

## 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. The International Centre For Environmental and Nuclear Sciences (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.

### **PROFICIENCY TESTING**

The ICENS Neutron Activation Laboratory reached the topmost level of performance, recognised as ‘consolidated state of the practice’ in the latest round of the IAEA-sponsored Wageningen Evaluating Programs for Analytical Laboratories (WEPAL) proficiency testing programme. Neutron Activation Analysis, Energy Dispersive X-Ray Fluorescence and

Total Reflection X-Ray Fluorescence techniques were used in this round of proficiency testing which involved 'blind' analysis of soil and plant samples provided by WEPAL.

#### **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 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.

After making a gap analysis to define priorities for paired sampling of soils and the food crops harvested from them, the island geochemical survey was extended over a more detailed scale 2 x 2 km<sup>2</sup> sampling grid to the parishes of Westmoreland, St Ann and Trelawny. Totals of 91 soil samples and 138 crop samples were collected. The analytical results will be used to measure element abundances as part of the ongoing environmental monitoring of rocks, soils, pastures, agricultural products, foodstuffs and medical samples. Work continued on improving the understanding of cadmium distribution in Jamaican soils and ICENS renewed collaboration with specialist geochemical laboratories in Canada and the UK in order to update interpretations.

The geochemical data obtained from rock and soil samples were also used to trace the spatial distribution of 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. The exact 'anatomy' of the mineralised structures still remains to be mapped in detail in this

terrain of difficult access. Gold may be much less abundant than copper in Jamaica but both metals continue to be in demand worldwide in spite of the recent fall in the gold price to US\$1,200 per ounce.

The unreliability of some items of ICENS laboratory equipment, such as the graphite furnace-atomic absorption spectroscope and flame atomic absorption spectroscope, both of which are now over 17 years old and almost unusable, continued to slow down ICENS operations. Both items need to be replaced as their manufacturers have discontinued the provision of maintenance and spare parts. The liquid nitrogen plant which supports the day to day gamma spectrography work of the NAA laboratory was repaired and recommissioned with grant assistance from the IAEA, which also donated a new thermoluminescence dosimetry system to ICENS to replace the existing old and unreliable instrument. Declining budgetary support from the GOJ made it impossible to replace key utility items such as field vehicles and ICENS continued to look for other sources of funding. Approaches to the local private sector for financial contributions to replace equipment were ignored.

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

Geochemical research focused on the speciation of 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) were studied.

New collaboration began with Japanese and Chinese scientists and a number of soil samples were shipped to them for Cd isotope ratio analysis which is currently not possible in Jamaica.

ICENS developed passive water samplers in-house from basic materials and deployed them in the Rio Cobre in order to make *in situ* determinations of trace metal associations with dissolved organic matter as a means for chemical profiling of the river water.

## **DESK STUDIES/REVIEWS**

Work began on a new review of the impact of cadmium on crops, animals and human systems. Geochemical analysis of foodstuffs: a Jamaican national database on the chemistry of foodstuffs.

Analytical work during 2012–2013 continued to concentrate on vegetables, fruit, grains and fish and ICENS tested numerous samples of Jamaican foods such as callaloo, sweet potato, cocoa and ackee 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.

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 database, which ICENS used to carry out the gap analysis mentioned above, is structured into sections on root vegetables, leafy vegetables, grains, fruits, 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**

The elemental content of human tissues is important for the preservation of good health. As samples of such tissues are scarce and difficult to obtain, ICENS work concentrated on blood, urine and placenta samples. ICENS continued to develop 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) a pilot survey of 100 blood samples was made to determine the concentrations of phosphorus, sulphur, iron, copper, zinc, selenium and rubidium in blood samples collected from blood donors and confirmed the potential value of the programme and the suitability of the chosen analytical methods. The results suggested new lines for research, such as possible zinc deficiencies in some members of the population.

A commonly examined element ratio is the copper/zinc ratio which helps to detect susceptibility to illnesses such as cancers and coronary heart diseases (CHD). In many cancer cases the Cu/Zn ratios are higher than in healthy people while for CHD the Cu/Zn ratios are lower than in healthy people. The implications of such relationships are not well understood but ICENS continued its research in this field because of the potential value of the work.

## **LEAD IN THE HUMAN POPULATION**

ICENS began new collaboration with the UWI Department of Chemistry to find ways to mitigate the toxic effects of lead in the human environment, concentrating on areas in St Andrew and St Catherine. It is important to monitor the distribution of lead in the urban environment because increasing evidence from studies in the USA and Australia indicates that children with untreated lead poisoning may be at risk of developing brain disorders that can cause criminal traits in later life. During 2013 US researchers recommended that even the maximum permissible blood levels for lead in adults should be reduced in the light of new evidence.

## **SOIL CONSERVATION AND CLIMATE CHANGE**

ICENS drew up plans to relaunch the ARCAL Project RLA/5/051 “Using Environmental (Fallout) Radionuclides as Indicators of Land Degradation in Latin American, Caribbean and Antarctic Ecosystems” approved through the International Atomic Energy Agency (IAEA) with new partners from MoAF (RPPD) with the aim of constructing a shared project database and website to allow participants and beneficiaries unrestricted open access to all the information, plus an online decision support system. The project has 14 participant countries in the Caribbean and Latin America.

## **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 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 visualisations 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).

During the year, ICENS became the Jamaican node of the Caribbean Knowledge and Learning Network (CKLN) linked to the C@ribNET broadband backbone which links the Caribbean to the global community of research and education networks (RENS) through Internet 2 in the USA, Géant in Europe and RedCLARA in Latin America.

In February ICENS launched in Kingston the OAS-funded 2008–2013 project ‘Institutional Strengthening for Promoting Best Practices in Science and Technology for the Caribbean States’. The final product was a core platform with a Digital Repository Database System set up on three identical servers in Jamaica (ICENS), Barbados (NCST/Ministry of Health) and Trinidad and Tobago (NIHERST) as the initial phase of a wider Caribbean-wide system for sharing digital information on science and technology.

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**

ICENS knowledge of nuclear energy continues to be relevant in 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 nuclear sources. In 2012 the World Nuclear Organisation reported that a total of 548 new power plants is under construction, on order, planned or proposed worldwide. 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.

During the year ICENS progressed the documentation contract work required by the US DOE to comply with conditions for the reactor core replacement. 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.

## **NEW PROJECTS**

### **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.

### **Mineral exploration**

As part of the new National Minerals Plan planned by the Ministry of Science, Technology, Energy and Mining, ICENS continued collaboration with Mines and Geology Division, UWI Geography and Geology Department and UWI Marine Geology Department to compile a new geological map of Jamaica with a separate overlay of mineral occurrence data. Both compilations were designed for online reference by potential international investors in the country’s mineral industry.

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

With Mines and Geology Division, a search began for natural and industrially generated pozzolans in Jamaica. A pozzolan is a mineral material that contains silica and alumina which when moist reacts with calcium hydroxide to develop cement-like properties. Such materials can

be used in cost effective road construction and repairs, trench filling and other civil engineering applications. ICENS submitted to funding agencies a proof of concept project designed to demonstrate their suitability in Jamaica.

During the year ICENS planned 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, however basic or low-tech they may be, 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, 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.

### PAPERS PRESENTED

- **Johann M.R. Antoine, Leslie A. Hoo Fung, Charles N. Grant** (Poster Presentation) “The contribution of rice to dietary mercury exposure in Jamaica.” ICMGP – The 11th International Conference on Mercury as a Global Pollutant. Edinburgh, Scotland. July 28–August 2, 2013.
- **Hanson, R.E., Grant, C.N., Hoo Fung, L., Rattray, R., Spence, A.** 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.
- **Preston J.A.** “The status of HEU to LEU core conversion activities at the Jamaica SLOWPOKE”. Canadian Nuclear Society and IAEA 2nd Technical Meeting on Small Reactors, Ottawa, Canada. November 7–9, 2012.
- **Adrian Spence, Claion Robinson** (*Oral Presentation*) Spectro-chemical analysis of the speciation of cadmium on montmorillonite in the presence of soil microbial biomass. 2013 International Symposium on Environmental Science and Technology (2013 ISEST)., Dalian Province, China. June 4–7, 2013.
- **Warner, Tracey-Ann.** “Assessing Lead (Pb) Contamination of Urban Soils in Kingston, Jamaica Using a GIS-based Approach. Conference

Proceedings Urban and Regional Information Systems Association (URISA) Caribbean GIS Conference, Montego Bay Jamaica, November 12–16, 2012.

## **PUBLICATIONS**

### **Referreed Journals**

- Grant C.N., H.T. Dennis, J.M.R.Antoine, L.A. Hoo Fung and G.C. Lalor. “Agglomerative hierarchical clustering analysis of twenty-six rice samples analysed by INAA, TXRF, ICP-OES and FAAS” *Journal of Radioanalytical and Nuclear Chemistry*, 2012 DOI: 10.1007/s10967-012-2379-5.
- 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.
- Preston J. “A Software Architectural Framework Specification for Neutron Activation Analysis.” *Journal of Radioanalytical and Nuclear Chemistry* (DOI: 10.1007/s10967-012-2346-1).
- Spence A., 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.
- Spence, A., Robinson, C. 2013. “Spectro-chemical analysis of the speciation of cadmium on montmorillonite in the presence of soil microbial biomass.” *Procedia Environmental Sciences* 18, 114–126.

### **Technical Reports**

- C.N. Grant, J. Preston, C. Chilian, G. Kennedy. “SLOWPOKE-II Refuelling – Past Experience and New Challenges.” Transaction of RRFM, St. Petersburg, Russia 2013.

- Preston J. “The status of HEU to LEU core conversion activities at the Jamaica SLOWPOKE”, Atomic Energy of Canada Limited (AECL) *Nuclear Review*, Vol. 1, No. 2, December 2012, p. 51–55.

## **INCOME GENERATION**

ICENS received a grant of US\$50,000 from the Organisation of American States (OAS) to complete the final Phase 3 of the project ‘Institutional Strengthening for Promoting Best Practices in Science and Technology for the Caribbean States.’

## **PUBLIC SERVICE**

### **Dr Richard Annells**

- Fellow, 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).

**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.

**Mrs 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

**Mrs. Joan Thomas**

- Member, Inner Wheel Club of Kingston.

**Ms Tracey-Ann Warner**

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