

## INTERNATIONAL CENTRE FOR ENVIRONMENTAL AND NUCLEAR SCIENCES (ICENS)



**Richard Annells, BSc, PhD *St. Andrews*, FIMMM, CEng  
Director General**

**T**here were no staff changes during the year. ICENS continued its science and technology projects in line with the guidelines set out by the ICENS Board of Directors and the Ministry of Science, Technology, Energy and Mining.

### **STRATEGIC PLANNING**

The ICENS Research Reactor Laboratory continues to build on its success in the WEPAL programme reported in UWI Mona News last year. The March 2014 Newsletter of the IAEA Division of Nuclear Fuel Cycle and Waste Technology (Volume 10, Number 1) reported that the strategic plan of the ICENS Reactor Laboratory topped the list of 31 strategic plans for effective utilization of research reactors (RRs) evaluated

in a 2013 review by a group of international experts. The plans were submitted by different laboratory managers around the world.

## **WORK OF THE DEPARTMENT**

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 fate of trace inorganic elements in the biosphere (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.

Work began on correlating the geochemical data obtained from rock and soil samples with the new bedrock geological map of Jamaica in order to interpret the likely underlying controls on anomalies and alteration haloes likely to help detect mineral occurrences associated with Cretaceous volcanic rocks and related intrusions. Copper sulphides and gold occur naturally in the Cretaceous volcanics of the oldest geological units in Jamaica and some copper, gold, lead and zinc in the Palaeogene volcanics and their lateral extensions in the Blue Mountains.

Two key items of ICENS laboratory equipment, the outdated graphite furnace-atomic absorption spectroscope and flame atomic absorption spectroscope (GF-AAS), were replaced after some years of malfunctioning. The IAEA supplied a new liquid nitrogen plant, an important item which supports the day to day gamma spectroscopy work of the NAA laboratory. The new thermoluminescence dosimetry (TLD) system donated by the IAEA was commissioned and staff trained in its use. 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. ICENS has continued to engage the local private sector to assist with the purchase of analytical equipment to realise cost savings from the services provided locally at ICENS. 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 scheduled for 2015. With these upgrades and the support of the IAEA the Centre can now become a first class analytical laboratory hub able to enhance the work of national and regional research programmes.

#### **TRACE ELEMENT SPECIATION IN SOILS**

The anomalous concentrations of cadmium and other potentially toxic metals (typically orders of magnitude above world averages) in soils overlying Miocene age White Limestone Supergroup are of particular concern to human and ecosystem health at the local spatial scale. However, when assessing the bioavailability and risks associated with metal contaminated soils, it's now generally accepted that the chemical speciation (partitioning of an element into different chemical forms) is more important than total content. As a result, a primary focus of recent and future work is to quantify and understand medium- to long-term changes in the bioavailability of a suite of risk elements in soils using a variety of strategies. These include (i) the chemical separation and analysis of the operationally defined metal fractions, (ii) isotope dilution mass spectrometry (IDMS) — considered by some geochemists as the 'gold standard' of defining bioavailability, and (iii) molecular-level studies focusing on metal-mineral and metal-ligand interactions. Critically, we are keen to study the dissolved organic matter (DOM) metal interactions using passive sampling devices as a means of providing a more representative overview of a particular environment. This knowledge may then be used to enhance trace metal remediation strategies which are currently underway. Allied to this, we have applied stable cadmium isotope ratio analysis and other geochemical techniques with the view of determining the provenance of the anomalous cadmium concentrations in local soils. Much of the success of current and future studies are based on strong collaborative support from the British Geological Survey, UK; Chongqing Institute of Green and Intelligent Technologies, China; and the Institute of Earth Sciences, Academia Sinica, Taiwan.

## DESK STUDIES/REVIEWS

### Reactor Safety Analysis

As part of the safety analysis for the upcoming SLOWPOKE core conversion computer modelling of the thermal hydraulics and neutronics was completed for the present Highly Enriched Uranium (HEU) core and the proposed Low Enriched Uranium (LEU) core. Modelling was performed using the Monte Carlo N-Particle Transport Code (MCNP5), in a three-dimensional Cartesian coordinate system, using data from engineering drawings of the reactor components. Calculations were performed on the super computer cluster at the Argonne National Laboratory in the USA. The modelled results confirmed that the new core will have superior safety and performance characteristics.

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

Analytical work during 2013-2014 continued to concentrate on vegetables, fruit, grains and fish; and numerous samples of Jamaican foods such as callaloo, sweet potato, cocoa, ackee and lion fish were analysed for calcium, potassium, magnesium, sodium, phosphorus, aluminium, boron, cadmium, cobalt, chromium, copper, iron, manganese, molybdenum, nickel, lead, strontium, and zinc. 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, security and compliance with relevant international food standards.

The database, which ICENS used to carry out the gap analysis mentioned above, will be structured into sections on root vegetables, leafy vegetables, grains, fruits, meats, seafood and processed or packaged foods and 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 work on the elemental content of human tissues concentrated on 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.

### **Rare earth elements**

ICENS continued to analyse for eleven rare earth elements (REE) in all soil samples collected and began a study of the provenance of the REE present in Jamaican bauxites and other rocks. It also proposed to funding agencies a new project to stimulate a small-scale Jamaican industry for recovering and exporting REE-bearing components separated from end-of-life electronic items such as mobile phones, computers and television sets. It is now widely recognised that such waste items are richer, more accessible and easier to refine than many naturally occurring REE ores: as already proven in Brazil, Mexico and Taiwan, their export could be profitable at SME scale.

### **Data Sharing**

Data sharing has been promoted by ICENS for many years 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 curation that is critical for sustaining the integrity of this important national endowment of data and information resources. The ICENS EShare data repository system was developed with this goal in mind and offers advanced indexing that allows the retrieval, re-examination and re-interpretation of geo-referenced samples and in its store.

### **Nuclear Power**

ICENS knowledge of nuclear energy continued to be relevant to analysis of the Jamaican energy situation. Nuclear power is a huge global industry supplying 15% of world electricity demand, with some countries (e.g. France) obtaining over 75% of their power from nuclear sources. While shale oil and natural gas 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.

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, the so called Small Modular Reactors (SMRs), producing between 10 MW and 300 MW of electricity, are now being seriously investigated. The unfortunate 2011 events in Fukushima however, have once again brought the use of nuclear power into question, almost putting a halt to the “nuclear renaissance”. The incredible energy density of nuclear fission (1 kg of uranium produces 400 000 kWh while 1 kg of oil produces only 4 kWh) and near zero greenhouse gas emissions, however, will continue to make this an option worthy of consideration. In this connection ICENS continues to take part in local and regional IAEA initiatives to support the rational considerations of nuclear energy in the region and will continue to monitor the development of the SMR’s.

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 Authority within the Bureau of Standards Jamaica (BSJ) as an integral part of discussions between the IAEA Office of Nuclear Security and stakeholders of the newly formed regulatory body.

## **PROJECTS**

### **Open system architecture for Neutron Activation Analysis (OpenNAA)**

ICENS continued to contribute to the IAEA coordinated research programme (CRP) on Development of an Integrated Approach to Routine Automation of Neutron Activation Analysis, with the development of OpenNAA, a modern open system architecture for NAA that facilitates the easy combination of data acquisition, sample changers, and data processing sub systems, to produce one tailor made system. To date an architectural framework specification has been developed along with a reference implementation, and standardized protocols for data acquisition, spectrum analysis, uncertainty estimates, and data management.

The development of OpenNAA was presented at the 2nd Research Coordination Meeting of the project which was held at the IAEA headquarters in Vienna, Austria in December 2013. The other members of the CRP from Algeria, Bangladesh, Brazil, Chile, China, Indonesia, Malaysia, Peru, EGYPT, MOROCCO, PERU, Russia, Slovenia, Syria, Australia, Canada, U.S.A., and The Netherlands, endorsed the efforts and a sub-group of institutes from Peru, Australia, Morocco and Jamaica was formed to further the development. This group is headed by John Preston.

### **Mineral exploration**

As part of the new National Minerals Plan planned by the Ministry of Science, Technology, Energy and Mining, ICENS completed compilation of the new geological map of Jamaica in collaboration with Mines and Geology Division, and The UWI Geography and Geology Department . Compilations of separate overlays of metallic and non-metallic mineral

occurrence data were almost complete by the end of the year. Both compilations are designed for online reference by researchers and potential international investors in the country's mineral industry.

### **Import substitution and new materials**

ICENS obtained funding from MSTEM to start the NEWMAT-1 proof of concept project designed to demonstrate the suitability of mixtures of mineral waste materials from quarries, outcrops, red mud deposits and construction sites for durable but low-cost road repairs and service trench fills in Jamaica. By the end of the year visiting expert Professor Peter Claisse (Coventry University, UK) had tested over 60 mixes at laboratory scale combinations, one of which, a mix of bauxite process waste, terra rossa soil, gypsum waste and lime had developed strength sufficient for patching road potholes.

During the year ICENS continued its search for funds to support two other research projects for developing new materials from Jamaican agricultural and industrial wastes in order to substitute imports and create new local job opportunities for Jamaican SMEs and small urban or rural communities. One project aims to develop environmentally friendly materials for packaging and food containers from banana plant waste as a means of substituting polystyrene which harms the Jamaican environment and is produced from expensive petroleum imports. The other project, already mentioned above, plans to devise a methodology to enable local SMEs or community groups to carry out the initial concentration of REE-bearing components from end-of-life electronic waste goods (e-waste) in order to make an exportable 'urban ore' material.

### **Public understanding of science and transfer of technology from ICENS to the wider community**

Jamaica shows little realisation that science can work to solve day to day societal problems, possibly because most of the essential household products, consumer goods or technologies it uses, are imported readymade. ICENS strives to do research that is useful and relevant to the practical



needs and protection of Jamaicans and which also demonstrates the important contribution that science can make to building a safe, sustainable and prosperous future. All countries with successful economies accept that R&D is a key capital investment in their future wealth and wellbeing and many have boosted their investment in R&D in order to power out of the financial recession.

Modest research projects such as those proposed by ICENS are designed to apply science to initiate useful locally-based SME or community scale enterprises in order to create new jobs and income and to substitute imports in order to bring ordinary Jamaicans more benefits in the long run than foreign-funded megaprojects or services. Events such as UWI Research Days could do more to attract potential sponsor groups such as business and political leaders, diplomats, funding agencies, international and local NGOs, investors, or research collaborators from the medical and scientific communities. ICENS already receives many visits each year from sixth form and tertiary students, some of whom will enter the next generation of career scientists. However Jamaica needs to make a realistic road map and needs study in order to define a critical path and resources for future science teaching in schools and the induction of young Jamaicans into careers in chemistry, physics, mathematics and engineering.

#### **Humanitarian Approach to Nuclear Weapons and the Prospects for a Ban**

The International Centre for Environmental and Nuclear Sciences, in collaboration with the International Campaign to Abolish Nuclear Weapons (ICAN) and the International Law and Policy Institute (ILPI), organized and hosted the eighth regional meeting on the “Humanitarian Approach to Nuclear Weapons and the Prospects for a Ban”. A total of 27 individuals from 14 different countries attended the roundtable. 12 of the participants were government officials, from 7 different countries (Costa Rica, Grenada, Jamaica, Mexico, St. Kitts and Nevis, St. Lucia, Trinidad & Tobago), while the rest were a mix of civil society, academics, and the Red Cross / ICRC. All funds for the meeting were provided by the Government of Norway. A full report on the meeting can be found

on the International Law and Policy Institute website (<http://nwp.ilpi.org/?p=2567>).

#### PAPERS PRESENTED

- **C.N. Grant, J. Preston, C. Chilian, G. Kennedy.** SLOWPOKE-II Refuelling – Past Experience and New Challenges. Transaction of RRFM, St. Petersburg, Russia, April 21–25, 2013.
- **R.E. Hanson, C.N. Grant, L. Hoo Fung, R. attray, A. Spence.** Cadmium speciation in Jamaican soils. “Clean energy through Chemistry” – The 44th IUPAC World Chemistry Congress and 47th IUPAC General Assembly. Istanbul, Turkey. August 11–16, 2013.
- **A. Spence, C. Robinson, R.E Hanson.** The effect of microstructural changes on the organic loading capacity of montmorillonite. “Chemistry in motion” – The 246th ACS National Meeting and Exposition. Indianapolis, IN, USA. September 8–12, 2013.

#### PUBLICATIONS

- **Leslie A. Hoo Fung, Johann M.R. Antoine, Charles N. Grant, Dayne St. A. Buddo.** Evaluation of dietary exposure to minerals, trace elements and heavy metals from the muscle tissue of the lionfish *Pterois volitans* (Linnaeus 1758). *Food and Chemical Toxicology* 60 (2013) 205–212.
- **Hoo Fung, L. A., Rattray, V. R., Lalor, G.C.** Cadmium in Jamaican Bush Teas. *West Indian Medical Journal*, 63:1 (2014). DOI: 10.7727/wimj.2012.322
- **A. Spence, R.E. Hanson, T. Johnson, C. Robinson, R.N. Annells.** 2013. (Bio) chemical characteristics of organic matter in a guano concretion of Late Miocene or 1 Pliocene age from Manchester Parish in Jamaica. *Analytical Chemistry Insights* 8, 51–52. .
- **A. Spence, C. Robinson,** 2013. Spectro-chemical analysis of the speciation of cadmium on montmorillonite in the presence of soil microbial biomass. *Procedia Environmental Sciences* 18, 114–126.

- **A Spence, C Robinson, R E Hanson.** The effects of microstructural changes on montmorillonite-microbial interactions. *Journal of Molecular Structure* 1056-1057 (2014) 157–165.
- **A. Spence, R.E. Hanson, C.N. Grant, L. Hoo Fung, R. Rattray.** 2014. Assessment of the bioavailability of cadmium in Jamaican soils. *Environ Monit Assess* DOI 10.1007/s10661-014-3722-9.

## **INCOME GENERATION**

ICENS received a grant of J\$6,845,000 for June-August 2014 from the Ministry of Science, Technology, Energy and Mining to carry out a proof of concept project ‘NEWMAT-1’ to develop mineral wastes into mixtures suitable for durable but low-cost road repairs and service trench fills in Jamaica.

## **PUBLIC SERVICE**

### **Dr Richard Annells**

- Fellow of: The Institute of Materials, Minerals and Mining, London.
- Chartered Engineer: The Engineering Council, London.
- Member, Coordinating Council, COMSATS (Commission on Science and Technology for Sustainable Development in the South).
- Member, Geological Society of Jamaica.

### **Mr Johann Antoine**

- Chairman, 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**

- 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).
- Member, Coordinating Council, COMSATS (Commission on Science and Technology for Sustainable Development in the South).

**Ms Leslie Hoo Fung**

- Chairperson, National Food Standards Committee (ISO TC34 Mirror Committee), Jamaica Bureau of Standards.
- Vice President (Public Relations) of the Laboratories Association of Jamaica
- 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.
- Appointed by PIOJ as National Point Of Contact for the Nuclear Information Management System (NUSIMS) of IAEA.

**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.

**Mrs. Joan Thomas**

- Member, Inner Wheel Club of Kingston.

**Ms Tracey-Ann Warner**

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