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Page 6 - 2nd line from bottom — or by those who feel that Lewis' estimations of dose received by Radiologists leave much to be desired.

Page 12 - last ¶. This is being stated as fact and not as pure conjecture. Subjectively.

Page 13 - line 9 — How can food have 10-100 times the mean bodyburden?

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SIGNIFICANCE OF SR^{90} IN LOCAL AND GLOBAL FAL[illegible]

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by

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Significance of Sr^{90} in Local and Global Fallout

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In recent months attention has been focused on the potential hazards to large populations from radioactive fallout as the result of testing of atomic weapons. In dealing with this problem the fallout has been classed as local, tropospheric and stratospheric. Local fallout consists of radioactivity which is carried down in a matter of minutes or hours by relatively large particles. Tropospheric fallout occurs largely as a result of water precipitation of relatively small particles. This fallout occurs in a matter of weeks or a month or so. Stratospheric fallout takes years and is also brought down by water precipitation after it manages to pass from the stratosphere into the troposphere by some mechanism not yet well known.

During weapons testing, exposures to local fallout are avoided and therefore the main concern is the tropospheric and stratospheric fallout. In time of war, however, local fallout would be of direct concern in all stages of recovery due to the extensive areas covered. Local fallout can cover tens of square miles from kilotonyield weapons and thousands of square miles from megaton yield weapons so that 50% or more of the United States can be blanketed with lethal radiation levels coming from local fallout by a multiweapon attack of 200 to

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300 megaton bombs. This type of fallout is involved in the Emergency Phase with objective, survival and Operational Recovery Phase with objective, early recovery of essential functions, referred to in Atomic Warefare Defense (1). Countermeasures based on shelters for early survival followed by reclamation are necessary to cope with these early phases. The tropospheric, stratospheric and old local fall-out would be involved in the Final Recovery Phase of atomic warfare defense with objective, recovery of normal functions.

The constitution of the radioactive mixture in the early local fall-out will differ from that involved in the tropospheric and stratospheric fallout because of the differences in time to reach the ground and the fractionation caused by differences in history and size of the particles. Thus the contributors to the internal hazards during the early phases will vary with time after burst.

This paper presents a discussion of (1) the relative contribution to the internal dose of the more important radionuclides during the early phases of radiological recovery and (2) the significance of Sr^{90} associated with fallout in the early and final phases.

Early Phases:

From the standpoint of quantity available, body retention, radioactive half-life and biological half-life, the following radionuclides present the major problems of irradiation inside the body; Neptunium-239, iodine-131, strontium-89 strontium-90 + yttrium-90, yttrium-91, zirconium-95 + niobium-95,

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ruthenium-103, ruthenium-106 + rhodium-106, tellurium-127, [illegible]um-129, cesium-137 + barium 137, barium-140 + lanthanum-140, ceri[illegible] + praseodymium-144 and promethium-147. The fraction of the [illegible]ctivity of these radionuclides at various times after burst are shown [illegible]ble 1. They have been considered recently (2) in evaluating the maximum permissible concentrations of the fallout mixture in air and water required to deliver to the critical organs (including the gastrointestinal tract) certain acute doses of importance in short term (1 to 90 days) military recovery or [illegible]al operations.

Table 2 presents the results of a typical calculation based on a dose of 15 rem in 90 days and on retention factors, effective energies and effective half-lives found in NBS Handbook 52 (3). It was found that most of the internal dose was due to approximately five radioisotopes and these contributors change in importance with time after burst as shown in Table 3. It is seen that in the early phases of radiological recovery from atomic warfare radionuclides of short half-lives may contribute greatly to the internal acute dose. Although not shown, calculations indicate that after approximately 90 days the Sr^{90} contribution to the chronic dose to bone becomes far greater than the contribution by other nuclides to the dose to their respective critical organs.

Final Recovery Phase:

As we approach the final phase of recovery or the period involved in living with a contaminated environment, Sr^{90} becomes of major concern

TABLE I

Fraction of Total Activity of Individual Isotopes at Various Times after Burst

Time	Np^{239}	I^{131}	$Ba^{140} + La^{140}$	Ru^{103}	Sr^{89}	$Zr^{95} + Nb^{95}$	Y^{91}	$Ce^{144} + Pr^{144}$	$Sr^{90} + Y^{90}$	$Ru^{106} + Rh^{106}$
3.5 hrs.	7.9×10^{-2}	1.0×10^{-2}	1.4×10^{-3}	2.4×10^{-4}	2.6×10^{-4}	2.9×10^{-4}	1.8×10^{-3}	5.5×10^{-5}	1.7×10^{-6}	4.2×10^{-6}
1 day	4.1×10^{-1}	5.6×10^{-2}	7.4×10^{-3}	1.3×10^{-3}	1.4×10^{-3}	1.5×10^{-3}	1.2×10^{-3}	2.9×10^{-4}	9.1×10^{-6}	2.2×10^{-5}
7 days	5.1×10^{-1}	2.9×10^{-2}	4.2×10^{-2}	9.2×10^{-3}	9.7×10^{-3}	1.1×10^{-2}	1.1×10^{-2}	2.2×10^{-3}	6.9×10^{-5}	1.7×10^{-4}
28 days	9.0×10^{-3}	4.0×10^{-2}	1.1×10^{-1}	5.5×10^{-2}	6.4×10^{-2}	7.7×10^{-2}	7.3×10^{-2}	1.8×10^{-2}	6.0×10^{-4}	1.4×10^{-3}
105 days	-	2.2×10^{-4}	7.8×10^{-3}	6.9×10^{-2}	1.1×10^{-1}	1.5×10^{-1}	1.2×10^{-1}	6.9×10^{-2}	2.7×10^{-3}	5.4×10^{-3}
1 yr.	-			7.1×10^{-3}	2.6×10^{-2}	6.9×10^{-2}	4.0×10^{-2}	2.6×10^{-1}	1.9×10^{-2}	2.4×10^{-2}

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TABLE 2

Maximum Permissible Concentration (μc/cc) in Water of Gross Fallout Material for 7 Exposure Times (n) at 11 Different Times after Burst to Deliver a Dose to the Critical Organ of 15 rem in 90 days.

n	Time After Burst					
	3.5 hrs.	1 day	7 days	28 days	105 days	1 yr.
1	2.5	0.48	0.13	7.1×10^{-2}	0.1	8.7×10^{-2}
7	40.54	0.10	2.4×10^{-2}	1.2×10^{-2}	1.5×10^{-2}	1.3×10^{-2}
21	0.32	5.9×10^{-2}	1.3×10^{-2}	5.4×10^{-3}	5.7×10^{-3}	4.5×10^{-3}
30	0.29	5.4×10^{-2}	1.1×10^{-2}	4.5×10^{-3}	4.4×10^{-3}	3.3×10^{-3}
60	0.25	4.6×10^{-2}	9.8×10^{-3}	3.3×10^{-3}	2.7×10^{-3}	1.8×10^{-3}
90	0.24	4.4×10^{-2}	9.2×10^{-3}	2.9×10^{-3}	2.1×10^{-3}	1.3×10^{-3}

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Table 3

Relative Contributions to the Gross Fallout Mixture Based on M.P.C. Values for Various Exposure Periods to Deliver a Dose of 15 rem in 90 days.

n	Time After Burst: 9.5 hrs.		7 days		28 days		105 days		1 yr.	
	Isotope	Relative Value	Isotope	Relative Value	Isotope	Relative Value	Isotope	Relative Value	Isotope	Relative Value
1	I^{131}	100	I^{131}	100	I^{131}	100	Sr^{89}	100	$Ce^{144} + Pr^{144}$	100
	Np^{239}	90	Np^{239}	21.1	Sr^{89}	34.1	$Ce^{144} + Pr^{144}$	40.7	$Sr^{90} + Y^{90}$	38.1
	$Ba^{140} + La^{140}$	13	$Ba^{140} + La^{140}$	13.6	$Ba^{140} + La^{140}$	27	$Zr^{95} + Nb^{95}$	35.3	Sr^{89}	16.0
	Sr^{89}	5.3	Sr^{89}	7.3	Y^{91}	11	Y^{91}	32.4	$Zr^{95} + Nb^{95}$	1.1
	$Zr^{95} + Nb^{95}$	1.5	Y^{91}	2.2	$Zr^{95} + Nb^{95}$	11	$Sr^{90} + Y^{90}$	8.0	$Ru^{106} + Rh^{106}$	1.0
30	I^{131}	100	I^{131}	100	I^{131}	100	Sr^{89}	100	$Ce^{144} + Pr^{144}$	100
	Np^{239}	33.3	$Ba^{140} + La^{140}$	20.2	Sr^{89}	72.2	$Ce^{144} + Pr^{144}$	57.8	$Sr^{90} + Y^{90}$	29.4
	$Ba^{140} + La^{140}$	18.5	Sr^{89}	15.0	$Ba^{140} + La^{140}$	38.2	$Zr^{95} + Nb^{95}$	37.9	Sr^{89}	10.9
	Sr^{89}	10.9	Np^{239}	7.8	Y^{91}	25.0	Y^{91}	37.9	$Zr^{95} + Nb^{95}$	7.8
	$Zr^{95} + Nb^{95}$	3.3	Y^{91}	5.1	$Zr^{95} + Nb^{95}$	22.8	$Sr^{90} + Y^{90}$	9.2	Y^{91}	5.3
90	I^{131}	100	I^{131}	100	I^{131}	100	Sr^{89}	100	$Ce^{144} + Pr^{144}$	100
	Np^{239}	50	Sr^{89}	23.2	Sr^{89}	100	$Ce^{144} + Pr^{144}$	95.5	$Sr^{90} + Y^{90}$	22.8
	$Ba^{140} + La^{140}$	20.4	$Ba^{140} + La^{140}$	22.5	Y^{91}	47.8	Y^{91}	50.0	Sr^{89}	6.7
	Sr^{89}	16.7	Y^{91}	10.7	$Ce^{144} + Pr^{144}$	42.3	$Zr^{95} + Nb^{95}$	40.6	$Zr^{95} + Nb^{95}$	5.1
	$Zr^{95} + Nb^{95}$	9.4	$Ce^{144} + Pr^{144}$	8.0	$Ba^{140} + La^{140}$	10.7	$Sr^{90} + Y^{90}$	11.6	Y^{91}	4.2

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whether it comes from local, tropospheric or stratospheric fallout due to its long radiological and biological half life, its chemical similarity to calcium and its relative concentration in the mixture.

An estimate of the potential hazard of Sr^{90} in the present and future fallout may be attempted by comparing an accepted permissible body burden with an estimate of the present and future body burden. Information on both the biological effects leading to the establishment of a permissible body burden and the expected eventual body content of Sr^{90} is inadequate.

The eventual Sr^{90} body burden may be estimated by extrapolation of direct measurements of Sr^{90} in bone samples or from indirect analysis of Sr^{90} concentrations throughout the ecological chains starting from soil concentrations through plants to animals to man.

Let us first consider the values presently being recommended for the maximum permissible body burden.

<u>Permissible Body Burden:</u>

The International Commission on Radiological Protection has accepted a maximum permissible level of 1 μc of Sr^{90} in the body for adults in special occupations; however this is not suitable for application to the whole population made up of children with their greater sensitivity and greater life expectancy and of individuals having varying stresses and strains. The commission has recently recommended that the permissible level of Sr^{90} for large populations be set at 1/10 of the occupational level (0.1 μc in the body or 100 micro-microcuries Sr^{90} per gram of

calcium).

It is of interest to note that the National Academy of Science's Subcommittee on Toxicity of Internal Emitters (4) arrived at a value of 0.05 μc of Sr^{90} in the body by consideration of the large variations in natural background radiation.

The biological effects of small amounts of deposited Sr^{90} are qualitatively determined by the effects of radium in human beings based on the assumption that 1 microcurie of Sr^{90} carries the same risk as 0.1 microcurie of radium. A resume of radium effects appeared in a report by the British Medical Research Council (5) which stated the following: "A suggestive destructive lesion in the dentine of the teeth has been observed in a patient who carried a body burden of approximately 0.15 microcurie of radium (probably a mixture of radium and mesothorium). Of 44 patients investigated by Looney et al., 36 had body burdens of 0.4 microcuries or more; clinically recognizable, but not malignant, bone lesions were observed in 32 of these. The lowest level of pure radium producing a bone sarcoma in this series was 3.6 microcuries. Sarcomata were seen in five other patients included in this study, but these patients may well have ingested a mixture of radium and mesothorium. Among these five, the lowest level associated with the production of a tumor was 0.52 microcurie of 'radium' (mixture)."

The British Medical Research Council further states "with all these considerations in mind, it would be unwise to fix the maximum allowable

concentration of radioactive strontium in the bones of the general population at more than one tenth of the level agreed for occupationally exposed persons. That is, the maximum allowable concentration should not be more than 100 micro-microcuries of strontium 90 per gramme of calcium. The British Medical Council viewpoint on the value for the permissible body burden is similar to that of the International Committee for Radiation Protection.

Recently an analysis of the increase in incidence of leukemia due to radiation exposure was reported by Lewis (6), based on leukemia in survivors of atomic bomb radiation in Japan, patients irradiated for ankylosing spondylitis, children irradiated as infants for thymic enlargment and radiologists. This report applies the results to the determination of the incidences of leukemia that would result from the recommended permissible body burden of 100 micro-microcuries of Sr^{90} per gram of calcium. The calculations indicate that 150 to 3,000 cases a year, in the United States would be expected from this body burden of Sr^{90}. The death rate from leukemia in the United States population in 1954 was 10,500 per year.

The analysis presented by Lewis was based on the thesis that radiation induced leukemia is proportional to the accumulated dose and also that the beta particles from the Sr^{90} - Y^{90} radionuclides damage the hematopoetic centers of the bone as is the case in external whole body radiation. This view is not shared by many scientists who believe that there is a threshold for radiation induced somatic damage and/or by those who do not believe that the beta particles reach the blood forming centers of bone marrow.

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This controversy can not be resolved at this time and must [illegible] evidence. In any case the margin of safety associated with [illegible] recommended permissible body burden is not very great as pointed out [illegible] Medical Council. It is therefore, of considerable interest to correlate this permissible body burden with the present and predicted future Sr^{90} body burden.

Estimation of the Body Burden:

Indirect Analysis: The indirect method of estimating the body burden involves following strontium 90 through the ecological chains of the ecosystems in the biosphere. Eisenbud and Harley (7) have presented data on Sr^{90} fallout from United States collecting stations covering the period October 1951 to September 1955 and from foreign stations covering the period October 1952 to September 1955. The findings indicate that the observed range of Sr^{90} on the surface collectors outside the United States (62 stations) is 1.8 millicuries per square mile in Peru to 24 millicuries per square mile at Iwo Jima. In the United States the accumulation varies from 2.1 at San Francisco to 23 at Salt Lake City. According to Kulp, Eckelmann and Schulert (8), Libby estimated that the average Sr^{90} fallout by the end of 1955 was 13 mc/mi^2 in the upper midwestern region of the United States. The soil data of Hardy and Morse (9) suggest an average of about 15 mc/mi^2 for the United States.

The amount of Sr^{90} in the soil which gets taken up by the plants

depends on the solubility of Sr^{90} compounds, root depth, a[illegible] of soil and the amount of exchangeable calcium. Kulp, Eckel[illegible] Schulert (8) refer to experiments which indicate that a[illegible] per cent of the Sr^{90} which has fallen out in the United States is in soluble form and is therefore available to plants. They also state that it is suspected that the megaton debris from the Pacific tests has a higher fraction of soluble Sr^{90} than debris from other tests, but this remains to be confirmed.

In 1955 Fuller and Flocker (10) demonstrated that the uptake of Sr^{90} is dependent upon exchangeable calcium in the soil (Figure 1). Hence in calculating the body burden through the ecological chains, cognizance must be taken of the variation in exchangeable calcium of soils throughout the world. According to Libby (9) this variation is from 0.[illegible] milliequivalents per 100 grams of soil. Hence it is not sufficient to merely consider averages in correlating the permissible body burden with strontium 90 per gram of available calcium.

An estimation of the amount of Sr^{90} expected in the body from fall-out requires information on uptake in each of the steps of the chains leading from soil to human bone. Although Sr^{90} will follow calcium throughout the chain it is discriminated against in most of the steps along the path. The ecological problem here is to get adequate experimental values for the discrimination factors. Kulp, Eckelmann and Schulert (8) have reported that strontium is discriminated against by a factor of about 1.4 when it goes from soil to plant and by a factor of about 8 in

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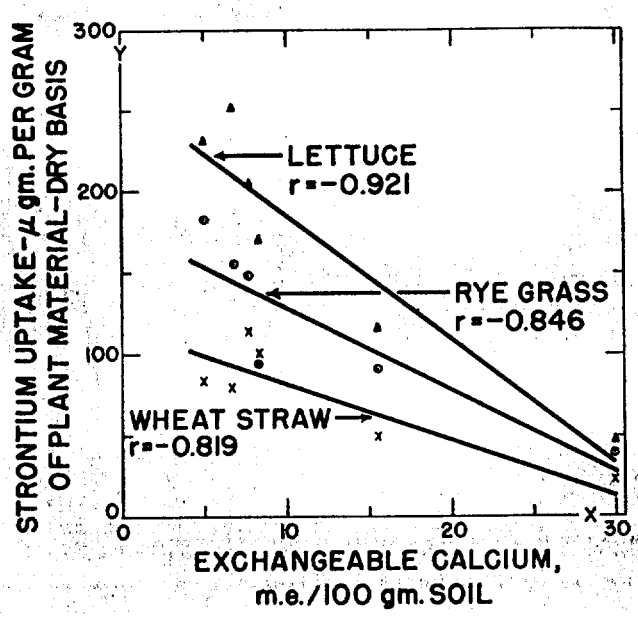

Figure 8. The relationship between the uptake of added strontium by three crops and exchangeable calcium content of some acid and calcareous soils.

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going from food to bone. Studies by Comar, Wasserman and Neid (12) on rats, stressing the importance of type of food, indicate that the discrimination factor is dependent on diet as shown in Table 4 taken from their report. As can be seen the $OR_{bone-milk} = 0.57$

$$OR_{bone-stock\ diet} = 0.27$$

OR is the "Strontium-Calcium Observed Ratio" and is defined as follows:

$$OR_{sample-precursor} = \frac{Sr/Ca \text{ of sample}}{Sr/Ca \text{ of precursor}}$$

In the chain from soil(s) to bone (b) via plant (p) and milk (m),

$$OR_{bone-soil} = (OR_{p-s})\,(OR_{m-p})\,(OR_{b-m})$$

According to Comar and Wasserman (13) there is a factor of 7 against strontium from the plant that the cow consumes to the milk produced.

The ecological chain from soil to human bone may be represented by the diagram shown in Figure 2.

It has been reported by Kulp et al (8) that the average American obtains 80 percent of his calcium from dairy products and the remainder mainly from vegetation. Therefore the overall observed ratio (OR_{b-s}) is given by:

$$(OR_{b-s}) = .8\,(OR_{p-s})\,(OR_{m-p})\,(OR_{b-m}) + .2\,(OR_{p-s})\,(OR_{b-p})$$
$$= .08$$

The values of (OR_{b-m}) and (OR_{b-p}) are approximate values extrapolated from animal data (11). However Harrison et al (13) have

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TABLE 4. Strontium-Calcium Observed Ratios and Percentage Excretion in the Rat. (Values represent mean ± stand. error of mean.)

Diet	Milk	Milk and corn	Commercial
No. of animals	4	3	4
Age at start and end of study, days	30–50	21–81	30–50
$OR_{bone-diet}$*	.57 ± .02	.45 ± .01	.27 ± .01
$OR_{retained-diet}$†	.57	.56	.30
$OR_{blood-diet}$	.46 ± .04	.43 ± .08	.21 ± .04
OR_{urine-} "	1.99 ± .01	1.47 ± .03	1.1 ± .03
OR_{feces-} "	1.41 ± .08	1.33 ± .05	1.27 ± .03
% excretion‡			
Ca 45 in urine	4.5 ± 1.1	5.7 ± .6	1.8 ± .3
Sr 89 " "	8.7 ± 1.9	8.4 ± .6	1.9 ± .2
Ca 45 in feces	44 ± 2	50 ± 3	71 ± 6
Sr 89 " "	62 ± 4	67 ± 2	90 ± 8

* $OR_{bone-diet} = \frac{Sr^*/Ca^* \text{ in bone}}{Sr^*/Ca^* \text{ in diet}}$.

† Calculated by difference from excretion values.

‡ $\frac{\text{Excretion during last 4 days of exp.}}{\text{Intake during last 4 days of exp.}} \times 100.$

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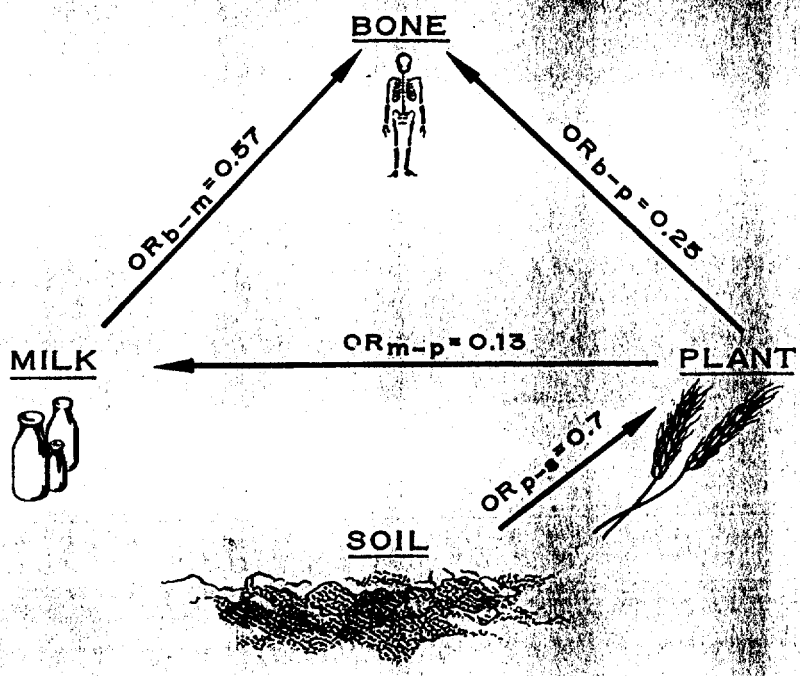

Fig 2

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reported that an adult man, receiving a somewhat higher stable strontium intake than normal, absorbed calcium about twice as much as strontium. This is in fair agreement with the value one would obtain by using the milk and plant weighted according to human diet (.8 x .57 + .2 x .25 = .456 + .05 = .506).

To obtain the body burden, $(Sr^{90}/Ca)_b$, from the above value of (OR_{b-s}), the value of the ratio $(Sr^{90}/Ca)_s$ in soil is needed. An estimate of this may be made from knowledge of the surface specific activity and the value for the exchangeable calcium in the soil. According to Kulp et al (8) the concentration of Sr^{90} in soil drops rapidly with depth so that most of the strontium is found in the top two inches of soil. Libby (9) has assumed that the soil contains an average of 20 grams of available calcium per square foot of soil to a depth of two and one half inches. Thus one millicurie of Sr^{90}/mi^2 is equivalent to 1.8 micro-microcurie of Sr^{90} per gram of available calcium. The range in the available calcium content reported by Libby was actually 0.4 to about 100 grams per square foot. Thus the range in the ratio of $\mu\mu c$ Sr^{90}/g available Ca is 90 to 0.36 for one millicurie of Sr^{90} per square mile. As stated before the surface contamination values range from 1.8 to 24 millicuries per square mile. From the ranges in data reported thus far the possible minimum and maximum values of the ratio of Sr^{90}/available Ca were determined and are shown in the second column of Table 5. Using these minimum and maximum values and the estimated observed ratio for humans $(OR_{bone-soil})$ of .08 the body burden values were calculated and are shown in the third column of Table 5. Included in this table are

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TABLE 5

Estimate of Body Burden Resulting From Fallout Through 1955

Surface Activity mc/mi^2	Sr^{90}/avail Ca uuc/gm	Body burden (at equilibrium) $uucSr^{90}/gmCa$
1.8	.65 min. 162 max.	0.05 min. 13 max.
24	8.6 min. 2160 max.	.7 min. 173 max.
4.4* Cardigan (Wales)	396	32

* Calculated by multiplying 1953 value of 1.1 by 4 (factor obtained from 1955 collections in England).

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values obtained from a city in Wales.

The estimates given above assumed that Sr^{90} in the soil is in equilibrium with the surface contamination. Also the calculations have not included (or corrected) for the amount entering the ecosystem through direct surface contamination on vegetation.

Direct Analysis

A direct determination of body burden may be obtained from the analysis of bone samples from humans as reported by Kulp et al (8) and from 17 stations throughout the world. The disadvantage to this approach in predicting the future body burden is that equilibrium may not have been reached at the time of sampling. Their data show an average Sr^{90} value for all ages of .12 uucSr^{90}/g Ca. Young children's bones showed three to four times (.36 to.48) this average value and a few values for individuals of various ages were ten to twenty times (1.2 to 2.4) the average. One value in Vancouver was 6.7 uucSr^{90}/gm Ca.

Prediction of Future Body Burden:

According to Kulp et al (8), taking decay into account, a total quantity of 26 millicuries per square mile from bursts through the fall of 1956

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would be available in the United States for equilibration with the human skeleton by 1970. This is twice the 1955 value of 13 μμc/mi² reported by Eisenbud and Harley (7). Assuming the fallout distribution is the same up to 1970 as it was up to 1956, the values of the body burden determined by the indirect method through the ecological chains would be as shown in Table 6, which also shows the predicted values from bone analysis based on the estimates made by Kulp et al (8). They predicted that the average world-wide bone content would rise from .12 μμcSr^{90}/ gm Ca in 1955 to 0.6 in 1956 and to 1.3 μμcSr^{90}/gm Ca in 1970.

The 1970 predictions are based on the explosions that have occurred up to the fall of 1956. As stated before the Sr^{90} surface activity in 1970 in the United States would be about 26 mc/mi². This is equivalent to 50MT of fission, since according to Libby (10), 1 megaton of fission distributed uniformly over the entire earth is equivalent to 0.5 mcSr^{90}/ mi². This relationship was used to estimate the amount of fission yield necessary to result in the world-wide and occupational maximum permissible levels from estimates of the predicted body burden levels. The results are shown in Table 7.

It can be seen that individuals, obtaining food primarily from soils such as that in Cardigan, Wales, would exceed the body burden of 100 μμc Sr^{90}/ gm Ca if 20 megatons of fission are added to the 50 megatons that have been released as of the fall of 1956. Further if the maximum possible ratio of 2160 μμc Sr^{90}/ gm Ca in plant producing

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TABLE 6

PREDICTION OF FUTURE BODY BURDEN
(BASED ON WEAPONS TESTED THROUGH 1956)

METHOD		Micro-Microcuries Sr^{90}/gmCa	
		1955	1970
ECOLOGICAL ANALYSIS (THIS REPORT)	MINIMUM	AT EQUILIBRIUM 0.05 to 0.7	AT EQUILIBRIUM 0.1 to 1.4
	MAXIMUM	13 to 173	26 to 346
	WALES	32	64
ECOLOGICAL ANALYSIS BASED ON U.S. AVERAGE VALUES		1955	1970
	AVERAGE	AT EQUILIBRIUM 1.9	AT EQUILIBRIUM 3.8
		1956	1970
BONE ANALYSIS (KULP *et al.*)	AVERAGE	0.6	1.3
	MAXIMUM	33.5*	72*

* Calculated by author from 6.7 of 1955 using same proportionality used by Kulp *et al.* to arrive at 0.6 for 1956 and 1.3 for 1970 average values from .12 average value determined in 1955.

TABLE 7

MT OF FISSION REQUIRED TO EVENTUALLY PRODUCE MPL

METHOD		1000 uucSr^{90}/gmCa	100 uucSr^{90}/gmCa
BONE ANALYSIS (KULP et al.)	AVERAGE	35,000	3500
	MINIMUM*	640	64
ECOLOGICAL ANALYSIS (BASED ON U.S. AVERAGE VALUES)	AVERAGE	11,600	1160
ECOLOGICAL ANALYSIS (THIS REPORT)	MINIMUM	2000 to 140	200 to 14
	MAXIMUM	35,000 to 500,000	3500 to 50,000
	VALUES	700	70

* Calculated by author on basis of maximum value in bone sample found by Kulp et al.

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soil (Table 5) actually does exist, individuals obtaining food from this soil would exceed the permissible body burden for large populations as the result of the Sr^{90} that has already been released (fall of 1956).

More data is required to determine whether or not these high ratios actually do exist in plant producing soils.

A very important problem also exists in relating the various sources of food supply to the number of individuals actually using each source. Kulp et al (2) have stated that although food grown in restricted areas of low available calcium content could have 10 to 100 times the mean body burden, it is clear that the general mixing of food sources in the diet of an urban population would make it impossible for most people of the world to exceed the average concentration by more than a factor of 10. In this connection Libby (14) has concluded that the food from outside of the calcium deficient area reduces by a factor of about 10 the increase in Sr^{90} pick-up rate which would be expected from the calcium deficiency in the soil if people lived entirely off the soil for their whole growing period of 20 years or so.

The minimum and maximum values are presented in this report to point out the possibility of certain individuals exceeding the maximum permissible body burdens from material already released. The exact numbers in this category await detailed analysis of Sr^{90} along the ecological chains in various geographical areas, and the parameters (such as discrimination ratios) involved along these chains.

In the case of atomic warfare, the levels of Sr^{90} may be many orders of magnitude greater than these present levels, so that the problem of living in a contaminated environment after survival of the emergency and recovery periods must be solved by adequate countermeasures. Our survival and recovery from the immediate effects of atomic warfare will have been in vain if we can not cope with the lasting global contamination.

Therefore it is imperative that ecological studies be promptly started on the urgent problems that would result from atomic warfare.

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REFERENCES

1. Atomic Warfare Defense, NAVDOCKS TP-PL-2 Bureau of Yards and Docks, Washington, D. C., 1956.
2. J. D. Teresi and C. L. Newcombe, In preparation.
3. National Bureau of Standards Handbook 52 (1953).
4. Pathological Effects of Atomic Weapons, NAS-NRC 452 (1956).
5. Medical Research Council, The Hazards to Man of Nuclear and Allied Radiations, Her Majesty's Stationery Office, (1956).
6. E. B. Lewis, Science 125 965 (1957).
7. M. Eisenbud and J. H. Harley, Science 124 251 (1956).
8. J. L. Kulp, W. R. Eckelmann, A. R. Schulert, Science 125 219 (1957).
9. W. F. Libby, Proc. Natl Acad. Sciences 42 365 (1956).
10. W. H. Fuller and W. J. Flocker, Technical Bulletin 130, Arizona Agricultural Experiment Station, University of Arizona, Tucson, Arizona (1955).
11. C. L. Comar, R. H. Wasserman and M. M. Nold, Proc. Soc. Exp. Biol. Med., 92 859 (1956).
12. C. L. Comar and R. H. Wasserman, Agricultural Research Program, Semiannual Progress Report for 1 July 13, Dec. 1953, AEC Rept. ORU-110 (April 1954) from reference (9).
13. G. E. Harrison, W. H. A. Raymond and H. C. Tretheway Clin. Sci. 14 681 (1955).

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REFERENCES (CONTINUED)

14. W. F. Libby, Presentation at the Spring Meeting of The American Physical Society, Washington, D. C., April 26, 1957.

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