

INTERNATIONAL CENTRE FOR ENVIRONMENTAL AND NUCLEAR SCIENCES (ICENS)



Charles Grant MSc, *University of Surrey*
Director General

After 31 years of operation the SLOWPOKE-2 Research Reactor at the International Centre for Environmental and Nuclear Sciences (ICENS) was successfully converted from Highly Enriched Uranium (HEU) to Low enriched Uranium (LEU). The removal of HEU (weapons grade material) from civilian use is in line with Jamaica's firm commitment to the three pillars of the Non-Proliferation Treaty: nuclear disarmament, nuclear non-proliferation and peaceful uses of nuclear technology. The final day of operation with the HEU core was on the 17th of July 2015, the fuel was removed from Jamaica's territorial control on the 4th of September at 2:13 am, making the Caribbean a HEU free zone.

The HEU has been safely and securely stored at the United States Department of Energy (USDoE) Savannah River Site, pending final disposition, which often involves blending to low enrichment and

distribution to the Tennessee Valley Authority for generation of electricity. The reactor achieved its first criticality with LEU on the 30th of September, 2015 and is expected to operate for another 40 years. This process was only possible through the kind assistance of the International Atomic Energy Agency in the development of a tripartite Project and Supply Agreement between the Governments of Jamaica and the United States of America and the International Atomic Energy Agency. The successful completion of the conversion required the development of new core configuration calculations and models; fuel fabrication, logistics for transportation, safety plans; regulatory licensing and security procedures; along with training for the safe transportation of fresh and spent fuel and strict adherence to international Safeguards Agreements. This project was funded almost entirely by the Government of United States of America and is valued at approximately 1 billion Jamaican dollars.

PROJECT ACHIEVEMENTS

New Low Enriched Uranium core successfully modelled; New low Enriched Uranium core designed; New Low Enriched Uranium core manufactured; New tools designed and fabricated for the removal Highly Enriched Uranium core; Mock up reactor built for training purposes; Nuclear Safety and Radiation Protection bill passed through both Houses of Parliament; Permits and licenses obtained to allow fresh fuel in and irradiated fuel out; New Low Enriched Uranium fuel shipped to Jamaica from the USA; Highly Enriched Uranium reactor core safely removed; New Low Enriched Uranium core assembled; New Low Enriched Uranium core installed and commissioned; New Low Enriched Uranium core fully operational; Efficiency of the reactor doubled.

ICENS STAFF MEMBERS TRAINED IN THE FOLLOWING AREAS

Reactor core modelling; Nuclear waste management; Nuclear security; Nuclear fuel transportation; Radiation shielding calculations; Fission criticality calculations; Emergency Preparedness.

Phase 2 of the reactor upgrades is scheduled to commence in 2016 and

will involve the move from analogue control systems to digital. Funding for this will be provided through the IAEA as a national project. The initial contracts for this project will be completed by the 1st of September 2016.

WORK OF THE DEPARTMENT

The main long term goals of ICENS are to contribute to the nation's socio-economic advancement through the innovative application of Science and Technology to national and regional issues. ICENS research continued to focus on the abundances and transfers of inorganic trace elements in the chain bedrock ► soil ► food ► humans. Over 50 elements were routinely determined, using NAA, EDXRF, TXRF, ICP-OES, AAS and ion chromatography, the technique used depending on the type of sample medium analysed.

Trace element speciation in soils

Geochemical research continues to focus on the speciation of trace elements such as Arsenic, Cadmium, Chromium, Mercury and Lead in Jamaican agricultural soils, i.e. its distribution pathways in a particular sample or material type. Effects such as the microstructural changes on the microbial organic matter loading capacity of clay minerals in soils (e.g. montmorillonite) and the role of ligand formation with anions continue to be studied.

Food Safety and Security

During the reporting period ICENS continued to search for new ways to grow export-quality agricultural products low in potentially toxic elements as a short-term venture aimed at helping Jamaican farmers to grow such produce without having to change field practice. Compilation of a Jamaican national database of food compositions continued, using the data for Jamaican farmed and processed foodstuffs with the ultimate aim of providing:

- Food composition tables setting out major and trace element contents to support nutrition and diet prescriptions and regulations as to elemental contents.
- Better understanding of how food plants and animals take up elements from soil, as a means to guide land use planning.
- Indications of the effects of elemental interactions on plant uptakes.
- Ways to ensure food quality and compliance with relevant international food standards.

The food database will be structured into sections on root vegetables, leafy vegetables, grains, fruits, seafood and processed or packaged foods. The database presently contains results of an estimated 1,500 analyses for up to 35 inorganic elements.

The chemistry of human tissues

ICENS continues its work on the elemental content of human tissues (blood, urine and placenta samples) building up background information on the trace element concentrations in human tissue in order to allow comparisons between healthy and diseased persons, using Total Reflection X-ray Fluorescence analysis (TXRF) on blood samples collected from blood donors.

Radiological Services

ICENS continues to provide radiation dosimetry, monitoring and radiological advisory services to over 2000 users of ionizing radiation in Jamaica and five other territories in the Caribbean region. The main users are Medical facilities (including Dentistry and Veterinary services), various industries and researchers.

MAJOR ACTIVITIES AND PROJECTS

Upgrade of Reactor Infrastructure at the University of West Indies SLOWPOKE Facility JM-1

The infrastructure of ICENS and most of the equipment is between 15 and 30 years old. Upon completion of the core conversion ICENS will be set to continue operations for another 40 years at an expanded level including regional partners. To facilitate this, much of the equipment and infrastructure will require upgrading. This project will have impact on the following national priorities as identified in the Jamaican Country Program Framework:

Legislative Framework and Regulatory Infrastructure for Radiation and Nuclear Safety and Security; human Health; Energy Planning; Management of Water Resources and Environmental Protection; Food and Agriculture; Radiation Technology; Human Resources Development.

This project has commenced in August 2016 and will last for four years; initial funding has exceeded €650,000.00.

Strengthening Cradle-to-Grave Control of Radioactive Sources in the Caribbean Region

While we are fully appreciative of the benefits of nuclear technology, we are also cognisant of the need for applying these technologies in a safe and secure manner. The unsafe use of radioactive sources can have a harmful effect on people and the environment and therefore a national regulatory infrastructure is necessary to establish the rules and guidelines for users of radioactive sources and, to ensure that the rules are implemented throughout the entire life of sources, i.e. from cradle to grave. Moreover, once radioactive sources have reached the end of their life cycle, they must be carefully managed and disposed of, so that they do not end up in the environment or come into contact with people in an unsafe way. For this reason, ICENS through the Government of Jamaica collaborated with the IAEA on a project to support the creation of infrastructure and human capacities for regulatory bodies in our

Region. From April 4th to April 8th, 2016 ICENS convened the first coordination meeting of the IAEA Regional Project “Strengthening Cradle to Grave Control of Radioactive Sources. The meeting was opened by his Excellency Yukiya Amano, the Director General of the IAEA and the permanent secretary of the Ministry of Science, Energy and Technology Ms Hilary Alexander. The meeting was attended by participants from Antigua and Barbuda, The Bahamas, Barbados, Cuba, Dominica, Honduras, Trinidad and Tobago, the United States and Venezuela and representatives of the IAEA as well as the Jamaican regulatory body.

Decommissioning of the UWI Chemistry Neutron Generator facility

As a direct result of the regional “Cradle to Grave” project on the final disposition of sealed radioactive sources the disused 7 Ci ²⁴¹Am-Be Neutron Generator in the Chemistry Department, was scheduled for removal by ICENS. With the assistance of the “Off-Site Source Recovery Project under the US DOE, National Nuclear Security Administration office of Global Material Security, Radiological Security” the facility was decommissioned on the 24th of August 2015. The source was packaged for export and has been shipped to the United States of America. This project was completed at no cost to the University or to the Government of Jamaica.

Developing a Capacity Building Programme to Ensure Sustainable Operation of Nuclear Research Reactors through Personnel Training

In Latin America and the Caribbean only six countries have Nuclear Research Reactors (NRR), these countries are: Argentina, Brazil, Chile, Jamaica, Mexico and Peru. Most of these NRR’s were commissioned during 1980’s, experience in specialized areas such as: Neutronic and Thermal-hydraulic calculations, operation, maintenance and management has been accumulated in a few senior staff members. These personnel are on average 55 years old, with many of them to retire in the next 10 years. In the region, with the exception of Argentina, there are not many technical or professional training/educational resources to specialize in

NRR operation, maintenance and management. This situation presents a challenge to the future operation of the regional NRR. As the training of nuclear professionals and technicians for reactors takes several years, building new human resources to preserve the nuclear knowledge amassed over the last 30 years is a high priority. This project seeks to transfer knowledge through theory and practical training to increase the number and quality of trained professionals and technicians in the operation and maintenance of Nuclear Research Reactors to ensure the sustainable operation of these for the regional supply of radioisotopes for diagnostic and medical therapy, industry and demand of technological services. This will be achieved through the joint development of online standardised e-learning modules that can be shared with all NRR's in the region.

Nuclear Technology

The long awaited “Nuclear Safety and Radiation Protection Act, 2015” came into effect on August 10, 2015. The Hazardous Substance Regulatory Authority (HSRA) was subsequently established with independence and authority to effectively perform the required functions pursuant to the Act, aimed at protecting human health and the environment while harnessing the benefits of nuclear technology. Although the Act explicitly prohibits the building of a nuclear power plant at this time (due largely to the present lack of human capacity to regulate the industry), it is the first all important step to open the debate on nuclear energy. ICENS’ knowledge of nuclear energy will therefore continue to be relevant to analysis of the Jamaican energy situation. Additionally, there has also been speculation on the installation of a 1000 Mw (electrical) plant at ALPART, which is well within the realm of current nuclear technology. Their use in Jamaica therefore deserves closer examination. In this connection ICENS takes part in local and regional IAEA initiatives to support the rational considerations of nuclear energy in the region.

IAEA Coordinated Research Project (CRP-T33001)

ICENS received funding from the IAEA in the sum of €4,000 in the first year for the submitted research proposal titled “Development of a spent

fuel management plan for the Jamaican SLOWPOKE-2 Research Reactor LEU fuel” under the IAEA’s “Options and Technologies for Managing the Back End of the Research Reactor Nuclear Fuel Cycle” Coordinated Research Project (CRP-T33001). The project report at the end of the first year was reviewed by the IAEA; the project has been extended and funded for an additional year.

ICENS Air Quality Programme

The purpose of the proposed programme is to set up an Air Quality Programme aimed at strengthening collaboration between the centre and the Ministry of Water, Land, Environment & Climate Change; improvement of the research and services profile of the centre, and community engagement.

Open system architecture for Neutron Activation Analysis (OpenNAA)

This is the second year of an ICENS 4 year coordinated research programme (CRP) with the IAEA to develop a modern architectural framework specification (OpenNAA), and reference implementation for Neutron Activation Analysis (NAA). The research aims to develop a modern open system architecture for NAA, that provides the required set of functionalities, and specifies a mechanism for the various hardware/software and software/software interactions among: data acquisition systems; specialised hardware such as sample changers and sample loaders; data analysis modules that perform peak search, area determination and identification; nuclide library management; peak energy and shape calibration; efficiency calibration; quantification; data I/O for storage and retrieval; and QA/QC functions.

Data Sharing

ICENS continued to add value to primary field and laboratory data by transforming them into information and knowledge products suitable for providing decision makers with GIS-based spatial visualizations and predictions based on terrain models to inform realistic options for

shaping national strategies and actions. Jamaican institutions can share georeferenced digital data and information online through the ICENS EShare system.

SPECIAL PROJECTS

Based on the findings in previous crop studies, ICENS in collaboration with the Ministry of Agriculture and Fisheries has sought to examine the elemental content of newly introduced crops to determine the heavy metal loading and their possible impacts on human and animal health.

Sorghum

Samples of food-grade white Sorghum bicolor samples were collected in batches and analyzed for major and trace elements to determine the levels of beneficial elements as well as potentially toxic elements in the locally grown variety and to determine the impact of the proposed substitution to the quality of the animal feed. This project was funded by Caribbean Broilers, Ministry of Agriculture and Fisheries.

Cassava

Samples of cassava grown at the Ministry of Agriculture and Fisheries' Bodles Research Station in Old Harbour were collected. These samples comprised of fourteen (14) varieties of cassava. The cassava samples were analysed for two related reasons. The first was to determine the levels of trace elements in all samples and to see if there were discernible differences related to the varieties and secondly to determine the cyanide content.

Elemental profile of Jamaican and international coffees

Twenty-four samples of coffee were analysed with a total of 384 elemental determinations made. The project was based on the concept that using the analytical techniques available at ICENS, including instrumental neutron activation analysis, flame and graphite furnace atomic absorption spectrophotometry and inductively coupled plasma optical emission

spectroscopy among others, one might be able to determine not only the growing origins of local vs internationally grown coffee samples but that one could potentially separate the intra-island growing regions, i.e., the Blue Mountain growing regions could be separated from other areas of coffee cultivation within the island.

Trace elements in Marijuana

In collaboration with the Department of Basic Medical Sciences' Masters of Science Degree in Forensics, ICENS has analysed several sub-species of marijuana samples and associated soils in three cohorts of the programme.

The Cayman Arsenic Investigation

The Government of the Cayman Islands sought the assistance of ICENS and PAHO relating to an arsenic issue in a particular community. A number of residents had been thought to have been exposed to arsenic arising from use of an adjoining property as a processing site for debris post Hurricane Ivan. ICENS was requested to perform a number of toxicological tests on a number of individuals in the neighbouring communities and on soil and food in the area. Bulk soil samples representing different landscape architecture were collected across Grand Cayman for arsenic analysis. In order to assess the possible transfer of arsenic through the food chain, paired plant-soil samples were collected from the debris storage site and adjacent properties. Fingernail and toenail clippings were collected from members (adults and children) of the households proximal to the debris storage site. Analysis of the samples confirmed elevated levels of arsenic in localised areas, the population closest to these areas also had discernibly higher body burdens of arsenic but at subclinical concentrations.

The collaboration between ICENS, the Cayman Island authorities and PAHO to provide a science based solution to a potential environmental issue was another opportunity to illustrate the direct positive impact science and technology could have on not only national but regional problems.

ICENS WORKSHOPS

1. The following Government bodies were trained in Safe and Secure Transport of Nuclear Materials: Jamaica Constabulary Force; Jamaica Customs Agency; Jamaica Defence Force; Ministry of National Security.
2. The following Government bodies were trained in Emergency Response for Radiological Material Transportation: Jamaica Fire Brigade; Office of Disaster Preparedness and Emergency Management; Ministry of Health; Kingston & St Andrew Corporation.
3. The following Government bodies were trained in Emergency Preparedness for Radiological accidents: Ministry of Health Jamaica; Jamaica Fire Brigade; Office of Disaster Preparedness and Emergency Management.

WORKSHOPS AND TRAINING COURSES ATTENDED

- As part of the management team for the project, Mr Charles Grant attended the First Coordination Meeting of the Project RLA/1/012 "Developing a Capacity Building Programme to Ensure Sustainable Operation of Nuclear Research Reactors through Personnel Training" in Lima, Peru from 8 to 11 March 2016.
- Mr. Haile Dennis attended Technical Meeting on Conversion of Miniature Neutron Source Reactors, December 14–15, 2015 – Vienna, Austria.
- Dr Adrian Spence made a presentation entitled 'Enhancing agricultural productivity and climate change mitigation and adaptation using combined geochemical approaches' at the IICA Regional Workshop and Training Course: Management of degraded soils using organic matter, Knutsford Court Hotel, June 13–16, 2016.
- Mr. Johann Antoine, Ms. Tracey-Ann Warner and Mr. Haile Dennis attended the First Coordination Meeting of the Project RLA/9/081 "Strengthening Cradle to Grave Control of Radioactive Sources" held at the Knutsford Court Hotel from April 4th to 8th, 2016.

- Mr. Johann Antoine attended the “Workshop on establishing and implementing a Periodic Safety Review Process for Research Reactors” held at the Vienna International Centre, Vienna Austria, from April 18th to 22nd, 2016.
- Mr. Johann Antoine attended the “Workshop on establishing and implementing a Periodic Safety Review Process for Research Reactors” held at the Vienna International Centre, Vienna Austria, from April 18th to 22nd, 2016.
- Mr. Richard Hanson attended Thermo Luminescent Dosimeter (TLD) Training, Rotunda Scientific, San Diego, California (Aug/Sept 2015).

S&T POLICY RECOMMENDATIONS

While ICENS is not a policy-making body, it continued to provide scientific/technical assistance and advice to a number of National and Regional Standard Committees, Boards and local Ministries:

- Ms. Tracey Warner attended the Meeting for the Establishment of a Framework for the Certification of Organic Product convened by the Bureau of Standards Jamaica (BSJ) and the follow up on 11th February 2015 and 24th November 2015 respectively.
- Ms. Tracey Warner and Ms. Leslie Hoo Fung attended Meeting/consultation convened by the Ministry of Industry Investment and Commerce (MIIC) to discuss the Draft National Quality Policy 2015 (November 11, 2015)
- As the Jamaican Board member to ARCAL (Acuerdo Regional de Cooperación para la Promoción de la Ciencia y la Tecnología Nucleares en América Latina y el Caribe), Mr Charles Grant attended the 17th regular meeting of the ARCAL Technical Coordination (OCTA) for the selection of project proposals for the 2018–2019 cycle in the region, in Vienna, Austria from 25 to 29 April 2016.
- Mr. Charles Grant and Mr. John Preston have been participating in meetings to prepare the drafting instructions for the Nuclear Safety and Radiation Protection (Authorization) Regulations.

- Spence A. American Chemical Society (ACS) National Meeting and Exposition, Boston, MA, USA, August 16–20, 2015 – Attended meeting as the 2015/2016 Faculty Advisor and Chemistry Ambassador for the International Student Chapter of the ACS at UWI, Mona.

OUTREACH

- May 15, 2015 – career day demonstration at Kids on Campus Care and Learning Centre.
- May 22, 2015 – career day demonstration at Wonder World Early Childhood Institution.
- August 14, 2015 – Host Port Royal Marine Laboratory (UWI) summer campers.
- November 2, 2015 – Host UTECH students.
- November 17 & 27, 2015 – Host Occupational Safety and Health (BSc) students (UWI)
- 2015 Cohort of the Environmental Chemistry CHEM2601 for a tour of ICENS Facilities (November 4th, 2015).
- 2015 Cohort of the Chemistry Graduate Programme OESH 3200 for a tour of the ICENS Facilities and hazard analysis (November 17th, 2015).
- Visit by 2015 cohort of University of Technology applied Geostatistics course students (November 2nd, 2015).
- Department of Geography and Geology students tour of the reactor (November 9th, 2015).

VISITORS TO ICENS

On April 4th, 2016 the Director General of the IAEA, His Excellency Mr. Yukiya Amano, paid a visit to the University of the West Indies, Mona Campus. One of his stops during this visit was to ICENS. While there Mr. Amano met with the Director General of ICENS, Mr. Charles Grant and members of the ICENS staff. Mr. Amano was given a tour of

the Centre including the JM-1 SLOWPOKE-2 reactor, the nuclear analytical laboratory and the spectroscopy laboratory. The parties discussed the plans for upgrading the reactor facility following the core conversion under the national IAEA project and the geochemical and food research conducted at ICENS. Mr. Amano's visit to ICENS was also highlighted in Jamaica Gleaner's article, "Nuclear gets Positive Energy – Government and Opposition agree as International Agency Offers Help Whenever the Country is Ready" published on April 10th, 2016.

Other notable visitors included, Mr. Conleth Brady (Director General's Office for Coordination, IAEA), Ambassador Daven Joseph (Antigua & Barbuda), Ms. Tyesha Turner (Ministry of Foreign Affairs, Government of Jamaica), Mr. Monot Bernard (AREVA, the French Nuclear and Renewable Power Company), Mr Hilaire Lionel Mansoux (Department of Nuclear Safety and Security, IAEA), Ms. Megan Lee Lobaugh (Department of Technical Cooperation, IAEA), Mr. Juan Carlos Benitez Navarro (Department of Nuclear Energy, IAEA), Mr. Thomas Agee (US Department of Energy), Ms. Shawn Smith (U.S. Nuclear Regulatory Commission), Ms. Jennifer Holzman (U.S. Nuclear Regulatory Commission) and Mr. Mario Rodriguez (U.S. Nuclear Regulatory Commission).

Collaborations:

US Department of Energy; International Atomic energy Agency; University of Chicago, Argonne National Laboratories; Ecolé Polytechnic de Montreal, Canada; Third World Academy of Sciences; Food and Agriculture Organization of the United Nations; Bureau of Standards Jamaica; University of Surrey, UK; Polytechnic of Namibia; British Geological Survey, UK; Institute of Earth Sciences, Taiwan; Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, China; University of Utah; Dublin City University, Dublin, Ireland; Ministry of Agriculture; COMSATS.

PAPERS PRESENTED

- Grant. CN. Progress on Conversion of the Jamaica SLOWPOKE Research Reactor to Operation with LEU Fuel. 36th INTERNATIONAL MEETING ON REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS, October 11–14, 2015, Seoul, Korea. (Invited paper)
- Grant. CN. “Lessons Learned on Strategic Planning for Enhanced Utilization of Low Power Research Reactors” at the International Conference on Research Reactors: Safe Management and Effective Utilization, Vienna Austria 16–20 November 2015. (Invited paper)
- C. Koclas, A. Muftuoglu, A. Teyssedou, C. Chilian and C. Grant. Design, Fabrication and Calibration of the Slowpoke-2 LEU Commissioning Rod Assembly. RRFM European Research Reactor Conference. March 13–17, 2016. Berlin, Germany.
- John Preston, Haile Dennis and Ronmccrea Cushnie. A Facility Infrastructure Management system for the JM-1 SLOWPOKE Research Reactor. RRFM European Research Reactor Conference. March 13–17, 2016. Berlin, Germany.
- Francesc Puig, Haile Dennis. Comparison of Measured and Calculated Neutronic and Thermal Hydraulic Reactor Parameters of the LEU-fuelled Jamaican SLOWPOKE-2 Research Reactor. RRFM European Research Reactor Conference. March 13–17, 2016. Berlin, Germany.
- Grant. CN, Dennis. H.T., Preston. JA. Conversion of the Jamaican SLOWPOKE-2 Research Reactor from HEU to LEU: Sharing our Experiences. Canadian Nuclear Society (CNS) Annual Conference, Toronto, June 19–22, 2016. (invited paper)

Conference Posters

- Johann Antoine, Leslie Hoo Fung and Charles Grant “The Dietary Intake of Minerals and Trace Elements from Jamaican and other Soluble Coffees using Instrumental Neutron Activation Analysis and associated techniques” at the Joint NAMLS 11/ MTAA 14

conference. Technical University of Delft in The Netherlands from August 23rd to August 28th, 2015 (Awarded best poster presentation)

- Johann Antoine, Charles Grant, Shonique Ebanks and Robin Rattray, “Sourcing the provenance of Jamaican Cannabis from four locations by elemental profiling using Instrumental Neutron Activation Analysis” at the Joint NAMLS 11/ MTAA 14 conference. Technical University of Delft in The Netherlands from August 23rd to August 28th, 2015.
- Ms. Tracey Ann Warner, “Documentation Experiences for the Jamaican Slowpoke-2 Research Reactor Conversion from HEU to LEU” at the 23rd WIN Global Annual Conference: Women in Nuclear Meet Atoms for Peace.
- Spence, A. Clay mineral protects microbial-derived organic matter as macromolecular structures under the harshest possible environmental conditions. Poster presentation, 26th Goldschmidt Conference, Yokohama, Japan, June 26–July 1, 2016.
- Spence, A. American Chemical Society (ACS) National Meeting and Exposition, Boston, MA, USA, August 16–20, 2015 – Attended meeting as the 2015/2016 Advisor for the International Student Chapter of the ACS at UWI, Mona. A grant of US\$6000.00 was awarded by the ACS to cover travel expenses to the meeting for the advisor and two new ACS student members.
- Antoine JMR., Hoo Fung LA., Grant C.N. The Dietary Intake of Minerals and Trace Elements from Jamaican and other Soluble Coffees using Instrumental Neutron Activation Analysis and associated techniques. 11th International Conference on Nuclear Analytical Methods in the Life Sciences, Delft University of Technology, the Netherlands, August 23–28, 2015.
- Hoo Fung, L.A., Rattray, V.R., Lalor G.C. Assessment of cadmium, mercury and lead concentrations in Jamaican conch, lobster, and tilapia. *Jamaican Journal of Science and Technology*.

PUBLICATIONS

The reallocation of staff to the SLOWPOKE-II Core Conversion ultimately affected the publication rate; however, ICENS still maintain a strong presence at international conferences.

Refereed Journal Articles

- Onjefu A, Kgabi NA, Taole SH, Mtambo OPL, Grant CN, Antoine JMR. (2016), Occupancy Factor Model for Exposure to Natural Radionuclides along the Coastline of Erongo Region, Namibia. *Journal of Geoscience and Environment Protection*. DOI: 10.4236/gep.2016.45012
- Puig F, Dennis HT. (2016). Neutron fluence effects on SLOWPOKE-2 beryllium reflector composition and reactivity. *Nuclear Engineering and Design*, 305: 451–460.
- Antoine JMR, Hoo Fung LA, Grant CN (2015), Geographic Determination of the growing origins of Jamaican and international coffee using instrumental neutron activation analysis and other methods. *Journal of Radioanalytical and Nuclear Chemistry*, 309 (2): 525–534.
- Antoine, J.M.R., Hoo Fung, L.A., Grant, C.N. (2015), Dietary intake of trace and heavy metals from consumption of instant coffees on the Jamaican market. *Jamaican Journal of Science and Technology*
- Spence, A., Rose, D., Clarke, J. Enhancing sustainable agriculture and climate change mitigation and adaptation through the use of plant growth-promoting rhizobacteria. In review at *Sustainable Production and Consumption*.
- Spence A., Kelleher BP. Photo-degradation of major soil microbial biomolecules is comparable to biodegradation: insights from infrared an diffusion editing NMR spectroscopies. *Journal of Molecular*.

Book Chapter

- Adrian Spence. Chapter 7: Carbon Sequestration in Soils. *Energy Science and Technology* (Multi-Volume Set). Executive Editor of the Series: J.N. Govil. Studium Press LLC, U.S.A

INCOME GENERATION

During the period August 1, 2015 to July 31st, 2016, income generated from Radiological and analytical services, amounted to approximately Seven Million Jamaican Dollars (J\$7,000,000.00) and Sixty-two thousand USA Dollars (US\$62,000.00).

PUBLIC SERVICE

Mr Johann Antoine

- Chairman of the National Mirror Committee on ISO Standard TC 93, technical committee on starch (bi-products and derivatives)
- Member, Codex committee on Methods of Analysis and Sampling

Mr Charles Grant

- Member of National Bioethics Committee
- ARCAL National Coordinator (Jamaica) and member of the ARCAL Technical Coordination Board (OCTA which oversees all ARCAL Projects.
- Member, Ministry of Energy Committee on Nuclear Energy as an option for Jamaica
- Member, NEPA/UNDP Committee for renewable wave energy technologies for the generation of electric power in small coastal Communities in Jamaica
- National Coordinator for Incident Reporting system for Research Reactors
- National Coordinator, IAEA Radiation Safety Information Management System).

Ms Leslie Hoo Fung

- Chairperson, National Food Standards Committee (ISO TC34 Mirror Committee), Jamaica Bureau of Standards
- Member, Royal Society of Chemistry, London
- Member, Codex Committee on Methods of Analysis and Sampling.
- ISO/IEC 17025 Assessor, Jamaica National Agency for Accreditation.

Ms Sandra Hunter

- Fellow of Institute of Chartered Accountants of Jamaica

Mr. John Preston

- Member, Land Information Council of Jamaica;
- Independent Member, GOJ Telecommunications Appeals Tribunal.

Dr Adrian Spence

- Associate Member, Royal Society of Chemistry
- Member, American Chemical Society
- Member, American society of Mass Spectroscopy
- Member, United Way Jamaica
- Director, Archer Daniels Midland Jamaica Flour Mills Foundation

Ms Tracey-Ann Warner

- ISO/IEC 17025 Assessor, Jamaica National Agency for Accreditation.