

INTERNATIONAL CENTRE FOR ENVIRONMENTAL AND NUCLEAR SCIENCES (ICENS)

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

Dr Richard Annells, previously of the British Geological Survey, took up the post of Director General in September 2011 on the retirement of **Professor Gerald Lalor**. In the same month Dr Adrian Spence, who recently graduated from Dublin City University with a doctorate in environmental and analytical chemistry, took up the position of Head of the Spectrometry Laboratory. Ms Joan Lewis, Financial Officer, left in November to follow a degree in Law and Mr Ryan Evans, Head, Administration and Finance, left in April on appointment to the Ministry of Finance. Ms Sandra Hunter, formerly of the Port Authority, was selected as the new Head, Finance and Administration. ICENS began the planning of new science and technology projects in response to the policy guidelines set out by the Ministry of Energy and Mining (renamed Ministry of Science, Technology, Energy and Mining in January 2012) and the ICENS Board of Directors.



WORK OF THE DEPARTMENT

The double use of geochemical data: 1) as a way to trace transfers of elements from soils to people; and 2) as a method for mineral exploration.

ICENS research continued to focus on the abundances and transfers of inorganic 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.

The geochemical survey was extended to stream sediments in the north of Manchester and Clarendon parishes. The analytical data obtained from the samples will be used to measure element abundances during the environmental monitoring of rocks, soils, pastures, agricultural products, foodstuffs and medical samples. The rock and soil sample data can also be used to map the spatial distribution of geochemical anomalies and alteration haloes to help detect mineral occurrences. Gold, copper, lead and zinc occur naturally in the Cretaceous volcanics of the oldest geological units in Jamaica but the exact ‘anatomy’ of the mineralised structures still remains to be defined in detail. To date gold in Jamaica seems to be much less abundant than copper which continues to be in demand worldwide.

Soil geochemistry

Research in soil geochemistry concentrated on three laboratory experiments related to the speciation of cadmium in Jamaican soils, i.e. its distribution pathways in a particular sample or matrix type. After several weeks of optimization experiments, 40 soil samples (generating 200 different fractions) were analysed by ICP-OES for cadmium and pH and organic matter information were collected for the same suite of 40 samples. Cadmium data for 40 plant samples from the corresponding soils were obtained for comparative analysis and interpretation of results is in progress.

The second experimental project on speciation used ICP-OES to analyse a total of 168 soil samples for cadmium during experiments on the adsorption and desorption kinetics of this element. The third project began an assessment of the adsorption of cadmium to montmorillonite-microbial complexes in soil in five separate experiments to generate a minimum of 15 complexes and controls for further analysis.

Geochemical analysis of foodstuffs

A Jamaican national database on chemistry of foodstuffs

The chemical analysis of Jamaican farmed and processed foodstuffs using ICP-OES and AAS continued with the ultimate aim of compiling a Jamaican national database to provide:

- Food composition tables setting out major and trace element contents to support nutrition and diet prescriptions and regulations as to elemental contents.
- A better understanding of how food plants and animals take up elements from soil and thus influence land use determinations.
- Indications of the effects of elemental interactions on plant uptakes.
- A way to ensure food quality and compliance with relevant international food standards.

The food composition database is now 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.

Analytical work on foodstuffs

Analytical work during 2011-2012 concentrated on vegetables, fruit and grains and fish.

ICENS tested numerous samples of Jamaican foodstuffs 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.

In the context of food safety ICENS carried out cluster analysis of 26 different types of white, parboiled and brown rice commonly sold in Jamaica. The white rice group included a product labelled 'brown rice' which may suggest that some adulteration occurred during processing. Hierarchical clustering proved to be a rapid method for analysing the dataset, correctly clustering rice samples to identify their location, cultivars and the possibly adulterated sample. The analysis shows that for future work the number of quantifications can be reduced to the 15 elements aluminium, bromine, calcium, iron, potassium, magnesium, manganese, sodium, phosphorus, rubidium, sulphur and zinc for rice type

identification and adulteration detection; and arsenic, cadmium and mercury for food safety.

Mercury toxicity in fish continued to be of Caribbean and global interest. During the report period ICENS analysed 95 fish samples - snapper, parrotfish, yellow goatfish, butterfish, jack and lionfish - for arsenic, bromine, caesium, calcium, cerium, chromium, cobalt, copper, europium, hafnium, iron, manganese, mercury, potassium, rubidium, scandium, selenium, silver, strontium, thorium and zinc. In view of the increasing popularity in Jamaica of consuming lion fish it was thought timely that an elemental analysis of locally caught fish be carried out. A total of 25 lion-fish caught at five different sites around Jamaica was analyzed for 32 elements, making a total of 800 determinations. Given the piscivorous nature of lion-fish and their position near the top of the marine food chain there exists the possibility of bio-magnification of certain toxic elements such as mercury.

About 26% of all the fish samples that ICENS analysed had mercury contents equal to or above 0.50 mg/kg, up to a value of 1.55 mg/kg which exceeds the average of 0.189 mg/kg found in snapper by the United States Food and Drug Administration. ICENS noted that selenium values ranged from 1.07 to 4.68 mg/kg and were always higher than the mercury values in the corresponding fish sample. Selenium is known to bind mercury and mitigate its deleterious effects and this mechanism seems to operate in the Jamaican samples. Other elements of interest include calcium (725 to 5397 mg/kg), potassium (0.6 to 1.3 %) and low values of arsenic (2.1 to 80.7 mg/kg).

Following the US Environmental Protection Agency standards, these findings indicate that attention should be paid to the consumption of snapper and lionfish especially by pregnant women from some sites on the South Coast. Work is in progress to determine whether advisories may be necessary.

The chemistry of human tissues

The elemental content of human tissues is of key importance to the preservation of good health. As sample tissue is not abundant and is

difficult to obtain, 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 areas that should be investigated, 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 implication of such relationships is not well understood but the preliminary findings do indicate the potential value of such work which ICENS will continue.

Lead in the human population

ICENS continued to work on issues related to mitigating the toxic effects of lead in the human environment. A resurvey of the effects of the heavy rains during 2010 on the ICENS 1995-2005 work done to isolate lead sources in Kintyre showed that these mitigation steps have held up very well but also revealed a few previously unknown exposures to lead waste. These exposures will require attention should people begin living closer to those particular areas. It is important to monitor the distribution of lead in the urban environment because studies in the US and Australia indicate that children with untreated lead poisoning may be at risk of developing brain disorders that cause criminal traits in later life.

Soil conservation

With RPPD, ICENS continued 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, for the 5 year period from 2009-2013. Work slowed down due to staff changes among the external collaborators but ICENS plans to relaunch the project with new partners from MoAF so that it can construct a common 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: Argentina, Bolivia, Brazil, Chile, Cuba, Dominican Republic, El Salvador, Haiti, Jamaica, Mexico, Nicaragua, Peru, Uruguay and Venezuela.

Rare earth elements

At the request of the University Chemistry department, which had succeeded in synthesizing several rare earth (REE) compounds of unusual composition, ICENS developed a method to determine elemental concentrations for dysprosium and terbium, the main elements of interest during this particular study. The results have accepted for publication in an international journal.

ICENS also started planning a new project to stimulate a small-scale Jamaican industry for recovering and selling on REE from components in end-of-life electronic items such as mobile phones, computers and television sets. It is now widely recognised that such waste items are richer and more accessible sources of REE than many naturally occurring ores.

Data Sharing

Since 1984 data sharing has been one of the priority activities of ICENS because ready access to existing information held by most Jamaican S&T institutions continues to be hard to achieve. ICENS recognises that collecting samples and data is expensive and it can provide the continuous and objective curation that is critical for sustaining the integrity of Jamaica’s important national endowment of data and information resources. The advanced indexing of the ICENS EShare 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.

As primary field and laboratory data are only raw materials ICENS continues to add value by transforming them into information and knowledge products suitable for providing high-level decision makers with GIS-based spatial assessments, interpretations, visualisations and predictions based on terrain models which can inform realistic options for action and the shaping of national strategies. Through the ICENS open access online EShare system Jamaican institutions can share georeferenced digital data and information online by means of an open access repository: 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).

Plans are in hand to link the new Ministry of Science, Technology, Energy and Mining to the EShare system. In May, the Caribbean Knowledge and Learning Network (CKLN) completed the construction of C@ribNET and linked 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. ICENS is preparing to participate actively in this venture as the Mona Campus of the UWI will be one of the nodes in the Jamaica RENS.

Nuclear Power

The ICENS prefeasibility study carried out at the request of the Minister of Energy and Mining was referred to in ongoing analysis of the current Jamaican energy situation. Nuclear power is now a huge global industry supplying 16% of world electricity demand: some countries (e.g. France) obtain 80% of their power from nuclear sources. As of 2012 a total of 548 new power plants is under construction, on order, planned or proposed

worldwide (World Nuclear Organisation). Although shale oil derived from fracking is becoming increasingly competitive, it is not available in Jamaica and nuclear power continues to compete with coal in price. The price gap in favour for nuclear power will increase over time with mandatory 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 benefit in the long term from uranium fuel that is 100 000 times more powerful than oil: 1 kg of uranium produces 400 000 kWh while 1 kg of oil produces only 4 kWh and uranium is not affected by short-term fluctuations in market price. Until recently the size and costs of nuclear power reactors excluded the application of nuclear energy for smaller countries but new safe, small, high efficiency reactors (10-125 MWe) that can be factory manufactured as modules small enough for transport to site exist as prototypes and could be available within ten years. For the first time nuclear energy for Jamaica within a decade deserves a full examination. In this connection ICENS participates in local programmes and regional IAEA initiatives to support the rational considerations of nuclear energy in the region.

NEW PROJECTS

Open system architecture for Neutron Activation Analysis (OpenNAA)

ICENS has entered into 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 will see the development of 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.

Open NAA 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 Energy and Mining ICENS initiated collaboration with Mines and Geology Division and UWI Geography and Geology Department and UWI Marine Geology Department on compilation of a new online geological map of Jamaica and a layer of mineral occurrence data for the orientation of 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 are suitable for use in cost effective road construction, road repairs, trench filling and other civil engineering applications and ICENS plans a proof of concept project that will emplace a test strip suitable for heavy vehicles on the Mona campus.

During the year ICENS also started to plan 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 of these projects aims to develop environmentally friendly materials for packaging and food containers from banana plant waste as a means of substituting polystyrene which is harming 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 components containing

rare earth elements (REE) 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

The Jamaican public shows little realisation that science is an important way to solve societal problems, possibly because of gaps in formal education and the circumstance that most of the day to day products or technologies it uses are imported readymade. ICENS strives to do research that is useful and relevant to the practical needs and ethics of Jamaican society as one way of demonstrating the importance of science and raising the level of interest in it. Most countries with successful economies recognise that R&D is a key capital investment in their future wealth and wellbeing and a surprising number of them are boosting their investment in R&D as a measure to rise out of the current financial depression. Events like UWI Research Days may need to attract more people from key groups such as business and political leaders, diplomats, funding and donor agencies, international and local NGOs, potential 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 show the interest required to enter the next generation of career scientists. However a well-conceived road map and needs study will have to be made 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

- **J.M.R. Antoine**, and C.N. Grant. The Development and Characterisation of the in-house Quality Control Material “Soil of Jamaica”. 13th International Symposium on Biological and Environmental Reference Materials (BERM13), IAEA, Vienna, June 25-29, 2012.

- **J.A. Preston.** Neutron Science Applications for Multi-Disciplinary Research Centres in Developing States. International Atomic Energy Agency Workshop/Technical Meeting on Innovative Applications of Small Research Reactors, Small Neutron Generators and Isotopic Neutron Sources, at City University of Hong Kong, Hong Kong (SAR), China, April 30 – May 3, 2012.
- **J.A. Preston.** Status of Radiation Monitoring Activities in Jamaica. IAEA Workshop on the Establishment and Maintenance of the International Radiation Monitoring Information System (IRMIS), March 19-21, 2012, Vienna Austria.
- **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. Presented at the tenth International Conference on Nuclear Analytical Methods in the Life Sciences (NAMLS10) in Bangkok, Thailand, January 15-20, 2012, *Journal of Radio Analytical and Nuclear Chemistry*.
- **J.A. Preston** and Grant C.N. A Software Architectural Framework Specification for Neutron Activation Analysis. 10th International Conference on Nuclear Analytical Methods in the Life Sciences (NAMLS10) in Bangkok, Thailand, January 15-20, 2012. *Journal of Radio analytical and Nuclear Chemistry*.
- **J.A. Preston.** ESHARE. Inter-Academy Panel / TWAS / Caribbean Academy of Sciences Program on Digital Knowledge Resources and Infrastructure in Developing Countries Technical Meeting on Open Access and Dissemination of Scientific Information in Central America and the Caribbean, Courtleigh Hotel, Kingston, December 5-6, 2011.
- **C.N. Grant,** HEU LEU Core Conversion of the SLOWPOKE-2 Reactor, Regional Practical Workshop on the Decommissioning of Radioactively Contaminated Facilities: August 22-26, 2011 – NECSA, South Africa.

PUBLICATIONS

- * **C.N. Grant, G.C. Lalor** and M. Balcazar, “Radon monitoring in sites of economical importance in Jamaica”, Applied Radiation and Isotopes, <http://dx.doi.org/10.1016/j.apradiso.2012.07.007>
- * **G.C. Lalor.** Cadmium. Second National Report on Chemicals in the Jamaican Environment. 41p.
- * **J.M.R. Antoine** and **C.N. Grant.** “The Development and Characterisation of the in-house Quality Control Material “Soil of Jamaica””. 13th International Symposium on Biological and Environmental Reference Materials (BERM13), Book of Synopses, IAEA, Vienna, June 25-29, 2012.
- * **J. M. R. Antoine, L. A. Hoo Fung, C.N. Grant, H.T. Dennis,** and **G.C Lalor.** 2012. “Dietary intake of minerals and trace elements in rice on the Jamaican market”. *Journal of Food Composition and Analysis* 26, 111-121.
- * **A. Spence,** and **Kelleher, B.P.** “FT-IR spectroscopic analysis of kaolinite-microbial interactions”. *Vibrational Spectroscopy*, 61, (2012). 151-155.

PUBLIC SERVICE

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- 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

- Member, ARCAL National Coordinator (Jamaica).
- Member, 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.
- Member, National Coordinator for Incident Reporting system for Research Reactors.
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- Chairperson, National Food Standards Committee (ISO TC34 Mirror Committee), Jamaica Bureau of Standards.
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