

**CESIUM-137 IN WOOD ASH**  
**RESULTS OF NATIONWIDE SURVEY**

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**by**

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My curiosity about wood ash and the radioactivity it might contain goes back to a visit to Vermont in 1981 when I read a "filler" in a small local weekly newspaper noting that during the 1800's, wood ash from Vermont was a major feedstock to the early U.S. potash industry. As an environmental Health Physicist with a strong intuitive streak (ENTP on the Myers-Briggs test), it seemed likely that if there were a significant quantity of potassium in wood ash there would also be an unusual concentration of weapons test fallout Cs-137 in wood ash, since cesium(Cs) and potassium (K) generally "move" together in biological systems. These two elements behave as alkali metals and form a number of compounds which have similar crystalline structure. After my initial inquiries in 1982 with several environmental monitoring labs indicated no measurements of Cs-137 in wood ash had been made, my curiosity about Cs-137 levels in wood ash sat idle and unassessed until late 1989. In 1989 during a visit to Vermont, I decided to clean out the ash from my wood-burning fireplace and submit it for germanium gamma spec analysis at the environmental lab at which I was working in 1989 as QA Officer. At that time, I brought a single wood ash sample back to the lab from Warren, Vermont, and submitted it as a potential solid sample "QA matrix" for future use as a relatively homogenous solid matrix which was likely to contain the natural Uranium-238 decay series isotopes, Thorium-232 decay series, and Potassium-40 along with some fallout Cs-137. The mix of gamma activity present in this first sample is clearly seen in SLIDE 2A Spectrum, Warren, Vermont). On a linear plot (Slide2), Cs-137 is the primary fission product (and major gamma) peak evident, greatly exceeding the height of the natural Uranium-238 and Thorium-232 series daughter gamma emitters shown for Ra-226, Pb-214, Bi-214, and the K-40 peak present (although K-40 exceeds Cs-137 on an activity basis).

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### Biography

#### Stewart A. Farber

Mr. Farber has over 20 years experience in environmental radiation monitoring, meteorological monitoring, emergency planning, and radiation protection program management. His experience includes independent consulting support to State Health Departments, town councils, consulting firms, utilities, manufacturers, lawfirms, and insurance companies related to public health and environmental issues and staff technical support to a dozen nuclear power plants in the Northeast.

His project management experience includes serving as the Project Manager for the design and start-up of a centralized lab in Massachusetts serving 7 sites which has, since 1977 established itself as the premier utility sponsored environmental radiation monitoring lab in the U.S. He worked as Project Manager for the first fully functional computer based emergency assessment and response system brought into operation in the U.S. following the TMI accident, and as Project Manager for the design, installation, and calibration of a wide-range gaseous effluent radiation stack monitor for a 3 unit BWR power plant. He received an A.B. in Chemistry ('67) from Brown University, an M.S.P.H. ('73) in Air Pollution Control from the UMass School of Public Health, and has completed graduate coursework in genetics, biostatistics and biochemistry at the University of Vermont, College of Medicine.

Following this first analysis, in early 1990 I analyzed three more samples of wood ash from various parts of New England as reported in the Health Physics Society's Newsletter in a feature article (See Slide 3A) titled, "Preliminary Study of Cs-137 Uptake by Trees and Its Implications for BRC, Waste Disposal, and Dosimetry (Health Physics Society's Newsletter, Vol. 18(4): Pages 1-5, 1990). The Cs-137 concentration of these first wood ash samples generally exceeded, by 50 to 100 times, the Cs-137 concentration typically measured in sample media collected and analyzed near operating nuclear power electric generating stations as part of routine Nuclear Regulatory Commission (NRC) required radiological environmental monitoring programs. The levels of radioactivity initially reported in the HPS Newsletter are noted in SLIDE 3, "Radioactivity Measured in Wood Ash."

Based on the elevated levels of weapons test fallout Cs-137 radioactivity reported for these first wood ash samples, I requested in the April 1990 Newsletter article that interested readers of the Health Physics Society Newsletter collect wood ash samples from their local environments, quantify the gamma activity and communicate the results to me. As a result of this request, 17 contributors (see SLIDE 4) submitted data on radioactivity in 47 samples of wood ash collected in 14 states.

Survey contributors include ten utilities with environmental radiation monitoring programs, three universities, one national laboratory, two state health departments, and one defense contractor. While this was an informal survey, each of the measurements accepted for inclusion in this paper is based upon a calibrated measurement geometry for gamma isotopic activity. In addition, each wood ash measurement reported K-40 activity of approximately 80,000 pCi/kg ash consistent with the known potassium content of typical wood ash (about 10% to 15% stable potassium by weight).

### **Summary of Cs-137 Survey Results Reported**

SLIDE 5 summarizes 47 Cs-137 wood ash measurements provided by 17 contributors from 14 states. Individual Cs-137 concentrations varied by a factor of about 250 (ranging from 79 pCi/kg in one California wood ash to 21,100 pCi/kg in a single New Hampshire sample. The state mean Cs-137 concentrations varied from 16,100 pCi/kg in Maine (n = 1) to 265 pCi/kg (n = 6) for California. Data from 11 New England wood ash samples recorded a Cs-137 mean of about 12,000 pCi/kg, suggesting that the levels of Cs-137 in New England trees may be higher than that indicated in wood ash from similar type trees burned in nearby New Jersey, New York, and Pennsylvania. It must be noted that each of the New England "state mean" Cs-137 concentrations is based on limited data (only 1 to 3 measurements); and, thus, little can be said with any certainty as to how representative a given quoted "mean" is of average state values. However, none of the 11 measurements made in New York or nine measurements in Pennsylvania approach the peak Cs-137 ash concentrations noted in New England, despite the average soil fallout deposition in Pennsylvania and New Jersey equaling or exceeding that reported for New England. The six Cs-137 wood ash measurements made in California are all quite low and are about 1% or less of the highest values measured in New England.

## Cesium Vs. Potassium Activity

SLIDE 6 plots the Cs-137 activity (pCi/kg ash) vs. K-40 (pCi/kg ash) measured for each sample. The K-40 concentration varies only by about a factor of 6 (from 28,000 pCi/kg in a Eucalyptus ash from California), to 154,280 pCi/kg (in avocado ash also from California) with most K-40 values measuring between 60,000 pCi/kg and 110,000 pCi/kg. The variation of potassium observed in ash does not explain the much larger range of Cs-137 concentrations reported which varied by a factor of over 250.

## Cs-137 in the Environment

Cs-137 is directly created in the fission process with a relatively high fission yield of about six atoms per hundred fissions (vs. about 3.8 atoms of Sr-90 per hundred fissions (NCRP, 1977)) regardless of the type of fission involved. Cesium-137 has a long physical half life (30 years) and because of its uptake and retention in biological systems this makes it one of the most important fission products. This high fission yield for Cs-137 results in about 0.17 megacuries of Cs-137 per megaton of fission yield in nuclear weapons detonations and in the production of about 1.2 kCi/MWt/year in thermal nuclear reactors. Nuclear weapons with a total fission yield of about 194 megatons of TNT were exploded in the atmosphere (primarily by the United States and U.S.S.R.) from the start of the nuclear age in 1945 to about 1971. These open air nuclear weapons tests introduced an estimated 34 megacuries of Cs-137 into the environment (National Research Council, 1971). Other authors calculate that a total of 38.6 megacuries of Cs-137 were introduced into the atmosphere and made available for worldwide distribution. A lower "official" government estimate of cumulative worldwide deposition has been published by DOE's Environmental Measurements Laboratory (EML), derived from a relatively small worldwide network of Sr-90 samplers (72 sites during 1976, 47 in the Northern and 25 in the Southern hemisphere). The EML published cumulative Cs-137 deposition estimate (See Slide 7A) is 15.4 MCi (peaking in 1966) in the Northern hemisphere (77% of global total) and 4.6 MCi (peaking in 1973) in the Southern hemisphere (23% of global total). The majority of this Cs-137 was produced by high yield airbursts which created particles having a mean diameter of a fraction of a micron or less. Deposition from the stratosphere is mainly in the hemisphere of origin, with a familiar peak in temperate latitudes. The maximum weapons test fallout deposition peak occurred in the spring and early summer. Throughout the temperate latitudes, this spring maximum occurs during a time of frequent precipitation and deposition increases during the early phases of tree growth. This factor is very important because generally during the peak of fallout, Cs-137 found in vegetation is due to deposition on the leaves and stems of plants rather than by uptake through the roots. This factor may help explain why mature trees cut recently, but growing during the peak years of weapons fallout, appear to have become a sizable "reservoir" for environmental Cs-137 deposition during 1958 to 1966.

Most of the airborne Cs-137 activity was injected into the low to middle stratosphere and resulted in relatively uniform worldwide contamination. In 1963, the U.S., Soviet Union, and United Kingdom agreed to stop open air testing of nuclear weapons, eliminating this source of Cs-137 contamination. However, France and the Peoples Republic of China continued testing and exploded about 20 weapons from 1971 to 1975, six in the northern hemisphere and a few open air small tests subsequently as late as 1980. However, these later tests since 1971 have added only a token amount to the pre-existing environmental

inventory, adding only a few percent to the total dose commitment in the Northern hemisphere vs. all earlier testing.

Estimates of the average cumulative Cs-137 deposition ( $\text{mCi}/\text{km}^2$ ) over the United States due to weapons test fallout are noted in SLIDE 7. As seen in SLIDE 7, during the early years of testing in Nevada, predominant fallout was localized in the western states, south and east of the Nevada Test Site. During the later years of atmospheric testing, differences throughout the country were minimized. In general, differences throughout the country are on the order of a factor of 2, although southern California is reported as being about 3 to 4 fold lower in weapons fallout than peak areas of the United States. SLIDE 7 deposition estimates are based on the measured concentration of Sr-90 in soil over grassy areas through the end of 1967. Cs-137 deposition can be estimated by multiplying the Sr-90 deposition by the observed constant ratio of Cs-137 to Sr-90 of 1.6. After correcting for radioactive decay from 1967 to 1991, the isolines shown in SLIDE 7 also correspond to the approximate Cs-137 deposition in  $\text{mCi}/\text{km}^2$  that would be present in 1990. As seen, Cs-137 deposition in 1990 (over grassy fields) would generally vary between 60 and 90  $\text{mCi}/\text{km}^2$  (60,000 to 90,000  $\text{pCi}/\text{m}^2$ ) with a small area of the southeast between 20 to 40  $\text{mCi}/\text{km}^2$  (20,000 to 40,000  $\text{pCi}/\text{m}^2$ ). The Cs-137 activity per kilogram of soil can be estimated by dividing the areal deposition in  $\text{pCi}/\text{m}^2$  by the mass of soil (based on 15 cm depth into which the deposition is assumed to be contained). The mass of soil per square meter to a depth of 15 cm is typically assumed to be 240  $\text{kg}/\text{m}^2$ . Thus, 60,000  $\text{pCi}/\text{m}^2$  would equate to an average of about 250  $\text{pCi}/\text{kg}$  of Cs-137 per kilogram of soil.

SLIDE 8 plots the observed relationship of reported Cs-137 in wood ash ( $\text{pCi}/\text{kg}$  ash) vs. the estimated Cs-137 deposition, estimated from SLIDE 7 and information supplied as to where the trees were cut for each wood ash measurement. While there is scatter to the data, in general, higher Cs-137 deposition appears to correlate with higher Cs-137 concentrations in wood ash. However, the relationship between Cs-137 in ash and reported Cs-137 deposition in soil is not linear. Other variables are likely to be contributing to the much higher levels of Cs-137 in wood ash collected in the eastern United States vs. wood ash from southern California.

It is clear from the literature that Cs-137, as well as Sr-90, can be absorbed by plants, such as trees, both by direct leaf surface (foliar) contamination from the air and from the soil after deposition from the air. A number of studies have been noted in the scientific literature related to dry deposition and plume depletion over forests and grasslands. These studies suggest that that forests may be viewed as filters for contaminated air. The amount of any fine particulate airborne effluent flux to the earth's surface can be about a factor of 5 to 12 times as great over a forest as over grassland, with the greatest difference occurring during neutral conditions. Airborne radioactivity is likely to behave analogously with observations by researchers (Little and Martin, 1972) who found that the soil concentrations for zinc and cadmium near a large smelting complex were about five times greater in woodland samples than in open field samples. This is apparently related to the greater amount of material deposited on the forested areas and subsequently transported to the underlying soil by various mechanisms. Numerous authors have concluded that the deposition velocity (the amount of material deposited per unit area per second) for common aerosols may range between 0.0001  $\text{cm}/\text{sec}$  for smooth surfaces to 10  $\text{cm}/\text{sec}$  or more, depending on particle and surface types and atmospheric conditions. The deposition velocity over a forest has been estimated as being at least 10  $\text{cm}/\text{sec}$  by several researchers. White and Turner (1971)

studied metallic salts over a deciduous forest to calculate deposition velocities as large as 21.1 cm/sec.

Cesium is generally considered to be less readily absorbed from soil by plants than Sr-90, especially as time elapses. The difference in uptake between Cs-137 and Sr-90 is strongly dependent on soil type.

### **Factors Contributing to Enhanced Cesium Uptake for Unit Cesium-137 Deposition in Environment**

Assuming that cesium is first deposited onto soil and growing trees are taking the cesium measured in their ash from the soil, a number of soil factors are known to influence plant uptake of radionuclides. These same soil factors may play an important role in the long-term equilibrium which is established between airborne deposition to trees or other plants and what activity is ultimately "excreted" by the plant to the soil once an equilibrium is established over time.

#### **Soil Factors**

Soil consists of minerals, organic matter, water, and air combined in a complicated physicochemical system that provides the mechanical foothold for plants in addition to providing nutrients required. Several factors have been identified in the literature as influencing Cs-137 uptake by plants from soil. The effect of potassium levels in soil and stable cesium levels in soil will be briefly reviewed since these two factors appear to be most important in influencing Cs-137 levels in plants.

#### **Potassium Levels in Soil**

In soils which contain the same quantities of clay minerals and organic matter, generally the most important factor influencing cesium uptake is the potassium content of the soil. First, an inverse relationship has been consistently observed between soil potassium content and Cs-137 uptake by plants. For example, it was found that areas of Jamaica characterized by organic soils low in potassium would yield grasses having elevated Cs-137 concentrations (Broseaus, 1970).

Other studies have shown that both the exchangeable potassium in the soil and the "residual" potassium (extractable in hot 2.0 N HCl) exert a strong influence in a series of experiments with 178 types of Swedish soil. This is well illustrated in SLIDE 9 for red clover. The uptake of Cs-137 decreased with increasing quantities of both types of potassium. The effect of exchangeable potassium is related to the competition between cesium and potassium ions in the process of absorption. In contrast, the relationship between residual potassium and the uptake of Cs-137 by plants relates to the fact that the content of micaceous clay minerals in soils determines both the quantity of residual potassium and the extent to which cesium is "fixed" by soil. It has been observed that the absorption of Cs-137 is increased when soils are depleted of exchangeable potassium by continued crop production.

## **Stable Cesium Levels in Soil**

Minerals which contain stable cesium are rare in most soils and the total cesium content of most soils is very low. Thus, cesium added to mineral soils in very small concentrations will be strongly sorbed by a process termed "edge fixation" whereby cesium, being less hydrated than other alkali ions, is bound on certain sites on the outside of some crystalline clay mineral particles or lattice interlayer surfaces in such a specific way that it is much more easily exchangeable with cesium than with potassium or other cations. The ability of soil to bind cesium in this way is slight so that the mean binding energy of cesium in soil decreases rapidly with increasing amounts of added stable cesium. Thus, this effect is most pronounced when trace levels of stable cesium are present than when macroquantities are present in the soil. This effect is clearly seen in SLIDE 10 where slight additions of stable cesium to sandy loam soil lead to sharp increases in uptake of Cs-137 by red clover. As more stable cesium is added the uptake of Cs-137 present rapidly levels off. This stable cesium effect is less pronounced for loam-type soil and lowest in heavy clay soil.

Returning to SLIDE 8, an attempt has been made to estimate "low", "medium", and "high" stable cesium levels in soil on a crude state-by-state basis for which data was available. For a given level of Cs-137 deposition, it is seen that generally the highest levels of Cs-137 in wood ash appear to be seen in wood from trees grown in areas reported as having "high" stable cesium levels vs. "low" stable cesium areas. There is some scatter to the plot since the stable cesium levels are estimated only and no stable cesium measurements were actually made.

Stable cesium is found in a variety of minerals found in New England. Pollucite (pollux) is a cesium aluminosilicate mineral similar to quartz in appearance. Deposits of pollucite have been reported in Maine and Massachusetts which contain  $Cs_2O$  at 36.7% by weight, among the highest fraction of stable cesium reported worldwide. Stable cesium is also found in the dispersed state in rocks including granite at much lower concentrations (up to 0.004%). The variable amounts of stable cesium apparently found throughout New England, and likely present wherever granitic-type soils are found, would be a source of stable cesium which would act to saturate the exchange sites in soil silicates and minerals, which would otherwise bind any carrier-free cesium deposited into the environment. Accordingly, this mechanism may be a major factor in explaining the elevated Cs-137 in wood ash from New England vs. levels noted in other areas.

## **Implications of Results**

SLIDE 12 notes the United States 1989 consumption of wood energy based on DOE estimates and the amount of wood ash estimated as being produced each year. About 1.5 million tons per year would be generated based on a 1% ash fraction. About 63% of all ash produced each year, or about 1 million tons, is generated by the industrial sector. The primary contributor to this sector is the pulp and paper industry which burns vast amounts of wood waste ("hogged fuel") and "black liquor" solids (high organic fraction obtained in pressing the wet, digested pulp mix and burned after drying for Btu and chemical recovery) in operating pulp and paper plants. Approximately 75 million tons of "black liquor" solids are burned by the 99 large pulp and paper mills operated by seven major paper producers in the United States. Based on a measurement made by one of the Cs-137 survey responders on

the Cs-137 level, measured in "black liquor", it can be estimated that each of the 100 large kraft paper mills operated in the United States processes and ultimately releases to the environment more than a Curie/year of Cs-137. If this were to be verified by actual measurements, each kraft paper mill is concentrating and discharging more Cs-137 to the environment in an uncontrolled manner than each of the 110 operating nuclear plants in the United States. The exact pathways for these potential releases have not been assessed.

As seen in Slide 12, the residential sector is responsible for an estimated 535,000 tons of wood ash/year (37% of the estimated total). Most residential wood ash is disposed of in municipal trash in sanitary landfills, used around the home as a fertilizer, or spread in place of sand for preventing slipping on ice in northern locations. The utility sector (a small number of plants presently totaling about 200 MWe) contributed in 1989 only about 8,000 tons/year of wood ash (less than 1% of the total). However, another 600 MWe of wood-fired electric generating capacity is on the drawing boards, and the wood ash from these plants could become a local disposal or recycling source. The ash from industrial wood burning is handled by commercial disposal companies in surprising ways, as shown in SLIDE 13. As noted, recycling firms have sprouted in the last few years to take ash from wood burning utilities and cogenerators and from the pulp and paper industry. The ash is being mixed with manure and the "recycled organic" product is delivered free to farmers to use as fertilizer in growing crops for human consumption, rather than being shipped to a dump site as a waste product. As an example, 50 large commercial farmers in the so-called "Northeast Kingdom" of Vermont receive 3,000 tons of wood ash from one 50 MWe wood burning power plant which is used to grow crops and raise such things as "organically raised pork". Recycling organic wood ash waste from wood burning is a sizable and rapidly growing practice which large waste disposal companies plan to expand across the United States and around the world. There are sizable gaps in the present state of knowledge about the transfer of elevated levels of Cs-137 and Sr-90 contained in wood ash laden organic fertilizer from soil -> crops -> animals and humans. Thus, it is not at present clear whether the wood ash recyclers' goal of achieving success and "environmental awareness" through organic waste recycling (rather than wood ash disposal in a dump) is a desirable practice. It is clearly an unregulated practice in that neither the EPA nor the NRC at present have any regulations which would restrict the use of wood ash as a fertilizer for human crop production, despite the presence of elevated levels of fission products from nuclear weapons testing. No matter what doses may result from Cs-137 or Sr-90 in trees burned by pulp and paper mills and utilities, ash can be used anywhere -- even directly for food production without monitoring and without consideration of the dose to man exceeding that calculated from nuclear plant operations and waste disposal practices.

At this point, woodburners and organic farmers might be asking a simple question: "Is it time to kiss my ash good-bye?" A simple calculation has been made of the dose from using wood ash as a fertilizer over a period of time (20 years). Based on the assumptions noted in Slides 14A - 14C, it is calculated that use of wood ash as a fertilizer can contribute about 1 mrem/year to an individual from eating vegetables, milk, and meat raised on fields fertilized with wood ash. While the dose is not large vs. the average radiation exposure of the U.S. population for all sources, it should be recognized as a potential contributor to population dose and studied sufficiently to document the validity of the calculation estimates presented. The National Council on Radiation Protection and Measurements in NCRP Report No. 93 (NCRP, 1987) calculates that the average annual effective dose equivalent from all sources



in the entire U.S. population is approximately 360 mrem, exclusive of tobacco products, or about 1 mrem/day.

### **Summary**

This paper has provided some new data which may aid in understanding how Cs-137 from nuclear testing behaves in the environment. This data suggests a significant role played by trees in removing radioactivity from the atmosphere and cycling radioactivity through the environment to man. This study suggests what may be a growing, and to date largely overlooked, pathway for exposure of members of the general public to nuclear weapons test fallout.

It is important that the implications of the data on fallout Cs-137 reported by the wood ash survey responders be considered by environmental monitoring specialists, and waste disposal engineers. Fallout Cs-137 contained in wood will concentrate in the ash when the wood is burned by a factor of about 100 for most hardwoods if the cesium present is not volatilized. Studies of Cs-137 losses (Blincoe, 1962) in ashing biological media have shown that Cs-137 was not significantly lost during dry ashing of bone vs. large percentage losses typically noted when muscle tissue and other biological media are ashed. The mineral content of bone is essentially calcium phosphate. Calcium (as CaO) typically represents the greatest fraction of wood ash being present at from 30% to 60% of total ash. It is quite likely the presence of calcium salts in wood ash substantially lessens the loss of Cs-137 during wood burning. Cs-137, despite being generally considered as a relatively volatile element, is likely to behave in a relatively non-volatile manner when present in wood ash's mixed mineral matrix high in calcium and potassium.

The gamma spec measurements of wood ash reported in this survey indicate that weapons test fallout Cs-137 varies in the same type of wood (oak) by about an order of magnitude, over relatively narrow geographical areas, as a significant fraction of the K-40 present. Cs-137 variations in wood ash ranging over two orders of magnitude are possible over larger geographical areas for relatively even deposition based on soil factors and the presence of different types of trees. This highlights how carefully environmental radiation measurements in a given media must be interpreted in order to judge whether any measurement in the environment is related to releases from any one facility. It also highlights how important it is to expand our present understanding of the factors which can cause variations in weapons test fallout fission products in trees, other plants, and their ash.

### **Implications Regarding Below Regulatory Concern (BRC or de minimus) Rulemakings/Waste Disposal**

Nuclear facilities and hospitals generate various waste streams with low levels of fission and activation products. Some users of radioactivity are finding it very difficult to dispose of even relatively minor waste sources such as septic sludges containing low levels of activity (less than 200 pCi/kg of Cs-137 and Co-60) because sewage treatment plants and landfills fear receiving "radioactive waste". As an example, these facility-related "radioactive" septic sludges are either disposed of as low-level radioactive wastes via a licensed disposal broker, or in some regulated manner with the dose impacts routinely measured and reported per the facility Off-Site Dose Calculation Manuals (ODCM) in Semiannual Effluent and Waste Disposal Reports to the NRC. These steps are required even though the total fission product

radioactivity contained in a facility's septic sludge (13.5 uCi in 75,000 kg of sludge in one typical case for a year) would be found in as little as 700 kg of wood ash. Yet, at the same time, a single state, such as Vermont, burns in excess of 750,000 cords of wood per year, which yields about 10,000 tons of wood ash per year, containing up to 100 times higher Cs-137 concentration in the ash than in the septic sludge. Wood ash from domestic use is casually disposed of without regulatory concern in landfills. More and more wood ash is being used as a commercial fertilizer by large farming enterprises, enriching the soil and possibly the crops grown in this soil in Cs-137 content. To date, no studies have been made documenting the levels of Cs-137 in "organically" grown crops despite their potentially elevated levels of Cs-137. Given that consumers buy "organically" grown produce thinking it avoids stable contaminants from using "chemical" fertilizers, it is clear most "green" consumers would be surprised to find they might be receiving elevated levels of weapons test radioactive fallout exposure via uptake of Cs-137 by trees and the subsequent use of wood ash as a fertilizer.

### **Multidisciplinary Nature of the Problem**

This radioactivity in wood ash issue poses a number of very interesting technical questions about the environmental behavior of Cs-137 and how much we have to learn about how the environment truly works. It also highlights the extent to which science is not being applied in a consistent or sensible manner in regulating risks. As scientists and engineers we are all involved in one way or another with more than \$125 billion spent each year by U.S. industry, government, and consumers for environmental regulation. Environment is big business and it will soon be very big business. As a society we have many past and new environmental challenges to meet. However, costly environmental regulation is too often based on weak science that is both inconsistent and illogical. Ignorance is not bliss. Our present environmental educational system is producing narrowly focused professionals and citizens who don't have the tools to understand complex issues that are basically multidisciplinary. The problem is wonderfully stated in the quote by the physicist Erwin Schrodinger shown in Slide 15.

Institutionalized denial of the general deficit of credible science to back up a stable regulatory environment fosters technical and economic misjudgments and limits problem solving. The problem of denial affecting judgment was recognized almost a hundred years ago by the author Leo Tolstoy (see Slide 16). This scientific denial adds to the burden on manufacturing, water supplies, agriculture, forestry, coastlines, and utilities. As so well stated by Dr. Henry Howe, Professor of Biological Sciences at the University of Illinois and Vice Chair of the Committee for the National Institutes for the Environment (Howe, 1992):

"In short, our scientific and political institutions are not prepared to think proactively. While innumerable natural processes that could affect lives and livelihoods remain uninvestigated, our society reacts belatedly and hastily to the crisis of the week. An uninformed public, impoverished educational and research infrastructure, and inattentive policy process will continue to create reactive regulatory chaos. Medical sciences react to disease to provide a cure, a system that works with the loss of some patients. For environmental security, both reactive and proactive science are critical. There is only one Patient Earth to win or lose."

## **Additional Research Needs**

This brief review has probably raised more questions than it has answered. Accordingly, I hope to stimulate research in the following areas:

- 1) Cs-137 levels in trees prior to burning and careful determination of losses in combustion.
- 2) Are there any significant combustion losses in high temperature combustion situations, such as paper mill boilers or proposed gas turbine wood-fired generators. If combustion losses are documented, where is the volatilized Cs-137 depositing, and what may be the resultant doses?
- 3) Related to all woodburning operations: Where is the ash dumped and what are the resultant doses to the public? If wood ash is widely used by commercial "organic farming" operations, what studies are appropriate to document this potential source of elevated radiation exposure from nuclear weapons test fallout?

Unlike mineral waters which have elevated levels of natural isotopes not subject in the past to government regulation, commercial organic farming producers who use wood ash as a fertilizer may be enriching their crops in fallout Cs-137 and Sr-90. The resulting levels of these manmade, fallout nuclides in wood ash may require monitoring and control under existing regulations to keep doses "Below Regulatory Concern" and may become a point of reference by which BRC policy is judged by the public, politicians, and regulators.

- 4) What are the Sr-90/Cs-137 ratios in wood and in wood ash? The Sr-90 content of wood ash probably is likely to be higher than the Cs-137 content because of the higher transfer factors for strontium from soil to plant. Accurate data is essential on this point. Any dose from the use of woodash due to Sr-90 would be likely to greatly exceed (by at least a factor of 10) the Cs-137 dose and should be assessed after additional measurements are performed.

**NOTE:** The views expressed in this paper are the personal observations of the author only and are not those of any corporate entity .

## References

Blincoe, C., "Ashing Procedures for Determination of Cesium in Plant and Animal Tissues," Analytical Chemistry, Volume 34, No. 6, Page 715, May 1962.

Broseaus, R. W., Wrenn, M. E., and Eisenbud, M., "Cesium-137/Strontium-90 in Milk and Grass from Jamaica," M. S. Thesis, New York University, 1970.

Fredrikson, L., et al, "Studies of Soil-Plant-Animal Interrelationship with Respect of Fission Products," Proc. 2nd U.N. International Conference on the Peaceful Uses of Atomic Energy, United Nations, New York, New York, Page 177, 1958.

Hottes, A. C., "1001 Garden Questions Answered", New York, New York, A. T. DeLaMare Co., Inc., 1945.

Howe, Henry F., "Forum Needed for Environmental Issues", in Environmental Protection, Vol. 3, No. 5, p. 37-38, June, 1992

Martin, A., and Blanchard, R. L., "The Thermal Volatilization of Cesium-137, Polonium-210, and Lead-210 from In Vivo Labeled Samples," Analyst, Volume 94, Page 441, 1969.

National Council on Radiation Protection and Measurements, NCRP Report No. 50, "Environmental Radiation Measurements," Washington, DC, 1976.

National Council on Radiation Protection and Measurements, NCRP Report No. 52, "Cesium-137 From the Environment to Man: Metabolism and Dose," Washington, DC, January 1977.

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

National Research Council, Panel on Radioactivity in the Marine Environment, "Radioactivity in the Marine Environment," National Academy of Sciences, Washington, DC, 1971.

Perel'man, F. M., "Rubidium and Caesium," translated by R. G. P. Towndrow, Pergamon Press Book, The Macmillan Co., New York, New York, International Series of Monographs on Nuclear Energy, Volume 2, 1965.

Little, P., and Martin, M. H., "A Survey of Zinc, Lead, and Cadmium in Soil and Natural Vegetation Around a Smelting Complex," Environmental Pollution, Volume 3, Page 241, 1972.

Shelton, J. W., "Solid Fuels Encyclopedia," Pownal, Vermont, Storey Communications, Inc., 1983.

White, E. J., and Turner, R., "A Method of Estimating Income of Nutrients in a Catch of Airborne Particles by a Woodland Canopy," Journal of Applied Ecology, Volume 7, Page 441, 1970.

Wise, L. E., "Wood Chemistry," Reinhold Publishing Corp., New York, New York, Page 435, 1944.

Slide 1

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Newton, MA**

**October 21, 1992**

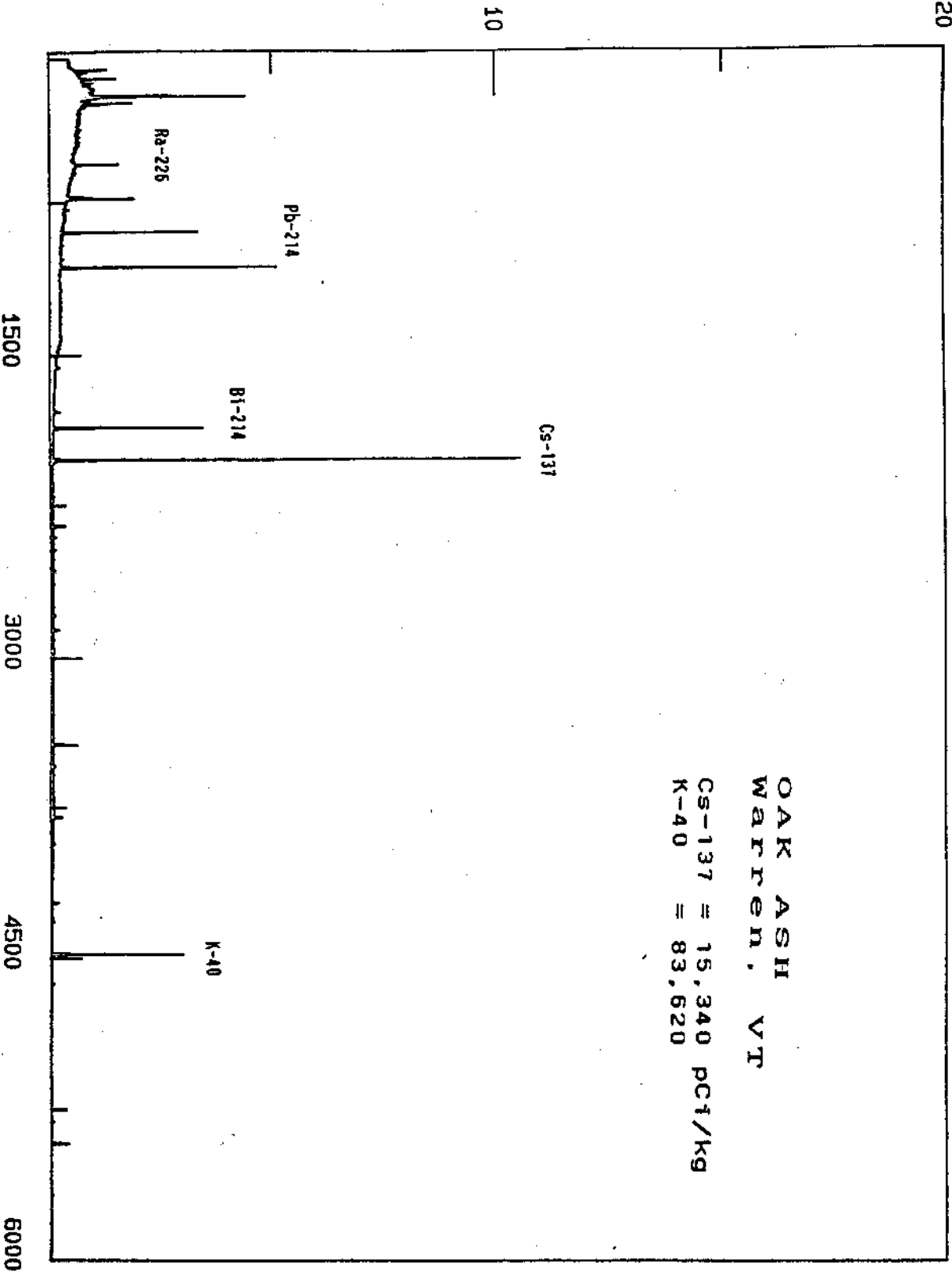
**by**

**Stewart A. Farber  
Consulting Scientist  
Public Health Sciences  
19 Stuart St.  
Pawtucket, RI 02860**

TYPE = -1 MCA # 2 SEGMENT # 1  
REALTIME = 10029.82 SECONDS. LIVETIME = 10000.00 SECONDS  
DATA COLLECTED AT 14:58:00 ON 19-JUN-91

20

COUNTS X 10<sup>-3</sup>



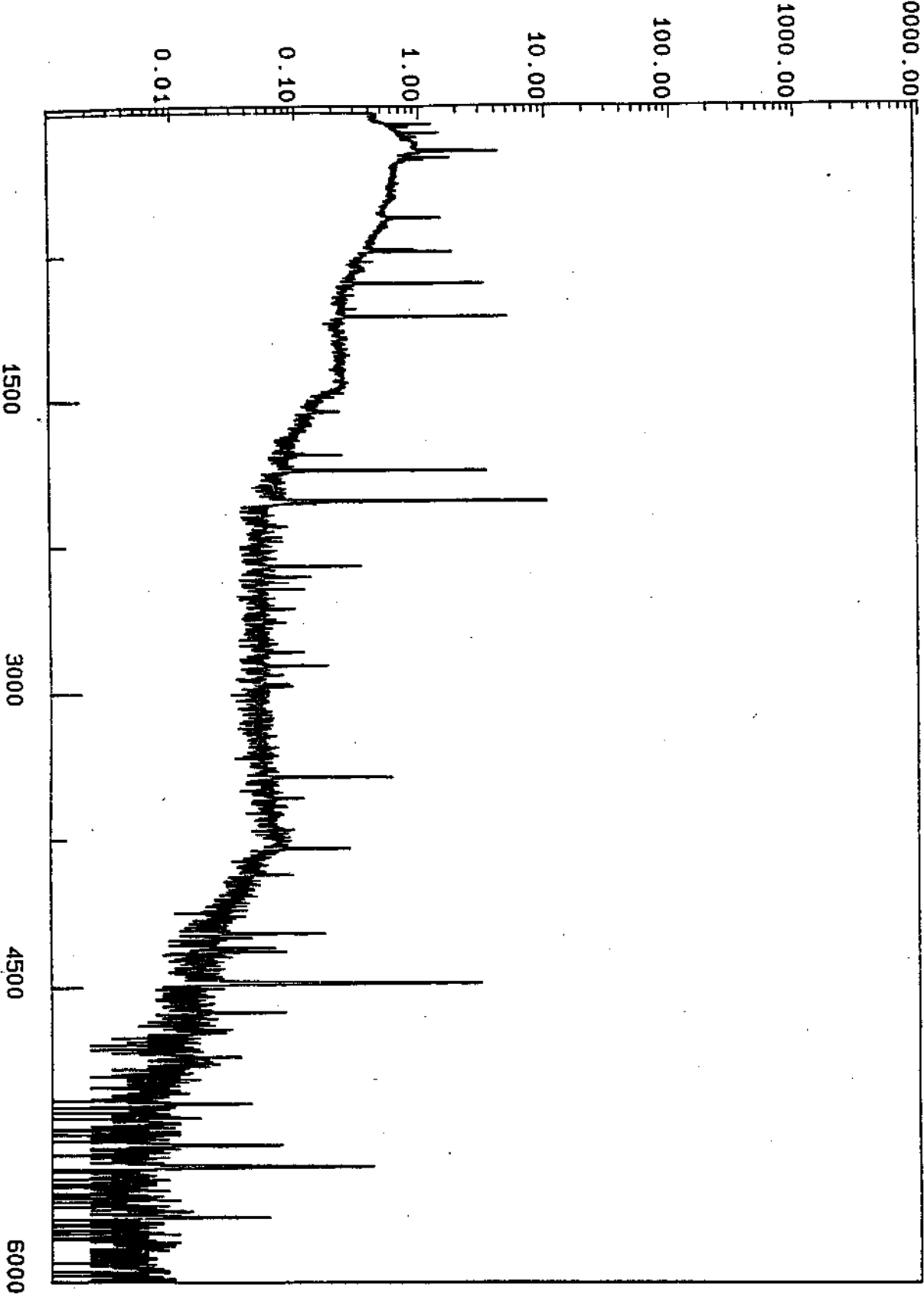
170602.CHN

CHANNEL NUMBER

SLIDE 2A

TYPE = -1 MCA # 2 SEGMENT # 1  
REALTIME = 10029.82 SECONDS, LIVETIME = 10000.00 SECONDS  
DATA COLLECTED AT 14:58:00 ON 19-JUN-91

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170602.CHN

CHANNEL NUMBER



SLIDE 3

Radioactivity Measured in Wood Ash

	Radioactivity (pCi/kg of Ash)	
	Cs-137	K-40
Warren, VT (oak, whole logs cut in 1985)	15,340 ±76	83,620 ±700
Vernon, VT (oak, whole logs)	1,587 ±57	79,700 ±1,300
North Adams, MA (oak slabs, outer layer)	4,360 ±48	41,200 ±560
Coventry, RI (90% oak, some birch)	13,600 ±93	93,700 ±960



# The HEALTH PHYSICS SOCIETY'S Newsletter

Volume XVIII, Number 4

April 1990

## Preliminary Study of Cs-137 Uptake by Trees and Its Implications for BRC, Waste Disposal, and Dosimetry

Stewart Farber  
Bolton, Massachusetts

### Introduction

As a consequence of a few serendipitous radiation measurements on a media/pathway not routinely measured in the U.S., this article presents some initial data that may be both significant and useful to the nuclear power industry. I feel it important to share some preliminary data on fallout Cs-137 recently measured in woodash, the implications of which should be considered by industry environmental monitoring/licensing specialists, internal dosimetry/WBC staff, and waste-disposal engineers. Further, I am seeking the cooperation of industry health physicists to build a database on what levels of Cs-137 are presently found in woodash across the U.S.

### Background

During a visit to Vermont in 1983, I read a small filler in a weekly newspaper noting that during the early 1800s, woodash from Vermont was a major feedstock to the early U.S. potash industry. As an environmental HP with a strong intuitive streak (ENTP on the Myers-Briggs test) involved in nuclear plant monitoring, it occurred to me that if woodash contained a significant quantity of potassium, it might also contain an unusual concentration of fallout Cs-137 in that cesium and potassium move together in biological systems since these two elements behave as alkali metals and form a number of compounds that have similar crystalline structure (i.e., isomorphous). My initial inquiry in 1983 with several utility environmental monitoring labs indicat-

The views expressed in this note are the personal observations of the author alone

ed that no measurements of this type had ever been made; the idea sat idle and unassessed until early 1990.

During the past month, after recently rejoining the Environmental Laboratory as Operations Support Manager, I collected a single woodash sample from Warren, Vermont, and had it analyzed by Ge(Li) gamma spectroscopy. The startling Cs-137 content of this initial sample is reported in Table 2. As every gardener knows, woodash serves as a source of potash and is used very commonly as a fertilizer/acid neutralizer. Various sorts of wood differ greatly in value as a plant food. In fact, when a metric ton of various woods is burned, the nominal amounts of total ash and potash vary greatly according to a garden reference text (Hottes, 1945), as shown in Table 1.

As is clear from Table 1, any apparently relatively non-volatile mineral elements, such as ionic cesium and potassium, contained in wood will concentrate into the ash when the wood is burned by the inverse of the percent-ash (i.e., a concentration factor of about 250 for spruce to a factor of about 70 for oak) less any losses due to volatilization of a given element and its compounds. Other authors (e.g., Russell, 1974, p. 42) report that oak woodash is about 0.25 percent of wet weight, which would yield a concentration factor of ash vs. wood for non-volatile radionuclides of about 400 versus the value of 70 estimated above. However, gamma spectral analysis of woodash samples from a wide geographic area are needed to document what of the fallout and natural radionuclides taken up by trees actually concentrate in wood ash when a

given wood is reduced to ash. As can be inferred from the table, most wood ash contains in excess of 10-percent potash (present as  $K_2O$ ) by weight. Other references indicate that woodash typically contains potassium as 10-30 percent of total ash (Wise, 1944), and woodash will thus generally contain K-40 levels of from 80,000 to 240,000 pCi/kg ash. This K-40 level will vary by a factor of perhaps 2 or so, depending on the type of wood burned. Calcium (as CaO) typically represents the greatest fraction of woodash being present at from 30-60 percent of total ash. Sr-90 is present in soil as a major fraction of the Cs-137 present in that the Sr-90/Cs-137 ratio in weapons fall-out is about 0.625 on an activity basis (Eisenbud, 1973, p. 379). Since strontium and calcium definitely move together, woodash is also very likely to contain significant levels of Sr-90. Further, Russell (1974, p. 17-18) found that although data were sparse for Sr-90, measurements of several types of trees indicated that Sr-90 enriched in trees relative to Cs-137. The

[Continued on page 3]

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SLIDE 4

Contributors

Name	Company
Frank Badger	Rockwell International
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Brian Clark	Seabrook Station
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W. Alan Homyk	Indian Point No. 2
Kjell Johannsan	Wisconsin Electric Power Company
Mike Nichols	Georgia Power Company
Dennis P. O'Dowd	NH Division of Public Health Services
Dennis Quinn	Indian Point No. 3
Dr. Claude W. Sill	Idaho National Engineering Lab
Joseph R. Stencel	Princeton University, Plasma Physics Lab
Peter Strickland	NE Utilities
Dave Spero	State of California - Dept. Health Services

SLIDE 5

Database of Wood Ash Radioactivity Measurements  
Sorted by State Mean on Cs-137 Concentration

State	Cs-137 Concentration State Mean	Number of Wood Ash Measurements	Cs-137 Range (pCi/kg-ash)
ME	16,100	1	
NH	15,770	3	10,300-21,100
RI	13,600	1	
CT	13,500	1	
VT	8,464	2	1,587-15,340
MA	8,251	3	4,360-14,050
NJ	5,160	3	2,580-6,700
NY	3,887	11	1,080-9,560
GA	3,500	1	
WI	2,110	2	1,420-2,800
SC	1,547	3	1,360-1,820
PA	1,459	9	L.T. 200-3,600
ID	794	1	
CA	265	6	79-469
	TOTAL	47	

## SLIDE 5A

DATABASE OF WOODASH RADIOACTIVITY MEASUREMENTS RANKED ON CS-137 CONCENTRATION  
(Sorted in descending Cs-137 Activity)

WOOD-CS.WK1

Wood Ash Type	Cut Vicinity of:	Cs-137		K-40		pCi Cs-13 gram - K	Cs-137 conc. Normalized to Peak Conc.	Other Nuclides Measured (or location details):
		pCi/kg	1 sigma	pCi/kg	1 sigma			
Mixed Oak/Maple	Newmarket, NH(see creosote)	21100	667	89900	4910	196	1.000	
Mixed Hardwoods	Augusta, ME	16100	120	102000	1200	132	0.763	Sr-90: 23470 +/- 220
Oak	Hollis, NH	15909	290	70011	2443	190	0.754	
Oak	Warren, VT	15340	76	83620	700	153	0.727	Sr-90: 9464 +/- 57
Mixed Hardwood	S.Eastern, MA	14050	240	63900	2100	183	0.566	
Oak/birch(<5%)	Coventry, RI	13600	93	93700	960	121	0.645	Be-7: 2450 +/- 190 pCi/
Oak	Woodus, CT	13500	95	79700	8767	141	0.640	
Unspecified	NH	10300	36	-	-	-	0.488	Be-7: 984 +/- 87 pCi/kg
Oak/Maple	Granby, NY	9590	223	80300	2640	100	0.455	lat: 43 , 21' long: 76
Oak	S.E. NJ	6700	700	58000	6000	96	0.318	
Hardwoods	Rochester, NY region	5581	1%	65175	1%	84	0.312	
Ash	Billerica, MA	6342	159	99299	2185	53	0.301	
Oak/Hardwood	S.Central NJ	6200	500	78000	8000	56	0.294	
CREOSOTE	Newmarket, NH	4680	248	11200	1420	348	0.222	
Hardwoods	Rochester, NY region	4458	1%	76304	1%	49	0.211	
Oak slabs(bark)	N. Adams, MA	4360	48	41200	560	88	0.207	
Hardwoods	Rochester, NY region	4317	1%	107608	1%	33	0.205	
Chinese Elm	Rochester, NY region	4216	1%	94871	1%	37	0.200	
Unknown	N.E. PA	3600	500	54000	8000	56	0.171	
Red Oak	Douglas County, GA	3500	400	77000	6000	38	0.166	
Oak/Maple	Upstate NY	3100	162	86900	3380	30	0.147	lat: 43 , 25' long: 76
Oak/Maple	Palermo, NY	3080	248	106000	5340	24	0.146	lat: 43 , 25' long: 76
Red Oak/Misc.	S.Central PA	3000	300	84000	8000	30	0.142	
Pine	Two Rivers, WI	2800	140	33400	1700	70	0.133	Sr-90: 289 +/- 135
Maple(mainly)	Princeton, NJ area	2580	42	62660	700	34	0.122	
Oak/Maple	Oswego, NY	2400	207	77300	4410	26	0.114	lat: 43 , 27' long: 76
Oak/Maple	Hornellsville, NY	2340	314	112000	8140	17	0.111	lat: 43 , 30' long: 77
Mixed Hardwood	Columbia, SC area	1820	-	47800	-	32	0.086	
Red Oak/Bl.Locust	S.Central PA	1800	200	65000	7000	23	0.085	
Ash woodash	Putnam County, NY	1600	150	140000	3600	10	0.076	
Mixed Hardwood	S.Eastern, VT	1587	57	79700	1300	17	0.075	Sr-90: 12640 +/- 130
Oak/Hickory	Columbia, SC area	1460	-	41300	-	29	0.069	
Maple	Valders, WI	1420	140	90700	3200	13	0.067	Sr-90: 526 +/- 197
Oak/Maple	S.Central PA(see creosote)	1400	100	85000	8000	14	0.066	
Mixed Hardwood	Columbia, SC area	1360	-	55400	-	17	0.064	
Pine/Maple/Ash	S.Central PA	1200	200	82000	8000	12	0.057	
Locust	Hopewell Jct., NY	1080	135	88000	-	10	0.051	
Hardwood	Vicinity Delta, PA	860	-	82000	-	9	0.041	
Pine Ash	ID	794	38	-	-	-	0.038	
Oak	S.Central PA	680	110	110000	10000	6	0.032	
Avacado	Southern CA area(Somis)	469	-	54280	-	3	0.022	
Oak (Blue/Valley)	Sacramento, CA	426	11	46880	310	8	0.020	
Cherry	S.Central PA	390	100	100000	10000	3	0.018	
Cypress/Mulberry	Southern CA area(Simi)	261	-	77894	-	3	0.012	Be-7: 848 pCi/kg
Walnut/Eucalypt.	Southern CA area(Ventura)	213	-	50889	-	3	0.010	
Juniper/Shade	Southern CA area(Chatsworth)	141	-	111343	-	1	0.007	Be-7: 1451 pCi/kg
Eucalyptus	Southern CA area	79	-	28004	-	2	0.004	Be-7: 437 pCi/kg
CREOSOTE	S.Central PA	58	26	2900	500	17	0.003	
Maple/Birch	S.Central PA	L.T. 200	-	57000	7000	2	0.000	

**SLIDE 5A**

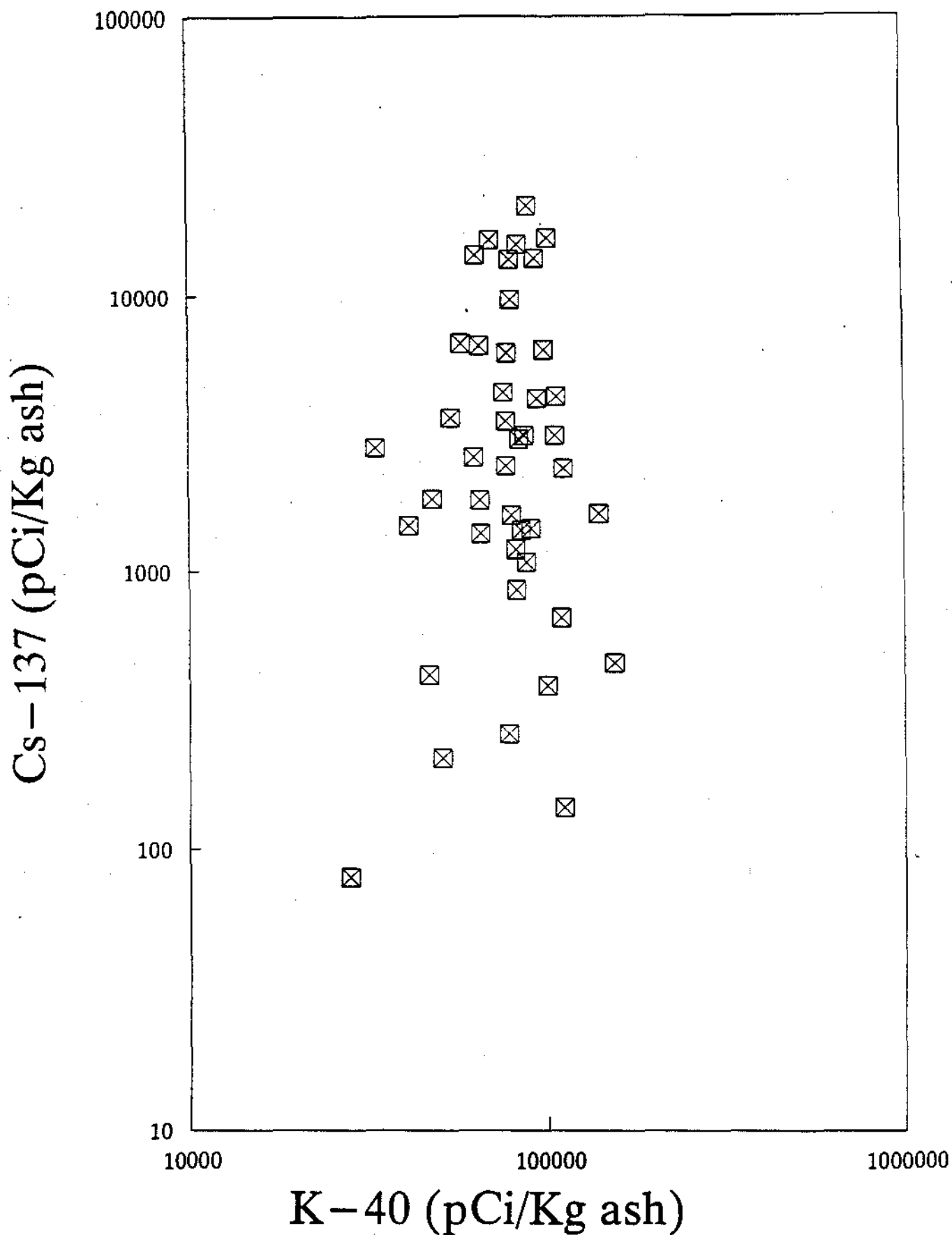
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(NOTE: SORTED by State Mean of wood ash measurements)

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SLIDE 6

# Cesium-137 vs. K-40 in Wood Ash



SLIDE 7

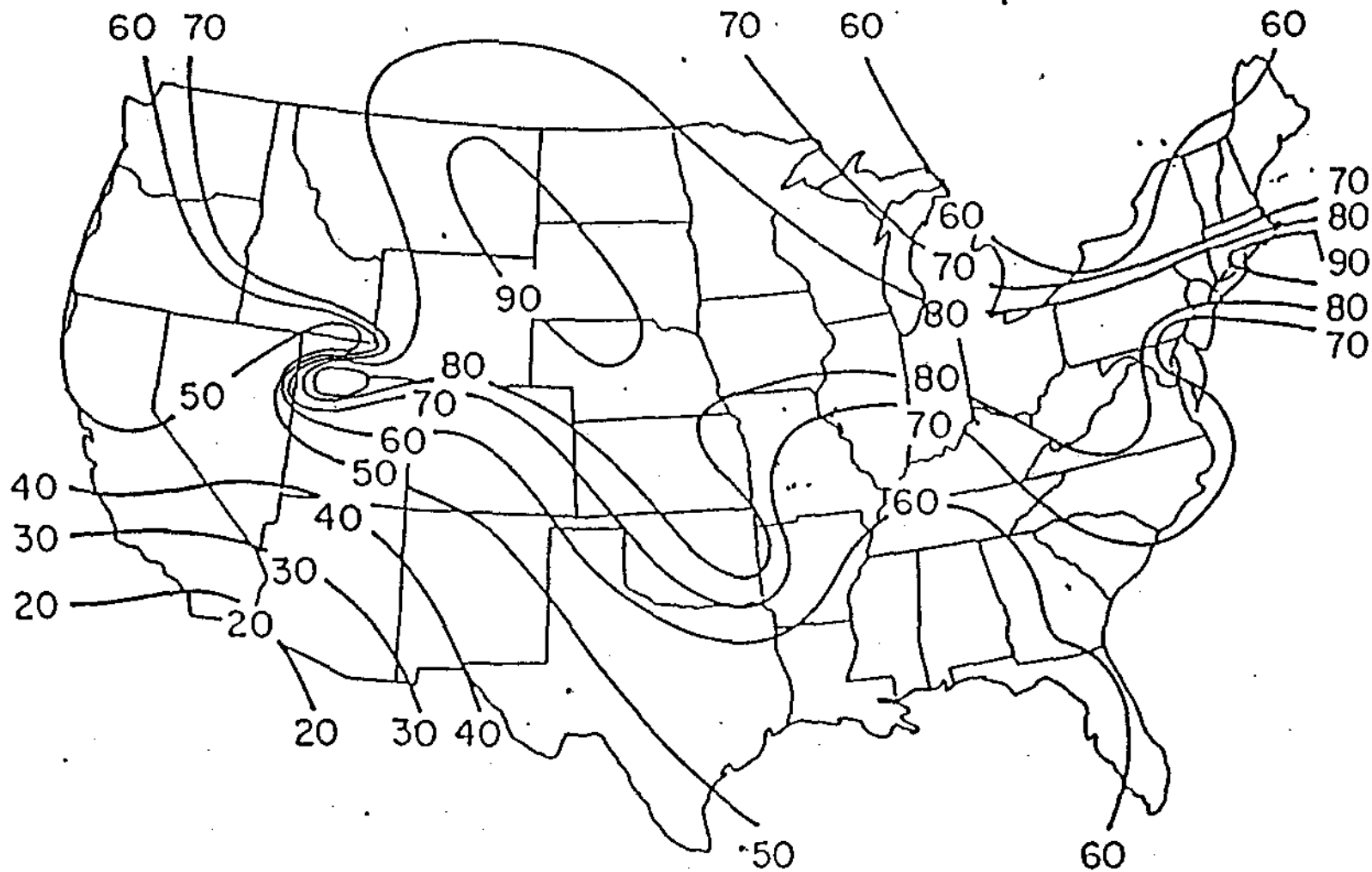


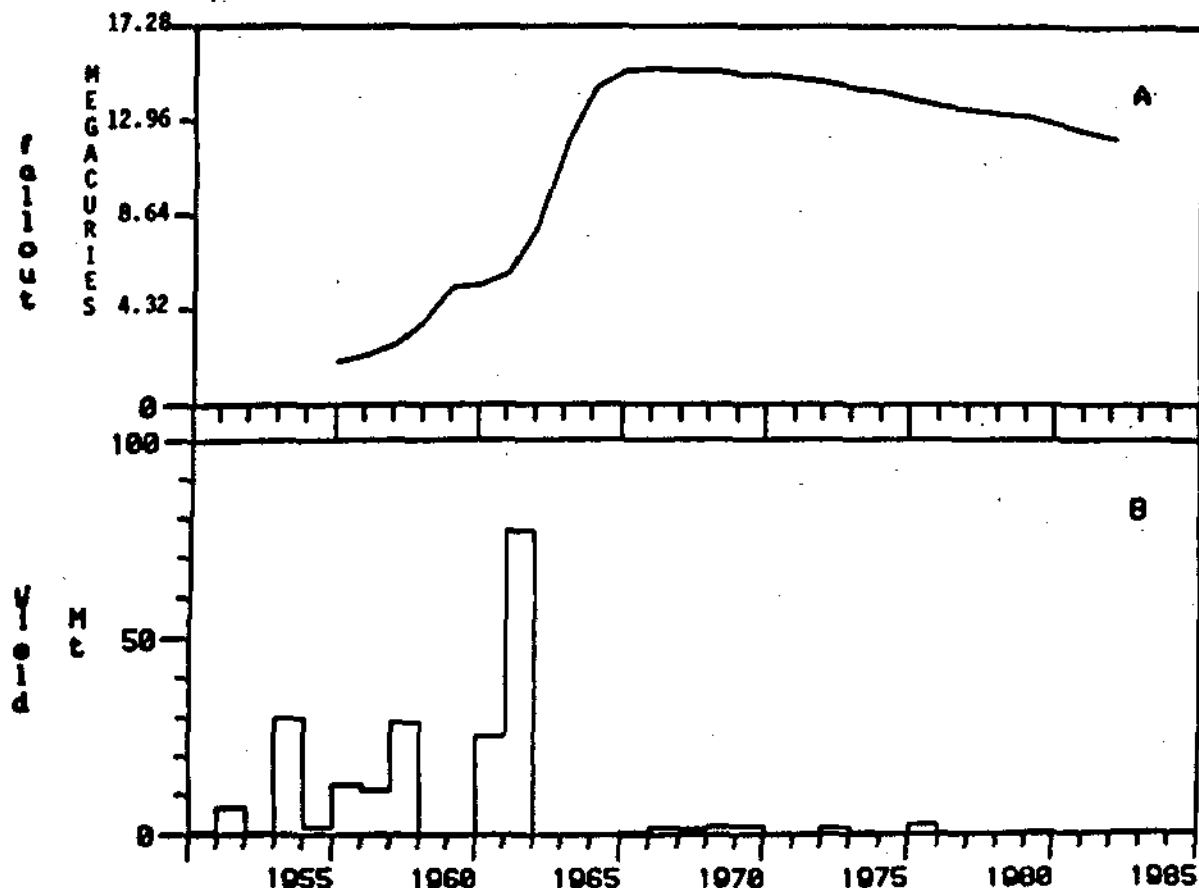
FIGURE 1 - Isolines of cumulative Sr-90 deposition in the continental United States (millicuries/square kilometer) based on an analysis of soils collected during 1966-67. Cs-137 deposition approximately 1.6 times value listed for Sr-90.

*Cesium-137 in Wood Ash - Results of Nationwide Survey - Presented at the 5th Annual Biofields Conference*



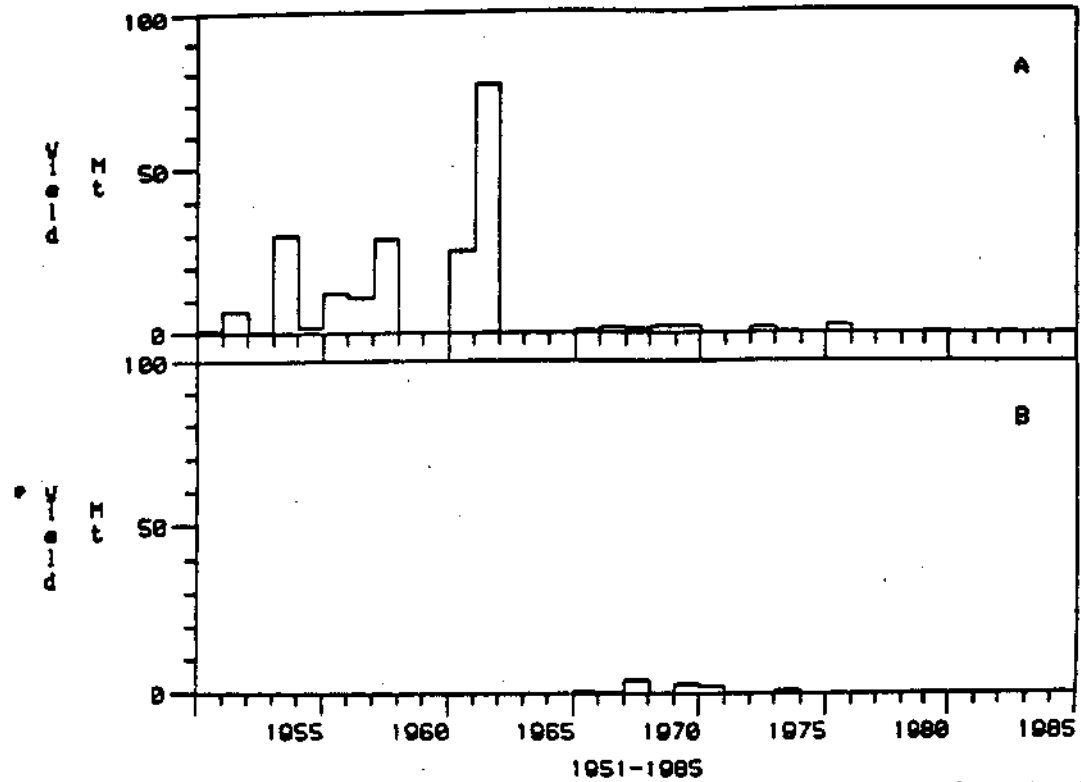
### Slide 7A

## Cumulative Cs-137 Deposition (Megacuries) In the Northern Hemisphere vs. Annual Nuclear Atmospheric Test Fission Yield



A - Cumulative Deposit of Cs-137 in the Northern Hemisphere  
B - Annual Estimated Fission Yield-Atmospheric Tests-Northern Hemisphere

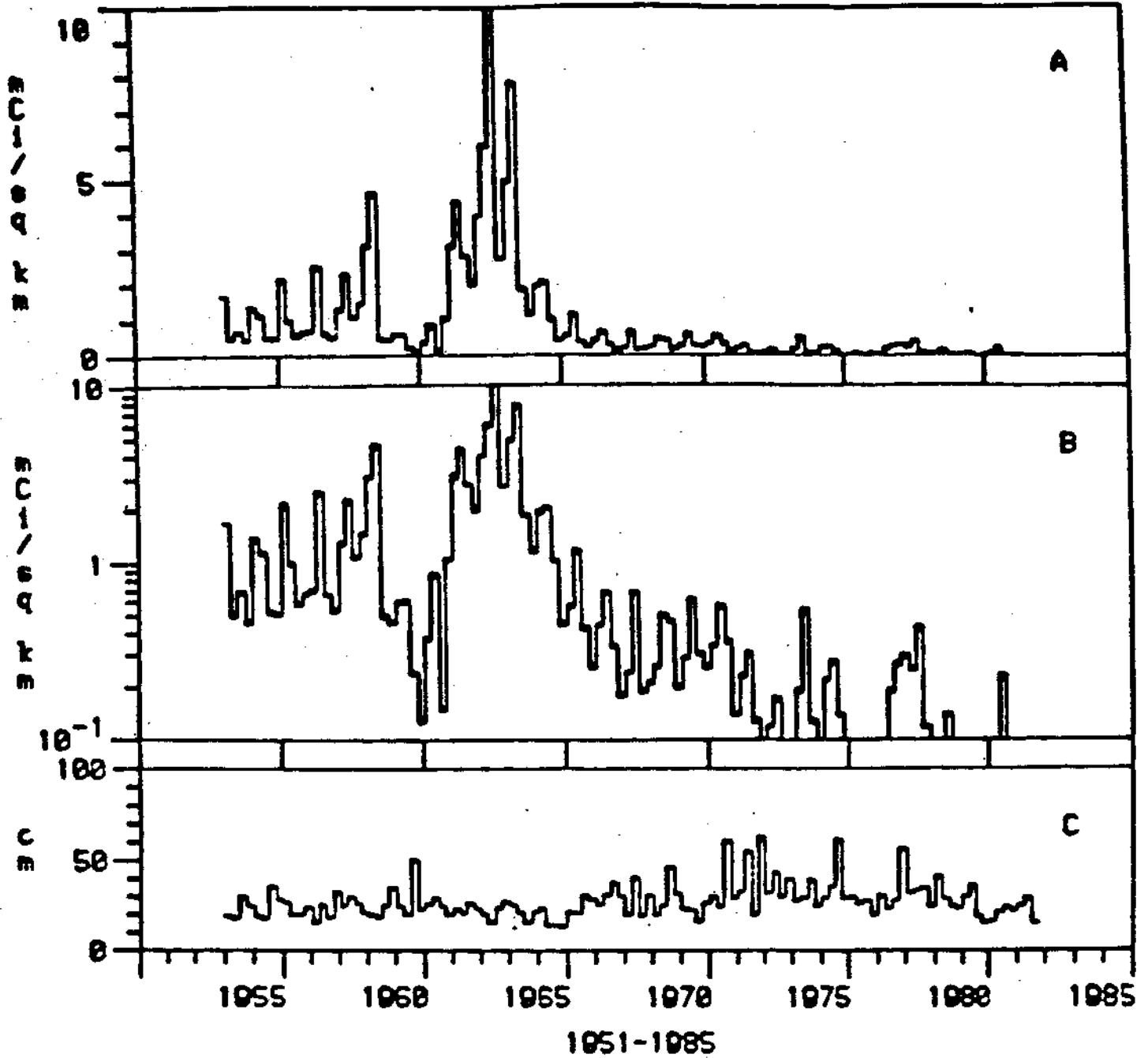
**Slide 7B**  
**Annual Estimated Fission Yield(Megatons)**  
**From Atmospheric Tests**  
**Northern/Southern Hemisphere**



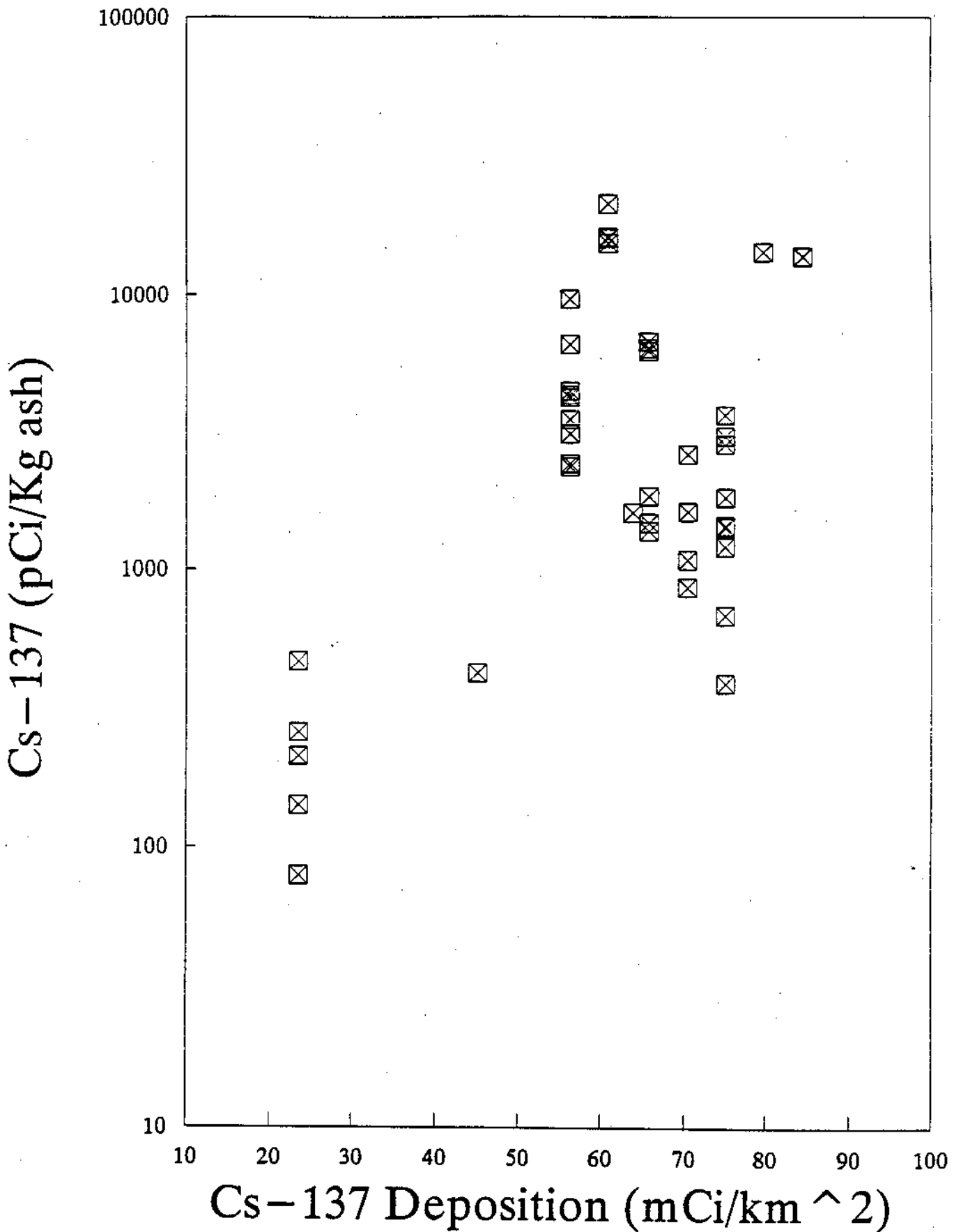
A - Annual Estimated Fission Yield-Atmospheric Tests-Northern Hemisphere  
 B - Annual Estimated Fission Yield-Atmospheric Tests-Southern Hemisphere

Slide 7C

Sr-90 Deposition - mCi/km<sup>2</sup>  
Site: New York, NY 1953-1983  
(Linear and Log Scales)



# Cs-137 in Ash vs Areal Deposition



SLIDE 9

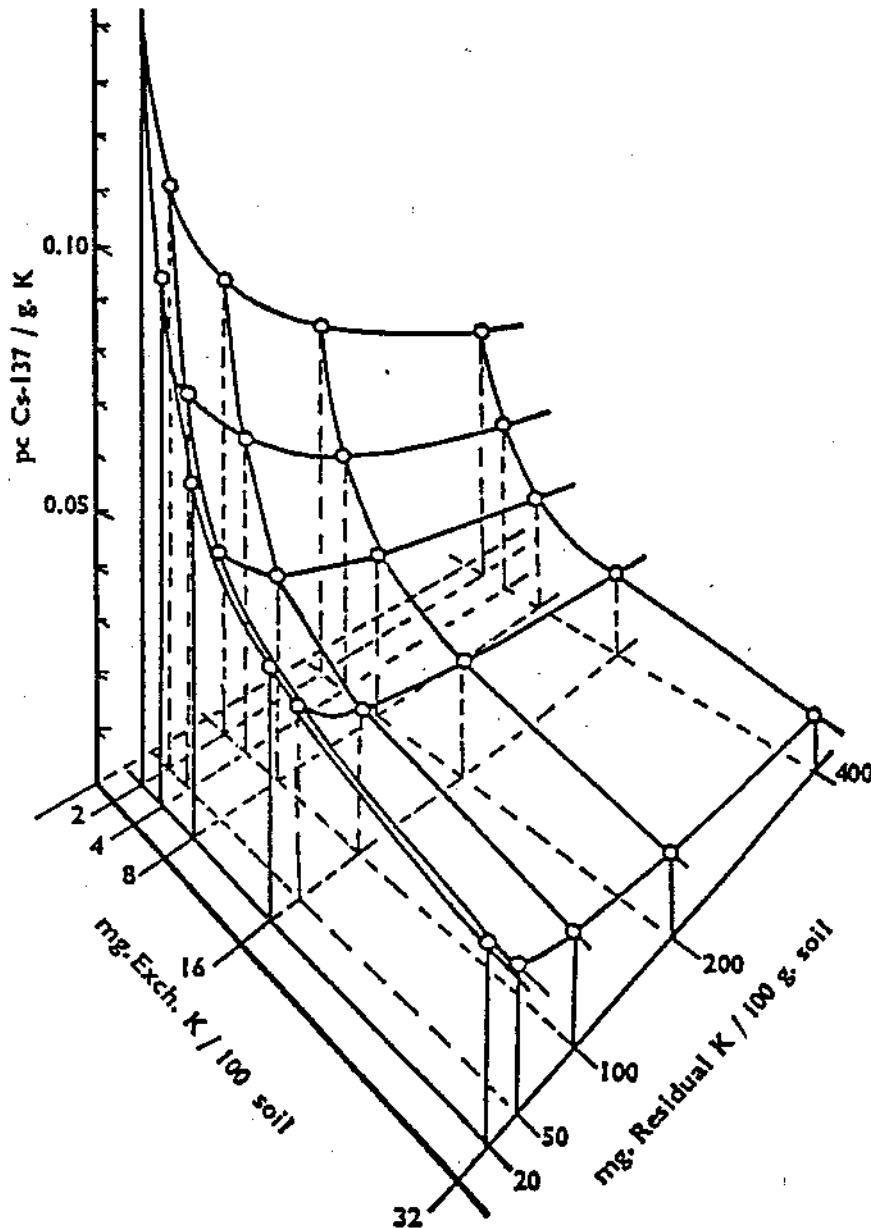


FIG. 15.5. Influence of exchangeable potassium and residual potassium on the absorption of caesium-137 by red clover. Mean results for experiments on 178 Swedish soils, expressed on basis of 1 mc Cs-137/km<sup>2</sup>.

SLIDE 10

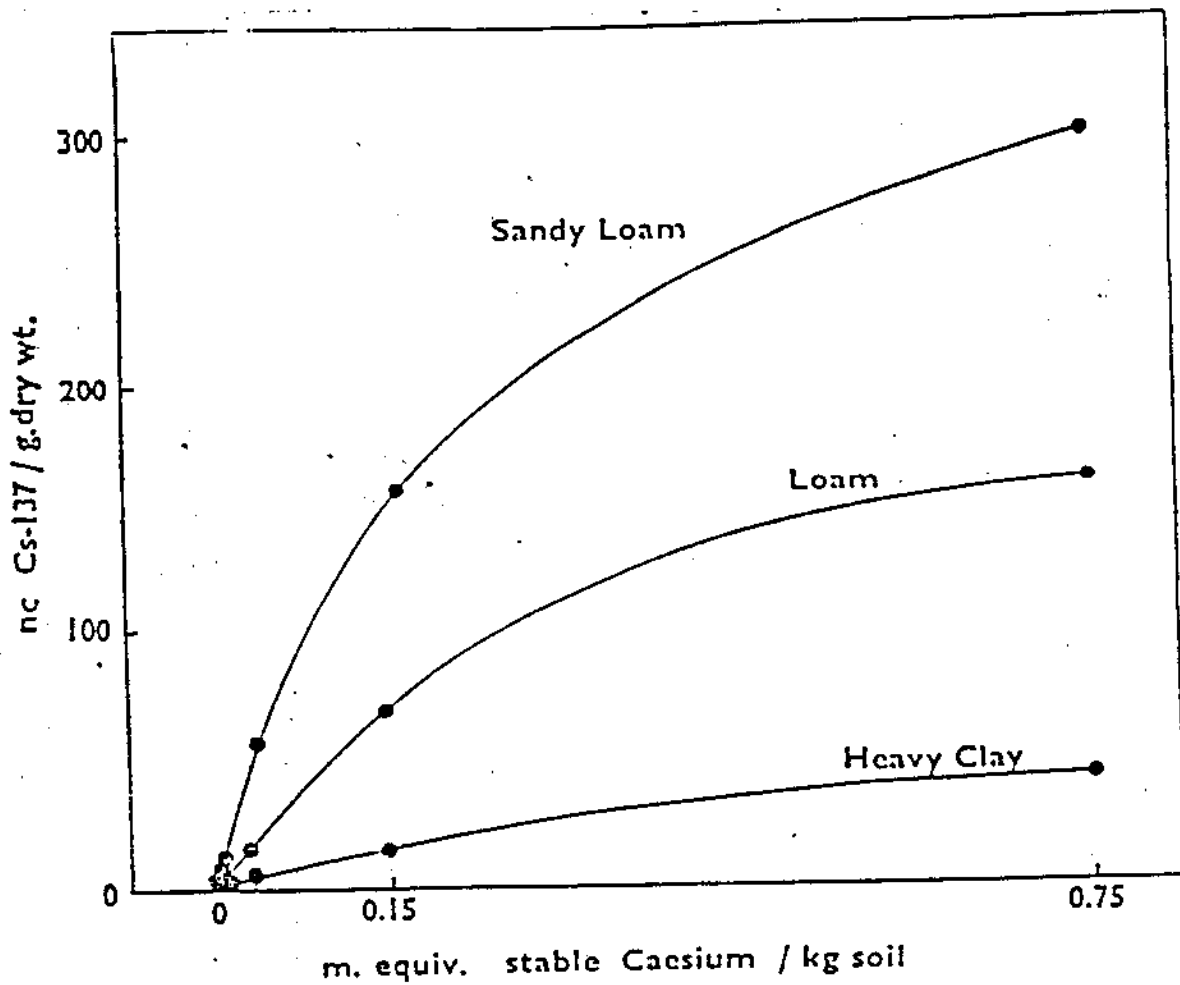
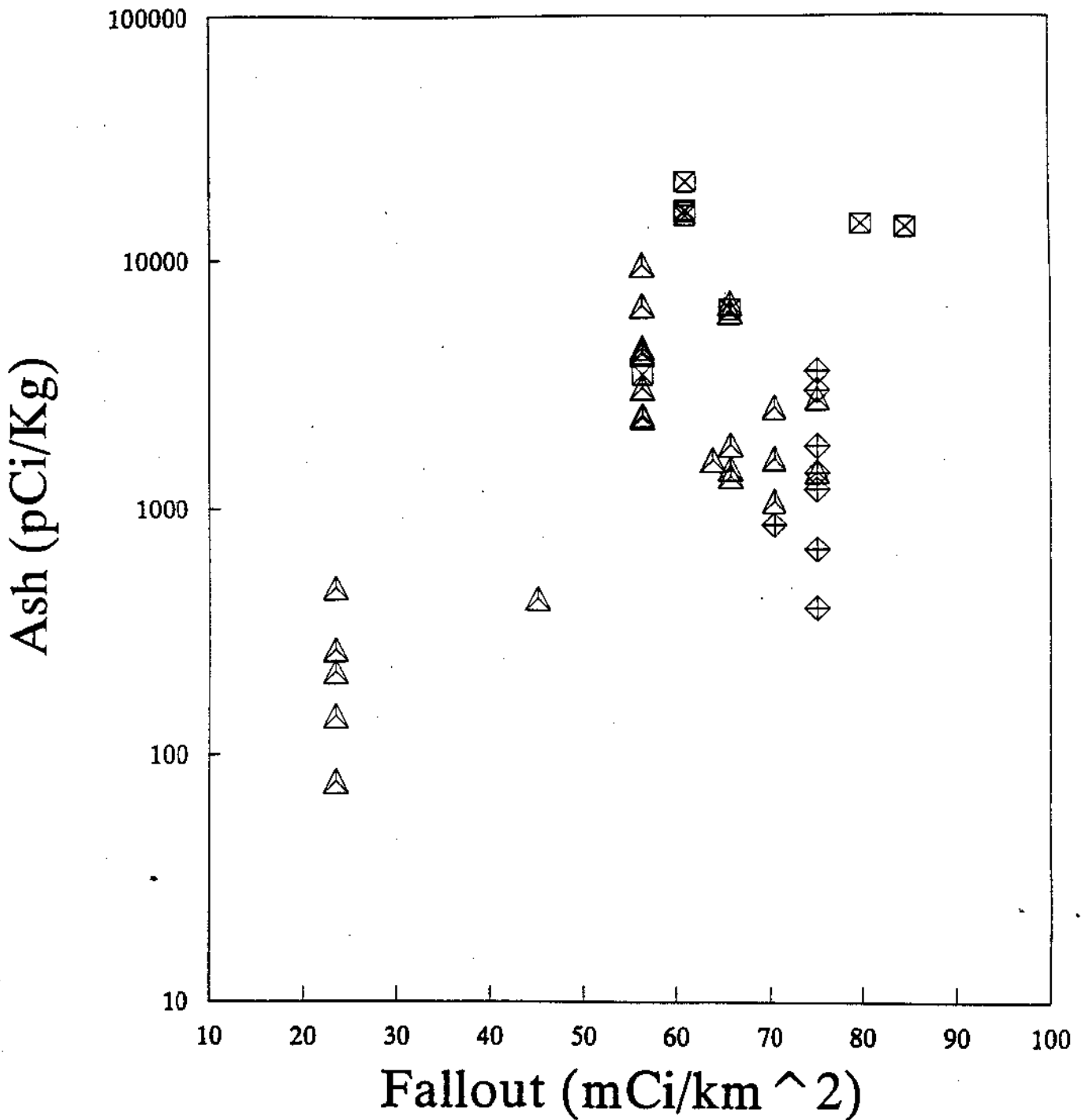


FIG. 15.3. Effects of addition of stable caesium to soil in the absorption of caesium-137 by red clover. Results of pot experiments in which 10  $\mu\text{c}$  Cs-137 were added per kg. soil

# Stable Cesium in Soil and Cs-137 in Ash and Fallout



- ⊠ High Stable Cs
- ⊞ Med. Stable Cs
- △ Low Stable Cs

SLIDE 12  
US Consumption of Wood Energy  
and Production of Ash 1989

Sector	Energy Consumption of Wood* (E12 BTUs)	Ash Production** (Tons)	Percent
Industrial	1,556	905,000	63
Residential	918	535,000	37
Utility	13	8,000	<1
Total	2,487	1,446,000	100

\* US DOE. "Estimates of U.S. Biofuels Consumption 1989". Energy Information Administration. SR/CNEAF/91-02, 4/91.

\*\* Tons Ash = 0.01 (tons ash/tons wood) x e12 BTU / 17.2E6 BTU/Ton Wood



# The business of recycling

## Helping the environment is firm's job

By Kathryn Van Sant  
Free Press Staff Writer

— His office is small, a single, second-floor room in a Street Victorian building.

But inside that room, has helped turn a one-state franchise into four offices in three states.

The office is humble because, said, "The business takes place out in the field."

works for, a company that organizes large-scale waste recycling services for commercial, industrial and municipal customers across New England.

Founded in in 1983 by, a former head of the Maine Audubon Society, has capitalized on growing demand for recycling services. Staffers such as — who holds a bachelor's degree in plant and soil science and a master's in agricultural economics, both from the University of Vermont — provide recycling consulting to customers and tackle the permitting and disposal of their waste.

"Our job is keeping your material out of the landfill," said. "The key to our success is we do this through environmentally sound programs."

That success brought high marks in New England Business Magazine's 1990 list of the region's fastest-growing companies. And the potential for a national presence came into being last week.

was in the midst of acquisition negotiations with a -based waste disposal giant last week, said.

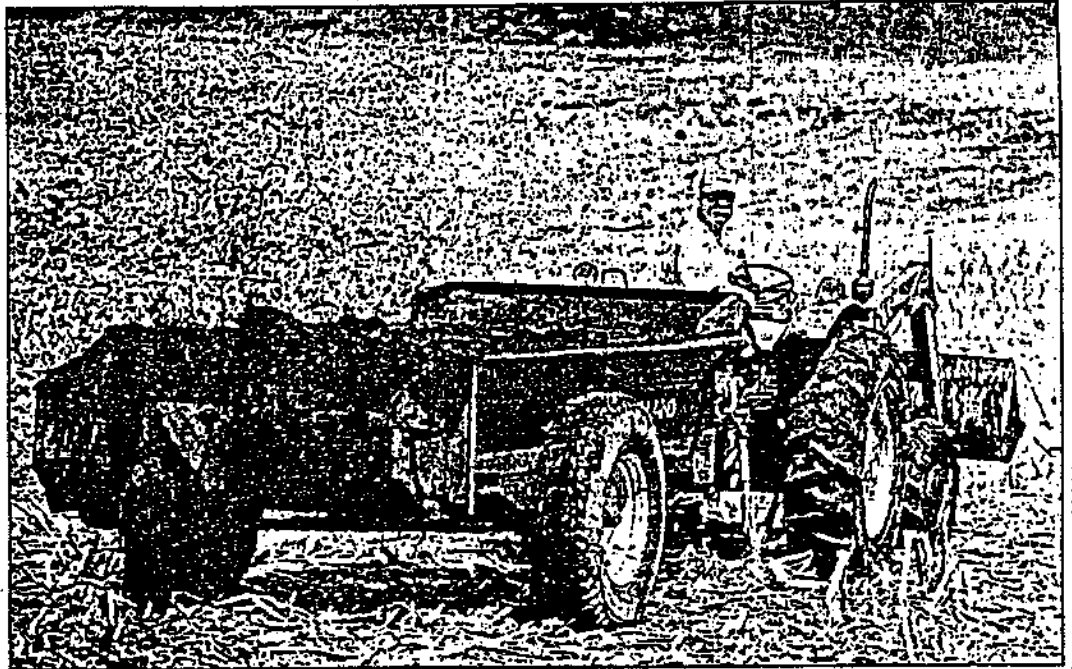
has been courted and won over by, the second-largest waste disposal company in the world," he said.

"has recognized the need for recycling and they chose us," said, who opened the office in the fall of 1987 to cover New Hampshire and Vermont.

But business quickly grew. There are two New Hampshire offices, in and, and has opened a New York office in.

The company serves three types of clients: municipalities, whose sludge and other waste recycles; the pulp and paper industry, whose byproducts handles; and electrical generators, which produce wood and coal ash that

*mixes business and environmental awareness helps firms deal with waste, and gets rid of some material by giving it to farmers for fertilizer.*



GAREN PIKE, Free Press

of spreads a mixture of manure and recycled wood ash on his fields. runs a resource conservation service that provides recycling services.

recycles into organic fertilizer. also markets landscaping products.

job is to "assess the waste problem and define appropriate recycling programs and strategies and do the permitting."

Because of Vermont's permit process and solid waste laws, operates a little differently in this state, he said.

"The solid waste district process is a little different. In other states it's a little easier to go in and provide assistance," said. "It takes a little more time, a little more work" in Vermont.

Another difference with Vermont is its size.

"There is not a lot of waste in Vermont," he said. "It's not a densely populated area."

But the fewer residents appear increasingly ardent about recycling, according to the Vermont Natural Resources Agency. It reported last month that during 1990, Vermonters recycled

70 percent more than they had during in 1987.

One of byproduct utilization programs takes wood ash and delivers it free to farmers to use as fertilizer.

"We soil-test the farm and deliver the exact amount of wood ash to bring it to the right Ph level," said. "The farmer gets the ash for free in return for spreading it in accordance with basic environmental guidelines."

That's a good deal for farmers, said, who grows corn and red clover on a former dairy farm in his native. "We love to see (successful) farmers and we can deliver to them several thousand dollars worth of ash on an annual basis," he said.

About 50 farmers in the Northeast Kingdom use the service, said.

And — who also grows the state's only USDA-certified antibiotic-free pigs — said he uses the recycled byproduct on his crops, with "super" results.

Though the company might expand beyond New England, is pursuing major Vermont opportunities as well.

The Central Vermont Solid Waste Management District is considering contracting with said. Under the pending deal, would handle all sludge, septic and organic waste in central Vermont.

The company also helps recycle "traditional" waste — glass, aluminum cans, newspapers and office paper.

said Vermonters' increased recycling will fit in well with plans.

"In Vermont, we'll see more and more industry who'll be more effectively recycling their waste," he said.

"Organics are the key to the future. There's a lot of bottle — and other recycling. The next step is organics. That's what is so exciting about — we're way ahead in that respect."

SLIDE 14

Dose From Agricultural Use of Woodash

Assumptions:	
Ash Cs-137 Conc.	10,000 pCi/kg
Ash Spread Rate	0.1 kg/m <sup>2</sup>
Soil Density	240 kg/m <sup>2</sup>
Soil Productivity	1 kg/m <sup>2</sup> /yr
Cesium Soil Kinetics:	
$\lambda_{\text{loss from root zone}}$	= 0.00062 y <sup>-1</sup>
$\lambda_{\text{radiation decay}}$	= 0.023 y <sup>-1</sup>
$\lambda_{\text{total}}$	= 0.0236 y <sup>-1</sup>
Vegetation to Soil Concentration Ratio ( $B_{iv}$ )	= 1
Human Uptake Rate (Average Vegetation, Milk, Meat)	= 400 kg/yr
Dose to Intake Ratio	= 5 mrem/10 <sup>5</sup> pCi

SLIDE 14  
(Continued)

Dose From Agricultural Use of Woodash

Soil Kinetics:

$$X_{\text{soil}} \text{ (pCi/m}^2\text{)} = \frac{P}{\lambda_{\text{total}}} (1 - e^{-\lambda_{\text{total}}t}) e^{-\lambda_{\text{decay}}t}$$

$$P = 0.1 \text{ kg/yr/m}^2 \times 10,000 \text{ pCi/kg} = 1,000 \text{ pCi/yr/m}^2$$

<u>t(y)</u>	<u>X<sub>soil</sub></u>	<u>t(y)</u>	<u>X<sub>soil</sub></u>
0	0 pCi/m <sup>2</sup>	10	7,077
1	966	20	10,064
2	1,866	30	10,783
3	2,703	50	9,294
5	4,204	100	3,847

SLIDE 14  
(Continued)

Dose From Agricultural Use of Woodash

Dose:

$$\begin{aligned} \text{Human Intake Rate} &= 400 \text{ kg/yr} \times 1 \times \frac{10,000 \text{ pCi/m}^2}{240 \text{ kg/m}^2} \\ &= 17,000 \text{ pCi/yr} \end{aligned}$$

$$\begin{aligned} \text{Dose From Year's Intake} &= \frac{5 \text{ mrem}}{10^5 \text{ pCi}} \times 17,000 \\ &= 1 \text{ mrem} \end{aligned}$$

**Slide 15**

**It seems plain and self-evident, yet it needs to be said:  
The isolated knowledge obtained by a group of specialists  
in a narrow field has in itself no value whatsoever, but  
only in its synthesis with all the rest of knowledge and  
only insomuch as it really contributes in this synthesis  
toward answering the demand, "Who are we?".**

**- Erwin Schrodinger**

**Slide 16**

**I know that most men—not only those considered clever, but even those who are clever and capable of understanding the most difficult scientific, mathematical, or philosophic problems—can seldom discern even the simplest and most obvious truth if it be such as obliges them to admit the falsity of conclusions they have formed, perhaps with much difficulty— conclusions of which they are proud, which they have taught to others, and on which they have built their lives.**

**-Leo Tolstoy, 1898**