The 30 kW Research Reactor Facility in Ghana: Past, Present and Future Programmes

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Abstract

The Ghana Research Reactor-1 (GHARR-1) is a small, simple, reliable and safe reactor design and constructed by China Institute of Atomic Energy (CIAE). GHARR-1 adopts the pool-tank structure and employs highly enriched uranium as fuel, light water as moderator and coolant, metal beryllium as reflectors. The reactor is cooled by natural convention. The rated maximum thermal power of GHARR-1 is 30 kW; the corresponding neutron flux is $1.0x10^{12}$ $cm^{-2}s^{-1}$. The refueling mode of the reactor is to totally change the old core with a new one, the lifetime being more than ten years. Since the commencement of operation of the low-flux miniature neutron source reactor (MNSR) in 1995, a significant number of research and development in the field of neutron activation analysis have taken place. During its 12 years of operation, after the first criticality, the reactor has been used as a neutron source for research, teaching and training to support several graduate and post graduate careers for students from universities in Ghana and the West African sub-region. Owing to the stable flux of the reactor and rapid proliferation in utilization, several analytical techniques have been developed. The GHARR-1 application in neutron activation analysis included: (i) Food analysis; (ii) Heavy metals determination in environmental samples; (iii) Determination of major, minor and trace elements in geological samples; (iv) And mineral prospecting among others. The educational programmes in place at the center are teaching and learning in nuclear engineering, nuclear physics, nuclear and radiochemistry and other related fields.

1.0 INTRODUCTION

Miniature Neutron Source Reactor (MNSR) is used as a source of neutrons for neutron activation analysis at research institutions, universities and hospitals [1]. Ghana's MNSR also known as Ghana Research Reactor-1, (GHARR-1) is located at the Ghana Atomic Energy Commission, Kwabenya-Accra. The reactor was commissioned in March 1995. The GHARR-1 is used mainly for neutron activation analysis, and for research. It can also be used to prepare radioisotopes with medium and short-lived half-lives and it is a good tool for training and education. The reactor complex contains 5 major components. Theses are the reactor assembly, control console, auxiliary systems, irradiation system and the pool. There are 5 inner irradiation tubes installed within the beryllium annulus. Five outer irradiation tubes are also installed outside the beryllium annulus. Several analytical tools and sample preparation

equipment are available at the GHARR-1 facility for use in different areas of research and development. For the past twelve years, the reactor has been used in determination of major, minor and trace elements in samples of archaeological, Environmental, geological and biological origin [2]. In the near future, GHARR-1 shall be used to support forensic studies in Ghana. GHARR-1's applicability in Large sample neutron activation analysis (LS-NAA) shall be investigated.

2.0 PAST ACTIVITIES

During the past twelve years, Ghana's MNSR has been used mainly for neutron activation analysis (NAA) and for education and training in the fields of method development and elemental analysis in various sample matrix. It has also been used in teching and learning in Nuclear Engineering, Applied Nuclear Physics and Nuclear and Radiochemistry for students from the universities and polytechnics.

The neutron activation analysis laboratory at the Centre has been engaged in many innovative research and development in NAA. Notable among them are:

Development and validation of analytical procedures and methods: These included; k_0 standardization method; the relative method; and neutron flux mapping [2].

Radioanalytical, quality assurance and quality control procedures in place at the Centre involves preconcentration NAA and speciation methods using cloud point extraction. The Centre in collaboration with the IAEA under the regional project RAF/0/018 Quality Management systems, is putting in place measures to have the Laboratory accredited with ISO 17025.

Analytical services: The Centre offers analytical services to clients and researchers in the following areas; Geochemistry including Hydrochemistry, soil fertility studies and mineral exploitation among others.

Research has also been carried out in environmental and health related studies. Vivid accounts on the results of these studies are documented elsewhere [2, 3, 4, 5, 6]

2.1 Commercialization

The centre has rendered services to many industries, research institutions, universities, and individuals. Some of the services carried out included: Analysis of borehole water, sediments and water from streams and rivers in mining areas, petroleum product analysis *etc*. We have also worked for some companies like Volta Aluminium Company (VALCO), West African Gas Pipeline Project, Environmental Priotection Agency (EPA), Panbros salt industry NGOs and Individuals, just to mention a few. These commercial activities generated modest funds, which help to sustain the running of the facility.

2.3 Education and Training

The reactor is has been used to train students from various universities in Ghana and the West African sub-region. In all more than 30 B. Sc dissertations have been produced, 20 M. Phil. and 5 Ph.D. theses in the past ten years.

3.0 PRESENT PROGRAMMES

The neutron activation analysis laboratory at the Ghana research reactor-1 Centre has been recently equipped with modern equipment for preparation of samples of various matrices and kinds. The analytical protocol development is in advanced state and the Laboratory is currently preparing for ISO 17025 Accreditation.

3.1 Human Resource Development

The decline in nuclear professionals worldwide has become a concern to all especially, Ghana and Africa. This is because, there is lack of specialized people to manage, operate and utilize existing facilities. To help solve this problem in Ghana and Africa, Ghana Atomic Energy Commission through the International Atomic Energy Agency and the Faculty of Science, University of Ghana has established the postgraduate School of Nuclear and Allied Sciences (SNAS). The objectives of the School, among others are:

(a) To undertake postgraduate programmes in the peaceful uses of nuclear and biotechnology techniques in Ghana and Africa leading to the award of M. Phil and Ph.D. degrees of the University of Ghana
(b) To equip graduates with the skills needed to maintain a critical research and development (R&D) capability in universities and research institutions and to develop workforce for the nuclear industry.
(c) To popularize nuclear science and technology programmes in order to attract highly qualified undergraduates
(d) To engage in hosting of AFRA and IAEA regional and interregional training courses/workshops/conferences/seminars
(e) To create international links with other institutions with a tradition in nuclear education and research for exchange of programmes and sharing of experiences. The GHARR-1 is the central equipment for teaching and learning at SNAS.

Presently about 15 M. Phil. and 4 Ph.D. students from the School of Nuclear and Allied Sciences (SNAS), University of Ghana are using the reactor for their theses work.

3.2 Application of GHARR-1 for Nuclear Power R&D

The Research reactor in Ghana is used for training nuclear scientist in reactor operation, core convention, reactor physics calculations *etc*. which will enable the country obtain the required manpower for its future nuclear power programmes.

3.3 Environmental studies

Environmental pollution studies using environmental samples such as sediments, soil, water and biological indicators like lichens are some of the past and on-going research projects being carried out at GHARR-1 Centre. The most interesting envirnmental studies being carried out presently at the Centre is the use of lichen transplants for monitoring of vehicular traffic emissions in the country.

Using lichen tranplants along some major roads in the capital city Accra, it was aobserved that manganese concentration of 1549±52 mg/kg exceeded the background concentration by a factor of about 3.0.. Whereas there may existed other possible sources of Mn in roadside environments, motor vehicles which use the Mn-based antiknock, contribute significantly to atmospheric Mn along roadsides.

From the research conducted, it was concluded that an inverse relationship exists between the distance from the source of pollution and the manganese concentration accumulated by lichens. Other conclusions are that Mn emission is directly proportional to traffic volume and populations with potential high exposures are those living near traffic lights. Lastly, persons living close to high-density traffic areas may be exposed to higher manganese arising from MMT combustion [4].

4.0 FUTURE PLANS

With the addition of modern sample preparation equipment and ugrading of the reactor facility, programmes such us forensic studies, low level detection, archaeological investigation, and large sample NAA are some of the activites planned for the near future.

4.1 Forensic studies

Forensic Science is the use of science for the purposes of the law, and it has played an important role in court cases for well over century. As science and technology have advanced, investigative methods have become more sophisticated, enabling substantial information to be extracted from forensic samples. No matter how well equipped, crime laboratories may periodically encounter evidence which requires expertise and facilities external to their organisations. This scenario is most probable particularly for the use of nuclear analytical techniques (NATs). The Ghana Research Reactor-1 facility is being resourced to enable the Centre provide services to support forensic investigation in the country.

The International Atomic Energy Agency (IAEA) is establishing a regional resources Centre for nuclear security in Ghana. The Laboratory will be used to support the training in this field. The nuclear forensic laboratory when fully established shall be used in teaching the students of School of Nuclear and Allied Sciences of the University of Ghana and other universities in Ghana in forensic science.

4.2 Low level detection

The Centre is planning to install low background detectors and Compton suppression gamma-ray counting system to enable the facility engage in low level detection.

4.3 Archaeological investigation

One of the most important areas of archaeology is the identification of the source and origin of ancient artefacts. Knowing the origin is very important for tracking correctly ancient civilization and history. It is generally accepted that the concentration of trace elements and more especially, rare earth elements are very useful for the characterization of pottery produced in a given origin, and the same time are good dicrimination among the chemical profiles typical of different areas. Usually archaeological materials are of very great

importance to the Archaeologist and are not to be destroyed or tempered with. Of all the methods used in trace elements inevstigations, INAA is one which is non-destructive. For INAA to be perfectly non-destructive with regrads to archaeological materials, it should be capable of performing bulk analysis. To offer this service in the near future, feasibility studies on the use of the GHARR-1 facility for bulk INAA and its subsequent use for archeological studies are being carried out. Presently, GHARR-1 is used in analysis of archeological pottery samples.

4.4 Large Sample NAA

The limitation of the size of the analytical portion becomes a problem when the amount of material collected for the analysis is larger, for example, soils, rocks, plant materials and food. Large portion of these materials (a few grams to a few kg) can easily be collected and analyzed using the Large Sample Instrumental Neutron Activation Analysis (LS-INAA) technique and are more closely representing the entity for which analytical data are required. The types of samples that can be analyzed using this technique (LS-INAA) are as listed below:

- Materials difficult to homogenize or in which homogenization causes contamination. Examples are recycled materials (plastics, electronic scrap); wood and twigs; mineral deposits; entire human or animal organs (liver, bone)

- Materials in which the inhomogeneity has to be localized. Examples can be found in (sediment, rock) drill cores or cultural artifacts

- Materials difficult to sub-sample. Examples are foodstuffs, animal fodder, raw materials

- Materials that must be kept integer and intact. Examples are cultural and art artifacts, archeological findings, forensic material

- Materials that cause radiolysis under normal reactor irradiation conditions.

On the other hand the sizes of samples that can be analyzed depend on the size of the irradiation sites. The GHARR-1 has two larger irradiation sites outside the beryllium annulus which can take a sample with a maximum diameter of 2.8 cm. The slanting tube in the irradiation facility can also take a sample whose diameter is not more than 4.0 cm (approx). Sample mass can range between a few grams to few kilograms depending upon sample type. The MNSR irradiation facility can be modified to suit LS-INAA technique. A new irradiation site can be created to accommodate desired sample size for the purpose of LS-INAA. This can be done by means of introducing a new slanting tube with its irradiation site located close to the reactor core. The tube can be made of aluminum or stainless steel. The large sample – surrounded by flux monitors – can be packed in a polyethylene container. The transfer of sample to the irradiation site can be done manually by lowering the sample to the irradiation site by means of a strong string attached to the sample.

5.0 CONCLUSION

In conclusion, we would like to say that the Ghana research reactor-1, installed and commissioned in Ghana in 1995, has been used extensively to support the socioeconomic development of the country. Plans have been put in place recently to use the reactor for human resource development in Nuclear Science and Technology. The GHARR-1 Centre has received enormous support and financial assistance from the IAEA/AFRA. This has greatly enhanced our performance in the area of research and commercialization, and capacity building. It is our cherished hope that these activities will be enhanced in the years to come to meet the expectations of local and international standards.

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