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Occurrence of Bismuth-207 at Eniwetok Atoll

DURING March 18–30, 1961, 308 samples of soil, water, algae, land plants, plankton, fish and invertebrates were collected at Eniwetok Atoll for assay of radioactivity. Two of the samples, taken from the bottom of the lagoon, contained a γ-emitting isotope not previously reported at the Eniwetok Test Site. One sample, which consisted primarily of radiolarians, foraminiferans, and small sand grains, was collected in a plankton net placed under the outflow of a salt water supply system for marine aquaria in which the intake pipe was located on the bottom of the lagoon near Eniwetok Island. The other sample was a specimen of a brown alga, *Dictyota divaricata* Lamouroux, collected in three feet of water in the lagoon off Glenn Island on the west side of the atoll.

The algal sample (wet weight 63 gm.) was dried, dry-ashed at 500° C. for 20 hr. (ash-weight 10·6 gm.), dissolved in 500 ml. of 12 *N* hydrochloric acid to which 20 mgm. of bismuth carrier had been added, and boiled to dryness. The γ-spectrum of the residue as determined by the use of a 3-in. by 3-in. sodium iodide (thallium) crystal connected to a 256-channel analyser contained the photopeaks of cobalt-57, cobalt-60, zinc-65, manganese-54 and ruthenium-106 –rhodium-106. In addition, photopeaks with energies of 0·088, 0·57, 1·064 and 1·77 were present. The latter correspond to the photopeaks of bismuth-207, an isotope with a physical half-life of eight years. The presence of bismuth-207 in the algal sample was verified by the following methods.

The ash, which had been treated with hydrochloric acid and dried, was dissolved in 50 ml. of 6 *N* hydrochloric acid and diluted to 1,000 ml. with distilled water.

'Dowex 50*W*–*X*8' resin (50–100 mesh) in the *H*-form was placed in a glass column (1·4 cm. diameter and 200 cm. length). The sample was passed through the column at a flow-rate of 1 ml./min. and the column was rinsed with 1 litre of 0·2 *N* hydrochloric acid. The sample eluate and rinse were combined and dried (anion fraction). The column was eluted with 1 litre of 5 per cent oxalic acid followed by 1 litre of 6 *N* hydrochloric acid. The last two fractions were collected and dried separately.

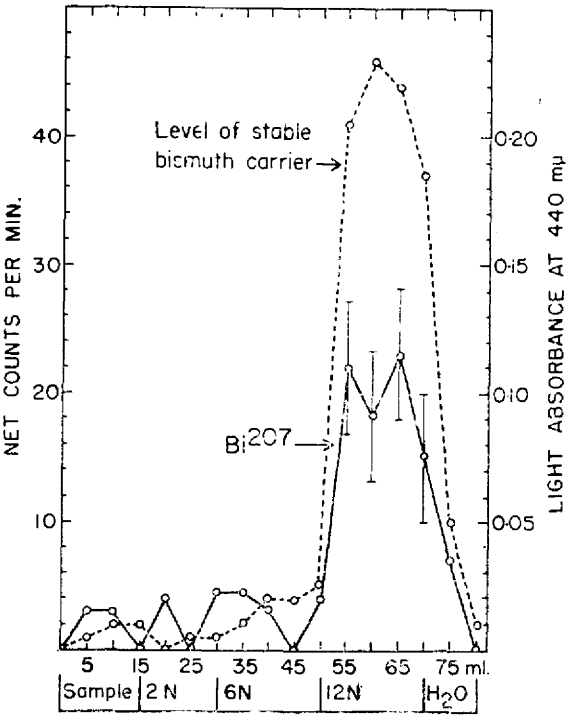
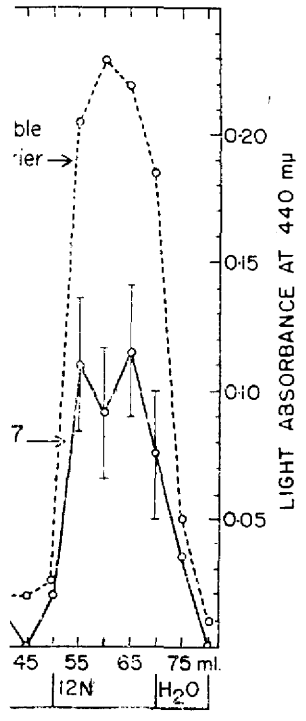


Fig. 1. The elution curve from 'Dowex-1' of bismuth carrier and bismuth-207 previously separated on a 'Dowex-50' ion-exchange column from a sample of alga collected at Eniwetok Atoll in March 1961. The dashed line is the elution curve for the bismuth carrier in which the levels of bismuth were determined by the iodide colorimetric test. The solid line indicates the γ activity of bismuth-207 in the eluted fractions. The 95 per cent confidence-levels for counting error are given

The γ-spectrum made from the anion fraction contained the photopeaks of ruthenium-106–rhodium-106 and bismuth-207. 98 per cent of the bismuth-207 was recovered in this fraction, and the remaining bismuth-207 was eluted in the oxalate fraction. After removal of the ruthenium from the anion fraction by distillation with perchloric acid only the photopeaks of bismuth-207 were present in the γ-spectrum.

An iodide colorimetric test for bismuth was made after removal of the ruthenium[1]. The sample was dissolved in 10 ml. of 2 *N* sulphuric acid. Five ml. of 1 per cent ascorbic acid together with 1 ml. of 1 per cent sodium sulphite, then 1 ml. of 10 per cent potassium iodide were added to three drops of the sample in 10 ml. of 2 *N* sulphuric acid. The solution exhibited the orange colour of iodobismuthite.



m 'Dowex-1' of bismuth carrier separated on a 'Dowex-50' ion-de of alga collected at Eniwetok shed line is the elution curve for levels of bismuth were determined t. The solid line indicates the in the eluted fractions. The ls for counting error are given

from the anion fraction of ruthenium-106–rhodium- per cent of the bismuth-207 action, and the remaining in the oxalate fraction. uthenium from the anion ith perchloric acid only the 207 were present in the

test for bismuth was made henium[1]. The sample was sulphuric acid. Five ml. of ogether with 1 ml. of 1 per hen 1 ml. of 10 per cent dded to three drops of the ulphuric acid. The solution ur of iodobismuthite.

A 'Dowex-1' resin column (100–200 mesh) 5 mm. by 8 cm. was converted to the Cl^- form with 6 *N* hydrochloric acid then treated with 25 ml. 2 *N* hydrochloric acid. The fraction which contained the bismuth was dissolved in 15 ml. 2 *N* hydrochloric acid and passed through the resin column at a flow-rate of 0·1 ml./min. The column was eluted with 15 ml. 2 *N*, 20 ml. 6 *N*, 20 ml. 12 *N* hydrochloric acid, and 10 ml. distilled water. The eluates were collected in 5-ml. fractions, dried in test tubes, then treated with heat and sulphuric acid to remove the chloride. Gamma counts for bismuth-207 were made from each fraction and the stable bismuth determined by the iodide colorimetric method. The amounts of iodobismuthite in the fractions were determined by light absorbance measurements at 440 mμ. The γ-radioactivity and the light absorbance in the fractions are shown in Fig. 1. Bismuth is known to be strongly adsorbed on to 'Dowex-1' resin at molarities of hydrochloric acid from 0–6, but is desorbed by 12 *N* hydrochloric acid[2]. In the separation described above both the γ-activity and the stable bismuth remained on the 'Dowex-1' during elution with 2 *N* and 6 *N* hydrochloric acid but were removed by 12 *N* hydrochloric acid.

A 20-mgm. sample of bismuth-207 made in the University of Washington cyclotron in 1956 was subjected to the same ion-exchange procedures used for the algal sample. Of the bismuth-207 introduced into the 'Dowex-50' column, 99·98 per cent was recovered in the anion fraction (sample eluate + 0·2 *N* hydrochloric acid wash). In the 'Dowex-1 column', the bismuth-207 remained attached to the resin during elution with 2 *N* and 6 *N* hydrochloric acid but was quantitatively removed by 12 *N* hydrochloric acid.

(The conversion of bismuth to a chloride complex in ash from biological material which is then separated by successive elutions from 'Dowex-50' and 'Dowex-1' columns would be an efficient method for separation of stable bismuth from these samples. The amount of stable bismuth separated may be determined with a colorimetric test. If carrier-free bismuth-207 were added to the sample before ashing, the yield for the stable element could be accurately determined by γ counting the added spike and the purified bismuth separation.)

Bismuth-207 in radioactive fall-out would be in the oxide form, which is insoluble in sea water. In the lagoon, therefore, it would be expected to occur in the bottom sediments.

The bismuth-207 found in the sample of *Dictyota* was probably adsorbed to the surface of the plant and not incorporated in its living material. Algae are

known to adsorb trivalent rare earths rapidly in the particulate form from sea water[3], and bismuth-207 probably would be adsorbed in a similar manner.

A possible mode of production of this isotope is bismuth-209 (n-$3n$) bismuth-207. The D–T reaction would result in neutrons with sufficient energy to produce bismuth-207 by this method[4].

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