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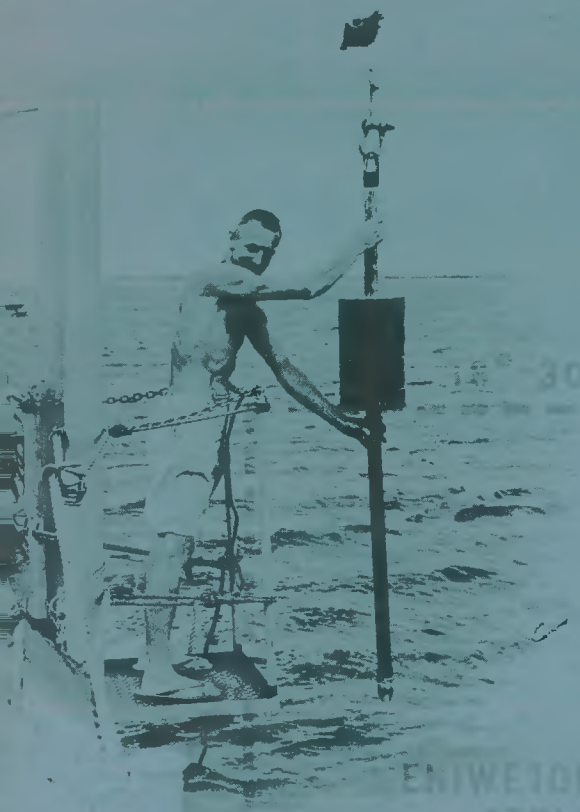
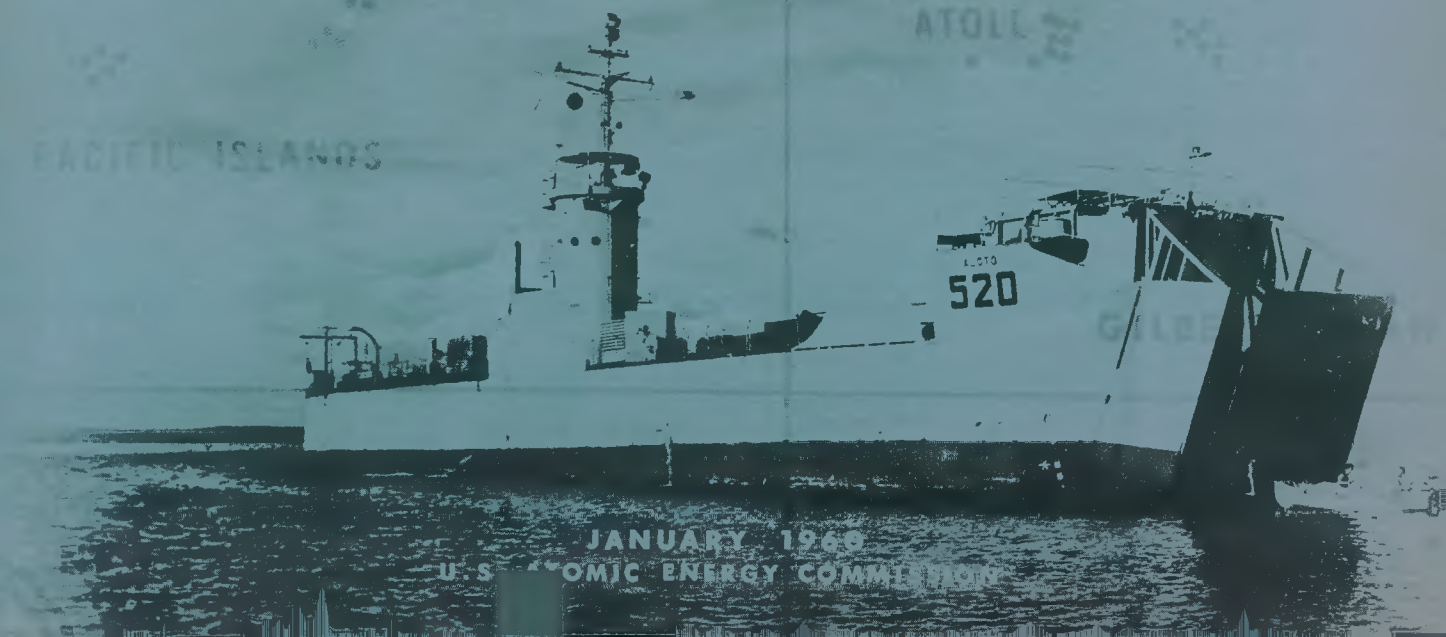
MARINE SCIENCES RESEARCH

Division of Biology and Medicine





JANUARY 1969
U.S. ATOMIC ENERGY COMMISSION

Subject Category: Biology and Medicine

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FOREWORD

This booklet on Marine Sciences is one in a series of such publications in preparation to describe the research supported by the Division of Biology and Medicine, U. S. Atomic Energy Commission. Its purpose is to acquaint interested scientists with the biomedical program of the Commission, its objectives and needs.

A grouping of current research contracts gives summary information provided by the principal investigator of each project.

The Marine Sciences program is the responsibility of the Environmental Sciences Branch, Division of Biology and Medicine, and is currently under the supervision of John N. Wolfe, Chief of the Branch and an Ecologist, and I. E. Wallen, Aquatic Biologist. Dr. Allyn H. Seymour, Assistant Director of the Laboratory of Radiation Biology, University of Washington, is employed as a consultant to the Division on matters pertaining to marine biology.

The usefulness of the series will depend upon the reaction of our readers. Suggestions for improvement would be most welcome.

Charles L. Dunham, M.D., Director
Division of Biology and Medicine

MARINE SCIENCES RESEARCH IN THE AEC

Marine Sciences Interests of the Atomic Energy Commission

Early in the planning for war-time utilization of atomic energy, it was realized that information concerning the effects of atomic radiation on aquatic organisms was essential to an understanding of possible hazards of nuclear operations. In 1943, the Manhattan Engineering District established the Applied Fisheries Laboratory (later the Laboratory of Radiation Biology) at the University of Washington to develop information about the possible effects of the operation of nuclear reactors on the Columbia River fisheries.

During and after the testing of atomic devices in the Pacific, oceanographic scientists from the University of Washington, Scripps Institution of Oceanography, the Naval Research and Development Laboratory, and other private and public agencies, have studied the effects of the addition of radioactive materials on the oceans and their contained life. Substantial numbers of unclassified reports have been published on various phases of these studies.

In addition to these studies of short term effects, the Smithsonian Institution in 1946 and 1947, under U. S. Navy auspices, made an extensive collection of marine organisms in the Marshall Islands area -- which had been selected for testing nuclear devices. These collections are available to investigators who wish to make comparisons of the biota before and after the Pacific operations. The Commission operates a Marine Biology Laboratory at Eniwetok Atoll in the Marshall Islands to assist in such studies and for other purposes.

The Commission's initial research effort in the Marine Sciences was closely aligned to military needs and to testing operations. Studies of circulation and mixing of ocean waters was of immediate concern along with research into the sedimentation and storage of radionuclides as well as their uptake, release and cycling by marine organisms.

Although not directly involved, the Commission has followed with considerable interest the experience and studies of the British in the operation of nuclear reactors on the sea coast. From a time preceding their initial operation the Commission has studied the effects and potential effects of the operation of production reactors on the Columbia River, and has been careful to avoid

releasing quantities of radioactivity that might approach the maximum permissible limits for long time radiation exposure recommended by the National Committee on Radiation Protection and Measurements and the International Commission on Radiological Protection.

The safe disposal of low level wastes has long been of concern, and, since 1950, the Commission has packaged small quantities of non-recoverable wastes for disposal at sea. Such wastes as slightly contaminated clothing, glassware, medical supplies, etc., are packaged in concrete and usually contained in barrels for disposal at sea. It has been considered that even though the concrete may not prevent escape of the wastes, leaking will be at such a low level that there is essentially no danger of exceeding maximum permissible levels of any radioisotope because of the essentially unlimited diffusion and dilution available in the sea. Sites for disposal are selected in part for their low production of commercially important organisms.

Many scientists have been involved in theoretical and practical studies of the potential effects on the oceans of the operation of nuclear surface ships and submarines and of the ocean disposal of packaged radioactive wastes. Study panels of the National Academy of Sciences - National Research Council have prepared evaluation reports, concerning (1) the problems of "Radioactive Waste Disposal from Nuclear-Powered Ships" and (2) the problems of "Radioactive Waste Disposal into the Atlantic and Gulf Coastal Waters." An additional report is in preparation concerned with the potential for wastes disposal into the Pacific.

As ideas are developed toward the peaceful uses of atomic detonations (Plowshare projects) the Commission has recognized the feasibility of developing the explosive capabilities of nuclear devices for major excavations such as harbors and canals. In this regard studies of the effect of such operations on marine and terrestrial life in the area have been given serious consideration. The first such project under consideration, an excavation in Northwest Alaska (Project Chariot), has already included an oceanographic study.

In planning for future successful development of nuclear engines for use in aircraft and unmanned vehicles, it has been considered likely that such vehicles may complete their mission and be disposed of, perhaps accidentally, into the ocean. Studies of diffusion

and dispersion of radioactivity under such conditions, both of a theoretical and of a practical nature, will be carried out before operation of the flight vehicles.

In the oceans as well as on land radioactive isotopes offer tremendous possibilities as research tools. Many processes of great interest in natural functioning of the environment and of its contained organisms may be studied by the use of radioactive tracers. The Commission has recognized the potential value of these tracers and has encouraged projects to develop new concepts of natural phenomena based on existing and additive effects of radioactive nuclides from fallout or other byproducts of its operation.

Marine Sciences Information Needed by the Commission

The information needed by the Commission to carry out its responsibility can be listed in various ways. The headings in the following discussion were selected for convenience and not in any order of priority.

1. Studies in and around wastes disposal areas. Physical and biological studies are required to predict and explain the diffusion and concentration resulting from the deposit of packaged low level wastes in the ocean. The Commission is continually gathering information that is applicable to such disposal but the breadth of information required is such that an expansion of effort is essential.

Information is needed concerning the effects of extremely low level radiation on marine organisms over a long period of time.

2. Circulation and mixing in estuaries and coastal waters.

As more and larger nuclear vessels are operated in coastal waters and as the number of power, production and research reactors increases, it may be anticipated that increasing quantities of long lived radioactive isotopes will find their way into estuaries and coastal waters. Information concerning the residence time of such isotopes may be gathered from studies of circulation and mixing processes. Predictions and monitoring of levels of radioactivity are likely to become more important at a later time when more radioactive materials have accumulated.

3. Open ocean research. The Commission has long recognized the importance of information about ocean currents in order to predict the distribution of radioisotopes produced by nuclear explosions. Such information and related knowledge of mixing processes are of importance in making predictions about the ultimate distribution of any radioactive isotopes that may appear in the ocean from any source. Any potential release of radioactivity from nuclear ships should be evaluated in relation to data on movement and dispersion of ocean waters.

Since nuclear reactors offer unique capabilities for service as power for oceanographic stations, for under-ocean pipelines, for dredging operations, for mining under-ocean resources, etc. it seems most important that research be accomplished in oceanography to precede and to accompany the development of such advanced reactors.

If manned or unmanned flight projectiles are launched over an ocean area it is necessary that the Commission have research results that make possible the prediction of effects of loss or disposal of such vehicles into the marine environment. The value of the high seas fisheries industry is such that studies applying to the potential effects of nuclear operations on the annual catch must have high priority.

4. Sedimentation. Particulate radioactive isotopes tend to be adsorbed or absorbed or to agglomerate and to be removed from suspension. Particulate size, incorporation into biological food chains, water movements, and other factors must be evaluated by substantial research in order to determine the rate of removal of radioactive nuclides from suspension in the oceans. Studies also must provide information concerning types and permanency of bonding of materials being removed. In addition, the Commission has supported projects which were designed to evaluate various flocculation agents as they might be used to decontaminate in the event of the accidental release of excessive radioactivity in the ocean.

5. Distribution of radioelements by organisms. University of Washington scientists found during early Pacific test operations that plankton organisms served as biological indicators of the presence of radioactivity. It was found that most radioisotopes are greatly concentrated by adsorption or to absorption by plankton species soon after the addition of isotopes and since those early days in the program plankton organisms are

regularly used in oceanic monitoring. Since many species of organisms, both mature and immature, compose the plankton and since the species present vary at any time and place it is necessary to isolate and identify the specific concentrating organism or organisms for each isotope in order to understand the existing phenomena and to predict future occurrences.

Research is being conducted with many planktonic and non-planktonic organisms. This research not only leads to a substantial increase in our knowledge of radiation of the particular species but also is concerned with biological food chains as they may concentrate and re-concentrate radionuclides.

In addition to the plankton organisms, various larger marine organisms including fishes and shellfishes are being studied for their ability to remove and retain radioisotopes as these may be added to water.

Existing Marine Sciences Contracts

The Atomic Energy Act directs the Atomic Energy Commission to support and foster research in the field of atomic energy. The following summaries describe the research in Marine Sciences supported by the Commission through its Division of Biology and Medicine.

Realizing that universities are natural centers for research and that trained manpower is essential to the scientific strength of the nation, the Commission has supported programmatic as well as fundamental research at university and private laboratories. The present program in Marine Sciences involves some thirteen institutions through twenty-eight separate contracts.

The summaries included here were provided by the principal investigator of each project. The size of the contracts varies widely: in some cases only a single investigator; in others a staff of more than twelve; some use outside consultants. Because of the rapidly changing nature of research, only the general objectives of the program are described in a number of cases. More specific reports are prepared for the Commission, and each investigator is urged to publish his findings in the open literature.

Although the projects may overlap among the topics listed as needing further study, the summaries are arranged in the same general sequence as the topics in the preceding section.

Contractor:	University of Connecticut, Marine Research Laboratory
Contract:	AT(30-1)2445
Brief Title:	Macroscopic Benthic Fauna of Selected Sites
Investigator:	John S. Rankin, Jr.

Scope of Work:

Three potential wastes disposal sites off Cape Cod will be examined as to kinds of animals present and abundance of each, relation between fauna and sediment, and stability of communities present. At the same time, in cooperation with the U. S. Coast and Geodetic Survey which will provide ship and personnel for collecting hydrographic data, collection will be made of sufficient numbers of the more abundant species of organisms for analysis of radioactivity by the U. S. Public Health Service. The combined studies should provide an understanding of existing conditions of biota and environment and set the background for future studies. Both quantitative and qualitative samples will be collected, using Van Veen and trawl dredges. Van Veen samples will be washed through screens of one-half millimeter size. All of the screening will be done on board ship as well as separation of organisms into major categories. Determination of populations will be carried out at Noank.

Contractor: University of North Carolina

Contract: AT(40-1)2593

Brief Title: Relationships between Estuarine Bottom Populations and Associated Sediment Types

Investigator: Joseph St. Jean, Jr.

Scope of Work:

Studies will be conducted on the relations existing between distribution and abundance of estuarine level bottom populations and the distribution of associated sediment types in Bogue Sound, North Carolina. Work will include studies of the sedimentary, hydrographic, and faunal distribution aspects from transects across the Sound with the objectives of (1) correlation of distribution and abundance of infauna and epifauna of the area, (2) sampling with studies of salinity, pH, currents, depth, turbidity, and standing crop, (3) development of means of relating standing crop to sediment distribution, and (4) collection of ecological data pertinent to paleontology, especially geological problems related to stratigraphic correlation and paleoecology of the Cretaceous and Tertiary sediments.

Contractor:	University of California, Scripps Institution of Oceanography
Contract:	AT (11-1) 34 **Project # 56**
Brief Title:	Hyperion Trace Radioactivity Study
Investigator:	T. R. Folsom

Scope of Work:

Samples of dried fertilizer coming from the Los Angeles Hyperion Sewage Treatment Plant were found to have traces of fission products and other activities in amounts easily studied by gamma ray spectrometer, but the ratio of the various activities was quite different from that which had been observed in other sewage samples, soils and other natural catchments of fallout. It appeared advisable to seek an explanation for these peculiarities, and to estimate the consequences by combining the techniques available in radiochemistry, sanitary engineering and in oceanography.

A cooperative investigating program involving the Bureau of Sanitation of the City of Los Angeles and sponsored by the Institute of Marine Resources of the University of California was proposed in March 1959 and has been financially supported by the Atomic Energy Commission since October 1959.

A comprehensive sampling program has been started in the plant, and gamma spectrometer assays are being made of cesium-137, cobalt-60, iodine-131 and other gamma activities. Already the general trends and magnitudes are becoming apparent: radiocesium appears to have a low steady background mounted by infrequent sudden larger inputs. Cesium appears to separate from potassium in the plant, and the cause of this is being now studied. Biological, chemical and physical agencies are being investigated. A system for more effective monitoring is being developed.

Contractor: University of Washington, Department of Oceanography

Contract: AT(40-1)1425

Brief Title: Productivity Studies in Puget Sound

Investigator: George C. Anderson

Scope of Work:

This is a continuing investigation of primary productivity and related factors in Puget Sound. 1958-59 was devoted primarily to seasonal collection of data which will form the basis for further study of seasonal fluctuation of phytoplankton, and of limiting factors and food-chain dynamics. Work in 1959-60 will include:

(1) Seasonal Studies

Seasonal studies will be largely confined to Hood Canal of Puget Sound, a highly productive area with large and rapidly changing populations of both phytoplankton and zooplankton. Particular attention will be given to the measurement of primary production with the use of carbon-14, and to factors influencing production. Investigations will be also made of diurnal fluctuations, the effect of added nutrients, and the factors contributing to the support of the phytoplankton maximum noted during the winter months.

(2) Phytoplankton-Zooplankton Relationships

The effects of grazing will be studied in both natural populations and laboratory populations. Considerable time will be devoted to laboratory culture of selected species of phytoplankton and zooplankton. Measurements of grazing will be made with algae tagged with phosphorus-32. Some of the experimental work will be carried out at the Friday Harbor Laboratories during the spring months of 1960.

(3) Residence Time of Phosphorus in Sea Water and Phytoplankton

Rates of phosphorus turnover will be studied seasonally at selected areas in Puget Sound. Radioactive phosphate tracer will

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be added to enclose sea-water samples, and activity in the dissolved and particulate phases will be measured as time progresses. The preliminary is to determine the sampling frequency and duration of the experiment required to determine the flux and equilibrium activity with sufficient accuracy; thereafter, the feasibility of separating the various size or trophic levels in the plankton will be studied.

Contractor: University of Texas, Institute of Marine Science

Contract: AT(40-1)2580

Brief Title: The Normal Zinc Cycle in a Productive Bay

Investigators: Patrick L. Parker and Howard T. Odum

Scope of Work:

The biogeochemistry of zinc is being studied in a representative estuarine environment. The concentration of zinc in samples of phytoplankton, invertebrates, benthic plants, vertebrates, bacteria and recent sediments is being determined. An attempt is being made to isolate a small area of a shallow bay by enclosing it in a fiber glass cylinder in order to study the rate of uptake of both radioactive and normal zinc by the organisms enclosed therein. Hourly diurnal sampling of this enclosed area should then yield data on the movement of the zinc in the community, its diurnal cycle, if any, and its loss to and regeneration from the sediments.

The concentration of zinc in samples collected from the bay through Aransas Pass out into the Gulf of Mexico (5 miles) is being determined. These samples include samples of the water. This should establish the concentration gradient, if there is one.

Contractor: Columbia University, Lamont Geological Observatory

Contract: AT(30-1)1808

Brief Title: Circulation of the Deeper Oceanic Waters

Investigator: Maurice Ewing

Scope of Work:

We propose to determine the time scale of ocean circulation and also to establish the basis for a survey of natural radiocarbon distribution to be used as a control for future tracer experiments following carbon-14 produced by nuclear tests to investigate ocean circulation. We will sample along the track of the research vessel VEMA during world-wide cruises at depths which represent the typical water masses. Particular attention will be paid to the isolated basins where circulation is expectably reduced.

A hydrographic program is planned to lend support to the overall carbon-14 program in the determination of water masses, and will investigate the nature of the deep circulation through standard hydrographic means. Water masses and their boundaries will be identified, and features of the chemistry of density indicating increased or reduced circulation may be quickly known.

Neutrally buoyant floats will be used for deep current measurements, such as study of water movement between the Pacific and Atlantic, as well as observations on movement of bottom water of Antarctic origin. Development will continue on a long-period float for detection of the average deep movement in the central oceans.

Bottom sediment thermal gradient measurements will be made, and thermoflux measurements from a great variety of areas may be expected. These measurements will be correlated with topographic and structural feature and with the studies of the bottom water circulation.

Contractor: Columbia University, Lamont Geological Observatory

Contract: AT (30-1) 2493

Brief Title: Rates of Transfer and Mixing of Carbon Dioxide in the Dynamic Carbon Reservoir

Investigator: Wallace Broecker

Scope of Work:

The following investigations will be carried out:

1. Monitoring atmospheric carbon-14 concentrations. Carbon dioxide collections will be made three times each month (on the 5th, 15th, and 25th) at four stations: College, Alaska; Alpine, N.J.; Kingston, Jamaica; and Antofagasta, Chile. At least two samples per year will be measured from each station with more frequent checks of the carbon-14 level at Alpine. The remainder of the samples will be held for analysis if detailed coverage proves warranted.

2. Analyses of from 10 to 20 marine shells collected between 1940 and 1950 and prior to 1915. These samples will be chosen to give wide coverage of the oceans. The analyses should establish the pre-bomb level of carbon-14 in the surface oceans as well as yield an estimate of the extent to which fossil carbon dioxide (from the burning of coal and oil) reduced the surface ocean carbon-14/carbon-12 ratio.

3. Tracer experiments with carbon-14 and chlorine-36 to determine the factors controlling the exchange rate of carbon dioxide between the oceans and the atmosphere. Preliminary experiments will be carried out in the laboratory using carbon-14 alone to determine the pH, temperature, ionic strength and air mixing dependence. Once this has been established, field experiments to determine the water agitation (surface area) effect will be carried out. The samples will be assayed using a liquid scintillation counter.

4. Analyses of organic material from bone, bone carbonate, muscle tissue, blood and breath carbon dioxide to determine the residence time of carbon in humans.

5. Analyses of the carbon-14/carbon-12 ratio in various chemical and mechanical fractions of selected soil types to determine the mean residence time of carbon in "humic" material.

Contractor: The Bermuda Biological Station for Research, Inc.

Contract: AT(30-1)2078

Brief Title: The Plankton Ecology and Related Chemistry and Hydrography of the Sargasso Sea

Investigator: John H. Ryther (Woods Hole Oceanographic Institution)

Scope of Work:

This project has as its principle objective the study of seasonal and annual variations in the production and distribution of plankton, including both plant and animal representatives and considering individual species as well as total populations, and the related chemical and physical factors, in a truely oceanic environment. The study is carried out from Bermuda where quick access to the deep sea provides a unique opportunity to make oceanographic observations at intervals of two weeks or less throughout the year.

To date we have completed two years of observations which include measurements of incident radiation, light penetration, temperature, salinity, inorganic and total phosphorus, nitrite, nitrate, silicate, primary organic production, chlorophyll and standing crops of phytoplankton and zooplankton. We are also carrying out such physiological experiments concerning the photosynthesis, growth, nutrition, metabolism, etc. of the phytoplankton and zooplankton as provide an aid to the understanding of their ecology.

Contractor: Woods Hole Oceanographic Institution

Contract: AT(30-1)2174

Brief Title: Radioelement Studies on the Oceans

Investigator: V. T. Bowen

Scope of Work:

Studies of the concentrations of radioisotopes in ocean water will be continued. Although the North Atlantic and equatorial South Atlantic oceans are the major sites of sampling, and the Sargasso Sea an area of special interest, samples from the Bering Sea are being processed, and some from the Arctic Ocean are planned. Measurement of strontium 90 and occasionally of cesium 137 are permitting conclusions about convective overturn, mixing in the horizontal plane, and the seasonal accumulation of precipitation on the open oceans. Samples taken from various depths permit inference of vertical components of diffusion and of convective mixing. Measurement of cerium 144 and promethium 147 appear to indicate rates of removal of radiocolloids from surface waters, and rates of sinking of particulate matter. We have begun processing of samples of plankton for analysis of these isotopes, and plan to examine also, samples of particulate matter from depth.

Analytical and radiochemical studies of plankton organisms will be continued and expanded, both of field collections, and of laboratory populations. About 25 trace constituents are now sought, as well as some major elements. Special attention is given to the rare earths. Studies are being continued on the metabolism of vanadium by several tunicate species in culture.

Contractor: University of Miami, Marine Laboratory

Contract: AT(40-1)2411

Brief Title: The Geochemistry of Radioactive Elements in the Marine Environment

Investigator: F. F. Koczy

Scope of Work:

1. Absolute age of marine sediments is determined by analysis of the ratio of protactinium-231 to thorium-230. As both isotopes are daughter products of uranium, and as it can be assumed that they are precipitated in a time period small compared to their half life, the ratio in sediment layers gives the age of formation of this layer, as long as no older sediment occurs. This method will be applied to several deep-sea cores in order to obtain an absolute chronology and to study the formation of deep-sea sediments.

2. Slow chemical processes in the sediment will be studied in the laboratory by the use of tracers. First results have been obtained with the adsorption of phosphorus on kaolin and the chemisorption of phosphorus on carbonates. Other components of the deep-sea sediment will be studied such as montmorillonite, phillipsite and manganese and iron hydroxides. Equilibrium constants of some of the important compounds in the sediment will be studied.

3. The formation of lime shells of foraminifera, coccolithophorides, pteropods, and some of the mollusca will be studied using calcium-45 as a tracer. Furthermore, we plan to study the calcium metabolism of certain marine bacteria, the role of which in the production of carbonate sediments seems to be important.

Contractor: University of California
Scripps Institution of Oceanography

Contract: AT(11-1)34, Project 44

Brief Title: Marine Geochemistry I

Investigator: Edward D. Goldberg

Scope of Work:

Geochronology:

A. A systematic study of the rates of accumulation of deep-sea clay sediments in the Pacific, Atlantic, and Indian Oceans is being made by the use of the ionium/thorium method. Although present results indicate that in a given area the rate is higher in valleys than on slopes, nonetheless, the South Pacific in general shows slower values (around 0.3 mm/1000 years) as compared to the North Pacific, Atlantic, and Indian Oceans (values of the order of millimeters/1000 years).

B. We have discovered a new cosmic-ray produced isotope in nature (silicon-32, reported in Phys. Rev. Letters, Vol. 3, p. 380, 1959, with a more complete article in Science). Silicon-32 has a half-life of around 700 years and its potential as a dating tool for siliceous deposits of a biological origin is currently under study. Over fifteen sponge samples from all over the world have been gathered for this problem.

Clay Mineralogy:

A study is being made of the clay minerals in the World ocean using quantitative x-ray diffraction techniques. At present the use of montmorillonite/illite ratio provides the most significant parameter for describing sedimentary domains, especially with respect to the origins of the precursors of the clays. The concentrations of kaolinite and chlorite will be ascertained subsequent to the construction of a hot-stage goniometer.

Trace Elements in Seawater:

The distribution of several trace elements in seawater, whose concentrations are of the order of parts per billion, have been chosen for study on the basis of their presumed chemical

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behavior. Work has been completed on the concentration of barium in the North and South Pacific using an isotope dilution technique with a 60 degree mass spectrometer. Barium is apparently undersaturated with respect to precipitation of the sulfate and is higher at great depths by a factor of five than at the surface. Both regeneration of barium from the sediments and transport from surface waters to depths by organisms have been invoked to explain its distribution. At present we are initiating work on lithium, again using isotope dilution methods with the 60 degree mass spectrometer.

Contractor: University of California
Scripps Institution of Oceanography

Contract: AT(11-1)34, Project 44

Brief Title: Marine Geochemistry II

Investigator: Gustaf Arrhenius

Scope of Work:

Knowledge of the modes of transfer of radioelements from seawater to ocean sediments is essential for the establishment of geochronological methods, for the prediction of the pathways of artificial radionuclides, and for tracing geochemical processes of importance in the material budget of the Earth.

Inference regarding these processes is drawn from studies of the partition of elements between minerals crystallizing from sea water. Apatite has been found to be an important transfer medium, concentrating large amounts of thorium, zirconium, hafnium, and rare earth elements, and in case of favorable redox conditions also uranium. The crystallite size of the apatite is found to have a marked influence on the rate of transfer.

A remarkably high content of thorium has been found in zeolites belonging to the phillipsite-harmotome series. In this case the thorium is not accompanied by the chemically similar rare earths, which indicates the operation of a highly selective process. The zeolite specimens with a high thorium content contain abundant microscopic inclusions of barite, and present investigations are aimed at determining whether the thorium is captured in the silicate or in the barite structure. The barite is, to a considerable degree, substituted with celestite ($SrSO_4$) which causes an unusual crystal habit.

Attempts at resolving the individual composition and structure of the numerous minerals which are aggregated into manganese nodules, have demonstrated that thorium occurs in a mineral fraction which is dominated by goethite (FeOOH) and authigenic iron silicates, whereas uranium is concentrated in a yet unidentified non-magnetic mineral.

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A study has been made by W. Sackett of the protactinium content of sediment samples from stratigraphically well-defined oceanic sequences. This work indicates that the protactinium/ionium ratio can advantageously be used for age determination. This method is complementary to the ionium/thorium method, insofar as it is based on different assumptions. The results obtained by the former method can thus provide an independent check of the assumptions involved in the latter.

Contractor: Columbia University, Lamont Geological Observatory

Contract: AT(30-1)2364

Brief Title: Age Determination Studies on Deep Sea Cores

Investigator: Wallace S. Broecker

Scope of Work:

The members of the uranium and thorium radioactive series have potential for the absolute dating of sedimentary deposits. Because of the different geochemical behavior of the various elements during weathering, solution, transport, and deposition, various types of inequilibrium are produced. If the degree of inequilibrium at the time of deposition of an ancient sediment can be predicted then measurement of the residual inequilibrium allows an age to be computed.

The geochemistry of these elements in the weathering cycle is not presently understood well enough to employ the disequilibrium method of age determination with any confidence. The behavior is being studied in the rivers, lakes, and sediments of the Great Basin interior drainage system. Because the lakes have no outlet they provide an ideal situation for such a study.

The concentration of ionium in ocean water is below its equilibrium value whereas it is found in excess in surface sediments. The ionium/uranium activity ratio approaches unity with increasing depth. This implies that ionium is deposited in the sediments preferentially to uranium. An attempt has been made to use the decay of ionium to date deep sea clays but the necessary assumptions have not been confirmed. This laboratory is currently studying the geochemistry of ionium in deep sea clays using carbon-14 dates on coexisting carbonates as a control.

In marine and perhaps fresh water carbonates, uranium is in great excess over ionium. With time equilibrium will be achieved. The reliability of such dates will be checked by comparison with radiocarbon dates. If the cross-check is satisfactory the method will be applied to carbonates beyond the range of radiocarbon dating.

Contractor: A & M College of Texas

Contract: AT(40-1)2061

Brief Title: A study of Some Factors Concerning Radioactive Materials in the Sea

Investigator: Richard G. Bader

Scope of Work:

The purpose of this investigation is to examine some of the pertinent factors which affect the distribution and localization of certain metallic ions in near shore marine waters. One major factor being considered is the relationship between the sedimentation process and the removal and retention of such ions from sea water. This part of the study will be conducted by investigating the organic adsorption by various minerals, i.e., montmorilionite, kaolinite, illite, quartz, calcite, etc. with the view of understanding the effect of the organic material on the uptake and retention of metals. The organic adsorption will be studied by using carbon-14 and tritium labeled organic compounds. The process of chelation and complexing of strontium, cesium, calcium, cobalt, etc. by various naturally occurring organic material will also be studied. In addition, the ability of the biota to strip or recycle metals which have become associated with mineral particles will be investigated. The experiments for this work fall into two categories: (1) to test directly whether benthic animals can strip organic material and metals from sediments by their normal digestive process and (2) to evaluate the role of the periphytic bacteria on the process of adsorption, desorption and recycling.

Contractor:	U. S. Bureau of Commercial Fisheries Shellfish Laboratory*
Letter Agreement:	AT(49-7)5
Brief Title:	Accumulation of Radioactivity by Marine Fish and Shellfish
Investigator:	Walter A. Chipman

Scope of Work:

Investigations are conducted at the radioisotope laboratory on the uptake and accumulation of radionuclides by marine fishery organisms and the effects of ionizing radiations on the development, growth, and well-being of these forms. Emphasis is placed on measurements of maximum accumulation levels and various factors affecting accumulation in marketable tissues of oysters, clams, scallops, crabs, shrimps, and various fishes. The radionuclides under study are those present in many radioactive wastes or those that might enter coastal waters from the use of atomic devices. These include a number of fission products and radionuclides of several metals. Consideration is given to mode of uptake and availability of radionuclides to marine life when present in the water in different physical and chemical forms. Since there is need for information on the passage of radionuclides through food chains leading to economically important species, the investigations include studies on several food organisms, including marine phytoplankton and zooplankton. The effects of radiation from accumulation of radionuclides in the bodies of marine fishes and shellfishes are studied following long-term exposures of the organisms to sea water containing the radioactive material. Damaging effects on the growth and development of the animals during their early life histories are determined. Comparisons of the radiosensitivity of various species and of different tissues of a species are made following exposure to external radiation from a cobalt-60 source.

* This project supported jointly with Bureau of Commercial Fisheries, U.S. Department of the Interior.

Contractor: University of Hawaii

Contract: AT (04-3) 330

Brief Title: A Study of the Effects of Ionizing Radiations upon Developing Sea Urchins

Investigator: Sidney C. Hsiao

Scope of Work:

A systematic study is made of the effects of graduated doses of X-rays, gamma rays and beta particles of different quantum energy (range = 0.067 - 1.701 Mev.) on the gametes and early developmental stages of the sea urchin Tripneustes gratilla. The developmental stages used are zygote, cleavage stages, newly hatched blastula, prism and early pluteus. In the case of gametes the ability of the irradiated sperm to fertilize normal eggs is measured in each dosage level of each type of radiation, and the ability of the differentially irradiated eggs to be activated by normal sperm is observed in a similar way. The effects on fertilization produced by irradiating both gametes are analyzed quantitatively according to type and dosage of radiation. The dosage mortality relations between the different stages of developing embryo and the irradiating agents are analyzed statistically in terms of LD 50 and its standard deviations. Rate of development and morphological changes produced under radiation are examined.

Contractor: Naples Zoological Station

Contract: AT (30-1) 2507

Brief Title: A Study of Iodine Metabolism and Evolution of Thyroid Function in Lower Vertebrates and Invertebrates

Investigator: Peter Dohrn

Scope of Work:

In order to further elucidate the biochemistry of iodine and its physiology in invertebrates and in lower vertebrates, we will study with the help of radioisotope iodine-131:

1. The nature of iodinated organic compounds in the endostyle of ammocoetes and in the thyroid of lampreys, in order to find out the mode of biosynthesis of thyroid hormones and the type of its secretion, transport and metabolism in lower vertebrates.

2. The fixation of iodine and the nature of iodinated compounds synthetized by Protochordata in order to decide if the capacity to synthetize thyroid hormones is limited or not to the vertebrates only.

3. Metabolism of iodine by Anthozoa and bacteria, in order to discover eventually an elementary thyroid function. This problem will be connected with the mode of action of thyroid hormones and its cellular metabolism in receptor tissues of upper vertebrates, that will also be studied.

Contractor: Naples Zoological Station

Contract: AT(30-1)2044

Brief Title: Research in Marine Biology using Radioisotopes

Investigator: Peter Dohrn

Scope of Work:

Incorporation of labeled sulfur and vanadium in blood cells of tunicates in relation to the biosynthesis of hemovanadin.

Action of vanadium upon the incorporation of labeled surfur in the mantle tissues of tunicates.

Incorporation of labeled nucleotides in the eggs of echinoderms and tunicates during development.

Deoxynucleotide metabolism in developing embryos and growing tissues with special reference to the enzymatic reactions involved in the synthesis of deoxynucleotide-polyphosphates.

Incorporation of tritiated compounds in nuclei of marine invertebrate larvae, with special reference to the effect of the radiation on the cytoplasm.

Physiology of fertilization investigated with labeled compounds (differentiation).

Contractor: Smithsonian Institution*

Contract: AT(30-1)2409

Brief Title: Systematic Zoological Research on the Marine Fauna of the Tropical Pacific

Investigator: Leonard P. Schultz, Fenner A. Chace, Jr., and Harald A. Rehder

Scope of Work:

The first objective is to bring together, catalogue, preserve, and maintain the collections of fishes, mollusks, and other marine invertebrates made under government auspices prior to and following the first nuclear experiments in the Pacific so that those collections will be readily available for study. The second objective is to arrange for the preparation of basic revisions or monographs of the groups of marine animals of the tropical Pacific and related regions in order to furnish reliable descriptive knowledge of the fauna of that little known area, both for its own sake and as a body of basic data by means of which any future faunistic changes resulting from nuclear tests in the area can be detected and interpreted. Contracts will be made with qualified specialists throughout the world to study, identify, and monograph material of the various groups in the national collections. Material of the major groups will be studied in Washington; that of the smaller groups will be shipped to the collaborators for study at their own institutions.

* This project supported jointly with Office of Naval Research.

Contractor: Woods Hole Oceanographic Institution

Contract: AT(30-1)1918

Brief Title: The Biology, Chemistry and Radiochemistry of Marine Plankton Populations

Investigator: Bostwick H. Ketchum and Vaughan T. Bowen

Scope of Work:

This program is a combined laboratory and field study of the ecology of marine phytoplankton and zooplankton populations.

The field observations are made on a line of stations extending from Montauk Point, Long Island to Bermuda. Conditions on these stations vary from the coastal environment with shallow waters to the unique environment of the slope water and the Gulf Stream, to the extremely clear water conditions found in the open ocean waters of the Sargasso Sea. The section thus gives a range of depth and of environmental conditions which would be difficult to equal in any other part of the world. Selection of these stations essentially reflects a use of the ocean as an experimental system in which the conditions of the experiment are set and determined by nature.

Observations are made at these stations at four times throughout the year to evaluate seasonal changes. At each visit the marine climate, as represented by salinity and temperature distribution is determined and the distribution of nutrients is evaluated. The standing crop of both phytoplankton and zooplankton at the various locations is also measured. Experimental determinations of the rate of photosynthesis by the phytoplankton populations are made under controlled light conditions on shipboard.

In the laboratory the experimental work includes studies of the effects of variations in environmental factors on the rates of growth and of photosynthesis of pure cultures of marine algae. The changes in the pigment content of the cells

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and in the rate of photosynthesis are studied as a function of the variation of temperature, light and nutrient conditions. Additional cruises are sometimes made in order to correlate the variations in the natural environment with the effects which have been found in the laboratory culture experiments.

The zooplankton are analyzed both for species composition, and for the elemental and organic constituents of the various groups of plankton. The ultimate objectives of this work is to assay the biomass in terms of various essential elements which it contains, and to determine the exchanges of materials which result from the growth and development of populations consisting of various species.

Contractor: University of Hawaii, Hawaii Marine Laboratory

Contract: AT(04-3)56

Brief Title: Uptake of Radioisotopes and Their Transfer through Food Chains by Marine Organisms

Investigator: Robert W. Hiatt

Scope of Work:

The research concerns the passage of long-lived radioisotopes through marine food chains and also how such ions get into and out of fish. A method has been developed for the interpretation of the results of radioactive tracer experiments with aquatic animals, independent of specific experimental conditions, and this method is being applied to the problem of the prediction of possible radiocontamination in known environmental conditions.

Investigations using the teleost Tilapia mossambica have shown that this fish accumulates calcium and strontium directly from the environment through its integument. Within limits, both fresh water and sea water adapted Tilapia accumulate radioactive calcium or strontium as an inverse function of the stable calcium plus strontium in their environment. However, the accumulation of either isotope is less when the environment contains only calcium or only strontium. By the application of radioisotope techniques, it has been conclusively shown that (a) all the exposed epithelia (gills, mouth, body) are uniformly permeable to strontium and calcium; (b) the gut is not a major site for absorption of these ions by Tilapia; and (c) Tilapia swallow approximately 10-15 milliliters of sea water per day and excrete only one to two milliliters of urine, whereas in fresh water they swallow none, but excrete as much as 15 milliliters of urine. The information obtained from every type of experiment implies that both calcium and strontium enter teleosts primarily by diffusion from the external medium.

Similar experiments are being performed using a variety of marine organisms with the aim of establishing the role of each in the transfer and concentration of specific radioisotopes from the environment or by way of the food chain. A variety of ions are being studied in each of these experimental procedures.

Contractor: University of Hawaii, Marine Laboratory

Contract: AT(04-3)235

Brief Title: An Investigation of the Possible Effects of Ingestion of Radioactive Fish and the Nature and Biology of Toxins Found in Certain Fishes

Investigator: A. H. Banner

Scope of Work:

The purpose of this investigation is to explore the cause of the Ciguatera type of toxicity found in fishes of the central Pacific. In this toxicity, fishes from restricted areas are found to be highly toxic when eaten, yet the same species are innocuous in other areas. The fish that is the basis of the present study is a red snapper, Lutjanus bohar.

Because of the marked increase in number of fish poisonings in the southern Marshalls during the period of nuclear experiments at Eniwetok, the toxicity has been attributed by the natives to radioactivity. The first aim of the investigation was to find if there was a correlation between the fish toxicity and radioactivity; results now at hand, based on fishes from Eniwetok and Majuro in the Marshall Islands, and from Christmas and Palmyra in the Line Islands, indicate that there is no such relationship. The second aim of the research is to attempt to ascertain the true cause of the toxicity. The most widely accepted hypothesis on the cause of toxicity is that the toxin comes to the fishes through the food chain; that hypothesis is at present being investigated through (1) feeding experiments which attempt to induce toxicity in normally nontoxic fishes; (2) studies on the food habits of toxic and nontoxic L. bohar; and (3) field studies of the food of the fishes to be undertaken extensively after the perfection of a field test for toxicity, at present under development.

Contractor: University of Hawaii

Contract: AT(04-3)15

Brief Title: Algal Productivity of the Tropical Pacific as Determined by Isotope Tracer Techniques

Investigator Maxwell S. Doty

Scope of Work:

Carbon-14 is being utilized in the development of a method of assaying primary productivity in the sea and on ocean shores. Thus far, the general range of variation to be expected with depth and geography has been explored. Currently, attention is being directed toward the interpretation of *in vitro* results in terms of natural productivity. The nature of the increase in phytoplankton productivity as oceanic island shores are approached has been determined. A daily rhythm to photosynthesizing ability of the phytoplankton has been discovered which is dependent upon the time of day the phytoplankton is sampled. The maximum of photosynthesizing ability seems to occur during the morning daylight hours and the minimum, which near the equator is often only one-sixth that of the morning fixation rate, occurs near 1900 hours in the evening, but this periodicity decreases as latitude increases. "Patchiness" of phytoplankton is being studied as well as productivity with depth, latitude, and longitude.

Contractor: University of Connecticut
Marine Research Laboratory

Contract: AT(30-1)2487

Brief Title: Radioactive Zinc-65 in Marine Organisms in Fisher's Island Sound and Its Estuaries

Investigator: Donald M. Skauen and John S. Rankin

Scope of Work:

Selected bivalve molluscs which have been collected at established stations in Fisher's Island Sound and its estuaries will be prepared for radioassay by extraction of zinc. The specific activities of zinc-65 will be determined on these samples.

Contractor: Columbia University

Contract: AT(30-1)2100

Brief Title: Pathological Effects in Pacific Reef Fishes Exposed to Radioactive Fallout

Investigator: Aubrey Gorbman

Scope of Work:

One of the most plentiful radioisotopes in radioactive fallout is iodine-131. It is known that certain environmental levels of radioiodine can lead to complete thyroid destruction in laboratory experiments in fishes. To learn whether such thyrotoxic levels of iodine-131 are achieved in areas of heavy fallout, several collections of coral reef fishes have been made at Eniwetok Atoll. These are being studied for indices of level of thyroidal epithelial injury, and injury to juxtathyroidal vascular, connective, and epithelial structures. This information is being correlated with known facts of ecological and food chain relationships of affected species.

Contractor: University of Washington
Laboratory of Radiation Biology

Contract: AT(45-1)540

Brief Title: Radioactivity Studies in the Central Pacific

Investigator: L. R. Donaldson

Scope of Work:

The work of the laboratory has included studies of the biological effects of ionizing radiations upon aquatic organisms and field studies in the Central and Western Pacific to determine the biological and geographical distributions of radioisotopes from the nuclear experiments at Bikini and Eniwetok Atolls.

Prior to the work in the Pacific, three years of research upon the effects of x-rays on aquatic organisms, especially fishes, provided valuable training and experience for the field studies. The x-ray experiments, for which the principal test animals were salmon and trout, were designed to study morphological, pathological and mortality effects. From the experiments it was determined that the number of morphological abnormalities was directly related to the amount of exposure but that the types of abnormalities were the same as occurred in the control lots; the reproductive tissues and the hematopoietic tissues of the kidney were especially sensitive to x-rays but all tissues were damaged in proportion to the dose received. The lethal dose for salmon and trout was about twice that for man.

Field work in the Pacific began with the first series of nuclear experiments at Bikini Atoll in 1946 and has been a part of all test series since that time. In the early surveys only the amount of radioactivity in biological samples was determined, but, later, both the amount and the identity of the radioisotopes present were determined. Biological samples -- marine and terrestrial -- as well as water and soil were analyzed. The greatest number of samples have been obtained at or near Eniwetok, Bikini and Rongelap (80 miles east of Bikini) Atolls.

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Five series of collections have been made of water and plankton from the high seas. The first collection, during March and April of 1955, was organized by the Health and Safety Laboratory of the New York Operations Office. The area in which samples were collected began to the east of the Marshall Islands and continued on to Eniwetok, to Guam, to the Phillipines and terminated near Japan. In each of two years, 1956 and 1958, samples were obtained from two surveys, one in the restricted area near Eniwetok and the other between Eniwetok and Guam. Other plankton and water samples have been obtained from Eniwetok, Bikini and Rongelap lagoons. In addition, biological samples of marine and terrestrial organisms for radiological analyses have been obtained from the following locations: areas in the Marshall Islands, other than Eniwetok and Bikini; the Gilbert Islands; the Caroline Islands; the Mariana Islands; the Palau Islands; and the Gulf of Siam. The total number of samples analyzed has been greater than 5,000 in some years. Not included in this total are 2,700 samples of tuna fish from the Japanese fishery in the Western Pacific that were analyzed in 1958-59.

The results of the Laboratory's work have been given in 61 reports most of which have been published by the Atomic Energy Commission; others have been published in journals such as Growth, Science, and Pacific Science. Some reports, especially the early ones, have been classified.

Of special interest is the present ecological program at Rongelap Atoll, an atoll accidentally hit by fallout from the Bravo event of March 1, 1954 and from which it was necessary to evacuate the native population. The natives were returned in June, 1957, at which time the radioisotopes in the environment were well below the levels considered to be hazardous but at a level where they could be detected and measured. Thus a unique opportunity was available for a field study of the movement of radioactive elements through the biosphere. Collections of samples for monitoring radioactivity were made during the first four years after the Bravo event and in 1958 an enlarged program was initiated to provide ecological information, as well as monitoring data. The

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objective of the program is to study the cycling of elements from the sea and lagoon onto the land and back to the sea. Information on the amount and kinds of radioisotopes present in the total plankton population and bottom sands of the lagoon has been obtained. A study of the relationship of radioactivity in fishes to the species, size, age and food habits of the fishes as well as to the environment in which the fishes are living has been undertaken. On land, lysimeter studies have been made to measure the movement of elements through soil and the effect of fertilizers upon this movement. Other work includes plant mapping which is a basic part of the program. Plant physiological and nutritional studies and observations upon birds to determine their role in the transfer of elements from the sea are a regular part of the survey.

Some of the significant results of the work in the Pacific are as follows:

(1) Plankton organisms are good biological indicators of radioisotopes in the sea. Relative to sea water the concentration in plankton is usually of an order of 1,000 or more.

(2) Shortly after a nuclear detonation the fallout levels of radioactivity in plankton are high due to the adsorption of radioisotopes to external surfaces and the accumulations of radioactive particles by filter feeding organisms. After a few weeks the radioisotopes present are limited in number and are principally those that have been absorbed.

(3) A few weeks after fallout the radioisotopes present in marine organisms are mostly the non-fission products, isotopes of iron, zinc, cobalt and manganese. Of the three long-lived fission products that might be expected -- strontium-90, cesium-137 and cerium-144, -- strontium-90 and cesium-137 are either absent or present in only small amounts. Some cesium-144 is found in plankton and algae. For terrestrial organisms living in the same general area the reverse is true, i.e., fission products are the primary radioactive materials present.

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(4) Radioisotopes falling into the sea near the Bikini-Eniwetok area flow westward with the surface currents of the North Equatorial system at a rate of advance of 7 to 10 miles a day.

(5) One year after the 1954 series, measurable amounts of radioactivity were found in the ocean waters 3,000 miles west of Eniwetok but the amount was less than that from potassium-40, a naturally occurring radioisotope in sea water.

(6) Fallout materials that reach the ocean waters below the thermocline move at a considerably slower rate than surface currents. It is expected that some radioactive materials remain in the deep water or ocean bottom near Bikini and Eniwetok Atolls.

(7) Gross changes or morphological abnormalities in fish populations have not been observed by this Laboratory although the destruction of thyroid tissue in fish collected from the immediate vicinity of a test site has been observed by another worker.

(8) The distribution of specific isotopes in tissues of many species of plants and animals, both marine and terrestrial, has been determined.

(9) From these data (8) the decline of radioactivity in various biological organisms can be predicted if the age of the fallout material is known.

(10) An indirect but important result of the work has been the benefit to productivity studies elsewhere from the knowledge of the distribution of radioisotopes in biological organisms in the Pacific.