

INTERNATIONAL CENTRE FOR ENVIRONMENTAL AND NUCLEAR SCIENCES (ICENS)



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The 2014–2015 academic year was a pivotal year for ICENS, after 31 years of operation of the SLOWPOKE-II research reactor the US Department of Energy agreed to convert the core reactor from Highly Enriched Uranium (HEU) to Low enriched Uranium (LEU). The 17th of July, 2015 marked the last day of operation of the SLOWPOKE-II reactor with HEU fuel. The new fuel will arrive in Jamaica in September, with installation to be completed by mid-October. 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 removal is also in line with the growing international consensus to eliminate civil uses of HEU. The project will be fully funded by the US Government at cost of over 6 million US dollars.

WORK OF THE DEPARTMENT

Although fifty percent of the scientific staff were seconded to the core conversion project our primary scientific programmes continued to operate.

Using geochemical data for two main purposes: 1) to trace environmental transfer of trace elements from soils to people; and 2) to explore for minerals.

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.

Two key items of ICENS laboratory equipment, the outdated graphite furnace-atomic absorption spectroscopy and flame atomic absorption spectroscopy (GF-AAS), were replaced and commissioned. The new thermoluminescence dosimetry (TLD) system donated by the IAEA was commissioned, a new and improved database for the dose reporting and archiving is being developed in-house. Continued GOJ budgetary shortfalls made it impossible to replace utility items such as field vehicles and ICENS continued to look for other sources of funding. At the invitation of the IAEA however ICENS submitted a request for a long overdue upgrade of its chemical and mineralogical laboratory equipment which will be implemented in step with the conversion of the Slowpoke research reactor core. With these upgrades and the support of the IAEA the Centre can now become a first class analytical laboratory hub able to more effectively support the work of national and regional research programmes.

Trace element speciation in soils

Geochemical research continues to focus on the speciation of trace elements such as cadmium 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 were studied.

Geochemical analysis of foodstuffs: a Jamaican national database on the chemistry of foodstuffs

As part of ICENS' continued efforts to provide support to Jamaica's agricultural sector and to help secure the nation's food safety and security, ninety-four (94) 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. Additionally three (3) composite samples were collected. The aim of this sampling is to use the analytical techniques available at ICENS to analyse the cassava samples for their content of beneficial elements and potential toxic elements as well. This may also lead to a determination as to what varieties potentially accumulate elements and whether this is significant enough to differentiate these varieties. Furthermore, the recent acquisition of an Ion Chromatography (IC) system should give ICENS the capability to measure the cyanide content of the cassava samples which will add another parameter to the investigation of varietal differences and the suitability of such varieties for various uses, such as pharmaceutical applications, the brewing industry and other non-traditional food applications.

ICENS continued to search for new ways to grow export-quality yams 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 and presently contains results of an estimated 1,100 analyses for up to 35 inorganic elements. It will eventually be made available for online reference by researchers through the ICENS web site.

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.

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 two cohorts of the programme. In the first investigation instrumental neutron activation analysis (INAA) was used to analyse both prepared leaf samples and the soils there were grown in and to use the trace element content of both to determine the provenance of the marijuana samples. As a proof of concept this proved to be successful and resulted in the completion of a thesis as a requirement of the degree. The second investigation involved the whole plant analysis of marijuana samples. Plants were separated into leaf, stem and bud compartments and analyzed to determine if particular trace elements accumulated preferentially in the varying plant tissue. This work also contributed to the successfully completion of the required M.Sc. thesis. This work has led to ICENS being invited to be a part of the quality testing infrastructure for the regulatory framework for medical marijuana

chaired and housed by the Bureau of Standards Jamaica. ICENS will be involved in the testing of soils for marijuana cultivation, particularly for heavy metals.

DATA SHARING

Data sharing has been a priority activity of ICENS since 1984 because ready access to existing information held by most Jamaican S&T institutions continues to be hard to achieve. Acquiring samples and data is expensive and the Centre can provide the continuous and objective curation that is critical for sustaining the integrity of the important national endowment of data and information resources. The advanced indexing of the ICENS EShare data repository system allows the retrieval, re-examination and re-interpretation of georeferenced samples and data collected over 30 years ago, so that they can be analysed using new techniques if necessary in-house or by other research laboratories.

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 : users include:

- Office of the Prime Minister (Environmental Management Division);
- Ministry of Agriculture (Rural Physical Planning Division (RPPD));
- University of the West Indies (Faculty of Pure and Applied Sciences and Department of Geography and Geology).

ICENS revised and restructured its web site during the year and started construction of an online viewer system for displaying selected island-wide geochemical maps for use by any enquirer.

NUCLEAR POWER

The long awaited Nuclear Safety and Radiation Act passed through both

houses of Parliament in July 2015. Although the Act explicitly prohibits the building of nuclear power plant at this time (due largely to the present lack 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. Nuclear power is a huge global industry supplying 16% of world electricity demand, with some countries (e.g. France) obtaining 80% of their power from low-enrichment (7% ^{235}U) nuclear sources. While shale oil derived from fracking is becoming competitive in countries such as the United States, it is not available in Jamaica and nuclear power continues to compete with coal in price. The price gap in favour for nuclear power is likely to increase over time with regulatory pressures to reduce emissions of carbon dioxide.

Nuclear power has less environmental impact than fossil fuels and, although 'up front' plant and fuel costs are high, users gain long term benefit from uranium fuel that provides decades of use with no risk of short-term fluctuations in market price. As a fuel uranium is also 100,000 times more powerful than oil: 1 kg of uranium produces 400 000 kWh while 1 kg of oil produces only 4 kWh. Until recently the size and costs of nuclear power reactors made nuclear energy impractical for smaller countries but a new generation of safe, small, high efficiency reactors (10-125 MWe) that can be factory manufactured as transportable modules exists as prototypes and could be available within ten years. Their use in Jamaica 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.

DESK STUDIES/REVIEWS

ICENS continued to progress the documentation contract work required by the US DOE to comply with conditions for the reactor core conversion. It also drafted a country specific Integrated Nuclear Security Support Plan (INSSP) for use by the new Jamaican radiation safety oversight committee within the Bureau of Standards Jamaica (BSJ) as an integral part of discussions between the IAEA Office of Nuclear Security and

stakeholders of the Radiation Safety Authority newly projected for Jamaica.

Documents produced to date include:

- Core Conversion Safety Analysis Report
- Safety Analysis Report for the SLOWPOKE-II with LEU fuel
- HEU defueling manual
- LEU commissioning manual
- Thermal Hydraulics and Neutronics for HEU and LEU fuel
- Radioactive material packing and shipping documentation
- Licensing plan
- Quality assurance plan
- Commissioning report
- LEU fuel information docket
- Modifications to operating license
- Training Plan
- Radiation protection plan
- Emergency response plan
- Security plan
- Environmental Impact Assessment

NEW PROJECTS

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

The Great Caribbean region is characterized by a significant maritime trade using the sea as a highway to facilitate the movement of persons and goods among seaside countries within the region. Associated with this traffic, occurrences have been reported at borders and inland of non-regulated trade accidentally involving radioactive sources or contaminated materials which need to be properly addressed upon positive detection. For years, the IAEA has been working on strengthening the control over

radioactive sources to avoid these occurrences and to protect the public and the environment from the hazards of ionizing radiation, as well as to prevent sources from becoming orphan. Against this background, a “cradle to grave” control of radioactive sources is essential, as promoted by the Code of Conduct on the Safety and Security of Radioactive Sources. This “Cradle-to-Grave” approach includes national policies and strategies, an adequate legal and regulatory framework, as well as adequate resources and infrastructures to ensure safe and secure management of radioactive sources. This project aims to contribute to establish and/or improve a sustainable, safe, adequate and permanent “cradle-to-grave” control of radioactive sources following a harmonized approach consistent with the IAEA Basic Safety Standards (BSS) and other international best practices. This project is scheduled to start running in 2016 with a four-year lifetime and would focus on countries within the Great Caribbean.

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 the next 30 to 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 is expected to commence in 2016 and last for four years.

Carbon biogeochemistry (carbon emissions and sequestration)

Dr Adrian Spence received a Mona Research Fellowship Grant Biogeochemical investigations of the response of regional terrestrial carbon inventories to global climate change – US\$46,000.00. A bench-top environmental carbon dioxide incubation chamber which will be used to carry out experiments under elevated CO₂ (13CO₂) atmosphere as a prerequisite to determining the fate of increasing atmospheric CO₂ concentrations. The environmental chamber will also provide us with the means to investigate the effects of global warming on the bioavailability and toxicity of risk elements soils. In addition, a density gradient gel electrophoresis (DGGE) system to assess the population dynamics of microbes (in particular the non-culturable fraction) in tropical soils in response to warming was also purchased. This is of special significance as the cycling of carbon in the environment cannot be understood without a molecular-level understanding of soil microbial biomass.

IAEA Coordinated Research Project (CRP-T33001)

ICENS received funding from the IAEA in the sum of 4,000 Euros 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 will be reviewed by the IAEA to determine if the contract will be renewed for another year, if requested.

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 research and services profile of the centre, and community engagement.

The developmental objectives for the proposed Programme include:

- To conduct AQ Monitoring and Source Apportionment Services
- Providing AQ Analytical Services to the Island and the Region
- To conduct Commissioned/Contract Research
- Training of Role Players; and
- Awareness and Capacity Building for local Communities.

Open system architecture for Neutron Activation Analysis (OpenNAA)

ICENS began a 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.

OpenNAA will maximise interoperability among hardware and software within the NAA application space, safeguarding these investments, and ensuring that all system components either purchased commercially or developed in-house will work together ‘out of the box’, at minimal cost.

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

- Spence A. Carbon sequestration in soils. In *Energy Science and Technology*; Chandra Sharma, U., Prasad, R., Shivakumar, S., Govil, J.N., Eds.; Studium Press LLC, USA, 2015; 1, pp 177–198.
- Nnenedi Kgabi, Charles Grant, Johann Antoine. Effects of Energy Production and Consumption on Air Pollution and Global Warming, *Journal of Power and Energy Engineering*, 2014, 2, 25–30, <http://dx.doi.org/10.4236/jpee.2014.28003>

Book Chapter

- Publication of the *Handbook of Mineral Elements in Food*. Edited by Miguel de la Guardia, Salvador Garrigues. Chapter 21: Vegetables and Fruits. **Leslie A. Hoo Fung, Johann M.R. Antoine, Charles N. Grant & Gerald C. Lalor.**

PAPERS PRESENTED

- **Warner, T.** An Integrated Management System (IMS) for JM-1 Slowpoke-2 Research Reactor in Jamaica: Experiences in Documentation. Conference Proceedings (Paper & Presentation) Canadian Nuclear Society 3rd International Technical Meeting on Small Reactors, Ottawa Canada November 5–7, 2014.
- **Dennis. H.T., Puig, F.** Neutronic analysis of the Jamaican SLOWPOKE-2 research reactor for the conversion from HEU to LEU fuel. Joint IGORR 2014/IAEA Technical Meeting on Enhanced Utilization of Zero Power Reactors and Subcritical Assemblies, Bariloche, Argentina, November 17–21, 2014.
- **Dennis. H.T., Puig, F.** Analysis of the Jamaican SLOWPOKE-2 research reactor for the conversion from HEU to LEU fuel. 35th International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, October 12–15, 2014.

- **Boyd C.O., Grant, C.N.** The International Centre for Environmental and Nuclear Sciences (ICENS) as a TSO in Enhancing Nuclear Safety and Security in Jamaica. International Conference on Challenges Faced By Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security: Strengthening Cooperation and Improving Capabilities. Beijing China, October 27–31, 2014.
- **Antoine, J.M.R., Hoo Fung, L.A., Grant, C.N.** Geographic Determination of the Growing Origins of Jamaican and International Coffee using Multi-Element Analysis. International Symposium on Food Safety and Quality: Applications of Nuclear and Related Techniques, Vienna, Austria November 10–13, 2014.
- **Rose, D., Clarke, J., Spence, A.** Plant Bacterization: An Option for Climate-Smart Agriculture Co-benefiting Food Security and Climate Change Mitigation and Adaptation. ACIDI/VOCA JaREEACH Climate Smart Agriculture Symposium – Positioning Jamaica's Agricultural Sector for Climate Change Resilience, Knutsford Court Hotel, July 16, 2015.
- **Hoo Fung LA., Rattray R., Lalor GC.** Assessment of cadmium, mercury and lead concentrations in Jamaican conch, lobster, and tilapia. 10th Faculty of Science and Technology Conference, UWI, Mona, June 9–11, 2015.
- **Hoo Fung LA., Rattray R., Lalor GC.** Contribution of some herbal (bush) teas to dietary cadmium exposure in Jamaica. Third International Conference on Cocoa, Coffee and Tea (CoCoTea), University of Aveiro, Portugal, June 22–24, 2015.
- **Antoine JMR., Hoo Fung LA., Grant C.N.** Elemental composition of Jamaican coffees. Third International Conference on Cocoa, Coffee and Tea (CoCoTea), University of Aveiro, Portugal, June 22–24, 2015.

INCOME GENERATION

ICENS received grants in excess of U\$ 500,000 for the 2014/15 from the USDoE to facilitate the core conversion process.

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 ;(RASIMS).

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.