History of the Radiological Health Program of the Pan American Health Organization: 1960–2006[1]

Gerald P. Hanson,[2] Cari Borrás,[3] and Pablo Jiménez[4]

Contents

[1] A summarized version of this article is available at the PAHO Journal: Hanson G, Borrás C, Jiménez P. History of the radiological health program of the Pan American Health Organization. *Pan Am J Public Health*. 2006; 20 (2/3): 87-98.

[2] Former Regional Advisor in Radiological Health for the Pan American Health Organization, Washington, DC, United States of America.
[3] Former Regional Advisor in Radiological Health for the Pan American Health Organization, Washington, DC, United States of America.
[4] Current Regional Advisor in Radiological Health for the Pan American Health Organization, Washington, DC, United States of America.

Send correspondence to: Pablo Jiménez, Pan American Health Organization, 525 23rd St. NW, Washington, DC, 20007; *e-mail:* jimenezp@paho.org.

Keywords: Delivery of health care, radiological health, radiology, radiation protection, radiotherapy, Pan American Health Organization, Americas.

Introduction

The radiological health program of the Pan American Health Organization (PAHO) was established in 1960. Although the program has undergone various organizational changes, it has been in continuous operation to the present, extending through the administrations of five of the Directors of the Pan American Sanitary Bureau (PASB, PAHO's Secretariat) in various PAHO divisions or areas of work. Its program emphasis has evolved according to the requirements of the PAHO Member States. However, the program has essentially remained a unit with activities revolving around research, training, radiation protection, and services in the areas of public health and clinical medicine.

1959–1975, PASB Director Abraham Horwitz

In the 1950s, the global superpowers were actively engaged in a nuclear arms race and were testing weapons in the atmosphere. Governments and people throughout the world were deeply concerned about the effects of worldwide radioactive fallout. Civil defense shelters were being constructed to protect against such fallout and against nuclear blasts, and schoolchildren were being taught to deal with a nuclear attack. Also, the peaceful uses of atomic energy were being promoted, and radioisotopes were being developed for diagnosis, research, and therapy.

The PAHO Radiological Health Unit was established in 1960 for the purpose of promoting the role of the public health authorities in the field of applied nuclear energy. It consisted of two professionals and a secretary. The Unit Chief was the Regional Radiological Health Advisor (Irvin Lourie), who was supported by a Health Physicist (Thomas Shea), the Specialized Technical Advisor.

As quoted from the PAHO Director's Annual Report for 1960, "The program of the unit will be directed in the near future along the following four main lines:

1. Stimulating national health services to develop procedures for the regulations governing the use of X-rays and radioisotopes and the disposal of radioactive wastes, based on the recommendations of the International Commission on Radiological Protection.
2. Promoting the teaching of basic health physics and radiological protection in schools of medicine, dentistry, public health, veterinary medicine, etc.
3. Fostering the use of radioisotopes for medical diagnosis, therapy, and research.
4. Encouraging research on applications of radiation that may be of importance to medicine, public health, or veterinary medicine." (1).

In 1962, the XVI Pan American Sanitary Conference approved a research policy for PAHO and requested that the Director of the PASB "take all possible steps to expand the research activities of the Organization, including specific projects and their financing, for the mutual benefit of the countries of the Region [of the Americas]" (2). In 1962, PAHO established the

Advisory Committee on Medical Research (ACMR). This had a stimulating effect on the research aspects of PAHO's technical programs, including radiological health.

In collaboration with physicist Merrill Eisenbud of New York University (NYU), preliminary studies were performed of food, water, and human teeth from the areas of Brazil with a high natural radiation background. Later, a conference was held to elucidate the public health significance of background radiation, and financial support was obtained for the Biophysics Institute of the University of Brazil and the Catholic University of Rio de Janeiro to conduct biological and physical studies from the Atomic Energy Commission of the United States of America. During the course of the project, numerous Brazilian scientists received training in Brazil and at New York University, and valuable information concerning chronic exposure in areas of high natural radiation background was obtained. PAHO continued to support this project until the end of 1975. By then, such development as paved roads and building construction had changed the character of the area.

In Chile, a coordinated research project on manganese poisoning in miners was initiated, with collaboration between the Brookhaven National Laboratory, for biochemical analysis, and the School of Medicine of the Catholic University of Chile, for clinical evaluation.

Funding was obtained from the U.S. National Institutes of Health for initial studies that attempted to coordinate the concentration of manganese in body fluids, hair, and tissues with the degree of intoxication. Through neutron activation analysis at BNL, the level of manganese was determined to help elucidate the mechanism by which the inhalation of manganese dust by miners induced a schizophrenia-like syndrome, followed by a neurological syndrome similar to Parkinson's disease or Wilson's disease.

Initiated in 1962, the project continued through 1974. It resulted in an understanding of the biochemical basis of action of various amino acids in chronic manganese poisoning and in Parkinson's disease.

In 1962 and 1963, plans were made to study the effects of irradiation at high altitudes on large animals (burros and llamas). In November 1964, a meeting was held in Lima, Peru, to develop a research project. The *altiplano* (highland plateau) of Peru was selected as a natural laboratory environment to determine if hypoxia exerts a protective influence by reducing the number of cases of aplastic anemia following high doses of gamma radiation, as well as to study the central nervous system syndrome. It was envisaged that this information might contribute to a better understanding of the development of leukemia in humans.

Scientific cooperation, as well as support for construction of the laboratory facilities, was provided by the U. S. Atomic Energy Commission. The project reached full scale in 1966 and finished in 1967.

Over the 1960–1964 period, the Radiological Health Unit also directed efforts toward such other areas as:

1. providing fellowships for training PAHO staff and national professionals,
2. preparing Spanish-language translations of training materials (manuals, pamphlets, slides, movies) and disseminating these materials,

3. promoting radiation control legislation and regulations and establishing national programs,
4. providing advice to governments concerning radiation exposure and control,
5. assisting governments in obtaining international support and arranging scientific collaboration, and
6. representing PAHO at international conferences and meetings.

A Regional program for the radiological surveillance of air and milk in Latin America and the Caribbean was in operation from 1962 to 1981. Using supplies provided by the USPHS, national personnel collected daily air samples and monthly-composite milk samples, which were forwarded through PAHO to the appropriate USPHS Laboratory for analysis. The results were then reported to the countries through PAHO and also published by the USPHS in its monthly *Radiological Health Data and Reports*. At its full operational status, the program consisted of 12 air-sampling stations and 6 milk-sampling stations. At the end of 1976, this program was revaluated and the radiation-in-air value, which had been based on gross beta measurements, was discontinued. Subsequently, in collaboration with the School of Public Health of the University of Texas, a program was organized to measure environmental radiation exposure using thermoluminescent dosimeters. By 1981, interest in environmental surveillance had waned. A final report was prepared and all activities were terminated.

Figure 1: Station operator (Dr. Francesco Parra Gil) and technician (Ms. Vilma Palacios) at the National Institute of Health's air sampling station in Guayaquil, Ecuador, 1965

Although several very promising research projects had been initiated and training materials had been prepared, and both the program staff and consultants had made numerous visits to the countries, by 1963 Lourie was disappointed that it had not been possible to establish a single national radiation protection program within the health ministries. He became convinced that it was imperative to assign a staff member to reside and to work in the field. Shea did not wish to leave the Washington, DC, area and decided to accept the position of Radiation Safety Officer at the University of Maryland.

Figure 2: Technician (Ms. Vilma Palacios), collecting a composite milk sample at a dairy in Guayaquil, Ecuador, 1965

It then became necessary to recruit a health physicist who would be willing to live and work in the field. By coincidence, a young engineer with both a Master's Degree in Sanitary Engineering and a Master's Degree in Radiological Health from the University of Michigan, and who had practical experience both as a State Radiation Control Program Director (Kansas) and as a Radiation Safety Officer at a federal government research and development laboratory, had contacted WHO Headquarters. Gerald Hanson was 28 years old

and had no facility with the Spanish language. Nevertheless, Lourie judged that he was mature enough to handle the responsibility. Hanson accepted the post and embarked on a crash program to learn rudimentary Spanish. In December 1964, the newly appointed Regional Advisor in Radiation Protection arrived at the PAHO "Zone" Office in Peru.

Stationed in Lima, Peru, Hanson was responsible for providing advice and establishing radiation protection programs within the health ministries of the countries of Latin America and the Caribbean. During the 1965–1968 period, Hanson made numerous visits to countries that had requested technical advice. The topics covered included identifying sources of radiation; carrying out radiation protection surveys in hospitals, medical centers, and industries; drafting legislation and regulations; organizing radiation protection services, including film dosimetry laboratories; training national staff, including identifying potential leaders for fellowship support; setting up and operating fallout monitoring programs; promoting and coordinating research; and coordinating activities with national and international radiation protection agencies.

Some of the situations that were encountered while making radiation protection surveys are shown below:

Figure 3: Argentina, 1965—Inadequate filtration and excessive tube housing leakage.

Figure 4: Jamaica, 1966—Room wall unshielded.

Figure 5: Uruguay, 1965: No protection for the operator.

Figure 6: Guatemala, 1967—Films drying in busy and dusty corridor.

Figure 7: Guyana, 1965—Operator has made his own protective apron using red lead paint.

Figure 8: Panama, 1965—No shielding for operator or medical staff.

Figure 9: Ecuador, 1979—"Point and shoot" radiography; human cassette holder.

Figure 10: Honduras, 1975— Technologists with defective protective apron.

Figure 11: Poorly maintained darkroom; note broken "safety light" replaced by a paper bag covering a common light bulb.

Figure 12: Peru, 1966—Regional advisor checking for alpha contamination in radium-loading room.

Figure 13: Chile, 1968—Regional advisor checking for radon-daughter concentration in copper mine.

A training team was formed by appointing two consultants: Jorge Román, an occupational health engineer from Peru, and Robert Bostrom, a training specialist from the U.S. Public Health Service (USPHS). Using excellent training materials (the *Basic Science Review* and the *Basic Manual on Radiation Protection)* that had been prepared in collaboration with the USPHS, short courses were presented in various countries.

In mid-1967, PAHO Regional Radiological Health Advisor Lourie felt he had no alternative but to resign. He had made the strongest case possible for increasing the resources available to the PAHO radiological health program but was informed by the Director that no additional funds or staff would be assigned. From that point onward—until Jorge Litvak, a

Chilean endocrinologist with training in nuclear medicine, joined PAHO in 1969—the program was implemented by the unit's secretary, Rida Luellsdorf, in Washington, DC, and Regional Advisor Hanson, now stationed in Santiago, Chile.

By the end of 1968, 10 countries had signed formal agreements with PAHO for assistance in establishing a radiation protection program within their health ministries. These countries were Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Guyana, Jamaica, Uruguay, and Venezuela. In the radiological fallout surveillance program, 12 stations in 10 countries were in operation, with all 12 forwarding daily air samples and 6 sending weekly to monthly composite milk samples. Also, with cooperation from the U.S. Atomic Energy Commission, six radiological health scientific libraries, with several hundred volumes each, were established. They were located in Argentina, Bolivia, Brazil, Chile, Colombia, and Venezuela.

In 1968, a seminal meeting on dosimetric requirements in radiotherapy centers took place in Caracas, Venezuela, with participation from the International Atomic Energy Agency (IAEA), PAHO, and the World Health Organization (WHO). The recommendations of the meeting included three key items:

1. preparation of a basic manual on dosimetry adapted to Latin American needs,
2. organization of Regional training courses in radiotherapy physics, and
3. creation of Regional dosimetry laboratories.

Figure 14: Symposium on the Need for Dosimetry in Radiotherapy Centers, Caracas, Venezuela, 22-26 April 1968
The participants were (as shown in the above photograph, Figure 14):
Front row from left: Roger Cloutier, physicist (Oak Ridge Associated Universities); Hugo Mugliaroli, physicist, CNEA, Argentina; Francisco Parra-Gil, nuclear medicine physician , National Institute of Health, Ecuador; Joaquin Solanas, health physicist, IVIC of the Ministry of Health , Venezuela, Mayer Zaharia, radiation oncologist, INEN (National Cancer Institute, Peru; Mario Gaitan Yanguas, radiation oncologist, National Cancer Institute, Colombia; E. Meyer physicist, CNEN, Brazil.
Second row from left: Daniel Joly, surgeon, PAHO Regional Advisor in Cancer; John Massey, physicist, Christie Hospital and Holt Radium Institute, Manchester, United Kingdom; Paul Pfalzner, physicist, IAEA Division of Life Sciences; Clemencia Garcia Villas-Mil, physicist, National Cancer Institute, Venezuela; Horst Eisenlohr, physicist, IAEA Division of Life Sciences; E. Bunde, physicist, University of Munich, Federal Republic of Germany; Gerald Hanson, health physicist, PAHO Regional Advisor in Radiation Protection; Walter Seelentag, radiologist, WHO Chief of Radiation Medicine.

Joly and Hanson had excellent rapport with the Latin American participants (Hanson, who was stationed in Santiago had also been officially designated by the Chilean Nuclear Energy Commission as its representative). Seelentag was new in the WHO post and had funds at his disposal. Together they steered the meeting toward the goal of improving medical radiation therapy practice in Latin America.

John Massey of the Christie Hospital in Manchester, United Kingdom, was selected to write the Manual; and on several occasions in 1969–1970, Massey and Mayer Zaharia, radiation oncologist of the National Cancer Institute in Lima, Peru, were brought to PAHO Headquarters in Washington, DC, where they worked with Litvak. When finished, the manuscript, including its Spanish translation, was handed over to the IAEA, and the world-renowned *Manual of Dosimetry in* Radiotherapy (the "Massey Manual") was published in 1970, bearing the logos of the IAEA, PAHO, and WHO (3).

In 1970, a Regional course for physicists specializing in radiotherapy was presented at the Puerto Rico Nuclear Center, jointly sponsored by PAHO and IAEA. Cari Borrás, who later became PAHO's Radiological Health Advisor, served as an instructor in this first course. Later, similar courses were organized in Brazil (1975), Chile (1975), and Mexico (1973).

Following PAHO's recommendation, in 1969 WHO established the first Regional Reference Center for Secondary Standard Dosimetry (SSD) within the laboratories of the Atomic Energy Commission of Argentina. For many years, this laboratory, and others throughout the world (including ones established within the Nuclear Energy Commission of Brazil and the Health Ministry of Mexico), received funding from WHO. The periodic newsletter of the Secondary Standard Dosimetry Laboratories (SSDLs) was published by WHO from 1970 until 1986, at which time the IAEA took over the responsibility. By the end of 2005, there were 81 SSDLs in 64 countries, and 13 of these laboratories were located in 13 different countries of the Americas.

Also arising out of the 1968 meeting in Caracas was the postal IAEA/WHO program for the intercomparison of radiation therapy doses, using thermoluminescent dosimeters (TLDs). Two physicists serving with the IAEA, Paul Pfalzner of Canada and Robert Loevinger of the United States, had devised a simple method for measuring the radiation dose from cobalt-60 teletherapy units by using capsules containing thermoluminescent powder that could easily be transported through the mail. PAHO and WHO immediately grasped the impact that such a system could have on improving the practice of radiation therapy, and they joined with IAEA to organize this service on a worldwide basis. From its inception in 1969 through the end of 2005, approximately 2,200 measurements (radiation-beam checks) were made in 330 hospitals or radiation therapy centers in 24 countries in the Americas. Since 1991, this has included measurements on linear accelerators. The results of the TLD program—now known as postal dose audits—are described in an article by Izewska et al. (4).

Participation in the 1968 Caracas meeting cemented Hanson's resolve to obtain training in medical physics. While conducting radiation protection surveys in hospitals and training national staff for this purpose, he was shocked by the lack of support for radiological physics. The hospital physicist was practically nonexistent, with probably no more than a dozen medical radiation physicists working in hospitals in all of Latin America and the

Caribbean (2 in Argentina, 5 in Brazil, 1 in Colombia, 1 in Jamaica, and 3 in Mexico). In contrast, in 2006 the International Organization for Medical Physics had around 600 members from 11 countries of Latin America and the Caribbean.

The PASB Director allowed Hanson a two-year leave of absence to obtain his doctoral degree at the University of California in Los Angeles (UCLA). Subsequently, Jorge Litvak was invited to take the vacant post of Regional Advisor in Radiological Health in Washington, DC, Jorge Román was appointed to the post of Regional Advisor in Radiation Protection in Santiago, Chile. During 1969 and 1970, Litvak and Román worked as a team, PAHO's program continued, and a general model for radiation protection legislation was prepared. In these two years, a record number of 18 fellowships was awarded for radiological health studies to officials from Argentina, Barbados, Bolivia, Brazil, British Honduras, Chile, Colombia, Costa Rica, Ecuador, Jamaica, Peru, Trinidad and Tobago, and Venezuela. During 1970, PAHO collaborated closely with IAEA concerning their programs in the Americas and bilateral agreements between the radiation protection authorities of the health ministries and the atomic energy commissions were signed in Argentina, Bolivia, Chile; and Costa Rica.

The team of Litvak and Román did not continue beyond the first few months of 1971. Román's contract was not renewed, and soon afterwards Litvak returned to Chile to become Dean of the Medical School of the University of Chile. By April 1971, Hanson had completed his doctoral studies at UCLA and had successfully defended his PhD thesis on *Organization of Radiation Therapy Services Related to Outcome*. He was informed there was no chance of returning to a duty station in the field and was assigned to the PAHO Washington Office, where he remained until he was invited to be the Chief of Radiation Medicine at WHO Headquarters in 1987.

The Radiological Health Unit entered into an era of close cooperation with the PAHO Cancer Unit and, in collaboration with the national cancer authorities of Brazil, held a study group meeting on *Training Personnel in Physics Applied to Radiotherapy* in Rio de Janeiro in 1972. Radiation oncologists, physicists, and cancer specialists from the Region met with PAHO staff and consultants to develop a plan to satisfy the need for radiotherapy physics services. PAHO invited Carlos Eduardo de Almeida, a young Brazilian student who was pursuing a degree in medical physics at the University of Texas' M. D. Anderson Hospital in Houston, Texas, to attend the meeting as a consultant. Subsequently, de Almeida made a significant contribution to the development of medical physics and radiation protection in the Region of the Americas.

In 1973, PAHO provided the Government of Haiti with a special type of cobalt-60 teletherapy unit called JANUS that had been designed by Ulrich Henschke, a radiation oncologist. With PAHO's support, Henschke and his colleagues provided operational assistance and training in radiation therapy.

The PAHO Radiological Health Unit also began working closely with the Pan American Development Foundation (PADF), and donations of used equipment were offered to countries in the Americas. PADF relied on PAHO's technical advice in deciding whether to accept the offers. During this period, PAHO also learned about a revolutionary new diagnostic X-ray machine whose design features included a fixed tube-to-focus distance and a support that firmly linked the tube and image receptor. Richard Chamberlain, a diagnostic

radiologist at the University of Pennsylvania who had developed the machine, named it the "Technamatic."

In the latter part of 1973, the vacant post of Regional Advisor in Radiological Health was filled. The Radiological Health Unit had a new chief, Godofredo Gómez Crespo, a physician from Spain, who had been the Regional Advisor in the WHO Regional Office for the Eastern Mediterranean. From 1974 to 1979, both the Regional Advisor in Radiological Health and the Regional Advisor in Radiation Physics were stationed in Washington, DC. Gómez Crespo devoted his efforts mainly to diagnostic radiology, nuclear medicine, and radiation therapy. Hanson worked in radiation protection, environmental surveillance, and support for radiation therapy, including the Postal TLD Intercomparison Program.

Soon after becoming the chief of the PAHO Radiological Health Unit, Gómez Crespo was introduced to Chamberlain and immediately recognized the utility of the Technamatic X-ray machine that Chamberlain had developed. The Unit's two Regional Advisors organized a pivotal working group meeting, held in March 1975 at PAHO Headquarters in Washington, DC, on planning and developing radiological facilities. Chamberlain, who was terminally ill, participated vigorously, along with experts from Europe, Latin America, and the United States, including Thure Holm, a diagnostic radiologist from Sweden who was an expert on X-ray equipment. The working group developed a diagnostic radiology system for primary care centers, including the specifications for a simple X-ray machine that could operate under adverse conditions. The working group also developed designs for appropriate X-ray rooms and plans for the training of radiology personnel. A year later, Philip Palmer, a diagnostic radiologist from the University of California in Davis who had also attended the March 1975 meeting, wrote a manual that provided the information needed to establish an X-ray department in a small hospital. PAHO published the text (5) in both English- and Spanish-language editions in 1978.

1975–1983, PASB Director Hector Acuña

Hector Acuña became the Director of the PASB in 1975. One of his first priorities was reorganizing the institution. The Radiological Health Unit became part of the Environmental Health Division, where it remained until 1979. Within the Environmental Health Division, the country-level projects dealing with air pollution, industrial hygiene, and radiation protection were consolidated within the division's core program of water supply and wastewater disposal. Within a few years, in most countries the country-level budget assigned for the entire environmental engineering program was less than the previous budgets for either industrial hygiene or radiation protection activities alone. During the 1970s, PAHO had made bilateral agreements with several Latin American and Caribbean governments to establish radiological protection programs. When the agreements reached the end of their timeframe, they were not renewed; and by 1977, none of the country radiation protection projects remained.

During his years in the Environmental Health Division, the Regional Advisor in Radiological Health continued to promote the primary care radiology system (PCRS) and the training of technologists. A prototype machine loaned by the University of Pennsylvania was tested for

three months in El Salvador in 1975, and a report on it was presented at the *Second International Symposium on the Planning of Radiological Departments* held in Philadelphia, Pennsylvania, USA, in 1976. Information concerning curricula in technologist training programs was obtained through visits to various countries; and in 1976, a meeting of directors of schools and programs in X-ray technology training was held in Caracas, Venezuela.

In the radiation protection area, continuing support was provided to the national programs through visits by the Regional Advisor in Radiation Physics and the Regional project's resources, because country projects had declined. The concept of incorporating the emerging activity of quality assurance into national programs was promoted, as were the radiation protection aspects of facility planning; quality assurance in diagnostic radiology, nuclear medicine, and radiation therapy; and the maintenance of radiological equipment. Contact was maintained with international organizations, such as the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU), to assure uniformity in PAHO's efforts to promote international standards. In 1975, PAHO hosted the meeting of the main commission of the ICRU; and in 1983, it hosted the meeting of the main commission of the ICRP.

The Radiological Health Unit was transferred from the Environmental Health Division to the Disease Prevention and Control Division in mid-1979; and soon after, Gómez Crespo left PAHO. The responsibilities of both the Regional Advisor in Radiological Health and the Regional Advisor in Radiation Physics were entrusted to Hanson. The Radiological Health Unit was now dealing with radiation medicine (diagnostic radiology, radiation therapy, and nuclear medicine) as well as protection from radiation hazards from any source.

In the area of diagnostic radiology, efforts focused on developing the simplified X-ray system. In 1980, a commitment was obtained from the General Electric Company to provide four prototypes of their new "Technamatic" machine for a field trial in Latin America. This was an updated version of Chamberlain's invention. The new machines incorporated an improved tube stand and an advanced inverter type of "multipulse" X-ray generator. Since Chamberlain had purposely left the name "Technamatic" in the public domain (without trademark protection), General Electric used the name because it sounded innovative. PAHO selected Colombia to receive the four machines since that country had an active primary care program. The machines were delivered in 1983, and the successful field trial was concluded in 1984.

Figure 15: Colombia, 1983—Patient room in a small hospital before conversion into X-ray room for field trial.

Figure 16: Colombia, 1984—The same room shown at left after conversion into an X-ray room for field trial.

Figure 17: Chest X-ray during field trial of Basic Radiological System

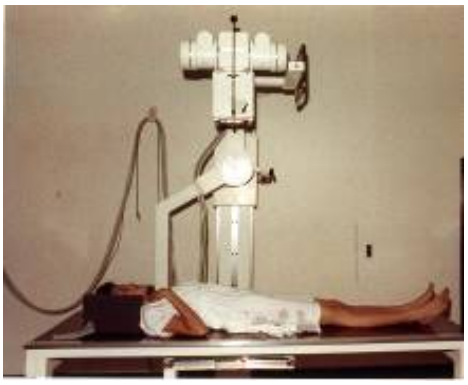
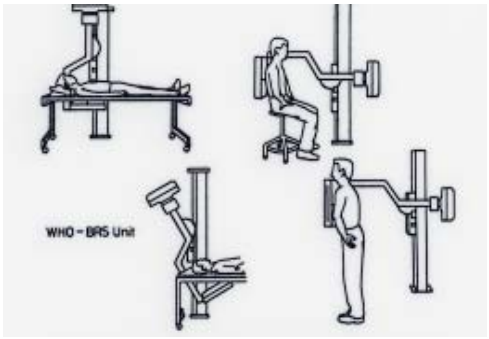
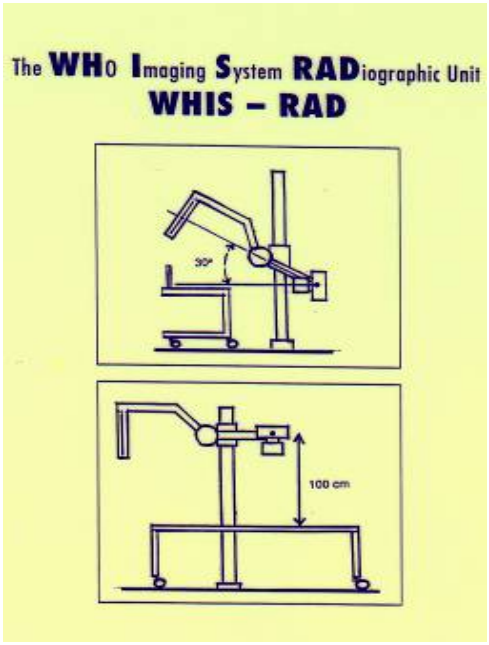


Figure 18: Abdominal exam during field trial of Basic Radiological System (BRS).



Figures 19–20 (above and right): The PAHO field trial of the BRS provided valuable support for WHO Headquarters, which eventually published *Manuals on Radiographic Positioning, Darkroom Technique and Radiographic Interpretation for the General Practitioner.* After several modifications, the WHO-BRS has evolved to be currently known as the WHIS-RAD.



In 1980, in collaboration with the Inter-American Social Security Research Center *(Centro Interamericano de Estudios de Seguridad Social,* CIESS), a seminar was held in Mexico City to assess the status of diagnostic radiology in the Region of the Americas. Also in 1980, the results of a survey of Spanish-language teaching materials for X-ray technologists that had been initiated the year before were published by PAHO. In 1981, in collaboration with Member States and the Inter-American College of Radiology, a rapid assessment of the radiological health situation was conducted by the Radiological Health Unit, using questionnaires covering diagnostic radiology, radiotherapy, nuclear medicine, and radiation protection. The production of training materials for technologists was promoted by the Radiological Health Unit through cooperation with other PAHO technical units in an international workshop on the training of middle level technicians held at PAHO Headquarters in Washington, DC, in 1981.

In the radiotherapy area, the IAEA/WHO Postal Dose Intercomparison Program for cobalt-60 teletherapy machines was gradually expanded, with an average of 60 radiotherapy centers per year being included over the 1979–1986 period. In 1980, PAHO provided follow-up technical cooperation, through visits by a radiation physicist to identify and correct errors in those radiotherapy centers where a deviation of greater that 5% between their reported measurements and the actual values measured in the IAEA laboratory had been found. This was the first time that such on-site follow-up was provided, a practice that both PAHO and the IAEA have continued to this date.

In the area of nuclear medicine, in collaboration with the USPHS Bureau of Radiological Health and the Federated Council of Nuclear Medicine Organizations, the Radiological Health Unit organized an international symposium on quality assurance, which was held in April 1981 at PAHO Headquarters, with 200 participants. The purpose was to review the status of nuclear medicine and to develop minimum standards for quality assurance programs. PAHO also collaborated in organizing a workshop on quality assurance for *in vivo* procedures in Santa Fe de Bogotá, Colombia (May 1981) and helped the IAEA and the Brazilian Association of Medical Physicists *(Associação Brasileira de Física Médica,* ABFM) organize a workshop on quality assurance in São Paulo, Brazil (September 1981). Again in collaboration with the USPHS Bureau of Radiological Health and the Federated Council of Nuclear Medicine Organizations, in 1982 PAHO hosted the *International Symposium on the Developing Role of Short-Lived Radionuclides in Nuclear Medical Practice*. With the same partners, PAHO also hosted the following symposia: *Single Photon Ultrashort-Lived Radionuclides in Medical Practice* (1983), *Clinical Applications of Radionuclide Studies of the Brain* (1984), and *The Role of Non-Invasive Imaging Modalities in Clinical Decision-Making: Coronary Artery Disease* (1985).

In radiation protection, the collaborative efforts of PAHO and the national radiation protection services of Argentina, Colombia, and Mexico resulted in the publication of Volume I of the revised *Manual básico de protección radiológica* [Basic Manual on Radiation Protection] by the Ministry of Health of Colombia. In collaboration with the Brazilian Institute of Radiation Protection and Dosimetry *(Instituto de Radioproteção e Dosimetria,* IRD) and with support from the U.S. Department of Energy, PAHO organized the *Regional Seminar on Radiation Accidents and Procedures for Managing Irradiated Persons*, which was held in Itaipava, Brazil, in December 1981. Seven years later, when a cesium-137 contamination accident occurred in Goiânia, Brazil, the Brazilian authorities were firmly in control of the situation and, using both national and local experts, skillfully handled the aftermath.

1983–1994, PASB Director Carlyle Guerra de Macedo

Soon after Carlyle Guerra de Macedo became the Director of the PASB in 1983, PAHO Headquarters staff members were assembled into groups for an introspective analysis that covered a period of several months. Shortly afterwards, the function of program coordinator was created in the various PAHO technical divisions and continued until 2003.

From 1983 until 1987, the PAHO Radiological Health Program continued on its main course, with radiation medicine (diagnostic radiology, radiation therapy, and nuclear medicine) and radiation protection being its major components.

A survey conducted by the Radiological Health Unit in 1983–1984 in cooperation with the health authorities of Argentina, Brazil, Colombia, Costa Rica, the Dominican Republic, Ecuador, Mexico, and Nicaragua showed that the use of X-ray equipment for diagnosis was low in small hospitals (ranging from 1% to 5% of patients) as compared to referral hospitals, where 20% to 30% of patients underwent an X-ray examination. This reinforced the priority given by PAHO and WHO to basic radiology at the Regional and global levels.

Four basic X-ray machines manufactured by the Siemens Corporation were delivered to Nicaragua in 1984 and, with the collaboration of WHO Headquarters staff (radiologist Eero Lehtinen), a field trial was conducted. In 1985, two machines manufactured by the Phillips Corporation were installed for a field trial in Chile. Results again demonstrated that with a short training period and proper supervision, excellent radiographs could be produced by local hospital staff.

In the radiotherapy area, efforts were made by the Radiological Health Unit to extend and improve the IAEA/WHO Postal Dose Intercomparison Program, following the recommendations of a working group meeting of the SSDL directors hosted by the M.D. Anderson Hospital in Houston in 1982. However, the results remained essentially the same, with only 60% of participating centers meeting the standard criteria of a deviation of 5% or less. In 1983 a key meeting, the *First International Symposium on Quality Assurance in Radiation Therapy: Clinical and Physical Aspects*, was held at PAHO Headquarters in Washington, DC, with the collaboration of radiological societies from Europe, Latin America, and the United States as well as government institutions. The participants reviewed experiences in radiation therapy from around the world, and a consensus was reached concerning minimal as well as optimal standards for both clinical and physical aspects of quality assurance.

The proceedings were published by Pergamon Press in 1984 on behalf of the co-organizers of the meeting (6). During 1984 and 1985, assistance was provided to Argentina in a successful effort that resulted in the production of a cobalt-60 teletherapy machine within the country. With PAHO's collaboration, Neutron Products, a United States company that refurbished used cobalt-60 units, provided valuable technical assistance to Argentine institutions. These included the Ministry of Health, the Atomic Energy Commission, and the Institute of Applied Research in Bariloche, which subsequently collaborated in designing and manufacturing the Argentine machine.

In the area of nuclear medicine, PAHO, in collaboration with the WHO Collaborating Center in Nuclear Medicine in Danbury, Connecticut, USA, launched a new program for evaluating the quality of nuclear imaging procedures in 1983, using specially designed "phantoms" that could be mailed. Designed by the American College of Pathologists, the phantoms simulated various human organs as required for the relevant nuclear imaging procedure. Nuclear physicians in the Region served as national coordinators for distribution of the phantoms in their respective countries.

In radiation protection, assistance was provided to 20 countries from 1983 to 1986, through visits by the PAHO Regional Advisor and consultants, on legislation, organization of services, radiation measurements, radiation accidents, shielding calculations, and training.

In April 1987, Hanson was invited to become the Chief of Radiation Medicine at WHO Headquarters in Geneva, Switzerland, and resigned from PAHO. In March 1988, Cari Borrás took over the position of Regional Advisor in Radiological Health at PAHO Headquarters in Washington, DC A native of Spain, Borrás had obtained the equivalent of a Master's Degree in Physics from the University of Barcelona in 1964 and had worked there at the Hospital of Santa Creu i Sant Pau as the first medical physicist in Spain until 1966, when she obtained a Fulbright Scholarship to pursue her studies in the United States. In 1974, she was awarded a Doctor of Science Degree upon defense of a thesis research project carried out at Thomas Jefferson University (TJU) in Philadelphia, Pennsylvania. By the time she joined PAHO, she had served as a consultant for PAHO on several occasions and had been the Chair of the International Affairs Committee of the American Association of Physicists in Medicine (AAPM) for eight years, having thus acquired significant international experience. With Hanson in Geneva and Borrás in Washington, an unprecedented era of cooperation ensued between WHO Headquarters (WHO/HQ) and PAHO.

From 1988 to 1994, under Director Macedo's administration, Borrás continued PAHO's technical cooperation. She worked at both the Regional and country levels. Her tasks included data collection and situation analysis; revision and development of standards and guidelines; preparation and distribution of publications; consultations in radiation medicine and in radiation protection; assessment of policies and resources for radiology services coverage and for radiation protection programs; training activities, such as courses, seminars, and congresses; organization of and participation in scientific meetings; promotion and development of quality assurance programs; support to and collaboration with WHO and IAEA programs; initiation of a network of radiological physics centers, equipment donations, and loans; the removal of spent radioactive sources; and assistance in case of radiological emergencies (7–11). The radiological health information collected from the countries was mainly published in PAHO's quadrennial *Reports of the Director* as well as in the *Health in the Americas* reports (12–15) and in the *Reports of the United Nations Scientific Committee on the Effects of Atomic Radiation* (UNSCEAR) (16).

Efforts centered mainly on education. The PAHO Regional Advisor lectured in 40 country and/or Regional training events that were organized and/or cosponsored by PAHO. The most significant one was a hands-on course on physical dosimetry in radiation therapy held in San Antonio, Texas, in August 1988, which was attended by 45 Latin American medical physicists. The event was cosponsored by the International Organization for Medical Physics (IOMP) and the medical physics societies of the United States (AAPM), Latin America (ALFIM), and Spain (SEFM), in collaboration with PAHO and the IAEA. Figure 21 shows most of the participants and some faculty.

Figure 21: San Antonio, Texas, USA, *Course on Radiation Therapy (Dosimetry)*

Seminars and courses on diagnostic radiology (mainly on quality control) were held in Mexico City, Mexico (1988, 1991); Chicago, Illinois (1988); San Jose, Costa Rica (1989); Buenos Aires, Argentina (1989, 1990, 1991); São Paulo, Brazil (1989, 1991); Caracas, Venezuela (1989, 1990, 1993); Panama City, Panama (1989); Santo Domingo, Dominican Republic (1990); Zaragoza, Spain (1990); Guatemala City, Guatemala (1991); San Cristóbal, Venezuela (1993; Santa Fe de Bogotá, Colombia (1993); Rio de Janeiro, Brazil (1994); and Havana, Cuba (1994). Quality control courses on radiation therapy were held in Lima, Peru (1988); Havana, Cuba (1992); Caracas, Venezuela (1994); and Rio de Janeiro, Brazil (1994). Courses and seminars on radiation protection were held in Lima, Peru (1989, 1992); Quito, Ecuador (1990, 1993); Kuwait, Kuwait (1990); Asunción, Paraguay (1992); Chiclayo, Peru (1992); Mérida, Venezuela (1993); Mexico City, Mexico (1993); Panama City, Panama (1994); Rio de Janeiro, Brazil (1994); and Chicago, Illinois (1994). Courses on radiological emergencies were sponsored in Mexico City, Mexico (1990), and Havana, Cuba (1994). Medical Physics workshops and congresses were held in Bariloche, Argentina (1988); Riberão Preto, Brazil (1990); Oro Verde, Argentina 1992); and Rio de Janeiro, Brazil (1994).

A different training approach was taken in developing and establishing the radiological physics centers, which were institutions that could provide *in situ* practical training in radiological physics to physicians, medical physicists, engineers, and technologists involved in diagnostic and therapeutic radiology services. The first center was established in Caracas, Venezuela, in 1993, as a consortium between the Radiology and Radiotherapy Departments of the Central University of Venezuela *(Universidad Central de Venezuela*, UCV) and the Venezuelan Institute of Scientific Research *(Instituto Venezolano de Investigaciones Científicas*, IVIC). Through the IAEA/WHO postal dose audits, which verified the accuracy of the calibration of high-energy radiotherapy units with TLDs, and through the quality assurance workshops on radiation therapy held during that period (7–15), it was ascertained that the source strength of most cobalt-60 units in Latin American and Caribbean countries was too

low for effective radiotherapy treatments. In 1993, PAHO—in collaboration with WHO, the IAEA, and the United Nations Industrial Development Organization—convened an advisory group meeting in Washington, DC, to assess the situation and make recommendations concerning the problems of existing teletherapy units, including both cobalt-60 units and current linear accelerators. The proceedings of the meeting, which were published by Los Alamos National Laboratory in December 1995 (17), also presented new alternative designs for teletherapy units.

Consultations with the countries of the Americas concerned radiation medicine and also radiation safety, including prevention, preparedness, and response in case of a nuclear accident or a radiological emergency. The most significant radiological accident during that period involved three workers in San Salvador, El Salvador, in February 1989, with a cobalt-60 industrial irradiator used for sterilizing medical products. The automatic mechanism that moved containers with materials to be sterilized into the room, around the irradiation sources, and out of the room through an elaborated conveyor belt system, stopped and could not be reinitiated. To assess the problem, the operator violated several interlock systems and entered the irradiation chamber accompanied by two colleagues working in the factory. Manually, they removed the containers that had jammed the mechanism and lowered the source rack into the water pool. The irradiator functioned again, until the next day when another malfunction occurred that alerted management. The three irradiated workers were hospitalized with what later on was recognized as acute radiation syndrome, and, in March 1989, they were transferred to a Mexican hospital for specialized treatment. The main operator died upon his return to El Salvador six months later, the second one needed to have both legs amputated, and the third one may develop cancer later in his life. The whole body doses involved were 8, 4 and 3 Gy respectively, with doses to the legs estimated as 100, 100 and 10 Gy. The event was described in a joint IAEA/PAHO/WHO publication (18).

Other minor accidents or incidents involved discarded brachytherapy sources in several Caribbean countries in the early 1990s. Concerned about potential exposures, PAHO contracted a United States company, NSSI/Sources and Services, to de-contaminate the premises where needed, to condition the sources, and to transport the sources to the United States for safe storage.

Their first job took place in 1991 and consisted of the removal of discarded brachytherapy sources from four countries, two of which had experienced radiation incidents involving improper disposal.

In Trinidad and Tobago, the encapsulation of some Cs-137 tubes had broken when they were removed from the disposable rubber Manchester applicators where they had been kept for years. When the tubes were placed in a newly acquired leaded safe, they contaminated it, as well as other brachytherapy sources. NSSI, aided by the local physicists, removed all the contaminated sources and placed them in secured containers for transport to the United States.

In the Dominican Republic, a radiation oncologist had cut a radium needle to fit it in the tandem of a gynecological applicator. When he saw the spilled radium salts, he tried to wipe them with a cloth that he then washed in a sink. In the process, he contaminated the

entire minor surgery suite. The radium sources had been placed in a safe, from where NSSI removed them, using a disposable glove box (Figures 22 and 23). After decontaminating the area, low activity items, which would have cost too much to transport, remained in an underground hole (Figure 24), where they had been placed prior to PAHO's intervention. The clinical areas were checked for potential residual contamination (Figure 25) and were found acceptable for re-use.

Figure 22: Disposable glove box used to remove radium sources from Instituto del Cibao, Santiago de los Caballeros, Dominican Republic, 1991.

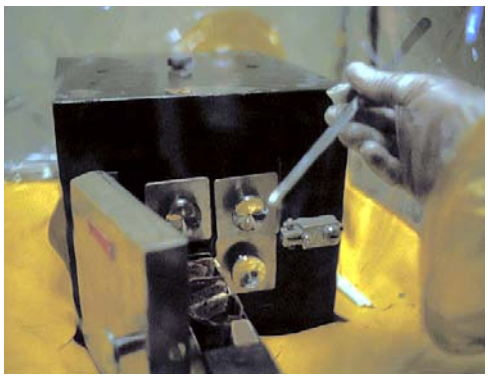


Figure 23: Removal of radium brachytherapy sources Leaded safe containing sources.

Figure 24 (left): Hole in the hospital garden where surgery items (with some remaining contamination) had been disposed of after being grossly decontaminated.

Figure 25 (above): Checking for residual radioactive contamination.

In Haiti, radium sources had been buried for safety purposes in a hole in the ground of the hospital garden in a room without a door to prevent access. In the process of removing these sources, other containers with sources unbeknown to the hospital staff appeared in another hole and were removed as well. Figures 26–28 show the room in which the sources had been stored, the improvised shielding erected to check the condition in which the sources were found—whether they were leaking or not—and the holes in the ground in which the sources had been buried.

Figures 26–28: Removal of brachytherapy sources from Institut Oncologique Nationale, Port-au-Prince, Haiti, 1991.

Figure 26: Garden shack built to store radioactive sources no longer in use.

Figure 27: Improvised shield to test whether sources were leaking.

Figure 28: Holes in the ground inside the shack containing radioactive sources, mostly radium.

Also in 1991, Puerto Rico requested the removal of nasopharynx applicator with radium that had not been used for decades.

Concerns were not limited to brachytherapy sources. In the early 1990s, industrial as well as medical sources were found in a hole in the garden of a Nicaraguan facility (Figure 29), near an incompletely built radioactive storage area. The hospital was abandoned after an earthquake and three cobalt-60 teletherapy sources, one, still in its original treatment unit (Figure 30), were kept in the abandoned hospital (Figure 31), risking a fate similar to that of Ciudad Juárez and Goiânia (19, 20). Two other industrial sources (one of which is depicted in Figure 32) were stored in the same facility. Eventually, the IAEA decommissioned and conditioned all the sources, but they are still in the same old facility.

Figure 29: Hole in the garden containing radioactive sources.

Figure 30: To the right, the abandoned clinic; and to the left, the repository for storage of discarded radioactive sources, which was never used.

Figure 31 (left): Old cobalt-60 teletherapy unit.

Figure 32 (above): Old container with radioactive sources for industrial use.

In Honduras, a discarded cobalt-60 teletherapy unit had allegedly been buried for several years in a garbage dump. In spite of a week-long survey with the assistance of the Government of Mexico, using a 5" NaI(Tl) detector and a multichannel analyzer, the source—presumably still in its head—could not be located. It was recommended that the Government periodically monitor the garbage dump and test the water in the area for potential radioactive contamination. Figures 33–34 show the site, located outside Tegucigalpa, and some of the recovery operations.

Figure 33 (above): View of the garbage dump where the cobalt unit was buried, with truck used in the survey.

Figure 34 (right): Ge(Li) Spectrometer used in the survey. A Honduran surveyor reads the Ge(Li) spectrometer brought by a Mexican agent in radioactive waste management.

It became very clear that response to radiological accidents could not be accomplished without the countries developing radiation safety legislation/regulations with adequate infrastructure. Information collected around the region revealed that of the 38 PAHO Member States, only 19 had radiation regulatory authorities; and in only two of them was the responsibility located in the ministry of health. The others were in atomic energy commissions, or the regulatory responsibilities were divided between two (or more) governmental agencies. This situation led PAHO to join the international radiation protection scene. When the Inter-Agency Committee on Radiation Safety (IACRS) was created at a meeting convened by IAEA in Vienna (1990), it was at Hanson's insistence that PAHO be invited to join in its own right. Later (1990–1993), during the preparation of the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (BSS), PAHO and WHO worked closely as a team to assure that the public health and medical aspects were adequately covered. PAHO, at the time, also strengthen its cooperation with the IAEA. In 1993, the two organizations co-sponsored a *Subregional Workshop on Control of Radiation Safety for Central America and the Caribbean* and tried to undertake a joint project to implement radiation protection measures. However, most of the Caribbean countries, which attended the Workshop invited by PAHO, were not Member States of the IAEA; so the project encountered financial restrictions. It became essential that the International Radiation Safety Standards be also PAHO's. On 28 September 1994, the XXIV Sanitary Conference endorsed the BSS (21), following the recommendation of the *113th Meeting of the PAHO Executive Committee* on 28 June 1994. Interestingly, the United Sates had opposed the BSS when first submitted by the IAEA Secretariat to its Board of Governors in early 1994 but agreed with a modified version presented at the PAHO Executive Committee. This decision was pivotal for the IAEA's Board of Governors to approve the Standards at its 847th Meeting on 12 September 1994. Figure 35 shows Borrás, setting next to Director Guerra de Macedo, convincing the Executive Committee to endorse the BSS. When the standards were published by the IAEA (1994) on behalf of the co-sponsoring organizations, PAHO's logo appeared along with the other five sponsoring organizations, including WHO.

Figure 35: Cari Borrás, PAHO Regional Advisor in Radiological Health—sitting next to PASB Director, Carlyle Guerra de Macedo—introduces the BSS to the *113th PASB Executive Committee,* Washington, DC, June 1994.

1995–2003, PASB Director Sir George A.O. Alleyne

Director George Alleyne thought that Regional Advisors should work on Regional Programs and discouraged country activities performed from Washington, DC. He emphasized the development of standards and guidelines. In the year 2000, PAHO's radiological health activities became part of the Essential Drugs and Technology Program within the Division of Health Systems and Services. Borrás became the program's coordinator, while also continuing to be responsible for radiological health activities with the help of temporary staff such as Jorge Skvarca and César Arias from Argentina, María Esperanza Castellanos from Colombia, and Damian Rudder from Trinidad and Tobago.

Following Alleyne's directives, guidelines on radiology services were presented in a 1997 publication, *Organization, Development, Quality Assurance and Radiation Protection in Radiology Services: Imaging and Radiation Therapy* (22). The text, which described the organizational and technical aspects of radiology services, was aimed at political leaders, administrators, planners, and health professionals, as well as ministries of health, and was intended to help them allocate resources and determine technological configurations for the provision of decentralized radiology services under health sector reform.

Regarding radiation safety, following the publication of the final version of the BSS by the IAEA in 1996 in English and in 1997 in Spanish, PAHO also contributed to and co-sponsored related IAEA publications. (23, 24).Guidelines for patient radiation protection were given at *the International Conference on the Radiological Protection of Patients in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiotherapy*, which was held in Málaga, Spain, in 2001 and co-sponsored by the IAEA, the European Commission (EC), PAHO, and WHO (25). It was attended by 800 people, 17 of them partially subsidized by PAHO. In 2002, the IAEA Board of Governors approved an *International Action Plan on the Radiological Protection of Patients*, to be carried out in co-sponsorship with the EC, PAHO, and WHO. PAHO, along with several other international organizations, also co-sponsored the IAEA's new requirements on preparedness and response for a nuclear or radiological emergency (26). PAHO also participated in an international conference on the management of radioactive waste from non-power applications, which was organized by the IAEA (27); it joined the Inter-Agency Committee on Response to Nuclear Accidents (IACRNA); and it became part of the Joint Radiation Emergency Management Plan of the International Organizations (28).

After the publication of the BSS and their endorsement by PAHO's *XXIV Sanitary Conference* in 1994, practically all the Latin American and Caribbean Radiation Protection and Health Authorities had revised their legislation/regulations and sent them to PAHO's radiological health program for comments. Significant examples of regulations of health authorities which were reviewed were from Brazil, Costa Rica, and Mexico. PAHO also increased its radiation protection technical cooperation in the area of non-ionizing radiation, providing advice on the health effects of electromagnetic fields (especially those of cellular telephones), lasers, microwaves, ultrasound, magnetic resonance, and ultraviolet light.

It also continued providing support to prevent radiological accidents. In 1995, NSSI/Sources and Services was again contracted to remove from Guyana radium sources jammed in an old storage vault consisting of a rotating drum with pie-shaped drawers inside an outer cylindrical shield. The mechanism was successfully dislodged (see Figures 37–38) and the sources transported to the United States for final disposal under PAHO ownership.

Figure 36: View of the room with the brachytherapy device full of radium sources.

Figure 37: Dislodging the mechanism to free the drawers containing the sources.

Figure 38: Dislodging the mechanism to free the drawers containing the sources.

Figure 39: Device showing how each drawer could be moved in to place to give access to the radium needles.

Figure 40: Checking activity of the radium sources before packing and removal.

Figure 41: CANATEX Simulation exercise, in which Hugo Prado from PAHO's Disaster Program (on the phone) is providing information of the situation advice by Jolyon Hendry (PAHO consultant) and the Regional Advisor on Radiological Health.

The collaboration between PAHO's radiological health and disaster programs, intensified. PAHO participated in desktop exercises simulating the response to nuclear accidents like CANATEX in 1999 (see Figure 41 above).

The educational activities continued. From January 1995 to February 2003, the Regional Advisor lectured in 83 countries and/or Regional training events that were organized and/or co-sponsored by PAHO (29–36). In diagnostic radiology, these were given in Santa Fe de Bogotá, Colombia (1995); Buenos Aires, Argentina (1995); Cancún, Mexico (1996, 2000, 2002, 2002); Havana, Cuba (1997, 2001); Oporto, Portugal (1998); Barcelona, Spain (1998); Mexico City, Mexico (1998); Caracas, Venezuela (1999); Rosario, Argentina (2000); Kingston, Jamaica (2000, 2001); Chicago Illinois, USA (2000); Port-of-Spain, Trinidad and Tobago (2000); Recife, Brazil (2000), and San Salvador, El Salvador (2001). In radiation therapy, the events occurred in New York City, NY, USA (1997); Havana, Cuba (1996); Pucón, Chile (1998); College Park, Maryland, USA (1998); Guayaquil, Ecuador (1998); Santo Domingo, Dominican Republic (1999); Guangzhou, China (1999); Huatulco, Mexico (2000); Tegucigalpa, Honduras (2000); Chicago, Illinois, USA (2000); Trujillo, Peru (2000); Caracas, Venezuela (2001); Montreal, Quebec, Canada (2002); Santa Fe de Bogotá, Colombia (2002); and Vienna, Austria (2002). There was one course in quality control of nuclear medicine in Havana, Cuba (1996), and several events related to medical devices and health technology assessment: in Lima, Peru (1995, 2000); Nice, France (1997); São Paulo, Brazil (1997, 2001, 2001); Havana, Cuba (1997); Mexico City, Mexico (2000); Philadelphia, Pennsylvania, USA (2001); and Plymouth Meeting, Pennsylvania, USA (2001). Most of the courses, however, were aimed at PAHO or WHO Member States and dealt with the implementation of the BSS in medical practice. These were given in Managua, Nicaragua (1995); Santa Fe de Bogotá, Colombia (1995); Buenos Aires, Argentina (1995, 1996); Cusco, Peru (1995, 1995); Chicago, Illinois, USA (1995); Asunción, Paraguay (1996, 1997); Havana, Cuba (1996, 1998, 1998); Lima, Peru (1997); Santiago, Chile (1997); Rio de Janeiro, Brazil (1997, 1999); Curaçao, Netherlands Antilles (1998); Mexico City, Mexico (1998); Hanoi, Vietnam (1999); Bethesda. Maryland, USA (1999); Málaga, Spain (2001); Bridgetown, Barbados (2001); Recife, Brazil (2001); and Washington, DC, USA (2001, 2002, 2003). Radiological emergencies and/or radiation waste courses and conferences were held in Rio de Janeiro, Brazil (1997); Havana, Cuba (1997); Philadelphia, Pennsylvania, USA (1999); Córdoba, Spain (2000); Oxford, United Kingdom (2000); and Qawra, St. Paul's Bay, Malta (2001). A couple of photos of these events are shown in Figures 42–43. A training manual, consisting of 1,200 slides, was developed by PAHO for the IAEA.

Figure 42: Medical Physics Congress co-sponsored by PAHO; the PAHO/WHO Representative (PWR) in Mexico, José Luis Zeballos, is shown at the extreme right of the head table.

Figure 43: The Regional Advisor (right) receives a diploma from Dulce María Martínez (left) from the Government of Cuba, in the presence of PASH Director George Alleyne, in recognition of the extensive work on quality assurance.

In 1995, a second radiological physics center was established in Tegucigalpa, Honduras, coordinated by the Autonomous University of Honduras (*Universidad Autónoma de Honduras*), which signed an agreement with the Ministry of Health to carry out activities of joint

interest, including a special degree program for radiation technologists. In 1997–1999, this center was partially subsidized, through PAHO, by the Ministry of Health of Spain.

PAHO continued to provide support during this period to the *World Health Imaging System for Radiography* (WHIS-RAD). In the mid-1990s, it purchased 11 of these units and installed them in Haiti (see Figures 44–46). In spite of the inherent reliability of the equipment, the services had serious problems because of lack of maintenance, poor X-ray technician training, and inadequate radiation protection measures (37).

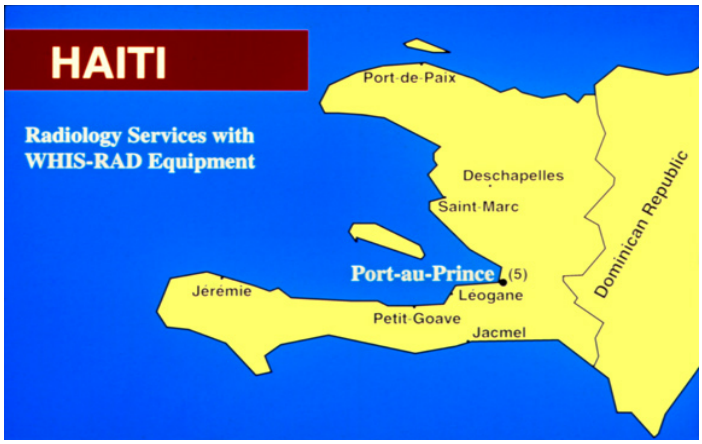


Figure 44: WHIS-RAD units in Haiti, mid 1990s.

Figure 45: Ste. Croix Hospital with radiology services using WHIS-RAD unit, Leogane, Haiti, 1990s.

Figure 46: Bennett WHIS-RAD unit. Haiti, 1990s.

Other efforts to upgrade radiology services involved Belize, Chile, Dominica, Haiti, St. Kitts and Nevis, and Trinidad and Tobago. Efforts to upgrade radiotherapy services were carried out in various countries of the Americas, helped by donations from US manufacturers and institutions, usually through an account set up at the Pan American Health and Education Foundation (PAHEF). These donations involved not only radiation measuring instruments for dosimetry and quality assurance tests but also sophisticated and expensive radiation equipment, such as an Alcyon II cobalt-60 unit which was installed in the *Instituto del Cibao*, Santiago de los Caballeros, Dominican Republic; manual Cesium-137 brachytherapy sources

that were shipped to the Hospital de Clinicas, La Paz, Bolivia; and a low dose rate Cesium-137 remote afterloading brachytherapy device, which was sent to the Hospital San Felipe in Tegucigalpa, Honduras. Figures 47–50 show the unit, a treatment planning system, a teaching session, and the first patient being treated.

Figure 47: Selectron brachytherapy unit donated by the US National Cancer Institute to the Hospital San Felipe, Tegucigalpa, Honduras.

Figure 48: Treatment planning system purchased with funds from the *Agencia Española de Cooperación Internacional* of Spain. Hospital San Felipe, Tegucigalpa, Honduras.

Figure 49: The Nucletron representative is teaching the Honduran radiation oncologist and medical physics the proper use of the Selectron.

Figure. 50: The first patient treated for gynecological cancer, Hospital San Felipe, Tegucigalpa, Honduras, mid-1990s.

Other technical cooperation projects involved a countrywide evaluation of radiation oncology centers in Colombia; planning of a completely new cancer treatment facility in Trinidad and Tobago, providing advice regarding the replacement of cobalt-60 therapy units by linear accelerators in Panama and facilitating the repair of a linear accelerator in Havana, Cuba, with extra-budgetary support from then Government of Spain, which also financed the training of physicians, nurses, engineers and medical physicists from Honduras in teletherapy and brachytherapy techniques (38).

Quality assurance programs in radiation therapy services continued to be promoted, mainly through the TLD IAEA/ WHO Regional postal dose audit. A meeting on this program for TLD program coordinators from the Region of the Americas was held in Santo Domingo, Dominican Republic, in July 1999.

If one of the participating Costa Rican facilities had acknowledged a significant deviation that had appeared for several years, it could have prevented the overexposure from August to October 1996 of 114 patients—many of them children—that occurred as a consequence of a miscalibration of a cobalt-60 unit. The physicist who calibrated the machine interpreted decimals of minutes as seconds and provided the facility with dose rate charts, which were in error by a factor of 1.76. By July 1997, 42 had already died, at least 7 of them due to the excess radiation. Of the surviving patients, 46 showed radiation-related symptoms that ranged from severe to mild. PAHO was requested to provide technical assistance (39); and a year later, the IAEA did their own investigation (40).

PAHO was also asked to investigate a radiotherapy overexposure incident that occurred in Panama, also involving a cobalt-60 teletherapy unit used for cancer therapy treatment. From August 2000 to March 2001, when three patients had already died with acute abdominal symptoms, three medical physicists improperly used a treatment planning software to calculate the treatment times of 28 patients undergoing radiotherapy treatment for pelvic cancers such as cervix, endometrium, rectum, and prostate. The error resulted in doses twice the prescribed values. The details of the Panama exposure have been published. (41-43).

In November 2001 and April 2002, Costa Rica again asked PAHO to assess potential radiation overexposures, this time caused by one or two medical linear accelerators. No evidence of overexposures was found. A third claim occurred in April 2002. Again, a medical investigation—under PAHO's auspice—concluded that there had been no overexposure.

Minor exposures to staff in radiotherapy facilities have also occurred. In Honduras and in Venezuela, cobalt-60 sources in teletherapy units used for cancer treatment failed to return to their safe position in the treatment head after patient treatment was completed, causing the radiation therapy technologist in each facility to receive an accidental exposure. However, in both instances the radiation levels were very low and no unwarranted effects were seen; nor are they expected.

Recognizing the need for standards in medical radiation dosimetry, PAHO cosponsored an international symposium in 2002 on *Standards and Codes of Practice in Medical Radiation Dosimetr*y (44). PAHO also promoted an accreditation program for radiotherapy services to be implemented in the countries of Latin America and the Caribbean. Relevant information on radiology services continued to be shared with UNSCEAR (45).

The most significant change in the radiological health program during this period was the initiative to support Regional research, extending previous country initiatives, mostly in Argentina, Bolivia, and Cuba. In 1999, the radiological health program won the research competition convened by PAHO's Director, with the theme of "Quality Assessment of Radiology Services," and prepared the terms of reference for the submission of projects. Seven countries applied, and five of them (Argentina, Bolivia, Colombia, Cuba, and Mexico) were awarded a research contract, which involved medical physicists and radiologists in these countries. While maintaining their own research interests, the five participants agreed to perform a common multicentric study aimed at correlating quality indicators for radiology services with the accuracy of the radiological interpretation. The results of this health services delivery research project have been published. (46).

In 2001, a Regional diagnostic radiology research program to evaluate the image quality and the average glandular dose in mammography units in countries of the Americas was undertaken by PAHO and the Inter-American College of Radiology, in collaboration with the IRD in Brazil and the Center for Devices and Radiological Health (CDRH) in the United States. Data from 61 units in 11 Latin American and Caribbean countries were collected and analyzed. Eighty-eight percent of the units evaluated complied with the image quality requirement, and only 8.5% of all the units exceeded the dose limit for the average glandular dose (47).5

2003 TO 2006, PASB Director Mirta Roses Periago

In January 2003, Mirta Roses Periago, who had previously served for eight years as the Assistant Director of the PASB, was the first woman to become the Director of the PASB. Her first mandate will be completed in 2008. Organizational changes were made, and the Radiological Health Program was relocated in the Area of Technology and Health Services Delivery (THS), first within the Health Services Organization Unit and finally within the Unit of Essential Medicines, Vaccines, and Health Technologies. Regardless of its location, the Radiological Health Program carries out its activities by interacting with numerous areas within PAHO, following the new management model implemented by Director Roses.

Pablo Jiménez joined PAHO in July 2002 as an associate professional expert and became the Regional Advisor of the Radiological Health Program in January 2004. A physicist, Jiménez received the Spanish equivalent of a Master of Sciences degree in Physics from the University of Madrid (*Universidad Complutense de Madrid*) in 1988, and a degree (equivalent to a medical specialty) in medical physics and radiation protection from Spain's Ministry of Health and Ministry of Education in 1996. The other professional who was working in the radiological health program at PAHO Headquarters during this period, as an associate professional officer, was Ileana Fleitas. A nuclear engineer from Cuba, she joined PAHO in February 2003 and returned to Cuba in February 2006, where she is now working as a PAHO staff member in the radiological health program. Figure 51 shows Jiménez and Fleitas discussing a PAHO project with the Minister of Health of Cuba.

Figure 51: Jiménez and Fleitas with the Cuban Minister of Health, Washington, DC, 2004.

The main activities since 2003 have included strengthening diagnostic imaging and radiotherapy services, promoting regulations to protect against both ionizing and non–ionizing radiation, and improving the countries' capacity to respond to radiological or nuclear emergencies. Emphasis has been placed on advising on technology management.

Concerning diagnostic imaging and radiation oncology services, currently around 150 high-energy radiotherapy units are checked annually in Latin America and the Caribbean through the IAEA/WHO TLD postal dose audit. The evaluation of radiation therapy and diagnostic imaging services has been continued in the Bahamas, Costa Rica, Guyana, Nicaragua, and Panama.

Technical advice and assessment in technology management were provided for the incorporation of new technology in Argentina, Costa Rica, Cuba, El Salvador, Guatemala, Trinidad and Tobago, Uruguay, and Venezuela.

The radiological health program has also been very active in organizing, cosponsoring, and supporting educational activities at the national, Regional, and global levels. The program organized a workshop on *Clinical Quality in Radiation Therapy* in Montevideo, Uruguay, as well as two subregional training workshops on *Quality Assurance in Radiology Services* for radiographers and radiological technologists in collaboration and cooperation with the International Society of Radiographers and Radiological Technologists (ISRRT); one in San Salvador, El Salvador for radiological technologists from Central America, and the other in Bridgetown, Guyana, for radiographers and radiological technologists from the Caribbean (see Figures 52 and 53).

Figure 52: First Workshop on Quality Assurance for Radiological Technologist from Central America and the Caribbean Region, El Salvador, 2005.

Figure 53: Quality and Safety in Radiology Services for Radiographers and Radiological Technologists from the Caribbean Region, Guyana, 2005

Within a project called *Teaching the Teachers Initiative for Ultrasound Training in Latin America and the Caribbean,* a total of 12 radiologists from 12 countries was selected to attend an intensive 12-week training program during 2005 and 2006 at the Jefferson Ultrasound Research and Education Institute, which is located in Philadelphia and is one of the PAHO/WHO Collaborating Centers (see Figure 54 on next page). A total of six educational centers in ultrasound will be established in the Region by the end of 2007.

The most important international meetings, congresses, and conferences where the radiological health program was represented and where support was provided during this period were the *XI Congress of the International Radiation Protection Association*, in Madrid, Spain; the *III Iberian Latin American and Caribbean Congress of Medical Physics*, in Rio de Janeiro (see Figure 55 below); the *Regional CRILA Congress,* in Lima; *National Infrastructures for Radiation Safety: Towards Effective and Sustainable Systems*, in Rabat, Morocco; and the *VI and VII Regional Congresses of the International Radiation Protection Association*, in Lima.

Figure 54: Meeting to start the project *Teaching the Teachers Initiative for Ultrasound Training in Latin America and the Caribbean* with the PAHO/WHO Collaborating Center Jefferson Ultrasound Research and Education Institute, Philadelphia, August, 2004.

Figure 55: First Course *Adquisición de datos, commissioning y garantía de calidad de sistemas de planeación en radioterapia,* Petrópolis, April 2005, organized by the *Centro de Estudios del Instituto de Biología de la Universidad del Estado de Río de Janeiro - CEBIO* and ALFIM.

Concerning other activities, national regulations were evaluated and comments on them were sent to the Bahamas, Bolivia, Honduras, Panama, and Paraguay. A Regional compilation of the national regulations on non–ionizing radiation was completed; a radiation emergency exercise was executed jointly with the Organization of American States, in Barbados; a self-evaluation guideline to respond to radiological emergencies was prepared and sent to Peru; and a workshop for Andean countries on dangerous radioactive materials was held in Quito, Ecuador.

In addition, the PAHO radiological health program actively participates in two IAEA Regional cooperation agreements for Latin America and the Caribbean (*Acuerdos Regionales de Cooperación para América Latina y el Caribe,* ARCAL) dealing with radiology and the education of medical physicists. One of the strategic lines consists of the establishment of a formal agreement with the IAEA's Technical Cooperation Department, which will include a joint Regional project for 2007/2008 to improve the quality of radiation therapy. Figures 56–57 illustrate some ARCAL events.

Figure 56: First Project Coordinators Meeting ARCAL LXXXIII *Strengthening the Performance of Professionals in the Medical Physics Fields,* Santo Domingo, Dominican Republic, February 2005.

Figure 57: Final meeting ARCAL LXXV *Determination of Guidance Levels for Conventional and Interventional Radiology,* Nicaragua, 14-18 November 2005.

At the global level, the practice of co-sponsoring relevant IAEA publications continued. PAHO participated in the 2004 version of the *Joint Radiation Emergency Management Plan of the International Organizations* (48). It also attended *the I and II Steering Panel Committee Meetings of the*

International Action Plan for the Radiological Protection of Patients, in Madrid, contributing to drafting the actions for 2006 and 2007 geared to promoting education and training, providing assistance, rendering services, fostering information exchange, and coordinating research in the areas of diagnostic and interventional radiology, nuclear medicine, and radiation therapy (49).

PAHO continued participating in the IAEA Radiation Safety Standards Committee (RASSC) Meetings and the WHO Radiation Emergency Medical Preparedness and Assistance Network (REMPAN) (See Figure 58). PAHO also organized and hosted the *XI Meeting of the IACRS*, a distinction it had not held since 1992 (See Figure 59). The PAHO radiological health program has now begun the process of revising the BSS.

Figure 58: 10th Radiation Emergency Medical Preparedness and Assistance Network Meeting, St Petersburg, Russian Federation, October 2004. Notice Margaret Chan, current WHO Director General, sitting in the first row, second from the right, when she was Director of the Department for Protection of the Human Environment at WHO/HQ.

Figure 59: XI Regular Meeting of the Inter-Agency Committee of Radiation Safety, PAHO Headquarters, Washington, DC, January 2005. Notice the current and two former Regional Radiological Health Advisors sitting at the head table.

Conclusions

PAHO's radiological health program has been in existence for nearly half a century. The program has focused on specific issues in keeping with the times, as well as on the priorities of PAHO's Member States. The latter have had at their disposal the most current scientific and professional knowledge and advice available, as well as a steady partner for continuously improving their national institutions.

As new discoveries and new challenges appear, the most important needs envisaged for the immediate future are as follows: education and training in evaluating, incorporating, and utilizing new technologies; support for strengthening radiological diagnostic and therapeutic services; support for research on analyzing and evaluating outcomes; implementing ways to safeguard patients and staff, including strengthening regulations; and improving the capacity to respond to radiological and nuclear emergencies.

With the continuing confidence and support of PAHO's Member States, the PAHO Radiological Health Program is expected to continue to respond to their needs.

Sinopsis

Historia del Programa de Radiología y Radioprotección de la Organización Panamericana de la Salud

El programa de radiología y radioprotección de la Organización Panamericana de la Salud (OPS) se estableció en1960. En ese entonces, las superpotencias mundiales se enfrascaban en la carrera armamentista; hacían pruebas con armas nuc1eares en la atmósfera y los pueblos y gobiernos del mundo les temían a los efectos de la lluvia radiactiva. Además, se comenzaba a fomentar el uso pacífico de las radiaciones en la medicina, la investigación y la industria, por lo cual se necesitaba una protección adecuada contra estas nuevas formas de energía. Como se señaló en el Informe anual del Director de la OPS, los objetivos de ese nuevo programa de la Organización eran:

1. incentivar la adopción de reglamentos aplicables al uso de las radiaciones en consonancia con las recomendaciones de la Comisión Internacional de Protección Radiológica;
2. promover la enseñanza de la física médica y de la protección radiológica;
3. ayudar a desarrollar las aplicaciones de los radioisótopos en el diagnóstico, el tratamiento y la investigación médica; y
4. impulsar las investigaciones relacionadas con el uso de las radiaciones en la medicina, la salud pública y la veterinaria.

Durante casi medio siglo, el programa de radiología y radioprotección de la OPS ha centrado su atención en diversos temas, según las necesidades y prioridades de los Estados Miembros. Para ello siempre ha contado con personal altamente calificado capaz de asesorar a los ministerios de salud acerca de las políticas relacionadas con las aplicaciones sanitarias de las radiaciones, y a las instituciones clínicas acerca de las modalidades radiológicas diagnósticas y terapéuticas más recientes. Como en sus inicios, el programa continúa prestando atención a las siguientes necesidades de la Región: la educación y capacitación del personal de radiología para que aprenda a evaluar, incorporar y utilizar con eficacia y seguridad las nuevas tecnologías; el apoyo gerencial y técnico para fortalecer los servicios radiológicos; el asesoramiento integral orientado a establecer o mejorar los programas gubernamentales de radioprotección, incluida la adopción de legislación y reglamentación para el control de las radiaciones ionizantes y no ionizantes; el fomento de la investigación para analizar y definir prioridades; y el fortalecimiento de la capacidad institucional con miras a responder a las emergencias radiológicas y nucleares. A pesar de que surgen nuevos retos a medida que se producen nuevos descubrimientos, el Programa de radiología y radioprotección de la OPS seguirá respondiendo a las necesidades de los Estados Miembros.

Palabras clave: Prestación de atención de salud, radiología, protección radiológica, radioterapia, Organización Panamericana de la Salud, Américas.

References

1. Pan American Health Organization. *Annual Report of the Director, 1960*. Washington, DC: PAHO; 1961. (Official Document No. 38).
2. Pan American Health Organization. *Annual Report of the Director*, *1962*. Washington, DC: PAHO; 1963. (Official Document No. 50).
3. International Atomic Energy Agency. *Manual of dosimetry in radiotherapy*. Vienna: IAEA; 1970. (Technical Report Series No. 110).
4. Izewska J, Vatnitsky S, Shortt KR. Postal dose audits for radiotherapy centers in Latin America and the Caribbean: trends in 1969–2003. *Rev Panam Salud Publica*. 2006; 20 (2/3): 161–172.
5. Palmer PES. *Radiology and primary care*. Washington, DC: Pan American Health Organization; 1978. *(PAHO Scientific Publication* No. 357).
6. Hanks G, Svensson G, eds. Quality assurance in radiation therapy: clinical and physical aspects. *Proceedings of the First International Symposium on Quality Assessment in Radiation Oncology, Washington, DC, 8–10 June, 1983*. New York: Pergamon Press; 1984. *(International Journal of Radiation Oncology, Biology Physics,* Volume 10, Supplement 1).
7. Pan American Health Organization. *Annual Report of the Director 1988*. Washington DC: PAHO; 1988. (Official Document No. 228).
8. Pan American Health Organization. *Annual Report of the Director 1990*, Washington DC: PAHO; 1991. (Official Document No. 243).
9. Pan American Health Organization. *Annual Report of the Director 1991*. Washington DC: PAHO; 1992. (Official Document No. 249).
10. Pan American Health Organization. *Annual Report of the Director 1992*. Washington DC: PAHO; 1993. (Official Document No. 256).
11. Pan American Health Organization. *Annual Report of the Director 1994*. Washington DC: PAHO; 1994. (Official Document No. 271).
12. Pan American Health Organization. *Report of the Director: Quadrennial 1986–1990, Annual 1989*. Washington, DC :PAHO; 1989 (Official Document No. 234).
13. Pan American Health Organization. *Report of the Director: Quadrennial 1990–1993; Annual 1993*. Washington, DC :PAHO; 1993. (Official Document No. 262).
14. Pan American Health Organization. *Health Conditions in the Americas: 1990 edition*. Washington, DC: PAHO; 1990. *(PAHO Scientific Publication* 524).
15. Pan American Health Organization. *Health Conditions in the Americas: 1994*. Washington, DC: PAHO; 1994. *(PAHO Scientific Publication* No. 549).
16. United Nations Scientific Committee on the Effects of Atomic Radiation. *Sources and effects of ionizing radiation*. New York: UN; 1993. (UNSCEAR 1993 Report to the General Assembly).
17. Borrás C, Stovall J, eds. *Design requirements for megavoltage X-ray machines for cancer treatment in developing countries: report of an Advisory Group Consultation*. Los Alamos: Los Alamos Nacional Laboratory; 1995. (LA-UR-95-4528).
18. International Atomic Energy Agency. *The radiological accident in San Salvador*. Vienna: IAEA; 1990.
19. Mexico. Comisión Nacional de Seguridad Nuclear y Salvaguardias, Secretaría de Energía, Minas e Industria Paraestatal. *Accidente por contaminación con cobalto-60*. México, DF: CNSNS; CNSNS-IT-001; 1984.
20. International Atomic Energy Agency. *The radiological accident in Goiânia*. Vienna: IAEA; 1988. Available from http://www-pub.iaea.org/MTCD/publications/PDF/.
21. Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organisation, Nuclear Agency of the Organisation for Economic Co-operation and Development, Pan American Health Organization, World Health Organization. *International basic safety standards for protection against ionizing radiation and for the safety of radiation sources*. Vienna: IAEA; 1996 (*Safety* series 115).
22. Borrás C, ed. Organization, development, quality assurance and radiation protection in radiology services: imaging and radiation therapy. Washington, DC: Pan American Health Organization; 1997.
23. Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organisation, Nuclear Agency of the Organisation for Economic Co-operation and Development, Pan American Health Organization, World Health Organization. *Radiation Protection and the Safety of Radiation Sources. Safety Series* No. 120, 1996.
24. International Atomic Energy Agency. *Radiation Protection in Medical Exposures. Safety Guide*. IAEA. Vienna. 2002.
25. International Atomic Energy Agency. Radiological protection of patients in diagnostic and interventional radiology, nuclear medicine and radiotherapy. *Proceedings of an international conference held in Málaga, Spain, 26–30 March 2001*.

Available from: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1113_scr/Pub1113_scr1.pdf [Website]. Accessed 15 February 2006.

26. International Atomic Energy Agency. *Preparedness and response for a nuclear or radiological emergency*. Vienna: IAEA; 2002.
27. Borrás C, Rudder DDG, Porte J, Archibald A, Miller C, Lokerse AF, et al. Radioactive waste management in British and Dutch Caribbean countries. In: *Proceedings, International Conference on Management of Radioactive Waste from Non-Power Applications—Sharing the Experience*. Vienna: IAEA; 2002. Pp. 84–89. (IAEA-CN-87/91).
28. International Atomic Energy Agency. *Joint Radiation Emergency Management Plan of the International Organizations*. Vienna: IAEA; 2002.
29. Pan American Health Organization. *The search for equity: Annual Report of the Director 1995*. Washington DC: PAHO; 1996. (Official Document No. 277).
30. Pan American Health Organization. *Annual Report of the Director 1996: Healthy people, healthy spaces*. Washington DC: PAHO; 1997 (Official Document No. 283).
31. Pan American Health Organization. *Annual Report of the Director 1998: Information for health*. Washington DC: PAHO; 1998 (Official Document No. 293).
32. Pan American Health Organization. *Advancing the people's health: Annual Report of the Director 2000*. Washington DC: PAHO; 2001 (Official Document No. 298).
33. Pan American Health Organization. *Promoting health in the Americas: Annual Report of the Director 2001*. Washington DC: PAHO; 2001 (Official Document No. 302)
34. Pan American Health Organization. *Leading Pan American health. Quadrennial report of the Director 1994–1997*. Washington, DC: PAHO; 1998. (Official Document No. 287).
35. Pan American Health Organization. *Charting a future for health in the Americas. Quadrennial report of the Director*. Washington, DC: PAHO; 2002. (Official Document No. 306).
36. Pan American Health Organization. *Health in the Americas: 2002 edition*. Washington, DC: PAHO; 2002. (PAHO Scientific and Technical Publication No. 587).
37. *Health Technology Assessment in Latin America and the Caribbean: Collection of Cases. Washington*, DC: PAHO, c1999. 12-18 (English), 13-20 (Spanish).
38. *Health Technology Assessment in Latin America and the Caribbean: Collection of Cases*. Washington, DC: PAHO, c1999. 19-24 (English), 21-26 (Spanish).
39. Borrás C. Radiation Therapy Overexposure. In *REMPAN 97. Proceedings Seventh Coordination Meeting of World Health Organization Collaborating Centers in Radiation Emergency Medical Preparedness and Assistance Network*. IRD. Rio de Janeiro, 1997, 51-53.
40. International Atomic Energy Agency (IAEA). *Accidental overexposure of radiotherapy patients in San Jose, Costa Rica*. Vienna: IAEA; 1998.
41. International Atomic Energy Agency (IAEA). *Investigation of an accidental overexposure of radiotherapy patients* in Panama. Vienna: IAEA; 2001.
42. Borrás C, Barés JP, Rudder D, et al. Clinical effects in a cohort of cancer patients overexposed during external-beam pelvic radiation therapy. *Int. J. Radiation Oncology Biol. Phys*. Vol 59, No.2, 2004; 538-550.
43. Borrás C. Overexposure of radiation therapy patients in Panama: problem recognition and follow-up measures. *Rev Panam Salud Publica*. 2006; 20 (2/3); 173–187.
44. Borrás C, Rudder D, Jiménez P. Use of imaging techniques in radiation oncology. In: *International Atomic Energy Agency. Standards and codes of practice in medical radiation dosimetry. Proceedings of an international symposium, Vienna, 25–28 November 2002*. Vienna: IAEA; 2003.
45. United Nations Scientific Committee on the Effects of Atomic Radiation. *Sources and effects of ionizing radiation*. New York: UN; 2000. (UNSCEAR 2000 Report to the General Assembly).
46. Fleitas I, Caspani CC, Borrás C, Plazas MC, Miranda AA, Brandan ME, et al. La calidad de los servicios de radiología en cinco países latinoamericanos. *Rev Panam Salud Publica*. 2006; 20 (2/3): 113–124.
47. Borrás C, Mota H, Skvarca JJ. Measurements of image quality and dose in 61 mammography units in 11 countries [conference presentation]. *89th Radiological Society of North America Scientific Assembly and Annual Meeting, 28 November–3 December 2004*, Chicago, Illinois, United States. Abstract available at: http://rsna2003.rsna.org/rsna2003/VBK/conference/event_display.cfm?id=66601.

    &em_id=3107772. Accessed on 19 February 2006.
48. International Atomic Energy Agency. *Joint Radiation Emergency Management Plan of the International Organizations*. Vienna: IAEA; 2004.
49. International Atomic Energy Agency. *International Action Plan for the Radiological Protection of Patients*. Available on the Internet from: http://www-ns.iaea.org/downloads/rw/radiation-safety/PatientProtActionPlangov2002-36gc46-12.pdf [Website]. Accessed 15 February 2006.