

PRNC ~ 81 (Rev. Jan. 1967) PUERTO RICO NUCLEAR CENTER ABSTRACTS OF PROGRAMS SUPPORTED BY THE AEC DIVISIONS OF: Nuclear Education and Training, Physical Research, Biology and Medicine, Isotopes Development 7/7 CRMA TID 4Y UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. AT (40-11.1892) FOR U.S. ATOMIC ENERGY COMMISSION. ---Page Break--- TABLE OF CONTENTS DIVISION OF NUCLEAR EDUCATION AND TRAINING Clinical Applications Division, Radiotherapy and Cancer Division, Agricultural Biosciences Division, Radioisotope Applications Division, Nuclear Science and Technology Division, Nuclear Engineering Division, Reactor Division, Health Physics Division, Medical Sciences and Radiobiology Division... 20 RNC Participation in USAEC Atoms in Action Exhibit... 22 DIVISION OF PHYSICAL RESEARCH Solid State Physics Program, Neutron Diffraction Program, Hot Atom Chemistry Program. DIVISION OF BIOLOGY AND MEDICINE Terrestrial Ecology Program I: The Rain Forest Project, Marine Biology Program, Estuarine and Marine Ecology Study, Specific Activity Approach, Schistosomiasis Project, Sugarcane Borer Program, Resonance in Radiation Program, Radiation Chemistry and Photochemical Chemistry Program. DIVISION OF ISOTOPES DEVELOPMENT Radiation Preservation of Tropical Fruits, ---Page Break--- Clinical Applications Division Sergio Triatary, M.D., Chief Scientist II, Lead; Aldo B.E. Lanaro, M.D., Associate Scientist II; Pedro Juan Santiago, M.D., Associate Scientist I (Part-Time). PURPOSE The main purpose of the program of this Division is teaching and training of Latin American physicians in the diagnostic and therapeutic uses of radioisotopes in humans. SOURCES AVAILABLE: 1. Basic Course Clinical Applications of Radioisotopes. This course consists of formal lectures, demonstrations, periods of discussion, and laboratory work. Its main purpose is to emphasize training in the use of clinical radioisotope techniques. 2. Orientation Course Clinical Applications of

Radioisotopes for Medical Residency "This is a non-credit course for Medical Residents designed for orientation only in the medical uses of radioisotopes. 3+ Course in a Medical Specialty. This is a course emphasizing the application of nuclear techniques in a special field of Medicine. A two-week course in the field of Pediatrics will be offered following the Basic Course in Clinical Applications of Radioisotopes in February and June 1967. 4. Training in Clinical Research. This course stresses research aspects in Clinical Medicine, and is designed to provide research facilities to trainees interested in clinical radioisotope research work. Special activities to increase the number of prospective candidates for the training courses have included several trips to South America by Dr. Lanaro during which he has visited hospitals, universities, and other institutions and participated in scientific meetings. ---Page Break--- Many prospective trainees would come to Puerto Rico provided maintenance expenses could be provided. Clinical Research: To complement the training program, research projects are active in the areas indicated: Thyroid disorders, Cancer detection, Gastrointestinal absorption, Problems of clinical radiation, Liver and kidney disorders. ---Page Break--- Radiotherapy and Cancer Division Dr. Victor A. Vargas, M.D. Chief Scientist; Dr. Jose X. Toad, Ph.D., Chief Scientist 1; Jeanne Ubivas, M.S., Chief Scientist; Dr. Antonie Bosch, M.D., Chief Scientist 1; Martha P. de Lozano, M.S. Research Associate; Zenaida Frias, M.S., Medical Research Statistician. PROS The main purpose of this Division is to train physicians and allied personnel in all aspects of the application of nuclear energy to cancer. A second purpose is to develop and carry out a research program to improve our knowledge in the cancer and radiation fields. CURRENT STATUS This Division offers two programs in Radiotherapy Training: (1) Radiotherapy Residency Program. The objective of this program is to prepare...

qualifies radiation therapist, This is an approved program that fulfills the requirements of the American Board of Radiology. Physicians with one year's internship or equivalent clinical experience are accepted for this training. The total training period lasts three years, but trainees are

required to take an additional fourth year of supervised practice (preceptorship) before admission to the specialty examinations. Trainees acquire a solid background in clinical cancer through supervised work with new, follow-up, and hospitalized cancer patients. They learn to diagnose the disease, determine the extent of the same, choose the appropriate treatment, and plan and conduct radiological therapy. Radiation therapy experience is acquired by working with radiation therapy machines of various voltages and teletherapy units, which include cobalt and cesium, and with the application of radioactive material such as radium, strontium, cobalt, and tritium. Trainees also become familiar with non-radiological cancer treatment methods, such as surgery and chemotherapy. In addition, they learn of cancer control activities in Puerto Rico; this includes the operation of a Central Cancer Registry, tumor clinic work, cancer detection, and public and professional education in cancer. ---Page Break---

(2) Special Short Residency Training Course, Second programs are available. Each of the persons participants can engage in a research project and may participate in all teaching activities of the Radiotherapy and Cancer Division; but are not given patient responsibility. An additional training activity is offered for Fourth Year Medical Students. Selected candidates receive one month of intensive in-service training, where they are exposed to cancer and radiotherapy clinical problems. Experienced radiotherapists from Latin America are hired as visiting staff. This allows them to become acquainted with the work of this Division and to carry out research projects. To complement the training programs, a number of research projects

are active in this Division. These include: (1) Investigation of the Role of Surgical Sterilization in the Biology of Cancer of the Uterine Cervix; (2) Study of Protraction of Weekly Radiation Doses in Cancer Patients Under Radiotherapy; (3) Carcinoma of the Uterine Cervix Associated with Pregnancy; (4) Determination of Optimal Tumor-Dose in Radiation Therapy of Cancer of the Esophagus; (5) Controlled study of the Split-Dose Technique in Radiotherapy of Cancer; (6) Study of Chreviosene Changes in Patients Undergoing Radiation Therapy for Cancer; (7) Exfoliative Cytology as a Tool for Determining Prognosis in Cases with Cervical Carcinoma submitted to Irradiation; (8) Surgical Adjuvant Breast Project; (9) Study of the Incidence of Leukemia in Patients with Cervical Cancer Treated with Radiation; (10) Clinical Dose-Treatment Relations. The Division is collaborating in various research projects conducted by other Divisions of FRNC; these are, study of thyroid function in patients with hyperplasia, tumor localization studies, gastrointestinal absorption studies, normal and neoplastic tissue cell-cycle studies, nice L.D.-50 studies, etc.

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Agricultural Bio-Sciences Division say Robert A. Luss, Ph.D., Chief Scientist; José A. Ferrer, M.H.S., Chief Scientist; Francie K. Ko, Ph.D., Associate Scientist II; David W. Walker, Th.D., Associate Scientist II; Gureekant W.N. Dechrande, Th.D., Associate Scientist I; José Cuevas, M.S., Research Scientist I. PIRIOS: To train students at the graduate and the post-graduate level for research in agriculture or biology, emphasizing nuclear techniques. To carry on continuing basic research programs which are concerned with problems in tropical agriculture that can be uniquely studied by nuclear techniques. Status Education and Training Eight students currently are working toward degrees in biology and agriculture—degrees which will be awarded by the University of Puerto Rico upon completion of course work and experimental thesis. In the

In the last five years, several students have continued their doctoral training in U.S. universities. In the last year, five persons have done post-graduate research in the Division, supported through relevant teams IABH, GINS, Kg, and the Peace Corps. These trainees spent 1 to 15 months at the site taking courses and/or participating in research projects; they then return to their home country to develop scientific projects there (e.g., in Taiwan, Caribbean countries). An additional THEA Fellow is in progress. Division staff are currently offering graduate level courses at the University,

where they hold appointments. This academic year, courses in Nuclear Techniques in Agriculture, Nuclear Techniques in Biological Research, and in Cytogenetics (both campuses) are being presented. Division staff members have served as Scientific Advisors with the ABO Exhibit "Atención en Acción" in El Salvador and Guatemala in 1965 and in Costa Rica and Nicaragua in 1956. Re-visualization of previous exhibit sites permits continued contact and cooperation with Central American scientists. ---Page Break--- IL, Research A. Radiobiology of sugarcane to increase the economic return from sugarcane (Puerto Rico's most important crop), the induction of plant substances with high energy content is being attempted. Initial experiments to determine the radio-sensitivity of seeds and buds to thermal neutrons produced in the PRKC megawatt reactor have been completed. Subsequently, thousands of seeds and vegetative buds have been irradiated, germinated, and planted in the field. Ongoing chemical screening for sugar content in the individual plants produced is being carried out via automated analytical techniques. Visible mutations such as wider sister leaves indicate that other favorable characteristics may be induced. Superior mutants will be propagated and evaluated in the University Agricultural Experiment Station's program of crop breeding and improvements. A similar program is concerned with the induction of resistance in sugarcane to the "citrus virus disease."

is uvienay. early 3 'thousand vlants have been grom fron irradioloc eco and these are in preceee oF sone screening by stririeial ingectirn sith the virus, B. Radiotsotove studi in suparcane Imertant problexe of beth imediste and long-range application, have been studied in sugarcane through the use o. radioisolopes. Several field and groonheuse cxzerinents which doo? with acronente practice were camletes this year. Fer examble, the elvect or e0il Factors (pil, density, moisture content) on the nutrient uptake and utilization or phomintes, sulfates, and trace cleaents har been @etermined. Also, che enfunceuent ox reliur abecrstion of uhosphatee by wetting agente vac measured; resulte will be of wae in the aerial spray application of Jertitizers to sugarcane, on increasingly more comin sractice. The enzymatic legradalion of auevore in the aigercane plant by invertase hes been the sibject or bicchosical Investigaticn. Factors which control invertase wermaticn have been deternines by measuring 'the incorzoration cr eciod carbon-11i labeled snino acide into the protein fraction of sugarcane neristen tiesie, Contacters auch a2 'pagnesiu. ion have been roan' cesential ror thie incormcratoin; the protein rorution is ceneidarably reduced by preeence of aulthydryl 'compourts. ©. Radiation preservation sanices Several exotic tropical iruits hove considerable sarket potential if their ripening could be delays te permit shivaent. To evaluate the process of rodiation oreservolion, a seriee oF experiments vere donc, Involving 20 varivt ics of mangoes Srradinted to different dcaes at' three Gisferent etogee o: ripening and stored ---Page Break--- at posteirradiation tenoeratures of 50 and 70°P, Fron these studies it wag found that 250 Kr. doses of gamma radiation extend the shelf- Life at 50°F by ayproximately twenty daye Tor certain varieties oF mangoes. Sich results hold prornise for the radiation preservation of thie fruit. Biochenical studies of softening of mangoes during and folloving irradiation also have been carried

out by measuring the extent of depolymerization of the pectic constituent in irradiated fruit, shortening was found due both to radiation-induced depolymerization of pectic acids and to the considerable polygalacturonase activity in the mango. D. Other projects within its structure, the Agricultural Bio-Sciences Division currently houses three projects supported through contracts with the USWC: Radiation Sterilization of the Sugarcane Borer, Radiation Preservation of Tropical Foods, and Resonance in Radiation Projects. While these projects are reported elsewhere, it should be pointed out that these are an integral part of the Division's program and, in turn, rely for their senior investigators on Division personnel. ---Page Break--- Radioisotope Applications Division SUF Ay Marry Stunt, Hi. D., Chief Scientist 11, heads Alec Gréatecn, Bi Dey associate Scientist 11

(Fovtefine); José P. 2. Castrtlíea, stats, The new Associate T (turret); Simpson, Th. D., Associate scientist 3; Gerardo cline Vass, lie Sy Research Associate TEs Resa Sontana ae Tirade, 4 B., Research Segoetats T. PROS, The main objective of the program is the training of scientists in the application of radioisotopes and ionizing radiation to the physical sciences to provide technical competence for their future work. A second objective is the offering of introductory training to students, irrespective of their field of interest, in radioisotopes and ionizing radiation as a background for their participation in other programs of PRIC. Current Courses with University credit 1. Radiochemistry Course (Chemistry M5 =! credit hours). A one semester course offered once a year for advanced undergraduate and graduate students. Three one-hour lectures and one four-hour laboratory period per week. A -proximate enrollment: 1 to 6. 2. Nuclear Techniques in Biological Research (Biology 372 = 3 credit hours). A course offered once a year for advanced undergraduate students. Three one-hour lectures and one

howr-hour laboratory yeriol ver week, Amrextiate enrollment: Wo 6. 3, Participation in Graduate and Undergraduate Research Courses. Research training in the fields of photo and radiochemical reactions found in the application of radioisotopes to chemical studies is offered to students pursuing the Ph.D. or M.S. degrees at the University of Puerto Rico, Rochester. Each student carries out an individual research project in accordance with the credits for which he registers in Chemistry 599 and Chemistry 397-300. ---Page Break--- Sweetis? Training: 1. Basic Course in Radiolactove Techniques = Your course is now being offered four or five times a year. We have had a total of 272 participants (6 (ns) including G) Latin Americans. The present rate of certification is approximately 39 per year. (This course was incorporated into the curriculum of the graduate program of Biochemistry and is eligible for the U.P. School of Medicine and Biochemistry and Nutrition credit hours). 2. Radiologics? Thysten = A special course offered to Residents in Radiology when requested ORGANIC CHEMISTRY PROGRAM PURPOSE: The purpose of the program is to provide advanced chemical training in organic chemistry with special emphasis on its nuclear aspects. The projects cover a relatively wide range of subjects in order to offer a broad experience to all members of the group, and the infusion of the varied aspects of organic chemistry is promoted by group seminars and discussions. CURRENT STATUS: The research topics include the use of S-35 in exchange reactions, the use of tritium, Cl-30 and C-14 for the determination of reaction mechanisms, the synthesis of boron compounds of potential use in neutron activation therapy, and the gamma radiolysis of dimethyl sulfoxide. The study of the gaseous radiolysis of dimethyl sulfoxide is of recent origin, but correlative studies concerning the physical properties of this substance have been in progress for some time. The boron project is currently inactive because of the departure of the research assistant who was involved.

in this work. PHOTOCHEMISTRY AND RADIATION CHEMISTRY. PROGRAM PURPOSE The purpose of the program is to provide advanced chemistry training in photochemistry and radiation chemistry, with special emphasis on the relations and distinctions between these. Also included are projects involving training in the use of quantum chemical calculations for evaluation of the experimental results. ---Page Break--- CORRECT STATUS 'The advanced chemical training in this area involves active participation in the experimental and theoretical projects detailed under "Matrix Isolation Studies of Products of Gamma Radiolysis of Heterocyclic Molecules", as well as participation in group seminars. -10- ---Page Break--- Nuclear Science and Technology Division SUF ven Hl. Uheclex, DB. Sox, Thy Di, Cihfer Scientists I, Mead (Part Time); Hidie Oréiz,'Ta. D.,"Chicr Scientist 1 (AI honors); Rev. Ignacio Contarel2, Mh. D., Associate Scientist II (Part-Time); Julio A. Gonzate, Ph. D., Associate Scientist II (Part-Time); Florencio Vazquez Martinez, Ph. D., Associate Scientist II (Part-Time); Ruvere E. Lee, M.S., Research Associate III; J. Eliein Trabal, D.

S., Research Associate I. The Division provides training and research facilities in fields of chemistry and physics related to nuclear science for students in the B.S. degree programs of the Departments of Chemistry, Physics and Nuclear Engineering of the University of Puerto Rico at Mayagüez. The Division also offers research facilities for workers at the pre-and post-doctoral level and the staff members carry out independent research. **CURRENT STATUS EDUCATION AND TRAINING** Seven graduate students are carrying out research for their MS degree in chemistry and one in physics in the Division. Members of the Division are currently teaching courses in the Departments of Chemistry and Physics of the University of Puerto Rico at Mayagüez, in nuclear physics and chemistry, radiochemistry, and solid state physics. Mr. Ruyert A. Lee is completing his thesis work for a Ph. D. in radiation chemistry.

from the University of Alberta, **CONSORTIUM PROGRAM** 'The fundamental mechanisms of the catalytic reactions of hydrogen chloride and hydrogen fluoride are being studied, using both gamma radiation and fission recoil particles. This study is part of the conversion of fission energy into electrical energy involving radiolysis of hydrogen and providing feed materials for fuel cells. ---Page Break--- Studies are being carried out on radiation-induced reactions of organic compounds in solution, and on the mechanisms of thermal rearrangements using isotopes. A program of research in hot-water chemistry is now supported by the Division of Research of the ABC. Two other research groups are financed by grants from the National Institutes of Health; one on the Synthesis of Thiocridines (3 assistants) and the other on the Radiolysis of Peptides (2 assistants). **PHYSICS PROGRAM** Radiation damage is investigated by means of hysteresis and dielectric analysis of measurements of capacitance and conductivity. The effect of temperature changes to $+10^{-3}^{\circ}\text{C}$ in the region of the Curie temperature has been studied. The compounds studied include triglycerides and alkali metal selenites. Work is being initiated on the formation of color centers in magnesium oxide and alkali halides, and on field emission from highly clean surfaces. Related studies, in conjunction with the Physics Department, University of Puerto Rico at Mayagüez (ilk J. Gemborg and F. Cruz-Videl) are concerned with the efficiency of color center formation in alkali halides as a function of the energy of incident monochromatic rays near the K absorption edge of the indices. ---Page Break--- **Nuclear Engineering Division B. Dey Chief Scientist T. Heats Aviva Be Scientist Ty Philip I. Osborne, Ph.D., Kenneth Solerstron, J. B. Rogearh Associate II: Carloe Wheeler, B.S., Research Associate II: Erich Hénden Veray, Ph.D. Research Associate** **PURPOSE** The main purpose of the Division program is to teach, train and do research in the basic sciences and engineering, contributing ve

development of the use of nuclear energy. University of Puerto Rico students in the program must be enrolled for graduate activities and be accepted in programs leading toward one of the Master of Science Degrees in engineering, usually nuclear engineering. Students from other universities in the United States or in Latin America may be accepted for participation in research for completion of these requirements. PRIC participates in the CRLIIG Graduate Fellowship Program for support of U.S. citizens doing thesis research. There are now 15 students working toward the degrees in Nuclear Engineering. In addition to the primary purpose, the Division also provides special non-degree training programs for technicians and for engineers and scientists. **CURRENT STATUS** The primary effort is on the educational program in Nuclear Engineering carried out in cooperation with the Department of Nuclear Engineering of the College of Engineering. Courses being taught are: **Core Courses:** 1. Elements of Nuclear Engineering (IEE BE 695) Four credit hours, Four lectures per week, Characteristics of the atomic nuclei, Radioactive decay, Interaction of radiation and matter, Basic neutronics. 2. Reactor Theory (IEE FY 621) Three credit hours, Three lectures per week, Neutron balance equation, Diffusion theory, Steady state theory, Bare homogeneous

reactor, Reflected reactor, Heterogeneous reactor, Time dependent reactor, Perturbation theory, Transport theory. 3. Mathematics of Nuclear Science 1 (IEE BG 675) Three credit hours per week. A more advanced study of some 75076. Complex variables, partial differential equations, special functions, transfer calculus. 4. Nuclear Measurements, credit for laboratory each week. Prerequisite: Physics list. Use of operation and thorough familiarization used in the application of specialized techniques such as: coincidence and anti-coincidence counting, pulse analysis, neutron spectrometry, gamma-ray spectrometry, etc. 5. Advanced Reactor Theory (IEE RG 622) Three credit hours, Three.

lectures per week. Prerequisite: Ki Eg Ocl. Advanced transport theory. Reactor Kinetics. Heterogeneous reactor theory. Prerequisites: th Bg 675, tia Ez G95, Ta Ee Gl. Corequisite: i Bg 676. 6. Mathematics of Modern Science II (Math 676) Three credit hours, Three lectures per week. More advanced study of some topics covered in Math 175-476. Sturm-Liouville systems, calculus of variations, integral equations, tensors, finite differences. 7. Reactor Laboratory (thx Bg 625) Two credit hours, Two three-hour laboratories each week. Prerequisite: la Eq 621, Laboratory problems involving the nuclear reactors. 8. Graduate Seminar (Hi Eg 616) One credit hour, Two hours per week. Reports and discussions on special topics in nuclear science and engineering. 9. Nuclear Reactor Technology (itu Bg 602) Four credit hours. Three lectures and one three-hour laboratory demonstration period each week. Prerequisite: thu Bg 605 and mu Sg 621. Steady-state and transient thermal conduction in fuel elements; thermal convection in heat exchanger design; liquid metal systems; breeding and conversion; an introduction to the economics of reactor operation; reactor engineering design problems. 10. Thesis (su Ez 699) One to six credit hours. One to six research periods each week. Research in the field of Nuclear Engineering and presentation of a thesis. Supplementary Courses: 1. Nuclear Reactor Metallurgy (tu Bg 612) Three credit hours. Two lectures and one three-hour laboratory each week. Corequisite: Ma Bg 601. An introduction to elementary physical metallurgy of the principal reactor materials such as aluminum, zirconium, uranium and high temperature alloys; mechanical properties; fabrication of nuclear fuels; radiation damage to reactor components. ---Page Break--- 2. Introduction to Nuclear Engineering (im Be 952) Three credit hours: This course is offered for advanced undergraduate and non-nuclear engineering graduate students. Three lectures each week. Fission and chain reactions, elements of reactor design, utilization of nuclear.

energy for never um radiation problems, Research 'The staff of the Nuclear Engineering Division and members of other PRIC Divisions are carrying out research through projects designed for student participation. These include: 1. Method of reactor Xenon peak, aimed at minimizing the after shutdown. 2. Measurement of the transfer function on the L-77 homogeneous reactor by the formulation techniques. 3. Study of the variation of the neutron characteristics occurring during the reactor operation due to the changes in isotopic composition of the core. 4. Effects of irradiation on the plexiglass. 5. Determination of neutron low rates in mines by use of the nuclear Doppler effect. 6. Determination of metal to metal diffusion coefficients by diffusion of radioactive nuclei. 7. The effect of material irradiation on the emissivity of graphite. 8. Determination of the heat-transfer coefficient for free convection of air between plate-type fuel elements. 9. Chronoactivation of reactor beamport neutrons by multiple critical angle scattering. De ---Page Break--- Reactor Division SDF Héctor Darceld, M. S., Chief Scientist I, Heads Richard Brom Campos, M. S., Associate Scientist I, Reactor Supervisors Ernesto Guerra, B. E., Reactor Supervisor: Six Reactor Operator PURPOSE, The main objective of this Division is the operation, maintenance, and protection of the two FRC reactors: an L-77 homogeneous reactor and an A.N.F. pool-type research reactor currently operating at a one-megawatt power level. The Division staff also

operates and maintains pneumatic tubes, hot cells, a gamma irradiation room, fuel element irradiators, a gamma pool, and all equipment necessary for the operation of these facilities and participates in the training of reactor operators and supervisors. SUMMARY The Reactor Division supports all other divisions and programs associated with the Puerto Rico Nuclear Center. In the pool-type research reactor, two six-inch beam tubes are being utilized by the neutron diffraction program for two

neutron spectrometers. A shielded room has been built around another six-inch beam tube for future experiments in biology and medicine. A borated water shutter has been built for this beam tube. A neutron monochromator, based on critical angle reflection techniques, is being built to be installed in a fourth beam tube. The fifth beam tube is scheduled for the experiments by Lee on the radiation product radiolysis of hydrogen halides. Presently, the one megawatt research reactor is operated on a sixteen-hours-a-day basis, at a continuous power of one megawatt. Studies are in progress for an increase of power to two megawatts and an increase in operation time to twenty-four hours, five days a week. Ultimate plans are to increase the power level to five megawatts continuous with pulsing capability with peak power of two thousand megawatts. The I-77 reactor is used for teaching and experiments suitable for a water boiler homogeneous type of course. An oscillator for dynamic experiments is being built. Be ---Page Break--- the demand: for the different necessary operation of the reactor, namely, continuous steady state, MLL power for researchers, versus variable Phu, change of parameterization and inter-stent operation required for any training, has moved the Division to consider the construction of another reactor to be planned on the whole. This last year, a reactor is to be built and put into operation by teams of the Division. This reactor will be operated on an error terms with the primary purpose to provide a usable quality where nuclear engineering and other graduate students may conduct laboratory experiments and research projects related to Division work. The Division and supervisors, and note: in the training, the reactor operators are worth noting that the Division has obtained two reactor positions at the cooperative mucker gave operator training to the BOIS startup team. The training of providing practical experience in reactor startup also articulates in training of twelve in a two-week summer course. In addition,

srovlene of DOME ciudenes stulyin; for the degree in nuclear Engineering of the University of Puerto Rico at Bayaguas, were supervised by a council of the "Nuclear Division." In the field of technical services to other organizations, members of this Division have been in close contact with the Columbia reactor. The director of the Division is a member of the BOWS Safety Committee, and was also invited to study group meetings in Caracas, organized by the International Atomic Energy Agency. Health Physics Division of Peter Paraskevoudakis, Ph.D., Associate Scientist II, Acting leads Pedro Cruz, M.S., Research Associate II; Heidi Pabon, M.S., Associate in Health Physics, and five Health Physics Assistants. SCORE 'The Division has two general responsibilities: (1) services associated with radiation and industrial safety, and (2) training and education, current spans In the area of services, Health Physics conducts the following programs: 1. Personnel Monitoring - This is the most extensive program. Dose assessment mainly by way of sensitive film is provided to the Nuclear Center, Bonus Fever Plant and the Cancer Hospital at Rio Piedras. During fiscal year 1966 more than 13,000 film packets were processed. 2. Area Monitoring - This program is limited to PRNC controlled areas and provides information on the operation of the different facilities of the installation in their relation to the use of radioactive material. 3. Environmental Surveillance - This program involves the collection and analysis of environmental samples such as soil, water, and vegetation beyond the area of the PRNC site. 4. Waste Disposal - The Health Physics Division has the responsibility for management and control of radioactive

wastes generated by PRUC. 5. Radioactive and Non-radioactive Hazardous Material Handling - The Division carries out routine inspections and checks to ensure safe handling of this type of material. Part of the program includes indoctrination of the personnel using the material in proper safety procedures. 6.

General Laboratory Safety - this program is in essence an extension of the previous one. Emphasis is given to the supervision of operations not covered under item 9 such as compliance with fire, electrical construction codes, etc. Periodic inspections and indoctrination of personnel are an integral part of this program. In addition to these procedures, Health Physics is in charge of supervising and directing decontamination operations. The Division operates two facilities, one for the calibration of radiation monitoring equipment and the other for nuclear accident dosimetry based on a dosimetry system originally developed by Thirst. In the area of training and education, the staff participates in the teaching and training of students and other workers in the principles and practice of radiation safety. This includes academic courses, seminars, and thesis research. In cooperation with the University of Puerto Rico, the Division offers a curriculum leading to an M.S. degree in Health Physics. This is an approved program for the Atomic Energy Commission Special Fellowship in Health Physics. A graduate course in Health Physics is offered for students not specializing in this field, with academic credit granted through the Biology Department of the University of Puerto Rico in Mayagüez. The Division also carries out research to support investigations in other divisions and programs. A recent development is the provision of dosimetry standards for researchers throughout PRIC. Using known techniques and developing new ones, accredited Health Physics provides energy and dose information for all neutron and gamma ray radiation facilities such as the reactor beam tubes, pneumatic tubes, thermal columns, pool area, the neutron and gamma irradiation facilities, the cobalt-60 sources, and other major sources as they are introduced.

Medical Sciences and Radiobiology Division STAFF Jorge M. Chiriboga, Ph.D., Assistant Director for Scientific Programs, Acting; Royiro Martinez Silva, M.

D., Associate Scientist 1; Julio 1. Colin, Ph. D., Associate Scientist (Ad honorem); José Hoel Correa, u."D., Associate Scientist (Ad honorem); Ivelisse Rodríguez de Oquendo, 11, 5., Research Associate I; Ana Sylvia Guesade de Rodríguez, H. S., Research Associate (Ad honorem); Couredo Asenjo, Mh. D., Chief Scientist (Ad honorem); José A. del Castillo, Ph. D., Chief Scientist (Ad honorem); Luis Otero Villaderbs, Th. D., Associate Scientist. PURPOSE 1. To teach and conduct research at different levels within the field of Radiation Biology. 2. To establish projects which have a bearing on the problems of Tropical Medicine (Field and Laboratory Studies on the Effects of Radiation on Host-Parasite Relationships). 3. To maintain a tissue culture for training and research, a facility to serve as a medium CURRENT STATUS 'Training - A four-week course in Tissue Culture and Radiotoxic Techniques at Cellular and Subcellular Level was offered from October 17 to November 10, 1965. The Course is designed to give emphasis to the basic subjects of tissue culture such as the applications of this technique to virology, radiobiology, etc. Microautoradiographic techniques, chromosome preparations, labeling and liquid scintillation counting of nucleic acids at the cellular level, and other techniques are included. Research - Work is being done on various research projects. The following will be a brief summary of the more important ones: 1. Two cell lines derived from a Danish chondrosarcoma are under study with special interest in karyotypes and metabolic functions. It is hoped that the radiobiological effects in vivo and in vitro can be compared. 2. Diploid human cells are under culture and the effects of radiation on the aging process are being studied. 3. A group under the direction of Dr. del Castillo is

trying to maintain living muscle cells of *Ascaris* in the tissue culture medium. 4. The effect of radiation on the host-parasite relationships in certain arthropod-borne viruses has been started utilizing tissue.

culture and host animal. 6. The Schistosomiasis studies conducted in this Division are reported in a separate abstract. 21 ---Page Break--- Participation of the Puerto Rico Nuclear Center in the USAEC Atoms in Action Exhibit in Latin America STAFF Fausto J. Tiufoz Ribaleneira, 5, Ch. B, Research Associate IZ, Program Director Eugenia P. de Audres, Administrative assistant: PRIC scientific staff participates as needed. PURPOSE: PRUC has been assigned responsibility for conducting a program of scientific research as part of the USARC Atoms in Action Exhibit. Research projects are selected on the basis of possible economic interests, the present status of scientific development in the host countries, similarity of projects to current PRNC research, and availability of PRNC staff to serve as consultants. A subsequent follow-up and evaluation of the experimental results is carried out by the PRIC scientists who participate in the Exhibit. CURRENT STATUS The Atoms in Action Exhibit has now visited four Central American countries. In February and March 1965 the Exhibit visited San Salvador, El Salvador, and in August and September 1965 the Exhibit was held in Guatemala City, Guatemala. In February and March 1956 the Exhibit was in San José, Costa Rica and in October and November 1966 the Exhibit was in Managua, Nicaragua. Salvadoran researchers used gamma radiation to determine the mortality sterilization dosages for *Leucocephala coffeicola*, an insect pest in coffee, and *Heliothis zea*, a cotton and corn pest. Preliminary results on radiation preservation of shrimp and cantaloupe melons were satisfactory. Genetic studies in some have shown in the first crop a total weight increase of 25 percent and a more vigorous strain has been obtained. Gamma radiation also improved coffee flavor and taste. Four graduate students of the University carried out thesis research with exhibit equipment. In Guatemala, entomology studies were focused on *Tonasvinsu postica*, citronella, and lemon grass plantation insect pests. In genetics,

the sexinun survival dose for corn wae detersined. Exeriwents to vevermine ation efiection on coffee flavor and taste, beer, and essential ofle ---Page Break--- were perforsed. Researchers from the Central Aericain Institute ior Industry (ICAIT1) carried out investigations on canned pineapple sterili- zation by ganna radiation and investijators of tae Nutritional Institute for Central anerie and Panama (ICAP) used Incayarina to study the degra- dation of vejetable ;rovein unier gana radiation, Twelve hundred under~ graduate stulents voluntarily attended © special program yreyared ty the PRC personnel, an? cir graduate stuients of the University of San Carlos yerformed thesis research under tne guidance of PRNC lecturiay acientiste Salvadorean researchers case to Guatansla to continue genetic studies on beans ond rice and entonoloicel studies on lielighthis sea. PRIC personnel Played an inyortant role in the donation of the Jana irradiation Facility 9f the exnivit Crom the Regional Office tor Central anerie and Panama abfairs (ROCAP, U.S. Departuent of State), to ICAITT. 'The research activities in Costa Rics dealt primarily with agricul tural problens with additions! topics in the :hysieal selences. Radio- active tracers were utilized to study organic cnemical reactions. Projects carried out inclwied work oa fish, potato, ant coffee pre servation vy radiation, been softesins by radiation, radiation effects on corn, rice, and vean ceou viability, effects of gana radiation on tthe hysteresis cycle of trighycine sulfate crystals, szfects of formic acid concentration on the Fricke dosimetry syztas, ratiation chemistry of titanium sulfate sclutions in sulfuric acid, and other chemical studies. In Kicaragus research projects have been started in food preser- vation using bananss, dean softening, sorghun 3eed viability ani sorgtun wenetics. Experiments are also being carried out in neutron dynamics: -3- ---Page Break--- Solid State Physics Program STUDY OF RADIAPTON DAMAGE IN ORGANIC CRYSTALS USING

ELECTRICAL

CONDUCTIVITY STAFF 'Amador Cobas, Ph. D., Associate Director; Shavel Zvi Weisz, Ph. D., Chief Scientist; Alfredo J. Torruelle, Ph. D., Associate Scientist (Ad honorem); George M. Simpson, Ph. D., Associate Scientist; Jesus M. TMharrats, Ph. D., Associate Scientist (Ad honorem); James A. Mair, Ph. D., Associate Scientist. I. PURPOSE 'The effects of radiation on organic crystals is the primary interest in this project. It is felt that such studies on well-defined crystalline structures can provide a firm foundation for a later study of more complex materials, including those of direct biological interest. Anthracene has been chosen as the initial material for study because this substance has been studied more than any other organic material. (CURRENT STATUS 'The damage induced by radiation is studied by measuring the changes in the electrical and optical properties before and after irradiation. The measurements at present are performed on anthracene single crystals. The electrical properties are studied by measuring the steady state and transient current-voltage characteristics. By applying an injecting electrode to the crystals (either highly absorbed light or iodine in a sodium-iodide solution), the current through the anthracene is space charge limited. From the transient and steady state behavior of the space charge limited current (SCLC) - voltage characteristics, carrier transport and trapping properties, such as mobility, trap density, trap depth, trapping lifetime, and capture cross section can be deduced. In this lab it was found that the measurement of the SCLC through anthracene is a very sensitive tool for the detection of damage induced by radiation. Our results indicate that by irradiating anthracene crystals with gamma or alpha rays, hole traps are introduced in the crystals. The presence of these traps was detected using steady state space charge limited current techniques using a NaI solution as the hole injecting electrode. = ah ---Page Break--- the changes in the steady state space charge limited.

current voltage characteristics for a crystal before and after irradiation the density of the introduced traps was calculated. The density of these was found to vary linearly with the absorbed radiation dose. The lifetime of the injected carriers was measured using the transient space charge limited current technique and the results indicate that the capture cross section of these traps for hole trapping is approximately of molecular size. The current voltage characteristics of irradiated anthracene crystals were compared with the current voltage characteristics of crystals grown from irradiated anthracene powder and very little difference was found. This result indicates that the defects introduced by irradiation are molecular rather than crystalline. In order to try to get a better understanding of the mechanisms involved in the space charge limited currents in insulators, which we use as the detection method in our investigation of radiation damage in anthracene crystals, a thorough theoretical study of injection of carriers into insulators has been done. Solutions for the time dependence of the current have been obtained for the case where the reservoir of the free carriers at the injecting electrode is time dependent. In this analysis the transient space charge limited current, where the carrier density at the reservoir is infinite and constant in time, becomes a special case of the problem. The optical properties are studied by measuring the radiation induced changes in absorption spectrum, in instantaneous fluorescence, and in delayed fluorescence. The delayed fluorescence is measured in scintillation grade anthracene crystals. They are exposed to radiation doses from 10^2 to 10^8 R. The excitation is by a high intensity red flash. The triplet excitons are produced by direct absorption in the triplet band and the singlet excitons are produced by two photon absorption and by triplet-triplet annihilation. The temporal response of the blue emission is continuously monitored both during and subsequent to

the excitation. Garsa radiation creates centers in the crystal that quench the singlets and the

triplets. The centers are paramagnetic and reduce the lifetime of the triplets; however, they do not affect the bimolecular triplet interaction rate constant. The density of the triplet quenching centers induced by one roentgen corresponds to the density of the hole traps measured by the S.C.1.0. method. By evaluating the density of the singlet quenching centers using the value of the bimolecular singlet interaction rate constant obtained from photoconductive measurements, it is found that this density is larger by three orders of magnitude than the density of the triplet quenching centers. Measurements are in progress to determine the bimolecular singlet interaction rate constant by optical methods. These measurements will permit determining the yield by which free carriers are produced in the singlet-singlet annihilation process. ---Page Break--- By use of multiple techniques, an individual single crystal of anthracene can be used as a wide range dosimeter, triplet-triplet annihilation limited current quenching in the range 10^9 to 10^8 and absorption spectroscopy above 10^7 R, ---Page Break--- Neutron Diffraction Program STAPe Mortiner I. Kay, Ph. D., Chief Scientist I, Principal Investigator; Seymour F. Kaplan, Ph. D., Associate Scientist II; Overt Kleinberg, Ph. D., Associate Scientist II; Ismael Almodévar, Ph. D., Associate Scientist II (part-time), PURPOSE The Neutron Diffraction Program is concerned with ideal and imperfect arrangements of atomic nuclear and magnetic spin systems in solids. Of particular interest to the program are magnetic structures of inorganic salts and the determination of the role of hydrogen in structures having important physical and chemical properties. Current status In collaboration with Dr. K. Okada, who returned to Japan in August after a two-year stay at PRC, the hydrogen positions in copper formate tetrahydrate have been determined at room temperature and some electrical,

Measurements made on the compound in the vicinity of the phase transition at $-W0^\circ\text{C}$, "Since antiferroelectricity was discovered, future work will consist of determining atomic positions in the presence of an electric field with the objective of demonstrating the atomistic basis for the electrical properties. Manganous formate dihydrate has been studied and the hydrogen positions determined. A comparison of the disordered tetrahydrate with the dihydrate structure shows clearly the reason for the greater stability of the latter. Dr. D. T. Cromer spent a year at PRNC on leave from Los Alamos Scientific Laboratory. While he was here, data was collected on the three types of alums $A^*B^*3(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$." The combination of PANG neutron data with ASL x-ray data has led to a complete elucidation of the $3 \times 3 \times 3$ chd y alum structures. The role of cation size, hydrogen bonding, and disorder on the structure has been elucidated. Interesting non-harmonic thermal motions have been noted. Neutron diffraction data was combined with x-ray diffraction data taken by Okeya and Stenple at IBM to produce a refined structure of tartaric acid, ---Page Break --- Data have been taken on Hall, (520), 2 (room temperature) and Tai at (130°C) to study the serzoeidatry transitions of interest to solid-state physics in ways. The aggregate structure determinations of CaCl_2 and HCl Hexahydrates have been collected by Dr. J. Kiciaber, at the U.S. Naval Research Laboratory. Other transition sets will be examined in the future. Work on the structure of molten SnCl_2 , by neutron diffraction using isotopic replacement of the Sn to ely separate terms in the radial distribution function is being carried out by Dr. Howard B. Ritter. Dr. Ritter is Research Professor of Chemistry at Stanford University in Oxford, Ohio and is currently spending one year as an Oak Ridge Research Participant in this Program, ---Page Break --- Bottom Chemistry Program SIF Oven H. Wheeler, D. Se., Ph. D. Chief Scientist 1, Principal Investigator, Carmen L. Gonzalez,

i.8. Research Associate 1. Score: 'The mechanism of the formation of radioactive products in the neutron activation of organometallic compounds containing carbon metal bonds is being investigated. Studies include work with short half-life isotopes. CURRENT STATUS: Studies have been completed on triphenylphosphine I and its oxide and on tetra-n-butylphosphonium chloride, and

also on diphenyl sulfide, sulfoxide and sulfone. Other work on cobaltocene and nickelocene has been completed and several publications are being prepared. Research in progress covers studies on similar compounds of mercury, thallium, iodine, selenium, bismuth and tin. The effect of radical scavengers is being studied. A gas-chromatographic vapor phase counting system is being constructed for ---Page Break--- Terrestrial Ecology Program, Part 1: 'The Rain Forest STAFF: Jerry R. Kline, Ph.D., Chief Scientist I, Principal Investigator; Cari P. Jordan, Ph.D., Associate Scientist I; George Drewry, M.A., Associate Scientist I; and visiting investigators. PURPOSE: (1) To study effects of gamma irradiation from 10,000 Curie Cesium on the Rain Forest system at El Verde. (2) To study some mineral cycles of the rain forest in relation to fall-out, atomic excavation, and plant nutrition. (3) To characterize the circuits and metabolic energy pulses of a complex terrestrial ecological system to understand the consequences of irradiation and fallout. CURRENT STATUS A. Radiation Effects Studies: The Rain Forest Project at El Verde involves irradiation of a plot of lower montane forest with gamma radiation from a 10,000 Curie Cesium source. After 15 months of pre-irradiation studies and preparations at the radiation and control areas, irradiation began January 1, 1965. The main site was irradiated for 3 months, the innermost zones receiving one million R. Post irradiation measurements are in progress showing effects of radiation according to dosage received, according to species, and according to various categories of ecological and...

cytological structure and function. Data emerging provide some factual basis for predicting effects of radiation on rainforests and the rates of regeneration of the living system. Recovery and Succession Studies: The radiation center is now in an active process of recovery from the effects of the gamma radiation. Studies are in progress to document the invasion of the area by new plants and to observe the recovery of old damaged plants. The radiation center has been subdivided into a grid of one-meter squares which are being studied individually for the occurrence of new plants and their rates of growth. Such studies will be repeated at regular intervals and the information gained will be used to construct a series of maps which will show a continuous record of the changes that occur during the recovery phase. Another method of documentation of the recovery process involves photographic comparisons of the irradiated area with other areas in the forest which have been damaged. Observations of this type indicate that the character of recovery in the irradiated areas is no different from that in areas of the forest which have had catastrophic damage from cutting or harvesting. Mineral cycle: Quantitative understanding is essential to the nature of the soils, and the ways such matters may process radioactivity entering in relation to all related activity will be the principal project. Radiometrics Evidence: In the edit that a substantial proportion of Heron product found in plant communities is in the form of surface formation on leaves and that only a minor part of these isotopes ever enters the metabolic pathways of the plants. Nevertheless, such observations suggest that the extensive surface root development and root invasion of organic litter on the ground suggests that this forest might be well adapted to the conservation of minerals by maintaining them in reasonably closed cycles. This view is reinforced by preliminary observations of soils which indicate low levels of fission products.

while the decaying litter at the 90.1 surface contains a large amount of radioactive isotopes. An experiment in progress was designed to test whether fall-cut isotopes were recycled from the forest floor through roots into understory plants. In this experiment, ^{13}Cs , Stn , and ^{85}Sr were sprayed in carrier-free aqueous solution directly on the forest floor. The results after one year indicate that most of the original radioactivity remained where it was first placed and much of the original organic litter was still highly radioactive. The rate of uptake of the isotopes by the understory trees was almost undetectably slow. 2. Effect of gamma irradiation on fission product retention by forest trees Samples were taken before and after the irradiation from forest trees in the irradiated control

centers. Measurement of Ce-137 and Cs-134 in these samples by gamma-ray spectrometry indicated no detectable effect of irradiation on the leaching of these elements in the forest system by rainwater. ---Page Break---

3. Neutron Irradiation Studies Thermal neutron irradiations of soils from various points in Puerto Rico and from Panama have been carried out. The most prominent isotopes which can be observed in these soils regardless of origin are: ^{59}Fe , ^{24}Na , ^{38}Cl , ^{75}Se , and ^{153}Sm . Samples of plant ash are also being prepared for study by thermal neutron irradiation. Plans have been completed and equipment constructed for an attempt to carry out fast neutron activation studies of soils and plants utilizing a special nuclear reaction which may generate fast (epithermal) neutrons in the presence of thermal neutrons.

4. Natural Radioactivity in the Environment Preliminary surveys of soil specimens from various locations in Puerto Rico have revealed certain sites of unusually high levels of radium daughters. These sites, which contain a factor of 5 more natural radioactivity than the El Verde site, may be of considerable value in future studies of the behavior of radioisotopes of the uranium decay series in natural environments. A suggested

preliminary use for these sites to study the possibility of radon transpiration by plants by examining wood from the trees of these locations for equilibrium: mixtures of lead-210 and polonium-210.

5. Radiostope Persistence in the Rain Forest 'The radionuclides ^{137}Cs , ^{90}Sr , ^{210}Pb , and ^{210}Po were observed to have extremely high persistence in the tropical forest at El Verde. Measurements made on samples collected from the forest on a monthly basis indicated that the rate of removal of the above nuclides from the forest system was controlled primarily by the physical half-life of the nuclide and that a biological half-life could not be experimentally defined. Such measurements were made at a time when the input of nuclides into the forest was negligibly small. They were interrupted by the arrival of fresh nuclear debris between 11 and 24 days after the Chinese atmospheric weapons test of May 1965. The sampling program is continuing.

D. Circuits and Metabolism A special PRIC proposal was prepared outlining an electrical analog circuit that might be prepared if authorized and budgeted. The system on the passive principle allows for flows in 35 compartments for which there are data available to get storage constants and rates. This system is under construction at the University of North Carolina by Howard T. Odum who is a consultant to the project.

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'The giant cylinder experiment was used to provide water budget and carbon metabolism data on the rain forest. 'The water budget, late was of particular interest for predictions of the fate of tritium in a tropical forest since this isotope is likely to be produced in large quantities by nuclear excavations. Attempts are being made to use the giant cylinder to study an annual cycle of metabolism and water use in the forest.

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Marine Biology Program STAFF Frank G. Loman, Ph.D., Chief Scientist 11, Program Director; Donald K. Phelps, Ph.D., Chief Scientist 1; Robert Y. Ting, Ph.D., Associate Scientist 1; John H. Wartin, Ph.

D., Associate Scientist I and Rail McClin, I. S., Research Associate. T. PURPOSE, 'The Marine Ecology Program at the Puerto Rico Seaquarium Center was started in January 1962 and is composed of six major research projects: land supporting areas of research, all of which are interrelated into an integrated research activity. 'The program was designed to provide measurements of the contribution and movement of trace elements in restricted but complete ecological and biogeochemical systems. The research includes investigation of the lithosphere and the marine bio- and hydrospheres. Specifically, the distributions and movements of selected trace elements are being followed from the rocks, minerals and soils of three river watersheds into the river waters, organisms and sediments, thence into the marine water at depths and distances offshore, through the marine biosphere and into the marine sediments.

CURRENT STATUS In order to obtain information on the interactions of the marine biosphere and hydrosphere,

measurements are being made to determine the influences of biological productivity, biological half-lives of trace elements, food webs, characteristics of trophic levels, and physical and chemical oceanographic factors on the distribution of trace elements in the marine waters offshore from the west coast of Puerto Rico. The effects of physical and chemical oceanographic conditions upon the distribution of organisms are being studied, with special emphasis on observations of the effects of varying amounts of mineral-rich silt upon the distribution patterns of marine organisms. The research projects include: (1) Measurements of Biological Productivity, (2) Analysis for selected trace elements, (3) Measurements of concentration factors of selected organisms for given radioisotopes, (4) Measurements of radioactivity and radioisotopes now present in the marine organisms, waters and sediments off the west coast of Puerto Rico, (5) Background measurements in physical and chemical oceanography.

and (6) Distribution of rare earths in the Alasco System. Supporting areas of research include investigations of the effects of interactions of river and sea water upon the precipitation of trace elements in estuarine environments, chemical and physical characteristics of marine sediments derived from three rivers which drain watersheds containing limestone, serpentine or rocks of volcanic origin; the characteristics of variability in trace element content of populations of organisms from a given environment, and the development of methods for analyzing trace elements in a variety of sample types. -3- ---Page Break--- Estuarine and Marine Ecology Study - Specific Activity Approach STAFF Frank G. Lowen, Ph. D., Chief Scientist II, Program Director; Donald J. P. Swift, Ph. D., Associate Scientist I; Rail McLin, H.S., Research Associate I; Henry Besselievre, Research Associate Id; plus technical staff, PURPOSE, The program is part of a feasibility study for a sea-level detainment facility in Central America under the management of Battelle Memorial Institute and is designed to develop and carry out investigations of stable element distribution throughout the marine and estuarine environments in the Darien area of Panama including the Gulf of Panama and the waters off the continental shelf in the Caribbean Sea from Punta Mosquito, Panama to Barranquilla, Colombia. The degree of potential hazard to man through contamination of those environments by radionuclides may then be predicted from these data. CURRENT STATUS This program is an extension of the Marine Biology Program at PRIC which is supported by the Environmental Sciences Branch of the USAEC Division of Biology and Medicine. A unique feature of the program is the "specific activity" approach-- a procedure of sampling and analysis which holds promise of successful application to marine contamination problems. This method is based upon two premises: 1, That the distribution patterns of biologically-available stable elements in the organisms and their environment may

The text used to predict approximately the distribution patterns of introduced radioisotopes of the same element. That if the specific activities (C1 of radioisotope/mean of corresponding stable element or carrier element) in the estuarine or marine environment are maintained below the allowable specific activities for radioisotopes in the human body, then no individual can obtain greater than the allowable amount of radioactivity from food derived from these sources. ---Page Break--- On the basis of the preliminary assessment of potentially critical radionuclides, a field collection program has been developed and two research vessels with an eight-man operating crew and seven scientific investigators will be sent to Panama in February 1957. The field teams will remain in the Panama area for three months making the collections which will include soils, river waters, sediment and organisms, marine water and sediments, and marine organisms including mollusks, plankton, seston, crustaceans, and fish. At the end of the first three-month survey, which will be conducted during the "dry" season, the research vessel "Shinada" will return to Puerto Rico. In August the collections for the "rainy" season will be made in Panama. The "Shinada" and the

crew will return to the site at that time. Stable element analysis for 10 elements will be done on approximately 4,250 samples in the Mayaguez Laboratory. The distribution patterns of the stable elements for which corresponding potentially dangerous radioisotopes may occur will be determined. From these data, the expected specific activities in human food items may be calculated and compared with those published in radiological safety codes and regulations. 3H.

---Page Break--- Schistosomiasis Project EFFECT OF IRRADIATION ON HOST-PARASITE RELATIONSHIP IN SCHISTOSOMA HAEMATOBIIUM Jorge Chiriboga, M.D., Assistant Director for Scientific Program; Acting Program Director; Julio I. Colén, Ph.D., Associate Scientist (Ad honorem); Ranilo Martinez Silva, M.D., Associate Scientist.

score Schistosomiasis is a worldwide parasitic disease with a complex life cycle for which there is not yet a known method of control. This project attempts to use all methods available through atomic energy to learn the basic mechanisms of the individual phases of the life cycle with the ultimate objective of finding a way to break the cycle. The principal aspects of this program may be divided into two: effects on the relationship between mice and *Schistosoma mansoni*, and effects on the relationship between snails and *Schistosoma mansoni*. One of the goals in the first part is to develop an effective vaccine with the mice which could later be used for man, and one of the goals of the second part is to effect a mutation in the snail host that would lead to a generation of snails immune to the parasite. A method of assessing the degree of infection, which is based on the number of *S. mansoni* ova which can be recovered from the feces of infected mice, using standardized observation procedures has been demonstrated. The optimum amount of radiation for cercarial exposure, to induce the greatest degree of resistance to challenge, has been determined with this method. An analysis of these results shows that the degree of variability is very high. A new method for determination of this parameter utilizing whole body radiation of the mouse is now under study. Preliminary results indicate that this method can be used for the following: a. determination of the optimal number of cercariae for immunization b. determination of a different schedule for immunization. Preliminary studies to determine the LD-50 of the snail *Biomphalaria glabrata* show that the value is in the range of 10,000-100,000. The development of snail embryos, to perfect the LD-50 determination, and to attempt to produce snail mutants. -B- ---Page Break--- Sugarcane Sorer Program: Induced Sterility for Population Control of the Sugarcane Borer (*Diatraea saccharalis*) in Puerto Rico STAFF David U. Walker, Ph. D.,

Associate Scientist II, Principal Investigator. PURPOSE: This program was begun in 1963 to determine the potential for control by radiation sterilization of the sugarcane borer (*Diatraea saccharalis*) (F.), Crambidae, Lepidoptera, and to study the dynamics of the species as it relates to a mass-release program. Optimal doses suitable for sterilization of the sugarcane borer have been determined. Adults are sterilized at 35 Kilorad doses without affecting their lifespan, oviposition rate, or feeding behavior. Immature stages are much more radiosensitive, with 9 Kilorad causing over 90% lethality. Factors involved in the mass-rearing of the Puerto Rican strain of this species have been studied. These include the following: 1. Artificial diet: vigorous adults of high fertility can be produced on a diet containing carrot powder, liquid corn stalk extract, corn stalk fiber, ascorbic acid, sugar, casein, sodium benzoate, and methyl paraben. Survival on this diet is eighty percent or higher, and adequate numbers are being produced to conduct small-scale field tests. Assuming fifty percent survival, food cost is 12 cents per adult. 2. Rearing conditions: Light, temperature, and humidity are controlled during laboratory rearing. Under these conditions, six days are required for egg maturation, thirty days for larval development, and seven to eight days for pupation. Adults produced from this diet live longer and produce more viable eggs than comparable individuals grown on sugarcane and other host plants. Eggs are collected daily and are placed on the food

immediately before hatching. Pupae are removed from the food as they form. Sex is determined in the pupal stage. Adults are collected as they emerge from the pupal case. 3. Mating conditions involving taxi (taxiing) and are influenced by temperature reduction and light decrease. Males are attracted to females by a sex attractant and by the specific wingbeat frequency. Mated females begin laying fertile eggs within one hour after mating. Female

oviposition occurs on the second and fourth days after fasting. Three hundred fifty eggs are laid per female (average) under normal conditions; they hatch at one hundred percent for fertilized females except during the period from December to March. Since in the dark (less than 1 A), a large steel cage has been constructed to permit determination of population decline under biotic conditions using corn as the host plant. Corn planted in the cage has been infested by a number of normal adults collected from nature. Population overloading by irradiated males and/or females has been done to measure population reduction. Larval populations are measured by direct visual observation of larval tunnels in stalks, and adult male population is determined by trapping at night during nuptial flight.

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Resonance in Radiation Program

STAFF Henry J. Gouws, Ph. D., Deputy Director and Robert A. Lage, Ph. D., Chief Scientist (part time), Primary Investigators, Francis K.S. Keo, Ph. D.; Florencio Vizquer, Ph. D.; and Peter Paraskevoudakis, Ph. D., Associate Scientists (all part time).

PURPOSE To answer the question "What are some of the unique effects of ionizing radiation on matter?" To understand, the project has studied x-radiation effects in the 5 to 20 KeV energy range on biological systems. This energy region is of considerable importance since it contains the K-absorption edges of the constituent atoms of most living systems.

STATUS Evaluation continues of the hypothesis that radiation damage in molecules can be a function of the site at which the photon is initially absorbed. It is postulated that absorption of an x-ray photon in the K shell of an atom will produce a highly ionized atom and that the final state of ionization will lead to major disruption of the molecule at the site of photon absorption. Using monochromatic x-rays, biological molecules were irradiated at energies above and below the K-absorption edge of selected target atoms. Damage was judged on the basis of effects observed per unit energy.

absorption, OF per photon absorbed, in the molecular system. Experiments in the energy range 6.1 to 0.3 Kev have shown increased inactivation of the catalase at or near the K absorption edge of iron (7.11 Kev), which is located at the active site of this enzyme. In another biological system, chromosomes in onion root tip cells treated with 5 bromodeoxyuridine have exhibited an increase in breakages caused by monochromatic x-rays at photon energies equal to or slightly greater than the K absorption edge of bromine (23.46 Kev). In contrast, there is no such effect on cells containing no added BUDR. Hence, in these two important types of molecules—enzyme and nucleic acid—it has been shown that the efficiency of damage production is a sensitive function of the photon energy. The significance of this finding in more complex biological systems (bacterial cells, HeLa cells) is at present being explored. <n ---Page Break---

Current project activity has been directed to several biological systems in an attempt to find optimal systems for demonstrating the Resonance

phenomenon. At this point, the effect has been shown in both the metalloenzyme catalase and BUDR-labeled chromosomes. Efforts now will be directed to developing mechanisms of the effect based on more quantitative studies. Initially, this will involve biochemical studies on structural changes in the catalase molecule irradiated at or near the K absorption edge of iron.

Supplementing the irradiation studies of biological molecules is the development of special equipment which permits absolute measurement of the very low photon fluxes generated in our highly monochromated (750 eV) x-ray beams. In addition, design and construction of high intensity field emission type x-ray sources have been carried out and the effect of various parameters (vacuum, cathode material, applied voltage, and cathode-anode spacing) on electron emission has been tested. 42 ---Page Break---

Radiation Chemistry and Photochemistry Program MATRIX ISOLATION STUDIES OF PRODUCTS OF

GAMA RADIOLYSIS OF HETEROCYCLIC MOLECULES STAFF

Alec Grimison, Ph. D., Associate Scientist; George Sinpoon, Ph. D., Associate Scientist; Mariel M. Blair, M.D., Associate Scientist, and W. Research Assistants. This program is concerned with the effects of gamma radiolysis on simple heterocyclic molecules, which can be considered as models for more complex substances of biological importance. Unstable species formed in this gamma radiolysis are trapped by carrying out irradiations in solid matrices at 77°K, and are studied under these conditions to elucidate their structure. CURRENT STATUS Optical devices have been designed and tested for the examination of optical spectra at liquid nitrogen temperatures. Current projects include the investigation of color centers formed by gamma irradiation of heterocyclic solutes in methyltetrahydrofuran and carbon tetrachloride matrices. These two solvents have been chosen to enhance radical anion and radical cation formation, respectively. Good agreement has been obtained on the literature values for the efficiency of production of color centers in the pure solvent. Systems which have proved particularly interesting are purine and tyrosine in methyltetrahydrofuran, and pyrrole in carbon tetrachloride. This last system is currently being investigated also by photochemical irradiation of rigid solutions. Theoretical work includes the prediction of the g vs. h Electron Spin Resonance spectra of likely radical species, using Molecular Orbital and Valence Band Techniques. A set of valence band calculations on triplet states of simple heterocyclic compounds is being done in collaboration with Dr. Zauli at the Instituto di Chimica Fisica, University of Bologna. ---Page Break---

Radiation Preservation of Tropical Foods STAFF

Horace D. Graham, Ph. D., and Robert A. Luse, Ph. D., Chief Scientists (Part time), Principal Investigators, Sureekant K. Dea, Ph. D., Associate Scientist I (Part time). PURPOSE To determine the feasibility of radiation preservation of bananas.

1, Determination of those factors of pre-irradiation condition, radiation dose, and post-irradiation treatment which delay ripening and maximize the shelf life of the food product, have qualitative or semi-quantitative criteria of ripening, such as softening, changes in color, spotting, and taste are utilized. These are supplemented by measurement of those characters associated with ripening, e.g., starch to sugar conversion and total acidity. 2, Measurement by appropriate biochemical assay of changes in various nutritional factors that accompany radiation pasteurization. This part is amenable to quantitative assay of vitamin levels and how they are affected by radiation dose and treatment. For bananas of the variety Monte Grise and mangoes of the varieties Native, Hafu, Seedling 110, and Hative-ayajuevano have been irradiated to determine if relatively low doses (5 gamma irradiation) can be used for the preservation of these tropical fruits. Major emphasis is placed on the influence of irradiation on the retardation of ripening in these fruits and on the levels of nutritionally important biochemical components such as ascorbic acid, carotenoids, sugars, starch, and on titratable acidity. Studies also are made of the effect of mango irradiation on the depolymerization of some of

the pectic constituents of mangoes. Bananas of known history and 90-120 days old at the time of cutting have been irradiated at 10, 20, 30, 40, and 50 kilorads and then, along with non-irradiated samples (controls), stored at 60°F, 75°F, and 60°F. Every seven days samples are taken and analyzed for the components noted above. At 65°F, using bananas 96-100 days, no retardation of ripening has been noticed. On the contrary, some stimulation was evident, but the pattern was erratic. At 50 kilorads, intense blackening of the fruits occurred; hence all subsequent work was limited to 40 kilorads. Retardation of ripening occurred at 75° and at 70-0 kilorads.

but there was no consistent relationship between the radiation dose and the extent of retardation. At this temperature and at an irradiation dose of 40 kilorads, there was little or no effect on the levels of sugar carotenoids but the titratable acidity increased and ascorbic acid decreased by about 29%. At 60°F retardation of ripening was more pronounced, but the fruit ripened much faster than at 75°F. Mature or almost ripe mangoes have been irradiated at 50, 100, 150 and 200 kilorads and stored at 50°F; non-irradiated controls were also included. Biochemical analyses were done on representative samples as described above for bananas. All fruits stored at 50°F kept well. The irradiated fruit remained green for 30 days. Fruit of the "Native" variety irradiated at 150 kilorads or above showed severe blackening of the pulp. This blackening progressed from the seed outwards and was not noticed in the other varieties. Durng or blackening of the skin occurred in all varieties when irradiated at 150 and 200 kilorads. The wide natural variations from fruit to fruit and from batch to batch hinder making any valid conclusions as to the effect of irradiation on the biochemical components assayed. Pectin constituents of mangoes of the variety Sindareha irradiated at 500, 1,000, 1,500 and 2,000 kilorads have shown a consistent decrease in the molecular weights of their highly methylated water soluble pectinic acid fractions with increasing radiation dose. However, increase in radiation dose did not cause a severe degradation of the low methoxyl pectins or the protopectin extracted from these fruits. Fractionation of pectins from control fruits with molecular sieve chromatography indicated the occurrence of at least two major fractions of distinct molecular size. It was inferred that the radiation-depolymerized pectins constitute sub-fractions of these major fractions. Study of their molecular weight distribution patterns therefore is contemplated, in order to determine the relationship between pectin.

depolymerization and fruit softening. = 45 - ---Page Break---