Publication No. 05-028-088

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FIPR

Florida Institute of
Phosphate Research

Prepared By

Post, Buckley, Schuh, & Jernigan, Inc.

Under a Grant Sponsored by the
Florida Institute of Phosphate Research
Bartow, Florida

OCTOBER 1990

The Florida Institute of Phosphate Research was created in 1978 by the Florida Legislature (Chapter 378.101, Florida Statutes) and empowered to conduct research supportive to the responsible development of the state's phosphate resources. The Institute has targeted areas of research responsibility. These are: reclamation alternatives in mining and processing, including wetlands reclamation, phosphogypsum storage areas and phosphatic clay containment areas; methods for more efficient, economical and environmentally balanced phosphate recovery and processing; disposal and utilization of phosphatic clay; and environmental effects involving the health and welfare of the people, including those effects related to radiation and water consumption.

FIPR is located in Polk County, in the heart of the central Florida phosphate district. The Institute seeks to serve as an information center on phosphate-related topics and welcomes information requests made in person, by mail, or by telephone.

Research Staff

Executive Director

Richard F. McFarlin

Research Directors

G. Michael Lloyd Jr.	-Chemical Processing
Gordon D. Nifong	-Environmental Services
Steven G. Richardson	-Reclamation
Hassan El-Shall	-Beneficiation
Robert S. Akins	-Mining

Florida Institute of Phosphate Research
1855 West Main Street
Bartow, Florida 33830
(863) 534-7160

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FINAL REPORT

Jerome J. Guidry, P.E., Principal Investigator
Charles E. Roessler, Ph.D. - University of Florida
W. Emmett Bolch, Ph.D. - University of Florida
James T. McClave, Ph.D. - Info-Tech, Inc.
Cindy C. Hewitt - Info-Tech, Inc.
Thomas E. Abel - Zellars-Williams, Inc.

POST, BUCKLEY, SCHUH & JERNIGAN, INC.
6635 East Colonial Drive
Orlando, Florida 32807

Prepared for

FLORIDA INSTITUTE OF PHOSPHATE RESEARCH
1855 West Main Street
Bartow, Florida 33830

Contract Manager: Gordon Nifong, Ph.D.

September 1990

DISCLAIMER

The contents of this report are reproduced herein as received from the contractor.

The opinions, findings and conclusions expressed herein are not necessarily those of the Florida Institute of Phosphate Research nor does mention of company names or products constitute endorsement by the Florida Institute of Phosphate Research.

PERSPECTIVE

Gordon D. Nifong, Ph.D.

Florida Institute of Phosphate Research

It has long been known that elevated levels of uranium occur naturally associated with the sedimentary phosphate deposits found in central Florida. Mainly because of its low solubility, uranium is not generally considered to be a major environmental hazard, but many of the members within the uranium decay series are more of a cause for concern. These would include radium-226, a radioactive element chemically similar to calcium; radon-222, a gas that is chemically inert but radioactive; several "short-lived" daughter products of radon; and finally two longer-lived decay products--lead-210 and polonium-210. All of the above are naturally occurring radioactive materials that are ubiquitous in the environment but tend to be elevated in phosphate-related materials. In general, lands containing waste clays or sand-phosphate "debris" tend to have the highest levels of radiation, followed by lands reclaimed generally with overburden and sand, next followed by mineralized unmined lands, and finally non-mineralized lands.

Since its inception, the Florida Institute of Phosphate Research has been interested in the environmental aspects of the phosphate industry. It is believed that all phases of ore mining, minerals processing, and land reclamation can be accomplished in an environmentally acceptable manner. Because of the array of radionuclides found in phosphate ores, much of that concern for the environment has been focused on the issue of radiation. Well over a dozen projects have been conducted or sponsored that directly address the topic of radiation, and numerous other projects have had radiological components as secondary issues. Strong interest exists not only in characterizing natural radionuclides as to their nature,, extent, and magnitude, but also in determining their effects on the population that lives and works in the phosphate region. The Institute has addressed both concerns.

Because inhalation of radon daughters likely accounts for half or more of human exposure to natural radiation, considerable effort has gone into this area. In 1987 the Institute completed a state-wide study of levels of indoor radon in Florida. Conducted by Geomet Technologies, the study confirmed that while radon was related to the prevalence of phosphate in the ground, levels were generally lower than those found in most other parts of the country. Also, it was determined that radon was not a problem solely on reclaimed lands; homes with elevated radon were found from north Florida to southeast Florida. Other work at about the same time, done by American Atcon Corporation, demonstrated that with little extra effort homes could be built so as to prevent the entry of most radon from the soil into the structure, even if the land were elevated in soil radium content.

Assessing the quality of water has been a goal of several Institute-sponsored studies. In 1981 the Institute sponsored a study by the state Department of Health and Rehabilitative Services to study radiochemical contamination in shallow drinking water wells in the phosphate region. Later this study was expanded to be state-wide in scope. Further water quality studies, done mainly at the University of South Florida and at Florida State University, have looked in detail at the radiological components of groundwater. An important finding has been that much radiation in many well waters in central Florida is due to polonium-210, a finding that helps explain the discrepancy that exists in many waters of high alpha radiation levels but low radium-226 levels.

In order to ensure that its radiation research program is comprehensive, the Institute has devoted much attention to the human food chain. In 1986 a study was completed by Post, Buckley, Schuh & Jernigan entitled "Radioactivity in Foods Grown on Florida Phosphate Lands." Its purpose was to characterize and quantify levels of radionuclides in foods grown on these lands, and to project radiation doses to consumers of these foods. Results found were that radionuclide content of some foods, especially leafy vegetables, were higher if the crop had been grown on reclaimed land versus control or non-mineralized land, but that total quantities of radionuclides were small even under worst case conditions. A typical individual eating foods grown on reclaimed lands would experience at most an increase of a few percent in his total yearly radiation dose from all environmental sources combined, and also total increased intake of radionuclides from these foods would still be only a few percent of the limits suggested by several scientific and regulatory authorities. One anomaly found in this earlier study was that radioactivity in foods did not always correlate with radioactivity in the soils on which the foods were grown. Foods grown on clays produced by phosphate beneficiation had lower levels of radionuclides than did similar foods grown on "debris" lands, even though soil radionuclides were higher in clays than in "debris." Part of the purpose of this current study was to investigate this discrepancy.

From a more general standpoint, however, as phosphate mining moves south within central Florida, reclaimed mined land becomes increasingly available. Agricultural production, either for forage or food production, undoubtedly will become a significant use for reclaimed land. Invariably the question arises as to the radionuclide content of crops grown on such lands, not only in foods grown for direct human consumption, but even in beef when cattle have grazed on forage from these lands. Work is currently in progress by Bromwell and Carrier, Inc., investigating vegetable production on sand/clay mixtures in the phosphate region. An even larger study, entitled "Polk County Mined Lands Agricultural Demonstration Project," and conducted by a consortium of interests under county direction, is now investigating the potential for agriculture on reclaimed clay settling areas. The growing of vegetables, grains, forage, and even ornamentals is under study in this multi-year project. Cattle are included as one component of this work. In both these latter studies, while the prime goal is to determine the feasibility of crop production on the restored land, environmental safety as to radiation is the major adjunct issue.

Another important consideration of the radiological safety of agricultural products is related to the use of phosphogypsum as an agricultural amendment. Phosphogypsum is an excellent source of calcium and sulfur to the soil, but the material contains a level of radium-226 some 20 to 30 times the value of most soils. Studies of this aspect of radionuclide uptake by crops have been done at several universities, the most recent being a current study underway in central Florida and conducted by the University of Florida. Early work has shown that radionuclide uptake by foods grown on lands to which phosphogypsum has been added is minimal, well within established dietary tolerances.

A central theme that runs through all the studies mentioned above is an evaluation of human exposure to radiation dose as contributed by some phase of the natural environment. As far as that dose contributed by foods ingestion is concerned, it seems not to be very cost-effective to re-study radiation every time some new crop is planted on some type of reclaimed land. This current study by Post, Buckley, Schuh & Jernigan represents an attempt to delve more deeply into the mechanisms of radionuclide uptake by crops and use the findings to better assess the contribution of foods to total radiation dose. It complements their earlier study of 1986 by adding significantly to the total database. It is now known that while radium content of soil is important in determining uptake by crops, the greatest variable is the nature of the crop itself. Moreover, a number of other soil parameters affect uptake, notably pH and cation exchange capacity. Perhaps even more important, this work further confirms the belief that ingestion of foods grown on reclaimed lands contributes only a small fraction of total human radiation dose. It is only with the type of information contained in this report that the public can make an informed decision on the impact of radionuclides in foods as compared to other radiological impacts common to our society. This work is most consistent with the societal goal of keeping radiation exposures to "as low as reasonably achievable."

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This study was conducted by a team of professional scientists from four organizations:

- Post, Buckley, Schuh & Jernigan, Inc.
- Zellars-Williams Company
- Info-Tech, Inc.
- University of Florida Department of Environmental Engineering Sciences

The author wishes to express his appreciation to the following persons who contributed to the success of this study: Christopher Amstutz and Cheryl Bledsoe for their analytical laboratory support; Kate Fontaine for her assistance in preparing this report; Tom Abel and Jim Moon for their assistance in the land characterization and field sampling tasks; Dr. Jim McClave and Cindy Hewitt for the statistical analysis tasks; Drs. Charles Roessler and Emmett Bolch for the data evaluation and dose assessment tasks; Brian Birky for his assistance in the development of the diet and dose models; and Dr. Gerald Kidder for his assistance in the evaluation of the soil chemistry data. The organization and coordination of this study which involved several organizations and numerous participants was made that much easier because of the commitment and professionalism of these project participants. Their assistance is thoroughly appreciated.

Jerome J. Guidry, P.E.

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Post, Buckley, Schuh & Jernigan, Inc. (PBS&J) was retained by the Florida Institute of Phosphate Research to study the radioactivity in foods grown on mined phosphate lands in the central Florida phosphate district. This study was a follow-up to a previous study of radioactivity in foods in which over one hundred food samples were collected from sixty two land parcels. While the initial study surveyed radioactivity in foods on a variety of land types including unmined lands and mined lands, this current study concentrated on lands which were reclaimed after phosphate mining. Since lands reclaimed from clay settling areas will constitute the majority of lands to be reclaimed, this current study concentrated mostly on foods grown on reclaimed clay lands.

Approximately seventy individual food samples were collected from five land parcels in the central Florida phosphate district and subjected to radioassay for radium-226, lead-210 and polonium-210. Corresponding soil samples were collected and analyzed for these radionuclides and also for a variety of soil chemistry parameters, The results of the radioactivity and soil chemistry analyses of these samples were integrated into the data base which had been created from the initial study and a variety of statistical analyses were conducted on this integrated data set. The results of these analyses indicated, as in the initial study, that concentrations of radium-226 and lead-210 observed in foods grown on mined phosphate lands were statistically higher than concentrations of these radionuclides exhibited in foods grown on unmined phosphate lands. Concentrations of polonium-210 observed in these foods were found to be extremely low; in fact, a substantial number of the measurements for polonium-210 were below the limit of detection of the analytical methodology.

Although the radioactivity concentrations measured in foods grown on mined phosphate lands were found to be statistically higher than in foods grown on other lands, the radiation dose to the consumers of these foods was found to be only a small fraction of the dose received by an average individual from other environmental sources of radioactivity. The study evaluated the dose to a hypothetical person who obtains all of the foods sampled in this study from reclaimed clay lands and the remainder of his diet from the general food pool. This person is estimated to receive 19.1 mrem per year in committed effective dose equivalent from the ingestion of the radionuclides reported in this study, This is only 2.7 mrem per year more than the estimated radiation dose to a similar individual who obtains all of his foods from lands unaffected by phosphate deposits or phosphate mining. Both of these dose levels are quite low and are not considered to be a health hazard.

INTRODUCTION

In 1986, a research team headed by Post, Buckley, Schuh & Jernigan, Inc. (PBS&J) under the sponsorship of the Florida Institute of Phosphate Research (FIPR) completed a study entitled "Radioactivity in Foods Grown on Florida Phosphate Lands." In this study, radioactivity concentrations measured in foods grown on mined phosphate lands were found to be higher than radioactivity concentrations measured in similar foods grown on unmined lands (Guidry, et. al., 1986). The radiation doses from these enhanced radioactivity levels were, however, estimated to be small. In this study, it was observed that on one of the land types studied, debris land, radioactivity concentrations were measured which suggest substantial uptake of radioactivity in foods. (Debris lands are those upon which the -14 mesh phosphate ore fraction has been disposed.) This study is a follow-up to the previous study of radioactivity in foods.

The single highest radium-226 concentration measured in the initial study was for spinach sampled on a parcel of debris land. Other food samples collected from this debris parcel also exhibited relatively high concentrations of radium-226 and other radionuclides. The foods from this parcel appeared to concentrate radioactivity significantly more than foods grown on the clay settling area sampled, despite the significantly higher soil radioactivity observed on the clay settling area. This suggests the possibility that other factors not measured in the debris land soil could contribute to the uptake observed.

The initial study also found no significant difference between foods grown on the clay settling area sampled and other mined parcels, despite the substantial difference in soil radium concentrations between these land types. Other studies of plant uptake on clay settling areas (Roessler, et. al., 1986) also indicate that radium uptake is not in proportion to the elevated soil radium on these lands. Since clay settling areas will account for substantial acreages in future reclaimed lands, and since sand-clay mixes are gaining acceptance as a reclamation technique, radioactivity uptake mechanisms on these lands is a source of public concern.

The observations noted suggest that relatively smaller quantities of radium are taken up from these higher radioactivity clays, even though more radium is present in the soil. The chemistry of the clays may, in fact, inhibit plant uptake. If this hypothesis can be substantiated, and if the same effect can be demonstrated for other radionuclides, the potential for agricultural use of these lands would be substantially enhanced.

It should be noted that few debris parcels exist, and no new debris lands are going to be created. The purpose of this study is not to study foods grown on debris lands per se, but to study the mechanisms by which radioactivity is taken up into the foods being grown on all lands. The debris lands and the clay settling areas are of particular interest in this current study, since: (1) both of these land types contain elevated radioactivity concentrations; (2) the foods to be collected on these lands are likely to contain more detectable levels of natural radioactivity than foods grown on low radioactivity soils; and (3) the higher concentrations that are expected will allow for more meaningful and more powerful statistical analyses of the data.

The initial study concentrated on evaluating radium-226 and isotopes of uranium and thorium as potential radiation dose contributors. To a lesser extent, lead-210 and polonium-210 were also studied. The study confirmed that radium-226 contributes a substantial fraction of the radiation dose received via consumption of the foods studied. This is consistent with previous findings from other studies. It was further determined that the uranium and thorium isotopes also contributed, but to a lesser degree.

While the lead and polonium results in the initial study were inconclusive, the limited data and the literature (Eisenbud, 1973; Hill, 1962; Napier, 1980; Pennington, 1983; UNSCEAR, 1977) suggest that these radionuclides can contribute substantially to the radiation dose from food consumption. Therefore, this study includes lead and polonium analyses.

The current study was conducted as a follow-up to augment the initial study's data and analysis. Since the radiation dose estimated from the consumption of foods grown on the lands evaluated in the initial study was low, this study did not duplicate any of the evaluations conducted in the first study. This second study did, however, use the same sampling, analysis, and evaluation methodologies, so that the data generated and the evaluations conducted could be integrated with the initial study, thereby producing a more sound basis for the conclusions reached.

OBJECTIVES

The objectives of the current study were to:

1. Identify debris parcels and reclaimed clay settling areas in the central Florida phosphate district on which goods were being grown, or on which food crops could be planted.

2. Obtain foods from these lands and submit them for radioassay for radium-226, lead-210, and polonium-210.

3. Evaluate the food:soil radioactivity ratios and the relationship of some soil chemical properties to these ratios.

4. Evaluate the radionuclide uptake by plants grown on phosphatic clays as it relates to soil concentrations.

5. Estimate the radiation dose to the affected population from the consumption of these foods.

6. Integrate these data with the data base developed in the initial study and determine the effect (if any) on the conclusions reached by the initial study.

DISCUSSION

Foods targeted for the current study included leafy vegetables, root crops, and legumes (peas and beans), since these foods exhibited the highest concentrations in the initial study. Of particular interest are the leafy vegetables, since these foods have been shown to be key indicators of radioactivity uptake.

The selection of radionuclides is based on the findings of the initial study. Radium-226 was shown to be a key contributor *to* the radiation dose, both from the concentrations measured and the dose conversion factors for radium-226. The uranium and thorium isotopes were found to contribute substantially less to the overall dose and, therefore, are not included here, Lead-210 and polonium-210 were considered in the initial study; but the cost for these analyses prohibited analysis of all samples. Some samples were assayed, but without definitive conclusions. These two radionuclides have been added to the current study.

In addition to the foods targeted for study, soil samples were collected from each of the sampled parcels and analyzed for the radionuclides discussed above, as well as for pH, cation exchange capacity and several other soil chemistry parameters. These additional parameters are reported to be factors in radioactivity uptake (Kangas, 1979). Samples of irrigation water, fertilizer, soil amendments, and other potential contributors to soil radioactivity were also sampled, assayed, and integrated into the study's data base. In addition, selected soil samples from the initial study were assayed for cation-exchange capacity and lead-210, since these samples were available without sampling cost.

At the time of this study, two other studies which relate to food production on phosphate lands were being conducted:

- Polk County Mined Land Agricultural Research Project
- Vegetable Production Potential of Selected Mixtures of Waste Phosphatic Clay and Tailings Sand.

Many of the samples which were collected for this study were obtained from those two on-going FIPR-sponsored projects, and the authors wish to acknowledge their cooperation.

LITERATURE REVIEW

Prior to commencement of the initial study of radioactivity in foods in 1983, most of the studies which addressed human exposure to phosphate-related radioactivity focused on exposures to industry personnel and to people residing in homes built on reclaimed phosphate lands (Bolch, et. al., 1977; Guimond, et. al., 1979; Kaufman, et. al., 1977; Kirchmann, et. al., 1980; Lindeken, et. al., 1977; Menzel, 1968; Roessler, et. al., 1980; USEPA, Reconnaissance, 1973). At that point, very little information had been developed to evaluate the impact of phosphate related radioactivity on human exposures through the food chain (Kangas, 1979; Witherspoon, 1982). Since 1983, a number of studies have been completed and several are currently underway which address the potential of radiation exposure to natural members of the uranium and thorium radioactivity series through the food chain. Because of the nature of reclaimed soil materials and the location of most of the reclaimed phosphate lands, agriculture is likely to be a major use for reclaimed phosphate lands.

TRANSFER OF RADIUM FROM SOIL TO PLANTS

Radioactivity uptake from soil is influenced by plant species; by soil factors such as type, pH, content of other alkaline earth elements, clay content, and exchangeable calcium and potassium; and by the chemical form of the radium (McDowell-Boyer, et al., 1979; Watson, et al., 1983). The transfer of a radionuclide from soil to a plant tissue of interest may be described in terms of the "concentration ratio" (CR), the unitless ratio of the activity concentration in the dry plant matter to the activity concentration in dry soil. Alternatively, this is called the "soil-to-plant transfer factor" when the concentration in the plant is expressed on a fresh weight basis (Till and Meyer, 1983). The radioactivity concentration on a dry weight basis is the most reproducible quantity; the concentration on a fresh weight basis enters directly into diet models; the two are interrelated by the moisture content.

It is often assumed that there is a linear relationship between radionuclide concentration of a given part of a specific plant type and the concentration of that radionuclide in the soil. Report 77 of the National Council on Radiation Protection and Measurements (NCRP) (NCRP, 1984b) quotes a study of 11 types of root and leafy vegetables grown on soil contaminated with uranium tailings in which a linear relationship was observed between radium-226 concentrations in vegetation and soil.

On the other hand, there is evidence that soil factors may significantly affect the transfer factor. Lindekin and Coles (1978) reported a garden experiment involving soils with radium-226 concentrations on the order of 0.5 picocuries per gram (pCi/g). The concentration factors for broccoli and turnips were on the order of 0.056 for a garden with a soil calcium level of 3,100 parts per million (ppm) and only about 0.025 for a garden with a soil calcium level of 5,200 ppm. In other words, the concentration factors were a factor of 2 lower for the soil with the higher calcium level.

The preliminary results of another study (Roessler et al., 1986), involving forages and grains, indicate a significant difference between two land types. The increase in radium-226 concentrations in crops grown on a former phosphate clay settling area with 20 pCi/g soil radium-226 was less than would be predicted by a direct proportion to the soil radium. Concentration ratios were an order of magnitude lower for forage crops grown on the clay settling area as compared to control areas with soil radium concentrations on the order of 0.3 pCi/g. Possible explanations include (1) an effect of the higher calcium level in the test area, (2) a difference in radium availability between the settled phosphatic clays and the natural soil of the control area, and/or (3) some regulatory mechanism limiting the uptake from the higher radium soils.

Soil-to-plant transfer factors for radium fall in the range of 0.00011 to 0.2 (fresh plant/dry soil) for the edible portion of food crops and in the range of 0.0011 to 1.4 (dry plant/dry soil) for pasture plants (NCRP, 1984a). In summarizing the literature, Watson, et al. (1984), report average transfer factors on the order of 0.01 for vegetables, 0.003 for fruit, and 0.6 for grain (all fresh plant/dry soil) and concentration ratios of about 0.1 for forages and hay (dry plant/dry soil).

As indicated above, Watson, et al. (1984) reported transfer factors on the order of 0.6 for grain. They state that grain tends to concentrate radium more than vegetables and fruit. On the other hand, the ratio of the typical radium-226 concentration in whole grain products, 2.3 pCi/kg (McDowell-Boyer, et al., 1989), to the typical value in U.S. soils, 0.6 pCi/g (NCRP, 1984b), suggests a transfer factor on the order of only 0.004.

The Florida study referenced above (Roessler, et al. 1986) determined radium-226 concentrations and plant:soil concentration ratios in forages and grains (corn, sunflower, and sorghum) grown on a former phosphate clay settling area (20 pCi/g soil radium-226) and in forage from control plots (0.3 pCi/g soil radium). The study indicated that:

1. The concentration ratios for forages were about an order of magnitude lower for the phosphate clay settling area (with elevated soil radium) than for the control area; and

2. The concentration ratios for the grain on the clay settling area were about an order of magnitude lower than for the forages and averaged about 0.001.

Unfortunately, to date this study has not determined radium-226 in grains from control areas. However, interpolation from the available data suggests that the concentration ratio for grains would not be greater than 0.01 for the control areas.

TRANSFER OF LEAD AND POLONIUM FROM SOIL TO PLANTS

Most soil radioactivity is concentrated in the upper 15 cm (humus layer) with intermediate values in the middle layer. It is possible that the acidity as well as the saturation condition at sites tend to enhance the solubility and availability of radionuclides for plant uptake.

The definition of the plant: soil concentration ratio (CR) as a constant value assumes that the concentration in the plant increases with increasing soil concentrations. This assumption is not substantiated by data for many plant types and elements. The Ibrahim and Whicker (1987) study of the uptake of lead-210 and polonium-210 vs. soil activity provides evidence of non-linearity of uptake.

These studies indicate a wide variation in concentration ratios for the radionuclides of interest in this study. They also suggest that these variations may be a function of food type and soil chemistry. The current study of radioactivity in foods on mined phosphate lands investigates these potential relationships.

PARCEL RECONNAISSANCE AND SELECTION

A major source of information used in the identification of debris parcels and reclaimed clay settling areas in the central Florida phosphate district were Florida Department of Natural Resources (FDNR) records, particularly, the Old Lands Reclamation Program. As part of the old lands program, a detailed survey of the central and northern Florida phosphate districts identified pre-1975 mined and disturbed areas and provided descriptions for each site. A total of 213 records were used to construct a master reference list (MRL) containing 24 known and 47 potential debris parcels.

The MRL was used as the basis for field reconnaissance of the old mined lands. All of the parcels were plotted on maps of Polk and Hillsborough counties. Then, these work maps were used *to* establish the most efficient routes for visiting the 71 parcels. During reconnaissance, each site was assessed to determine present land use and potential availability for gardening. Scintillometer surveys were conducted on accessible parcels to determine relative radiation levels.

The Polk County Cooperative Extension Service has existing gardens at two locations in Polk County: (1) IMC Fertilizer, Inc. (IMCF) Phosphoria Mine, and (2) Agrico Chemical Company's Ft. Green Mine. A concurrent FIPR study conducted by Bromwell and Carrier has experimental gardens on a reclaimed settling area at C.F. Industries' North Pasture mine in Hardee County. Each of these gardens contained targeted vegetable crops.

Field reconnaissance eliminated all but two potential locations for a garden on debris: Mulberry High School, at Mulberry, Florida, and Noranda's Hopewell Mine near Keysville, Florida. Many of the parcels were eliminated because they did not contain debris. Some were eliminated because heavy industry at the site would interfere with gardening. Several existing gardens were observed on potential debris parcels, but they were small backyard plots which did not have the targeted leafy and root vegetables. The Williamson lease on debris land at the Hopewell Mine, which had provided samples for the initial study, also provided collard green samples for the current study. However, the lease was terminated after June 1987 and no further planting occurred.

Initially, the Mulberry High School site was thought to be the best location because of the availability of students enrolled in the school's agriculture curriculum. Soil samples were obtained from this and other locations and subjected to grain size and chemical analyses *to* determine soil constituents. Compared results (Tables 1 and 2) show that the high school garden is predominantly clay and not debris. At the Hopewell site the soil is primarily +150 mesh (approximately 0.1 millimeter average diameter) and has a relatively high phosphate content. Hopewell management granted permission to garden on the Section-4 debris pile.

TABLE 1

SCREEN ANALYSIS RESULTS

Samples	% Moisture	% +150 Mesh	% -150 Mesh
IMCF #l	25.0	5.8	94.2
IMCF #2	22.8	2.7	97.0
Mulberry High School	30.4	10.7	89.3
Hopewell-Williamson Lease	14.2	86.2	13.8
Hopewell-Section 4 Debris Pile	9.8	95.0	5.0
Hopewell-Big Debris Pile	7.6	96.6	3.4

TABLE 2

SOIL CHEMICAL ANALYSIS RESULTS

Samples	% P_2O_5[1]	% CaO[1]
Polk County-IMCF Clay Settling (#1)		
Head	9.24	13.72
+150	8.67	13.59
-150	9.26	14.35
Hopewell-Williamson Lease		
Head	14.77	20.76
+150	14.83	21.66
-150	12.20	17.24
Hopewell-Big Debris Pile	14.02	20.04
Hopewell-Section 4 Debris Pile	17.16	25.48
Mulberry High School		
Head	11.10	13.26
+150 Mesh	2.82	4.43
-150 Mesh	11.97	14.61

---

[1] Methods Used and Adopted by the Association of Florida Phosphate Chemists, Sixth Edition, 1980.

FIELD SAMPLING

Sampling for this current study was conducted at six locations (see Figure 1). External gamma radiation, as measured with an EDA Model GRS-500 Spectrometer/Scintillometer, and associated land types are presented in Table 3. Table 4 summarizes the vegetables sampled and their respective locations.

Table 3
Sampling Location Descriptions

Location	Scintillometer Reading (cps[1])	Land Type
Agrico, Ft. Green	90 - 115	reclaimed clay settling
IMCF, Phosphoria	80 - 105	reclaimed clay settling
Mulberry H.S.	160 - 180	probably clay settling
CFI, North Pasture Mine	70 - 120	sand-clay mix, experimental
Hopewell Section 4	130 - 150	debris pile
Hopewell Williamson	45 - 130	debris

[1] Total counts per second above 0.40 MeV

When available, two replicates of at least five kilograms each were collected to represent each vegetable sample. However, when this quantity was not available, smaller samples were obtained. If foods were grown in large quantities, the samples were collected (by hand picking) from different sections of the field. At smaller plots, where there was only one or two rows and quantities were limited, all of the plants were taken. Under these circumstances approximately half of the plants would be selected at random along the entire length of the row as the first replicate. The remaining plants comprised the second replicate.

For nearly all vegetable samples, at least one surface soil sample was collected. This was accomplished by compositing grab samples from the upper six inches of soil adjacent to each plant sampled. Grab samples were taken with a hand trowel which was washed with deionized water between replicate samples and between different parcels.

FIGURE 1
FOOD SAMPLING LOCATIONS

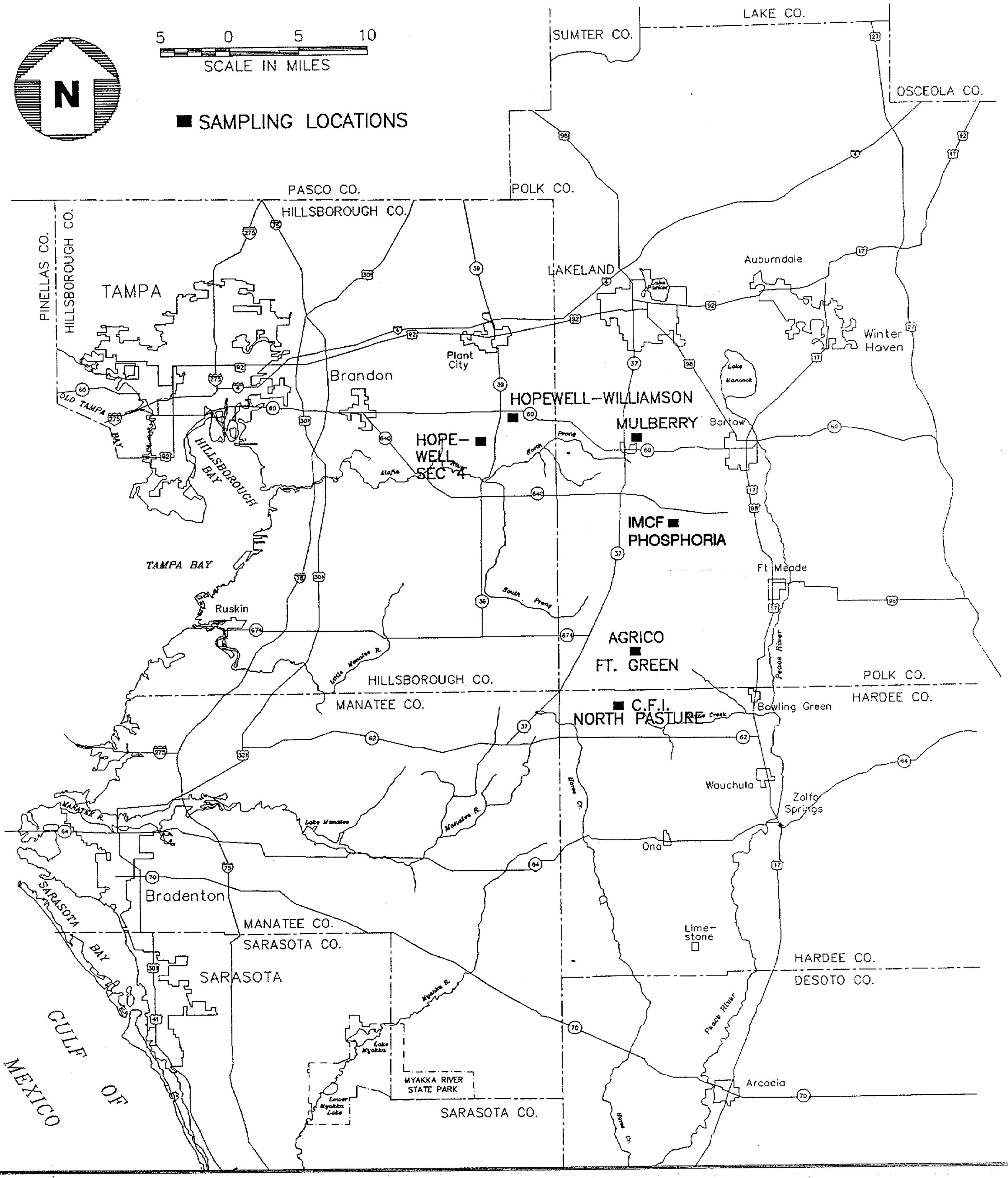


TABLE 4

FOOD SAMPLING LOCATIONS

	Agrico, Ft. Freen	IMCF, Phosphoria	CFI, North Pasture	Hopewell, Section 4	Hopewell, Williamson	Mulberry H.S.
Turnips		X	X	X		
Broccoli	X	X				
Lettuce	X	X		X		
Strawberries	X					
Cabbage	X	X	X	X		
Collards		X			X	
Zucchini						X
Yellow Squash			X			X
Irish Potatoes						X
Corn	X					X
Okra		X				
Mustard	X	X	X	X		
Carrots		X		X		
Parsley		X				
Swiss Chard		X				
Rice	X					
Spinach		X		X		

Irrigation water and fertilizer samples were acquired for the gardens at Ft. Green, Phosphoria, and Hopewell Section 4. Irrigation water was placed in one-quart vessels containing 2.5 milliliters of 16 N nitric acid.

FT. GREEN AND PHOSPHORIA

At Ft. Green and Phosphoria, Polk County's Cooperative Extension Service is maintaining large gardens to determine yields of various crops on reclaimed clay settling areas. In addition, they prepared a smaller, separate plot at Phosphoria to grow targeted foods for this study. With the exception of okra, all of the vegetable samples from Phosphoria were collected from this smaller garden. Preparation of these garden plots entailed clearing existing growth with a grader and planting crops into the tilled, moist clay. Wells at each site provide water for irrigation.

MULBERRY HIGH SCHOOL

Gardening at Mulberry High School is conducted as part of the agriculture curriculum. The plot has been cleared and tilled by conventional methods. Over the years, soil amendments such as sand and peat have been placed in the garden area. Records are not available concerning the quantities and exact locations of these amendments. Irrigation water is provided by the local water supply system.

CFI NORTH PASTURE

A vegetable production study conducted by Bromwell and Carrier for FIPR was designed to determine how different sand:clay ratios affect growth and nutrient uptake. The parcel was divided into four areas of varying sand:clay ratios: 2, 4, 6, and 8:1. Within each of these areas, three separate rows were developed: one with no peat added as a soil amendment, one with peat added at a rate of 45 tons per acre, and one with peat added at a rate of 90 tons per acre. Phosphogypsum was added to some of the individual plots as an additional soil amendment. The study design provided a variety of different soil mixes for vegetable sampling.

Sampling for this study took place at the same time that Bromwell and Carrier was sampling for the vegetable production study. Bromwell personnel would harvest and weigh the vegetables and collect enough sample for their analytical needs. The remainder of the harvested sample from selected plots was collected, bagged, and labeled as the Bromwell project team completed their sampling.

HOPEWELL SECTION-4 DEBRIS GARDEN

In April 1987, management of the Hopewell Mine granted permission to plant a garden on the Section-4 debris pile. A winter garden was planned because it would be able to yield the greatest number of targeted foods during a single season. Preparation over the ensuing months consisted of preparing a garden plot plan, establishing a planting schedule, and determining the most cost-effective alternative for garden irrigation.

An individual with appropriate experience was retained to manage the gardening effort.

Site clearing and irrigation system installation began during the last week of August. The garden site is on grassy pastureland, so a commercially available product was used to clear existing vegetation. By mid-September, irrigation was installed and planting completed. Cabbage and broccoli were planted as transplants and the other vegetable plants were nurtured from seed. The debris is a well-drained medium and required daily watering. Fertilizer and insecticide were applied weekly.

The first crops to mature, mustard and turnips, were sampled at the end of October. Because of the mild winter that year, the garden did not produce anticipated yields of the remaining vegetables. A large animal intrusion and an unexpected freeze in late February also contributed *to* reducing the yield. Despite these problems, the most important foods which had been targeted for production on the debris garden were collected.

SAMPLE PREPARATION AND RADIOASSAY

SAMPLE PREPARATION

All foods were prepared as for normal human consumption, except that no foods were cooked. Drying was accomplished at 100°C for approximately 24 hours. Individual food types were prepared as follows:

1. Leafy Vegetables - All leaves were washed with cold tap water to remove dirt and foreign matter, patted dry with paper towels, then dried. In the case of collard and mustard greens, the excess stems were removed.

2. Root Foods - Root foods were washed of dirt and foreign matter using cold tap water and a vegetable brush. Skins were not removed before slicing and drying. In the case of radish and turnips, the tops and roots were removed.

3. Garden Fruits - Garden fruits were washed of visible foreign matter using cold tap water, patted dry, then sliced and diced before drying. No peels were removed.

4. Legumes - Legumes were rinsed with cold tap water, patted dry, then either shelled or diced, depending on the normal method of human consumption.

5. Rice - Husks were removed but no drying was done.

RADIUM-226 IN SOILS

Radium-226 was determined in the dried sample by high resolution gamma-ray spectrometry, according to the procedure published by Bolch, et al. (1977). In this method, a portion of the sample is weighed into a 0.5-liter Marinelli beaker which is then capped and sealed with a bead of cement. The sealed sample is stored at least two weeks to allow ingrowth of gaseous radon-222 (and its short-lived decay products) to radioactive equilibrium with the long-lived parent radium-226 in the sample. The sample is then counted on a high resolution gamma-ray spectrometer. The radium-226 content of the sample is calculated from the counts associated with the 295.2, 352.0 and 609.4 keV peaks of the lead-214 and bismuth-214 radon daughters. Results are reported as picocuries of radium-226 per gram of dry soil (pCi/g).

RADIUM-226 IN FOODS

A portion of dried food sample was weighed into a 250 ml container which was then capped and sealed. The sealed sample was stored for a minimum of two weeks to allow ingrowth of gaseous radon-222 and its daughter products to equilibrium with the parent radium-226 in the sample. The sample was then counted on a high resolution gamma-ray spectrometer in the same manner as the soil sample. Results are reported as picocuries of radium-226 per kilogram of fresh food (pCi/kg).

LEAD-210/POLONIUM-210 IN FOODS AND SOILS

Bismuth-207 and polonium-209 tracers and lanthanum carrier were added to an appropriate aliquot of dried sample. The sample was then solubilized with a combination of nitric acid, hydrochloric acid and hydrogen peroxide. The analytes of interest were then coprecipitated with ammonium hydroxide. The precipitate was redissolved in acid and the bismuth and polonium spontaneously deposited on a nickel disc.

The disc was beta counted for bismuth-210, gamma assayed for bismuth-207 and assayed by alpha spectroscopy for polonium-209 and polonium-210. The lead-210 is determined from the bismuth-210 ingrowth and bismuth-207 fractional recovery. Results are reported as picocuries of lead-210 or polonium-210 per gram of dry soil or per kilogram of fresh food.

SOIL CHEMISTRY ANALYSIS

Selected soil samples were composited and submitted to A & L Southern Agricultural Laboratories in Pompano Beach, Florida for basic test S1A. This analysis provided the following results which were used in this study:

- Organic matter (OM) expressed as a percent
- Potassium (K) in parts per million (ppm)
- Magnesium (Mg) in ppm
- Calcium (Ca) in ppm
- pH
- Hydrogen (H) in milliequivalents per one hundred grams (meq/100g)
- Cation exchange capacity (CEC) in meq/100g

STATISTICAL ANALYSIS

EXPERIMENTAL DESIGN

The objectives of the statistical analysis were as follows:

- Analyze food radioactivity concentrations to identify differences between foods and lands.

- Determine the relationship, if any, between the concentration level in the food and: (1) the concentration in the soil, (2) the soil type, (3) the chemistry of the soil, and (4) the food type. Of special interest is the relationship for radium-226.

- Test and augment the conclusions of the initial study.

The experimental design utilized to accomplish these objectives is a two-way factorial, with the factors being land types and food types. The factorial is 6x5, using 6 land types and 29 foods grouped into 5 food types. Replication within the factor level combinations (that is, combinations of land and food types) occurred on two levels:

1. Some of the land-food type combinations were sampled more than once. These samples are referred to as parcels.

2. Samples selected within parcels were almost always replicated either two or three times.

Three within-parcel replicates were selected for most of the parcels in the initial study, but the number of replicates was reduced to two in the current study. The initial study revealed that the parcel-to-parcel variability exceeded that among replicates. Therefore, the within-parcel replication for food samples was reduced, and more resources were devoted to increasing the number of parcels for each land-food type combination, especially those on which mean food radium levels were found to be relatively high in the initial study.

To improve the power of the statistical analysis and to facilitate reference to the food evaluations, foods were combined into several categories as shown in Table 5. The category names listed under "Food Type" will be used throughout the text to refer to the listed foods. Since few of the foods sampled in the initial study were analyzed for polonium-210 and lead-210 and since concentrations for these radionuclides were desirable as controls for the current study, several food samples were collected from three grocery stores in the Orlando area and analyzed for radioactivity. It was theorized that these results could be used in the dose evaluation of the control. It was presumed that, if the radioactivity concentrations in these samples were similar to those exhibited by control and mineralized parcels in the initial study, then

TABLE 5
LANDS/FOOD MATRIX

FOOD TYPE	FOOD	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND	TOTAL
CAUL/BROC	BROCCOLI		1	1	1		3	1	7
	CAULIFLOWER	1			1				2
CAUL/BROC		1	1	1	2	0	3	1	9
LEAFY	CABBAGE		1	1	1		7	1	11
	COLLARD GREENS	1	1	3	4		2	2	13
	LETTUCE						3	1	4
	MUSTARD GREENS	1		1	2		8	1	13
	PARSLEY						1		1
	SPINACH	1		1	2		1	2	7
	SWISS CHARD						1		1
	TURNIP GREENS	2		2	4	1	9	1	19
LEAFY		5	2	8	13	1	32	8	69
SEEDS/GRAINS	LIMA BEANS					1			1
	PEAS	1		2	3	3	1		10
	RICE	1			1		1		3
	YELLOW CORN	2	1		2	2	1		8
SEEDS/GRAINS		4	1	2	6	6	3	0	22
ROOTS/TUBERS	CARROTS	1	1	1	2		3	1	9
	RADISH	2		1	3		1		7
	POTATOES		1			3			4
	TURNIP ROOT	1	1	2	3	1	9	2	19
ROOTS/TUBERS		4	3	4	8	4	13	3	39
GENERAL	CUCUMBER	1	1		1	1			4
	EGGPLANT			1	1				2
	GREEN BEANS		1	1	1	1		1	5
	GREEN PEPPER	1		1	2		1		5
	OKRA						2		2
	ONIONS			3	3		1		7
	STRAWBERRIES		1	2	2		1		6
	TOMATO	1	1	1	2		1		6
	WATERMELON			2	2	1			5
	YELLOW SQUASH		1	3	3	2	3	1	13
	ZUCCHINI			2	2	3			7
GENERAL		3	5	16	19	8	9	2	62
TOTAL		17	12	31	48	19	60	14	201

the polonium and lead results could be used for the control evaluation. This, however, was not the case and, since the origin of these foods could not be determined, most of the analyses do not include the grocery store samples.

Because the emphasis for this current study was on certain land-food type combinations, not all land-food type combinations were sampled with equal frequency. The number of samples for each land-food type combination is shown in Table 5. Notice that the samples collected from local grocery stores are treated as a land type for comparison purposes.

The analysis of unbalanced factorial designs requires special care. Analyses of the food measurements discussed in the following sections carefully partition the variability attributable to parcel-to-parcel differences and that attributable to within-parcel replication. Then the appropriate statistical tests are conducted to determine which land-food type differences are statistically significant. Replicates of the within-parcel soil concentration (radium-226, polonium-210, lead-210) and chemistry (pH, hydrogen, cation exchange capacity, organic matter, potassium, magnesium, calcium) measurements were composited prior to analysis, resulting in one measurement per parcel. Therefore, when soil parameters were analyzed, only parcel-to-parcel variability was estimated. When regression analyses were performed to relate food and soil parameters, the geometric means of the within-sample replicates of the food parameters were computed for each parcel, generating one measurement per parcel for both food and soil parameters.

ANALYSIS

The first step in the statistical analysis was to compare land types according to each soil concentration and soil chemistry parameter. Then, the land types, food types, and foods were compared utilizing the measured radium, lead and polonium concentrations. The second major component of the statistical analysis was to relate radioactivity concentrations measured in foods to the concentration measured in the soil, the soil chemistries, and the corresponding soil and food type designations. Of special interest is the relationship of radium-226 in the food with the radium-226 in the soil, the soil chemistry, the land type, and the food type. It should be emphasized that the objective of evaluating this relationship was to determine the probable nature and strength of the relationships, and not to establish a precise predictive mechanism, although mechanisms *to* estimate food concentrations were developed.

Analysis of variance (ANOVA) was utilized to determine statistically significant differences between land types, food types, and individual foods within food types. Two types of ANOVA were conducted. The first was performed on the logarithmic transform of the parameters, except for hydrogen and pH. This transform has the effect of comparing the geometric means of the parameters, and the arithmetic means of hydrogen and pH. The primary reason for the transformation is to account for the rightward skewness in the frequency distributions of most of the parameters. That is, standard ANOVA on untransformed values requires that the distribution of the parameter be approximately normal. However, most biological and chemical measurements possess distributions that are rightward skewed. The pH values are already logarithmic transforms, so no further transformation is necessary. The hydrogen values are calculated percentages of the binding sites in the soil which are taken up by hydrogen ions (Griffith, 1989); since these values are not calculated when the pH is greater than 7.0, they are reported as zero and the logarithmic transform does not apply.

The use of logarithmic transformed ANOVA requires the assumption that the parameter's frequency distribution is lognormal. This means that, while the distribution of the values themselves may be rightwardly skewed, the logarithms of the values are assumed to possess a normal distribution. Of course, the fact that the distribution associated with a parameter is rightwardly skewed does not guarantee that the distribution is lognormal. For this reason, a second ANOVA that requires no distributional assumptions about the parameters was performed. This nonparametric analysis of variance is performed on the ranks of the measurements, rather than on the measurements themselves. That is, the measurements are ranked from largest to smallest, and the ANOVA is conducted utilizing the ranks of the measurements. Of course, the greatest disadvantage to the nonparametric ANOVA is that magnitudes of the differences between measurements play little role in the analysis; only the rank order matters. Nevertheless, when distributional assumptions are in doubt, the nonparametric ANOVA provides an alternative analysis that requires no such assumptions.

Analysis of residuals was used to test the lognormality assumption (and normality in the case of pH and hydrogen) necessary for the validity of the parametric ANOVA. The distributions of the residuals of the transformedvariables appeared to be approximately normal for nearly every parameter. In addition, both parametric and nonparametric ANOVAs were performed for several of the parameters in order to determine the robustness of the results. In almost every case the nonparametric and parametric analyses were in agreement. Therefore, the lognormal assumption appears to be reasonable, and the following results are all based on parametric ANOVAs.

If the ANOVA indicates a difference among the means for the various factor combinations (land type and food type, for example), a multiple comparison procedure is applied to determine which pairs of means are significantly different from a statistical standpoint. The least squares multiple comparison procedure was used to compare pairs of means from groups determined by the ANOVA to contain pairs of means that differ. Pairwise comparisons were made only if the ANOVA revealed a significant effect at the 0.05 level. The multiple comparisons were declared significant at several levels: less than 0.01, 0.01 to 0.02, and 0.02 to 0.05. The (less than) 0.01 level of significance provides maximum protection against concluding that differences are significant, when in fact they are not (Type I error). However, the 0.01 to 0.02 and 0.02 to 0.05 levels of significance provide useful information, since the error of not declaring real differences statistically significant (Type II error) is also of concern in this study.

For the purpose of the statistical analysis, food concentration values for the current study that were measured at less than the detection limit or at zero were estimated at one-half the detection limit. This provides a more reasonable result for the statistical analysis for those results which were below detection limits and also provided a result which could be logarithmically transformed for those results which were reported as zero. Food concentration values that were measured at less than the detection limit or at zero for the initial study were estimated by the methodology utilized in that study, which was at one-half the lowest value reported for the corresponding food. No estimation was necessary for the soil concentrations and chemistry parameters since none of the reported results were reported below the detection limits of the analytical procedure.

LAND TYPE DIFFERENCES BASED ON SOIL PARAMETERS

The soil concentration and chemistry parameters were analyzed to determine if the land types differed according to each measured soil characteristic. The first step was to determine if the Bromwell parcel should be treated as a separate land type, or if it could be combined with the reclaimed or clay parcels. While *most* of the foods from the Bromwell parcel were collected from 8:1 sand:clay plots, some 2:1 sand:clay samples were included in the study to supplement the design matrix. Soils collected from the Bromwell parcel exhibited radiological and chemical characteristics which, for almost all parameters, were statistically similar to samples collected from the clay settling areas. Therefore, the Bromwell soils were grouped with the clay soils, providing a more balanced and complete experimental design.

Once the Bromwell data had been classified as clay, the next step was to determine whether land types could be grouped according to the soil characteristics. Table 6 presents the results of the multiple comparison tests, and Table 7 gives the adjusted geometric means on which these comparisons are based. (These results are computer generated and include several decimal places. Results should be considered accurate to two significant figures.) All multiple comparisons follow an ANOVA which indicates a significant difference between land types at the 0.05 level. Each difference shown in Table 6 is significant at the 0.01 level of significance unless otherwise noted. If the significance of the multiple comparisons is low, at the 0.02 or 0.05 level, the difference is footnoted. The differences listed in Table 6 are ordered by the magnitude of the geometric means, providing a ranking for comparison purposes.

The soil radium-226 results suggest grouping the mineralized and control land types. The ranking of the geometric means agrees with the results for food radium from the initial study. Clay and debris parcels exhibit higher average concentrations of radium-226 than the other land types, and their concentrations are not significantly different from each other. The reclaimed parcels exhibit the next highest concentrations of

TABLE 6

MULTIPLE COMPARISON ANALYSIS
SOIL RADIOACTIVITY AND CHEMISTRY

Soil Radium-226:
DEBRIS > RECLAIMED, CONTROL, MINERALIZED
CLAY > RECLAIMED, CONTROL, MINERALIZED
RECLAIMED > CONTROL, MINERALIZED

Soil Polonium-210: (CLAY, DEBRIS, RECLAIMED)
DEBRIS > RECLAIMED
CLAY > RECLAIMED

Soil Lead-210: (CLAY, DEBRIS, RECLAIMED)
DEBRIS > RECLAIMED
CLAY > RECLAIMED

pH:
CLAY > CONTROL, MINERALIZED, DEBRIS, RECLAIMED
CONTROL > RECLAIMED[2]
MINERALIZED > RECLAIMED[2]

Hydrogen:
CONTROL > RECLAIMED, DEBRIS, MINERALIZED, CLAY

Cation Exchange Capacity:
CLAY > RECLAIMED, DEBRIS, MINERALIZED
CONTROL > RECLAIMED, DEBRIS, MINERALIZED

Organic Matter:
CONTROL > MINERALIZED, RECLAIMED, DEBRIS, CLAY
MINERALIZED > DEBRIS, CLAY
RECLAIMED > CLAY[2]

Potassium:
CLAY > CONTROL[2], DEBRIS, MINERALIZED, RECLAIMED
CONTROL > MINERALIZED, RECLAIMED
DEBRIS > MINERALIZED[2], RECLAIMED[1]

Magnesium:
CLAY > CONTROL[1], DEBRIS, RECLAIMED, MINERALIZED
CONTROL > DEBRIS, RECLAIMED, MINERALIZED

Calcium:
CLAY > RECLAIMED, DEBRIS, MINERALIZED
CONTROL > RECLAIMED, DEBRIS, MINERALIZED

---

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 7

ADJUSTED GEOMETRIC MEANS OF SOIL CHARACTERISTICS BY LAND TYPE AND SOIL PARAMETER

PARAMETER	CONTROL	MINERALIZED	RECLAIMED	CLAY	DEBRIS
Radium-226	0.627235	0.470668	5.17497	16.0048	16.0682
Lead-210			8.48916	22.7505	25.2064
Polonium-210			7.52469	18.6297	20.8287
pH[1]	6.08095	6.04167	5.53039	7.19147	5.90000
Hydrogen[1]	6.00000	0.960000	1.93194	0.543902	1.29697
Cation Exchange Capacity	19.2014	3.40941	6.10695	26.4014	5.33671
Organic Matter	8.06793	3.10956	2.36137	1.78862	1.95616
Potassium	104.311	26.4506	21.5236	248.151	61.8508
Magnesium	382.966	73.2717	87.2598	956.145	113.754
Calcium	2159.52	342.189	629.733	3092.74	548.695

[1] Not a geometric mean

soil radium, and they are significantly greater than concentrations measured on both the control and the mineralized parcels. The geometric means of the radium concentrations measured in the soils from the control and mineralized parcels are nearly equal, and are therefore not significantly different.

These results are illustrated in Figure 2. The adjusted geometric means are represented by a symbol within the two standard error range for the mean. Notice the extremely low values and tight ranges for the control and mineralized lands and the high values and broad ranges for the clay and debris lands.

The polonium-210 and lead-210 results shown in Table 6 should be viewed with caution since they are based on a limited number of measurements (mostly during the current study) on the three land types shown. However, the findings for these two parameters are consistent with each other and with the radium-226 results: soils from the clay and debris parcels exhibit significantly higher levels of radioactivity, on average, than soils from the reclaimed parcels.

The groupings of the land types by soil chemistry parameters are not as consistent as for the soil radioactivity parameters. For example, control and mineralized parcels could be combined according to the pH levels, but not for any of the other soil chemistry parameters. All of the means of the soil chemistry parameters for control lands rank relatively high. Note that many of the control lands were muck lands near Lake Apopka, where local farming provided an abundance of foods on low radioactivity soils. The means of the soil chemistry parameters for clay lands also rank high, except for hydrogen and organic matter. However, caution should be exercised when drawing conclusions from the analysis of the soil chemistry parameters. Since the soil samples were composited for each parcel, the sample sizes for all but pH are quite small: Control 6, Debris 8, Mineralized 10, Reclaimed 12, and Clay 27.

LAND TYPE, FOOD TYPE, AND FOOD DIFFERENCES BASED ON FOOD RADIOACTIVITY CONCENTRATIONS

The statistical evaluation of the differences in food radioactivity concentrations between land types, food types, and individual foods are described in the following sections. As with the previous analyses, some comparisons are significant at the 0.02 and 0.05 levels. Actual significance levels are indicated on each of the comparison tables.

Radium-226

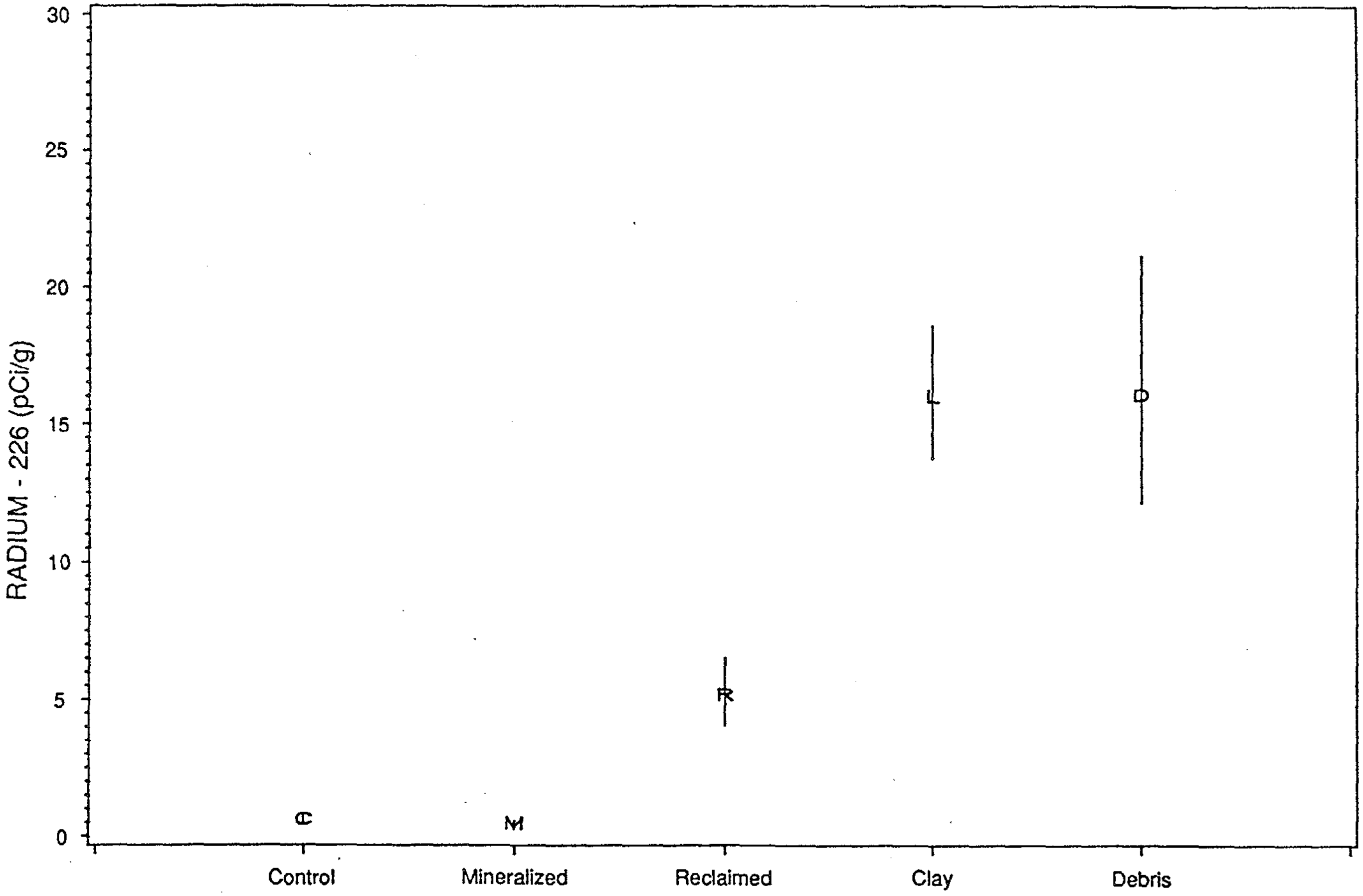
Comparisons of the geometric means of radium-226 revealed that the land-food type interaction is significant. The presence of interaction means that the differences in food radioactivity concentrations between land types depends on the food type, and conversely the difference in food radioactivity concentrations between food types depends on the land type. Thus, certain food types may have different mean levels of radium-226 on

Figure 2

LAND TYPE COMPARISONS

Radium-226 In Soil

(pCi/g)



the clay land type, while not differing significantly on control or mineralized lands. To determine how the interaction is manifested in terms of differences among the adjusted geometric means, land types were compared by food type, and food types were compared by land type. The significant differences are shown in Tables 8 and 9. Figure 3 graphically displays these differences, and Table 10 lists the adjusted geometric means being compared.

Table 8 shows that the control and mineralized land types cluster in the lowest group for all food types. The clay, debris, and reclaimed lands cluster at the high end, with the only exception being the roots/tubers food type. The roots/tubers foods grown on reclaimed land yield, on the average, lower concentrations of radium than the debris and clay land types. For this food type the reclaimed land type groups with the control and mineralized lands. The limited number of grocery store samples exhibited radioactivity concentrations which were found to be not significantly different from the other land types. The grocery results for radium-226 are drawn from a very small sample size consisting of a sample of potatoes and a sample of green beans.

Figure 3 graphically displays these differences by plotting the adjusted geometric mean along with the two standard error range for the mean. Notice for leafy foods that concentrations observed on reclaimed, clay, and debris lands are significantly higher than those observed on control and mineralized lands.

Table 9 shows that food type differences are dependent upon the land type. The roots/tubers foods have higher mean levels of radium-226 than the general foods when grown on clay and debris lands. The leafy foods exhibit radium-226 levels which are greater than those for general foods on all land types but the control. The mean levels for leafy foods are also greater than for seeds/grains foods grown on clay, mineralized, and reclaimed lands. The leafy and roots/tubers food types cluster on all but the reclaimed land type, where the leafy mean level exceeds that for roots/tubers. No significant differences are found on control lands and with the grocery samples.

Adjusted geometric means by land type and food type are listed in Table 10. Similar data by land type and specific food are shown in Table 11 and in Figures 4 through 8. The only food sampled on all land types was turnip roots; turnip greens were sampled on all except the grocery store land type. (Note that the grocery store samples were treated as a separate land type.) Of the two, only turnip greens showed significant differences among land types. Table 11 and Figure 5 illustrate that the mean level of radium-226 in turnip greens is significantly greater for clay and reclaimed lands than for mineralized and control lands. This finding is in agreement with the initial study.

TABLE 8

MULTIPLE COMPARISON ANALYSIS
FOOD RADIUM-226
COMPARE LAND TYPES WITHIN FOOD TYPES

CAUL/BROC	DEBRIS	>	MINERALIZED[2]
	CLAY	>	MINERALIZED[2]
GENERAL	CLAY	>	MINERALIZED, CONTROL[1]
LEAFY	RECLAIMED	>	MINERALIZED, CONTROL
	DEBRIS	>	MINERALIZED, CONTROL
	CLAY	>	MINERALIZED, CONTROL
ROOTS/TUBERS	DEBRIS	>	RECLAIMED, MINERALIZED, CONTROL
	CLAY	>	RECLAIMED, MINERALIZED, CONTROL
SEEDS/GRAINS	RECLAIMED	>	MINERALIZED

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 9

MULTIPLE COMPARISON ANALYSIS
FOOD RADIUM-226
COMPARE FOOD TYPES WITHIN LAND TYPES

DEBRIS	LEAFY	>	GENERAL
	ROOTS/TUBERS	>	GENERAL
CLAY	LEAFY	>	GENERAL, SEEDS/GRAINS
	ROOTS/TUBERS	>	GENERAL[1], SEEDS/GRAINS[1]
RECLAIMED	LEAFY	>	SEEDS/GRAINS[2], ROOTS/TUBERS, GENERAL
	SEEDS/GRAINS	>	GENERAL
GROCERY	NO SIGNIFICANT DIFFERENCES		
MINERALIZED	LEAFY	>	GENERAL[1], SEEDS/GRAINS[1]
CONTROL	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

Figure 3

LAND/FOOD TYPE COMPARISONS

Radium-226 In Foods

(pCi/kg)

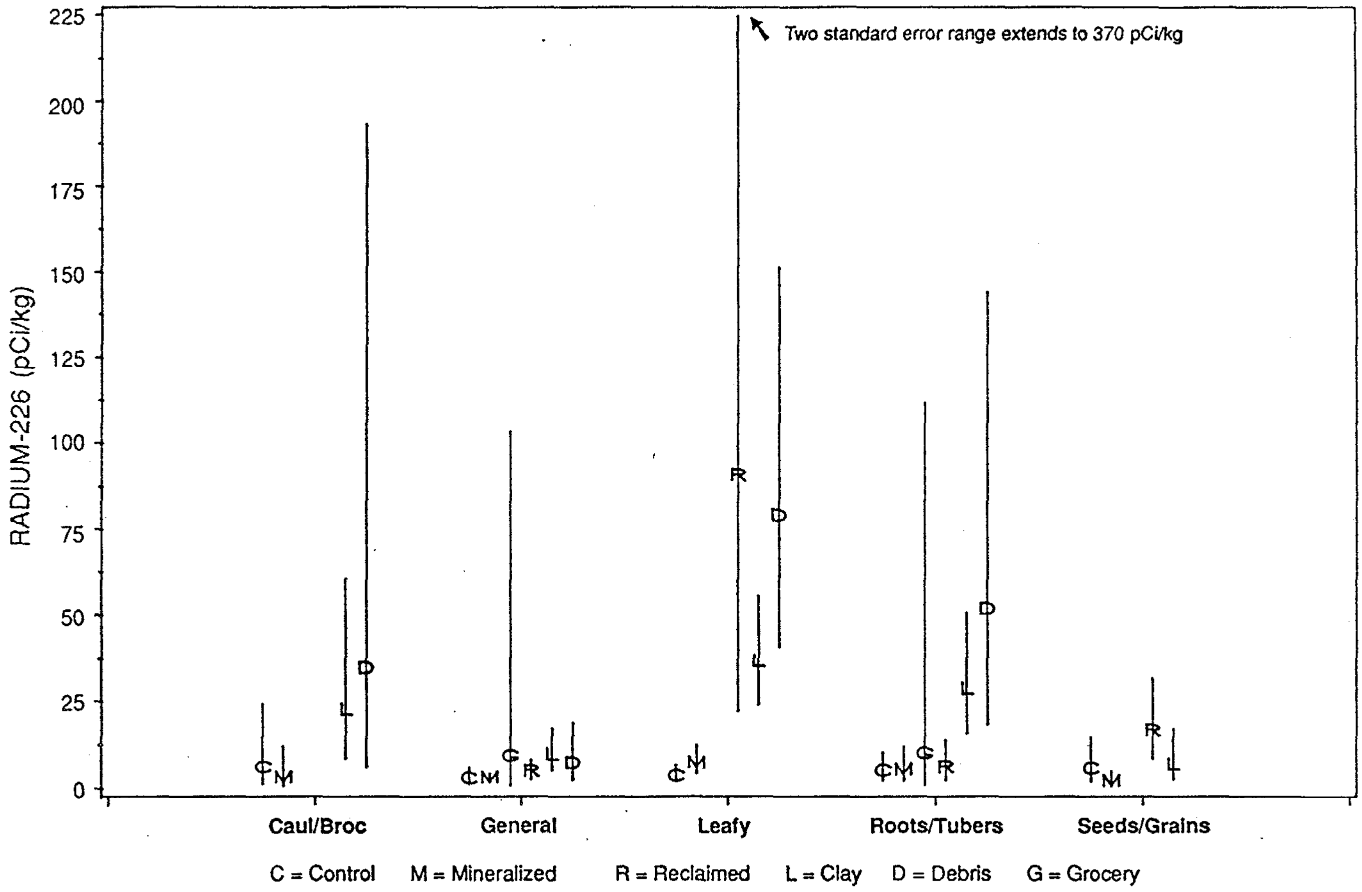

Two standard error range extends to 370 pCi/kg

TABLE 10

RADIUM-226 IN FOOD (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND FOOD TYPE

FOOD TYPE	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC	6.02535		3.00330	4.25393		22.5845	34.6747
LEAFY	4.15986		8.02255	6.23171	90.8566	42.7642	79.9758
SEEDS/GRAINS	5.35992		1.87165	3.77439	11.5933	6.75768	
ROOTS/TUBERS	4.50359	9.85000	5.23945	4.80538	5.03671	22.6096	39.9200
GENERAL	2.66626	9.12300	3.03256	2.97154	5.50152	9.83585	7.09830

Figure 4

SPECIFIC FOOD COMPARISONS

Radium-226 In Foods
(pCi/kg)
Food Type = Caul/Broc

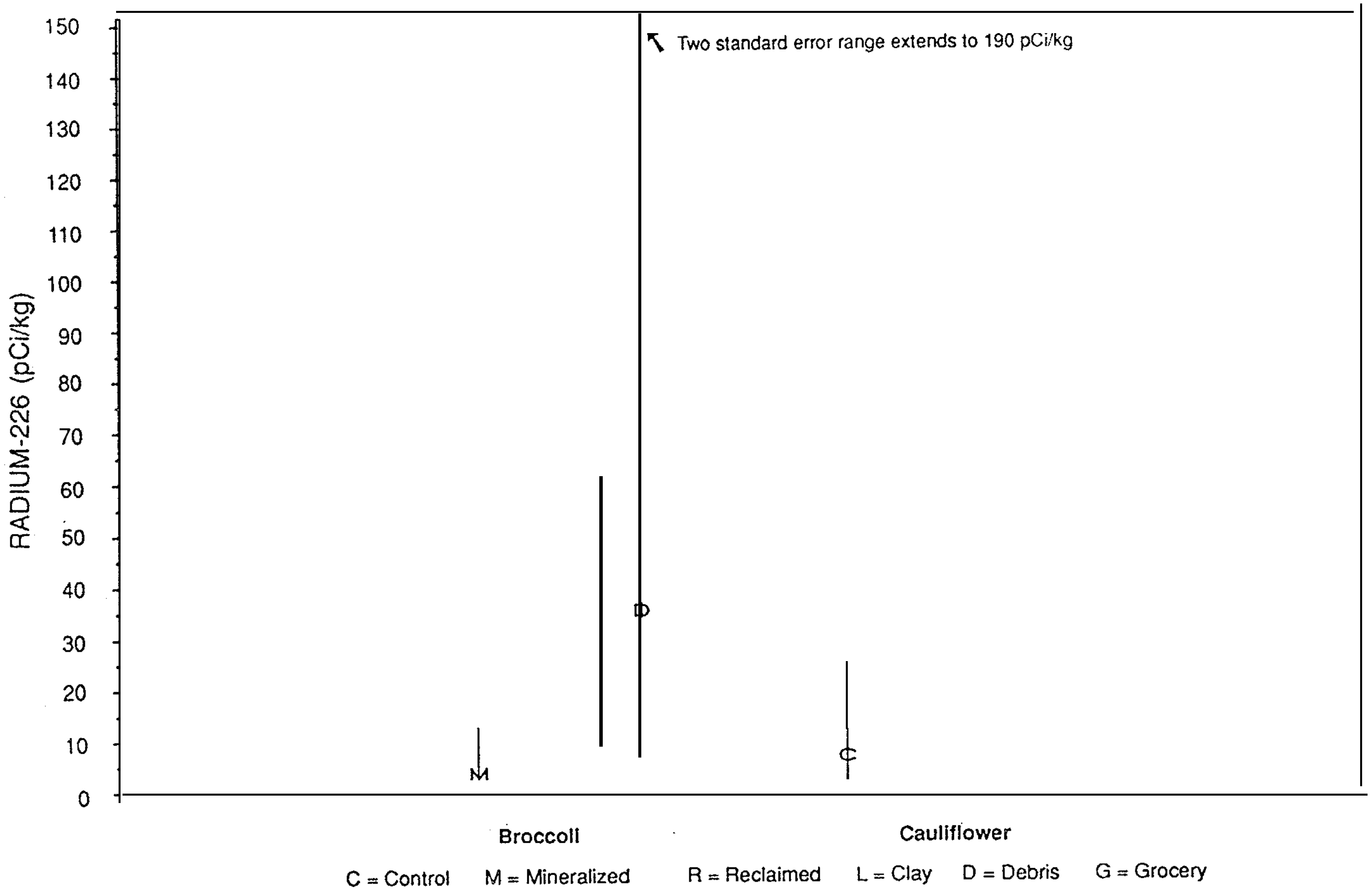


Figure 5

SPECIFIC FOOD COMPARISONS

Radium-226 In Foods

(pCi/kg)

Food Type = Leafy

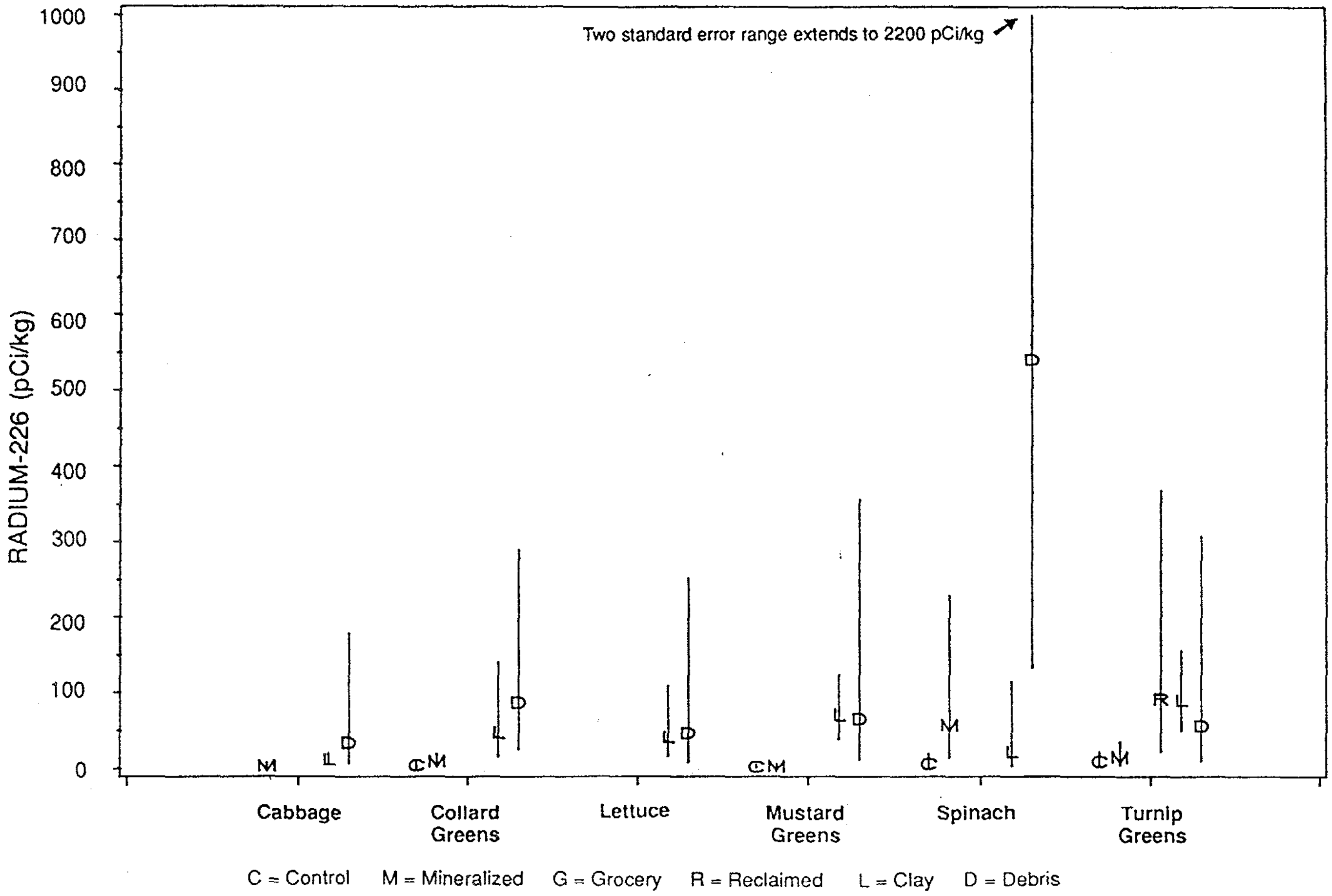


Figure 6

SPECIFIC FOOD COMPARISONS

Radium-226 In Foods

(pCi/kg)

Food Type = Seeds/Grains

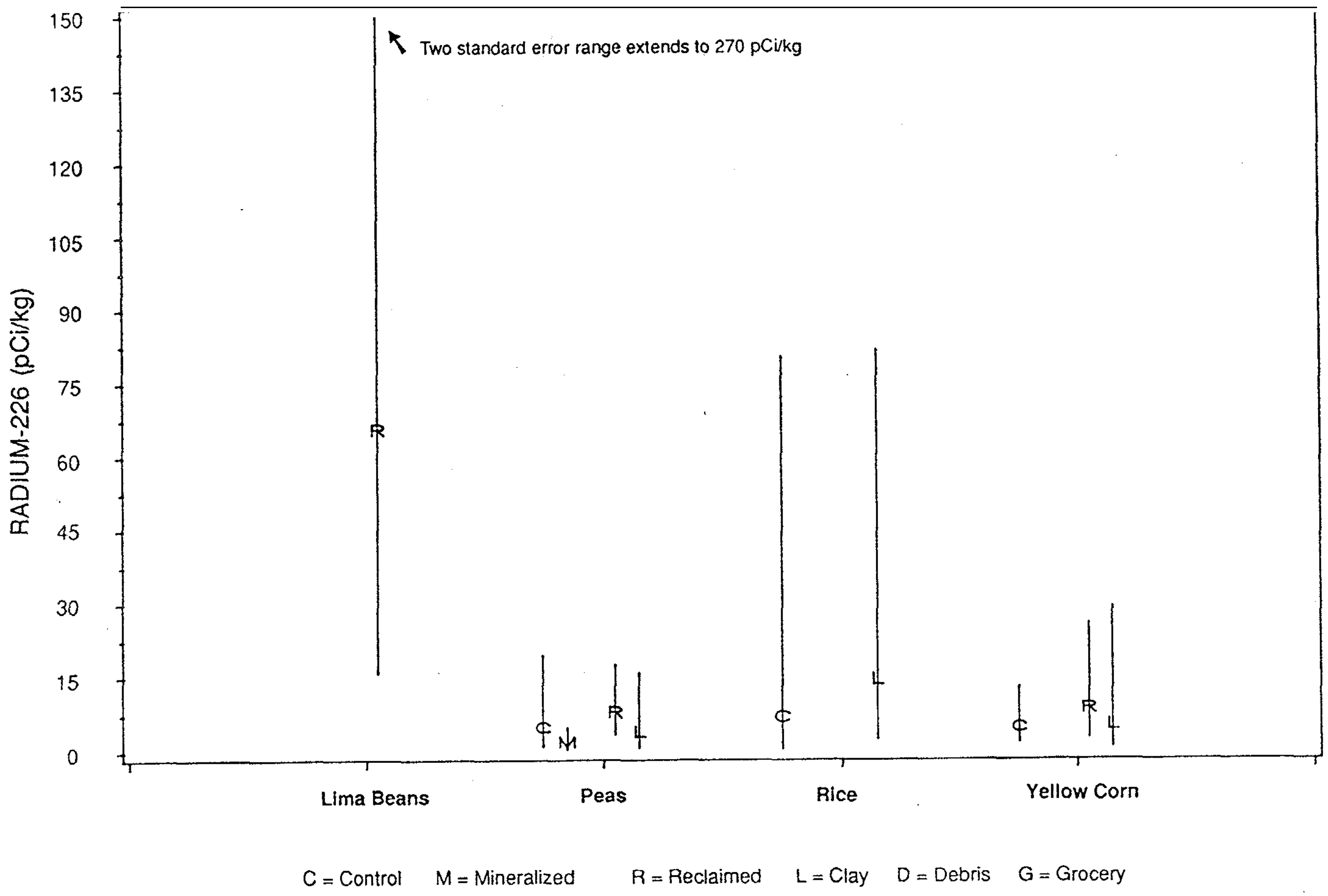


Figure 7

SPECIFIC FOOD COMPARISONS

Radium-226 In Foods

(pCi/kg)

Food Type = Roots/Tubers

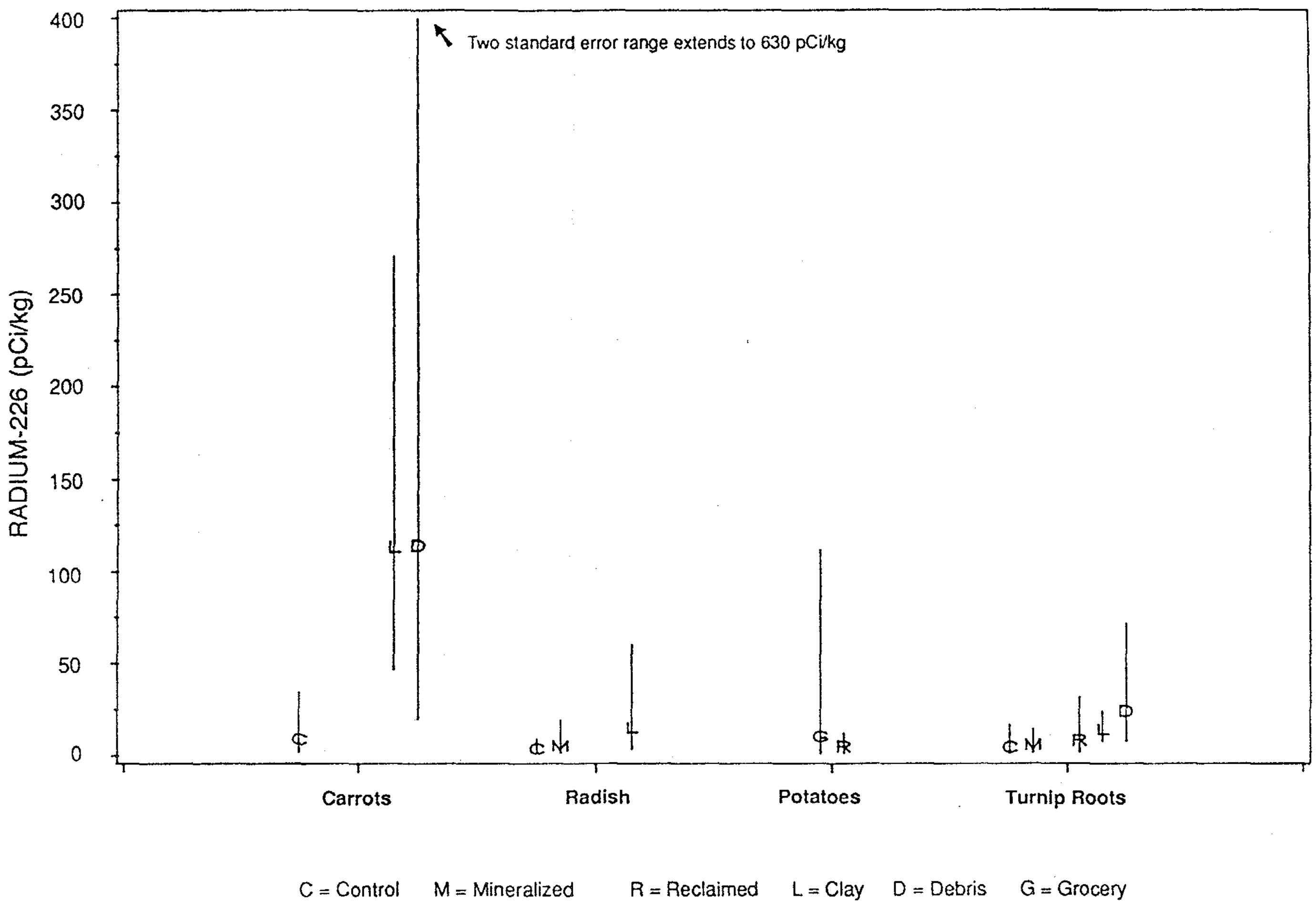


Figure 8

SPECIFIC FOOD COMPARISONS

Radium-226 In Foods

(pCi/kg)

Food Type = General

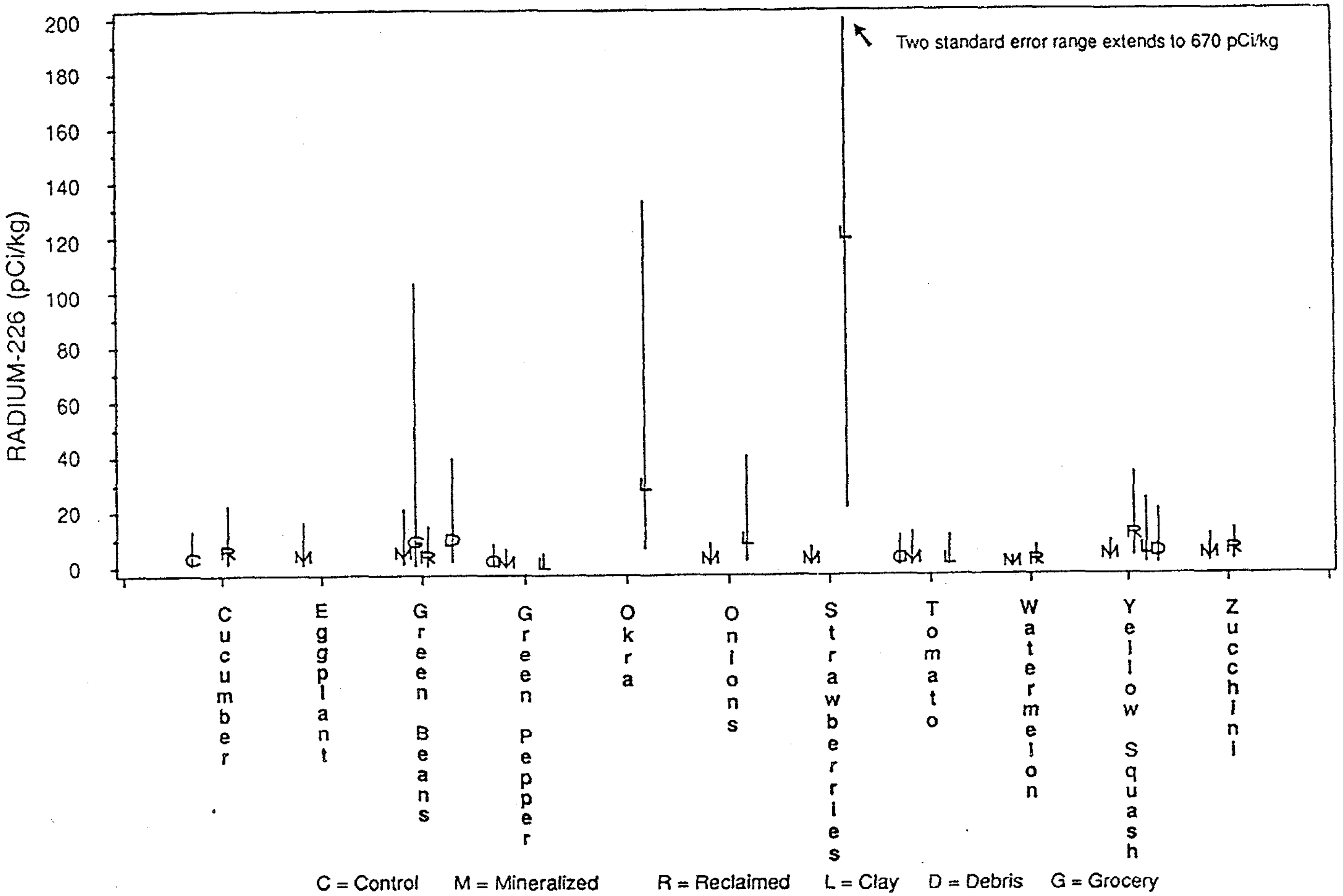


TABLE 11

RADIUM-226 IN FOOD (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND SPECIFIC FOOD

FOOD TYPE	FOOD	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC	BROCCOLI			3.00330	3.00330		22.5845	34.6747
	CAULIFLOWER	6.02535			6.02535			
LEAFY	CABBAGE			2.0961	2.0961		10.5339	32.195
	COLLARD GREENS	2.93444		8.1726	6.3263		46.0683	86.234
	LETTUCE						40.4084	45.412
	MUSTARD GREENS	1.34406		1.5326	1.4352		69.6092	64.225
	PARSLEY							
	SPINACH	4.82499		56.4802	16.5081		20.8126	540.260
	SWISS CHARD							
	TURNIP GREENS	8.09052		13.1625	10.3195	90.8566	89.5455	55.473
SEEDS/GRAINS	LIMA BEANS					65.7100		
	PEAS	4.85228		1.87165	2.57117	7.9148	3.9646	
	RICE	7.10000			7.10000		14.6969	
	YELLOW CORN	4.89456			4.89456	8.6326	5.2962	
ROOTS/TUBERS	CARROTS	8.52376			8.52376		113.071	113.829
	RADISH	3.37745		4.87716	3.81752		14.898	
	POTATOES		9.85000			4.33982		
	TURNIP ROOT	4.23085		5.43057	4.99696	7.87361	13.849	23.641
GENERAL	CUCUMBER	3.21597			3.21597	5.5975		
	EGGPLANT			4.05297	4.05297			
	GREEN BEANS		9.12300	5.15674	5.15674	3.6824		9.78889
	GREEN PEPPER	2.10426		1.65500	1.86616		1.256	
	OKRA						30.097	
	ONIONS			3.12174	3.12174		9.908	
	STRAWBERRIES			2.80825	2.80825		120.797	
	TOMATO	2.80088		3.08403	2.93905		2.822	
	WATERMELON			1.24477	1.24477	1.8688		
	YELLOW SQUASH			4.11339	4.11339	11.2159	6.076	5.14725
	ZUCCHINI			4.30550	4.30550	5.5740		

Other foods showed significant differences between land types; these differences are listed in Table 12. The majority of the foods listed are mainly from the leafy food type with the concentrations in foods collected from clay and debris lands being significantly greater than those collected from control and mineralized lands.

Comparing the foods within a land type produced the significant differences listed in Table 13. Among foods grown on debris land, spinach produced the highest mean level, significantly higher than the levels from a number of other foods. Levels in collard greens and carrots exceed those in green beans and yellow squash. Mustard and turnip greens have significantly higher levels than yellow squash.

Mean levels of radium-226 found on clay lands are highest for strawberries. Several other foods grown on clay land exhibit significantly higher levels of radium-226; in particular, carrots, turnip greens, mustard greens, and collard greens, as in the debris land. All of the foods listed in Table 13 for the clay lands had a significantly higher level than green peppers. Strawberries, turnip greens, mustard greens, collard greens, and lettuce all have significantly higher levels than yellow squash. Strawberries, carrots, turnip greens, collard greens, and lettuce all have significantly higher levels than peas, tomatoes, and cabbage.

Among foods grown on reclaimed land, only turnip greens, lima beans, and yellow squash have significantly higher levels of radium-226 than other foods grown on that land. Turnip greens and lima beans both exhibit higher levels than zucchini, potatoes, greens beans, and watermelon at the 0.01 significance level.

When comparing foods grown on mineralized land, spinach, turnip greens, collard greens, turnip roots, and peas show higher levels of radium-226. The only difference between foods grown on control land was for turnip greens; however, that difference is at the 0.05 significance level.

In summary, the land types grouped as in the initial study. The foods grown on clay, reclaimed, and debris lands generally have higher mean radium-226 levels than those grown on control and mineralized lands. The leafy food type again exhibited higher radium content, and the general food type (which includes garden fruit) had a low average, as in the initial study. A number of foods were found to be significantly different within land type, especially among the leafy and roots/tubers food types.

Lead-210

The measurements of lead-210 in the food were limited to grocery, clay, debris, and some reclaimed and control lands (no mineralized observations). There were some values at the detection limit, but not to the extent of limiting the statistical analysis. The adjusted geometric means are presented in Tables 14 and 15. The ANOVA and multiple comparison results are listed in Tables 16 through 19.

TABLE 12

MULTIPLE COMPARISON ANALYSIS
FOOD RADIUM-226
COMPARE LAND TYPES WITHIN FOODS

BROCCOLI	DEBRIS	>	MINERALIZED[2]
	CLAY	>	MINERALIZED[2]
STRAWBERRIES	CLAY	>	MINERALIZED
CABBAGE	DEBRIS	>	MINERALIZED[1]
	CLAY	>	MINERALIZED[2]
COLLARD GREENS	DEBRIS	>	MINERALIZED, CONTROL
	CLAY	>	MINERALIZED[1], CONTROL
MUSTARD GREENS	CLAY	>	MINERALIZED, CONTROL
	DEBRIS	>	MINERALIZED, CONTROL
SPINACH	DEBRIS	>	MINERALIZED[2], CLAY, CONTROL
	MINERALIZED	>	CONTROL[1]
TURNIP GREENS	RECLAIMED	>	MINERALIZED[2], CONTROL
	CLAY	>	MINERALIZED, CONTROL
CARROTS	DEBRIS	>	CONTROL[2]
	CLAY	>	CONTROL
PEAS	RECLAIMED	>	MINERALIZED[2]
ALL OTHERS	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 13

MULTIPLE COMPARISON ANALYSIS
FOOD RADIUM-226
COMPARE FOODS WITHIN LAND TYPES

DEBRIS	SPINACH	>	TURNIP GREENS[2], LETTUCE[2], BROCCOLI[1], CABBAGE[1], TURNIP ROOT, GREEN BEANS, YELLOW SQUASH
	CARROTS	>	GREEN BEANS[2], YELLOW SQUASH
	COLLARD GREENS	>	GREEN BEANS[2], YELLOW SQUASH
	MUSTARD GREENS	>	YELLOW SQUASH[2]
	TURNIP GREENS	>	YELLOW SQUASH[2]
CLAY	STRAWBERRIES	>	CABBAGE, TURNIP ROOT[1], ONIONS[2], YELLOW SQUASH, YELLOW CORN[1], PEAS, TOMATO, GREEN PEPPER
	CARROTS	>	BROCCOLI[1], RADISH[1], RICE[2], TURNIP ROOT, CABBAGE, ONIONS, YELLOW SQUASH, YELLOW CORN, PEAS, TOMATO, GREEN PEPPER
	TURNIP GREENS	>	BROCCOLI[1], RICE[2], TURNIP ROOT, CABBAGE, ONIONS, YELLOW SQUASH, YELLOW CORN, PEAS, TOMATO, GREEN PEPPER
	MUSTARD GREENS	>	TURNIP ROOT, CABBAGE, ONION[1], YELLOW SQUASH, YELLOW CORN, PEAS, GREEN PEPPER
	COLLARD GREENS	>	CABBAGE[2], YELLOW SQUASH[2], YELLOW CORN[2], PEAS, TOMATO, GREEN PEPPER
	LETTUCE	>	CABBAGE[2], YELLOW SQUASH[2], YELLOW CORN[2], PEAS, TOMATO, GREEN PEPPER
	OKRA	>	TOMATO[2], GREEN PEPPER
	BROCCOLI	>	PEAS[2], TOMATO[1], GREEN PEPPER
	SPINACH	>	GREEN PEPPER[1]
	RADISH	>	MUSTARD GREENS[2], GREEN PEPPER[1]
	RICE	>	GREEN PEPPER[2]
	TURNIP ROOT	>	TOMATO[2], GREEN PEPPER[1]
	CABBAGE	>	GREEN PEPPER
	ONIONS	>	GREEN PEPPER[2]
RECLAIMED	TURNIP GREENS	>	YELLOW SQUASH[2], YELLOW CORN[1], PEAS[1], TURNIP ROOT[1], CUCUMBER, ZUCCHINI, POTATOES, GREEN BEANS, WATERMELON
	LIMA BEANS	>	YELLOW CORN[2], PEAS[2], TURNIP ROOT[2], CUCUMBER[1], ZUCCHINI, POTATOES, GREEN BEANS, WATERMELON
	YELLOW SQUASH	>	WATERMELON[2]
GROCERY	NO SIGNIFICANT DIFFERENCES		

TABLE 13 (CONTINUED)

MINERALIZED	SPINACH	>	TURNIP ROOT, GREEN BEANS[1], RADISH[1], EGGPLANT, ONIONS, TOMATO, BROCCOLI, STRAWBERRIES, PEAS, GREEN PEPPER, WATERMELON
	TURNIP GREENS	>	ONIONS[2], STRAWBERRIES[2], CABBAGE[2], GREEN PEPPER[1], MUSTARD GREENS[1], WATERMELON
	COLLARD GREENS	>	MUSTARD GREENS[2], ZUCCHINI, YELLOW SQUASH, CABBAGE, PEAS[2], MUSTARD GREENS, WATERMELON
	TURNIP ROOT	>	WATERMELON[2]
	PEAS	>	MUSTARD GREENS
CONTROL	TURNIP GREENS	>	MUSTARD GREENS[2]

---

[1] Significant at 0.02 level

[2] Significant at 0.05 level

TABLE 14

LEAD-210 IN FOOD (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND FOOD TYPE

FOOD TYPE	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC		9.25800				16.0733	60.0933
LEAFY		14.8828				29.6366	32.0319
SEEDS/GRAINS	61.5650	117.124		61.5650	0.500000	30.3901	
ROOTS/TUBERS		8.25542			2.0000	2.45161	7.81005
GENERAL		6.59115			0.707107	5.63994	

TABLE 15

LEAD-210 IN FOOD (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND SPECIFIC FOOD

FOOD TYPE	FOOD	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC	BROCCOLI		9.25800				16.0733	60.0933
	CAULIFLOWER							
LEAFY	CABBAGE		9.1290				5.502	122.609
	COLLARD GREENS		24.2630				42.675	33.293
	LETTUCE						17.623	75.561
	MUSTARD GREENS						35.842	0.500
	PARSLEY						51.804	
	SPINACH						71.135	166.490
	SWISS CHARD						118.320	
	TURNIP GREENS						70.728	40.475
SEEDS/GRAINS	LIMA BEANS							
	PEAS							
	RICE	61.5650			61.5650		51.1228	
	YELLOW CORN		117.124			0.500000	18.0654	
ROOTS/TUBERS	CARROTS		0.5000				2.08571	5.9657
	RADISH							
	POTATOES		35.8530			2.0000		
	TURNIP ROOT		31.3850				2.55270	10.2245
GENERAL	CUCUMBER		0.5000					
	EGGPLANT							
	GREEN BEANS		12.6550					
	GREEN PEPPER							
	OKRA						27.8435	
	ONIONS							
	STRAWBERRIES		45.9430				49.0408	
	TOMATO		15.7320					
	WATERMELON							
	YELLOW SQUASH		2.7200			1.00000	0.8608	
	ZUCCHINI					0.50000		

TABLE 16

MULTIPLE COMPARISON ANALYSIS
FOOD LEAD-210
COMPARE LAND TYPES WITHIN FOOD TYPES

CAUL/BROC	NO SIGNIFICANT DIFFERENCES		
GENERAL	CLAY	>	RECLAIMED
	GROCERY	>	RECLAIMED[2]
LEAFY	NO SIGNIFICANT DIFFERENCES		
ROOTS/TUBERS	NO SIGNIFICANT DIFFERENCES		
SEEDS/GRAINS	GROCERY	>	RECLAIMED
	CONTROL	>	RECLAIMED[1]
	CLAY	>	RECLAIMED

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 17

MULTIPLE COMPARISON ANALYSIS
FOOD LEAD-210
COMPARE FOOD TYPES WITHIN LAND TYPES

DEBRIS	NO SIGNIFICANT DIFFERENCES		
CLAY	LEAFY	>	ROOTS/TUBERS
	SEEDS/GRAINS	>	ROOTS/TUBERS
	CAUL/BROC	>	ROOTS/TUBERS
	GENERAL	>	ROOTS/TUBERS[2]
RECLAIMED	NO SIGNIFICANT DIFFERENCES		
GROCERY	NO SIGNIFICANT DIFFERENCES		
CONTROL	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 18

MULTIPLE COMPARISON ANALYSIS
FOOD LEAD-210
COMPARE LAND TYPES WITHIN FOODS

CABBAGE	DEBRIS	>	CLAY
MUSTARD GREENS	CLAY	>	DEBRIS
YELLOW CORN	GROCERY	>	RECLAIMED
	CLAY	>	RECLAIMED[1]
ALL OTHERS	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level

TABLE 19

MULTIPLE COMPARISON ANALYSIS
FOOD LEAD-210
COMPARE FOODS WITHIN LAND TYPES

DEBRIS	SPINACH	>	MUSTARD GREENS
	CABBAGE	>	CARROTS[2], MUSTARD GREENS
	LETTUCE	>	MUSTARD GREENS
	BROCCOLI	>	MUSTARD GREENS
	TURNIP GREENS	>	MUSTARD GREENS
	COLLARD GREENS	>	MUSTARD GREENS
	TURNIP ROOT	>	MUSTARD GREENS[2]
CLAY	SWISS CHARD	>	CABBAGE, TURNIP ROOT, CARROTS, YELLOW SQUASH
	SPINACH	>	CABBAGE[2], TURNIP ROOT, CARROTS, YELLOW SQUASH
	TURNIP GREENS	>	CABBAGE, TURNIP ROOT, CARROTS, YELLOW SQUASH
	PARSLEY	>	CABBAGE[2], TURNIP ROOT, CARROTS[1], YELLOW SQUASH
	RICE	>	TURNIP ROOT, CARROTS[1], YELLOW SQUASH
	STRAWBERRIES	>	TURNIP ROOT[1], CARROTS[1], YELLOW SQUASH[1]
	COLLARD GREENS	>	TURNIP ROOT[1], CARROTS[1], YELLOW SQUASH
	MUSTARD GREENS	>	CABBAGE, TURNIP ROOT, CARROTS, YELLOW SQUASH
	OKRA	>	TURNIP ROOT[2], CARROTS[2], YELLOW SQUASH[2]
	YELLOW CORN	>	YELLOW SQUASH[2]
	LETTUCE	>	TURNIP ROOT, CARROTS[2], YELLOW SQUASH[1]
	BROCCOLI	>	TURNIP GREENS[2], TURNIP ROOT[1], CARROTS[2], YELLOW SQUASH[1]
RECLAIMED	NO SIGNIFICANT DIFFERENCES		
GROCERY	YELLOW CORN	>	CUCUMBER[1], CARROTS[1]
	STRAWBERRIES	>	CUCUMBER[2], CARROTS[2],
	POTATOES	>	CUCUMBER[2], CARROTS[2]
CONTROL	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

Table 16 shows that the seeds/grains foods grown on control and clay land and from the grocery store samples have a significantly higher level of lead content than seeds/grains foods grown on reclaimed land. However, the validity of this result is questionable, since the number of reclaimed and control observations was small, and most were at or below the detection limit. The significant difference between grocery store and reclaimed lands for the general food type is at the 0.05 significance level, and is therefore even more questionable than the seeds and grains result.

Table 17 shows that food types grown on clay lands yield significant differences, with the roots/tubers food type ranking significantly lower than all others. Table 18 gives the significant comparisons between lands for a given food. Cabbage, mustard greens, and yellow corn yield significantly different levels of lead when grown on the various land types. The significant comparisons are few and reveal no overall pattern.

Table 19 lists the significant comparisons between foods for a given land. The food differences of significance were found mainly on the debris and clay lands. Remember that for lead-210, only a limited number of food samples were available from reclaimed lands and that no measurements *were* available from mineralized lands.

Examination of Table 19 reveals that among foods grown on debris land, spinach, cabbage, lettuce, broccoli, turnip greens, collard greens, and turnip roots exhibit higher levels of lead than mustard greens. This finding is of limited value, however, since it is based on only one mustard green sample.

Many foods grown on clay lands yielded significant differences. Notice that spinach, turnip greens, collard greens, lettuce, and broccoli again exhibit higher levels of lead-210. Interestingly, turnip roots, carrots, and yellow squash exhibit significantly lower levels and mustard greens significantly higher levels. The significant differences between foods from the grocery store samples are all at the 0.02 and 0.05 significance levels, and therefore are not discussed in any further detail.

Any summary of the lead results should be made with care since the number of samples was limited, producing a design that was extremely unbalanced. However, some patterns did emerge from the lands and foods sampled in this study. The clay lands exhibited significantly lower concentrations of lead for the roots/tubers foods versus all other food types. This result is supported by the specific food comparisons of turnip *roots* and carrots.

Polonium-210

The measurements of polonium-210 in foods were limited to grocery store, clay, debris and some reclaimed and control lands (no mineralized observations). The polonium-210 levels in food grown on control lands and from the grocery samples were always at or below the detection limit. Thirty-four percent of the clay, 43 percent of the reclaimed, and 58 percent of the debris land observations were at or below the detection limit. The necessity of estimating values for the detection limit observations coupled with the already small number of parcels with polonium measurements limited the power of the statistical tests. The adjusted geometric means are listed in Tables 20 and 21.

The ANOVA declared a difference between foods, with the multiple comparisons indicating that the differences occurred on the clay lands. Parsley, Swiss chard, spinach, turnip greens, lettuce, and mustard greens yielded higher mean concentrations. Notice that the leafy foods of spinach, turnip greens, and mustard greens yielded higher concentrations for all radionuclides. The ANOVA and multiple comparison results are listed in Tables 22 through 25.

TABLE 20

POLONIUM-210 IN FOODS (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND FOOD TYPE

FOOD TYPE	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC		0.500000				3.35703	0.500000
LEAFY		0.500000				5.07806	2.59916
SEEDS/GRAINS	0.500000	0.500000		0.500000	1.62122	1.72190	
ROOTS/TUBERS		0.500000			2.05100	1.32041	1.07983
GENERAL		0.500000			0.606995	0.962892	

TABLE 21

POLONIUM-210 IN FOODS (pCi/kg)
ADJUSTED GEOMETRIC MEANS
BY LAND TYPE AND SPECIFIC FOOD

FOOD TYPE	FOOD	CONTROL LAND	GROCERY SAMPLES	MINERALIZED LAND	UNMINED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND
CAUL/BROC	BROCCOLI		0.500000				3.35703	0.500000
	CAULIFLOWER							
LEAFY	CABBAGE		0.500000				0.7368	1.3345
	COLLARD GREENS		0.500000				0.5000	0.7257
	LETTUCE						7.5659	5.9963
	MUSTARD GREENS						5.3938	13.4870
	PARSLEY						34.1560	
	SPINACH						19.5702	28.1970
	SWISS CHARD						22.4004	
	TURNIP GREENS						18.8863	0.5000
SEEDS/GRAINS	LIMA BEANS							
	PEAS							
	RICE	0.500000			0.500000		0.50000	
	YELLOW CORN		0.500000			1.62122	5.92986	
ROOTS/TUBERS	CARROTS		0.500000				1.76106	2.33206
	RADISH							
	POTATOES		0.500000			2.05100		
	TURNIP ROOT		0.500000				1.21612	0.50000
GENERAL	CUCUMBER		0.500000					
	EGGPLANT							
	GREEN BEANS		0.500000					
	GREEN PEPPER							
	OKRA						1.07238	
	ONIONS							
	STRAWBERRIES		0.500000					
	TOMATO		0.500000					
	WATERMELON							
	YELLOW SQUASH		0.500000			0.736885	0.91241	
	ZUCCHINI					0.500000		

TABLE 22

MULTIPLE COMPARISON ANALYSIS
FOOD POLONIUM-210
COMPARE LAND TYPES WITHIN FOOD TYPES

LEAFY	CLAY	>	GROCERY[2]
ALL OTHERS	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 23

MULTIPLE COMPARISON ANALYSIS
FOOD POLONIUM-210
COMPARE FOOD TYPES WITHIN LAND TYPES

DEBRIS	NO SIGNIFICANT DIFFERENCES		
CLAY	LEAFY	>	ROOTS/TUBERS[1], GENERAL[2]
RECLAIMED	NO SIGNIFICANT DIFFERENCES		
GROCERY	NO SIGNIFICANT DIFFERENCES		
CONTROL	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

TABLE 24

MULTIPLE COMPARISON ANALYSIS
FOOD POLONIUM-210
COMPARE LAND TYPES WITHIN FOODS

TURNIP GREENS	CLAY	>	DEBRIS[1]
ALL OTHERS	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level

TABLE 25

MULTIPLE COMPARISON ANALYSIS
FOOD POLONIUM-210
COMPARE FOODS WITHIN LAND TYPES

DEBRIS	NO SIGNIFICANT DIFFERENCES		
CLAY	PARSLEY	>	CARROTS[2], TURNIP ROOT[1], YELLOW SQUASH[2], CABBAGE, COLLARD GREENS[1], RICE[1]
	SWISS CHARD	>	TURNIP ROOT[2], CABBAGE[1], COLLARD GREENS[2], RICE[2]
	SPINACH	>	TURNIP ROOT[2], CABBAGE[1], COLLARD GREENS[2], RICE[2]
	TURNIP GREENS	>	CARROTS[1], TURNIP ROOT, OKRA[2], YELLOW SQUASH[2], CABBAGE, COLLARD GREENS[1], RICE[1]
	LETTUCE	>	CABBAGE[2]
	MUSTARD GREENS	>	TURNIP ROOT[2], CABBAGE
RECLAIMED	NO SIGNIFICANT DIFFERENCES		
GROCERY	NO SIGNIFICANT DIFFERENCES		
CONTROL	NO SIGNIFICANT DIFFERENCES		

[1] Significant at 0.02 level
[2] Significant at 0.05 level

REGRESSION ANALYSIS INTRODUCTION

The intent of the regression analysis is to determine whether the food concentration content can be modeled as a function of the soil parameters, the land type, and the food type. Ideally, the value of the concentration in food could be projected by knowing only the soil characteristics and the food type.

A multiplicative model is postulated, which means that changes in the level of food concentration occur as multiples of changes in soil parameters. For example, a multiplicative model relating food radium to soil radium has the form:

$$\text{Food Radium} = a \times (\text{Soil Radium})^{b}$$

where a and b are constants to be estimated using available data. This is to be contrasted with the more common additive model, which has the form:

$$\text{Food Radium} = a + b \times (\text{Soil Radium})$$

The multiplicative model is generally more useful in biological and ecological modeling. The reasons are several: changes in biological parameters are often measured in terms of orders of magnitude, which is more consistent with multiplicative models. Also, the statistical support for multiplicative models is the lognormal distribution, which often more adequately fits biological parameters than the normal distribution, which is the support for additive models.

For each of the food radioactivity parameters (radium-226, polonium-210, and lead-210), the regression analysis followed approximately the same procedure. As an example, using food radium-226 as the dependent variable, the purpose of the regression analysis was to determine what other variables (independent variables) were related to food radium-226 and what model might best describe that relationship. First, an analysis was conducted which allowed only soil parameters (such as soil radium-226, pH, cation exchange capacity, etc.) as independent variables if they were statistically significant. Then the analysis allowed food type and soil parameters to enter the model. A third evaluation allowed only food type and soil radium-226 as independent variables. Then, a relationship was investigated which involved only food type and land type as the independent variables. Finally, food type, land type, and soil parameters were allowed to enter the model.

This procedure was repeated for polonium-210 and lead-210. Each analysis generated a family of equations which can be used to estimate food radioactivity concentrations for a variety of food types, land types, and soil parameters. It must be noted that the models which are presented are only a few of those which can be generated from the data. Also, the models are based on the specific data collected in this study, mostly from clay lands. Care must be exercised if they are used for foods, lands, or other parameters which are different from those specifically sampled in this study.

Radium-226 Results

A total of 88 observations were available for this analysis. Each observation includes measurements on the following parameters: food and soil radium (radium-226), food and soil polonium (polonium-210), food and soil lead (lead-210), cation exchange capacity (CEC), organic matter (OM), potassium (K), magnesium (Mg), calcium (Ca), pH, and hydrogen (H).

The radium measurements were made on 29 foods planted on 5 types of land. The matrix in Table 26 shows the number of measurements for each food and land type. Notice that the majority of the measurements were made on the clay lands and leafy foods.

Simple Correlations

The simple correlation matrix for the logarithmic transforms (consistent with the multiplicative model assumption) of food radium and soil parameters is shown in Table 27. The letter "L" preceding a parameter refers to the logarithm of the parameter. That is, L CEC refers to the logarithm of cation exchange capacity. Note that the simple correlation of food and soil radium is at 0.54, which is higher than any other soil parameter's correlation with food radium. The value is especially remarkable in light of the fact that this simple correlation does not take either the food or land type explicitly into account. Other statistically significant positive simple correlations with food radium include: potassium (0.32), pH (0.46), magnesium (0.31), calcium (0.25) and CEC (0.24). Two parameters are significantly negatively correlated with food radium: hydrogen (-0.34) and organic matter (-0.34).

Many of the soil parameters are significantly intercorrelated, indicating a kind of statistical "redundancy" in the parameters. This means that one must be cautious in the interpretation of the regression results: the fact that one soil parameter is excluded from a model does not necessarily imply that it is uncorrelated with the food radium. The intercorrelations may indicate that another parameter with which the excluded parameter is highly correlated is acting as its proxy in the model. For example, because soil radium content is so closely correlated with land type, the land type might replace soil radium in the model.

Stepwise Regression

A number of stepwise regression procedures were utilized *to* ascertain the models with the most power in this sample of 88 observations. Any model determined using stepwise regression may be significantly altered if a different sample is used; stepwise regression is most useful as a screening device to determine those factors most highly correlated with the dependent variable, food radium. One also learns about the intercorrelations among the parameters as the model becomes more complex.

TABLE 26

NUMBER OF OBSERVATIONS FOR RADIUM-226 REGRESSION

FOOD TYPE	FOOD	CONTROL LAND	MINERALIZED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND	TOTAL
CAUL/BROC	BROCCOLI		1		3	1	5
GENERAL	CUCUMBER	1		1			2
	OKRA				1		1
	STRAWBERRIES		1		1		2
	YELLOW SQUASH		2	2	2	1	7
	ZUCCHINI		2	3			5
GENERAL		1	5	6	4	1	17
LEAFY	CABBAGE				6	1	7
	COLLARD GREENS	1	2		1	2	6
	LETTUCE				3	1	4
	MUSTARD GREENS				8	1	9
	SPINACH	1	1		1		3
	TURNIP GREENS	2	1	1	8	1	13
LEAFY		4	4	1	27	6	42
ROOTS/TUBERS	CARROTS				2	1	3
	POTATOES			3			3
	TURNIP ROOT	1	1	1	8	2	13
ROOTS/TUBERS		1	1	4	10	3	19
SEEDS/GRAINS	RICE				1		1
	YELLOW CORN	1		2	1		4
SEEDS/GRAINS		1	0	2	2	0	5
TOTAL		7	11	13	46	11	88

TABLE 27

SIMPLE CORRELATION MATRIX FOR THE LOGARITHMIC TRANSFORMS

RADIUM-226

PEARSON CORRELATION COEFFICIENTS / PROB >]R] UNDER H0:RHO=0 / N = 88

	LFRA	LSRA	PH	H	LORGMAT	LCEC	LK	LMG	LCA
LFRA	1.00000	0.53600	0.46188	-0.33853	-0.33572	0.23875	0.32487	0.30726	0.25137
	0.0000	0.0001	0.0001	0.0013	0.0014	0.0251	0.0020	0.0036	0.0182
LSRA	0.53600	1.00000	0.59331	-0.31255	-0.55293	0.48827	0.52832	0.52093	0.48076
	0.0001	0.0000	0.0001	0.0030	0.0001	0.0001	0.0001	0.0001	0.0001
PH	0.46188	0.59331	1.00000	-0.56758	-0.43262	0.58826	0.56213	0.71665	0.64910
	0.0001	0.0001	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
H	-0.33853	-0.31255	-0.56758	1.00000	0.58255	0.10567	-0.04164	-0.09979	0.03837
	0.0013	0.0030	0.0001	0.0000	0.0001	0.3272	0.7001	0.3549	0.7227
LORGMAT	-0.33572	-0.55293	-0.43262	0.58255	1.00000	-0.00360	-0.08176	-0.03498	-0.03135
	0.0014	0.0001	0.0001	0.0001	0.0000	0.9735	0.4489	0.7463	0.7719
LCEC	0.23875	0.48827	0.58826	0.10567	-0.00360	1.00000	0.80247	0.85843	0.98141
	0.0251	0.0001	0.0001	0.3272	0.9735	0.0000	0.0001	0.0001	0.0001
LK	0.32487	0.52832	0.56213	-0.04164	-0.08176	0.80247	1.00000	0.83399	0.74372
	0.0020	0.0001	0.0001	0.7001	0.4489	0.0001	0.0000	0.0001	0.0001
LMG	0.30726	0.52093	0.71665	-0.09979	-0.03498	0.85843	0.83399	1.00000	0.81317
	0.0036	0.0001	0.0001	0.3549	0.7463	0.0001	0.0001	0.0000	0.0001
LCA	0.25137	0.48076	0.64910	0.03837	-0.03135	0.98141	0.74372	0.81317	1.00000
	0.0182	0.0001	0.0001	0.7227	0.7719	0.0001	0.0001	0.0001	0.0000

Any parameter that was statistically significant at the 0.15 level was admitted to the model. As soon as no new parameter can be added to the model at that level of significance, the variable selection stops. Note that a parameter may enter the model at an early step, and later be eliminated because its significance has dropped below the 0.15 level. This happens because different combinations of the intercorrelated parameters may result in dramatic changes in the pairwise relationships between food radium and any one parameter in the model.

Since pH is a function of hydrogen, hydrogen was not allowed to enter the stepwise regressions models. It was determined that of the two, pH was not only a better indicator of soil chemistry but also a more commonly measured parameter.

Soil Parameter Model

The first stepwise regression relates the food radium to the soil parameters, without regard to the food or land type. Table 28 shows that two parameters were significant: soil radium and pH. The estimated model is

$$\ln(FRa) = 0.37 + 0.39 \times \ln(SRa) + 0.29 \times pH + error$$

where FRa is the level of radium-226 in the food, and SRa is the level of radium-226 in the soil. Converting this logarithmic equation to the corresponding multiplicative model, the estimated model for calculating the radium-226 level in food becomes:

$$FRa = 1.45 \times SRa^{0.39} \quad e^{0.29 \times pH} \times error$$

where e = 2.71828..., the so called "natural number." The error term on the end of the model is included as a reminder that this equation is an estimate based on 88 sample points, and that the use of the model for estimating levels of food radium must be accompanied by a recognition of the potential error associated with such estimates.

The implication of this model is that food radium increases in proportion to roughly the square root of soil radium, and increases by additional pH in the soil, all other things held constant. This last phrase is an important constraint, since we have seen from the simple correlation matrix that the soil parameters are highly intercorrelated, implying that most of them vary together (either directly or inversely), so that "all other things held constant" is not a realistic condition to impose. Nevertheless, these data indicate that this relationship best describes the overall variation of food radium across all land types.

Figure 9 presents the food to soil radium regression equation, adjusting for the pH parameter in the model. Notice that the food radium increases more slowly than the soil radium (approximately as the square root), as implied by the regression coefficient between zero and one. The presence of the adjusted (to a common pH value) data values allows a visual assessment of the model's fit. The standard error of the model is

TABLE 28

STEPWISE REGRESSION
SOIL PARAMETER MODEL
RADIUM-226

R SQUARE = 0.31923572

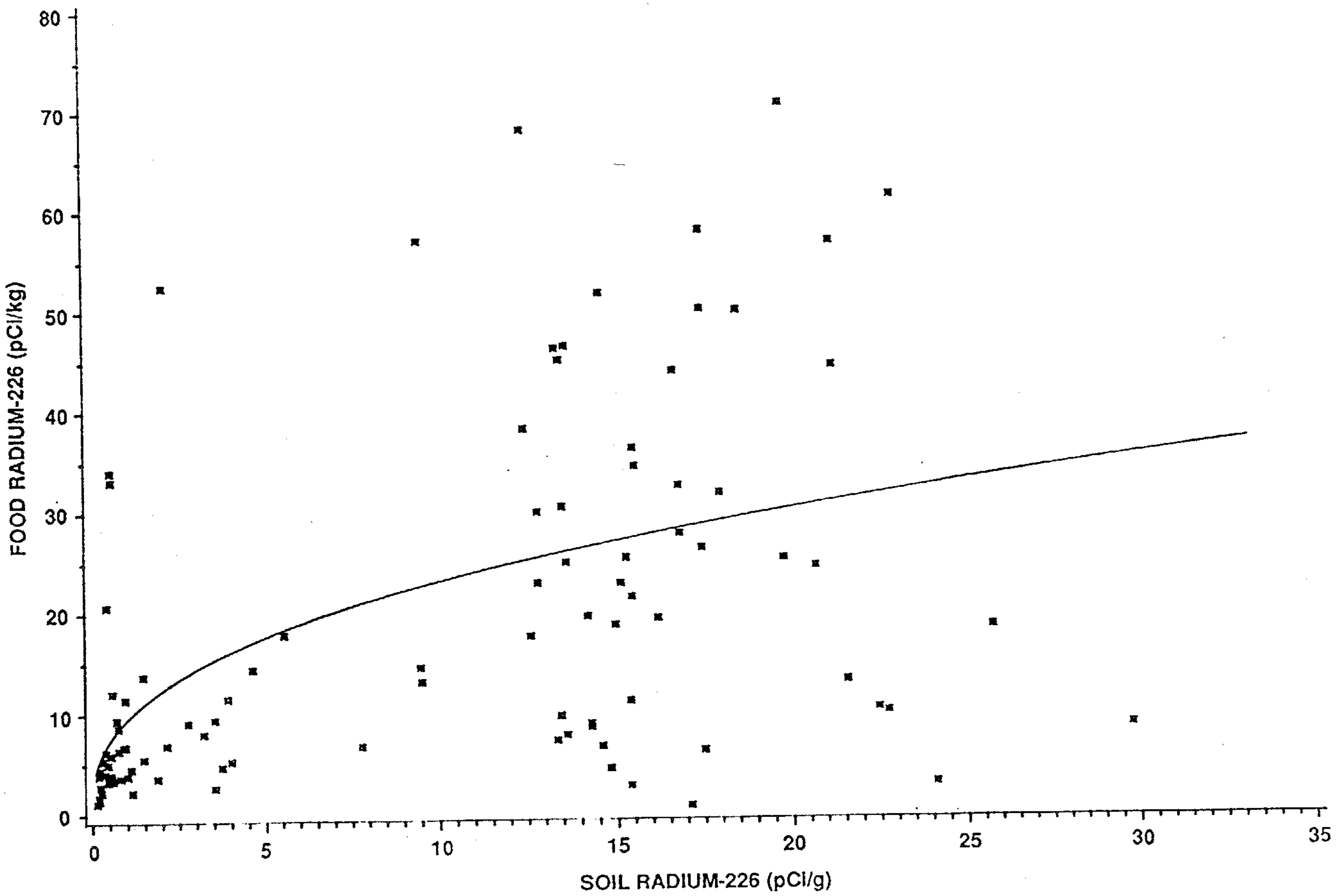
	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	45.08815841	22.54407920	19.93	0.0001
ERROR	85	96.14966440	1.13117252		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.36986332				
LSRA	0.38935500	0.10707405	14.95725481	13.22	0.0005
PH	0.29007117	0.14524722	4.51151425	3.99	0.0490

Figure 9

SOIL PARAMETER MODEL

Food Radium-226 (pCi/kg) vs Soil Radium-226 (pCi/g)
Adjusted for pH



the square root of the Mean Square Error given in Table 28. That is:

$$\begin{aligned} \mathit{Standard\ Error} &= \sqrt{\mathit{Mean\ Square\ Error}} \\ &= \sqrt{1.13117} = 1.06 \end{aligned}$$

To see how this affects the model's usefulness for estimation, we can calculate an approximate 95 percent confidence factor by exponentiating twice the standard error:

$$\begin{aligned} 95\ \%\ \mathit{Confidence\ Factor} &= e^{2 \times (\mathit{Std.\ error})} \\ &= e^{2.12} = 8.39 \end{aligned}$$

This factor implies that one can be approximately 95 percent confident that the true food radium content will be within the interval:

$$\frac{\mathit{Estimated\ Value}}{8.39} < \mathit{True\ Value} < \mathit{Estimated\ Value} \times 8.39$$

The multiple R-square for this model is 0.32, indicating that this model accounts for 32 percent of the total sample variability in food radium.

Thus the food radium model over all land and food types shows a significant positive correlation with soil radium and soil pH. The utility of the model for estimation is limited, however, since it accounts for only 32 percent of the observed variability in food radium, and the 95 percent confidence factor exceeds 8. We next try to improve the model by accounting for the specific food type in which the radium is measured.

Food Type and Soil Parameter Model

The next model is shown in Table 29, wherein the food type is taken into account prior to the introduction of the soil parameters. This has the effect of accounting for the mean level of food radium in each food type prior to introducing the soil parameters into the model. A convenient way of interpreting effects of the soil parameters in this model is that they are adjustments to the mean levels found in each food type.

The net effect of the introduction of food type to the model is that five different models are estimated, one for each food type, as follows:

$$\begin{aligned} &\mathit{Leafy}: && \mathit{FRa} = 3.29 \times \mathit{SRa}^{0.41} \times \mathit{CEC}^{-0.28} \times e^{0.36 \times pH} \times \mathit{error} \\ &\mathit{Roots/Tubers}: && \mathit{FRa} = 1.28 \times \mathit{SRa}^{0.41} \times \mathit{CEC}^{-0.28} \times e^{0.36 \times pH} \times \mathit{error} \\ &\mathit{Caul/Broc}: && \mathit{FRa} = 1.21 \times \mathit{SRa}^{0.41} \times \mathit{CEC}^{-0.28} \times e^{0.36 \times pH} \times \mathit{error} \\ &\mathit{General}: && \mathit{FRa} = 1.11 \times \mathit{SRa}^{0.41} \times \mathit{CEC}^{-0.28} \times e^{0.36 \times pH} \times \mathit{error} \\ &\mathit{Seeds/Grains}: && \mathit{FRa} = 0.68 \times \mathit{SRa}^{0.41} \times \mathit{CEC}^{-0.28} \times e^{0.36 \times pH} \times \mathit{error} \end{aligned}$$

TABLE 29

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER MODEL
RADIUM-226

R SQUARE = 0.51190945

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	72.30097680	10.32871097	11.99	0.0001
ERROR	80	68.93684601	0.86171058		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.19116934				
CABR	-1.00195069	0.44881018	4.29465940	4.98	0.0284
GNRL	-1.08756680	0.28574106	12.48325998	14.49	0.0003
RTTB	-0.94196158	0.25823193	11.46589373	13.31	0.0005
SDGR	-1.59108891	0.44018972	11.25824096	13.06	0.0005
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LSRA	0.40466817	0.09809378	14.66481511	17.02	0.0001
LCEC	-0.28115977	0.12532320	4.33715415	5.03	0.0276
PH	0.35672280	0.14107654	5.50951784	6.39	0.0134

These models imply that food radium still varies roughly as the square root of soil radium. Additionally, food radium appears to decrease by additional CEC in the soil. Finally, the addition of pH to the soil increases the amount of radium in the food.

Note that the only difference among the models is that the leading constant differs; the exponents of the soil parameters in the model are the same for all models. This is an assumption associated with this no <u>interaction</u> model; we will examine <u>interaction</u> models, allowing varying parameter coefficients and exponents, in a later section. These leading constants imply that the leafy vegetables are associated with the highest geometric mean level of food radium, with all cauliflower/broccoli, roots and tubers, and general food types significantly less on the average. Seeds and grains exhibit the lowest mean levels.

Figure 10 shows the regression equation for each food type adjusted for the CEC and pH parameters in the model. Notice how the estimate of food radium depends roughly on the square root of the soil radium, and how the level of soil radium varies among food types. This model accounts for significantly more variability than the previous one, with a model R-square of 51 percent. However, the 95 percent confidence factor is still relatively high, at 6.40.

<u>Food Type and Soil Radium</u>

A regression allowing only food type and soil radium in the model is given in Table 30. The estimated models are similar to the above, with the leafy vegetables again associated with the highest geometric mean level of food radium and the coefficient for soil radium approximately the same.

Leafy: $FRa = 14.08 \times SRa^{0.46} \times error$
Caul/Broc: $FRa = 6.22 \times SRa^{0.46} \times error$
Roots/Tubers: $FRa = 5.45 \times SRa^{0.46} \times error$
General: $FRa = 5.24 \times SRa^{0.46} \times error$
Seeds/Grains: $FRa = 2.74 \times SRa^{0.46} \times error$

This model is clearly an improvement over the traditional plant:soil ratios. The model accounts for 46 percent of the total sample variability in food radium, with a 95 percent confidence factor of 6.8.

<u>Food Type and Land Type Model</u>

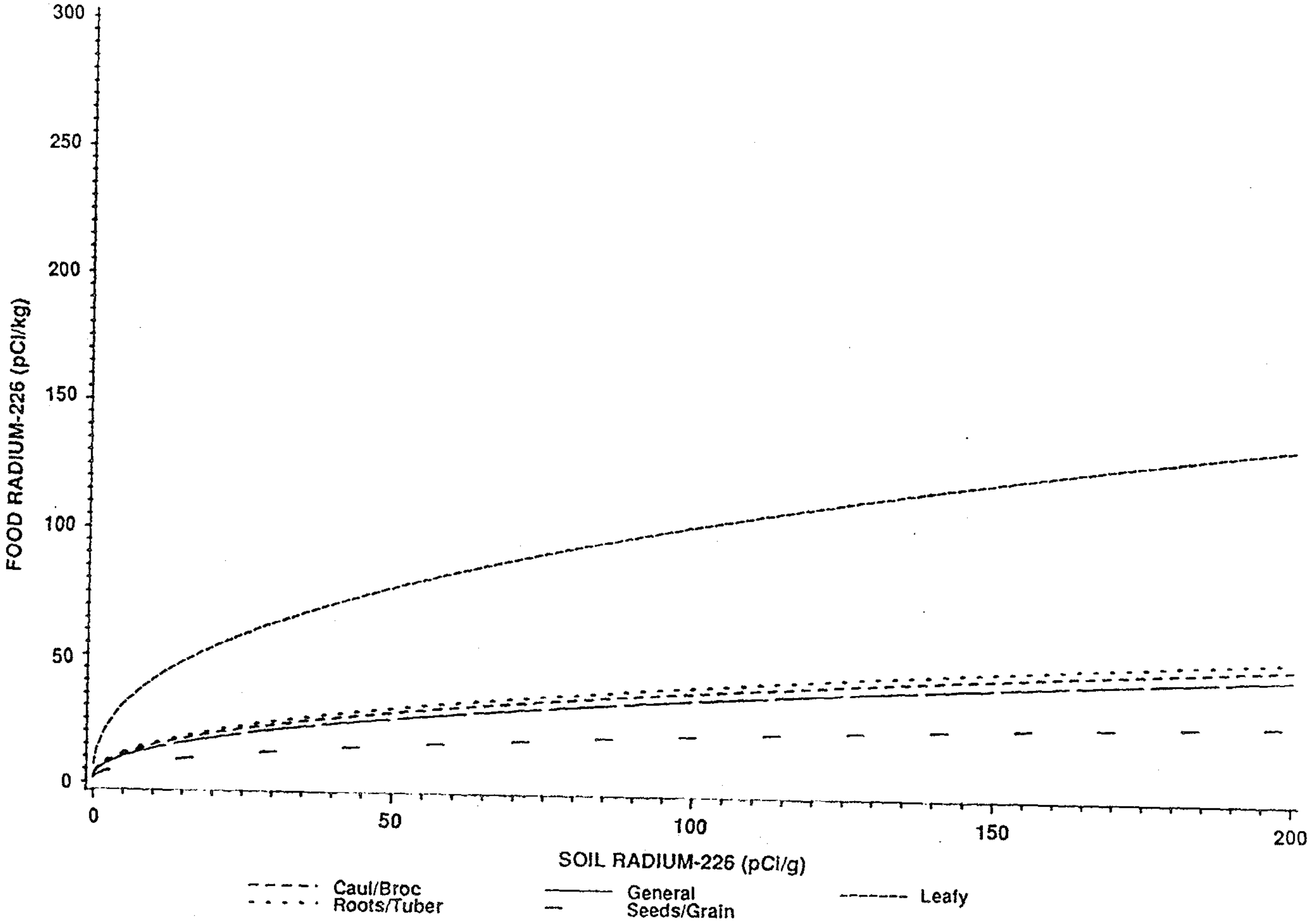
The stepwise regression relating food radium as a function of only food type and land type is given in Table 31. Since no soil parameters are considered in this model, the estimated models are constants differing by the food and land type times the error term. The constants and therefore the estimated values are given in Table 32.

Figure 10

FOOD TYPE AND SOIL PARAMETER MODEL

Food Radium-226 (pCi/kg) vs Soil Radium-226 (pCi/g)

Adjusted Regression Lines



```
                         STEPWISE REGRESSION
                FOOD TYPE AND SOIL RADIOACTIVITY MODEL
                             RADIUM-226

R SQUARE = 0.46281071

                   DF       SUM OF SQUARES      MEAN SQUARE         F     PROB>F

REGRESSION          5          65.36637700      13.07327540     14.13     0.0001
ERROR              82          75.87144581       0.92526153
TOTAL              87         141.23782281

                      B VALUE       STD ERROR      TYPE II SS         F     PROB>F

INTERCEPT          2.64488048
CABR              -0.81709295      0.45507676      2.98289600      3.22     0.0763
GNRL              -0.98896764      0.28983532     10.77273725     11.64     0.0010
RTTB              -0.94962005      0.26595887     11.79601483     12.75     0.0006
SDGR              -1.63577660      0.45506561     11.95540939     12.92     0.0006
LEFY               0.00000000      0.00000000      0.00000000      0.00     1.0000
LSRA               0.46138818      0.08212809     29.20209513     31.56     0.0001
```

TABLE 31

STEPWISE REGRESSION
FOOD TYPE AND LAND TYPE MODEL
RADIUM-226

R SQUARE = 0.49948824

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	70.54663214	8.81832902	9.85	0.0001
ERROR	79	70.69119067	0.89482520		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.99673583				
CABR	-0.93155820	0.45033168	3.82906901	4.28	0.0419
GNRL	-0.99020651	0.30418147	9.48253084	10.60	0.0017
RTTB	-0.92544241	0.26827185	10.64846018	11.90	0.0009
SDGR	-1.15793066	0.46661265	5.51049106	6.16	0.0152
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	0.93207852	0.32999934	7.13866594	7.98	0.0060
CTRL	-1.01147968	0.45960247	4.33398912	4.84	0.0307
DEBR	1.12355635	0.41527137	6.55034144	7.32	0.0083
MINL	-0.24816172	0.40125490	0.34226864	0.38	0.5380
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000

Table 32

Food-Type/Land-Type Model
Radium-226

Food Type	Land Type				
	Debris	Clay	Reclaimed	Mineralized	Control
Leafy	61.58	50.85	20.02	15.62	7.28
Caul/Broc	24.26	20.03	7.89	6.15	2.87
Roots/Tubers	24.41	20.15	7.94	6.19	2.89
General	22.88	18.89	7.44	5.80	2.70
Seeds/Grains	19.34	15.97	6.29	4.91	2.29

These results are in general agreement with the ANOVA results previously discussed. The debris lands are associated with the highest geometric mean levels of food radium, followed closely by the clay lands. The leafy vegetables are again associated with the highest geometric mean level of food radium, even when grown on the control lands. The model accounts for 50 percent of the total sample variability in food radium, with a 95 percent confidence factor of 6.6. This model accounts for only one percent less variability than the food type and soil parameter model. The following food type, land type, and soil parameter model investigates the possible correlation between the land type and soil radium content.

Food Type Land Type and Soil Parameter Models

The next regression model takes the mean levels of both food type and land type into account prior to testing the soil parameters for their contribution to the model. An example of the estimated models is given below for the food type caul/broc, and for all land types. These results are derived from the regression analysis given in Table 33 and can be produced for all food type and land type combinations.

CAUL/BROC *DEBRIS* $FRa = 3.20 \times OM^{0.82} \times Mg^{-0.30} \times e^{0.47 \times pH} \times error$

CLAY $FRa = 3.01 \times OM^{0.82} \times Mg^{-0.30} \times e^{0.47 \times pH} \times error$

RECLAIMED $FRa = 1.03 \times OM^{0.82} \times Mg^{-0.30} \times e^{0.47 \times pH} \times error$

MINERALIZED $FRa = 0.59 \times OM^{0.82} \times Mg^{-0.30} \times e^{0.47 \times pH} \times error$

CONTROL $FRa = 0.20 \times OM^{0.82} \times Mg^{-0.30} \times e^{0.47 \times pH} \times error$

STEPWISE REGRESSION
FOOD TYPE, LAND TYPE, AND SOIL PARAMETER MODEL
RADIUM-226

R SQUARE = 0.55814830

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	78.83165121	7.16651375	8.73	0.0001
ERROR	76	62.40617160	0.82113384		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.55338474				
CABR	-1.08649033	0.43766272	5.06041997	6.16	0.0153
GNRL	-1.08703593	0.29468322	11.17354347	13.61	0.0004
RTTB	-1.06981163	0.26342921	13.54255828	16.49	0.0001
SDGR	-1.36689510	0.45411044	7.43980162	9.06	0.0035
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	1.63364624	0.56795877	6.79354368	8.27	0.0052
CTRL	-1.07696963	0.52021853	3.51924273	4.29	0.0418
DEBR	1.69515499	0.44748509	11.78353596	14.35	0.0003
RECL	0.56584523	0.40299270	1.61888090	1.97	0.1644
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000
LORGMAT	0.81644592	0.32027532	5.33607400	6.50	0.0128
LMG	-0.29773763	0.15174079	3.16138028	3.85	0.0534
PH	0.46733010	0.18413758	5.28903714	6.44	0.0132

The model coefficients reveal about the same results for the food type effects. The soil type coefficients reveal that the control samples have the lowest average levels of food radium,followed by the mineralized samples. The reclaimed samples are next, and the clay and debris samples are significantly higher than all others. These results are generally consistent with the ANOVA results described in previous sections. Three soil parameters are significant after the food and land type have been taken into account: organic matter, magnesium, and pH. Interestingly, the soil radium does not contribute significantly once the soil type has been introduced, probably because the land type is a proxy for the soil radium level. That is, because soil radium content is so closely correlated with land type, the land type replaces soil radium in the model. Organic matter and pH are positively correlated, while the magnesium parameter is negatively correlated after food and land type are in the model. The R-square value for this model is at 56 percent, with the 95 percent confidence factor still high at 6.12.

Interaction Models

The previous models have postulated relationships between the amount of food radium found in foods and the various soil parameters found to be significantly correlated with food radium. Because the soil parameters were introduced independently of the food type and land type, the above models all tacitly assume that the relationships found between food radium and the soil parameters are the same for each food and land type. That is, although the introduction of food and land type adjusts the level of the food radium geometric mean, the slopes of the relationships with the soil parameters are assumed to be constant across both food and land type.

To determine whether the assumption of constant slopes (in the log-log domain) is reasonable, we must introduce interaction into the models. Interaction terms permit the slopes of the relationships between food radium and soil parameters to differ for different food and land types. For example, the relationship between food radium and soil radium might be stronger (i.e., a greater slope) for leafy vegetables than for other food types. This can only be examined by interacting soil radium with food type.

The first interaction model, shown in Table 34, forces food type into the model, and then enables stepwise selection from any soil parameter and any of the pairwise interactions between the soil parameters and the food types. Examination of the selected variables reveals that soil radium and pH again appear in the model, with food radium still varying approximately as the square root of each. Soil radium and pH do not appear in the model with an interaction term indicating the same positive relationship for all food types.

Cation exchange capacity, organic matter, and magnesium appear in the model with interaction terms. The CEC soil parameter is present interacting with the caul/broc food type (LCECCABR). CEC has a negative correlation with food radium for caul/broc.

TABLE 34

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER INTERACTION MODEL
RADIUM-226

R SQUARE = 0.57773949

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	10	81.59866814	8.15986681	10.54	0.0001
ERROR	77	59.63915467	0.77453448		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.80034729				
CABR	-2.55058955	1.11347681	4.06405475	5.25	0.0247
GNRL	-3.72095324	0.82426650	15.78388403	20.38	0.0001
RTTB	-4.38941361	0.94592474	16.67787034	21.53	0.0001
SDGR	-2.07678452	1.67492473	1.19078413	1.54	0.2188
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LCECCABR	-0.57426920	0.34339154	2.16617036	2.80	0.0985
LORGRTTB	0.69965024	0.40929916	2.26319004	2.92	0.0914
LMGLEFY	-0.47766897	0.13217194	10.11617398	13.06	0.0005
LMGSDGR	-0.39244991	0.24265940	2.02588585	2.62	0.1099
LSRA	0.43672260	0.09376613	16.80196567	21.69	0.0001
PH	0.42879157	0.13175283	8.20376642	10.59	0.0017

The roots/tubers food type is present in an interaction term with organic matter (LORGRTTB). Organic matter has a positive correlation with food radium for roots/tubers.

Two magnesium interactions are present in this model. The first with the leafy food type reveals a negative relationship between food radium and magnesium (LMGLEFY), and the second also shows a negative relationship between these parameters for the seeds/grains food type (LMGSDGR). Thus, the relationship between radium in the food and magnesium in the soil depends on the food type. This model has an overall R-square of 58 percent, with a 95 percent confidence factor of 5.8.

A second interaction model is presented in Table 35. In this model both food type and land type are forced into the model prior to the introduction of the interaction between the soil parameters and the food types. As in the similar non-interaction model (Table 33), no soil radium terms are found significant. Again, the land types apparently act as a sufficient proxy for this parameter.

Magnesium and pH now appear with interaction effects while organic matter is introduced having the same positive correlation over all food and land types. Magnesium is significantly positively correlated with food radium for the general food type and negatively correlated for the leafy food type, as in the previous interaction model. The leafy food type also interacts with pH, being significantly positively correlated with food radium. The model's R-square is 60 percent, with a 95 percent confidence factor of 5.7.

Great care must be exercised in the interpretation of these interaction models. The introduction of interaction terms creates even more intercorrelation among the parameters, and thus increases the possibility of redundancy and substitutability of variables. It is often tempting to over-interpret these somewhat complex models, assuming that terms not included are unimportant. Therefore, these interaction models are not necessarily used for the estimation of radium in food, but for the investigation of the relationship between food radium and the soil parameters dependent upon the food type.

Calcium Models

Soil calcium is generally considered to have a significant, negative influence on the uptake of radium-226 by plants. Surprisingly, in the analysis of the data from this study, soil calcium was not found to be statistically significant in the stepwise regression analyses. It is possible that the calcium effect is proxied by some other parameter. Because it is generally accepted that calcium does indeed affect radium uptake, an analysis was conducted which forced it into a food type model. This analysis suggests that soil calcium has a negative influence comparable in magnitude to soil magnesium. The model is shown in Table 36. The regression equations are as follows:

TABLE 35

STEPWISE REGRESSION
FOOD TYPE, LAND TYPE, AND SOIL PARAMETER INTERACTION MODEL
RADIUM-226

R SQUARE = 0.59740347

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	12	84.37596594	7.03133050	9.27	0.0001
ERROR	75	56.86185687	0.75815809		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.66101906				
CABR	-0.38393012	1.29577058	0.06655917	0.09	0.7678
GNRL	-2.24959634	1.47053020	1.77427556	2.34	0.1303
RTTB	-0.45207961	1.25401329	0.09853382	0.13	0.7195
SDGR	-0.87568860	1.28714300	0.35091793	0.46	0.4984
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	1.46417569	0.42748419	8.89418278	11.73	0.0010
CTRL	-0.79127165	0.50842274	1.83637366	2.42	0.1238
DEBR	1.46898989	0.41958959	9.29282978	12.26	0.0008
RECL	0.56273048	0.38950001	1.58250721	2.09	0.1527
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000
LMGLEFY	-0.47498301	0.16474296	6.30234519	8.31	0.0051
LMGGNRL	0.35061348	0.18978623	2.58754320	3.41	0.0686
PHLEFY	0.52167103	0.20284850	5.01429173	6.61	0.0121
LORGMAT	0.47201585	0.28397827	2.09460788	2.76	0.1007

TABLE 36

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER MODEL
RADIUM-226
(Calcium Model)

R SQUARE = 0.53443751

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	9	75.48279063	8.38697674	9.95	0.0001
ERROR	78	65.75503218	0.84301323		
TOTAL	87	141.23782281			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.21648113				
CABR	-1.06830823	0.44474579	4.86411523	5.77	0.0187
GNRL	-1.10767180	0.28407203	12.81739134	15.20	0.0002
RTTB	-1.02427684	0.26103323	12.98008431	15.40	0.0002
SDGR	-1.78592438	0.45077261	13.23260905	15.70	0.0002
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LSRA	0.52225949	0.11812932	16.47751398	19.55	0.0001
PH	0.60901781	0.18389945	9.24556671	10.97	0.0014
LORGMAT	0.48857424	0.26666695	2.82980900	3.36	0.0707
LCA	-0.23176628	0.15420543	1.90430071	2.26	0.1369
LMG	-0.22118167	0.15144296	1.79818537	2.13	0.1482

Leafy: $FRa = 3.38 \times SRa^{0.52} \times e^{0.61 \times pH} \times OM^{0.49} \times Ca^{-0.23} \times Mg^{-0.22} \times error$

Roots/Tubers: $FRa = 1.21 \times SRa^{0.52} \times e^{0.61 \times pH} \times OM^{0.49} \times Ca^{-0.23} \times Mg^{-0.22} \times error$

Caul/Broc: $FRa = 1.16 \times SRa^{0.52} \times e^{0.61 \times pH} \times OM^{0.49} \times Ca^{-0.23} \times Mg^{-0.22} \times error$

General: $FRa = 1.11 \times SRa^{0.52} \times e^{0.61 \times pH} \times OM^{0.49} \times Ca^{-0.23} \times Mg^{-0.22} \times error$

Seeds/Grains: $FRa = 0.57 \times SRa^{0.52} \times e^{0.61 \times pH} \times OM^{0.49} \times Ca^{-0.23} \times Mg^{-0.22} \times error$

Both calcium and magnesium appear in the model at relatively high significance levels of 0.14 and 0.15, respectively. The coefficients are both negative with food radium appearing to decrease by additional calcium and magnesium in the soil. Soil radium and pH are highly significant at the 0.01 level, with organic matter significant at 0.08. This model accounts for approximately the same amount of variability as the previously discussed models. The R-square is 53 percent, generating a 95 percent confidence factor of 6.3.

Discussion

We should examine all the models discussed, and try to see whether certain patterns repeat often enough to warrant further investigation. First, none of the models has great estimating power. Even the most complex model has a standard error of 0.87, which means that if the model were to be used to estimate the level of food radium in some future sample, the range of potential error would be a factor of 6. That is, an estimation of 8 pCi/kg would have a 95 percent confidence interval of approximately 1 to 48. Note also that the model could only be used for samples drawn from locations similar to those utilized in this study, for foods grown in this study, and for methods of analysis identical to those used in this study.

Despite the failure of the model to provide precise estimations, several interesting patterns emerged from the analysis. The correlation of food radium-226 and soil radium-226 is quite strong, and strongest for leafy foods. The models show that food radium increases in proportion to roughly the square root of soil radium. However, when land type is introduced into the model first, the soil radium level becomes redundant and is dropped from the model.

The soil parameter pH is always found in the model, with the correlation consistently being positive with food radium. The models imply that with the addition of pH, the food radium concentration increases. Organic matter, magnesium,and cation exchange capacity also appear in several models,with organic matter always positively correlated with food radium. Both of the stepwise interaction models show a significant negative correlation between magnesium and food radium for the leafy food type.

Lead-210 Results

A total of 62 observations were available for the lead-210 analysis. The matrix in Table 37 shows the number of measurements for each food and land type. Notice that there are no measurements for the control and mineralized lands and that the majority of the measurements were of leafy foods on clay lands. This limits the usefulness of the lead-210 models since they are based on a narrow range of lead results.

Simple Correlations

The simple correlation matrix for the logarithmic transforms of food lead and soil parameters is shown in Table 38. The simple correlation of food and soil lead is at 0.29, the only statistically significant correlation between food lead and the soil parameters. The other soil parameter with a correlation exceeding 0.1 (in absolute value) is organic matter at -0.13.

Stepwise Regression

The regression methodology used for the analysis of lead was the same as that used for the radium analysis. That is, the same models have been analyzed and are discussed in the following sections.

Soil Parameter Model

The first stepwise regression relates food lead to the soil parameters, without regard to the food or land type. Table 39 shows that only soil lead was significant at the 0.15 level. The estimated model is

$$FPb = 0.575 \times SPb^{1.03} \times error$$

The model shows a significant positive relationship between food lead and soil lead. The slope is positive, as was indicated by the simple correlation. This model also indicates that as soil lead increases, so does lead in the food, roughly a one-to-one correspondence. The R-square for this model is 0.08, indicating that only 8 percent of the total sample variability of the lead measurements is accounted for by this simple model. The use of this model is extremely limited since the model accounts for only 8 percent of the observed variability in food lead, and the 95 percent confidence factor is 30.

Figure 11 gives the regression equation in the log domain. Notice the clustering of the soil lead values between 2.5 and 4.0. This illustrates the fact that the soil lead samples are primarily from the clay lands. Therefore the regression models will be limited since the variability in the soil lead reflects samples from clay lands only and the results are limited in range.

TABLE 37

NUMBER OF OBSERVATIONS FOR LEAD-210 REGRESSION

FOOD TYPE	FOOD	CONTROL LAND	MINERALIZED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND	TOTAL
CAUL/BROC	BROCCOLI				3	1	4
GENERAL	OKRA				1		1
	STRAWBERRIES				1		1
	YELLOW SQUASH			1	2		3
	ZUCCHINI			1			1
GENERAL		0	0	2	4	0	6
LEAFY	CABBAGE				6	1	7
	COLLARD GREENS				1	2	3
	LETTUCE				3	1	4
	MUSTARD GREENS				8	1	9
	PARSLEY				1		1
	SPINACH				1	1	2
	SWISS CHARD				1		1
	TURNIP GREENS				8	1	9
LEAFY		0	0	0	29	7	36
ROOTS/TUBERS	CARROTS				2	1	3
	POTATOES			1			1
	TURNIP ROOT				8	1	9
ROOTS/TUBERS		0	0	1	10	2	13
SEEDS/GRAINS	RICE				1		1
	YELLOW CORN			1	1		2
SEEDS/GRAINS		0	0	1	2	0	3
TOTAL		0	0	4	48	10	62

TABLE 38

SIMPLE CORRELATION MATRIX FOR THE LOGARITHMIC TRANSFORMS

LEAD-210

PEARSON CORRELATION COEFFICIENTS / PROB >]R] UNDER HO:RHO=0 / N = 62

	LFPB	LSPB	PH	H	LORGMAT	LCEC	LK	LMG	LCA
LFPB	1.00000	0.28577	0.07233	0.03157	-0.12888	-0.05543	-0.00132	0.01847	-0.08767
	0.0000	0.0244	0.5764	0.8075	0.3181	0.6687	0.9918	0.8867	0.4981
LSPB	0.28577	1.00000	0.11991	0.08680	0.00574	0.00608	-0.19090	0.08816	0.02293
	0.0244	0.0000	0.3533	0.5023	0.9647	0.9626	0.1372	0.4956	0.8596
PH	0.07233	0.11991	1.00000	-0.72535	-0.34702	0.40387	0.24411	0.48346	0.46401
	0.5764	0.3533	0.0000	0.0001	0.0057	0.0011	0.0559	0.0001	0.0001
H	0.03157	0.08680	-0.72535	1.00000	0.20632	0.01480	0.09502	-0.04518	-0.08158
	0.8075	0.5023	0.0001	0.0000	0.1076	0.9091	0.4626	0.7273	0.5285
LORGMAT	-0.12888	0.00574	-0.34702	0.20632	1.00000	-0.01311	-0.10781	0.02601	-0.05198
	0.3181	0.9647	0.0057	0.1076	0.0000	0.9195	0.4042	0.8410	0.6883
LCEC	-0.05543	0.00608	0.40387	0.01480	-0.01311	1.00000	0.80550	0.78551	0.97073
	0.6687	0.9626	0.0011	0.9091	0.9195	0.0000	0.0001	0.0001	0.0001
LK	-0.00132	-0.19090	0.24411	0.09502	-0.10781	0.80550	1.00000	0.76176	0.69676
	0.9918	0.1372	0.0559	0.4626	0.4042	0.0001	0.0000	0.0001	0.0001
LMG	0.01847	0.08816	0.48346	-0.04518	0.02601	0.78551	0.76176	1.00000	0.66376
	0.8867	0.4956	0.0001	0.7273	0.8410	0.0001	0.0001	0.0000	0.0001
LCA	-0.08767	0.02293	0.46401	-0.08158	-0.05198	0.97073	0.69676	0.66376	1.00000
	0.4981	0.8596	0.0001	0.5285	0.6883	0.0001	0.0001	0.0001	0.0000

TABLE 39

STEPWISE REGRESSION
SOIL PARAMETER MODEL
LEAD-210

R SQUARE = 0.08166580

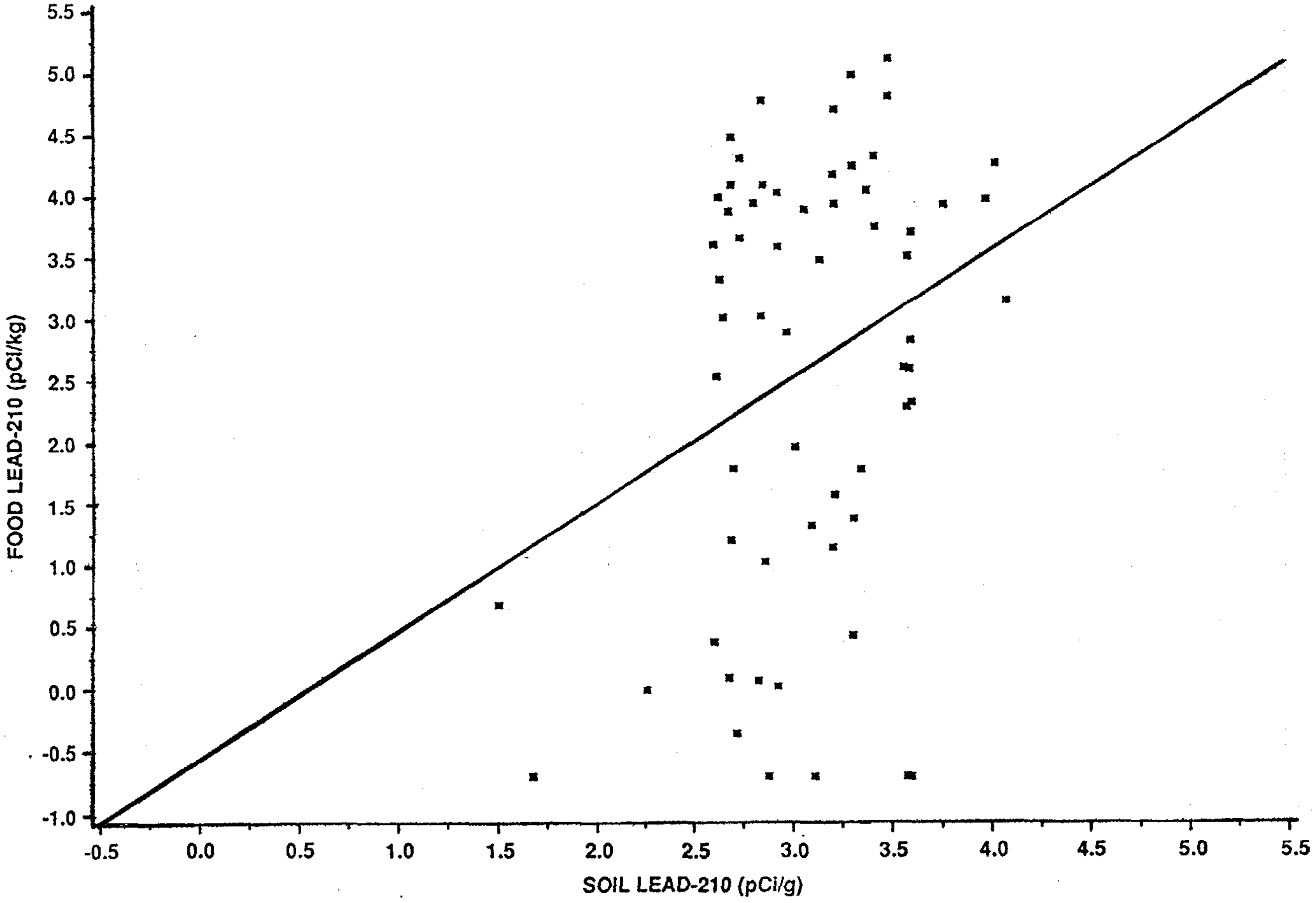
	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	15.31981483	15.31981483	5.34	0.0244
ERROR	60	172.27174788	2.87119580		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-0.55370678				
LSPB	1.02630956	0.44430686	15.31981483	5.34	0.0244

Figure 11

SOIL PARAMETER MODEL

Food Lead-210 (pCi/kg) vs Soil Lead-210 (pCi/g)
Log Domain



Food Type and Soil Parameter Model

The next model is shown in Table 40, wherein the food type is taken into account prior to the introduction of the soil parameters. Examination of Table 40 reveals that after food type has been taken into account, no soil parameters are statistically correlated with food lead. The model coefficients imply that the leafy vegetables are associated with the highest geometric mean level of food lead. This finding is in agreement with the food type and soil parameter model for radium. The caul/broc food type has the next highest geometric mean level of food lead, with the seeds and grains next, and the general and roots/tubers food types having the lowest mean levels of food lead. The model's R-square is 38 percent with a 95 percent confidence factor of 18.

Food Type and Soil Lead

A regression allowing only food type and soil lead in the model is given in Table 41. We know from the previous regression that the soil lead effect will not be significant at the 0.15 level. Investigation of Table 41 shows that soil lead is significant at the 0.29 level. The estimated models are:

Leafy: $FPb = 6.87 \times SPb^{0.47} \times error$

Caul/Broc: $FPb = 5.03 \times SPb^{0.47} \times error$

Roots/Tubers: $FPb = 0.71 \times SPb^{0.47} \times error$

General: $FPb = 0.87 \times SPb^{0.47} \times error$

Seeds/Grains: $FPb = 1.67 \times SPb^{0.47} \times error$

These models imply that food lead varies roughly as the square root of soil lead. The leading constants imply that leafy vegetables are indeed associated with the highest geometric mean level of food lead. This model accounts for 39 percent of the variability, only one percent more than the previous model. The 95 percent confidence factor is still high at 17.

Food Type and Land Type Model

The stepwise regression relating food lead as a function of only food type and land type is given in Table 42. Since no soil parameters are considered in this model, the estimated models are constants differing by the land and food type times the error term. The constants and therefore the estimated values are given in Table 43.

TABLE 40

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER MODEL
LEAD-210

R SQUARE = 0.37704799

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	70.73102135	17.68275534	8.62	0.0001
ERROR	57	116.86054136	2.05018494		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3.40412301				
CABR	-0.29727750	0.75464947	0.31814609	0.16	0.6951
GNRL	-2.36639801	0.63138504	28.79917481	14.05	0.0004
RTTB	-2.34478443	0.46330996	52.51164417	25.61	0.0001
SDGR	-1.35909481	0.86043277	5.11515332	2.49	0.1197
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000

TABLE 41

STEPWISE REGRESSION
FOOD TYPE AND SOIL RADIOACTIVITY MODEL
LEAD-210

R SQUARE = 0.39120350

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	73.38647589	14.67729518	7.20	0.0001
ERROR	56	114.20508682	2.03937655		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.92656008				
CABR	-0.31060819	0.75274827	0.34723516	0.17	0.6815
GNRL	-2.06619771	0.68246417	18.69310550	9.17	0.0037
RTTB	-2.26606561	0.46720816	47.97572399	23.52	0.0001
SDGR	-1.41463657	0.85954099	5.52400421	2.71	0.1054
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LSPB	0.46738991	0.40959874	2.65545454	1.30	0.2587

TABLE 42

STEPWISE REGRESSION
FOOD TYPE AND LAND TYPE MODEL
LEAD-210

R SQUARE = 0.44633753

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	83.72915518	13.95485920	7.39	0.0001
ERROR	55	103.86240753	1.88840741		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.34031430				
CABR	-0.31868162	0.72476173	0.36510621	0.19	0.6619
GNRL	-1.62851883	0.66805086	11.22179207	5.94	0.0180
RTTB	-2.17615109	0.44928058	44.30354694	23.46	0.0001
SDGR	-0.62121563	0.87236834	0.95759233	0.51	0.4794
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	1.98889429	0.80416545	11.55123121	6.12	0.0165
CTRL	0.00000000	0.00000000	0.00000000	0.00	1.0000
DEBR	2.37416842	0.92518817	12.43536680	6.59	0.0130
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000

Table 43

Food-Type/Land-Type Model
Lead-210

Food Type	Land Type				
	Debris	Clay	Reclaimed	Mineralized	Control
Leafy	41.04	27.92	3.82	-	-
Caul/Broc	29.84	20.30	2.78	-	-
Seeds/Grains	22.05	15.00	2.05	-	-
General	8.05	5.48	0.75	-	-
Roots/Tubers	4.66	3.17	0.43	-	-

These results are in general agreement with the ANOVA results previously discussed. The leafy food type again exhibits the highest geometric mean level of food lead. The land type coefficients reveal that debris has the highest average level of food lead, followed by clay, and then reclaimed. Remember that there are no measurements on control and mineralized lands. The R-square for this model is 45 percent, with a 95 percent confidence factor of 16.

Food Type, Land Type, and Soil Parameter Model

The next regression model takes the mean levels of both food type and land type into account prior to testing the soil parameters for their contribution to the model (Table 44). No soil parameters were significant after taking the food and land type into account. Notice that this model is identical to the previously discussed food type and land type model.

Interaction Models

The first interaction model, shown in Table 45, forces food type into the model, and then enables stepwise selection from any soil parameter and any of the pairwise interactions between the soil parameters and the food types. Examination of Table 45 reveals that several interaction terms are significantly correlated with food lead. Two terms in the model are interactions with the soil parameter organic matter: leafy (positive) and roots/tubers (negative). Potassium is found to have a negative correlation with food lead for the caul/broc food type. This interaction as well as the organic matter interactions have significance levels exceeding 0.10, suggesting the results may be an anomaly of the data. Magnesium enters the model, having a positive correlation with food lead for the general and seeds/grains food types. The soil parameter pH is also found to have a negative correlation for the general food type. The other significant parameter in the model is the interaction of cation

TABLE 44

STEPWISE REGRESSION
FOOD TYPE, LAND TYPE, AND SOIL PARAMETER MODEL
LEAD-210
(SAME AS FOOD TYPE AND LAND TYPE MODEL)

R SQUARE = 0.44633753

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	83.72915518	13.95485920	7.39	0.0001
ERROR	55	103.86240753	1.88840741		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.34031430				
CABR	-0.31868162	0.72476173	0.36510621	0.19	0.6619
GNRL	-1.62851883	0.66805086	11.22179207	5.94	0.0180
RTTB	-2.17615109	0.44928058	44.30354694	23.46	0.0001
SDGR	-0.62121563	0.87236834	0.95759233	0.51	0.4794
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	1.98889429	0.80416545	11.55123121	6.12	0.0165
CTRL	0.00000000	0.00000000	0.00000000	0.00	1.0000
DEBR	2.37416842	0.92518817	12.43536680	6.59	0.0130
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000

TABLE 45

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER INTERACTION MODEL
LEAD-210

R SQUARE = 0.61704336

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	115.75212909	10.52292083	7.32	0.0001
ERROR	50	71.83943362	1.43678867		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.89729594				
CABR	4.11724853	2.61235185	3.56897677	2.48	0.1213
GNRL	-3.08564551	6.52168483	0.32163651	0.22	0.6382
RTTB	1.13396796	1.41729908	0.91975351	0.64	0.4274
SDGR	-102.98342163	35.88726151	11.83169296	8.23	0.0060
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LCECRTTB	-0.69326916	0.37617977	4.87984222	3.40	0.0713
LORGLEFY	0.93897232	0.63717552	3.12018471	2.17	0.1468
LORGRTTB	-1.46088770	0.98466902	3.16261270	2.20	0.1442
LKCABR	-0.84025409	0.54000845	3.47866857	2.42	0.1260
LMGGNRL	2.97618751	0.86278541	17.09652655	11.90	0.0012
LMGSDGR	14.10738896	4.95588558	11.64242996	8.10	0.0064
PHGNRL	-2.50143637	1.36991682	4.79052840	3.33	0.0738

exchange capacity (CEC) with the roots/tubers. CEC has a negative relationship with food lead for this food type. The model's R-square is 62 percent, with a 95 percent confidence factor of 11.

A second interaction model is presented in Table 46. Both food type and land type are forced into the model prior to the introduction of the interaction terms. CEC, organic matter, potassium, and magnesium again enter the interaction model. CEC has a positive correlation with the seeds/grains food type and potassium has a negative correlation with the caul/broc foods. However, both of these effects are significant at the 0.12 and 0.14 levels, respectively. Organic matter and magnesium appear as in the previous regression model, this time with both being positively correlated with the general food type. The only other significant term in the model indicates a negative relationship between calcium and food lead for the roots/tubers. The model's R-square is 59 percent, with a 95 percent confidence factor of 12.

Calcium Models

As discussed above, calcium is generally considered to have an effect on the uptake of radioactivity by foods. While this effect is believed to be strongest for radium uptake, a regression analysis was also conducted for food lead with soil calcium being forced as an independent variable. Since the majority of the samples were drawn from clay lands, this relationship of food to soil lead was investigated for this land type only. The relationship between food lead and the soil parameters of lead, pH, organic matter, and calcium gave the following estimated models:

Leafy: $FPb = 0.13 \times SPb^{0.42} \times e^{1.01 \times pH} \times OM^{1.18} \times Ca^{-0.46} \times error$

Roots/Tubers: $FPb = 0.009 \times SPb^{0.42} \times e^{1.01 \times pH} \times OM^{1.18} \times Ca^{-0.46} \times error$

Caul/Broc: $FPb = 0.04 \times SPb^{0.42} \times e^{1.01 \times pH} \times OM^{1.18} \times Ca^{-0.46} \times error$

General: $FPb = 0.02 \times SPb^{0.42} \times e^{1.01 \times pH} \times OM^{1.18} \times Ca^{-0.46} \times error$

Seeds/Grains: $FPb = 0.05 \times SPb^{0.42} \times e^{1.01 \times pH} \times OM^{1.18} \times Ca^{-0.46} \times error$

The regression coefficient suggests that food lead varies roughly as the square root of soil lead (see Table 47). However, this relationship is not statistically significant at the 0.15 level. pH, organic matter, and calcium are significant at the 0.05, 0.06, and 0.17 levels, respectively. Notice that pH and calcium were not significant at the 0.15 level in the food type and soil lead model previously discussed. This could be due to either the fact that this model is based solely on clay land values or due to the possible multicollinearity of the independent variables. The possibility of multicollinearity is emphasized by the effect of adding magnesium to this model. Once magnesium is added, the significance of organic matter and calcium is much less. This further illustrates the caution needed in the interpretation of these exploratory models.

TABLE 46

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER INTERACTION MODEL
LEAD-210

R SQUARE = 0.58660301

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	110.04177614	10.00379783	6.45	0.0001
ERROR	50	77.54978657	1.55099573		
TOTAL	61	187.59156271			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2.08304565				
CABR	3.61704177	2.74067085	2.70149327	1.74	0.1929
GNRL	-12.92540078	4.46176008	13.01625987	8.39	0.0056
RTTB	3.06071863	3.07428897	1.53733334	0.99	0.3242
SDGR	-45.94576354	28.14823230	4.13237091	2.66	0.1089
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	1.32225904	1.05697006	2.42727133	1.56	0.2168
CTRL	0.00000000	0.00000000	0.00000000	0.00	1.0000
DEBR	1.31618181	1.10163024	2.21396461	1.43	0.2378
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000
LCECSDGR	13.34148350	8.28262962	4.02422604	2.59	0.1135
LORGGNRL	1.87656981	1.03587800	5.09005919	3.28	0.0761
LKCABR	-0.84160502	0.57106912	3.36860348	2.17	0.1468
LMGGNRL	1.48847894	0.67267564	7.59424490	4.90	0.0315
LCARTTB	-0.68647720	0.39265528	4.74067243	3.06	0.0866

TABLE 47

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER MODEL
LEAD-210
CLAY LANDS ONLY

(Calcium Model)

R SQUARE = 0.51568440

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	63.81680335	7.97710042	5.19	0.0002
ERROR	39	59.93486195	1.53679133		
TOTAL	47	123.75166530			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-2.07887176				
CABR	-1.10894640	0.80621727	2.90758092	1.89	0.1768
GNRL	-1.84528484	0.69394799	10.86645490	7.07	0.0113
RTTB	-2.66518203	0.46590987	50.28805416	32.72	0.0001
SDGR	-0.91719825	0.97600160	1.35718881	0.88	0.3531
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LSPB	0.42275877	0.52934166	0.98023006	0.64	0.4293
PH	1.01380043	0.49012518	6.57515239	4.28	0.0453
LORGMAT	1.17868504	0.59433470	6.04433155	3.93	0.0544
LCA	-0.45822637	0.32314816	3.09009401	2.01	0.1641

Discussion

The complex regression models for lead account for a significant amount of variability. However, interpretation of these results should be made with extreme caution, since it is tempting to infer too much from these complex models, especially when there are several significant interaction terms. It is also easy to forget that the sample is concentrated on the clay lands, with some debris samples, and very few from reclaimed lands.

Food and soil lead contents are positively correlated, although the strength of the correlation does not approach that for radium levels. The estimated values based on even the best interaction model would have 95 percent confidence intervals indicating potential variability by a factor of 11.

Polonium-210 Results

A total of 51 observations were available for the polonium-210 analysis. The matrix in Table 48 shows the number of measurements for each food and land type. The design matrix is almost identical to the matrix for lead-210. There are no measurements for control and mineralized lands and the majority of the measurements were made of leafy foods on clay lands.

Simple Correlations

The simple correlation matrix for the logarithmic transforms of food polonium and soil parameters is shown in Table 49. Note that the simple correlation of food and soil polonium is not statistically significant with a correlation coefficient of 0.02. No soil parameters show any statistically significant correlation with polonium in the food; however, the two highest are: pH (0.15) and calcium (0.08).

Stepwise Regression

The regression methodology used for the analysis of polonium was as in the above discussion for radium and lead. The same models were postulated, and the results are discussed in the following sections.

Soil Parameter Model

The first stepwise regression relates food polonium to the soil parameters, without regard to the food or land type. There were no soil parameters significant at the 0.15 level to allow admittance to the model. Thus, these data reveal no ability to estimate the polonium concentration in the food based on the soil radioactivity concentration and soil chemistry.

TABLE 48

NUMBER OF OBSERVATIONS FOR POLONIUM-210 REGRESSION

FOOD TYPE	FOOD	CONTROL LAND	MINERALIZED LAND	RECLAIMED LAND	CLAY LAND	DEBRIS LAND	TOTAL
CAUL/BROC	BROCCOLI				2	1	3
GENERAL	OKRA				1		1
	YELLOW SQUASH			1	2		3
	ZUCCHINI			1			1
GENERAL		0	0	2	3	0	5
LEAFY	CABBAGE				6	1	7
	COLLARD GREENS				1	2	3
	LETTUCE				2	1	3
	MUSTARD GREENS				6	1	7
	PARSLEY				1		1
	SPINACH				1	1	2
	SWISS CHARD				1		1
	TURNIP GREENS				5	1	6
LEAFY		0	0	0	23	7	30
ROOTS/TUBERS	CARROTS				2	1	3
	POTATOES			1			1
	TURNIP ROOT				5	1	6
ROOTS/TUBERS		0	0	1	7	2	10
SEEDS/GRAINS	RICE				1		1
	YELLOW CORN			1	1		2
SEEDS/GRAINS		0	0	1	2	0	3
TOTAL		0	0	4	37	10	51

TABLE 49

SIMPLE CORRELATION MATRIX FOR THE LOGARITHMIC TRANSFORMS

POLONIUM-210

PEARSON CORRELATION COEFFICIENTS / PROB >]R] UNDER HO:RHO=0 / N = 51

	LFPO	LSPO	PH	H	LORGMAT	LCEC	LK	LMG	LCA
LFPO	1.00000	0.02328	0.14704	0.07390	-0.00641	0.06369	-0.00677	0.04670	0.07905
	0.0000	0.8712	0.3032	0.6063	0.9644	0.6570	0.9624	0.7448	0.5814
LSPO	0.02328	1.00000	0.24288	-0.11920	-0.08191	-0.03489	-0.11267	0.04779	-0.00093
	0.8712	0.0000	0.0859	0.4048	0.5677	0.8079	0.4312	0.7391	0.9948
PH	0.14704	0.24288	1.00000	-0.71600	-0.39363	0.40458	0.26427	0.51957	0.47674
	0.3032	0.0859	0.0000	0.0001	0.0043	0.0032	0.0609	0.0001	0.0004
H	0.07390	-0.11920	-0.71600	1.00000	0.24540	0.06820	0.10472	-0.04245	-0.02091
	0.6063	0.4048	0.0001	0.0000	0.0826	0.6344	0.4646	0.7674	0.8842
LORGMAT	-0.00641	-0.08191	-0.39363	0.24540	1.00000	-0.06160	-0.13629	0.00817	-0.11954
	0.9644	0.5677	0.0043	0.0826	0.0000	0.6676	0.3403	0.9546	0.4034
LCEC	0.06369	-0.03489	0.40458	0.06820	-0.06160	1.00000	0.88064	0.87423	0.97590
	0.6570	0.8079	0.0032	0.6344	0.6676	0.0000	0.0001	0.0001	0.0001
LK	-0.00677	-0.11267	0.26427	0.10472	-0.13629	0.88064	1.00000	0.75442	0.82072
	0.9624	0.4312	0.0609	0.4646	0.3403	0.0001	0.0000	0.0001	0.0001
LMG	0.04670	0.04779	0.51957	-0.04245	0.00817	0.87423	0.75442	1.00000	0.80318
	0.7448	0.7391	0.0001	0.7674	0.9546	0.0001	0.0001	0.0000	0.0001
LCA	0.07905	-0.00093	0.47674	-0.02091	-0.11954	0.97590	0.82072	0.80318	1.00000
	0.5814	0.9948	0.0004	0.8842	0.4034	0.0001	0.0001	0.0001	0.0000

Food Type and Soil Parameter Model

Examination of the model in Table 50 reveals that after food type has been taken into account, no soil parameters are statistically correlated with food polonium. The model coefficients infer that the leafy vegetables are associated with the highest geometric mean level of food polonium (as in food radium), with all other food types significantly less on the average. The general and roots/tubers food types exhibit the lowest mean levels. The model's R-square is 0.15, indicating that only 15 percent of the polonium variability is accounted for by food type. The 95 percent confidence factor is 20. The model is not statistically significant at the 0.1 level, thus providing insufficient evidence to infer that the differences among the geometric means for the six food types are real.

Food Type Land Type and Soil Parameter Model

The next regression model takes the mean levels of both food type and land type into account prior to testing the soil parameters for their contribution to the model (Table 51). The leafy food type again exhibits the highest geometric mean level of food polonium. The soil type coefficients reveal that clay has the highest average level of food polonium, followed by reclaimed, and then debris. Remember that there are no measurements on control and mineralized lands. It is interesting that potassium is significant after the food and land type effect have been taken into account. Potassium is negatively correlated with food polonium. The R-square for this model is only 22 percent, and the model as a whole is not statistically significant. The 95 percent confidence factor drops slightly to 19.5.

Interaction Models

The first interaction model, shown in Table 52, forces food type into the model, and then enables stepwise selection from any soil parameter and any of the pairwise interactions between the soil parameters and the food types. Examination of Table 52 reveals that several interaction terms are significantly correlated with food polonium. Two terms in the model are interactions with the leafy food type: organic matter (positive) and pH (positive). Organic matter is also significantly positively correlated with food polonium for the caul/broc food type. This model accounts for slightly more variability than the previous one, with a model R-square of 29 percent, and the model is statistically significant. The 95 percent confidence factor is 17. Clearly, variable interactions play an important role in the determination of food polonium.

A second interaction model is presented in Table 53. Both food type and land type are forced into the model prior to the introduction of the interaction terms. No interactions entered the model at the required significance level. Therefore, the model is identical to the food type, land type, and soil parameter model in Table 51.

TABLE 50

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER MODEL
POLONIUM-210

R-SQUARE = 0.14545444

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	17.57603054	4.39400764	1.96	0.1169
ERROR	46	103.25927111	2.24476676		
TOTAL	50	120.83530166			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.33415766				
CABR	-0.75783603	0.90723820	1.56631487	0.70	0.4079
GNRL	-1.55653991	0.72372572	10.38349922	4.63	0.0368
RTTB	-1.13703958	0.54708522	9.69644260	4.32	0.0433
SDGR	-0.81081290	0.90723820	1.79295698	0.80	0.3761
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000

TABLE 51

STEPWISE REGRESSION
FOOD TYPE, LAND TYPE, AND SOIL PARAMETER MODEL
POLONIUM-210

R SQUARE = 0.21614860

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	26.11838179	3.73119740	1.69	0.1361
ERROR	43	94.71691986	2.20271907		
TOTAL	50	120.83530166			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	4.54083918				
CABR	-1.25368540	0.95771049	3.77457238	1.71	0.1975
GNRL	-1.71111096	0.80897002	9.85486312	4.47	0.0402
RTTB	-1.32836659	0.55965473	12.40951021	5.63	0.0222
SDGR	-0.76701244	0.95741816	1.41371091	0.64	0.4275
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	0.56429682	0.94080197	0.79246098	0.36	0.5518
CTRL	0.00000000	0.00000000	0.00000000	0.00	1.0000
DEBR	-0.98375370	1.06481496	1.88011141	0.85	0.3607
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000
LK	-0.64525985	0.38275592	6.26014754	2.84	0.0991

TABLE 52

STEPWISE REGRESSION
FOOD TYPE AND SOIL PARAMETER INTERACTION MODEL
POLONIUM-210

R SQUARE = 0.28830315

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	34.83719867	4.97674267	2.49	0.0308
ERROR	43	85.99810299	1.99995588		
TOTAL	50	120.83530166			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-5.08289570				
CABR	-2.73508721	5.67673644	0.46426432	0.23	0.6324
GNRL	4.86051345	2.83127716	5.89413314	2.95	0.0932
RTTB	5.28001377	2.79573511	7.13343136	3.57	0.0657
SDGR	5.60624046	2.87798387	7.58904533	3.79	0.0580
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
LORGLEFY	1.28003556	0.83598396	4.68887440	2.34	0.1331
LORGCABR	14.86788577	8.66661801	5.88599024	2.94	0.0934
PHLEFY	0.83824581	0.37412114	10.04011527	5.02	0.0303

TABLE 53

STEPWISE REGRESSION
FOOD TYPE, LAND TYPE, AND SOIL PARAMETER INTERACTION MODEL
POLONIUM-210

R SQUARE = 0.21614860

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	26.11838179	3.73119740	1.69	0.1361
ERROR	43	94.71691986	2.20271907		
TOTAL	50	120.83530166			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	4.54083918				
CABR	-1.25368540	0.95771049	3.77457238	1.71	0.1975
GNRL	-1.71111096	0.80897002	9.85486312	4.47	0.0402
RTTB	-1.32836659	0.55965473	12.40951021	5.63	0.0222
SDGR	-0.76701244	0.95741816	1.41371091	0.64	0.4275
LEFY	0.00000000	0.00000000	0.00000000	0.00	1.0000
CLAY	0.56429682	0.94080197	0.79246098	0.36	0.5518
CTRL	0.00000000	0.00000000	0.00000000	0.00	1.0000
DEBR	-0.98375370	1.06481496	1.88011141	0.85	0.3607
RECL	0.00000000	0.00000000	0.00000000	0.00	1.0000
MINL	0.00000000	0.00000000	0.00000000	0.00	1.0000
LK	-0.64525985	0.38275592	6.26014754	2.84	0.0991

Discussion

The results of the polonium regression analysis should be viewed with caution. The modeling process was limited by the small number of observations, with the majority of these observations being leafy foods on clay lands.

The correlation of food and soil polonium is very weak. Organic matter and pH are significantly correlated with food polonium for the leafy foods in the interaction model when adjusted for only food. Potassium was negatively correlated with food polonium after taking into account the food and land type.

DATA EVALUATION

CHARACTERISTICS OF THE LAND PARCELS

Radionuclide Characteristics

Measurements of soil radioactivity and soil chemistry are summarized for the various land classes in Table 54. The five land classes present three major radioactivity concentration categories:

(1) Low (<1 to 2 pCi/g):
  - Control
  - Mineralized
(2) Intermediate/Variable (average 5 pCi/g, range 1 to 50 pCi/g):
  - Reclaimed
(3) Elevated (>10 pCi/g):
  - Clays
  - Debris.

Radium-226 analyses were performed on soil samples associated with most food samples; lead-210 and polonium-210 analyses were performed on a sub-set of soil samples (those collected in the current study). Where the data were available, the lead-210/radium-226 and the polonium-210/radium-226 ratios were examined to determine the extent to which these radionuclides were in radioactive equilibrium, the degree of uniformity within a land type, and whether there were differences between land types. If the ratios are relatively constant within land types, then conclusions can be drawn about the lead-210 and the polonium-210 source presented to the food, even when only radium-226 data are available.

For the reclaimed lands, the ratio for both radionuclides was on the order of 80 percent; individual ratios were as low as approximately 50 percent and all ratios were less than 100 percent except for one lead-210/radium-226 value of 1.40 for the lowest activity soil (3 pCi/g radium-226) and a single polonium-210/radium-226 value of 1.03 for a soil with moderately elevated radioactivity (9 pCi/g radium-226).

By contrast, ratios tended to be higher for clay lands and debris lands. Lead-210/radium-226 ratios were on the order of 140 to 150 percent with only one value less than 90 percent and maximum values approaching 300 percent. Polonium-210/radium-226 ratios were on the order of 116 percent; four clays and no debris samples had values less than 90 percent and maximum values ranged to nearly 200 percent. Lead-210 and polonium-210 analyses were not performed for control and mineralized lands; ratios for these lands types should be comparable to what is generally reported for U.S. soils.

From these observations it can be concluded that phosphate mining-related lands that have elevated radium-226 are likely to have elevated lead-210 and polonium-210 and hence consideration should be given to these daughter radionuclides as well as to radium-226. For reclaimed lands, the daughter nuclides are likely to be present in the soil at levels on the

TABLE 54

SUMMARY OF SOIL RADIOACTIVITY AND CHEMISTRY BY LAND CATEGORY

	CONTROL[1]	MINERALIZED	RECLAIMED	CLAY	DEBRIS
Ra-226					
Mean[2], pCi/g	0.6 (54)[3]	0.4 (94)	5.2 (76)	16.0 (34)	16.1 (21)
[Min-Max]	[0.1- 1.5]	[0.1- 2.1]	[0.2-48.9]	[9.4-25.1]	[11.2-22.0]
Pb-210					
Mean, pCi/g	--	--	7.5 (7)	18.6 (31)	22.5 (9)
[Min-Max]	--	--	[4.2-24.9]	[11.8-58.8]	[13.1-36.4]
Po-210					
Mean, pCi/g	--	--	8.5 (7)	22.8 (24)	25.21 (9)
[Min-Max]	--	--	[1.5-27.5]	[9.6-49.1]	[12.2-30.7]
Pb-210/Ra-226					
Mean	--	--	0.76 (7)	1.44 (31)	1.34 (9)
[Min-Max]	--	--	[0.49-1.40]	[0.78-2.88]	[0.93-2.09]
Po-210/Ra-226					
Mean	--	--	0.78 (7)	1.18 (24)	1.14 (9)
[Min-Max]	--	--	[0.45-1.03]	[0.58-1.95]	[0.90-1.76]
pH					
Mean	6.1 (35)	6.0 (43)	5.5 (51)	7.2 (25)	5.9 (18)
[Min-Max]	[5.2-7.3]	[4.8-8.0]	[4.5-7.3]	[5.9-8.0]	[4.7-7.6]
CEC					
Mean (meq/100g)	19 (6)	3.4 (10)	6.1 (28)	26.4 (19)	5.3 (12)
[Min-Max]	[3.1-30.1]	[2.1-8.7]	[1.0-36.6]	[2.9-41.6]	[3.0-35.6]
Organic Matter					
Mean (%)	8.1 (6)	3.1 (10)	2.4 (28)	1.7 (19)	2.0 (12)
[Min-Max]	[2.9-9.9]	[2.1-6.0]	[0.8-4.6]	[1.7-3.8]	[1.2-2.4]
H					
Mean (meq/100g)	6.0 (6)	1.0 (10)	1.9 (28)	0.5 (19)	1.3 (12)
[Min-Max]	[0.6-10.4]	[0.1-2.3]	[0.0-17.2]	[0.0-5.7]	[0.0-4.2]
Ca					
Mean (ppm)	2159 (6)	342 (10)	630 (28)	3093 (19)	548 (12)
[Min-Max]	[300-3650]	[150-850]	[50-3870]	[330-3920]	[368-3550]
Mg					
Mean (ppm)	383 (6)	73 (10)	87 (28)	956 (19)	114 (12)
[Min-Max]	[106-519]	[29-269]	[8-1150]	[113-2210]	[37-2050]
K					
Mean (ppm)	104 (6)	26 (10)	22 (28)	248 (19)	62 (12)
[Min-Max]	[42-215]	[5-143]	[1-211]	[34-391]	[17-280]

---

[1] Control includes both organic soils (Lake County and Orange County) and sand soils (Hillsborough County)
[2] Mean = geometric mean except for pH and hydrogen
[3] Values in parentheses indicate number of samples in mean

order of 80 percent of the radium-226 concentration; while for clay and debris lands, the daughter radionuclide concentrations are likely to exceed the radium-226 concentration.

Chemical Characteristics

Soil chemistry measurements are also summarized in Table 54. The various land classes present a range of values for the chemical characteristics, thus offering the opportunity to examine the effect of various soil characteristics on the transfer of the several radionuclides to the plant types studied.

Summary of Radionuclide and Chemical Characteristics

Table 55 presents a descriptive summary of the lands in this study. The values of the chemical characteristics are described as low, medium, and high in the context of the overall range of values observed; this does not necessarily represent adequacy or deficiency for plant requirements.

1. Low radioactivity lands (Control and Mineralized) In these lands, soil concentrations of radium-226 averaged about 0.5 pCi/g and individual samples ranged from 0.1 to 2.0 pCi/g. All samples from these lands were collected during the initial study and they were not analyzed for lead-210 and polonium-210; however, concentrations of these radionuclides would be expected to be similar to radium-226 (i.e., in approximate radioactive equilibrium). These lands exhibited a wide range of organic matter content. All five samples from Orange and Lake Counties (presumably muck lands) had organic matter concentrations of 9.9 percent. All the other samples had much lower concentrations, ranging from 2.1 to 6.0 percent. The values of pH were generally in the slightly acid to neutral range (average 6.0, ranging from 4.8 to 8.0). The two land classes generally exhibited two levels of cation concentration and CEC:

Control lands:
cation concentrations: a wide range of values;
generally medium to high.
CEC: generally high.

Mineralized Lands:
cation concentrations: generally low.
CEC: generally low.

2. Intermediate/variable radioactivity lands (Reclaimed) The average soil radium-226 concentrationwas intermediate (5 pCi/g) but individual samples results were highly variable, ranging from low (<1 pCi/g) to elevated (49 pCi/g). Lead-210 and polonium-210 were present at comparable levels but at slightly less than equilibrium with the radium-226. Organic matter concentrations were generally low and pH was in the slightly acid range.

TABLE 55

SUMMARY OF LAND CHARACTERISTICS

LOW RADIOACTIVITY LANDS

Ra-226: Low; 0.5 (0.1 to 2.0) pCi/g
Pb-210 and Po-210 not measured but expected to be in approximate radioactive equilibrium with Ra-226.
pH: Slightly acid to neutral; 6.0 (4.8 to 8.0).

Control Lands

Organic Matter: Three sites high (9.9%); one low (2.9%)
Cations: Wide range; generally medium to high levels.
- Ca: 2200 (300 - 3600) ppm — High (Low to High)
- Mg: 380 (110 - 520) ppm — Medium
- K : 100 (42 - 210) ppm — Medium (Medium to High)

CEC: 19 (3 - 30) meq/100 g — High (Low to High)

Mineralized Lands

Organic Matter: Generally low (2-6%)
Cations: Generally low to medium levels.
- Ca: 340 (150 - 850) ppm — Low (Low to Medium)
- Mg: 73 (29 - 270) ppm — Low (Low to Medium)
- K : 26 (5 - 140) ppm — Low (Low to Medium)

CEC: 3 (2 - 9) meq/100 g — Low (Low to Medium)

INTERMEDIATE/VARIABLE RADIOACTIVITY LANDS - RECLAIMED LANDS

Ra-226: Intermediate with a wide range; 5 (<1 - 49) pCi/g.
Pb-210 and Po-210: Generally less than radioactive equilibrium with Ra-226:
- Pb-210/Ra-226: 0.8 (0.5 - 1.4)
- Po-210/Ra-226: 0.8 (0.4 - 1.0)

Organic Matter: Generally low; 1.4 (0.8-4.6)%
pH: Generally acid; 5.5 (4.5 - 7.3)
Cations: Variable; generally low to medium levels.
- Ca: 630 (50 - 3900) ppm — Medium (Low to High)
- Mg: 87 (8 - 1200) ppm — Low (Low to High)
- K : 22 (1 - 210) ppm — Low (Low to High)

CEC: 6 (1 - 37) meq/100 g — Medium (Low to High)

TABLE 55 (CONTINUED)

SUMMARY OF LAND CHARACTERISTICS

ELEVATED RADIOACTIVITY LANDS

Ra-226: Elevated; 16 (9 - 22) pCi/g
Pb-210 and Po-210 generally in excess of radioactive equilibrium with Ra-226:
    Pb-210/Ra-226: 1.4 (0.8 - 2.9)
    Po-210/Ra-226: 1.2 (0.6 - 2.0)

Organic Matter: Low concentrations; (1.7 - 3.8%)

Clay Lands

pH: Acid to neutral: 7.2 (5.9 - 8.0)
Cations: Wide range; generally high levels.
    Ca: 3100 (330 - 3900) ppm   High (Low to High)
    Mg: 960 (110 - 2200) ppm   High (Medium to High)
    K : 250 (34 - 390) ppm   High (Low to High)

CEC: 26 (3 - 42) meq/100 g   High (Low to High)

Debris Lands

pH: Generally acidic; 5.9 (4.7 - 7.6)
Cations: Wide range: generally medium levels.
    Ca: 550 (370 - 3500) ppm   Medium (Low to High)
    Mg: 110 (37 - 2000) ppm   Medium (Low to High)
    K : 62 (17 - 280) ppm   Medium (Low to High)

CEC: 5 (3 - 36) meq/100 g   Medium (Low to High)

CRITERIA FOR QUALITATIVE RANKING OF SOIL CHARACTERISTICS

	Low	Medium	High
Radioactivity (pCi/g)	<2	2 - 10	>10
Organic Matter (percent)	<5	5 - 10	>10
Calcium (ppm)	<500	500 - 1000	>1000
Magnesium (ppm)	<100	100 - 500	>500
Potassium (ppm)	<50	50 - 150	>150
CEC (meq/100g)	<5	5 - 10	>10

Cation concentrations were highly variable but on the average tended to be low to medium. CEC also was variable but was at a medium level on the average.

3. Elevated Radioactivity Lands (Clay and Debris) Radium-226 concentrations were on the order of 10 to 20 pCi/g and lead-210 and polonium-210 concentrations were of comparable magnitude but generally in excess of radioactive equilibrium with the radium-226. Organic matter concentrations were low. The two classes showed slight differences in pH and noticeable differences in cation concentration and CEC.

Clay lands:
pH: generally neutral.
cation concentrations: wide range, high on the average.
CEC: wide range, high on the average.

Debris lands:
pH: generally acidic.
cation concentrations: wide range, medium on the average.
CEC: generally low to medium.

FACTORS AFFECTING RADIONUCLIDE TRANSFER

While 29 different foods were examined in this study, neither the planting practices at the land parcels available for study or the resources allocated to this study permitted a study of all foods on all land types. As mentioned previously, for the purpose of examining radionuclide transfer from soil to food and for developing models, the data were examined on the basis of the five food categories that had been designated on the combined basis of plant type and portion of plant harvested for consumption:

1. Leafy,
2. Cauliflower and broccoli (i.e. flowering Brassica),
3. Seeds and grains,
4. General (largely garden fruit), and
5. Roots and tubers

Radium-226

Soil Radium-226

Radium-226 in the foods was indeed strongly correlated to the soil radium-226 concentration. As indicated in the statistical analysis, plant radium-226 concentration varied as approximately the square root of the soil radium concentration, with the exact coefficient depending upon the model employed. This is contrary to the statement in NCRP Report 77 that cites a linear effect with soil concentration. On the other hand, this is consistent with findings in the initial study (Guidry, et al. 1986), University of Florida studies of radionuclides in forages raised on a reclaimed settling area (Roessler et.al. 1986), and a report by Simon and Ibrahim (1987) in which the increased radium-226 in foods was not linearly proportional to the increased radium-226 in soil.

Food Category

The most influential factor affecting the relationship between plant radium-226 and soil radium-226 was the food category. The statistical relationship depended upon the model used. In general, other factors being equal, leafy foods exhibited the highest concentrations of radium-226. Foods in the roots/tubers and caul/broc categories exhibited substantially lower radium-226 levels. The lowest observed concentrations were found in the seeds/grains and the general categories.

Soil Chemistry

As discussed in the statistical analysis, a number of the regression models identified various soil parameters as having a potential influence on food radium-226. In approximate order of influence, these included:

- pH: positive; all models,
- CEC: negative; selected models,
- Organic matter: positive, selected models, and
- Magnesium: negative; some models.

The most influential soil chemistry factor was pH which was significant each time it appeared in a model. Several of the models suggest that the radium-226 concentration in the foods increases roughly 40 percent per unit increase in pH.

Several of the statistical models suggest that CEC has a negative effect on food radium-226; that is, radium-226 concentration in the food decreases as CEC increases. The interaction model indicated that this effect is largely observed within the caul/broc category. The lower radioactivity mineralized lands had generally low values of CEC while the clay lands had generally medium to high CEC levels. Thus high CEC appears to limit the uptake of radium-226 from the clay lands.

The factor that appeared next most often in the regression models was Organic Matter (OM) which had a positive effect on food radium-226 content. The interaction model indicated that this effect was manifest in the roots/tubers category. Except for some of the control parcels, levels of OM were generally low. Thus low OM also appears to limit the uptake of radium-226 from the clay and debris lands.

In some models, soil magnesium had a significant influence on food radium-226. The overall effect was a negative influence. Interaction models indicated that this effect was manifest in the leafy and the seeds/grains categories with a possible positive influence in the general category. Control and mineralized lands had generally low to medium levels of magnesium while the levels in debris and clay lands were medium to high. Here again, magnesium appears to limit the radium-226 uptake from the elevated radioactivity lands.

Soil calcium is generally considered to have a significant, negative influence on the uptake of radium-226 by plants. Surprisingly, in the analysis of the data from this study, soil calcium did not enter as a significant factor in the stepwise regression analyses. However, when forced into the model, soil calcium had a negative influence comparable in magnitude to soil magnesium. CEC, which is calculated from the concentrations of various exchangeable cations, pre-empts calcium in the statistical model. This suggests that, in a simplified model, CEC is a better factor in the estimation of potential radium-226 uptake than the concentration of any individual cation.

Lead-210

Lead-210 analyses were limited to food-soil sample pairs from the reclaimed, clay, and debris land categories. Furthermore, the majority of the measurements were of leafy foods on clay lands. Thus the levels of radioactivity were observed over a limited range, levels of soil chemistry were somewhat limited in range, and the data for the categories other than leafy are limited. Consequently, the data present only limited opportunity to define the factors influencing lead-210 uptake by foods.

Soil Lead-210

Food lead-210 is correlated positively with soil lead-210 but this correlation is not as strong as was the case for radium-226. Again the food radioactivity varies roughly with the square root of the soil radioactivity.

Food Category

When food type was introduced as a factor in the model, it was the strongest factor influencing food lead-210 (even to the exclusion of soil lead-210). As with radium-226, the ranking depended on the model. But, in general, the leafy foods exhibited the highest lead-210 concentrations. Foods from the caul/broc category contained intermediate concentrations followed by foods from the seeds/grains and general categories. The roots/tubers foods contained the lowest concentrations of lead-210.

This ranking was similar to that observed for radium-226 except that the roots/tubers category had the lowest concentrations of lead-210 as contrasted with intermediate concentrations of radium-226.

Soil Chemistry

The soil chemistry data did not present a clear picture of the factors which may influence lead-210 uptake in foods. Some of the statistical evaluations suggested an effect from pH, OM, and calcium, but the relationships were not strong and the models often suggested contradictory effects. No clear-cut relationships were found.

Potential Effect of Atmospheric Deposition

It has been reported that a major source of lead-210 in plants is deposition from the atmosphere (lead-210 resulting from the decay of airborne radon-222). In this study, the highest concentrations were observed in the above-ground plant parts with the greatest surface area. This suggests that deposition from the atmosphere may be the major source of lead-210 in the foods in this study, possibly even overshadowing the effect of soil lead-210 and soil chemistry factors.

Polonium-210

Polonium-210 analyses were limited to food-soil sample pairs from the reclaimed, clay, and debris land categories. Furthermore, as was the case for lead-210, the majority of the measurements were of leafy foods on clay lands. Thus the levels of radioactivity were observed over a limited range, levels of soil chemistry were somewhat limited in range, and the data for the categories other than leafy are limited. Since almost 40 percent of the food measurements were below the limit of detection for the analytical method, the data present an even more limited opportunity to define the factors influencing polonium-210 uptake by foods. There was no significant correlation of food polonium-210 with any soil factors including soil polonium-210.

Again, the food category was the major factor correlated with food radioactivity. The highest concentrations were observed in the leafy category and the lowest in the roots/tubers category. These observations again suggest that deposition from the atmosphere may be more significant than soil polonium-210 and other soil parameters.

ESTIMATION OF FOOD RADIOACTIVITY

The statistical analysis considered a variety of models which attempt to relate food radioactivity to various parameters such as food type, land type, and soil parameters. As mentioned in those analyses, numerous other models can be constructed from the regression parameters which are listed in the various model tables. It may be beneficial, however, to provide a family of models for a variety of situations. When soil radioactivity data are not available and a simple screening model would be useful for screening lands for potential food production, a simple Land-Type/Food-Type Model might suffice. If more detailed information is available on the soil chemistry, a Soil Parameter Model might be useful. For this reason, the authors have compiled a summary of suggested models for estimating food radioactivity concentrations. As mentioned previously, caution must be exercised in using these models since the sampling design was not balanced. Also, most of the lead-210 and polonium-210 results were obtained from clay lands. Note also that the model could only be used for samples drawn from locations similar to those utilized in this study and for foods grown in this study.

Since food type can always be selected as an independent variable, all of the models which are discussed here include food type. The remaining parameters vary with degree of model complexity. Three levels of complexity are discussed here. The successive levels require increasing amounts of information about the land. The choice of level will depend on the amount of available information and the desired degree of sophistication. The types of estimators, in order of increasing complexity, are those based on (1) land type, (2) soil radioactivity, and (3) multiple soil parameters.

These estimators are only discussed for radium-226 and lead-210 because of the limited amount of food polonium-210 data above the limit of detection of the analytical procedure. Fortunately, this is not a serious omission since, as described below in the dose assessment, polonium-210 is not a significant dose contributor relative to radium-226 and lead-210 for any of the land categories or any of the foods.

Food-Type/Land Type Model

This is the simplest type of estimator, requiring only land type as input information. It might be employed for preliminary, scoping estimates for specific land types.

Radium-226

The observed geometric mean values serve as one form of estimator. These results are summarized in Table 56 and presented in Figure 12. Note that no data were reported for several food-type/land-type categories and some means are based on only one observation. If the assumption is made that there is a simple systematic effect of land type and food type without interaction, then a simple food-type/land-type model can be fit to the data and estimated values obtained to provide values for the missing cells and to smooth out the response in a systematic fashion. The results of using this simplified modeling technique are summarized as the second set of entries in each cell in Table 56 and plotted in Figure 13. Note that the estimated concentrations in foods reflect the general levels of soil radioactivity in the various land classes:

a) generally low for control and mineralized lands,
b) somewhat increased for reclaimed lands, and
c) highest for clay lands and debris lands.

However, levels were generally higher for debris lands than for clay lands, possibly due to the fact that cation concentrations were generally lower in debris soil than in clay soil.

Superimposed on the land-type effect is a food-type effect. There was a general trend for increasing concentrations from the general (largely garden fruit) to the seeds/grains to the roots/tubers to the flowering Brassica (cauliflower/broccoli) to the leafy categories. When the food and land categories are arranged as in Figure 13, it results in a response surface with the steepest rise along the diagonal from "general-on-control" to "leafy-on-debris".

It should be noted that the estimated geometric means shown in Table 56 are based on a larger data set than those listed in Table 32. This is due to the difference between the methodology used for the statistical analysis and that used in determining the proposed models for estimating radioactivity concentrations. In the statistical analysis, various models were developed to demonstrate the types of models which can be available to the analyst in the use of these data. To permit direct comparison of all the models, the data set for the statistical analysis was restricted to the subset of samples for which soil chemistry data were available. In the case of radium-226, this required the exclusion of some radium-226 observations from the initial study since soil chemistry information for those observations were not available. For the purpose of suggesting a

Table 56

Radium-226 in Foods (pCi/kg)
Observed Geometric Means by Food Type and Land Type
Estimated Values from Food-Type/Land-Type Model

Food Category	Control	Mineralized	Reclaimed	Clay	Debris
General					
Observed	3.6 [1.5][1]	3.0 [1.2]	4.7 [1.3]	9.6 [1.4]	7.1 [1.6]
No. of Samples	8	16	8	9	2
Estimated	2.6 [1.3]	2.6 [1.2]	5.9 [1.3]	11.3 [1.3]	18.6 [1.4]
Seeds/Grains					
Observed	5.5 [1.6]	1.9 [1.6]	16.5 [1.4]	6.8 [1.6]	-
No. of Samples	5	2	6	3	0
Estimated	3.5 [1.4]	3.6 [1.4]	8.1 [1.4]	15.5 [1.4]	25.6 [1.5]
Roots/Tubers					
Observed	5.9 [1.5]	5.1 [1.6]	5.8 [1.5]	28.6 [1.3]	51.9 [1.7]
No. of Samples	7	4	4	13	3
Estimated	4.6 [1.3]	4.7 [1.3]	10.6 [1.4]	20.3 [1.2]	33.3 [1.4]
Caul/Broc					
Observed	6.0 [2.0]	3.0 [2.0]	-	22.6 [1.6]	34.7 [2.4]
No. of Samples	2	1	0	3	1
Estimated	4.8 [1.6]	4.8 [1.6]	11.0 [1.7]	20.9 [1.5]	34.4 [1.6]
Leafy					
Observed	3.5 [1.4]	7.2 [1.3]	90.9 [2.0]	37.0 [1.2]	79.0 [1.4]
No. of Samples	7	8	1	32	8
Estimated	9.1 [1.3]	9.2 [1.3]	20.9 [1.4]	39.9 [1.2]	65.6 [1.4]

---

[1] Values in square brackets indicate the standard error of the geometric mean.

$$\textit{Approximate } 95\% \textit{ upper confidence limit} = \textit{Mean} \times (\textit{std. error})^2$$

$$\textit{Approximate } 95\% \textit{ lower confidence limit} = \frac{\textit{Mean}}{(\textit{std. error})^2}$$

Figure 12

OBSERVED RADIUM-226 CONCENTRATIONS

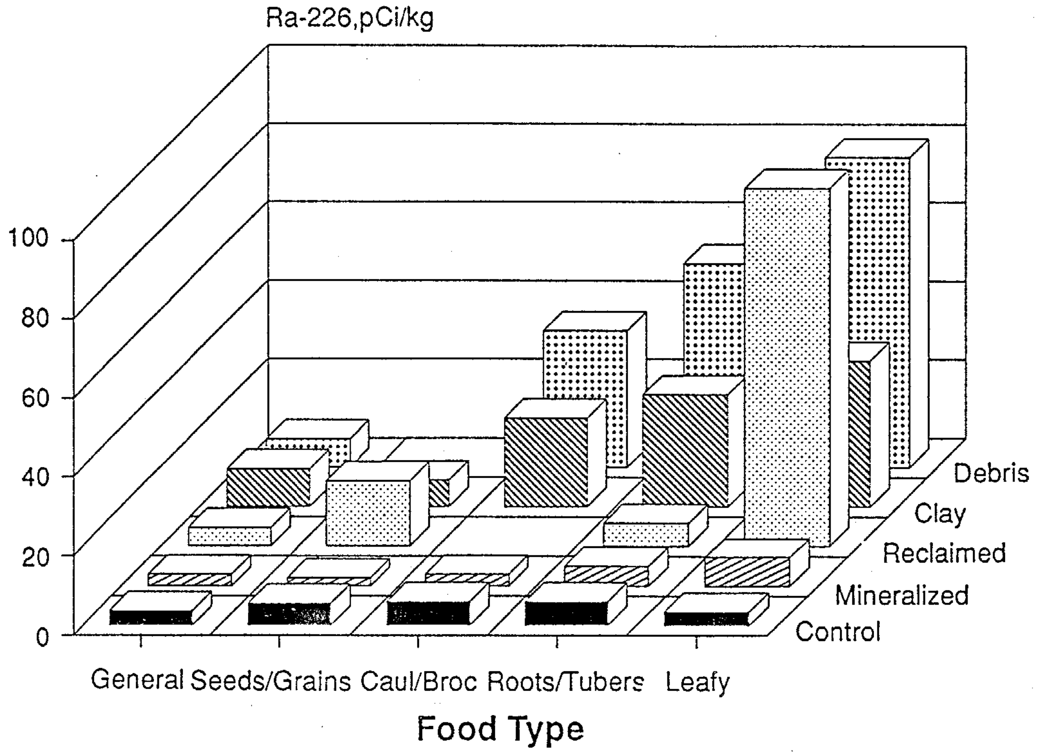
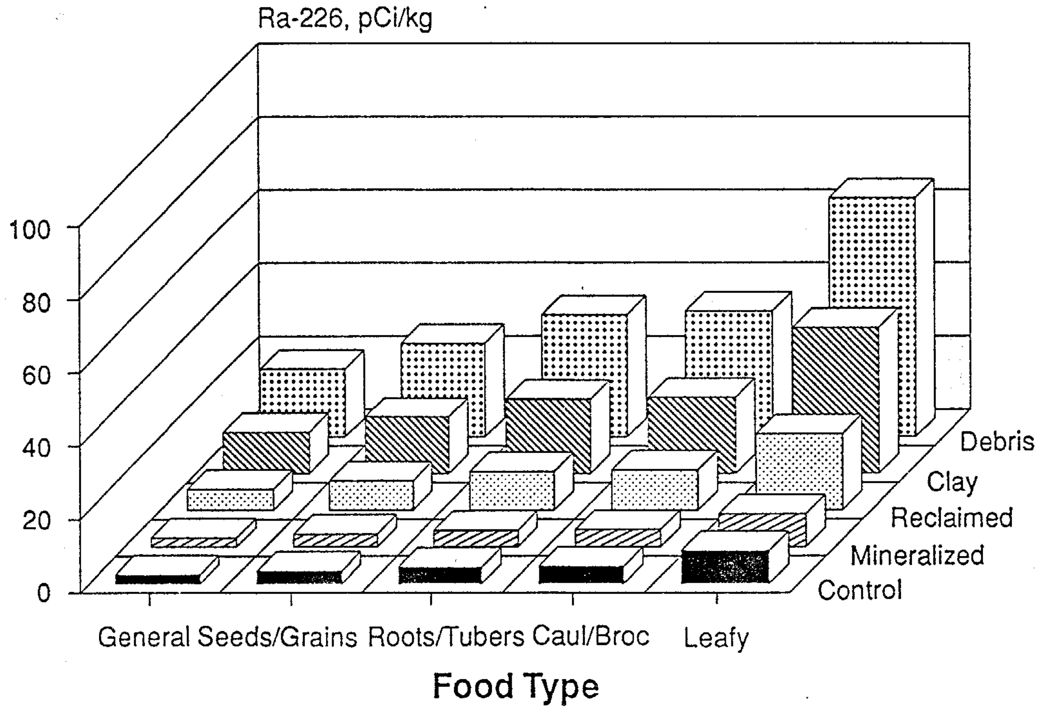


Figure 13

ESTIMATED RADIUM-226 CONCENTRATIONS

Food Type/Land Type Model



preferred radium-226 model which does not use the soil chemistry parameters, the entire radium-226 data set was used. Thus, the estimated geometric means are different, but similar in value.

Lead-210

For this radionuclide, samples were collected from reclaimed, clay and debris lands. The observed geometric mean concentrations are presented in Table 57; the three sampled land categories are presented in Figure 14. Data are missing for even more food-type/land-type cells than for radium-226. Again, assuming a systematic effect, a simple food-type/land-type model was fitted to the data and estimated values were obtained for each of the food-type/land-type cells; these results are also presented in Table 57 and are depicted in Figure 15. There was not as close a correspondence between observed and estimated values as for radium-226; the lead-210 estimates were based on fewer data and a less complete design than for radium-226.

Again the estimated concentrations in foods reflect the general level of soil radioactivity in the various land classes with the highest concentrations in foods from debris lands. The superimposed food effect is similar to that for radium-226 with a slightly different order of foods. In this case the steepest increase is along the diagonal from the "roots/tubers-on-reclaimed" cell to the "leafy-on-debris" cell.

Soil Radioactivity Model

This type of estimator represents the next degree of complexity and might be used when soil radioactivity levels are known but no additional soil data are available. Estimation of food radioactivity from soil radioactivity is commonly used in radiological assessment. Conventionally, a simple plant:soil ratio is applied for various food types. However, the multiplicative model introduced for this study allows the investigation of relationships other than the simple linear ratio.

Radium-226

Table 58 lists the models which are suggested for the five food categories. Note that food radium-226 is approximately a square root function of soil radium-226.

Lead-210

Table 58 lists the models which are suggested for the five food categories. Again food radioactivity is approximately a square root function of soil radioactivity.

Table 57

Lead-210 in Foods (pCi/kg)
Observed Geometric Mean by Food Type and Land Type
Estimated Values from Food-Type/Land-Type Model

Food Category	Reclaimed	Clay	Debris
Roots/Tubers			
Observed	2.0 [4.2][1]	2.3 [1.5]	7.8 [2.1]
No. of Samples	1	10	2
Estimated	0.4 [2.3]	3.2 [1.5]	4.7 [1.8]
General			
Observed	0.7 [2.1]	10.6 [1.8]	-
No. of Samples	2	4	
Estimated	0.7 [2.2]	5.5 [1.9]	8.0 [2.2]
Seeds/Grains			
Observed	ND[2] [2.8]	30.4 [2.1]	-
No. of Samples	1	2	
Estimated	2.1 [2.6]	15.0 [2.3]	22.0 [2.6]
Caul/Broc			
Observed	-	16.1 [1.8]	60.1 [2.8]
No. of Samples		3	1
Estimated	2.8 [2.9]	20.3 [2.0]	29.8 [2.2]
Leafy			
Observed	-	38.2 [1.3]	31.8 [1.5]
No. of Samples		29	7
Estimated	3.8 [2.3]	27.9 [1.3]	41.0 [1.6]

---

[1] Values in square brackets indicate the standard error of the geometric mean.

$$\text{Approximate 95\% upper confidence limit} = \text{Mean} \times (\text{std. error})^2$$

$$\text{Approximate 95\% lower confidence limit} = \frac{\text{Mean}}{(\text{std. error})^2}$$

[2] Non-detectable. Adjusted to 0.5 for data analyses

Figure 14

OBSERVED LEAD-210 CONCENTRATIONS

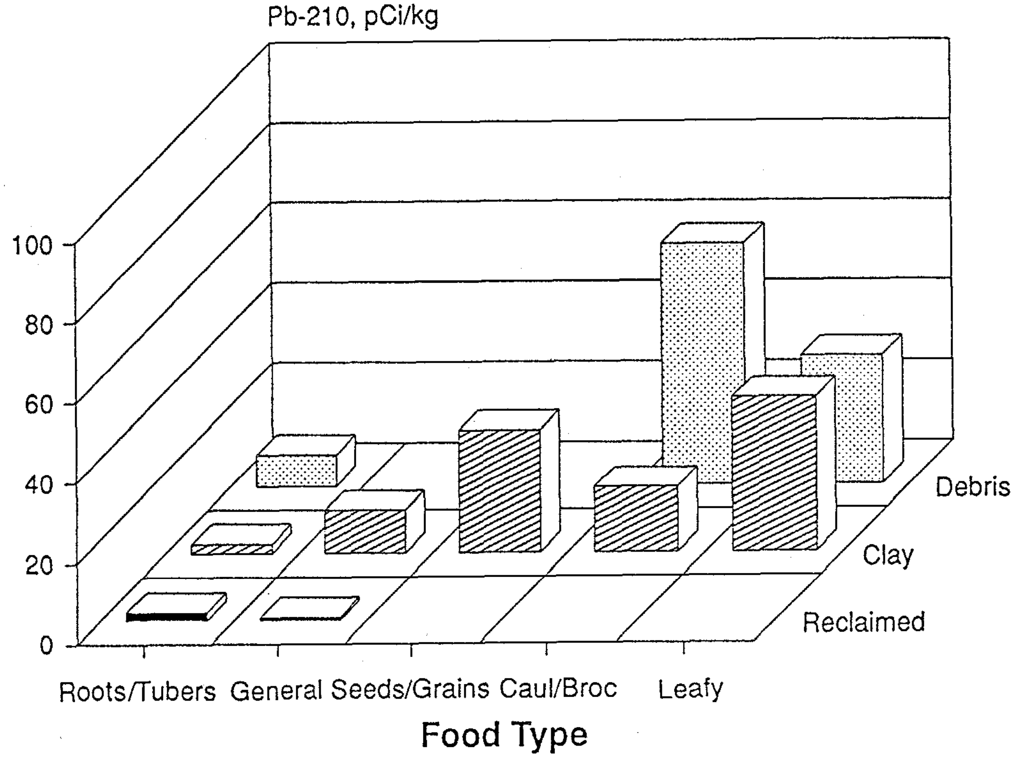


Figure 15

ESTIMATED LEAD-210 CONCENTRATIONS

Food Type/Land Type Model

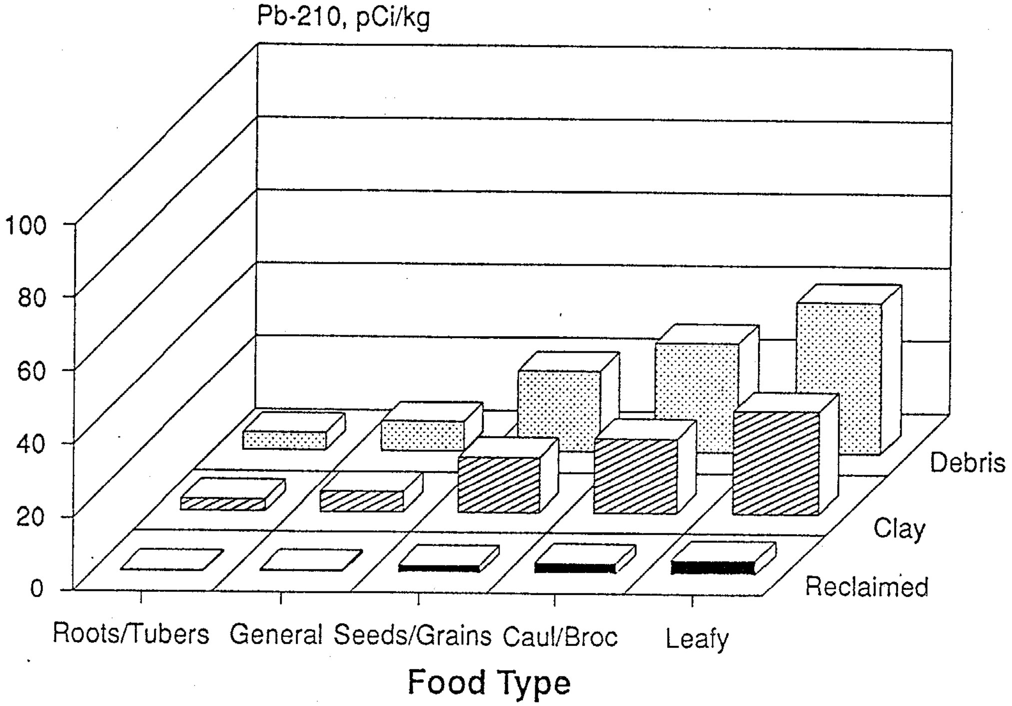


TABLE 58

SUGGESTED MODELS FOR ESTIMATING FOOD RADIOACTIVITY CONCENTRATIONS[1]

RADIUM-226[1]

FOOD-TYPE/LAND-TYPE MODEL

Food Type	Concentration in pCi/kg for Indicated Land Type				
	Debris	Clay	Reclaimed	Mineralized	Control
Leafy	65.6	39.9	20.9	9.2	9.1
Caul/Broc	34.4	20.9	11.0	4.8	4.8
Roots/Tubers	33.3	20.3	10.6	4.7	4.6
General	18.6	18.6	5.9	2.6	2.6
Seeds/Grains	25.6	15.5	8.1	3.6	3.5

SOIL RADIOACTIVITY MODEL[2]

Leafy: $FRa = 16.42 \times SRa^{0.42}$

Caul/Broc: $FRa = 7.25 \times SRa^{0.42}$

Roots/Tubers: $FRa = 5.78 \times SRa^{0.42}$

General: $FRa = 4.46 \times SRa^{0.42}$

Seeds/Grains: $FRa = 4.12 \times SRa^{0.42}$

SOIL PARAMETER MODEL[3]

Leafy: $FRa = 3.29 \times SRa^{0.41} \times CEC^{-0.28} \times e^{0.36 \times pH}$

Roots/Tubers: $FRa = 1.28 \times SRa^{0.41} \times CEC^{-0.28} \times e^{0.36 \times pH}$

Caul/Broc: $FRa = 1.21 \times SRa^{0.41} \times CEC^{-0.28} \times e^{0.36 \times pH}$

General: $FRa = 1.11 \times SRa^{0.41} \times CEC^{-0.28} \times e^{0.36 \times pH}$

Seeds/Grains: $FRa = 0.68 \times SRa^{0.41} \times CEC^{-0.28} \times e^{0.36 \times pH}$

---

[1] 95 percent confidence interval is multiplicative using a factor ranging from 6 to 8

[2] FRa = food radium-226 concentration in pCi/kg
SRa = soil radium-226 concentration in pCi/g

[3] CEC = cation exchange capacity in meq/100g
pH is expressed in pH units

TABLE 58 (continued)

LEAD-210[1]

FOOD-TYPE/LAND-TYPE MODEL

Food Type	Concentration in pCi/kg for Indicated Land Type		
	Debris	Clay	Reclaimed
Leafy	41.0	27.9	3.8
Caul/Broc	29.8	20.3	2.8
Seeds/Grains	22.1	15.0	2.1
General	8.1	5.5	0.8
Roots/Tubers	4.7	3.2	0.4

SOIL RADIOACTIVITY MODEL[2]

Leafy: $FPb = 6.87 \times SPb^{0.47}$

Caul/Broc: $FPb = 5.03 \times SPb^{0.47}$

Roots/Tubers: $FPb = 0.71 \times SPb^{0.47}$

General: $FPb = 0.87 \times SPb^{0.47}$

Seeds/Grains: $FPb = 1.67 \times SPb^{0.47}$

---

[1] 95 percent confidence interval is multiplicative using a factor ranging from 16 to 17.

[2] FPb = food lead-210 concentration in pCi/kg

SPb = soil lead-210 concentration in pCi/g

Multiple Parameter Model

This represents the third level of complexity and could be used when detailed soil radioactivity and chemistry data are available. While many models are possible, this set was selected as the best representation based on the available data in this study.

Radium-226

Table 58 lists the multiple parameter models which are suggested.

Lead-210

As discussed above, no soil parameters correlatedwith food lead at the 0.15 level. Therefore, no models are suggested for estimating food lead with a multiple parameter model.

DOSE EVALUATION

INTRODUCTION

The biological effects which may occur from exposure to radioactivity are assumed to be linearly proportional to the radiation dose received by the exposed individual. In this context, the radiation dose absorbed by an individual is expressed in thousandths of a rem (mrem). The evaluation of potential radiation doses to humans from radioactivity in foods requires the following:

1. scenarios describing the individuals or populations for which the dose is to be estimated,

2. a diet model describing the average intake of various food items, and

3. a dosimetry model to convert radionuclide intake to dose.

The dose calculation scenario describes the individual for which the dose is being calculated and specifies the source of that individual's food. For the purpose of this study, foods are separated into "sampled" foods and "non-sampled" foods. "Sampled" foods are those potentially affected by the several land types under study. The radioactivity concentrations in these foods are available from laboratory measurements. "Non-sampled" foods are those not sampled in this study, and are assumed to be derived from a general food pool available to the population. Radionuclide concentrations for "non-sampled" foods and drinking water are taken from the literature.

INTAKE SCENARIOS

The "sampled" foods consumed by a typical individual are likely to be a combination of those grown on mined lands and those originating elsewhere. Since debris lands are no longer being created, these lands were not considered in the definition of the intake scenarios. Reclaimed and clay lands will continue to be created by phosphate reclamation procedures. Since, of these two, the average food concentrations observed on clay lands were higher than on reclaimed lands, the intake scenarios were defined for foods obtained from clay lands to be conservative. For the purpose of the dose assessment, three individuals were defined:

1. Control individual - a reference individual who consumes "sampled" foods that do not originate on mining-related lands.

2. Local individual - an individual in the phosphate mining region whose "sampled" foods are a mixture of foods from both clay and unmined lands. This individual can be considered an average for the region. For the local individual's diet, it is assumed that ninety percent of the "sampled" foods were obtained from unmined lands. Although the authors believe that only a few percent of the local individual's diet would

come from clay lands, ten percent was assumed to be conservative.

3. Maximum individual - obtains one hundred percent of his diet of "sampled" foods from clay lands. The authors do not expect that any individual reflects this worst-case scenario.

The "local" and "maximum" individuals can be compared to the "control" individual to determine incremental doses.

DIET MODEL

The "total diet" model used for this study considers the consumption of all food items, including such specific items as meats, milk and milk products, condiments, and beverages. The diet model used for this assessment is shown in Table 59. It is based on the revised FDA diet with regrouping from the 201 items in that diet (Pennington, 1983). All sampled items are retained as unique items. Groupings were developed on a general plant-type basis with considerations made for diet substitution.

Food intake quantities were derived from the FDA values for a young adult male. Values are available for other age groups and for females in the same groups. However, the dose conversion factors selected for the dose analysis are for adult males, and other sex or age group calculations would involve additional assumptions and corrections in the calculations.

DOSE COMPUTATION

Radiation doses were calculated in terms of committed effective dose equivalent (CEDE). The CEDE is a dose quantity that expresses the long-term dose received from an annual intake of radioactivity and provides for summing the effects of ingestion of various radionuclides that have different distributions in the body and different biological turnover rates. CEDEs were calculated from the estimated annual radionuclide intakes using dose conversion factors (DCFs) expressed as CEDE per unit intake (mrem/pCi) from Federal Guidance Report No. 11 (USEPA, 1988). This is the latest compilation of ingestion DCFs and is based on the dosimetry methodology of ICRP Publication Number 30 (ICRP, 1977).

Doses were calculated with the aid of a computerized Lotus 1-2-3^R spreadsheet. A worksheet was prepared for each mining-related land category and radionuclide combination. Table 60 shows an example worksheet for one such combination. The table includes all the essential elements necessary to make a wide variety of calculations and to draw numerous conclusions. The heading of the worksheet displays the land category of interest, radionuclide, and dose conversion factor. Each

TABLE 59

TOTAL DIET MODEL

	INTAKE (g/day)	SAMPLED
DAIRY		
Milk	280.99	NO
Cheese	22.41	NO
MEAT		
Beef	129.27	NO
Pork	39.54	NO
Other	69.00	NO
FISH	20.06	NO
EGGS	30.95	NO
CEREAL FOOD		
Corn Grain	5.18	NO
Grain	4.55	NO
Cereals/Bread	174.70	NO
CAULIFLOWER/BROCCOLI		
Cauliflower	0.71	YES
Broccoli	2.80	YES
LEAFY/COLE VEGETABLES		
Cabbage	7.04	YES
Collard Greens	0.45	YES
Lettuce	23.38	YES
Mustard Greens	0.45	YES
Spinach	3.28	YES
Turnip Greens	0.45	YES
Other	0.76	NO
Celery	0.62	NO
LEGUMES		
Green Peas	7.29	NO
Other Beans	25.71	NO
Nuts	4.94	NO
Other	11.28	NO
SEEDS/GRAINS		
Blackeyed Peas	5.61	YES
Rice	22.94	YES
Yellow Corn	14.41	YES
TUBERS/ROOTS		
Carrot	2.92	YES
Onion	4.19	YES
Radish	0.32	YES
Turnip	0.42	YES
Potatoes	85.22	NO

TABLE 59 (CONTINUED)

	INTAKE (g/day)	SAMPLED
GARDEN FRUIT		
Cucumber	2.62	YES
Green Beans	8.80	YES
Green Pepper	1.99	YES
Strawberries	1.23	YES
Tomato	25.18	YES
Watermelon	3.44	YES
Yellow Squash/Zucchini	1.26	YES
Other	6.55	NO
TREE FRUIT		
Citrus		
Orange	85.26	NO
Grapefruit	7.78	NO
Lemon	10.71	NO
Other	60.36	NO
SOUPS	36.82	NO
CONDIMENTS	54.12	NO
DESSERTS	78.30	NO
BEVERAGE	1172.44	NO
WATER	512.00	NO
TOTAL:	3071.80	

---

[1] Developed from 201-category revised FDA diet (Pennington, 1983).

TABLE 60

EXAMPLE DOSE CALCULATION

CLAY LAND　　Pb-210　　DCF: 5.4E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN CLAY (pCi/kg)	CCN UNMINED (pCi/kg)	INTAKE CLAY (pCi/yr)	INTAKE UNMINED (pCi/yr)	% OF TOTAL INTAKE CLAY
BROCCOLI	3.51	16.07	4.00 RT	2.06E+01	5.13E+00	2.14
LEAFY						
Cabbage	7.04	5.50	5.43 T	1.41E+01	1.40E+01	1.47
Collard Grns.	0.45	42.68	5.43 T	7.01E+00	8.92E-01	0.73
Lettuce	23.38	17.62	5.43 T	1.50E+02	4.64E+01	15.61
Mustard Grns.	0.45	35.84	5.43 T	5.89E+00	8.92E-01	0.61
Spinach	3.28	71.14	5.43 T	8.52E+01	6.51E+00	8.84
Turnip Grns.	0.45	70.73	5.43 T	1.16E+01	8.92E-01	1.21
----->	35.05			2.74E+02	6.95E+01	28.46
SEEDS/GRAINS						
Blackeyed Pea	5.61	15.00 E	3.00 RT	3.07E+01	6.15E+00	3.19
Rice	22.94	51.12	61.56	4.28E+02	5.16E+02	44.44
Yellow Corn	14.41	18.06	3.00 RT	9.51E+01	1.58E+01	9.86
----->	42.96			5.54E+02	5.38E+02	57.49
ROOTS						
Carrot	2.92	2.09	1.90 T	2.23E+00	2.02E+00	0.23
Onion	4.19	3.20 E	1.40 T	4.90E+00	2.14E+00	0.51
Radish	0.32	3.20 E	1.73 T	3.70E-01	2.00E-01	0.04
Turnip	0.42	2.55	1.73 T	3.93E-01	2.67E-01	0.04
----->	7.85			7.89E+00	4.64E+00	0.82
GENERAL						
Cucumber	2.62	5.50 E	1.00 RT	5.27E+00	9.58E-01	0.55
Green Beans	8.80	5.50 E	1.00 RT	1.77E+01	3.21E+00	1.83
Green Pepper	1.99	5.50 E	1.00 RT	4.00E+00	7.27E-01	0.41
Strawberries	1.23	49.04	1.00 RT	2.20E+01	4.49E-01	2.29
Tomato	25.18	5.50 E	1.00 RT	5.06E+01	9.20E+00	5.25
Watermelon	3.44	5.50 E	1.00 RT	6.92E+00	1.26E+00	0.72
Squash / Zucc	1.26	0.86	1.00 RT	3.96E-01	4.60E-01	0.04
----->	44.53			1.07E+02	1.63E+01	11.09
TOTALS:	133.90			9.64E+02	6.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED,	SAMPLED FOODS	6.33E+02
		TOTAL	2.32E+03
	MINED,	SAMPLED FOODS	9.64E+02
		TOTAL	2.65E+03
DOSE:	NON-SAMPLED FOODS		9.02E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.40E+00
		TOTAL	1.24E+01
	MAX INDIV,	SAMPLED FOODS	5.17E+00
		TOTAL	1.42E+01
	LOCAL INDIV,	SAMPLED FOODS	3.58E+00
		TOTAL	1.26E+01

worksheet is designed to calculate the dose for the "maximum" individual. The first column contains the diet items selected for this study followed by their respective intake quantities (g/day from Table 59) in the second column. The third column indicates the geometric mean concentrations in pCi/kg for the specific food item from the mining-related land category of interest. Only clay lands are discussed here. Worksheets for other land types are included in the appendix. The radioactivity concentration for unmined land is given in the fourth column. The unmined category includes food from both control and mineralized lands since these foods exhibited radioactivity concentrations which were not statistically different. Columns five and six show calculated intakes in pCi/yr for the mining-related and unmined lands, respectively. These values are the products of the dietary intake (second column),the respective concentrations, and a conversion factor of (365.25 days/year)/(1000 g/kg) = 0.36525 to reconcile units. The final column displays the contribution of each food item to the total intake for the mined land category. Since dose is directly proportional to intake for a particular radionuclide, these percentages can easily be used to determine specific food items and general food categories that are major contributors to the dose from sampled foods.

Gaps in the database for unmined lands were filled with values taken directly or derived from literature sources and are correspondingly coded. Missing data for the mining-related lands were estimated (E) by considering trends in the overall data set. In most cases, a simple food-type/land-type model was adequate for these estimations. However, some foods exhibited much higher concentrations than others in their category on other lands where measurements were available. In such situations, the ratio of the concentration in that food to the geometric mean of the concentrations of the other measured foods was applied as a multiplier to the modeled value for the deficient land-type. Data for specific foods from Tracy et al (1983) were used where available, and geometric means for analagous categories in the Tracy data set were used otherwise (T). Where analagous categories were not available,values were estimated by taking the ratio of the modeled values for the category of interest and the leafy category on reclaimed land. This ratio was multiplied by the Tracy value for the leafy category on unmined land to yield the estimate (RT).

Intake totals for non-sampled foods (from Table 61) and for sampled foods from mining-related and unmined lands are listed at the bottom of each worksheet. Concluding the worksheets are the dose totals for the three intake scenarios. For the local individual, the dose from sampled foods is calculated as follows:

$$\textit{Dose} = 0.9 \times \textit{(dose from control)} + 0.1 \times \textit{(dose from clay)}$$

This reflects the definition of the local individual as obtaining ten percent of his diet of sampled foods from mining-related lands and the remainder from unmined lands.

Radionuclide intake from non-sampled foods was calculated from concentrations derived from the literature. Table 61 lists the food intakes, radioactivity concentrations, calculated radioactivity intakes, and doses for foods not sampled in this study. These values are compiled from the food intakes from Table 59 and the radionuclide concentrations as derived from the literature.

Table 62 lists foods sampled in this study that were either insignificant in the diet or for which insufficient quantities were sampled for dose calculations. Where appropriate, they were used to estimate values in other foods. Cauliflower and eggplant were sampled only once and only from unmined land. Other foods sampled on only one land type with no corresponding control samples were also omitted from consideration. The decision to omit potatoes was augmented by the unlikely use of clay lands for its production.

RESULTS

Radionuclide intakes and doses for radium-226 and lead-210 are summarized in Tables 63 and 64 from the calculational worksheets A-1 through A-6 in Appendix A. Results are presented for the control individual (sampled foods from unmined land) and for both the local individual and the maximum individual. In Table 64, the dose contributions for these two radionuclides and contributions from uranium and thorium radionuclides estimated in the initial study are summed. Tables A-7 and A-8 list the intakes and doses for all of the land types studied.

Table A-9 shows the analysis for the grocery store samples collected in the Orlando area. The worksheet displays lead-210 concentrations with values for other radionuclides and foods noted at the bottom. These data are insufficient to allow further analysis. Information concerning the locations of origin for the sampled foods was not available. Initially, these samples were intended to provide lead-210 results to augment the radium-226 results on control lands, assuming that the grocery store samples would exhibit radionuclide levels similar to those on control lands. This assumption appears to have been unfounded. The geometric means of the grocery store samples for the general food category ranged from two to two hundred times higher than the literature values. Moreover, the grocery measurements were generally higher than measurements of samples from reclaimed lands, casting further doubt on their reliability as controls.

Control values for radium-226 in the non-sampled diet were derived from the literature as noted in Table 61. The total intake of lead-210 for that portion of the diet was assigned the same total as radium-226 assuming a 1:1 ratio according to Holtzman (1980). That estimated intake for a Florida resident is much higher than the well-documented intake for the U.S. citizen accepted in NCRP Report No. 94 (NCRP, 1987) from a compilation of extensivedata from the same publication by Holtzman. Those data show a normal value of about 1.4 pCi/day with little variability (+/- 0.3 pCi/day).

TABLE 61

NON-SAMPLED PORTION OF THE TOTAL DIET

	INTAKE (g/day)	CCN UNMN (pCi/kg) Ra-226	Pb-210	INTAKE (pCi/yr) Ra-226	Pb-210
DAIRY					
Milk	280.99	2.51 La	NA	257.61	NA
Cheese	22.41	0.22 R	NA	1.80	NA
MEAT					
Beef	129.27	3.98 I	NA	187.92	NA
Pork	39.54	0.91 R	NA	13.14	NA
Other	69.00	0.91 R	NA	22.93	NA
FISH	20.06	1.30 R	NA	9.52	NA
EGGS	30.95	5.00 R	NA	56.52	NA
CEREAL FOOD	184.43	2.00 R	NA	134.73	NA
LEAFY/COLE VEG.	1.38	4.50 R	NA	2.27	NA
LEGUMES/CORN	49.22	4.50 R	NA	80.90	NA
TUBERS/ROOTS					
Potatoes	85.22	2.10 T	NA	65.37	NA
Other	1.10	2.00 R	NA	0.80	NA
GARDEN FRUIT					
Other	6.55	4.50 R	NA	10.77	NA
TREE FRUIT					
Citrus					
Orange	85.26	1.65 I	NA	51.38	NA
Grapefruit	7.78	1.63 I	NA	4.63	NA
Lemon	10.71	1.52 I	NA	5.95	NA
Other	60.36	4.50 R	NA	99.21	NA
SOUPS	36.82	2.25 Ea	NA	30.26	NA
CONDIMENTS	54.12	0.01 Eb	NA	0.20	NA
DESSERTS	78.30	0.22 Eb	NA	6.29	NA
BEVERAGE	1172.44	1.00 Eb	NA	428.23	NA
WATER	512.00	1.13 Lb	NA	211.32	NA
TOTAL:	2937.91			1681.75	1681.75 H
DOSE: (mrem/yr)				2.22	9.02

KEY:		
	La	Dairy samples from Polk Co. (Watson et al., 1984)
	R	Russell et al., 1966
	I	From the initial study
	T	Tracy et al., 1983
	Ea	Geometric mean of Russell vegetables and water
	Eb	Estimated from general data trends
	Lb	Average of 38 values for Florida (Watson et al., 1984)
	NA	No values were assigned for individual categories
	H	Total estimated assuming a 1:1 ratio for Ra-226 and Pb-210 (Holtzman et al., 1980)

TABLE 62

OTHER SAMPLED FOODS

			RADIOACTIVITY CONCENTRATION (pCi/kg)		
	NO. OF SAMPLES	RADIO-NUCLIDE	UNMINED	RECLAIMED	CLAY
CAULIFLOWER[1]	1	Ra-226	6.02		
		Pb-210			
		Po-210			
PARSLEY[1,2]	1	Ra-226			
		Pb-210			51.80
		Po-210			34.16
SWISS CHARD[1,2]	1	Ra-226			
		Pb-210			118.32
		Po-210			22.40
LIMA BEANS[1]	1	Ra-226		65.71	
		Pb-210			
		Po-210			
POTATOES[3,4]	3	Ra-226		4.34	
		Pb-210		2.00	
		Po-210		2.05	
EGGPLANT[1]	1	Ra-226	4.05		
		Pb-210			
		Po-210			
OKRA[3]	2	Ra-226			30.10
		Pb-210			27.84
		Po-210			1.07

[1] Insufficient sampling
[2] Item is an insignificant contributor to the diet
[3] Item sampled on only one land type
[4] Item is not likely to be grown on mining-related lands

Results for polonium-210 are displayed in Table A-10. The data were insufficient for dose assessment. Generally low food concentrations coupled with a small DCF indicate that the doses from this radionuclide would not be significant in this study. The polonium-210 to lead-210 activity ratio in the average total diet for the U.S. citizen is about 1.3 according to NCRP Report Number 94; however, foods measured for both radionuclides in this study indicate that polonium-210 levels are much lower.

DISCUSSION

As shown in Table 64,the majority of the dose is due to lead-210. Attributable doses from the uranium and thorium series were 0.3 mrem per year for the local individual and 2.7 mrem per year for the maximum individual.

The NCRP established in Report Number 91 (NCRP, 1987) a "negligible individual risk level" (NIRL) considered to be a trivial risk that can be dismissed from consideration. According to the NCRP, "the utilization of the NIRL is especially important in regard to environmental issues involving exposure of populations". The NIRL corresponds to an annual effective dose equivalent of 1 mrem which represents an annual risk for fatal health effects of one in ten million. Certainly many of the specific food items considered independently (as would be appropriate for parcels of land used to grow a specific food item for distribution in the general food pool) would fall below the NIRL. As an upper limit, the NCRP suggests that continuous exposure to sources in addition to natural background should not exceed 100 mrem/yr. The EPA uses a limit of 25 mrem/yr for individual pathways. These reference levels can be used to interpret the dose assessment results listed in Table 64.

The total attributable dose due to clay lands for the local individual is below the NIRL. For the maximum individual, that dose is 2.7 mrem/yr, which is much less than the 25 mrem/yr upper reference level. It represents a sixteen percent increase over the control dose. Based on NCRP 91, this dose would represent an annual risk of less than one in a million.

To further put these doses in perspective, Table 65 lists a composite of information presented in NCRP Report Number 93 (NCRP, 1987b). Total annual average effective dose equivalents to a member of the U.S. population are shown by source for comparison to the 39 mrem attributable to radionuclides in the body. Of that amount, the lead-210 - polonium-210 pair and potassium-40 contribute most of the annual dose with radium-226 and all other radionuclides contributing much less. The doses shown on Table 64 which are attributable to foods grown on clay lands represent a small fraction of the annual average dose received by a member of the U.S. population, even in the case of the hypothetical maximum individual.

Table 63

RADIONUCLIDE INTAKE FROM FOOD CONSUMPTION (pCi/yr)

	Control Individual	Local Individual	Maximum Individual
Ra-226	1915	1987 (72)[1]	2586 (671)
Pb-210	2315	2348 (33)	2646 (331)

[1] Values in parentheses are the intakes attributable to foods grown on clay lands and is equal to the difference between the intake beside it and the intake of the control individual. (Rounding may cause discrepancies.)

Table 64

RADIONUCLIDE DOSE (mrem/yr)

	Control Individual	Local Individual	Maximum Individual
Ra-226	2.5	2.6 (0.1)[1]	3.4 (0.9)
Pb-210	12.4	12.6 (0.2)	14.2 (1.8)
U-238, U-234[2]	0.4	0.4 (ND)[3]	0.5 (0.1)
Th-230, Th-232, Th-228[2]	1.1	1.1 (ND)[3]	1.0 (ND)[3]
Total	16.4	16.7 (0.3)	19.1 (2.7)

[1] Values in parentheses are the doses attributable to foods grown on clay lands and is equal to the difference between the dose beside it and the dose to the control individual. (Rounding may cause discrepancies.)

[2] From Guidry et al. (1986)

[3] Difference not detectable at the 0.1 mrem/yr level

Table 65

ANNUAL AVERAGE TOTAL EFFECTIVE DOSE EQUIVALENT
(mrem/yr)

Man-Made			
	Diagnostic X-Rays	39	
	Nuclear Medicine	14	
	Other	7	
	Subtotal		60
Natural			
	Inhaled Radon	200	
	Cosmic Radiation	27	
	Cosmogenic	1	
	Terrestrial Radiation	28	
	In the Body		
	Pb-210, Po-210	15	
	K-40	19	
	Ra-226	1	
	All Others	4	
	Subtotal		295
	Rounded Total		360

CONCLUSIONS/RECOMMENDATIONS

CONCLUSIONS

Based on the results described in the previous sections, it can be concluded that foods grown on mined phosphate lands (including reclaimed, debris and clay lands) exhibit higher concentrations of radium-226 than foods grown on unmined lands (including phosphate mineralized and unmineralized lands). This is consistent with the findings of the initial study. Since this study did not investigate levels of lead-210 and polonium-210 in foods grown on unmined lands, conclusions regarding relative concentrations of these radionuclides in foods grown on mined and unmined lands cannot be drawn. The higher concentrations exhibited by those foods grown on mined phosphate lands result in higher rates of ingestion for radium-226 and higher radiation doses to those individuals ingesting these foods. The doses however are quite low, even for the hypothetical maximum individual who consumes all study foods from clay lands. The estimated doses, even to the maximum individual, would be a small fraction of natural exposure to environmental radioactivity and would not be considered to be a health hazard.

The statistical analyses which were conducted on the data generated from this and the previous study indicate that radium-226 and lead-210 in foods vary approximately as the square root of radium-226 and lead-210 in soil. The results for polonium-210 were inconclusive due to the large number of measurements which were below the limit of detection of the analytical methodology. The effects of soil chemistry on the uptake of radium-226 and lead-210 by foods depended on the statistical model employed. However, in the case of radium-226, food concentrations were positively correlated with pH in all of the models employed and negatively correlated with cation exchange capacity for selected models. For lead-210, the soil chemistry data did not present a clear picture of those factors which might affect lead-210 uptake in foods.

It is important to note that the models which were developed from the statistical data base generated for this and the previous study can only be used for samples drawn from locations similar to those utilized in these studies and for foods grown in these studies. These models represent only a few of the models which are available from the analysis of these data. The integrated data base which was used in this study has been provided to the Florida Institute of Phosphate Research in a form suitable for analysis on the Statistical Analysis System.

RECOMMENDATIONS

Based on the low radiation doses which have been estimated from the data collected in this and the previous study, a recommendation to limit food production on mined phosphate lands does not appear to be warranted. Although the foods collected from mined lands did exhibit statistically higher levels of radium-226 than similar foods collected on unmined lands, the resulting radiation doses from the consumption of these foods are low. The authors do however recommend that, all other things being equal, if clay lands are to be used for commercial food production, preference be given to those foods (such as garden fruits and those in the general category) which exhibited the lowest concentrations of radioactivity.

BIBLIOGRAPHY

Baker, D.A.. 1976. User Guide for Computer Program Food. Richland, Washington: Batelle Pacific Northwest Labs.

Baker, D.A. et al. 1976. Food: An Interactive Code to Calculate Internal Radiation Doses from Contaminated Food Products. Richland, Washington: Batelle Pacific Northwest Labs.

Bernard, S.R. and W.S. Snyder. 1975. Metabolic Models for Estimation of Internal Radiation Exposure Received by Human Subjects from the Inhalation of Noble Gases. Health Physics Division Annual Progress Report for Period Ending June 30, 1975. ORNL5046: 197-204.

BEIR, Committee on Biological Effects of Ionizing Radiations. 1980. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980. Washington, D.C.: National Academy Press.

Blanchard, R.L. and J.B. Moore. Lead-210 and Polonium-210 in Tissues of Some Alaskan Residents as Related to Consumption of Caribou or Reindeer Meat. Health Physics. 18: 127-134.

Bogen, D.C., Welford, G.A., and Morse, R.S. 1976. General Population Exposure of Stable Lead and Pb-210 to Residents of New York City. Health Physics 30, 359.

Bolch, W.E. et al. 1977. Uranium and Radium Concentration in Florida Phosphate Fractions by GeLi Spectrometry, in Proceedings of the Health Physics Society 10th Midyear Topical Symposium, Natural Radioactivity in Man's Environment, October, 1976. Rensselaer Polytechnic Institute, eds. pp. 400-414.

Cowart, J.B. 1980. Variation of Uranium Isotopes in Some Carbonate Aquifers, in Natural Radiation Environment III, Vol. I. W. Lowder and T. Gesell, eds. p. 711.

Cullen, T.L. 1978. Low Level Radiation. Biological Interactions, Risks and Benefits. T. Cullen and P. Franca, eds. p. 423.

deBartoli, M., and Gaglione, P. 1972. Ra-226 in Environmental Materials and Foods. Health Physics 22, 43-48.

Drury, J.S. et al. 1983. Radioactivity in Foods. Oak Ridge National Laboratory. ORNL Report #5963.

Dunning, D.E. Jr., et al. 1981. Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities. Oak Ridge National Laboratory. NUREG/CR 0150 Vol. 3, ORNL/NUREG/TM-190/V3.

Eckerman, K.F., Wolbarst, A.B., and Richardson, A.C.B. 1988. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11.

Eisenbud, M. 1973. Environmental Radioactivity. 2nd ed. New York: Academic Press.

Eisenbud, M. et al. 1964. Naturally Occurring Radionuclides in Foods and Waters from the Brazilian Areas of High Radioactivity, in The Natural Radiation Environment, Proceedings from the First International Symposium on the Natural Radiation Environment (April 10-13, 1963), pp. 837-854.

Florida Statutes, Chapter 378. 1978. Tallahassee, Florida.

Garten, C.T. Jr. et al. 1981. Comparative Uptake of Uranium, Thorium, and Plutonium by Biota Inhabiting a Contaminated Tennessee Foodplain. Journ. Environ. Quality. Vol. 10, No. 2, pp. 207-210.

Gesell, T.F. and H.M. Prichard. 1975. The Technologically Enhanced Natural Radiation Environment. Health Physics. 28: 361-366.

Griffith, Lynn. Telephone Conversation Between Jerome J. Guidry, Post, Buckley, Schuh & Jernigan, Inc. and Lynn Griffith, A & L Southern Agricultural Laboratories, December 18, 1989.

Guidry, J.J. et al. 1986. Radioactivity in Foods Grown on Florida Phosphate Lands. Florida Institute of Phosphate Research. Publication No. 05-015-038.

Guimond, R.J. et al. 1979. Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands. U.S. Environmental Protection Agency. EPA-520/4-78-013.

Hamilton, E.I. 1972. The Concentration of Uranium in Man and His Diet. Health Physics. 22: 149-153.

Harley, J.H. (ed.). 1972. Health and Safety Laboratory Procedures Manual. U.S. Energy Research and Development Administration. HASL-300.

_____. 1987. Naturally Occurring Sources of Radioactive Contamination, Prepared for Radionuclides in the Food Chain. A Symposium Sponsored by the International Life Sciences Institute.

Hawkins, William. 1983. Agricultural Uses of Reclaimed Phosphate Lands, in Proceedings of the Symposium on Reclamation and the Phosphate Industry, Florida Institute of Phosphate Research Publication No. 03-036-010.

Healy, J.W. and J.C. Rodgers. A Preliminary Study of Radium - Contaminated Soils. Los Alamos Scientific Laboratory. LA-7391-MS.

Hill, C.R. 1962. Identification of Alpha-Emitters in Normal Biological Materials. Health Physics. 8: 17-25.

Holtzman, R.B. et al. 1979. Contamination of the Human Food Chain by Uranium Mill Tailings Piles. Argonne National Laboratory. NUREG/CR-0758, ANL/ES-69.

Holtzman, R.B. 1980. Normal Dietary Levels of Radium-226, Radium-228, Lead-210, and Polonium-210 for Man, in Natural Radiation Environment III, Vol. I. W. Lowder and T. Gessell, eds. p. 755.

ICRP. 1959. Recommendations of the International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation. ICRP Publication No. 2. Oxford: Pergamon Press.

_____. 1969. The Assessment of Internal Contamination Resulting from Recurrent or Prolonged Uptakes. ICRP Publication No. 10A. Oxford: Pergamon Press.

_____. 1975. Report of the Task Group on Reference Man. ICRP Publication No. 23. Oxford: Pergamon Press.

_____. 1977-82. Limits for Intakes of Radionuclides by Workers. ICRP Publication No. 30 and Supplements. Oxford: Pergamon Press.

Ibrahim, S.A. and Whicker, F.W. 1987. Plant Accumulation and Plant/Soil Concentration Ratios of ^{210}Pb and ^{210}Po at Various Sites Within a Uranium Mining and Milling Operation. Environmental and Experimental Botany. Vol. 27, No. 2, pp. 203-213.

Kangas, P. 1979. The Biochemistry of Radium, for the Center for Wetlands. Unpublished paper.

Kanipe, L.G. 1977. Handbook for Analytical Quality Control in Radioanalytical Laboratories. Tennessee Valley Authority. EPA-600/7-77-008.

Kaufmann, R.F. and J.D. Bliss. 1977. Effects of Phosphate Mineralization and the Phosphate Industry on Radium-226 in Ground Water of Central Florida. U.S. Environmental Protection Agency. EPA/520-6-77-010.

Kirchmann, R. et al. 1980. Accumulation of Radium-226 from Phosphate Fertilizers in Cultivated Soils and Transfer to Crops, in Natural Radiation Environment III, Proceedings of a Symposium Held at Houston, Texas, April 23-28, 1978, Vol. 2. CONF-780422. U.S. Department of Energy Symposium Series 51. pp. 1667-1672.

Klement, A.W. 1965. Natural Radionuclides in Foods and Food Source Materials, in Radioactive Fallout, Soils, Plants, Food, Man. E. Fowler, ed.

Lalit, B.Y. and T.V. Ramachandran. 1980. Natural Radioactivity in Indian Foodstuffs, in Natural Radiation Environment III, Proceedings of a Symposium Held at Houston, Texas, April 23-28, 1978, Vol. 2 CONF-790422, U.S. Department of Energy Symposium Series 51, pp. 800-809.

Lindeken, C.L. and D.G. Coles. 1977. The Radium-226 Content of Agricultural Gypsums, in Paper prepared for Symposium on Public Health Aspects of Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission Report NUREG/CP-0001, 369-375.

Lotus 1-2-3 User's Manual. 1983. Cambridge, Massachusetts: Lotus Development Corporation.

Manatee County. 1980 and 1984. Unpublished studies of groundwater samples collected in Manatee County, Florida. Manatee County Public Health Unit, Bradenton, Florida.

Marshall, J.H. et al. 1973. Alkaline Earth Metabolism in Adult Man. Health Physics. 24: 125-132.

McDowell-Boyer, L.M. et al. 1979. Review and Recommendations of Dose Conversion Factors and Environmental Transport Parameters for Lead-210 and Radium-226, Final Report. Oak Ridge National Laboratory. ORNL/NUREG-56.

Menzel, R.G. 1965. Soil-Plant Relationships of Radioactive Elements. Health Physics. 11: 1325-1332.

_____. 1968. Uranium, Radium, and Thorium Content in Phosphate Rocks and Their Possible Radiation Hazard. Journ. Agr. Food Chem. Vol. 16, No. 2: 231-234.

Methods Used and Adopted by the Association of Florida Phosphate Chemists. 1980. Sixth Edition, Section IX.

Miller, M.L. et al. 1980. Lognormal Analysis of Naturally Occurring Radionuclides in Soil and Vegetation of the Hanford Area, in National Radiation Environment III, Proceedings of a Symposium Held at Houston, Texas, April 23-28, 1978. Vol. 2 CONF-780422. U.S. Department of Energy Symposium Series 51. pp. 826-831.

Mistry, K.B. et al. 1970. Radioactivity in the Diet of Population of the Kerala Coast Including Monazite Bearing High Radiation Areas. Health Physics. 19: 535-542.

Mordberg, Y.L. and I.L. Shalayev. 1973. Method of Evaluating the Content of Natural Radioactive Isotopes of the Uranium and Thorium Family in Drinking Water and Food. Gig. Sanit. 8: 52-55.

Morse, R.S. and G.A. Welford. 1971. Dietary Intake of Lead-210. Health Physics. 21: 53-55.

Napier, B.A. 1980. Assessment of Effectiveness of Geologic Isolation Systems, ARRRG and Food--Computer Programs for Calculating Radiation Dose to Man From Radionuclides in the Environment. PNL-3180, uc-70. Richland, Washington: Battelle Pacific Northwest Laboratory.

NCRP. 1975. Natural Background Radiation in the United States. Rpt. No. 45. Washington, D.C.: National Council on Radiation Protection and Measurements.

_____. 1984a. Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment, Report 76 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

_____. 1984b. Exposures from the Uranium Series with Emphasis on Radon and Its Daughters. Report 77 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

_____. 1987a. Recommendations on Limits for Exposure to Ionizing Radiation. National Council on Radiation Protection and Measurements Report No. 91 (NCRP, Bethesda, MD).

_____. 1987b. Ionizing Radiation Exposure of the Population of the United States. National Council on Radiation Protection and Measurements Report No. 93 (NCRP, Bethesda, MD).

_____. 1987c. Exposure of the Population in the United States and Canada from Natural Background Radiation. National Council on Radiation Protection and Measurements Report No. 94 (NCRP, Bethesda, MD).

Oakes, T.W. and K.C. Shank. 1979. Concentrations of Radionuclides and Selected Stable Elements in Fruits and Vegetables. Oak Ridge National Laboratory.

Osburn, W.S. 1965. Primordial Radionuclides: Their Distribution, Movement, and Possible Effect Within Terrestrial Ecosystems. Health Physics. 11: 1275-1295.

Parzyck, D.C. et al. 1979. An Integrated Assessment of the Impacts Associated with Uranium Mining and Milling. Oak Ridge National Laboratory. ORNL/TM-6677.

Pennington, Jean A.T. 1983. Revision of the Total Diet Study, Food List and Diets. Journal of the American Dietetic Association. Vol. 82, No. 2.

Percival, D.R. and D.B. Martin. 1974. Sequential Determination of Radium-226, Radium-228, Actinium-227, and Thorium Isotopes in Environmental and Process Waste Samples. Analytical Chemistry. Vol. 46, No. 12: 1742-1749.

Persson, B.R. 1976. Lead-210, Polonium-210, and Stable Lead in the Foodchain: Lichen, Reindeer and Man, <u>in</u> Natural Radiation Environment II, Proceedings of the Second International Symposium on the Natural Radiation Environment Held in Houston, Texas, August 7-11, 1972. CONF-720805-P-1. U.S. Department of Energy. pp. 347-367.

Public Health Service. 1970. Radiological Health Handbook. U.S. Department of Health, Education and Welfare.

Roessler, C.E. et al. 1980. The Effect of Mining and Land Reclamation on the Radiological Characteristics of the Terrestrial Environment of Florida's Phosphate Regions, in Proceedings of the Symposium: The Natural Radiation Environment III, Held in Houston, Texas, April 23-28, 1978. CONF-780422. U.S. Department of Energy Symposium Series 51.

Roessler, C.E., Wood, J.G., and Shavers, M. 1986. Radionuclide Uptake by Forages, Phase I - Radium-226 Data Collection, final report to International Minerals and Chemical Corp. University of Florida, Gainesville, Florida.

Rupp, Elizabeth M. 1980. Age Dependent Values of Dietary Intake for Assessing Human Exposures to Environmental Pollutants. Health Physics. Vol. 39, No. 2: 151-163.

Russell, R.S. and K.A. Smith. 1966. Naturally Occurring Radioactive Substances: The Uranium and Thorium Series, in Radioactivity and Human Diet. Chapter 17. Pergamon Press, Oxford.

Ryan, M.T. and S.J. Cotter. 1980. An Integrated Assessment of the Phosphate Industry. Oak Ridge National Laboratory. ORNL-5583, ORNL/EV/OT1-2001.

SAS Institute. 1982. SAS User's Guide: Statistics, 1982 Edition. Carey, North Carolina.

Sill, C.W. n.d. An Analytical Standard for the Uranium Milling Industry. Unpublished paper prepared for Health Services Laboratory. U.S. Energy Research and Development Administration.

_____. 1974. Simultaneous Determination of Alpha-Emitting Nuclides of Radium through California in Soil. Analytical Chemistry. Vol. 46, No. 12: 1725-1737.

_____. 1977a. Determination of Thorium and Uranium Isotopes in Ores and Mill Tailings by Alpha Spectrometry. Analytical Chemistry. 49: 618.

_____. 1977b. Simultaneous Determination of Uranium-238, Uranium-234, Thorium-230, Radium-226, and Lead 210 in Uranium Ores, Dusts, and Mill Tailings. Health Physics. 33: 393-404.

Sill, C.W. and C.P. Willis. 1977. Radiochemical Determination of Lead-210 in Uranium Ores and Air Dusts. Analytical Chemistry. Vol. 49, No. 2: 302-306.

Simon, S.L. and S.A. Ibrahim. 1987. The Plant/Soil Concentration Ratio for Calcium, Radium, Lead, and Polonium: Evidence for Non-linearity with Reference to Substrate Concentration. J. Environ. Radioactivity 5, pp. 123-142.

Stroube, William B. Jr., et al. 1985. Survey of Radionuclides in Foods, 1978-1982. Vol. 49, No. 5.

Till, J.E. and Meyer, H.R. 1983. Radiological Assessment, NUREG/CR-3332 ORNL-5968, U.S. Nuclear Regulatory Commission, Washington, D.C.

Tracy, B.L., Prantl, F.A., and Quinn J.M. 1983. Transfer of Ra-226, Pb-210 and Uranium from Soil to Garden Produce - Assessment of Risk. Health Physics 44, 469-477.

Turner, R.C. et al. 1958. The Naturally Occurring Alpha-Ray Activity of Foods. Health Physics. 1: 268-275.

UNSCEAR. 1972. Ionizing Radiation: Levels and Effects. Official Records of the General Assembly. Twenty-seventh Session. Vol. 1, Supplement No. 25 (A18725). United Nations Scientific Committee on the Effects of Atomic Radiation.

_____. 1977. Sources and Effects of Ionizing Radiation. Official Records of the General Assembly, Thirty-second Session. Supplement No. 40 (A/32/40). United Nations Scientific Committee on the Effects of Atomic Radiation.

_____. 1982. Ionizing Radiation: Sources and Biological Effects. Report to the General Assembly.

USDA. 1968. Food Consumption of Households in the South, Spring 1965. Household Food Consumption Survey, 1965-1966. U.S. Government Printing Office.

U.S. Department of the Interior, Bureau of Mines. 1978. Evaluation of the Phosphate Deposits of Florida Using the Minerals Availability System. Contract No. J0377000.

USEPA. 1973a. Environmental Analysis of the Uranium Fuel Cycle Part I - Fuel Supply. U.S. Environmental Protection Agency.

_____. 1973b. Reconnaissance Study of Radiochemical Pollution from Phosphate Rock Mining and Milling. National Field Investigations Center.

_____. 1975. Preliminary Findings Radon Daughter Levels in Structures Constructed on Reclaimed Florida Phosphate Land. U.S. Environmental Protection Agency. ORP/CDS-75-4.

_____. 1976. National Interim Primary Drinking Water Regulations. U.S. Environmental Protection Agency.

_____. 1979. Radiological Environmental Resource Document. Draft Environmental Impact Statement, Swift Agricultural Chemicals Corporation, Duette Mine.

_____. 1988. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. U.S. Environmental Protection Agency. EPA-520/1-88-020.

USGS Open File Report No. 80-1223. 1981. Data on Groundwater Quality with Emphasis on Radionuclides, Sarasota County, Florida. Tallahassee, Florida.

USNRC. 1977a. Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR, Part 50, Appendix I. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. Regulatory Guide 1.109.

_____. 1977b. Measuring, Evaluating, and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Airborne Effluents from Uranium Mills. U.S. Nuclear Regulatory Commission. Regulatory Guide 4.14.

_____. 1982. Calculation Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operation. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. Regulatory Guide 3.51.

_____. 1983. Radiological Assessment, A Textbook on Environmental Dose Analysis. U.S. Nuclear Regulator Commission, Office of Nuclear Regulatory Research.

Watson, A.P. et al. 1984. Radium-226 In Drinking Water and Terrestrial Food Chains: Transfer Parameters in Normal Exposure and Dose. Nuclear Safety. Vol. 25, No. 6.

Welford, G.A. and R. Baird. 1967. Uranium Levels in Human Diet and Biological Materials. Health Physics. 13: 1321-1324.

White, G.C. et al. 1981. Factors Affecting Radionuclide Availability to Vegetables Grown at Los Alamos. Journ. Environ. Quality. Vol. 10, No. 3: 294-299.

Williams, E.G. et al. 1965. Background Radiation in Florida. Florida State Board of Health.

Windham, S.T. et al. 1976. Radiation Dose Estimates to Phosphate Industry Personnel. U.S. Environmental Protection Agency. EPA-520/5-76-014.

Witherspoon, John. Telephone Conversation Between Jerome J. Guidry, Post, Buckley, Schuh & Jernigan, Inc. and John Witherspoon, Ph.D., Oakridge National Laboratory, November 16, 1982.

Zellars-Williams, Inc. 1980. Evaluation of Pre-July 1, 1975 Disturbed Phosphate Lands. Lakeland, Florida.

Zimmer. 1978. Marinelli Beaker Calibration. Systems Application Studies. EG&G Ortec, PSD No. 8.

_____. 1979. Data Reduction of Low Activity Gamma Spectra. System Application Studies. EG&G Ortec. PSD No. 11.

______. 1980. LLD versus MDA. Systems Application Studies. EG&G Ortec. PSD No. 14.

APPENDIX A

DOSE WORKSHEETS

TABLE A-1

RECLAIMED LAND Ra-226 DCF: 1.3E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN REC (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE REC (pCi/yr)	INTAKE UNMN (pCi/yr)	% OF TOTAL INTAKE REC
BROCCOLI	3.51	9.23 E	3.00	1.18E+01	3.85E+00	1.33
LEAFY						
Cabbage	7.04	20.90 E	2.10	5.38E+01	5.40E+00	6.07
Collard Grns.	0.45	20.90 E	6.33	3.43E+00	1.04E+00	0.39
Lettuce	23.38	20.90 E	5.04 E	1.78E+02	4.30E+01	20.13
Mustard Grns.	0.45	20.90 E	1.44	3.43E+00	2.37E-01	0.39
Spinach	3.28	20.90 E	16.51	2.50E+01	1.98E+01	2.82
Turnip Grns.	0.45	90.86	10.32	1.49E+01	1.69E+00	1.68
----->	35.05			2.79E+02	7.12E+01	31.48
SEEDS/GRAINS						
Blackeyed Pea	5.61	7.91	2.57	1.62E+01	5.27E+00	1.83
Rice	22.94	26.00 E	7.10	2.18E+02	5.95E+01	24.58
Yellow Corn	14.41	8.63	4.90	4.54E+01	2.58E+01	5.12
----->	42.96			2.80E+02	9.06E+01	31.53
ROOTS						
Carrot	2.92	94.42 E	8.52	1.01E+02	9.08E+00	11.35
Onion	4.19	10.60 E	3.12	1.62E+01	4.78E+00	1.83
Radish	0.32	10.60 E	3.82	1.23E+00	4.42E-01	0.14
Turnip	0.42	7.87	5.00	1.21E+00	7.71E-01	0.14
----->	7.85			1.19E+02	1.51E+01	13.46
GENERAL						
Cucumber	2.62	5.60	3.22	5.36E+00	3.08E+00	0.61
Green Beans	8.80	3.68	5.16	1.18E+01	1.66E+01	1.33
Green Pepper	1.99	5.90 E	1.87	4.29E+00	1.36E+00	0.48
Strawberries	1.23	255.90 E	2.81	1.15E+02	1.26E+00	12.97
Tomato	25.18	5.90 E	2.94	5.43E+01	2.70E+01	6.12
Watermelon	3.44	1.87	1.24	2.35E+00	1.56E+00	0.27
Squash / Zucc	1.26	7.90	4.11	3.64E+00	1.89E+00	0.41
----->	44.53			1.97E+02	5.28E+01	22.19
TOTALS:	133.90			8.86E+02	2.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED,	SAMPLED FOODS	2.33E+02
		TOTAL	1.92E+03
	MINED,	SAMPLED FOODS	8.86E+02
		TOTAL	2.57E+03
DOSE:	NON-SAMPLED FOODS		2.22E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.08E-01
		TOTAL	2.53E+00
	MAX INDIV,	SAMPLED FOODS	1.17E+00
		TOTAL	3.39E+00
	LOCAL INDIV,	SAMPLED FOODS	3.94E-01
		TOTAL	2.61E+00

TABLE A-2

CLAY LANDS   Ra-226   DCF: 1.3E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN CLAY (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE CLAY (pCi/yr)	INTAKE UNMN (pCi/yr)	% OF TOTAL INTAKE CLAY
BROCCOLI	3.51	22.58	3.00	2.89E+01	3.85E+00	3.20
LEAFY						
Cabbage	7.04	10.53	2.10	2.71E+01	5.40E+00	3.00
Collard Grns.	0.45	46.07	6.33	7.57E+00	1.04E+00	0.84
Lettuce	23.38	40.41	5.04 E	3.45E+02	4.30E+01	38.18
Mustard Grns.	0.45	69.61	1.44	1.14E+01	2.37E-01	1.27
Spinach	3.28	20.81	16.51	2.49E+01	1.98E+01	2.76
Turnip Grns.	0.45	89.55	10.32	1.47E+01	1.69E+00	1.63
----->	35.05			4.31E+02	7.12E+01	47.67
SEEDS/GRAINS						
Blackeyed Pea	5.61	3.96	2.57	8.11E+00	5.27E+00	0.90
Rice	22.94	14.70	7.10	1.23E+02	5.95E+01	13.63
Yellow Corn	14.41	5.30	4.90	2.79E+01	2.58E+01	3.09
----->	42.96			1.59E+02	9.06E+01	17.61
ROOTS						
Carrot	2.92	113.07	8.52	1.20E+02	9.08E+00	13.33
Onion	4.19	9.91	3.12	1.52E+01	4.78E+00	1.68
Radish	0.32	14.90	3.82	1.72E+00	4.42E-01	0.19
Turnip	0.42	13.85	5.00	2.13E+00	7.71E-01	0.24
----->	7.85			1.40E+02	1.51E+01	15.44
GENERAL						
Cucumber	2.62	11.30 E	3.22	1.08E+01	3.08E+00	1.20
Green Beans	8.80	11.30 E	5.16	3.63E+01	1.66E+01	4.02
Green Pepper	1.99	1.26	1.87	9.16E-01	1.36E+00	0.10
Strawberries	1.23	120.80	2.81	5.43E+01	1.26E+00	6.00
Tomato	25.18	2.82	2.94	2.59E+01	2.70E+01	2.87
Watermelon	3.44	11.30 E	1.24	1.42E+01	1.56E+00	1.57
Squash / Zucc	1.26	6.08	4.11	2.80E+00	1.89E+00	0.31
----->	44.53			1.45E+02	5.28E+01	16.07
TOTALS:	133.90			9.04E+02	2.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED, SAMPLED FOODS		2.33E+02
		TOTAL	1.92E+03
	MINED, SAMPLED FOODS		9.04E+02
		TOTAL	2.59E+03
DOSE:	NON-SAMPLED FOODS		2.22E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.08E-01
		TOTAL	2.53E+00
	MAX INDIV,	SAMPLED FOODS	1.19E+00
		TOTAL	3.41E+00
	LOCAL INDIV,	SAMPLED FOODS	3.97E-01
		TOTAL	2.62E+00

TABLE A-3

DEBRIS LAND   Ra-226   DCF: 1.3E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN DEB (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE DEB (pCi/yr)	INTAKE UNMN (pCi/yr)	% OF TOTAL INTAKE DEB
BROCCOLI	3.51	34.67	3.00	4.44E+01	3.85E+00	1.55
LEAFY						
Cabbage	7.04	32.20	2.10	8.28E+01	5.40E+00	2.88
Collard Grns.	0.45	86.23	6.33	1.42E+01	1.04E+00	0.49
Lettuce	23.38	45.41	5.04 E	3.88E+02	4.30E+01	13.49
Mustard Grns.	0.45	64.22	1.44	1.05E+01	2.37E-01	0.37
Spinach	3.28	540.25	16.51	6.47E+02	1.98E+01	22.52
Turnip Grns.	0.45	55.47	10.32	9.11E+00	1.69E+00	0.32
----->	35.05			1.15E+03	7.12E+01	40.07
SEEDS/GRAINS						
Blackeyed Pea	5.61	25.60 E	2.57	5.25E+01	5.27E+00	1.83
Rice	22.94	82.18 E	7.10	6.89E+02	5.95E+01	23.96
Yellow Corn	14.41	25.60 E	4.90	1.35E+02	2.58E+01	4.69
----->	42.96			8.76E+02	9.06E+01	30.48
ROOTS						
Carrot	2.92	113.83	8.52	1.21E+02	9.08E+00	4.22
Onion	4.19	33.30 E	3.12	5.10E+01	4.78E+00	1.78
Radish	0.32	33.30 E	3.82	3.85E+00	4.42E-01	0.13
Turnip	0.42	23.64	5.00	3.64E+00	7.71E-01	0.13
----->	7.85			1.80E+02	1.51E+01	6.26
GENERAL						
Cucumber	2.62	18.60 E	3.22	1.78E+01	3.08E+00	0.62
Green Beans	8.80	9.79	5.16	3.15E+01	1.66E+01	1.09
Green Pepper	1.99	18.60 E	1.87	1.35E+01	1.36E+00	0.47
Strawberries	1.23	806.68 E	2.81	3.62E+02	1.26E+00	12.61
Tomato	25.18	18.60 E	2.94	1.71E+02	2.70E+01	5.95
Watermelon	3.44	18.60 E	1.24	2.34E+01	1.56E+00	0.81
Squash / Zucc	1.26	5.15	4.11	2.37E+00	1.89E+00	0.08
----->	44.53			6.22E+02	5.28E+01	21.65
TOTALS:	133.90			2.87E+03	2.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED, SAMPLED FOODS		2.33E+02
		TOTAL	1.92E+03
	MINED,	SAMPLED FOODS	2.87E+03
		TOTAL	4.56E+03
DOSE:	NON-SAMPLED FOODS		2.22E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.08E-01
		TOTAL	2.53E+00
	MAX INDIV,	SAMPLED FOODS	3.79E+00
		TOTAL	6.01E+00
	LOCAL INDIV,	SAMPLED FOODS	6.57E-01
		TOTAL	2.88E+00

TABLE A-4

RECLAIMED LAND Pb-210 DCF: 5.4E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN REC (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE REC (pCi/yr)	INTAKE UNMN (pCi/yr)	% OF TOTAL INTAKE REC
BROCCOLI	3.51	26.23	4.00 RT	3.36E+01	5.13E+00	19.88
LEAFY						
Cabbage	7.04	3.80 E	5.43 T	9.78E+00	1.40E+01	5.78
Collard Grns.	0.45	3.80 E	5.43 T	6.24E-01	8.92E-01	0.37
Lettuce	23.38	3.80 E	5.43 T	3.25E+01	4.64E+01	19.19
Mustard Grns.	0.45	3.80 E	5.43 T	6.24E-01	8.92E-01	0.37
Spinach	3.28	3.80 E	5.43 T	4.55E+00	6.51E+00	2.69
Turnip Grns.	0.45	3.80 E	5.43 T	6.24E-01	8.92E-01	0.37
----->	35.05			4.87E+01	6.95E+01	28.76
SEEDS/GRAINS						
Blackeyed Pea	5.61	2.10 E	3.00 RT	4.30E+00	6.15E+00	2.54
Rice	22.94	5.94 E	61.56	4.98E+01	5.16E+02	29.43
Yellow Corn	14.41	0.50	3.00 RT	2.63E+00	1.58E+01	1.56
----->	42.96			5.67E+01	5.38E+02	33.53
ROOTS						
Carrot	2.92	0.40 E	1.90 T	4.26E-01	2.02E+00	0.25
Onion	4.19	0.40 E	1.40 T	6.13E-01	2.14E+00	0.36
Radish	0.32	0.40 E	1.73 T	4.62E-02	2.00E-01	0.03
Turnip	0.42	0.40 E	1.73 T	6.17E-02	2.67E-01	0.04
----->	7.85			1.15E+00	4.64E+00	0.68
GENERAL						
Cucumber	2.62	0.70 E	1.00 RT	6.71E-01	9.58E-01	0.40
Green Beans	8.80	0.70 E	1.00 RT	2.25E+00	3.21E+00	1.33
Green Pepper	1.99	0.70 E	1.00 RT	5.09E-01	7.27E-01	0.30
Strawberries	1.23	39.91 E	1.00 RT	1.79E+01	4.49E-01	10.60
Tomato	25.18	0.70 E	1.00 RT	6.44E+00	9.20E+00	3.81
Watermelon	3.44	0.70 E	1.00 RT	8.80E-01	1.26E+00	0.52
Squash / Zucc	1.26	0.71	1.00 RT	3.27E-01	4.60E-01	0.19
----->	44.53			2.90E+01	1.63E+01	17.15
TOTALS:	133.90			1.69E+02	6.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS	1.68E+03
pCi/yr	UNMINED, SAMPLED FOODS	6.33E+02
	TOTAL	2.32E+03
	MINED, SAMPLED FOODS	1.69E+02
	TOTAL	1.85E+03
DOSE:	NON-SAMPLED FOODS	9.02E+00
mrem/yr	CONTROL INDIV, SAMPLED FOODS	3.40E+00
	TOTAL	1.24E+01
	MAX INDIV, SAMPLED FOODS	9.07E-01
	TOTAL	9.93E+00
	LOCAL INDIV, SAMPLED FOODS	3.15E+00
	TOTAL	1.22E+01

TABLE A-5

CLAY LAND Pb-210 DCF: 5.4E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN CLAY (pCi/kg)	CCN UNMINED (pCi/kg)	INTAKE CLAY (pCi/yr)	INTAKE UNMINED (pCi/yr)	% OF TOTAL INTAKE CLAY
BROCCOLI	3.51	16.07	4.00 RT	2.06E+01	5.13E+00	2.14
LEAFY						
Cabbage	7.04	5.50	5.43 T	1.41E+01	1.40E+01	1.47
Collard Grns.	0.45	42.68	5.43 T	7.01E+00	8.92E-01	0.73
Lettuce	23.38	17.62	5.43 T	1.50E+02	4.64E+01	15.61
Mustard Grns.	0.45	35.84	5.43 T	5.89E+00	8.92E-01	0.61
Spinach	3.28	71.14	5.43 T	8.52E+01	6.51E+00	8.84
Turnip Grns.	0.45	70.73	5.43 T	1.16E+01	8.92E-01	1.21
----->	35.05			2.74E+02	6.95E+01	28.46
SEEDS/GRAINS						
Blackeyed Pea	5.61	15.00 E	3.00 RT	3.07E+01	6.15E+00	3.19
Rice	22.94	51.12	61.56	4.28E+02	5.16E+02	44.44
Yellow Corn	14.41	18.06	3.00 RT	9.51E+01	1.58E+01	9.86
----->	42.96			5.54E+02	5.38E+02	57.49
ROOTS						
Carrot	2.92	2.09	1.90 T	2.23E+00	2.02E+00	0.23
Onion	4.19	3.20 E	1.40 T	4.90E+00	2.14E+00	0.51
Radish	0.32	3.20 E	1.73 T	3.70E-01	2.00E-01	0.04
Turnip	0.42	2.55	1.73 T	3.93E-01	2.67E-01	0.04
----->	7.85			7.89E+00	4.64E+00	0.82
GENERAL						
Cucumber	2.62	5.50 E	1.00 RT	5.27E+00	9.58E-01	0.55
Green Beans	8.80	5.50 E	1.00 RT	1.77E+01	3.21E+00	1.83
Green Pepper	1.99	5.50 E	1.00 RT	4.00E+00	7.27E-01	0.41
Strawberries	1.23	49.04	1.00 RT	2.20E+01	4.49E-01	2.29
Tomato	25.18	5.50 E	1.00 RT	5.06E+01	9.20E+00	5.25
Watermelon	3.44	5.50 E	1.00 RT	6.92E+00	1.26E+00	0.72
Squash / Zucc	1.26	0.86	1.00 RT	3.96E-01	4.60E-01	0.04
----->	44.53			1.07E+02	1.63E+01	11.09
TOTALS:	133.90			9.64E+02	6.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED,	SAMPLED FOODS	6.33E+02
		TOTAL	2.32E+03
	MINED,	SAMPLED FOODS	9.64E+02
		TOTAL	2.65E+03
DOSE:	NON-SAMPLED FOODS		9.02E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.40E+00
		TOTAL	1.24E+01
	MAX INDIV,	SAMPLED FOODS	5.17E+00
		TOTAL	1.42E+01
	LOCAL INDIV,	SAMPLED FOODS	3.58E+00
		TOTAL	1.26E+01

TABLE A-6

DEBRIS LAND   Pb-210   DCF: 5.4E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN DEB (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE DEB (pCi/yr)	INTAKE UNMN (pCi/yr)	% OF TOTAL INTAKE DEB
BROCCOLI	3.51	60.09	4.00 RT	7.70E+01	5.53E+00	3.38
LEAFY						
Cabbage	7.04	122.61	5.43 T	3.15E+02	1.40E+01	13.84
Collard Grns.	0.45	33.29	5.43 T	5.47E+00	8.92E-01	0.24
Lettuce	23.38	75.56	5.43 T	6.45E+02	4.64E+01	28.31
Mustard Grns.	0.45	0.50	5.43 T	8.21E-02	8.92E-01	0.00
Spinach	3.28	166.49	5.43 T	1.99E+02	6.51E+00	8.75
Turnip Grns.	0.45	40.48	5.43 T	6.65E+00	8.92E-01	0.29
----->	35.05			1.17E+03	6.95E+01	51.44
SEEDS/GRAINS						
Blackeyed Pea	5.61	22.00 E	3.00 RT	4.51E+01	6.15E+00	1.98
Rice	22.94	62.26 E	61.56	5.22E+02	5.16E+02	22.89
Yellow Corn	14.41	22.00 E	3.00 RT	1.16E+02	1.58E+01	5.08
----->	42.96			6.83E+02	5.38E+02	29.95
ROOTS						
Carrot	2.92	5.97	1.90 T	6.36E+00	2.02E+00	0.28
Onion	4.19	4.70 E	1.40 T	7.20E+00	2.14E+00	0.32
Radish	0.32	4.70 E	1.73 T	5.43E-01	2.00E-01	0.02
Turnip	0.42	10.22	1.73 T	1.58E+00	2.67E-01	0.07
----->	7.85			1.57E+01	4.64E+00	0.69
GENERAL						
Cucumber	2.62	8.00 E	1.00 RT	7.66E+00	9.58E-01	0.34
Green Beans	8.80	8.00 E	1.00 RT	2.57E+01	3.21E+00	1.13
Green Pepper	1.99	8.00 E	1.00 RT	5.81E+00	7.27E-01	0.26
Strawberries	1.23	456.19 E	1.00 RT	2.05E+02	4.49E-01	8.99
Tomato	25.18	8.00 E	1.00 RT	7.36E+01	9.20E+00	3.23
Watermelon	3.44	8.00 E	1.00 RT	1.01E+01	1.26E+00	0.44
Squash / Zucc	1.26	8.00 E	1.00 RT	3.68E+00	4.60E-01	0.16
----->	44.53			3.31E+02	1.63E+01	14.54
TOTALS:	133.90			2.28E+03	6.33E+02	100.00
TOTAL DIET:	3071.81					

INTAKE:	NON-SAMPLED FOODS		1.68E+03
pCi/yr	UNMINED,	SAMPLED FOODS	6.33E+02
		TOTAL	2.32E+03
	MINED,	SAMPLED FOODS	2.28E+03
		TOTAL	3.96E+03

DOSE:	NON-SAMPLED FOODS		9.02E+00
mrem/yr	CONTROL INDIV,	SAMPLED FOODS	3.40E+00
		TOTAL	1.24E+01
	MAX INDIV,	SAMPLED FOODS	1.22E+01
		TOTAL	2.12E+01
	LOCAL INDIV,	SAMPLED FOODS	4.28E+00
		TOTAL	1.33E+01

TABLE A-7

RADIONUCLIDE INTAKE FROM FOOD (pCi/yr)

	LOCAL INDIVIDUAL			MAXIMUM INDIVIDUAL		
	SAMPLED FOODS	TOTAL DIET	ATTRIB.	SAMPLED FOODS	TOTAL DIET	ATTRIB.
CONTROL						
Ra-226	233	1915		233	1915	
Pb-210	633	2315		633	2315	
MINING-RELATED						
RECLAIMED						
Ra-226	298	1985	65	886	2568	653
Pb-210	587	2269	0	169	1851	0
CLAY						
Ra-226	300	1987	67	904	2586	671
Pb-210	666	2348	33	964	2646	331
DEBRIS						
Ra-226	497	2184	264	2874	4556	2641
Pb-210	798	2480	165	2279	3961	1646

NOTE: "ATTRIB." is the intake attributable to the mining-related land of interest, and is equivalent to the difference of the sampled value and the corresponding control value. Zero entries indicate that no additional intake was detected.

TABLE A-8

RADIONUCLIDE DOSE FROM FOOD (mrem/yr)

		LOCAL INDIV.			MAXIMUM INDIV.		
		SAMPLED FOODS	TOTAL DIET	ATTRIB.	SAMPLED FOODS	TOTAL DIET	ATTRIB.
CONTROL							
	Ra-226	0.3	2.5		0.3	2.5	
	Pb-210	3.4	12.4		3.4	12.4	
	TOTAL	3.7	14.9		3.7	14.9	
MINING-RELATED							
RECLAIMED							
	Ra-226	0.4	2.6	0.1	1.2	3.4	0.9
	Pb-210	3.2	12.2	0.0	0.9	9.9	0.0
	TOTAL	3.6	14.8	0.0	2.1	13.3	0.0
CLAY							
	Ra-226	0.4	2.6	0.1	1.2	3.4	0.9
	Pb-210	3.6	12.6	0.2	5.2	14.2	1.8
	TOTAL	4.0	15.2	0.3	6.4	17.6	2.7
DEBRIS							
	Ra-226	0.7	2.9	0.4	3.8	6.0	3.5
	Pb-210	4.3	13.3	0.9	10.2	21.7	6.8
	TOTAL	5.0	16.2	1.3	16.0	27.2	12.3

NOTE: "ATTRIB." is the dose attributable to the mining-related land of interest, and is equivalent to the difference of the sampled value and the corresponding control dose. Zero entries indicate that no additional dose was detected.

TABLE A-9

GROCERY Pb-210 DCF: 5.4E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN GROC (pCi/kg)	CCN UNMN (pCi/kg)	INTAKE GROC (pCi/yr)	INTAKE UNMN (pCi/yr)
BROCCOLI	3.51	9.26	4.00 RT	1.19E+01	5.13E+00
LEAFY					
Cabbage	7.04	9.13	5.43 T	2.35E+01	1.40E+01
Collard Grns.	0.45	24.26	5.43 T	3.98E+00	8.92E-01
Lettuce	23.38		5.43 T		4.64E+01
Mustard Grns.	0.45		5.43 T		8.92E-01
Spinach	3.28		5.43 T		6.51E+00
Turnip Grns.	0.45		5.43 T		8.92E-01
----->	35.05				6.95E+01
SEEDS/GRAINS					
Blackeyed Pea	5.61		3.00 RT		6.15E+00
Rice	22.94		61.56		5.16E+02
Yellow Corn	14.41	117.12	3.00 RT	6.16E+02	1.58E+01
----->	42.96				5.38E+02
ROOTS					
Carrot	2.92	0.50	1.90 T	5.33E-01	2.02E+00
Onion	4.19		1.40 T		2.14E+00
Radish	0.32		1.73 T		2.00E-01
Turnip	0.42	31.38	1.73 T	4.84E+00	2.67E-01
----->	7.85				4.64E+00
GENERAL					
Cucumber	2.62	0.50	1.00 RT	4.79E-01	9.58E-01
Green Beans	8.80	12.66	1.00 RT	4.07E+01	3.21E+00
Green Pepper	1.99		1.00 RT		7.27E-01
Strawberries	1.23	45.94	1.00 RT	2.06E+01	4.49E-01
Tomato	25.18	15.73	1.00 RT	1.45E+02	9.20E+00
Watermelon	3.44		1.00 RT		1.26E+00
Squash / Zucc	1.26	2.72	1.00 RT	1.25E+00	4.60E-01
----->	44.53				1.63E+01
TOTALS:	133.90				6.33E+02
TOTAL DIET:	3071.81				

NOTE: Potatoes had 35.85 pCi/kg Pb-210 and 9.85 pCi/kg Ra-226.
All crops analyzed for Po-210 had levels less than detectable.
Green beans had 9.12 pCi/kg Ra-226.

TABLE A-10

Po-210 DCF: 1.9E-03 (mrem/pCi)

DIET ITEM	INTAKE OF ITEM (g/day)	CCN REC (pCi/kg)	CCN CLAY (pCi/kg)	CCN DEB (pCi/kg)	CCN UNMN (pCi/kg)
BROCCOLI	3.51		3.36	0.50	
LEAFY					
Cabbage	7.04		0.74	1.33	
Collard Grns.	0.45		0.50	0.73	
Lettuce	23.38		7.57	6.00	
Mustard Grns.	0.45		5.39	13.49	
Spinach	3.28		19.57	28.20	
Turnip Grns.	0.45		18.89	0.50	
----->	35.05				
SEEDS/GRAINS					
Blackeyed Pea	5.61				
Rice	22.94		0.50		0.50
Yellow Corn	14.41	1.62	5.98		
----->	42.96				
ROOTS					
Carrot	2.92		1.76	2.33	
Onion	4.19				
Radish	0.32				
Turnip	0.42		1.22	0.50	
----->	7.85				
GENERAL					
Cucumber	2.62				
Green Beans	8.80				
Green Pepper	1.99				
Strawberries	1.23				
Tomato	25.18				
Watermelon	3.44				
Squash / Zucc	1.26	0.61	0.91		
----->	44.53				
TOTALS:	133.90				
TOTAL DIET:	3071.81				

APPENDIX B

RAW DATA

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=BEEF LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BEEF	HILLS	99	1	251	24	1.762								
BEEF	HILLS	99	1	252	24	14.247								
BEEF	HILLS	99	1	253	24	2.505								

FOOD CATEGORY=BEEF LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BEEF	HILLS	28	1	241	24	4.790								
BEEF	HILLS	28	1	242	24	3.562								
BEEF	HILLS	28	1	243	24	2.321								

FOOD CATEGORY=CIT LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
ORANGE	ORANG	49	2	431	2	5.402								
ORANGE	ORANG	49	2	432	2	4.767								
ORANGE	ORANG	49	2	433	2	4.321								
ORANGE	ORANG	50	2	441	2	2.388								
ORANGE	ORANG	50	2	442	2	0.197	*							
ORANGE	ORANG	50	2	443	2	1.288								
ORANGE	ORANG	51	2	451	2	0.608								
ORANGE	ORANG	51	2	452	2	0.439								
ORANGE	ORANG	51	2	453	2	0.777								
ORANGE	ORANG	52	2	461	2	3.953								
ORANGE	ORANG	52	2	462	2	0.997								
ORANGE	ORANG	52	2	463	2	2.083								

FOOD CATEGORY=CIT LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
ORANGE	GROC	70	3	961	2				0.500		*	25.490		

FOOD CATEGORY=CIT LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GRAPEFRUIT		53	2	521	3	1.724								
GRAPEFRUIT		54	2	541	3	1.741								
GRAPEFRUIT		56	2	581	3	1.702								
GRAPEFRUIT		57	2	591	3	1.948								
GRAPEFRUIT		57	2	592	3	1.106								
GRAPEFRUIT		57	2	593	3	0.705								
GRAPEFRUIT		59	2	651	3	2.446								
GRAPEFRUIT	POLK	5	0	51	3	2.342								
GRAPEFRUIT	POLK	5	0	52	3	1.766								
GRAPEFRUIT	POLK	5	0	53	3	1.716								
LEMON		57	2	611	38	0.419								
LEMON		58	2	621	38	3.047								
LEMON		59	2	661	38	2.736								
ORANGE		53	2	471	2	1.374								
ORANGE		53	2	481	2	2.534								
ORANGE		54	2	531	2	0.197	*							

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=CIT LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
ORANGE		55	2	561	2	1.445								
ORANGE		55	2	562	2	2.034								
ORANGE		55	2	563	2	0.748								
ORANGE		55	2	571	2	0.197	*							
ORANGE		55	2	572	2	2.098								
ORANGE		55	2	573	2	0.637								
ORANGE		57	2	601	2	0.812								
ORANGE		57	2	602	2	3.026								
ORANGE		57	2	603	2	0.746								
ORANGE		59	2	641	2	1.096								
ORANGE	HARDE	16	1	51	2	1.361								
ORANGE	HARDE	16	1	52	2	1.090								
ORANGE	HARDE	16	1	53	2	1.209								
ORANGE	HARDE	17	1	61	2	0.394								
ORANGE	HARDE	17	1	62	2	2.029								
ORANGE	HARDE	17	1	63	2	1.234								
ORANGE	HARDE	18	1	71	2	3.192								
ORANGE	HARDE	18	1	72	2	2.778								
ORANGE	HARDE	18	1	73	2	2.572								
ORANGE	HARDE	19	1	81	2	6.535								
ORANGE	HARDE	19	1	82	2	4.868								
ORANGE	HARDE	19	1	83	2	4.610								
ORANGE	HARDE	20	1	91	2	4.682								
ORANGE	HARDE	20	1	92	2	8.894								
ORANGE	HARDE	20	1	93	2	5.300								
ORANGE	HARDE	21	1	101	2	2.206								
ORANGE	HARDE	21	1	102	2	1.167								
ORANGE	HARDE	21	1	103	2	3.720								
ORANGE	HILLS	2	0	21	2	2.455								
ORANGE	HILLS	2	0	22	2	3.073								
ORANGE	HILLS	2	0	23	2	1.445								
ORANGE	HILLS	3	0	31	2	1.555								
ORANGE	HILLS	3	0	32	2	2.911								
ORANGE	HILLS	3	0	33	2	1.285								
ORANGE	HILLS	36	2	221	2	1.994								
ORANGE	HILLS	36	2	222	2	0.986								
ORANGE	HILLS	36	2	223	2	2.476								
ORANGE	MANTE	15	1	41	2	5.382								
ORANGE	MANTE	15	1	42	2	3.995								
ORANGE	POLK	4	0	41	2	2.463								
ORANGE	POLK	4	0	42	2	1.558								
ORANGE	POLK	4	0	43	2	2.275								
SATSUMO CITRUS	HILLS	36	2	31	27	1.245								
SATSUMO CITRUS	HILLS	36	2	32	27	1.417								
SATSUMO CITRUS	HILLS	36	2	33	27	2.179								
TANGERINE		58	2	631	39	2.290								

FOOD CATEGORY=CIT LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GRAPEFRUIT	HILLS	46	2	231	3	3.333								
GRAPEFRUIT	HILLS	46	2	232	3	2.387								
GRAPEFRUIT	HILLS	46	2	233	3	3.887								
ORANGE	HILLS	47	2	241	2	16.050								
ORANGE	HILLS	47	2	242	2	10.662								
ORANGE	HILLS	47	2	243	2	8.341								
ORANGE	HILLS	47	2	251	2	1.848								
ORANGE	HILLS	47	2	252	2	1.939								
ORANGE	HILLS	47	2	253	2	2.525								
ORANGE	POLK	10	0	101	2	3.298								
ORANGE	POLK	10	0	102	2	2.661								
ORANGE	POLK	10	0	103	2	9.407								
ORANGE	POLK	10	2	311	2	7.722								

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=CIT LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
ORANGE	POLK	10	2	312	2	14.009								
ORANGE	POLK	10	2	313	2	9.169								
ORANGE	POLK	13	1	23	2	1.478								
ORANGE	POLK	13	2	291	2	3.824								
ORANGE	POLK	13	2	292	2	1.903								
ORANGE	POLK	13	2	293	2	2.483								
ORANGE	POLK	14	2	301	2	2.737								
ORANGE	POLK	14	2	302	2	4.455								
ORANGE	POLK	14	2	303	2	2.453								

FOOD CATEGORY=GRAIN LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
RICE	AGRI	64	3	591	49	36.000			0.500		*	66.164		
RICE	AGRI	64	3	592	49	6.000			0.500		*	39.501		
YELLOW CORN	AGRI	64	3	231	5	5.500			6.981			16.400		
YELLOW CORN	AGRI	64	3	232	5	5.100			5.037			19.900		

FOOD CATEGORY=GRAIN LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
RICE	EVER	69	3	601	49	7.100			0.500		*	61.565		
YELLOW CORN	ORANG	7	0	71	5	3.063								
YELLOW CORN	ORANG	7	0	72	5	12.455								
YELLOW CORN	ORANG	7	0	73	5	5.722								
YELLOW CORN	ORANG	33	1	301	5	5.569								
YELLOW CORN	ORANG	33	1	302	5	3.896								
YELLOW CORN	ORANG	33	1	303	5	2.903								

FOOD CATEGORY=GRAIN LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
YELLOW CORN	GROC	70	3	951	5				0.500		*	117.124		

FOOD CATEGORY=GRAIN LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
YELLOW CORN	MULB	66	3	221	5	11.000			1.490			0.500		*
YELLOW CORN	MULB	66	3	222	5	7.000			1.764			0.500		*
YELLOW CORN	POLK	24	1	161	5	11.841								
YELLOW CORN	POLK	24	1	162	5	7.139								
YELLOW CORN	POLK	24	1	163	5	7.246								

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=LEAF LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BROCCOLI	AGRI	64	3	91	17	26.000						4.800		
BROCCOLI	AGRI	64	3	92	17	22.000						3.000		
BROCCOLI	AGRI	64	3	671	17	87.843			7.311			61.304		
BROCCOLI	AGRI	64	3	672	17	46.790			21.934			46.076		
BROCCOLI	IMC	67	3	701	17	6.193			1.584			7.720		
BROCCOLI	IMC	67	3	702	17	9.114			0.500		*	54.915		
CABBAGE	AGRI	64	3	681	37	18.398			0.500		*	12.063		
CABBAGE	AGRI	64	3	682	37	33.463			0.500		*	14.953		
CABBAGE	BW	63	3	131	37	28.000			0.500		*	2.000		
CABBAGE	BW	63	3	132	37	17.000			0.500		*	4.000		
CABBAGE	BW	63	3	141	37	28.000			0.500		*	12.000		
CABBAGE	BW	63	3	142	37	24.000			0.500		*	3.000		
CABBAGE	BW	63	3	151	37	35.000			0.500		*	10.000		
CABBAGE	BW	63	3	152	37	18.000			0.500		*	16.000		
CABBAGE	BW	63	3	161	37	26.000			0.500		*	0.500		*
CABBAGE	BW	63	3	162	37	19.000			0.500		*	1.000		
CABBAGE	IMC	67	3	711	37	0.500		*	0.500		*	4.393		
CABBAGE	IMC	67	3	712	37	0.500		*	52.424			42.170		
CABBAGE	POLK	35	2	401	37	3.432								
CABBAGE	POLK	35	2	402	37	2.893								
CABBAGE	POLK	35	2	403	37	5.006								
COLLARD GREENS	IMC	67	3	611	25	131.928			0.500		*	30.741		
COLLARD GREENS	IMC	67	3	612	25	124.750			0.500		*	59.243		
COLLARD GREENS	POLK	35	2	761	25	11.265								
COLLARD GREENS	POLK	35	2	762	25	20.110								
COLLARD GREENS	POLK	35	2	763	25	19.985								
LETTUCE	AGRI	64	3	101	44	23.000						7.300		
LETTUCE	AGRI	64	3	102	44	43.000						7.000		
LETTUCE	IMC	67	3	641	44	56.939			10.502			19.646		
LETTUCE	IMC	67	3	642	44	27.671			6.843			53.998		
LETTUCE	IMC	67	3	691	44	44.865			9.525			32.427		
LETTUCE	IMC	67	3	692	44	62.272			4.787			17.043		
MUSTARD GREENS	AGRI	64	3	251	30	50.600			3.081			10.900		
MUSTARD GREENS	AGRI	64	3	252	30	31.100			3.569			8.400		
MUSTARD GREENS	AGRI	64	3	253	30	36.800			1.708			10.500		
MUSTARD GREENS	BW	63	3	511	30	52.734			10.406			58.033		
MUSTARD GREENS	BW	63	3	512	30	144.110			12.205			56.464		
MUSTARD GREENS	BW	63	3	521	30	150.295			2.394			33.690		
MUSTARD GREENS	BW	63	3	522	30	161.213			28.864			106.887		
MUSTARD GREENS	BW	63	3	531	30	29.106			7.762			31.721		
MUSTARD GREENS	BW	63	3	532	30	59.851			4.613			42.829		
MUSTARD GREENS	BW	63	3	541	30	35.492			0.500		*	40.496		
MUSTARD GREENS	BW	63	3	542	30	36.962			3.308			34.484		
MUSTARD GREENS	BW	63	3	543	30	25.376			3.340			33.713		
MUSTARD GREENS	BW	63	3	551	30	58.548			6.973			26.743		
MUSTARD GREENS	BW	63	3	552	30	211.716			26.613			97.978		
MUSTARD GREENS	BW	63	3	561	30	160.522			51.039			98.278		
MUSTARD GREENS	BW	63	3	562	30	160.633			8.022			49.403		
MUSTARD GREENS	IMC	67	3	651	30	56.045			0.500		*	30.889		
MUSTARD GREENS	IMC	67	3	652	30	34.140			1.947			9.271		
PARSLEY	IMC	67	3	281	45				26.894			57.800		
PARSLEY	IMC	67	3	282	45				43.379			46.430		
SPINACH	IMC	67	3	731	4	21.918			25.572			82.133		
SPINACH	IMC	67	3	732	4	19.763			14.977			61.610		
SWISS CHARD	IMC	67	3	291	46				21.929			121.000		
SWISS CHARD	IMC	67	3	292	46				22.882			115.700		
TURNIP GREENS	BW	63	3	801	23	154.403			26.860			33.500		
TURNIP GREENS	BW	63	3	811	23	47.166						76.134		
TURNIP GREENS	BW	63	3	812	23	86.380			109.543			102.800		
TURNIP GREENS	BW	63	3	821	23	72.212			164.093			118.800		
TURNIP GREENS	BW	63	3	822	23	56.216			25.362			20.300		
TURNIP GREENS	BW	63	3	823	23	53.382			12.927			73.400		
TURNIP GREENS	BW	63	3	831	23	274.700						152.541		
TURNIP GREENS	BW	63	3	832	23	329.440						139.135		
TURNIP GREENS	BW	63	3	841	23	75.594			96.251			38.530		
TURNIP GREENS	BW	63	3	842	23	86.875			72.333			80.300		
TURNIP GREENS	BW	63	3	843	23	64.471			162.230			132.920		

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=LEAF LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
TURNIP GREENS	BW	63	3	851	23	72.212						164.969		
TURNIP GREENS	BW	63	3	852	23	52.925						73.829		
TURNIP GREENS	IMC	67	3	261	23	74.800			8.165			48.200		
TURNIP GREENS	IMC	67	3	262	23	61.800			8.748			49.300		
TURNIP GREENS	IMC	67	3	263	23	64.900			6.763			47.700		
TURNIP GREENS	IMC	67	3	621	23	121.620			0.500		*	73.878		
TURNIP GREENS	IMC	67	3	622	23	63.504			0.500		*	57.258		
TURNIP GREENS	POLK	35	2	281	23	94.738								
TURNIP GREENS	POLK	35	2	282	23	85.643								
TURNIP GREENS	POLK	35	2	283	23	54.341								

FOOD CATEGORY=LEAF LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CAULIFLOWER	HILLS	39	2	111	32	7.854								
CAULIFLOWER	HILLS	39	2	112	32	4.770								
CAULIFLOWER	HILLS	39	2	113	32	5.839								
COLLARD GREENS	LAKE	30	1	271	25	7.008								
COLLARD GREENS	LAKE	30	1	272	25	0.691								
COLLARD GREENS	LAKE	30	1	273	25	5.218								
MUSTARD GREENS	LAKE	30	2	681	30	0.297	*							
MUSTARD GREENS	LAKE	30	2	682	30	8.546								
MUSTARD GREENS	LAKE	30	2	683	30	0.955								
SPINACH	LAKE	30	2	671	4	3.521								
SPINACH	LAKE	30	2	672	4	3.459								
SPINACH	LAKE	30	2	673	4	9.223								
TURNIP GREENS	LAKE	29	1	261	23	8.774								
TURNIP GREENS	LAKE	29	1	262	23	4.936								
TURNIP GREENS	LAKE	29	1	263	23	5.500								
TURNIP GREENS	ORANG	33	1	311	23	9.387								
TURNIP GREENS	ORANG	33	1	312	23	16.093								
TURNIP GREENS	ORANG	33	1	313	23	7.794								

FOOD CATEGORY=LEAF LAND CATEGORY=DEB

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BROCCOLI	DEBG	68	3	751	17	12.548			0.500		*	41.078		
BROCCOLI	DEBG	68	3	752	17	95.819			0.500		*	87.911		
CABBAGE	DEBG	68	3	771	37	7.299			0.500		*	184.459		
CABBAGE	DEBG	68	3	772	37	142.007			3.562			81.497		
COLLARD GREENS	HOPE	6	3	171	25	121.000			0.500		*	19.000		
COLLARD GREENS	HOPE	6	3	172	25	97.000			0.500		*	22.000		
COLLARD GREENS	HOPE	6	3	181	25	75.980			2.219			61.029		
COLLARD GREENS	HOPE	6	3	182	25	62.010			0.500		*	48.162		
LETTUCE	DEBG	68	3	661	44	68.426			5.072			57.804		
LETTUCE	DEBG	68	3	662	44	30.139			7.089			98.773		
MUSTARD GREENS	DEBG	68	3	501	30	59.590			8.928			0.500		*
MUSTARD GREENS	DEBG	68	3	502	30	69.221			20.374			0.500		*
SPINACH	DEBG	68	3	1021	4				28.197			166.490		
SPINACH	HILLS	6	0	61	4	753.131								
SPINACH	HILLS	6	0	62	4	1091.355								
SPINACH	HILLS	6	0	63	4	191.854								
TURNIP GREENS	DEBG	68	3	491	23	67.587			0.500		*	36.543		
TURNIP GREENS	DEBG	68	3	492	23	45.530			0.500		*	44.831		

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=LEAF LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BROCCOLI	GROC	70	3	891	17				0.500		*	9.258		
CABBAGE	GROC	70	3	901	37				0.500		*	9.129		
COLLARD GREENS	GROC	70	3	931	25				0.500		*	24.263		

FOOD CATEGORY=LEAF LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
BROCCOLI	HILLS	23	1	141	17	2.837								
BROCCOLI	HILLS	23	1	142	17	3.039								
BROCCOLI	HILLS	23	1	143	17	3.142								
CABBAGE		53	2	491	37	8.801								
CABBAGE		53	2	492	37	5.912								
CABBAGE		53	2	493	37	0.177								
COLLARD GREENS		53	2	501	25	0.140								
COLLARD GREENS		53	2	502	25	9.938								
COLLARD GREENS		53	2	503	25	4.112								
COLLARD GREENS	POLK	44	2	341	25	13.997								
COLLARD GREENS	POLK	44	2	342	25	9.688								
COLLARD GREENS	POLK	44	2	343	25	20.288								
COLLARD GREENS	POLK	61	2	731	25	42.348								
COLLARD GREENS	POLK	61	2	732	25	11.203								
MUSTARD GREENS	HILLS	37	2	81	30	2.976								
MUSTARD GREENS	HILLS	37	2	82	30	2.033								
MUSTARD GREENS	HILLS	37	2	83	30	0.595								
SPINACH	POLK	62	2	751	4	53.761								
SPINACH	POLK	62	2	752	4	103.434								
SPINACH	POLK	62	2	753	4	32.401								
TURNIP GREENS	HILLS	41	2	371	23	2.468	*							
TURNIP GREENS	HILLS	41	2	372	23	20.725								
TURNIP GREENS	HILLS	41	2	373	23	11.637								
TURNIP GREENS	POLK	44	2	351	23	15.027								
TURNIP GREENS	POLK	44	2	352	23	27.340								
TURNIP GREENS	POLK	44	2	353	23	21.266								

FOOD CATEGORY=LEAF LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
TURNIP GREENS	HILLS	11	1	231	23	220.667								
TURNIP GREENS	HILLS	11	1	232	23	61.402								
TURNIP GREENS	HILLS	11	1	233	23	55.354								

FOOD CATEGORY=LEG LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
PEAS	POLK	35	2	271	26	2.401								
PEAS	POLK	35	2	272	26	4.199								
PEAS	POLK	35	2	273	26	6.181								

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=LEG LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
PEAS	ORANG	32	1	291	26	4.288								
PEAS	ORANG	32	1	292	26	4.213								
PEAS	ORANG	32	1	293	26	6.324								

FOOD CATEGORY=LEG LAND CATEGORY=DEB

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GREEN BEANS	HILLS	6	2	261	35	14.143								
GREEN BEANS	HILLS	6	2	262	35	4.097								
GREEN BEANS	HILLS	6	2	263	35	16.188								

FOOD CATEGORY=LEG LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GREEN BEANS	GROC	70	3	941	35	9.123			0.500		*	12.655		

FOOD CATEGORY=LEG LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GREEN BEANS	HILLS	41	2	161	33	5.638								
GREEN BEANS	HILLS	41	2	162	33	5.065								
GREEN BEANS	HILLS	41	2	163	33	4.802								
PEAS	HILLS	37	2	61	31	2.278								
PEAS	HILLS	37	2	62	31	0.700								
PEAS	HILLS	37	2	63	31	1.684								
PEAS	POLK	44	2	91	31	3.845								
PEAS	POLK	44	2	92	31	3.583								
PEAS	POLK	44	2	93	31	1.162								

FOOD CATEGORY=LEG LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GREEN BEANS	HILLS	11	0	111	8	3.715								
GREEN BEANS	HILLS	11	0	112	8	3.390								
GREEN BEANS	HILLS	11	0	113	8	3.965								
LIMA BEANS	POLK	24	1	191	20	72.655								
LIMA BEANS	POLK	24	1	192	20	54.219								
LIMA BEANS	POLK	24	1	193	20	72.024								
PEAS	HILLS	11	2	211	31	3.642								
PEAS	HILLS	11	2	212	31	8.807								
PEAS	HILLS	11	2	213	31	2.267								
PEAS	POLK	24	1	151	18	6.777								
PEAS	POLK	24	1	152	18	8.041								

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=NTF LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
GREEN PEPPER	POLK	35	2	381	21	1.204								
GREEN PEPPER	POLK	35	2	382	21	10.148								
GREEN PEPPER	POLK	35	2	383	21	0.162	*							
OKRA	IMC	67	3	241	36	47.000			2.300			14.600		
OKRA	IMC	67	3	242	36	39.000			0.500		*	53.100		
OKRA	POLK	35	2	391	36	21.157								
STRAWBERRIES	AGRI	64	3	111	41	128.000						65.000		
STRAWBERRIES	AGRI	64	3	112	41	114.000						37.000		
TOMATO	POLK	35	2	411	1	0.744	*							
TOMATO	POLK	35	2	412	1	2.602								
TOMATO	POLK	35	2	413	1	11.599								
YELLOW SQUASH	BW	63	3	571	15	31.872			0.500		*	1.482		
YELLOW SQUASH	BW	63	3	581	15	14.147			1.665			0.500		*
YELLOW SQUASH	POLK	35	2	321	15	0.497	*							

FOOD CATEGORY=NTF LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CUCUMBER	HILLS	40	2	121	28	3.684								
CUCUMBER	HILLS	40	2	122	28	2.817								
CUCUMBER	HILLS	40	2	123	28	3.205								
GREEN PEPPER	HILLS	40	2	131	21	2.685								
GREEN PEPPER	HILLS	40	2	132	21	5.066								
GREEN PEPPER	HILLS	40	2	133	21	0.685								
TOMATO	HILLS	38	2	101	1	1.489								
TOMATO	HILLS	38	2	102	1	7.338								
TOMATO	HILLS	38	2	103	1	2.011								

FOOD CATEGORY=NTF LAND CATEGORY=DEB

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
YELLOW SQUASH	HILLS	6	1	131	15	5.263								
YELLOW SQUASH	HILLS	6	1	132	15	5.660								
YELLOW SQUASH	HILLS	6	1	133	15	4.578								

FOOD CATEGORY=NTF LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CUCUMBER	GROC	70	3	921	28				0.500		*	0.500		*
STRAWBERRIES	GROC	70	3	981	41				0.500		*	45.943		
TOMATO	GROC	70	3	991	1				0.500		*	15.732		
YELLOW SQUASH	GROC	70	3	971	15				0.500		*	2.720		

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=NTF LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
EGGPLANT	HILLS	43	2	181	34	1.741	*							
EGGPLANT	HILLS	43	2	182	34	10.976								
EGGPLANT	HILLS	43	2	183	34	3.483								
GREEN PEPPER	MANTE	25	1	201	21	3.907								
GREEN PEPPER	MANTE	25	1	202	21	3.581								
GREEN PEPPER	MANTE	25	1	203	21	0.324								
STRAWBERRIES	HILLS	48	2	701	41	7.503								
STRAWBERRIES	HILLS	48	2	702	41	3.565								
STRAWBERRIES	HILLS	48	2	703	41	0.249								
STRAWBERRIES	HILLS	60	2	711	41	5.783								
STRAWBERRIES	HILLS	60	2	712	41	3.899								
STRAWBERRIES	HILLS	60	2	713	41	3.266								
TOMATO	POLK	1	0	11	1	2.981								
TOMATO	POLK	1	0	12	1	2.148								
TOMATO	POLK	1	0	13	1	4.581								
WATERMELON	MANTE	26	1	211	22	1.963								
WATERMELON	MANTE	26	1	212	22	1.730								
WATERMELON	MANTE	26	1	213	22	0.893								
WATERMELON	MANTE	26	1	221	22	2.199								
WATERMELON	MANTE	26	1	222	22	0.180								
WATERMELON	MANTE	26	1	223	22	3.099								
YELLOW SQUASH	HILLS	37	2	71	15	4.033								
YELLOW SQUASH	HILLS	37	2	72	15	3.952								
YELLOW SQUASH	HILLS	37	2	73	15	1.532								
YELLOW SQUASH	HILLS	42	2	171	15	0.995								
YELLOW SQUASH	HILLS	42	2	172	15	7.035								
YELLOW SQUASH	HILLS	42	2	173	15	5.459								
YELLOW SQUASH	POLK	44	1	181	15	7.480								
YELLOW SQUASH	POLK	44	1	182	15	4.845								
YELLOW SQUASH	POLK	44	1	183	15	9.970								
ZUCCHINI	HILLS	41	2	141	11	5.574								
ZUCCHINI	HILLS	41	2	142	11	5.671								
ZUCCHINI	HILLS	41	2	143	11	6.763								
ZUCCHINI	HILLS	48	2	361	11	7.899								
ZUCCHINI	HILLS	48	2	362	11	5.853								
ZUCCHINI	HILLS	48	2	363	11	0.644	*							

FOOD CATEGORY=NTF LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CUCUMBER	HILLS	11	2	41	28	8.743								
CUCUMBER	HILLS	11	2	42	28	7.482								
CUCUMBER	HILLS	11	2	43	28	2.681								
WATERMELON	POLK	24	2	331	22	0.090	*							
WATERMELON	POLK	24	2	332	22	9.811								
WATERMELON	POLK	24	2	333	22	7.392								
YELLOW SQUASH	HILLS	45	2	191	15	8.623								
YELLOW SQUASH	HILLS	45	2	192	15	5.779								
YELLOW SQUASH	HILLS	45	2	193	15	4.373								
YELLOW SQUASH	MULB	66	3	191	15	23.000			1.086			0.500		*
YELLOW SQUASH	MULB	66	3	192	15	19.000			0.500		*	2.000		
ZUCCHINI	HILLS	11	0	131	11	1.289								
ZUCCHINI	HILLS	11	0	132	11	2.941								
ZUCCHINI	HILLS	11	0	133	11	3.243								
ZUCCHINI	HILLS	11	1	111	11	5.289								
ZUCCHINI	HILLS	11	1	112	11	10.645								
ZUCCHINI	HILLS	11	1	113	11	5.708								
ZUCCHINI	MULB	66	3	201	11	12.000			0.500		*	0.500		*
ZUCCHINI	MULB	66	3	202	11	10.000			0.500		*	0.500		*

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=ROOT LAND CATEGORY=CLAY

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CARROTS	IMC	67	3	271	6	157.000			1.402			0.500		*
CARROTS	IMC	67	3	272	6	132.000			2.705			1.700		
CARROTS	IMC	67	3	273	6	132.000			1.388			1.500		
CARROTS	IMC	67	3	721	6	45.470			6.357			0.500		*
CARROTS	IMC	67	3	722	6	71.241			0.500		*	32.189		
CARROTS	POLK	35	2	691	6	205.089								
CARROTS	POLK	35	2	692	6	391.044								
CARROTS	POLK	35	2	693	6	74.690								
ONIONS	POLK	35	2	421	29	8.230								
ONIONS	POLK	35	2	422	29	19.572								
ONIONS	POLK	35	2	423	29	6.038								
RADISH	POLK	35	2	21	7	25.967								
RADISH	POLK	35	2	22	7	11.896								
RADISH	POLK	35	2	23	7	10.704								
TURNIP ROOT	BW	63	3	801	14	47.544			2.016			0.500		*
TURNIP ROOT	BW	63	3	811	14	14.542						22.554		
TURNIP ROOT	BW	63	3	812	14	12.642			1.216			0.500		*
TURNIP ROOT	BW	63	3	821	14	9.550			2.000			2.000		
TURNIP ROOT	BW	63	3	822	14	8.681			2.531			0.500		*
TURNIP ROOT	BW	63	3	823	14	11.774			2.458			1.100		
TURNIP ROOT	BW	63	3	831	14	25.653						4.874		
TURNIP ROOT	BW	63	3	832	14	0.500		*	2.016			0.500		*
TURNIP ROOT	BW	63	3	841	14	11.937			0.500		*	47.080		
TURNIP ROOT	BW	63	3	842	14	44.124			0.500		*	47.080		
TURNIP ROOT	BW	63	3	843	14	1.605			3.160			26.910		
TURNIP ROOT	BW	63	3	851	14	10.255						4.345		
TURNIP ROOT	BW	63	3	852	14	8.844						5.409		
TURNIP ROOT	IMC	67	3	261	14	17.600			0.500		*	0.500		*
TURNIP ROOT	IMC	67	3	262	14	15.800			1.642			1.300		
TURNIP ROOT	IMC	67	3	263	14	17.700			0.500		*	2.100		
TURNIP ROOT	IMC	67	3	631	14	26.162			0.500		*	0.500		*
TURNIP ROOT	IMC	67	3	632	14	37.544			0.500		*	20.115		
TURNIP ROOT	POLK	35	2	281	14	17.556								
TURNIP ROOT	POLK	35	2	282	14	17.815								
TURNIP ROOT	POLK	35	2	283	14	15.819								

FOOD CATEGORY=ROOT LAND CATEGORY=CTRL

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CARROTS	ORANG	8	0	81	6	7.821								
CARROTS	ORANG	8	0	82	6	10.760								
CARROTS	ORANG	8	0	83	6	7.359								
RADISH	LAKE	31	1	281	7	2.223								
RADISH	LAKE	31	1	282	7	3.058								
RADISH	LAKE	31	1	283	7	2.748								
RADISH	ORANG	9	0	91	7	2.729								
RADISH	ORANG	9	0	92	7	6.342								
RADISH	ORANG	9	0	93	7	4.591								
TURNIP ROOT	ORANG	33	1	311	14	5.082								
TURNIP ROOT	ORANG	33	1	312	14	2.948								
TURNIP ROOT	ORANG	33	1	313	14	5.055								

FOOD CONCENTRATIONS
(pCi/kg)

BY FOOD CATEGORY AND PARCEL CATEGORY

FOOD CATEGORY=ROOT LAND CATEGORY=DEB

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CARROTS	DEBG	68	3	741	6	165.458			0.500		*	71.180		
CARROTS	DEBG	68	3	742	6	78.310			10.877			0.500		*
TURNIP ROOT	DEBG	68	3	491	14	30.721			0.500		*	6.245		
TURNIP ROOT	DEBG	68	3	492	14	27.510			0.500		*	16.740		
TURNIP ROOT	HILLS	6	1	121	14	15.808								
TURNIP ROOT	HILLS	6	1	122	14	13.766								
TURNIP ROOT	HILLS	6	1	123	14	32.650								

FOOD CATEGORY=ROOT LAND CATEGORY=GROC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
CARROTS	GROC	70	3	911	6				0.500		*	0.500		*
POTATOES	GROC	70	3	1001	9	9.850			0.500		*	35.853		
TURNIP ROOT	GROC	70	3	1011	14				0.500		*	31.385		

FOOD CATEGORY=ROOT LAND CATEGORY=MIN

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
ONIONS		53	2	511	29	2.273	*							
ONIONS	HILLS	37	2	51	29	6.247								
ONIONS	HILLS	37	2	52	29	5.555								
ONIONS	HILLS	37	2	53	29	4.547								
ONIONS	HILLS	60	2	721	42	1.381	*							
ONIONS	HILLS	60	2	722	42	2.762								
ONIONS	HILLS	60	2	723	42	3.981								
RADISH	HILLS	41	2	151	7	4.651								
RADISH	HILLS	41	2	152	7	2.851								
RADISH	HILLS	41	2	153	7	8.749								
TURNIP ROOT	HILLS	41	2	371	14	1.474	*							
TURNIP ROOT	HILLS	41	2	372	14	7.914								
TURNIP ROOT	HILLS	41	2	373	14	5.193								
TURNIP ROOT	POLK	44	2	351	14	6.325								
TURNIP ROOT	POLK	44	2	352	14	12.256								
TURNIP ROOT	POLK	44	2	353	14	5.462								

FOOD CATEGORY=ROOT LAND CATEGORY=REC

FOOD DESCRIPTION	PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	RA-226	ZERO	DET LMT	PO-210	ZERO	DET LMT	PB-210	ZERO	DET LMT
POTATOES	HILLS	11	0	121	9	4.572								
POTATOES	HILLS	11	0	122	9	4.864								
POTATOES	HILLS	11	0	123	9	2.976								
POTATOES	HILLS	11	2	201	9	0.733								
POTATOES	HILLS	11	2	202	9	3.684								
POTATOES	HILLS	11	2	203	9	13.730								
POTATOES	MULB	66	3	211	9	6.060			2.051			2.000		
TURNIP ROOT	HILLS	11	1	231	14	13.670								
TURNIP ROOT	HILLS	11	1	232	14	5.439								
TURNIP ROOT	HILLS	11	1	233	14	6.565								

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=CLAY

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
AGRI	64	3	91	17	BROCCOLI	15.660		22.840
AGRI	64	3	92	17	BROCCOLI	16.730		21.220
AGRI	64	3	101	44	LETTUCE	14.790		17.100
AGRI	64	3	102	44	LETTUCE	15.800		24.100
AGRI	64	3	111	41	STRAWBERRIES	15.620		21.760
AGRI	64	3	112	41	STRAWBERRIES	15.340		20.940
AGRI	64	3	231	5	YELLOW CORN	14.440	19.630	18.400
AGRI	64	3	232	5	YELLOW CORN	15.190	19.435	20.600
AGRI	64	3	251	30	MUSTARD GREENS	16.640	24.513	34.450
AGRI	64	3	252	30	MUSTARD GREENS	17.020	25.711	40.330
AGRI	64	3	253	30	MUSTARD GREENS	16.770	25.160	32.510
AGRI	64	3	591	49	RICE	20.018	36.104	48.040
AGRI	64	3	592	49	RICE	25.167	49.105	38.242
AGRI	64	3	671	17	BROCCOLI	22.914	24.402	53.216
AGRI	64	3	681	37	CABBAGE	25.722	42.971	36.086
BW	63	3	131	37	CABBAGE	15.510	18.133	15.470
BW	63	3	132	37	CABBAGE	14.460	12.515	19.780
BW	63	3	141	37	CABBAGE	14.480	15.751	15.150
BW	63	3	142	37	CABBAGE	15.800	17.125	14.700
BW	63	3	151	37	CABBAGE	15.750	17.608	15.840
BW	63	3	152	37	CABBAGE	15.130	16.957	11.800
BW	63	3	161	37	CABBAGE	13.600	14.526	17.360
BW	63	3	162	37	CABBAGE	14.860	14.335	13.190
BW	63	3	511	30	MUSTARD GREENS	12.440	16.232	23.920
BW	63	3	512	30	MUSTARD GREENS	12.440		35.765
BW	63	3	521	30	MUSTARD GREENS	13.460	17.685	14.600
BW	63	3	522	30	MUSTARD GREENS	13.460		14.943
BW	63	3	531	30	MUSTARD GREENS	12.800	14.732	13.508
BW	63	3	541	30	MUSTARD GREENS	13.300	16.602	19.755
BW	63	3	542	30	MUSTARD GREENS	12.330	19.900	18.400
BW	63	3	543	30	MUSTARD GREENS	15.390	18.900	17.800
BW	63	3	551	30	MUSTARD GREENS	11.990		30.015
BW	63	3	552	30	MUSTARD GREENS	14.870		20.473
BW	63	3	561	30	MUSTARD GREENS	15.628		29.946
BW	63	3	562	30	MUSTARD GREENS	15.151		24.700
BW	63	3	842	14	TURNIP ROOT	14.700	13.600	19.213
BW	63	3	843	14	TURNIP ROOT	16.493	9.600	14.200
IMC	67	3	241	36	OKRA	15.010	18.860	15.500
IMC	67	3	242	36	OKRA	16.070	15.906	12.500
IMC	67	3	261	14	TURNIP ROOT	9.490	10.125	14.590
IMC	67	3	271	6	CARROTS	10.590	16.788	16.900
IMC	67	3	281	45	PARSLEY		14.016	16.554
IMC	67	3	291	46	SWISS CHARD		14.936	17.200
IMC	67	3	611	25	COLLARD GREENS	16.420	10.201	30.476
IMC	67	3	621	23	TURNIP GREENS	19.768	24.935	24.594
IMC	67	3	641	44	LETTUCE	16.654	13.707	23.022
IMC	67	3	651	30	MUSTARD GREENS	21.187	19.486	36.358
IMC	67	3	691	44	LETTUCE	21.155	23.443	58.845
IMC	67	3	701	17	BROCCOLI	17.485	11.201	17.152
IMC	67	3	711	37	CABBAGE	17.090	26.540	35.206
IMC	67	3	721	6	CARROTS	18.497	33.747	27.309
IMC	67	3	731	4	SPINACH	20.679	28.649	55.717
POLK	35	2	21	7	RADISH	22.600		
POLK	35	2	22	7	RADISH	23.700		
POLK	35	2	23	7	RADISH	21.900		
POLK	35	2	271	26	BLACKEYE PEAS	23.900		
POLK	35	2	272	26	BLACKEYE PEAS	24.500		
POLK	35	2	273	26	BLACKEYE PEAS	23.900		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=CTRL

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
HILLS	38	2	101	1	TOMATO	0.206		
HILLS	38	2	102	1	TOMATO	0.237		
HILLS	38	2	103	1	TOMATO	0.295		
HILLS	39	2	111	32	CAULIFLOWER	0.379		
HILLS	39	2	112	32	CAULIFLOWER	0.297		
HILLS	39	2	113	32	CAULIFLOWER	0.280		
HILLS	40	2	121	28	CUCUMBER	0.185		
HILLS	40	2	122	28	CUCUMBER	0.204		
HILLS	40	2	123	28	CUCUMBER	0.203		
HILLS	40	2	131	21	GREEN PEPPER	0.255		
HILLS	40	2	132	21	GREEN PEPPER	0.315		
HILLS	40	2	133	21	GREEN PEPPER	0.256		
LAKE	29	1	261	23	TURNIP GREENS	0.704		
LAKE	29	1	262	23	TURNIP GREENS	0.753		
LAKE	29	1	263	23	TURNIP GREENS	0.872		
LAKE	30	1	271	25	COLLARD GREENS	0.836		
LAKE	30	1	272	25	COLLARD GREENS	0.756		
LAKE	30	1	273	25	COLLARD GREENS	0.895		
LAKE	30	2	671	4	SPINACH	0.831		
LAKE	30	2	672	4	SPINACH	0.829		
LAKE	30	2	673	4	SPINACH	0.653		
LAKE	31	1	281	7	RADISH	1.200		
LAKE	31	1	282	7	RADISH	1.020		
LAKE	31	1	283	7	RADISH	1.220		
ORANG	7	0	71	5	YELLOW CORN	0.940		
ORANG	7	0	72	5	YELLOW CORN	1.010		
ORANG	7	0	73	5	YELLOW CORN	0.916		
ORANG	8	0	81	6	CARROTS	0.586		
ORANG	8	0	82	6	CARROTS	0.823		
ORANG	8	0	83	6	CARROTS	0.772		
ORANG	9	0	91	7	RADISH	0.800		
ORANG	9	0	92	7	RADISH	0.565		
ORANG	9	0	93	7	RADISH	0.515		
ORANG	32	1	291	26	BLACKEYE PEAS	0.970		
ORANG	32	1	292	26	BLACKEYE PEAS	0.899		
ORANG	32	1	293	26	BLACKEYE PEAS	0.839		
ORANG	33	1	301	5	YELLOW CORN	1.170		
ORANG	33	1	302	5	YELLOW CORN	1.040		
ORANG	33	1	303	5	YELLOW CORN	1.130		
ORANG	33	1	311	14	TURNIP ROOT	1.540		
ORANG	33	1	312	14	TURNIP ROOT	1.450		
ORANG	33	1	313	14	TURNIP ROOT	1.460		
ORANG	49	2	431	2	ORANGE	0.920		
ORANG	49	2	432	2	ORANGE	0.843		
ORANG	49	2	433	2	ORANGE	0.791		
ORANG	50	2	441	2	ORANGE	0.615		
ORANG	50	2	442	2	ORANGE	0.451		
ORANG	50	2	443	2	ORANGE	0.394		
ORANG	51	2	451	2	ORANGE	0.139		
ORANG	51	2	452	2	ORANGE	0.147		
ORANG	51	2	453	2	ORANGE	0.091		
ORANG	52	2	461	2	ORANGE	0.229		
ORANG	52	2	462	2	ORANGE	0.185		
ORANG	52	2	463	2	ORANGE	0.379		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=DEB

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
DEBG	68	3	491	14	TURNIP ROOT	17.451	30.698	36.433
DEBG	68	3	661	44	LETTUCE	16.797	17.912	30.316
DEBG	68	3	741	6	CARROTS	17.498	20.139	28.364
DEBG	68	3	751	17	BROCCOLI	15.489	16.342	17.307
DEBG	68	3	771	37	CABBAGE	17.964	26.978	32.535
HILLS	6	0	61	4	SPINACH	13.700		
HILLS	6	0	62	4	SPINACH	13.200		
HILLS	6	0	63	4	SPINACH	13.800		
HILLS	6	1	121	14	TURNIP ROOT	14.400		
HILLS	6	1	122	14	TURNIP ROOT	11.200		
HILLS	6	1	123	14	TURNIP ROOT	15.300		
HILLS	6	1	131	15	YELLOW SQUASH	15.100		
HILLS	6	1	132	15	YELLOW SQUASH	16.000		
HILLS	6	1	133	15	YELLOW SQUASH	12.100		
HILLS	6	2	261	35	GREEN BEANS	22.000		
HILLS	6	2	262	35	GREEN BEANS	20.900		
HILLS	6	2	263	35	GREEN BEANS	21.800		
HOPE	6	3	171	25	COLLARD GREENS	14.040	12.897	13.110
HOPE	6	3	172	25	COLLARD GREENS	13.680	12.239	15.310
HOPE	6	3	181	25	COLLARD GREENS	13.690	14.525	13.540
HOPE	6	3	182	25	COLLARD GREENS	13.480	14.525	14.200

LAND CATEGORY=MIN

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
HARDE	16	1	51	2	ORANGE	0.351		
HARDE	16	1	52	2	ORANGE	0.537		
HARDE	16	1	53	2	ORANGE	0.254		
HARDE	17	1	61	2	ORANGE	0.265		
HARDE	17	1	62	2	ORANGE	0.231		
HARDE	17	1	63	2	ORANGE	0.367		
HARDE	18	1	71	2	ORANGE	0.271		
HARDE	18	1	72	2	ORANGE	0.295		
HARDE	18	1	73	2	ORANGE	0.376		
HARDE	19	1	81	2	ORANGE	0.634		
HARDE	19	1	82	2	ORANGE	0.671		
HARDE	19	1	83	2	ORANGE	0.782		
HARDE	20	1	91	2	ORANGE	1.120		
HARDE	20	1	92	2	ORANGE	0.452		
HARDE	20	1	93	2	ORANGE	0.405		
HARDE	21	1	101	2	ORANGE	0.281		
HARDE	21	1	102	2	ORANGE	0.388		
HARDE	21	1	103	2	ORANGE	0.427		
HILLS	2	0	21	2	ORANGE	0.401		
HILLS	2	0	22	2	ORANGE	0.456		
HILLS	2	0	23	2	ORANGE	0.168		
HILLS	3	0	31	2	ORANGE	0.391		
HILLS	3	0	32	2	ORANGE	0.284		
HILLS	3	0	33	2	ORANGE	0.268		
HILLS	23	1	141	17	BROCCOLI	0.410		
HILLS	23	1	142	17	BROCCOLI	0.378		
HILLS	23	1	143	17	BROCCOLI	0.334		
HILLS	36	2	31	27	SATSUMO CITRUS	4.820		
HILLS	36	2	32	27	SATSUMO CITRUS	1.020		
HILLS	36	2	33	27	SATSUMO CITRUS	1.790		
HILLS	37	2	51	29	GREEN ONIONS	0.449		
HILLS	37	2	52	29	GREEN ONIONS	0.491		
HILLS	37	2	53	29	GREEN ONIONS	0.449		
HILLS	41	2	141	11	ZUCCHINI	0.413		
HILLS	41	2	142	11	ZUCCHINI	0.350		
HILLS	41	2	143	11	ZUCCHINI	0.448		
HILLS	41	2	151	7	RADISH	0.522		
HILLS	41	2	152	7	RADISH	0.480		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=MIN

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
HILLS	41	2	153	7	RADISH	0.644		
HILLS	41	2	161	33	BUSH POLE BEANS	0.462		
HILLS	41	2	162	33	BUSH POLE BEANS	0.444		
HILLS	41	2	163	33	BUSH POLE BEANS	0.511		
HILLS	42	2	171	15	YELLOW SQUASH	0.253		
HILLS	42	2	172	15	YELLOW SQUASH	0.283		
HILLS	42	2	173	15	YELLOW SQUASH	0.204		
HILLS	43	2	181	34	EGGPLANT	0.513		
HILLS	43	2	182	34	EGGPLANT	0.422		
HILLS	43	2	183	34	EGGPLANT	0.821		
HILLS	48	2	361	11	ZUCCHINI	1.050		
HILLS	48	2	362	11	ZUCCHINI	1.020		
HILLS	48	2	363	11	ZUCCHINI	0.990		
HILLS	60	2	711	41	STRAWBERRIES	0.502		
HILLS	60	2	712	41	STRAWBERRIES	0.433		
HILLS	60	2	713	41	STRAWBERRIES	0.452		
MANTE	15	1	41	2	ORANGE	0.365		
MANTE	15	1	42	2	ORANGE	0.392		
MANTE	15	1	43	2	ORANGE	0.371		
MANTE	25	1	201	21	GREEN PEPPER	0.208		
MANTE	25	1	202	21	GREEN PEPPER	0.223		
MANTE	25	1	203	21	GREEN PEPPER	0.170		
MANTE	26	1	211	22	WATERMELON	0.187		
MANTE	26	1	212	22	WATERMELON	0.297		
MANTE	26	1	213	22	WATERMELON	0.152		
MANTE	26	1	221	22	WATERMELON	0.152		
MANTE	26	1	222	22	WATERMELON	0.149		
MANTE	26	1	223	22	WATERMELON	0.136		
POLK	1	0	11	1	TOMATO	0.431		
POLK	1	0	12	1	TOMATO	0.623		
POLK	1	0	13	1	TOMATO	0.470		
POLK	4	0	41	2	ORANGE	0.102		
POLK	4	0	42	2	ORANGE	0.111		
POLK	4	0	43	2	ORANGE	0.117		
POLK	5	0	51	3	GRAPEFRUIT	0.390		
POLK	5	0	52	3	GRAPEFRUIT	0.280		
POLK	5	0	53	3	GRAPEFRUIT	0.382		
POLK	34	2	11	12	CITRON	0.610		
POLK	34	2	12	12	CITRON	0.346		
POLK	34	2	13	12	CITRON	8.900		
POLK	44	1	181	15	YELLOW SQUASH	1.060		
POLK	44	1	182	15	YELLOW SQUASH	1.030		
POLK	44	1	183	15	YELLOW SQUASH	0.816		
POLK	44	2	91	31	PURPLE HULL CROWDER	0.690		
POLK	44	2	92	31	PURPLE HULL CROWDER	0.529		
POLK	44	2	93	31	PURPLE HULL CROWDER	0.503		
POLK	44	2	341	25	COLLARD GREENS	0.385		
POLK	44	2	342	25	COLLARD GREENS	0.490		
POLK	44	2	343	25	COLLARD GREENS	0.478		
POLK	44	2	351	14	TURNIP ROOT	0.585		
POLK	44	2	352	14	TURNIP ROOT	0.592		
POLK	44	2	353	14	TURNIP ROOT	0.615		
POLK	61	2	731	25	COLLARD GREENS	0.574		
POLK	62	2	751	4	SPINACH	2.070		
POLK	62	2	752	4	SPINACH	2.130		
POLK	62	2	753	4	SPINACH	2.150		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=REC

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
HILLS	11	0	111	8	POLE BEANS	19.900		
HILLS	11	0	112	8	POLE BEANS	21.400		
HILLS	11	0	113	8	POLE BEANS	4.680		
HILLS	11	0	121	9	POTATOES	8.540		
HILLS	11	0	122	9	POTATOES	7.740		
HILLS	11	0	123	9	POTATOES	7.170		
HILLS	11	0	131	11	ZUCCHINI	1.730		
HILLS	11	0	132	11	ZUCCHINI	2.370		
HILLS	11	0	133	11	ZUCCHINI	1.620		
HILLS	11	1	111	11	ZUCCHINI	3.710		
HILLS	11	1	112	11	ZUCCHINI	2.540		
HILLS	11	1	113	11	ZUCCHINI	2.290		
HILLS	11	1	231	14	TURNIP ROOT	3.100		
HILLS	11	1	232	14	TURNIP ROOT	3.440		
HILLS	11	1	233	14	TURNIP ROOT	4.210		
HILLS	11	2	41	28	CUCUMBER	2.120		
HILLS	11	2	42	28	CUCUMBER	1.980		
HILLS	11	2	43	28	CUCUMBER	2.350		
HILLS	11	2	201	9	POTATOES	3.300		
HILLS	11	2	202	9	POTATOES	5.220		
HILLS	11	2	203	9	POTATOES	3.030		
HILLS	11	2	211	31	PURPLE HULL CROWDER	4.240		
HILLS	11	2	212	31	PURPLE HULL CROWDER	6.490		
HILLS	11	2	213	31	PURPLE HULL CROWDER	2.340		
HILLS	45	2	191	15	YELLOW SQUASH	13.700		
HILLS	45	2	192	15	YELLOW SQUASH	14.300		
HILLS	45	2	193	15	YELLOW SQUASH	14.900		
HILLS	46	2	231	3	GRAPEFRUIT	7.040		
HILLS	46	2	232	3	GRAPEFRUIT	10.800		
HILLS	46	2	233	3	GRAPEFRUIT	3.000		
HILLS	47	2	241	2	ORANGE	23.800		
HILLS	47	2	242	2	ORANGE	1.530		
HILLS	47	2	243	2	ORANGE	47.400		
HILLS	47	2	251	2	ORANGE	0.591		
HILLS	47	2	252	2	ORANGE	1.800		
HILLS	47	2	253	2	ORANGE	0.463		
MULB	66	3	191	15	YELLOW SQUASH	12.910	9.361	8.170
MULB	66	3	192	15	YELLOW SQUASH	12.290	10.592	11.240
MULB	66	3	201	11	ZUCCHINI	8.600	8.829	4.250
MULB	66	3	202	11	ZUCCHINI	10.540	7.573	6.740
MULB	66	3	211	9	POTATOES	3.220	1.459	4.500
MULB	66	3	221	5	YELLOW CORN	28.840	27.520	20.360
MULB	66	3	222	5	YELLOW CORN	30.700	26.465	24.870
POLK	10	0	101	2	ORANGE	13.400		
POLK	10	0	102	2	ORANGE	12.200		
POLK	10	0	103	2	ORANGE	38.800		
POLK	10	2	311	2	ORANGE	42.000		
POLK	10	2	312	2	ORANGE	42.900		
POLK	10	2	313	2	ORANGE	48.900		
POLK	12	1	11	12	CITRON	0.217		
POLK	12	1	12	12	CITRON	4.930		
POLK	12	1	13	12	CITRON	6.070		
POLK	13	1	21	2	ORANGE	7.060		
POLK	13	1	22	2	ORANGE	8.510		
POLK	13	1	23	2	ORANGE	1.750		
POLK	13	2	291	2	ORANGE	1.590		
POLK	13	2	292	2	ORANGE	0.874		
POLK	13	2	293	2	ORANGE	14.400		
POLK	14	2	301	2	ORANGE	8.810		
POLK	14	2	302	2	ORANGE	11.500		
POLK	14	2	303	2	ORANGE	9.470		
POLK	24	1	151	18	ZIPPER PEAS	4.610		
POLK	24	1	152	18	ZIPPER PEAS	4.040		
POLK	24	1	153	18	ZIPPER PEAS	3.240		
POLK	24	1	161	5	YELLOW CORN	4.430		
POLK	24	1	162	5	YELLOW CORN	4.260		
POLK	24	1	163	5	YELLOW CORN	5.280		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CONCENTRATIONS
(pCi/g)

BY LAND CATEGORY

LAND CATEGORY=REC

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	RA-226	PO-210	PB-210
POLK	24	1	171	19	PEAS	5.230		
POLK	24	1	172	19	PEAS	5.750		
POLK	24	1	173	19	PEAS	5.770		
POLK	24	1	191	20	LIMA BEANS	1.460		
POLK	24	1	192	20	LIMA BEANS	2.460		
POLK	24	1	193	20	LIMA BEANS	2.390		
POLK	24	2	331	22	WATERMELON	3.920		
POLK	24	2	332	22	WATERMELON	2.690		
POLK	24	2	333	22	WATERMELON	4.220		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CHEMISTRY

BY LAND CATEGORY

LAND CATEGORY=CLAY

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
AGRI	64	3	91	17	BROCCOLI	2.5	322	1350	3110	7.2	0.0	27.6
AGRI	64	3	231	5	YELLOW CORN	3.8	341	1510	3270	7.2	0.0	29.8
AGRI	64	3	251	30	MUSTARD GREENS	2.2	314	1930	2950	7.6	0.0	31.6
AGRI	64	3	591	49	RICE	2.1	296	1570	3920	7.7	0.0	33.4
AGRI	64	3	592	49	RICE	1.8	290	1560	3700	7.7	0.0	32.2
AGRI	64	3	671	17	BROCCOLI	2.0	34	113	330	6.6	0.2	2.9
AGRI	64	3	681	37	CABBAGE	1.8	252	1990	3630	7.5	0.0	35.4
BW	63	3	132	37	CABBAGE	1.2	329	705	2160	7.0	0.1	17.6
BW	63	3	161	37	CABBAGE	1.0	296	760	2800	6.9	0.3	21.4
BW	63	3	511	30	MUSTARD GREENS	1.0	395	538	2050	7.4	0.0	15.7
BW	63	3	512	30	MUSTARD GREENS	2.4	147	370	7940	7.2	0.0	43.2
BW	63	3	521	30	MUSTARD GREENS	0.9	152	400	7900	7.3	0.0	43.2
BW	63	3	522	30	MUSTARD GREENS	2.5	239	617	1340	8.0	0.0	12.5
BW	63	3	531	30	MUSTARD GREENS	1.0	240	670	1300	7.6	0.0	12.7
BW	63	3	541	30	MUSTARD GREENS	0.9	235	640	1630	7.4	0.0	14.1
BW	63	3	542	30	MUSTARD GREENS	0.9	200	330	7880	7.3	0.0	42.7
BW	63	3	543	30	MUSTARD GREENS	1.3	190	370	7640	7.3	0.0	41.8
BW	63	3	551	30	MUSTARD GREENS	1.5	127	431	9460	7.5	0.0	51.2
BW	63	3	552	30	MUSTARD GREENS	2.3	171	499	9580	7.4	0.0	52.5
BW	63	3	561	30	MUSTARD GREENS	1.4	152	572	1360	7.7	0.0	12.0
BW	63	3	562	30	MUSTARD GREENS	2.3	183	690	1500	7.6	0.0	13.7
BW	63	3	842	14	TURNIP ROOT	1.1	182	660	1270	7.8	0.0	12.3
BW	63	3	843	14	TURNIP ROOT	0.9	232	640	1150	7.8	0.0	11.7
IMC	67	3	261	14	TURNIP ROOT	2.5	391	2090	3390	7.0	0.2	35.6
IMC	67	3	281	45	PARSLEY	2.8	261	2210	3230	7.3	0.0	35.2
IMC	67	3	291	46	SWISS CHARD	2.5	285	2140	3550	7.1	0.0	36.3
IMC	67	3	611	25	COLLARD GREENS	1.8	286	1760	3670	7.2	0.0	33.8
IMC	67	3	621	23	TURNIP GREENS	1.9	342	2040	3410	7.2	0.0	34.9
IMC	67	3	641	44	LETTUCE	1.8	286	1900	3670	6.1	5.7	40.6
IMC	67	3	651	30	MUSTARD GREENS	2.0	238	1860	3220	6.4	3.2	35.4
IMC	67	3	691	44	LETTUCE	2.1	289	2180	3540	6.2	5.0	41.6
IMC	67	3	701	17	BROCCOLI	1.7	313	2110	3690	7.2	0.0	36.8
IMC	67	3	711	37	CABBAGE	1.8	263	1740	3560	6.7	1.6	34.6
IMC	67	3	721	6	CARROTS	2.2	305	704	3460	6.9	0.4	24.3
IMC	67	3	731	4	SPINACH	2.5	353	700	3520	5.9	5.0	29.3
POLK	35	2	21	7	RADISH					8.0		
POLK	35	2	22	7	RADISH					7.8		
POLK	35	2	23	7	RADISH					7.8		
POLK	35	2	271	26	BLACKEYE PEAS					7.9		
POLK	35	2	272	26	BLACKEYE PEAS					8.0		
POLK	35	2	273	26	BLACKEYE PEAS					7.7		

LAND CATEGORY=CTRL

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
HILLS	38	2	101	1	TOMATO					6.9		
HILLS	38	2	102	1	TOMATO					6.2		
HILLS	38	2	103	1	TOMATO					6.1		
HILLS	39	2	111	32	CAULIFLOWER					7.2		
HILLS	39	2	112	32	CAULIFLOWER					6.5		
HILLS	39	2	113	32	CAULIFLOWER					6.8		
HILLS	40	2	121	28	CUCUMBER	2.9	42	106	300	5.8	0.6	3.1
HILLS	40	2	131	21	GREEN PEPPER					6.2		
HILLS	40	2	132	21	GREEN PEPPER					6.4		
HILLS	40	2	133	21	GREEN PEPPER					6.1		
LAKE	29	1	261	23	TURNIP GREENS	9.9	112	473	2360	5.3	7.2	23.2
LAKE	30	1	271	25	COLLARD GREENS	9.9	142	519	3610	5.7	6.0	28.7
LAKE	30	2	671	4	SPINACH					5.4		
LAKE	30	2	672	4	SPINACH					5.5		
LAKE	30	2	673	4	SPINACH	9.9	46	507	3600	5.5	7.8	30.1
LAKE	31	1	281	7	RADISH					7.2		
LAKE	31	1	282	7	RADISH					7.2		
LAKE	31	1	283	7	RADISH					6.9		
ORANG	7	0	71	5	YELLOW CORN					5.8		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CHEMISTRY

BY LAND CATEGORY

LAND CATEGORY=CTRL

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
ORANG	7	0	72	5	YELLOW CORN					6.1		
ORANG	7	0	73	5	YELLOW CORN					6.2		
ORANG	8	0	81	6	CARROTS					6.3		
ORANG	8	0	82	6	CARROTS					6.1		
ORANG	8	0	83	6	CARROTS					5.9		
ORANG	9	0	91	7	RADISH					7.3		
ORANG	9	0	92	7	RADISH					7.3		
ORANG	9	0	93	7	RADISH					7.3		
ORANG	32	1	291	26	BLACKEYE PEAS					5.3		
ORANG	32	1	292	26	BLACKEYE PEAS					5.4		
ORANG	32	1	293	26	BLACKEYE PEAS					5.3		
ORANG	33	1	301	5	YELLOW CORN	9.9	195	489	3650	6.0	4.0	26.8
ORANG	33	1	311	14	TURNIP ROOT	9.9	215	489	3020	5.2	10.4	30.1
ORANG	33	1	311	23	TURNIP GREENS					5.9		
ORANG	33	1	312	23	TURNIP GREENS					5.8		
ORANG	33	1	313	23	TURNIP GREENS					5.9		
ORANG	49	2	431	2	ORANGE					5.5		
ORANG	49	2	432	2	ORANGE					5.3		
ORANG	49	2	433	2	ORANGE					4.8		
ORANG	50	2	441	2	ORANGE					5.7		
ORANG	50	2	442	2	ORANGE					5.4		
ORANG	50	2	443	2	ORANGE					5.6		
ORANG	51	2	451	2	ORANGE					5.8		
ORANG	51	2	452	2	ORANGE					6.5		
ORANG	51	2	453	2	ORANGE					5.9		
ORANG	52	2	461	2	ORANGE					5.0		
ORANG	52	2	462	2	ORANGE					5.2		
ORANG	52	2	463	2	ORANGE					6.0		

LAND CATEGORY=DEB

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
DEBG	68	3	491	14	TURNIP ROOT	2.1	17	119	368	6.8	0.1	3.0
DEBG	68	3	661	44	LETTUCE	1.2	280	2050	3550	7.6	0.0	35.6
DEBG	68	3	741	6	CARROTS	2.2	27	84	460	6.1	0.5	3.6
DEBG	68	3	751	17	BROCCOLI	1.6	35	113	430	6.3	0.4	3.6
DEBG	68	3	771	37	CABBAGE	2.4	54	108	430	6.5	0.3	3.5
HILLS	6	0	61	4	SPINACH					5.7		
HILLS	6	0	62	4	SPINACH					5.5		
HILLS	6	0	63	4	SPINACH					5.1		
HILLS	6	1	121	14	TURNIP ROOT	2.0	41	38	690	4.9	3.0	6.9
HILLS	6	1	122	14	TURNIP ROOT	2.2	46	43	560	4.8	2.9	6.2
HILLS	6	1	123	14	TURNIP ROOT	2.2	85	37	590	4.9	2.7	6.2
HILLS	6	1	131	15	YELLOW SQUASH	2.1	92	82	530	4.7	3.6	7.2
HILLS	6	1	132	15	YELLOW SQUASH	2.2	127	104	580	4.7	4.2	8.3
HILLS	6	1	133	15	YELLOW SQUASH	2.2	104	88	420	4.8	2.7	5.8
HILLS	6	2	261	35	GREEN BEANS					5.5		
HILLS	6	2	262	35	GREEN BEANS					5.5		
HILLS	6	2	263	35	GREEN BEANS					5.4		
HOPE	6	3	171	25	COLLARD GREENS	1.8	198	60	500	4.8	3.1	6.6

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CHEMISTRY

BY LAND CATEGORY

LAND CATEGORY=MIN

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
HARDE	16	1	51	2	ORANGE					5.0		
HARDE	16	1	52	2	ORANGE					4.6		
HARDE	16	1	53	2	ORANGE					4.8		
HARDE	17	1	61	2	ORANGE					5.9		
HARDE	17	1	62	2	ORANGE					5.6		
HARDE	17	1	63	2	ORANGE					5.1		
HARDE	18	1	71	2	ORANGE					7.0		
HARDE	18	1	72	2	ORANGE					6.9		
HARDE	18	1	73	2	ORANGE					6.1		
HARDE	19	1	81	2	ORANGE					5.1		
HARDE	19	1	82	2	ORANGE					5.0		
HARDE	19	1	83	2	ORANGE					5.7		
HARDE	20	1	91	2	ORANGE					6.2		
HARDE	20	1	92	2	ORANGE					5.9		
HARDE	20	1	93	2	ORANGE					5.7		
HARDE	21	1	101	2	ORANGE					6.5		
HARDE	21	1	102	2	ORANGE					5.3		
HARDE	21	1	103	2	ORANGE					5.8		
HILLS	2	0	21	2	ORANGE					4.9		
HILLS	2	0	22	2	ORANGE					5.2		
HILLS	2	0	23	2	ORANGE					5.4		
HILLS	3	0	31	2	ORANGE					5.5		
HILLS	3	0	32	2	ORANGE					5.9		
HILLS	3	0	33	2	ORANGE					5.5		
HILLS	23	1	141	17	BROCCOLI	3.0	29	29	310	5.4	0.7	2.6
HILLS	36	2	31	27	SATSUMO CITRUS					5.0		
HILLS	36	2	32	27	SATSUMO CITRUS					4.9		
HILLS	36	2	33	27	SATSUMO CITRUS					4.9		
HILLS	37	2	51	29	GREEN ONIONS					6.5		
HILLS	37	2	52	29	GREEN ONIONS					6.8		
HILLS	37	2	53	29	GREEN ONIONS					6.8		
HILLS	41	2	141	11	ZUCCHINI	2.1	5	58	370	6.3	0.3	2.6
HILLS	41	2	151	7	RADISH					7.3		
HILLS	41	2	152	7	RADISH					7.6		
HILLS	41	2	153	7	RADISH					6.6		
HILLS	41	2	161	33	BUSH POLE BEANS					8.0		
HILLS	41	2	162	33	BUSH POLE BEANS					8.0		
HILLS	41	2	163	33	BUSH POLE BEANS					8.0		
HILLS	42	2	171	15	YELLOW SQUASH	3.8	47	108	500	5.5	1.2	4.7
HILLS	43	2	181	34	EGGPLANT					5.5		
HILLS	43	2	182	34	EGGPLANT					5.1		
HILLS	43	2	183	34	EGGPLANT					4.8		
HILLS	48	2	361	11	ZUCCHINI	6.0	143	269	850	5.7	1.8	8.7
HILLS	60	2	711	41	STRAWBERRIES	2.8	20	92	610	6.9	0.1	4.0
MANTE	15	1	41	2	ORANGE					4.5		
MANTE	15	1	42	2	ORANGE					4.6		
MANTE	15	1	43	2	ORANGE					4.2		
MANTE	25	1	201	21	GREEN PEPPER					7.0		
MANTE	25	1	202	21	GREEN PEPPER					6.6		
MANTE	25	1	203	21	GREEN PEPPER					7.1		
MANTE	26	1	211	22	WATERMELON					6.2		
MANTE	26	1	212	22	WATERMELON					5.7		
MANTE	26	1	213	22	WATERMELON					5.4		
MANTE	26	1	221	22	WATERMELON					6.1		
MANTE	26	1	222	22	WATERMELON					6.1		
MANTE	26	1	223	22	WATERMELON					6.5		
POLK	1	0	11	1	TOMATO					5.7		
POLK	1	0	12	1	TOMATO					5.9		
POLK	1	0	13	1	TOMATO					6.4		
POLK	4	0	41	2	ORANGE					6.1		
POLK	4	0	42	2	ORANGE					5.6		
POLK	4	0	43	2	ORANGE					6.0		
POLK	5	0	51	3	GRAPEFRUIT					5.4		
POLK	5	0	52	3	GRAPEFRUIT					5.0		
POLK	5	0	53	3	GRAPEFRUIT					5.2		
POLK	34	2	11	12	CITRON					5.0		
POLK	34	2	12	12	CITRON					5.5		
POLK	34	2	13	12	CITRON					6.1		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CHEMISTRY

BY LAND CATEGORY

LAND CATEGORY=MIN

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
POLK	44	1	181	15	YELLOW SQUASH	2.8	16	53	190	4.8	1.3	2.7
POLK	44	2	91	31	PURPLE HULL CROWDER					5.2		
POLK	44	2	92	31	PURPLE HULL CROWDER					5.1		
POLK	44	2	93	31	PURPLE HULL CROWDER					5.0		
POLK	44	2	341	25	COLLARD GREENS	2.1	17	37	180	5.1	0.8	2.1
POLK	44	2	351	14	TURNIP ROOT	3.7	34	37	150	4.8	1.0	2.1
POLK	61	2	731	25	COLLARD GREENS	4.6	30	106	390	4.9	2.3	5.2
POLK	62	2	751	4	SPINACH	2.1	31	129	370	6.7	0.1	3.1

LAND CATEGORY=REC

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
HILLS	11	0	121	9	POTATOES	1.0	15	43	550	4.7	3.2	6.3
HILLS	11	0	122	9	POTATOES	1.3	6	8	3870	4.8	17.2	36.6
HILLS	11	0	123	9	POTATOES	1.2	3	14	720	4.7	3.8	7.5
HILLS	11	0	131	11	ZUCCHINI	1.0	1	9	130	4.8	0.6	1.3
HILLS	11	0	132	11	ZUCCHINI	0.9	1	10	160	5.1	0.5	1.4
HILLS	11	1	111	11	ZUCCHINI	1.8	3	19	2780	5.7	3.7	17.8
HILLS	11	1	112	11	ZUCCHINI	1.9	6	44	340	5.3	0.9	3.0
HILLS	11	1	113	11	ZUCCHINI	1.8	6	62	340	5.4	0.9	3.1
HILLS	11	1	231	14	TURNIP ROOT	4.4	15	139	720	5.7	1.3	6.1
HILLS	11	1	231	23	TURNIP GREENS					5.2		
HILLS	11	1	232	14	TURNIP ROOT	4.1	5	220	710	5.8	1.3	6.7
HILLS	11	1	232	23	TURNIP GREENS					6.7		
HILLS	11	1	233	14	TURNIP ROOT	3.9	10	222	920	6.1	1.1	7.6
HILLS	11	1	233	23	TURNIP GREENS					5.5		
HILLS	11	2	41	28	CUCUMBER	2.6	4	47	400	5.5	0.8	3.2
HILLS	11	2	42	28	CUCUMBER					6.0		
HILLS	11	2	43	28	CUCUMBER	2.8	5	113	530	5.7	1.0	4.6
HILLS	11	2	201	9	POTATOES	2.7	21	145	530	5.8	0.9	4.8
HILLS	11	2	202	9	POTATOES	3.7	19	118	650	5.3	1.9	6.2
HILLS	11	2	203	9	POTATOES	2.1	23	39	300	4.8	1.7	3.6
HILLS	11	2	211	31	PURPLE HULL CROWDER					5.6		
HILLS	11	2	212	31	PURPLE HULL CROWDER					5.9		
HILLS	11	2	213	31	PURPLE HULL CROWDER					5.5		
HILLS	45	2	191	15	YELLOW SQUASH	2.0	171	131	450	5.0	2.6	6.4
HILLS	45	2	192	15	YELLOW SQUASH					5.3		
HILLS	45	2	193	15	YELLOW SQUASH	1.7	71	90	440	5.1	1.9	5.0
HILLS	46	2	231	3	GRAPEFRUIT					5.0		
HILLS	46	2	232	3	GRAPEFRUIT					5.5		
HILLS	46	2	233	3	GRAPEFRUIT					5.1		
HILLS	47	2	241	2	ORANGE					4.4		
HILLS	47	2	242	2	ORANGE					4.3		
HILLS	47	2	243	2	ORANGE					4.6		
HILLS	47	2	251	2	ORANGE					4.5		
HILLS	47	2	252	2	ORANGE					4.5		
HILLS	47	2	253	2	ORANGE					4.2		
MULB	66	3	191	15	YELLOW SQUASH	2.6	46	537	1880	7.3	0.0	14.0
MULB	66	3	192	15	YELLOW SQUASH	3.1	163	559	2000	6.8	0.5	15.6
MULB	66	3	201	11	ZUCCHINI	4.5	203	29	1380	5.5	2.7	10.4
MULB	66	3	202	11	ZUCCHINI	4.6	180	405	1600	6.2	1.6	13.4
MULB	66	3	211	9	POTATOES	3.5	68	206	910	5.5	2.3	8.7
MULB	66	3	221	5	YELLOW CORN	4.1	210	1150	2870	6.5	2.0	26.5
MULB	66	3	222	5	YELLOW CORN	4.2	211	1140	2700	6.7	1.1	24.6
POLK	10	2	311	2	ORANGE					6.1		
POLK	10	2	312	2	ORANGE					6.0		
POLK	10	2	313	2	ORANGE					6.0		
POLK	12	1	11	12	CITRON					4.6		
POLK	12	1	12	12	CITRON					4.5		
POLK	12	1	13	12	CITRON					5.1		
POLK	13	1	21	2	ORANGE					6.3		
POLK	13	1	22	2	ORANGE					6.0		
POLK	13	1	23	2	ORANGE					6.0		
POLK	13	2	291	2	ORANGE					6.9		

RADIOACTIVITY IN FOODS GROWN ON MINED PHOSPHATE LANDS

SOIL CHEMISTRY

BY LAND CATEGORY

LAND CATEGORY=REC

PARCEL DESC	PARCEL SAMPLE	EPISODE SAMPLE	SOIL SAMPLE	FOOD SAMPLE	FOOD DESC	ORGANIC MATTER	K	MG	CA	PH	H	CEC
POLK	13	2	292	2	ORANGE					6.0		
POLK	13	2	293	2	ORANGE					6.2		
POLK	14	2	301	2	ORANGE					6.5		
POLK	14	2	302	2	ORANGE					7.1		
POLK	14	2	303	2	ORANGE					7.1		
POLK	24	1	151	18	ZIPPER PEAS					5.6		
POLK	24	1	152	18	ZIPPER PEAS					5.9		
POLK	24	1	153	18	ZIPPER PEAS					6.1		
POLK	24	1	161	5	YELLOW CORN	2.3	36	16	70	4.5	0.8	1.4
POLK	24	1	162	5	YELLOW CORN	1.5	12	16	70	4.8	0.5	1.0
POLK	24	1	163	5	YELLOW CORN	0.8	7	22	50	4.6	0.5	1.0
POLK	24	1	171	19	PEAS					5.7		
POLK	24	1	172	19	PEAS					5.3		
POLK	24	1	173	19	PEAS					4.5		
POLK	24	1	191	20	LIMA BEANS					5.1		
POLK	24	1	192	20	LIMA BEANS					5.4		
POLK	24	1	193	20	LIMA BEANS					5.2		
POLK	24	2	331	22	WATERMELON					5.2		
POLK	24	2	332	22	WATERMELON					5.5		
POLK	24	2	333	22	WATERMELON					5.2		