Preliminary Study on the National Radiation Monitoring Program for Uranium Mining in Tanzania

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1. Introduction

The united republic of Tanzania(Tanzania) has no power or research reactors but plans to commence uranium mining. One of the major uranium development projects is the Mkuju River Project.

Uranium ore contains natural uranium comprising of ^{238}U(99.2739%), ^{235}U(0.7205%) and ^{234}U(0.0056%), which are radioactive. Of these, ^{238}U and its progeny significantly contribute to the radiological hazards in uranium mines due to the high abundance. ^{238}U decays naturally into a succession of 13 other radioactive nuclides. All of these nuclides are metals except one, ^{222}Rn, which is a radioactive gas. The activity concentration of ^{238} U in soil is the global median value of 35 Bq/kg [1]. In uranium mining and milling, the radionuclides of main concern are ^{226}Ra and ^{222}Rn, respectively, for aquatic and airborne releases [2]. In addition, ^{210}Pb and ^{210}Po are the radionuclides of radiological concern in mining areas owing to their half-life and radiotoxicity [3].

Radiation monitoring program are a key aspect of the role of the regulatory authority and the project operator in the uranium mining and milling. An effective monitoring program is very important in terms of financial and technical resources in Tanzania. Some challenges such as environmental conservation issues and public concern are anticipated during operation of mining and milling facilities. Therefore, Tanzania need to establish the pre-operational, operational, post-operational radiation monitoring programs for uranium mining areas reflecting the domestic conditions and in line with international safety standards.

In this study, we reviewed the current status of uranium mining in Tanzania, regulatory system of uranium mining, the impacts of uranium mining on humans and the environment, and design of the national monitoring program.

2. Materials and Results

2.1 Current Status of Uranium Mining in Tanzania

The major uranium development projects is the Mkuju River Project, which is located in southern Tanzania, as shown Fig.1 [4]. This area has been classified as a UNESCO World Heritage since 1982. The project is the first uranium mine to receive a license from Tanzania's ministry of energy and mineral resources in 2013. The project is operated by the Russian Federation's Uranium One Inc. through Mantra Tanzania, which is the daughter company of Uranium One. The Mkuju River site has the mineral resource of approximately 58,500 tons of uranium. In-Situ Recovery (ISR) mining technology, which also called In-Situ Leaching(ISL) mining technology, is being assessed as the method to be used in recovering uranium.

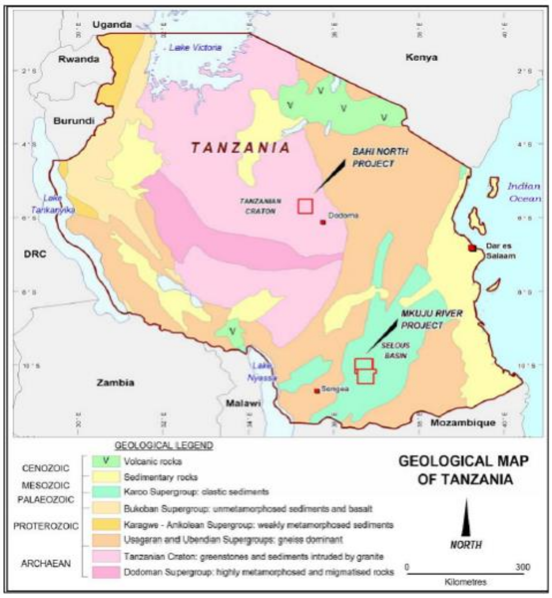

Fig. 1. Geological map of Tanzania showing Mkuju River Project location

2.2 Regulatory system of Uranium Mining in Tanzania

In 2003, The Atomic Energy Act was legislated to control the activities associated with or using ionizing radiation in Tanzania. The Tanzania Atomic Energy Commission(TAEC) was established by the Act No.7. Under the Act, TAEC established the regulation on radiation safety in mining and processing of radioactive ores and the regulation on packaging and transport of radioactive material in 2011. According to the Act, an ore is classified as radioactive material if its radioactivity concentration exceeds 74 Bq/g. The Mining Act is the legal framework governing mineral exploration, construction, mining and milling, processing, and disposal. Under the Mining Act, the mining(radioactive minerals) regulations were established by the ministry of energy and minerals(MEM) in 2010. The National Environmental

Management Council(NEMC) was established by the Environmental Management Act of 2004. Under the Act, NEMC established the regulation on the environmental impact assessment(EIA) and audit in 2005. According to the regulation, the licensee has to implement the EIA prior to its commencing. Fig.2 shows the regulatory system of uranium mining in Tanzania.

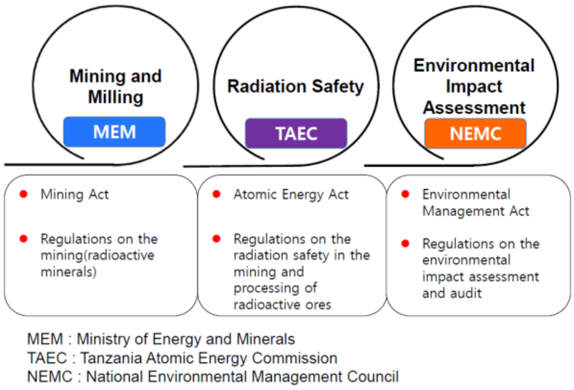

Fig. 2. Regulatory system of uranium mining in Tanzania

2.3 Impacts of Uranium Mining on Humans and the Environment

Uranium and its decay products emit various ionizing radiation such as alpha and beta particles, and gamma radiation. Uranium ores contain all the decay products which they may or may not be in equilibrium with the parent radionuclides. Typical ore with a uranium content of 0.2% has radioactivity of about 25,000 Bq/kg for ^{238}U [5]. The total radioactivity including all the ^{238}U by-products and the ^{235}U decay chain will exceed 360,000 Bq/kg [5], under the assumption of equilibrium. Therefore, uranium ores should be managed with a great deal of caution due to the risks of exposure to ionizing radiation. When the ore remains buried underground, the risks are very low due to stopping by a thick layer of soil. However, the radiological situation is varied as soon as the uranium extraction begins. Namely, radioactive dust is transferred to the atmosphere by mining operation, extraction and crushing of ore, tailing management, etc.. Particularly, because tailings contain some long half-life radioisotopes, they should be controlled a long term concern. According to the UNSCEAR report 1982, about 70% of the original radioactivity from uranium mining areas remains in the tailings due to ^{230}Th($T_{1/2}$=80,000 years) and its daughters, in particular ^{226}Ra($T_{1/2}$=1,600 years). In addition, radon gas may be moved into the atmosphere by diffusion from radioactive waste rocks and tailings. Surface water or underground water may be contaminated by uranium and its by-products. In Tanzania, most of population in mining areas depend on groundwater to serve as potable water. Therefore, the people living in the areas may be at risk if there is uncontrolled releases into the environment. Some of decay products are very radiotoxic when ingested. For example, ^{210}Pb and ^{210}Po are the most radiotoxic elements. When ingested, a given activity of ^{210}Po gives a radiation dose 4. 8 times higher than the same activity of ^{239}Pu [5].

In uranium mining and milling, the radionuclides of main concern are ^{238}U, ^{230}Th, ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po. If the uranium ores contain ^{232}Th with significant fraction, ^{232}Th, ^{228}Ra , ^{220}Rn are also concerned. Some physical properties of monitoring target radionuclides are shown in Table 1.

Table I: Physical properties of monitoring target radionuclides

nuclides	Radiation (principal)	Half-life	# of atoms (per Bq)	Dose[1)] (Sv/Bq)
^{238}U	α	$4.5x10^{9}$ a	$2.1x10^{17}$	$4.5x10^{-8}$
^{232}Th	α	$1.4x10^{10}$ a	$6.4x10^{17}$	$2.3x10^{-7}$
^{230}Th	α	$7.5x10^{4}$ a	$3.5x10^{12}$	$2.1x10^{-7}$
^{226}Ra	α	1,600 a	$7.4x10^{10}$	$2.8x10^{-7}$
^{222}Rn	α	3.82 d	$4.8x10^{5}$	-
^{210}Pb	β	22.2 a	$1.0x10^{9}$	$6.9x10^{-7}$
^{210}Po	α	138.4 d	$1.7x10^{7}$	$1.2x10^{-6}$

Note 1) : Committed effective dose for ingestion and adult (IAEA GSR Part 3)

Radiological hazards associated with uranium mining arise mainly from external and internal radiation exposure. The external exposure is due to gamma radiation, which is emitted by uranium decay products and its quantity is directly related to the uranium ore grade [6]. The major gamma emitters in the ^{238}U series are ^{214}Pb and ^{214}Bi. Internal exposure is due to long-lived alpha emitters(^{238}U, ^{230}Th, ^{226}Ra), radon(^{222}Rn) and its short-lived decay products(^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po) in ^{238}U series. Radiological health risk of concern that is associated with uranium mining is lung cancer largely due to inhalation of radon and its daughters, particularly polonium radioisotope.

2.4 Design of National Monitoring Program

The primary objectives of environmental radiation monitoring for uranium mining areas are to characterize actual or potential exposure to the public or worker, and to demonstrate compliance with regulatory requirement, and to ensure that controls on the release of radioactive materials are commensurate with the risk [7]. The monitoring program should be established considering types of mining method and its surrounding environment, quality and quantity of radionuclides that are expected to be released, environmental status of mining sites such as population, agricultural activities, river or lake etc..

In order to develop the most effective and economical environmental monitoring program, transfer pathways and critical groups are well defined and identified. Fig. 3 shows the pathways of exposure in uranium mining areas.

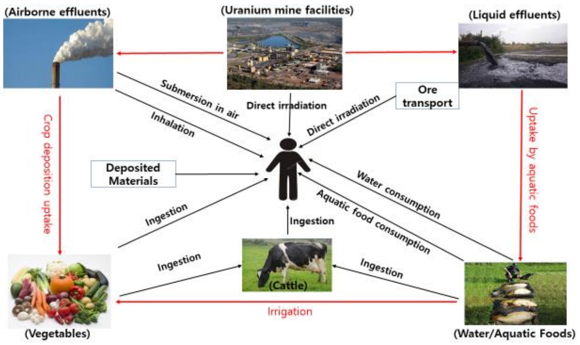

Fig. 3. Pathways of exposure in uranium mining areas.

When designing an environmental monitoring program, the monitoring program should deal with the transfer pathways identified during the pre-operational phase. It should be also take into account the information on background concentrations and on levels of discharge. The design of the monitoring program should also be reconsidered from time to time in order to incorporate new information and to reflect update monitoring technology. The proper design of a sampling program and the choice of sample media are essential to achieve the monitoring objectives. Water sampling is particularly important, since most of population in uranium mining areas in Tanzania use groundwater to serve as drinking water. Also the water is used for irrigation. Therefore, groundwater monitoring is essential for both operating and closed facilities. Atmospheric monitoring programs generally focus on airborne particulates and radon. Finally the gamma radiation monitoring the surrounding area is necessary in order to check an abnormal operation of mining facilities.

3. Conclusions

Tanzania faces some challenges in establishing the national environmental radiation monitoring program. At present, pre-operational monitoring has been carried out by the Russian operator under TAEC's supervision to get baseline data and the basic information for the development of appropriate monitoring and surveillance program during operation. This preliminary study will be very useful for developing our national environmental radiation monitoring program for uranium mining and milling areas, reflecting the domestic conditions and in line with international safety standards.

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