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Uses of Nuclear Energy

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PEACEFUL USES OF NUCLEAR ENERGY IN THE
ENGLISH-SPEAKING CARIBBEAN a/

a/ This document was prepared by Professor Gerald C. Lalor, ECLAC
Consultant. The views expressed in this paper are those of the author
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QUESTION

ANSWER

1. The first step in the analysis of a system is to identify the system boundaries. This involves defining the scope of the system and the inputs and outputs. The next step is to identify the components of the system and their interactions. This can be done by creating a block diagram or a flowchart. The third step is to determine the system's behavior under various conditions. This is often done by conducting experiments or simulations. The final step is to evaluate the system's performance and make any necessary adjustments.

2. The system is a closed system, meaning that it does not exchange matter with its surroundings. However, it does exchange energy with its surroundings. This is because the system is at a higher temperature than its surroundings, and heat will flow from the system to the surroundings. The system is also a dynamic system, meaning that its state changes over time.

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PEACEFUL USES OF NUCLEAR ENERGY IN THE ENGLISH-SPEAKING CARIBBEAN

PREFACE

This study was commissioned by the Economic Commission for Latin America and the Caribbean (ECLAC) as a contribution to a meeting of experts from Latin America and the Caribbean which is to be held in ECLAC headquarters during April 15-18, 1985. The report from this meeting will be submitted to the Conference Preparatory Committee of the United Nations Conference for the Promotion of International Co-operation in the Peaceful Uses of Nuclear Energy which is scheduled for 1986.

TERMS OF REFERENCE

The study deals with the English-speaking Caribbean countries according to the following assignment:

1. Obtain the necessary information and demand for and on issues related to nuclear energy for Belize, Jamaica, St. Lucia, and Trinidad and Tobago;

2. Prepare a report of approximately 20 pages covering:

(a) potential needs and priorities in peaceful non-power uses of nuclear energy,

(b) present and potential problems in the development of nuclear energy,

(c) the scope for sub-regional, regional and international co-operation in the area of peaceful uses of nuclear energy.

The theme of nuclear power is excluded from the terms of reference of the Caribbean paper.

INTRODUCTION

The English-speaking Caribbean sub-region consists of those former territories of Great Britain whose shores are washed by the Caribbean sea. This covers a wide-spread area starting from Belize in Central America, across and slightly north to the Bahamas Islands, southwards to Jamaica, eastwards to the British Virgin Islands, then southwards through a chain of very beautiful islands, including Barbados, which ends with Trinidad just off the coast of Venezuela, and with a further extension, to the mainland territory of Guyana.

/The distances

The distances between farther points within the sub-region are quite large: Belize city is separated from Nassau in the Bahamas by some 1 500 kilometres and from Trinidad by over 3 000 kilometres. Despite this there is a commonality which goes beyond a mere use of the same language. Some expressions of this include the regional University of the West Indies (UWI), which serves all the territories, the Caribbean Common Market (CARICOM), the Caribbean Development Bank, and not least the West Indies cricket team.

Although many of the territories are densely populated, the population of the sub-region is, in absolute terms, quite small. The total population is only some 5.4 million persons and Jamaica, with just over two million contains some forty percent of this number. With the exception of Trinidad, which has petroleum, agriculture and tourism dominate the Caribbean economies. These countries have been buffeted by the oil shocks and have felt keenly the harsh winds of the present world economic recession. They are all either in real difficulty, or in a state of cautious watchfulness.

In this situation all efforts are being made to increase efficiency and productivity, and to find new products and markets. Perhaps never before in the history of this region has there been greater need to apply the available science and technology to the economic benefit of its people. No doubt this is something the Caribbean share with all the countries of Latin America, and is also a situation which could present an opportunity to demonstrate the benefits of nuclear science and technology.

Table 1 summarizes some basic information on the region. This information is presented to give some idea of the scale of the countries involved.

Nuclear Science and Technology

The most conspicuous, and important, application of nuclear science and technology is of course its use as a source of energy. The growth of nuclear energy for electricity generation has been slower than was initially expected, but although there are still problems associated with the technology, nuclear energy already provides a considerable share of the electricity generating capacity in many countries. This proportion is likely to increase since, despite the present oil glut, petroleum is a wasting asset and none of the alternative energy sources proposed appears to be comparable to nuclear in terms of size of output and energy density.

The generally held view seems to be that it would be unrealistic for a region like the Caribbean to consider nuclear power plants over the next decade. The reasons which lead to this conclusion include the following:

Table 1

SOME BASIC INFORMATION ON SELECTED
CARIBBEAN TERRITORIES

Territory	Area (sq.km.)	Population
Anguilla	91	8 500
Antigua/Barbuda	442	76 000
Bahamas	13 492	249 000
Barbados	430	250 500
Belize a/	22 958	160 000
British Virgin Islands	207	14 300
Cayman Islands	260	16 700
Dominica	750	83 000
Grenada & possessions	689	109 200
Guyana a/	214 970	850 000
Jamaica	10 991	2 160 900
Montserrat	102	12 500
St. Kitts/Nevis	269	49 000
St. Lucia	616	124 000
St. Vincent	389	100 000
Trinidad/Tobago	5 128	1 128 600
Turks/Caicos Islands	430	7 346
		5 399 546

a/ Mainland territory.

1. The relatively small scale of base-load electricity requirements.

2. The very high capital costs of nuclear electricity plants, coupled with foreign exchange shortages and high interest rates.

3. The very significant manpower requirements of high technical quality required to construct, operate, maintain, and regulate a nuclear power plant.

Yet there is also the view that there may be possibilities for nuclear power in the future, perhaps twenty years on, and that certain types of developments of peaceful uses of nuclear science and technology could help to develop manpower base, experience, and some of the skills which would then be necessary. Of more immediate importance is the

/realization,

realization, by some members of the community, that nuclear science can make major contributions in areas other than energy generation. The contributions to medicine, agriculture, environmental studies, insect control, mineral exploration, geology and geochemistry, education, industry, science and technology, nutrition, etc., can be very important, but this appreciation is not yet sufficiently widespread.

This report is not concerned with the present, or even future prospects of nuclear power; indeed as outlined above these presently appear to be rather slight. It deals instead with the applications of nuclear science and technology already being carried out, or presently being planned, in a number of English-speaking Caribbean territories and indicates possible developments and the scope for co-operation.

Due to the limited time available, this study could not attempt a full overview of the entire sub-region, nor indeed provide even an in-depth survey of the countries selected, but it should nevertheless present a picture which can be discussed and even extrapolated with fair confidence. As mentioned in the first section the countries originally selected for the study were Belize, Jamaica, St. Lucia and Trinidad and Tobago, but it soon became obvious that Barbados should be included.

The applications of non-medical uses of nuclear energy have not been numerous in most of the countries in the sub-region, but these are expected to increase manifold in the not too distant future since the Centre for Nuclear Sciences on the Mona Campus of UWI will be supporting research on the sub-regional scale.

On the other hand, the medical applications of nuclear energy, the uses of x- and gamma radiation, and of even a limited number of isotopes are so obvious, that in most countries in the Caribbean, it is the medical profession that has long spearheaded the applications of nuclear energy.

PRESENT APPLICATIONS

This section deals with the present, or recently past work which has been carried out in selected Caribbean countries in non-energy peaceful uses of nuclear science and technology. The time available for this study was too brief to ensure that all relevant information has been captured, but because the volume of work done to date is not too extensive and the sources of information are very knowledgeable, this survey will at the very least give a good overall indication of the present position and future prospects. The information is presented on an area by area basis for each country.

/BARBADOS

BARBADOS

Barbados is a densely populated country with a good educational system, and good public services and facilities. The main sources of income are tourism and sugar production. Although the available land areas are small some efforts are being made at agricultural diversification. Barbados hosts a Campus of the University of the West Indies including a section of its Faculty of Medical Sciences.

Judging from the number of reports of work published in the international journals, Barbados does not approach either Jamaica or Trinidad in the amount of research being conducted. But there is a good deal of interest there in developments in science and technology, and there is growing support for "relevant research".

As far as could be ascertained, outside of the field of medicine, there is very probably no work at all which involves peaceful uses of nuclear energy being done in Barbados. There are no facilities being used for research, and no work involving the use of isotopes or radiation is in progress or being planned for the foreseeable future in science in the Ministry of Agriculture, the Sugar Research Unit, the Bellairs Research Unit for studies in marine biology or even within the University campus. This is a somewhat surprising situation but is probably only temporary.

Medical applications

Apparently the only user of nuclear techniques is the medical profession. In this case the facilities are quite good and there are a reasonable number of qualified staff. Both diagnostic and therapeutic services are provided at the Queen Elizabeth Hospital in the capital city, Bridgetown. This hospital also provides services by arrangement for the smaller territories in the sub-region.

1. Diagnostic Uses of X-Rays

The x-ray diagnostic department houses six rooms fitted with x-ray equipment. The equipment was supplied by a variety of firms and appears to serve the needs well. There are so many other medical applications in Barbados that there is no need to dwell on this one.

2. Nuclear Medicine and Radiation Therapy

The work in nuclear medicine is not extensive but the unit operates two gamma counters and a Picker gamma scanner. The main isotopes used are tellurium (from a molybdenum cow) and iodine-131. Some phosphorous-32 is used for bone therapy.

A variety of radiation sources is available for radiation therapy. These are:

1. A General Electric 100 kev unit for superficial x-ray therapy.
2. A strontium-90 beta-plaque for eye treatments.
3. An Amersham Caesium-137 Afterloading system for intracavitary applications using disposable plastic applicators.
4. A cobalt-60 Theratron unit.
5. A variety of radium needles with radium contents varying from 0.5 to 5.0 mg.

The department is staffed as follows:

- 1 Radiotherapist/Oncologist at the Consultant level
- 1 Senior Registrar
- 1 Medical Registrar
- 2 Assistants

This department provides radiotherapy for Barbados mainly, but also accepts patients by arrangement from the smaller islands and Guyana. In addition to its service programmes it carries out a teaching programme for UWI medical students by way of a five week clerkship.

3. Radiation safety

The attention to radiation safety and personnel monitoring are quite impressive. A film badge service is used and arrangements are now being made to carry out the entire process locally.

BELIZE

Belize is a mainland territory with a strong Spanish influence. Although English is the official language, some 40% of the population speaks Spanish. Its economy is heavily dependent on the export of sugar and timber, but the manufacturing industries are growing in size and importance.

Belize does not have a Campus of the University of the West Indies. However there is a University Centre with a small staff which carries out a number of programmes and maintains close contact with the University. There is a College of Arts, Science and Technology for the technician level training and there is a branch of the Caribbean Agricultural Research and Development Institute (CARDI).

/Medical Applications

Medical applications

There are no radiotherapy units in Belize and no present plans to develop one. Patients requiring radiation treatment are sent to a hospital in Merida, Mexico.

There are about eight x-ray units for routine x-ray work: chest, abdomen, upper and lower gastro-intestinal tract and intravenous pyleograms. Two units are in Belize City and one in each of the other districts. The staff appear to be well trained but the equipment is outdated. The programme is now being evaluated with a view to possible expansion.

Agriculture

Belize is a country with great agricultural potential. In addition to sugar cane, there are for example, rice, corn and soya beans. Fertilizer trials are being carried out. It is expected that the tempo will increase shortly. CARDI employs three scientists in Belize and are quite active there.

There are, however, no applications of isotopes, but there is interest in possible studies on soil nutrients, particularly phosphorous. The Ministry now has neither facilities nor personnel, so it was felt that joint projects, say with UWI, would be a good starting point.

ST. LUCIA

As is shown in Table 1, St. Lucia is a small country and, as might be expected at this time, the applications of nuclear science and technology would not be extensive. It was confirmed that there have been very few local applications of isotopes or nuclear techniques in the past.

Agricultural applications

The largest research operation in St. Lucia is the West Indies Banana Research Centre (WINBAN). This organisation serves Dominica, Grenada, St. Lucia and St. Vincent. The unit has been and appears to be making substantial contributions to agriculture in the Windward Islands.

There has been little use of isotopes in agriculture in St. Lucia. The only reported work was done as long ago as 1964. This was a study using phosphorous-32 to determine:

/(a) The

(a) The extent of root spread of crop bananas (they found this to be about 7 feet) and the best locations at which to apply fertilizers.

(b) The physiological relationships between the "follower" and "mother" plant.

There are now plans to make use of the non-radioactive nitrogen-15 in tracer studies to determine plant uptake of nitrogen and the fate of applied fertilizers.

Applications in Medicine

The only "nuclear applications" consist of the usual use of x-rays. There are two hospitals both possessing x-ray diagnostic facilities.

1. The Victoria Hospital

This Government operated hospital has no facilities for work with isotopes or radiation. It operates a single General Electric diagnostic unit which is now seven years old. Maintenance is done by local staff, or as necessary, by a service facility from Puerto Rico. Personnel monitoring is done by a film badge service. The films are read overseas and the results returned; the turnaround time is longer than desired. No area monitoring is carried out as this is not considered necessary.

The hospital does not now have the services of a radiologist. No local radiologists are available so foreign contract officers have been appointed in the past; one is expected shortly.

2. St. Judes Hospital

This hospital is operated by the sisters of Milwaukee with financial assistance from the government of St. Lucia. Again only medical diagnostic work is carried out; there is no work with isotopes and no other radiation sources. The x-ray unit is a Canadian Picar.

Geoprospecting

A reconnaissance scale study was carried out in 1984 by the Los Alamos National Laboratory. Data were obtained on 307 stream sediment samples and 55 beach sand samples to identify areas favourable for the exploration of mineral resources. The samples were analysed for 51 elements using neutron activation analysis, delayed neutron counting and x-ray fluorescence techniques. The report and geochemical atlas have been completed. However, no local was trained in the use of these nuclear techniques.

TRINIDAD AND TOBAGO

Trinidad is the most highly industrialized country in the sub-region and is a producer of petroleum. It has a Campus of the University of the West Indies which includes the Faculties of Agriculture and Engineering of that institution; the headquarters of the Caribbean Agricultural Research and Development Institute (CARDI), the Caribbean Industrial Research Institute (CARIRI), and the Caribbean Epidemiological Centre (CAREC) as well as a number of other scientific and medical departments and institutions, including the Institute of Marine Affairs. These contribute to a significant and steadily growing scientific and technological capability of impressive potential. There is obviously a good deal of infrastructure already in place and, in addition to all this, there is a remarkable new medical and veterinary complex which is close to completion.

1. The Caribbean Epidemiological Centre (CAREC)

The Caribbean Epidemiological Centre was formed in 1975 and took over the activities of the Trinidad Virus Laboratory. CAREC was organized mainly to establish and consolidate disease surveillance in the sub-region and to provide diagnostic facilities for virology, and supportive and referral laboratory services for bacteriology and parasitology.

CAREC appears to be a well equipped and excellent facility. Although there is equipment and the capability for radio-immunoassays, none are presently being carried out. In the recent past iodine-125 labelled antibodies were purchased in kits and used in diagnosing hepatitis-B. This work has been suspended, though the capability remains, by the more economic enzyme-linked immunosorbent assay (ELISA) tests. A difficulty was that the scale of the diagnostic kits was so large that there was considerable wastage of the relatively short-lived, and expensive, iodine labelled antibody. The only present application of isotopes is the use of carbon-14 in surveillance of streptococcal infections.

CAREC has no difficulty with the handling of radioisotopes. There is a qualified and trained staff accustomed to dealing with very dangerous biological materials so the transition to isotopes presents no difficulty. Personnel radiation monitoring at CAREC is arranged by the National Radiotherapy Centre.

2. The Caribbean Industrial Research Institute (CARIRI)

This is a non-profit research institute founded in 1970 to assist in the development of industry through its research and services. Its general scope of activities include Chemistry, Economics, Electronics, Engineering, Food Technology, Materials Technology, Microbiology and Petroleum Testing. The Institute is staffed and equipped to carry out its mission; it is certainly one of the best equipped institutes in the region.

Nevertheless, CARIRI has not been making much of peaceful uses of nuclear energy except for work in x-ray fluorescence and diffraction. One application involved the development of an isotope dilution method for the analysis of sulphur in sour crudes; another is the future use of carbon-14 as a mechanistic tool in certain fermentation studies. Neither project has reached the application stage, but CARIRI would be able to support almost any likely interest which might develop in their laboratories.

3. The Caribbean Agricultural Research and Development Institute

The Caribbean Agricultural Research and Development Institute was founded in 1975 to contribute to the agriculture of the sub-region. Its headquarters is located at the St. Augustine Campus of UWI but there are research stations in other territories. The staff in Trinidad present a bright picture of agricultural development and activity, but there has been little involvement in the uses of isotopes. There is some interest but no immediate plans to begin using nuclear techniques.

4. The UWI Faculty of Agriculture

The Faculty of Agriculture of the University of the West Indies is located in Trinidad but maintains a number of operations, particularly involving research and extension work in some of the other territories. It has some 50 professional level staff and reasonably good facilities including a field station.

Despite the wide range of its activities it has been but little concerned with peaceful uses of nuclear energy, although it is likely that these applications will increase in the near future. The interest is particularly high in the Department of Soil Sciences which has used isotopes (P-32 and S-35) in the past for plant nutrition studies. Their recent work involves nitrogen uptake studies with nitrogen-15, and they would also be interested in studies on soil microstructure using radiotracers.

5. The National Radiotherapy Centre

The National Radiotherapy Centre was founded in 1972. It is the specialised unit responsible for the therapeutical uses of radiation in Trinidad. The unit operates with the following major items of equipment:

- (a) Two cobalt 60 therapy units, Theratron models 780 and T80; (Atomic Energy of Canada Ltd.);
- (b) A Philips RT305 deep x-ray unit;
- (c) A Philips RT100 superficial x-ray unit;

Sealed caesium-137 sources are used for the treatment of cervical cancers.

The staff comprises: one oncologist (who is also Head of the Centre), two medical physicists, and five radiographers. The Centre presently treats about 700 patients yearly.

The Centre, as expected, is highly conscious of radiation safety and has its complement of radiation monitors and secondary standard ionisation equipment. There are no official National guidelines but international regulations are followed.

6. Immunology Department, Port-of-Spain General Hospital

This unit performs the usual endocrine diagnostic tests. They are equipped for gamma and beta counting and general medical radioisotope work.

7. Applications in Industry

There are five or six private companies using radioisotopes for non-destructive testing by gamma radiography. The first of these is as much as ten years old. The isotopes used are iridium-192 of activities ranging from 25 to 90 Curies and cobalt-60 at about 5 Curies for materials thicker than 1.1/2 inches. These are quite potent sources and it is not surprising that ultrasound is becoming an attractive alternative in Trinidad.

JAMAICA

Jamaica is the largest of the English-speaking Caribbean islands. Its economy is based on agriculture, bauxite mining and alumina production, tourism and a variety of manufacturers. Jamaica has long possessed a quite active scientific and agricultural research community. It hosts the oldest campus of the University of the West Indies and the major portion of the University's medical school. It maintains a major agricultural

/effort through

effort through the Ministry of Agriculture, the department of Botany at UWI, a research unit of the Faculty of Agriculture, and a section of CARDI.

There has long been interest in the use of isotopes in various types of investigations, and a considerable number of small projects in science, technology and agriculture have been mounted in the past; but until recently, except in medicine, there has been no sustained effort. Now, however, Jamaica is in the unique position among the English-speaking Caribbean islands in that it has recently opened a Centre for Nuclear Sciences and therefore the interest in peaceful uses of nuclear energy is unusually high.

A number of examples of programmes and activities, which is by no means exhaustive, is given below:

Medical Applications

Medical applications of nuclear methods are quite numerous in Jamaica. These include both routine uses and research studies. The former includes diagnostic applications and radiotherapy.

1. The Use of X-Rays

Many Government hospitals operate x-ray diagnostic services. These are standard facilities, although of course they vary in size and operational capabilities depending on the location. The University Hospital of the West Indies operates a reasonably well-equipped Department of Radiology and has recently taken delivery of a computerised x-ray tomography unit. Private hospitals also operate x-ray equipment, as do many dentists. Because these facilities are to be expected as part of any adequate medical services, and most of them are of longstanding application, they are not further treated in this report.

2. Isotope Diagnostic Units

There are at least two diagnostic units in Jamaica which make use of isotopes. A very brief description of the work of each follows:

(a) Endocrine Diagnostic Laboratories Ltd.

Endocrine Laboratories Ltd. is a small privately owned medical diagnostic unit located in a private Kingston Hospital. The main isotopes used are: iodine-125 for measurements of thyroid function;

chromium-51 and cobalt-57 for blood volume studies. The isotopes are imported in kits from the United States of America and Canada. Counting is carried out with an Abbott auto-gamma counter with an automatic sample changer.

(b) The Department of Nuclear Medicine

The Government of Jamaica also operates a Department of Nuclear Medicine which is housed in the University Hospital of the West Indies. This department is equipped with a rectilinear Raytheon scanner.

The unit does a little therapeutic work, concentrating on the treatment of thyroid cancers with iodine-131.

(c) Therapeutic Units

The Government of Jamaica operates two radiotherapy units, one in the Kingston Public Hospital in Kingston, the capital city, the other at the Cornwall Regional Hospital in the west of Jamaica in Montego Bay, the second largest city. The unit in Kingston appears to be the more important of the two, and is briefly described below:

(i) Kingston Public Hospital

The unit at the Kingston Public Hospital is perhaps the oldest regular user of radiation and isotopes in the country. It is a very active unit, the demands on which seem readily to justify expansion, which is not apparently possible in the present economic situation in Jamaica. The equipment with which the unit operates includes the following:

- A General Electric x-ray system for the treatment of superficial skin cancers and keloids.
- An Atomic Energy of Canada Ltd. THERATON-80, equipped with 9000 Ci of Co-60 (last changed in August 1983) for the treatment of deep-seated cancers.
- A strontium-90 source for beta radiation therapy, e.g. eye pterygia.
- Radium needles are also used for interstitial and intercavitary therapy.
- There is, of course, also a range of ancillary instrumentation and devices for dose measurement and calibration, and radiation monitoring.

/Patients from

Patients from other Caribbean islands are treated at the Kingston Public Hospital, although this presents a problem since the unit cannot cope with even the local demand. There are presently 600 new cases per annum reporting for treatment at this unit.

Uses of Isotopes in Agricultural and Biological Investigations

Isotopes have been used for several years now in research in agriculture and biology. The work has been very ad hoc with each application being carried out by a different group as the situation arose. Some examples are reported below.

1. Mutation studies on Soya Beans

Work was done in the Department of Botany at UWI to modify soya bean stocks to obtain varieties more suited to the Jamaican environment. Selected seeds were subjected to varying doses and dose rates of gamma radiation in an effort to modify their genetic properties. The gamma irradiation was done in Puerto Rico and the seeds returned to Jamaica for field tests. The genetic lines were followed for a number of generations to identify any permanent beneficial effects which may have occurred. Favourable results were reported but the work has not been followed up.

2. Studies on Possible Insect Vectors of Lethal Yellowing

This was an attempt to identify the insect vector responsible for the spread of the "Lethal Yellowing" disease which has virtually wiped out what was once the commercial variety of coconut palm in Jamaica. The work consisted of feeding experiments with phosphorous-32, coupled with subsequent trapping and counting measurements. The experiments were not successful in identifying the vector.

3. Photosynthetic Productivity

There is a joint project between the University of Guelph, Canada, and the Departments of Botany and Zoology at the UWI on photosynthesis and productivity in the Hellshire Bay area on the south coast of Jamaica. This programme makes use of carbon-14 uptake studies. The counting will be carried out on liquid scintillation counters already at UWI.

4. Studies of Moisture Contents of Soils

A study of plant, soil, water relationships is under way to examine the efficient use of water under multi-crop systems. The crops include bananas, gungu peas and sweet potatoes. Water determinations are done, by use of a neutron probe, at depths ranging from 10 to 60 cm.

/to examine

to examine the competition between the various root systems for water, and to indicate the extent of irrigation needed.

Uses of Isotopes in Chemical and Biochemical Investigations

This is a fairly widely used application of radiotracers in research at the Mona Campus of UWI. The users have included the following university departments: Biochemistry, Botany, Chemistry, Zoology and the Tropical Metabolism Research Unit. In much of the research the objective has been to deduce the biochemical pathway by which a plant produces chemical compounds, which may be of interest because of their biological activity. In these studies the activity is introduced in some particular and well characterized form and its subsequent fate determined by chemical and radiological examination. Liquid scintillation counting is a favoured technique for such studies.

Research in the Tropical Metabolism Research Unit and the Department of Biochemistry include studies on levels of growth and thyroid hormones and insulin in both normal and malnourished children. Work is also in progress on the affinity of erythrocytes and mammary gland cells for insulin and also the number of sites available for binding the hormones.

Iodine-125 labelled hormones, imported in kit form are used.

The Use of Isotopes and Ionizing Radiation in Industry

It is very difficult to assess the extent of the routine usage of isotopes and ionizing radiation in industry since there is no central register of isotopes in Jamaica. One hears of the use, or past use, of ionizing radiation for non-destructive testing of welded joints and for density and thickness gauging, but it was not possible in the time available to assess the extent of usage.

The organisations which appear to have made most use of methods involving isotopes are the bauxite companies and the Jamaica Bauxite Institute. Mixing and settling in the Bayer Process for the manufacture of alumina have been studied using gold-198. The settling of liquors in the red mud disposal ponds has been approached by use of radioiodine as a tracer.

The bauxite companies and the Bauxite Institute use x-ray diffraction and x-ray fluorescence in their analytical laboratories. The Bauxite Institute uses a soft gamma source containing americium-241 for measuring the settling of solids in liquors.

/Most applications

Most applications of nuclear methods in industry are carried out by the bauxite producers and the Institute. This is not surprising since bauxite is the largest industry in the country. But even in this industry, in the instances for which it was possible to obtain information, any novel problem involving nuclear methods was contracted out to overseas consulting groups and there is little in-house knowledge or expertise in applications of isotopes or radiation.

It does seem that there is wide scope for applications of radioisotopes and for radiation based methods of non-destructive testing. Usage is however only likely to increase significantly if the expertise is available locally.

The Centre for Nuclear Sciences

The Mona Campus of the University of the West Indies has initiated a programme of development in peaceful uses of nuclear energy. A small Centre for Nuclear Sciences was formally opened in June 1984 and several programmes are now in place. The main item of equipment in the Centre is the Atomic Energy of Canada Ltd. SLOWPOKE-2 reactor. This is a very simple, safe, low power reactor which was specially designed for university and hospital laboratories. It is particularly suited for neutron activation analysis and the production of small quantities of radioisotopes.

The UWI SLOWPOKE facility operates with a maximum neutron flux of 10×10^{11} neutrons per cm. squared per second and with very high flux stability. The reactor is fitted with three radiation sites within the core for sample volumes of 7 ml., and with two outer sites at which a larger volume of samples (27 ml) can be irradiated, though at a lower maximum neutron flux of about 5×10^{10} . For neutron activation analysis, the reactor is supported by two hyperpure germanium detectors, multichannel analyzers, and micro-computers.

Isotope production for supply to medical and other users will begin once proper facilities for the handling of the activities have been put in place. The Centre is also equipped for x-ray fluorescence studies, but the present priority is neutron activation analysis.

The Centre operates with a small core staff of scientists, technologists, technicians and support staff, now totalling seven. Individual researchers from University departments or other institutions execute, with Centre guidance, their own research programmes, which however normally contribute to the general aims of the Centre.

/Capital funding

Capital funding for the construction of the building was provided by the European Development Fund (EDF) and the Government of Jamaica. The reactor and associated equipment was provided by the EDF. Most of the other instrumentation, including micro computers, was provided by the International Atomic Energy Agency, which was very much involved at all stages of the efforts, and which has been providing technical assistance, advice and training. The recurrent expenditures are presently met by the Government of Jamaica and by the University. It is expected, however, that many of the programmes will be self-supporting.

A selection of the programmes presently underway at the Centre follows.

1. Elemental Mapping in Jamaica

This major programme is aimed at obtaining as much information as is possible on the chemical constituents, including trace elements, of soils, rocks, water, plants, etc., and of examining the possible influences of chemical composition and interactions in several areas which include agriculture; plant, human and animal nutrition; and medicine. A number of semi-independent projects have been devised which will though capable of standing on their own, contribute to the overall project. Suitably chosen samples are being analysed for some fifteen elements at this time and the analytical methods are continuously being extended to increase this number. The analytical results together with such other information on the samples such as exact location and sample type are stored in data banks for interactive recall and comparison with a variety of other information and data. A selection of the sub-projects follows:

(a) Environmental Studies

Environmental studies which make use of nuclear techniques are, in the main, being carried out by staff of the Departments of Chemistry and Botany, and their research students in association with the Centre for Nuclear Sciences. Two are mentioned below:

- (i) The use of lichens as environmental monitors of trace metal pollutants in the neighbourhood of certain large industrial plants.
- (ii) The provision of base line data in sea coast areas to contribute to a programme of coastal management.

/(b) Radiometric

(b) Radiometric Surveys and Uranium Prospecting

There have been reports of locations which produce radiation counts significantly above background levels. A few of the Jamaican mineral springs have also been reported to be somewhat radioactive. A radiometric survey of the island is now in progress. The main equipment being used in the field is a vehicle-mounted sodium iodide detector and four-channel spectrometer. There have been difficulties with the fragility of the sodium iodide detector system and assembly but this seems to have been overcome.

Samples from the field are analysed in the Centre. One method being used is instrumental neutron activation analysis by measuring the extremely small amounts of neptunium-239 formed by neutron irradiation of samples containing uranium.

Some of the first results have been submitted for a degree of Master of Science (UWI) in Geology. This work is continuing.

(c) Geochemical Prospecting

River sediments in one of the larger river basins of Jamaica, the Wag Water basin, are being collected for examination by neutron activation analysis, x-ray fluorescence, and atomic absorption. In addition to obtaining geological and geochemical information of interest the results will contribute to the mapping programme outlined above. It is also expected to demonstrate to local geoscientists the value of river sediment analysis as a major aid in geoprospecting in Jamaica. This work will be extended to other river basins as the availability of funds and personnel permit.

2. Development of a Thermoluminescent Dosimetry Service

Prior to 1984 all personnel monitoring for workers in the sub-region was done by film badge services in Europe and North America. The badges were dispatched by post and the results mailed back to the institution. The users report that the turnaround times are long, sometimes exceeding three months. It could be argued that, at the very least, this has had psychological effects and could lead to poor work habits.

The Centre for Nuclear Sciences, therefore, operates its own dosimeter service using two element lithium fluoride disc badges to record exposure to beta and gamma radiation, and the following equipment:

1. A Toledo automatic TLD reader
2. A strontium-90 irradiator for calibration
3. A micro-computer for data handling and file management.

All Centre staff and several locations within the working areas of the building are routinely monitored and a pilot project is in place to examine the feasibility of providing a national service which could be expanded across the sub-region if the demand exists.

TRAINING IN NUCLEAR SCIENCE, TECHNOLOGY AND APPLICATIONS

This study would be incomplete without mention of the educational system by which scientists and technicians are produced. The sub-region has two Universities. One, the University of Guyana, is a national institution; the other, the University of the West Indies, is a regional university, directly supported by all the countries in Table 1, except Guyana to which, however, it also provides substantial services. In addition to the two universities there are a number of other tertiary institutions which supply much needed manpower at the technician and middle management levels. The output from UWI at the Bachelor's Degree level is fairly substantial, as shown in Table 2 which lists the results for those areas with direct bearing on this study.

Table 2
INFORMATION ON THE NUMBER OF GRADUATES FROM UWI

Academic Area	Number of Graduates	
	(1980)	(1984)
Agriculture	69	52
Engineering	156	128
Medicine	107	91
Natural Sciences	262	320

UWI does not offer a programme of nuclear engineering. Some aspects of nuclear science and technology are provided in the normal courses in Chemistry and Physics and, to a lesser extent in the biological sciences and medicine. The Chemistry Department operates a small radioisotope laboratory for its undergraduate students. This laboratory contains an isotope neutron activation apparatus, utilizing an Americium/Beryllium source, with a neutron flux of about 10×10^6 neutrons per cm squared per sec. There is also some fairly simple equipment for single channel spectroscopy and other counting. No other university department provides

/undergraduates with

undergraduates with the opportunity to be properly introduced to examples of the usefulness of applications of radiation and isotopes. The graduate students are, on the whole, in a similar position although some do have the opportunity to work with isotopes in their research projects.

POTENTIAL NEEDS AND PRIORITIES

There are many obvious needs typical, perhaps of developing countries, but these vary considerably from country to country and from programme to programme. Firstly, there are those programmes which are already in place: these require, as always, more funds, more staff, more equipment, training, and a certain amount of technical assistance. Depending on the country and the programme, some of these matters can well be dealt with internally. For other countries, external assistance, both financial and in expertise, would be necessary. Some of this might be obtainable within the sub-region, some would have to be sought from extra-regional sources. These needs are well known to all persons involved in development of any sort and can be taken as given.

But it is certainly not merely a matter of funds, equipment and the things that go with these. There must also be the conviction that applications of nuclear energy are feasible, safe and worthwhile. This can only come about through education and example. A first priority therefore might be to strengthen those units and programmes which are already in existence, and to build on their successes. This will require that these successes be publicized in some way so that other workers can begin to appreciate the power of nuclear techniques. In this respect, the Centre for Nuclear Sciences at UWI is perhaps the institution with the single most important role to play in this development.

It appears that none of the countries examined has any formal set of national regulations for work with isotopes and radiation sources. The major institutions will of course have their own guidelines, and the Centre for Nuclear Sciences has developed a comprehensive set of regulations based on international standards, and particularly on the Canadian regulations for the operation of SLOWPOKE reactors. There is now the need throughout the sub-region for a formal set of regulations to be promulgated by each government to ensure the safe use and expansion of applications of nuclear energy. These should include the registration of radiation sources above a specified size, the ensuring that all persons who work with such sources are properly trained and appreciate and enforce the appropriate safety measures.

The Centre for Nuclear Sciences has a responsibility to provide the necessary example in this and to be a ready source of information but is prepared to act further only if requested to do so.

PRESENT AND POTENTIAL PROBLEMS

The constraints which suppress the development of applications of nuclear energy vary, as ought to be expected, with the stage of scientific and technological development in any particular country. This in turn depends to a large extent on the number and quality of available scientists and technologists.

If a country has little industry, and its research and development efforts are, for whatever reason, limited, there must be severe problems in the application of almost any technology. A sufficient knowledge base may not exist even to allow the decision that a particular technology is applicable to a given problem, nor given a set of results, what to do with them. In such a case the country will need to depend heavily on external assistance.

Yet even if work is completed by an external source, with full local acceptance, unless particular efforts are made to ensure its adoption into the fabric of knowledge of the society, and appropriate plans for follow-up are executed, the benefits will probably at best be short term. An understanding of this, and of the limits of the financial and particularly human resources of many countries, is a key to dealing with the problem. Considered in this light the lack of progress in applying nuclear methods and techniques in some countries is hardly surprising. Yet the application of nuclear techniques can itself help to develop scientific capability.

It is difficult to see how the general development of science and technology in the Caribbean can be much hastened. But this would certainly be aided by concentrating support, in the main, on problems which are of interest to the policy makers, and possible users of the results. This is a consequence of the scarcity of most resources, and the urgency with which social and economic problems are viewed.

Belize, St. Lucia and the other territories which do not have either a University Campus or a research tradition will exhibit a low level of scientific awareness. Often the problem therefore is to make a start. This is not unique to nuclear energy; but applications of nuclear energy do have the disadvantage of unfortunate associations, and are often considered to be highly sophisticated. There is also the commonly held, though poorly understood, fear of the harmful effects of radiation.

Although most uninitiated persons accept, and accept with surprisingly little concern, even extensive use of x-rays for medical and dental diagnoses, there are rather powerful concerns about the

/effects of

effects of the use of any radioactive materials, nuclear reactors, etc., on the safety and well-being of the community. This can only be overcome by insisting on the most stringent safety regulations and practices, and by education.

Within any particular country the opportunities depend on the particular discipline. Applications of nuclear technology tend first to be in medicine because of the inevitable use of x-rays as a diagnostic tool. The next development has been the use of radiation in cancer therapy. Thereafter it seems a likely step to the use of isotopes etc., in what has become known as nuclear medicine. But the two latter steps were only possible in countries with a certain measure of resources.

The problems at each stage of these developments are mainly: lack of funds, staffing and staff development, and training. Even in the teaching hospitals the numbers of specialists in radiology and nuclear medicine are inadequate, and replacement of the present staff would be very difficult since medical graduates seem to prefer other specializations. In one territory there was the interesting suggestion that this is because patients suffering from carcinomas usually begin treatment so late, with consequently high death rates, that other physicians see radiation therapy as "but one step away from the undertaker".

Whether this is general or not, there are frequent complaints of lack of adequate training, inadequate equipment, and lack of access to adequate maintenance and support services. There is the need for medical physicists and more trained nuclear instruments technologists. Much of the medical equipment is rather old (but there are some x-ray tomography units); and some of the cancer treatment units appear to be in need of expansion. It was also said that there is need for greater understanding on the part of physicians and consultants on the advantages and potential of nuclear methods as diagnostic aids.

As shown by the example of Barbados, the establishment of even fairly sophisticated programmes in the medical field does not necessarily lead to applications in other disciplines. It may well be that cross-fertilization and internal technology transfers are themselves problems to be addressed.

In the areas of the other applications it was also stated that the shortage of facilities, training, and lack of appreciation of how best nuclear techniques might be applied were powerful disincentives to a more widespread use of the methods.

A fair number of workers have already received some training in various courses on, for example, the uses of isotopes in hydrology, geology and agriculture. The problem has been that after this training no further progress was often made. This has been explained as due to lack of facilities in the main, but this explanation must be viewed with caution, since in cases where there was a strong incentive to carry out work, at least minimal and sometimes much better facilities have been obtained.

THE SCOPE FOR CO-OPERATION

The English-speaking Caribbean is unusually well placed for co-operative efforts. The territories are so similar, and the needs often so comparable, that advances in one territory are often readily transferable to others. Communications between the territories either by telecommunications, by schooner for the closer islands, or by air for the farther separated ones, are quite good.

The existence of a sub-regional university with good infrastructure and staff, which is already committed to co-operation, and which operates an already functional centre dedicated to applications of nuclear science provides a firm base for future developments. The operations of the Centre are presently concentrated in Jamaica, but as its work develops and funds become available, its mandate will be extended to include the sub-region.

Another sub-regional institution, CARDI, which has particular responsibility for agricultural development, could contribute to developments in the applications of nuclear methods to agriculture.

Moreover the CARICOM Secretariat arranges a series of meetings of Ministers responsible for various portfolios such as education, agriculture, health, and science and technology, which provide an excellent opportunity for discussions on, and the making of policy with regard to, co-operation and co-ordination.

There is therefore quite remarkable scope for sub-regional co-operation in peaceful applications of nuclear energy in the Caribbean. Already there is a considerable amount of ongoing co-operation in the medical field, but even here more could be done, particularly in terms of patient treatment and exchange and transfer of knowledge and techniques.

The development of a sub-regional dosimetry and radiation safety advisory service is an immediate option for co-operation. The presence of equipment for thermoluminescent dosimetry and of trained personnel at the Mona Campus offers an excellent opportunity to do this.

Environmental and geochemical programmes could be readily regionalized and other areas such as insect control and food irradiation are considered suitable for sub-regional co-operation. No doubt the range of possible programmes would grow as successes are achieved.

Co-operation is also possible within the larger Caribbean region, which would include the territories of Central America, Cuba, Hispaniola, Puerto Rico, the Dutch Antilles, and Venezuela. In particular, Mexico already has much to offer; its work on insect sterilization is worth close examination throughout all the region. There would perhaps be some difficulties with language but this is hardly insuperable. Collaboration might be further encouraged if it fell within the framework of support by the Organisation of American States and/or under the auspices of the United Nations.

The Caribbean territories were all at one time or the other colonies, and have maintained quite close links each with its former colonial power. One aspect of this relationship is the Lome Conventions between the European Economic Community and various African, Caribbean and Pacific countries. This establishes a base for possible co-operation within the so called ACP territories and between the Caribbean and European countries.

All the above types of collaboration have a great deal to offer and will no doubt be pursued as and when the interest of the Caribbean in the peaceful applications of nuclear energy grows.

SUMMARY AND CONCLUSIONS

Applications, needs, problems, and prospects for peaceful uses of nuclear energy have been reviewed for five English-speaking Caribbean countries.

The extent of applications differs significantly from country to country. In Belize and St. Lucia the only medical applications are the normal use of x-rays in diagnoses. Barbados, Trinidad, and Jamaica, have much more sophisticated programmes which involve the uses of radiation sources, radiotracers and other nuclear instrumentation.

In the non-medical field there seems to be nothing in Barbados or Belize and very little in St. Lucia. There is interest, however, in various possible applications. Trinidad and Jamaica have several activities, with considerable scope for growth. Jamaica is unique in that it possesses a Centre for Nuclear Sciences which includes a small research reactor and which receives generous support from the Government.

/In summary

In summary, the following main points can be made: Firstly, there are definite limits to the amount of scientific manpower available so that "nuclear" applications can only be one of many possible interests; secondly, there has been relatively little nuclear experience, so that many easy possible applications might well be missed; thirdly, training, per se, is not of much use unless there are opportunities to make use of the training, except that it might help provide a more understanding climate; and fourthly, there is in most countries, the ever present lack of funds not only to purchase equipment and to develop infrastructure but also to pay the salaries necessary to attract and maintain good staff. The shortage of foreign exchange is another problem which has been becoming apparent during the last few years.

The most significant problems are the lack of human and financial resources, but human problems seem to be the more important. Nevertheless the following must be emphasized:

1. There is a core of people, who are already active and enthusiastic.
2. Although there is room for improvement in the equipment available, the situation is not at all hopeless.
3. A considerable amount of work is already in progress and there is interest in its expansion.
4. There seems to be a good deal of willingness to exchange information and to co-operate in other ways.
5. There seem to be excellent possibilities for co-operation at the sub-regional, regional, and international levels.

As already mentioned one should not expect applications in the uses of nuclear energy to outstrip the levels of science and technology which the countries presently enjoy. There is however enough interest, particularly in the larger territories to indicate that these applications will continue to increase in number.

Appendix

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