# Reports

## Ratio of Cesium-137 and Strontium-90 Radioactivity in Soil

*Abstract.* The similarity in genesis and the more pertinent physical characteristics of fission-produced $Cs^{137}$ and $Sr^{90}$ suggests the use of the first as a convenient monitor for the other prior to uptake in the biosphere. Results are presented which indicate the feasibility of this approach in the case of soils.

As repeatedly pointed out by Anderson (*1*), the desirability of using $Cs^{137}$ as a monitor for $Sr^{90}$ is predicated on the fact that the gamma rays emitted by $Cs^{137}$, because of their penetrability and discrete energy, can be quantitated with comparative ease from bulk samples of low specific activity without recourse to the more time-consuming and costlier chemical processes required for the measurement of the $\beta$-emitter $Sr^{90}$ (*2*). This consideration is most apparent in the analysis of soils, where the technical requirements of accurate $Sr^{90}$ measurements are most stringent.

During the fission process, approximately 1.76 atoms of $Cs^{137}$ are formed for each atom of $Sr^{90}$ (*3*); this leads to a $Cs^{137}/Sr^{90}$ activity ratio of 1.83 (*4*). This ratio should be universally prevalent in fallout if no fractionation occurs from the time of detonation to the time of deposition on the ground. Published data show no glaring departures from this value in several media of fallout transport. Thus, sampling of the surface air by the U.S. Naval Research Laboratory in 1957 at 12 locations throughout the world indicated an over-all value of 2.10 $\pm$ 0.31 (*5*). The data of Stewart *et al.* (*6*) on rain water collected from January 1956 through June 1958 from 16 sites around the world show an average value of 1.54 $\pm$ 0.22 for the ratio of total $Cs^{137}$/total $Sr^{90}$ activity present therein; they also imply that, owing to sampling difficulties, the true ratios are somewhat higher.

If, as visualized in all mechanisms of fallout transport, rain is the primary means of conveyance from the atmosphere to the ground, then the activity ratio in soil should closely approximate that found in rain water except in cases of severe differential leaching. In order to verify the correctness of this hypothesis it was thought advisable to measure directly the $Cs^{137}$ and $Sr^{90}$ content of soil. To this end, nine samples (*7*) analyzed for $Sr^{90}$ by chemical means (*2*) at the Health and Safety Laboratory of the U.S. Atomic Energy Commission (*8*) were analyzed for $Cs^{137}$ by scintillation spectrometry (*9*) at Argonne National Laboratory (*10*). The results are shown in Table 1. They supersede preliminary ratios for some of these soils where activity arising from the unsuspected presence of $Mn^{54}$ was erroneously attributed to $Cs^{137}$ (*11*).

The average value of the activity ratio for all nine samples is 1.62 $\pm$ 0.34, a value in good agreement with that of Stewart *et al.* (*6*). It should be noted that the ratio is not constant with depth at any given location and that further variation is introduced in going from one soil type to another. The differences in values are not within experimental error and presumably reflect differences in the ion-exchange properties of the soils in question (*12*). Comparison of total $Cs^{137}$ with total $Sr^{90}$ activity in soil tends to smooth out these variations. This was done by assuming that all fission activity was present in the top 6 inches of soil having a constant density, adding the observed concentrations in the proper proportions, and then determining the ratio. The results for the three soils for which sampling was done in two layers and for the two soils sampled to a depth of 6 inches are shown in the last column of the table. Both average values are in accord with the observations of rain water and with the theoretical value. An interesting comparison between ratios for rain water and soils at the same location may be made at Ottawa, Canada, where the total activity ratio in rain water from June 1956 to June 1958 was 1.32 (*6*) and the average soil value for 1957–58 was 1.44 $\pm$ 0.06. Taken at face value, this agreement between two decidedly low values suggests that the activity ratios may well vary in rain water and hence in soils, in various parts of the world, but that if this is so, the variation cannot be very large.

Since cesium and strontium behave chemically much like potassium and calcium, respectively, they are expected to be metabolically active in both plants and animals. Hence the activity ratio under such circumstances will depend not so much on the soil ratio as on the metabolic and ecological characteristics of the living specimen or product involved. However, if these factors remain constant, once the activity ratio has been established empirically for a

Table 1. Concentration of $Cs^{137}$ and $Sr^{90}$ in soil.

| Sample No.* | Depth (in.) | Date collected | $Cs^{137}$ ($\mu\mu c$/kg) | $Sr^{90}$ ($\mu\mu c$/kg) | $Cs^{137}/Sr^{90}$ Individual sample | $Cs^{137}/Sr^{90}$ Top 6 in. |
|---|---|---|---|---|---|---|
| | | | *Ithaca, New York* | | | |
| 56114 | 0–2 | 10–56 | 188 ± 12 | 101 ± 4.5 | 1.86 ± 0.20† | |
| 57813 | 0–2 | 10–57 | 377 ± 44 | 167 ± 4.5 | 2.26 ± 0.33 | 1.87 ± 0.27† |
| 57814 | 2–6 | 10–57 | 25.7 ± 0.8 | 31.1 ± 2.2 | 0.83 ± 0.09 | |
| | | | *Ottawa, Canada* | | | |
| 57276 | 0–6 | 4–57 | 63.2 ± 9.3 | 45.9 ± 2.3 | 1.38 ± 0.27 | 1.38 ± 0.27 |
| 58270 | 0–6 | 1958 | 81.1 ± 4.3 | 54.5 ± 2.2 | 1.49 ± 0.15 | 1.49 ± 0.15 |
| | | | *Kawailoa, Hawaii* | | | |
| 57996 | 0–2 | 12–57 | 411 ± 23 | 219 ± 7.7 | 1.88 ± 0.17 | 1.82 ± 0.20 |
| 57997 | 2–6 | 12–57 | 35.9 ± 3.5 | 23.2 ± 2.3 | 1.55 ± 0.32 | |
| | | | *Leilehua, Hawaii* | | | |
| 57998 | 0–2 | 12–57 | 226 ± 5 | 171 ± 1 | 1.32 ± 0.04 | 1.48 ± 0.08 |
| 57999 | 2–6 | 12–57 | 48.7 ± 3.9 | 23.9 ± 1.3 | 2.04 ± 0.28 | |
| Averages | | | | | 1.62 ± 0.34‡ | 1.61 ± 0.19‡ |

* Beltsville numbers, according to the U.S. Department of Agriculture numbering system. † Deviation due to counting statistics. ‡ Average deviation from the mean.

*Instructions for preparing reports.* Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

specified crop or animal product grown in a given locality for a representative length of time, subsequent measurements of $Cs^{137}$ should be sufficient to monitor the $Sr^{90}$ concentration as a function of time. This may be illustrated in the case of the U.S. Public Health Service measurements on the $Cs^{137}$ and $Sr^{90}$ content of milk (*13*). The results for 1958 show that the average monthly $Cs^{137}/Sr^{90}$ activity ratio for 10 sampling stations in the United States varied from as low a value as $6.28 \pm 1.28$ to as much as $15.45 \pm 5.62$, with an average value of $10.09 \pm 2.27$; however, the variation about the mean found at any one station does not exceed $\pm 40$ percent (Salt Lake City), and average variation per station is $\pm 27$ percent for a 6- to 12-month period.

According to the findings in soil, it seems likely that the $Sr^{90}$ concentration in this medium can be determined to within an error of 20 percent by measuring the $Cs^{137}$ content and dividing by 1.6. The need for extending these observations to soils from other localities is obvious. Furthermore, if errors of 20 to 40 percent are tolerable in the estimates of $Sr^{90}$, relatively inexpensive surveys of wide coverage could be undertaken by monitoring $Cs^{137}$ not only in soil but also in a great variety of material of ecological importance.

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#### References and Notes

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2. AEC Health and Safety Laboratory, *Laboratory Manual No. NYO-4700.*
3. W. H. Langham and E. C. Anderson, *Health Phys. J.*, in press.
4. The half-life of $Cs^{137}$ is 26.6 years, that of $Sr^{90}$ is 27.7.
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6. N. G. Stewart, R. G. D. Osmond, R. N. Crooks, E. M. R. Fisher, M. J. Owers, *U.K. Atomic Energy Authority Publ. No. AERE HP/R 2790* (1959), p. 9.
7. The soil samples were supplied through the courtesy of L. T. Alexander, Soil Survey Laboratory, U.S. Department of Agriculture.
8. The advice and cooperation of J. H. Harley of the Health and Safety Laboratory, U.S. Atomic Energy Commission, is gratefully acknowledged.
9. P. F. Gustafson, L. D. Marinelli, S. S. Brar, *Science* **127**, 1240 (1958).
10. This work was performed under the auspices of the U.S. Atomic Energy Commission. Many helpful discussions with L. D. Marinelli and J. E. Rose are hereby acknowledged. Credit in assisting with much of the spectral data goes to S. S. Brar.
11. P. F. Gustafson, *Argonne Natl. Lab. Rept. No. 5919* (1958), p. 62.
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## Electrical Output of a Receptor Membrane

*Abstract.* The electrical output of the receptor membrane of the nonmyelinated ending of Pacinian corpuscles is a function of the electrical gradients across the receptor membrane. The generator potential of the receptor membrane in response to equal mechanical stimuli varies linearly with the intensity of polarizing currents passed through the membrane. The production of a generator potential leaves a refractory state in the receptor membrane which is independent of the amount of charge transferred across the membrane but is dependent on a factor related to the strength of the stimulus which produced the response.

The receptor membrane of the nonmyelinated nerve ending of Pacinian corpuscles has the peculiarity that small regions of it can be excited independently. When a mechanical stimulus is applied to a small portion of nerve ending, the resulting electric response is confined to that region which has been stimulated mechanically and is not propagated to nonstimulated regions of the same receptor membrane by local circuit excitation (*1-3*). The generator potential of the entire receptor membrane appears to be built up by spatial summation of the electric activity of small independently excitable membrane regions (*generator elements*) (*2*).

For analytical purposes, the output of each generator element may be considered all-or-nothing with respect to the strength of the mechanical stimulus. The entire input-output relation of the receptor membrane—namely, the finely graded relation between stimulus strength and generator potential amplitude—may then be accounted for by spatial summation of the activity of such generator elements (*2*). The experiments described in the present report reveal that, although the electrical output at each generator element may be all-or-nothing with respect to the strength of the mechanical stimulus, it is graded with respect to the electrical gradients across the generator element.

The membrane potential of the receptor membrane was changed by passing inward or outward currents through the nonmyelinated nerve ending, while generator potentials were produced in this membrane by mechanical stimulation with a piezoelectric crystal stimulator. The capsules of single isolated Pacinian corpuscles were removed by microdissection. Each such preparation, consisting mainly of a nonmyelinated ending, has already been shown to have essentially the same mechanoreceptor properties as it has in the intact corpuscle (*4*). The decapsulated preparation offered a relatively naked nonmyelinated ending onto which polarizing currents were directly applied, and from which mechanically elicited generator potentials were directly led off with nonpolarizable electrodes, as is shown in Fig. 1.

When steady inward or outward currents are passed through the receptor membrane, the amplitude of the generator potential in response to a mechanical stimulus of constant strength varies as a linear function of the polarizing current (Fig. 2). The rate of rise of the generator potential is also a func-

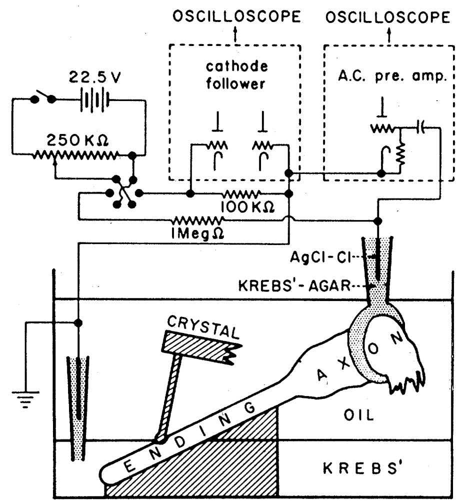


Fig. 1. Set-up for mechanical stimulation, polarization, and recording of the receptor membrane.

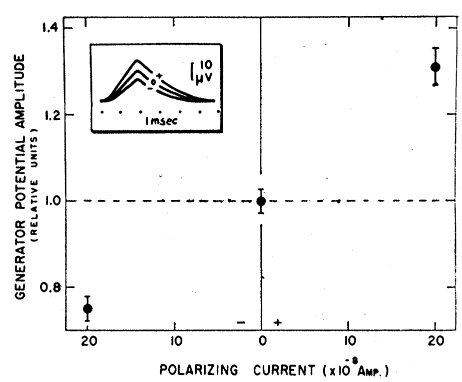


Fig. 2. Amplitude of mechanically elicited generator potential as a function of polarizing current. The mean amplitude of generator potential in response to equal mechanical stimuli is determined for various intensities of current flowing inward (hyperpolarizing, +) or outward (depolarizing, −) across the receptor membrane. The vertical bars subtend the standard error of the mean of approximately 30 generator potentials in each case. At any chosen current intensity, the polarizing current was on for at least 30 seconds before the start of each series of generator potential determinations. This allowed stable measurements. The inset shows three individual generator potentials (one of each series) whose mean amplitude is plotted in the main figure.