PROGRESS REPORT

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Phase I. Radiation and Radioisotope Studies
with Laboratory and Domestic Animals

Subsection: "Agricultural Impacts of Nuclear
Power Generation"

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PROGRESS REPORT

I. Background of Activities Performed Under AEC Contract

A. Studies on Radioactive Contamination

Investigators have been involved with interpretive studies on radioactive contaminants since the early 1960's. In 1960, the Department of Physical Biology formulated one of the first studies that incorporated the concept of analysis and assessment to radioactive contamination of the food chain. This study combined agricultural and food consumption expertise with the physical and biological sciences to investigate the problems of fallout radiocontaminants and to develop and amplify the critical pathway concept in human and animal food chains. These capabilities were expanded into an interpretive capability which led to numerous experimental studies and to the development and testing of various remedial (or countermeasures) concepts.

The early efforts at assessment were designed to evaluate the effectiveness and efficiency of radiation monitoring networks on a national and international scope. Later work was directed toward specific experimental programs designed to investigate unique relationships or indicator patterns that could be used in local and national planning. Brief abstracts of the work in a chronological order from 1962 to date are presented to show the diversity and coverage of these activities (full details have been reported or published).

1. Planning Study for Evaluation of Radioactive Contamination of the Food Chain.

Summary:

a. Monthly fluid milk consumption data from 36 major United States metropolitan areas were developed and used in conjunction with data

from the Public Health Service milk radionuclide monitoring network. These are the only milk consumption data available on a monthly basis and provide an excellent method of appraising radionuclide intake from fluid milk. Analyses of these data provide a better indication of the nature and magnitude of geographic differences which, in turn, have a direct bearing on total radionuclide intake levels.

b. The contribution of milk to the total diet radionuclide intake in 1962 varied from nearly 100 percent for ^{131}I to ranges of 30-60 percent for ^{90}Sr and 30-70 percent for ^{137}Cs . Variations of the latter type were caused by differences in the fallout rate, although other factors such as geographic area, time, age, income, etc. are also important variables.

c. The estimated ^{90}Sr intake from major fruits and vegetables was 685 picocuries during 1961. Potatoes were the most important contributors followed by cabbage, lettuce, carrots, onions and celery.

d. The observance of ^{131}I in leafy vegetables during 1962 could have presented a situation among specific population categories in which ^{131}I intake levels might have been one-third higher than the levels estimated if milk were the only contributor.

e. Analysis of many milk sampling programs, both state and nationwide, for ^{90}Sr and ^{137}Cs revealed some differences in results when sampling sites were duplicated and indicate how more effective sampling programs could be developed.

f. Investigation of some meteorological factors and their relationship to ^{90}Sr in milk indicates the possibility of establishing predictive equations using variables such as total rainfall during month, number of times rains fell and number of thunderstorms recorded. Pre-

liminary equations for a few selected areas show the validity of this approach.

g. Estimates of total dietary ^{90}Sr intake derived from analyses of individual foods compared favorably to studies in which the total diet was analyzed for ^{90}Sr . Ratios utilizing individual foods can then be utilized for dietary estimates in the absence of total diet analyses.

h. Experimental studies on the relationships between soil ^{90}Sr levels and edible foods grown on soils indicate the nature of uptake patterns under controlled conditions.

i. Data from major foreign programs have been incorporated into a continuing review of programs dealing with food chain contamination. Updating and refinement of all food consumption data are performed regularly. These data are used with reported radionuclide levels in foods to obtain the best possible estimates of radionuclide intake for domestic and foreign consumers.

2. Development of Alternative Methods of Estimating Dietary ^{90}Sr

Abstract: Controlled studies have been completed on the relationships between the $^{90}\text{Sr}/\text{Ca}$ ratios in the diet and urine ($\text{OR}_{\text{urine/diet}}$) of a group of adults and 4 to 5 year-old children. The results were constant enough to indicate that on a population basis urinary analyses would be satisfactory for monitoring of dietary levels. In adults, the dietary $^{90}\text{Sr}/\text{Ca}$ was essentially the same as the urinary $^{90}\text{Sr}/\text{Ca}$; in children the dietary $^{90}\text{Sr}/\text{Ca}$ was about 0.5 the value of the urinary $^{90}\text{Sr}/\text{Ca}$.

3. Estimation of ^{137}Cs Body Burdens by Measurements of Diet, Urine, and Whole Body

Abstract: Dietary and urine samples from controlled studies with children and adults were analyzed for $^{137}\text{Cs}/\text{K}$ ratios and body burdens calculated by direct whole body counting were compared with those calculated from urinary values. The agreement was only fair, but the urinary method was considered potentially useful for monitoring purposes. More precise knowledge of urinary/diet relationships as a function of age would be expected to improve the agreement.

4. Removal of ^{90}Sr and ^{137}Cs by Processing and Preparation Practices

Abstract: Home and commercial processing procedures have been found to remove up to 60% of the ^{90}Sr and ^{137}Cs fallout contamination from important vegetables. For possible practical application, it is necessary to establish the validity of removal factors under varying conditions that might be encountered.

5. Dietary ^{90}Sr Reductions through Food Substitutions in the Fruit and Vegetable Category

Abstract: Detailed consideration is given to fruits and vegetables as contributors of ^{90}Sr to population diets. Taking into account the relative contributions of specific items of both ^{90}Sr and important nutrients (primarily Vitamins A and C), estimates are presented of reductions in ^{90}Sr intake that can be obtained by practical shifts of consumption within the category of fruits and vegetables with nutritional balance being maintained.

6. Determination of a Mathematical Model for Prediction of Radionuclides in Milk

Abstract: Efforts were directed toward developing a model capable of predicting the levels of radionuclides in milk from climato-

logical data and air levels of radioactivity. These models could be linked to procedures found to be satisfactory for calculation of total dose-commitment to the population from known levels of specific radio-nuclides in milk. In addition, they would provide a prediction capability for milksheds in the event of accidental or emergency conditions resulting from releases of radioactivity. The general concepts of such an approach are described.

7. Summary of Worldwide ^{90}Sr , ^{137}Cs Levels

Abstract: A continuous evaluation is made of levels of radionuclides as reported from various locations in the world. Eventually correlations should be developable among such parameters as site of release, magnitude of detonation, and meteorological factors.

8. ^{90}Sr and ^{137}Cs Studies in Soils and Vegetables from Local Areas

Abstract: Taking advantage of control plot studies carried on by other departments, limited observations are made from year to year on ^{90}Sr and ^{137}Cs levels in soils and vegetables under commercial growing conditions. Data are used to compare uptake patterns for vegetables consumed in greatest quantities.

9. Reconsideration of the ^{131}I Contribution from Fruits and Vegetables

Abstract: It has been taken for granted that fresh milk is the only important source of fallout ^{131}I for the human population. However, a detailed consideration suggests that under certain conditions fresh fruits and vegetables could also be important contributors of ^{131}I to total diets.

10. Integration, Updating and Evaluation of Changes in Food Consumption Data Related to Radionuclide Intake

Abstract: This study is part of a continuing appraisal of all food consumption as it relates to radiocontamination of the food chain. Estimates of radionuclide intake are prepared for various population groups in order to examine the effects of changes in consumption patterns. Consideration of geographic, socio-economic, seasonal and age influences are taken into account insofar as data are available. Data sources include the various Situation Reports (Food, Vegetable, Fruit, etc.) published by the U. S. Department of Agriculture as well as consumer surveys and individual food item appraisals.

11. Urine/Diet Studies Among Teenagers -- Continuation of Alternative Methods Development for Estimating Dietary ^{90}Sr .

Abstract: Studies conducted with two groups of teenagers (13 and 16 years) further quantify the age dependent relationship of the $\text{OR}_{\text{urine/diet}}$ which was observed in earlier studies among adults and pre-school children. Incorporation of the teenage data into prediction equations gives a more reliable base for the use of urinary samples to estimate dietary ^{90}Sr .

12. Pooled Urine Samples for Estimating Radionuclide Levels

Abstract: Sampling procedures and collection patterns were developed for urinary sampling of defined population groups. Pooled urine samples were collected in two communities to examine the following age categories: a) 1-4½ years, b) 4½ - 9½; c) 9½ - 14½; d) 14½ - 19½; e) 19½ - 24½; and f) 24½ and over. Analyses were made for ^{90}Sr and ^{137}Cs to determine their usefulness in estimating dietary levels and body burdens.

13. Non-Milk Contribution of ^{131}I to Diet

a) Comparison between milk and non-milk foods.

Abstract: Non-milk ^{131}I could make a significant contribution to total ^{131}I intake among certain population groups. Estimations have been made for some of these groups during the June-September 1962 period. The possibility of a 20 to 40 percent non-milk ^{131}I contribution was indicated for farm families, rural families with gardens and other non-urban population categories. Since there are nearly 50 million persons in the United States included in these groupings, the nature and magnitude of this contribution should be more carefully examined. Appropriate remedial measures may simply require converting to processed foods when the occasion demands action, but no-procedures or plans have been established to meet this need.

b) Experimental ^{131}I studies in pasture and food plants.

Abstract: Green beans and pasture were grown in adjacent plots and contaminated with ^{131}I solutions. A bean/pasture ratio of 0.03 to 0.05 was indicated. Removal rates for washing were calculated and averaged 40-50 percent for field application studies. Laboratory studies indicate a similarity to field studies if similar air, light and temperature conditions are present. Increasing ^{131}I concentration levels from 1 to 5 $\mu\text{Ci } ^{131}\text{I}/\text{liter}$ did not influence removal rates under rinsing experiments.

14. Practicality of Decontamination Processes as Related to Food Technology

Abstract: Milk ^{90}Sr levels were used to estimate ^{90}Sr levels for the four major dietary sub-groups (Dairy, Grain, Fruits and Vegetables and Animal Protein Foods) in various countries of the world. These data were then modified on the basis of expected effects from standard food

preparation and processing practices to determine the amount of ^{90}Sr normally removed prior to consumption. Reductions in total dietary ^{90}Sr intake were estimated to fall in the 10 to 30 percent range. Direct correspondence between the degree of marketing services performed and the level of ^{90}Sr removal was noted. Thus, the more developed countries could expect greater reductions and still retain the economic capability for achieving further reductions. Nearly 80 percent of the dietary ^{90}Sr intake could be eliminated in developed countries if maximal counter-measures were employed. Since the less developed countries cannot achieve this reduction without outside aid, it is necessary to examine these differences and consider appropriate emergency policies for improvement of these capabilities.

15. Soil and Vegetable ^{90}Sr and ^{137}Cs Levels on Sites Under Continuous Cultivation

Abstract: Experimental plots kept under continuous cultivation show the pattern of ^{90}Sr and ^{137}Cs levels during the years 1963-1968. Soil levels during this period were relatively consistent, apparently the increases in deposition were nearly matched by the soil losses associated with normal cultivation and harvesting practices. In contrast, the ^{90}Sr and ^{137}Cs levels in vegetables are more directly related to deposition rates (which declined significantly during the latter part of this period). Cultivated site ^{90}Sr levels continue to be significantly lower than uncultivated sites, reflecting the availability of ^{90}Sr for uptake by plants.

16. Fallout Studies and their Relationship to the General Problem of Environmental Radiocontamination

Abstract: The widespread studies on radioactive fallout produced by nuclear weapons testing have provided a valuable "base-line" set of observations for problems that may arise as peaceful uses of atomic

energy continue to expand. Principles of monitoring, methods of collecting samples, analytical procedures and remedial measures are all part of the available or known technology that can be fully utilized to give better insights into the new problems of nuclear power reactor releases, fuel reprocessing wastes, nuclear mining and excavation techniques and nuclear propulsion. The ability to use known relationships and available data from fallout studies are examined from the viewpoint of assessing the radioactive environment for a specific area. In particular, the area considered involves the Finger Lakes Region of Upstate New York and the situation concerns the feasibility of locating nuclear power reactors on these lakes. Baseline data on radiation levels in the environment are presented to show information readily available and indicate areas where specific gaps exist.

17. Studies of ^{131}I Uptake and Retention in Food Plants.

Abstract: ^{131}I was applied as a spray (NaI solution) to various pasture and food plants to examine uptake, retention and removal characteristics under controlled conditions. Comparisons were made between pasture and various types of plants in an effort to develop some inter-relationships or indicator mechanisms that could be utilized under emergency releases of radioactivity. Data show a pasture to leaf lettuce ratio of 2:1, a pasture to green bean ratio of 60:1 and a pasture to tomato ratio of 180:1. Distribution of ^{131}I on various plant parts indicated that the leaf and stem (or vine) portion received more than 80 percent of the activity. Time sequenced uptake in green beans showed an early 20 to 30 per cent uptake pattern followed by an increase to the 50 to 60 percent level after two hours had elapsed.

18. Data Appraisal and Summary Evaluation of Radioactive
Fallout in Foods

Abstract: The presence of radioactive fallout in our environment resulting from the extensive nuclear testing of the 1950's and 1960's and accompanied by the extensive monitoring programs in operation throughout the world have provided us with valuable baseline information on the distribution of radioactive materials in our environment. Prediction models and indicator mechanisms have been developed and refined, giving us a high degree of utility and capability for assessing the impact of intentional or unintentional releases of radioactive materials. Much is now known about pathways, critical groups and remedial measures and this will greatly assist planning and operations during the coming decades of nuclear power and other peaceful uses of atomic energy.

Fallout data from state, national and international networks have been summarized by latitudinal bands because of normal weather patterns that conform to this type of distribution throughout the world. More than 25,000 machine punched cards were included in this summary. Peak levels were observed in each latitudinal band during 1963-1965 with very high levels being noted for special or unique food and population categories.

Accompanying the observation of radioactive materials has been the full development of remedial or countermeasures designed to provide alternatives or preventive actions in the event of high level releases. Iodine-131 would be the radionuclide of greatest concern and also the one with the greatest number and most effective countermeasures available. Conditions requiring extensive countermeasures for ^{90}Sr , ^{137}Cs and other radionuclides would only be expected under large scale releases far beyond normal peacetime activities (nuclear war). Under

those circumstances the normal pressures to avoid starvation and maintain life would be of greatest immediate concern rather than the more distant future hazard implicit from radioactive materials in the environment.

19. Retention and Removal of ^{131}I from Contaminated Vegetables

Abstract: Retention and removal patterns for ^{131}I applied in spray solutions to major vegetable crops were investigated under control plot studies. The experiments were designed to examine situations that might result in the event of accidental radioactive releases from nuclear facilities. Results of these studies indicate that expedient utilization of standard household food preparation procedures can remove 75 to 90 percent of the ^{131}I deposited on the edible portion of many vegetables; thus, it would seem to require extremely high values of ^{131}I contamination before the use of these vegetables would be completely restricted. Other investigators have shown that the removal of ^{90}Sr and ^{137}Cs also takes place through normal food preparations that occur in the home, commercial eating establishments, or in canning factories. Although the magnitude of these reductions are generally smaller than for ^{131}I (averaging less than 50 percent in most cases) they are important factors to consider in reducing radionuclide intake. In addition, such information might permit the use of many food products that otherwise might be destroyed or avoided because of the fear that accompanies any accidental or intentional release of radioactivity.

20. Nuclear Energy Expansion and the Impact of Radioactive Releases

Abstract: A review of the problems associated with energy expansion points to increased use of nuclear generating facilities. In order to gain better public acceptance of this type of electric power generation more emphasis and study must be conducted on the weak links

associated with such nuclear generation. For example, additional studies must be conducted on the environmental impact of large fuel reprocessing facilities, a broader consideration of radioactive releases to the aquatic environment, standardized and regular reporting techniques among operating facilities and a great emphasis upon risk/benefit relationships for nuclear and non-nuclear applications to permit more complete comparative analyses.

B. Modeling and Prediction from Experimental Data

The major objective of research efforts in this category has been to utilize our special capabilities and facilities for the investigation of radioactive contaminants that are most likely to present significant health hazards to man, animals, or the environment. The endpoint of all of this research is to be able to predict within a reasonable degree of certainty the consequences of the release to the environment of given quantities of a radionuclide.

We have never approached this undertaking with the idea that our group alone would be able to make all of the contributions needed to attain this objective for even one radionuclide. Our approach has been to survey the area to determine the needs and then to relate these needs to facilities, time, and personnel available.

Over the years that this contract has been in force, a large amount of information has become available for certain radionuclides. These provided the necessary parts so that prediction procedures were developed that could fit the events that were being followed in the human population. Our particular research emphasis has shifted from a heavy emphasis on radiostrontium metabolism during early years to an emphasis on radioiodine and radiocesium metabolism.

Secretion of radionuclides into milk has been of special interest to us and, in the last few years, we have been working to develop a model that would allow the prediction of the intake commitment from milk of particular radionuclides after release of these to the environment. The following section, extracted from last year's AEC Report from this laboratory, illustrates the approach utilized.

a. Predictive Model for Human Intake Commitment from Milk

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A necessary prerequisite for the development of a nuclear industry is that guidelines, standards, monitoring programs, safety measures, and hazard prediction procedures be available. Our particular effort over the years has been to determine the amounts of radioactive materials that will get into milk. From these data and others available in the literature, we have developed a prediction procedure that will allow a rapid evaluation of the radionuclide commitment of the human population after deposition of radioactive material on pastures.

The basic equation of this prediction model is:

$$C_{(T+d)} = M_{(T)} v e^{-\lambda(T-d)} \quad (1)$$

T = time in days of milk secretion after the start of deposition on pasture.

d = days from secretion of a particular milk sample until its consumption by the human population.

$C_{(T+d)}$ = amount of radionuclide consumed by an average human being at time T+d.

$M_{(T)}$ = amount of radionuclide in μCi secreted by the cow into each liter of a particular milk sample on any particular day.

λ = fractional rate of decay for the radionuclide under consideration (day $^{-1}$)

v = number of liters of milk consumed daily by an average member of the population.

The value M_T has the form:

$$M_T = gbI_0 \frac{\theta}{\lambda + v - \theta} e^{-\lambda T} \sum_{i=1}^n \left[a_i \left[\frac{e^{-k_i T} e^{-(\theta-\lambda)T}}{\theta - k_i - \lambda} - \frac{e^{-k_i T} - e^{-vT}}{v - k_i} \right] \right]$$

where

g = square meters of completely grazed pasture necessary to provide the daily nutrient requirement of a cow.

b = biological availability of the radionuclide deposited.

I_0 = amount of a radionuclide available for deposition/sq. meter of pasture.

t = time of consumption of radioactivity by cow after the start of the deposition.

T = time of milk secretion after the start of deposition.

λ = fractional rate of radionuclide decay.

θ = fractional rate of radionuclide deposition.

v = fractional rate of loss of radionuclide from grass due to all processes but radioactive decay.

$$\beta = \frac{0.693}{\theta}$$

$$p = \frac{0.693}{v}$$

M_T = units of radionuclide per liter of milk.

$k_1, k_2, k_3 \dots k_i$ = fractional rate of loss of radionuclide from a biological compartment.

n = number of exponential terms in the general equation.

$a_1, a_2, a_3 \dots a_i$ = fraction of radionuclide in a particular compartment.

This equation is intended to be put to use by developing a series of ratios of the total amount ingested by man to infinite time per unit volume of milk consumed daily divided by the concentration in milk on any particular day. This is expressed as

$$F = \frac{\int_0^{\infty} C_{(T+d)} dt}{C_{(T+d)}} = \frac{\int_0^{\infty} M_{(T)} e^{-\lambda(T+d)} dt}{M_{(T)} e^{-\lambda(T+d)}}$$

Once "F" values have been calculated for a particular radionuclide for given rates of deposition and loss from vegetation all that is needed is to assay a sample of milk for the radionuclide and then to multiply the concentration per liter by the appropriate F value. The figure that results is the radionuclide intake to which an average human would be committed if he continued his normal milk consumption.

From our data and that in the literature, we have been able to derive the equation for the transfer of a single dose of either radioiodine, radiostrontium, or radiocesium into the milk of cows. These equations are the basis of calculations relating to the transfer of ^{90}Sr , ^{89}Sr , ^{137}Cs , ^{134}Cs , ^{129}I , ^{131}I , ^{133}I , and ^{135}I into the milk of cows after deposition on feedstuffs. We have undertaken the task of compiling tables of F values for these isotopes for periods of up to 50 days after deposition. Other variables are the deposition rate and the halftime on pasture. Table A is a sample page from this write up for ^{133}I . Because of the short half life of this radionuclide (20.8 hr) it is unnecessary to extend the tables beyond 10 days after deposition. The deposition halftime is listed as 0.0 (upper right hand corner of the page) and indicates that the deposition is so rapid as to be considered instantaneous. Table B is the situation where this deposition half time is 0.31 days. The values heading the columns across the page are the half-times of the radioiodine on pasture. Note that this half-time value does not include radioactive decay--the F value takes that into account.

DEPOSITION T-1/2 = 9.00

TABLE A F VALUES

DAYS	HALF-TIME OF PASTURE LOSS IN DAYS								
	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0
1	2.4 (-)	2.5 (-)	2.5 (-)	2.5 (-)	2.5 (-)	2.5 (-)	2.6 (-)	2.6 (-)	2.6 (-)
2	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)	3.5 (-)
3	7.3 (0.2)	7.0 (0.2)	6.9 (0.2)	6.9 (0.2)	6.8 (0.2)	6.8 (0.2)	6.8 (0.2)	6.7 (0.2)	6.7 (0.2)
4	16.8 (0.7)	15.7 (0.6)	15.2 (0.6)	14.9 (0.6)	14.7 (0.6)	14.5 (0.6)	14.4 (0.5)	14.3 (0.5)	14.2 (0.5)
5	40.8 (2.2)	36.7 (1.8)	34.8 (1.7)	33.7 (1.6)	33.0 (1.5)	32.5 (1.5)	32.2 (1.5)	31.7 (1.4)	31.3 (1.4)
6	102. (6.)	88.1 (5.0)	81.9 (4.4)	78.3 (4.1)	76.1 (4.0)	74.5 (3.8)	73.3 (3.7)	71.7 (3.6)	70.7 (3.5)
7	258. (17.)	214. (13.)	195. (11.)	184. (11.)	177. (10.)	172. (10.)	169. (9.)	164. (9.)	161. (9.)
8	656. (47.)	523. (34.)	466. (29.)	435. (26.)	415. (25.)	402. (23.)	392. (23.)	378. (22.)	370. (21.)
9	1680. (130.)	1283. (87.)	1119. (72.)	1031. (65.)	976. (60.)	938. (57.)	911. (55.)	874. (52.)	850. (50.)
10	4300. (330.)	3150. (220.)	2690. (180.)	2450. (160.)	2300. (150.)	2200. (140.)	2120. (130.)	2020. (120.)	1960. (120.)

DEPOSITION T-1/2 = 0.31

TABLE B F VALUES

DAYS	HALF-TIME OF PASTURE LOSS IN DAYS								
	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0
1	3.3 (0.1)	3.4 (0.1)	3.5 (0.1)	3.5 (0.1)	3.5 (0.1)	3.6 (0.1)	3.6 (0.1)	3.6 (0.1)	3.6 (0.1)
2	3.0 (-)	3.0 (-)	3.0 (-)	3.0 (-)	3.1 (-)	3.1 (-)	3.1 (-)	3.1 (-)	3.1 (-)
3	5.1 (0.1)	5.0 (-)	5.0 (-)	5.0 (-)	4.9 (-)	4.9 (-)	4.9 (-)	4.9 (-)	4.9 (-)
4	10.7 (0.4)	10.3 (0.3)	10.0 (0.3)	9.9 (0.3)	9.8 (0.3)	9.7 (0.3)	9.7 (0.3)	9.6 (0.3)	9.6 (0.3)
5	24.9 (1.2)	23.0 (1.0)	22.1 (0.9)	21.6 (0.9)	21.2 (0.9)	21.0 (0.8)	20.8 (0.8)	20.6 (0.8)	20.4 (0.8)
6	60.6 (3.4)	53.9 (2.8)	50.9 (2.5)	49.1 (2.4)	47.9 (2.3)	47.1 (2.2)	46.5 (2.2)	45.7 (2.1)	45.2 (2.1)
7	151. (9.)	129. (7.)	120. (7.)	114. (6.)	110. (6.)	108. (6.)	106. (6.)	104. (5.)	102. (5.)
8	382. (26.)	314. (20.)	285. (17.)	268. (16.)	257. (15.)	250. (14.)	245. (14.)	237. (13.)	233. (13.)
9	975. (70.)	768. (50.)	681. (43.)	633. (39.)	603. (36.)	583. (34.)	568. (33.)	547. (31.)	534. (30.)
10	2490. (190.)	1890. (130.)	1640. (110.)	1502. (95.)	1419. (88.)	1362. (83.)	1320. (80.)	1264. (75.)	1228. (72.)

Pasture halftimes need to be determined experimentally.

As an example, suppose that the milk sample collected from a milk receiving plant gave a reading of 100 pCi of ^{133}I /liter of milk at 48 hours after deposition. If the pasture halftime is estimated at 15 days the appropriate F value is 3.5. The intake commitment of an average human consuming 1 liter of this milk per day is $3.5 \times 1000 = 3500$ pCi. The figure in the bracket is the 95% confidence interval for the F value. In this case it was too small to be accurately computed. Note that the values for ^{133}I intake commitment do not take into account delay between measuring the activity in milk and consumption of the milk. Any delay would markedly reduce the potential uptake. This will be dealt with in the full writeup.

Table C presents data useful for predicting the affects of counter-measures against ^{133}I . If a 50% reduction is desired and the pasture loss halftime is 15 days it would be necessary to stop consumption of milk within 1.6 days of the start of grazing of contaminated pastures by cattle or order the removal of all cattle from pastures to barn feeding within 19 hours after deposition of the ^{133}I .

Similar tables have been prepared for all radionuclides listed previously. Since this is a lengthy compilation it will not be included here. It is intended to publish this in the form of a T.I.D. document to make it available to interested health physicists. At this moment, the writeup is not yet complete; in addition, some consideration is being given to including data for lactating goats using the same procedures as used for cattle.

In addition to developing a compendium of F values, our work in

the past three years has included the estimation of the error associated with among-cow variation. These values appear in the brackets in the tables and are intended to give an indication of the reliability of the estimates given by the use of the F value. Note that this is the error associated with the cow and doesn't include sampling errors and errors associated with measurement of deposition rate or pasture halftimes.

As an example of the error calculations we will discuss briefly how the values were computed for cesium.

The data for each animal were handled separately to obtain the equation for the milk transfer function using a least squares curve fitting program. The transfer function for each individual cow was incorporated into equation 1 and the F values obtained for the period 0 to 50 days after the start of ingestion of radioactivity. The F values of all 18 cows for particular days were statistically analyzed to obtain the mean F value, the standard error (S.E.), the 95% confidence interval (C.I.) and the percent relative standard error (% R.S.E.). For the calculations of F it was necessary to assign values for β and ρ and then to make arbitrary over- and underestimates of these values of ρ and β . These F values provide some insight to the bounds within which F is likely to fall under various efficiencies of measuring ρ or β and the significance of the cow variance to the overall error.

The calculated mean F values for ^{137}Cs are presented in Table D under conditions where the deposition time (β) has been so short as to be considered instantaneous and the pasture loss half-time (ρ) to be 15 days. The calculated values cover a period of 50 days although for practical purposes only the F values for the first 20 days would be useful.

DEPOSITION T-1/2 = 0.20

TABLE C MAXIMUM INITIATION TIME FOR COUNTERMEASURES (DAYS)

COUNTERMEASURE - STOP DRINKING MILK

PERCENT REDUCTION	HALF-TIME OF PASTURE LOSS IN DAYS								
	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0
99	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
98	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
96	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
93	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
90	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6
85	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
80	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
70	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
60	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4
50	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
40	1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0
30	2.2	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.4
20	2.7	2.8	2.8	2.8	2.9	2.9	2.9	2.9	2.9
10	3.5	3.6	3.7	3.7	3.7	3.8	3.8	3.8	3.8

COUNTERMEASURE - REMOVE COWS FROM CONTAMINATED PASTURE

PERCENT REDUCTION	HALF-TIME OF PASTURE LOSS IN DAYS								
	5.0	7.5	10.0	12.5	15.0	17.5	20.0	25.0	30.0
90	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
85	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
80	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
70	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
60	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6
50	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8
40	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
30	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4
20	1.6	1.7	1.8	1.8	1.8	1.8	1.8	1.9	1.9
10	2.4	2.5	2.5	2.6	2.6	2.6	2.6	2.7	2.7

Included in Table D are the standard errors and the 95% confidence intervals of the mean F values. Both of these parameters are small in comparison to the F values; the S.E. is only 7 to 8% of the F value at day 1 and less than 0.7% of the minimum F value. The confidence intervals reflect these standard errors and show that only 5% of the time would the day 1 F value for ^{137}Cs fall outside the limits of 132 and 176 for "instantaneous" deposition and 3103 and 4429 when $\beta = 5$. At the time of the minimum F value the C.I. ranges from 36.4 to 37.6 and 46.5 to 46.9 for the short and long deposition times, respectively.

Figure A is a plot of the % RSE versus days after the start of the ingestion of radioactivity by the cow. The % RSE is the standard error of an F value times 100 divided by the mean F value. For Figure A the representation is for situations where $\beta \approx 0$ and ranges from 5 to 25 days. It can be seen that the % RSE falls off rapidly at first, reaches a minimum and then begins to increase. The initial rate of fall is about the same for all curves regardless of the value of ρ , however, the smaller the value of ρ the sooner a minimum % RSE is reached and passes.

Overall, this figure shows that when F is the basis of the predictive model the error due to cattle will initially be a small fraction of the mean F and that this error contribution will decrease rapidly during the first 10 days after the start of ingestion of radioactivity by the cow.

In addition to the milk secretion function our equation requires estimates of ρ and β . The literature does not provide estimates of the error associated with the measurement of ρ or β or how the error is

Table. D Mean "F"₁₃₇ Values, Standard Errors and 95% Confidence Intervals for Conditions of Instantaneous Deposition Pasture Half Time of 15 Days.

Deposition T _{1/2} (β) "Instantaneous"		15 Days		
Pasture T _{1/2} (ρ)	Day	Mean "F"	Std. Error	95% C. I.
	1.	154.3 ±	10.50 ±	22.16
	2.	62.0 ±	2.70 ±	5.70
	3.	46.2 ±	1.24 ±	2.61
	4.	40.7 ±	0.70 ±	1.49
	5.	38.3 ±	0.46 ±	0.98
	6.	37.3 ±	0.34 ±	0.72
	7.	37.0 ±	0.27 ±	0.58
	8.	37.1 ±	0.23 ±	0.49
	9.	37.6 ±	0.20 ±	0.42
	10.	38.2 ±	0.18 ±	0.37
	11.	39.0 ±	0.16 ±	0.33
	12.	40.0 ±	0.14 ±	0.30
	14.	42.2 ±	0.11 ±	0.24
	16.	44.8 ±	0.10 ±	0.21
	18.	47.8 ±	0.09 ±	0.19
	20.	51.1 ±	0.10 ±	0.20
	25.	60.7 ±	0.15 ±	0.33
	30.	72.4 ±	0.26 ±	0.54
	40.	104.0 ±	0.59 ±	1.24
	50.	149.6 ±	1.13 ±	2.39

Figure A. The change in the % R.S.E. of F values with time after the start of ingestion of radiocesium by dairy cows. The situation portrayed is for rapid deposition and pasture loss halftimes of 5, 10, 15, 20 and 25 days.

Figure B. The assumed true value of F when $\beta \approx 0$ and $\rho = 15$. The shaded portions indicate the 95% C.I. of F due to cow variation while the fine dashed lines indicate the bounds of F when ρ varies from the mean 15 day value by ± 1 and ± 3 days.

likely to change with time. Therefore, in order to determine how the F values would respond to various errors we have assumed true values for ρ and β with fixed over- and underestimates of these values. For one instance we have assumed $\beta \cong 0$ with no error and that $\rho = 15$ with over- and underestimates of 1 and 3 days; also included is the C.I. of the milk transfer function. The data for these calculations are shown in Figure B; the curves represent the maximum deviation of F from the assumed true value of F under the stated conditions.

At day 1 with $\rho = 15 \pm 1$ day F could fall somewhere between 122 and 188; this is a maximum deviation from the true value of F of about 21%. From the figure it can be deduced that about two-thirds of this range will be attributable to the differences among cows. If $\rho = 15 \pm 3$ days F will likely be estimated within the bounds of 106 to 211, resulting in a maximum deviation in the estimate of radionuclide likely to be ingested by the human population of about 34%. About 40% of this range could be attributed to cattle. At 7 days after the start of ingestion of radioactivity by cows estimates of F could range from 34.5 to 39.5 and from 30.6 to 43.5 with a maximum deviation from the true F estimate of 7 and 18%, respectively, for the situation of $\rho = 15 \pm 1$ or 15 ± 3 days. In the same order the cow contribution to the deviation will be about 20 and 8%.

This figure suggests that the use of F can provide reasonable estimates of the intake commitments of the human population. These estimates are more precise as the time after the start of ingestion of radioactivity by dairy cattle increases, nevertheless, the day 1 estimates can be of value in determining if a particular contaminating event may

warrant the institution of remedial measures. Since the average time between production of milk and its consumption by city dwellers is about three days in the United States, adequate time is available for health authorities to closely assess a situation that at day 1 indicates that protective measures might be needed.

Lengemann, F. W., Consumption of Radionuclides from Milk by Man After Radionuclide Contamination of Pastures: A Predictive Model. Zentralblatt für Veterinärmedizin Beiheft 11: 77-87 (1970).

Lengemann, F. W. and R. A. Wentworth, A Predictive Model for Radiocesium Intake from Milk: Errors Associated with Among-Cow Variation. Health Physics 22: 135-141 (1972).

b. Effect of Countermeasures on Predicted Human Intake Commitment of Radionuclides from Milk.

Summary: The effectiveness of taking contaminated milk out of the food chain or of removing contaminated feed from the ration of cattle at various time periods after a contaminating event in reducing human intake of radioisotopes of Sr, I and Cs has been calculated. In addition, experiments involving the feeding of dietary supplements to livestock have been conducted to test the effectiveness of such countermeasures. Stable I and Ca, perchlorate, ferric ferrocyanide, sodium alginates, anion exchange resins, and other materials have been found to alter levels of I, Cs and Sr in milk to varying degrees.

II. Current Activities

Major emphasis of work underway is of an assessment nature relating to the environmental effects of continued nuclear power expansion. Particular concern is being devoted toward the emerging concepts of nuclear energy parks and their areas of influence.

Serious concern over the safety of such plants is felt both by the public and among some scientists. Of major concern are the releases of radioactivity to the environment not only through routine losses but also through a variety of possible accidental conditions, including a catastrophic accident resulting in the loss of containment. Because of human safety considerations, these plants are normally placed in areas of low population density which are often agricultural in nature. It appears important, therefore, to calculate the magnitude of the agricultural economic loss as well as the intake commitments of radionuclides for people consuming products from affected areas following various degrees of radionuclide releases.

In the initial considerations of this study, New York State is being used as a model inasmuch as: (a) this state has a contiguous electric power generating pool, (b) numerous nuclear power generating reactors of various types and sizes are in operation, under construction, or in planning stages, (c) a nuclear fuel reprocessing plant is located in the western part of the state and (d) the state is one of the major dairy, fruit, and vegetable growing areas of the country.

Toward this end, agricultural data have been assembled which conform to the major land form regions in New York State (Figure 1) and which are located within or adjacent to existing or projected nuclear facilities.

Land Form Regions in New York State

Figure 1.

At the present time, the New York Power Pool has four nuclear generating units and a reprocessing facility that are approved for operation:

<u>Unit</u>	<u>Type</u>	<u>Location</u>	<u>Size (MW)</u>
Indian Point #1	PWR	Hudson Valley	262
Indian Point #2	PWR	Hudson Valley	873
Ginna #1	PWR	Lake Ontario	490
Nine Mile Point #1	BWR	Lake Ontario	610
Nuclear Fuel Services	Reprocessing	Western Plateau	---

Two other units (Fitzpatrick and Indian Point #3) should be operational within the next year, with plans for 14 additional units to be operative by 1990 (1). Three of these units (Nine Mile Point #2, Jamesport 1 and Somerset 1) are in accelerated planning stages at the present time and are scheduled to become operational prior to 1983. When all of these units are completed and operating, the geographical distribution throughout the agricultural regions of New York State will be as follows:

<u>Region</u>	<u>Units</u>	<u>MW</u>	<u>Area Characteristics</u>
Lake Ontario	7	6579	Agricultural (Fruit, Dairy)
Catskill-Hudson	7	7528	Agricultural (Poultry) and Suburban
Long Island	5	5720	Agricultural (Potatoes, Vegetables, Ducks), and Suburban
North Country (St. Lawrence)	1	1300	Agricultural (Dairy)
Not Specified-PASNY	1	1200	
Totals	21	22327	

As indicated by the groupings, it is becoming common practice to utilize multiple units per site, and in the case of Nine Mile Point and Fitzpatrick units, the sites are contiguous. Thus, the concept of Nuclear Energy Centers seems to be evolving in the New York Power Pool.

The location of these facilities in regions noted for agricultural output emphasizes the need for complete impact assessments to evaluate the effects on food production, marketing and consumption patterns. For example, the Erie-Ontario region accounts for about one-fourth of the revenue derived from crops in New York State (2, 3). The area is an extensive fruit and vegetable growing region and is also a preferred area for electric generating facilities of all types, especially nuclear. A similar situation exists on Long Island where about one-fifth of New York farm crop revenues originate, primarily from intensive truck farming operations. Thus, two of the preferred nuclear site regions are located in areas near intensive agricultural operations which produce over 40 percent of New York State field and truck crop revenues. The relative agricultural importance of the sites that correspond with favored nuclear siting areas is shown in Table 1 (Tables 2 and 3 show the relative importance of the major fruits and vegetables grown in New York State).

Table 1. New York State Agricultural Output for Regions in the Vicinity of Operating and Proposed Nuclear Facilities 2, 3

<u>Region</u>	<u>New York State Farm Revenue</u>		
	<u>All Farm Products</u>	<u>Livestock and Livestock Products</u>	<u>Field and Truck Crops</u>
	(percent of total)		
Erie-Ontario-Oneida Plain	11	5	26
Catskill-Hudson Foothills and Basin	16	19	11
Long Island	8	3	20
North Country (St. Lawrence)	7	9	3
Western Plateau	8	9	5
Totals	50	45	65

Table 2. Production Ranking and Economic Valuation - New York State
Fruit Production - Agricultural Statistics, 1973

<u>Processing</u>	<u>% of Total N.Y. Crop</u>	<u>N.Y. Rank</u>	<u>Economic Value - 1972 (million dollars)</u>
Apples	60	2nd	\$26.6
Grapes	95+	2nd	18.0
Cherries (Tart)	95+	2nd	2.3
Pears	40	5th	.9
Total Processing Value			\$47.8
<u>Fresh</u>			
Apples	40	2nd	17.8
Grapes	3	9th	.6
Cherries (Sweet)	75+	5th	.9
Pears	60	5th	1.3
Strawberries	90	11th	.8
Peaches	90+	14th	1.2
Total Fresh Market Value			\$22.6

Table 3.. Production Ranking and Economic Valuation - New York State
Vegetable Production - Agricultural Statistics, 1973

<u>Processing Market</u>	<u>% of Total Crop</u>	<u>N.Y. Rank</u>	<u>Economic Value - 1972</u> (million dollars)
Potatoes	40	8th	\$ 9.3
Dry Beans	100	10th	4.3
Snap Beans	86	3rd	7.2
Sweet Corn	60	7th	2.2 E
Cabbage	30	1st	1.5
Tomatoes	34	11th	1.3
Green Peas	100	--	1.1
Red Beets	100	2nd	.8
Total Processing			\$ 27.4
<u>Fresh Market</u>			
Potatoes	60	8th	19.4
Sweet Corn	40	3rd	5.8
Onions	100	4th	15.9
Cabbage	70	3rd	9.4
Lettuce	100	7th	2.2
Cucumbers	100	8th	1.9
Carrots	95+	9th	2.3
Tomatoes	66	12th	3.4
Celery	100	4th	2.5
Cantaloupes	100	10th	.8
Snap Beans	14	3rd	3.8
Cauliflower	100	2nd	2.2
Green Peppers	100	10th	.6
Total Fresh Market			\$ 70.2

About half of the annual farm products revenue in New York State can be considered to be in the general vicinity of operating or planned nuclear facilities (reactors and reprocessing units). The economic significance of agricultural production from these areas ranges from 400 to 500 million dollars (1964 dollars converted to 1973 via wholesale farm products index).

Within these areas are located over 22,000 commercial farms, whose average per farm total investment values range from \$75,000 to more than \$400,000. In terms of statewide totals, the five areas represent 47 percent of all commercial farms and about 57 percent of total commercial farm investment values. Thus, any disruption of normal farming operations due to accidental releases of radioactivity could produce significant financial and marketing problems in addition to the recognized public health implications of such releases.

Detailed breakdowns of agricultural productivity for each of the land regions in nuclear development areas have been completed so that full impact criteria could be evaluated if accidental releases occur. Table 4 shows the summaries consolidated for land farm regions for the major product crops identified in Census of Agriculture surveys. It is obvious that these regions represent about three-fourths of New York agricultural productivity and warrant special concern if public receptivity to nuclear power is to be of a positive nature.

Some special product concentration areas are shown in Table 5-9. It is evident that detailed pre-planning is required if agricultural productivity is to be maintained in the event of emergency conditions.

The evidence for agricultural impact assessments to provide a basis for action planning seems obvious and is the basis for new research proposed in the coming years.

Table 4. Agricultural Production Summaries for Regions in the Vicinity of
Nuclear Facilities in New York State⁴

<u>Regions</u>	<u>Class 1-5 Farm Totals</u>					
	<u>Livestock</u>		<u>Fruit</u>		<u>Vegetables</u>	
	<u>Units</u>	<u>% of State</u>	<u>Acres</u>	<u>% of State</u>	<u>Acres</u>	<u>% of State</u>
Erie-Ontario- Oneida Plain	374219	22.2	74132	56.6	95284	51.7
Catskill-Hudson Foothills & Basin	177759	10.5	29646	22.2	40275	21.8
Western Plateau	277594	16.4	1146	0.9	4060	2.2
North Country	235309	13.9	2333	1.8	2383	1.3
Long Island	1858	0.1	514	0.4	4081	2.2
Totals	1,066739	63.1	107771	81.9	146083	79.2

Table 5. Agricultural Product Concentration in New York State in
Erie-Ontario-Oneida Plain

<u>Crops</u>	<u>Percent of State Totals</u>
Cherries	75.7
Snap Beans	74.0
Plums and Prunes	68.1
Tomatoes	65.8
Cucumbers	60.5
Peaches	60.0
Grapes	59.7
Cabbage	59.5
Cantaloupes	58.5
Watermelons	58.5
Pears	55.5
Apples	50.8
Carrots	50.7
Asparagus	44.8
Onions	41.9
Sweet Corn	38.5
Celery	38.2
Strawberries	37.4
Lettuce	36.8
Peas	32.5
Beets	31.2
<u>Livestock</u>	
Dairy Cows	21.2
Other Cattle	23.0

Table 6. Agricultural Product Concentration in New York State in
Catskill-Hudson Foothills and Basin.

<u>Crops</u>	<u>Percent of State Totals</u>
Celery	53.9
Onions	50.5
Lettuce	42.0
Pears	33.3
Apples	31.7
Plums and Prunes	26.2
Watermelons	22.0
Sweet Corn	20.4
Peaches	18.5
Asparagus	14.5
Tomatoes	8.7
<u>Livestock</u>	
Dairy Cows	10.3
Other Cattle	11.2

Table 7. Agricultural Product Concentration in New York State in
Western Plateau

<u>Crops</u>	<u>Percent of State Totals</u>
Tomatoes	24.3
Snap Beans	23.6
Raspberries	21.0
Stawberries	17.5
Dry Onions	17.4
Sweet Corn	14.1
Potatoes	10.2
Cauliflower	10.0
<u>Livestock</u>	
Dairy Cows	15.8
Other cattle	16.5

Table 8. Agricultural Product Concentration in New York State in
North Country

<u>Crops</u>	<u>Percent of State Totals</u>
Apples	3.0
Potatoes	3.0
<u>Livestock</u>	
Dairy Cows	14.9
Other Cattle	13.9

Table 9. Agricultural Product Concentration in New York State on
Long Island

<u>Crops</u>	<u>Percent of State Totals</u>
Cauliflower	51.4
Potatoes	50.9
Watermelon	29.3
Strawberries	18.4
Peaches	10.2
Cucumbers	10.2
Cabbage	9.9
Lettuce	8.3
Tomatoes	6.2
Asparagus	5.5
<u>Livestock</u>	
Dairy Cows	.1
Other Cattle	.1

Other emphasis must be devoted toward specific "situation analyses" regarding radionuclides in the environment. Such an appraisal is included as an example of the continuing capability provided by this Department over the years. The question posed was one dealing with the significance of the various radionuclides of strontium and lanthanum that might be absorbed by humans if pastures were contaminated from nuclear power plant emissions. Drawing on past research data from this laboratory and elsewhere, we arrived at the following estimates.

Transfer functions for the estimation of levels of radioisotopes of Sr and La absorbed by humans via the milk route have been calculated. The starting point of these calculations was the contamination level of pasture (Activity/m²). For a single deposition condition this is the initial level of activity on the grass before decay on grass or weathering has taken place and is symbolized as A⁰. Such transfer function may be calculated as the product of eight factors.

$$TF_{\text{Pasture-man}} = F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot F_5 \cdot F_6 \cdot F_7 \cdot F_8$$

where Activity absorbed = $TF_{\text{pasture-man}} \cdot A^0$

and

A⁰ = Initial activity on grass (μCi/m)

F₁ = Cow pasture utilized area factor (m² /day)

F₂ - Pasture weathering factors (days)

F₃ = Radionuclide decay on pasture

F₄ = Fraction of Sr and La consumed by cow transferred to milk (days · L⁻¹)

F₅ = Radionuclide decay while in cow

F₆ = Radionuclide decay in milk prior to consumption

F₇ = Consumption rate of Milk (L · days⁻¹)

F₈ = Fraction of radionuclide absorbed by human

These factors are discussed in greater detail below. For the case of a single deposition of isotopes of Sr and La values, the following table might be used. Note that many of these values are not constants and may be different under varying conditions so that the final transfer functions are not fixed.

Factors Involved in TF pasture-man

Value of factor for:					
Factor	⁹⁰ Sr	⁸⁹ Sr	⁹¹ Sr	¹⁴¹ La	Reference and Notes
F ₁	.45	.45	.45	.45	Ref. 5
F ₂	20.2	20.2	20.2	20.2	Assumes 14 day pasture t _{1/2}
F ₃	.9986	.791	.0280	.0115	Assumes 14 day pasture t _{1/2}
F ₄	.00073	.00073	.00073	<.0001	See below
F ₅	.9992	.894	.0893	.0077	See below
F ₆	.9998	.961	.00574	2.78x10 ⁻⁶	Assumes 3 day transit time
F ₇	1	1	1	1	Assumes 1 L./day milk consumed
F ₈	.19	.19	.19	<.02	Adult (Ref. 6)
TF grass-milk-human	.126*	.0857*	1.8x10 ⁻⁶ *	4.5x10 ⁻¹³	

If one wishes to be very conservative in estimates of F₆ and F₈ :

F	1	1	1	1	Milk consumed immediately after production
F	.61	.61	.61	<.06	Infant (Ref. 7)

TF becomes .404* .286* 1.01x10⁻³* 4.8x10⁻⁷*

* Units of: Ci absorbed/(Ci/m² on pasture)

Now to obtain activity absorbed by human, multiply the "TF" value times " A^0 ". Note that decay between source of activity and time of deposition on grass has not been included and should be calculated when the meteorological considerations are made. These estimates are conservative in that the radionuclides deposited on grass are assumed to be in a 100% available (absorbable) form whereas in actual deposits they will be somewhat less than 100% available.

It turns out that transfer functions worked out in this manner can be used for both the single deposition condition and for the continuous deposition condition. For the single deposition case A^0 is, as stated, the total activity deposited on an area of grass (before decay or weathering) and the product of A^0 and "TF" is in units of total activity absorbed over time by a person due to this deposition. In the case of continuous deposition A^0 may be redefined as the amount of activity deposited per day on a unit area (again before decay and weathering) in which case the product of A^0 and TF is now in units of activity absorbed by a person per day when equilibrium is reached.

Comments on factors used above:

F1 Area grazed by cow will differ with pasture condition and management practices (Ref. 1).

F2 This is the integrated activity level on grass over time where pasture loss is exponential

$$= \frac{t_{1/2}}{.693}$$

F3 Depends on weathering $t_{1/2}$ as well as on physical $t_{1/2}$

$$F2 \cdot F3 = \frac{1}{\frac{.693}{t_{1/2 w}} + \frac{.693}{t_{1/2 p}}} \quad \text{where } t_{1/2 w} \text{ is due to weathering and } t_{1/2 p} \text{ is physical half life.}$$

See Figure 2 for a plot of how F_2 . F_3 changes with these half lives.

- F₄. Based on equation for transfer of Sr to milk (average of data from 39 cow experiments of various research workers - equation by Lengemann and Wentworth).

$$C = .049e^{-.813t} + .0082e^{-.302t} + .00091e^{-.118t} + .00033e^{-.023t} - .05844e^{-1.61t}$$

where C = % dose/liter milk, t = time after single dose minus .27 days

Factor 4 is the integral of this equation

No data was found on the transfer of ingested La to milk or the absorption of La by humans. In some experiments done recently with chicks at the laboratory of Dr. Wasserman and associates, indications were that La absorption was very small - at least an order of magnitude less than Sr (pg. 285, our last AEC Progress Report - May, 1973). F_4 and F_7 would seem to be upper limits with actual values unknown.

- F₅ Calculated by introducing decay into previous equation for Sr.

Lacking such data for La, it was assumed that the shape of such a curve would be similar to that of Sr.

- F₆, F₇, F₈ Typical or literature values for Sr. See note concerning La under F_4 above.

Figure 2. Product of Factors $F_2 \times F_3$ as a Function of Weathering of Radionuclides on Grass

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