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Kenya's Proposed Research Reactor: Leveraging Nuclear Technologies for Sustainable Healthcare

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ABSTRACT

The government of Kenya recognizes the importance of research and development in realizing the country's vision in economic development and quality of life. Research reactors will be key in Kenya's medium- and long-term development plans in areas of research, industry, healthcare, education and training. Nuclear Power and Energy Agency, in collaboration with key stakeholders, is carrying out a feasibility study for the Kenya Nuclear Research Reactor (KNRR) project. The commissioning of the KNRR facility is projected for the year 2030. Radioisotope production has been identified as a priority utilization for the proposed RR facility to ensure self-sufficiency in production and availability of cost-effective radioisotopes for medical and other applications both for the country and the region. Further, the current and projected local and regional demand for radioisotopes for medical applications have been quantified. The prioritized radioisotopes are Mo-99/Tc-99m, I-125, I-131, Ir-192 and Lu-177. Successful implementation of KNRR project will improve the quality of healthcare in the country.

INTRODUCTION

The government of Kenya recognizes the importance of research and development in realizing the country's vision in economic development and quality of life. Research reactors will be key in Kenya's medium- and long-term development plans in areas of research, industry, healthcare, education and training. Nuclear Power and Energy Agency, in collaboration with key stakeholders, is carrying out a feasibility study for the Kenya Nuclear Research Reactor (KNRR) project. The commissioning of the KNRR facility is projected for the year 2030. [1]. Radioisotope production has been identified as one of priority utilization for the KNRR. Radioisotopes have a wide range of applications in various fields, including nuclear medicine, industry, agriculture, and research. The commercial production of radioisotopes concentrates on two main areas: medicine and industrial applications. As one of the most powerful tools to diagnose diseases, radioisotopes are extensively used in the medical field. The applications of radioisotopes are expanded to the therapy of cancers and other malignant diseases in recent years. In the most recent advancements in medical radiation technology, theranostics and targeted radioisotope therapy is fast catching pace. Radioisotopes have also been used for a variety of industrial applications such as non-destructive testing, gauging, process tracing, and environmental monitoring. The production and application of some of the frequently used medical radioisotopes is given shared hereafter.

Mo-99 is the most frequently used radioisotope with more than 80% of diagnostic nuclear medical procedures worldwide [2,3]. Its daughter isotope, Tc-99m, is used for imaging and functional studies of the brain, myocardium, thyroid, lungs, liver, gallbladder, kidneys, skeleton, blood, and tumors for 40 million diagnostic images annually. I-131 has a half-life of 8.02 days, is mainly used for thyroid cancer treatments. I-131 is produced by the neutron activation reaction of tellurium and dispensed as solution and capsule products [4,5]. Ir-192 is used medically in brachytherapy to treat various types of cancer. It is also widely used in non-destructive testing (NDT) [6,7]. I-125, with a half-life of 59.4 days, is mainly used for biological assays, nuclear medicine

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imaging and radiation therapy [8,9]. Lu-177 has a half-life of 6.6 days, is a new important radionuclide for cancer treatment. It emits a beta particle with moderate energy, which animal experiments suggest would be useful for treating moderate size tumors while sparing nearby healthy tissue. In addition, it has a gamma photon that allows imaging of its bio-distribution in patients. This allows a more accurate estimate of target and critical organ dosimetry [10,11].

MATERIALS AND METHODS

The prefeasibility studies were conducted in all the hospitals in Kenya with either the capacity to handle nuclear medicine and molecular imaging procedures; or those with the potential and are already at some stage of capacity building. Assessment and quantification of stakeholder needs was conducted in these facilities with a focus on production and utilization of the following the radioisotopes discussed below. More than 95% of Mo-99 is produced through fission of U-235. Since fission-based Mo-99 has advantages of high specific activity, High yield and economic aspect than any other method. Fission Mo-99 based on chromatographic Mo-99/Tc-99m generators is the most generally used radioisotope in practice owing to its relatively simple processing and handling, reliability of product quality and high radioactive concentration. It can be obtained through elution from fission Mo-99 based on a chromatographic column generator; elution from irradiated Mo-99 based on a gel generator; and separation from irradiated Mo-99 compounds by solvent extraction. I-131 is produced as follows: preparation of target material (TeO_2) and target capsules, irradiation in the reactor, irradiated target handling, distillation and chemical treatment in the hot cell, and quality control of the product. Ir-192 is normally produced by neutron activation of natural-abundance iridium metal, usually in nuclear reactors. Ir-192 is used in the production of radioactive "sealed sources" that emit a focused beam of Ir-192 gamma radiation on a target testing material. I-125 is produced by the electron capture decay of Xe-125, which is an artificial isotope of xenon, itself created by neutron capture of stable Xe-124. The separation and purification of I-125 produced at the target was used by dry distillation. Lu-177 can be produced in reactors using Lu-176 or Yb-175 target material. In the latter case, Lu-177 is derived from Yb-176(n,γ)Yb-177($T_{1/2}$=1.911 hours)→Lu-177. When Yb is used to produce Lu-177, the resulting Lu-177 contains various Yb isotopes. However, the two (Yb and Lu) can be separated, and Lu-177 derived from Yb is very efficient for radio-immunotherapy owing to its high specific activity.

RESULTS AND DISCUSSION

Radioisotopes have been used extensively for research and technical development in industrial, scientific and medical sectors in Kenya. The prospects of various radioisotopes were investigated for both medical and industrial fields through the communication with stakeholders and summarized in Table 1.

Table (1): Prospects for various radioisotope in Kenya

Application Fields	Radioisotope	Main Use	Suitability in Kenya	
			Current	Future
Medical Fields	At-211	Alpha therapy	N/A	High
	Co-57	PET GC, SPECT, Calibration	High	High
	F-18	Alzheimer diagnosis	Low	High
	Ge-68	PET Calibration	Low	High
	I-131	Thyroid cancer therapy and diagnosis	High	High
	Ir-192	Treatment	High	High
	Mo-99/Tc-99m	Imaging examination	High	High
	Re-188	Treatment	N/A	Medium
	Y-90	(Liver cancer) treatment	N/A	Medium
	Sr-90	Eye treatment	Low	High
	I-125	Prostate permanent seed implant	Low	High
	Co-60	External beam radiotherapy	Medium	Medium
		Brachytherapy	N/A	Low

Kenya has previous experience dealing with medical isotopes that are produced from cyclotrons. There are two producers of cyclotron radioisotopes in Kenya as illustrated in Table 2.

Medical radioisotope consumers in Kenya

Most of the research reactor-based radioisotopes are imported from South Africa. A totally, 35,986 GBq of radioisotopes have been imported from overseas in the past decade. Molybdenum 99 is the first critical consumed radioisotope. There are two (2) hospitals (Kenyatta National Hospital and Aga Khan University Hospital) which are end-users of Tc-99m distributed over Kenya. Totally, 960 GBq of Tc-99m was consumed in 2019, which has been relatively constant for the past decade. Iridium-192, I-131 and I-125 are also important radioisotopes that are utilized in medical applications. Table 3 shows some of hospitals that importing radioisotopes for medical application in Kenya.

Table (2): Cyclotron Owner (Kenya)

No	The Owner	Location	Make	Model	Energy	Isotopes
1.	Aga Khan University Hospital	Nairobi	GEMS PET Systems AB	5755381-1	7.8MeV	F-18
2	Kenyatta University Teaching, Referral & Research Hospital	Nairobi	GE PETrace	800 cyclotron Series	15 MeV	F-18

Table (3): Hospitals Importing Medical Radioisotopes in Kenya

No	The Owner	Location	Isotopes
1.	Kenyatta National Hospital	Nairobi	I-125, I-131, Ir-192, and Tc-99
2.	Aga Khan University Hospital	Nairobi	I-125, I-131, Ir-192, and Tc-99
3.	Kenyatta University Teaching, Referral & Research Hospital	Nairobi	Tc-99, Ir-192
4.	Nairobi Hospital	Nairobi	I-125, I-131, Ir-192
5.	Moi Teaching and Referral Hospital	Eldoret	I-125, I-131, Ir-192
	Eldoret Hospital (former Equra Health Kenya)	Eldoret	Ir-192
6.	Texas Cancer Centre	Nairobi	I-131
7.	Coast General Teaching & Referral Hospital	Mombasa	Ir-192
8.	Nakuru Level 5 Hospital	Nakuru	Ir-192
9.	Garissa Level 5 Hospital	Garissa	Ir-192

Table (4): Summary of the current and future needs for radioisotopes in Kenya

	Radioisotope	RI quantity (radioactivity, MBq)		Stakeholder
		Current Need	Future Needs	
1	Mo-99/Tc-99m	960 GBq	9600GBq	Hospitals
2	I-131	202 GBq	1129 GBq	Hospitals
3	I-125	44 GBq	444 GBq	Hospitals
4	Lu-177	N/A	TBD	Hospitals
5	Ir-192	7400GBq	29,600GBq	Hospitals

Based on the general information, a summary of the current and future needs for medical radioisotopes in Kenya are as shown in Table 4. Estimated needs are also expected to increase gradually.

CONCLUSION AND RECOMMENDATIONS

The government of Kenya recognizes the importance of research and development in realizing the country's vision in economic development and quality of life. Research reactors will be key in Kenya's medium- and long-term development plans in areas of research, industry, healthcare, education and training. Nuclear Power and Energy Agency, in collaboration with key stakeholders, is carrying out a feasibility study for the Kenya Nuclear Research Reactor (KNRR) project. Radioisotope production has been identified as one of priority utilization for the KNRR. Radioisotopes have a wide range of applications in various fields, including nuclear medicine, industry, agriculture, and research. Successful implementation of KNRR project will improve the quality of healthcare in the country through production of the required radioisotopes for both diagnostic and therapeutic nuclear medicine; as well theranostics.

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