Implications of Iodine 131 in Fallout

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THE INCREASED testing of nuclear devices within the past few years has raised questions concerning the health implications of radiation from fallout. Early interest centered around strontium 89, strontium 90, and cesium 137. More recently, attention has been focused on iodine 131 (I-131) in our food supply, particularly in milk (*1–4*).

Nature and Distribution of I-131

Iodine 131 has a half-life of approximately 8 days. Since the half-life is the time required for the radioactivity to decrease by 50 percent, about 3 percent of the original material remains after 40 days. Thus, radiation from I-131 is of significance only within weeks after a nuclear explosion. Activity going into the stratosphere (above 40,000–50,000 feet) is of little concern because it decays before returning to earth. However, the I-131 injected into the troposphere (the atmosphere below the stratosphere) returns to earth, primarily via the rain. The amount ultimately reaching the soil is of little concern because it undergoes radioactive decay and disappears before it can be absorbed by plants to be transmitted in the food chain. Inhalation may account for some I-131 accumulation in animals and man but, based on experience from past fallout levels, this is not considered a primary route (*5*). At very high levels, such as in the Windscale accident, inhalation may become more important (*2*).

I-131 in the Food Chain

Radioactive iodine from the atmosphere is deposited on plants consumed by the cow. A portion of the amount consumed is deposited in the cow's thyroid gland, a portion is lost in her urine, and another portion is excreted in her milk. The latter portion has been estimated to be approximately 6 percent of that ingested, but is subject to seasonal variation, with higher values in spring and summer (*6*). Although human exposure can occur also from ingestion of fresh fruits and vegetables, this is considered minor because most residual surface contamination is removed by washing or peeling before consumption (*5*).

In 1957, Wolff suggested that milk was a major dietary source of I-131 (*7*). This might be anticipated, as the processing of milk is designed to bring the freshest possible product to the consumer. With a time interval between the cow and consumer of only 2–4 days, there is little time for loss by radioactive decay. On the other hand, other dairy products can be relatively low in activity because the time required for processing permits I-131 to decay (*8*).

Milk Monitoring

I-131, as well as strontium 89, strontium 90, cesium 137, barium 140, and stable calcium concentrations in pooled samples of pasteurized milk, is measured in approximately 60 cities by the Public Health Service Monitoring Network (*9*). The frequency of measurement depends on fallout levels; when fallout levels are increased the measurements are more frequent. There are several reasons for monitoring milk: (*a*) milk samples are easily obtained at all seasons of the year, thereby permitting a

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continuous surveillance program showing both geographic and time variations; (*b*) most of the radionuclides considered of health interest are carried in milk; (*c*) milk and milk products represent a significant part of the diet for all age groups, particularly children; and (*d*) values from the milk measurements may be used to estimate fallout in the total diet.

Metabolism of Iodine

At normal dietary levels, nearly 100 percent of the iodide ingested is either retained in the thyroid gland or excreted in the urine within 24–48 hours, the actual distribution depending somewhat on the individual's need for iodine. After concentration by the thyroid gland, iodide is quickly oxidized and bound to protein forming a complex of compounds known collectively as thyroglobulin. The biological half-life of thyroglobulin is estimated as 6–8 days with about four times as much excreted through the urine as in the feces. A small amount of iodide is found in the blood. The thyroid to serum iodide ratio for most animals, including man, is approximately 25:1 (*10*). Therefore, the thyroid receives the largest radiation dose from I-131, but the amount depends upon the amount of stable iodine ingested during the preceding time interval (*11*). As a generalization, the human thyroid gland that functions normally concentrates approximately 30 percent of the initial quantity of I-131 in 24 hours (*12*). Because of rapidly growing cells, the thyroid gland of infants is believed to be more sensitive to a specific intake of I-131 than the adult thyroid gland.

Animal Studies

In 1954, Van Middlesworth observed that I-131 from 1953 tests appeared in the thyroid glands of cattle (*13*). This indicated that monitoring the thyroid glands of grazing animals was a sensitive and informative index for evaluating the biological exposure of animal populations to I-131 and illustrated that this radionuclide might be present in food consumed by man during and immediately after nuclear tests.

Studies on the injurious effects of single or daily administration of I-131 to sheep and swine have been conducted by Bustad and associates (*14*). A seasonal variation of thyroidal I-131 was noted in sheep, with maximum uptake from April to July, whereas only a suggestion of a seasonal variation was observed in swine. In sheep, as perhaps in other ruminants, approximately equal percentages of a daily dose were excreted in urine and feces, whereas in swine a greater percentage was excreted in urine. In young lambs, the thyroid uptake, expressed as percent of dose, was the same for *in vivo* and *in vitro* labeling of the milk; the maximal uptake was 10 percent of the dose per gram of thyroid.

Although there are species differences, it has been shown that cattle, swine, and sheep fetuses also may concentrate radioactive iodine, particularly during the latter part of gestation (*14, 15*).

Bustad and associates have reported the results of feeding sheep levels of I-131, ranging from 5,000 $\mu\mu$c to 1,800,000,000 $\mu\mu$c daily for 4 years. (The symbol $\mu\mu$c=micromicrocurie, a millionth of a millionth of a curie which, in turn, is equivalent to the radioactivity of 1 gram of radium.) Daily feeding of 5,000,000 $\mu\mu$c was the lowest level in which detectable lesions of the thyroid gland were noted. No thyroid abnormalities were observed when 150,000 $\mu\mu$c per day were fed, starting during the dam's pregnancy and continuing throughout the lifespan of the sheep (*16*). The observations have now been extended to cover up to 11 years (personal communication from L. K. Bustad, Hanford Laboratories, General Electric Co., November 1962).

Experience in Humans

Van Middlesworth has reported the concentration of I-131 in 175 human thyroid glands collected from autopsies in Memphis during November 1954 to August 1955. The values ranged from 1 $\mu\mu$c to 100 $\mu\mu$c per gram of thyroid tissue (*17*). Eisenbud and associates studied the I-131 content of human thyroid glands after the resumption of nuclear tests in 1961. For adults drinking less than 1 quart of milk daily, the value was 57 $\mu\mu$c $\pm$ 33 $\mu\mu$c per thyroid compared with 83 $\mu\mu$c $\pm$ 29 $\mu\mu$c for children drinking approximately 1 quart per day (*18*).

The mere presence of radioactive iodine in the thyroid gland, however, is not proof of injury. Little information is available concerning injury produced at low levels of human exposure. The Federal Radiation Council estimated the radiation dose to infant thyroids from fallout resulting from nuclear tests through 1961 as 0.1 rem to 0.2 rem (radiation equivalent in man) per year during and immediately following testing, based on the time of highest concentration of I-131. The average value for all age groups would be approximately one-tenth of this value (*19*).

There is concern about the effect of I-131 on the development of thyroid carcinoma in infants. It has been calculated that persons who drank milk in a three-county area of New York during 1953 could have received a total dose up to 30 rad (the rad is a unit for measuring the absorped dose of radiation). Lade recently reviewed the records of children in this area who were under 2 years of age during the 1953 fallout, and reported no deaths attributable to thyroid cancer since 1953. One child, who was 20 months old in April 1953, developed a thyroid carcinoma, but Lade concluded that this is the number to be expected in this population due to chance. He pointed out that "it seems most unlikely that an event which has resulted in no increase of thyroid carcinoma during the ensuing 9 years will lead to such an effect in the future" (*20*).

A panel of experts appointed by the National Academy of Sciences has reviewed the available literature on human exposure. They concluded: ". . . it appears that iodine 131 is considerably less effective than comparable doses of externally applied X-rays in producing thyroid cancer. The magnitude of the difference cannot be stated since not a single confirmed case due to iodine 131 is known. From comparable therapeutic results, X-rays appear to be from 5 to 15 times as effective as iodine 131. In making this comparison it must be kept in mind that X-rays are ordinarily delivered at a high dose rate in a single sitting or in a few divided doses" (*11*).

Dunning (*4*), in a critical review of the problem, said "For purposes of gaining some insight into the relation of radiation doses versus possible effects let us assume that there is a major testing period each and every year for a lifespan of 70 years and that the upper estimate (0.2 rem from past testing) of the Federal Radiation Council's average dose to the child's thyroid is correct. The radiation dose to the adult would correspond to about 20 millirads per year, however, due principally to the increase in mass of the adult thyroid compared to that of the child (about 20 grams to 2 grams). (The radiation dose to the fetus' thyroid is less than the child's since the lesser percentage of uptake of iodine 131 more than compensates for the smaller mass of the fetus' thyroid.) Thus, if man is conceived, born, lives his full lifespan in an environment of iodine 131 such as to produce 200 millirads per year to the thyroid as a child, his 70-year lifetime dose might be about two rads. This total dose of two rads (spread out over many years but with higher annual doses during early childhood) may be compared with doses of a few thousand rads and higher (delivered in weeks) that the panel of experts (NAS) referred to as the therapeutic dose for which there was no evidence of thyroid cancer production (except for one doubtful case). Of course, such estimates are not precise, nor can they be with our knowledge today. They do, however, give some perspective to the problem. It is also correct that like any 'average' number there will be radiation doses higher and lower, but it is unlikely that the same locality would receive the highest fallout in the country year after year."

Radiation Protection Guides

The reports issued by the Federal Radiation Council, an advisory group to the President of the United States, provide the basic framework of radiation protection standards in this country (*12*, *19*, *21*). It is important to emphasize that the FRC guides are based on lifetime exposures. However, for administrative and regulatory purposes, the FRC deemed that averages for intakes be based on a 1-year period.

The FRC introduced the term "radiation protection guide" (RPG), defined as "the radiation dose which should not be exceeded without careful consideration of the reasons for doing so." Using this definition, the Council established an RPG of 0.5 rem for the annual whole body dose for the general population. However, the whole body RPG is 10 times higher (5 rem) for radiation workers. The RPG for the thyroid gland of radiation workers was established as 30 rems yearly. On the other hand, the Council recommended that the annual RPG for thyroid tissue should be 1.5 rem for persons in the general population, and 0.5 rem for the average received by the general population. These guides are based on the most sensitive group in the population, namely children (*12*).

The Federal Radiation Council developed guidelines for the average daily intake of I-131 which would not exceed the RPG for the general population. Several factors were considered in deriving these intakes: (*a*) the weight of the thyroid gland, (*b*) the percentage of the iodine intake which reaches the gland, and (*c*) the average retention time. Therefore, the foregoing guides were based on the weight of a child's thyroid (2 grams), and they need to be adjusted upward when applied to adults (since the weight of the adult thyroid gland is approximately 20 grams, the guides are adjusted upward by a factor of 10). It was assumed that the average thyroid gland concentrates 30 percent of the initial quantity of I–131 in 24 hours, both in the adult and in the child, and that the average retention time for the adult and child is 7.6 days (*12*).

On the basis of the above known factors and assumptions, it was calculated that an average daily intake of 80 $\mu\mu$c of I–131 would meet the RPG of 0.5 rem for averages of suitable sample of an exposed population group. The value of 80 $\mu\mu$c was rounded to 100 to keep within the precision of the data (*12*).

To provide guidance, the FRC established three ranges of daily transient intakes as operating criteria (*12*): Range I=0 $\mu\mu$c to 10 $\mu\mu$c per day or 0 $\mu\mu$c to 3,650 $\mu\mu$c per year. (Daily intakes in this range would not be expected to result in any appreciable number of persons in the population reaching a large fraction of the RPG.) Range II= 10 $\mu\mu$c to 100 $\mu\mu$c per day or 3,650 $\mu\mu$c to 36,500 $\mu\mu$c per year. (Daily intakes in this range would be expected to result in exposures to population groups which on the average would not exceed the RPG.) Range III= 100 $\mu\mu$c to 1,000 $\mu\mu$c per day or 36,500 $\mu\mu$c to 365,000 $\mu\mu$c per year. (Daily intakes in this range would be expected to result in exposures to a substantial number of the population which would exceed the RPG if continued for a sufficient period of time.)

Application of Guides to Fallout

The guides were developed primarily for use in the industrial field under "normal peacetime operations." They were conservatively established with the assumption that compliance would be relatively feasible. However, on August 17, 1962, the FRC noted that "there has been widespread misunderstanding concerning these guides . . .," particularly as applied to I–131 in fallout (*22*).

In September 1962, the FRC stated its position on current fallout levels. This report emphasized that "the RPG's are not a dividing line between safety and danger in actual radiation situations nor are they alone intended to set a limit at which protective action should be taken or to indicate what kind of action should be taken." When applied to fallout, the guides "can be used as an indication of when there is a need to consider whether any protective action should be undertaken under all the relevant circumstances." The Council believes that "any possible health risk which may be associated with exposures even many times above the guide levels would not result in a detectable increase in the incidence of disease." Therefore, they caution that "radiation exposure anywhere near the guides involves risks so slight that countermeasures may have a net adverse rather than favorable effect on the public well-being. The judgment as to when to take action and what kind of action to take to decrease exposure levels involves consideration of all factors" (*23*).

Similarly, the National Advisory Committee on Radiation has emphasized that countermeasures should not be instituted lightly: ". . . the Committee urges the avoidance of independent countermeasure action. Not infrequently, such action involves the use of countermeasures which are associated with risks approaching or exceeding those of the contaminant" (*24*).

Should it become necessary, great care must be exercised in applying the RPG's to daily instances. For example, for the month of May

1962, Des Moines, Iowa, reported an average of 90 $\mu\mu c$ of I-131 per liter (about a quart) of milk, a value below the 100 $\mu\mu c$ level of Range II. Yet, the peak value for the month was 300 $\mu\mu c$ per liter, a value 3 times the level of Range II (*25*). The total for the year September 1961–August 1962 was 32,750 $\mu\mu c$, a value below the 36,500 $\mu\mu c$ per year established for the most susceptible group (*26*). If countermeasures had been invoked on the basis of the peak value for the month of May, they would not have been in agreement with the basic philosophy of the RPG's. The daily intake values are based on a yearly average, which, in turn, is based on a lifetime exposure for the most susceptible group. Furthermore, to receive this level of radioactivity, an infant would have had to consume 1 liter of milk per day and an adult 10 liters a day to achieve the same theoretical thyroid concentration. In actual practice, the average infant consumes about 0.7 liter of milk daily. Finally, if a station reported a yearly total near the top of Range II (36,500 $\mu\mu c$) this would correspond to an intake of approximately 24,000 $\mu\mu c$ when corrected for I-131 decay during the 48-hour delay normally occurring between the time of processing and consumption. Assuming that an infant consumed 0.7 liter of milk daily, this intake would correspond to a yearly intake of about 17,000 $\mu\mu c$, a figure half of that reported.

Possible Control Measures

Although the application of control measures is not currently deemed necessary, certain methods have been suggested as being of potential value in the event of a nuclear war or other marked increase in fallout contamination. Several of these capitalize on the rapid decay of I-131 because of its short half-life.

One suggestion is to place the most susceptible groups (children less than 2 years old, lactating mothers, and pregnant women) on evaporated milk or nonfat powdered dry milk. Since the average time required for those products to reach the consumer is approximately 2 months, nearly all the radioactive iodine would have decayed. Stored, refrigerated milks also might be an effective means for reducing population exposures. However, the storage and refrigeration space required to conduct such a control measure make this method impractical at the present time. The pooling of fresh milk from contaminated areas with that from uncontaminated areas has been suggested. However, this method is generally considered to be unsatisfactory as it would be both difficult and costly (*24*).

Decontamination of milk to remove I-131 has received considerable study. Gregor has developed an electrodialytic process in which ion-exchange membranes are used (*27*). Although the method as reported is for strontium 90 removal, it reportedly also will remove I-131 (personal communication from H. P. Gregor, Polytechnic Institute of Brooklyn, November 1962). Murthy and associates have described an anion exchange resin technique which removes 98 percent of the I-131 from milk (*28*). If developed, such procedures may have value should fallout contamination reach high levels.

The addition of stable iodine or thyroid extracts to the diet has been suggested as a means of controlling uptake of I-131. The effect of stable iodine on I-131 uptake has been investigated in man and sheep (*29*, *30*). However, the National Advisory Committee on Radiation Protection has concluded that the use of stable iodine or thyroid extracts "as countermeasures should usually be reserved for limited application due to dangers inherent in the administration of food additives and medicants to large population groups" (*24*).

Uncontaminated or stored feeds fed to cows reduce substantially the amount of I-131 in their milk (*24*). This method was employed with varying success during 1962 in Utah and Minnesota when the yearly I-131 levels in the milk supply approached the top of Range II of the RPG's.

Eller (*31*) recently reported that milk from cows that grazed on marginally managed farms, where the land was poor and crop management inadequate, tended to contain relatively high levels of I-131 and strontium 90 when contrasted with well-managed farms. These radionuclides were reduced by 50 percent through optimal fertilization of a marginal farm. A more detailed discussion of possible control measures has been given by Read (*32*).

With regard to control measures, the National

Advisory Committee on Radiation Protection report recommended that the PHS should (*a*) intensify its efforts to control environmental contamination and (*b*) expand its research and development programs in radiation control, including surveillance and countermeasures (*25*). The successful completion of such research, coupled with the additional studies underway in other government and industrial laboratories, should provide suitable countermeasures for application if needed in the future.

Because fallout originates from nuclear testing, the cessation of testing might be considered as a countermeasure. From this point of view, the recent ban on atmospheric testing may be expected to reduce fallout in the food supply. However, underground testing is permitted by the treaty, and, therefore, isolated instances of fallout could occur from this source. The potential magnitude of these effects has been recently pointed out (*33*). The question of whether to conduct underground nuclear weapons tests involves decisions in which the benefits from testing must be balanced against the risks of such testing.

Summary

Iodine 131 has a half-life of approximately 8 days. Fallout, which comes primarily from the troposphere, is therefore significant only within weeks after a nuclear explosion.

Dairy cows secrete in their milk approximately 6 percent of the amount of iodine 131 they ingest. Because of the short time interval between the processing of milk and its consumption, milk is believed to be the primary source of iodine 131.

Approximately 30 percent of the ingested quantity of iodine 131 is concentrated in the thyroid gland. However, no case of thyroid cancer in man has been found to be caused by iodine 131.

The radiation protection guides established by the Federal Radiation Council are based on lifetime exposures, primarily for industry. These guides are not a dividing line between safety and danger, and they are not intended to dictate when or what kind of action should be taken. Averages for intake levels are based on infants and young children. Exposures many times the guide levels would probably not result in an increased incidence of disease.

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Several readers have commented that they receive *Public Health Reports* several months after publication because of the time required for transport by boat to overseas addresses. Shipment by air, however, would cost an additional $1.40 per copy for numbers mailed to Africa, Asia, and the South Pacific. The charges per copy for airmail to Europe would be $1.00 and to South America 60 cents.

It is technically possible to send the journal in microform by airmail, at no more than the price of a post card, but microforms are useful only to those who have access to an instrument for reading them. The full contents of most issues of *Public Health Reports* can be printed on a single microform at a reduction of less than 20 to 1.

It would be helpful to learn whether many readers of *Public Health Reports* are interested in receiving microform editions. Direct comments to Public Health Reports, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C., 20201.

Exhibits

Bovine Mastitis Control

Bovine mastitis control as a cooperative effort by State and local regulatory agencies, the dairy processor and producer, and milk laboratories is described in an exhibit created by the environmental services of the Public Health Service. A pamphlet is distributed with the display.

The exhibit is available on loan from the Special Projects Section, Milk and Food Branch, Division of Environmental Engineering and Food Protection, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C., 20201. Requests should be made several months in advance of the date desired. The branch pays costs of shipping and installing at large national and regional meetings. Assembly instructions are in the crate.

Specifications: No. EEFP–12 Bovine Mastitis Control. Free-standing exhibit, 7 feet 6 inches high, 10 feet 2 inches wide, and 36 inches deep, total weight 210 pounds including the crate. Lighting fixtures require one outlet totaling 500 watts. Outside crate measurements are approximately 30 to 91 by 86 inches.

Food Protection For the Consumer

A food service sanitation exhibit uses color transparencies to show typical program guides, research, training, and technical assistance provided by the Public Health Service to States, communities, and industry. Copies of the 1962 Food Sanitation Manual and other guides of the Division of Environmental Engineering and Food Protection are included.

The exhibit is available on loan free from the Milk and Food Branch, Division of Environmental Engineering and Food Protection, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C., 20201, if requested sufficiently in advance of the date desired. Allow at least 2 months. Instructions for assembling are attached to the packing crates.

Specifications: No. EEFP–11, Food Protection for the Consumer. Free-standing exhibit, 7 feet 6 inches high, 10 feet 3 inches wide, and 36 inches deep; total weight 509 pounds including 2 packing crates; crate measurements 30 by 31 by 97 inches and 34 by 40 by 80 inches. Lighting fixtures require one outlet totaling 1,500 watts.