No. NP-13756 (Vol. II), European Nuclear Energy Agency, 1964.
16. H. J. Dunster, The Disposal of Radioactive Liquid Wastes into Coastal Waters, in *Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958*, Vol. 18, pp. 390-399, United Nations, New York, 1958.
17. United Kingdom Atomic Energy Authority, Environmental Monitoring Associated with Discharges of Radioactive Waste During 1964 from U.K.A.E.A. Establishments, British Report AHSB(RL)R-66, November 1965.
18. C. L. Weaver, A Proposed Radioactivity Concentration Guide for Shellfish, *Radiol. Health Data*, 8(9): 491-494 (September 1967).
19. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Report No. 5, Superintendent of Documents, U. S. Government Printing Office, Washington, July 1964.
20. J. K. Soldat, Environmental Evaluation of an Acute Release of ^{131}I to the Atmosphere, *Health Phys.*, 11(10): 1009-1015 (October 1965).
21. E. G. Struxness et al., Comprehensive Report of the Clinch River Study, USAEC Report ORNL-4035, Oak Ridge National Laboratory, April 1967.
22. C. A. Pelletier, The Sensitivity of Environmental Surveys to Atmospheric Releases from Nuclear Facilities, thesis, University of Michigan, February 1966.
23. J. Rivera, personal communication, Nov. 23, 1967.
24. R. D. Grundy and D. R. Snavely, Fallout from the Third Chinese Nuclear Test—May 9, 1966, *Radiol. Health Data*, 8(6): 301-316 (June 1967).
25. J. R. Coleman and R. Liberace, Nuclear Power Production and Estimated Krypton-85 Levels, *Radiol. Health Data*, 7(11): 615-621 (November 1966).
26. I. L. Ophel, Environmental Consequences of Radioactive Waste Disposal, Canadian Report AECL-2478, August 1966.
27. Oak Ridge National Laboratory, Health Physics and Safety Annual Report for 1966, USAEC Report ORNL-4146, August 1967.
28. J. Sedlet and F. S. Iwami, Environmental Radioactivity at Argonne National Laboratory; Report for 1964, USAEC Report ANL-7104, Argonne National Laboratory, October 1965.
29. J. Sedlet, Environmental Radioactivity at Argonne National Laboratory, January–June 1967, *Radiol. Health Data* (in press).
30. T. H. Essig and J. K. Soldat (Eds.), Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966, USAEC Report BNWL-439, Battelle–Northwest, June 1967.
31. C. A. Pelletier, personal communication, Dec. 4, 1967.
32. Savannah River Laboratory, Effect of the Savannah River Plant on Environmental Radioactivity, USAEC Report DPST-67-30-2, August 1967.
33. W. L. Marter, personal communication, Nov. 7, 1967.

1082131