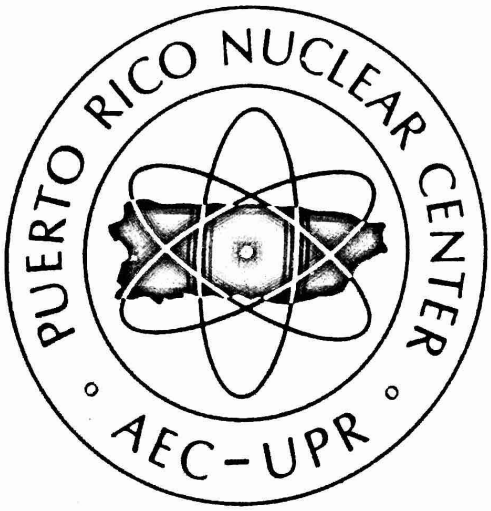
PRNC – 176
Distribution Category UC-02

PUERTO RICO NUCLEAR CENTER

ANNUAL REPORT, 1973



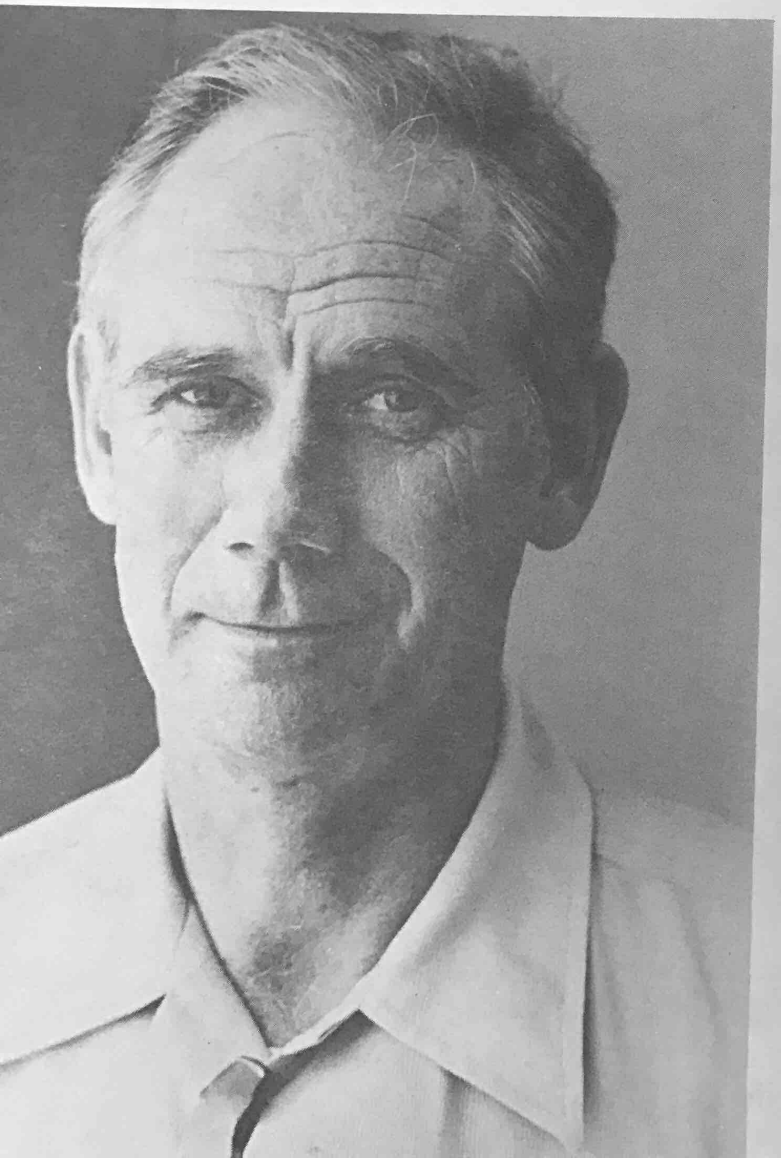
OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40-1)-1833 FOR U S ATOMIC ENERGY COMMISSION

Dr. Arturo Morales Carrión
President, University of Puerto Rico

TABLE OF CONTENTS

* The Environmental Impact Studies Section will be published as a separate volume except for the Guayanilla Bay Project included in this Report.

Dr. Lawrence S. Ritchie
Director



Dr. Frank G. Lowman
Associate Director at Mayagüez

OFFICE OF THE DIRECTOR

An evaluation of the Puerto Rico Nuclear Center (PRNC) may advisedly begin with a brief statement of its conception, development, and its currently stated mission.

PRNC was established to implement in part President Eisenhower's "Atoms for Peace" proposal, and his expressed intent to "hasten the beneficial uses of the nuclear forces throughout the hemisphere both in industry and in combating diseases" (OAS, Panama, 1956).

From the beginning in October 1957, PRNC has been operated by the University of Puerto Rico under contract with the Atomic Energy Commission. Its initital function was to provide training in nuclear technology that would contribute to the technological development of Latin America. From a Basic Course in Radioisotope Techniques the breadth of the training program has continued to increase to include active participation in the graduate programs of the University of Puerto Rico leading to the Ph.D. and M.S. degrees in fields such as Chemistry, Biology, Physics, Radiological Health, Nuclear Engineering, Agriculture, and others, participation in a Medical Residency Program in Radiation Oncology, offering a new 5 month Course in Nuclear Medicine, providing Nuclear Reactor Supervisor and Operator Training Courses, offering Summer Workshops on Electrical Power Generation for secondary teachers, providing thesis research opportunities for students from universities located in continental United States and other countries, and many other specialized training activities.

Early in the history of PRNC, research programs were developed to supplement the training activities. This development continued until research was being conducted in Terrestrial Ecology, Marine Biology, Radiation Oncology, Nuclear Medicine, Tropical Parasitology, Virology, Tropical Agriculture, Health Physics, the Physical Sciences, and Nuclear Engineering. This research development characterized PRNC as a training-research institute, and fostered collaborative endeavours in the graduate programs of the UPR Medical Sciences Campus, the UPR Rio Piedras Campus, the UPR Mayaguez Campus, and with outside institutions.

A new phase of program development was thus introduced: Training in Research. This has primarily been carried out by providing opportunities for thesis research to graduate students.

The most recent statement of the mission of PRNC includes the following points:

a. Provide training and education in the Nuclear Field for Latin American and Puerto Rican students utilizing Spanish as the medium of instruction to the extent possible.
b. Conduct research directed toward the needs of Puerto Rico and continental U.S.A., best carried out in this semi-tropical island environment.
c. Operate a nuclear training and research laboratory with a relatively modest budget for program and equipment that can serve as a model for a developing country.

The current program of PRNC is oriented toward problems of the tropics in a broad spectrum of disciplines, and is thus fulfilling the above expressed mission.

During FY-1973, a total of 225 students received training at PRNC. From this group there were 34 from South America, 10 from Central America, 8 from the Caribbean, 164 from Puerto Rico, 5 from continental USA, and 4 from Asia (See Tables 1,2,3—pp. 18-21). During the first 6 months of FY-1973, 32 students were doing thesis research at PRNC including several students from universities in continental USA, who are doctoral degree candidates. (See Table 5—p. 23)

Research accomplishments during 1973 are shown as published manuscripts, while current research activities are presented in the text of this Report. Publications include articles in scientific journals, complete papers included in the proceedings volume of scientific meetings, and topical reports published as part of the PRNC numbered report series.

Complementing its training-research mission are a number of services provided for Puerto Rico by PRNC. Impressive work is being done in relation to environmental impact studies for fossil and nuclear power plant sites. Much of this work is publishable and affords many leads for basic research. The Medical School of the University of Puerto Rico relies on the Radiation Oncology and Nuclear Medicine Divisions for teaching and training of their students in these fields. Services to the Puerto Rico Department of Health are provided through patients received by the Medical Divisions. Also an intensive assessment has been made on the hazards of X-rays over the entire Island in hospitals, medical and dental offices, and private laboratories through the X-Ray Survey Project. The Department of Agriculture is assisted through studies of fascioliasis, the liver fluke that affects cattle, sheep, and man. The causative parasite is virtually world-wide and its control constitutes a scientific challenge. Of probable practical applications to world food needs are investigations on oyster and shrimp (mariculture and fish culture) by the Radioecology Division.

PRNC exists to provide services in the broadest sense for Latin American countries. Each Division provides a combination of opportunities for nuclear training through formal courses, practical courses, graduate training in research, and through services such as radiation therapy, nuclear medicine diagnostic procedures, film badge services, reactor services, and others. The overall program in nuclear applications to Medicine, Marine Biology, Ecology, Agriculture, Bio-Medical Sciences, Physical Sciences, and Engineering is oriented toward problems of the tropics.

Financial support for Latin American students is provided primarily through fellowships from the International Atomic Energy Agency (IAEA). the Pan American Health Organization (PAHO), the Organization of American States (OAS), and the PRNC Student Economic Aid Program, a fund provided through the University of Puerto Rico. PRNC could accommodate at least twice as many students from outside of Puerto Rico, but additional fellowship support would be needed to accomplish this objective.

Development of the peaceful applications of nuclear energy has continued since the close of World War II at an increasing rate in a continually larger number of countries.

One can expect that the potential for development will continue indefinitely. Nuclear Medicine has been stated to be the Medicine of tomorrow. Environmental protection measures require basic ecological investigations that utilize nuclear tools. Agriculture of an advanced order for the tropics appears to be an urgent need.

PRNC should have an exciting future if it remains in the forefront of development and utilization of nuclear energy applications that can contribute to the resolution of problems of human existence.

The following summaries are included as a supplement to this section to provide an appreciation of the educational backgrounds of the senior staff and the scientific productivity of PRNC:

a. Senior Staff
b. Publications
c. Papers Presented
d. Seminars

Senior Staff

Director's Office				
Lawrence S. Ritchie	Director	Ph.D.	Northwestern University	Parasitology
Frank G. Lowman	Associate Director	Ph.D	University of Washington	Radiation Biology
Frank G. Lowman	Assoc. Dir.-Environmental Sciences			
Víctor A. Marcial	Assoc. Dir.-Medical Sciences	M.D.	Harvard University	Radiation Therapy
Marie Barton	Executive Assistant to the Director	B.S.	New York University	Business Administration
Training and Information Division				
Frederick E. Rushford,	Head	B.S.	Trinity College	General Science
Luis F. Baez-Melendez	Technical Associate I-Reproduction		University of Puerto Rico	Basic Studies-Electronics
Radiation Oncology Division				
Víctor A. Marcial	Head	M.D.	Harvard University	Radiation Therapy
Antonio Bosch	Senior Scientist I	M.D.	Universidad Autónoma de Mexico	Radiation Therapy
Zenaida Frías	Scientific Associate III-Med. Statistics	M.P.H.	University of Michigan	Bio-Statistics
José M. Tomé	Senior Scientist I (ad honorem)	M.D.	University of Zaragoza	Radiation Therapy
Jeannie Ubiñas	Senior Scientist I (ad honorem)	M.D.	Universidad Autónoma de Mexico	Radiation Therapy
Nuclear Medicine Division				
Aldo E. Lanaro	Head	M.D.	Universidad de Buenos Aires	Nuclear Medicine
René C. Dietrich	Scientist II	M.D.	Universidad Mayor de San Andrés	Nuclear Medicine
Myrta Cancel de Pagán	Scientific Associate II	B.S.	University of Puerto Rico	Zoology
Carmen C. de Villodas	Research Assoc. I-Nursing Services		Diaz Garcia School of Nursing	Nursing
Elba M. Velez Martínez	Admin. Assoc. I-Secretarial		University of Puerto Rico	Secretarial Science
Biomedical Sciences Division				
Frederick F. Ferguson	Acting Head	Ph.D.	University of Virginia	Parasitology
Jorge M. Chiriboga	Senior Scientist II	M.D.	Universidad de San Marcos	Medicine-Biochemistry
Raymond A. Brown	Senior Scientist I	Ph.D.	California Institute of Technology	Physical Chemistry of Proteins
Delfín D. De León	Senior Scientist I	D.V.M.	University of the Philippines	Veterinary Medicine
Julio I. Colón	Senior Scientist I	Ph.D.	University of Chicago	Microbiology
Felix Liard-Bertin	Scientific Assoc. III	B.S.	University of Puerto Rico	Electron Microscopy
Víctor A. López	Senior Associate		Inter American University	Microbiology
Jesús M. Cora Cora	Research Assoc. I	B.S.	University of Puerto Rico	Parasitology
Medical Physics Section				
E. Theodore Agard	Head	Ph.D.	University of Toronto	Medical Physics
José C. Pacheco	Research Assoc. III	M.S.	University of Puerto Rico	Radiological Health
Cecilia Ramírez	Technical Assoc. I	B.S.	University of Puerto Rico	Biology
Radioecology Division				
Kenneth W. Watters	Head	Ph.D.	University of Washington	Fisheries
Marine Biology Section				
Seppo E. Kolehmainen	Head	Ph.D.	University of Tennessee	Ecology
Mario D. Banus	Scientist II	Ph.D.	Massachusetts Institute of Technology	Physical Chemistry (Marine Zoology)
Dinkar P. Kharkar	Scientist II	Ph.D.	The Indian Institute of Science	Chemistry
George A. Seiglie	Scientist I	M.S.	Universidad de la Habana	Geology-Civil Engineering
Tin Mo	Scientist I	Ph.D.	Texas A and M University	Radiochemistry and Chemical Oceanography
Fausto Muñoz-Ribadeneira	Scientist I	M.S.	University of Puerto Rico	Chemical and Nuclear Engineering
Mounir T. Moussa	Scientist I	Ph.D.	University of Utah	Geology
Rosa Julia Santiago	Research Assoc. II	M.S.	University of Puerto Rico	Health Physics
John R. Montgomery	Research Assoc. III	M.S.	Old Dominion University	Chemical Oceanography
Terrestrial Ecology Section				
Richard G. Clements	Head	Ph.D.	University of Georgia	Agronomy
George Drewry	Scientist II	Ph.D.	University of Texas	Zoology
Arthur McB. Block	Scientist I	Ph.D.	Rutgers University	Physical Chemistry
José A. Colón	Research Associate I	B.S.	University of Puerto Rico	Biology

Environmental Impact Studies Section

Michael J. Canoy	Head	Ph.D.	University of North Carolina	Zoology
Elwyn D. Wood	Scientist II	Ph.D.	University of Alaska	Oceanography
F. Douglas Martin	Scientist II	Ph.D.	University of Texas	Zoology
Marsh J. Youngbluth	Scientist I	Ph.D.	Stanford University	Biology
James D. Parrish	Scientist I	Ph.D.	University of Rhode Island	Oceanography
José A. Suárez Caabro	Scientist I	Ph.D.	University of Havana	Zooplankton
Paul Yoshioka	Scientist I	Ph.D.	Scripps Institute of Oceanography	Zoology
Ellsworth H. Wheeler	Scientist I	Ph.D.	University of Rhode Island	Zooplankton
Robert Kendall	Scientist I	Ph.D.	Nova University	Physical Oceanography
Gary P. Owen	Research Assoc. II	M.S.	Scripps Institute of Oceanography	Marine Biology
Russell W. Davis	Research Assoc. II	M.S.	University of Puerto Rico	Marine Biology
Helen Mo	Research Assoc. III	M.S.	Texas A and M. University	Bacteriology
Leslie Piastro	Research Assoc. III	M.S.	University of Puerto Rico	Marine Science-Icthyology
María Luisa Nazario	Research Assoc. III	M.S.	University of Puerto Rico	Biology-Entomology
Vance P. Vicente	Research Assoc. II	M.S.	University of Puerto Rico	Marine Microbiology
Thomas Purcell	Research Assoc. II	M.S.	Old Dominion University	Phytoplanktonology
Joseph Kimmel	Research Assoc. II	M.S.	Old Dominion University	Icthyology
Paul Davis	Research Assoc. II	M.A.	Cal. State College, Hayward	Marine Biology
Mary E. Nutt	Research Assoc. II	M.S.	University of New Hampshire	Zoology
Carmen Cintrón	Research Assist. III	M.S.	University of Puerto Rico	Cytology
Byron S. Smith	Senior Associate	B.A.	Manchester College	Physics-Mathematics

Tropical Agro-Sciences Division

Francis K. S. Koo	Head	Ph.D.	University of Minnesota	Plant Genetics
David W. Walker	Senior Scientist I	Ph.D.	Washington State University	Entomology
José A. Ferrer-Monge	Senior Scientist I	Ph.D.	Louisiana State University	Genetics
Shreekant N. Deshpande	Scientist I	Ph.D.	Purdue University	Food Technology
Arturo Cedeño	Scientist I	Ph.D.	University of California	Plant Physiology
José Cuevas-Ruiz	Senior Associate	M.S.	University of Puerto Rico	Biology
Kenneth P. Mackay	Research Assoc. II	B.Ch.E.	Lawrence Institute of Technology	Metallurgy

Applied Physical Sciences Division

José P. A. Castrillón	Head	Ph.D.	Universidad de Buenos Aires	Organic Chemistry
Rafael Arce-Blanco	Scientist II	M.A.	Harvard University	Physics
Manfred Eberhardt	Scientist I	Ph.D.	Universitat Tubingen	Organic Chemistry
George A. Simpson	Scientist II	Ph.D.	University of Notre Dame	Chemistry
Rafael Arce-Quintero	Scientist I	Ph.D.	University of Wisconsin	Physical Chemistry
Rosa Santana de Tirado	Research Assoc. III	M.S.	University of Puerto Rico	Chemistry
Betzaida Castilla	Research Assoc. I	B.S.	University of Puerto Rico	Chemistry

Nuclear Applications Division—Nuclear Science and Technology Section

Julio A. Gonzalo	Head	Ph.D.	Universidad de Madrid	Solid State Physics
Mortimer I. Kay	Senior Scientist I	Ph.D.	University of Connecticut	Physical Chemistry
Rastko Maglic	Scientist II	Ph.D.	Massachusetts Institute of Technology	Physics
Florencio Vázquez	Scientist II	Ph.D	Universidad de Madrid	Electrical Engineering
Ramar Shankar Singh	Scientist I	Ph.D.	University of Rhode Island	Electrical Eng.-Solid State
Rupert A. Lee	Scientist I	Ph.D.	University of London	Chemistry
Pier Paolo Delsanto	Scientist I	Ph.D.	University of Torino	Physics
Federico A. Herrero	Scientist I	Ph.D.	University of Florida	Physics
Mohyi E. M. Abu Zeid	Scientist I	Ph.D.	University of Tennessee	Physics

Nuclear Applications Division—Nuclear Engineering Section

Donald S. Sasscer	Head	Ph.D.	Iowa State University	Nuclear Engineering
Aviva E. Gileadi	Senior Scientist I	Ph.D.	Pázmany Péter University	Physics
Eddie Ortiz Muñiz	Senior Scientist I	Ph.D.	Texas A. and M. University	Physics
Knud B. Pedersen	Scientist II	Ph.D.	Iowa State University	Nuclear Engineering
Heriberto Plaza Rosado	Scientist II	Ph.D.	Texas A. and M. University	Nuclear Engineering
Néstor Azziz	Scientist II	Ph.D.	Pennsylvania State University	Physics

Health and Safety Division

Fernando A. Vallecillo	Actg. Head	B.S.A.	University of Puerto Rico	Health Physics
Roberto Ortiz Muñiz	Senior Scientist I	M.S.E.	University of Michigan	Electrical Engineering
Porfirio A. Toledo	Scientific Assoc. III	M.S.	University of Puerto Rico	Radiological Health
Michael Gileadi	Scientist I	M.S.	University of Puerto Rico	Sanitary Science
Nimia Esther Irizarry	Scientific Assoc. I	M.S.	University of Puerto Rico	Radiological Health
Alice Ortiz de Caraballo	Research Associate I	B.S.	University of Puerto Rico	Biology

Reactor Division

Richard Brown Campos	Head	M.S.	University of Puerto Rico	Nuclear Technology
José E. Rivera-Guzmán	Reactor Supervisor	B.S.	University of Puerto Rico	Physics
Miguel A. Rodríguez	Chief Reactor Operator			
Juan J. Pérez Muñiz	Reactor Operator			
Sergio D. Rodríguez	Reactor Operator II		University of Puerto Rico	Engineering

Administration and Services Division

Luis E. Boothby	General Administrative Officer	B.S.A.	University of Puerto Rico	Administration
Peter A. Willman	Scientist I	M.S.	Massachusetts Institute of Technology	Mathematics
Felipe Pérez Matos	Acting Administrative Officer II	B.B.A.	University of Puerto Rico	Administration
Pedro Vélez Mendoza	Administrative Officer I		University of Puerto Rico	Administration
Nélida Banuchi de Gómez	Administrative Officer I		University of Puerto Rico	Secretarial Science

Technical Services Division

Stephen H. Walsh	Head	B.S.	U.S. Naval Academy	Line
Sigfredo Torres	Engineer Associate II		Santiago de Compostela University	Pre-Medical Program

Technical Services-Mechanical Services Section (Mayaguez)

Nelson Quiñones	Head		University of Puerto Rico	Engineering

Technical Services-Mechanical Services Section (Rio Piedras)

David Rodríguez Medina	Head		World University	Surveying

Technical Services-Electronics Section (Mayaguez)

Henry L. Besselievre	Head	B.S.	University of Puerto Rico	Physics

Technical Services-Electronics Section (Rio Piedras)

Carlos J. Laguer	Engineer I		University of New Mexico	Electronics

Technical Services-Glassblowing Section

Víctor L. Lequerique	Scientific Associate II			

Publications

Office of the Director

1. Ritchie, L. R., Chemical Control of Snails, *Epidemiology and Control of Schistosomiasis (Bilharziasis)*, N. Ansari, Editor, published on behalf of the World Health Organization by S. Karger, Basel, Switzerland, Chapter 10, 458-532 (1973).

Training and Information

1. PRNC-157, *Annual Report 1972*

Radiation Oncology

1. Bosch, A., Frias, Z., and Valda, G. C., Prognostic Significance of Ureteral Obstruction in Carcinoma of the Cervix Uteri, *Acta Radiol. Scand.* **12**, 47-56 (1973).
2. Marcial, V. A., Radiation Therapy of Gynecological Cancers, *7th Nat. Cancer Conf. Proceedings*, J. B. Lippincott Company, Phila. and Toronto, 243-49 (1973).

Biomedical Sciences

1. Medina, R. R. and Ritchie, L. S., PRNC-169, *Molluscicidal Activity of Some Plants Against the Snail Vectors of Trematodes: Search for Toxic Plants, Definitive Screening and Comprehensive Laboratory Evaluation of Solanum nodiflorum Against Lymnaeids.* (1973).
2. Gomes, P.,Velarde, A., Chiriboga, J. and De Leon, D., A Simple Method for Mass Production of *Fasciola hepatica* Miracidia, *J. of Agr. Univ. of P.R.*, **57**, 87 (1973).

Radioecology

1. Kolehmainen, S., Experimental Uptake and Chemical Fractionation of ^{59}Fe and ^{131}I in a Turtle Grass Bed, *Proc. 3rd. Nat. Symp. on Radioecology* (1973).
2. Kolehmainen, S., Ecology of Sessile and Free-Living Organisms on Mangrove Roots in Jobos Bay, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 141-173 (1973).
3. Kolehmainen, S., Ecology of Turtle Grass *(Thalassia testudinum)* Beds in Jobos Bay, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 115-140 (1973).

4. Kolehmainen, S., Morgan, T. and Castro, R., Mangrove Root Communities in a Thermally Altered Area in Guayanilla Bay, *PRNC-162, Aguirre Power Project Environmental Studies Annual Report*, 320-364 (1973).
5. Martin, F. D., The Distribution and Ecology of the Fishes of Jobos Bay, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 225-151 (1973).
6. Mo, T., Thermal Neutron Activation Analysis of Airborne Particulate Matter in the South Coastal Area of Puerto Rico, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 421-427 (1973).
7 Schroeder, P., Study of the Effect of Heated Water on Turtle Grass, *Thalassia testudinum* Konig, in Guayanilla Bay, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 304-319 (1973).
8. Seiglie, G. A., Foraminifers From Jobos Bay, Report No. 5, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 21-41 (1973).
9. Suarez-Caabro, J.A. and Shearls, E. A., Macrozooplankton of Jobos and Guayanilla Bays, Southern Puerto Rico, and its Fluctuations under Special Conditions, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*,
10. Szmant-Froelich, A., The Zonation and Ecology of the Jobos Bay Coral Reefs, *PRNC-162, Aguirre Power Project Environmental Studies 1972 Annual Report*, 174-224 (1973).

Marine Biology

1. Muñoz-Ribadeneira, F. J., Ortiz Torres, J., Dissolution of Copper from Different Size Chalcopyrite Ore Particles in Sea Water-Sulfuric Acid Solutions (in Spanish) *Quimica y Farmacia*, Quito, Ecuador, X 18, 56-72 (1973).
2. Seiglie, G. A., Pyritization in Living Foraminifers, *J. Foraminiferal Res.* 3, No.1 1-6 (1973).

Terrestrial Ecology

1. Jordan, C.F. (ANL), Kline, J. R. (ANL) and Sasscer, D. S., A Simple Model of Strontium and Manganese Dynamics in a Tropical Rain Forest, *Health Physics*, Pergamon Press 24, 477-89 (1973).
2. Kline, J. R., Colón, J. A., and Brar, S. S.(ANL), Distribution of ^{137}Cs in Soils and Vegetation on the Island of Puerto Rico, *Health Physics*, 24, 469-75 (1973).

Tropical Agro-Sciences

1. Cabrera-Mosqueda, L., Cuevas-Ruiz, J. and Deshpande, S. N., Changes in the Activity of Pectin Methylesterase in Post Irradiation Storage of Papayas (in Spanish), *Rev. Soc. Quim. Mexicana*, 15 (3), 107-109 (1971).

2. Cabrera-Mosqueda, L., Cuevas-Ruiz, J. and Deshpande, S. N., Physical and Chemical Changes in the Preservation of Papayas by Gamma Radiation (in Spanish) *Rev. Soc. Quim. Mexicana*, 16(4), 149-150 (1972).
3. Cuevas-Ruiz, J., Koo, F.K.S., and Morales-Muñoz, A., Effects of Gamma Irradiation on Sweet Potato Stem Cuttings, *J. of Agr. Univ. of P.R.*, 57, No. 4, 351-54 (1973).
4. Koo, F.K.S. and Cuevas Ruiz, J., Exploratory Induction of Solid Mutation in Yams by Gamma-irradiation, *Genes, Enzymes and Populations*, edited by Adrian M. Srb. in 1973. Plenum Press, N.Y.
5. Koo, F.K.S., Ferrer-Monge, J. A., Otero, A., Bulla, I., Alemañy, A., Effect of Fast Neutrons and Gamma Rays on Soybean Seedling Growth and Malate Dehydrogenase Isozyme Pattern Following Seed Irradiation, *Proceedings FAO/IAEA Res. Coord. Mtg.* on the Use of Seeds as Bio Monitors for Neutron Irradiation, Technical Reports Series No. 141, 95-103 (1973).
6. Walker, D.W., PRNC-161, *Insect Sterility Program Technical Report* (1973).

Applied Physical Sciences

1. Eberhardt, M. K., and Grimison, A., Variable Electronegativity SCF-MO Calculations Using the Linderberg Equation. I. Heat of Atomization of Aromatic Hydrocarbons, *Rev. Latinoamer. Quim.* 4, 35-43 (1973).
2. Eberhardt, M. K., and Yoshida, M., Radiation-Induced Homolytic Aromatic Substitution. I. Hydroxylation of Nitrobenzene, Chlorobenzene, and Toluene, *J. Phys. Chem.* 77, 589-97 (1973).
3. Grimison, A. and Eberhardt, M. K., Self-Consistent Field—Molecular Orbital Calculations of Spectra of Ketyl Radicals and Radical Anions of Uracil and Cytosine. *J. Phys. Chem.*, 77, 1673-5 (1973).

Nuclear Sciences

1. Cruz-Vidal, B. A., Böning, K., (Technischen Universität, München, West-Deutschland) and Vogl, G. (Technischen Universität), Measurement of Stored Energy of KCl after 4.6°K Reactor Irradiation, *J. Phys. Chem. Solids*, 34, 1909-1916 (1973).
2. Gonzalo, J. A., Rigorous Scaling-Law Equation of State Near the Critical Point, *Phys. Rev. Letters*, 8, No.7, 3482-3 (1973).
3. Gonzalo, J. A. and Nazario, I., γ-Irradiation Effects on the Dielectric Properties of KDP, *J. Phys. Chem. Solids*, 34, 921-2 (1973).
4. Gonzalo, J. A., Equation of State for the Heisemberg Model Near T_C, *Proc. Int. Conf. on Magnetism*, Moscow, USSR, 282 (1973).
5. Gonzalo, J. A., The Formative Value of the Sciences in an Intergral Human Education (in Spanish) *Puerto Rico Science Teachers Assoc. Rev.* 3, (1973).

6. Kay, M. I., The Structure of Sodium Nitrite at 150°, 185°, 225°C, *Ferroelectrics* 4, 235-43 (1972).
7. Kay, M. I. and Kleinberg, R., A Neutron Diffraction Study of Triglycine Sulfate, *Ferroelectrics*, 5, 45-52 (1973).
8. Kay, M. I. and Kleinberg, R., The Crystal Structure of Triglycine Sulfate, *Ferroelectrics*, 5, 45-52 (1973).
9. Maglic, R., Van Hove Singularity in Iron Density of States, *Phys. Rev. Letters*, 31, No.8, 546-8 (1973).
10. Mercado, A. and Gonzalo, J. A. , Brillouin Scattering in Triglycine Fluoberyllate, *Ferroelectrics*, 5, 229-234 (1973).
11. Mercado, A. and Gonzalo, J. A., Ferroelectric Behavior of Triglycine Fluoberyllate Near T_c, *Phys. Rev. B.*, 7, 3074-9 (1973).
12 Mohyi-Eldin, A. Z., Solvent's Dependence of Pyrene Monomer and Excimer Fluorescence, *Int. J. of Quantum Chem.*, 6, 279-93 (1973).
13. Newnhan, R. E. (Penn State U.); Wolfe, R. W. (Penn State U.); Horsey, R. S. (Penn State U.); Diaz Colón, F. A. (UPR); and Kay, M. I., The Crystal Structure of Bi_2 (Sr,Ba)Ta_2O_9, *Materials Res. Bull.*, 8, 1183-96 (1973).
14. Singh, R. S. and Mitra, S. S., Change of Force Constant at a Point Defect in Solids, *Solid State Comm.* 12, 867 (1973).
15. Singh, R. S., Long Wavelength ($\vec{K}\rightarrow o$) IR Active Optical Phonons in $NaHF_2$, *J. Chem. Phys.* 58, 4703 (1973).
16. Zuluaga, B. (UPR) and Lee, R. A., Gamma Ray Induced Copolymerization of Styrene and Crotonic Acid, *Revista Latinoamericana de Quimica* 4, 14-18 (1973).

Nuclear Engineering

1. Covello, A., (U. and Istituto Nac. di Fisica Nucleare, Napoli, Italy), Manfredi, V.R., and Azziz, N., Hole-Vibration States in ^{115}In, *Nuclear Physics*, *A*201, 215-24 (1973).
2. Gileadi, A. E., Computerized Cumulative Dose Recording System, *DHEW Publication (FDA) 73-8028, Health Physics in the Healing Arts* (Seventh Midyear Topical Symposium, Health Physics Society, San Juan, Puerto Rico, December 11-14, 1972) pp 408-414 (1973).
3. Gileadi, A. E. and Griffin, L., PRNC-163, *Experimental Determination of Absorbed Gamma Doses in Lead Cylinders* (in Spanish) (1973).
4. Gileadi, A. E. and Kuppusamy, N., PRNC-160, *Computer Aided Decomposition of Gamma Spectra Emitted by Certain Radioactive Nuclides.* (1973).
5. Ortiz, E. and Arenas-Rosillo, Gilberto M., PRNC-164, *Gas Stopping Power Measurements for Alpha Particles*, (1973).
6. Sasscer, D. S. and Rosado-Meléndez, M., PRNC-166, *Absolute Flux Determination Using Activity Ratio of Consecutively Produced Radioisotopes*, (1973).

Health and Safety

1. Rivera, E. and Paraskevoudakis, P., PRNC-171, *A Method to Determine Gaseous Effluents form the Puerto Rico Nuclear Center TRIGA Flip Reactor*, (1973).
2. Perez-Rivera, J. and Paraskevoudakis, P., PRNC-170, *Possibilities of Partial Damage of Horseradish Peroxidase Molecule by Monochromatic X-Radiation*, (1973).

Reactor

1. Brown, R. and Rivera, J. E., PRNC-168, *Technical Specifications for the Puerto Rico Nuclear Center L-77 Reactor*. (1973).

Joint Radiation Survey

1. Gileadi, M., *Joint Dental Radiation Survey, Puerto Rico 1968*, 1-168 (1973).
2. Gileadi, M., Methods and Results-Joint Radiation Survey Puerto Rico-1968, *DHEW Publication (FDA) 73-8028*, Health Physics in the Healing Arts, (Seventh Midyear Topical Symposium, Health Physics Society, San Juan, Puerto Rico, December 11-14, 1972) 79-87 (1973).
3. Gileadi, M., 1968 Joint Radiation Survey(abstract), Appendix I, *DHEW Publication (FDA) 73-8047*, Population Exposure to X-Rays, U.S. 1970, A Report on the Public Health Service X-Ray Exposure Study, 65-66 (1973).
4. Gileadi, M., Joint Dental Radiation Survey in Puerto Rico, 1968, *Radiation Data and Reports* 14, No.6 351-55 (1973).
5. Gileadi, M. and Gileadi, A. E., Collimation in Reducing Male Gonadal Doses in Puerto Rico, 1968, *Health Phys. J.*, 25, 43-49 (1973).

Papers Presented

Office of the Director

1. Paraskevoudakis, P. and Pérez-Rivera, J., Partial Damage of the Horseradish Peroxidase Molecule by Low Doses of Monochromatic X-rays, presented (by P.P.) at the 21st Annu. Meet. Rad. Research Soc., St. Louis, Mo., April/May 1973.

Nuclear Medicine

1. Lanaro, A. E., Dietrich, R. and Velez García, E. (UPR Med. Dept.), The Gammagraphy with ^{67}Ga in the Study of Patients with Lymphomas, presented (by A.E.L.) Annu. Meet. of the Puerto Rico Medical Assoc., San Juan, P.R., November 1973.
2. Lanaro, A. E., Bosch, A., and Dietrich, R. C., Techniques for the Study of the Esophagus Transit in the Anger Camera (in Spanish) presented (by A.E.L.) XIII Int. Congr. of Radiology, Madrid, Spain, October 1973.
3. Lanaro, A. E., Bosch, A., and Dietrich, R. C., Techniques for the Study of the Esophagus Transit in the Anger Camera (in Spanish) presented (by A.E.L.) at Annu. Meet., P.R. Med. Assoc. , San Juan, P.R., November 1973.
4. Dietrich, R., Sánchez, J. (UPR Hosp.), Lanaro, A. E. and Martínez Picó, A., Determination of the Pulmonary Perfusion in the Fallot Tetralogy by Means of the Gammagraphy, (in Spanish), presented (by R.D.) at Annu. Meet, Puerto Rico Med. Assoc., San Juan, P.R., November 1973.
5. Dietrich, R., Sánchez, J., Lanaro, A. E. and Martínez-Picó, A., Radioangiocardiography in Congenital Heart Diseases, presented (by R.D.) at XXIII Annu. Meet. Puertorican Heart Assoc., San Juan, P.R., September 1973.

Radioecology

1. Drewry, G. E., Acoustic Interaction in Male *Leptodactylus albilabris* of Puerto Rico, presented (by G.E.D.) at 53rd Annu. Meet. Amer. Soc. of Ichthyologists and Herpatologists, San José, Costa Rica, June 1973.
2. Kolehmainen, S. E., Morgan, T. O. and Castro, R., Mangrove Root Communities in a Thermally Altered Area in Guayanilla Bay, Puerto Rico, presented (by S.E.K.) at Thermal Ecology Symp., Savannah River Laboratory, May 1973.
3. Martin, S. G., Survey of the Potential for Oyster Mariculture in Puerto Rico, presented at the First Caribbean Oceaneering Conf., San Juan, P.R., February 1973.

4. Wood, E. D., Geochemical Behavior of Some Alkaline Earth, Transition, and Heavy Metals in the Añasco River-Ocean System, presented at Amer. Geophysical Union 54th Annu. Meet., Washington, D.C., December 1973.
5. Wood, E. D. and Acosta-Cintron, N., Geochemical Behavior of Some Alkaline Earth, Transition, and Heavy Metals in the Añasco River-Ocean System, presented (by E.D.W.) at Amer. Geophysical Union Fall Meet., San Francisco, Calif., December 1973.

Applied Sciences

1. Simpson, G. A. and Bernasconi, F., Biphotonic Photoionization of Some Heterocyclic Compounds in Rigid Glasses, presented (by G.A.S.) at Seventh Caribbean Chem. Conf., Mayagüez, P.R., January 1973.
2. Vázquez, S. and Castrillón, J. P. A., Adducts of Some Meso Heteroanthracenes with Mercury and Cadmium Halides, presented (by J.P.A.C.) at Seventh Caribb. Chem. Conf., Mayagüez, P. R., January 1973.

Nuclear Science and Technology

1. Gonzalo, J. A., Equation of State for the Heisemberg Model Near T_C, presented at Int. Conf. on Magnetism, Moscow, USSR, August 1973.
2. Gonzalo, J. A., On the Temperature Dependence of the MnO_2 Spiral Structure Through T_N, presented at Int. Conf. on Magnetism, Moscow, August 1973.
3. Kay, M. I., Kleinberg, R. and Gonzalo, J. A., Neutron Diffraction Phase Transformation Studies of Several Ferroelectric Materials, presented (by M.I.K.) at the 7th Caribbean Chem. Conf., Mayagüez, P.R., January 1973.
4. Maglic, R. C., Kay, M. I., Possibility of the Electric Dipole Density Determination with Polarized Neutrons, presented (by R.C.M.) at XIX Magnetism Conf., Boston, Mass., November 1973.
5. Newnham, R. E. (Penn State), Wolfe, R. W. (Penn State), and Kay, M. I., Displacing Phase Transitions With No Change in Symmetry, presented (by R.E.N.) at Amer. Crystallogr. Ass. Meet., Gainesville, Florida, January 1973.
6. Singh, R. S., Treviño, S., Prask, H. J., Massa, N. and Mitra, S. S., Longwavelength $(\vec{K} \sim 0)$ IR Active Optical Phonons in Na-, K- and $C_8N_3 \cdot$, presented (by R.S.S.) at Annu. Meet. Amer. Phys. Soc., New York, January-February 1973.

Nuclear Engineering

1. Gileadi, A. E., Nater, C. E. (P.R. Health Dept.) and Gileadi, M., X-Ray Diagnosis-Associated Radiation Exposure in Puerto Rico, presented (by A.E.G.) at Regional Conf. Rad. Protection, Jerusalem, March 1973.

Seminars

Rio Piedras

Dr. Víctor A. Marcial, "Status of Clinical Trials Under the Radiation Therapy Oncology Group" (January 26).

Dr. Antonio Frías, Pediatrics Instructor, UPR School of Medicine, "Granulocyte Procurement and Transfusion" (February 2).

Dr. Omar M. Salazar, "Leukemia in Puerto Rico: Age and Sex Distribution, Survival" (February 9).

Dr. Francisco Muñiz, UPR School of Medicine, and Dr. Fernando Cabanillas, third year resident in internal medicine, "Hodgkin's Antigen" (February 16).

Dr. Lauren V. Ackerman, Washington University, St. Louis, "Cancer of the Breast" (February 20) and "Environmental Cancer" (February 23).

Dr. George Hillyer, UPR Biology Dept., and Dr. Raymond A. Brown, "The Immunology of *Schistosoma mansoni* " (February 21).

Dr. Arthur McB. Block, "Turbidity Measurements on Non-absorbing Biological Systems" (March 21).

Dr. Francisco Muñiz, UPR School of Medicine, "Immunotherapy of Cancer I" (March 30).

Dr. George A. Simpson, "The Photochemistry of Indole at Low Temperatures" (April 11).

Dr. Henry S. Kaplan, School of Medicine, Stanford University, Palo Alto, California, "Present Management of Hodgkin's Disease" (April 16), "Carcinoma of the Prostate" (April 20).

Dr. R. Capranica, Cornell University, "Sensory Processing in the Auditory System of Tree Frogs" (May 23).

Dr. J. J. Loftus-Hill, Cornell University "Neutral Pacemakers in Frogs" (May 23).

Dr. E. Theodore Agard, "High Energy Electron Dosimetry" (June 6).

Dr. A. McB. Block, "Plant Growth Regulators" (August 1).

Dr. E. Theodore Agard, "The Physics in Radiotherapy" (September 1).

Dr. Roberto Mass, Dir. Nuclear Medicine Institute, Mexico, "Some Considerations about the Interpretation of an Isotopic Renogram" (September 5).

Dr. Raymond A. Brown, "What is Modern Immunology" (October 3).

Dr. George A. Simpson, "Chemiluminescence of Some α–Peroxylactones" (November 7).

Dr. John W. Harris, U. of California, "Recent Developments in the Chemical Radiosensitization of Anoxic Tumor Cells" (November 21).

Dr. Juan Reforzo Membrives, Professor, University of Buenos Aires, "Thyroid Function and Iodine Supply" (December 3).

Dr. Manfred K. Eberhardt, "Radiation-Induced Homolytic Aromatic Substitution" (December 4).

Mayagüez

Dr. J. Felcher, Argonne National Lab., "Neutron Diffraction-Magnetic Structures" (January 18).

Dr. H. Smith, Oak Ridge National Lab., "Neutron Diffraction-Lattice Instabilities" (January 25).

Dr. E. Stanley, M.I.T., "Critical Phenomena" (January 26).

Dr. B. V. Conger, U. of Tennessee and UT-AEC Agr. Res. Lab., "Effects of Sparsely and Densely Ionizing Radiations on Seeds" (March 8).

Dr. Alex Bonilla, UPR, "Calorimetric Studies of Phase Transitions" (July 6).

Dr. Richard L. Doty, Purdue University, Indiana, "The Effects of Sulfur Dioxide on the Deposition, Distribution and Excretion Patterns of Inhaled Insoluble Particulate Matter (Iron-59 Labeled)" (July 12).

Mr. Frank Melhoun, Marine Resources Development Foundation (PRINUL), "New Tools for Ocean Exploration" (August 13).

Dr. Karen Lukas, U. of Rhode Island, "The Ecology and Taxonomy of Endolithic (boring) Algae of Reef Corals" (August 31).

Dr. Fernando Díaz, Assoc. Professor, UPR, "Phase Transitions in the Bismuth Titanate Ferroelectric Family" (September 6).

Dr. Rafel Nezer, Prof. Hebrew University, Israel, "Electron Microscopy of Insect Chromosomes" (September 7).

Dr. Mario D. Banus from Boston, Mass., "Lead, Zinc, and Cadmium Budget in a Salt Marsh" (October 2).

Mr. Thomas E. Prinslow, Boston U. Marine Program, "The Effects of Ration Size and Detritus on *Fundulus heteroclitus*" (November 6).

Dr. Rastko Maglic, ''Electronic Specific Heat of Nickel Palladium and Platinum" (November 9).

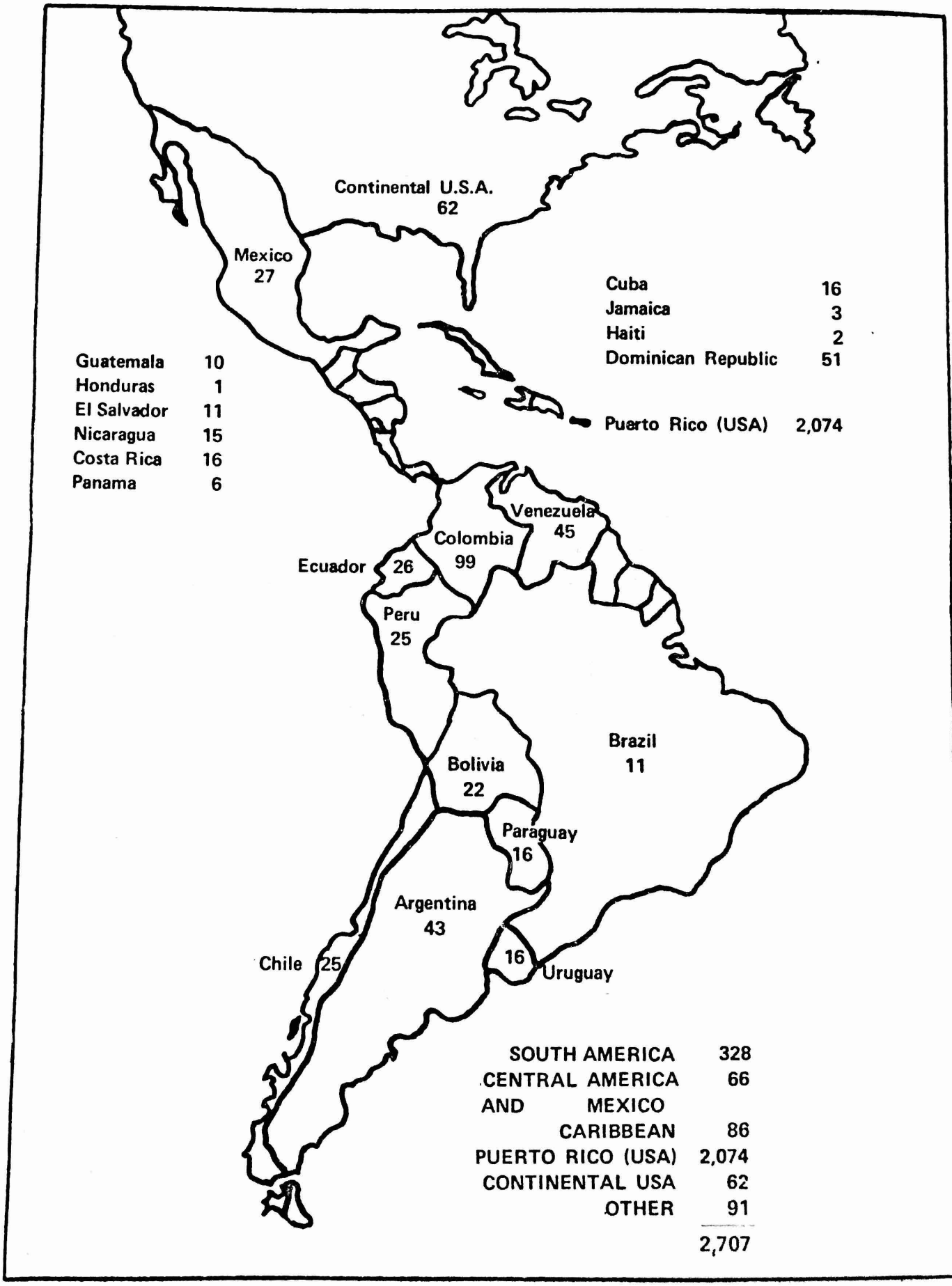
Dr. Paul M. Yoshioka, Scripps Institution of Oceanography, La Jolla, California, "The Ecology and Population Dynamics of the Bryozvan *Membranipora serrilamella*" (November 16).

Mr. Robert J. Beyers, Savannah River Ecology Lab., "Ecological Studies on a Southeastern Reservoir Receiving Effluents from a Nuclear Reactor" (November 30).

Dr. Julio A. Gonzalo, "Cooperative Phenomena and the Equation of State". (November 30).

Mr. Thomas W. Purcell III, Old Dominion University, "Phytoplankton Succession in the Lafayette River, Norfolk, Virginia" (December 13).

FIGURE 1
GEOGRAPHIC DISTRIBUTION OF PRNC STUDENTS, FY-1958 THROUGH FY-1973



TRAINING AND INFORMATION

The Training and Information Division provides centralized direction and coordination for the training and information activities of the Puerto Rico Nuclear Center. The Division Head serves as Training Officer for the laboratory.

Responsibilities in the training area include registering all PRNC students; maintaining a master file on all students trained at PRNC; preparation of reports for the USAEC; scheduling the utilization of teaching facilities; provision of audio-visual equipment; assisting in the preparation of courses, seminars, symposia, and meetings; administration of fellowship programs; and providing personal assistance to students in matters including immigration and housing.

Information activities include the preparation of manuscripts for USAEC patent clearance and publication release, maintenance of master files on all PRNC publications, operation of a USAEC Film Library, operation of a Technical Reference Room, operation of two Reproduction Shops, provision of editorial and translation services, preparation of PRNC reports including the Monthly Highlights and the Annual Report, and giving assistance to visitors. The Division Head serves as Technical Information Officer and Public Information Officer for PRNC.

SUMMARY OF PRNC TRAINING ACTIVITIES

The international character of the students trained at PRNC is reflected in Figure 1. Fundamental objectives of the training program offered by the laboratory include the provision of Spanish-language nuclear education for Latin American and Puerto Rican students, conducting studies related to the needs of Puerto Rico and mainland United States best done in this tropical island location, and providing an example of a nuclear laboratory of a relatively modest size with a limited budget that would be in the range of a developing country's economic resources.

The origin of PRNC students by geographic areas from Fiscal Year 1969 through Fiscal Year 1973 is presented in Table 1 and by country is presented in Table 2. The majority of students from Puerto Rico are principally from the graduate programs of the University of Puerto Rico and many of them come to PRNC to do thesis research. The students then receive academic credit and their M.S. or Ph.D. degree from the University.

The geographic distribution of non-U.S. citizens trained at PRNC during Fiscal Year 1973, including the type of training received appears in Table 3. The enrollment in PRNC training courses during Fiscal Year 1973 and a summary of thesis research activity at PRNC during the period of July 1 through December 31, 1973, are presented in Tables 4 and 5.

PRNC Fellowship Support. A summary of the students supported by the PRNC Student Economic Aid Program during Fiscal Year 1973 is presented in Table 6. The Organization of American States did not offer fellowships for study at PRNC during Fiscal Year 1974 but it is anticipated that the program will continue during Fiscal Year 1975. A summary of all students supported by the OAS Regional Program in Nuclear Energy at PRNC from the time it was initiated in 1969 through 1973 appears in Table 7.

STUDENT LUNCHEON

On August 22, 1973, a Luncheon was held in honor of all students receiving training at PRNC Río Piedras. The entire San Juan area staff and all students were invited. Dr. Ritchie, Acting Director of PRNC, and Mr. Rushford, Training Officer, addressed the group.

STAFF

Mr. Frederick E. Rushford, Head of the Training and Information Division participated in a Workshop for USAEC Librarians held at the Technical Information Center in Oak Ridge on October 3-5. Enroute to Oak Ridge Mr. Rushford stopped in Washington, D.C. to meet with Mr. Harold Young at the USAEC Division of Biomedical and Environmental Research on October 1. On December 1, Mr. Rushford spoke on the PRNC Training Program before a special AEC Review Committee.

Miss Iraida Oliver de Padovani, UPR Librarian in charge of the PRNC Technical Reading Room, took courses in Library Science at the University of Florida during June and July.

Mr. Roberto Rivera Castrolopez retired.

TECHNICAL REFERENCE ROOM — Mayagüez

The PRNC Technical Reference Room functions as an autonomous branch of the UPR Mayagüez Campus Library. A summary of the Reference Room activities during 1973 is presented in Table 8.

Table 1
Geographical Distribution of PRNC Students
Fiscal Years 1968 through 1973

Geographical Area	Fiscal Years					
	1968	1969	1970	1971	1972	1973
South America	15	27	24	50	48	34
Central America & Mexico	8	7	7	12	3	10
Caribbean	5	8	8	6	6	8
Puerto Rico (USA)	152	129	141	110	155	164
Continental USA	15	20	5	5	12	5
Europe, Asia, Africa	15	9	5	2	4	1
Total Students	210	200	190	185	218	225

Table 2
PRNC STUDENTS BY COUNTRY
(A student is counted once each fiscal year he is in training)

	*1958-68	69	70	71	72	73	Total
Argentina	17	3	4	6	6	7	43
Bolivia	9	-	1	5	5	2	22
Brazil	2	1	-	2	2	4	11
Canada	-	-	-	1	-	-	1
Chile	18	3	1	1	1	1	25
Colombia	48	8	10	12	12	9	99
Costa Rica	6	1	1	5	2	1	16
Cuba	9	2	2	1	-	2	16
Dominican Republic	26	6	6	3	4	6	51
Ecuador	11	3	5	4	1	2	26
El Salvador	9	-	-	-	-	2	11
Formosa	12	-	-	1	1	-	14
Germany	2	-	-	-	-	-	2
Great Britain	5	-	-	-	-	-	5
Greece	-	-	2	1	-	-	3
Guatemala	6	2	1	-	-	1	10
Haiti	1	-	-	1	-	-	2
Honduras	-	-	-	1	-	-	1
Hungary	1	-	-	-	-	-	1
India	9	-	1	-	1	2	13
Indonesia	-	-	-	-	1	1	2
Israel	1	1	1	-	-	-	3
Jamaica	-	-	-	1	2	-	3
Japan	1	-	-	-	-	-	1
Korea	-	2	-	-	1	-	3
Lebanon	2	-	-	-	-	-	2
Liberia	2	1	-	-	-	-	3
Malay	-	-	-	-	-	1	1
Mexico	18	1	2	3	1	2	27
Nicaragua	5	2	3	2	-	3	15
Panama	2	1	-	2	-	1	6
Paraguay	6	3	2	2	1	2	16
Peru	16	2	0	1	3	3	25
Philippine Islands	5	1	-	-	-	-	6
South Africa	1	-	-	-	-	-	1
Spain	17	2	1	-	-	-	20
Thailand	-	2	-	-	-	-	2
Turkey	1	-	-	-	-	-	1
United Arab Republic	1	-	-	-	-	-	1
Uruguay	7	1	1	3	2	2	16
Venezuela	21	2	1	14	15	2	45
Total Non-U.S. Citizens	297	50	45	72	51	56	571
Total U.S. Citizens	1390	149	146	115	167	169	2136
Total Students	1687	199	191	187	218	225	2707

*Total number of students trained at PRNC from its first year of operation FY-58 through FY-68.

Table 3

GEOGRAPHICAL DISTRIBUTION OF NON-U.S. CITIZENS TRAINED AT PRNC - FISCAL YEAR 1973

SOUTH AMERICA

Country and Student(s)	Training
ARGENTINA	
1. Luisa N. E. Pérez	Radioisotope Techniques Course, Clinical Radioisotope Applications Course Special Training in Radioimmunoassay.
2. Vilma Stolfi de Rótolo	Special Training in the Utilization of Radioisotopes in Immunology.
3. Anibal J. Camnasio	PRNC Portion of M.S. degree Program in Physics - UPR Mayaguez Campus
4. Jorge D. Caputto Escudero, M.D.	Radioisotope Techniques Course, Clinical Radioisotope Applications Course, Special Training in Radioimmunoassay.
5. Ricardo Decillis, M.D.	Radioisotope Techniques Course, Clinical Radioisotope Applications Course, Special Training in Radioimmunoassay.
6. Juan C. Carranza Archaval	Nuclear Measurements and Instrumentation Course
7. Hernán Castro Vita, M.D.	Residency in Radiotherapy
BOLIVIA	
1. Dario A. Jordán Medrano	PRNC Portion of M.S. degree Program in Radiological Health - UPR Medical Sciences Campus.
2. Alejandro Trigo Chávez	Radioisotope Techniques Course, Clinical Radioisotope Applications Course.
BRAZIL	
1. Ingrid Erdelyi	M.S. degree Program in Radiological Health - UPR Medical Sciences Campus Clinical Radioisootpe Applications Course, Special Course in Medical Physics.
2. Clovis Abrahao Hazin	M.S. degree Program in Radiological Health- UPR Medical Sciences Campus.
3. Joao Soares de Almeida, M.D.	Clinical Radioisotope Applications Course.
4. Augusto Tullman Neto	Special Training in Mutation Breeding and Radiobiology.
CHILE	
1. Patricio Donoso	Special Training in Radiation Protection
COLOMBIA	
1. Alfonso D. Parra Flores	Special Training in *Fasciola hepatica*.
2. Rubén Restrepo	Special Training in Artificial Rearing of *Nezara viridula*.
3. José N. Urdinola Calero	AGRO-415 Special Problems in Agronomy - UPR Mayaguez Campus.
4. Gilberto Arenas Rosillo	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus.
5. Carlos Hernández Pardo	M.S. degree Program in Physics - UPR Mayaguez Campus.
6. Eblis Alvarez Salgado	HORT-605 Nuclear Techniques in Agriculture - UPR Mayaguez Campus.
7. Roberto F. Amaris	M.S. degree Program in Chemistry - UPR Mayaguez Campus.
8. Moises Camacho Galván	M.S. degree Program in Chemistry - UPR Mayaguez Campus.
9. Gentil Estévez Gómez	Special Training in Nuclear Physics, M.S. degree Program in Physics - UPR Mayaguez Campus.
10. Santiago Gómez Figueroa	Special Training in Agrobiosciences, M.S. degree Program in Radiological Health - UPR Medical Sciences Campus.
ECUADOR	
1. Luis A. Rodríguez Gordon	Applied Health Physics Course
2. Angel B. Reyes Vega	Special Course in Reactor Control
PARAGUAY	
1. Héctor D. Colman Rolón	CHEM 608- Radiation Chemistry - UPR Mayaguez Campus.
PERU	
1. Oscar G. Allain Soberón	HORT 426-Special Problems in Horticulture, UPR Mayaguez Campus.
2. Percy C. Naranjo Williams, M.D.	Radioisotope Techniques Course. Clinical Radioisotope Applications Course.

Table 3 Continued

URUGUAY	
1. Ariel Alonso Oroz	Special Training Reactor Supervision and Operation.
2. Alvaro Luongo Céspedes, M.D.	Special Course in Medical Physics and Radiotherapy.
VENEZUELA	
1. Luciano E. Griffin	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus.
2. Socrates Molero Fernández, M.D	Radioisotope Techniques Course.

CENTRAL AMERICA AND MEXICO

Country and Student(s)	Training
COSTA RICA	
1. Alvaro Montoya	CHEM 566 - Food Chemistry - UPR Mayaguez Campus
EL SALVADOR	
1 Emilio S. Bonilla Alfaro	HORT 605 - Nuclear Techniques in Agriculture - UPR Mayaguez Campus.
2. Obdulio E. Maldonado	Special Training in Nuclear Instrumentation & Radioisotope Applications.
GUATEMALA	
1. José R. Ortíz Montenegro	HORT 605 - Nuclear Techniques in Agriculture - UPR Mayaguez Campus.
MEXICO	
1. José Mireles Sahagun	Special Training in Nuclear Engineering.
2. Assad Sabag Tiscareño, M.D.	Radiation Therapy Training.
NICARAGUA	
1. Eddie Ríos Olivares	Special Training in Virology.
2. Dylia Saavedra	CHEM 608 - Radiation Chemistry - UPR Mayaguez Campus
3. Ernesto Terán H.	HORT 605 - Nuclear Techniques in Agriculture - UPR Mayaguez Campus.
PANAMA	
1. Eduardo Durán McKenley	Special Training in Fascioliasis

CARIBBEAN

Country and Student(s)	Training
CUBA	
1. Rosalía M. Alonso Castro	Orientation Course in Clinical Applications of Radioisotopes
2. María de L. Cortés Alemán	Orientation Course in Clinical Applications of Radioisotopes
DOMINICAN REPUBLIC	
1. Gustavo J. Fernández Hernández	Radioisotopes Techniques Course. Clinical Radioisotope Applications Course.
2. Freddy Medina	M.S. degree Program in Biology - UPR Rio Piedras Campus
3. Ramón Ricart Espinosa	Biochemistry of Fasciola (Research)
4. Paul Payano Quezada	Radioisotope Techniques Course.
5. Abraham Musalem Michelem	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus.
6. Jesús E. Michelem Embareck	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus.

EUROPE, ASIA, AFRICA

Country and Student(s)	Training
INDIA	
1. Shri N. Kuppusamy	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus.
2. I. K. Lingappan	M.S. degree Program in Nuclear Engineering - UPR Mayaguez Campus
INDONESIA	
1. Peter H. Thé, M.D.	One Month-Radiotherapy Training Course.
MALAY	
1. Dip S. Sidhú, M.D.	One Month-Radiotherapy Training Course.

Table 4

PRNC STUDENT ENROLLMENT
Fiscal Year 1973

Training Activity	Duration (Months)	X Enrollment =	Student Months
Rio Piedras			
PRNC Portion - Ph.D. degree Chemistry - UPR Rio Piedras	6-12	1	12*
PRNC Portion - M.S. degree Chemistry - UPR Rio Piedras	6-12	5	36*
Radioisotope Techniques Course	1	17	17
Special Training - Liquid Scintillation	1- 6	1	6
Clinical Radioisotope Applications Course	2	15	30
Special Training - Radioimmunoassay	1	3	3
Orientation Course - Clinical Radioisotope Applications	.1	46	4.6
Radiotherapy and Cancer Residency Program	6-12	3	24
Radiotherapy and Cancer Short Term Course	1- 2	7	8
Radiotherapy and Cancer-One Month Course	1	2	2
Radiation Therapy Training Course	8	1	8
Special Course in Medical Physics and Radiotherapy	3	1	3
Special Course in Medical Physics	1- 4	3	6
PRNC Portion-M.S. degree in Biology-UPR Rio Piedras	6-12	3	21*
PRNC Portion-Ph.D. degree Microbiology-UPR Med. Sciences	6-12	1	12*
PRNC Portion-M.S. degree Microbiology-UPR Med. Sciences	6-12	2	18*
Virus Project	1- 6	1	6
Special Training in Virology	1- 6	1	6
Effect of Cortisone Upon Strongyloids Infections in Mice-Research Project	1- 6	1	6
Definitive Screening of Candidate Molluscicide-Research	1- 6	1	6
Egg Laying in *Physa* cubensis	1- 6	1	1
Comparative Study of the Amino Acids Present in the Mucus Substance of *Biomphalaria* glabrata and *Physa* cubensis	1- 6	1	6
Effect of Certain Toxic Plants Against *Physa* cubensis	1- 9	1	9
Fasciola Hepatica Program	1- 6	11	16
Special Training in Animal Caretaking	1	1	1
Evaluation of Molluscicide Effects of Prolonged Application	1- 5	1	5
Special Training-Isotopes on Immunology	1- 3	1	3
PRNC Portion-M.S. in Radiological Health-UPR Med. Sciences	6-12	16	102
Terrestrial Ecology Program-Summer Research	1- 3	2	4
Special Training-Nuclear Instrumentation and Radioisotopes Application	1-12	1	12
Sub Total		151	399
Mayagüez			
PRNC Portion-M.S. degree in Physics, UPR Mayagüez	6-12	3	24*
PRNC Portion-M.S. degree in Chemistry, UPR Mayagüez	6-12	5	36*
Special Training-Nuclear Physics	1- 6	1	6
Individual Courses	1- 6	39	44
PRNC Portion-M.S. Nuclear Engineering	6-12	13	84*
Special Training-Nuclear Engineering	1- 4	1	4
Reactor Supervisor Training	1	17	17
Special Training-Agrobiosciences	1	1	1
Insect Sterility Program	1- 4	1	4
PRNC Portion-M.S. in Biology, UPR Mayagüez	6-12	5	36*
Special Training-Mutation Breeding and Radiobiology	1- 6	1	6
Special Training-Reactor Instrumentation and Control	1-12	2	13
Applied Health Physics Course	1- 4	3	6
ORAU Laboratory Graduate Participation	1- 6	1	6
PRNC Portion-Ph.D. in Biology, University of Miami	6-12	1	12*
Sub Total		94	299
Oak Ridge Research Participants		10	
Grand Total		295	698

* Products that are low are due to some students being part-time

Table 5
THESIS RESEARCH ACTIVITY AT PRNC
JULY 1—DECEMBER 31, 1973

	Thesis Title	Student - University	Advisor - Division	Student Months
1.	Ecology Survey of Turtle Grass, *Thalassia testudinum* Koning, in a Thermally Altered Bay in Puerto Rico.	Peter B. Schroeder - Univesity of Miami	Dr. Frank G. Lowman - Director's Office	6
2.	Comparative Physiological and Ethological Ecology of Some Puerto Rican *Anolis* Lizards.	Robert H. Harwood - University of California	Dr. Richard Clements - Terrestrial Ecology	1
3.	Aquatic Hyphomycetes as Indicators of Organic Pollution.	David E. Padgett - Ohio State University	" " " "	4
4.	Chemistry of Rainfall Inputs to a Tropical Forest.	Jose A. Colon - UPR, Rio Piedras	" " " "	6
5.	Changes in Water Quality in the Freshwater Streams of the Caribbean National Forest.	Elvira P. Cuevas - UPR, Rio Piedras	" " " "	6
6.	Leaf Litter Decomposition in a Tropical Rainforest (*Dacryodes excelsa*)	Fred La Caro - UPR, Rio Piedras	" " " "	6
7.	Genetic Analysis of the Microsporum Gypsum Complex at the Molecular Level.	Jose A. Carrasco - UPR, Med. Sci. Campus	Dr. J. Colón - Medical Sciences Campus	6
8.	Effects of Radiation on the Synthesis of Protein and Nucleic Acids of Sindbis.	Nitza M. Davila - UPR, Med. Sci. Campus	" " " "	6
9.	Characterization of Flavoring Compound in Coffee.	Angel Aguilar - UPR, Mayaguez	Dr. S. N. Deshpande - Tropical Agro-Sci.	5
10.	Characterization of the Degradation Products of Enzymatic and Radiation Breakdown of Fatty Acids by Electron Spin Resonance and Gas Liquid Chromatography.	Jose M. Ortiz - UPR, Mayaguez	" " " "	5
11.	Electrophoretic Analyses of Several Seed Protein Fractions of *Glycine mas L.*	Ileana Rivera - UPR, Mayaguez	Dr. Ferrer Monge - Tropical Agro-Sci.	5
12.	Mutagenic Effect of MNNG on Histidine Operon in *E. coli* Strain C.	Carmen Baerga - UPR, Mayaguez	Dr. F.K.S. Koo - Tropical Agro-Sciences	5
13.	Equation of State for Liquid Vapor Transitions	Gentil Esteves - UPR, Mayaguez	Dr. J. Gonzalo - Nuclear Sciences	5
14.	Thermoluminescence Spectra from Ferroelectric $NaNO_2$.	Prudencio Martínez - UPR, Mayaguez	" " " "	5
15.	Specific Heat of Second-order Transition Ferroelectrics in the Critical Region.	Aníbal Camnasio - UPR, Mayaguez	" " " "	5
16.	Continuous Calculation of the Photonuclear Reaction Cross Section iz zr^{90}	Héctor Santiago - UPR, Mayaguez	" " " "	5
17.	Dependence on the Optical Parameters of the Photonuclear Cross Sections in a Continuous Calculation.	Félix E. Hernandez - UPR, Mayaguez	Dr. P. P. Delsanto - Nuclear Sciences	5
18.	Gamma Induced Copolymerization.	Héctor D. Colman - UPR, Mayaguez	Dr. R. Lee - Nuclear Sciences	5
19.	Radiolysis of Aqueous Solution of Chromium Complexes.	Moisés Camacho - UPR, Mayaguez	" " " "	5
20.	The Effect of an Applied Field on Copolymer Formation.	María B. Colón - UPR, Mayaguez	" " " "	5
21	Radiolysis of Fluorotoluenes	Josefina Rodríguez-UPR, Mayagüez	" " " "	2
22	Radiolysis of Aqueous Solutions of Sulfur Containing Amino Acids.	Luz Del Mar Garcia - UPR, Mayagüez	" " " "	5
23	Radiolysis of Pectic Acid. (Work not completed)	José Escabí - UPR, Mayagüez	Dr. R. Lee and " " Dr. Deshpande	5
24.	Determination of the Concentration of Trace Elements in Some Food in P.R. Using Instrumental Neutron Activation Analysis.	K. Lingappan - UPR, Mayaguez	Dr. H. Plaza - Nuclear Engineering	5
25.	Natural Radiation Exposures in Puerto Rico.	Daniel Lebrón - UPR, Mayaguez	Dr. A. Gileadi - Nuclear Engineering	5
26.	Technique for Measuring Gas Stopping Power of Alpha Particles Using Two Solid State Detectors.	Jesús Michelem - UPR, Mayaguez	Dr. E. Ortiz - " "	5
27.	Computation of Fission Product Inventories and Related Radiation Levels.	Abraham Musalem - UPR, Mayaguez	Dr. A. Gileadi - " "	5
28.	Applicability of the Activity Ratio Technique for the Determination of Various Nuclear Parameters.	Pedro López - UPR, Mayaguez	Dr. D. Sasscer - " "	5
29.	Determination of Prompt Neutron Decay Constant by Stochastic Methods. (Work not completed)	Rafael L. Ufret - UPR, Mayaguez	Dr. A. Gileadi - " "	5
30.	Nitriles as Liquid Scintillation Solvents.	Lidia Scarano - UPR, Rio Piedras	Dr. J. Castrillón - Applied Physical Sciences	6
31.	Aromatic Nitriles as Solutes in Liquid Scintillation.	Carmen Velázquez - UPR, Rio Piedras	" " " " "	6
32.	Intermediate Species Produced During Photolysis of Heterocyclic Compounds Detected by EPR Techniques.	Lorna Ramírez - UPR, Rio Piedras	Dr. A. Grimison and " " Dr. R. Arce " " "	5

Table 6

PRNC Student Economic Aid Program - Fiscal Year 1973 - $10,000.00

Name	Country	Training	Inclusive Dates	Grant
1. Percy C. Naranjo Williams, M.D.	Peru	Clinical Radioisotope Applications	Jul 72 - Aug 72	300
2. Jorge D. Caputto Escudero, M.D.	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	775
3. Ricardo G. Decillis Caló, M.D.	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	675
4. Luisa N. E. Pérez	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	100
5. Joao Soares Almeida, M.D.	Brazil	Clinical Radioisotope Applications	Jul 72 - Aug 72	300
6. Freddy Medina	Dominican Republic	M.S. in Biology	Jul 72 - Sep 72	600
7. Alberto J. Moreno	Colombia	M.S. in Physics	Jul 72 - Sep 72	600
8. Assad Sabag Tiscareño	Mexico	Radiation Therapy	Aug 72 - Mar 73	2,400
9. Gilberto Arenas Rosillo	Colombia	M.S. in Nuclear Engineering	Oct 72 - Dec 72	300
10. Eddie Ríos Olivares	Nicaragua	Special Training in Virology	Nov 72 - Dec 72	250
11. Alejandro Trigo Chávez	Bolivia	Clinical Radioisotope Applications	Feb 73 - Mar 73	500
12. Gentil Estevez	Colombia	M.S. in Physics	Apr 73 - Jun 73	1,250
13. Luciano Griffin	Venezuela	M.S. in Nuclear Engineering	Jun 73 - Jun 73	250
14. I. K. Lingappan	India	M.S. in Nuclear Engineering	Jul 73	300
15. Jesús E. Michelen	Dominican Republic	M.S. in Nuclear Engineering	Jul 73	300
16. Abraham Musalem	Dominican Republic	M.S. in Nuclear Engineering	Jul 73	300
17. Eduardo M. Durán	Panama	Special Training in Fascioliasis	Jul 73 - Aug 73	400
18. Moisés Camacho	Colombia	M.S. in Chemistry	Jul 73 - Aug 73	400

Copying, duplicating, and photographic services are provided to support the research and training effort of the laboratory. Mr. Luis Báez, who is in charge of this operation is shown in this view of the Reproduction Shop located in the Bio-Medical Building.

Table 7

OAS-Regional Scientific and Technological Development Program-Nuclear Energy

Activity at the Puerto Rico Nuclear Center

July 1, 1969 through August 15, 1973

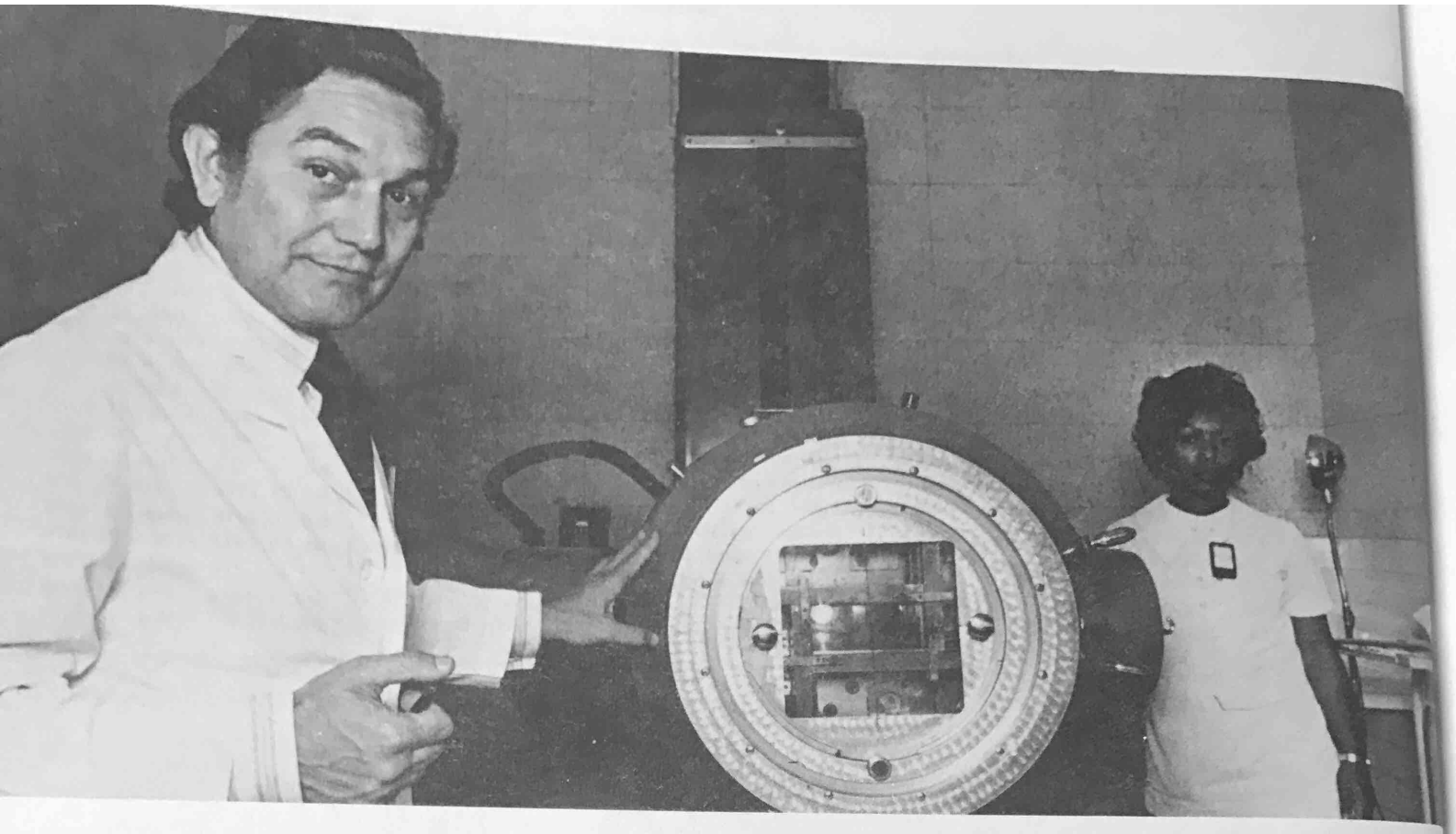
	NAME	COUNTRY	TRAINING	DIVISION	INCLUSIVE DATES
1.	Manuel Lagunas	Chile	Chemistry, Radiolysis	Nuclear Sciences	July 1, 1969 - July 31, 1970
2.	Angela E. Vallejos	Paraguay	Hot Atom Chemistry	Nuclear Sciences	July 1, 1969 — July 30, 1970
3.	Oscar Aragón	Nicaragua	M.S. in Chemistry	Nuclear Sciences	July 1, 1969 — Dec 31, 1970
4.	Genaro Coronel Martínez	Paraguay	M.S. in Physics	Nuclear Sciences	July 1, 1969 — Dec 3, 1970
5.	Julio Alberto Mainardi	Argentina	M.S. in Physics	Physical Sciences	July 1, 1969 — Sept. 7, 1970
6.	Rafael Pereira Ramos	Colombia	M.S. in Chemical Education	Physical Sciences	July 1, 1969 — Dec 31, 1970
7.	Juanita Freer Calderón	Costa Rica	Chemistry	Physical Sciences	July 26, 1969 — Oct 31, 1970
8.	León Pereira	Colombia	M.S. in Physics	Physical Sciences	Aug 6, 1969 — June 24, 1971
9.	Lisandro Vargas Zapata	Colombia	M.S. in Physics	Physical Sciences	Aug 13, 1969 — June 24, 1971
10.	Ricardo Gerdingh Landin	Mexico	M.S.in Radiological Health	Health Physics	Oct 1, 1969 — July 31, 1970
11.	Massayoshi Yoshida	Brasil	Radiation Chemistry	Physical Sciences	Dec 1, 1970 — Aug 31, 1971
12.	Eleuterio Molinas Villasanti	Paraguay	M.S. in Radiological Health	Health Physics	Aug 1, 1971 — Aug 31, 1972
13.	Anfbal Jorge Camnasio	Argentina	M.S. in Physics	Nuclear Sciences	Jan 1, 1972 — June 30, 1973
14.	Gentil A. Esteves Gómez	Colombia	M.S. in Physics	Nuclear Sciences	Jan 10, 1972 — April 10, 1973
15.	Angel B. Reyes Vega	Ecuador	Reactor Operations	Reactor	Jan 10, 1972 — Sept. 9, 1972
16.	José Mireles Sahagun	Mexico	Nuclear Engineering	Nuclear Engineering	Jan 10, 1972 — Oct. 16, 1972
17.	Santiago Gómez Figueroa	Colombia	M.S. in Radiological Health	Health Physics	Jan 12, 1972 — July 31, 1973
18.	Ariel Alonso Oroz	Uruguay	Reactor Operation and Supervision	Reactor	Feb 1, 1972 — Feb 9, 1973
19.	Clovis Abrahao Hazin	Brasil	M.S. in Radiological Health	Health Physics	Feb 15, 1973 — Aug 15, 1973

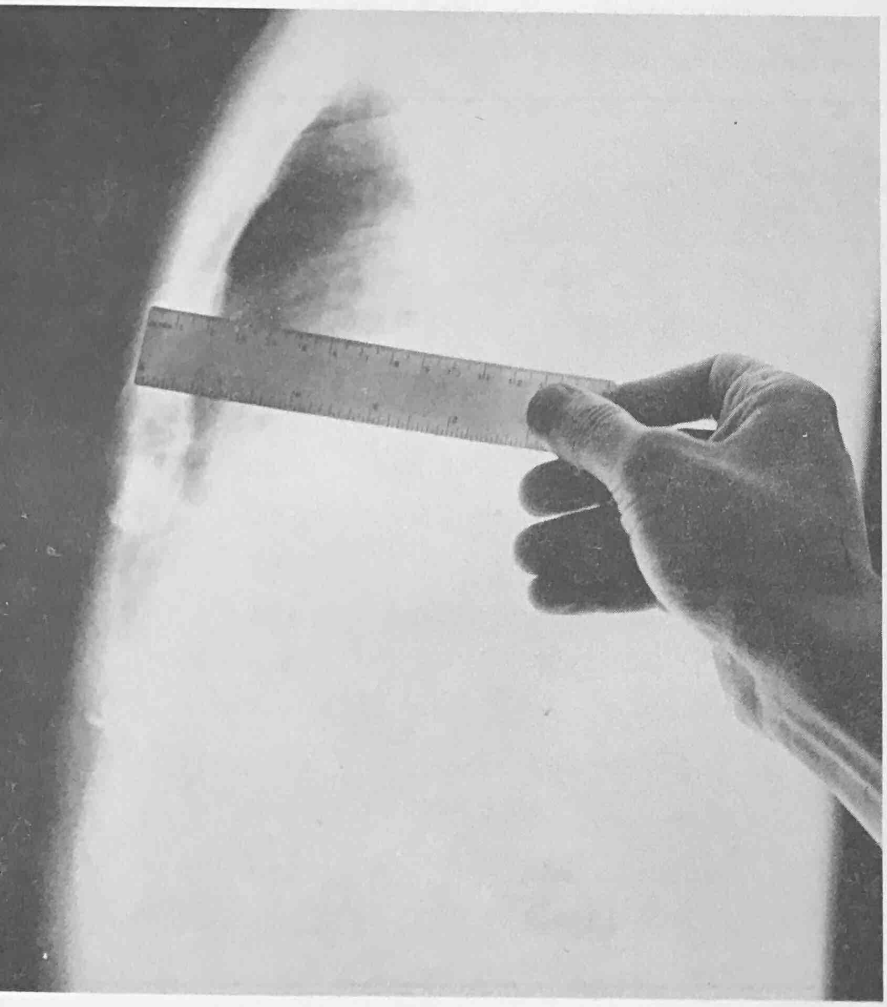
Table 8

SUMMARY OF PRNC MAYAGUEZ — TECHNICAL REFERENCE ROOM

Activities During 1973

Consultations		536
Staff	303	
Students	233	
Circulation		746
Staff	501	
Students	245	
Interlibrary Loans		952
Intralibrary Loans		752
Films Loaned		193
New Material		15,104
Books	309	
Journals	655	
AEC Publications	944	
Movies	3	
Foreign Publications	125	
Microfiche	13,068	





A radiation oncologist and a radiation therapy technologist at PRNC operate a cobalt teletherapy unit which is utilized in the treatment of certain forms of cancer of frequent occurrence in Puerto Rico. The Radiation Oncology Division carries on an intensive program of clinical research with the objective of finding better and safer radiotherapeutic techniques. This cobalt teletherapy unit contains an 8000 curie high intensive source that permits treatments with source skin distance of 100 cm. The picture shows the diaphragm of the unit through which the gamma rays come out when in operation. The unit has been set in a horizontal position in preparation for the treatment in the sitting position of a patient with the diagnosis of carcinoma of the esophagus.

RADIATION ONCOLOGY

The Radiation Oncology Division conducts an advanced program of education and research in the field of radiation therapy of cancer. It functions as the Radiotherapy Department of the University Hospital and the Radiation Therapy Program of the University of Puerto Rico School of Medicine. The program collaborates with the Radiotherapy Department of the San Juan Veterans Administration Hospital and the Radiotherapy Institute of the Metropolitan Hospital in San Juan; both of these institutions contribute their case material for research projects in the Division, as does the San Juan Municipal Hospital. The program utilizes equipment, operating rooms, hospital beds, out-patient facilities, clinical laboratories, pathology laboratories, radiodiagnostic facilities, and other medical services for the care of cancer patients in the University Hospital and the centralized facilities of the Puerto Rico Medical Center. The Division also collaborates with the University of Puerto Rico School of Dentistry, and the Cancer Research Center of the Medical Sciences Campus of the University of Puerto Rico. It provides radiological physics and radiotherapy consultation services to the Veterans Administration Hospital and the Ponce Oncologic Hospital. Other institutions in the community benefit from this program, particularly where it pertains to electron beam therapy of cancer; since this is the only facility of its kind in Puerto Rico.

Besides support from PRNC, which constitutes the main source of funds for this Division the program receives partial assistance from the University of Puerto Rico School of Medicine, from the University Hospital, and from the National Cancer Institute through grants for education and research to the School of Medicine.

TRAINING ACTIVITIES

The education programs include: the Radiotherapy Residency Program (long-term training); Short-term Radiotherapy Training (one to several months); in-service training for medical students on cancer and radiation therapy (summer fellows); in-service training for radiological physicists and radiotherapy technicians; and a lecture course in radiotherapy and cancer for third year medical students and fourth year dental students. Two lectures in the Basic Radioisotope Techniques Course are offered by personnel from the Radiation Oncology Division. Radiotherapists from this division also provide teaching on cancer and radiotherapy matters for interns, residents, and attending physicians who participate in the multidisciplinary cancer management conferences that take place at the University Hospital and at the Veterans Administration Hospital.

The Radiotherapy Residency Program has the approval of the American Board of Radiology and conforms with its requirements for straight radiation therapy training. The program is listed in the Directory for Internships and Residency Training in the USA under the University of Puerto Rico School of Medicine Affiliated Hospitals.

The Short-Term Radiotherapy Training for one month or longer is offered to physicians who want to become acquainted with the techniques utilized in the Division. The participation of these physicians may involve research activities, besides the regular training program of the Division. These physicians are not assigned patient responsibility unless the candidate obtains a permanent or temporary license to practice Medicine in Puerto Rico.

In-service training is offered to medical students (Summer Fellows) and to students of medical physics and radiotherapy technicians. The medical students become acquainted with the clinical problems and current research in the fields of cancer and radiation therapy. They are involved with patient care and are assigned research projects during their stay in the Division. Trainees in radiological physics and radiotherapy technology perform supervised work in the Division's facilities under experienced staff members.

A four-hour radiotherapy lecture course for third year medical students forms part of the curriculum of the University of Puerto Rico School of Medicine. This highlights epidemiology of cancer in Puerto Rico, simple concepts of radiological physics, the effects of radiation on the human body, and includes clinical radiotherapy. Two one-hour lectures are offered each year to 4th year students at the University of Puerto Rico School of Dentistry.

This program stopped using the facilities of the Oncologic Hospital in February 1973. The program continued utilizing the facilities of the University Hospital and at times, the VA Hospital for educational and research aspects, and the Metropolitan Hospital for research projects. The educational activities include: lectures, seminars, multidisciplinary cancer management conferences, treatment planning exercises, patient care under supervision (evaluation and planning of new cases, review of patients under therapy, and follow-up), brachytherapy planning and insertion, and radiological physics. The residents continued rotating through surgical, pathology and nuclear medicine. In addition, they spent periods of rotation in the Medical Physics Program of PRNC and at the PRNC Biomedical Sciences Division for radiobiology training and laboratory experience. A list of trainees is given below (Table 1).

Table 1
Trainees, 1973

Name	Country	Date	Present Position
Short-Term Radiotherapy Training			
Dr. Asaad Sabag	Mexico	8/1/72 to 3/31/73	Intern, Hosp. Auxilio Mutuo
Dr. Peter The	Indonesia	Jan.	V.A. Hospital, Bronx
Dr. Dip S. Sidhu	Malay	Feb.	V.A. Hospital, Bronx
Training Course for Medical Students			
Antonio Bunker	Puerto Rico	Jun.-July	UPR School of Medicine
Reinaldo O. de los Heros	Cuba	Jun.-July	UPR School of Medicine
José Meléndez	Puerto Rico	Jun.-July	UPR School of Medicine
Oscar Rodríguez López	Puerto Rico	Jun.-July	UPR School of Medicine
Long-Term Radiotherapy Training			
Dr. Omar M. Salazar	Cuba	July 1970	4th Yr. Resident, N.Y.
Dr. Luz Toro de Berríos	Puerto Rico	Jan. 1970	P.R. Dept. of Health
Dr. Nini M. Bermúdez	Puerto Rico	Jul. 1972	2nd Yr. Resident, N.Y.
Dr. Hernán Castro Vita	Argentina	Jan. 1973	2nd Yr. Resident
Dr. Rafael A. Sánchez	Dom.Republic	Jul. 1973	1st Yr. Resident

RESEARCH ACHIEVEMENTS

Research by Residents.

1. Brain Tumors Treated at the University of Puerto Rico School of Medicine Radiation Therapy Program. Dr. Omar M. Salazar reviewed the experience with 135 cases of brain tumors treated in this Division. Doctor Salazar has completed the information on the follow-up of cases and has made correlations on the type of tumor, treatment, and survival achieved. A paper for publication has been finished based on part of these data, which will have the title "Post-operative Radiotherapy in the Treatment of Intracerebral Astrocytoma: Sixteen Years Experience."

2. Acute Leukemia at the University Hospital of the University of Puerto Rico School of Medicine. Dr. Omar M. Salazar reviewed the experience with acute leukemia on 240 patients at the University Hospital. Correlations of type, age, sex, treatment, and survival have been made and a paper has been prepared that will be submitted for publication.

3. Identification of Human Tumor Antigens in the Laboratory. Dr. Raymond Brown from the Biomedical Sciences Division, and Dr. Omar M. Salazar have conducted a study to identify tumor antigens in portions of human tumors removed in the operating room. A report of this work will appear in the Biomedical Sciences Division annual report.

Research by Medical Students.

Title	Name
1. Cancer Incidence in Puerto Rico	Dr. José Meléndez
2. Cancer Detection and Diagnosis	Dr. Oscar Rodríguez López
3. Cancer Etiology	Dr. Antonio Bunker
4. Hormonal Aspects of Cancer	Dr. Reinaldo O. de los Heros
5. Genetic Aspects of Cancer	Dr. José Meléndez
6. Immunologic Aspects of Cancer	Dr. Oscar Rodríguez López

Research by Staff — Intramural Projects.

1. *Floor of the Mouth Project.* This project continues in progress as described in last year's annual report. The follow-up is being continued on these cases, but the fact that access to the Oncologic Hospital has been interrupted makes the task difficult for gathering information on some of the cases. Analysis on a partial sample of the cases will be made during 1974.

2. *Effect of the Therapeutic Irradiation of the Lung as Studied by Pulmonary Function and Lung Scan.* This is a collaborative project between the Radiation Oncology and the Nuclear Medicine Divisions (see report of the latter).

Extramural Projects (National Collaborative Research Projects). This Division has continued its participation in the Radiation Therapy Oncology Group (RTOG) which is an organization of academic institutions involved in collaborative clinical research projects on radiation therapy of cancer. During 1973 this Division participated in the following projects:

1. *Split-Course Project.* The Split-Course Project compares continuous standard irradiation versus split-course radiotherapy for cancer of selected sites. The study is headed by Dr. Víctor A. Marcial. The staff of this Division continued accessing cases for this national project during the year 1973. Up to the first part of December 1973, a total of 284 patients had been accessed by the different institutions participating in this project. This program registered 52 patients. During 1973, of a total of 129 patients entered, 28 were contributed by the University of Puerto Rico, which represents the largest number of patients for any given institution. The results of this study, as of January 1974, will be presented at the meeting of the RTOG members in Denver, Colorado. Data presented at a meeting of participants held in Philadelphia in June 1973 showed no difference in the two groups.

2. *Carbogen Study.* This study attempts to evaluate the effect of radiotherapy when the patient is breathing a combination of 5% CO_2 under normobaric conditions versus radiotherapy with the patient breathing air. The study is headed by Dr. Philip Rubin of the University of Rochester School of Medicine. The study has registered 127 patients of which 23 were accessed by the University of Puerto Rico. In 1973, 90 patients were registered of which 22 were contributed by this program, representing the largest contribution for any institution in the nation. It is too soon to have an evaluation of the results of this project.

3. *Treatment of Brain Metastases.* This project attempts to find optimal ways of treating brain metastases. It is directed by Dr. Frank Hendrickson from Chicago. As of December 1973 the project had incorporated 998 patients. It has already been found that the long programs of irradiation (4000 rads in 4 weeks) do not produce better results than shorter regimes.

Other projects in the RTOG are: Hyperbaric Oxygen Project, the Head and Neck Radiotherapy and Surgery Project, Rectal Cancer Project, and the Lung Cancer Project. Presently, the following projects have been discussed for inititation in the near furture: Non-Hodgkin's Lymphoma protocol and the Brain Glioma Protocol.

SUPPORTIVE SERVICES

Patient service is an indispensable component of the activities of the Radiation Oncology Division of the Puerto Rico Nuclear Center. The University of Puerto Rico School of Medicine depends entirely on this support for radiation oncology service to its cancer patients, which in turn forms the basis for student, intern and resident learning of cancer. For its service activities, the Division utilizes the space and equipment available at the Biomedical Building. This corresponds to a space area of approximately 5,000 sq. ft. distributed into therapy rooms, examining rooms, office space, lecture room, and waiting area. The therapy equipment includes the following: One Cobalt teletherapy unit, one 100 Kv X-ray unit, and a 12 MEV linear accelerator. In May 1973, the installation of the 12 MEV linear accelerator was finished, but this equipment was not available for patients until the second

Table 2
Case Load of Radiation Oncology Division, 1973

Site		No. of Cases	
A. New Cases Treated			314
ORAL CAVITY		25	
Anterior 2/3 of tongue	5		
Floor of mouth	6		
Oral mucosa	4		
Other	10		
OROPHARYNX		35	
Base of tongue	13		
Tonsil	17		
Faucial arch	5		
Other	----		
HYPOPHARYNX		7	
Pyriform sinus	3		
Other	4		
NASOPHARYNX		3	
RESPIRATORY SYSTEM		29	
Bronchus and lung	7		
Larynx	18		
Paranasal sinuses	2		
Other	2		
DIGESTIVE SYSTEM		24	
Esophagus	19		
Other	5		
BREAST		31	
FEMALE GENITAL ORGANS		10	
Cervix Uteri	5		
Endometrium	1		
Ovary	3		
Other	1		
MALE GENITAL ORGANS		4	
URINARY ORGANS		13	
Bladder	9		
Kidney	3		
Urethra	1		
SKIN		36	
BRAIN AND NERVOUS TISSUE		20	
BONE AND CONNECTIVE SYSTEM		2	
LYMPHATIC AND HEMATOPOIETIC SYSTEM		47	
Hodgkin's Disease	6		
Other	41		
OTHER		28	
B. Teletherapy Applications			8,376
C. Intracavitary and Interstitial Therapy (Jan.-June)			28
D. Follow-up			1,960

half of the year. The initial utilization of this equipment has been for electron beam therapy as it constitutes the only facility of its type in Puerto Rico and the surrounding Caribbean area. The patients managed with electron beam are of the type that require a boost of irradiation or a significant dose in or near the surface without contributing radiation to the underlying structures. Electron beams of 3, 7, and 11 MEV have been utilized. The Program has all the elements necessary for adequate radiation therapy, but it has lacked beds for intermediate and acute hospital care which are very scarce at the University Hospital. Hostel type of beds have been available. The University Hospital has offered to make available a number of beds of the intermediate category to be used by the oncology programs under the Cancer Research Center. It is expected that these beds will be available during 1974.

The total number of patients seen in the program during the year 1973 was below the previous volume seen in this Division. (See Table 2). This number of patients is inadequate for the clinical research needs of this program. This was due to the fact that the Oncologic Hospital did not permit access to its patients after July 1, 1973. The total number of patients seen were those coming for service through the University Hospital, and those contributed to research projects by the Municipal Hospital, the San Juan V. A. Hospital, and the Metropolitan Hospital. This situation will change for 1974.

The Department of Health has planned a new pattern of referral of cancer patients from its outlying hospitals into the cancer treating centers, beginning January 1974. This new referral system will increase the number of cancer patients at the University Hospital and the cases available to this program.

A detailed list of the types of patients seen in the Division during 1973 is shown in Table 2.

STAFF ACTIVITIES

Cancer Research Center Project (CRC). During 1973 the Cancer Research Center Planning Project continued with participation of several members of the Radiotherapy staff. In October the Dean of the Medical School decided to proceed with the preparation of an operational grant proposal to meet the February 1, 1974, deadline. Dr. Enrique Pérez Santiago was appointed Director for the CRC. Dr. Víctor Marcial was appointed Chairman of the Steering Committee and Associate Director for Clinical Programs of the Center. PRNC, and in particular the Radiation Oncology Division, will have a prominent role in the activities of the proposed Cancer Research Center.

Meetings attended.

Dr. A. Bosch: VI Congreso Nacional de Radiología, in Pueblo, Mexico and served as a visiting Professor at the University of Wisconsin in Madison.

Dr. J. Tome: American Society of Therapeutic Radiologists in New Orleans.

Dr. Víctor Marcial: PRNC Technical Committee, Mayaguez;
Clinical Cancer Training Committee of the National Cancer Institute in Bethesda;
Radiation Therapy Oncology Group, Atlanta;
American Radium Society, Colorado Springs;
Visiting Professor, University of Vermont, Burlington;
Radiation Therapy Oncology Group, Philadelphia;
VI Congreso Nacional de Radiologia, Puebla, Mexico;
VIII International Congress of Radiology, Madrid;
West Coast Cancer Foundation Cancer Conference in San Francisco, California and the Annual Conference of Teachers of Radiation Therapy, University of California, San Francisco;
Annual Meeting of the American Cancer Society, New York;
Inauguration of the New Memorial Hospital for Cancer, New York;
Conference on New Directions for Research in Endometrial Cancer, Marco Island, Florida;
American Radium Society Executive Committee, Las Vegas.

Table 1
Nuclear Medicine Training Activities — 1973

A - Formal Courses
Basic Clinical Radioisotope Applications Course

Name	Country	Duration
(1) Dora H. Barnes	Puerto Rico	5 Feb — 30 Mar 73
(2) Ruth E. Maldonado	Puerto Rico	" "
(3) Francisco Torres	Puerto Rico	" "
(4) J. Ramírez Ledesma	Puerto Rico	" "
(5) Gustavo J. Fernández	Dominican Republic	" "
(6) Alejandro Trigo	Bolivia	" "
(7) Obdulio Maldonado	El Salvador	" "
(8) F. Rivera Bonilla	Puerto Rico	2 Jul — 24 Aug 73
(9) Francisco Morales	Puerto Rico	" "
(10) Paul Payano	Dominican Republic	" "
(11) Sócrates Molero	Venezuela	" "
(12) Luis Aponte Merced	Puerto Rico	" "
(13) Carmen Martínez	Puerto Rico	" "

B - Special Training

Name	Country	Topic	Duration
(1) J. Ramírez Ledesma (MD)	Puerto Rico	Nuclear Medicine	1 month
(2) C. Salazar	Venezuela	Anger Camera	1 month
(3) S. García (MD)	Puerto Rico	Nuclear Medicine	1 month

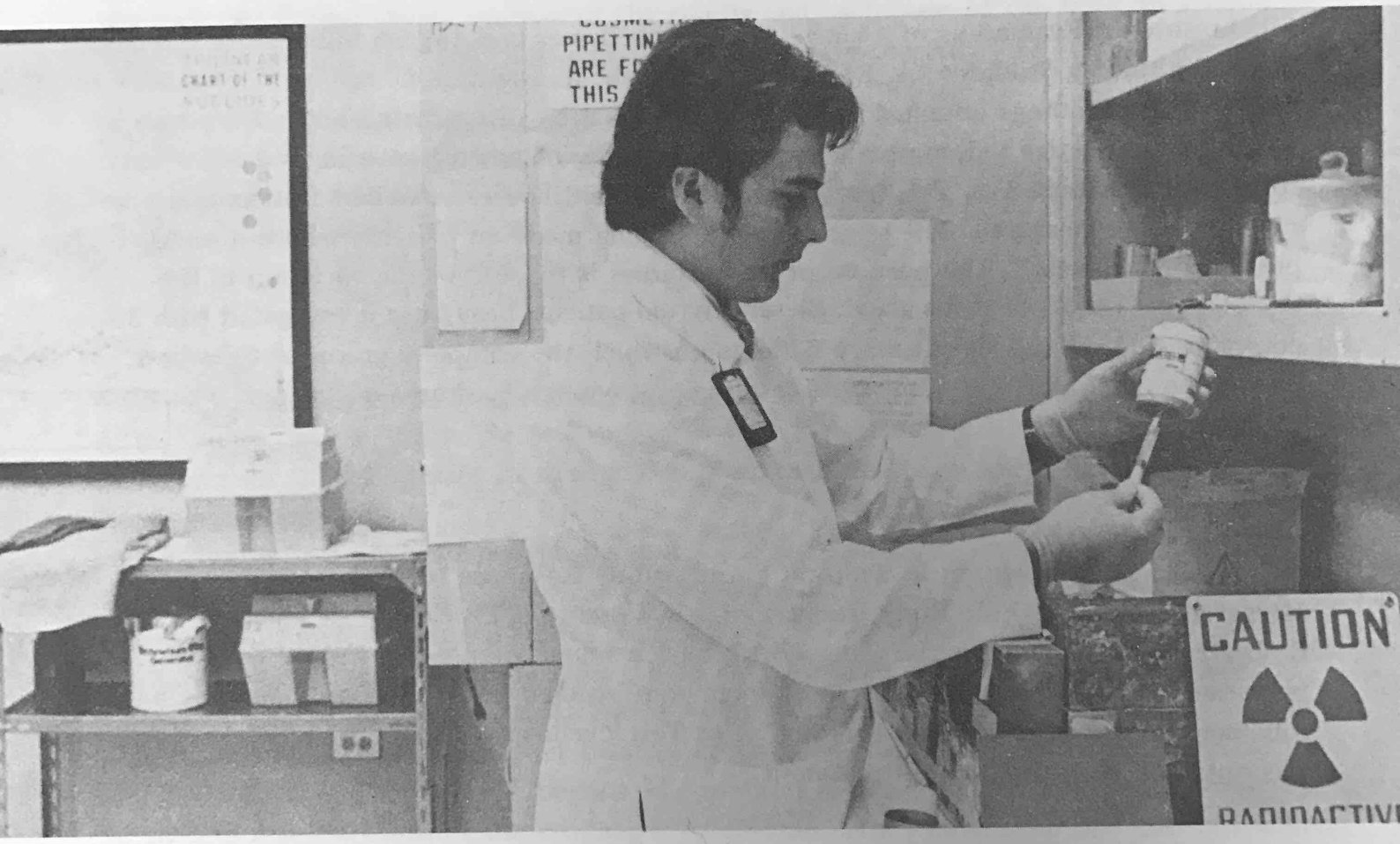
C - University Related Training

Course Title	Participants	Duration
Elective Course in Nuclear Medicine	Cristóbal Picó Martínez	3 weeks
Nuclear Medicine Course in Hematology	María I. Velázquez (MD)	1 week
	Francisco R. Vizcarrondo (MD)	"
	Jenaro Haddock Suárez (MD)	"
	Luis J. Suau Ferrer (MD)	"
Pathological Anatomy Course	2nd Year Medical Students	2 Lecture Demonstrations
Biochemistry and Nutrition Course	100 Students	Short Lecture Demonstrations and Tour
M.S. degree Program in Radiological Health	100 Students	2 Lectures-4 Demonstrations
Nuclear Medicine Course, for Diagnostic Radiology Residents	22 Residents	12 Conferences
Orientation Course on Clinical Radioisotope Applications for Medical Technologists Course	59 Students	2 weeks
Lectures in Pathology	Medical Students	2 Lectures

The above training activities were organized by Dr. A. E. Lanaro, and Dr. R. Dietrich shared the instructional responsibilities. Drs. J. Vázquez Plard, UPR School of Medicine; and Drs. J. P. A. Castrillón, J. Chiriboga, A. Bosch and Mr. P. Toledo from other PRNC Divisions gave lectures for the Basic Clinical Radioisotope Applications Course.

NUCLEAR MEDICINE

The major role of the Nuclear Medicine Division is clinical research in Nuclear Medicine in support of training in the medical use of radioisotopes for physicians and technicians principally from Latin America and Puerto Rico. Service to community hospitals lacking radioisotope facilities assures the patient load necessary for the development of research and training.



Mr. Alejandro Trigo Chávez, Nuclear Medicine Division Trainee, prepares dose to be administered to patient. Safety measures to prevent radiation contamination of working personnel are shown in this photo of hot room.

TRAINING ACTIVITIES

Table 1, opposite page; summarizes the training activities of the Nuclear Medicine Division during 1973.

RESEARCH ACHIEVEMENTS

Radioisotopic Evaluation of Changes in Normal Tissues and Organs Induced by Radiation: Lung Study — A. E. Lanaro, A. Bosch, R. Dietrich, A. Elias, V. Marcial and Z. Frias. Changes in function of normal tissues and organs were noted after therapeutic irradiation with observations before, during and at the end of treatment with a five-year follow-up. Sixty (60) perfusion scannings and 14 ventilation tests with ^{133}Xe were done on 18 patients with following diagnoses: Breast cancer 10, Hodgkin's disease 3, and 1 case each of gastric carcinoma, Wilm's tumor, Lymphoepithelioma, and Thymoma. This is a small preliminary group of patients, so that it is too early to make definitive evaluations.

Radioisotopic Evaluation of Change in Normal Tissues and Organs Induced by Radiation: Thyroid-pituitary Studies — A. E. Lanaro, A. Bosch, R. Dietrich, C. Saenz, V. Marcial, and Z. Frías. Findings obtained in 1970 on the function of irradiated normal thyroids by means of radioactive iodine uptake, warrant screening of new cases, using measurements for new parameters. T-3, T-4, free T-4, antithyroid antibodies as well as uptake and scanning are being measured. The same studies are being made on patients whose normal pituitary is irradiated. The purpose of these studies is to observe the variation in the thyrotrophic function of the gland. Eleven thyroid patients have been investigated with 35 complete studies, and six pituitary patients on which the complete group of tests have been done 34 times. The number of cases is not enough to draw conclusions. The work is being continued.

Vitamin B_{12} Absorption in Tropical Sprue and its Response to Different Therapy as Measured with the Whole Body Counter — J. J. Corcino (UPR School of Medicine), R. Dietrich and A. E. Lanaro. This work was continued intensively. Ninety tests were performed in 77 new patients. Nine of them were studied before and after therapy with folic acid, and four of them before and after Tetracycline. It seems that a better response was obtained with the second treatment.

Absorption of ^{57}Co-Labelled Vitamin B_{12} in Children with Intestinal Diseases as Measured with the Whole Body Counter — P. J. Santiago, I. Ramírez (UPR School of Medicine), R. Dietrich, and A. E. Lanaro. Very little progress was made on this project since its start in 1971, because Dr. Santiago had heavy academic duties and therefore only a small number of patients were sent. Six children were studied, 3 with Sprue and 3 with other intestinal disorders.

Lung Scanning in Congenital Heart Diseases — R. Dietrich, J. Sánchez, A. Muñoz, A. E. Lanaro, A. Martínez Picó. This study which began in 1970 gave very satisfactory results during 1973. 23 tests were performed on 23 patients. The diagnoses were as follows:

Fallot's Tetralogy (Post Surgery)	18 cases
Interventricular Septal Defect	3 "
Interatrial Septal Defect	1 "
Truncus Arteriosus	1 "

For cases of Fallot's Tetralogy the tests were performed after surgery to evaluate treatment results.

Dynamic Radio-cardiovascular Studies — R. Dietrich, J. Sánchez, A. E. Lanaro, A. Martínez Picó. This work (see 1971 *Annual Report*) has had the clinical support of the Pediatric Cardiologists, because of the results and usefulness of the tests. In 1973 a total of 25 patients with the following abnormalities were tested:

Interatrial Septal Defect	7
Interventricular Septal Defect	6
Pulmonary Stenosis	5
Fallot's Tetralogy	3
Truncus Arteriosus	2
Mitral Regurgitation	1
Tricuspid Atresia	1

Dynamic Studies in the Diagnosis of Esophagus Carcinoma — A. Bosch, R. Dietrich, A. E. Lanaro, and Z. Frías. Several variations were introduced in the technique proposed by Kazem for the fulfillment of the radioesophagogram in the dynamic study of the esophageal transit.

These modifications have provided a more sensitive technique, and seemingly earlier detection. The technique is being used for the diagnosis of esophagus carcinoma and for the evaluation of the response to the treatment of this carcinoma in collaboration with the Radiotherapy and Cancer Division. There have been 18 carcinoma cases evaluated, 3 of them before, during and at the end of therapy.

In collaboration with the Cancer Control Program of the Health Department and with Drs. I. Martínez and L. Toro de Berrios, the method is being applied as a possible way for the poblational detection of the esophagus carcinoma. There have been 585 cases of which 117 were positive and 468 negative. These are being evaluated by other methods. The manuscript on this study is ready to be submitted for publication.

Follow-up of Patients with ^{131}I Therapy (see 1970 *Annual Report*). Again, hyperthyroid patients treated with ^{131}I in this Division were asked to come for an annual checkup. Clinical examinations and thyroid uptake tests were made on 89 patients. The condition of these patients at present is as follows: hypothyroid 21; hyperthyroid 12; euthyroid 56.

Evaluation of Liver Detoxification Function with Phenobarbital ^{14}C — A. A. Rodríguez Olleros (UPR School of Medicine), A. E. Lanaro, R. Dietrich, and J. P. A. Castrillón. Measuring the urinary elimination in dogs of Phenobarbital ^{14}C - in 24 and 48 hours, to evaluate the disintoxication function of the liver against this substance. Different degrees of hepatic lesions are produced by administering great doses of thyoacetamyde. There have been 6 tests performed in normal dogs and 1 on the same animals with a certain degree of lesion. The quantity is not enough in order to determine results.

Use and Usefulness of ^{67}Ga in Lymphoma Localization — A. E. Lanaro, E. Vélez García and R. Dietrich. By request of the Hematology and Chemotherapy Section of the University Hospital, the usefulness of the ^{67}Ga application for the diagnosis of lymphomas and determination of Hodgkin's disease is being evaluated. Satisfactory results were obtained on 25 cases of which 19 were positive and 6 negative.

SUPPORTIVE SERVICES

During 1973, a total of 6,247 diagnostic and therapeutic procedures were carried out by the Nuclear Medicine Division (see Table 2)

Table 2
Teaching and Service Procedures
Performed During 1973 (Total, 6247)

Procedure	Clinical teaching	Teaching	Service
Thyroid studies	536	599	1157
Gastrointestinal	23	24	88
Hematology	3	54	5
Liver studies	7	27	10
Circulation studies	17	51	21
Renal studies	36	77	93
Organ and Tumor localization	309	242	711
Water and electrolytes		4	
Anger Camera			
Static studies	243	279	664
Dynamic studies	240	163	554
Spleen Function		10	
Total	1414	1530	3303

STAFF ACTIVITIES

Attendance at Scientific Meetings. Dr. R. Dietrich attended, the Nuclear Cardiology Symposium held at John Hopkins, Baltimore; the Annual Convention of the Hermanos Meléndez Hospital, Dorado, Puerto Rico; the Annual Convention of the Puerto Rican Heart Association, San Juan, and the 71st Annual Meeting of the Puerto Rico Medical Association, San Juan.

Dr. A. E. Lanaro attended, the Annual Convention of the Hermanos Meléndez Hospital, Dorado, Puerto Rico; the 20th Annual Meeting of the Society of Nuclear Medicine, Miami Beach; the 18th Annual Meeting of the Health Physics Society, Miami Beach; the Symposium of the IAEA on Radioimmunoassay, Istanbul; the XII International Congress of Radiology, Madrid, where he served as president of the Symposium on Progress of Therapy with Radionuclides; the 71st Annual Meeting of the Puerto Rican Medical Association, San Juan and visited Dr. Donato's Laboratory in Pisa, Italy, to discuss Cardiologic Dynamic studies.

Visitors. Dr. James Smith, Director, Central Office, Veterans Administration who was accompanied by Dr. Julio Víctor Rivera, Veterans Administration, Puerto Rico

Mr. Germán Ortiz, Nuclear Chicago Representative in Puerto Rico, accompanied by Nuclear Chicago staff members.

Dr. Roberto Maass, Director, Nuclear Medicine Institute, Mexico.

Dr. G. Gómez Crespo, Regional Adviser, Radiation and Health, Pan American Health Organization, Washington.

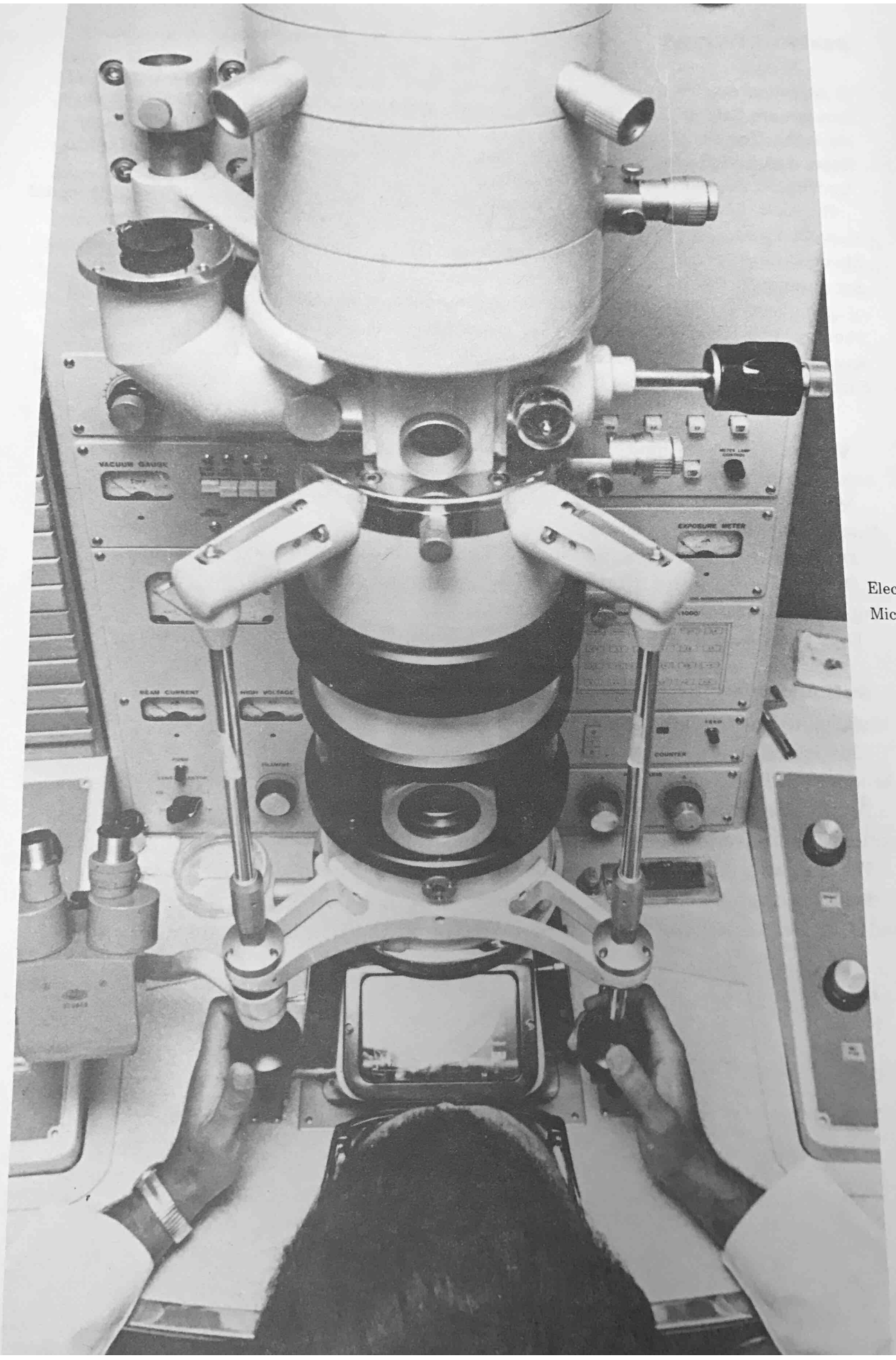
Dr. J. Reforzo Membrives, Director of "Clínica de Endocrinología" of Buenos Aires.

Staff Appointments. Dr. A. E. Lanaro was promoted from Clinical Associate in Medicine to Assistant Clinical Professor of Medicine by the UPR School of Medicine.

Miss Inés Rivera was appointed Administrative Assistant II with a Joint Appointment between the PRNC and the UPR School of Medicine.

An Ad Honorem appointment was extended to Dr. Jorge Sánchez for FY 1974 for his participation in various research projects, and training activities.

The following Ad Honorem appointments were continued during FY 1974 for Drs. Pedro J. Santiago, J. J. Corcino, Mario Rosa García, Julio Víctor Rivera, Francisco Aguiló, and A. Rodríguez Olleros for their participation in the training and research.



Electron
Microscope

BIOMEDICAL SCIENCES

During the report period, this Division assumed its share of the general commitment of the Puerto Rico Nuclear Center to improve socioeconomic levels and conditions of public health in Latin American countries through training offered in formal courses and research utilizing nuclear technology. Instructional needs of individual trainees were carefully considered. Research was confined to well known problems of the tropics. Both training and investigation were increased in scope and importance through several cooperative activities. Research materials and equipment continued to be very adequate for the tasks assigned. Professional disciplines were well represented, but subprofessional personnel continued at a low level in number, job preparation and experience. Of those employed in the Division, 17 were full-time, 10 were part-time contributors.

TRAINING ACTIVITIES

Thesis Research Completed. The following students completed their M.S. Thesis Research:

Freddy Medina (Dominican Republic) "Biological Control of Snail Vectors of Trematodes by Means of Toxic Plants: Definitive Screening and Comprehensive Laboratory Evaluation of *Solanum nodiflorum* against Lymnaeids" (with Department of Biology, UPR Rio Piedras)

Mr. Gualberto Borrero (Puerto Rico) "The Effect of Gamma Radiation on Viral Infection: Reactivation of Coxsackie Virus (Type A-10) and Sindbis (AR-86 Strain) in Immune Animals" (with Department of Microbiology, UPR School of Medicine).

Thesis Research in Progress. The following students are conducting research for Ph.D. Theses:

Mr. José Carrasco (Puerto Rico) "Genetic Analysis of the *Microsporum gypseum* Complex at the Molecular Level" (with Department of Microbiology, UPR School of Medicine).

Mr. Félix Liard Bertin (Puerto Rico)"Ultra-Structural Aspects of *Schistosoma mansoni*" (with Department of Medical Zoology, UPR School of Medicine). This work is part of the divisional *Schistosoma* project.

Mr. Eddy Ríos (Nicaragua) "Radiation for the Reactivation of Viruses from Latency" (with Department of Microbiology, UPR School of Medicine).

The following students are conducting research for the M.S. Theses:

Ann Sukri Mercer (Puerto Rico) "The Effect of Gamma Radiation on Viral Growth in Sindbis Infected L Cell Monolayers" (with Department of Microbiology, UPR School of Medicine)

Robert R. Saylor (Puerto Rico) "Detection of Herpes Simplex Type 1 and 2 Puerto Rico in Human Exfoliative Epithelium of the Cervix by the Immunofluorescence Technique" (with Department of Microbiology, UPR School of Medicine)

Eduardo M. Durán (Panama) "Radiobiological Techniques Applied to the Life Cycle of *Sepedon caerulea*" (with Department of Biology, UPR Rio Piedras)

Formal Courses for Academic Credit. PRNC 510 "Radiation Biology", was taken by the following students:

Roberto E. Cuenca-Fajardo, Colombia; Eduardo Durán Sands, Panama; César Picón Chavez, Perú; Germán Contreras Ramírres, Colombia; Rosalinda González, Brenda Manich, Cruz M. Nazario, and Haydee Pérez from Puerto Rico. Instructor, Dr. Jorge Chiriboga.

PRNC 515 "Radiation Effects on Mammals and Humans", was taken by the following students: Abrahao Hazin Clovis, from Brazil; Santiago Gómez Figueroa, Plumey Colón, Hilda M. Santos, Asterio Portalatín, Nimia E. Irizarry Cancel, and Victor M. Velázquez, from Puerto Rico. Instructor, Dr. Jorge Chiriboga.

Support University Biomedical Education Program (SUBE). This Federal program provides opportunities for undergraduate and post graduate students from limited socio-economic backgrounds for research and stimulation of creativity in the biomedical sciences and related areas.

Participants:

Justo O. Ramírez, who is being familiarized with the maintenance of the *Schistosoma mansoni* cycle in the laboratory.

Enid A. Acosta, who is studying the molluscicidal effects of prolonged application of TBTO (tri-n-butyltin oxide) on *Lymnaea cubensis* in the laboratory.

Oak Ridge Associated Universities (ORAU)

Mr. Freddy Medina, an instructor at the Puerto Rico Junior College, was an ORAU Research Participant. He is working with a student, Miss Enid A. Acosta, summer ORAU Undergraduate Research Trainee, on these tests:

a. Screening for additional plants that are toxic to freshwater snails.
b. Propagation of selected seedling and mature plants in freshwater snail habitats for the purpose of observing any molluscicidal effects.
c. Lengthy applications of plant toxicants against life stage of *Biomphalaria glabrata* and *Schistosoma mansoni.*

In a similar appointment another student, Mr. José M. Fragoso, helped investigate the effects of prolonged application of four molluscicides against *Biomphalaria glabrata* and free living larvae of *Schistosoma mansoni.*

Special Training. Mrs. Wilma Stolfi de Rotôlo (Argentina) received training for 3 weeks in the use of isotopes in immunology.

Twenty-two undergraduates from the University of Puerto Rico, Interamerican University

and the Puerto Rico Junior College have spent time at the Division outside their classroom schedules for familiarization in schistosomiasis and fascioliasis; intervals ranged from 2-12 months. Two additional persons, one from continental United States, and one from Colombia were likewise involved. Several of the above gave technical support in research projects.

Seminars. Opportunities to present original research publicly was mediated through scheduled seminars in schistosomiasis, fascioliasis, and general parasitology. Some special seminars were presented, for example, that on a summary of immunology basic to the trematodiases and cancer.

Lectures and Demonstrations. A miscellany of specialty lectures and exhibitions of research materials and methods was provided by the Division Staff to area university classes in parasitology and selected high school biology classes. A steady stream of candidate future scientists accrued from this important endeavour.

RESEARCH ACHIEVEMENTS

Research goals of the Division were furthered by development of cooperative plans involving a number of extramural agencies and institutions including the University of Puerto Rico Agricultural Experiment Station; Puerto Rico Department of Agriculture; Puerto Rico Department of Health; U. S. Department of Agriculture; Cornell University Department of Entomology; The UPR Department of Biology; The Pan American Health Organization; and the UPR School of Medicine, Departments of Biochemistry, Microbiology and Medical Zoology.

Intramural cooperative projects were initiated, for example, radio-labeling of hycanthone (or derivatives), the candidate schistosomiasis drug and tri-n-butyltin oxide, a candidate molluscicide, both by the Division of Applied Physical Sciences; utilization of certain data of the Terrestrial Ecology Division in interpretation of a study of snail vectors of *Fasciola* and *Schistosoma* in a humid coastal belt of Puerto Rico.

Primary new investigations during the year included some aspects of alleged algal etiology of tropical sprue, ecology of the dengue fever virus, and extensions of the study of plant sources of molluscicides.

The research endeavours of the Division are reported under the project titles, including schistosomiasis, virology and fascioliasis.

STAFF ACTIVITIES

Collaborative involvements. Support was given to the Puerto Rican Committee for Bilharzia Control, the Caribbean Committee for Bilharzia Research, the formative Bilharzia Control Commission of Puerto Rico, and the Committee on Molluscicides, WHO.

The Division cooperated with Dr. George Hillyer of the Biology Department, UPR Rio Piedras in the SUBE project. Doctors L. S. Ritchie, F. F. Ferguson and R. A. Brown provided lectures and demonstrations to that department.

Dr. Susan Spetch of the Department of Pharmacology, UPR School of Medicine, studied axonal transport in neonatal hamsters using the divisional scintillation counter.

Meetings attended.

Dr. Delfín de León; 110th Annual American Veterinarian Medical Association Meeting at Philadelphia and visited the Animal Health Research Department, New Jersey.

Drs. L. S. Ritchie and F. F. Ferguson; the 7th Annual Meeting of the Caribbean Committee for Bilharzia Research, Pointe-a-Pitre, Guadaloupe.

Dr. R. A. Brown; the 22nd Annual Meeting of the American Society of Tropical Medicine and Hygiene, Houston, and the 57th Annual Meeting of the Federation of American Societies for Experimental Biology, Atlantic City.

Dr. Julio I. Colón; the 73rd Annual Meeting of the Microbiology Society, Miami and the 57th Annual Meeting of the Federation of American Societies for Experimental Biology, Atlantic City, and the joint meeting of the American Cancer Society-National Cancer Institute, New York City.

Dr. Jorge Chiriboga; The Pan American Congress of Veterinarians and Zootechnics, Colombia; with the U.S. Department of Agriculture and the Smithsonian Institute, in Washington, D.C., to discuss a grant proposal entitled: "Pilot Study on Biological Control of the Intermediate Snail Host of Fascioliasis in Puerto Rico by Using a Sciomyzid Fly" and to lecture on fascioliasis to the Universidad Autónoma de Santo Domingo, Dominican Republic.

Drs. L. S. Ritchie and J. Chiriboga; with ecologists of the U.S. Department of Agriculture to promote bio-control of fascioliasis, Washington, D.C.

Appointments. Dr. Frederick F. Ferguson, who recently retired as Chief of Tropical Diseases Laboratories, CDC, San Juan, was retained first as Consultant and then as Acting Head of the Medical Sciences and Radiobiology Division.

In consonance with collaborative efforts the Division has granted nine Ad Honorem appointments to peers. In turn two Ad Honorems were given to Division Staff members. Two Division members were granted the rank of Associate Professor in the UPR Department of Zoology.

VISITORS

Dr. Howard W. Bond, Chairman of the Department of Medicinal Chemistry of the University of Rhode Island, Kingston, R.I., while on sabbatical leave, spent two months in the Division, collaborating with Mr. Freddy Medina testing local plant extracts as candidate molluscicides.

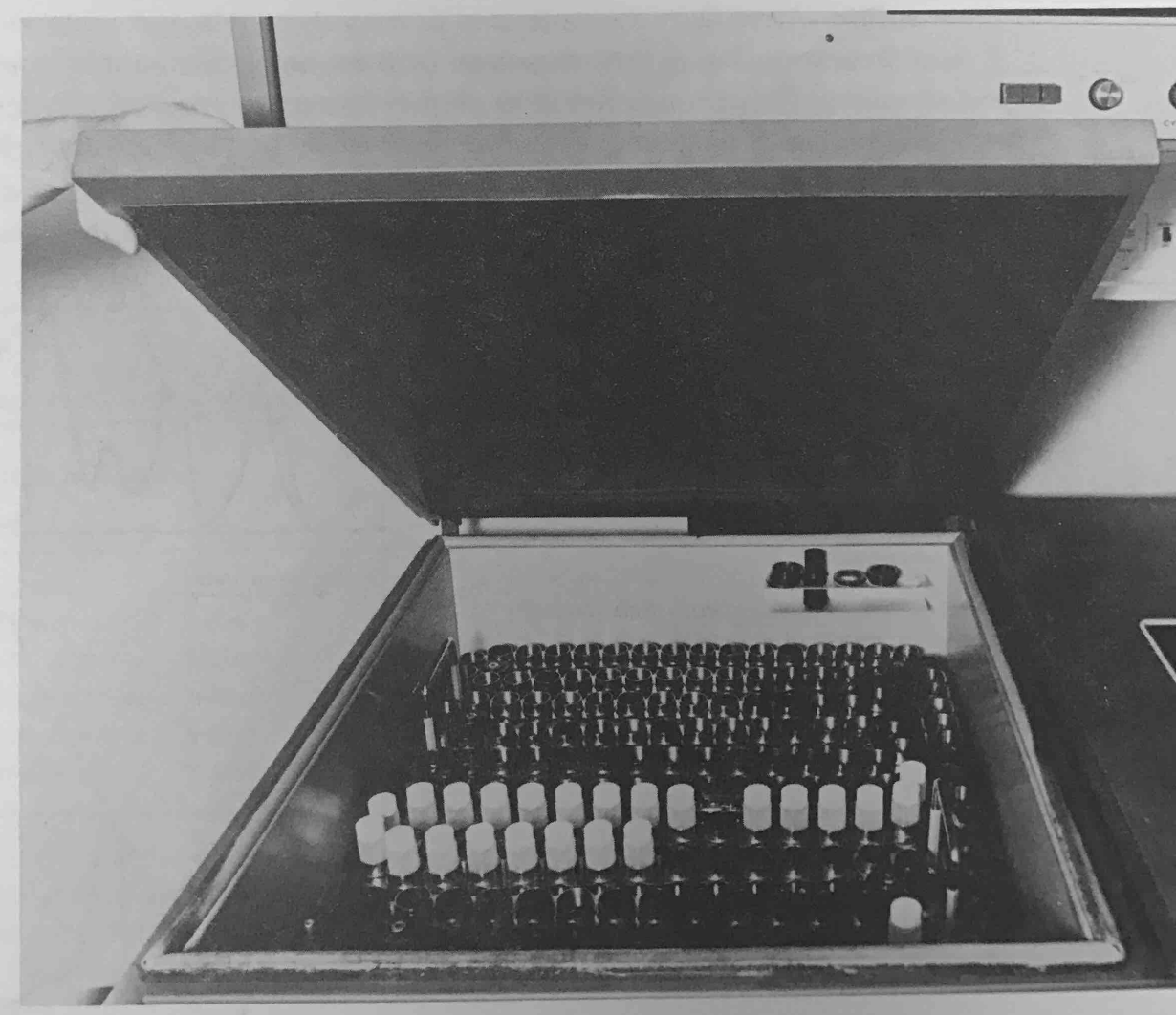
The Division was privileged to brief Doctors M. M. Leveque and E. Pointier (Pasteur Institute, Paris) on local schistosomiasis.

Miss Mercedes Vargas, Acting Director, Department of Parasitology and Microbiology, Universidad Autónoma, Dominican Republic, discussed cooperative study plans with Division Staff.

Louisiana State University Fellows, receiving training in tropical medicine in cooperation with the Department of Medical Zoology, School of Medicine, were our guests on June 28.

Some samples are shown in the automatic sample changer of a scintillation counter. This machine has the capability to count both α-emitting isotopes through the use of a sodium iodide crystal and β-emitting isotopes by means of liquid scintillation. Isotopes of both the α and β types are frequently used in biological studies at the Nuclear Center.

The facility is also used by other investigators from the University of P.R. and Medical School.



Schistosomiasis Project

THE EXO-ANTIGENS OF *SCHISTOSOMA MANSONI* WORMS

Exo-antigens (excretions) of both the infective cercariae and the eggs of *Schistosoma mansoni* were purified, and identified by means of radio-immune assay, using ^{131}I as the label. The antigens could not be labeled after phenol extraction, but their existence was apparent when they inhibited the binding of the labeled crude antigen; however, labeling was possible after treatment with phenyl isocyanate. Both exoantigens were also purified by fractional alcohol precipitation and DEAE absorption. After the products of three purifications were labeled, their compounds were separated on a P-10 molecular sieve column and the fractions assayed for activity with the results shown in Figure 1. There appear to be five antigens, differing in size, in both the egg and cercarial preparation. The smallest antigen has an apparent molecular weight of 3000 Daltons. Competitive inhibitors to these antigens have been demonstrated in both the serum and urine of infected mice.

A radio-immune assay for the detection of these antigens would be useful for epidemiological screening; for this, one needs to prepare hyperimmune sera. Since the purified antigens are not suitable for immunization, immunogenic preparations using the purified antigens as haptenes are being prepared.

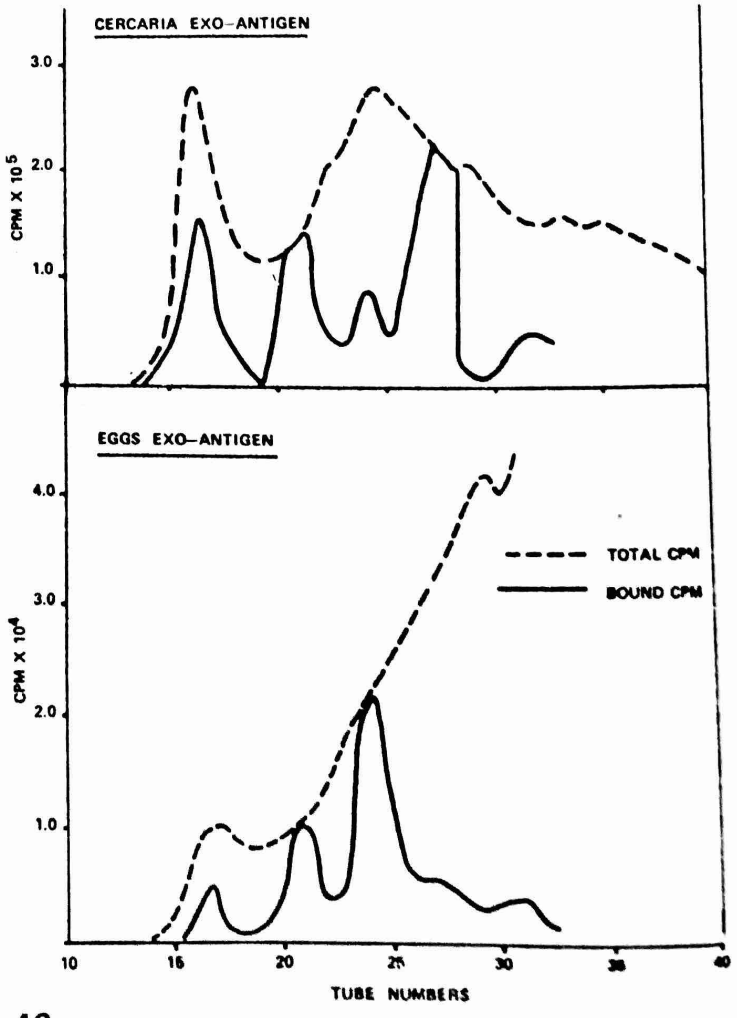


Figure 1. Exo-antigens from *Schistosoma mansoni* cercariae and eggs.

DELAYED EFFECTS OF IRRADIATION ON *SCHISTOSOMA MANSONI* WORMS

Irradiation of *S. mansoni* cercariae before infection of the mouse results in fewer worms surviving to adulthoodd, and those worms which survive are stunted. If in addition the mouse host is irradiated before cercarial infection, the stunting of the worms is partially reversed, but the average number of survivors is not changed.

The reversal of the stunting of the worm by irradiation of the host suggested an immune phenomenon and a change in the antigenic properties of the worm by irradiation. In a preliminary experiment, mice received a series of injections of purified, aggregate-free, cercarial exo-antigens after infection with irradiated cercariae. The mean length of male worms was 4.6mm and 4.98mm and of female worms 5.86mm and 7.37mm in the control and injected group, respectively. The length difference in the female worms was highly significant. The preliminary data implies that the exo-antigens are important for the growth of the worm.

Irradiated (2000R) and normal cercariae were allowed to pass through freshly excised mouse skin and were collected in a tissue culture medium containing calf serum. After different times of *in vitro* culture, the schistosomules (young worms) were injected into mice, allowed to mature to adults and the survivors were counted (Table 1). After one day *in vitro* the irradiated worms survived better *in vivo* than the normal ones. The normal schistosomule possibly coats itself with host antigen within 24 hours after its transformation from the cercarial stage. It it were to coat itself with bovine antigens from the calf serum, this would be a disadvantage in the mouse. The experiment will be repeated in media with mouse serum.

Table 1

Effect of *In Vitro* Culture on Survival of Schistosomules from Irradiated and Normal Cercariae Before Intraperitoneal Infections in Mice.

Time in Culture		Number of Survivors		Ratio N/I
		Normal	Irradiated (2000R)	
Cercariae		386	75	5.2
Schistosomules	0-days	284	80	2.8
Schistosomules	1-day	14	15	0.9
Schistosomules	2-days	20	63	0.3
Schistosomules	4-days	4	7	0.6
Schistosomes	6-days	0	11	0.0

Data obtained by irradiating mice at different times after infection established that the developing worm can be damaged by doses of irradiation smaller than those effective in the cercarial stage (Table 2). Irradiation with 900 Rads given in the first two weeks of development damages the immature *Shistosoma* parasites so that they were not able to copulate. Irradiation given after 4 weeks had minimal effect on copulation.

However, in all cases there is less hepatic granuloma which implies that there is either less egg production or less reaction by the host to the egg.

Table 2

Effects of *In Vivo* Irradiation Upon Worm Development in Mice

Radiation/ weeks after infection	Deaths/ number of Mice	Mice Perfused		Days After Infection	Mean Worm Count	Percent in Copula	Liver Granulomas
		Moribund	Survivors				
0	20/20						0
1	16/20		4	40	20	5.6	0
2	15/20		5	47	32	2.1	0
3	19/19						0
4	16/19		3	58	23	41.5	+
5	18/18	2		50	48	29.0	∓
6	18/18	4		50	29	36.0	±
7	18/18	4		56	39	40.5	± to +
Controls		1		48	32	82.0	+++
No radiation		6		50	42	49.0	++

TUMOR EXO—ANTIGENS

In collaboration with Dr. O. M. Salazar, a resident in the Radiation Oncology Division, an attempt was made to extrapolate the results obtained with the *Schistosoma mansoni* antigens to a tumor system. The supernatant of a cell suspension from a squamous cell carcinoma was processed in a manner similar to the parasite antigen and the fractions were tested. Between 2-5% of some of the fractions from the P-10 column were bound preferentially and consistently to serum of patients with squamous cell carcinoma. An attempt to extrapolate the data to the Hodgkins tumor system is being done and is encouraging. Obviously, a successful definition of a tumor antigen would be important. However, it should be remarked, that a successful extrapolation from parasite to tumor implies that one is dealing with a general phenomenon. A similar approach to other blood-borne parasites would probably be fruitful if one could establish similarities between *S. mansoni* and tumor immunologies.

ULTRASTRUCTURAL STUDIES OF *SCHISTOSOMA MANSONI* LIFE STAGES

The treatment of tissues for electron microscopy involves drastic conditions that may produce undesirable artifacts. Consequently, the several steps used for the preparation of the specimens must be critically evaluated.

In our studies with the cercariae of *Schistosoma mansoni* it has been observed that adequate depiction of the glycocalyx seen surrounding the cercariae is dependent on the concentration of sucrose, or glucose, and $CaCl_2$ in the buffer and fixatives. This structure

Figure 2. Exterior surface of *S. mansoni* egg showing shell pore and microbarbs (Ritchie-Berrios Durán Method) X150,000

Figure 3. Exterior surface of *S. mansoni* egg showing shell pore and microbarbs (Toro-Goyco Method) X150,000

is best shown using low concentrations of glucose and $CaCl_2$; it disappears with relatively high concentrations of sucrose (10%). Some of these findings must now be reevaluated before undertaking some of the planned sophisticated histochemical investigations. The studies on the Cerkarienhullen reaction, a diagnostic test, will be completed after the above parameters are elucidated.

Histochemical studies on the cercarial sensory bulbs are underway. Both the phosphate and acetylcholinesterase content was demonstrated. Light microscopy, fluorescence methods, and scanning electron microscopy are being used to support these findings.

Some data has been collected on the diagnostic circumoval test of Oliver-Gonzlez with *S. mansoni* eggs being recovered by two different methods. In the Ritchie-Berríos Durán method the eggs are concentrated by a density gradient between two concentrations of NaCl. The newer method of Toro-Goyco providing less debris makes use of pinguinaine, a proteolytic enzyme. Toro-Goyco and Cancio have shown that the eggs prepared with the aid of the enzyme react more promptly and more intensively with the required homologous antiserum. Our current explanation as observed under the transmission electron microscope is that the eggs recovered by the Ritchie-Berríos Durán method (Figure 2) are covered by a fibrillar membrane or debris; this is not so with the enzyme-based test of Toro-Goyco (Figure 3)

CONTINUOUS EXPOSURE OF *BIOMPHALARIA GLABRATA*, THE SNAIL VECTOR OF *SCHISTOSOMA MANSONI*, TO DIFFERENT TOXICANTS

Tri-butyl-tin oxyde (TBTO) was compared with three other prominent toxicants for effects on the egg laying of *B. glabrata*. Snails were exposed continuously to 10-fold dilutions of TBTO, Niclosamide, copper sulfate and Frescon for 2 weeks and the eggs laid during this period were counted. A concentration of 10^{-7} gram/gram TBTO completely inhibited egg laying while Niclosamide and copper sulfate reduced it by almost 90% and Frescon by less than 50%. At 10^{-8} and 10^{-9} dosages, TBTO reduced laying by 96% and 60%, respectively, while corresponding figures for the others were less than 50%. A useful bio-assay of TBTO dosage levels was developed using the criterion of cercarial mortality.

MOLLUSCICIDAL PLANTS IN PUERTO RICO

In the work of Mr. Freddy Medina for his Master's thesis, 103 plants were screened for molluscicidal activity. Of these 17 were toxic for lymnaed snails and 6 notably so. One plant, *Solanum nodiflorum*, was selected for comprehensive evaluations. Both its roots and leaves were toxic for *Lymnaea collumella* and *Lymnaea cubensis*. Data obtained with the roots of the plants are shown in Table 3. Four other specimens of snails were tested. The order of decreasing susceptibility for *S. nodiflorum* was as follows: *L. columella*, *B. glabrata*, *L. cubensis*, *Marisa cornuarietis* and *Tarebia granifera*. The need for a field feasibility test to proceed comprehensive laboratory evaluation is apparent.

Table 3

Molluscicidal Effects of Roots of *Solanum nodiflorum* against *Lymnaea cubensis*

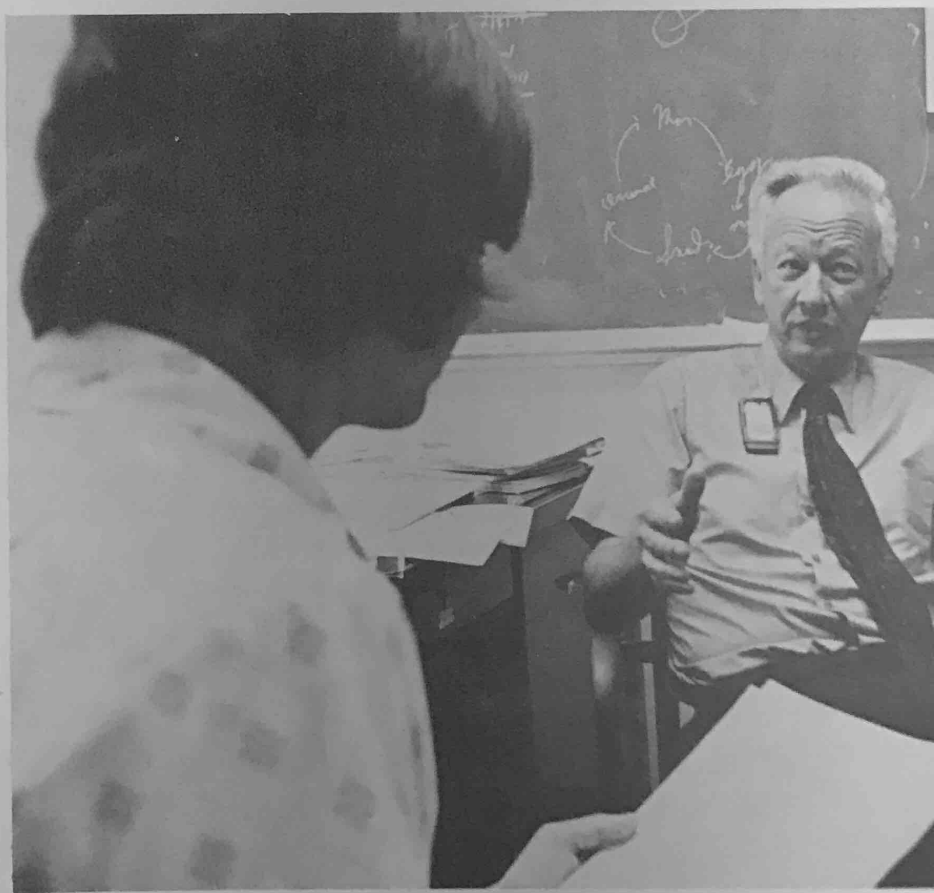
Concentration ppm	24 — 24 hrs Exposure-Recovery	24 — 48 hrs Exposure-Recovery	48 — 24 hrs Exposure-Recovery	48 — 48 hrs Exposure-Recovery
25	16%	18%	20%	27.5%
40	18	34	24	58
50	37.5	46	47.5	60
60	50	56	60	65
70	55	60	70	85
80	65	85	92.5	95
90	85	89	100	100
100	100	100	100	100
		Statistical Determinations		
LC_{50}	67ppm (59.82 — 75.04)	60ppm (50.84 — 70.80)	55ppm (49.10 — 61.60)	36ppm (29.50 — 43.92)
LC_{90}	92ppm	83ppm	78.1ppm	78ppm

LC_{50} and LC_{90} = Lethal concentration 50% and 90% respectively.

$$\% \text{ mortality} = \frac{\text{Number of snails killed}}{\text{Total number of snails exposed}} \times 100$$

Controls-Snails remained normal without losses.

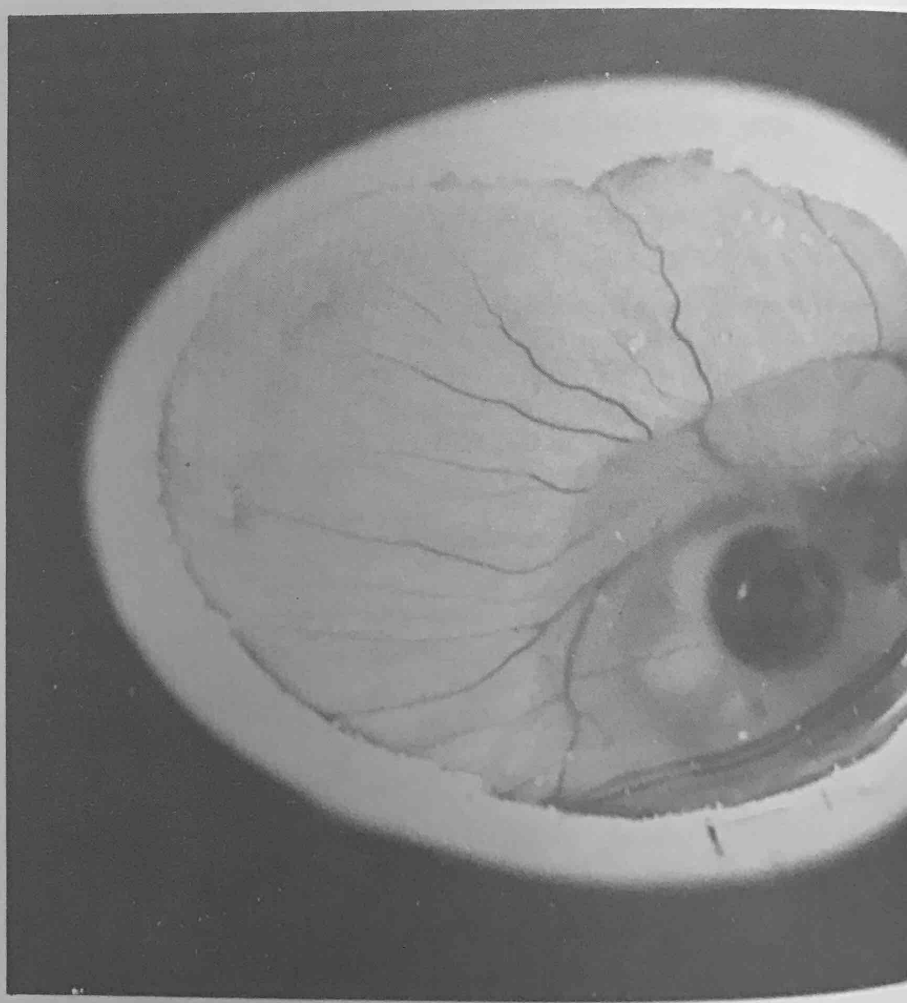
40 - 50 snails were used for each test and controls.



Dr. Raymond Brown is seen discussing Schistosomiasis research with a University of Puerto Rico student. The National Institute of Health has funded a cooperative project between the biology department and the Nuclear Center for the training and aid of underprivileged minority group students. These students take part in research projects and are paid a stipend by the National Health Institute.

The complexity of the animal body and the variety of experimental animals determine the procedures to be used in experimental infections The mouse is a very convenient laboratory animal for growing virus.

Local lesions result from viral infections of either natural or artificial layers of susceptible cells. A useful post system to produce localized lesions is the chorioallantoic membrane of the chick embryo.



Virology Project

The purpose of this project is to study the potential impact of gamma irradiation on virus infections in wild arthropods and vertebrates. The isolation of Coxsackie type A10 virus from the blood of sick wild rats, caught in a small irradiated portion of the rain forest, and from organs of one rat found dead, led to studies of the changes induced by radiation in the virus host relationship. We hope to answer some fundamental questions in virology and immunology, especially those related to long-lasting viral immunity, and the synthesis of neutralizing antibodies and interferon.

Latency (i. e. infection of an organism by a virus with no apparent ill effects) is a commonly seen and noteworthy phenomenon. Gamma radiation is being used to elucidate the mechanism by which latent infections are established and activated.

EFFECT OF RADIATION ON SINDBIS VIRUS REPLICATION IN L. CELLS

The replication of Sindbis virus in L cells (clone 929) has been studied. Sindbis virus multiplies rapidly in a 24-hour old monolayer, yielding a maximum supernatant titer at 8 hours after infection with the destruction of the cells after 24-48 hours. Figure 1 shows that no significant difference was detected on the growth curve of the virus when it was grown in irradiated and non-irradiated cells.

EFFECT OF RADIATION AT VARIOUS TIMES AFTER VIRUS INFECTION

Twenty-four hour L cell monolayers formed in 250 ml Falcon tissue bottles, seeded with 8 x 10^5 cells/ml (10 ml/bottle), were infected with a multiplicity of infection equal to one. The monolayers were irradiated with 700 rads at 0, 1, 3 and 5 hours after infection, and the viral activity present in the cell media was titrated in chick fibroblast monolayers. The results of a typical experiment are shown in Figure 2. When the infected monolayers were irradiated one hour after infection a viral upsurge was observed at five hours, which exceeded the non-irradiated control by 5 fold. When the infected monolayer was irradiated at three hours after infection the titer at eight hours was reduced to one sixth that of the non-irradiated control. Irradiation done at 5 hours after infection had no effect on the viral supernatant titer when compared with the non-irradiated control at eight hours. The results indicated that radiation of 700 rads given one hour or three hours after infection altered the normal replication cycle of Sindbis virus. Studies are being conducted to determine how radiation, given at a specific time, affects the replication of the virus in L. cells.

REPLICATION OF SINDBIS VIRUS IN L CELLS

Sindbis virus growth appears to be dependent upon the growth phase of L cell monolayers. Twenty-four hour old monolayers infected with this virus resulted in rapid replication of the virus with complete lysis of the monolayer within 24-48 hours. On the other hand, monolayers allowed to grow to confluence for ten days or more until the cells were packed and rounded, supported virus growth either poorly or not at all. A typical growth curve of Sindbis virus in packed cell monolayers is shown in Figure 3. After infection, the titer of the virus in the cell medium dropped rapidly for 24 hours; at this time the monolayers were trypsinized and a 1:2 split was performed. When the cells were released from the packed state by trypsinization, the virus was released to the cell medium. The viral titer of these trypsinized cells increased for 24 hours and then began to fall unitl no virus was present in the cell medium. This took approximately 9 days and by this time the cells had again formed a confluent packed monolayer.

EFFECT OF TRYPSINIZATION ON SINDBIS VIRUS TITER IN PACKED L CELL MONOLAYERS

An experiment in which the packed L cells were infected and trypsinized at intervals of several days is shown in Figure 4. Each time the monolayers were trypsinized virus was released, yet the cells did not lose their integrity as no cell lysis was observed and confluent packed monolayers were formed in 10 days. The maximum viral titers reached after trypsinization decreased with successive treatments, which suggested that more and more non-viral producing cells were forming the monolayers.

EFFECT OF RADIATION ON SINDBIS VIRUS TITER IN PACKED L CELL MONOLAYERS

Several experiments were performed, using irradiation to determine if the virus was in a latent state in the packed monolayer. The production of Sindbis virus in packed cells was followed for ten days. The titer dropped from 2.2×10^6 to 2×10^3 plaque forming units/ml. At this time, one group of monolayers was trypsinized while other groups were irradiated with 700 rads. As shown in Figure 5, irradiation of monolayers did not increase the viral titer while trypsinization did so by several logs.

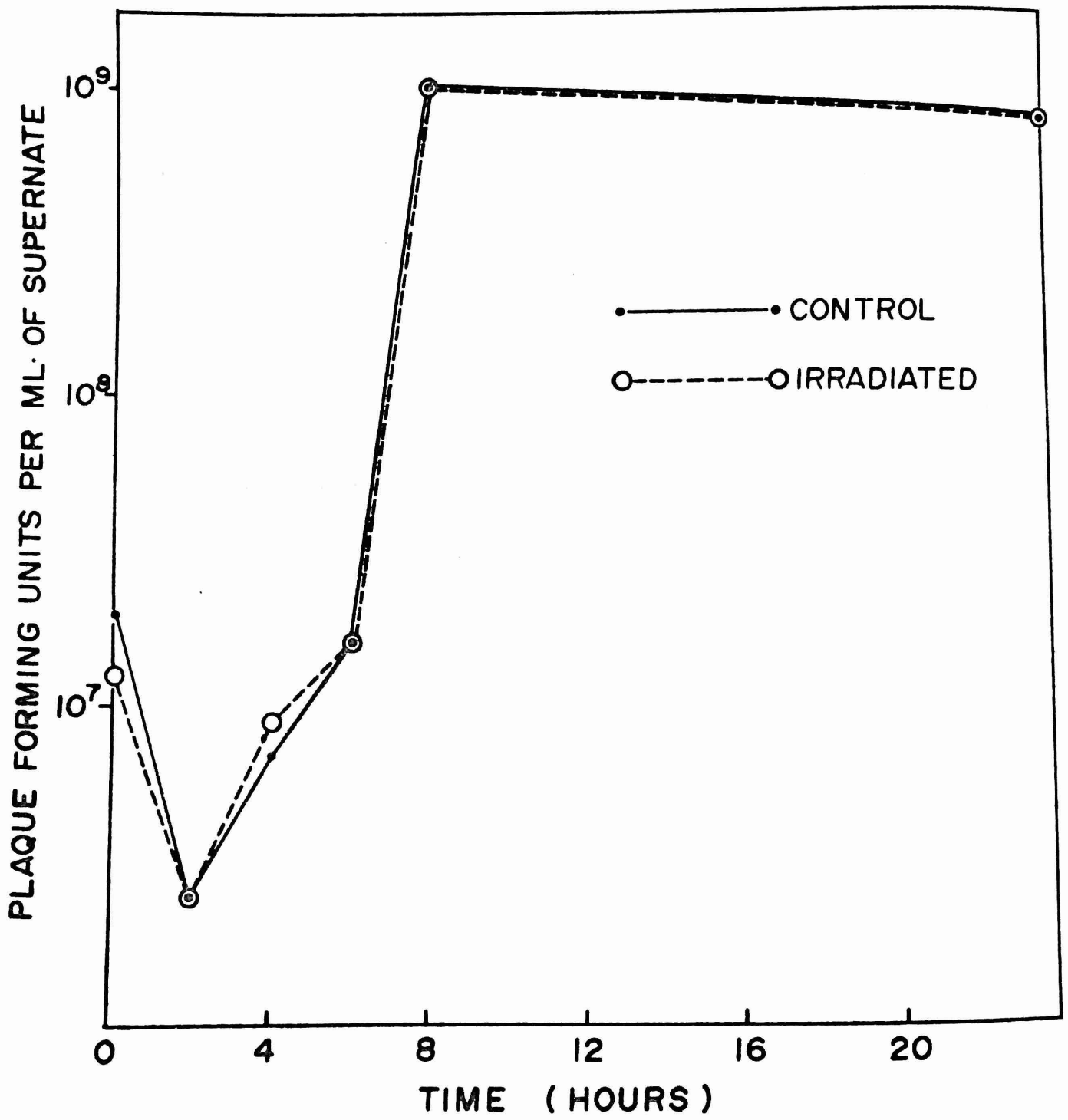
SUSCEPTIBILITY OF INDIVIDUAL CELLS OF THE PACKED MONOLAYERS TO VIRAL INFECTION

In order to determine the susceptibility of individual packed cells to virus infection, an experiment using the "infective centers" technique was performed. The idea was to find out if the cell pack was composed of two types of cells, one susceptible and another type resistant to the viral infection. The packed monolayers were infected and 30 minutes later were washed and trypsinized, and the cells were counted. They were then diluted and plated on chick fibroblast monolayers just as if they were virus. The results indicated that 100% of the cells were susceptible to the viral infection. The susceptibility of packed cells that were infected and put through six cycles of trypsinization and monolayer formation over a period of two months, was also determined by using the "infective centers" technique. The results this time indicated that only 8% of the cells were susceptible to the viral infection. These results suggest that the packed monolayers formed in the presence of virus were composed of cell types, which are resistant to the viral infection.

SUMMARY

A practical outcome of our current studies has been the development of viral latency in tissue culture. As the cell mass reaches a maximum, viral propagation stops, but reactivation is possible by trypsinizing the cells. This provides a means for studying the mechanisms of viral latency.

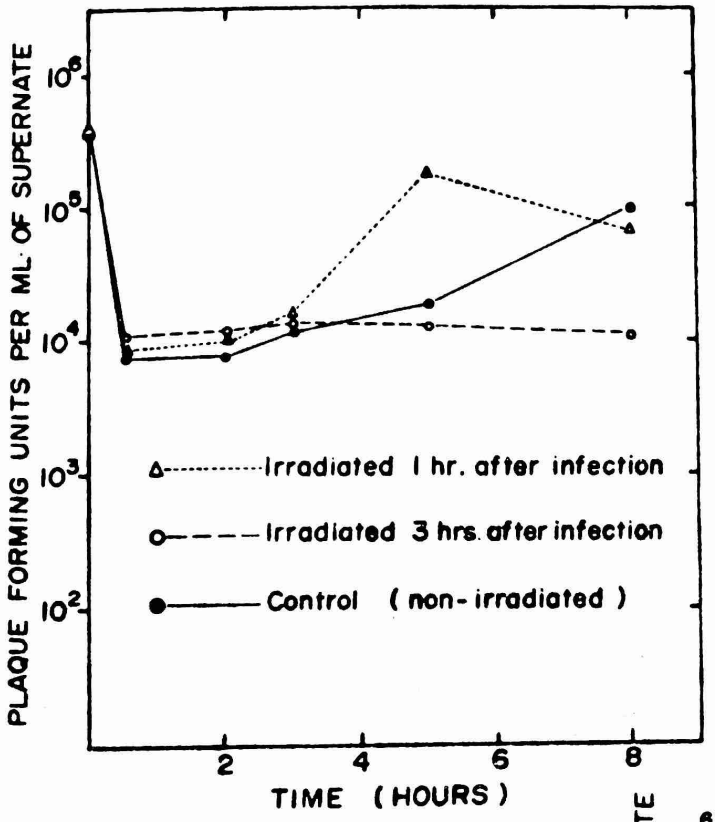
FIGURE 1
SINDBIS VIRUS GROWTH CURVE IN RADIATED AND NON—IRRADIATED L--CELLS



Thirty ml Falcon tissue culture bottles seeded with five mils of L-cells (8 X 10^5 cells/ml) were allowed to grow for 24 hours. Some bottles were irradiated with 700 rads while others served as the unirradiated control. Virus was added at moi = 20. Samples from cell medium were taken at the indicated times.

FIGURE 2

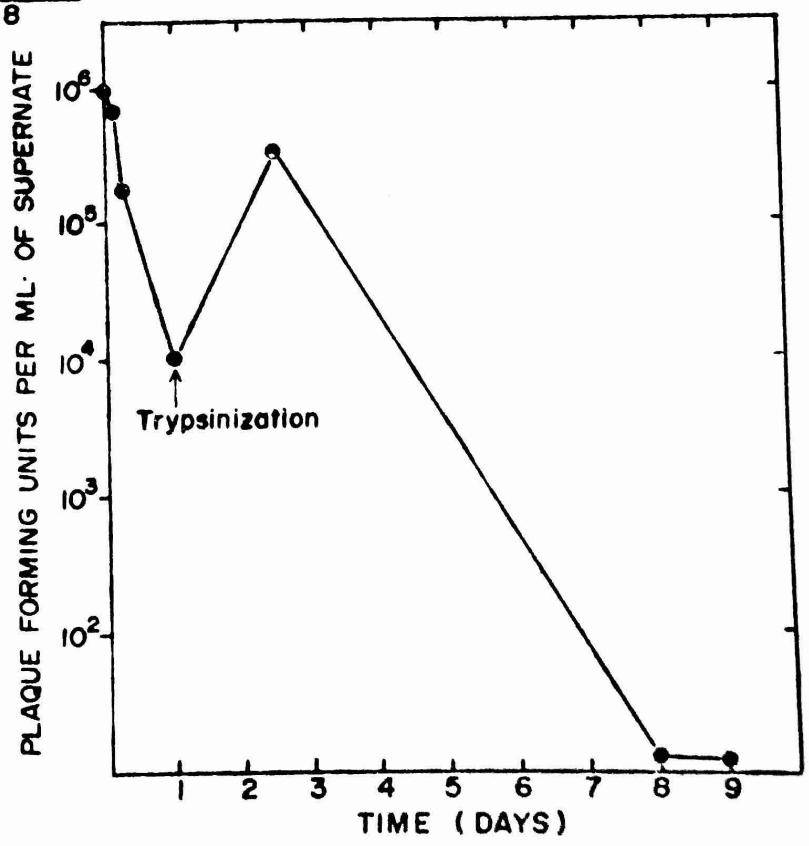
THE PRODUCTION OF SINDBIS VIRUS IN L-CELLS IRRADIATED AT VARIOUS TIMES AFTER INFECTION



Twenty-four hour L-cell were infected with a moi=1. Different L-cell monolayers were irradiated at various times after infection and the virus in the cell medium was titrated.

FIGURE 3

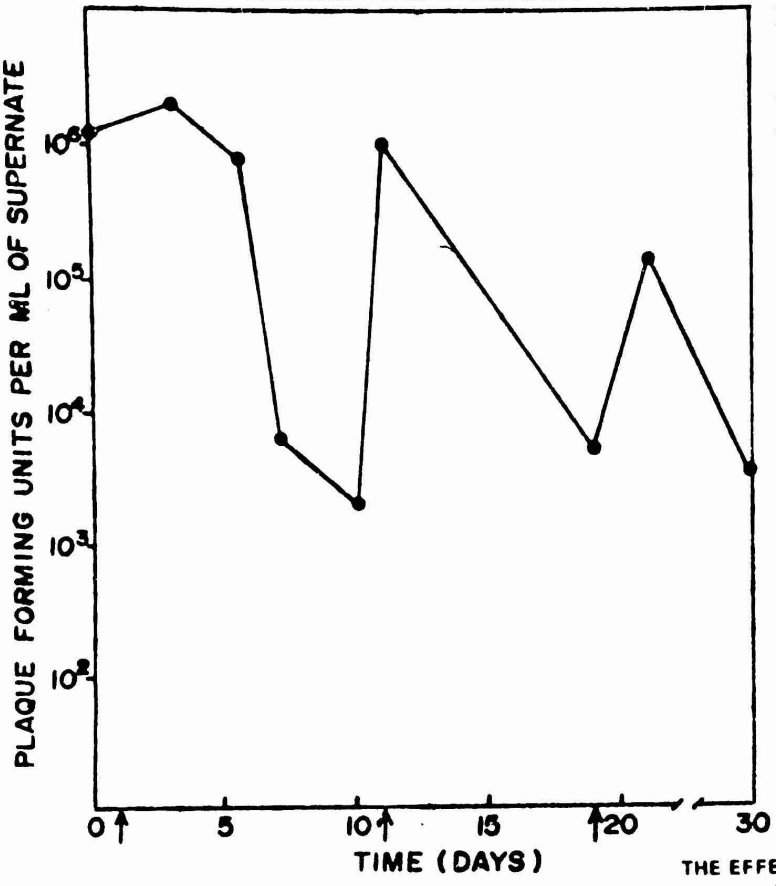
THE EFFECT OF TRYPSINIZATION ON SINDBIS VIRUS PRODUCTION IN PACKED L-CELL MONOLAYERS



Five mis of L-cells (8×10^5 cells/ml) were seeded into 30 ml Falcon plastic bottles and allowed to grow for two weeks. The cells were infected with Sindbis virus and the free virus was titrated for 24 hours at which time the cells were trypsinized and split into two bottles. The arrow shows the time at which the cells were tripsinized.

FIGURE 4

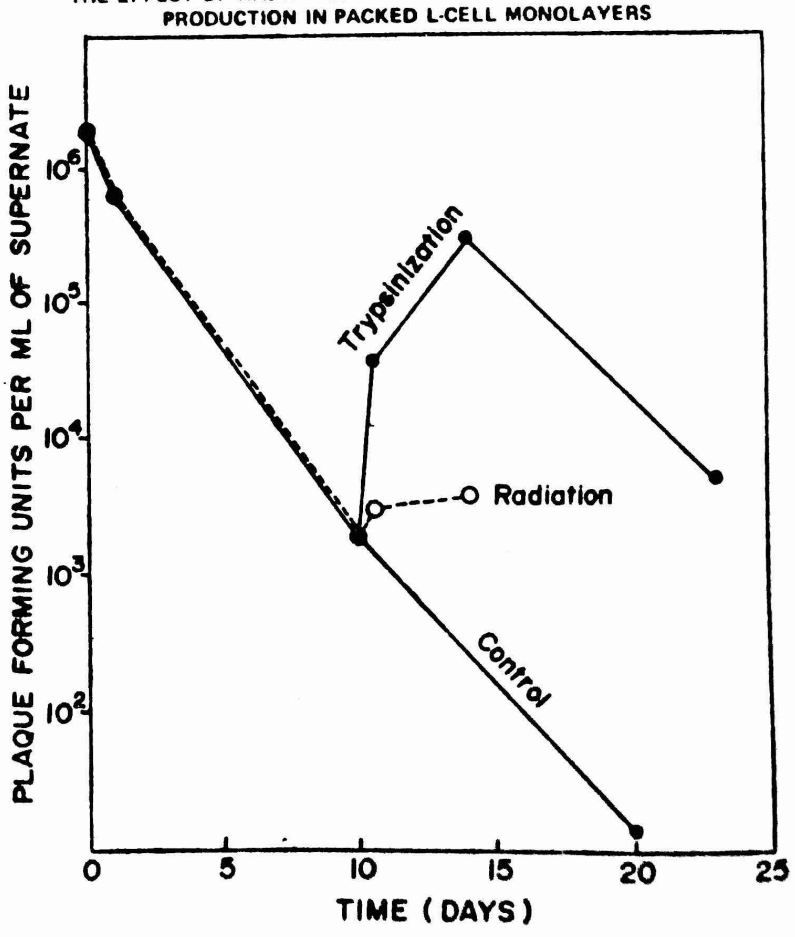
THE EFFECT OF TRYPSINIZATION ON SINDBIS VIRUS PRODUCTION IN PACKED L-CELL MONOLAYERS



Packed L-cell monolayers were infected with Sindbis virus and trypsinized at the days indicated by the arrows. Free virus was titrated at the indicated times.

FIGURE 5

THE EFFECT OF RADIATION AND TRYPSINIZATION ON SINDBIS VIRUS PRODUCTION IN PACKED L-CELL MONOLAYERS



Packed L-cell monolayers were prepared as described previously and infected with Sindbis virus. Supernatant titers were taken for 10 days. Some monolayers were kept as control, some were trypsinized while others were irradiated with 700 rads. The free virus was titrated at the indicated times from each group of monolayers.

Fascioliasis Project

The fascioliasis research project at the Puerto Rico Nuclear Center has been strengthened by continued interest and contractual agreements with the Puerto Rico Department of Agriculture. Moreover, a cooperative alliance with the U. S. Department of Agriculture and Cornell University afforded opportunities to study a biological control measure against the molluscan intermediate host of *Fasciola hepatica*, the liver fluke of cattle, sheep and man.

EPIDEMIOLOGICAL STUDIES ON SNAIL VECTORS

The distribution of the two snail vectors of fascioliasis is being studied in two subtropical ecological zones in Puerto Rico. Both seasonal population dynamics of these snails and their *F. hepatica* infection are under observation on three farms with varying climatic conditions, especially rainfall. This study will require several years, but striking differences in the epidemiologies are already apparent.

There is a direct correlation between rainfall and snail population density, especially for *Lymnaea cubensis*. Moreover, the rate of snail infection relates to rainfall.

ISOLATION PURIFICATION AND IMMUNOLOGICAL STUDIES OF *FASCIOLA HEPATICA* EXO–ANTIGEN LABELLED WITH ^{75}SE + METHIONINE

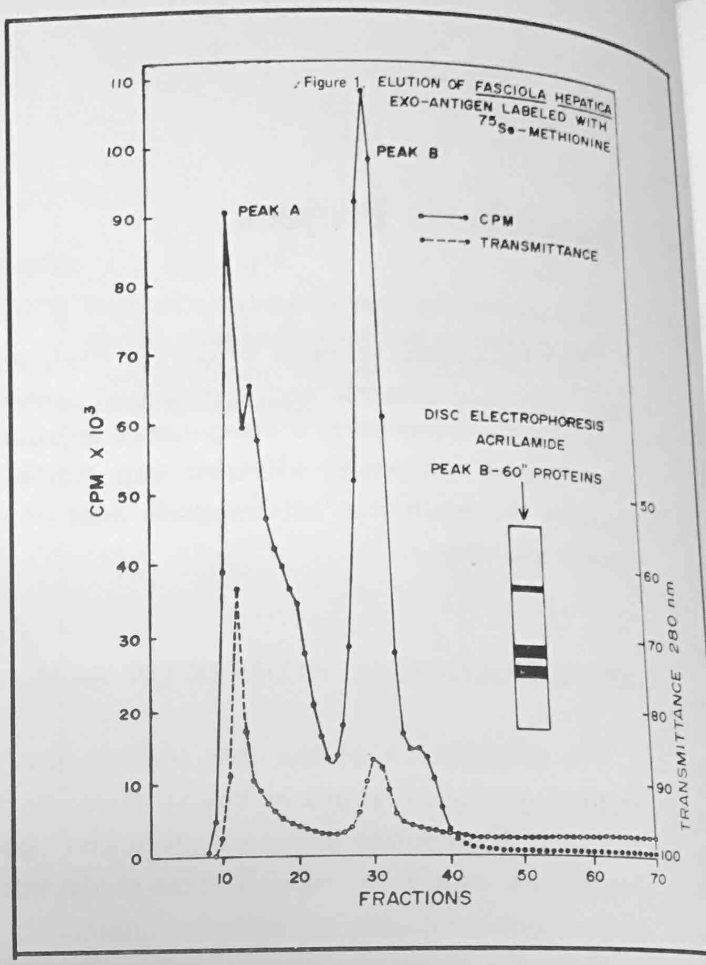
Immunization attempts using fragmented *Fasciola hepatica* have been fruitless. However, we have obtained adequate protection of rats by using irradiated metacercariae, a fact which leads us to believe that exo-antigen produced by the live parasite is indispensable for the production of immunity.

We have incubated adult flukes with ^{75}Se + methionine, and have obtained a series of proteins marked with this isotope. These proteins have been purified first by using Sephadex 100 and then by gel electrophoresis.

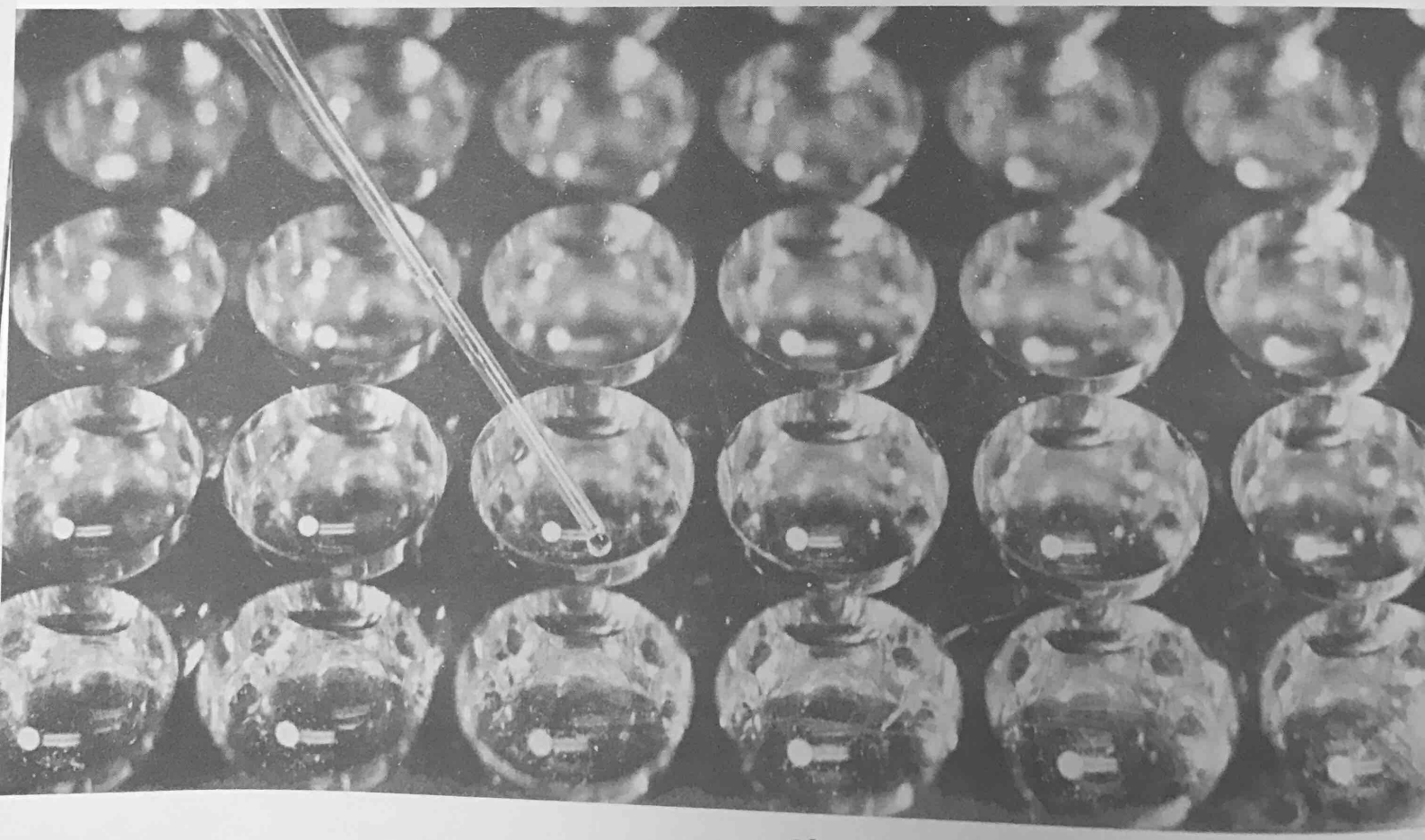
In the graph of the Sephadex elution curve (Figure 1), we find two peaks that we call "A" and "B". The "B" peak specifically precipitates with *Fasciola*-positive rat serum, but not with negative serum. In addition, by using Farr's method of ammonium sulfate precipitation we can observe a high specific binding.

In the "A" and "B" fractions eluted from the Sephadex and purified by gel electrophoresis we can observe 5 bands in "A" and only one in "B".

Future studies will be in 2 directions; first the use of marked proteins for a radioimmunological diagnosis that is greatly needed in *Fasciola*, and second, the analysis of the role of these exo-antigens in the immunological protection against *Fasciola*.



The microtiter plate is utilized in the Fascioliasis Project of the Puerto Rico Nuclear Center to isolate individual metacercariae (the infective form of the *Fasciola* worm ingested by cattle). These larvae are being irradiated for experimental vaccination of rats and cattle. Excellent success has already been achieved in rats. In Peru this disease has virtually eliminated animal husbandry in the Andes and it is recognized as a human health problem. In the United States it causes millions of dollars in losses from condemned infected cattle livers.



BIOCHEMICAL TESTING FOR HEPATIC MALFUNCTION DUE TO FASCIOLIASIS

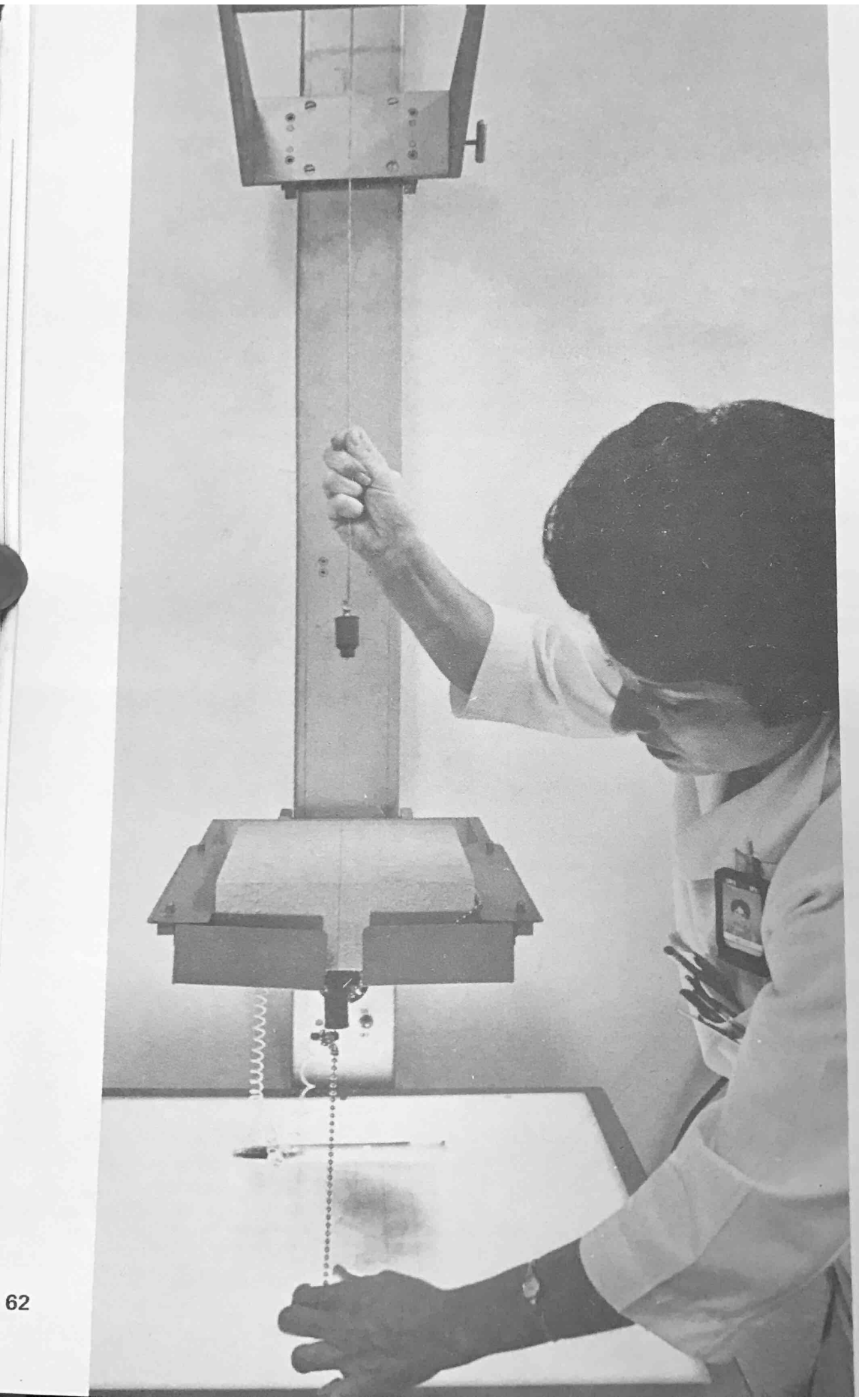
The degree of *F. hepatica* liver damage in rats was assayed by determination of serum glutamic pyruvic transaminase levels in serum samples. SGPT levels were determined for untreated rats and those inoculated with metacercariae as irradiated with 1.5, 2.5, and 5.0 Kilorads. Pre-test samples of blood were taken from each group of 20 rats weighing 200-300 grams. Following standard SGPT testing, which included control transaminase from rat liver mitochondria, it was concluded that 1) The method is satisfactory, 2) Correlation exists between radiation dose and SGPT levels, 3) Immunizing with metacercariae irradiated with 2.5 Kilorads seemingly causes increased hepatic damage, 4) Return of SGPT levels to normal is adversely affected by irradiation of infective metacercariae. Obviously, attainment of immunity with single-dose irradiation of metacercariae without hepatic damage is worth future testing.

BIOLOGICAL CONTROL

The aquatic larvae of sciomyzid flies feed solely on tissues of freshwater snails and afford a natural means of *Lymnaea* control. Although a species of *Sepedon* was released in Hawaii for experimental control purposes, no adequate evaluation of the method was made. For our investigation a dairy farm at Jayuya, Puerto Rico, was selected for the following reasons:

1. There is a high prevalence of fascioliasis in the cattle.
2. Two rivers passing through the farm and adjoining swamps are heavily populated with both of the local snail vectors, *L. columella* and *L. cubensis*.
3. Both snail vectors are highly infected with *F. hepatica*.
4. Weather conditions (low temperature and high precipitation favor snail propagation.
5. A sciomyzid fly is present (*Sepedon caerulia*).

Our future investigations will center on use of *Sepedon* for control of snail vectors in this area of high rainfall. Comparisons will be made in areas of lower rainfall.



This styrofoam poly-shaper is used for making styrofoam molds in which blocks will be formed to shield critical areas of the body during radiotherapy. From a block of styrofoam a portion of the required shape is cut by wire, heated by an electric current. The shape of the styrofoam removed is determined by moving a pointer held at the lower end, over an illuminated radiograph on which the required shape is marked. The equipment is being manipulated by Miss Cecilia Ramirez, a dosimetrist in the Medical Physics Section.

Medical Physics Section

The most important activity of the Medical Physics Program during the past year was the acceptance and putting into operation of the new Mevatron XII Clinical Linear Accelerator. This accelerator introduces into the Caribbean area, for the first time, the capability of electron therapy at either of three select energies 3, 7, and 11 MeV. It also produces X-rays of 8 MeV energy. The machine arrived at the Puerto Rico Nuclear Center on February 26, 1973 and, after installation and testing, it was accepted on May 30, 1973. Collection of physical data and training programs for the operators were conducted by the Medical Physics Program during the ensuing months, and the first patient was treated with electrons on September 24, 1973.

The Medical Physics Program also provides, 1) radiation dosimetry and treatment planning services to the Radiation Oncology Division, 2) supervision of the Whole Body Counter and the Cobalt-60 irradiation facilities, 3) scientific programs designed to improve the techniques used in the above operations, 4) educational programs for Radiotherapy residents and other participants in graduate degree programs, and 5) consultation services to some local hospitals.

TRAINING ACTIVITIES

On the job training of 1-2 months duration was provided for 5 students, one each from Argentina, Ecuador, Chile, San Salvador and the Dominican Republic. Two were provided Fellowships by PAHO and one by I.A.E.A. the other two were residents in the Radiation Oncology Division.

Six students received additional training in Medical Physics following their completion of the M.S. Degree in the Radiological Health graduate program. Four were from P.R., and one each from Brazil and Colombia; a seventh student from the continental U.S. joined the above students for their summer training.

RESEARCH ACTIVITIES

Dosimetry Studies on the Mevatron XII Clinical Linear Accelerator. The isocentric technique was selected for positioning and treating tumors with the 8 MeV photons of the new linear accelerator. The dosimetry calculations for this technique involves the use of Tumor-Maximum Ratios (TMR'S), which have not been reported for this energy. These measurements and collection of other data for electron dosimetry with the linear accelerator are in progress.

Application of Lif Thermoluminescence to Electron Dosimetry. Studies of the response of Lif thermoluminescent dosimeters to various high energy gamma and beta irradiation emitted by the Mevatron XII linear accelerator are in progress. Central axis depth dose data obtained for TLD results are in good agreement with those obtained using ionization detectors and photographic techniques. Comparisons are also being made with Fricke dosimeters. TLD responses at maximum depth dose show a dependence on beta ray energies.

TLD Measurements of Radiation Exposures to Newborn Babies with two Different Types of X-ray Machine. CaF_2 (Dy) TLD was used to measure radiation exposures to the skin and gonads of newborn babies during chest radiography with field-emission and conventional X-ray units. Phantom measurements at unit film densities were also made and show no significant difference in exposures from the two units, with approximately 7 mr to the skin, 4 mr to the mid-plane of the phantom, in the beam, and less than 0.5 mr to the location of the gonads during chest radiography. Patient measurements agreed with these values for the field-emission unit, but with the conventional unit, skin exposures were in general higher, up to a factor 2. These differences may be caused by a lack of density control and greater flexibility in the choice of exposure factors with the conventional unit.

STAFF

Dr. E. Theodore Agard visited the M.D. Anderson Hospital and Tumor Institute in Houston Texas during the period January 28 to February 14, 1973. While there, he attended a one-week course on "Computer Methods in External Beam, Interstitial and Intracavitary Dosimetry" and reviewed methods of high energy X-ray and electron dosimetry. Dr. Agard also gave a seminar on "In Vivo Measurement of Calcium by Neutron Activation Analysis, and Associated Dosimetry". On this trip, he also visited the Physics Department The Peter Bent Brigham Hospital, in Boston to learn their experiences with the Mevatron XII linear accelerator, similar to the one subsequently installed at the Puerto Rico Nuclear Center.

The following scientific meetings were attended by Dr. Agard during the period of this report: Annual Conference of the American Association of Physicists in Medicine in San Diego, California, July 28 to August 3, 1973; Third Congress of the International Radiation Protection Association in Washington, D.C., September 9-15, 1973 and the combined Annual Meeting of the Radiological Society of North America and Winter Meeting of the American Association of Physicists in Medicine, in Chicago, Illinois, November 25 to December 1, 1973. After the AAPM meeting in San Diego, a visit was also made to the headquarters of the Applied Radiation, manufacturers of the Mevatron XII linear accelerator, to settle certain outstanding matters related to the delivery of the linear accelerator.

Dr. Agard assumed the duties of Acting Director of the Radiological Health Training Program in November, on the retirement of Dr. Peter Paraskevoudakis from this position.

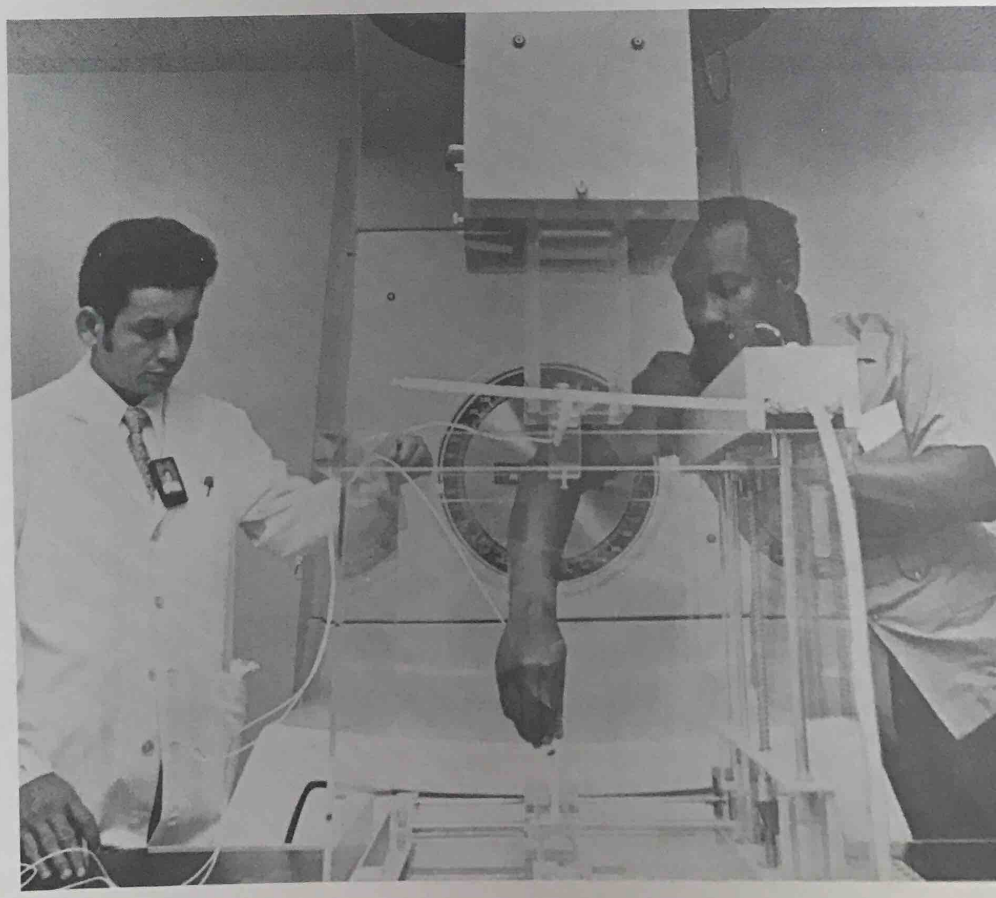
Mr. José C. Pacheco attended the Second Conference on the use of Dedicated Computers in Radiation Oncology, held at the Mount Sinai School of Medicine on May 15, 1973. He also visited the Memorial Hospital and Sloan Kettering Institute to look into their computerized dosimetry service.

Mr. Porfirio A. Toledo who had joined the Medical Physics Program on a part time basis in January, and was working mainly with the Whole Body Counting facility, spent two weeks of training on Whole Body Counting from May 29 to June 8, 1973 at the O.R.A.U. Medical Division. Mr. Toledo resigned his position in the Medical Physics Program to devote the equivalent time to the Radiological Health Training Program in the University of Puerto Rico School of Public Health.

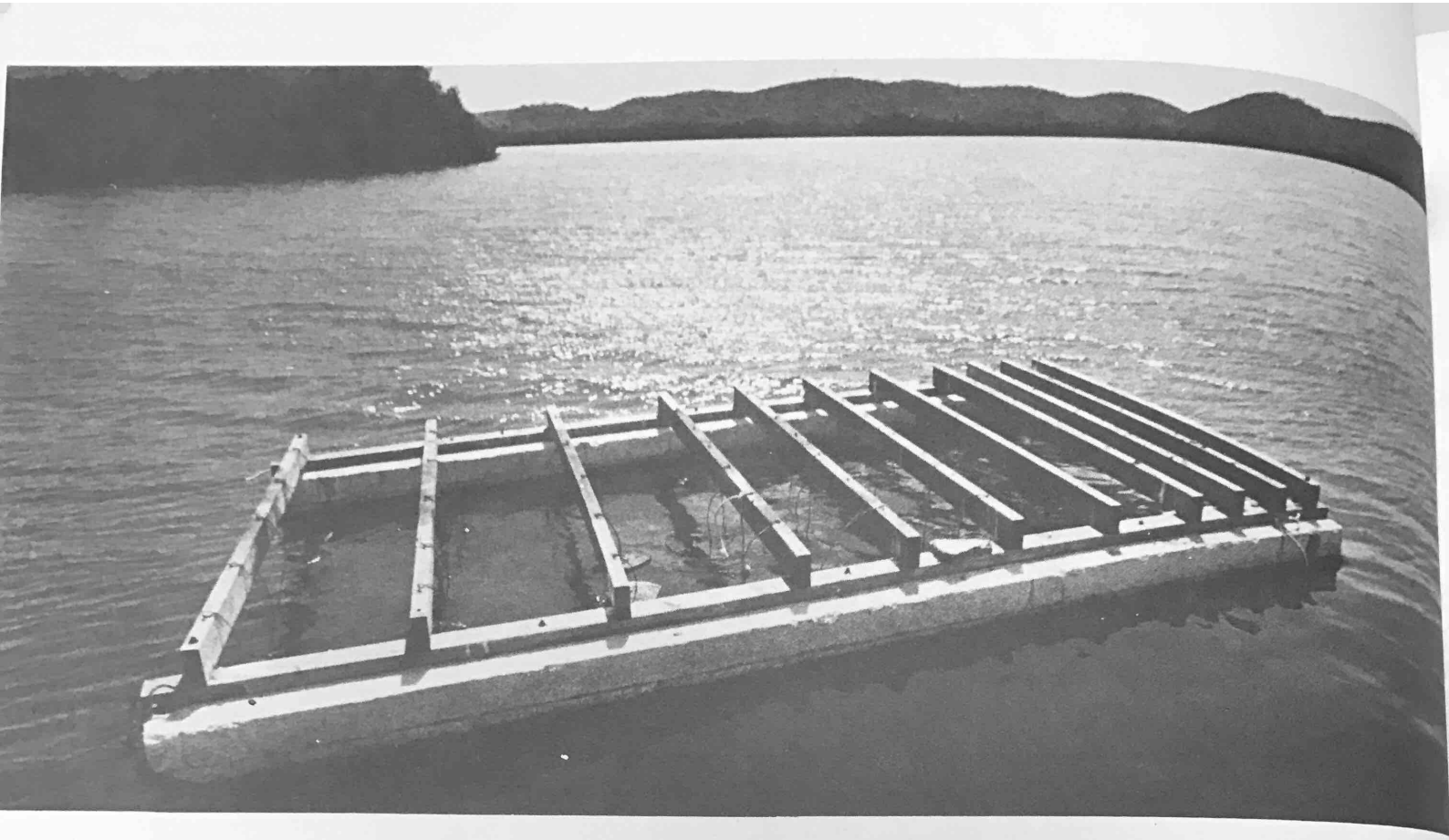
Dr. George A. Simpson form the Physical Sciences Division, in charge of the Gamma Radiolysis Project, joined the Medical Physics Program on a part time basis from July 1 and has been working largeley on thermoluminescent dosimetry.

Miss Cecilia Ramírez, who has been associated with Medical Physics at Puerto Rico Nuclear Center for many years as an employee of the UPR Medical School, joined staff of the Medical Physics Program on a part time basis as a Research Associate II on July 1.

Miss María de los A. Amaro worked as a technical Associate in the Medical Physics Program from January 1 to June 30, 1973. Mr. Néstor Rodríguez resigned on November 30 from his post as Scientific Assistant I in charge of operating the Cobalt-60 facility.



The linear accelerator is capable of producing X-rays of 8 Mev energy and electrons of 3, 7, or 11 Mev. The machine has brought a new dimension of radiation therapy into Puerto Rico as the very penetrating and sharply-defined beam of radiation is capable of delivering a higher dose to deep-seated tumors with less dose to surrounding tissues than any other radiation source on the Island. In addition the electrons are very suitable for treating the skin since the range of penetration into tissue is very limited, from 0.5 cm to about 3.0 cm depending on the energy chosen.
Before patients can be treated, it is necessary to determine the distribution of radiation in the body under different operating conditions. This is done by use of an automatic isodose plotter. Water is placed in the plastic container to simulate human soft tissue and the water, charted by the detectors in it, is reproduced on a chart outside the room, where the remote controls for this plotter are located.



A floating raft used for growing oysters in Laguna Rincón. Strings of substrates with oysters are hanging down from the wooden cross pieces

These juvenile Japanese oysters, *Crassostrea gigas*, are part of the Mariculture Program of the Radioecology Division. The Program is attempting to start a commercial oyster-farming industry in Puerto Rico, working with the mangrove oyster, American oyster, and Japanese oyster. On a pilot study scale, market-size mangrove oysters have been grown in three months, the largest reported mangrove oyster (104 mm.) has been grown, and the Japanese oyster has been grown to maturity from seed, and induced to spawn.

RADIOECOLOGY

The Radioecology Division currently has eight research projects in progress. These are: Jobos Bay, Site Selection, and Islote projects, all supported by the Puerto Rico Water Resources Authority; Marine Biology, Bikini, and Terrestrial Ecology, supported by the U.S. Atomic Energy Commission, and two Mariculture projects, one of which is supported by the U.S. Department of Commerce and the Puerto Rico Department of Agriculture, and the other by the National Science Foundation. The Division provides centralized administrative and logistic support to the projects, leaving investigators free to pursue research activities.

Mariculture Project

The Mariculture Fisheries Development Project, started on July 1st, 1973, is a joint study by the University of Rhode Island's International Center for Marine Resource Development and the Radioecology Division of the Puerto Rico Nuclear Center. It is funded by the National Science Foundation's Industrial Incentives Program.

The overall objective of the project is to examine methods of improving the present Puerto Rican harvest fishery, and of implementing a new mariculture industry in Puerto Rico. Studies to date have focussed on two broad areas: technological studies of ways of improving the yield of the fish trap fishery and starting a mariculture industry, and socio-economic studies of the recipient populations in fishing villages and of barriers that might exist to implementing new technologies.

A project of this scope has broad implications in Puerto Rico, and cannot be successfully completed without cooperation from private industry and government on a wide scale. Project investigators have worked extensively in several southwestern Puerto Rican fishing villages, and have obtained the interest and trust of many fishermen. Contact has also been established with several Commonwealth agencies, among them the Department of Agriculture, the Department of Natural Resources, and the Economic Development Administration (Fomento). The Department of Agriculture has been very helpful in providing space and information gained from their Exploratory Fishing and Fisheries Statistics programs. The Aguadilla Regional College of the University of Puerto Rico has expressed interest in starting a vocational training program for commercial fisheries, with the Puerto Rico Nuclear Center and the University of Rhode Island aiding in developing a curriculum and providing materials.

Fish Culture Project

On December 15th, 1972, the Fish Culture Project, supported by Public Law 88-309 Funds, was started by the Puerto Rico Nuclear Center in an effort to determine which marine organisms were most suitable for commercial mariculture production, if any. Until that time, there had been virtually no work on mariculture done in Puerto Rico, even though animals exist, on the island, which have been cultured elsewhere.

In order to attempt to establish a mariculture industry in Puerto Rico, there are several non-technical factors which must be considered. Among these are: 1) Who is likely to be the culturist, a corporation with capital and expertise at its command, or an individual? 2) If an individual, what will his resources be? 3) Is the operation going to compete with, cooperate with, or enhance existing fisheries? 4) Will there be a market for the product?

Of equal importance are technical factors, such as: 1) How much of the life-cycle of the animal can be controlled? 2) How hardy is the animal? 3) What does it eat, and is the food cheap and readily available? 4) How efficient at converting food is the animal? 5) How does it grow?

All of these factors are being investigated, as well as several others, in selecting animals suitable for culture. Ultimately the broader aspects of competitive land use, existing fisheries, and socio-economic backgrounds will also have to be taken into account.

Before concentrated work could be started on animals, a sea-water laboratory was needed as a base to work from. With the cooperation of the Puerto Rican Department of Agriculture, offices and working space were obtained at their Fisheries Laboratory at Guanajibo. Construction of a sea-water lab was started as soon as possible, and by May 1973,oysters and fish were stocked in aquaria. The lab initially had a 1200 gallon capacity which has since been expanded to 2000 gallons.

As collection and feeding of organisms continued, it became clear that work had to be rapidly concentrated on as few species as possible. The species were selected on the basis of certain criteria, including reasonable market price, ready availability of juveniles, and lack of complication in the techniques needed to raise them. The mangrove oyster, *Crassostrea rhizophorae*, met these criteria better than any of the other animals available. There exists a body of scientific literature and experience in the culture of oysters, and a commercially valuable oyster fishery has been carried on in Puerto Rico for some time. The life-cycle of the oyster has been determined, an abundance of natural food is available, and oyster rearing techniques are unsophisticated.

Even though fish sampling and feeding are being continued, work was concentrated on oysters. Growth and survival studies of *C. rhizophorae* done in baskets showed that the Laguna Rincón area of Boquerón Bay was a good site. A raft was anchored in the lagoon utilizing various types of cultch material in order to see if spat could be collected and grown. In three months, market sized oysters were harvested from this raft. A second raft

was put out using rubber cultch, which had showed the best results on the original raft. Baskets containing imported specimens of *C. virginica* and *C. gigas* were suspended from the rafts. These animals also exhibited excellent growth and low mortality when put into the lagoon (Figure 1). Maximum growth rates of 0.5 to 0.8 mm per day were noted for both *C. virginica* and *C. gigas*, and maximum growth of 0.6 mm per day was observed for mangrove oysters growing on cultch. Ways of reducing fouling on cultch strings and baskets have been studied. So far, dipping in quicklime and Sevin, a commercial insecticide, has shown promise.

While a basic method for raft culture of oysters has been developed, and the animals clearly show an excellent growth potential, the present system is too inefficient in labor and yield to be commercially feasible. Therefore, a spat-setting and grow-out system is being developed using flexible sheeting in frames. Spat will be set on intertidal collectors near the mangroves. The frames will then be removed and set into rafts for "grow-out". The frames are easier to handle than cultch strings and permit rapid lime-treatment and harvesting. It is hoped that this method will be proven by the end of 1974, so that other coastal areas of Puerto Rico may be examined for their oyster culture potential.

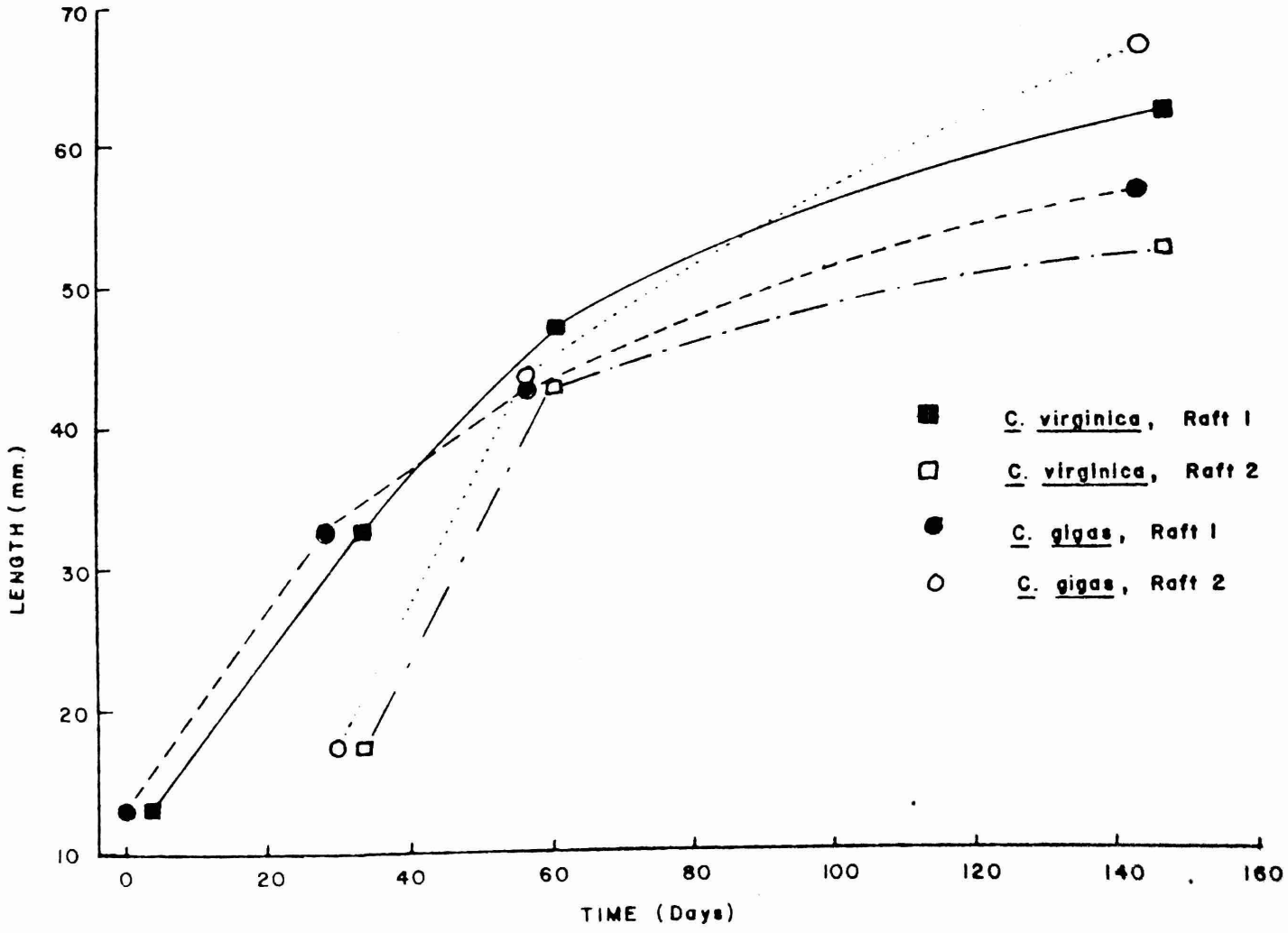
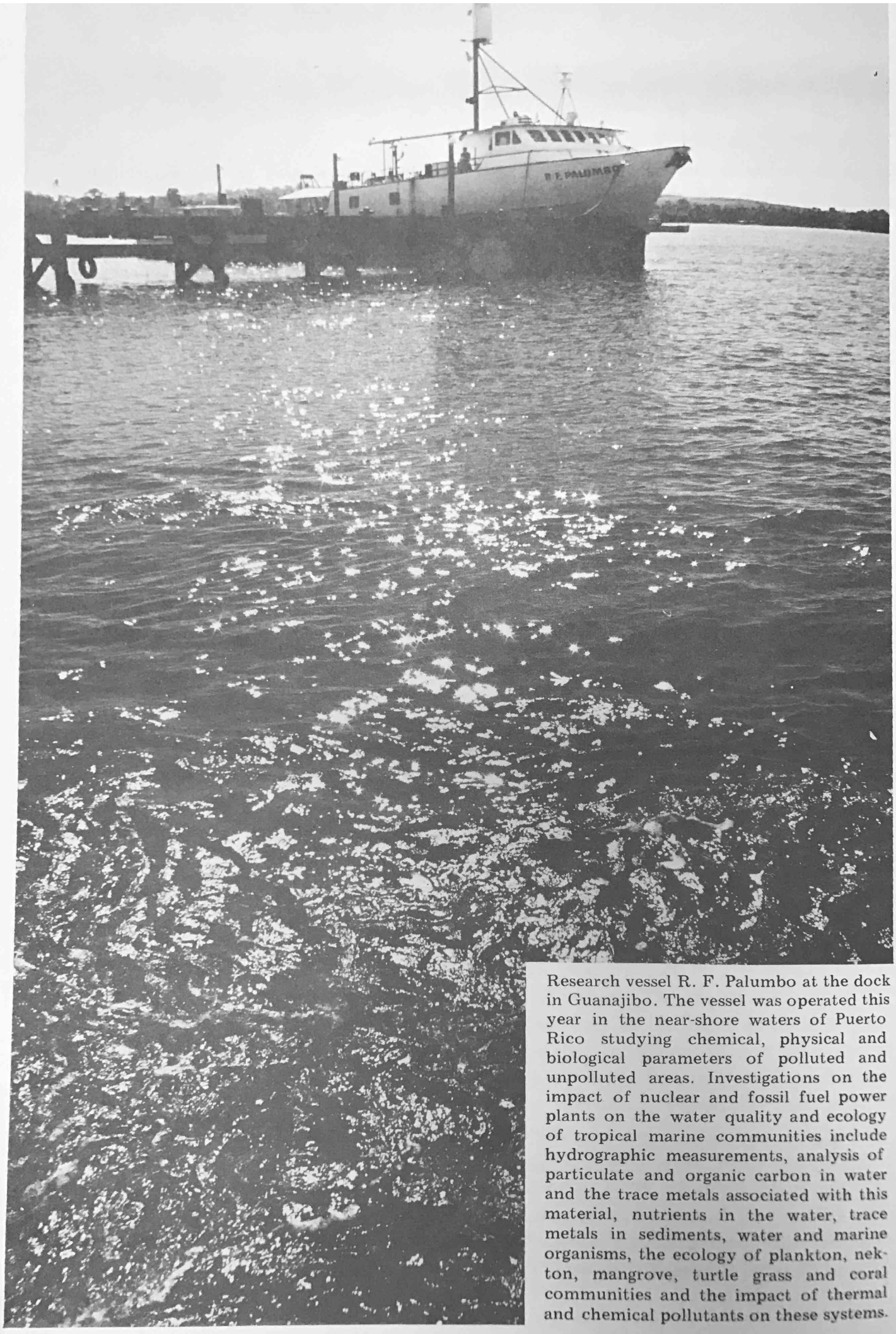


Figure 1. Growth of *C. gigas* and *C. virginica* in Rincon Lagoon (modal length)



Research vessel R. F. Palumbo at the dock in Guanajibo. The vessel was operated this year in the near-shore waters of Puerto Rico studying chemical, physical and biological parameters of polluted and unpolluted areas. Investigations on the impact of nuclear and fossil fuel power plants on the water quality and ecology of tropical marine communities include hydrographic measurements, analysis of particulate and organic carbon in water and the trace metals associated with this material, nutrients in the water, trace metals in sediments, water and marine organisms, the ecology of plankton, nekton, mangrove, turtle grass and coral communities and the impact of thermal and chemical pollutants on these systems.

Marine Biology Section

In the past, the scope of the Marine Biology Section has been directed primarily toward radionuclide contamination and the cycling of trace elements in the marine environment and coastal watersheds. In these studies the emphasis has been placed on refinement of the specific activity model and the testing of its accuracy, especially with regard to the effects of the physical and chemical form of elements to the uptake of the elements by aquatic organisms. The mission of the program has now been broadened to include the impact of power production on the water quality and the ecology of tropical marine communities.

Studies in pollution ecology are needed in Puerto Rico and other tropical areas where economical growth is changing the environment from a rural undeveloped agricultural land to an urban and highly industrialized area. The impact of man's activities are producing general deterioration of the terrestrial and marine environment. Studies on pollution ecology are a natural outgrowth of the environmental assessment studies for electrical power plant siting by the Radioecology Division of the PRNC, and the interim needs of the Atomic Energy Commission and the Commonwealth of Puerto Rico.

The facilities of the Marine Biology Program have steadily been improved both for chemical, radiochemical, oceanographic and ecological studies. An improvement during the past year was the completion of the dock for Palumbo, a repair shop building for outboard motor boats and a launching ramp at Punta Guanajibo. A 2,000 sq. ft. wet laboratory is planned to be completed in FY-75 at the dock area. This laboratory will make it possible to study the uptake of trace elements and radionuclides in microcosms of marine communities and to conduct controlled experiments on the impact of thermal and chemical pollution on tropical marine organisms and ecosystems.

Cooperative programs have continued with the University of Puerto Rico, University of Rhode Island, University of Miami, Puerto Rico Inter-National Undersea Laboratory, and different governmental agencies in the Commonwealth of Puerto Rico.

Studies in the Marine Biology Section fall into three categories: 1. Marine ecological and pollution studies, 2. Oceanographic and limnological studies, and 3. Analytical methods.

MARINE ECOLOGICAL AND POLLUTION STUDIES

Tropical marine ecosystems have not been studied as widely as the temperate ones. Therefore, the ecology of many tropical marine organisms and ecosystems is poorly known. In order to understand the impact caused by different man-made stresses on individual species or communities, basic ecological studies are conducted in the near-shore marine communities. These studies also enable us to construct pathways of trace elements and

radionuclides in the food chains. In the past year ecological studies have been carried out on mangrove and coral reef ecosystems and benthic foraminiferal assemblages.

Pollution studies are conducted on thermal effects in the turtle grass beds and on siltation effects in the coral reef ecosystem. Trace elements are being analyzed in various invertebrates and fish. Heavy metal concentrations in ascidians are studied to evaluate their usefulness as indicator organisms for hydrocarbon pollution. This is done by analyzing specific heavy metals, like nickel, vanadium and chromium that are found in crude oil. Transuranium studies in marine ecosystems have been initiated by utilizing bomb crater sediments from the Bikini Test Site. Transuranium elements leached out from the sediments into sea water are used to study the uptake of these elements by marine organisms in laboratory conditions.

Ascidian Populations — S. E. Kolehmainen. Ascidians constitute a significant proportion of the biomass in several benthic ecosystems in the Caribbean. In the mangrove root community they are often the dominant group (Kolehmainen, 1973a; Kolehmainen *et at.*,) and in turtle grass *(Thalassia testudinum)* beds they contribute up to 25% of the biomass of benthic animals (Kolehmainen, 1973b). In coral reefs ascidians are not a major group, but they are found in most locations. (Szmant-Froelich, 1973).

The role of ascidians in the tropical ecosystems is poorly known. This study was made to obtain quantitative information on the abundance of ascidians and their preference in substrate. Number of species, species diversity, density and biomass of ascidians were studied along a 50m. east-west transect which includes a coral reef and an algal flat. The sample site was the PRINUL underwater habitat located 6 miles west of Punta Ostiones off the west coast of Puerto Rico (Figure 1).

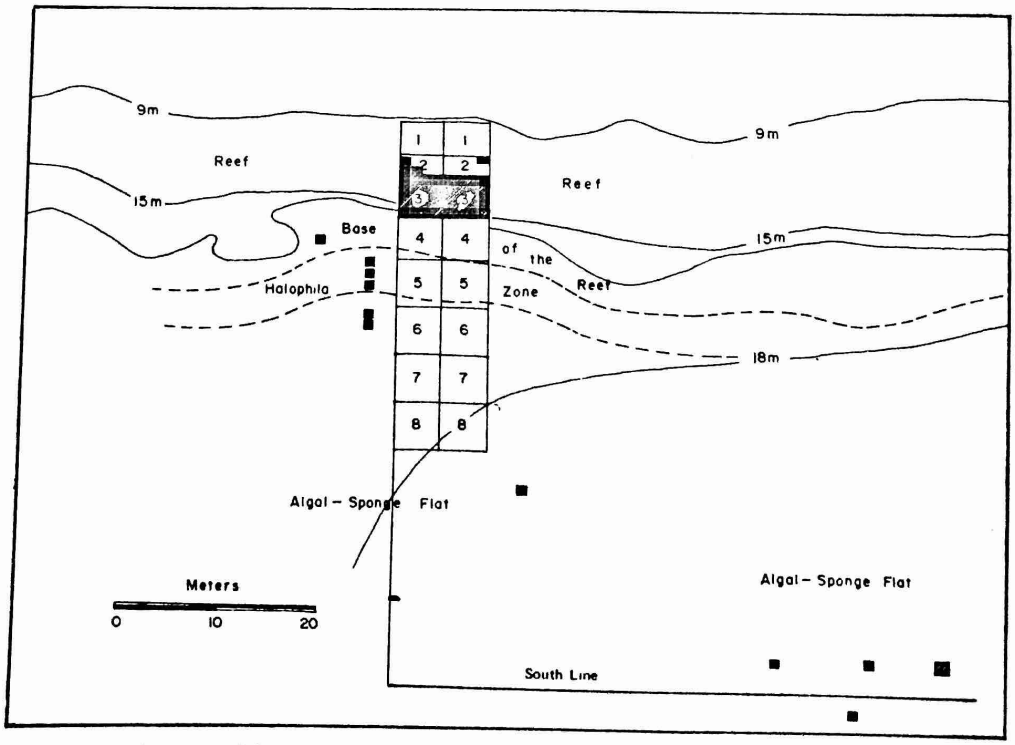


Figure 1. Sampling stations and benthic communities at the reef area 10 km west of Punta Ostiones and west coast of Puerto Rico.

Ascidians were abundant both on the reef and on the flat. On the algal flat they were the most significant group in the biomass after the sponges and algae. The number of species, density, species diversity and biomass followed a similar trend throughout the transect. The values were high on the reef, decreased to zero at the base of the reef and increased again to another maximum on the algal flat (Table 1, Figure 2).

The distribution of ascidians was related to the substrate. Ascidians appear to require a hard or semi-hard substrate that does not shift excessively. The sediments at the base of the reef were very fine clay and calcareous silt that is easily resuspended in the surge. Ascidians are not able to live under these conditions. The *Halophila* zone about 10 meters from the base of the reef, where sediments were composed of silt and fine sand, had only one species, a small unidentified styelid species that had up to 400 ind./m^2 (Table 1). The number of species increased with the distance from the *Halophila* zone to about 30 m from the reef, after which distance the population was more or less uniform.

Ascidia nigra, *Clavelina gigantea* and *Styela partita* were found only on hard substrate on the reef. However, *Ascidia nigra* has been found on turtle grass beds on coarse sand (Kolehmainen, 1973b). *Clavelina (purpurascent?)* was found mainly on the gorgonians of the reef, but a few small colonies were also seen on the sand and on the algal flat. *Aplidium lobatum*, *Botrylloides nigrum* and *Symplegma viride* were found on macroalgae on the algal flat. *Microcosmus helleri*, *Pyura vittata*, and *Herdmania momus* were found in the crevices on the reef and embedded in the sediments on the algal flat. *Styela* sp. (a small unidentified sp.) was found always embedded in the top 5 mm layer of sediments. *Symplegma viride* and *Diplosoma macdonaldi* were also found on the decorator crab, *Microphrys bicornutus*. Other species did not seem to have a specific preference for their substrate.

The biomass of ascidians decreased with the depth on the reef, but on the algal flat the biomass was uniform (Table 1). The biomass on the reef was similar to those found on the fringing reefs of Jobos Bay (Szmant-Froelich, 1973). Eleven species were common, both for the reef and the algal flat. Six species were found only on the reef and 7 species only on the algal flat (Table 1). In the fringing reefs of Jobos Bay, 9 species were found (Szmant-Froelich, 1973), compared to 17 species on the reef at the site. Most species in this study have been found also on mangrove roots (Kolehmainen, 1973a; Kolehmainen *et al.*, 1973b) and in *Thalassia testudinum* beds (Kolehmainen, 1973b). The total number of ascidian species found in these studies in Puerto Rico is 32, out of which 5 species were not previously reported by Van Name (1930, 1945).

The distribution of ascidians in Puerto Rico seems to be different from that in Jamaica. *Ascidia nigra* is common on reefs in Puerto Rico, while in Jamaica it has not been found on reefs (Goodbody, personal communication). *Clavelina (purpurascent?)* is found in Puerto Rico from 4 meters depth down, but according to Goodbody no specimens have been found in depths less than 30 meters in Jamaica.

The biomass of ascidians was significant especially on the algal flat. In spite of the abundance of ascidians no animals were observed feeding on them. Goodbody (personal communication) has noticed fish readily feeding on colonial ascidians that do not have a tough test.

Table 1
Biomass of Ascidians in Different Zones in Grams of Wet Weigh per Square Meter

Species	Location						
	Reef at 10-12 m	Reef at 12-16 m	Base of Reef	*Halophila* No 4/5	Algal-Sponge flat No.5	No.5/5	S-line
Aplidium lobatum							1.05
Ascidia interrupta		0.05					
Ascidia nigra	7.50	6.75					
Botrylloides nigrum					0.2	0.2	2.91
Botryllus planus							0.29
Clavelina gigantea	1.52	1.12					
Clavelina oblonga							+
Clavelina sp (purpurascent ?)	0.75	0.69				0.2	+
Cystodytes dellechiaiae	5.80	1.10					+
Didemnum candidum	1.60	1.45			0.1	0.1	2.54
Diplosoma macdonaldi	0.13				0.1		0.86
Distaplia bermudensis	0.06					0.3	
Echinoclinum verrilli		0.05				0.2	2.63
Ecteinascidia conklini							3.20
Ectenascidia turbinata	0.05	0.02					
Eudistoma capsulatum	1.35	1.23					0.82
Herdmania momus	24.00	2.10					4.06
Microcosmus helleri	1.95	0.75			0.8	3.2	3.43
Perophora bermudensis		+				0.1	0.05
Polycitor olivaceus		0.02					
Pyura vittata	0.13	0.30					1.54
Styela partita		0.05					
Styela sp.				19.9	24.8	26.0	7.94
Symplegma viride							0.69
Tridemnum savignii							0.05
Total	45.49	15.68	0	19.9	26.0	30.0	32.06

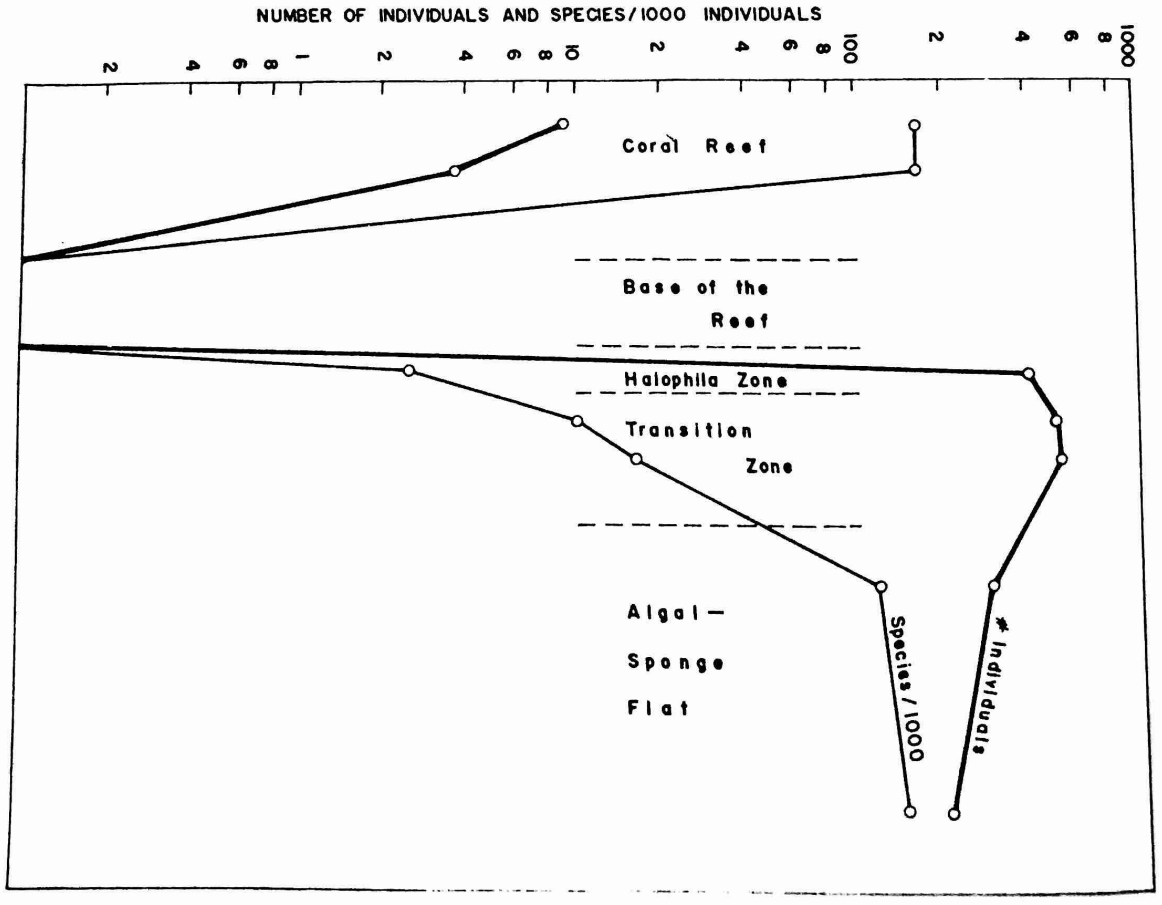


Figure 2. Diversity as species per 1000 individuals and number of individuals of ascidians through a 100m transect covering the coral reef, *Halophila* zone and algal-sponge flat.

REFERENCES

1. Kolehmainen, S.E. 1973a. Ecology of sessile and free-living organisms on mangrove roots in Jobos Bay. p. 141-173. *In* Aguirre Power Project, Environmental Studies 1972, Ann. Rep. PRNC-162 (Puerto Rico Nuclear Center).
2. Kolehmainen, S.E. 1973b. Ecology of turtle grass (*Thalassia testudinum)* beds in Jobos Bay. p. 115-140. *In* Aguirre Power Project, Environmental Studies 1972, Ann. Rep. PRNC-162 (Puerto Rico Nuclear Center).
3. Kolehmaninen, S.E., T.O. Morgan and R. Castro. 1973a. Mangrove root communities in a thermally altered area in Guayanilla Bay, Puerto Rico. *In* Thermal Ecology (J.W. Gibbons and R. R. Sharitz, Eds.) AEC Symp. Ser. CONF-730505.
4. Kolehmainen, S.E., T.O. Morgan and R. Castro. 1973b. Mangrove root communities in a thermally altered area in Guayanilla Bay, p. 320-364. *In* Aguirre Power Project, Environmental Studies 1972, Ann. Rep. PRNC-162 (Puerto Rico Nuclear Center).
5. Szmant-Froelich, A. 1973. The zonation and ecology of the Jobos Bay coral reefs, p. 174-224. *In* Aguirre Power Project, Environmental Studies 1972, Ann. Rep. PRNC-162 (Puerto Rico Nuclear Center).
6. Van Name, W.G. 1930. The ascidians of Porto Rico and the Virgin Islands. Scientific Survey of Porto Rico and the Virgin Islands. New York Acad. Sci. 10:401-512.
7. Van Name, W.G. 1945. The North and South American ascidians. Bull. Am. Mus. Nat. History, 84, p.476.

Trace Metals in Ascidians — S. E. Kolehmainen. Ascidians are the only animals known to actively concentrate vanadium. They also concentrate chromium, lead, selenium and nickel. Venezuelan crude oil refined in Puerto Rico contains large amounts of vanadium and nickel. Ascidians have been collected down current and upcurrent from a petrochemical complex on the south coast of Puerto Rico and are being analyzed for vanadium, nickel, lead and chromium. The objective of this work is to ascertain whether heavy metal concentrations in ascidians may be used to trace pollution from the petrochemical industry.

Thermal Studies in Guayanilla Bay — P. Schroeder. Investigations on the effects of elevated temperatures have been continued in Guayanilla Bay at a fossil fuel electrical plant. The biomass and density of turtle grass (*Thalassia testudinum*) and associated invertebrates have been studied around the intake of the cooling water and near the outflow of the cove where water from the cove entrains with bay water, resulting in a Δt of + 7°C. *Thalassia* beds are surviving at temperatures +3 to +4°C Δt.

In transplant experiments, sections of turtle grass beds have been exposed to different temperatures up to +10°C Δt in the cove for nine weeks . These experiments demonstrated that *Thalassia* plants survive in temperatures up to 35°C. Pigment analyses on these transplant samples indicate that the xanthophyll to chlorophyll ratio exhibits a positive correlation to increased temperature. Analyses on stored starch and sugar are being completed.

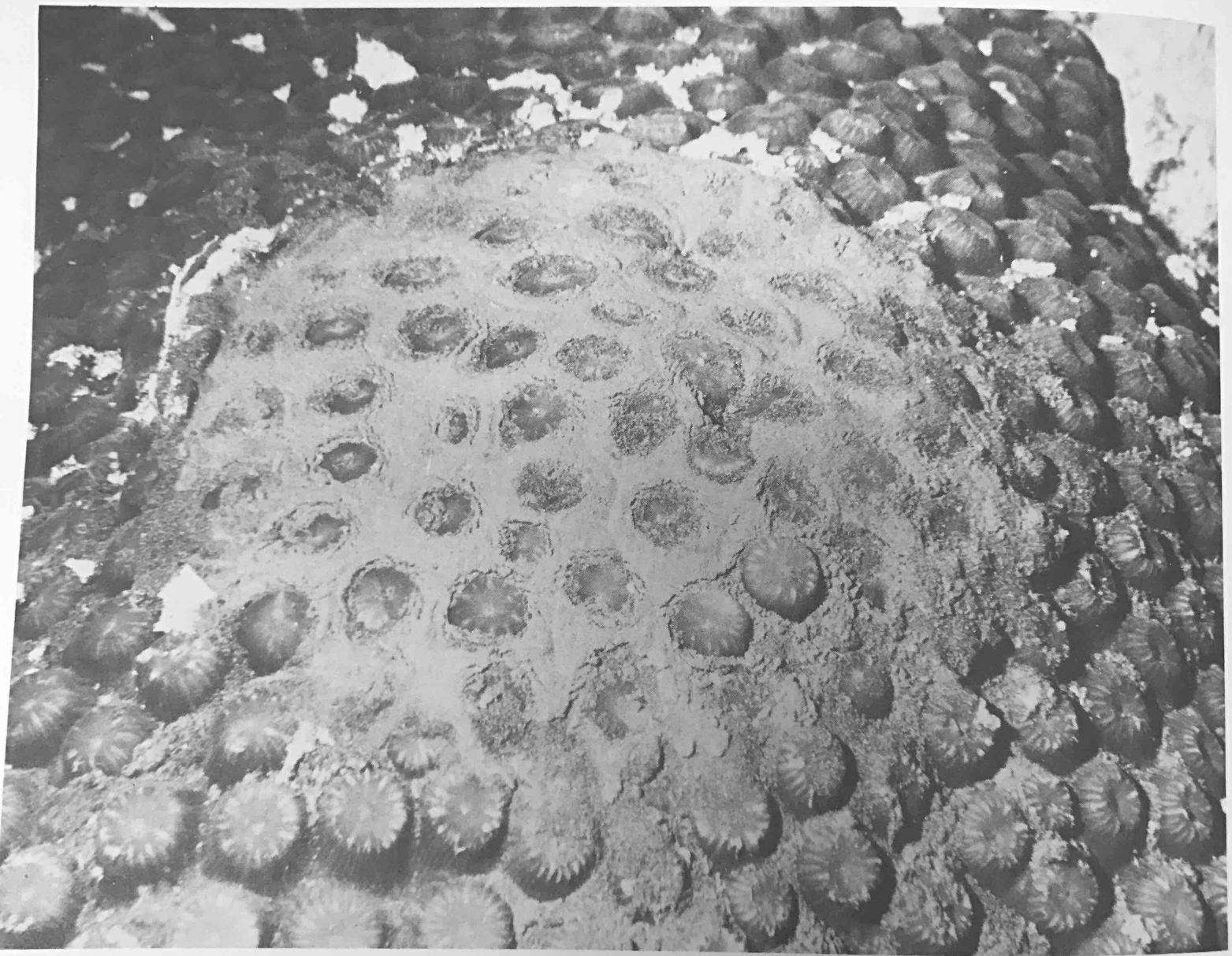


Figure 1. Sediments being transported by the ciliary action on a *Montastrea cavernosa* coral. Calices have been uncovered by the extension of coral polyps.

Laboratory experiments on the uptake rates of ^{59}Fe, ^{137}Cs, ^{54}Mn, ^{65}Zn, ^{110}Ag, ^{57}Co, ^{60}Co in *Thalassia* show significant differences in the uptake rates of these radionuclides between the temperature range from 20°C to 40°C. In the leaves the slowest and lowest uptake was observed usually at high temperatures, between 38°C and 40°C, and the fastest uptake around 36°C.

Siltation Experiments on Corals *In Situ* — S. E. Kolehmainen. Poor land management, industrialization and dredging are causing increasing siltation in the tropics, and coral reefs are dying at an alarming rate in Australia *(Fairbridge and Teichert, 1948)*, Hawaii *(Levin, 1970; Johannes, 1972)*, Florida *(Barada, 1971, 1972)*, the Virgin Islands *(van Eepoel and Grigg, 1970)*, and Puerto Rico. Deposition of sediments on coral colonies is suggested as the factor most detrimental to coral reefs in turbid water *(Roy and Smith, 1970)*. Additional factors are reduction in light *(Johannes, 1972; Verwey, 1931)*, abrasion of polyps by suspended sediments *(Wiens, 1961; Levin, 1970)*, flocculation of plankton *(Bartsch, 1961)*, and a change of the substrate to a loose shifting bottom where coral planulae cannot settle *(Edmondson, 1928; Levin, 1970; Johannes, 1972)*.

Corals are able to survive for short periods when completely covered with sand and sediments (*Vaughan, 1916; Edmondson, 1928; Marshall and Orr, 1931*). They can remove sediments from their surfaces by ciliary action *(Vaughan, 1916; Marshall and Orr, 1931)* and extension of polyps (*Marshall and Orr, 1931; Hubbard and Pocock, 1972)* and thus escape smothering to some degree. Data have not been available, however, as to how much sediment corals can remove under acute or prolonged siltation. These factors are important both in understanding ecological consequences of siltation stresses on corals and in planning dredging operations and soil conservation practices in tropical coastal areas.

Clay and silt-size particles of (1) terrigenous laterite soil, (2) near-shore dredgings, and (3) calcareous reef sediments were applied as layers 1 to 6 mm thick on the corals *Siderastrea siderea*, *Montastrea cavernosa* and *Diploria strigosa*. A bottomless glass bottle 131 mm diameter was placed on a horizontal coral surface, and the bottom edge was sealed with non-toxic modeling clay. A premeasured volume of sediment was poured into the bottle, and after half an hour the bottle and the modeling clay were removed. The removal of sediment and the mortality of coral polyps were estimated visually at intervals of a few hours. The experiment was conducted from an underwater habitat at depths between 9 and 18 m at a reef 10 km west of Punta Ostiones on the west coast of Puerto Rico *(Kolehmainen, 1974)*.

Mechanisms used by the coral for removing sediments were: secretion of mucus, movement of cilia and extension of polyps; in addition, water currents, gravity and activities of fish caused removal. As soon as the sediment began settling on the coral, heavy secretion of mucus was observed. The mucus entrapped sediment and made it viscous. In this state ciliary movement, extension of polyps, and gravity caused sediment to be transported, first to the grooves between corallites and then toward the edges of the coral head (Fig. 1). *M. cavernosa* and *D. strigosa* released more mucus, removed more sediment and suffered

a lower mortality with the same initial thickness of sediment than *S. siderea* (Table 1 and Figure 2). A layer of 1.5 mm of sediment caused mortality in *S. siderea* while *D. strigosa* and *M. cavernosa* often removed a 3 mm layer of sediment completely or suffered only low mortality (Table 1). The rate of removal of sediments also was slower in *S. siderea* than in the other species (Figure 2) which points out that *S. siderea* is the most sensitive to smothering of these three corals.

The effect of water currents on the removal of sediment was small. Disturbance by fish swimming and browsing for food at the sediment-covered coral head was responsible for clearing the coral in about 10% of the tests. Corals were able to remove the sediments even when the glass bottles were left in place; thus, the corals were able to remove sediments without the help of outside factors.

Calcareous sediments and dredgings formed sulfides which caused an anaerobic microenvironment to develop on the coral more quickly than with laterite sediments, thus causing higher mortality (Table 1). The toxicity of sulfides in the sediments to corals has previously been reported *(Maragos, 1972).*

Coral tissue covered with sediment became increasingly pale with continued burial. Coral covered completely with sediment turned white within 30 hours due to disintegration of tissues.

Three specimens each of the corals *Agaricia agaricites, Eusmilia fastigiata, Madracis asperula, Montastrea cavernosa, Porites astroides, P. porites* and *Siderastrea siderea* were placed near an engineering experiment that produced large quantities of fine suspended sediment similar to the calcareous sediment used in the acute sedimentation experiment. During 9 days two sediment gauges registered a deposition of 1.5 mm depth of sediments per day on the average. None of the coral species died or showed any signs of stress.

Smothering effects of sediment seem to kill coral when the siltation is heavy, *e.g.*, due to hurricanes, heavy floods or effects of adjacent dredging operations. In this study corals with high mucus production, large polyps and a rough surface seem to remove sediment faster than species with low mucus production small polyps and a smooth surface. Previous studies have also indicated that corals with large polyps are more capable of removing sediments than species with small polyps *(Mayor, 1918; Marshall and Orr, 1931; Hubbard and Pocock, 1972).*

Mucus serves as a protective coating preventing macroalgae and other sessile organisms from settling on the coral. Normally corals use a large proportion of their energy requirements in mucus production *(Johannes, 1967).* Since it appears that siltation forces corals to increase the release of mucus, it seems that at high siltation rates corals may be energetically incapable of maintaining the required rate of mucus production. The corals may then become covered by sediment and macroalgae. On the west coast of Puerto Rico the near-shore fringing reefs in turbid water are being covered and killed by green algae, *Halimeda* spp. and *Caulerpa* spp. The excessive growth of macroalgae on corals in turbid water could be a result of diminished mucus production and eutrophication that usually occurs with turbidity.

Table 1
The Area of Dead Coral as a Percentage of the Area Covered Initially with Different Thicknesses of Sediments

Sediment	Thickness mm	*Siderastrea siderea* Dead Area-%	Range	No.of Tests	*Montastrea cavernosa* Dead Area-%	Range	No.of Tests	*Diploria strigosa* Dead Area-%	Range	No.of Tests
Laterite	1	0	(0)	2						
	1.5	43.3	(15-75)	3						
	2				0	(0)	2	0	(0)	2
	3	48.3	(40-55)	3	0	(0)	3	0	(0)	3
	6	70	(50-90)	3	23.3	(50-40)	3			
Dredgings	1	0	(0)	3						
	2	67.5	(35-100)	2	5	(0-10)	2	0	(0)	3
	3	89	(80-100)	5	5	(0-20)	5	26.3	(0-85)	4
	6				31.7	(25-40	3	14	(0-50)	5
Calcarous	2	82.5	(80-85)	2	0	(0)	2			
	3	77.7	(65-90)	3	14.0	(0-70)	5	8.8	(0-35)	4
	6				28.3	(0-45)	3	30.0	(15-45)	3

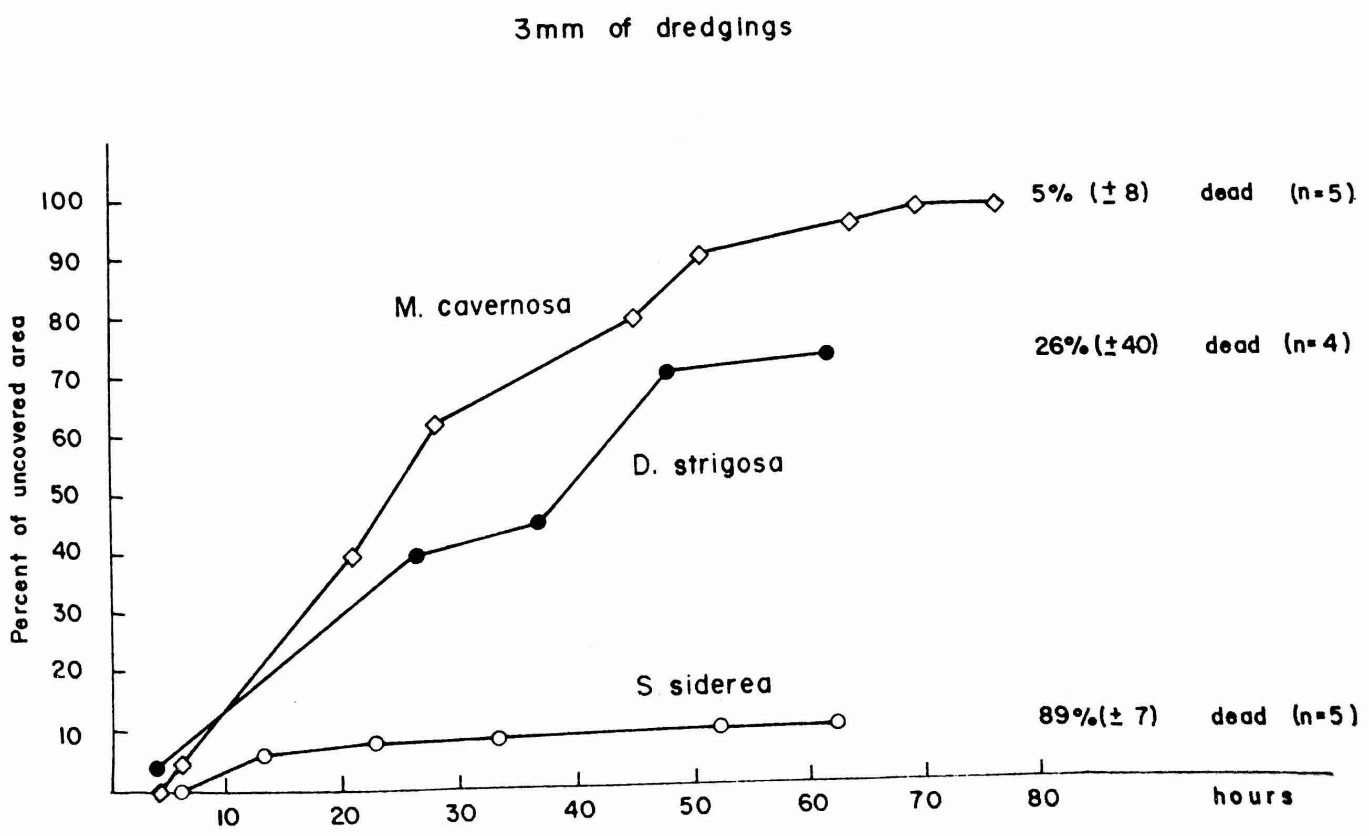


Figure 2. The removal of a 3mm layer of dredgings as percentage of initially covered area by the three species of corals as a function of time.
The percentages on the right show the area of coral killed.

Corals can remove thick layers of sediment even when the siltation is prolonged. However, continuous heavy-siltation eventually kills coral reefs. Therefore, introduction of man-made siltation — *e.g.*, dredging, filling and dumping operations — would be less damaging to coral reefs and probably to most benthic communities if done intermittently, allowing benthic organisms to recover between siltation periods.

REFERENCES

1. Barada, B. 1971. The rape of Florida's coral reefs. Skin Diver Magazine 20:14-19.
2. Barada, B. 1972. Termites in retreat. *Ibid.* 22:52-55.
3. Bartsch, A.F. 1970. Setteable solids, turbidity and light penetration as factors affecting water quality. p. 118-127. *In* Biological problems in water pollution. (C.M. Tarzwell, Ed.) U.S. Public Health Serv. Publ. No. W60-3.
4. Edmondson, C.H. 1928. The ecology of an Hawaiian Coral reef. Bernice P. Bishop Mus. Bull. 45.
5. Fairbridge, R.W. and C. Teichert. 1948. The Low Isles of the Great Barrier Reef: a new analysis. Geogr. Journal 3:67-88.
6. Hubbard, J.A.E.B. and Y.P. Pocock. 1972. Sediment rejection by recent scleratinian corals: a key to paleo-environmental reconstruction. Geologische Rundschau, 61: 598-626.
7. Johannes, R.E. 1967. Ecology of organic agregates in the vicinity of a coral reef. Limnol. and Oceanog. 12:189-195.
8. Johannes, R.E. 1972. Coral reefs and pollution, p. 364-375. *In* Marine Pollution and Sea Life (Ruivo, Ed.), Fishing News (Books) Ltd., London.
9. Kolehmainen, S.E. 1974. Siltation experiments on corals *in situ*. Submitted to Nature.
10. Levin, J. 1970. A literature review of the effects of sand removal on a coral reef community. Univ. Hawaii, UNIHI-SEAGRANT-TR-71-01.
11. Maragos, J.E. 1972. A study of the ecology of Hawaiian reef corals. Ph.D. thesis, Univ. of Hawaii.
12. Marshall, S.M. and A.P. Orr. 1931. Sedimentation on Low Isles reef and its relation to coral growth. Great Barrier Reef Expedition 1928-29, Scientific Reports, Vol. 1, No.5, pp. 94-133.
13. Mayor, A.C. 1918. Toxic effects due to high temperature. Pap. Dept. Mar. Biol., Carn. Inst. Wash. 12:172-178.
14. Roy, K.J. and S.V. Smith, 1970. Sedimentation and coral reef development in turbid water: Fanning Lagoon. Hawaii Institute of Geophysics Contribution No. 358.
15. Van Eepoel, R.P. and D.I. Grigg, 1970. Survey of the ecology and water quality of Lindberg Bay, St. Thomas. Water Pollution Report, Caribbean Res. Institute, January, 1970, 6p.
16. Verwey, J. 1931. Coral reef studies. The depth of coral reefs in relation to their oxygen consumption and the penetration of light in the water. Treubia 13:169-198.
17. Wiens, H.J. 1962. Atoll environment and ecology. Yale Univ. Press., New Haven and London, 532p.

Effect of Elevated Temperatures on Mangrove Seedlings. — M. D. Banus. In general, the juvenile forms of organisms are the most sensitive to stresses. Therefore viviparous mangrove seedlings may show sub-lethal detrimental reactions to long-term exposures before an effect could be observed in mature trees. The effect of temperature on the survival, rooting and growth of mangrove seedlings is being studied using the thermal plume from the new Aguirre Power Plant in Jobos Bay as the heat source.

When ripe mangrove seedlings fall into sea water they generally float horizontally at first and slowly become vertical over a period of ten days to five weeks (Davis, 1940). Roots develop over a period of twelve weeks. The survival and rooting of Puerto Rican mangrove seedlings in fresh water and Joyuda lagoon mud were studied by La Rue and Muzik (1954). They observed poor survival and rooting in sea-water but their seedlings were generally small and immature and they did not take into account floating and righting behavior. Therefore, before placing them in the thermal plume, the floating and rooting behaviors of several batches of seedlings have been observed.

Batches of 100 seedlings were used in all experiments. The first three batches were separated according to increasing maturity as shown in Table 1. For all batches 82 - 91% of the seedlings initially floated either horizontally or at an angle of less than 30%. Batches # 1 and #2 were kept in running sea water in fiberglass tanks outdoors under a roof. Batch #3 was held in a 4´ x 4´ cage in a tidal bay behind a mangrove island near Punta Ostiones. The cage that was used in full sunlight was on a platform. This cage was the prototype of units to be used in Jobos Bay. (Fig. 1)

The behavior of the seedlings after several weeks is shown in Table 2. The immature seedlings in batch #1 had tilted only partially toward the vertical after 39 days. The more mature seedlings of batch #2 had a large portion in the vertical position and less than 1/3 still horizontal. For both batches a substantial number of horizontal and near horizontal floating seedlings had started roots. This is in contradiction to the work of Teas and Montgomery (1968). They reported that seedlings remain unrooted until the lower end contacts a suitable substrate. Most of the cotyledons of batch # 1 had blackened, many completely. Even th tips of the mature cotyledons of batch # 3 had some blackening. Cotyledons from this batch started to split after 40 days, several weeks before those from batches 1 and 2.

The rapid tilt to vertical for seedlings in batch #3 may be due to their increased maturity or to the exposure to ambient sunlight. Sunlight indeed was shown to be the factor in the following experiment: Batches #1 and #2 were each split randomly into two equal sub-batches. One of each sub-batch was kept under the original conditions while the other was kept in a large flowing sea-water tank exposed to full ambient sunlight. After seven days, the seedlings from batch #2 kept under the original conditions showed no significant change from Table 2; 75% were still either horizontal or $<30°$ from it. However, 78% of the 50 seedlings put in the sun were vertical or close to it and only 12% were between horizontal and 30°. Over half the seedlings of both sub-batches had roots. In the sunlight, both vertical and horizontal seedlings had roots while out of the sun all horizontally floating seedlings had roots and only one seedling in vertical position had roots. The less mature seedlings in batch #1 showed the same taype of behavior to less significant

Viviparous mangrove seedlings one month after falling from the tree. At this stage the seedlings have sunk to the bottom, rooted and have their cotyledons splitting A large proportion of mangrove seedlings reach this stage in nature, but only a few settle in a place where the depth of water and lighting conditions are suitable for growing.

Mangrove seedling cages at Punta Ostiones. These cages are used to study the floating, tilting and rooting behavior of viviparous mangrove seedlings in the field. The cage on right has young mangrove plants raised from seedlings in this cage. Similar cages have been set up in Jobos Bay for studying the effects of elevated temperatures on the behavior of mangrove seedlings.

degrees. All batches will be followed for the formation of roots and the development of leaves. When the behavior of the seedlings in ambient sea water is better understood, the effect of the thermal plume will be monitored.

REFERENCES

Davis, J.H. 1940. The Ecology and Geologic Role of Mangroves in Florida. Papers from the Tortugas Laboratory, Carnegie Institute Washington **32**: 307-412.

La Rue, C.D. and T.J. Muzik. 1954. Growth, Regeneration and Precocious Rooting in *Rhizophora Mangle* Papers of the Michigan Acad. Sci., Art. and Ltrs. XXXIX: 9-29.

Teas, H.J. and F. Montgomery. 1968. Ecology of Red Mangrove Seedling Establishment. ABS Bulletin **15**(2): 56-57.

Table 1

Separation of Mangrove Seedling Batches According to Increasing Maturity

Batch	Number 1	Number 2	Number 3
Length (cm)	27.27 ± 3.09	30.05 ± 3.61	30.32 ± 4.12
Weight (g)	13.42 ± 2.72	17.60 ± 3.12	20.99 ± 4.41
Ratio L/W	2.3	1.71	1.44
Position	**Percent in Each Position**		
Horizontal	71	49	40
5-30°	16	33	51
30-60°	3	4	5
60-90°	6	7	1
Vertical	4	7	3

Table 2

Behavior of Mangrove Seedlings After Several Weeks

Seedling Batch	Number 1		Number 2		Number 3	
Immersion Conditions	Full Shade Flowing Sea Water 25 ± 1.5°C		Full Shade Flowing Sea Water 25 ± 1.5°C		Ambient Sunlight Tidal Sea Water 25 - 29°C	
Days of Immersion	39		39		20	
	% of Total	% of Group with Roots	% of Total	% of Group with Roots	% of Total	% of Group with Roots
Horizontal	39	15	29	10	0*	0
5-30°	51	25	52	27	6	0
30-60°	1	0	1	0	3	0
60-90°	3	0	2	0	1	0
Vertical	5	0	16	20	90	49
Decaying	1	0	0	0	0	0

* At 12 days none were horizontal

Foraminiferal Assemblages of the Antillean Caribbean and the Panamanian Provinces, Paleoecological Significance — G.A. Seiglie. The Antillean Caribbean foraminiferal province is subdivided into five subprovinces according to the best known foraminiferal faunas. The Gulf of Mexico is characterized by an *Amphistegina* fauna in the middle shelf and by a *Buliminella* - *Nonionella* fauna in middle shelf delta environments with fine sediments (Phleger, 1960; Poag and Sweet, 1972). The Antilles subprovince contain an *Amphistegina* - *Archaias* fauna in shallow reefs (Seiglie, 1968) and a *Fursenkoina* and *Florilus* fauna in fine sediments of bays.

The Venezuelan subprovince is characterized by an *Amphistegina* - *Textularia* fauna (Seiglie, 1966) in the reef complex and the mix of carbonate and detrital sediments and a *Buliminella* - *Nonionella* fauna in the areas submitted to upwelling waters (Seiglie and Bermúdez, 1963), a *Nonionella* fauna in delta environments (Nota, 1958) and *Florilus* and *Fursenkoina* faunas in the inner shelf (Seiglie and Bermúdez, 1963). Foraminiferal fauna of the Venezuelan subprovince affected by the cold upwelling waters of Cariaco Trench is closer to the Gulf of Mexico subprovince than to the Antilles subprovince. The other two subprovinces are transitional, one of them off the southeastern coast of North America, from north Florida to Cape Hatteras (Wilcoxon, 1964) and the other off the coast of southern Brazil (Boltovskoy, 1964). Enough information is not available from other areas of this province. (Fig. 1).

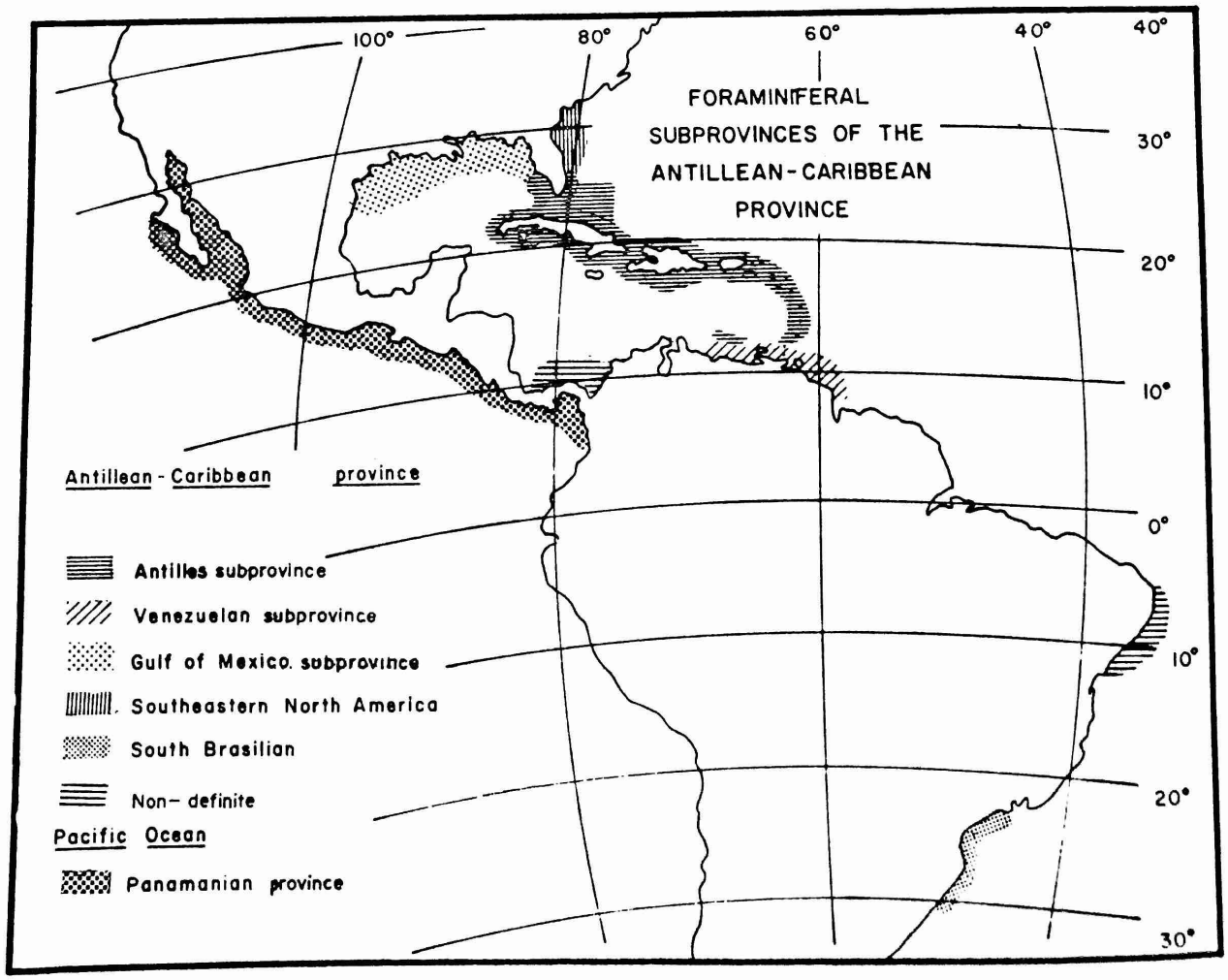


Figure 1. Panamanian province and subprovinces of the Antilles.

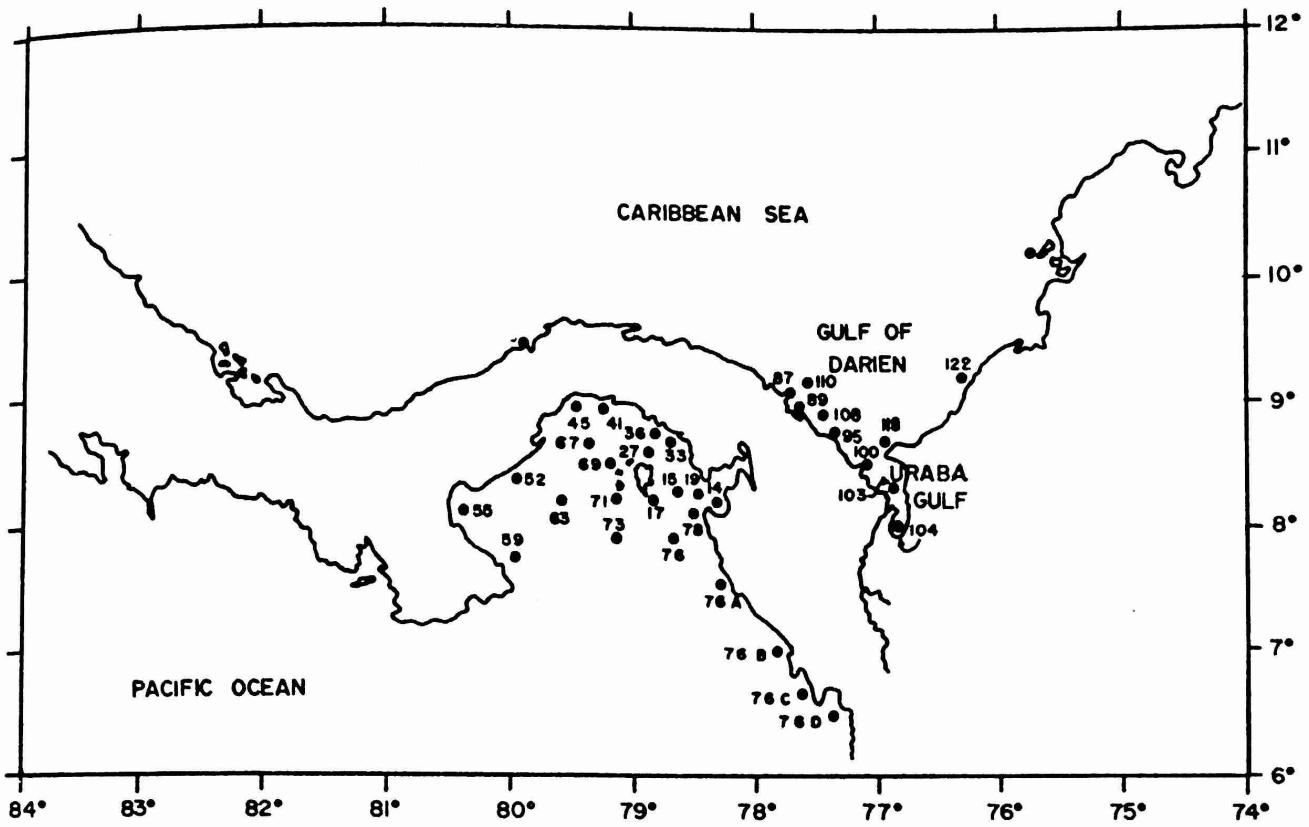


Figure 2. Position of Stations off the coasts of Panama and Colombia.

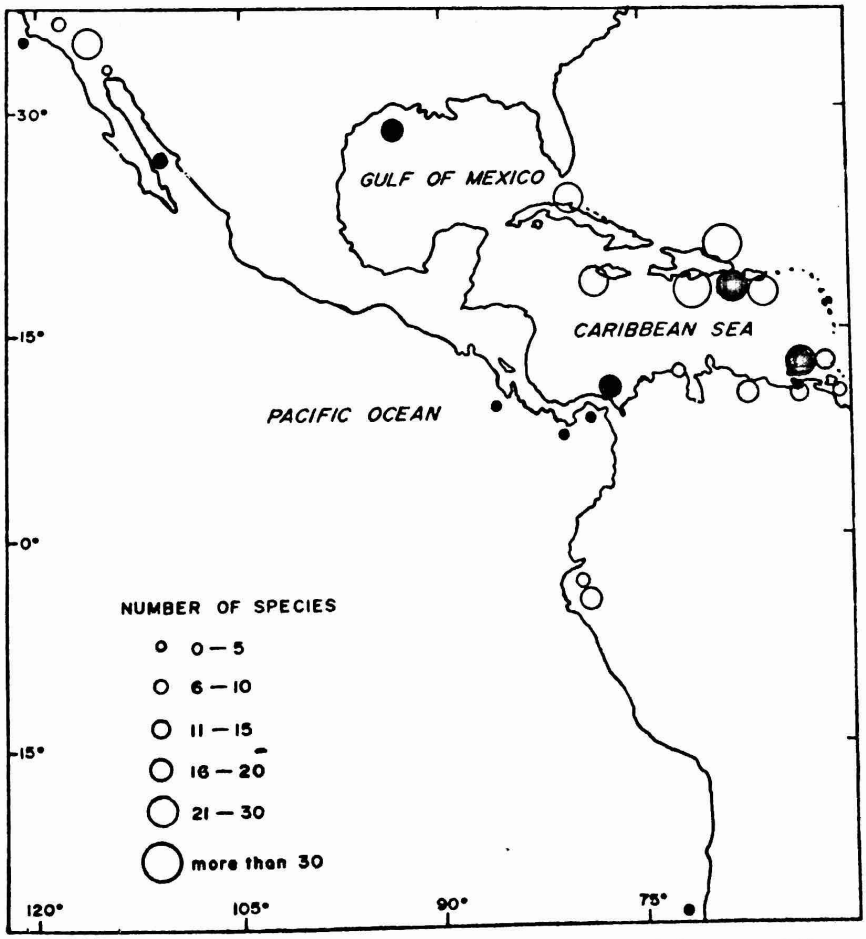


Figure 3. Number of species of agglutinated foraminifer of the Caribbean and Panamanian provinces. White spheres: Oligocene and Miocene species. Black spheres: Recent species.

The Panamanian foraminiferal faunas were studied from samples taken on board R/V Shimada (former research vessel of the PRNC) in year 1967. (Fig. 2.)

The foraminiferal faunas of the Caribbean coast of Panama and Colombia are related to both the Venezuelan and the Antilles subprovince. North Brazilian foraminiferal fauna is also related to these two subprovinces.

The foraminiferal assemblages of the Pacific coasts of Panama and Colombia show a closer relation to the California faunas than to the Caribbean ones. Pacific upwelling has prevented the development of most of typical Caribbean assemblages of the Pacific coasts of Panama and Colombia (Table 1).

The Antillean Caribbean province contains a large variety of agglutinated foraminifers in the outer shelf, the most significant of which are: *Bigenerina textularioidea*, *Liebusella soldanii*, *Glaucoammina trilateralis*, and *Clavulina mexicana* (Phleger and Parker, 1951; Greiner, 1970; Seiglie, 1966, 1971). This is the most significant difference with the Panamanian province, where the outer shelf agglutinated foraminifers are rare. Upwelling waters in most of the Panamanian province is a significant ecological factor that may be related to the scarcity of agglutinated foraminifers. Similar differences are present, at least from the Oligocene to the Pliocene between both provinces. The Antillean Caribbean province contains a higher diversity of agglutinated foraminifers from the Oligocene to Pliocene than the Panamanian province. (Fig. 3.) These faunas suggest that ecological differences were similar from the Oligocene to the Pliocene and also in the Holocene.

REFERENCES

1. Boltovskoy, E., 1964. Provincias zoogeográficas de América del Sur y su sector antártico según los foraminíferos bentónicos. Inst. Biol. Mar., Mar del Plata, Bol: 7: 91-98.
2. Greiner, G.O.G. 1970. Distribution of major benthonic groups on the Gulf of Mexico continental shelf. Micropalent. 16(1): 83-100.
3. Nota, D.J.G. 1958. Sediments of the Western Guiana Shelf. Rept. Orinoco Shelf Exp. 2: 98p.
4. Phleger, F.B.. 1960. Sedimentary patterns of microfauna in the northern Gulf of Mexico. Am. Assoc. Petr. Geol. Tulsa 267-381.
5. Phleger, F.B. and Parker, F.L., 1951. Ecology of Foraminifera, northwest Gulf of Mexico, pt. II. Foraminifera Species Geol. Soc. America, Mem. 46: 1-64.
6. Poag, C.W., and Sweet, W.E. 1972. Claypile bank, Texas continental shelf, *In* R. Rezak and V. J. Henry, *ed.* Contributions on the geological and geophysical oceanography of the Gulf of Mexico, 223-262.
7. Seiglie, G.A. 1966. Distribution of foraminifers in the sediment of Araya-Los Testigos shelf and upper slope. Caribbean Journal of Science 6: 92-117.
8. Seiglie, G.A. 1968. Relationships between the Distribution of Amphistegina and the Submerged Peistocene Reefs off Western Puerto Rico. Tulane Stud. Geol. 6: 139-147.
9. Seiglie, G.A. and Bermúdez, P.J. 1963. Distribución de los foraminíferos del Golfo de Cariaco. Inst. Univ. Oriente, Bol. 2 (1): 5-87.

Table 1

Assemblages of the Panamanian province and of the Antillean-Caribbean subprovinces

	Near-shore assemblages	Beach * assemblages	Reef and carbonate sediment assemblages	Inner to middle shelf assemblages in fine sediments	Middle to outer shelf assemblages in coarse sediments
Antilles subprovince	*Ammonia catesbyana* var. (Antilles) *A. parkinsoniana* (S. Florida) *Ammobaculites salsus* *Cribroelphidium poeyanum* *Quinqueloculina* ssp	*Rotorbinella rosea* *Archaias angulatus* *Amphistegina gibbosa* *Homotrema rubrum*	*Rotorbinella rosea* *Archaias angulatus* *Amphistegina gibbosa* *Homotrema rubrum* *Quinqueloculina lamarckiana*	*Fursenkoina punctata* *Florilus grateloupii*	1) Assemblages of agglutinated foraminifers: *Bigenerina textularioidea* *Liebusella soldanii* *Glaucoammina trilateralis* 2) Carbonate sediments: *Amphistegina gibbosa*
Venezuelan subprovince	*Ammonia parkinsoniana* *Ammonia catesbyana* var. *Cribroelphidium* spp. *Quinqueloculina* spp.	1) *Quinqueloculina poeyana* *Q. bicornis* *Q. subpoeyana* 2) *Textularia* spp.	*Amphistegina gibbosa* *Quinqueloculina lamarckiana* *Homotrema rubrum* *Textularia* spp.	*Fursenkoina punctata* *Florilus grateloupii* *Buliminella elegantissima* *B. silviae* *Nonionella "opima"*	1) Assemblages of agglutinated foraminifers: *Bigenerina textularioidea* *Liebussella soldanii* *Glaucoammina trilateralis* 2) Carbonate sediments: *Amphistegina gibbosa*
Gulf of Mexico subprovince	*Ammonia parkinsoniana* *Cribroelphidium gunteri* *C. incertum mexicanum* *Ammobaculites salsus*		*Amphistegina gibbosa and Asterigerina carinata*	*Buliminella elegantissima* B. miss *B. mississippensis* *Nonionella "opima"*	1) Assemblages of agglutinated foraminifers: *Liebusella soldanii* *Bigenerina textularioidea* 2) Carbonate sediments: *Amphistegina gibbosa*
Panamanian province	*Ammomarginulina foliacea* *Ammonia* *Cribroelphidium spinatum* *C. gunteri*			*Bulimina marginata denudata* *Florilus grateloupii basispinatus* *Fursenkoina punctata forma sandiegoensis*	No assemblage of agglutinated foraminifers or *Amphistegina* in the outer shelf.

* All assemblages transported.

(After: Bandy and Arnal, 1951; Cushman and Kellett, 1929; Drooger and Kaasschieter, 1958; Phleger and Parker, 1951; Poag and Sweet, 1972; Seiglie, 1966; Walton, 1964; this paper)

Seiglie, G.A., 1971. Foraminíferos de las Bahías de Mayagüez y Añasco y sus alrededores. Parte 2. Foraminíferos aglutinados. Distribución general y especies de la plataforma exterior. Rev. Española Micropal. 3: 255-76.

Wilcoxon, J.A. 1964. Distribution of foraminifera of the Southern Atlantic coast of the United States. Cushman Found. Foram. Res., Contr. 15: 1-24.

Transfer Studies of the Transuranium Elements Through the Marine Environment — Tin Mo. The transuranic elements are among the most hazardous materials known to man[1] and increasing use of these elements in both defense and peaceful fields will increase the potential for environmental contamination due to accidental release. At present, not much is known about the biogeochemistry and radioecology of the transuranic alpha emitters. Studies on the environmental and biological interactions of the transuranic elements are more urgently needed now than before since the results may serve as a realistic guide for the safe development of increased nuclear power generation necessary to assist the United States to regain and maintain energy self-sufficiency[2,3,4].

A simplified method of analysis of $Pu^{239,240}$ and Am^{241} in sediments, water and biological samples has been developed. In addition, a study has been started to measure the transfer rates of $Pu^{239,240}$ and Am^{241} from sediments to water and from water to benthic algae, phytoplankton, zooplankton, and to marine animals of higher trophic levels.

The simplified technique for the analysis of $Pu^{239,240}$ and Am^{241} is adapted and modified from the coprecipitation method of Lieberman and Moghissi[5] for alpha spectroscopic determination of uranium, thorium and plutonium. Plutonium is separated and purified by triisoctylamine and thenoyltrifluoroacetone extractions and coprecipitated with less than 500μg of lanthanum fluoride onto a membrane filter. Americium is separated and purified by selective adsorption and elution off AG 1-x8 Anion and Dowex 50-Wx8 cation resin columns, followed by coprecipitation with less than 500μg of lanthanum fluoride onto a membrane filter. The chemical yield on each case is better than 95%.

Typical alpha spectra of the Pu and Am fractions separated from Tewa Crater sediment from Bikini Atoll and from Bikini plankton are shown in Fig. 1. Within the limits of resolution imposed by the coprecipitated sample and the solid state detector the alpha peak from the tracer Pu^{242} is separated from that of the $Pu^{239(240)}$ and the alpha peak of the tracer Am^{243} is separated from that of the Am^{241}, thus quantitative determination of the nuclides may be accomplished.

In the experiments on transfer of transuranic elements from sediment to water about 100 grams each of Tewa bottom sediment from Bikini Atoll was shaken with 10 liters of sea water which had been previously filtered through a 0.45μ membrane filter. One liter aliquots are being removed at 90 minutes and at 1, 2, 4, 8, 16, 32 and 64 days, allowed to settle for 5 days and filtered through a 0.45μ membrane filter. As each liter of water is removed, it is replaced by an equal amount of filtered sea water so that the total water volume remains constant.

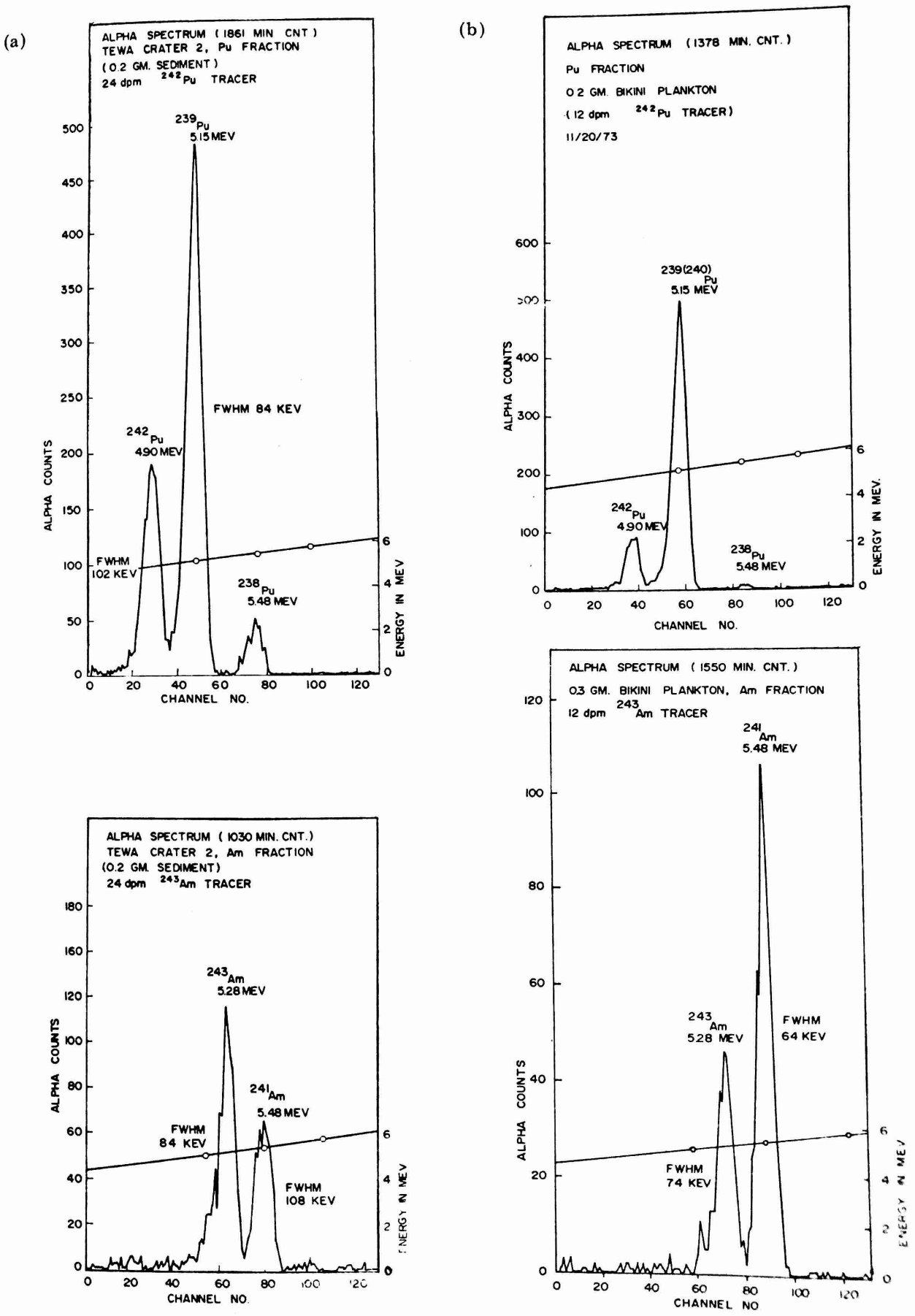


Figure 1. Typical Alpha Spectra of the Pu and the Am Fractions from (a) the Tewa Crater Sediment, and (b) a Bikini Plankton

Fig. 2 shows the alpha spectra of the purified plutonium fractions from the first liter of sea water leach removed after 90 minutes of shaking and from the suspended particles of size fraction greater than 0.45μ which remained suspended after 5 days of settling. The $Pu^{239,240}$ activity in the water was measured to be 0.0034 ± 0.0004 d/m/g of filtered sea water. The measured distribution coefficient from sediment to water was, thus, 1.3 x 10^{-5} in the filtered sea water. The activity in the particulate fraction larger than 0.45μ which remained suspended in the water after 5 days of settling was 0.0018 ± 0.0003.

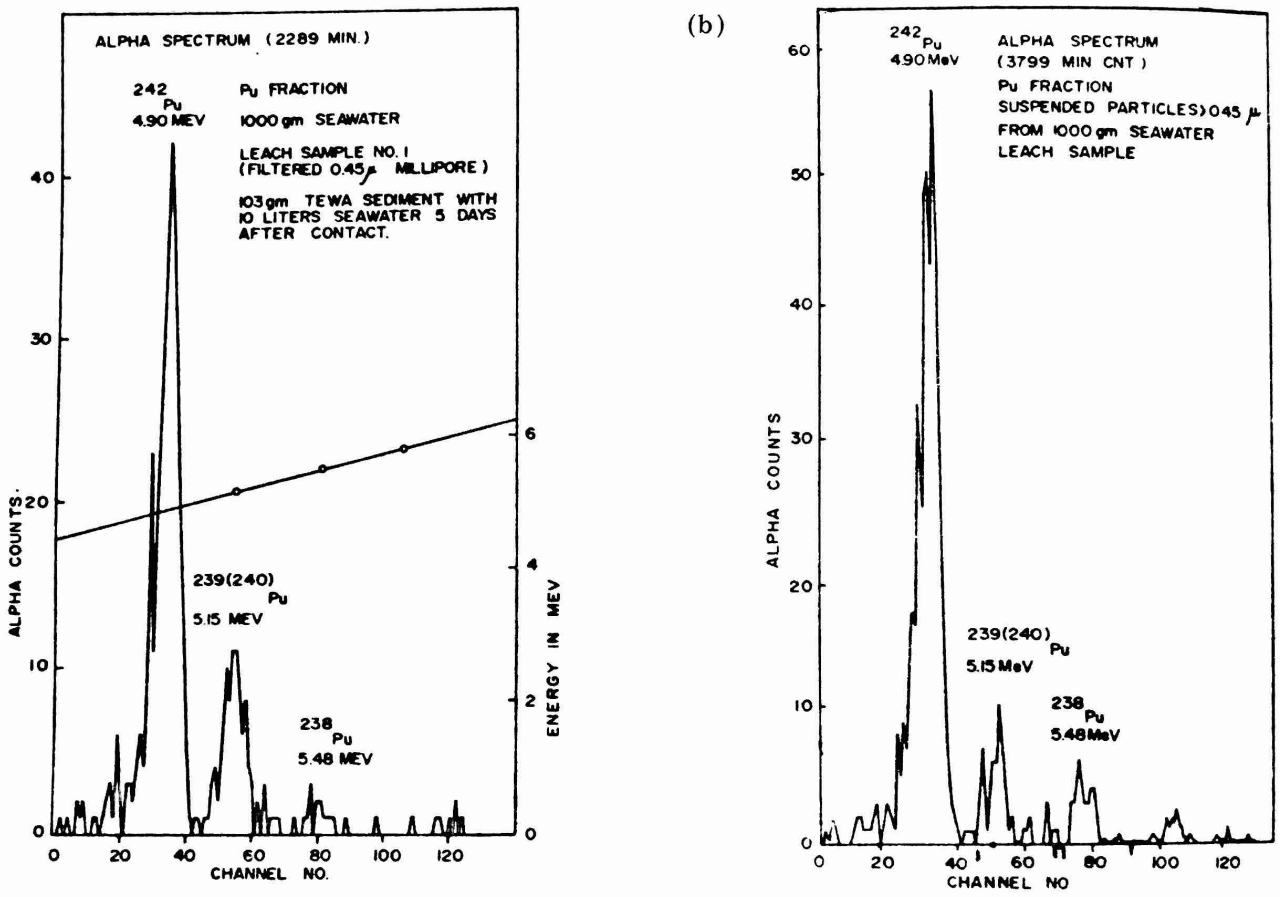


Figure 2. The Alpha Spectra of Purified Pu Fractions from (a) the First 1000 ml of Leach Water and, from (b) the Suspended Particles of Size Fraction greater than 0.45μ

REFERENCES

1. Langham, W.H. 1972. The Biological Implications of the Transuranium Elements for Man, Health Phys. **22**, 943 and references 2, 17, 18, 21-27 therein.
2. Rogers, L.R. and Henderson, C.L. 1971. AEC Implementation of the National Environmental Policy Act in its Licensing and Regulation of Nuclear Facilities, Proc. 3rd Nat. Symp. on Radioecology, held at Oak Ridge, Tenn, May 1971, 1, 63 CONF-710501-P1.
3. Strauch, 1971. The Year 2000-Nuclear Power and Man, Proc. 3rd Nat. Symp. on Radioecology, Oak Ridge, Tenn. May 1971. 1, 53. CONF-710501-P1.
4. Ray, D.L. 1973. The Nation's Energy Future, a report to Richard M. Nixon, President of the United States, 1 December 1973. WASH-1281, 1, 47.
5. Lieberman R. and Moghissi, A.A. 1968. Coprecipitation Technique for Alpha Spectroscopic Determination of Uranium, Thorium and Plutonium, Health Phys. **15**, 359.

OCEANOGRAPHIC AND LIMNOLOGICAL STUDIES

These investigations include water current measurements, analyses on particulate and dissolved organic carbon in water, trace metals associated with soluble organic complexes, soluble and particulate trace metals, nutrients in water, trace metals in water, sediments and marine organisms, and experiments on the effects of organic and inorganic forms of metals on the behavior of these elements in aquatic ecosystems. Studies have been conducted in the near-shore waters of the west coast of Puerto Rico and in the watersheds of the Guanajibo and Añasco Rivers.

Water Currents in the Cabo Rojo Platform Area — S. E. Kolehmainen. The Cabo Rojo Platform is a shoal area off the west coast of Puerto Rico with dimensions of about 15 by 20 nautical miles. The area has three off-shore fringing coral reefs, several submerged coral reefs and large areas of shallow turtle grass beds. This platform is the most important fisheries area of all of Puerto Rico.

Information on the offshore and inshore currents in this area is limited and does not allow predictions as to where suspended sediments, nutrients and trace elements from river outflows are carried. Visual observations show that the water from the Guanajibo River is transported several miles off-shore. Under certain conditions this murky water is carried over coral reef areas, thus contributing to the increasing siltation in the benthic communities and the deterioration of coral reefs.

Ocean currents on the west coast of Puerto Rico are created by the North Equatorial current flowing westward along the north and south coast of the island modified by the trade winds and the tides. On the Cabo Rojo Platform the currents flow mainly north and south. The northerly current is stronger than the southerly one and the net flow is to the north. In the summer months the currents range from 0.1 to 0.8 knots and in the winter from 0.2 to 1.2 knots.

Trace Element Distribution in Añasco Bay Sediment Samples — E. D. Wood. The Añasco River - Estuary system has received the attention of numerous workers (Lowman, et al., 1965, Trace elementes in sediment and water; Lowman et al., 1966, Radio-isotopes in marine organisms; Phelps, 1966, Stable element partitioning in benthos; Lowman et al., 1966, Trace elements in river organisms; Wolf, 1972, Distribution of trace elements in particules. These studies pertained to the transport and distribution of both radionuclides and stable elements in marine sediments, water and biota. The objective of this study is to investigate the transport of some trace elements by the river system and their incorporation into the sediments. This is one phase of the above mentioned studies which requires more thorough investigation. Of interest for biological purposes is the deposition of harmful elements (Cu, Cd, and Pb) and the availability of necessary elements (Fe, Co, Mn, etc.). Iron and zinc are of importance because of the fact that activation products ^{59}Fe and ^{65}Zn are concentrated in the food webs. The elements being studied are first order transition metals, cadmium and lead and the alkaline earths magnesium, calcium, and strontium.

Añasco Bay is located on the west central coast of Puerto Rico (Fig. 1) and receives large quantities of sediments from the Añasco River. The river drains over 500 km^2 of exposed extrusive and sedimentary rocks. Erosion is a problem in Puerto Rico especially during the rainy season from June to November. Annual rainfall approaches 250 cm yr^{-1} in the mountains of Puerto Rico. Much of the rainfall is sudden and heavy causing flash floods which seep large amounts of sediment into the bay. The heavy rainfall leaches trace elements from the soil. The working of the soil and continuous construction work also contribute to the erosion problem. The Añasco River also carries large amounts of organic material to the sea in the form of partially treated sewage, industrial wastes and agricultural wastes (mainly from sugar cane). The drainage area contains three general zones. The mountains are of dioritic and granodioritic plutonic rocks which contain hydrothermal alterations and copper sulfide zones. The uplands are sublateric red acid silty clay soils. The valley lowlands (5%) are silty clay soils neutral to slightly acid (Fig. 1).

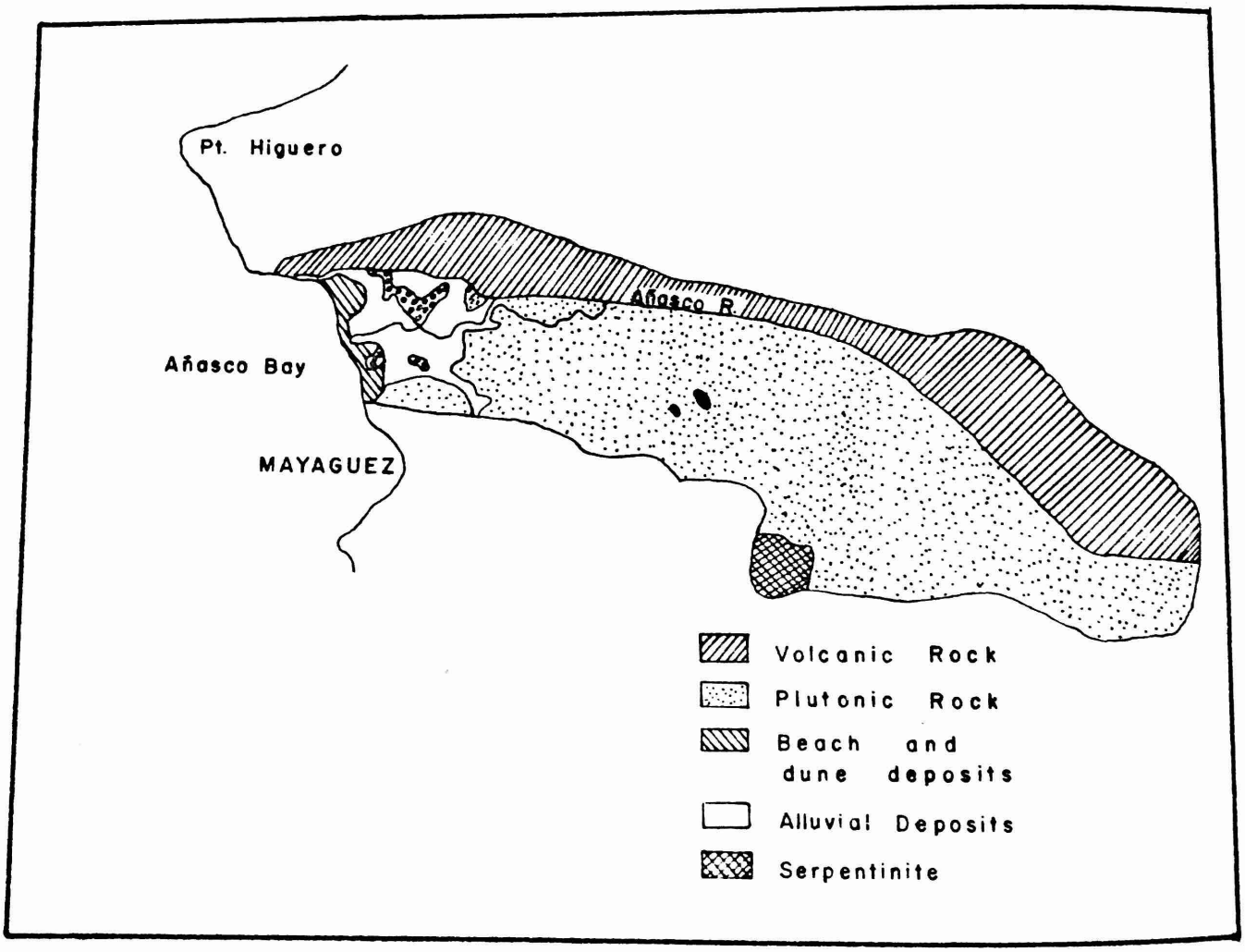


Figure 1. The geology of the Añasco River watershed.

The silt-laden river water spreads over the Añasco Bay while the iron rich fines coagulate and precipitate carrying many dissolved substance with it. The sand size particles drop out near the river's mouth and are incorporated into the beach deposits north and south of the river mouth.

The general circulation of the bay is to the north around Pt. Cadena to P. Higuero where it is confronted by a westerly current from the north coast causing an off-shore flow at the confluence. The degree of mixing is a function of the wind. The dominant wind over Puerto Rico is from the southeast with local variations. In the region of the Añasco River mouth the winds are generally off-shore except for afternoon on-shore breezes.

The degree of siltation is so high near the mouth of the river as to exclude most benthic life. The lack of oxygen in some bay sediments due to the high organic content also limits benthic life. However, coral reef areas on the north and south fringes of the bay have abundant sea life.

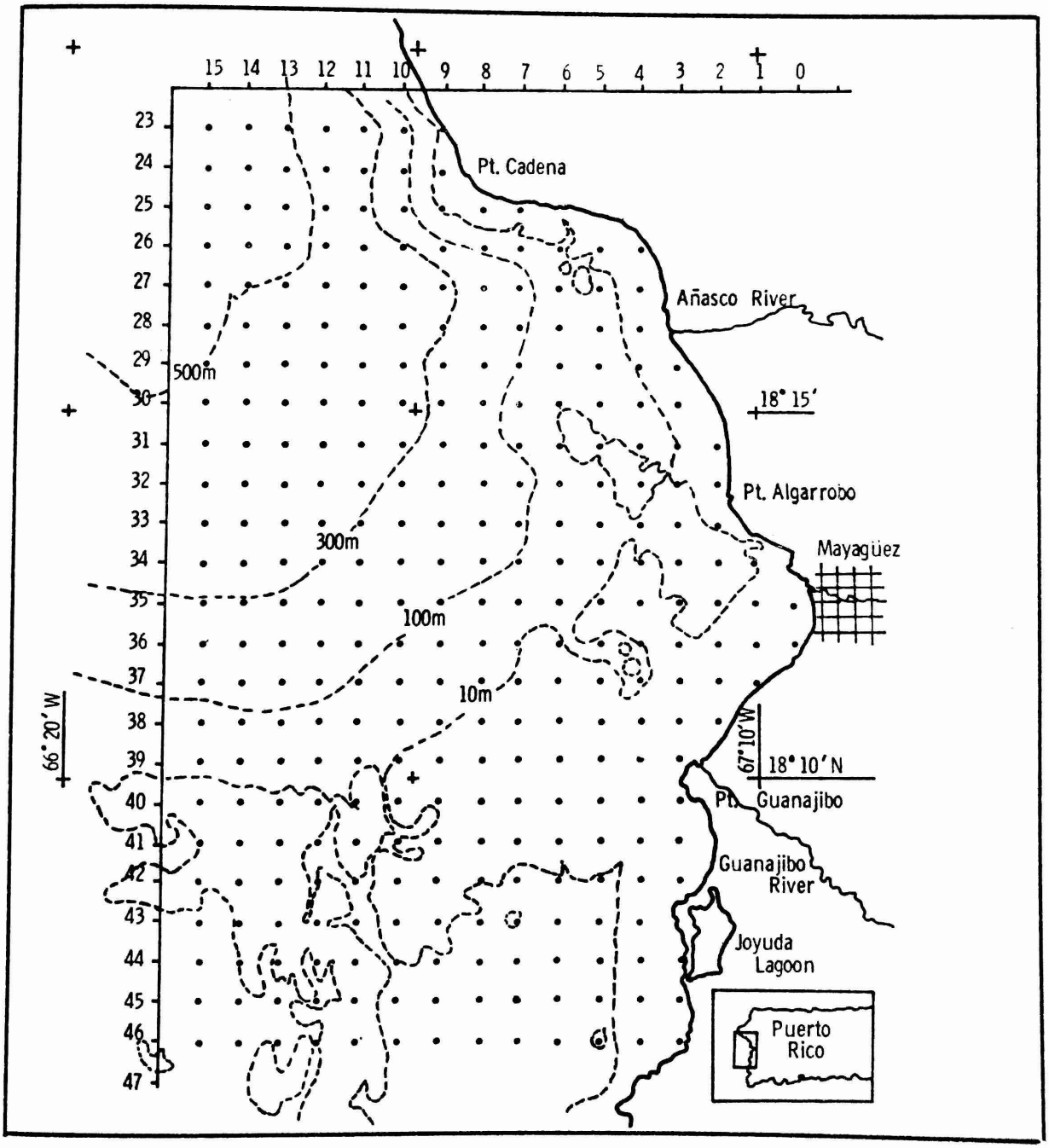


Figure 2. A 1000m grid used for sampling sediments in Añasco and Mayagüez Bays.

Añasco Bay was sampled for sediments on a 1 km grid (Fig. 2). Sediments were taken with a Shipek grab from the RMV *R.F. Palumbo* in waters ≤ 6 m in depth and in shallow waters from a dory with an Ekman grab.

Precautions were taken to minimize contamination. The sediments were homogenized by stirring. Then two samples of about 50 g each were stripped of metals with 50 ml 6N HCL. The mixtures were stirred periodically for 24 hours, then allowed to stand undisturbed over night before the acid solution was decanted into new polyethylene bottles. Three washings with water were added to the acid solution to make up to 100 ml. A portion of the acid solution was then removed and anlyzed by AAS for the following metals: Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, Pb, Sr and Zn.

The chemical data together with depth of the sample and distance from the river mouth was computer analyzed by a linear correlation coefficient program. The program gives a +1 for a 1:1 relationship between variables, 0 for no correlation and a −1 for a 1:1 inverse relationship. The slopes of the curves and error are also given. The final output is a selected listing of correlation coefficients greater than ± 0.7.

The data show a very strong correlation between Ca-Sr-Cd-Pb in one group and Cr-Mn-Fe-Co-Ni-Cu-Zn in another. There is little correlation between magnesium and other elements. Sample depth and distance from the river mouth were positively correlated with the first group and negatively with the second group of elements.

Preliminary work on river water shows that most of the elements studied are being carried in suspension rather than dissolved. The higher molar concentration of salts in sea water vs. river water is responsible for the coagulation of suspended matter and its eventual flocculation and incorporation into the sediments.

The distribution of trace elements in the Añasco Bay is much as might be predicted from the current patterns. Copper, for example, is one of the first elements to be incorporated into the sediments and shows a "bi-modal" distribution in the bay (Fig. 3) with the prime tongue to the northwest and a secondary distribution to the south. The currents in the bay are usually counter-clockwise to the north along the shore, with periodic reversals, depending upon the wind and tide. At times, the bay waters may be traced to Pt. Higuero. A large load of organic matter causes near-shore sediments to become anoxic. The dark sulfide minerals are visible in surface waters during periods of strong south winds, when bottom sediments are stirred up.

The observed data can be explained by the tendency for elements to enter into complex formation. Ca, Sr, Cd, and Pb tend to be present as chlorides and carbonates, whereas Mn and Fe exist as oxides and/or hydroxides.

The negatively charged hydroxides (Mn and Fe) then attract the positively charged ions of Cr, Co, Ni, Cu and (Zn). Zinc and copper also tend to form chloride complexes and are found in solution. The high amounts of copper are due to the high influx of copper sulfide minerals in the Añasco River watershed.

Lead and cadmium are found in the carbonate fraction due to limited substitution of Cd for Ca and Pb for Sr. This substitution would be greater except for the differences in electronegativity, Ca and Sr being much more ionic than Cd and Pb (Figs. 4 & 5). Also, the carbonate complex is probably the limiting compound in the solubility of Pb in sea water.

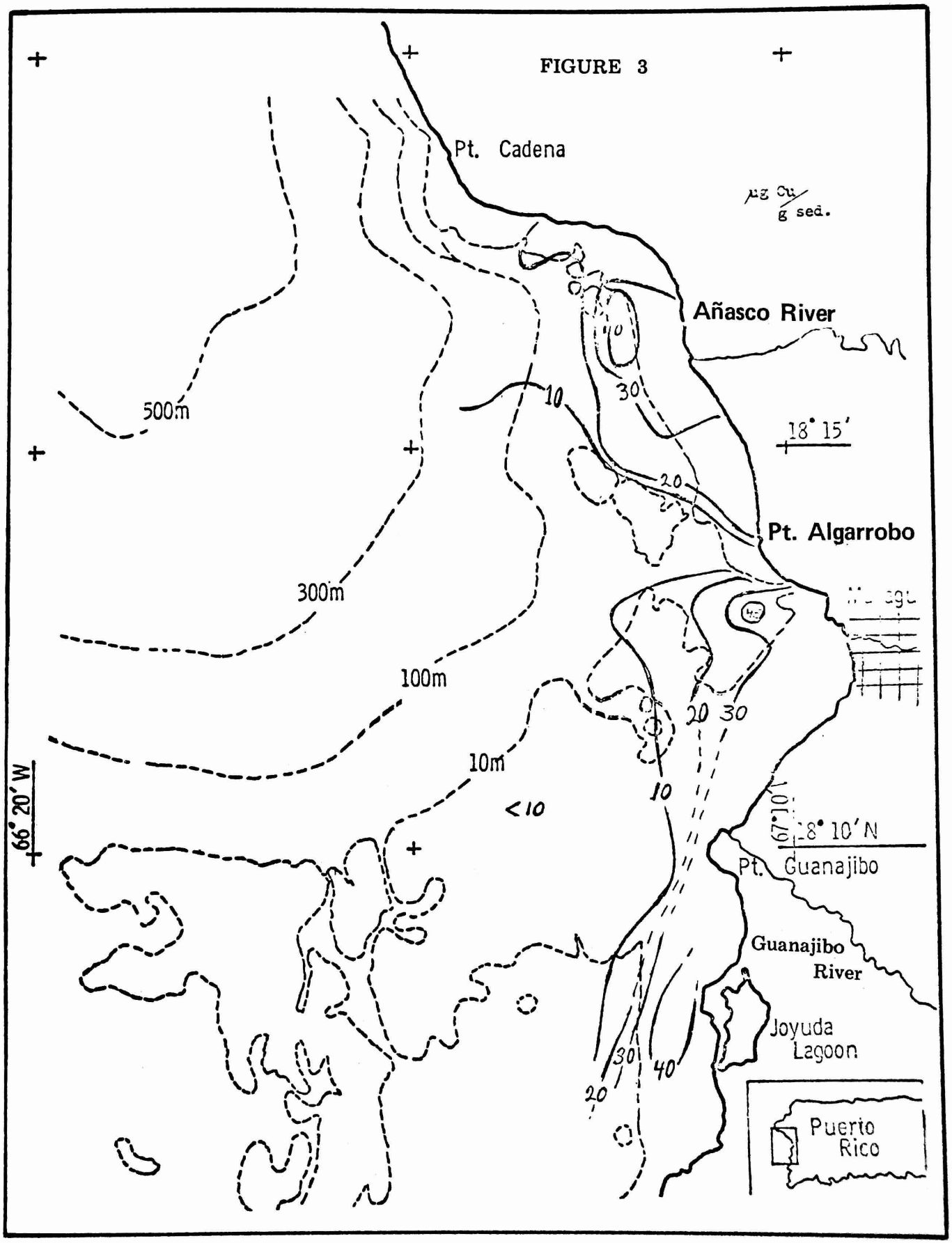


Figure 3. Distribution of copper in sediments. Values given as µg Cu/g dry weight. Copper concentrations were highest in anoxic sediments near the river mouths.

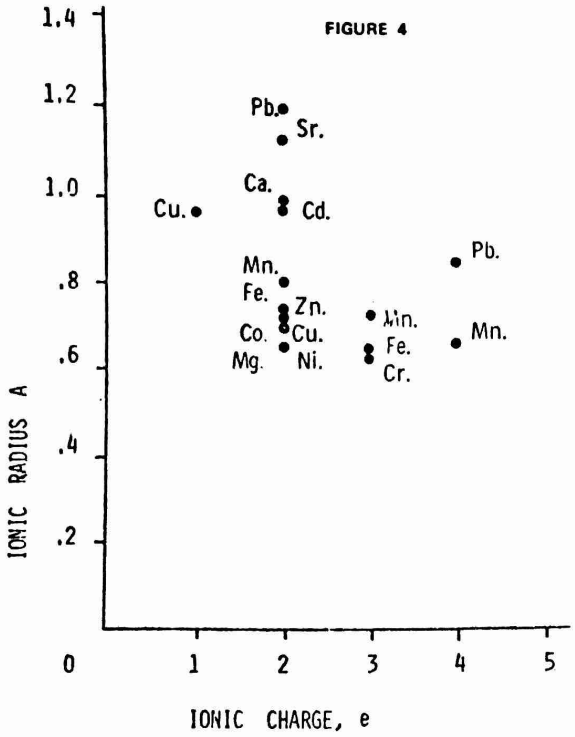


Figure 4. Ionic radius of elements as a function of ionic charge. Note the similarity between Pb and Sr, and Ca and Cd.

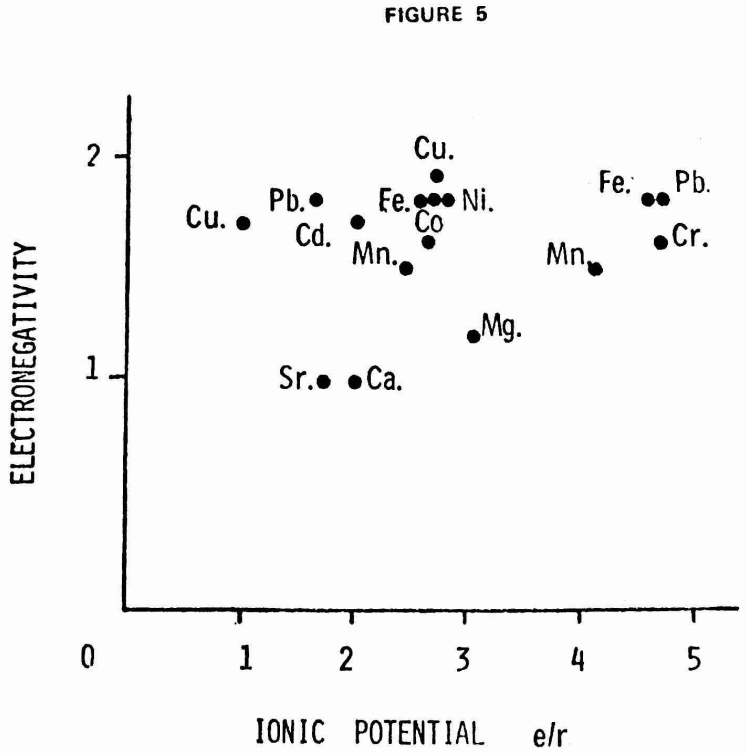


Figure 5. Elemental electronegativity as a function of ionic potential. Transition elements are closely grouped, but the covalent bonding characteristics of Cd and Pb are distinctly different from those of Ca and Sr.

REFERENCES

1. Lowman, F.G., R.A. Stevenson, R. McClin Escalera and S. Lugo Ufret, 1966. The Effects of River Outflows upon the Distribution Patterns of Fallout Radioisotopes in Marine Organisms, *Radioecological Concentration Processes*, Pergamon Press, London and N. Y.
2. Lowman, F.G., L. Quiñones, M. Miro, I. Oliver de Padovani, E. Ramos, V. Roman de Vega and H. J. Bielen, 1965. Investigations of Trace Element Distribution in Marine Waters and Sediments. *5th Inter-American Symposium on the Peaceful Application of Nuclear Energy.*
3. Lowman, F.G., D.K. Phelps, R. McClin, V. Roman De Vega, I. Oliver de Padovani, 1966. Interactions of the Environmental and Biological Factors on the Distribution of Trace Elements in the Marine Environment. *Disposal of Radioactive Wastes into Seas, Oceans and Surface Waters*, IAEA, Vienna.
4. Phelps, D.K., 1966. Partitioning of the Stable Elements Fe, Zn, Sc and Sm Within a Benthic Community, Añasco Bay, Puerto Rico. *Radioecological Concentration Processes.*
5. Wolfe, D., 1972. Trace element interactions in suspended particulates and sediments from the Añasco River, Puerto Rico. *Atlantic Estuarine Fisheries Center Annual Report to the Atomic Energy Commission.* July 1972, Beaufort, N.C.

Detection of Chelating Agents in the Guanajibo, Añasco and Culebrinas Rivers of Western Puerto Rico — J. R. Montgomery. As part of the continuing study at Puerto Rico Nuclear Center of trace metal transport from the terrestrial to the marine environment and the interaction at the juncture of the river and ocean waters (Lowman and Ting, 1973, Lowman, et al. 1966, Lowman et al. 1966b, Lowman et al. 1965), an attempt has been made to quantify and detect the presence of metal chelators in the water. The importance of chelators in trace metal transport (Goldberg, 1957; Johnston 1964; Barber and Ryther 1969; Fukai, 1969; Schnitzer, 1971; Barker and Zeitlin, 1972; Lewis et al. 1972; Manahan, 1972; Kunkel and Manahan, 1973) has been investigated and speculations have been made as to the importance of chelators in marine waters (Duursma, 1970). The increased input of organic material from untreated domestic, industrial, and agricultural wastes into the rivers on the west coast of Puerto Rico may increase the presence of chelators. (Bender, Matson and Jordan, 1970).

The presence of organic chelators in tropical rivers has not been demonstrated due to the lack of an adequate method. However, a method has been found (Kunkel and Manahan, 1973) which, althought it does not specifically identify the organic chelators can give a quantitative estimate as to their concentration.

The concentration of strong heavy metal chelators has been monitored in the three major rivers on the west coast of Puerto Rico: Río Culebrinas, Río Grande de Añasco and Río Guanajibo with major emphasis on the Río Guanajibo (See Fig. 1). Through future studies, the concentration of chelators in the water will be related to the rainfall, known sources of pollution, concentration of dissolved organic carbon, and dissolved inorganic phosphate.

The three rivers and their geographic and geologic features are shown in Table I (Lowman et al. 1966b).

Table 1

Area of Watershed, Annual Rainfall and Geological Substrate
(From Lowman, et al. 1966b)

Location	Hectares	Annual Rainfal Centimeters	km^3	Geological Substrate
Culebrinas	36,000	231	0.83	Limestone, Some volcanic
Añasco	52,000	241	1.25	Volcanic, Some limestone
Guanajibo	35,200	175	0.62	Serpentinite
				Assorted sedimentary

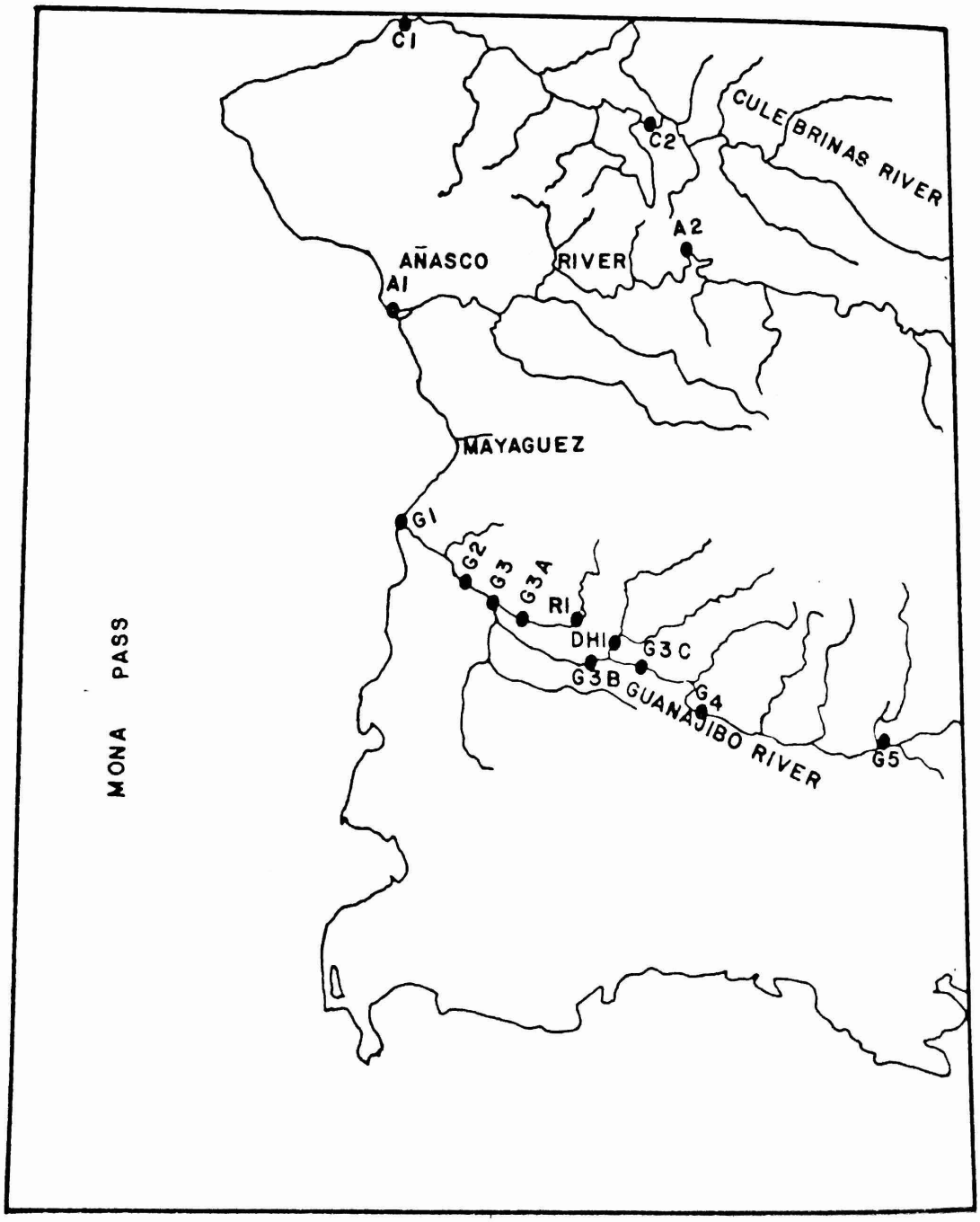


Figure 1. West Coast of Puerto Rico with the sampling station shown in different watersheds.

The sampling sites are shown in Fig. 1. All samples were collected with a plastic container and immediately placed in clean 500ml screw cap plastic bottles and stored in the dark, on ice. The samples were filtered through acid washed 0.4 μ Nucleopore(R) filters upon arrival at the laboratory, usually within 3 to 4 hours. Subsamples were taken for dissolved inorganic phosphate and particulate organic carbon. All water used to make the reagents and for rinsing was double glass-distilled over $K_2S_2O_8$ and H_3PO_4. This precaution was necessary as apparently the regular laboratory distilled water contained organic chelators leached from the resin columns or distilled over from the deionized water (Wangerski, 1965). All filtering apparatus was washed in hot acid dichromate and rinsed with the low carbon distilled water. The samples were analyzed in duplicate along with two blanks prepared in the low carbon distilled water.

The method for determining copper equivalent chelating capacity depends on the relationships shown below:

1. $Cu^2 + 20H^- = Cu(0H)_2$
2. $K_s = \{Cu^{2+}\}\ \{0H^-\}^2 = 3 \times 10^{-20}$
3. $\{Cu^{2+}\} = \dfrac{K_s}{\{0H-\}^2} = \dfrac{3 \times 10^{-20}}{\{1 \times 10^{-4}\}^2} = 3 \times 10^{-12}$

At pH 10, the quantity of copper in solution is therefore extremely small and below the practical detection limit of the Perkin-Elmer 303 atomic absorption spectrophotometer. Any copper remaining in solution at pH 10 is assumed to be bound to a strong chelating agent, while the remainder of the copper is precipitated as in equation (1).

To obtain the equivalent copper chelating capacity, the samples are filtered through 0.4 μ Nucleopore(R) filters, and a 50.0 ml aliquot is taken. Five ml of 5×10^{-2} M $CuSO_4$ is added, then the pH is slowly adjusted to 10 ± 0.2 with 5×10^{-2} M Na_2CO_3. The precipitate should contain copper, if not, additional copper is added. The sample is heated to boiling until the precipitate changes to light blue/grey or brown. The cooled sample is diluted to 100.0 ml with low carbon distilled water. The sample is filtered through a 0.4 μ Nucleopore(R) filter and the filtrate is acidified with nitric acid. To determine the copper remaining in solution, the filtrate is anlyzed by atomic absorption spectrophotometry. The concentration of strong heavy metal chelating agents in the original sample are then expressed in units of mg/l copper equivalent chelating capacity (i.e. the number of milligrams of copper which can be chelated by the chelating agent present in one liter of solution).

The Guanajibo River has been most extensively studied and has eight sampling locations from the mouth (G1) to the head at Sabana Grande (G5). Sampled also, are two tributaries of the Guanajibo River, the Rosario River (R1) and the juncture of the Duey River and Hoconuco (DH1). The sampling sites chosen are near larger towns and above and below the Eureka sugar mill. These sites are noted in Fig. 1. The results are shown in Tables 2 and 3. At the P 0.05 level there is no significant difference in the mean concentration of copper equivalent chelating capacity between the Guanajibo River and its two tributaries and between the Añasco and Culebrinas Rivers. However, the change in mean concentration of copper equivalent chelating capacity in February 13, 1974, for the Guanajibo River is significantly different from the December and January levels at the $P < 0.05$ level.

Table 2

Strong heavy metal chelating agents in the Guanajibo River and tributaries, Añasco River and Culebrinas River. The concentration of chelators is expressed as mg/l copper equivalent chelating capacity with the $P<0.05$ confidence limits.

Station	14 Dec 1974	17 Jan 1974	24 Jan 1974	13 Feb 1974
GUANAJIBO RIVER				
Sabana Grande				
G5	0.68 ± .18	0.6 ± .22		River too low to obtain sample
San German				
G4	0.4 ± .18	0.24 ± .22		0.66 ± .28
G3	0.8 ± .18	0.66 ± .22		Sample contaminated
G3A	0.4 ± .18	0.46 ± .22		0.4 ± .28
G3B	0.06 ± .18	0.24 ± .22		1.3 ± .28
G3C	0	0.24 ± .22		1.5 ± .28
G2	0.4 ± .18	0.46 ± .22		0.4 ± .28
Mouth G1	0.6 ± .18	0.46 ± .22	0.6 ± .17	1.0 ± .28
GUANAJIBO RIVER TRIBUTARIES				
Rio Rosario				
R1	0	0.18 ± .22		1.3 ± .28
Rio Duey/Hoconuco				
DH1	0.2 ± .18	0.3 ± .22		0.62 ± .28
Añasco River				
Mouth A1			0.54 ± .17	0.6 ± .28
Head A2			0.30 ± .17	1.3 ± .28
CULEBRINAS RIVER				
Mouth C1			0.22 ± .17	Salinity too high for this method
Head C2			0.18 ± .17	0.35 ± .28

The presence of chelators for the December 1973 and January 1974 sampling periods shows a very consistent patterns with the highest values at station G3 and G5 and the lower values at G3B and G3C. The concentration of chelators seems to increase after station G3A which is just below the Eureka sugar mill. The high values for G5 are probably due to either plankton blooms or run off from a cow pasture near the site. The greatest change came in the February sampling when the peak values are located just below the town of San German. The mean value of chelators for the Guanajibo River were significantly higher during this sampling time and are probably due to the increased organic load from the sugar mill, decreased rainfall and the increased concentration of organic matter due to the slower river flow during this period.

The combined mean concentration of chelators for the Guanajibo River, and tributaries for December 1973 and January 1974 periods was 0.38 mg/l (N = 21, Std. dev. 0.228) and 0.90 mg/l (N = 8, Std. dev. 0.435) for the February 1974 sample. The combined mean for the Añasco River and Culebrinas was 0.50 mg/l, Std. dev. 0.386) for the January and Febraury 1974 sampling period. In comparison the values found for temperate fresh waters appear to be higher, see Table 4 (Kunkel and Manahan, 1973).

The mean total (Particulate + organic + ionic) copper concentration in the Guanajibo River for the period November 1972 to February 1973 was 1.0μg/l (N = 21, S.D. 1.5) The mean organically bound copper for this same period was 0.27μg/l (N = 7, S.D. 0.19) (Montgomery, unpublished manuscript). Obviously although there is more than sufficient chelator available in the river to chelate all the copper present only a fraction of the copper, approximately 30%, is organically complexed. A possible explanation for this is the high (Ca^{2+}) / (Cu^{2+}) ratio which probably prevents the formation of larger concentrations of organically complexed copper because of the competition of the Ca^{2+} ion for the chelators. (Stumm and Morgan, 1970). However, it is possible that more of the copper is associated with particulate organic material, as suggested by Stumm and Morgan (1970). The particulate organic carbon, in the Guanajibo River, ranges from 140 to 2,000μg/l (Montgomery, unpublished data).

The higher levels of chelators found in temperate waters by Kunkel and Manahan, 1973, (Fig. 4), can best be explained by the vastly different distribution of organic matter in temperate and tropical terrestrial ecosystems. In temperate climates approximately 50% of the organic matter is in the soil where it can be easily leached into the rivers. On the other hand, the tropical system retains most of the organic matter in the biomass. Also, the proportion of organic matter in the litter of a tropical system is much less than the temperature system. (Odum, 1971). Therefore, smaller quantities of organic material can be leached from the tropical soil into the rivers. Also, even when the organic material is releasable from the biomass, as can happen during the sugar cane harvest, the larger amounts of rainfall in the tropicals effectively dilutes the organic matter.

The role of organic chelators in the transportation of trace metals, although not as important quantitatively as the metals sorbed on the suspended clay/silt fraction, may be a significant transport mechanism especially at the river/ocean interface where the majority of the clay/silt fraction precipitates (Lowman, et. al., 1965).

Table 3

Mean concentration of strong heavy metal chelating agents of the Rio Guanajibo (Including Tributaries) Rio Grande de Añasco and Rio Culebrinas as mg/l equivalent copper chelating capacity.

Date	Statistics	Rio Guanajibo	Rio Añasco	Rio Culebrinas
14 Dec 74	Mean	0.35 mg/l		
	Number	10		
	Standard deviation	0.285		
17 Jan 74	Mean	0.35 mg/l		
	Number	10		
	Standard deviation	0.178		
24 Jan 74	Mean	0.6 mg/l	0.42 mg/l	0.20 mg/l
	Number	1	2	2
	Standard deviation		0.170	0.0283
13 Feb 74	Mean	0.90 mg/l	0.95 mg/l	0.35 mg/l
	Number	8	2	1
	Standard deviation	0.435	0.495	

Table 4

Levels of total strong heavy metal chelating agents in typical water samples (From Kunkel and Manahan, 1973)

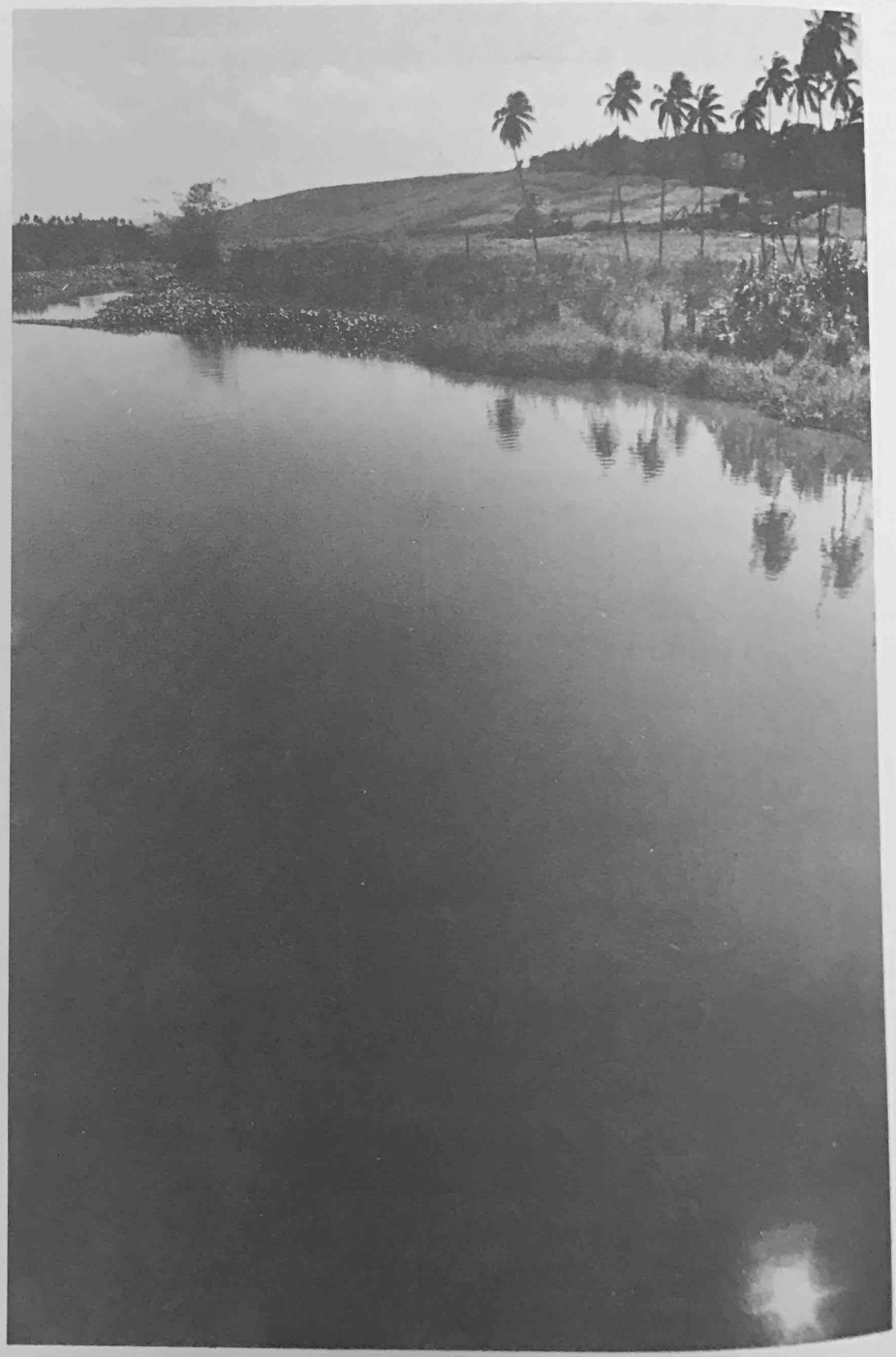
Sample Source	Total Chelating Agent Concentration, mg/l copper Equivalent Chelating Capacity
Bee Fork Creek, Mo.	1.48
Courtois Creek, Mo.	0.98
Water from a fountain pool fed with tap water and supporting algal growth	1.10
Eastern Kansas oilfield brine with high transition and heavy metal levels	31.5
Tap water*	0.00
Raw sewage*	3.39
Primary sewage effluent*	3.01
Activated sludge sewage effluent*	0.90

*From Columbia, Missouri

REFERENCES

1. Barker, D.R. and J.H. Ryther, 1969. Organic chelators affecting primary production in the Cromwell current upwelling. J. Exp. Mar. Bio. Ecol. 3:191-199.
2. Barker, D.R. and H. Zeitlin, 1972. Metal ion concentrations in sea Surface microlayer and size separated atmospheric aerosol samples in Hawaii. J. Geophys. Res. 77:5076-5086.
3. Bender, M.E., W.R. Matson and R.A. Jordan. 1970. On the significance of metal complexing agents in secondary sewage effluents. Envir. Sci. Techn. 4:520-521.
4. Duursma, E.K., 1970. Organic chelation of ^{60}Co and ^{65}Zn by leucine in relation to sorption by sediments. p. 387-397. *In* Organic matter in Natural Waters. D.W. Hood (Edit.) Institute of Marine Science, Univ. of Alaska, Publication No. 1.
5. Fukai, R. 1969. On the chelation of some radionuclides in a sea water medium. Rapp. Comm. Int. Mer. Medit. 19(5):935-936.
6. Goldberg, E.D. 1957. Marine geochemistry, chemical scavengers of the sea. J. Geol. 62:249-265.
7. Johnston, R. 1964. Sea water the natural medium of phytoplankton II Trace metals and chelation, and general discussion. J. Mar. Biol. Ass. U.K. 44:87-109.
8. Kunkel and Manahan. 1973. Atomic absorption analysis of strong heavy metal chelating agents in water and waste water. Anal. Chem. 45(8)1465-1468.
9. Lewis, A.G., P.H. Whitfield and A. Raminarine. 1972. Some particulate and soluble agents affecting the relationship between metal toxicity and organism survival in the calanoid copepod *Euchaeta japonica*. Mar. Biol. 17:215-221.
10. Lowman, F.G. and R.Y. Ting. 1973. The state of cobalt in sea water and its uptake by marine organisms and sediments, p. 369-384. *In* Radioactive Contamination of the Marine Environment. IAEA, Vienna.
11. Lowman, F.G., L. Quiñones, M. Miró, I.O. de Padovani, E. Ramos, V.R. de Vega and H. J. Bielen. 1965. Investigations of trace element distribution in marine waters and sediments. 5th Inter-American Symposium on the Peaceful application of Nuclear Energy, Valparaiso, Chile, 1964, Pan American Union, Washington, D.C.
12. Lowman, F.G., D.K. Phelps, R. McClin, V.R. de Vega, I.O. de Padovani and R.J. Garcia. 1966a. Interaction of the environmental and biological factors on the distribution of trace elements in the marine environment. p. 250266. *In* Disposal of radioactive wastes into Seas, Oceans and Surface waters. International Atomic Energy Agency. Vienna.
13. Lowman, F.G., R.A. Stevenson, R. McClin and S. Lugo Ufret. 1966b. The effects of river outflows upon the distribution patterns of fallout radioisotopes in marine organisms. Intern. Symp. on Radiological Concentration Processes, Stockholm.
14. Manahan, S.E. 1972. Environmental Chemistry. Willard Grant Press, Boston, Mass.
15. Odum E. 1971. Fundamentals of Ecology. W.B. Saunders, Co., Philadelphia, London, and Toronto. 574 p.

16. Perkin-Elmer. 1973. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer, Corp., Norwalk, Connecticut.
17. Schnitzer, M. 1971. Organic compounds in aquatic environments. Samuel D. Faust and J.V. Hunter (Ed.), Marcel Dekker, New York, N.Y.
18 Stumm, W. and J.J. Morgan. 1970. Aquatic chemistry. Wiley-Interscience, New York, 583p.
19. Wangerski, P.J. 1965. The organic chemistry of sea water. American Scientist. 53:358-374.



The mouth of the Rio Guanajibo, The concentration of trace metals, nutrients, particulate organic carbon and strong heavy metal chelators in the river is being studied in order to determine the effect of the river out-flow on adjacent coastal areas.

Ionic, Particulate and Organic Forms of Zinc, Copper, Lead, Chromium and Cobalt in in the Rio Guanajibo and Coastal Zone — J. R. Montgomery. Analyses of the total concentration of trace metals in natural water samples often is complicated. One of the more important problems is the determination and defining of the physical and chemical state of trace metals (National Academy of Science, 1971). Most extracting methods recover only the ionic fraction (Lowman and Ting 1973). Yet there are large amounts of organic material in rivers and coastal waters (Vallentyne, 1957; Duursma, 1960; Provasoli, 1963; Wangerski, 1965 and Wagner, 1967). Soluble organics can form complexes with the trace metals (Johnson, 1964; Slowey and Jefferies, 1967; Matson, 1968; Williams, 1969; Lowman and Ting, 1973) and these complexes play an important role in the biological uptake of certain metals from sea water (Lowman and Ting, 1973). Therefore, the determination of the total concentration of a trace metal using a method which only determines the ionic complexes can underestimate the true concentration of the metal and its biogeochemical role.

The source of waste discharges into the Guanajibo River watershed (see Figure 1) have been detailed in a report (Water Resources Research Institute, 1964). The largest source of pollution, as measured by 20 days B.O.D., was the Eureka Central, a sugar mill located on the Rosario River, (Fig. 1). The concentration of particulate and soluble trace metals for the Guanajibo River has been previously determined (Lowman et al., 1966). The interaction of ocean and river water from the West Coast of Puerto Rico and effects of rivers on the total trace metal concentration in coastal waters have been shown (Lowman et al., 1966). The Amazon River and Yukon River were examined (Gibbs, 1973) for the various fractions of trace metals for Fe, Cu, Co and Mn, and showed that the majority of the metals are not in solution. The method used, however, does not lend itself to comparison with the present method. The objectives of this study were to determine the concentrations of inorganic, organic and particulate fractions of Zn, Cu, Pb, Cr and Co. Sampling was designed to detect changes in the fractionation due to the discharges of domestic, agricultural and industrial wastes, and the physical and chemical reactions in the river/ocean mixing zone.

All samples were 10 l surface samples and were collected in acid washed cubitainers(R) then filtered through acid washed 0.45mμ Millipore(R) filters in an all plastic holder. The filtering was completed within 8 hours of sample collection. The filters, both samples and blanks, were then dry-ashed at 400°C, dissolved with concentrated HCl and diluted to 20 ml with distilled water. This was referred to as the particulate fraction. The filtrate was allowed to flow throug a Chelex-100(R) (50-100 mesh) (Bio-Rad Corp.) column and then an Amberlite (R) XAD-2 (Rohm and Haas) column at 5 ml/min.

The ionic fractions of the metals were retained on the Chelex 100 column (Riley and Taylor 1968) and the organic complexes were retained on the Amberlite XAD-2 column (Lowman, personal communication and Grieser and Pietrzyk, 1973 as quoted in Chu and Pietrzyk, 1974). The particulate matter was defined as material which does not pass through a 0.45mμ Millipore(R) filter.

Chelex 100. The resin in sodium form pretreated with 6N HCL and washed with distilled water untill all traces of HCl were removed. A 20 ml slurry of the washed and

treated resin was placed into a 1.5 cm I.D. ×10 cm plastic column and kept covered with liquid.

Amberlite XAD-2. 10 g of resin was placed into a 1.5 cm I.D. × 10 cm column and treated with 100 ml 1N HCl, then rinsed with 100 ml distilled water. The two columns were then connected in series with the Chelex 100 column on top.

Chelex 100. The column was eluted with 40 ml hot concentrated HCl. The acid extracts were dried to approximately 5 ml and then diluted to 20 ml with distilled water. A Chelex 100 blank was treated in the same way.

Amberlite XAD-2. The resin was removed and dried and then ashed at 400°C. The ashes were dissolved with concentration HCl and diluted to 10 ml with distilled water. The Amberlite(R) blank was treated in the same way.

All the fractions were analyzed on a Perkin-Elmer Model 303 atomic absorption spectrophotometer under standard conditions (Perkin-Elmer, 1973) using known concentrations of metals dissolved in acid and distilled water to prepare calibration curves.

The sampling period extended from November, 1972 to February 27, 1973. All comparisons between stations were made on the means of the pooled data for these sampling dates. The sample sites are shown in Figure 1 and include the Río Rosario (RI), a tributary of the Río Guanajibo, the head of the Río Guanajibo at Sabana Grande (G5), the mouth of the Río Guanajibo (GI) and the river/ocean mixing zone (L4). The data is arranged to show the concentration, in μg /l, for each fraction and the percent of the total concentration.

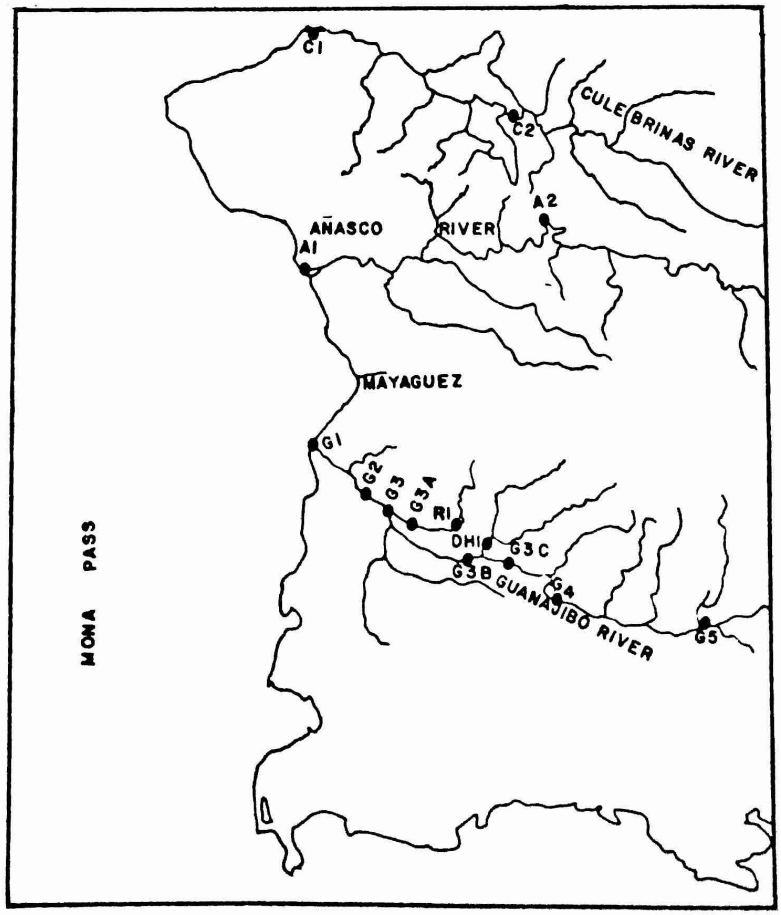


Figure 1. West Coast of Puerto Rico

A. Ionic, particulate and organic fractions of Cr, Co, and Pb.

As there were no significant differences ($P<0.05$t tests) between the four stations, R1, G5, Ga, and L4 within the fractions for Cr, Co and Pb, the pooled mean of each fraction as a percent of the total metal concentration is shown in Table 1. There was a significant difference between the mean of pooled fractions of Co and Cr. Pb showed a difference between the mean pooled ionic and organic fractions only.

Table 1
The Mean Percent of the Total Metal Concentration of the Ionic, Particulate and Organic Fractions for the Pooled Stations (R1 + G5 + G1 + L4) for Lead, Chromium and Cobalt

	Ionic	Particulate	Organic
		LEAD	
Number of Samples	6	6	6
Mean	71.7%	25.2%	3.2%
S.D.	13.8	17.9	7.8
		COBALT	
Number of Samples	7	7	7
Mean	61.9%	30.8%	7.30%
S.D.	20.2	20.4	12.8
		CHROMIUM	
Number of Samples	6	6	6
Mean	33.5%	66.2%	5.70%
S.D.	22.1	24.4	4.47

B. The ionic, particulate and organic fractions of Cu^{2+} and Zn^{2+}

Copper. The only significant difference in copper concentrations was in the particulate fractions (Table 2) between stations G1 to R1 and R1 to L4 (t value 4.67 and 4.034 respectively) The ionic fractions of copper remained at the same percentage of 19% (N=8, S.D. 11.2) for the river stations to the river/ocean mixing zone. However, the particulate fraction increased from 57% (N=4, S.D. 13) at the head of the river (RI + G5) to 77% (N=2, S.D. 2.9) at the river mouth, GI, and then decreased in the ocean (L4) to 34% (N=1) of the total copper concentration. The organic fraction increased from a mean of 18.0% (N=7, S.D. 9.5) for the sampling stations in the Guanajibo River (RI + G5 +GI) to 53% (N=1) in the river/ocean mixing zone (L4).

Table 2

Mean Percent of Total Metal Concentration for the Pooled Data of Ionic, Particulate, and Organic Forms of Copper with the Number of Samples Analyzed (N) and Standard Deviation (S.D.)

The stations were pooled when no significant difference could be detected between the stations ($p<0.05$, t tests).

Stations	Ionic	Particulate	Organic
All Stations			
R1+G5+G1+L4			
Mean	19		
N.	8		
S.D.	11		
River Stations			
R1+G5+G1			
Mean			18
N.			7
S.D.			9.5
Head of River			
R1+G5			
Mean		57	
N.		4	
S.D.		13	
River Mouth			
G1			
Mean		77	
N.		2	
S.D.		2.9	
River/Ocean			
Mixing Zone L4			
Mean		34	54
N.		1	1
S.D.		N/A	N/A

Table 3

Mean Pooled Concentration of Ionic, Particulate, and Organic Forms of Zinc in μg./l. with the Number of Samples Analyzed (N) and Standard Deviation (S.D.)

The stations were pooled when no significant difference could be detected between the stations ($p<0.05$, t tests).

Stations	Ionic	Particulate	Organic
All Stations			
R1+G5+G1+L4			
Mean	5.3		
N.	9		
S.D.	2.9		
River Stations			
R1+G5+G1			
Mean		83.	11
N.		8	8
S.D.		6.8	8.1
River/Ocean			
Mixing Zone L4			
Mean		43	53
N.		1	1
S.D.		N/A	N/A

Zinc. The concentration of the three fractions and the percent of the total zinc concentration are shown for each sampling date and station in Table 3. There was no significant difference between the stations in ionic zinc fraction. The pooled mean ionic fraction is 5.3% (N=19, S.D. 2.9). However, there was a significant decrease in the particulate zinc from the river stations (RI + G5 + G1), 83.1% (N=8, S.D. 6.8), to the river/ocean mixing zone (L4), 43% (N=1). The organic zinc fraction increased from 11% (N=8, S.D. 8.1) at the river stations (RI + G5 + G1) to 52.7% (N=1) in the river/ocean mixing zone.

Samples collected on January 27, 1973 were used to determine changes, in the ionic particulate, and organic fractions, with the distance seaward from the river mouth. Samples were taken 500, 1000, and 2000 meters from the river mouth. A decrease in the ionic Fe, from 15.8% in the river mouth to a mean of 3.7% in the ocean, was the only significant difference ($p<0.05$, t value 34.92) (Table 4). A comparison between the pooled samples (river plus ocean stations) ionic, particulate and organic fractions for all seven metals showed that the only significant difference was between the ionic and particulate fractions and between the particulate and organic fractions of Zn, Mn and Cr.

The results indicate that the soluble organic fraction can be over 50% of total soluble metal. Therefore, a method which only detects the soluble ionic fraction will lead to serious errors.

The results for the particulate fraction agree with those found by others (Lowman, 1966; Eichholz et al. 1967; Johnson, et al. 1967; Kharkar, et al. 1968). It appears that the majority of the trace metals in the river water are adsorbed on clay/silt particles. Up to 84% of the zinc and 80% of the copper was in the particulate fraction.

The controversy over whether metals are "complexed" by organic compounds in natural waters is still being debated. (Duursma, 1960; Corcoran and Alexander, 1964; Johnston, 1964; Matson 1968; Prakash and Rashid, 1968; Bender, et al. 1970; Stumm and Morgan, 1970; Rashid, 1971; Barker and Zeitlin, 1972). However, it appears certain that large part of Zn and Cu in natural waters exist as organic complexes. The results of this study substantiate this, as up to 53% of the copper and zinc were found in the organic fraction. This agrees with the results of the hypothetical ligand and metal system divised by Stumm and Morgan (1970) where Cu, Zn and Ni exist as appreciable nitriloacetic acid complexes and Fe^{3+} exists as a nocardamine complex.

In order to understand the biogeochemical pathways of the trace metals the true chemical form of the metals should be analyzed. The difference between toxicity and the biological uptake in the marine environment depend intimately on the chemical form of the element. A good example of the importance of the chemical fractionation is the relative toxicities of inorganic and organic mercury compounds.

In conclusion, the concentration of the ionic, particulate and organic forms of seven trace metals was determined. The particulate fraction was usually the largest fraction except for cobalt and lead, which were mostly in ionic fraction. The organic fraction for zinc copper and iron ranged from 5% to 53% with the highest values in the sea water.

Table 4

Concentration of the Ionic Particulate and Organic Fractions of Trace Metals in μg./l. and Percent of the Total Concentration at Increasing Distance from The Guanajibo River Mouth on January 24, 1973.

Stations	Trace Metals	Total Conc. μg./l.		Percentage		
				Ionic	Particulate	Organic
River Mouth	Zinc	4.46		4.9	91.5	3.6
500m		3.34		2.4	67.7	29.9
1000m		4.56		3.1	90.4	6.6
200m		2.00		10.0	40.0	50.0
			Mean	5.1	72.4	22.5
			S.D.	3.4	24.2	21.8
River Mouth	Copper	1.10		18.2	81.8	36.4
500m		1.86		10.8	69.9	19.4
1000m		2.40		8.3	75.0	16.7
2000m		1.62		21.0	30.1	48.1
			Mean	14.6	64.2	30.2
			S.D.	6.0	23.3	14.8
River Mouth	Cobalt	2.54		50.4	18.9	30.7
500m		2.10		57.1	22.9	20.0
1000m		1.58		20.3	45.6	34.1
2000m		1.86		71.0	0	29.0
			Mean	49.7	21.9	28.5
			S.D.	21.4	18.7	6.0
River Mouth	Manganese	14.46		34.4	64.3	1.2
500m		8.38		16.7	82.3	1.0
1000m		10.54		2.7	95.4	1.9
2000m		2.24		33.9	56.3	9.8
			Mean	21.9	75.6	3.5
			S.D.	15.2	17.6	4.2
River Mouth	Iron	8.0		15.8	55.8	28.5
500m		17.98		3.5	93.1	3.3
1000m		7.78		3.9	72.0	24.2
2000m		9.48		a	2.93a	1.81a
			Mean	3.7	73.0	18.7
			S.D.	0.28	18.7	13.5
River Mouth	Lead	5.26		81.0	0	19.0
500m		2.50		73.3	26.7	0
1000m		0		0	0	0
2000m		3.80		57.9	0	42.1
			Mean	53.1	6.7	15.3
			S.D.	36.6	13.4	20.0
River Mouth	Chromium	3.30		17.0	74.5	8.5
500m		2.86		19.6	73.4	7.0
1000m		3.64		0	90.7	9.3
		1.56		47.4	14.1	38.5
			Mean	21.0	63.2	15.8
			S.D.	19.6	33.7	15.2

a. Sample lost, values shown are in μg./l.

REFERENCES

1. Barker, D.B. and H. Zeitlin,1972. Metal-ion concentrations in sea-surface, micro-layer and size separated atmospheric aerosol samples in Hawaii. J. Geophys. Res. 77(27): 5076-5086.
2. Bender, M.E., W.R. Matson and R. J. Jordan,1970. On the significance of metal complexing agents in secondary sewage effluents. Envir. Sci.Techn. 4: 520-521.
3. Chu, C. and D.J. Pietrzyk, 1974. High pressure chromatography on XAD-2, a porous polystyrene-Diviny(1) benzene Support - Separation of organic bases. Anal. Chem. 46(3): 330-336.
4. Corcoran, E.F. and J.E. Alexander, 1964. The distribution of certain trace elements in tropical sea water and their biological significance. Bull. Mar. Sci. 14:594-602.
5. Duursma, E.K. and W. Sevenhuysen, 1966. Note on chelation and solubility of certain metals in sea water at different pH values. Neth. J. of Sea Res. 3(1): 95-106.
6. Duursma, E.K. 1960. Dissolved carbon, nitrogen and phosphorous in the sea. Neth. J. Sea Res. 1: 1-148.
7. Eichholz, G.G., T.F. Craft and A.N. Galli, 1967. Trace element fractionation by suspended matter in water. Geochim. Cosmochim. Acta 31: 737-745.
8. Gibbs, R.J. 1973. Mechanisms of trace metal transport in rivers. Science 180:71-73.
9. Johnson, V., N. Cutshall and C. Osterberger, 1967. Retention of Zn^{65} by Colombia River Sediment. Water Res. Research 3 (1): 99-102.
10. Johnston R., 1964. Sea water the natural medium of phytoplankton II Trace metals and chelation, and general discussion. J. Mar. Biol. Assn. U.K. 44:87-109.
11. Kharkar, D.P., K.K. Turekian, and K.K. Bertine, 1968. Stream supply of dissolved silver, molybdenum antimony, selenium, cobalt, rubidium and cesium to the oceans. Geochim. Cosmochim. Acta 32: 285-298.
12. Lowman, F.G., D.K. Phelps, R. McClin, V.R. De Vega, I.O. de Padovani and R. J. Garcia. 1966. Disposal of radioactive wastes into seas, oceans and surface waters. International Atomic Energy Agency, Vienna.
13. Lowman, F.G. and R. Ting. 1973. The state of cobalt in sea water and its uptake by marine organisms and sediments, p. 369-384. *In* Radioactive contamination of the Marine Environment. International Atomic Energy Agency, Vienna, Austria.
14. Matson, W.R. 1968. Trace metals, equilibrium and kinetics of trace metal complexes in natural media. Ph. D. thesis. Dept. of Chemistry, Mass. Inst. of Techn., Mass.
15. Prakash A. and Rashid, M.A., 1968. Limnol. Oceanog. 13:598-606.
16. Provasoli, L., 1963. Organic regulation of phytoplankton fertility p. 165-219. *In* The Sea Vol. 2, M.N. Hill (Ed.) Interscience, John Wiley and Sons, New York, New York, 554 p.
17. Rashid, M.A., 1971. Role of humic acids of marine origin and their different molecular weight fractions in complexing di and Tri-valent metals. Soil Science 3(5):298-306.

18. Riley, J.P. and D. Taylor, 1968. Chelating resins for the concentration of trace elements from sea water and their analytical use in conjunction with atomic absorption spectrophotometry. Anal. Chem. Acta **40**: 497-485.

19. Slowey, J.F.. L.M. Jeffrey, and D.W. Hood. 1967. Evidence for organic complexed copper in sea water. Nature **214**:377-378.

20. Stumm, W. and J.J. Morgan, 1970. Aquatic Chemistry, Wiley-Interscience, New York, London, Sydney, and Toronto. 583 p.

21. Vallentyne, J.R. 1957. The molecular nature of organic matter in lakes and oceans, with lesser reference to sewage and terrestrial soils. J. Fish. Res. Bd. Can. **14**: 33-82.

22. Wagner, F.S. Jr., 1969. Composition of the dissolved organic compounds in sea water. A review Contr. Mar. Sci. **14**: 115-153.

23. Wangerski, P.J., 1965. The organic chemistry of sea water. Am. Scient. **53**:358-374.

24. Water Resources Research Institute, University of Puerto Rico, Mayaguez. Report of Sanitary quality of the Guanajibo River Watershed. June 22 - July 6, 1964.

25. Williams, P.M., 1969. The association of copper with dissolved organic matter in sea water. Limnol. Oceanog. **14**: 156-158.

Dissolved Inorganic Phosphate in the Guanajibo River Water, Sediments, and Clays. — John R. Montgomery. The National Academy of Sciences report on *Marine Environmental Quality* states: "Although considerable deposition of pollutants has been observed in sediments near river mouths and considerable transport to the deep ocean also occurs, the chemical factors governing the efficiency of deposition and transport in solution are poorly understood"/(1971).

As an example of this, clay surfaces have been shown to adsorb phosphate, (Keup 1968, Carrit and Goodgal 1954, Williams et al. 1971; Pomeroy et al. 1965, Jitts 1959, Seschappa 1953), therefore the ultimate fate of the clay will also determine where the phosphate is transported and deposited. Adsorption depends on surface charges, therefore changes in ionic strength and pH will effect the adsorbing powers of the clay. The ionic strength and pH both change where river and ocean meet. To ascertain the ultimate fate of the phosphate transported by the river an experimental plan has been devised to,(1) Determine the type of clays suspended in the river water and in the river and marine sediments. (2) Determine in the laboratory whether these clays can and do adsorb phosphate and the function of changing pH, Eh and oxygen concentration on their adsorbing ability. (3) To measure the concentration of the loosely bound interstitial and adsorbed phosphate in the sediments. (4) Determine the initial baseline values of both soluble and particulate phosphate in the river and coastal waters and their sediments.

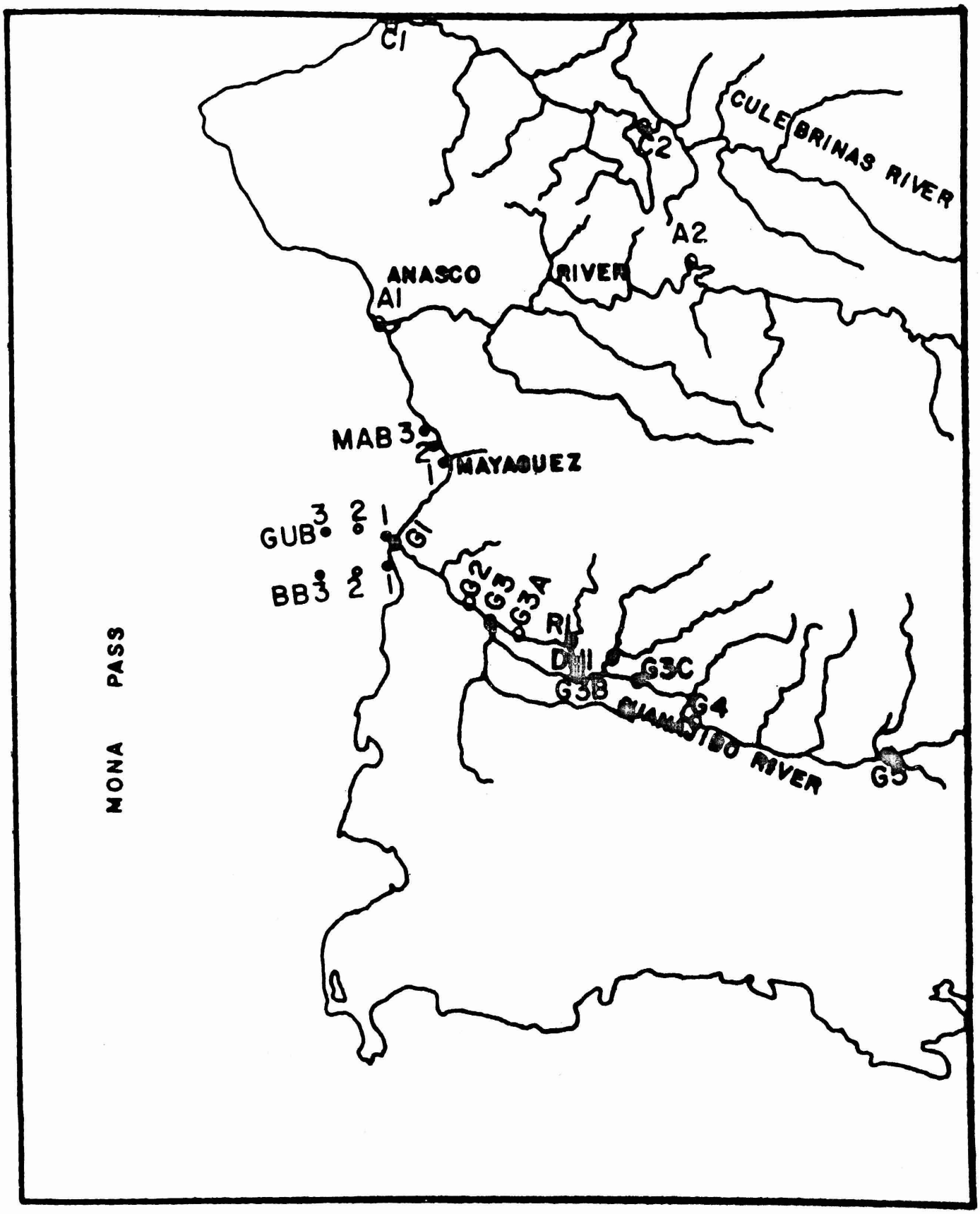


Figure 1

West Coast of Puerto Rico
with sampling stations.

Table 1

Dissolved Inorganic Phosphate for the Water in the Guanajibo River and Tributaries from November 1, 1972 to January 17, 1974

Stations	G1	G2	G3	G3A	G3B	G3C	G4	G5		
Distance from River mouth, in km	0	6	7.5	10.6	13.4	17.6	25	37	*RI	*DHI
	P expressed as μg. at./l									
Date										
Nov. 1, 1972	3.4									
Nov. 8, 1972	4.1									
Nov. 9, 1972	4.7								0.80	
Nov. 11, 1972	4.8	5.2	5.3				3.9	1.1	1.2	
Nov. 20, 1972	3.7	3.7	3.6		4.1		2.9	1.0		1.6
Nov. 30, 1972	5.0	4.2	4.2		4.2		2.7	1.1	0.91	1.4
Dec. 6, 1972	5.0	2.0	3.0		1.1		1.6	1.0	0.70	1.6
Jan. 24, 1973	8.7	7.4	7.8		7.8		5.7	1.7	0.93	1.5
Feb. 1, 1973	8.7	6.7	7.6		7.6		4.4	0.71	0.69	1.3
Feb. 2, 1973	7.8/7.8									
Feb. 13, 1973	9.1	8.5	8.7		9.6		2	0.78	0.80	1.1
Feb. 20, 1973	-	5.51	8.81		8.81		2.87	0.95	1.1	1.4
Jul. 31, 1973	4.2	3.2	3.8	0.73	6.1	6.6	5.1	1.1	0.7	2.5
Sep. 19, 1973										
Sep. 26, 1973										
Oct. 17, 1973	3.37	4.34	1.19			5.01	1.51	.866		
Nov. 23, 1973										
Jan. 3, 1974										
Jan. 17, 1974	9.53	9.58	9.58	1.65	9.24	9.29	3.2	1.28	1.77	0.92

*RI - Rio Rosario

*DHI - Ríos Duey and Hoconuco

Table 2

Mean Values for Dissolved Inorganic Phosphate, in μg at.P/l for the Ocean Stations BB-1,2,3, GUB-1,2,3, and MAB-1,2,3, from November 1972 to February 1974

Station	GUB-1	GUB-2	GUB-3	BB-1	BB-2	BB-3	MAB-1	MAB-2	MAB-3
Number of Samples	15	6	9	9	5	4	3	3	2
Mean (μg at./l)	0.89	.55	.70	.55	.23	.21	2.4	.27	.50
S.D.	.99	.82	.79	.51	.17	.10	2.7	.37	.57

All samples were collected and stored in polyethylene bottles, on ice and in the dark. A drop of 1:1 ($^{V}/_{V}$) toluene and CCl_4 mixture was added. The samples were filtered within 3 hours through a 0.45μ pore size Millipore$^{(R)}$ filter. The filtrate was then analyzed spectrophotometrically for dissolved inorganic phosphate by the single solution, molybdenum blue, ascorbic acid method, as described by Strickland and Parsons (1965). A Beckman D.U. with a 10 cm pathlength cell was used at 885 nm, to analyze the samples. Reagent and turbidity blanks were determined and standard curves were prepared prior to each set of samples.

Sediment cores in duplicate were collected from the river mouth in 3.5 cm x 20 cm plastic cylinders. The concentration of dissolved inorganic phosphate was determined in eight serial, 1 cm x 3.5 cm diameter slices and one slice taken from the bottom of the core. The slices were extruded and the wet weight determined. The wet weight/dry weight ratio was determined on sediment from the duplicate core. The sediment slices were first shaken with 100 ml distilled water. The concentration of phosphate was then determined for this water. The water was decanted and 2.5 ml of 2N NaOH in 100 ml of distilled water was added to the sediment slices to free phosphate that was adsorbed on the sediment (Rockford, 1951). After one hour the dissolved inorganic phosphate in this decanted water was determined. The water was decanted and discarded and 2.5 ml of 2N NaOH in 100 ml distilled water solution was added again and allowed to sit for 24 hours at which point the dissolved inorganic phosphate in the liquid was determined.

Laterite clay, from farmlands near the Guanajibo River, was suspended in distilled water in a one liter graduated cylinder. After two hours the supernatant was decanted, yielding a solution containing a majority of clay/silt sized particles of 0.004 m. (Krumbein and Pettijohn 1938). The supernatant was well mixed and a subsample taken to determine the concentration of the solids. An assumption was made that the majority of the solids would be clay/silt particles. This subsample was dried and suspensions of this clay were made, in distilled water, so as to yield 11.4 mg/l, 28.5 and 57 clay concentrations. For each clay concentration, a set of four duplicate samples, denoted A, B, C, D, were prepared under the following experimental conditions: Sample A had a preservative of 1:1 ($^{V}/_{V}$) toluene and CCl_4, Sample B had no preservative, Sample C had distilled water and preservative and Sample D had distilled water and no preservative. Samples A through D for each clay concentration then had dissolved inorganic phosphate added to yield 4.1 μg at. P/l and the pH adjusted to 7.5. The samples were placed in 125 ml Erlenmeyers, sealed with Saran $^{(R)}$ wrap and swirled for 24 hours at room temperature. At the end of 24 hours the samples were filtered through cleaned 0.45 m pore size Millipore filters and the phosphate determined on four 25 ml sub-samples of the filtrate for each sample.

Determination of dissolved inorganic phosphate has been obtained for the water and sediments of the Guanajibo River from the head of the river (at Sabana Grande) to the coastal waters at the river mouth. (Figure 1). The values for concentration of dissolved phosphate in microgram atoms of phosphorous per liter for the Guanajibo River are listed in Table 1. The dissolved phosphate for the coastal zone are shown in Table 2.

When there are two values listed for one station the upper value is the surface phosphate concentration and the lower values is the bottom phosphate concentration. In general, the dissolved inorganic phosphate increases to a maximum at the river mouth (Station G-1). The highest values for phosphate occur when the rainfall decreases and the river becomes anaerobic and the sediment releases phosphate. The phosphate values rapidly decrease in the coastal zone as compared to the values at the river mouth.

The results, expressed as μg at. P/g dry sediment are shown in Table 3. There is more than sufficient phosphate in the sediment reservoir to maintain a high level of phosphate in the water column.

The resulst of the clay adsorption are shown in Table 4. When the results were tested ($P<0.05$, t test) a definite interaction was found between suspended clay sized particles and dissolved inorganic phosphate. However, the only significant difference from distilled water occured when the clay concentration was between 28.5 and 58 mg/l inclusively. The percent phosphate adsorbed for the 28.5 mg/l clay suspension was 9.8% and 29.7% for the 57 mg/l suspension. The results have been corrected for the distilled water control. The difference in the adsorption of phosphate between these two clay suspensions was significant ($P<0.05$, t test).

The concentration of phosphate in the Guanajibo River is very high as compared to the coastal zone and open ocean. Therefore, if this nutrient enters the open waters at the concentration found at the river mouth a large increase in plankton biomass would be expected. It appears that the phosphate in the river water rapidly decreases as it enters the ocean water. This is probably due to the settling out, in the ocean, of the colloidals and particulates in the river water. This mechanism could also cause the dissolved inorganic phosphate to precipitate, especially if adsorbed on to the clay/silt particles (Carrit and Goodgal 1954; Lowman, 1965). Ten to 30% of the dissolved inorganic phosphate was adsorbed on clay/silt levels below the normal concentration found in the Guanajibo River. The adsorption seems to increase as the concentration of clay increased.

Once the dissolved inorganic phosphate is precipitated it enters the sediment where it can act as a reservoir of easily released nutrients. The amount of phosphate in the sediments at the river mouth is at least an order of magnitude higher than that in the water. This sediment phosphate can be released by stirring with distilled water only. Therefore it is loosely bound to the sediment and can be continually released to the ocean water by wave action.

The phosphate in the Guanajibo River appears to peak just below the Eureka Central (Station G3A), a sugar mill. The organic load from the mill is very high, especially during the harvest season when precipitaion is at its lowest. Obviously, the phosphate is released by microbial action in the river thereby producing a lag in the phosphate concentration.

Table 3

Concentration of Dissolved Inorganic Phosphate, μg at.P/g Dry Weight Sediment, in Guanajibo River Sediment at Varying Depths.
The phosphate was released by distilled water, 2N NaOH for 1 hour and 24 hours.

	No. 1	No.2	No.3
Death in cm from the Surface of the core.	Sediment slice washed with 100 ml distilled water. P in μg at./g dry sediment	Sediment maintained for 1 hour in a solution of 2.5 ml 2N NaOH + 100 ml distilled water. P in μg at./g dry wet sediment.	Sediment maintained 24 hrs in a solution of 2.5 ml 2N NaOH + 100 ml distilled water. P in μg at./g dry wt Sediment.
1	051	Sample lost	1.53
2	044	0.42	1.93
3	036	0.40	1.94
4	022	0.38	1.66
6	.027	0.34	1.94
7	.023	0.41	1.59
8	.014	0.47	1.78
9	.020	0.52	2.16
Bottom (approx. 30 cm)	.020	0.52	2.16

Table 4

Sorption of Dissolved Inorganic Phosphate (4.1 μg at.P/l) by Varying Concentrations of Clay Suspension

Clay Suspension mg/l	Mean Concentration of Phosphate Remaining in Solution
11.4	3.63
28.5	3.44 **
57	2.63 **
Distilled water Control	3.77

** Significantly different from the distilled water control at the $P<0.05$ level.

REFERENCES

1. Carrit, D.E. and S. Goodgal, 1965. Sorption reactions and some ecological implications. Deep Sea Research 1:224:243.
2. Jitts, H.R., 1959. The adsorption of phosphate by estuarine bottom deposits. Aust. J. Mar. and Fresh W. Res. 10: 7-21.
3. Keup, L.E., 1968. Phosphorous in flowing water. *In* Water Research, Pergamon Press, 2: 373-386. Great Britain.
4. Krumbein, W.C. and F.J. Pettijohn 1938. Manual of Sedimentary Petrography, Appleton - Centure-Crafts, Inc. New York.
5. Lowman, F.G., L. Quiñones, M. Miró, I.O. de Padovani, E. Ramos, V. Román de Vega and H.J. Bielen. 1965. *In* 5th Inter-American Symp. on Peaceful Application of Nuclear Energy, 241-256. Valparaiso, Chile, 1964. Pan American Union, Washington, D.C.
6. National Academy of Sciences, 1971. Marine Environmental Quality Report of the Ocean Science Committee of the NAS-NRC Ocean Affairs Board. National Academy of Sciences, Washington, D.C.
7. Pomeroy, L.E., E.E. Smith and Carol M. Grant, 1965. The exchange of phosphate between estuarine water and sediments. Limnol. Oceanog. 10:167-172, 1959.
8. Rochford, D.J., 1951. Studies in Australian estuarine hydrology I. Introduction and comparative features. Austral. J. Mar. Fresh W. Res. 2:1-116.
9. Seschappa, G. 1953. Phosphate content of mudbanks, along the Malaba Coast. Nature 171:526-527.
10. Strickland, J.D.H. and T.R. Parsons, 1965. A manual of Sea water Analysis. Fisheries Research Board of Canada, Ottawa, Canada, 203p.
11. Williams, J.D.H., J.K. Syers, S.S. Shukla and R.F. Harris, 1971. Levels of inorganic and total phosphorous in lake sediments as related to other sediment parameters. Environ. Sci. Techn. 5(11): 1113-1120.

ANALYTICAL METHODS

One of the objectives of the Marine Biology Section is to develop new analytical and radiochemical methods for sea water, sediments and marine organisms. This is done by developing new techniques and modifying existing techniques for marine samples. During the past year effects of the pH on the ferric hydroxide coprecipitation method have been investigated and a simple method for preparing samples for alpha spectrometry have been developed.

Studies on the Coprecipitation of Some Transition Metals by the ($FeCl_3$ - NH_4OH) Method from a Sea Water Matrix — F.J. Muñoz Ribadeneira. Ferric hydroxide coprecipitation is a widely used method for preconcentrating trace metals froms sea water. The general

method is as follows: to sea water aliquot, previously adjusted with 6N HCl to pH 2.0, ten mg of $FeCl_3$ solution per liter is added, then 6N NH_4OH is added slowly until a pH of 9.0 is achieved. The coprecipitation is completed with the aid of Separan flocculant. Twenty four to forty eight hours later the precipitate is separated by filtration and dissolved in 6N HCl.

Care must be taken in adjusting the final pH because even small changes in the final pH can cause considerable variation in the yield of some metals. In order to test the effect of pH, coprecipitation experiments were carried out from pH6 to 10 for lead and zinc and from pH 8 to 10 for cobalt, copper, nickel, manganese, and cadmium. The final concentrations of all metals were calculated to be 5 ppm for quantitative yield when the precipitate was dissolved in 6N HCl and the volume of the dissolution made up to 100 ml. All the salts were added in inorganic form and the analysis were carried out by atomic absorption spectrophotometry. Data were obtained from samples to which only one of the metals under study were added and from five replicate samples to which all the elements were added. Blanks for each set of experiments were taken into account and results calculated from appropriate standard curves. Table 1, summarizes the results.

Table 1

Percent Recovery of Transition Metals from Sea Water by Ferric Chloride Coprecipitation

Element	pH 8	pH9.0*	Max. % Recovery *	% Recovery at pH 9.0 **
Zn	40.0	70.0	95.0 at pH 9.4	85.0 ± 3.8
Pb	100.0	100.0	100.0 at pH 9.0	100.0
Co	6.5	74.0	88.0 at pH 9.7	83.0 ± 4.4
Cu	86.0	93.0	93.0 at pH 9.8	92.5 ± 3.2
Ni	8.6	75.0	87.0 at pH 9.7	84.8 ± 5.2
Mn	13.0	92.0	95.0 at pH 9.8	93.8 ± 2.1
Cd	16.3	16.0	65.0 at pH 9.8	34.5 ± 10.6

*Individual samples for each one of the elements.

** Data from five replicate samples, where all the elements were added.

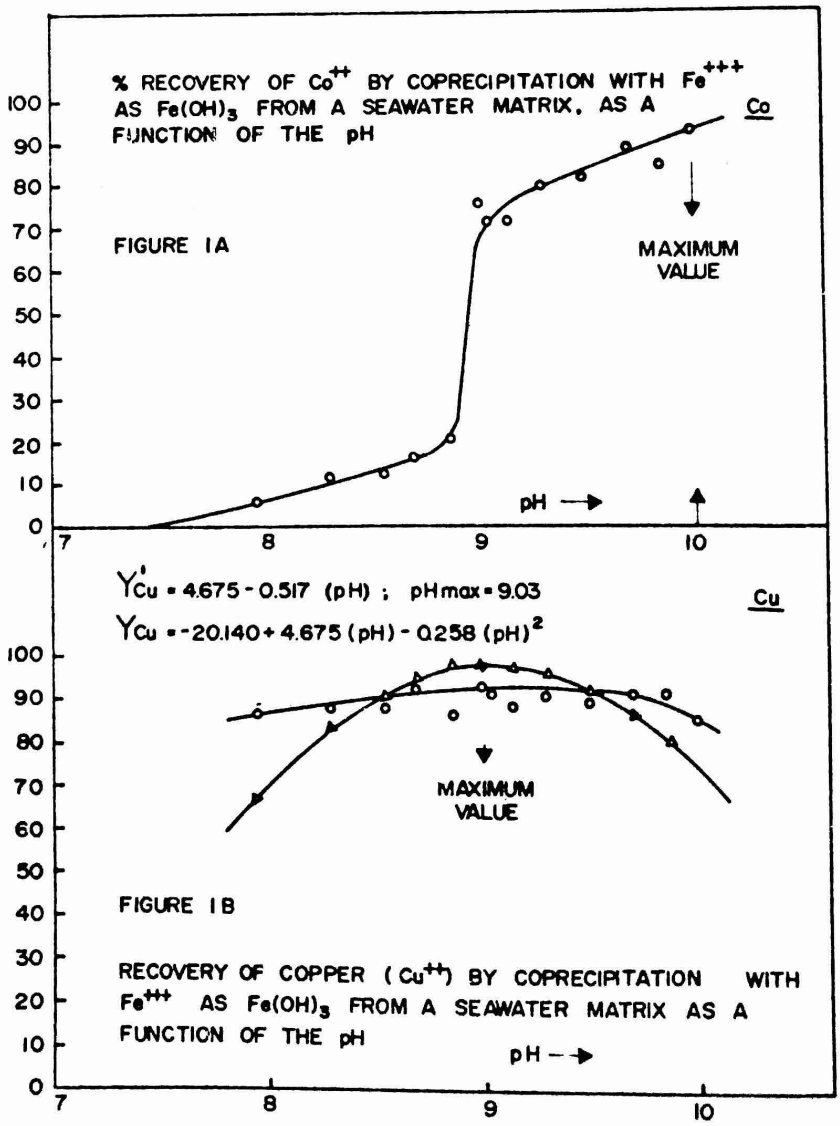
Data in Table 1 indicate that inorganic lead can be recovered quantitatively with the ($FeCl_3$–NH_4OH) coprecipitation method; but this method gives low yields for cadmium in sea water. The recovery of Zn, Co, Cu, Ni and Mn vary from 70% to 93% at pH 9. (Table 1). Studies on samples to which only one of these metals were added, indicate that to improve the yield of the coprecipitation, pH values higher than 9.0 should be used; this apparently contradicts with the well known fact that hydroxides of Co, Zn, Cu, Ni and Mn are soluble in excess of NH_4OH. This would indicate formation of some chemical compound between the hydroxides of these metals and ferric hydroxide, which are less soluble in an excess of NH_4OH, or that the ferric hydroxide traps very efficiently the hydroxides of

these metals reducing at the same time the effects of redissolution. Recovery in a mixture of all seven elements (5 replicates) at pH 9.0 is lower than when these elements are co-precipitated separately at the same pH (Table I). The relative standard deviation of the yield in the mixture samples is in the order of 5% with exception of Cd which has a value up to 30%.

The coprecipitation yields of Co, Zn, Ni, Mn as a function of the pH gives a sigmoid curve, similar to a titration type curve. Figure I -A represents data for Co and Figure I-B the data for Cu. The latter figure suggests a tendency of the formation of hydrated copper-ferrites ($CuO_x Fe_2 0_3 y.nH_2 0$). The data in this case could be represented as a second order equation, of which the first derivative gives a maximum recovery at pH. 9.0.

Data for Co could be represented by a "Modified Sigmoid Function" (Fig. 2).The first derivative of this function shows that the highest recovery is obtained at pH 9.0, confirming the results presented in Figure I A.

Results indicate that a pH of 9.5 should be used to coprecipitate Co, Zn, Cu, Ni and Mn in sea water and that the ferric hydroxide coprecipitation method can be used for preconcentration of Cd with only limited success at pH 9.8. The possibility of extending this studies to organo-metallic compounds in a sea water matrix is being planned.



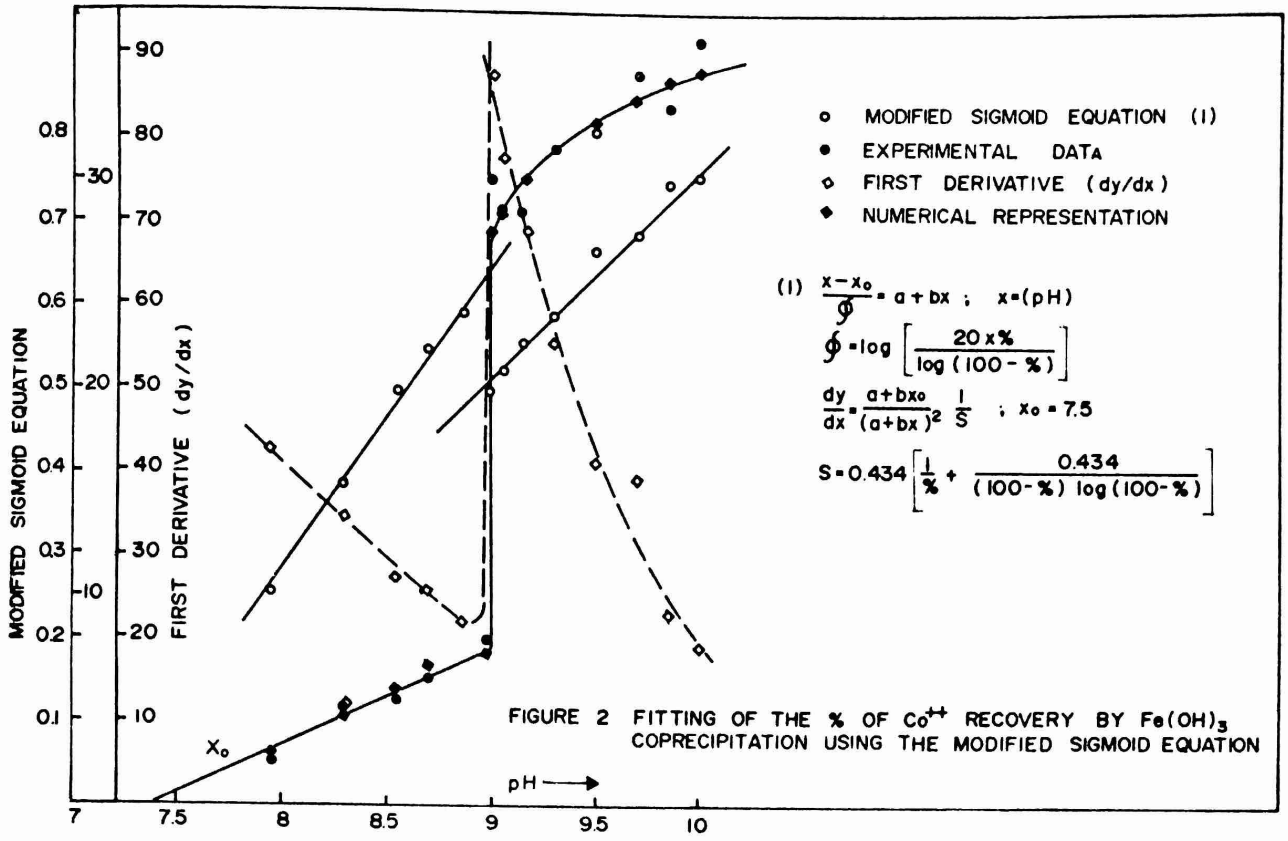
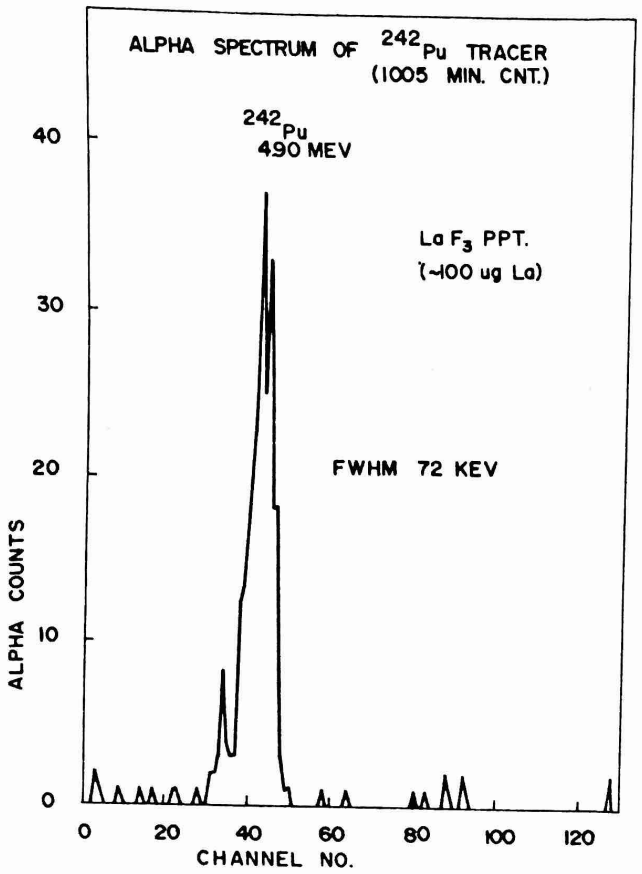
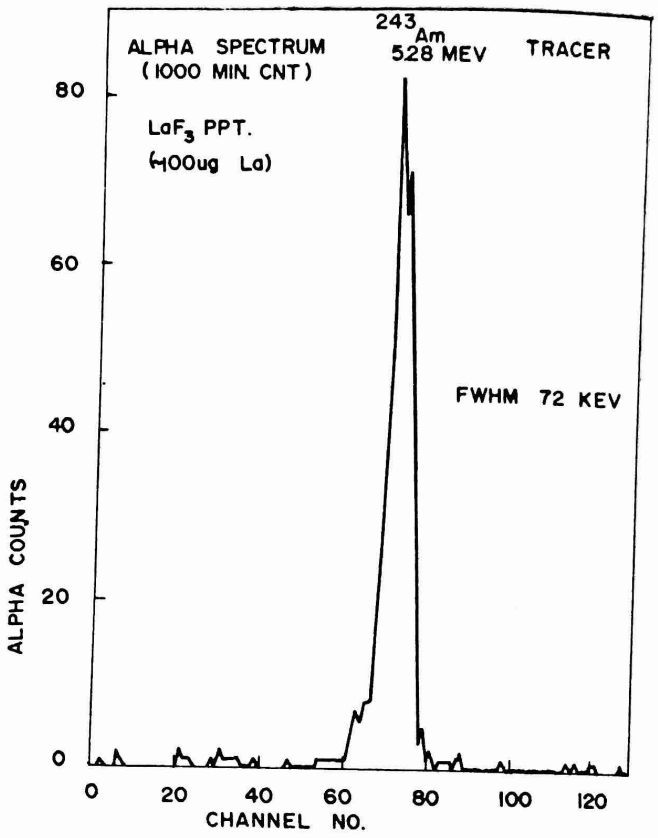


FIGURE 2 FITTING OF THE % OF Co^{++} RECOVERY BY $Fe(OH)_3$ COPRECIPITATION USING THE MODIFIED SIGMOID EQUATION

A Fast, Simple and Economical Method of Preparing Counting Sources for Alpha Spectrometry — Tin Mo and F. G. Lowman. The technique adopted and modified from the coprecipitation method used by Lieberman and Moghissi (1) for alpha spectroscopic determination of uranium thorium, and plutonium, The technique was extended for coprecipitating americium isotopes successfully with trace quantities of lanthanum fluoride (less than 500 μg) contrary to what was reported by Moore (2) at the Oak Ridge National Laboratory.

The alpha spectra of ^{242}Pu (4.90 MeV alphas) and ^{243}Am (5.28 MeV alphas) tracers coprecipitated with 100μg lanthanum fluoride are shown in Figure 1, together with the alpha spectrum of an electroplated transuranium standard. The chemical yield in each case is more than 95 per cent. The general quality of the spectra and the resolution of the peaks obtained with the lanthanum fluoride coprecipitated alpha sources on the Millipore filter membranes are comparable to those of the electroplated source. This technique of preparing alpha counting sources is simpler, faster, and more economical than the conventional and widely used electroplating methods (3), (4), (5). The time required to prepare one source by this technique is less than one hour compared to two hours or more for the electroplating technique.





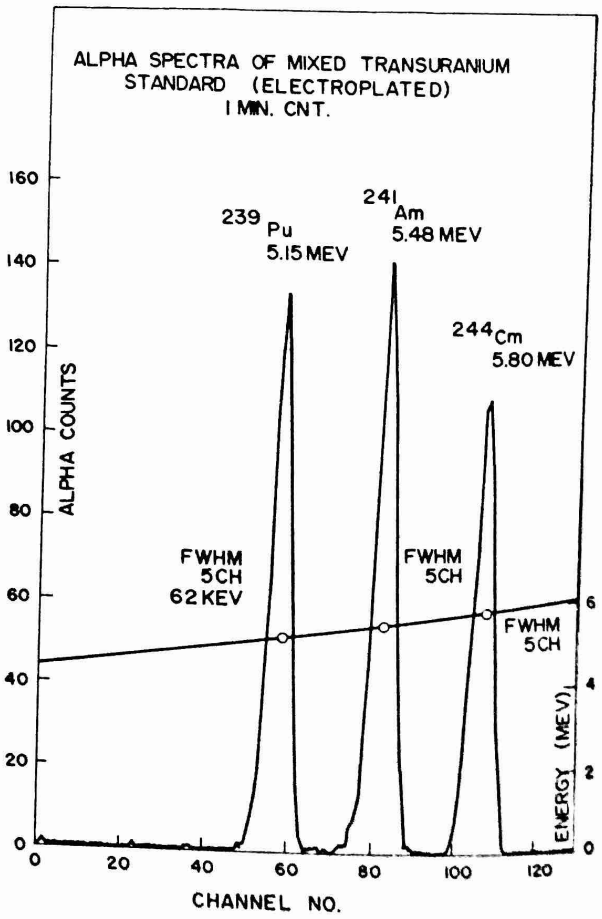


Figure 1. Comparison of the alpha Spectra of ^{242}Pu and ^{243}Am tracers coprecipitated with lanthanum fluoride with that of an electroplated transuranium standard.

REFERENCES

1. Lieberman, R. and A. A. Moghissi, Coprecipitation Technique for Alpha Spectroscopic Determination of Uranium, Thorium and Plutonium, Health Phys. **15**, 359 (1968)
2. Moore, F.L., Separation of Americium from Other Elements: Application to the Purification and Radiochemical Determination of Americium, Anal. Chem. **35**, 715 (1963).
3. Donnan, M. Y. and E. K. Dukes, Carrier Technique for Quantitative Electrodeposition of Actinides, Anal. Chem. 36, 392 (1964).
4. Talvitie, N. A., Electrodeposition of Actinides for Alpha Spectrometric Determination, Anal. Chem. 44, 280 (l972).
5. Puphal, K. W. and D. R. Olsen, Electrodeposition of Alpha-Emitting Nuclides from a Mixed Oxalate-Chloride Eletrolyte, Anal. Che. 44, 284 (1972).

Bikini Atoll Project

During October-November 1972, samples of marine waters, sediments, algae, plankton, invertebrates, and vertebrates were collected in and near Bikini Atoll for the analysis of transuranium elements.

Biological and sediment samples were weighed for wet, dry, and ash weights; water samples were processed in the field to pre-concentrate the transuranium elements. Spikes of Pu^{242} and Am^{243} were added to 200 to 400 liters to check chemical yield and the transuranium elements were coprecipitated with ferric hydroxide. The precipitate was dissolved in the laboratory, iron was removed by ether extraction and plutonium and americium were separated by ion exchange. The purified radioelements were electroplated on stainless steel discs for alpha spectrometry.

Biological and sediment samples were dry ashed at 450°C and spiked with Pu^{242} and Am^{243} for determination of chemical yield. The ash was dissolved in acid and the plutonium was purified by ion exchange and TTA extraction. Americium was subsequently separated by ion exchange. The radioelements were electroplated for counting.

The principal sources of transuranium elements in Bikini Lagoon are provided by the three weapons craters formed by the detonation of the Bravo, Tewa and Zuni fusion devices (Fig. 1). The redistribution of the radionuclides in and near the lagoon is accomplished mainly by the deeper water currents of the lagoon and to a lesser extent by the surface currents. Storms and high winds stir up the sediments in the craters and introduce them into the water circulation pattern of the lagoon.

In Figure 1 the distribution pattern of $Pu^{239,240}$ in the deeper waters of Bikini Lagoon is shown. The arrows indicate the deep water current pattern in the lagoon during the winter months as reported by Von Arx (1948).

In general, the deeper waters contained greater amounts of $Pu^{239,240}$ than did the surface waters (Figs. 1,2). The highest value for $Pu^{239,240}$ activity (283d/m/1000L) occurred in the deep water (51M depth) at a station 9600 meters north of the Zuni Crater and the second highest activity of the same radionuclides (258d/m/1000L) was also in the deep water (50 M depth) at a station 4500 meters southwest of the Bravo Crater, inside the lagoon.

The high value of plutonium activity in the water north of the Zuni Crater is expected on the basis of the deep-water current pattern in the lagoon during the winter. The deep currents transport sediment westward from the Tewa Crater past the Bravo Crater where sediments from that source are added. The deep current then passes southwest, thence southeast and east to the center of the lagoon. Just east of the area of highest $Pu^{239,240}$ activity in the deeper waters there is a slight sill, thus it might be expected that sediments from the two northern craters would be deposited in this area. In the southern part of the lagoon the deep currents move westward from Enyu Island past the Zuni Crater, turn clockwise past the area of high $Pu^{239,240}$ activity and the sill and proceed eastward to the

east reef of the atoll where they turn south to complete the gyre. Thus, Zuni crater also provides a source of contaminated sediments for the central area of high $Pu^{239,240}$ content; however, the major contribution to this area appears to be derived from the Tewa Crater, based on the observed $Pu^{238}/Pu^{239,240}$ ratios. The ratios $Pu^{238}/Pu^{239,240}$ (in the deeper waters of Bikini Atoll) were 0.014 for Tewa Crater; 0.063 for Bravo Crater; 0.13 for Zuni Crater and 0.012 for the area of high activity in the center of the lagoon.

On the basis of the distribution of $Pu^{239,240}$ in the deeper waters of Bikini Lagoon there appears to be a deep current during the winter which was not described by Von Arx. In the western part of the Atoll the highest levels of $Pu^{239,240}$ (Fig. 1) and Pu^{238} (Fig. 3) extend southwestward from the Bravo Crater to the western-most end of the lagoon, a distance of about 13 km. It appears that the west end of the counter clockwise gyre of the northern deep currents extends further down the inside of the west reef of Bikini Atoll than had been previously described. On the basis of the isotope ratio $Pu^{238}/Pu^{239,240}$, a major part of the plutonium activity in this area is derived from the Tewa Crater and not from the Bravo Crater.

The distribution pattern of $Pu^{239,240}$ in the surface waters of Bikini Atoll may be explained by vertical mixing of deep and surface waters in the northern part of the atoll near the Tewa Crater and in western Bikini Lagoon along the west reef (Fig. 2). In addition, the reduced values of plutonium activity in the surface water of the southern part of the lagoon may be explained by dilution of the lagoon water by relatively uncontaminated ocean water flowing in over the east reef and through the eastern part of Enyu pass. This is in agreement with the patterns for the surface currents described by Von Arx.

The distribution pattern of Pu^{238} in Bikini Lagoon is significantly different from that of $Pu^{239,240}$, primarily because of the difference in sources. The activity of $Pu^{239,240}$ in the deeper waters from the Tewa Crater was 60 to 75% of that in the Bravo crater. However, the activity of the Pu^{238} in the deeper waters from the Tewa Crater was only 10 to 20% of that in the other two craters and the highest amounts of the nuclide was found in the deeper waters of the Zuni Crater. On the basis of levels of activity of Pu^{238} in the deeper waters of the west end of the lagoon, it appears that only limited movement of sediments occurs from the Bravo Crater to the southwest (Fig. 3). The distribution pattern of Pu^{238} in the southern part of the Atoll (Fig. 2) may be explained if the Zuni Crater is assumed to be the source and the deep winter water currents (Fig. 1) are assumed to provide the transport for the contaminated sediments. However, the isotope ratio $Pu^{238}/Pu^{239,240}$ in the same area does not entirely support this interpretation.

The distribution pattern of $Pu^{239,240}$ in net plankton is shown in Figure 5. On the basis of the samples collected in this survey, it appears that the major uptake of $Pu^{239,240}$ by these organisms occurs in the area of the Tewa Crater and in the western part of the atoll southwest of the Bravo Crater. Johnson (1954) observed that much of the plankton lived mainly in the deeper water of the lagoon which represented 70 to 90 percent of the living space in the lagoon for this group of organisms. Even at night when plankton normally move toward the surface about two-thirds of the organisms remained in the deeper water. Thus, the movement of the plankton would be expected to be influenced mainly by the circulation patterns of the deeper waters.

The northern deepwater gyre passes the Tewa Crater through the area of high $Pu^{239,240}$ content along the west reef then turns eastward. The highest level of radiation in the plankton occurs in the far western part of this area. Plankton containing relatively high levels of $Pu^{239,240}$ appear to be swept eastward out of this contaminated region by the deep currents. The plankton just north of the Enyu Pass on the south side of the Atoll are mixed with relatively uncontaminated plankton swept in from the open sea through the eastern part of Enyu Pass.

The amounts of $Pu^{239,240}$ per unit volume of plankton are many times the levels found in the water (Fig. 6). Concentration factors of 2600 for plutonium in marine plankton have been reported by other investigators; based mainly on laboratory uptake experiments. In the present work the concentration factors for open-sea plankton appear to be about 2×10^4, a factor about 8 times that previously reported.

In the eastern and southern parts of Bikini Lagoon concentration factors of 1.2 to 1.7 $\times 10^4$ are observed. These low values probably result from low-activity plankton being swept from the open ocean across the east reef into the water of the lagoon which contains relatively large amounts of $Pu^{239,240}$. In the west end of the lagoon the apparent concentration factor is about 1.7×10^5 or 8 times the value observed for open-sea plankton. West of the Atoll, in the open sea, the apparent concentration factor is about 4.8×10^5 or about 20 times the open-sea value. These apparently high concentration factors probably are due to plankton from the lagoon (with large amounts of $Pu^{239,240}$) being swept across the west reef into sea water which has been diluted to relatively low activity compared to the water in the lagoon.

Additional analyses are under way for $Pu^{239,240}$, Pu^{238} and Am^{241} in water, plankton, sediments, and marine macroorganisms from Bikini Lagoon. In the fall of 1974 another survey is planned for Bikini Atoll in which tides and water currents in areas of interest will be measured. In addition, metered plankton hauls with simultaneous water sampling and collections of organisms comprising well-defined food webs will be made.

REFERENCES

1. Von Arx, W.S. 1948. The circulation systems of Bikini and Rongelap Lagoons. Am. Geophys. Union Trans. **29**, 861-870.
2. Johnson, M.W. 1954. Plankton of the Northern Marshall Islands. U. S. Geol. Survey Prof. Paper **260-F**, 301-314.

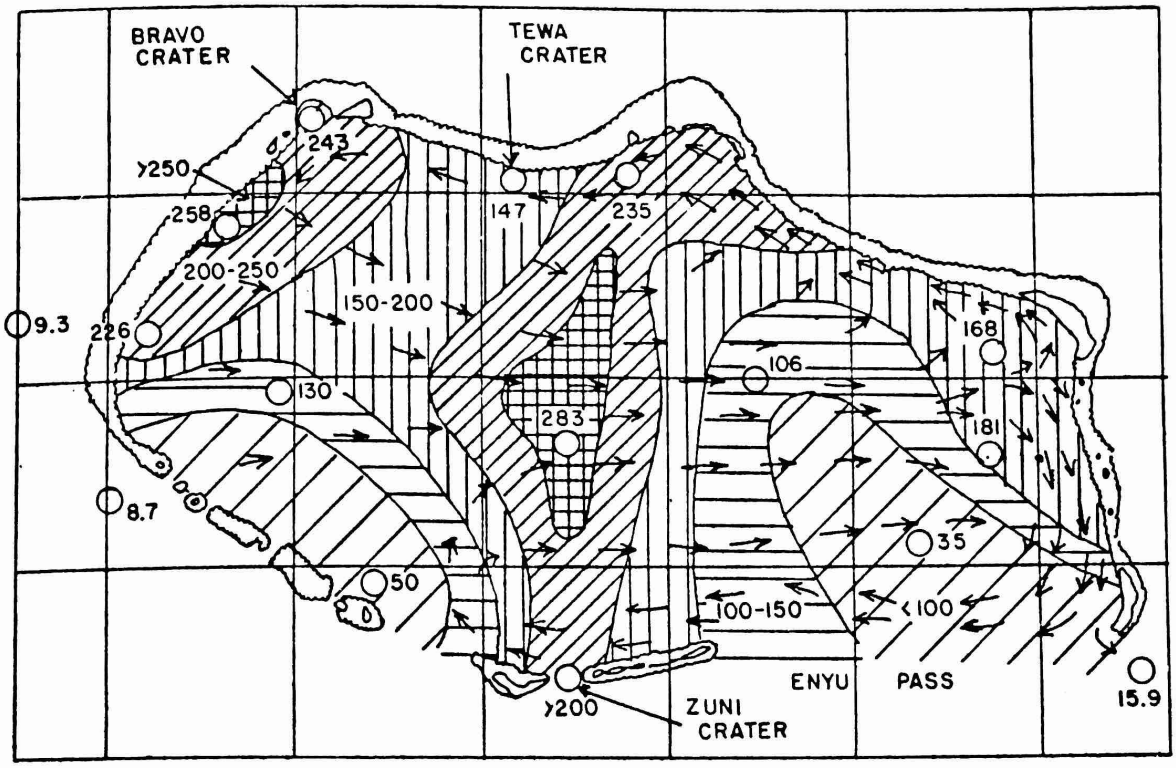


FIG. 1. CONTENT OF $Pu^{239,240}$ IN DEEP WATER (d/m/1000 L.). ARROWS INDICATE DEEP CURRENTS DURING WINTER.

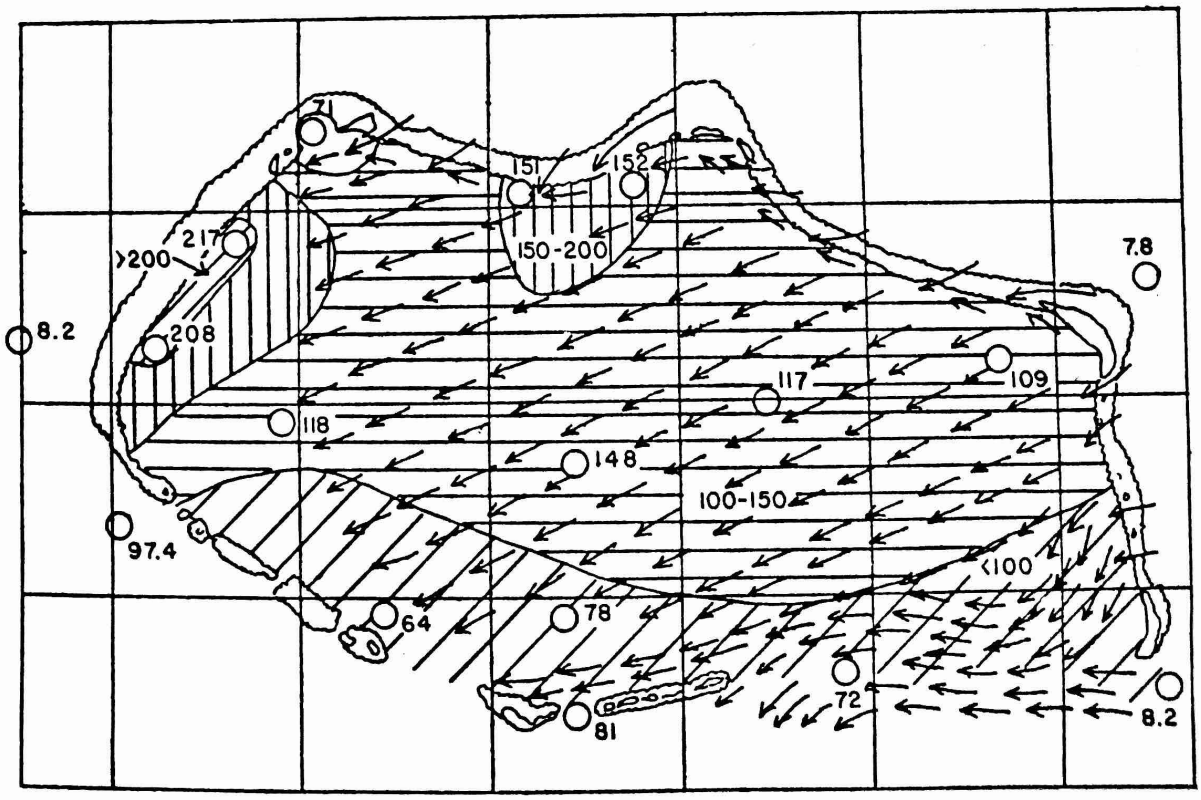


FIG.2. CONTENT OF $Pu^{239,240}$ IN SURFACE WATER (d/m/1000L). ARROWS INDICATE SURFACE CURRENTS DURING WINTER.

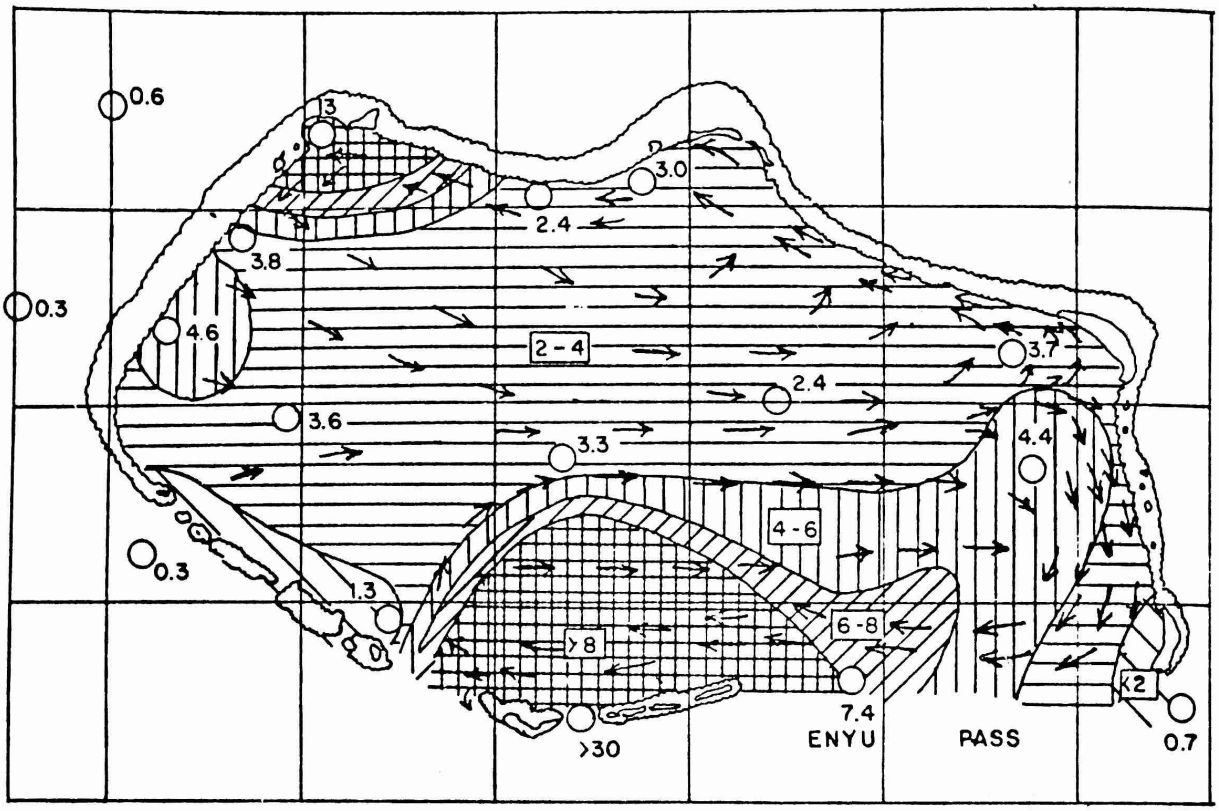


FIG. 3. CONTENT OF Pu^{238} IN DEEP WATER (d/m/1000L)

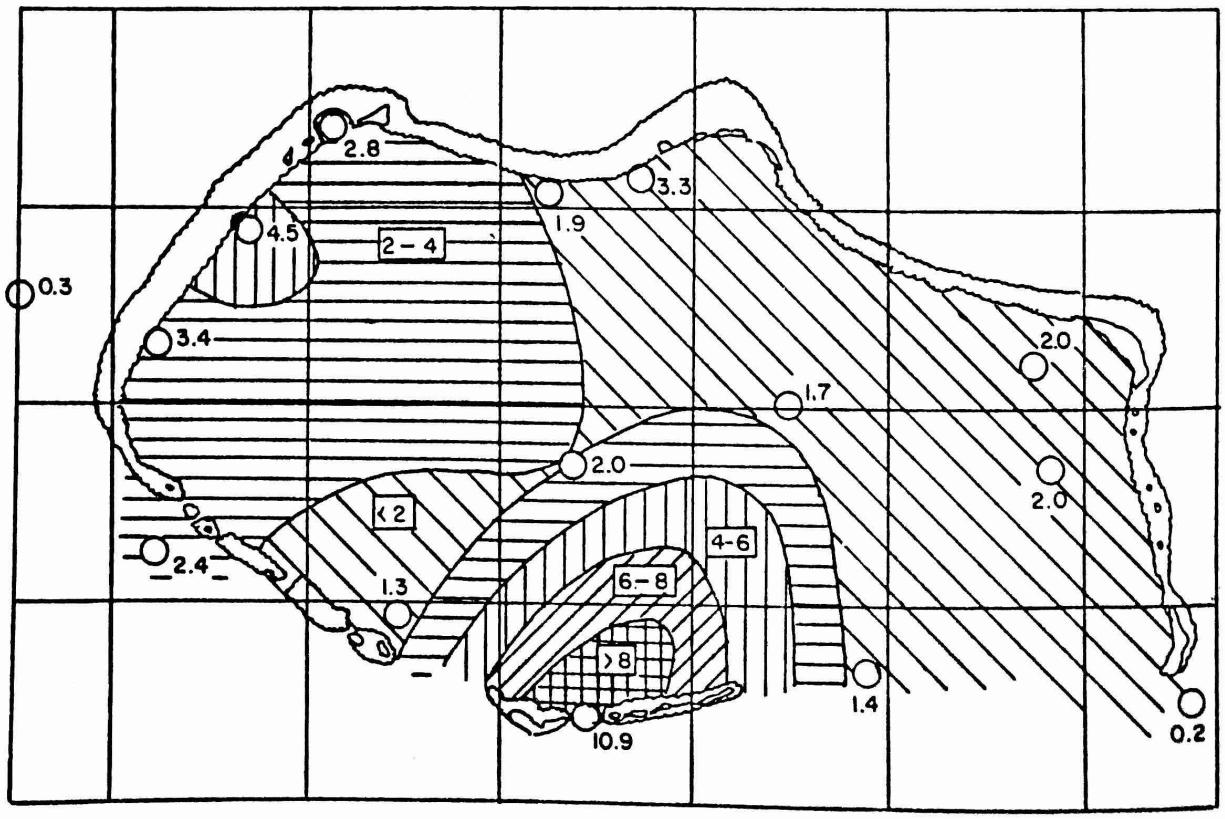


FIG 4. CONTENT OF Pu^{238} IN SURFACE WATER (d/m/1000 L)

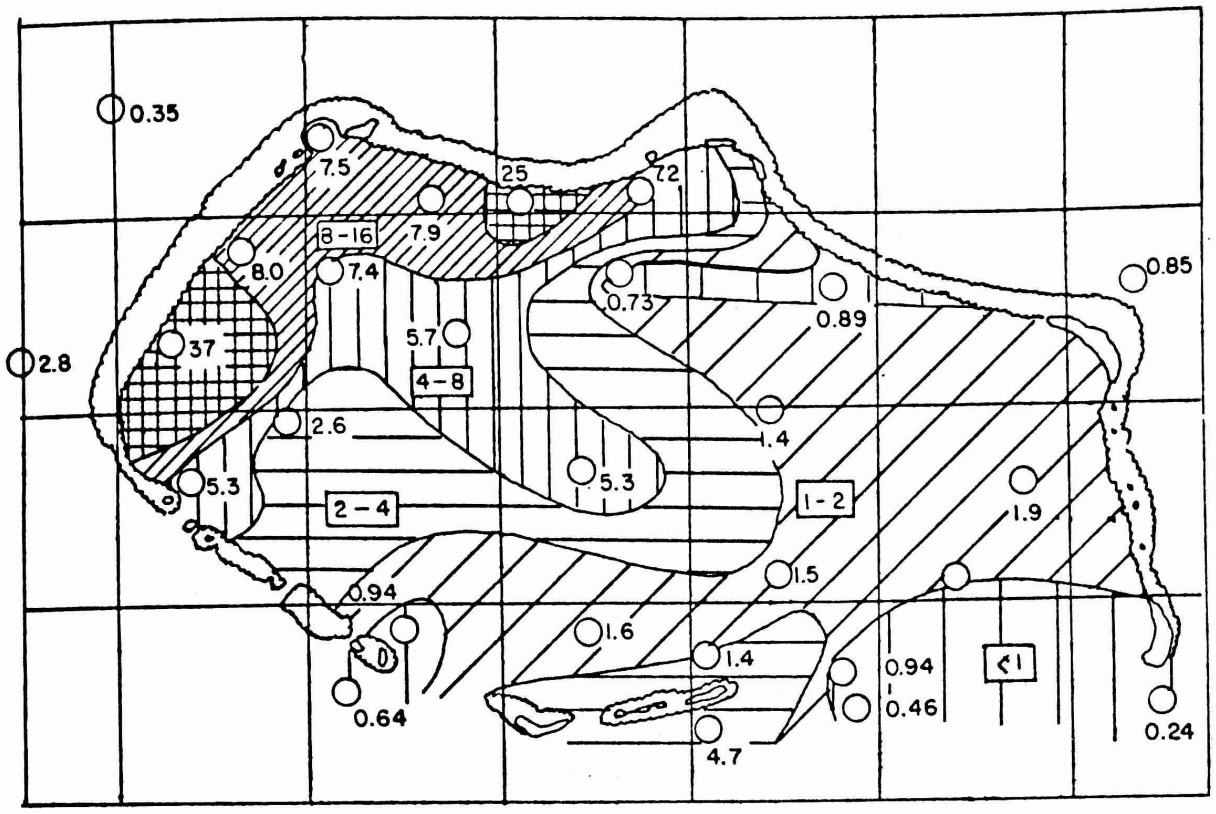


FIG. 5. DISINTEGRATIONS PER MINUTE PER GRAM OF $Pu^{239,240}$ IN LIVE PLANKTON

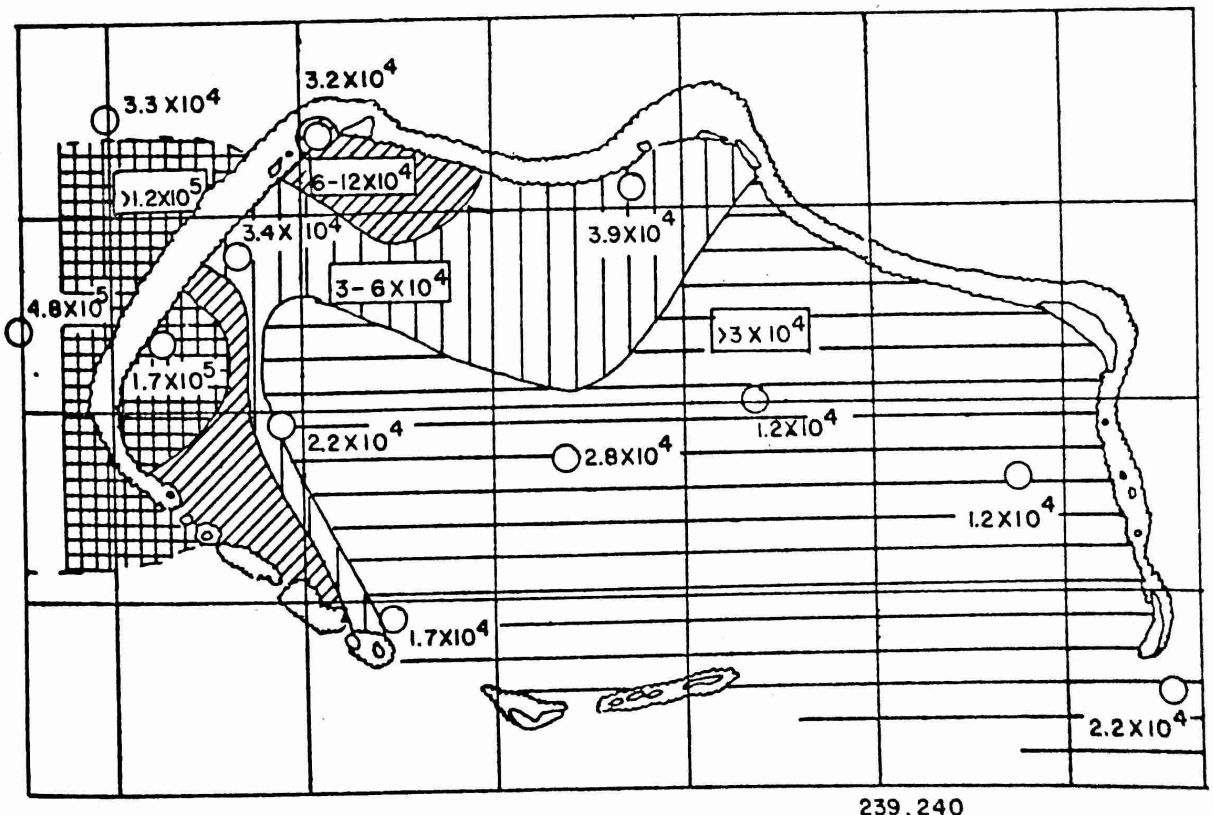
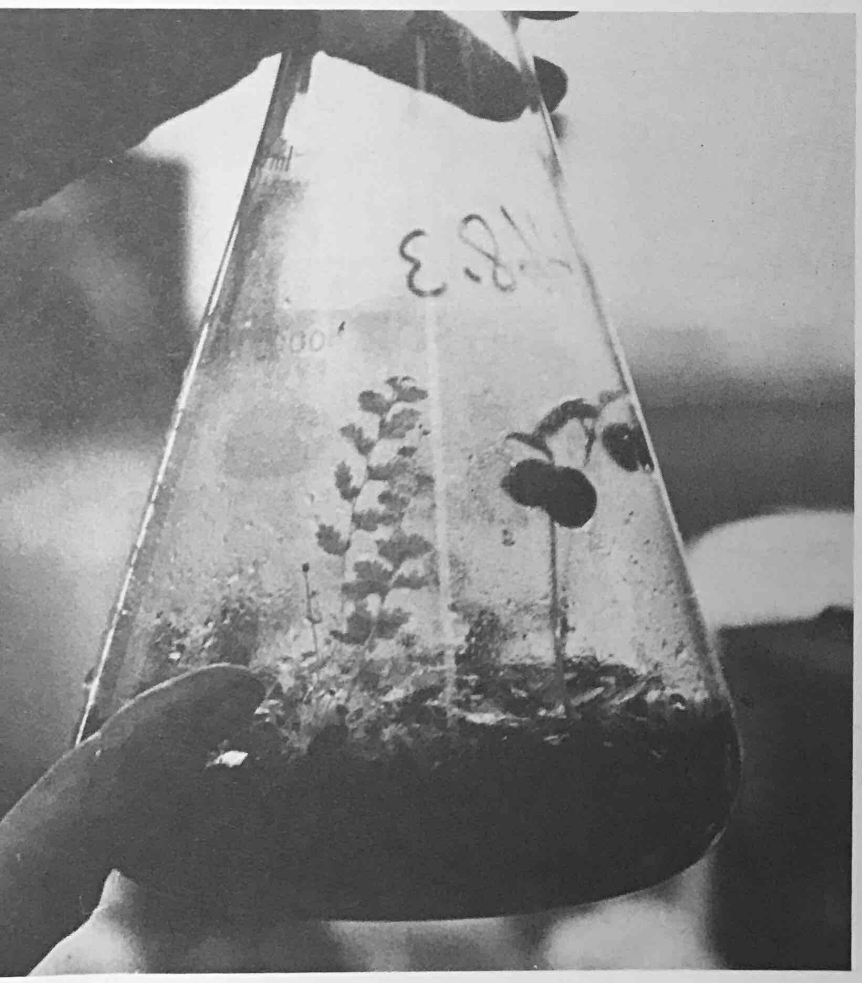


FIG. 6. CONCENTRATION FACTORS IN MIXED PLANKTON FOR $Pu^{239,240}$ BASED ON THE ACTIVITY IN WET PLANKTON AND IN THE WATER FROM THE SAME STATION

The determination of the chemical composition of freshwater streams is part of an overall study to assess the effects of land use patterns on water quality in the Espĭritu Santo Watershed. This research effort is being carried out by Elvira Cuevas and will be submitted as a Masters Thesis to the Department of Biology, University of Puerto Rico, Rio Piedras.



Decomposition of forest leaf litter under laboratory conditions and subsequent extraction of the by-products from the soil has shown that the presence of organic compounds known to have inhibitory effects on plants. Investigations are underway to quantify the amount of inhibitors present under natural conditions and the amounts required to affect the growth of forest species.

Terrestrial Ecology Section

The major activities of the Terrestrial Ecology Program this past year have been centered on the cycling of stable elements in the El Verde Rain Forest. Specifically, efforts were directed toward the completion and reporting of the Rainfall Interception Study, completion of the bi-annual census of plants in the radiation center and completion of ongoing animal ecology studies.

Additional studies were initiated this past year that dealt with mineral cycling. Such studies included the tagging of the giant tree fern, *Cyathea arborea* with P-32 and measurement of spore dispersal; a leaf litter decomposition investigation designed to measure the effect of time of leaf drop, rainfall, temperature and humidity on rate of leaf decomposition; the decomposition of leaves in a freshwater stream by aquatic fungi, study on the chemistry of rainfall, an investigation on the physico-chemical properties of growth inhibitors and an investigation on the extraction efficiency of Cd-109 using the APDC/MIBK method.

Two important departures were made this year which broadened the activities of the Program. The first involves a study on the changes in water quality of fresh water streams with time as affected by altitude and land use. The second was the participation of the Program's personnel in an environmental study for the siting of a nuclear plant on the north coast of Puerto Rico.

TRAINING ACTIVITIES

Biology 380-Special Problems in Biology. UPR Rio Piedras. Dr. Richard G. Clements, Visiting Professor (ad honorem)

1. Elvira Cuevas - Comparison of Structural Characteristics Among *A. cristatelus*, *A. cooki* and *A. monensis.*
2. José Colón - Chemistry of Sediments from Freshwater Streams of the Luquillo National Forest.
3. Fred LaCaro - Leaf Decomposition in a Tropical Forest.

M.S. Thesis Research.

1. Measurement of Spore Dispersal of the Giant Tree Fern, *Cyathea arborea*, using P-32 David Conant, University of New Hampshire - Dr. Richard G. Clements, advisor.
2. Chemical Inputs to the Tropical Rainforest via Rainfall. José A. Colón, Department of Biology, UPR - Dr. Richard G. Clements, advisor.
3. Changes in Water Quality of Freshwater Streams as Influenced by Land Use Patterns. Elvira Cuevas, Department of Biology, UPR - Dr. Richard G. Clements, advisor.

4. Aquatic Hyphomycete Flora of Two Rain Forest Streams in Northeastern Puerto Rico. Stephanie L. Hamilton, Department of Botany, Ohio State University. Dr. Roland Seymour, advisor.
5. The Effect of Moisture, Temperature, Humidity and Time of Leaf Drop on the Rate of Leaf Decomposition. Fred La Caro, Department of Biology, UPR - Dr. Richard G. Clements, advisor.

Ph. D. Thesis Research

1. Regrowth of Plants in the Cesium 137 Irradiated Center. María L. Lebrón, Department of Botany, University of North Carolina - Dr. Frank McCormick, advisor and Dr. Richard G. Clements, PRNC advisor.
2. Contribution of Aquatic Hyphomycetes to Decomposition of Submerged Leaf Litter. David Padgett, Department of Botany, Ohio State University. Dr. Roland Seymour, advisor and Dr. Richard G. Clements, PRNC advisor.

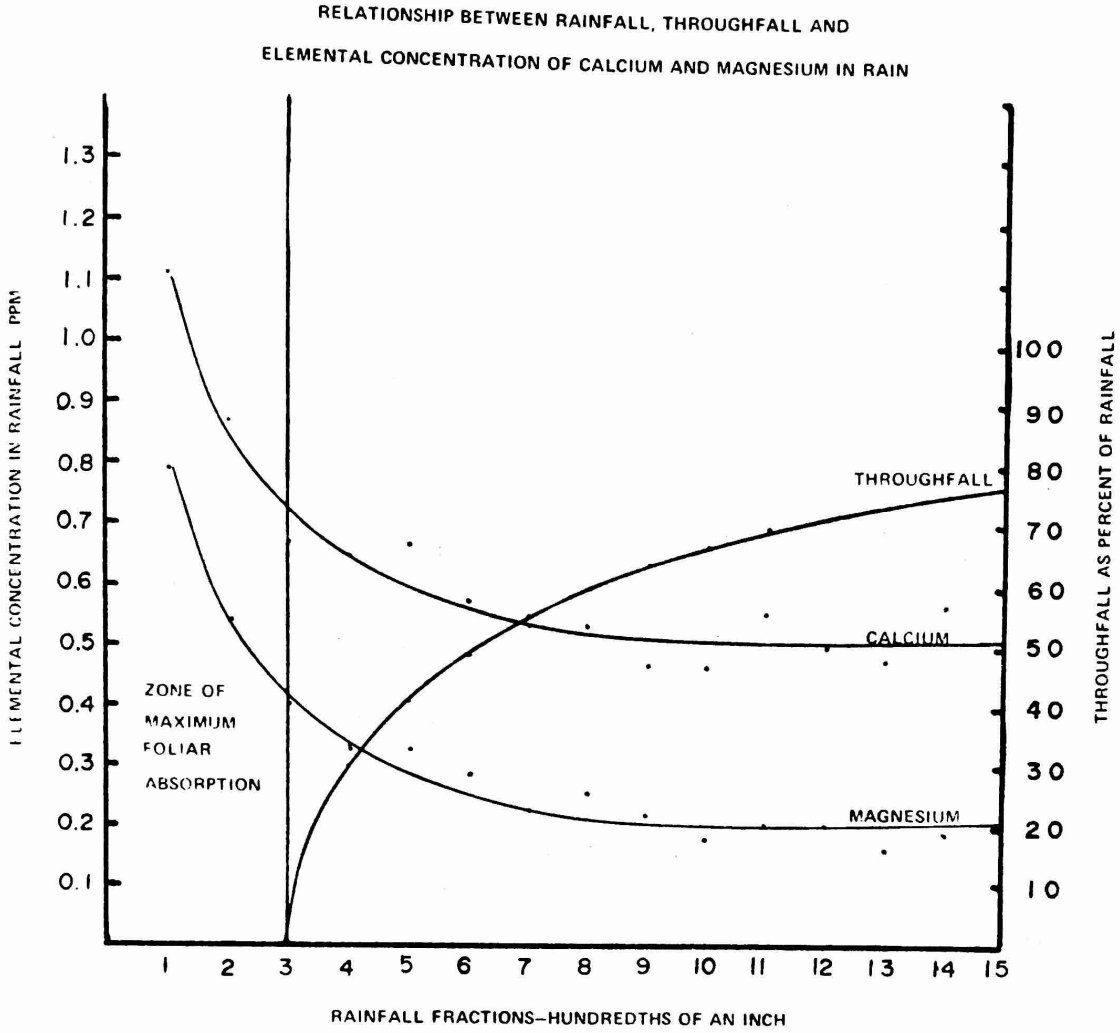
Special Training

1. Dr. Leo J. Newland, Texas Christian University. ORAU Research Participant. Trace Element Chemistry of Water and Sediments in the Espiritu Santo Watershed. With Dr. Richard G. Clements.

RESEARCH ACHIEVEMENTS

Rainfall Interception Study. Results of this investigation have shown that the factors of intensity, duration and overall distribution of storm by storm size must be taken into consideration in determining the fate of isotopes that reach the forest via rainfall. While the relationships between rainfall-throughfall and rainfall-stemflow are best described by a linear equation, neither is a constant percentage of rainfall but varies with storm size. On the average it requires approximately .03 to .05 inches of rainfall, depending upon antecedent conditions, to satisfy the wetting requirements of the vegetation and produce throughfall. Preliminary chemical analyses of rainfall by .01 inch fractions have indicated that the first .04 inches had the highest concentration of Ca, Mg, Na and K. This quantity coincides with the amount of rain required to wet the vegetation and the elements contained therein are available for foliar absorption. These relationships are shown in Figure 1. Frequency distribution of storms by storm class intervals of 0.1 inch showed tha 69% of the storms were 0.1 inch or less. While the small storm contributes very little to the total annual rainfall, the impact of small storms on the chemical inputs to this tropical ecosystem is major.

FIGURE 1



Census of Vegetation in the Radiation Center. This is a continuing effort to measure and document the recovery and succession of plants following gamma radiation. In October, the sixth complete census of the 672 square meter plots was completed. Since 1969, the census has been made on a bi-annual basis. All plants are identified, measurements are made on heights, diameter and number of individuals. The 1971 and 1973 census data have been transferred to IBM cards for data reduction and analyses. Attempts are being made to review the censuses of earlier years and transfer this information to IBM cards. Upon completion of the 1975 census, 10 years following irradiation, a complete review and analysis of recovery and succession will be done. Because this area is unique, a decision will be made at that time whether to terminate or continue following the recovery. Tentative plans are for continuation, but at 5 year intervals:

Animal Ecology. Research has been centered on the population dynamics of *Eleutherodactylus coqui*, representing the frog species, and of *Anolis cristatellus*, representing the lizards. Also as part of our understanding of the vertebrates, island-wide mapping on the distribution of *Eleutherodactylus* and *Anolis* species was started. During the course of the mapping of species distribution, a new species of frog was discovered and it is the only live-bearing frog known from the western hemisphere.

Eleutherodactylus coqui was chosen for the population dynamics study because of the discovery that this species would take up residence and breed in small shelters made from bamboo internodes. The use of these shelters has permitted close observation on the behavior and reproduction of this species which was never before possible. Identification of shelter occupants through tow-clipping has yielded information on the movements and reproduction in this frog along with an insight into the population levels and size of the reproductive pool.

Preliminary results suggest an adult population density between 500-600 individuals per acre which maintains a fairly constant reproductive population of approximately 200 individuals. Due to the territorial behavior of the species, the mark recapture techniques cannot be utilized for population estimates. This study will be concluded in February 1974.

Measurement of Spore Dispersal of the Giant Tree Fern, *Cyathea arborea*, using P-32. This study was initiated in 1972 as part of an overall investigation on the ecology of *Cyathea arborea* by the investigator for a Master of Science degree. In 1972, studies were conducted on aspects of spore dispersal, gametophyte growth and maturation and sphorophyte growth. Preliminary work was done on a technique for tagging the spores with P-32. As a result on this work, a mature tree fern was tagged during June 1973, by drilling a hole in the trunk just below the crown and injecting P-32. Following the tagging of the area of sporangial maturation, spore dispersal and distribution were measured from near the plant out to 100 ft. with a special sampler developed by the investigator. Spores were collected on filter paper and counted by liquid scintillation. Work was completed in September 1973, and will be reported in early 1974.

The Effect of Moisture, Temperature, Humidity, and Time of Leaf Drop on the Rate of Leaf Decomposition. Decomposition of leaf litter is an important aspect in the cycling of elements within the forest systems. The procedure most commonly used is the enclosure of a known amount of leaf litter in nylon mesh bags, placement in the field, and subsequent re-weighing over time to determine decomposition. The method has the disadvantage in that the leaves do not decompose in a natural environment.

To circumvent this problem, a multi-faceted study was initiated this past year to study the decomposition of individual leaves over time as influenced by changes in temperature, humidity, and rainfall distribution. Starting last September sets of 150 individual leaves of the species *Dacryodes excelsa* were placed on the forest floor at two week intervals. Prior to placement the air-dried leaves were weighed to 4 decimal places and assigned an identification number which was attached to a monofilament line tied to the petiole of each leaf.

Every two weeks 10 leaves are havested at random from each set, and returned to the laboratory for determination of the oven dry weight. The difference between the initial weight, corrected to an oven dry basis, and the final oven dry weight is used as a measure of the decomposition process. Temperature and humidity are recorded at ground level with a recording hygrometer and rainfall is measured at the El Verde Station.

Preliminary results show a sharp weight loss in the range of 15 to 20 percent in the

initial two week period of each set. This is followed by a much reduced, but constant, disappearance with time. Some of the first sets of leaves are showing trends of leveling off in weight loss as the dry season is approached. If this is the case, decompositional activity may not begin again until the on-set of rains in April-May 1974. Final data collection is scheduled for September 1974.

The Aquatic Hyphomycete Flora of the Rain Forest. The first work on the aquatic fungi was initiated by Dr. Roland Seymour from Ohio State University in 1970. In early 1973, Stephanie Hamilton of Ohio State conducted an investigation on the "Aquatic Hyphomycete Flora of Two Rain Forest Streams" as her thesis research. This work was completed in March and the thesis submitted and approved. The following is the summary:

"Freshwater hyphomycetes from the Quebrada Jiménez and Sonadora were collected and identified. Foam spora in relation to daily rainfall, species composition in abundance with other tropical areas, frequency in distribution, and percent relative density were discussed. A total of 39 species representing 29 genera and 12 unidentified forms were recorded."

A second study on the Hyphomycetes was initiated this past year by David Padgett, doctorate candidate from Ohio State University. The title of the dissertation is "The Contribution of Aquatic Hyphomycetes to Decomposition of Submerged Leaf Litter". The objectives of the study are to determine the contribution of this aquatic fungal group to the brakdown of submerged leaves of five (5) predominant dicotyledonous species. Leaf discs will be submerged and random samples removed over time to determine changes in dry weight, caloric and protein content and intensity of sporulation of hyphomycetes infesting the leaf discs. Data will be collected through August 1974.

Investigations on the Physio-Chemical Properties of Growth Inhibitors. Preliminary investigations have begun on the possible role that growth regulators, produced during the decomposition of leaf litter, might play in the population dynamics of a forest.

Ground leaf material from each of 10 of the dominating species of the rain forest was added to 200 grams of forest soil and placed in 1 liter flasks, moistened, and allowed to decompose over a six month period. The soil-leaf mixture was extracted with warm ethanol and methanol solvents. After concentration, the residues of the extractions were taken up in small quantities of ether. The presence of aryl hydroxy substituted cinnamic and benzoic acids in these extracts was established using thin-layer chromatographic techniques. Determination of the relative quantities of these known growth regulators and their effect on rain forest species is pending.

In conjunction with this work, two theoretical investigations have been completed and submitted for publication. The ground state electronic properties of various growth regulators were evaluated by computer. The evaluation employed the semi-empirical method using complete neglect of differential overlap (CNDO/2) and closely related method using "intermediate" neglect of differential overlap (INDO).

In the first study, self-consistent field molecular orbital (SCF-MO) calculations were carried out using CNDO/2 for a group of known plant auxins. These were indole-3-acetic

acid, (IAA) 1-naphthalene acetic acid (NAA), phenoxyacetic acid, 4-chlorophenoxyacetic acid, 2,4 dichlorophenoxyacetic acid (2,4-D) and 2,6 dichlorophenoxyacetic acid. Total energies, dipole moments, energies of the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO), total electron densities, pi-orbital densities and orbital coefficients of the HOMO and LUMO at individual atoms were derived for the lowest energy configuration of each molecule. Upon comparison of published work on auxin activity with this analysis, the data suggest that auxin activity is more closely associated with the electron donating ability of the ortho position of the phenoxyacetic acids.

In a second study, it was possible to use SCF-MO procedures to calculate a priori single ionization potentials. In the absence of experimental data these potentials are approximations of the oxidation potential of the molecules. They can be used to compare ease of oxidation for members of a homologous series or for a group of compounds having similar structures. Molecules evaluated were: indole-3-acetic acid (IAA), α-naphthaleneacetic acid (NAA), phenoxyacetic acid (POA), 4-chlorophenoxyacetic acid (4CL-POA), 2,4 dichlorophenoxyacetic acid (2,4-D), 2,6 dichlorophenoxyacetic acid (2,6-D), and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). The order of stability of these molecules to conditions favoring environmental oxidation was found to be:

$$2,4,5\text{-T} > \text{4CL-POA} > \text{POA};2,4\text{-D} > 2,6\text{-D} > \text{IAA} > \text{NAA}$$

Determination of Extraction Efficiency of ^{109}Cd (II) Using the APDC/MIBK Method. The extraction efficiency of cadmium from aqueous samples using the APDC/MIBK method was determined using ^{109}Cd as a tracer. Selected factors such as pH, initial concentration of cadmium, and APDC concentration were evaluated and the following results obtained: extraction efficiency of cadmium approached 100% in the pH range 2.5 to 9. Below 2.5 extraction efficiency reduced rapidly to 0% at pH 1. The pH experiments were conducted at a concentration level exhibited only by the radioisotope (162 picograms/liter). Secondly, the effect of initial cadmium concentration on the extraction efficiency was determined in the range of 1 to 500μg/1 (ppb). Extraction efficiencies were carried out at a pH of 2.8 using 2 ml of a 2% APDC/MIBK solution per liter. Efficiencies were in excess of 99.5% at 1 and 10ppb. At 50 ppb, the efficiency had dropped to 85% and at 500 ppb, 6.5%. Thirdly, effect of APDC concentration was investigated and shown to have a marked influence on the extraction of ^{109}Cd. At 1 ppb, use of a 2% APDC solution effected an extraction of 99.5%; a 0.2% APDC solution extracted 43%; while 0.02 and 0.003% APDC solutions resulted in extractions of 1.4 and 0.2%, respectively.

These data clearly point out the need for standardization of the technique for extraction of cadmium from aqueous systems. The effect of pH was negligible for most common operating ranges, but initial cadmium concentration is extremely important. Any initial concentration in excess of 10 ppb results in depressed recoveries. Recoveries of less than one-half of the original can be expected for initial concentrations which exceed 100 ppb. The chelated concentration affects the extraction efficiency, but the effect varies with a third parameter concentration.

Changes in Water Quality of Freshwater Streams as Influenced by Land Use Patterns. This study began in October 1973, with the following objectives:

1. To determine the effect of land use patterns on the water quality of the rivers in the Espíritu Santo Watershed.
2. To determine the gradation of biological parameters in streams believed to be in an oligotrophic state to areas where eutrophication may be increasing.
3. To determine the effects of flash floods on the biological parameters measured.

Bi-monthly collections and measurements began in October 1973, for the parameters of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), CO_2, pH, Temperature, Turbidity, Chlorides, Hardness, and Water Chemistry. The 10 stations or sampling sites were chosen to represent areas under forest areas in pastures, mixed farming, and human impact. The altitudinal gradient ranges from approximately 40 ft. above mean sea level to over 1,600 ft.

The river, tributary system and station locations are shown in Fig. 2. Preliminary results are summarized in Table 1. The trend is a general increase in the value of all parameters measured as one moves from the higher to lower elevations with the exception of DO which decreases slightly. Free carbon dioxide and COD values are normal for natural surface waters as are the pH values which range between 6.5 and 7.5. BOD values range from very low to zero and are supported by zero productivity data at all stations. Plankton sampling to date indicates no plankton present in the streams.

This study will be continued through the dry season and is scheduled to terminate in April 1974.

Table 1

Summary of Water Quality Parameters for the Espiritu Santo Watershed

October to December, 1973

Vegetative Cover	Temp. °C	DO mg/l	CO_2 mg/l	Salinity mg/l	BOD mg/l	COD mg/l
Forest	20.4	8.5	2.1	26.2	0.17	6.7
Grassland	22.5	8.6	2.8	28.8	0.27	4.9
Upper Estuary	24.3	8.2	3.8	860.0	0.48	40.0

Environmental Study for Siting of a Nuclear Plant. This year the Puerto Rico Nuclear Center was contracted by the Puerto Rico Water Resources Authority to conduct an environmental study for the siting of a Nuclear Plant on the Island's north coast. The Terrestrial Ecology Program under the Division of Radioecology was assigned the responsibility for that phase of the study pertaining to terrestrial communities. In addition the Program is providing radiological studies for the area. Five staff members of the Program

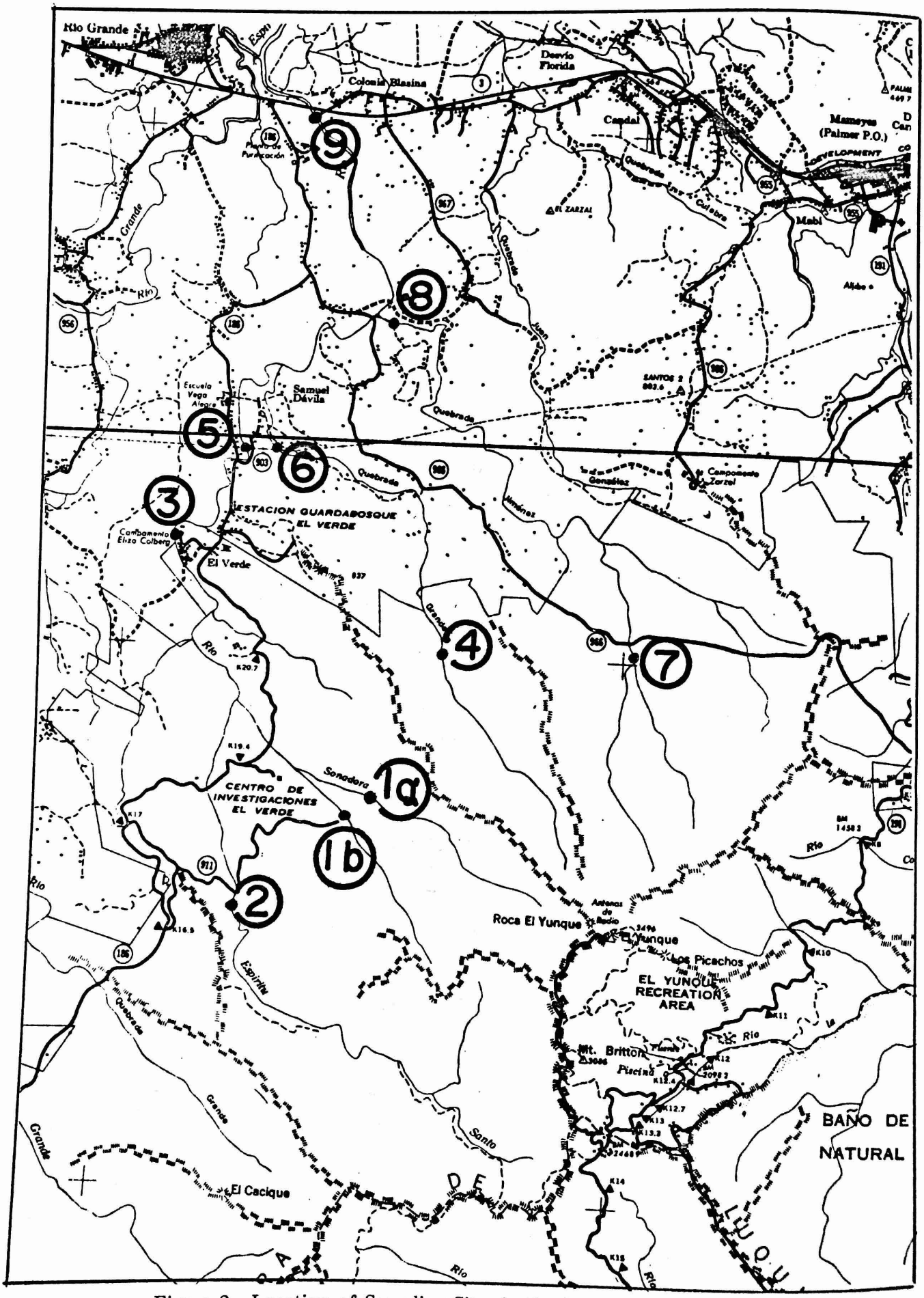
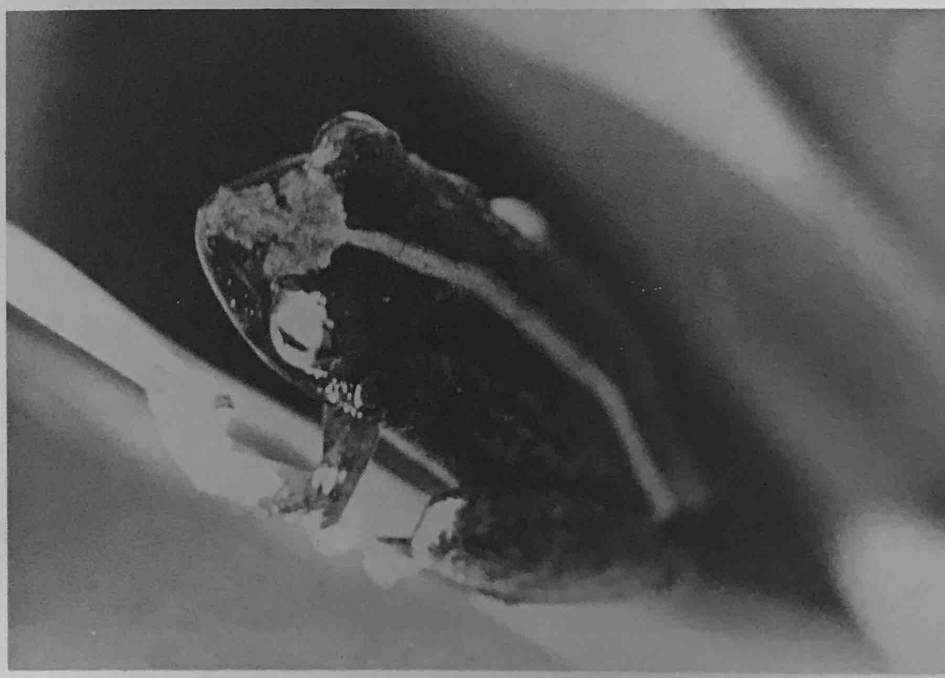


Figure 2. Location of Sampling Sites in the Espiritu Santo Watershed

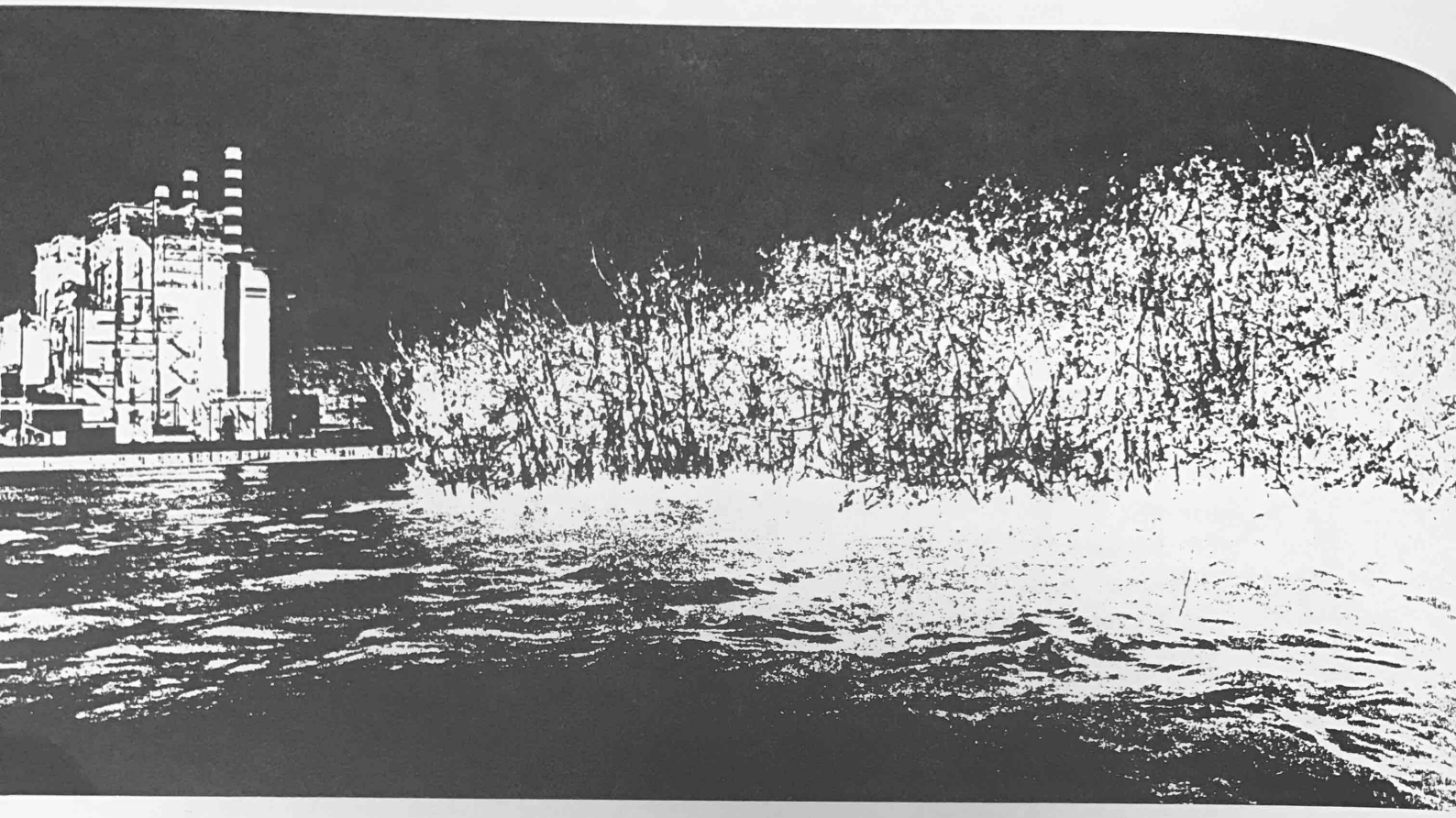
are participating part-time on these terrestrial studies. The funding is provided by PRWRA at the level of $81,000 for the one year study which is scheduled for completion in September 1974.

Cooperative Work with Other Agencies:

1. U. S. Forest Service. Ad Hoc Committee on Caribbean National Forest. Dr. Richard G. Clements.
2. U.S. Forest Service. Ad Hoc Committee on Baño de Oro, a Natural Research Area, Drs. Richard G. Clements and George E. Drewry.
3. Environmental Quality Board, Commonwealth of Puerto Rico. Special Advisory Committee to the Executive Director Dr. Richard G. Clements.
4. Water Resources Authority, Commonwealth of Puerto Rico. Site Selection Committee. Dr. Richard G. Clements.
5. University of Puerto Rico, President's Advisory Committee on the Environment. Dr. Richard G. Clements.
6. Environmental Quality Board, Commonwealth of Puerto Rico. Dr. Richard G. Clements, Scientific Advisor for Research Program on the Microclimate and the Environment (MATE).
7. U.S. Soil Conservation Service, USDA. Committee on Rare and Endangered Plant Species. Dr. Richard G. Clements.
8. University of Puerto Rico, Dept. of Chemistry, Theoretical Interpretation of Experiments in Physical Organic Chemistry; Training of Graduate Students in Computer Simulation, Dr. Arthur McB. Block.
9. Economic Development Laboratory, Commonwealth of Puerto Rico. Interpretation of Mass Spectral Data, Dr. Arthur McB. Block.



The discovery that *Eleutherodactylus coqui* would take up residence and breed in small shelters led to its selection for an in depth study on population dynamics. This unique characteristic of *E. coqui* has permitted close observation on the behavior and reproduction of this species. The size of the adult varies with habitat location, with the largest individuals inhabiting the forests of the mountainous regions.



Thermal outfall and mangroves at the 39°C isotherm in Guayanilla Bay. (Negative Rendition)

Dr. E. D. Wood pilots a Cessna aircraft used in infra red scanning studies of the thermal plumes.

Environmental Impact Studies Section

The Environmental Impact Studies Section will be published in a separate volume with the exception of the following report on the Guayanilla Bay Project.

Guayanilla Bay Project

Guayanilla Bay is a thermally altered bay on the south coast of Puerto Rico having some areas with temperatures in excess of 40°C. It has served as a natural laboratory for studying thermal effects on tropical ecosystems. The main studies in this program have included thermal tolerance of species and communities and the use of species diversity indices as indicators of stress. Three publications which characterize the work have resulted from these studies.

Kolehmainen, Morgan and Castro considered the mangrove root communities in the thermally altered area of the bay. Table 1 illustrates species composition of organisms living on mangrove roots on 9 October 1971. The reduction in species from station 2 to station 7 seems to reflect the increase in temperature over the same distance. This pattern holds for all sampling dates and the stations 5, 6 and 7 are significantly different from all other stations at the 95 per cent confidence level.

Table 1
Mangrove Root Comunities

Station	Control	1	2	3	4	5	6	7
Temperature °C	30.0	31.2	31.8	33.2	34.5	35.5	36.7	37.1
Spp. Algae	6	3	5	8	7	4	5	5
Spp. Invertebrates	90	45	69	67	58	25	21	10
Total No. Spp.	96	48	74	75	65	29	26	15

The sudden change in numbers between stations 4 and 5 also illustrates that a large number of organisms in Guayanilla Bay seem to have upper thermal limits lying in the 34-35°C area. The thermally most tolerant species are bluegreen algae, an encrusting sponge *(Halisarca sp.)*, a calcareous tube dwelling poluchaete *(Pomatostegus stellatus)*, the tree oyster *(Isognomon alatus)*, a periwinkle *(Littorina angulifera)*, two barnacles *(Balanus spp.)* and two crabs *(Aratus pisonii* and *Pachygrapsus transversus)*. Coelenterates, echinoderms and ascidians are the most sensitive species and may prove to be useful indicators of thermal stress.

Seiglie has found several effects of thermal addition on the microbenthos of Guayanilla Bay. Among these are a shift of nematode to foraminiferan ratio postulated to be due to lower tolerance to stress of the nematodes. A second effect is a shift in foraminiferal assemblages to an Ammonia-Quinqueloculina-Ammolaculities assemblage. The thirds is a reduction in species Diversity.

Martin and Patus have noted a similar reduction in species diversity of fishes. While Seiglie found Shannon values of under 1.17 for the thermally polluted area, Martin and Patus found their lowest value to be 3.66. This difference is due to the greater number of fish species available for capture as compared to the species in the microbenthos. The values found by Martin and Patus are of interest when compared to the values reported in the literature concerning species diversity and stress.

Several ecologists and biometricians believe that that species diversity can be an indicator of stress on aquatic systems. Values below 1.0 represent highly polluted areas, values below 2.0 indicate stress and values above 2.0 represent relatively unstressed ecosystems. This contention is backed up by evidence from Texas bays and North Carolina estuaries. Values found in Guayanilla range from 3.66 in the hottest areas to 4.86 in the main part of the bay (See Table 2). It is obvious that the temperate values have no application to tropical waters. This is not surprising when one considers how well the latitudinal shift in diversity is documented elsewhere. Species diversity indices may prove to be useful indicators of stress but normative data from Puerto Rico and The Caribbean should be gathered before limits are stated. It would seem though that healthy aquatic ecosystems here may normally have values above 4.0.

Table 2
Shannon Species Diversity Values (bits/individual)

Jobos	H'	Guayanilla	H'
Reef and Cay	5.309	Reef	4.788
*Inner Bay	3.852	Inner Bay	4.863
Central Bay	5.122	*Thermal Cove	3.661
Ship Channel	4.813		

*The most stressed part of each respective bay.

TROPICAL AGRO-SCIENCES

The Tropical Agro-Sciences Division is engaged in both training and research. Training is conducted in two forms: 1) formal teaching and thesis supervision provided for the University of Puerto Rico graduate students, and 2) special training in selected disciplines provided for the post-graduates and visiting scientists. Research activity is centered on the problems of major importance in tropical agriculture, in particular on food production and food quality improvement. Nuclear science and its application are emphasized in teaching, training and research.

EDUCATIONAL AND TRAINING ACTIVITIES

To fulfill the educational and training goal, staff members teach graduate courses at the University of Puerto Rico. The staff also supervises graduate student thesis research required for partial fulfillment of the M.S. degree in Agriculture, Biology or Chemistry at the University. To meet special needs of the trainees at the post-graduate levels, the Division provides guidance and instruction in individualized research and training.

Instruction. During 1973, Division staff, holding *ad honorem* or joint appointments at the various science departments of the University, taught the following courses:

Agro	552	Nuclear Techniques in Agriculture — Dr. F. K. S. Koo and Dr. S. N. Deshpande
Hort	426	Special Problems in Horticulture — Mr. J. Cuevas-Ruiz
"	605	Nuclear Techniques in Agricultural Research — Mr. J. Cuevas-Ruiz and Dr. S. N. Deshpande
Biol	614	Nuclear Techniques in Biological Research — Dr. J. A. Ferrer-Monge and Dr. S. N. Deshpande
"	618	Cytogenetics — Dr. J. A. Ferrer-Monge
"	699	Research (Thesis) — Dr. J. A. Ferrer-Monge and Dr. F. K. S. Koo
Chem	566	Food Chemistry — Dr. S. N. Deshpande
"	571	Nuclear Chemistry — Dr. S. N. Deshpande
"	601	Radiochemistry — Dr. S. N. Deshpande
"	699	Chemistry Research (Thesis) — Dr. S. N. Deshpande
CiFi	648	Photophysiology and Crop Productivity — Dr. A. Cedeño-Maldonado

Graduate Research. During 1973, six graduate students were active in thesis research under the supervision of the Division staff members. Four students completed their investigations. Research topics reflect the broad interests of the Division:

1. Mutagenic effect of N-methyl-N'-nitro-N-nitrosoguanidine on histidine operon of

Escherichia coli strain C (completed)— Carmen Baerga (Puerto Rico) under Dr. F.K.S. Koo.

2. Electrophoretic analyses of several seed protein fractions in *Glycine max* (L) Merrill (completed) — Ileana Rivera (Puerto Rico) under Dr. J. A. Ferrer-Monge.
3. Effect of low doses of gamma radiation on higher plants (completed) — Eblis Alvarez (Colombia) under Dr. J. A. Ferrer-Monge
4. Characterization of some flavouring compounds of Puerto Rican coffee by means of gas liquid chromatography (completed) — Angel A. Aguilar (Ecuador) under Dr. S. N. Deshpande.
5. Effect of ionizing radiation on the Kreb's cycle and the kinetics of the activity of the pectic enzymes in pineapple — José M. Ortiz (Guatemala) under Dr. S. N. Deshpande.
6. Microanalysis of sulfur-containing amino acids by isotopic dilutions of ^{14}C-labelled silyl derivatives — María Arzola (Puerto Rico) under Dr. S. N. Deshpande.

Special Training. The Division has been active in technical and scientific training programs. Mr. Augusto Tulmann Neto, Geneticist from the Centro de Energía Nuclear na Agricultura in Brazil received nine months of training in mutation breeding and radiobiology under the sponsorship of the International Atomic Energy Agency.

Dr. Nestor A. Cardona, Professor of Chemistry at the Chemistry Department, UPR, was engaged in studies of the effect of ionizing radiation on the structure and activity of lipoxidase in soybeans as a Summer Research Participant under the auspices of the Oak Ridge Associated Universities.

RESEARCH ACTIVITIES

The Division conducts basic research, particularly concerning improvement of important tropical food crops. The research activities may be presented under the following categories.

Crop Improvement. The day-neutral selections from the gamma-irradiated soybean varieties, Hill and Lee, were tested again in the field trials last summer at Isabela. The selections late in flowering and/or maturity generally yielded higher than the early ones. Selections from the high protein crosses were also included in the test. A few selections appear highly promising as they are high in yield and/or protein content. Also some of the selections show better heat tolerance in the laboratory test.

Additional analyses for vitamins A and C content in plantains were made with the new clonal collections of the Harton variety. Significant differences in vitamin contents of the fruits were observed among collections at both green and ripe stages (Table 1). There was also appreciable difference in pulp :peel ratio among the collections. The promising clones with respect to the nutritional value as identified by biochemical analyses in the past two years are being propagated in a newly established nursery.

As a preliminary step for sweet potato improvement by mutation breeding, varietal response to gamma radiation at doses of 500-3,500 rads were investigated to determine

the optimum dose for treating the stem cuttings in three locally-grown varieties, Gem, Blanquita and Cobre. Varietal differences were found in both the control and irradiated materials, with respect to the number of cuttings with buds that survived and sprouted. Among the controls, Gem variety had the highest percentage of surviving cuttings. The irradiated Blanquita variety, however, had a higher percentage of surviving cuttings than the other two varieties at the highest dose (3,500 rads), although the same variety appeared

Table 1
Exemplified data of determination of ascorbic acid and total carotenoids content in fruits and pulp: peel ratio in clonal collections of plantain variety Harton

Clone	Maturity Stage	Ascorbic Acid mg/100 g pulp	Carotenoids ug/g pulp	Pulp: Peel Ratio
L-2	Green	19.92	248	1.91
	Ripe	15.40	236	1.36
L-3	Green	18.17	328	2.22
	Ripe	24.42	285	2.76
N-1	Green	22.56	313	1.75
	Ripe	24.19	255	2.98
N-3	Green	17.18	244	1.67
	Ripe	20.31	195	1.38
Q-3	Green	17.66	250	1.67
	Ripe	18.66	293	2.62

to be inferior in this respect at the intermediate dose range. It is apparent that if a 50-percent stem-cutting survival is desired in the mutation induction work, the optimum dose would be approximately 2,000 rads, as the doses observed for the 50-percent stem-cutting survival for the three varieties ranged from approximately 1,750 to 2,500 rads. If a higher survival index is desired, say about 75 percent, then the appropriate dose would be about 1,500 rads. These suggested optimum doses (1,500-2,000 rads) might be considered the most appropriate for sweet potato mutation work in general, although the recommendation is based on stem-cutting survival only and not on mutation induction efficacy. Among the three varieties, the Blanquita control had the most vigorous growth based on the measurement of vine length 6 weeks after planting the cuttings. The radiation effect on growth also was evident as the shoots grew less with increasing doses. Cobre variety was affected the least by radiation insofar as growth was concerned, whereas Gem variety was the most affected. Considering the results as to the proper dose range for a 25- to a 50-percent growth reduction in the three varieties, again it appears reasonable to suggest that approximately 1,500 to 2,000 rads be used as an adequate dose range for sweet potato mutation work.

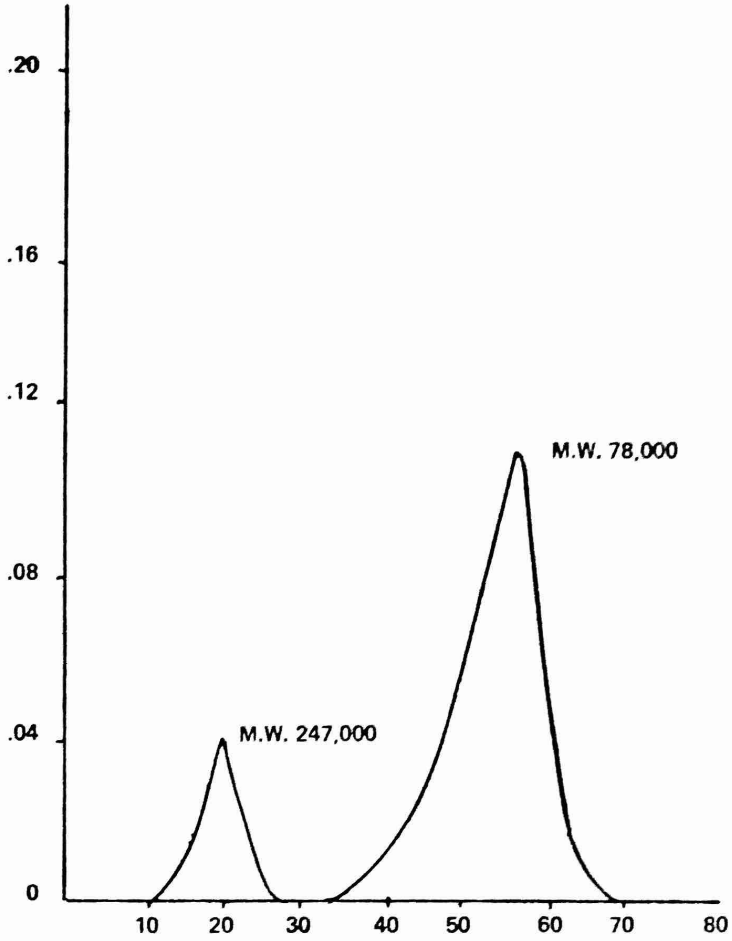
Food Science. In order to study the effect of ionizing radiation and the possible interaction of roasting temperatures, two types of coffee beans, *Coffea canephora* L. var. Robusta and *C. arabica* L. var. Bourbon were subjected to different radiation doses and roasting temperatures. The doses of radiation were 0.5, 1 and 12 krads, and the roasting temperatures used were 200°C and 250°C. The controls consisted of unirradiated samples and unroasted green beans. As predicted, depolymerization and other forms of degradation due to irradiation did result in liberation of fructose, galactose, glucose and sucrose from the corresponding glucosans. Soluble nitrogenous compounds were also released by radiation and as theorized there was some indication of the Maillard type condensation products being formed under the influence of radiation. These non-volatile compounds were undoubtedly responsible for the aroma comparing the unirradiated samples or extracts of green coffee not subjected to roasting. Caffeic acid appeared to resist the roasting temperatures while chlorogenic acid underwent pyrolysis and decomposition at the temperatures used in roasting of coffee beans. The concentration of chlorogenic acid was always lower than that of caffeic acid.

Over the past years it has been observed that there is a consistent increase in the activity of pectin methylesterase over a period of time in post irradiation storage of fruits. Presumably this could be due to liberation of the enzyme from cellular degradation, and then by structural changes caused in the configuration of the enzyme due to the joint effect of metabolic activity in storage and radiolysis. To study these effects, pineapple fruits of Spanish Red variety were subjected to gamma irradiation at 40 krad and 80 krad doses. Unirradiated fruits served as controls. These fruits, stored at 70°F, were analyzed for the pectic content, enzyme concentration, and the activity of pectin methylesterase at 0, 4, 8, 16, and 20 day intervals. The most interesting results of these studies came from molecular sieve chromatography. It was observed that pectin methylesterase exists in at least two fractions with molecular weights of 247,000 and 78,000, respectively. There seemed to be no influence of the irradiation treatment on the molecular weight in that, in both the controls and the irradiated samples, the peak indicating the high molecular weight fraction remained the same. This higher molecular weight fraction did vanish in storage (Figures 1 and 2) but this was a result of the metabolic activity, since this fraction disappeared in both the control and the irradiated samples essentially in the same manner.

Studies of gamma radiation preservation of yam variety Florido continued with an additional intermediate dose (7.5 krads) to determine the optimum dose below 10-krad level to reduce the wight loss in tubers during post-irradiation storage. The non-irradiated control had 100% sprouting at 160 days in storage, but the irradiated series had 45, 9 and 3% sprouting for 5, 7.5 and 10 krads, respectively, at 200 days in storage. The tubers irradiated at 5 and 7.5 krads had little or no change in flavor whereas the 10-krad-treated one tasted sweet. This investigation was conducted in cooperation with the Agricultural Experiment Station, UPR.

Protein Content of Seed Legumes. A comparative study was made of the protein content in soybean variety Hill and bean variety Jamapa. As for the whole seed, Hill had 41.2% protein (on sample dry weight basis) as against 26.3% for Jamapa. The soybean seed coat and cotyledons contained 9.5% and 43.9% protein, respectively, about 53% and 66% more protein than

Figure 1. Fractionation of pectin methylesterase from irradiated fruits with sephadex G-100, cross-linked dextran at 0 day in storage.



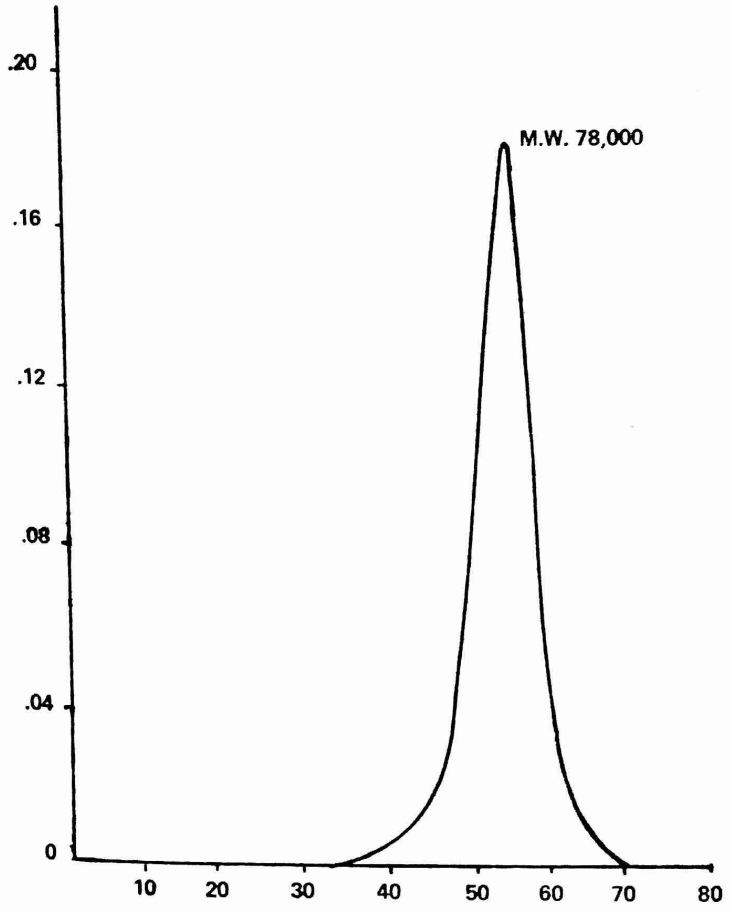


Figure 2. Fractionation of pectin methylesterase from irradiated fruits with sephadex G-100 cross-linked dextran at 12 days in storage.

the bean seed coat and cotyledons. However, the embryo protein contents for both legumes were essentially the same (39.9% for soybean vs. 41.0% for bean). The major portion of the protein was found in cotyledons. Soybean cotyledons contained 95.5% of the total seed protein as against 96.4% for the bean.

The seed protein content was compared in the pods harvested from the lower, middle and upper part of the bean plants of the varieties, Carioca and Jamapa. It was found that the pod position had no influence on the seed protein content although the seeds in the lower and middle pods were significantly heavier than those from the upper pods. However, the effect of seed size on protein content became evident when the two varieties were compared. Jamapa with lower seed weight was found to have significantly higher protein content than the large-seeded Carioca. The finding that the protein content of the seed is independent of its position on the plant suggests that seeds from the whole plant can be bulked for reliable protein determination.

Genetics and Radiobiology. Following the treatment of *Escherichia coli* strain C with N-methyl-N'-nitro-N-nitrosoguanidine, 17 histidine-requiring mutants were obtained in a total of 1859 isolates which were originally made from the treated material plated on the membrane filters. By means of complementation test, two, eight, three and four mutations were found to involve genes G, D, B and F, respectively, in the histidine operon. Based on the reversion test using 2-aminopurine, 14 mutants were found to be transition mutants and three were transversions. Of 17 *his* mutants, 13 produced spontaneous revertants. By testing these revertants using bacteriophage T4 ochre and amber, all 13 *his* mutants were identified as missense mutants.

In the investigation of low dose radiation effect (250-1,000 rads) on *Phaseolus vulgaris* and *Oryza sativa*, the total free amino acid content (TFAA), seedling height, fresh and dry weight were used as indices for measurement. Significant radiation retardation effect on plant height, fresh and dry weight was observed at upper dose level(s) in the 10 day-old *Phaseoulus* seedlings, but in *Oryza*, the effect was noted only on fresh weight in the 20 day-old seedlings. Also in *Phaseolus*, a dose of 1,000 rads produced a significant increase in TFAA in the stems of the 10 day-old seedlings. All such radiation effects disappeared as the seedlings grew older. No increase in TFAA due to radiation was observed in the leaf tissues of both *Phaseolus* and *Oryza* at any age up to 30 days. All these findings seem to suggest a differential sensitivity to radiation of stem and leaf primordia as well as a repair or recovery mechanism in young seedlings.

STAFF

Dr. Arturo Cedeño-Maldonado joined the Division on March 1, with the primary responsibility for developing research programs in crop plant physiology. He holds a joint appointment at the College of Agricultural Sciences and Agricultural Experiment Station, UPR.

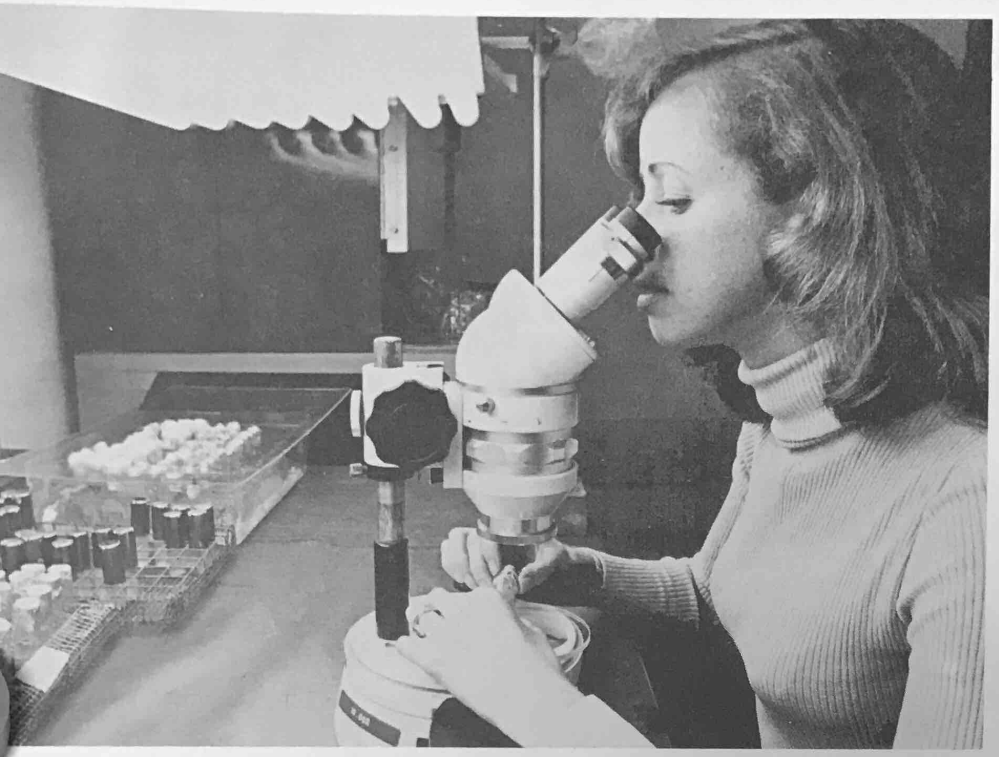
Dr. Francis K.S. Koo attended the USAEC Bio-Medical Program Directors Meeting held at AEC Headquarters in Germantown. Following the meeting, he visited the Agency for International Development Headquarters in Washington, D.C. acquiring information on the present status of development of international agriculture programs sponsored by the Agency.

Mr. José Cuevas-Ruiz attended the 33rd Annual Meeting of the Institute of Food Technologists in Miami Beach.

Mr. Augusto Tulmann Neto, Geneticist from the Centro de Energia Nuclear na Agricultura (CENA) in Brazil, spent nine months in the Division as an IAEA Fellow. His training and research program was involved mainly in the areas of mutation breeding and radiobiology.

Dr. Néstor A. Cardona, Professor of Chemistry, UPR, joined the Tropical Agro-Sciences Division as an Oak Ridge Summer Research Participant, investigating the effect of ionizing radiation on the structure and activity of lipoxidase in soybeans.

In tropical countries the plantain, or cooking banana, replaces the potato of temperate countries as a source of starch and other nutrients. The development of plantain clones with high contents of ascorbic acid and carotenoids and good pulp-to-peel ratios are under development by the staff of the Tropical Agro-Sciences Division. A total of 78 different clones of 6 varieties of plantains have been collected from different climatic regions, fruits grown and analyzed for food content. Materials from 15 clones superior in Vitamins A and C have been propagated for future development and analysis.



Miss Milagros Beauchamp checking the development of anthers in culture of various plant species.

Ken MacKay examining larval sugarcane borers on the leaf of a corn plant in the field cage test. The adult moths released in this cage have laid eggs on the leaves. After hatching, the young larvae feed upon leaf tissue before tunneling into the stem.

Insect Control Project

The field evaluation of Inherited Partial Sterility (IPS) for population suppression and eradication of lepidopteran pests is the major part of this program. In the laboratory fractionated doses have been used for sterilizing female sugarcane borers and both sexes of wax moths. In addition, the specific chemical attributes of resistant varieties of the common bean, *Phaseolus vulgaris*, to the bean pod borer, *Chalcodermes ebininus* Boheman (Curculionidae, Coleoptera) are being analyzed. This work has been started by comparing the fatty acids in the most resistant and susceptible varieties of beans.

FIELD TEST OF IPS

The field test is being conducted in a large cage at the Federal Experiment Station in Mayagüez. The cage is 80 feet wide and 160 feet long. The framework is covered with 40 mesh saran screen and divided with screen panels into 8 separate small cages that are 40 × 40 × 10 feet. Each small cage represents approximately one-fortieth of an acre. Corn is planted in plastic pails and the test insects are liberated in the cages.

Ibadan corn varieties were selected for the cage tests because of their high susceptibility to the sugarcane borer. These varieties produce reasonably hardy plants even when subjected to the considerable drought stress of the pails. In addition these varieties are somewhat more resistant to attack by the corn aphid. Aphid attack was a serious limiting factor in producing corn in the cage when other borer susceptible varieties were tested. The pail method of rearing the host plant is far from ideal because of the drought problems, aphids, and growth of wild grasses and weeds in the cages.

At the writing of this report the total F_1 population in four types of releases have been counted (Table 1). Two series of controls are included. The first control was a cage of corn plants, with no insect release of any type to check if there was a wild population in the test cages. The second control was a release of 15 pairs of normal males and normal females. Two series of tests are included in these results. The first, called the MC series, is an evaluation of the hypothetical model under field conditions. In this series of tests 15 mated females were released in each cage: 14 females had previously mated with irradiated males in the laboratory, and one female that had previously mated with a normal male in the laboratory. The plants were harvested and the F_1 population census was made while the F_1 population was in the third larval stage. On the basis of the number of females released, the population increase in the normal release cages was 4.3, close to the five-fold expected in the MC series, the increase was 1.5. There is a bias in the direction of low counts in this series due to the fact that the counts had to be made early since the cages were needed for other tests. As a result the population estimates were made before the larvae had been dispersed in the plant host material, and because the small larvae produce small tunnels the young larvae are more often overlooked than the larger larvae.

Population is based on the number of individuals of the subsequent generation divided by the number of females in the previous generation. Thus a total population of 15 F_1 individuals from a P generation release of 15 females would be a generation ratio of 1.0, 30 F_1 individuals from 15 P_1 females would be 2.0.

In the second test series (Table 1) 14 semi-sterile males were released with each normal male and normal female. The total F_1 population in three cages was 11. In the first test there were no F_1 individuals. The average net F_1 population was a reduction to 0.393 of the original female population.

These preliminary results in the field support the hypothesis of Walker and Pedersen (1969) which were based on laboratory data.

A second series of field tests is planned for the latter part of this fiscal year to compare the effect of season on the reproductive capability under field conditions. Previous data indicate that the net reproductive rate is lower in the winter months.

We are indebted to Dr. Robert Jackson, the Senior Entomologist at the Sugarcane and Corn Investigations Program in Houma, Louisiana for supplying the test insects. Due to budget and facilities limitations we were unable to produce the large numbers of test insects simultaneously that were needed. Through a cooperative arrangement with Dr. Jackson and with the permission of the Plant Quarantine Services of the Commonwealth of Puerto Rico and the US Department of Agriculture the arrangements for obtaining the insects needed for the field test were made possible.

Table 1
Cage Test Results Summarized

Control Series	No. Plants	Released MS:MN:FN	Time Harvested Days	Population in Generation F_1	F_2	F_3
CK/CK	100	0: 0: 0	60	0	--	--
CK May	125	0:15:15	50	50	--	--
CK1	108	0:15:15	75	64	--	--
CK2	135	0:15:15	67	70	--	--
CK3	144	0:15:15	65	88	--	--
CK4	144	0:15:15	67	53	--	--
					65.0 (4.3)	
First Test Series						
MC1	146	0: 0:14:1	36	39	--	--
MC2	155	0: 0:14:1	36	13	--	--
MC3	100	0: 0:14:1	37	22	--	--
MC4	148	0: 0:14:1	33	16	--	--
					22.5 (1.5)	
Second Test Series						
T1	126	210:15:15	70	0	--	--
T2	123	98: 7: 7	67	6	--	--
T3	118	98: 7: 7	52	5	--	--
					3.67 (0.393)	

FRACTIONATED DOSES FOR STERILIZING FEMALE LEPIDOPTERA

The first of the two models presented for population eradication was based upon a single release of partially-sterile males at a high overflooding ratio (14:1). This is the model being tested in the cage. If semi-sterile females were to be released into a natural population (as was originally suggested) then they would produce semi-sterile offspring which would, in turn, contribute to the future population. As a result, crop damage would be increased. This results in some difficult alternatives. The first is to discard the large numbers of females that would have been produced in the "factory rearing method" or find a better method for fully-sterilizing these females while retaining their mating competitiveness in relation to wild females. Then they may be released in a different area, one that is geographically isolated from the area where the semi-sterile males are released.

The latter is the preferable solution since it allows for full utilization of the rearing capacity of the insect factory. Therefore ways are being sought for producing fully sterile females without imparing their mating competitiveness. Female sugarcane borers and female wax moth can be successfully sterilized at lower doses by exposing them to two equal factions (Tables 2 and 3). Similar results have been reported by Toba and Kishaba working with female cabbage looper moths.

Table 2
Comparison of Single and Fractionated Exposures
to Female Sugarcane Borer Moths[1]

Exposure K/rads	Percent Egg Hatch	
	Single	Fractionated
0	96.0	96.0
8.8	14.2	4.8
17.6	13.5	0.4
22.0	2.1	0
29.3	0	0

Table 3
Comparison of Single and Fractionated Exposures
to Male and Female Wax Moths[1]

Exposure (Krads)	Percent Egg Hatch	
	Single	Fractionated
Normal Female, Normal Male		
0	96.0	96.0
Irradiated Female, Normal Male		
1.1	49.9	91.0
2.2	37.0	92.5
3.3	18.3	66.5
6.6	12.0	0
13.2	0	0
19.8	0	0
Normal Female, Irradiated Male		
1.1	100	94.3
2.2	100	92.0
3.3	100	94.3
6.6	89.0	93.0
13.2	79.0	60.0
19.8	15.0	20.0

It appears from the results that adult female borers may be sterilized for field release by irradiationg them at a total fractionated dose of 17.6 krads. This is nearly 10 krads less than the dose required when given as a single exposure.

HOST PLANT RESISTANCE

Fatty acids have been extracted from bean pods using a chloroform-methanol procedure. and analyzed by gas-liquid chromatography.

The extraction procedure is as follows: Pods are weighed, triturated in a Waring blender, extracted with Folch solution, filtered, then agitated with a solution of sodium chloride and refrigerated overnight; following this the chloroform layer is separated, filtered again and evaporated to 10 ml. in a water bath. The fatty acids are saponified by boiling in methanol with potassium hydroxide, and extracted with hexane. Methylation is accomplished by treatment with boron trifluoride in a reflux condenser in methanol solution. The extract is then standardized to a 5 ml. sample size.

Samples are injected into a column packed with 30 percent diethyl glycol succinate, using helium carrier gas at 20 ml per minute flow rate. Methyl ester standards of fatty acid standards are compared with the unknown samples.

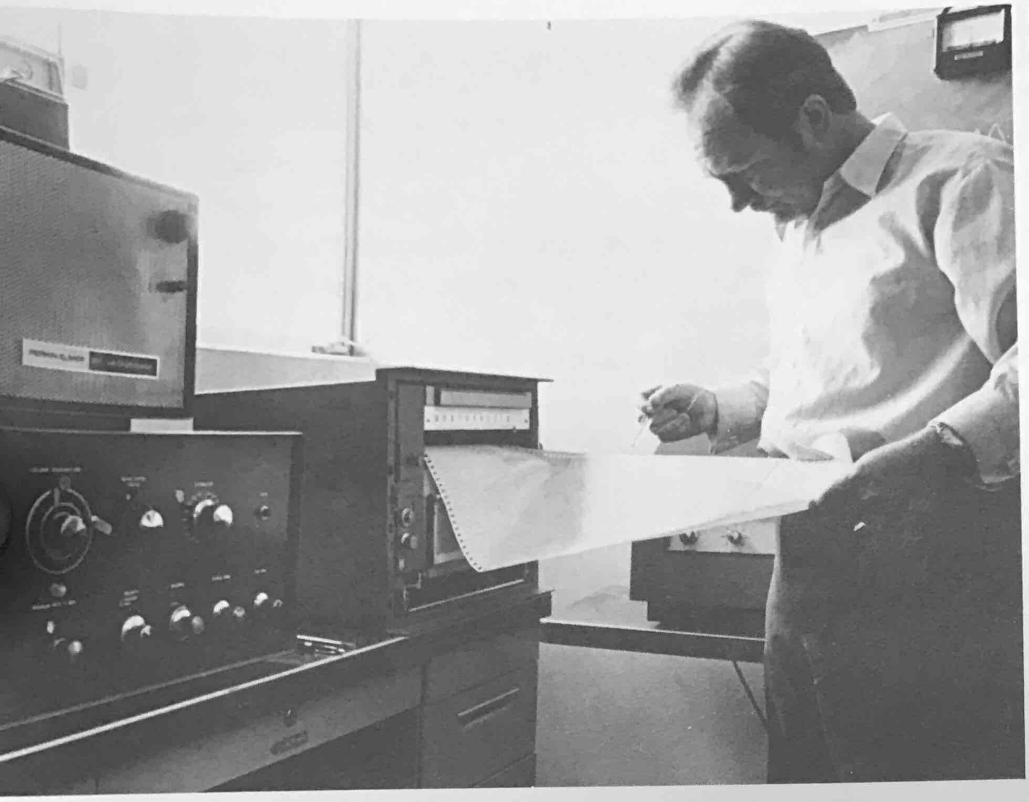
The preliminary analyses show that the saturated fatty acids of C14 to C20 chain length are present in greater abundance in the susceptible varieties. The unsaturated fatty acids, linolenic and linoleic acids, are more abundant in susceptible varieties.

TRAINING ACTIVITIES

Dr. Walker gave seminars at the University of Puerto Rico in Mayagüez and continued to advise the thesis research of Alba Rivera-Detres who is working with the hemolymph proteins of IPS afflicted lines of the sugarcane borer. The effect of monochromatic light upon initiation of mating flight of the mosquito *Aedes aegypti* is being studied by two other students, Magda Barreto and María Vargas, as a special problem in the Biology Department. Dr. Walker and Dr. Chester Moore, Medical Entomologist, are working jointly on this problem. Dr. Shree Deshpande continues giving consulting help on the host plant project, and Dr. Niilo Virkki of the Commonwealth Experiment Station continues with his help with insect genetics problems.

STAFF ACTIVITIES

Dr. Walker's part-time teaching appointment at the University has enabled the program to continue the field test at the same funding level. This has allowed continuation of the field test and the host resistant project simultaneously.



Dr. M. K. Eberhardt examining a gas chromatogram. Different peaks on the chart correspond to different products of the reaction in study.

Mrs. Rosa S. de Tirado weighing a reagent which is going to be used in the preparation of labeled tributyltin oxide. This substance is a powerful molluscicide utilized in the control of schistosomiasis.

APPLIED PHYSICAL SCIENCES

A major objective of the Applied Physical Sciences Division is to provide advanced training for Puerto Rican and Latin American trainees, primarily through participation in research with high energy radiation and radioisotopes. This program is geared to regional needs, and includes an introductory training course in the use of radioisotopes. Scientific personnel are encouraged to participate in the academic activities of the natural sciences departments of the University of Puerto Rico, Río Piedras through joint appointments.

TRAINING ACTIVITIES

The educational activities of the Division range from a four-week noncredit training course in the techniques of radioisotope applications to research training in the laboratories of the Center. The four-week course was offered twice during 1973 for a total of 17 students.from the following countries:

Dominican Republic	2
Bolivia	1
San Salvador	1
Venezuela	1
U.S. Citizens	
Puerto Rico	10
Cuba	1
Continental	1

The following Courses were also given by Mrs. R. Santana de Tirado:

1. The Laboratory Section of the Course "Radiation Detection" offered to the students of the M.S. Degree Program in Radiological Health.
2. A Short Course on "Radioisotope Techniques" offered to a group of Hematologists from the UPR School of Medicine.
3. A Short Course on "Basic Instrumentation in Radioisotopic Work" to a group of Medical Technologists from the UPR School of Medicine.
4. Additional Lectures and Demonstrations on Radioisotope Techniques.

Support for University Biomedical Education (SUBE) Program. The Division is collaborating with the University of Puerto Rico in the Support for University Biomedical Education in Puerto Rico. (SUBE) Program. The main objective of this program is to provide opportunities to undergraduate and graduate students from social, educational and culturally limited backgrounds for research and creativity in the biomedical sciences and related areas.

The SUBE Program includes at present 9 Projects. The Project submitted by this Division is entitled "Thioxanthone Derivatives as Potential Trypanosomicides" and is under the supervision of Dr. José Castrillón.

Two Puerto Rican students are participating in the Thioxanthone Project: graduate student Miss Marisol Rodríguez and undergraduate student Miss Deborah Narváez.

At PRNC it has been shown that thioxanthone derivatives are highly active "in vitro" against *Trypanosoma cruzi*, the organism responsible for Chagas' disease. It must be emphasized that Chagas' disease poses a formidable health problem in Latin America where it can be estimated that more than ten million people are infected. Moreover, the first effective drug was put in the market just recently.

The project aims at obtaining chemotherapeutic substances against this disease by introducing suitable substituents on the side phenyl rings of the thioxanthone molecule while preserving the central highly polar ring which is assumed to be responsible for the effect against *T. cruzi*.

Thesis Research. The following M.S. Theses were sponsored by the Division and successfully defended during 1973 (see also Radiation Chemistry).

1. Influence of Chemical Structure on Quenching — Elsa Gómez (Puerto Rico); directed by Dr. José Castrillón.
2. Aromatic Nitriles as Scintillation Solutes — Carmen Velázquez (Puerto Rico); directed by Dr. José Castrillón.
3. Adducts of Cadmium and Mercury Halides with Some Mesoheteroanthracenes — Sonia Vázquez (Puerto Rico); directed by Dr. José Castrillón.

RESEARCH ACHIEVEMENTS

The research activities of the Applied Physical Sciences Division include studies on radiation effects and radioisotopes, and work supporting these studies. The projects are described briefly below:

Radiation Effects. The effects of high-energy deposition in chemical systems were studied in order to clarify the mechanisms of radiation-induced changes. In some systems the emphasis is on the initial, or primary, products of radiations; in others, on the final products resulting from secondary chemical reactions.

1. Matrix Isolation Studies of the Gamma Radiolysis of Heterocyclic Molecules — G. A. Simpson and Rafael Arce-Quintero. This project receives support from the AEC Division of Biology and Medicine and is described elsewhere in this Annual Report.
2. Radiation-Induced Aromatic Substitution — M. K. Eberhardt. Work on radiation induced homolytic aromatic substitution has been continued with emphasis on the hydroxylation, phenylation and nitration of benzene in aqueous solution. Two papers in which mechanisms for these reactions are proposed, have been submitted for publication. It is hoped that this work will help to understand the effect of radiation on biological systems.

Radioisotopic Studies .

1. Preparation of Tributyltion Oxide Labelled with ^{113}Sn — Rosa Santana de Tirado and José Castrillón. The preparation of high specific activity tributyl tin oxide (TBTO) has been requested by the Medical Sciences Division. TBTO is a potent molluscicide and there is interest in determining the fate of the tin in mammals and other organisms.

   Several cold runs with satisfactory chemical yields have been performed in preparation for the hot synthetic work.
2. Liquid Scintillation Counting —José Castrillón. Work on new scintillation solvents has been continued. In particular, some solvents which show promise for the counting of aqueous samples have been examined.

Supporting Research. One of the essential function of the Applied Physical Sciences Division is to provide technical assistance to other division or programs needing its particular expertise or facilities. The projects described below may not directly involve the use of radiation or radioisotopes buth they provide supporting information needed for the projects listed above, or for similar projects in other divisions.

1. The Conformation of Mesoheteroanthracenes — A. McB. Block and J. Castrillón. The problem of the frequency for the symmetric flapping of thianthrene has been initiated using all-valence-electron, self-consistent-field (SCF) methods. A reasonable set of coordinates has been developed based upon two undistorted benzene rings and an S-C aromatic distance of 1.74Å, which is consistent with the C-S-C bond angle of 91° in the thiophene molecule. No recent calculations of this molecule have appeared, and the most appropriate of modern all-valence-electron SCF methods is CNDO/2 since the number of orbitals that must be considered is quite large (78). The curvature of the flapping mode will be calculated and, using the harmonic oscillator approximation, the fundamental frequency will be estimated.
2. The Stability of Aryl-substituted N-t-butyl Bensamide Radical Cations — A. McB. Block, Dr. Robert Tsai (the Economic Development Laboratory, E.L.A.) and Dr. George Rubottom (Department of Chemistry, UPR). This study is concerned with the stability of aryl-substituted N-t-butyl benzamide radical cations during fragmentation of these species in mass spectrometry. Electron releasing groups were shown to aid hydrogen transfer from a t-butyl group to the carbonyl oxygen. Indeed, CNDO/2 prediction showed this carbonyl oxygen to have the greatest spin density and nearly all os the spin density of the radical cation was in the orbital.that protrudes outward toward the equivalent methyl groups. An estimation of the activation potential is now underway. Intensities of the mass spectrometric peaks for the $-NO_2$, -H and OCH_3 was qualitatively predicted by CNDO/2 calculations; ionization potentials were predicted to within 6% for all three molecules using the adiabatic approximation.
3. The Cyclooctatrienyne Radical Anion — A. McB. Block, Dr. Gerald Stevenson (Dept. of Chemistry, UPR). INDO calculations were made to rationalize the electron spin resonance pattern exhibited by species resulting from the Na-K reduction of halo-substituted cyclooctatetraene. The INDO calculation of coupling constants

supports the conclusion that a meta-stable species observed at liquid nitrogen temperatures is an eight-sided analoque of benzyne: the cyclo-octatrienyne radical anion.

4. The Oxidation of Sulfides to Sulfoxides — J. Castrillón. Techniques for achieving the controlled oxidation of the parent sulfides to sulfoxides which are of interest to other projects are being examined.

STAFF

Dr. A. McB. Block whose work was partially supported by this Division is now full-time with the Terrestrial Ecology Section. Collaborative efforts are being continued.

Heterocyclic Molecules Project

The objective of these studies is the identification of the species formed by gamma radiolysis of heterocyclic molecules of possible biological importance. Therefore, emphasis is on direct observation of the normally labile intermediates formed after the absorption of high energy radiation. This is done by the matrix isolation technique, in which the molecule is irradiated in a rigid matrix at low temperature so that radicals and radical ions are stabilized for extended periods and can be characterized by spectroscopic techniques. The results of quantum mechanical calculation of electronic properties of heterocyclic radicals and ions are used in conjunction with experimentally measured properties to identify unknown intermediates. Flash photolysis and low temperature photolysis experiments are also used.

THESIS RESEARCH - Ph. D. Degree

Use of Single-Center Expansions in Photoionization Cross Section Calculations — Gladys Rodríguez (Puerto Rico) to be completed in 1975; supervised by Dr. A. Grimison.

Optical Absorption and EPR Studies of Intermediates Stabilized at Low Temperatures — L. Ramírez (Puerto Rico) to be completed in 1977; supervised by Dr. R. Arce-Quintero

THESIS RESEARCH — M.S. Degree

Luminescence Quantum Yields of Some Aromatic and Heterocyclic Compounds — B. Castilla (Puerto Rico) to be completed in 1976; under joint direction of Drs. J. Castrillón and G. A. Simpson

UNDERGRADUATE RESEARCH

Flash Photolysis of Purine in Aqueous Solutions — L. Jiménez (Puerto Rico), Oak Ridge Undergraduate Participant from UPR under joint direction of R. Arce-Quintero and G. A. Simpson. During the photolysis of aqueous purine solutions, the production of the solvated electron, and two visible and near uv-absorbing purine-transients have been characterized in terms of a biphotonic mechanism. Studies to define the nature of the purine transients by the effect of added electron scavengers are in progress.

Absorption Spectra of Heterocyclic Intermediates Produced by Gamma-Radiolysis at 77°K. — M. Charron (Puerto Rico) Oak Ridge Undergraduate Participant from UPR under joint direction of R. Arce-Quintero and G.A. Simpson. The identification of the

absorption spectra of the indole radical anion λ max:360 nm and near 1200 nm, has been made on the basis of electron scavenging effects by indole and on effect of photolysis of intermediates.

STAFF RESEARCH

Theorectical Calculations of Ion-Radical Absorption Spectra. — A. Block. In the attempt to make spectral assignments of ion-radicals of indole and purine, a calculational procedure has been developed. The VESCF (PPP) program is used to provide optimum geometrical parameters. The optimized geometry is used with standard C-H and N-H bond distances with the all valence electron calculation (INDO)) to obtain optimum electron densities for the radical cation and anion in each case. These electron densities are then re-introduced into a recently expanded pi-SCF calculation from which excitation energies for transitions of open shell "molecules" may be obtained with fairly complete configuration interaction taken into account.

Absorption and EPR Studies of Intermediates Stabilized at 77°K. — L. Ramírez and R. Arce-Quintero (M.S. Thesis-submitted for publication). The ultraviolet irradiation (290 nm — 390 nm) of indole, purine, indazole, acridine and quinoline in 2-methyltetrahydrofuran glass at 77°K produces trapped radicals. Two ESR signals are found at 77°K during illumination, one at high magnetic field (3250 gauss) and the other at low field (1300-1500 gauss). The decay lifetimes, $\tau_D = (1/k_D)$, obtained for the low field intermediates are 6.1, 1.9, 3.9, 3.1 and 1.6 seconds for indole, purine, indazole, acridine and quinoline respectively. These decay times are similar to the phosphorescence decay lifetimes of the corresponding heterocyclics under similar conditions, suggesting that the low field intermediate involved is the lowest triplet state of the molecule. The rate of formation of matrix radicals (high field signal) varies as the n_Rth power of the incident light intensity $I_o{}^n R$ where $1.6 \leqslant n_R \leqslant 2$. This correlates with a biphotonic process involving the lowest excited state of the heterocyclics. The radical formation can be attributed to sensitized energy transfer from a highly excited state of the heterocyclic to the solvent. Quantum yields for triplet production at 77°K are 0.34 for indole, 0.51 for purine, 0.55 for indazole, 0.15 for acridine, and 0.94 for quinoline. Solvent radical yields, which depend on the light intensity, have been determined. Under the experimental conditions no signals attributable to trapped electrons or cations have been observed. The dependence of the low field ESR signal as a function of the intensity of exposure is in accordance with the theoretical mechanism.

The Ph.D. thesis work will be an extension of the M.S. Thesis plus inclusion of studies of triplet-tripet absorption spectra of heterocyclics, with special regard for elucidating the mechanism of solvent/matrix radical formation.

Photochemistry of Indole at 77°K — A. Grimison and G. A. Simpson. The results in this area involve computer simulation of kinetic data for the assumed biphotonic photo-

ionization mechanism. The computer program has been used to calculate the concentration of intermediates and products of the reaction based on known experimental parameters. The results so obtained served as a use ful check on the mechanistic interpretation. The conclusion derived from the results is that the inefficiency in production of recombination luminescence due to radical cations and electrons is due to inefficient photoionization of the triplet state. Concurrent EPR studies are in support of this conclusion.

Luminescence Quantum Yield of Aromatic and Heterocyclic Compounds. — B. Castilla, Luminescence quantum yields of compounds are being measured at 23° and -196°C using a rhodamine B quantum counter and 9,10-diphenylanthracene as standard. Of particular interest to the research goals of the project are the preliminary results for indole. At 23° a value of 0.26 for the fluorescence quantum yield, and at -196°C values of 0.53 and 0.31 have been obtained for the fluorescence and phosphorescence quantum yields respectively. These studies are applied to both the heterocyclic compounds of interest to this project and to those aromatic compounds of interest to the Applied Physical Sciences Division liquid scintillation counting research.

Flash Photolysis of Indole in Aqueous Solution. — J. R. Revuelta, Oak Ridge Summer Participant. The study of intermediates produced during photolysis of indole in aqueous solutions has been extended. Absorption spectra and kinetic data have been obtained for the solvated electron, and four indole transients: 1) the triplet, 2) the radical cation, 3) an unassigned species considered to be cationic, and 4) a radical, possibly indolyl. The results are consistent with monophotonic processes involving the indole exciplex and indicate complex photochemical degradation processes of indole.

Application of LiF Thermoluminescence to Electron Dosimetry. — T. A. Agard (Medical Physics, PRNC) and G. A. Simpson. (See Medical Physics for discussion).

Mechanism of Direct and Rubrene Enhanced Chemiluminescence During α-Peroxylactone Decarboxylation. — W. Adam and Y. Faris (UPR) and G. A. Simpson. Direct chemiluminescence measurements during the decarboxylation of t-butyl and dimethyl α-peroxylactones in benzene or carbon tetrachloride afforded singlet yields or 4.9×10^{-4} for both excited t-butyl aldehyde and acetone, respectively. The required fluorescence quantum yields were determined to be 0.91×10^{-3} for t-butyl aldehyde and 1.2×10^{-3} for acetone, respectively. The triplet yields were found to be 1.5×10^{-1} for t-butyl aldehyde and 5.3×10^{-2} for acetone, respectively, by means of rubrene enhanced chemiluminescence measurements. From this data the ratio in efficiencies of triplet and singlet excited state production was calculated to be 300 ± 55 for t-butyl and 110 ± 25 for dimethyl system, indicating a great preference for the formation of triplet excited carbonyl products in the α-peroxylactone decarboxylation. On the basis of a detailed kinetic analysis of the chemiluminescence itensities and decay times as a function of α-peroxylactone, rubrene concentration, quenching experiments, and the oxygen effect, a unified mechanisms is proposed in which rubrene functions as enhancer by way of triplet-triplet annihilation.

STAFF ACTIVITIES

Dr. George A. Simpson has served as acting project director since January, 1972. and is now director. He has joint appointments to both the UPR Chemistry Department, Río Piedras and PRNC's Medical Physics Section.

Dr. Rafael Arce-Quintero has a joint appointment with the project and the Chemistry Department of UPR, Río Piedras.

Dr. A. Block, Terrestrial Ecology Section, Dr. A. Grimison, UPR and José Revuelta, University College of the Sacred Heart, have also collaborated with the project on an *Ad Honorem* basis.

NUCLEAR APPLICATIONS

Nuclear Science and Technology Section

The Nuclear Science and Technology Section supports the M.S. degree programs in Chemistry and Physics of the University of Puerto Rico at Mayagüez by providing opportunities for graduate students to do research and for faculty to teach specialized advanced courses. Research facilities are also made available to graduate students of Nuclear Engineering and Electrical Engineering, and to pre- and post-doctoral students from other universities interested in working at PRNC.

One of the most important commitments of the section is to promote and encourage cooperative research efforts among our scientific staff and the science teaching staff at the UPR, Mayagüez.

TRAINING ACTIVITIES

Graduate Courses. During 1973 eight graduate courses were taught by PRNC personnel, with academic credit given by UPR:

Course	Professor	Enrollment
587 597 Introduction to Solid State Physics	Dr. R. S. Singh	5
608-Radiation Chemistry	Dr. R. A. Lee	7
673-Chemical Kinetics	Dr. R. A. Lee	6
661- 671-Theory of Electricity and Magnetism	Dr. P. P. Delsanto	6
606-Nuclear Physics	Dr. P. P. Delsanto	2
649-Introduction to Physical Statistics	Dr. R. Maglic	5

Thesis Research. The following students from Colombia, Argentina and Puerto Rico have completed thesis research under Nuclear Science Division staff supervision:

Student	Thesis Title	Advisor
Roberto F. Amaris	Radiolysis of Fluoroform	Dr. R. A. Lee
Aníbal J. Camnasio	Specific Heat and Lattice Dynamics of TGS and DTGS	Dr. J. A. Gonzalo
César Pérez Arenas	Study of Bent Neutron Monochromatizing Mirror Systems	Dr. W. Fiala
José A. Moreno-Bernal	Energy Transfer in Binary Solutions with 1,2,4-Trimethyl Benzene as a Donor	Dr. M-E.M. Abu-Zeid

The following students from Colombia, Paraguay, Cuba and Puerto Rico are doing thesis research under Nuclear Science Division staff supervision.

Gentil Estevez	Equation of State for Liquid Vapor Transitions	Dr. J. A. Gonzalo
Prudencio Martínez	Thermoluminescence Spectra from Alkali Halides	Dr. J. A. Gonzalo
Héctor D. Colman	Gamma Induced Copolymerization	Dr. J. A. Gonzalo
Josefina Rodríguez	Electron Impact Studies of Fluorotoluenes	Dr. R. A. Lee
María B. Colón de Olmo	Radiolysis of Aqueous Solutions of Difluorobis-ethylenediamine-Cobalt III Nitrate	Dr. R. A. Lee
Luz del Mar García	Radiolysis of Aqueous Solutions of Sulfur Containing Amino-acids	Dr. R. A. Lee
José Escabí Pérez	Radiolysis of Pectic Acid	Dr. S. Deshpande & Dr. R. A. Lee
Héctor Santiago Chamorro	Continuum Calculation of the Photonuclear Reaction Cross-Sections in Zr^{90}	Dr. P. P. Delsanto
Félix E. Fernández Sánchez	Dependence on the Optical Parameters of the Photonuclear Cross Sections in a Continuum Calculation	Dr. P. P. Delsanto
Osvaldo Matos	Raman Scattering of Hydrogen Bonded Ferroelectric Crystals	Dr. R. S. Singh
José R. López Santiago	Excimeric Properties of Carcinogenic Compounds	Dr. M.E.M. Abu-Zeid

RESEARCH COMPLETED

Brillouin Scattering in Triglycine Fluoroberyllate — A Brillouin Scattering system has been built up using a He-Ne laser, a piezoelectrically scanned Fabry-Perot interferometer and a multiscaler counting system. The angular dependences of frequency shift and intensity of the quasi-longitudinal and quasi-transverse acoustic modes propagated within the plane perpendicular to the ferroelectric $\bar{b}$ axis for triglycine fluoroberyllate have been studied. The quasi-longitudinal components were well resolved within the limits of the 128 multichannel analyzer employed, but the quasi-transverse ones were poorly resolved due to the strong central component caused by imperfections in our single crystal samples.

From these results, information about some of the sound velocities, Pockel's coefficients and other physical parameters was obtained and compared to data from triglycine sulfate. An attempt to study the sound velocity relaxation of the quasi-longitudinal modes as a function of temperature through the transition (T_c=73.3°C) was unsuccessful, but indicated an upper limit of 1% change, similar to the case of triglycine sulfate.

Rigorous Scaling-Law Equation of State Near the Critical Point--Making use of the scaling properties of $H(\epsilon,M)=M^{\delta}h(\epsilon/M^{1/\beta})$ it is shown that the "scaling function" h(x) can be expressed rigorously as $h(x)/h(0)=[(x_0+x)/x_0]^{\beta(\delta-1)}$ in the neighborhood of the critical point. This result is in agreement with the known mean field model prediction, directly obtainable from power series expansion, and with accurate numerical results for the Ising and Heisemberg models.

Equation of State for the Heisemberg Model Near T_c. Recently, Milosevic and Stanley have done numerical calculations on the Heisemberg model for various lattices (s.c., f.c.c. and b.c.c.) and various spins (S=1/2, S=∞) which show that the equation of state is rather independent of lattice type and spin. In this communication it is shown that a simple expression $h(x_0+x)/h(x_0) = [(x=+x)/x_0]^{\beta(\delta-1)}$ can be obtained rigorously for the "scaling function." This expression, substituting appropriate values for the exponents β and δ, is shown to be in very good agreement with the numberical calculations of Milosevic and Stanley, as well as with experimental results on various systems undergoing ferromagnetic transitions ($CrBr_3$, EuO, Ni and ordered Pd_3Fe). While applied here to the Heisemberg model, it will be shown that the validity of this simple expression is quite general, and rests only on the scaling assumption. Comparisons will also be made with the mean-field and Ising models. The above equation is equivalent to that proposed some time ago by Arrot and Noakes for nickel.

A further detailed comparison is given between experimental data for Ni and $CrBr_3$ and this simple equation of state using the $\beta(\delta-1)$ value which fits best the Heisemberg model numerical results of Milosevic and Stanley. The normalization values for magnetization (M_s) and field (H_s) were determined from data near T_c (critical isotherm, coexistence curve, and $kT_c=H_sgH/\mu\beta$). The resultant x_0^1s from both sets of data (x_0=0.243 for Ni, and x_0=0.230 for $CrBr_3$) are in good agreement with each other and suggest a possible relationship $x_0 \sim (1/\delta)$ similar to the mean-field case.

The Dipolar Theory of Ferroelectrics Revisited. An analysis of experimental data has been done for various ferroelectrics within the framework of the dipolar theory, along the same lines of recent work on TGS and TGFB. A simple method is applied which, using solely dielectric data near T_c, leads to the determination of the main parameters of the theory. The resulting numbers (N) of elementary dipoles per unit volume appear to be close to the numbers of unit cells per unit volume as determined from crystallographic data. The elementary. dipole moments ($/\mu$) are reasonably consistent with observations of low temperature spontaneous polarization. The mean-field coefficients (β) appear to be consistent with an independent evaluation of the "reaction" field in cases for which

quasi-point-dipoles in the lattices can be assumed. The relative contributions of the dipolar polarization to the total (dipolar plus atomic) polarization appears to be larger in the more ionic ferroelectrics. The transition entropy due to the order-disorder process can account for the observed values in most (but not all) cases. No adjustable parameters have been used.

Longwavelength ($\vec{K}\sim o$) IR Active Optical Phonons in Na-, K-, Rb- and CsN_3. S. Trevino and H. J. Prask (Feltman Research Laboratories and NBS) and N. Massa and S. S. Mitra (U. of Rhode Island). The polarized reflection spectra of crystalline KN_3 and pressed pellets of Li-, Na-, K-, Rb- and C_sN_3 have been measured with $2cm^{-1}$ resolution in the far-infrared region (75-400 cm^{-1}). The longwavelength ($\vec{K}\sim o$) transverse and longitudinal optical phonons have been obtained by Kramer-Kronig analysis and classified according to their symmetry. By comparing the result of crystalline KN_3 and its pellet, symmetry of the phonons in other materials were assigned. The TO phonons obtained by measuring thin film IR absorption agree well.

Experimental Set-Up for Raman Scattering. F/1.0-2.0 focusing and collecting optics for a Spex 1401 double monochromator has been designed and tested. Using a cooled photomultiplier tube and the photon counting system, Raman spectra of carbon tetrachloride, Benzene and single crystal $NaNO_3$ have been measured. In each case, all the known lines have been observed with $\pm 1cm^{-1}$ compared to their previous values.

Change of Force Constant Around a Point Defect in a Solid — S. S. Mitra (Laboratoire des Hautes Pressions, C.N.R.S., France) participated in this work. The local or gap mode frequencies of a host lattice-point defect system, XY:Z may be predicted from the properties of the end member pure crystals XY and XZ alone whenever pertinent data on pure crystals are available, without invoking any arbitrary force constant softening. In this instance the molecular model has been used, and relevant examples from alkali halides are presented. A modification of the Green's function technique is also discussed.

Longwavelength ($K\rightarrow o$) IR Active Phonons of $NaHF_2$ and KHF_2 — S. Trevino and H. J. Prask (FRL and NBS) participated in this work. The reflection spectra of pressed pellets of $NaHF_2$ and KHF_2 were measured with $2cm^{-1}$ resolution at room temperature. The TO and LO phonons were obtained by Kramers-Kronig analysis. The assignments were made by comparison with our earlier study of metal azides.

Elastic and Elasto-Optic Constants of Ammonium Perchlorate. Using Brillouin scattering technique, the elastic and elasto-optic constants of Ammonium perchlorate have been measured at room temperature. The polarized Brillouin scattering spectra yielded the nine elastic constants (in the units of 10^{11} dynes/cm^2) as follows: $C_{11}=2.51$, $C_{22}=2.46$, $C_{33}=3.15$, $C_{44}=0.66$, $C_{55}=0.47$, $C_{66}=1.03$, $C_{12}=1.63$, $C_{13}=1.15$, $C_{23}=0.76$; as well as twelve elasto-optic constants. Their symmetry relations and the thermodynamic properties of this crystal were studied.

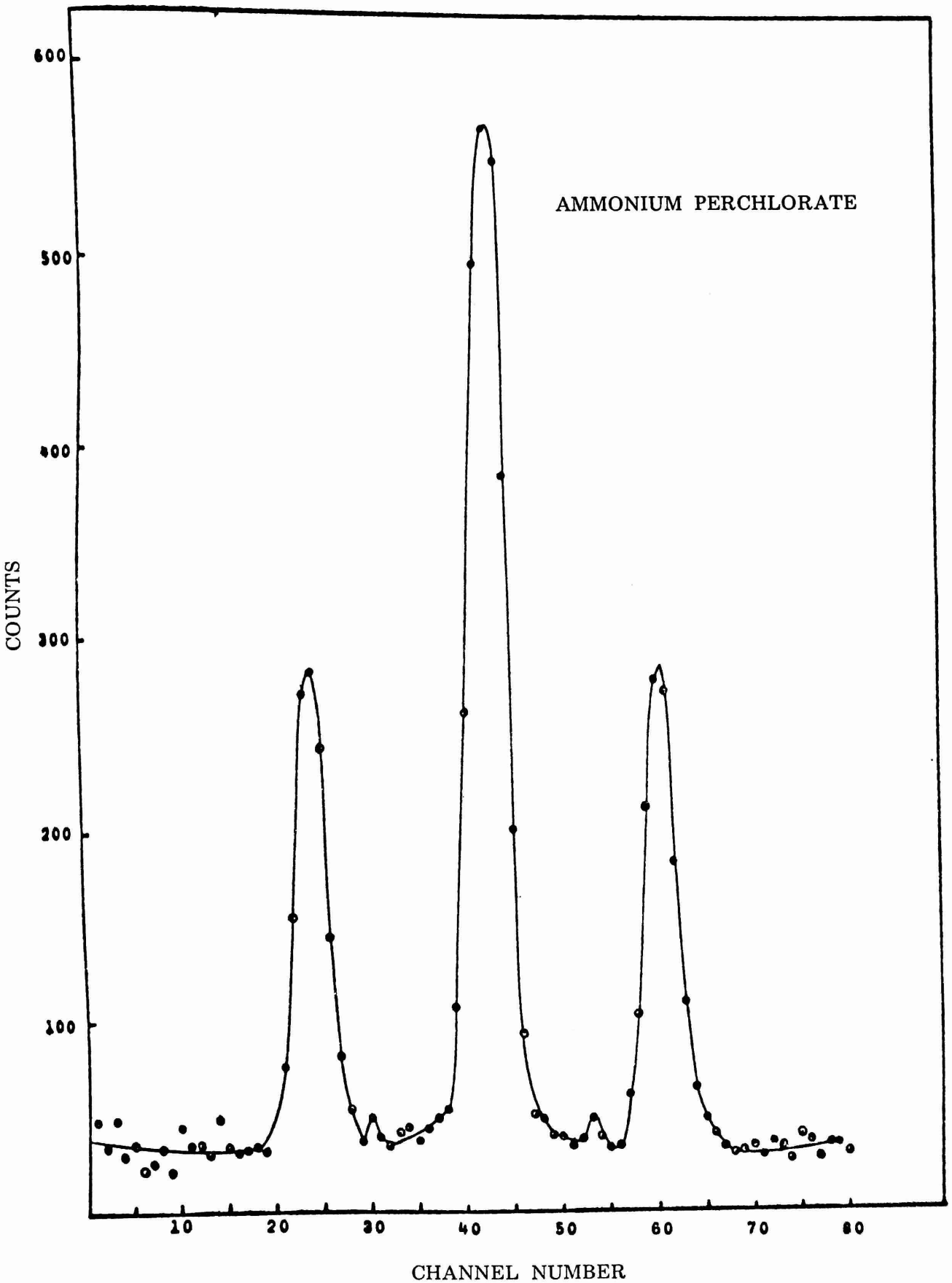


Figure 1. Brillouin Spectra of Ammonium Perchlorate

Energy Transfer in Binary Solutions with 1,2,4-Trimethyl Benzene as a Donor. Energy transfer from 1,2,4-trimethyl benzene to eight other organic molecules in cyclohexane has been investigated using a simple kinetic reaction scheme that is independent of both donor and acceptor concentrations. The absolute quantum yields of different acceptors used have been determined very accurately relative to that of the donor. This scheme was also found to be independent of donor acceptor kinetics. Some important molecular parameters such as fluorescence and internal quenching rate constants have been evaluated. Using the values of those rate constants, the rates at which the energy is transferred from the donor to the acceptor molecules per mole per liter have been estimated. Assuming constant acceptors molar concentrations (10^{-4} M/ℓ) the fraction of energy that is transferred from the donor to the different acceptor molecules was calculated. These values were found to be in reasonable agreement with the critical transfer distances estimated from Förster formula. Finally, the values of the critical concentrations and the mutual distances between donor and acceptor molecules were also calculated and discussed.

Ferroelectric Specific Heat of TGS and DTGS. The specific heats of triglycine sulfate (TGS) and deuterated triglycine sulfate (DTGS), single crystals, have been measured (a) in the temperature interval 100-400°K, and (b) around the respective critical region. In the low temperature side both experimental curves are almost coincident, as expected, and show a marked temperature dependence, indicative of strong anomalous anharmonicity. The heat of transition (ΔQ) is 1.91±0.10 and 1.90±0.10 joule/g, respectively. The entropy change is $\Delta S=(6.21\pm0.30)\times10^{-3}$ joule/g°C, approximately the same for both crystals. Around the transition, data were collected every $\sim$ 0.02°C. The specific heat discontinuity at T_c was substantially different: $\Delta C_p=0.24\pm0.03$ joule/g for TGS and $\Delta C_p=0.48\pm0.03$ joule/g for DTGS. Calculations based upon phenomenological and dipolar theory[1] of ferroelectrics, corrected for pressure dependence show fair agreement with these results.

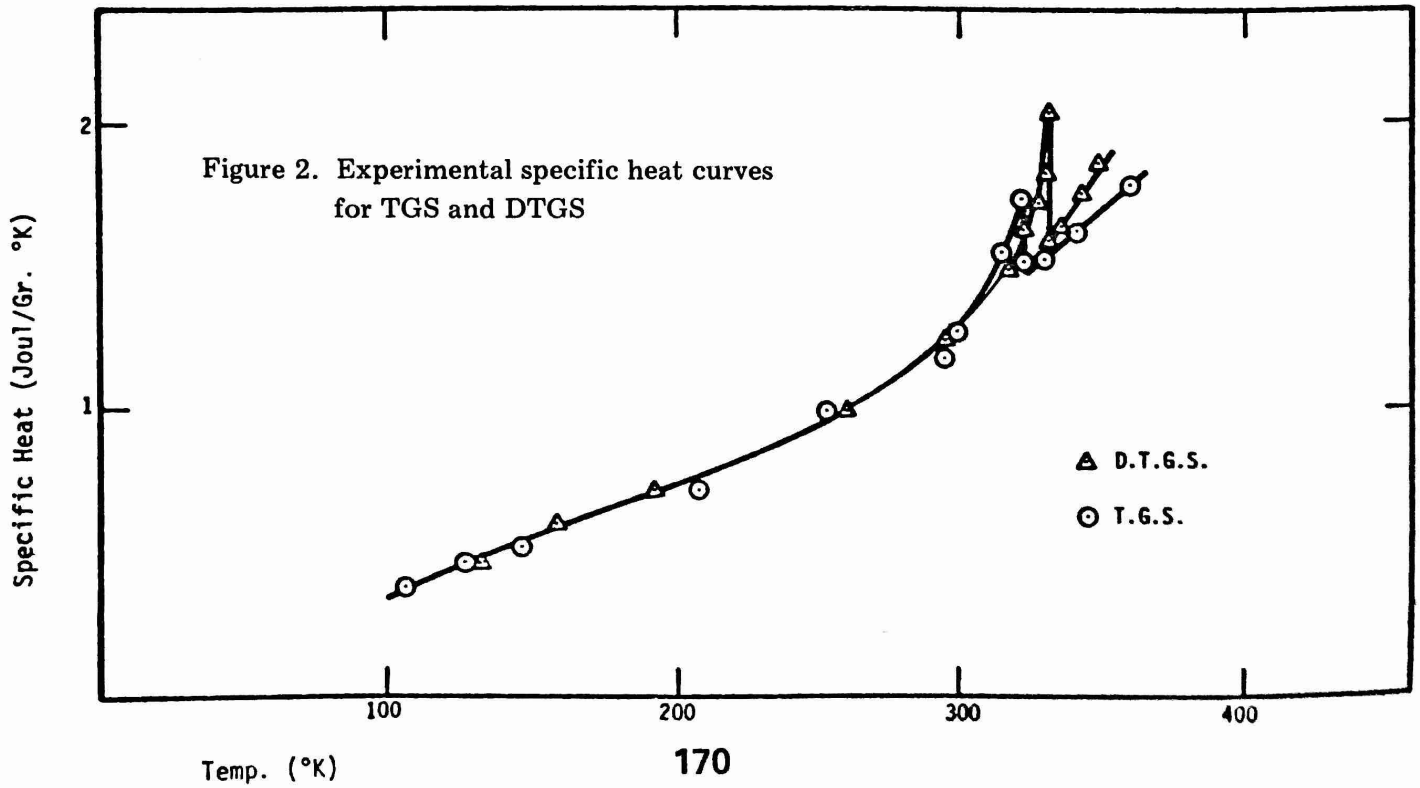
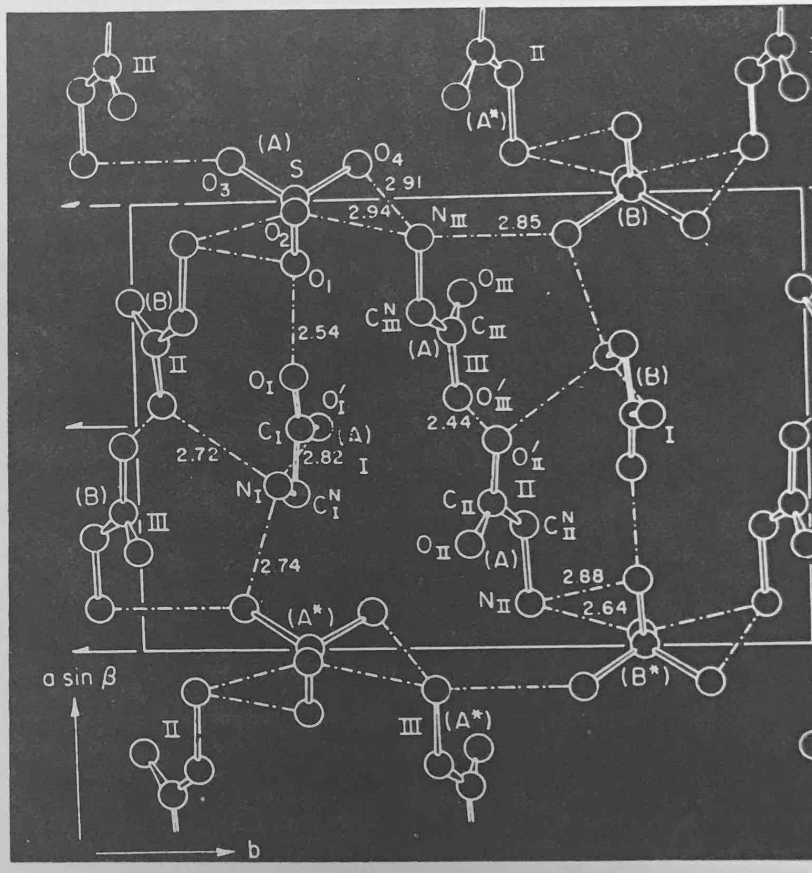


Figure 2. Experimental specific heat curves for TGS and DTGS



Mr. Aníbal Camnasio from Argentina conducted his thesis research for the M.S. Degree in Physics on the specific heat and lattice dynamics of triglycine sulfate (TGS) and deuterated triglycine sulfate (DTGS).

RESEARCH IN PROGRESS

Ferroelectric Materials in Energy Conversion. Ferroelectrics are ideal materials for energy conversion. They can store more electrostatic energy per unit volume ($U=1/2\ [\epsilon E^2]$) than any other dielectric material. The available work, using a new method of conversion (not previously tried as far as we know) involving purely thermal switching of the spontaneous polarization, can be estimated as

$$W=1/2\ (E_s P_s)=1/2\ (\beta P_s^2)$$

where $\beta \simeq 4\pi T_c/C$, T_c = transition temperature, C = Curie constant, and P_s = spontaneous polarization. Table 1 gives a comparison of estimated efficiencies for various ferroelectrics working at $(T_c-\Delta T) \pm \Delta T$ for $\Delta T \simeq 10°C$. Preliminary experimental work on small scale prototypes utilizing this under way.

Table 1
Comparison of Various Ferroelectrics as Energy Converters

Material		TGS	SbSI	$BaTiO_3$	(Ni)
T_c(°K)		322	289	383	627
P_s M_s (esu) (gauss)	(1)	6.3×10^3	4.5×10^4	6.0×10^4	1.2×10^2
β γ		0.98	0.015	(0.033)	(5000)
C_p(joul/cm³)	(2)	2.85	1.94	3.34	5.7
W(joul/cm³)	(1)	1.94	1.58	(5.94)	(3.76)
Q(joul/cm³)	(1)	57	39	67	115.
$\eta=W/Q$		3.4	4.0	(8.9)	(3.2)
$\eta=\Delta T/T_c$	(3)	3.1	3.4	2.6	1.6

Note: (1) For $\Delta T=T_c-T=10°C$. (2) Around T_c. (3) Carnot efficiency. W is a measure of the "Specific power output" per cycle. (Compare, for example with the specific power output of a Si photovoltaic cell, approximately 0.005 watts/cm³).

Anharmonicity in Ferroelectric Crystals. A modified version of the dipolar theory has been developed and applied to several representative ferroelectrics using data near T_c. The contribution due to ionic polarization was taken care of by means of the parameter $K=P_d/P$ (where P_d=dipolar polarization, P=total polarization). While K=constant for the vicinity of T_c, it appears to show appreciable temperature dependence for larger temperature intervals. This dependence can be connected to increasing anharmonicity as the

spontaneous field grows larger. A generalization of the theory which takes into account the spontaneous deformation energy of the lattice leads to a K which is a function of polarization. Preliminary results indicate that calculations of anomalous thermal expansion low temperature spontaneous polarization, elastic constants and "soft" mode behavior for TGS are in good agreement with the observed behavior.

Brillouin Scattering of $NaNO_2$ around the Transition Temperature. The Brillouin Scattering equipment has been improved and a new set of mirrors within a reflectivity of 98.0% and a flatness of $\lambda/200$ has been mounted. This allows a greater finesse and contrast, necessary to resolve some peaks close to the Rayleight peak. The system is now able to work up to $5cm^{-1}$ of free spectral range, close to the lower limit obtained with Raman Equipment. The first Brillouin spectrum of $NaNO_2$, at room temperature, shows transverse and longitudinal shifts at about $.25cm^{-1}$ and $.52cm^{-1}$. A special furnace is now completed to proceed further with the experiments around the transition temperature (T_c=160°C).

Temperature Dependence of Elastic Constants in Ammonium Perchlorate. The elastic and elasto-optic constants of ammonium perchlorate have been studied at room temperature. The Debye temperature and the Grüneisen constant have been obtained. It is the interest of the present work to study these properties with temperature up to and through the transition temperature. Pressure scanning has been incorporated into the Brillouin system and which improves the stability and resolution that is required for precision temperature measurements.

Raman Spectra of Triglycine Sulphate (TGS) and Deuterated TGS in its Para- and Ferroelectric Phases. Plans are to investigate the Raman spectra of TGS and DTGS near T_c. Based on the group theoretical analysis, single crystal spectra will be studied in the following polarizations: X(ZZ)Y, X(YZ)Y, X(YY)Z, X(YX)Z, Y(ZX)Z, where symbols outside of the parenthesis refer to the direction of propagation while inside of it to the polarization. Sample holder and temperature variation facilities are currently being developed.

Lattice Dynamics of Ammonium Perchlorate-A group Theoretical Analysis. Using group theoretical technique, symmetry properties of the phonons of NH_4ClO_4 throughout the Brillouin zone are being investigated. This will be helpful in assignment of the phonon frequencies measured by inelastic neutron scattering method. With the known zone-center optic and acoustic phonons by optical technique, lattice dynamical properties will be explored.

Excimeric Properties of Carcinogenic Compounds. Spectroscopic properties of carcinogenic molecules are under investigation with special emphasis on their excimeric properties, energy transfer, binding energies, as well as thermodynamic properties of these molecules. Intense laser beam is being used as a source of excitation and the experimental arrangements are shown in figures. Data analyzation is in progress and more details about it will be announced soon.

Polarized Neutron Spectrometry. In October of 1973 the Technical Committee of the Puerto Rico Nuclear Center approved a proposal for the construction of the polarized neutron spectrometer. The spectrometer is to be built at the Triga-Flip Reactor in Mayagüez as a joint project of the Physics Department of the University of Puerto Rico and P.R.N.C. The construction will require a rehabilitation of the horizontal experimental channel of the Reactor.

This spectrometer will provide an opportunity for research with polarized neutrons, a method which has an inherently high sensitivity. It may be used consequently even when the source of neutrons is of moderate strength. If the high beam polarization of the spectrometer is achieved as anticipated, the competition from the labs having High-Flux Reactors may be partly neutralized.

The instrument basically consists of a standard neutron diffractometer equipment supplemented with the "beam resonance" apparatus. Planned experiments include: several experiments in the field of Magnetism, a new experiment on a ferroelectric sample (P_bTiO_3) and scattering experiments with the materials of potential significance for the Life Sciences.

An old diffractometer obtained some five years ago from the Physics Department of the Brookhaven National Laboratory will be used for the spectrometer. The P.R.N.C. offered to lend the counting electronics for the initial use with the unit. It is hoped that a grant from A.E.C.'s D.B.R. will be approved for this project.

STAFF

Mr. Aurelio Mercado successfully defended his thesis for the M.S. degree, Physics, on May 18, 1973. He worked under the supervision of Dr. Julio A. Gonzalo on "Dielectric and Light Scattering Study of Ferroelectric Triglycine Fluoberillate." Mr. Mercado left to Massachusetts Institute of Technology to continue studies toward his Ph.D. in Oceanography.

Mr. Roberto Amarís, a Colombian student, defended his thesis for the M.S. degree, Chemistry on May 16, 1973. He worked under the supervision of Dr. R. A. Lee on "Radiolysis of Fluoroform." Mr. Amaris returned to Colombia to continue working at the Chemistry Department, University of Antioquia.

Dr. Manuel Gómez, Director of the Physics Department, University of Puerto Rico, Río Piedras, spent the month of June as a guest scientist with the Solid State group of the Nuclear Sciences and Technology Section at Mayagüez. He was doing theoretical work on cooperative phenomena.

Mrs. Josefina A. Rodríguez, graduate student in the UPR Chemistry Department Mayagüez, completed the experimental part of her thesis "Electron Impact Studies of Ortho, Meta, and Para Fluorotoluenes" at PRNC. Dr. Rupert A. Lee is serving as Thesis Advisor.

Dr. J. A. Gonzalo, Head Nuclear Sciences and Technology Section, visited the Brookhaven National Laboratories to discuss results on ferroelectricity and cooperative phenomena with Drs. G. Shirane, D. Cox and B. C. Frazer.

Mr. Gentil Estevez a student from Colombia began his thesis research toward the Master's degree in Physics under Dr. J. A. Gonzalo's supervision. His thesis title is "Equation of State for Liquid Vapor Transitions near T_C.

Dr. R. S. Singh attended two special summer schools at Massachusetts Institute of Technology, one on "Cooperative Phenomena and Phase Transitions" and the other on "Bio-materials."

Dr. Mohyi E. Abu-Zeid, Scientist I (Joint Appointment) was transferred from Health and Safety Division to Nuclear Sciences and Technology Section effective Dec. 1, 1973.

Neutron Diffraction Project

The Neutron Diffraction program at the Puerto Rico Nuclear Center has been concerned with the molecular geometry of Ferroelectric Crystals and their phase transitions. Use is made of thermal neutron scattering instead of the similar x-ray diffraction experiment because the neutrons are able to determine positions of light atoms in the presence of heavier ones since the scattering length of an atom is not directly proportional to atomic number. The neutron interacts with the "point" nucleus of the atom rather than an electron cloud. Thus thermal vibrations and electronic effects are not correlated in the neutron experiment. In addition, radiation damage is not effected by low energy neutrons, a feature which may be critical in such materials as Triglycine sulfate where radiation changes the electrical and thus perhaps structural properties of the crystal.

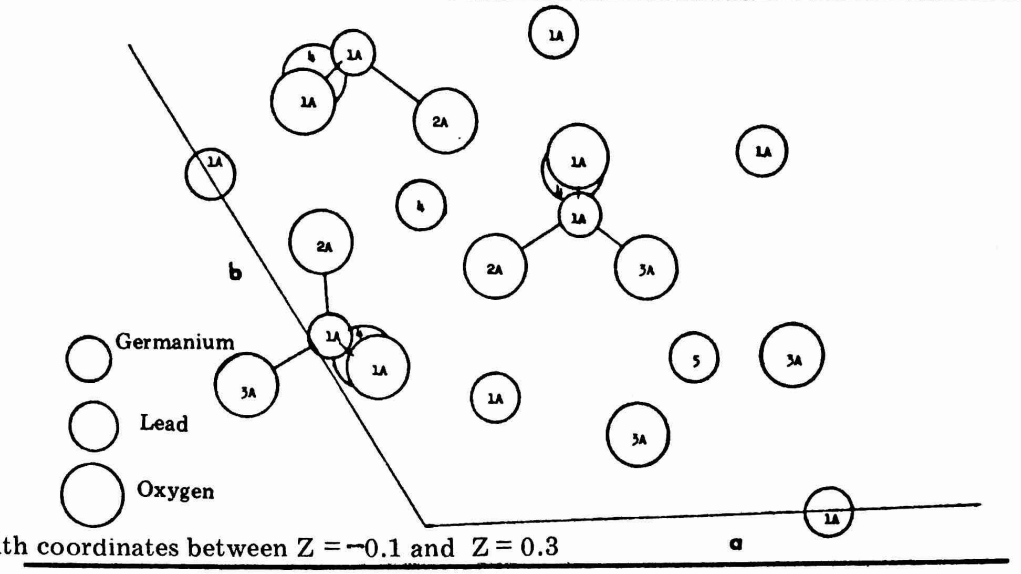
Work is being carried out on Ferroelectric materials to help understand the basic phenomena involved in their transitions, notably the atomic motions that give rise to a spontaneous polarization. These polarizations and the corresponding electrical, mechanical and optical properties have found use as piezoelectric transducers, infrared detectors, optical gates and, in the future, perhaps optical memories.

The project is supported by N.S.F. Grant GH32964.

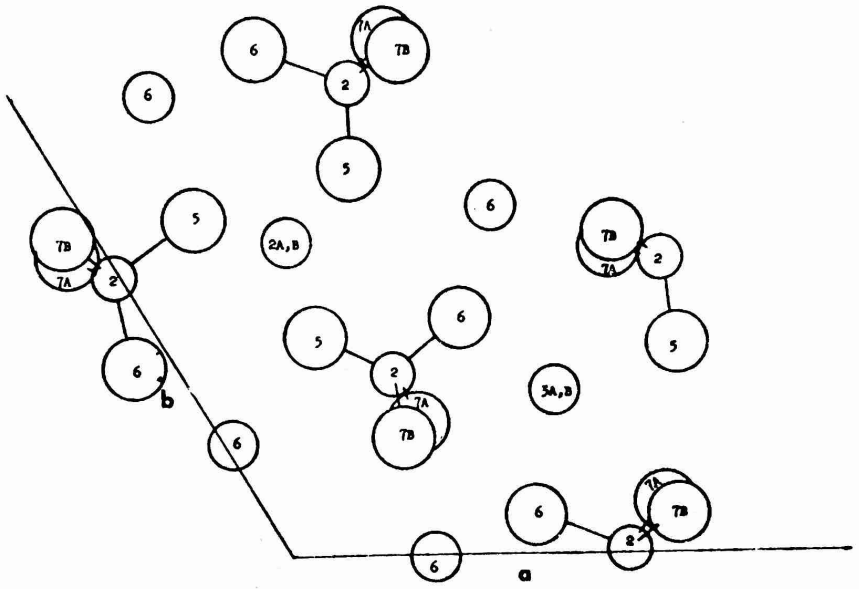
RESEARCH ACTIVITIES

Lead Germinate. Results of crystal structural studies are available on several compounds. $Pb_5Ge_3O_{11}$ has been shown to be optically active, ferroelectric, and enantromorphous at room temperature. The material has possible uses in optical memory systems.
A view of the structure looking down the *c* axis of the Ferroelectric phase is given in Figure 1. Since the *c* axis is 10A the structure has been divided into three parts. Fig. 1a contains all atoms with Z coordinates between −0.1 and 0.3. Fig. 1c contains atoms with Z coordinates between 0.7 and 1.1. Figs. 1a and c show the nasonite layer and Fig. 1b the apatite layer. Pb4, Pb5 and 04 are shown in Figs. 1a and 1c, since they have coordinates very close to Z = 0. The oxygen 4 atom is shared by the two oxygen tetrahedra about Ge1A and Ge1B, forming a Ge_2O_7 group. Superposition of tracings of Fig. 1a and 1c show that the Ge1B tetrahedron is noticieably rotated about a line parallel to *c* through 04, counterclockwise with respect to the group about Ge1A. The projections also show that both tetrahedra are rotated in opposite directions about axes perpendicular to *c*, so that the projection of the shared 04 on to the (001) plane is closer to the Germanium than the 01A or 01B projection.

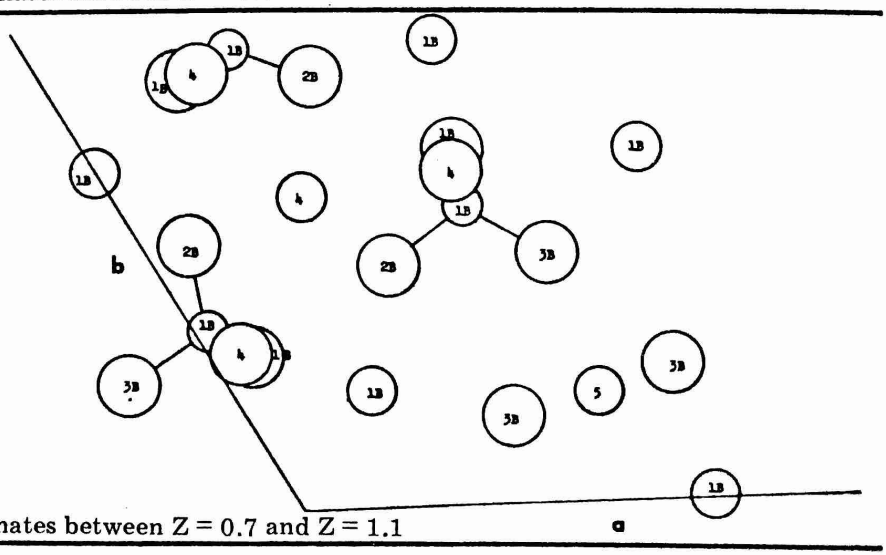
The Pb-O distances and geometry may be compared to results of neutron structures of yellow and red PbO by Kay and Leciejewicz respectively. The Pb-O_4 tetragonal pyramids found in the



(a) Atoms with coordinates between Z = −0.1 and Z = 0.3



(b) Atoms with coordinates between Z = −0.3 and Z = 0.7



(c) Atoms with coordinates between Z = 0.7 and Z = 1.1

Figure 1. View of Lead Germinate looking down *c* axis. Numbers given correspond to atomic labels used in Table 1. All atoms are in three fold symmetry sites except the lead atoms at 1/3, 2/3 and 2/3, 1/3 which are on unitary sites on the three fold axis.

red phase with Pb-0 distances of 2.30A distort in the yellow phase to 2.22 and 2.49A. The pyramidal geometry with lead at the apex probably keeps the Pb^{+2} lone pair electrons away from the near neighbor oxygen atoms. This feature, i.e. maintaining all near oxygen neighbors on one side of the lead in pyramidal geometry, seems to be maintained for most of the lead atoms.

During polarization reversal, the atoms move to an enatiomorphous structure. Those atoms labeled with A and B in Fig. 1, go from $(X_A Y_A Z_A)$ to $(X_B Y_B \bar{Z}_B)$ and from $(X_B Y_B Z_B)$ $(X_A Y_A \bar{Z}_A)$. Those atoms near the quasimirror planes at Z =0.0 and .5 merely cross it, going from XYZ to $XY\bar{Z}$. Thus the collection of atoms at points $(XYZ)_i$ transform to a new collection at $(XY\bar{Z})_i$ which yields a non-superposable mirror image of the first set.

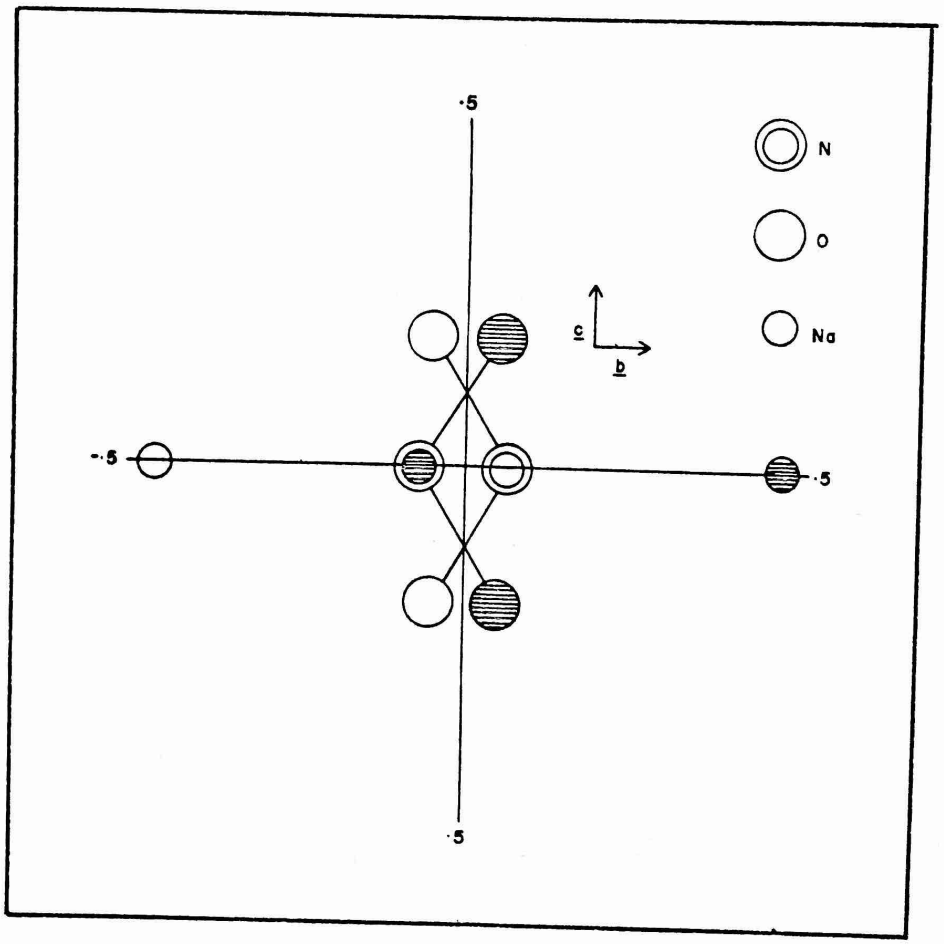


Figure 2. Representation of section of disordered Sodium Nitrite Cell at X = 0. Reverse structure is shaded with horizontal lines. Above the transition temperature the two sets of positions have equal probability of being filled, i.e. there is an average mirror plane at y = 0. Below the transition the proportion of obverse to reverse structure is temperature dependent. At the transition temperature the space group change from Im2m to Immm.

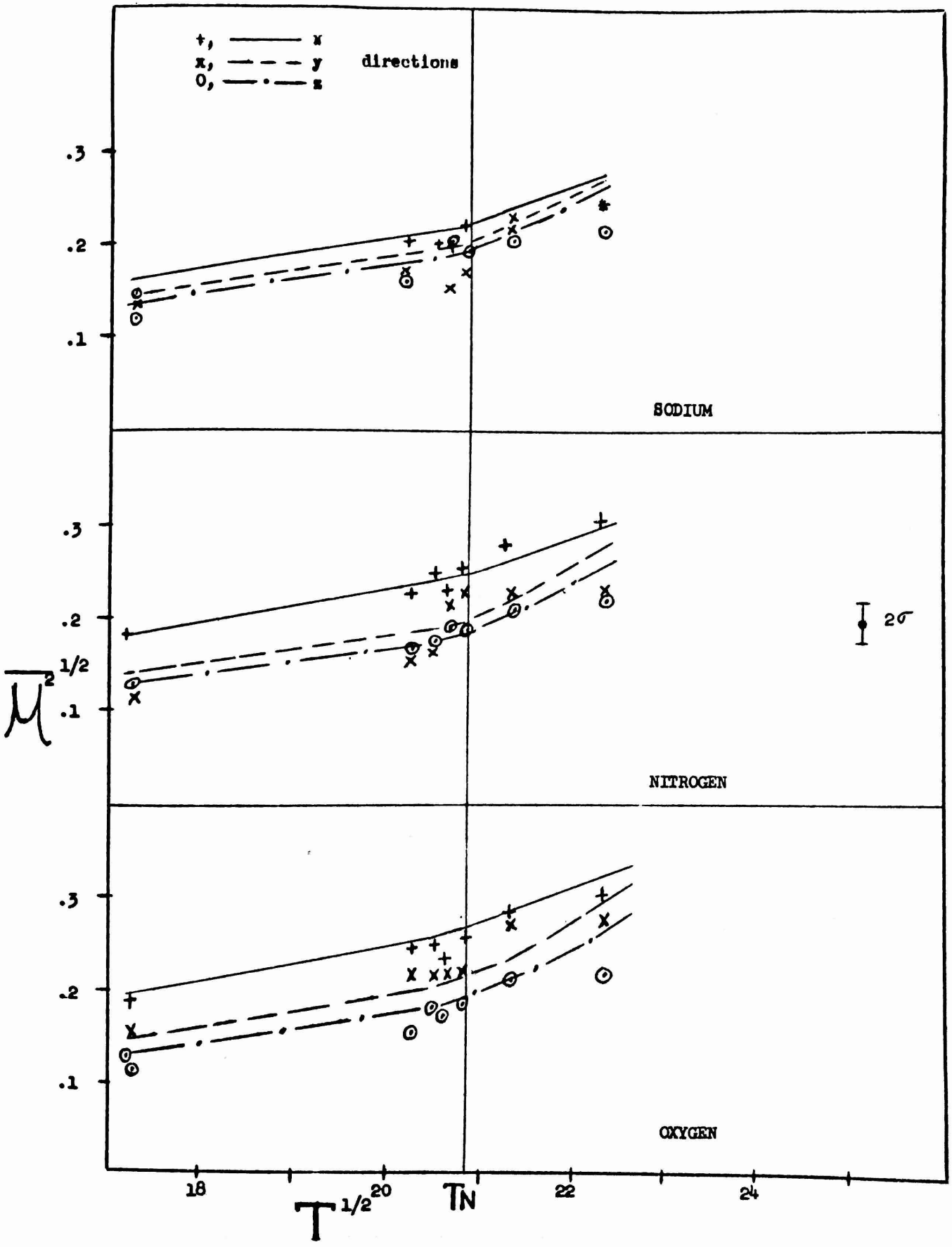


Figure 3. Root mean square amplitudes of vibration plotted vs. $T^{1/2}$ degrees Kelvin. Continuous curves are calculated from spectroscopic frequencies[2,3,5] and elastic compliances as described in text. The points are measured values for each atom in principal directions (Table 3). Data from ref 15, 16 are also included.

Sodium Nitrite. The phase transition mechanism in sodium nitrite has presented a rather elusive problem, with various experiments presenting differing results.

Fig. 2 shows part of the $Na\ NO_2$ unit cell. In the ferroelectric phase at low temperatures the crystal consists of what might be called the obverse (empty circles) or reverse (shaded circles) structures. As the transition temperature is approached more and more of the structure reverses until the long range order parameter, S, reaches about 0.5 (S = 1-2 X, where X is the fraction reversed), at which time the dipoles become sinusoidally distributed in *a* with a temperature dependent period of less than 8 lattice translations, the transition temperature is about 164°.

The distance moved by the various atoms through the transition, ignoring paths, vary from or 0.3 Å for sodium to about 0.7 Å for nitrogen. If a rotational path is presumed, the latter atom is displaced by more than one angstrom. The motions are then about three to five times the normal total rms amplitudes of motion of most atoms, and about 5 to 10 times the rms amplitude of even a single low (100 cm^{-1}) energy mode. The frequency that seems connected with the transition is about two orders of magnitude lower than most optic modes.

Neutron diffraction experiments have been previously carried out by Shibuya et. al. and Kay who seem to find strong indications of rotation about the *c* axis. One of the data sets collected with good precision and temperature control was taken with the crystal at 162° ± 1°; i.e. within 2° of the transition and with a long range order parameter of 0.54. This data provides a quasi-mirror position for the transition. Data were also collected at room temperature to provide amplitudes of motion in the [100] direction that were not previously determined by the two dimensional studies .

Since the above data were collected, a note by Niimura and Muto appeared which would seem to provide unequivocal evidence for *c* axis rotation.

Root mean square amplitudes extracted from the thermal parameters are plotted in Figure 3 vs. the square root of the absolute temperature.

Where appropriate, at elevated temperature several other models were tried. The first considered the nitrite nitrogen atom to be a two dimensional torsional oscillator. Finally a model used previously in which a fraction f_1 of the atoms are in obverse position, a fraction f_2 in reverse, and a fraction f_3 rotating. At 150°, there was no improvement in fit by adding a rotor. At 162° letting 7% of the ions rotate about *c* caused R to drop from 0.032 to 0.030 and the weighted R from 0.046 to 0.044.

Lastly, an effort was made to correlate the amplitudes of motion and their temperature dependence with spectroscopic data.

The amplitudes due to the accoustic modes were calculated from the high temperature approximation to the Debye Waller Factor. Using the lattice dynamical data of Sakurai et.al. a set of sound velocities were estimated from the initial alopes of the accoustic branches.

Up to the transition, Fig. 3 shows that the general slopes and calculated magnitudes are in fair agreement with observations (about as well as can be expected from the very severe approximations noted above). The plotted points in Fig. 3 are experimental and the curves calculated.

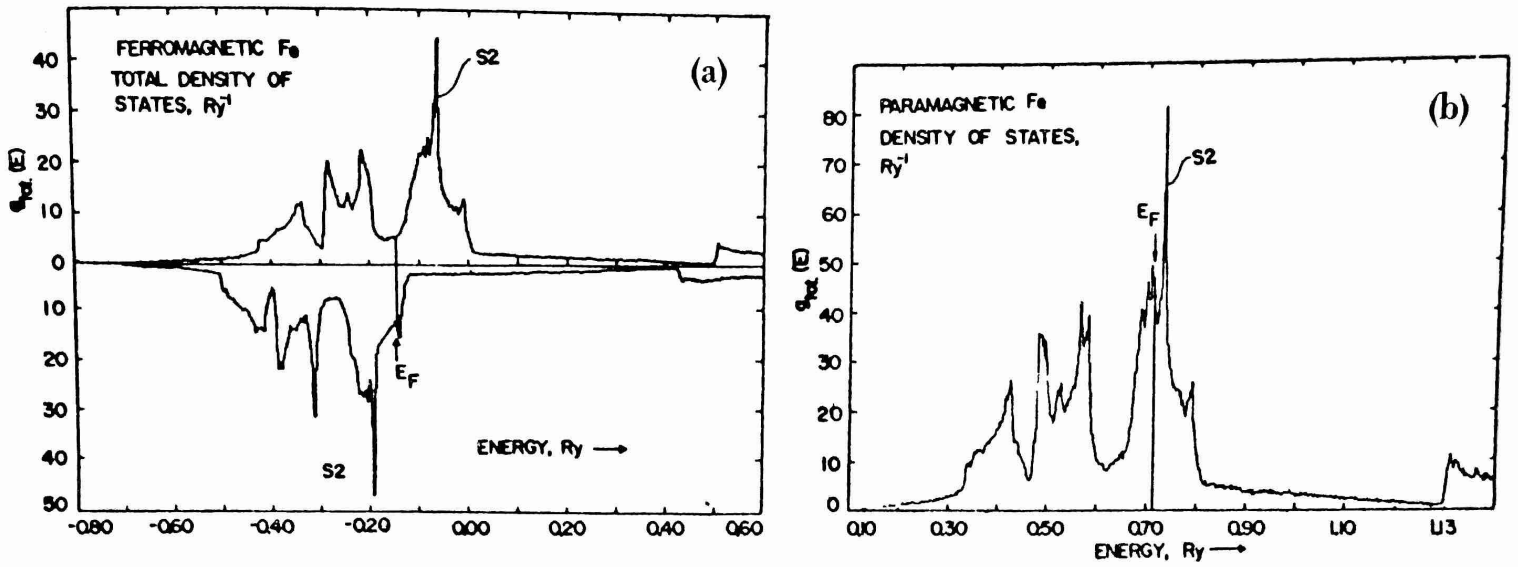


Figure 4. Total density of states for (a) ferromagnetic and (b) paramagnetic iron.

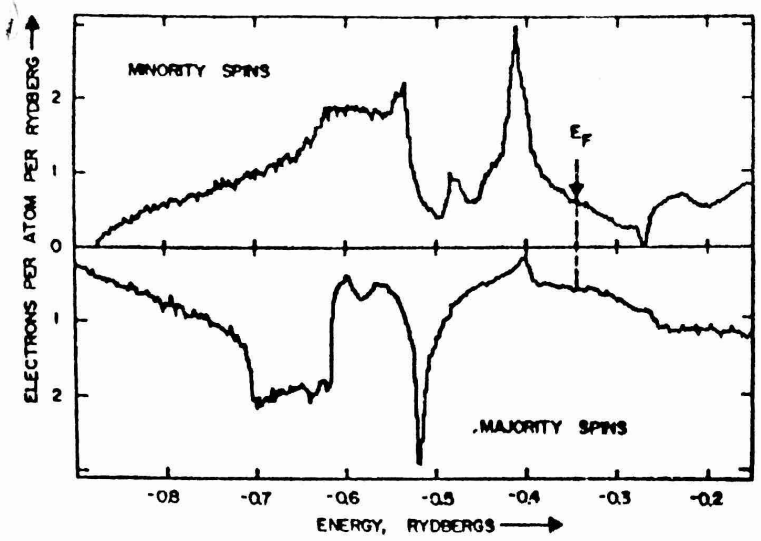


Figure 5. Conduction-electron density of states for ferromagnetic iron.

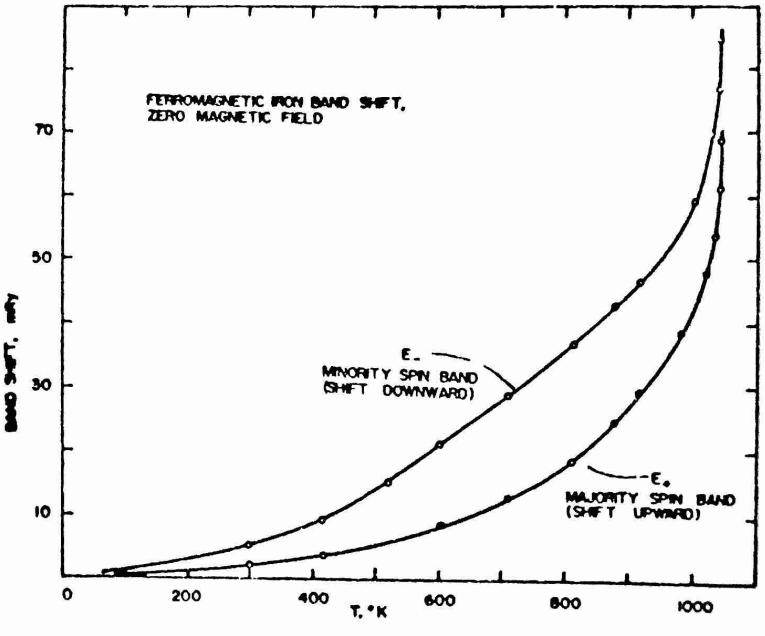


Figure 6. Band shifts with temperature for iron.

Fig. 2 shows a discontinuity of about 20% in the rms amplitude in the y direction for all three atoms in the vicinity of the transition. A probable reason for this discontinuity is the existence of some small "static" displacements or distribution of atoms over a small range of y values due to close approaches of atoms in regions where polarization is reversed.

Some rotation was probably found about the *c* axis in the data reported here. While the improvement in data fit was small, the same result was noted at 155°C. An attempt to include a rotation about *a* led to no improvement in fit at all above or below the transition.

Further evidence for the *c* rotation is found in high compliance in the *a* direction. A small significant increase in N-Na distance with temperature just below the transition is also noted. This could be indicative of an Na-N bond loosening.

Van Hove Singularity in the Iron Density of States. Preston, Hanna and Heberle in 1962 found a small discontinuous increase in the γ-ray energy emitted by an iron nucleus when an iron sample was heated through the Curie point, Tc = 1043°K. This was one of the earliest Mossbauer measurements done on a ferromagnetic substance. The anomally has not yet been properly explained. Attempts to explain the sudden energy shift (isomer shift) of the γ-rays were made from different view points. The shift has been attributed to: 1) the abrupt change in the Debye temperature of iron, 2) the change of the electronic wave functions near Tc, 3) collapse of the spin up and spin down electron energy bands with no singularities included.

However, common to all these theoretical attempts was a failure to explain the pertinent experimental data: the size of the effect and the temperature interval in which it takes place. The differences between the experiment and the best theory was of the order of 10-fold (difference in ΔT, Treves's theory).

Our study of the electronic density of states for metalic iron indicated the presence of a strong Van Hove - like singularity near the Fermi level, S2. It is occupied in the spin up band and empty in the spin down band. When the sample passes through the curie temperature the occupied S2 - singularity abruptly gets depopulated causing the isomer shift jump. Both the size of the effect and the temperature interval ($\Delta T = 0.2°K$) agree with the experiment.

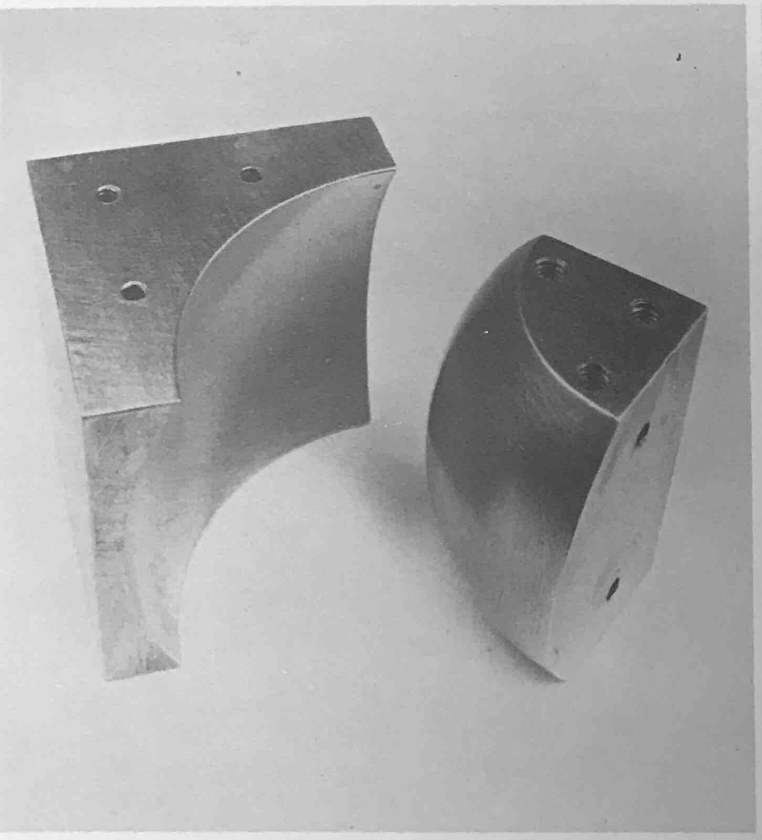
This calculation was possible because we calculated first the density of states for paramagnetic and ferromagnetic phase for Fe as well as the density of states for conduction electrons, Figures 4, 5, 6. To calculate ΔT, the bands were shifted in accordance with the observed temperature dependence of the magnetization, M(T), see the Figure for the calculated shift. A paper was published in *Phys. Rev. Letters*, August 1973 dealing with this problem.

Polarized Scattering. A new experimental idea for the scattering of polarized neutrons by a Ferroelectric crystal has been proposed by us recently. Electrically neutral neutrons interact with the charges in the ferroelectric crystal.via a relativistic interaction which is sufficiently large to be detected and measured. Detailed calculations have been completed showing that new information about the charge density will be possible to obtain this way. The experiment is in the planning stage and the preliminary parts have been carried out at PRNC.

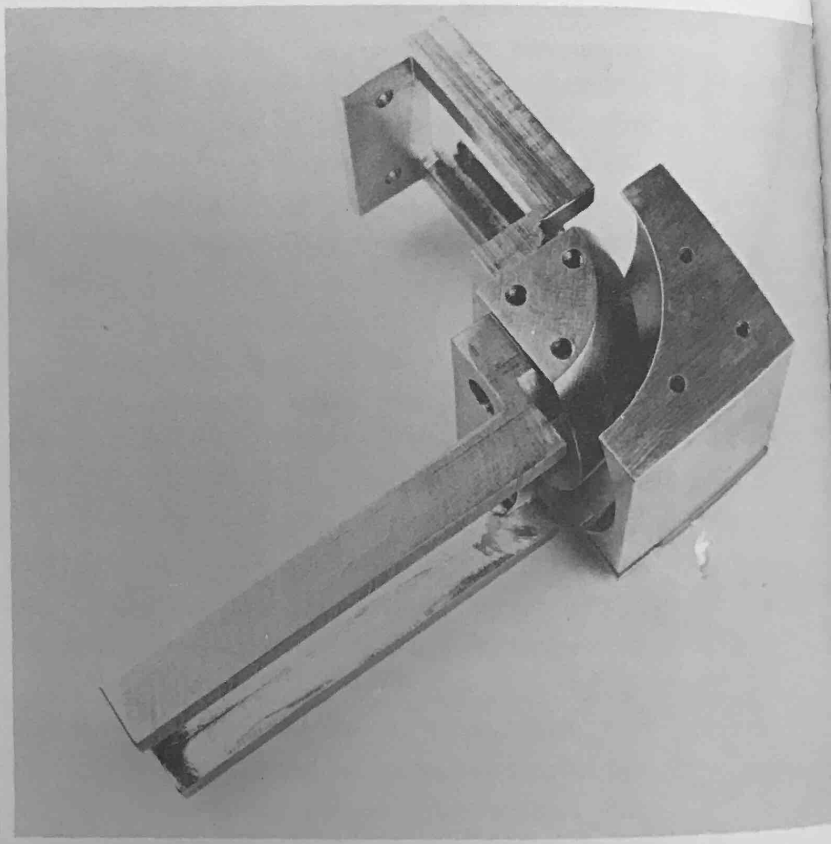
Related Projects. Several projects started at the Argonne National Lab. by Dr. Maglic, were finished in 1973. This includes papers submitted for publication dealing with the specific heat of paramagnetic nickel (*Int. Journal of Magnetism*, accepted) and a paper on the Polarized Neutron Study of the powdered samples of Uranium-Phosphorus system (submitted to the *Physical Review*). The first paper was done in collaboration with Drs. G. S. Knapp and R. J. Jones, both from A.N.L. The second was a collaboration with a group from England.

A polarized neutron spectrometer is being designed and constructed by Dr. R. Maglic under U.P.R. and A.E.C. auspices and support.

Studies will be carried out, mainly as part of the U.P.R. education and research program.



Concave and convex spherical 90° sections of Electron Energy Analyzer.



Electron Energy Analyzer assembly.

Hot Atom and Radiation Chemistry Project

This program provides short research topics to Latin American and Puerto Rican students working towards their M.S. degree. Since the program is a sub-section of the Nuclear Science and Technology Section of the Nuclear Applications Division, a full description of its educational aspects have been reported under that divisional report. All the work concerning Drs. Lee and Delsanto belong to this program.

RESEARCH ACTIVITIES

Theoretical Studies. The object of this investigation is to evaluate molecular excitation and ionization yields of high energy radiation e.g. 1 Mev electrons in a simple (e.g. diatomic) gas. A calculation of this kind has been performed for water vapour by I. Santar and J. Bednar (Institute of Nucl. Research, Czechoslovak Academy of Science, Prague). They have used the so called "optical approximation" i.e. a simplified treatment based on the first order Born Approximation (Bethe formula). They have further simplified their treatment introducing phenomenologically into their formulas the spectral density of the oscillator strength $\frac{df(E)}{dE}$ obtained experimentally by previous researchers.

The present work consists of an evaluation of G_{exc} and G_{ion} directly from the Bethe formula, without unnecessary simplifications. In addition the oscillator strength is being evaluated theoretically both because it is desireable to have a more "a priori" treatment and because, sufficient experimental data for the oscillator strength often do not exist (as is the case for the hydrogen halide molecules in which we are mostly interested). Work is also in progress towards an even more meaningful way of calculating G_{exc} and G_{ion} based on a method recently derived and successfully applied* to the calculation of photonuclear reactions. These preliminary calculations have shown the practicability of the New Method. In fact it requires relatively little computer time and at the same time it is a very flexible technique, easily adaptable to more sophisticated or different problems.

An application of the New Method to the problem of calculating G_{exc} and G_{ion} is in progress and a detailed report will be presented at the 5th International Congress of Radiation Research.

Primary Processes in Radiation Chemistry. Electron Impact Excitation.

1. The construction of the electron spectrometer is essentially complete and assembly of available parts has begun. The vacuum chamber which will house the spectrometer has

*R. F. Barrett, P. P. Delsanto: A New Treatment of the One Particle Continuum in Nuclear Reaction Theory. Submitted to *Physical Review C.*

been tested for leaks and a suitable vacuum (about $3x10^{-1}$ torr) has been obtained.

The enclosed pictures show the spherical surfaces which make up the electron monochromator. The first picture shows the two spherical sections unmounted. The spherical radius of the concave surface is 1.125" and the radio of the convex surface is 0.875". The second picture shows the spherical sections assembled to form the electron deflector which will serve as monochromator in the electron spectrometer. The two pieces are mounted on a square metal plate, but are insulated electrically from the plate by kel-F spacers (not visible in the picture). The two tracts bolted to the convex piece are lens racks used for mounting cylindrical electrostatic lenses.

2. With the monochromator and a special collision chamber, the first experiment to be done will be that of photon emission by electron impact. the following two systems are to be studied first:

$$e + N_2 \rightarrow e + N_2^* \rightarrow e + N_2 + Hr$$

$$e + HCl \rightarrow e + HC1^* \rightarrow e + HCl + hr$$

The dependence on electron kinetic energy of the emitted photon intensity will be of particular interest in this study in determining the characters of the molecular energy levels involved, as well as cascading mechanisms following the initial excitation by electron impact.

3. After the above experiments are concluded the energy analyzer will be added to the spectrometer to carry out the measurements of energy-loss spectra of electrons in collision with hydrogen halide molecules, and scattered through 0° and 90° with respect to their initial direction of motion. These experiments are of a broader scope than the first set of experiments, since they will provide capacity to observe excitation to energy levels whose existence cannot be verified by photonic emission.

4. A theoretical calculation[2] has been carried out and preliminary results were reported at the last meeting of the American Physical Society. In this work the cross section for vibrational excitation of H_2 by proton impact has been calculated with a Gaussian pulse representation of the transition matrix element for the collision. The gaussian pulses were fitted to the matrix elements obtained from the ground state potential surface of H_3^+. Good agreement was obtained with experimental results. Further work on interpretation of these results in the light of the existence of competing processes (e.g., Multiquantum vibrational transitions and curve crossing to excited H_3^+ states) is being done at the moment. However, the preliminary results suggest that the principal feature giving rise to the observed experimental results[3] is the predominance of the transition matrix element at distances ranging from 1 to 3 Å between the proton and the H_2 molecule.

Radiolysis of Pectinic Acid. Pectinic acid is a linear polymer of partially methylated polygalacturonic acid residues held in glycosidic linkages. The primary effect of ionizing radiations is to cause cleavage of the 1,4-glycosidic linkage resulting in depolymerization and liberation of a carbonyl group. While demethylation is not caused by radiation, initial degree of methylation does seem to influence depolymerization indirectly by the α-β-transelimination mechanism. Also slight demethylation caused by pectic enzymes and treatment with bivalent ions tend to reduce depolymerization. This appears to be

caused by the inhibition of the free radicals in gel consistency. To study these effects, pectinic acid solutions were demethylated and treated with 0.01m $Cacl_2$ and 1.0M $Cacl_2$. These gels formed by ionic bonding were exposed to 25, 50 and 100 kilorads. The unirradiated solutions served as controls. The gels were treated with ion exchange resins to remove calcium chloride, and the pectic constituents were precipitated from the solutions with 4 volumes of alcohol, dried in a vacuum oven and pulverized. The number average ($\bar{M}n$) and weight average molecular weights ($\bar{M}w$) were deduced from end group analyses and intrinsic viscosities of the reprecipitated solutions. The methoxy content were determined by saponification, distillation of methyl alcohol, its oxidation to formaldehyde and reaction with 4,5-dihydroxy-2,7 naphthalene disulfonic acid. Attempts were also made to fractionate the degradation products by molecular sieve chromatography with cross linked dextran gels but these are not conclusive. The results indicate that the molecular weight ($\bar{M}w$) of the control solution is 5.6×10^4 and fter irradiation it is reduced to 2.64×10^4. The methoxy content and the total uronide contents remained almost the same, meaning thereby that neither the glycosidic ring is broken nor does demethylation occur.

Isolation of the degradation products by molecular sieving will be continued to study molecular weight distribution ($\bar{M}n/\bar{M}w$). The protective action of the gel consistency will be verified by comparing the migration behaviour of the free radicals in sols and gels by electron spin resonance spectroscopy. To study the kinetics of depolymerization by the -α-β-transelimination mechanism, the free carbonyl groups would be labelled C^{14} by Kiliani synthesis and the radioactivity will be correlated with the degree of unsaturation which accompanies degradation by this mode.

Radiolysis of Aqueous Methionine and Ethionine Solutions. Deaerated 0.1M aqueous solutions of methionine and ethionine in 10 ml quantities have been irradiated with ^{60}Co gammas. The $G(H_2)$ values for both the methionine and ethionine solutions are the same (o.34). The dose rate used in these experiments was 0.590×10^{17} ev/ml/min.

The methionine solutions gave two products which were observed from paper chromatography analysis to be homocysteine and α-aminobutyric acid. The G values of those products were 0.14 and 0.24. These were obtained by adding labelled C^{14} methionine before irradiation, then counting the two radioactive spots in the chromatogram.

Essentially the same procedure as above is being used for the ethionine solutions. Again two products were obtained from the paper chromatography. The C^{14} study is presently being carried out.

Radiolysis of Aqueous Solutions of $Co(en)_2F_2^+$Ion. Aqueous solutions of $CisCo(en)_2F_2NO_3$ (0.01M) have been irradiated with ^{60}Co gammas. By measuring the optical density at 500mμ using a Cary 14 spectrophotometer it was observed that the G(-M) value decreased with the time of irradiation. The cis compound did not isomerize to the trans compound. In acid solutions the G(-M) again decreased with dose but on the whole these values were lower than in the previous experiments.

In the case of trans $Co(en)_2F_2NO_3$ solutions it was observed that the trans form produced the cis configuration. The G(cis) value increased with dose. Thin layer chromatography

and electrophoresis are being used to try and identify the other products of the radiolytic decomposition.

STAFF

Dr. R. A. Lee organized the 7th Caribbean Chemical Symposium. This was sponsored by the Chemistry Department, UPR-Mayagüez. Over 100 chemists attended from countries in the Caribbean area, South America, Canada, U.K. and continental U.S. There was a special session devoted to Radiation Chemistry.

During the summer Dr. Lee spent two months at University Chemical Laboratory, University of Cambridge, England, with Professor Jack Lewis. There he carried out some preliminary studies on the effects of radiation on some Ruthenium carbonyls.

NUCLEAR APPLICATIONS

Nuclear Engineering Section

The Nuclear Engineering Section is engaged in both teaching and research. Section staff members teach graduate courses at the University of Puerto Rico and direct the thesis work of nuclear engineering students. They conduct research on their own projects and also assist the staff of other PRNC divisions as the need arises.

TRAINING ACTIVITIES

Scientists on the staff of the Nuclear Engineering Section all hold joint appointments at PRNC and UPR. The faculty of the Nuclear Engineering Department of UPR is composed of such staff members. The Head of the PRNC Nuclear Engineering Section is also the Chairman of the UPR Nuclear Engineering Department. The Section provides the classrooms, offices, laboratories, and equipment and most of the administrative personnel required for the education and training of the graduate students at the UPR Nuclear Engineering Department.

Special Courses. Short courses varying in length from one week to three months covering a variety of topics related to nuclear engineering are offered approximately once a year for scientists, engineers and others who have an interest or need for knowledge in the nuclear field.

During the first week in June a one-week Summer Workshop on "The Risks and Benefits of Electrical Power Generation in Puerto Rico", carrying one hour of academic credit, was offered for high school science teachers. This workshop was jointly sponsored by the United States Atomic Energy Commission, the Puerto Rico Nuclear Center, the Mayagüez Campus of the University of Puerto Rico, and the Puerto Rico Water Resources Authority. The purpose of the workshop was to provide secondary science teachers with sufficient background to enable them to guide their students and communities towards a more factual and less emotional consideration of the risks and the benefits of electrical power generation in Puerto Rico

Thirty four (34) participants from 17 cities and towns throughout Puerto Rico attended the workshop.

Master of Science Degree Program. UPR, in close cooperation with the PRNC Nuclear Engineering Section, offers a Master of Science degree in Nuclear Engineering. Students with a B.S. in Engineering and a grade average above a prescribed minimum are eligible for the M.S. program. Requirements for the M.S. degree include 30 credit hours of graduate course work, a thesis, and a final oral examination.

During 1973 a total of 19 graduate students were enrolled in the Master of Science degree program in Nuclear Engineering. As is shown in Table 1, six of these students graduated with the M.S. degree in Nuclear Engineering in May 1973, six students are now primarily engaged in thesis research, most of whom are expected to graduate in May 1974, and the remaining seven are taking a full load of academic course work.

The topics of the twelve thesis projects in which Nuclear Engineering students were conducting research during 1973 are listed in Table 2. Six of these projects were completed by the six students who graduated in 1973.

Table 1
Summary of Student Progress in the Master of Science Degree Program in Nuclear Engineering During 1973

Name	Citizenship
Awarded M.S. Degree	
Alcaraz, Juan R.	U.S.
Arenas Rosillo, G.	Colombia
Griffin, Luciano	Venezuela
Kuppusamy, N.	India
Rodrĩguez, T.	U.S.
Rosado Meléndez, M.	U.S.
Primarily Engaged in Thesis Research	
Lebrón, D.	U.S.
Lingappan, K.	India
López Sullivan, P.	U.S.
Michelen, J.	Dominican Republic
Musalem, A.	Dominican Republic
Ufret, R.	U.S.
Primarily Engaged in Course Work	
Andreu, C.	U.S.
Cajigas, J.	U.S.
Chellappan, S.	India
Carrero, D.	U.S.
González, A.	U.S.
Pérez, R.	U.S.
Reyes, L.	U.S.

Graduate Courses. The staff of the Division taught 9 semester length graduate courses in Nuclear Engineering and one undergraduate course, exclusive of the Summer Workshop discussed above under "Special Courses." The courses, professors and number of students in these courses are shown in Table 3.

Table 2

Student Thesis Research Projects

Student		Title of Thesis	Major Professor
Alcaraz, Juan R.	*	Experimental Determination of Thermal Neutron Diffusion Length of Water as a Function of Temperature Using (n, γ) Reactions	H. Plaza
Arenas Rosillo, G.	*	Gas Stopping Power Measurements for Alpha Particles.	E. Ortiz
Griffin, Luciano	*	Experimental Determination of the Gamma Dose Absorbed into a Cylindrical Calorimeter.	A. Gileadi
Kuppusamy, N.	*	Computer Aided Decomposition of Gamma Spectra Emitted by Mixtures of Certain Radioactive Nuclides.	A. Gileadi
Lebrón, D.		Natural Radiation Exposures in Puerto Rico.	A. Gileadi
Lingappan, K.		Determination of the Concentration of Trace Elements in Some Foods in Puerto Rico Using Instrumental Neutron Activation Analysis.	H. Plaza
López Sullivan P.		Applicability of the Activity Ratio Technique for the Determination of Various Nuclear Parameters.	D. Sasscer
Michelen, J.		A Technique for Measuring Gas Stopping Power of Alpha Particles Using Two Solid State Detectors.	E. Ortiz
Musalem, A.		Computation of Operating History and Cooling Time Dependent Fission Product Inventories, Related Radiation Levels and Thermal Effects.	A. Gileadi
Rodrĭguez, T.		Thermal Neutron Flux Measurements for the Triga-Flip Reactor of Puerto Rico Nuclear Center.	K. Pedersen

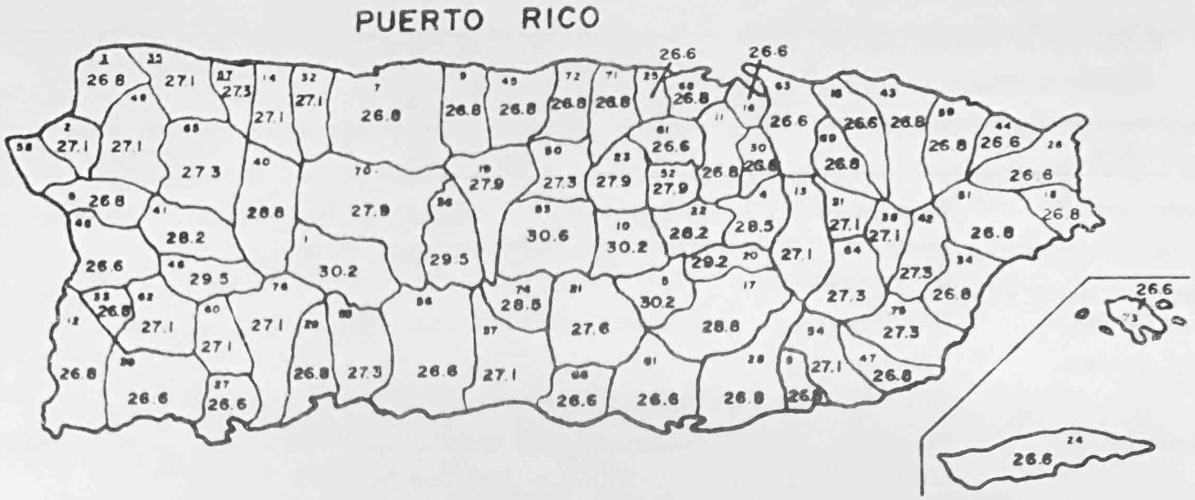
* Completed

Table 3

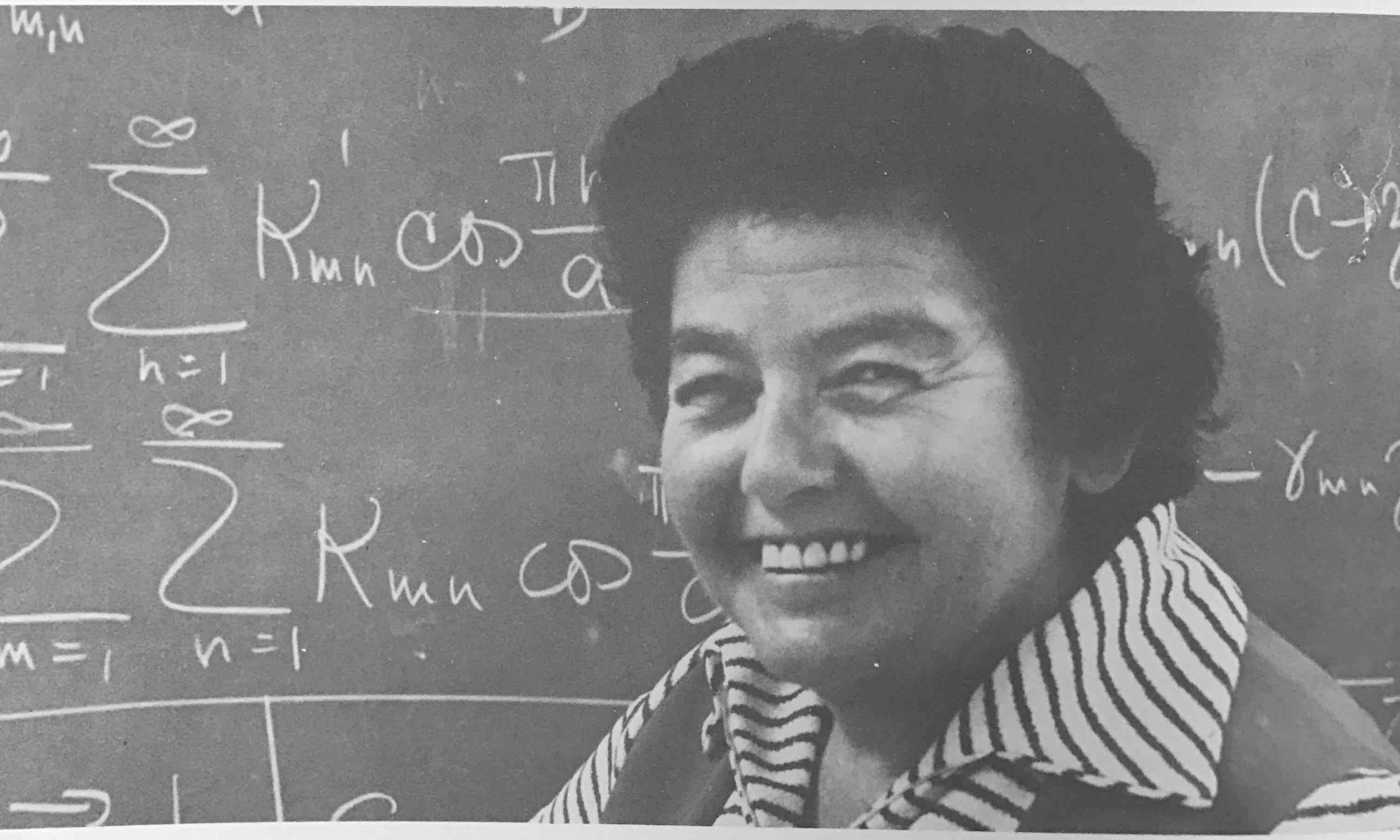
Graduate Courses Taught by Nuclear Engineering Staff

Course	No. of Students	Professor
Elements of Nuclear Engineering	7	D. S. Sasscer
Mathematics of Modern Science I	7	A. E. Gileadi
Reactor Theory	7	A. E. Gileadi
Nuclear Measurement & Instrumentation	7	H. Plaza
Advanced Reactor Theory	5	K. Pedersen
Mathematics of Modern Science II	5	A. E. Gileadi
Nuclear Reactor Technology II	6	H. Plaza
Reactor Laboratory	6	H. Plaza
Seminar	5	Staff
Risks and Benefits of Electrical Power Generation in Puerto Rico	34	Staff

Figure 1. Cosmic radiation dose equivalent rate for each municipality in Puerto Rico (mrem / year per person)



1 ADJUNTAS
2 AGUADA
3 AGUADILLA
4 AGUAS BUENAS
5 AIBONITO
6 AÑASCO
7 ARECIBO
8 ARROYO
9 BARCELONETA
10 BARRANQUITAS
11 BAYAMON
12 CABO ROJO
13 CAGUAS
14 CAMUY
15 CAROLINA
16 CATAÑO
17 CAYEY
18 CEIBA
19 CIALES
20 CIDRA
21 COAMO
22 COMERIO
23 COROZAL
24 CULEBRA
25 DORADO
26 FAJARDO
27 GUANICA
28 GUAYAMA
29 GUAYANILLA
30 GUAYNABO
31 GURABO
32 HATILLO
33 HORMIGUEROS
34 HUMACAO
35 ISABELA
36 JAYUYA
37 JUANA DIAZ
38 JUNCOS
39 LAJAS
40 LARES
41 LAS MARIAS
42 LAS PIEDRAS
43 LOIZA
44 LUQUILLO
45 MANATI
46 MARICAO
47 MAUNABO
48 MAYAGUEZ
49 MOCA
50 MOROVIS
51 NAGUABO
52 NARANJITO
53 OROCOVIS
54 PATILLAS
55 PEÑUELAS
56 PONCE
57 QUEBRADILLAS
58 RINCON
59 RIO PIEDRAS
60 SABANA GRANDE
61 SALINAS
62 SAN GERMAN
63 SAN JUAN
64 SAN LORENZO
65 SAN SEBASTIAN
66 SANTA ISABEL
67 TOA ALTA
68 TOA BAJA
69 TRUJILLO ALTO
70 UTUADO
71 VEGA ALTA
72 VEGA BAJA
73 VIEQUES
74 VILLALBA
75 YABUCOA
76 YAUCO



Advanced Engineering mathematics class conducted by Dr. A. E. Gileadi as part of Nuclear Engineering Masters Program

RESEARCH IN PROGRESS

Exposure to Natural Background Radiation in Puerto Rico — A. E. Gileadi and D. Lebrón. Population exposure to natural background radiation in Puerto Rico is evaluated as a function of geographic location, elevation, and magnetic latitude. Estimates of the mean cosmic radiation dose equivalent rate for each municipality in Puerto Rico were made. These estimates were obtained on the basis of the distribution of population with elevation in Puerto Rico and published cosmic radiation literature and data. These results will be used, with data on terrestrial radiation and living habits, to estimate by means of a computer code the dose equivalent per person per year due to natural background in Puerto Rico; and this will be checked with CoF_2 (Dy)-TLD dosimetry.

Computerized Fission Product Inventory System — A. E. Gileadi and A. Musalem. A computer code, that calculates data required for the environmental assessment and safety evaluation of nuclear reactors, has been developed and is now operative on the University of Puerto Rico PDP-10 computer. For a given reactor with a given operating history and a given cooling time, the code furnishes, among others, the following: (a) fission product number, densities, and activities, (b) beta and gamma radiation levels, (c) energy distribution of fission product gammas, and (d) rate of decay heat generation.

A sample of preliminary results is presented in Figure 1 which shows the nuclear density build up of the fission products Selenium-85, Bromine-85 and Krypton-85 as a function of time after startup of a cold, clean PRNC, TRIGA FLIP reactor when the thermal neutron flux is 5×10^{12} neutrons/cm^2-sec.

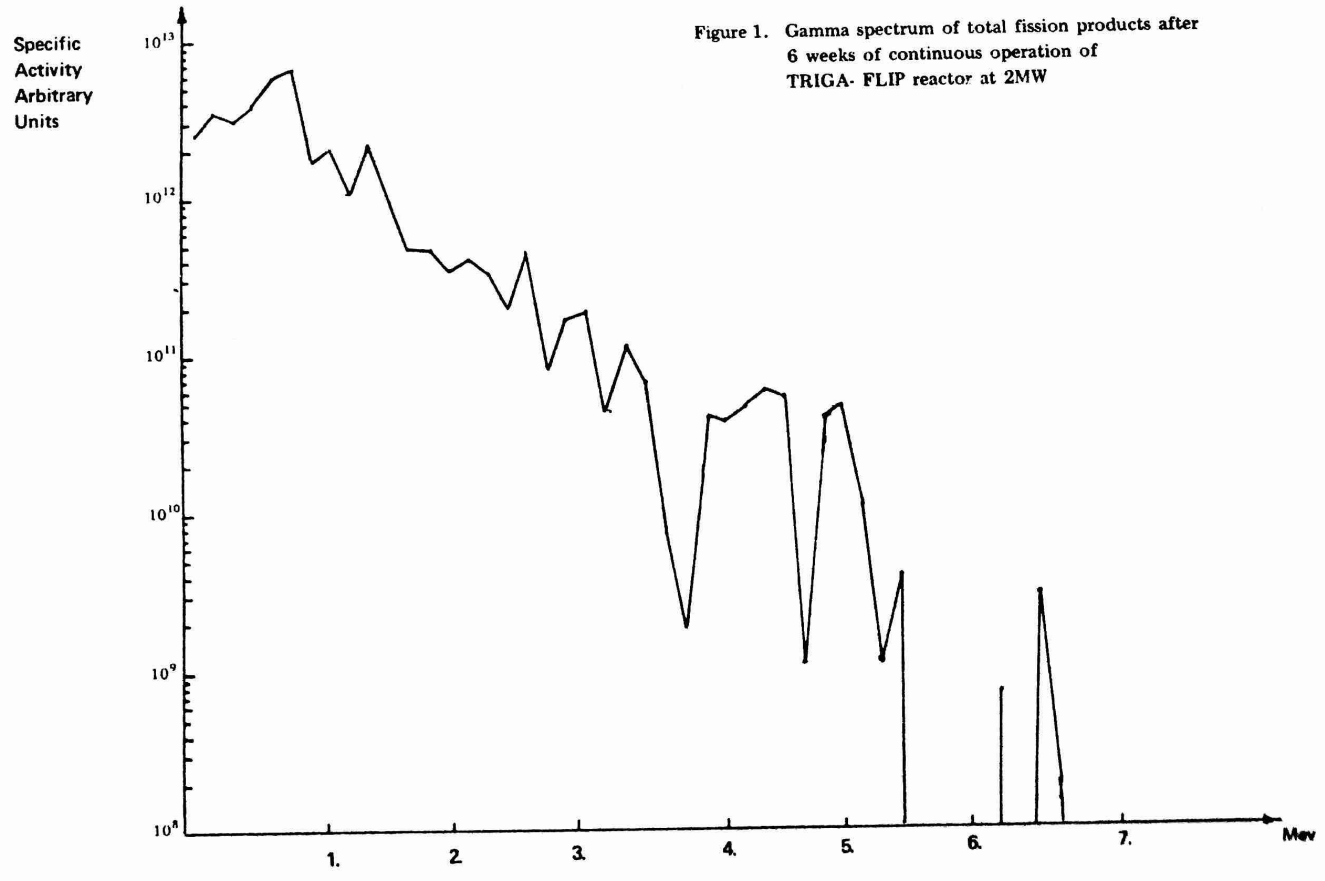
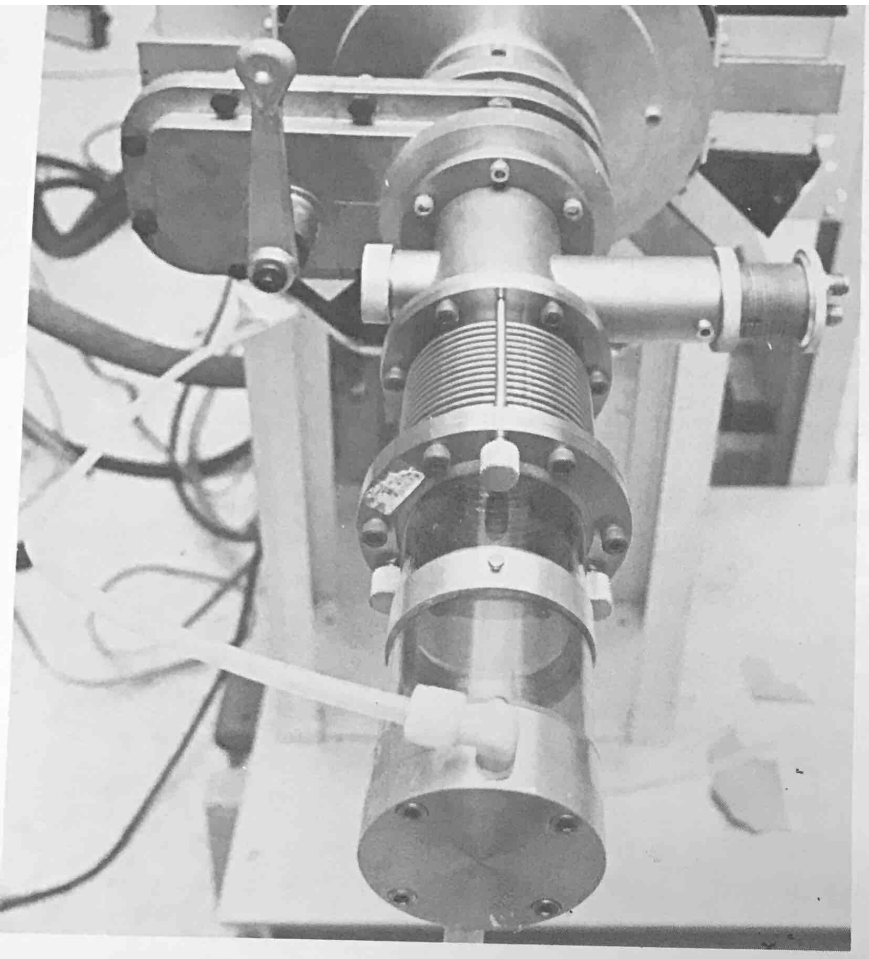
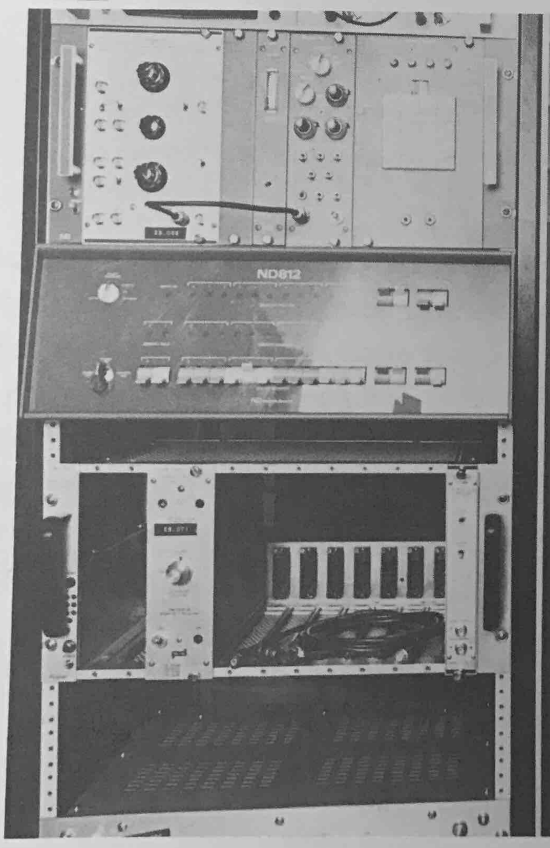


Figure 1. Gamma spectrum of total fission products after 6 weeks of continuous operation of TRIGA- FLIP reactor at 2MW



14 MeV Neutron Generator installed at the Puerto Rico Nuclear Center.

Graduate student changing a sample to be counted at the high resolution, GeLi detector equipped, Multichannel Analyzer of the Nuclear Engineering Division.



A Technique for Measuring Gas Stopping Power of Alpha Particles Using Two Solid State Detectors — E. Ortiz and J. Michelen. A method for measuring the stopping cross section for alpha particles from Am^{241} in the range from 1-5 Mev in the following gases: Air, O_2, N_2, CO_2, N_2O, C_3Ho, C_2Ho, C_2H_o, CH_4, C_2H_4, CCl_2F_2, CF_4 was developed by using two solid state detectors and varying the distance from the source to the detectors as well as the pressure in the chamber.

The variation of the stopping cross section for alpha particles in CF_4, C_3H_8, C_2H_6 and CH_4 is shown in Figure 2.

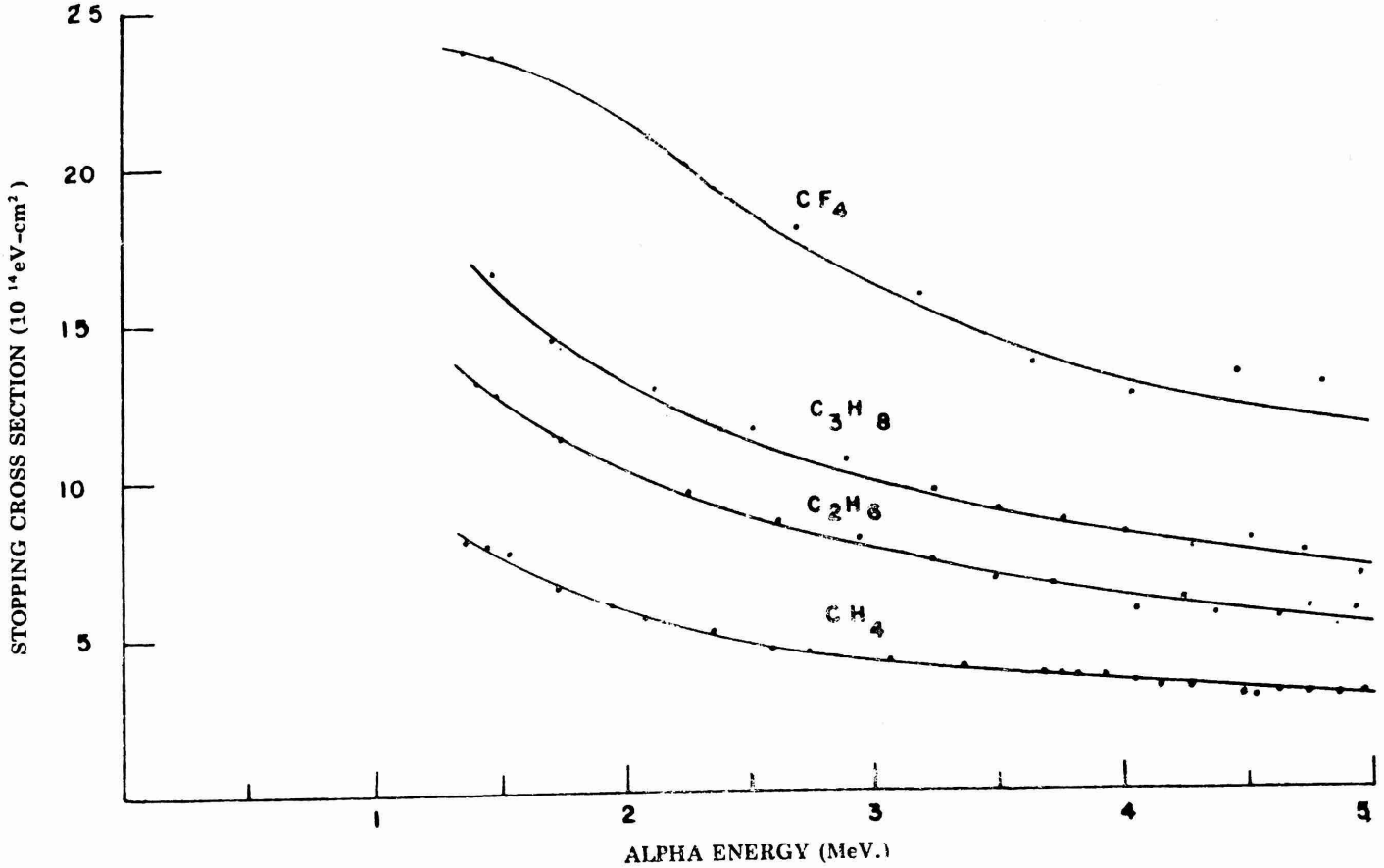


Figure 2. Stopping Cross Sections of CF_4, C_3H_8, C_2H_6 and CH_4 for alpha particles.

Mercury, Arsenic, Cadmium and Cobalt Determination in the Average Puerto Rican Diet Using Instrumental Neutron Activation Analysis — H. Plaza and K. Lingappan. The mercury, arsenic, cadmium and cobalt concentrations in foods that represent major parts of the typical Puerto Rican diet were determined by using instrumental neutron activation analysis (INAA). Daily intake of these elements was estimated for an average diet. These results shown in Table 4 indicate that the concentration level of arsenic is well below the tolerance level in all of the foods analyzed and that the average daily cobalt consumption from the diet is very low compared to cobalt consumption reported for Japan and the United States.

Daily mercury intake from the diet, however, is almost twice that of the provisional tolerable value set by Joint FAO/WHO Expert Committee on Food Additives (1972) and

the daily intake of cadmium is also above the value specified by WHO and high compared to other parts of the world. Fresh milk alone contributes more than 40% of the total daily intake of mercury and cadmium.

Table 4
Estimated Daily Intake of Mercury, Arsenic, Cadmium and Cobalt in the Average Puerto Rican Diet.
(All values in micrograms)

Foods	Mercury	Arsenic	Cadmium	Cobalt
Fresh milk	31.3	60.6	115.1	1.3
Evaporated milk	5.6	2.3	- - - -	- - -
Potatoes	4.0	4.6	46.1	6.0
Rice	11.4	11.5	24.7	- - -
Wheat	3.8	1.3	8.0	- - -
Beans	5.4	11.3	10.0	6.5
Tomato sauce	2.4	0.9	15.5	0.5
Coffee	2.8	0.8	12.2	3.7
Eggs	2.4	0.5	11.8	0.1
Corn meal	0.2	0.1	0.6	- - -
Beer	1.0	13.4	22.2	0.4
Orange	1.0	0.6	6.5	1.1
Codfish	4.6	2.9	4.0	0.1
Sugar	0.1	0.2	- - - -	0.7
Total Daily Intake	76.2	111.0	281.7	20.4

Table 5
Flux Values at Full Power (1200 Kw) Obtained by the Activity Ratio Technique with Dysprosium and The Coincidence Counting Technique with Gold.

Dysprosium Samples	Time in Reactor in seconds	Flux $\frac{d}{o}^{n}$ / cm^2--sec
1	3600	6.36×10^{12}
2	3600	7.81×10^{12}
3	8990	6.26×10^{12}
4	7200	4.80×10^{12}
Gold Samples		
1 A	900	6.72×10^{12}
1 B	900	6.81×10^{12}
2	900	$6,69 \times 10^{12}$

Applicability of an Activity Ratio Technique for the Determination of Absolute Thermal Neutron Flux — D. S. Sasscer and P. López Sullivan. An investigation is being made to determine if the absolute thermal neutron flux can be obtained from the ratio of the activities of the consecutively produced radioisotopes of the 28 percent abundant stable isotope, dysprosium-164.

The absolute thermal neutron flux was determined at a location in the pool of the PRNC reactor approximately 3 inches from the core by the method under investigation and by the gold foil method. Table 5 presents these results as a function of irradiation time of dysprosium. The flux predicted by the consecutive isotope method appears to be in substantial agreement with that predicted by the gold foil method; however, to date, a greater uncertainty appears in the flux determined by the dysprosium method. Continued work is necessary to determine if the uncertainty in the consecutive isotope method is due to experimental error or is inherent with the method.

RESEARCH COMPLETED

Experimental Determination of Absorbed Gamma Doses in Lead Cylinders — A.E. Gileadi and Luciano Griffin. The effect of gamma heating has been studied exposing a set of lead cylinders to (a) Gamma rays emitted by a cobalt-60 source of approximately 7000 curies source strength (b) the gamma field existing inside the thermal column of the RV-1 reactor (Reactor Venezolano-1), and measuring the resulting temperature distribution with respect to time and space.

The results of direct dosimetry executed with lead cylinders of various sizes exposed to Co-60 gamma rays are shown in Table 6. As may be seen from the results the absorbed dose rate per unit of mass increases with decreasing volume of the cylinder, due primarily to the self shielding effect of lead.

Computer Aided Decomposition of Gamma Spectra Emitted by Certain Radioactive Nuclides — A. E. Gileadi and N. Kuppusamy. A computer code PRGA, written in FORTRAN IV, has been developed in order to perform decomposition of certain gamma spectra obtained by means of a Ge(Li) diode equipped multichannel data acquisition system. The code uses spectra of the individual standards and those of the mixtures as input data and calculates the mixing factors pertinent to each component, using linear least squares fit techniques. PRGA is presently operative on the PDP-DEC-10 computer at the Computer Center of the University of Puerto Rico, Mayagüez Campus. Table 7 shows a comparison between mixing factors determined experimentally and by the PRGA code. Discrpancies are well within the boundaries of those published for similar methods.

Table 6
Dose Ratio, Dose Ratio by Unit of Mass, Heat Transfer Coefficient by Convection Determined From the Experimental Data

Absorbent No. Mass(gr)	Coordinates of the Measuring Point	Dose Ratio Cal/sec	Dose Ratio by Unit of Mass		Heat Transfer Coefficient(h)
			Cal/gr sec	Rad/sec	$Cal/cm^2\ sec^0C$
No.1 38760 gr	D (r=o; z=L/2)	1.29	$.51X10^{-4}$	21.3	$1.76X10^{-4}$
	C (r=R; z=o)	1.97	$.52X10^{-4}$	21.8	$1.76X10^{-4}$
	A (r=o; z=–L/2)	1.97	$.52X10^{-4}$	21.3	$1.76X10^{-4}$
	B (r=o; z=o)	2.16	$.57X10^{-4}$	23.8	$1.85X10^{-4}$
No.2 7814 gr	A (r=o; z=L/2)	.71	$.91X10^{-4}$	38.0	$1.33X10^{-4}$
	D (r=o; z=–L/2)	.67	$.86X10^{-4}$	36.0	$1.40X10^{-4}$
No.4 180 gr	B (r=o; z=o)	.03	$1.4X10^{-4}$	58.6	$2.70X10^{-4}$

Table 7
Comparison of Premeasured and PRGA-Computed for Three Component Source Mixtures

Sample Number	Component	Mixing Factors		% Discrepancy
		Premeasured	PRGA-Computed	
1	$11Na^{22}$	2	1.86	7.0
	$27Co^{57}$	1	0.90	10.0
	$25Mn^{54}$	2	1.99	0.5
2	$11Na^{22}$	0.33	0.32	3.0
	$27Co^{57}$	5.00	5.12	2.4
	$27Co^{60}$	0.15	0.17	13.3
3	$11Na^{22}$	3.33	3.09	7.2
	$27Co^{57}$	2.5	2.37	5.2
	$27Co^{60}$	0	0.07	--

STAFF

For the academic year 1973-74 Knud B. Pedersen was on sabbatical leave from the University of Puerto Rico. The Puerto Rico Nuclear Center cooperated in allowing Dr. Pedersen to study for a three month period at Oak Ridge National Laboratory. During his stay at Oak Ridge he was involved with the writing of Environmental Statements for the Seabrook and Douglas Point nuclear power stations. This work involved the writing of the thermal analysis and plant sections of the reports.

HEALTH AND SAFETY

The Health and Safety Division deals with all health and safety problems. It operates at Río Piedras and Mayagüez providing the services needed by both laboratories for a safe operation. The following services are provided: Personnel monitoring, Area monitoring, Calibration of equipment, Radioactive material handling, Environmental surveillance, Dosimetry, Decontamination, Waste disposal, Industrial safety, and Fire safety.

Staff members of the Division participate in teaching programs including the indoctrination of personnel in safety measurement of radiation, industrial safety and hygiene, and fire prevention.

TRAINING ACTIVITIES

The M.S. degree program in Radiological Health continues serving and preparing students. This program has been developed in conjunction with the UPR School of Public Health and the Department of Environmental Health, San Juan.

Ten students enrolled in the 1973-74 M.S. degree Program: Haydee Pérez Kraft, Rosalinda González Paul, Cruz María Nazario Delgado, Brenda Manich Morales, César Picón Chávez, Alvaro Peña Díaz, Germán Ramírez Contreras, Roberto Cuenca Fajardo, Asterio Santos and Víctor Velázquez.

Students who received special training in the applied Health Physics Program were Marcelo Donoso, Chile; and Obdulio Maldonado, El Salvador.

SERVICES

Education. An M.S. degree Program in Radiological Health at the UPR Medical Sciences Campus offered by the School of Public Health in conjunction with PRNC and special training in Applied Health Physics to fit the needs of Latin American students.

Personnel Exposure. The personnel exposure dosage for PRNC has continued to be less than 1 rem.

A total of thirteen Government and private institutions used our services for this year.

Environmental Surveillance. A total of three samples of soil, water and vegetation of the surrounding grounds of the institutuion are anlyzed each month.

General Safety. The Division continues the supervision, for a safe operation, of the Co^{60} irradiator facilities, the medical radiation units at the Radiation Oncology Division,

the TRIGA reactor program, the L-77 reactor, the neutron generator facility, and the gamma pool facilities.

The industrial safety and fire protection programs continue. Inspection of working areas and fire protection equipment are conducted on a monthly basis.

Table 1
Health and Safety Services - 1973

1.	Film service:	Neutron	Beta-Gamma
	PRNC	600	3740
	University Hospital		16
	Oncologic Hospital		2540
	Military and Rosales Hospital, El Salvador		600
	Medical Center, Mayagüez		1003
	Local Civil Defense		72
	Experimental Station, Lajas		72
	Metropolitan Hospital		126
	Centro de Salud, Adjuntas		36
	Dr. Dixon Ramírez		4
	Medical Services		64
	Total	600	8273
2.	Area monitoring samples analyzed:		
	Smears		
	Water		
	Air		
	Total	344	
3.	Review of questionnaires for reactor experiments:	34	
4.	Review of requests for use of irradiation facilities other than reactor:	13	
5.	Review of requests for radioisotopes procurement:	21	
6.	Medical dispensary cases seen:		
	Number of accident cases treated	34	
	Number of accidents reported to State Insurance Fund	27	
	Number of pre-employment examinations performed	36	
	Civil Service Commission Standard Form-78 prepared	16	
	Non-occupational related cases treated	100	
	Health certificates completed	12	
	Total	225	
7.	BONUS power plant surveillance:	1	
8.	Leak tests conducted:		
	Neutron	8	
	Other	8	
	Total	16	

Indoctrination. Indoctrination of personnel for safety is done through fire drills, radiation evaluation drills, personal contact, films, and printed material.

STAFF

Mr. Efigenio Rivera resigned as Assistant Head, Mayagüez, and no one has been appointed to fill the position to date. Dr. Peter Paraskevoudakis resigned as Division Head and Mr. Fernando Vallecillo was appointed as Acting Division Head.

Miss Nimia Irizarry joined the Division in August.

During the month of June, Mr. Porfirio Toledo attended a two week orientation period at Oak Ridge Operations Office. Miss Dina Tryfona received training course at ORO.

During the last week of October Miss Nimia Irizarry attended the National Safety Congress held in Chicago, Illinois. Following this she attended a one week orientation period in the Fire Protection and Safety Branch of ORO.

A smear taken in one of the laboratories to detect radionuclide contamination.

Joint Radiation Survey Project

The primary objective of the Joint Radiation Survey is to evaluate health hazards due to x-ray diagnosis from medical and dental procedures in Puerto Rico. By virtue of this objective, and since x-rays constitute an ionizing radiation, this project is among those to be emphasized according to a *Report by the Joint Committee on Atomic Energy on Authorization, Appropriations for the Atomic Energy Commission for Fical Year 1974.* which declares with respect to the proposed Budget for Biomedical and Environmental Research "The committee is pleased that within the Commission's biomedical program emphasis continues to be placed on experiments and studies which are directed toward obtaining scientific data pertaining to human health, particularly the evaluation of adverse effects of ionizing radiation on man . . . "

It has been established that exposure to ionizing radiation is statistically correlated with the incidence rate of certain malignancies, to shortening of the life span, and to other congenital malformations and diseases. Radiation injury to the genetic material is particularly harmful, since it may harm not only the individual, but also his offspring, sometimes several generations removed from the irradiated parent.

In order to appreciate the extent of the potential radiation hazards attributed to x-ray diagnosis, it should be pointed out that diagnostic x-rays account for 90% of the man-made exposure of the average person in the U.S. and for 94% of the gonadal exposure.

In Puerto Rico, as well as in the U.S., substantial efforts are being made to reduce unintentional irradiation of the patient's body during routine x-ray examinations without interfering with the diagnostic objective. With this same goal in mind, the present research project was initiated in Puerto Rico 1968, sponsored jointly by the Department of Health of the Commonwealth of Puerto Rico and by the Puerto Rico Nuclear Center.

WORK ACCOMPLISHED

In order to evaluate the health hazards, both in frequency as well as in magnitude, the work on this Survey has been divided into the following parts:

a) collection of statistical data
b) dosimetry
c) evaluation of quantifers

Since it has been established that approximately 90% of the genetically significant dose associated with x-ray diagnosis is due to a relatively limited group of routine abdominal examinations, data collection was limited to that group, which consists of nine routine abdominal examinations.

The islandwide annual rate of each abdominal examination considered in this survey was determined by age, sex group, geographic location, and type of medical facility.

Chest x-rays, while contributing individually very little to the genetical dose, were included because of their frequency.

For the 1968 part of the Survey, dosimetric measurements were performed in several medical facilities, both *in vivo* and also using a phantom in lieu of the patient. Dosimetric instrumentation included Victoreen ion chambers, TLD-LiF dosimeters and high sensitivity film packages.

Quantifiers used to characterize the health hazard include: a) per capita annual gonadal dose, b) mean gonadal dose per diagnostic procedure and c) genetically significant dose.

Data processing was carried out using the IBM-360 and PDP-10 computers at the University of Puerto Rico Mayagüez Computing Center.

Partial results of the Survey have been published as enumareted below:

1. Gileadi, M., Joint Dental Radiation Survey in Puerto Rico-1968. Department of Health, Puerto Rico Nuclear Center and School of Dentistry, University of Puerto Rico, January 1973.
2. Gileadi, M., et *al.*, X-Ray Diagnosis Associated Radiation Exposure in Puerto Rico. Trans: Regional Conference on Radiation Protection, Jerusalem, Israel. March, 1973.
3. Gileadi, M., Methods and Results: All Insular Results. Trans: 7th Midyear Topical Symposium, Health Physics Society. San Juan, December 1972. (published March, 1973)
4. Gileadi, M., Dental Radiation Survey, Puerto Rico-1968., *Radiation Data and Reports*, 14.6 351/55, June 1973.
5. Gileadi, M., et *al.*, Collimation in Reducing Male Gonadal Doses in Puerto Rico-1968. *Health Physics J.*, **25**, 43-49, (1973).
6. (In press) Gileadi, M., Radiation Exposure Due to Medical and Dental X-Ray Diagnosis in Puerto Rico. Submitted for publication in the *Amer. J. of Pub. Health.*

Part of the results obtained in the Joint Radiation Survey-Puerto Rico-1968 have been included in the *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation - 1972*, New York, as well as in the comprehensive report *Population Exposure-U.S. 1970*, to be published by the Bureau of Radiological Health, Washington, D.C.

WORK IN PROGRESS

Compiling of all 1968 data is now completed and is prepared for publication in book form as a comprehensive summary. This work includes, among other aspects, a complete census of all diagnostic x-ray units operative in Puerto Rico (medical and dental) in 1968.

An attempt has been made to include all available information necessary to present a complete picture of radiation protection in Puerto Rico associated with x-ray diagnosis (1968). Some of the most significant results derived within the Survey are presented herewith:

Table 1
Some Significant Results
JOINT RADIATION SURVEY PUERTO RICO 1968-73

Total Number of Operative Diagnostic Medical, Dental and Therapeutic X-ray Units	Western Region	Southern Region	Northern Region	Total
	122	142	729	993
Annual Rate of All Diagnostic Medical and Dental X-ray Examinations	231,783	250,137	1,175,234	1,657,154
Annual Rate of All Diagnostic and Therapeutic X-ray Procedures	231,783	252,990	1,181,068	1,665,841

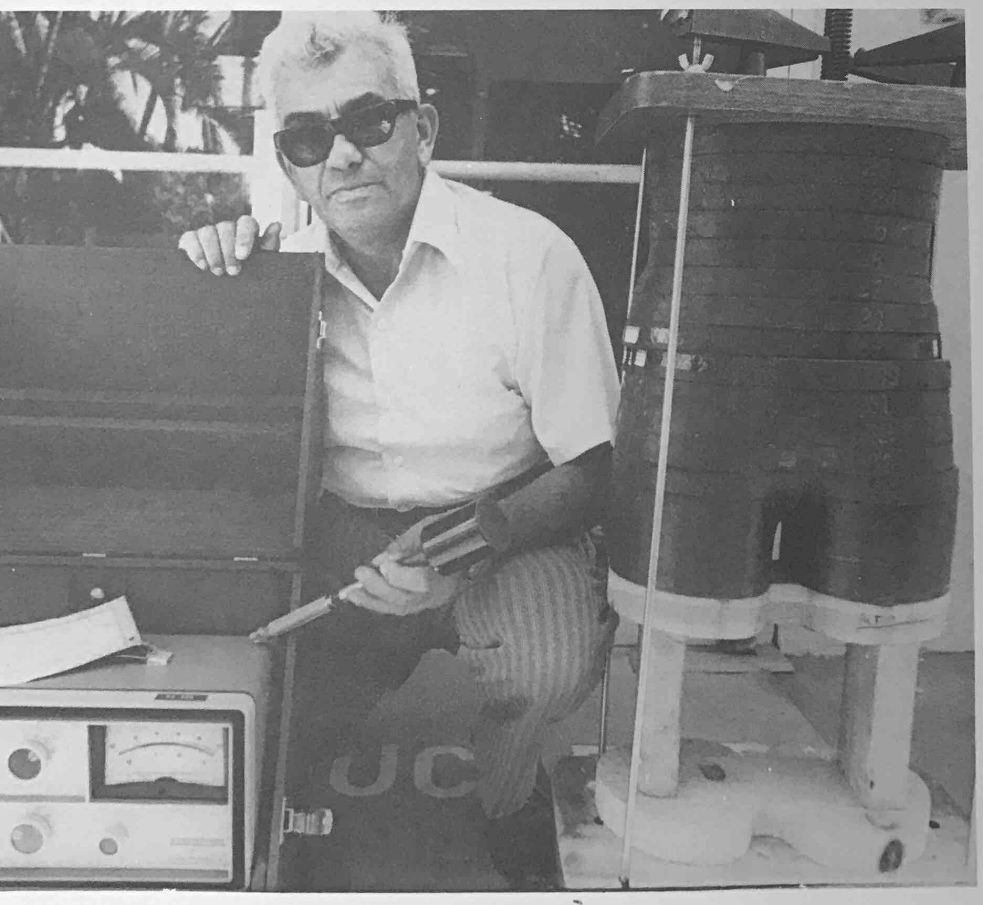
Distribution of Diagnostic Medical X-ray Examinations by Type Facility	Hospitals & Clinics :	690,944 (49.3%)
	Health Centers, Public Health Units and Dispensaries :	347,949 (24.8%)
	Private Offices and Others :	363,966 (25.9%)
	Total :	1,402,859 (100%)

Distribution of Diagnostic Medical X-ray Examinations by Body Area	Chest	Abdomen	Others	Total
	649,647 (46.3%)	377,850 (26.9%)	375,269 (26.8%)	1,402,859 (100%)

Average Gonadal Dose per Person by Sex per year (in millirads)	Male	Female	Mean per Person
	72.70	99.99	86.43

Genetically Significant Dose by Sex and by Body Area	Male	Female
Abdominal	19.77	23.35
Chest	0.12	0.06

Total Annual Genetically Significant Dose per Person 43.3 Millirads



The new Radocon II, Model 555, instrument for diagnostic dosimetry obtained by the Joint Radiation Survey 1968-1973. Used for gonadal dose measurement in vivo and on the Rando-Phantom, Model Ran-100, used in lieu of the patient. The Radocon II was used for measurements in various medical facilities in the 1973 Survey. Principal investigator is Michael Gileadi, Scientist I.

FUTURE PLANS

To evaluate the trends in x-ray diagnosis, as well as to assess the progress achieved in a five year period, the work initiated in 1968 will be continued and a parallel survey for 1973 will be started. This plan has the approval of the Secretary of Health of the Commonwealth of Puerto Rico, Dr. José A. Alvarez de Choudens.

Data collection for 1973 is presently in progress. All data referring to public medical facilities (hospitals, public health centers, dispensaries, etc.) for the first trimester of 1973 are complete, and approximately 60% of the second trimester data are accumulated. It is expected that by the end of the present fiscal year, all January 1-December 31, 1973 data will be complete.

Dosimetric measurements will be carried out both *in vivo* and on a phantom in the Western, Southern and Northern regions of the island, using, among others, the recently acquired Radocon-II Model 555 dosimeter with an integrating ratemeter,designed specifically for radiological dosimetry. Parallel to Radocon-II measurements, and simultaneously with them, TLD-CaF(Dy) and film dosimeters will also be exposed.

It is expected that by June 30, 1974, both statistical and dosimetric data will be accumulated, and that fiscal year 1975 will be used to process the data, derive the results, and complete the 1973 summary. This will include a detailed evaluation of trends and an assessment of progress in the field of radiation protection in Puerto Rico from 1968 to '73.

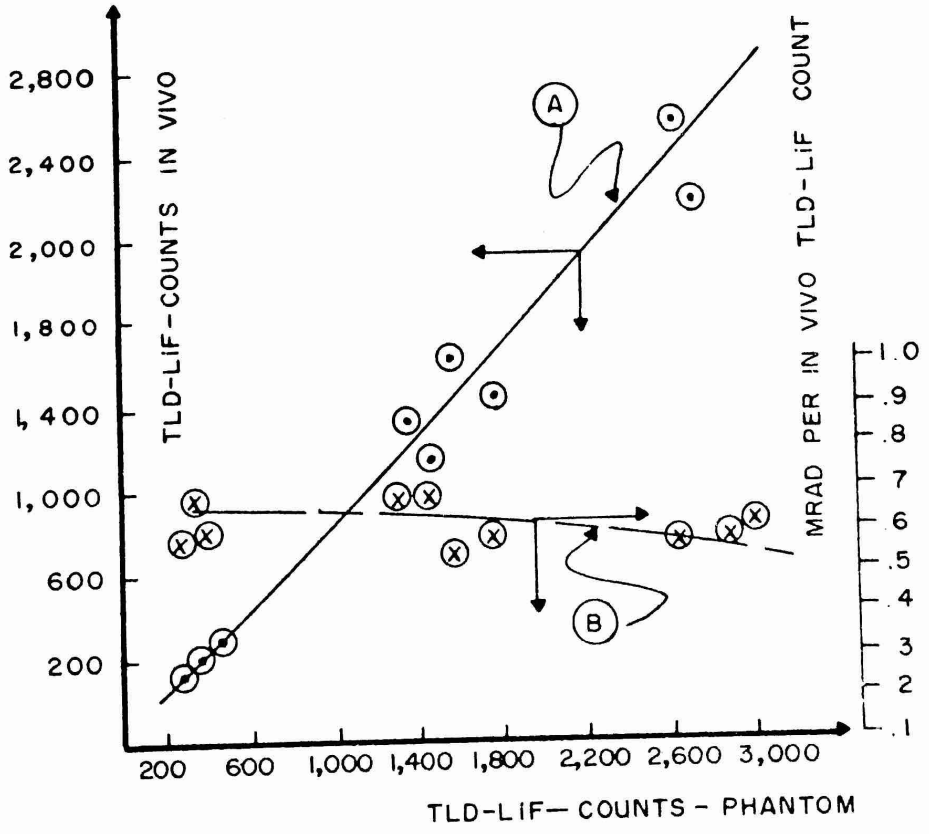
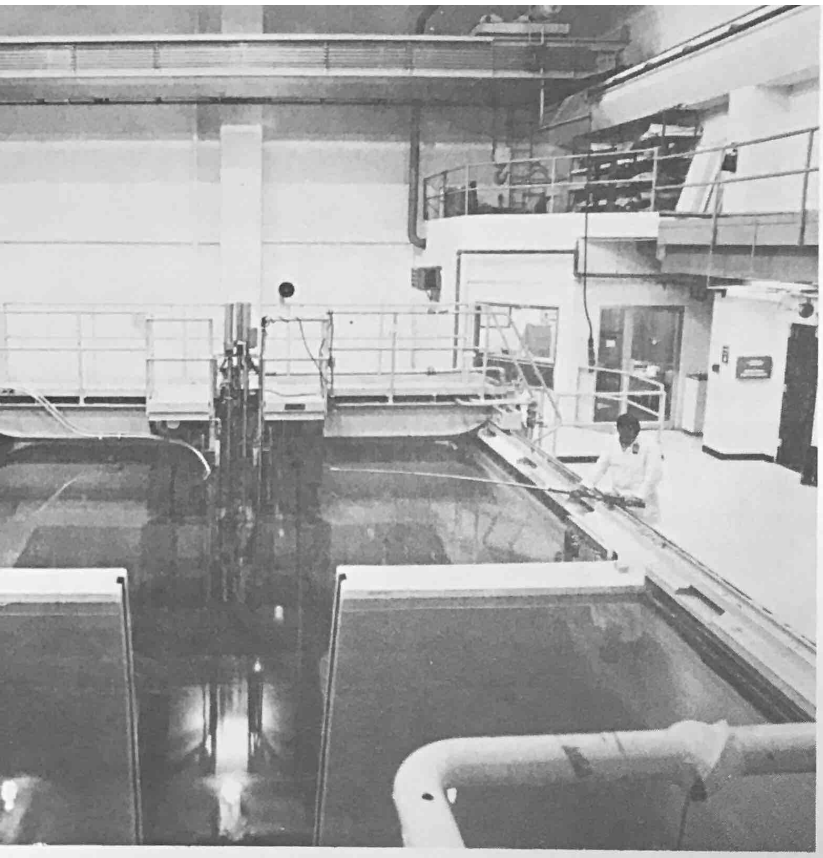
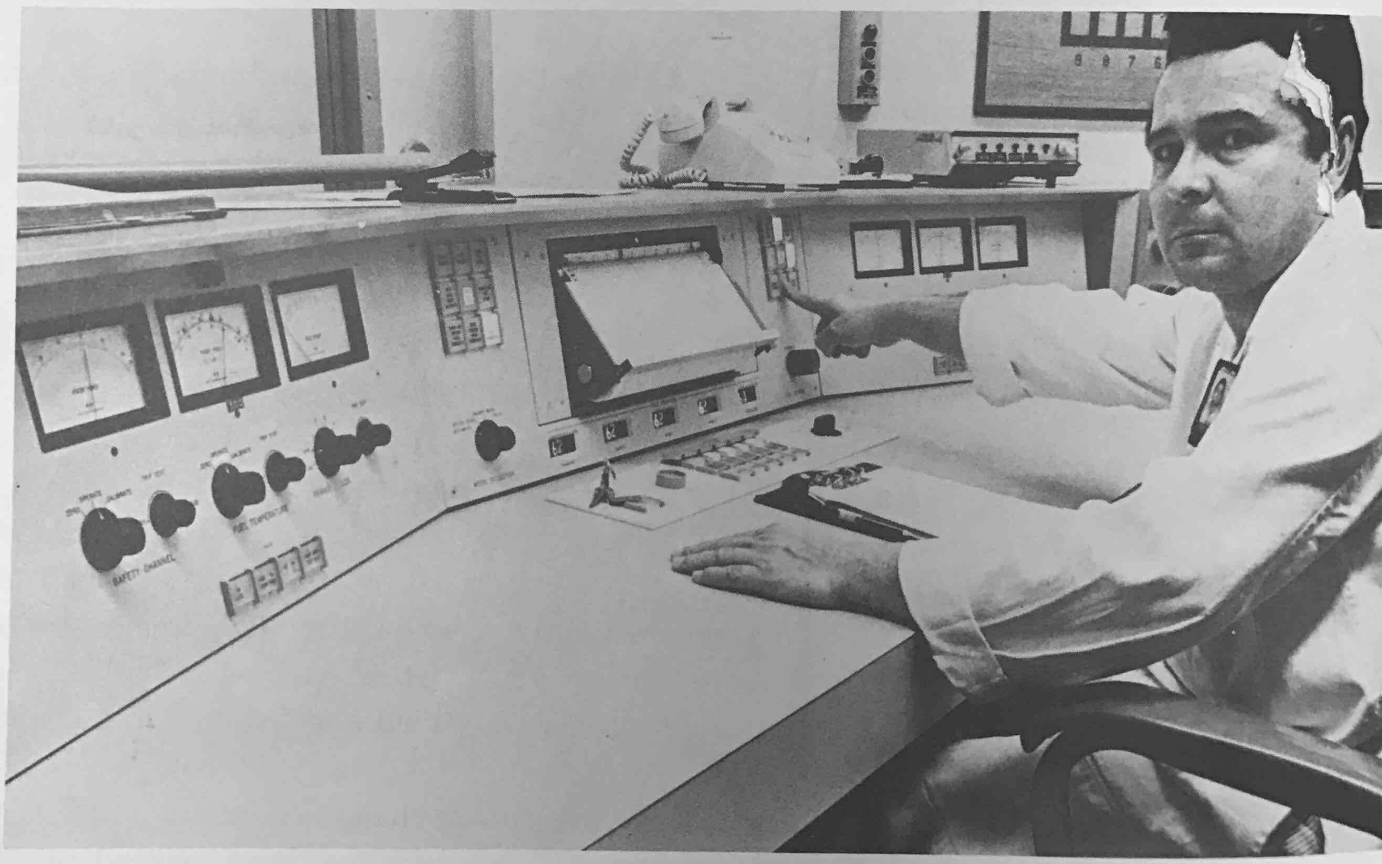


Fig. 1. Correlation of *in vivo* data with those obtained on phantom under identical radiological circumstances.



View of reactor room showing pool, reactor bridge and core (illuminated portion at bottom center of photograph). Control room is in the far right corner.



Mr. Miguel Rodrĭguez, reactor operator is shown at the console of the Triga reactor.

REACTOR OPERATIONS

The Reactor Operations Division provides neutron and gamma irradiation services to other PRNC divisions as well as training and education in reactor operations and related subjects. The Division operates and maintains (1) a 2-MW pool-type research reactor with 2000-MWt pulsing capability; (2) a 10-W aqueous homogeneous L-77 reactor; (3) a cobalt-60 gamma irradiation pool; (4) a cobalt-60 reactor pool gamma irradiation facility; (5) a 150-kV particle accelerator for the production of 14-MeV neutrons; and (6) two high level hot cells.

Irradiation services rendered during this year are summarized below:

1. 1402 megawatt-hours of operation at a nominal power level of 1.2 megawatts.
2. 64 side-of-core irradiations accumulating a total of 96 hours of irradiation time.
3. 38 in-core rabbit irradiations accumulating 2 hours 40 minutes of irradiation time.
4. 6 side-of-core rabbit irradiations accumulating a total of 26 minutes or irradiation time.
5. The Neutron Diffraction program utilized the neutron beams for a total of 1,116 hrs.

During the year the L-77 reactor was operated during three hours for instrument checks and to perform laboratory experiments for nuclear engineering students. The energy generated was 30 watt-hours.

A total of 229 irradiations were performed in the gamma pool accumulating 2564 hours of irradiation time.

TRIGA REACTOR MODIFICATIONS

The tests that were initiated during December 1972 were continued in January 1973. The purpose of the tests were to determine the origin of the power oscillations that were noticed during the early phases of reactor start-up. It has been concluded that the power oscillations are caused by a changing void fraction in the reactor core associated with nucleate boiling which occurs at power. Based on this conclusion Gulf General Atomic proposed several changes in the core configuration to correct the oscillations.

Fuel cluster and fittings were modified by changing the fuel pin square pitch to a triangular pitch so as to increase pin spacing. The design was such that better distribution of the coolant water was achieved. The modified end fittings were installed in the reactor during June 1973.

Several power runs and core configuration changes were made during June. The power oscillations were substantially reduced. A power run during July demonstrated that the oscillation amplitude increased with increasing coolant water temperature. It was concluded that the reduced oscillations did not represent a safety hazard. On October a request was sent to the AEC to authorize reactor operations at rated power and in all modes of operation.

A 16,500 curie cobalt 60 source was received by the Division during the summer. The source consists of 12 flat strips of approximately 1400 curies each. A source holder-irradiator was designed and constructed for the cobalt source. It was installed and placed in operation in the gamma radiation pool.

A set of procedures incorporating both cobal sources now in the gamma pool was placed in effect.

TRAINING ACTIVITIES

As part of the M.S. program in Radiological Health, the Reactor Division offered the course PRNC 555, Safety in Reactor Operations, during the spring of 1973.

During the summer, Mr. R. Brown attended a two week Nuclear Power Reactor Safety course offered by the Massachusetts Institute of Technology.

During the year the Reactor Operations Division initiated a retraining program for its reactor operators in compliance with AEC regulations. By the end of the year the retraining program was almost complete and requalification is expected early in 1974.

PRNC-168, "Technical Specifications for the Puerto Rico Nuclear Center L-77 Reactor" were approved and placed in effect in February 1973. Also, "Procedures for Operating the Cobalt 60 Gamma Pool Irradiation Facility," were written and approved during the summer.

The work initiated by Mr. Efigenio Rivera to determine radioactive argon production by the TRIGA reactor resulted in a successful thesis presentation published as PRNC 171.