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The Significance of Stochastic CTMC Over Deterministic Model in Understanding the Dynamics of Lymphatic Filariasis With Asymptomatic Carriers

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Capacity building to strengthen nuclear security in the safety, operation and utilization of research reactors in Africa

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ABSTRACT

Research reactors are indispensable for developing countries to benefit from the many quiet applications of nuclear science and technology, particularly in health services, food security, water resources, education and training and the development of nuclear technology. However, only eleven of the world's 220 operational research reactors are operational on the African continent. This means that only 3% of the world's nuclear research reactor capacity has access to 17.2% of the world's population in Africa. In this regard, there is a major gap in the nuclear power sector in Africa that needs to be filled for the economic development of developing countries, including the advent of micro and small modular reactors. Since research reactors encompass a wide range of facilities that involve different aspects and security considerations compared to other facilities in the nuclear industry, the nuclear security culture for personnel who work or are expected to work in nuclear reactors is essential for compliance with nuclear safety requirements. In this context, capacity building in the areas of security, operation and use of research reactors is important in order to strengthen the nuclear safety of this installation in developing countries. This paper addresses the need for human resource capacity building in Africa, particularly in Tanzania.

INTRODUCTION

Research reactors are indispensable tools for building capacity in nuclear science and technology for socio-economic development [1]. However, many developing countries are still barely benefiting from recent advances in nuclear science and technology [1]. As a result, the development of nuclear science and technology has generally responded to the wishes of developed countries and thus has only served to broaden the gap between industrialized and developing countries [2]. Quiet use of nuclear energy is universally useful especially to developing countries that lack adequate access to water, food, health services, electricity and industries that are a prerequisite for sustainable economic development, to mention a few.

Research reactors are essential for developing countries to benefit effectively from numerous peaceful uses of nuclear energy, mainly in the fields of agriculture, health, water resources, education and training and for industrial development [2]. However, only eleven research reactors are operational on the African continent, out of the 220 operational research reactors in the world [2]. This means that only 3% of the world's nuclear research reactor capacity has access to 17.2% of the world's population in Africa [2]. This implies that the establishment of research reactors in developing countries poses many challenges, including high costs and reliable infrastructure, the time required to develop sound legal and regulatory frameworks, sustainable safety and technical and economic [3]. Although there are other dynamic features that are hard

to examine from a political perspective due to their nature, explicitly the “status” and stature related with mastery in nuclear technologies, lack of personnel capacity in this field and government commitments are major driving factors that hinder the establishment of reactor facilities in developing countries. Most research reactors in developing countries are within reach to universities for education, training and research. However, African students interested in nuclear science and its applications cannot access adequate facilities at their home university, they have to transfer to universities abroad. During their studies overseas due to the lack of opportunities close to their home country, the most gifted and capable African students will be tempted to stay overseas and this strong factor will continue to facilitate the brain drain from developing countries [2]. Operation of more research reactors in Africa would go a long way in inspiring African students and scientists to stay at home or return to their home countries and contribute to the continent's economic growth. In this context, increased investment in human resources is a precondition for the sustainable use of nuclear energy and its applications strongly depend on the availability of qualified scientists, engineers and technicians. Many African countries still lack sufficient nuclear training opportunities and face high staff turnover and a lack of specialized professionals in key areas. In addition, research reactors encompass a wide range of facilities ranging from different safety aspects and considerations compared to other facilities in the nuclear industry, nuclear security culture, personnel who work or are expected to work in nuclear reactors is responsible for compliance with safety standards requirements of the utmost importance. For instance, staff at research reactors may lack a genuine nuclear safety culture; in particular, one might think that research needs can take precedence over compliance with safety requirements [4]. In this context, capacity building in the areas of safety, operation and use of research reactors is important in order to strengthen the nuclear security of this installation in developing countries.

Africa's current capabilities and increasing demand for research reactors

Population increase in Africa continent is estimated to double by 2050 as a result the increase will have direct impact on electricity demand in Africa. In view of this, the International Energy Agency's (IEA's) *African*

Energy Outlook 2019 forecasts a quadruple to eightfold increase in the continent's electricity demand [5]. The current energy gap in Africa details that more than 600 million people in the continent have no access to electricity yet the distribution is spatially uneven to the little available [6]. The combination of the rapidly growing population [7-8] and projected climate changes[7] increase more demand for green electricity. Concerns about climate change have highlighted the benefits of nuclear power in terms of minimal greenhouse gas emissions. Furthermore, the consistent record of nuclear safety and productivity over the past two decades has resulted in relatively low and stable nuclear operating costs [1].

In this context, nuclear energy, is expected to play an important role along with other low-carbon sources of energy, especially with the advent of micro and small modular reactors. Currently, there are eleven research reactors in eight countries across the continent, however, there is increasing government interest throughout the continent in developing nuclear reactor facilities [9] whereby out of 29 new reactors under construction worldwide, 16 are in developing countries. In addition, 17 African states have so far shown interest in embarking into project: some have active nuclear research programme plan in hand, while others are considering the prospect of a nuclear build [9]. Research reactors are the primary way African countries engage with nuclear technology and research. Research reactors are a proven first step in launching a nuclear power program. As African countries consider adopting nuclear energy in the future, research reactors play a vital role in setting the groundwork, promoting public understanding of the useful applications of nuclear energy [3]. Unlike nuclear power plants, accessibility to research reactors for the general public and even school is easy and safe to organize accessibility. Such convenience access to a nuclear facility plays essential role in sparking professional interest in nuclear science and relieving fears about nuclear energy and radiation.

Future prospects for research reactors in Africa

The peaceful applications of nuclear science and technology is universally beneficial and even more so for developing countries where there is inadequate access to water, food, health services, electricity and industries being a requisite for sustainable economic development [2]. In view of this, nuclear science and technology

application is indispensable for effective socio-economic development in developing countries.

Nuclear energy is "already a reality" in Africa and many African countries are planning or contemplating the deployment of reactor units, Costes [2]

To complement this, the continent has always taken steps to establish reactor units in Africa, in collaboration with the TRICO I research reactor at the University of Kinshasa in the Democratic Republic of Congo in 1958 [9]. This was soon followed by the Egypt and South Africa, indicating the continent's commitment to providing researchers with access to modern nuclear analysis techniques and radiation facilities [9]. To date, twelve research reactors have been built in eight countries on the continent, all members of the International Atomic Energy Agency [9]. The African governments have taken advantage of application of nuclear science and technology where a number of its applications are in progress. The technology has been expanded to address socio-economic problems in health, agriculture, water resources, and research for sustainable economic development. Attention is also being paid to the industrial sector through extractive and mineral processing, petrochemicals industries, mineral exploration, and exploitation. There are also plans to operate e.g. Gamma Irradiation Facility, Research Reactor and Nuclear Power Plants for electricity generation. One of the advantages of research reactors is not least that the products and services they can provide, such as the irradiation of materials or the production of radioisotopes, can be promoted commercially to create revenue to at least finance part of the research reactor's operation [3]. The commercial services and products that the research reactor would offer includes the production of radioisotopes for mining, nuclear medicine, agriculture, neutron activation analysis for soil fertility for agriculture purposes, medical diagnosis, mining (characterization of minerals) or environmental pollution measurements; and the production and characterization of reference materials [3].

Although the government has shown interest to invest in the application of nuclear science technology, lack of human resources capacity in this field is the major driving factor that hinder the establishment of nuclear facilities in Tanzania and other developing countries in Africa. Like any advanced technology, nuclear technology - whether in the field of nuclear energy or

in other nuclear applications - offers great benefits, but it also carries risks. For these technologies to remain viable as development tools, they must be safe, secure, and used only for peaceful purposes. Competent nuclear professionals with skills are needed for the management, operation, utilization and regulation of the country's research reactors and other nuclear related facilities in a safe and secure manner. In order to support the development and applications of various aspects of nuclear technology in the country, it is essential to build both institutional and human capacities.

While there are several universities in South Africa offering nuclear education, a number of other countries in sub-Saharan Africa now offer nuclear science and engineering courses, including Nigeria and Ghana [10]. Although there are no operational research reactors in Central and East Africa or in any Francophone country in Sub-Saharan Africa, a number of governments are committed to building institutional and human capacity. For instance The Government of the United Republic of Tanzania (URT) conducted a preliminary feasibility study for a possible research reactor project and concluded that a research reactor could be an extremely useful tool to contribute to the scientific resources of the country, improving health care and increasing industrial and agricultural productivity. In addition, the URT has requested an Expert Mission under the IAEA project URT0007 to establish a Graduate School of Nuclear Science and Technology (NuST) at the Nelson Mandela African Institution of Science and Technology (NM-AIST) in Arusha that would be running several programmes to close the identified gaps in nuclear science and technology. Other sub Saharan countries that have shown interests in establishing nuclear reactors includes Kenya, and Senegal while Zambia is planning for an establishment of nuclear power [11]. In order to secure the availability of qualified human resources in nuclear science and technology, African Member States have accorded special attention to the many challenges and constraints that have been affecting their human resource systems and plans in the field of Nuclear Science and Technology. Since there is no opportunity for a higher education system in the field of nuclear science and technology in many African member countries the IAEA supports the member states to build a stronger higher education system of their own in order to bridge the existing gap of expertise in Nuclear Science and Technology. This thinking has brought about the

need for a Master degree programme in Nuclear Science and Technology to be offered in the NM-AIST, one of the appropriate educational establishments in the Sub Saharan African region. Hence, the Nuclear Science and Technology programme graduates will be experts in Nuclear Science and Technology and it is expected that the industrial linkage of the graduates and regional industries participating in the programme will enhance the graduate's skills in solving regional problems and so bettering the life of the people.

CONCLUSION

To ensure the safe and efficient operation of research reactors, their operation must be based on strategic planning, sound management and adequate funding. The sustainability of research reactors requires the availability of human resources with appropriate knowledge, skills and capabilities. Achieving an appropriate level of qualification requires a complex combination of knowledge, know-how, skills and experience in a working environment. Greater investment in human resources is therefore a prerequisite for the construction of reactor facilities in Africa. While the African government can provide the most modern facilities in terms of infrastructure, many African countries still have insufficient nuclear education opportunities for masters and doctoral students and face high staff turnover and a lack of specialized professionals. For this reason, the IAEA is the main actor for the development of human resources through scholarships and training for university Lecturers of the Member States. This will strengthen the teaching of nuclear sciences and technologies in their home universities and that will enhance creation of many competent nuclear professionals (scientists and engineers) that will be employed to the anticipated research reactors thus can operate and utilize the facilities in a safe and secure manner.

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