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Evaluation of Radiological Impact of Abandoned Uranium Mining in Mika, Nigeria

*Victor Ntyak Bakut and Juyoul Kim**
Department of NPP Engineering, KEPCO International Nuclear Graduate School,
658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014
**Corresponding author: jykim@kings.ac.kr*

1. Introduction

In Nigeria's northeast, there are several mineral resources, mainly uranium, and there are a number of commercially viable occurrences that show possible mineralization [1]. The Nigerian Uranium Mining Company (NUMCO), with the intention of exploring and utilizing all accessible uranium ore resources, started uranium exploration in the 1970s. In northeastern Nigeria, close to the Cameroonian border, exploration activities ranging from reconnaissance to semi-detailed levels covered over 112,346 km^2. Basement complex rocks cover notable regions including Gubrunde, Mika (114 ppm), and Ghumchi (2,000 ppm) [2]. In the Mayo Lope syncline, Bima Sandstone sediments of Bille and Passam Hills reveal uranium concentrations of 1,826 – 2,375 ppm, respectively. Mika holds an estimated uranium reserve of 52T eU at 0.63% eU grade, 130m deep [3]. A past open pit small-scale mining in Mika raises concerns among residents. Therefore this study examines the specific consequences of abandoned uranium mine site in Mika.

2. Methods Materials

Mika is positioned at latitude 8˚58′34.5″N and longitude 11˚37′34.81″E in Taraba State's Yorro Local Government Area (LGA) in Northeastern Nigeria as shown in Figure 1. Yorro's landscape is characterized by undulating and mountainous terrain, with around a quarter of the land suitable for agriculture. It is part of the Shebshi Mountain range extending into Cameroon. Settlements in Yorro LGA are dispersed, composed of farmsteads with thatched huts and fenced compounds of live plants known as Kerina. Sandy loam soil develops on basement complex rocks, and vegetation varies from tall trees at mountain bases to shrubs on hillslopes and grasses on peaks. The region boasts mineral resources including iron ore and gemstones. Hunting, farming, cattle rearing, and trading are common activities, cultivating yam, maize, groundnut, guinea corn, Bambara nut, millet, tiger nut, and cassava [4]. The climate features about seven months of dry and five months of wet seasons. Annual precipitation is approximately 100 mm, with August as the wettest and January as the coldest month.

Figure 1. Mika uranium mine location, Yorro LGA-Nigeria [5]

The study conducted a comprehensive assessment of radiological impacts from airborne emissions at the Mika uranium mine site using the MILDOS-AREA computer code. This specialized software is designed to evaluate potential health hazards stemming from airborne emissions during uranium recovery, with a primary focus on the radiological risks associated with ^{238}U and ^{232}Th, along with their decay series [6]. The Gaussian plume model, incorporated in MILDOS, was utilized to analyze the dispersion of radionuclide pollutants continuously released into the atmosphere. The software encompasses seven distinct source types, such as point, area, well fields, packaging, and land application, tailored for uranium mining methods. The study specifically considered point and area sources for this research. Input source terms, including yellowcake, ore pad, grizzly dump hopper, and tailings, were examined (as shown in table 1). The dispersion model required various meteorological data, such as stability class, wind speed, mixing height, ambient temperature, and rainfall rate, for precise calculations. Figure 2 shows the windrose for 30 years.

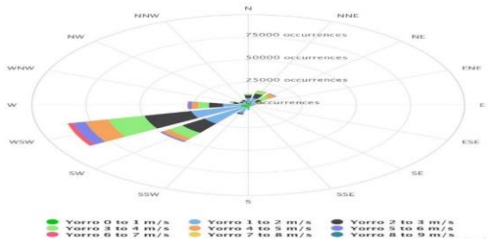

Figure 2 illustrates a windrose diagram for Mika site, comprising meteorological data spanning from 1993 to 2023. It indicates that the most common wind direction is from the west-southwest, and the prevailing wind speed ranges from 1m/s to 2m/s.

MILDOS-AREA relies on comprehensive data about potential receptors exposed to radioactive emissions. A receptor includes local residents, workers, and any population in the proximity of emission sources. The study focused on four hypothetical receptors near Mika's uranium mining site, strategically placed downwind to maximize dose reception. In addition, exposure pathways considered includes inhalation, cloud shine, and ground shine, as well as dose coefficients based on ICRP and IAEA standards.

Table 1 provides a summarized overview of input parameters, their descriptions, and the corresponding references utilized for inputting data into the MILDOS software for the purpose of modeling.

Items	Values/Description	Reference
Individual receptor considered	Fence Boundary NE, Grazing Area ENE, Nearest Residence NE, Nearest Village ENE	Assumed
Source types	Yellowcake stack, Ore pad, Grizzly dump hopper, Tailings 1, Tailings 2	Assumed
Radionuclide activity concentrations: ^{238}U, ^{232}Th and their radioactive decay products	^{238}U: 3 Bq/g ^{232}Th: 2 Bq/g	Table 1 [3]
Plume Rise: momentum driven Effluent exit velocity (m/s) Inside Stack diameter	2 1.5	Default values
Metrological parameters: Seasons Rainfall Rate (mm/yr) Anemometer height (m) Ambient Temperature (K)	2 (Wet and Dry) 100 10 28.3	Default values

3. Results and Discussion

The primary radiation source of concern is the tailings as shown in Figure 3, a byproduct of surface mining operations. Tailings are waste rock materials containing concentrated radioactive elements and their decay products, leading to elevated radiation levels in the vicinity. Surface mining, as conducted at the Mika site, can have significant environmental repercussions due to the large quantity of waste rock generated. Proper waste disposal methods are crucial to mitigate the radiological risks, ensuring the safety of nearby communities and the environment. Effective management of these waste rock materials is essential.

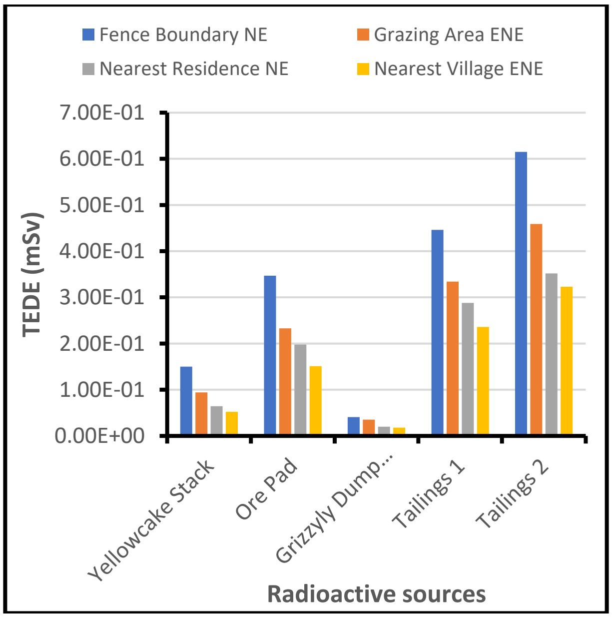

Figure 3 displays radiation doses from various source terms within permissible levels for standard mining activities. Tailings 2 records the highest dose, followed by tailings 1 and the ore pad.

At the Mika uranium mine, the fence boundary, located 1.2 km from the sources, receives an annual Total Effective Dose Equivalent (TEDE) of approximately 1.6 x 10^{-1} mSv/yr as shown in Figure 4, which is below the International Atomic Energy Agency (IAEA) recommended limit of 1 mSv/yr for public exposure [7]. The graph illustrates a consistent reduction in doses as the receptor distance from the mining site increases. This suggests that the population residing 3 km away from the Mika mining area is within safe limits, and the environment remains suitable for habitation. Figure 5 offers a detailed depiction of the source term positions, emphasizing the prevalent west-southwest wind direction, and the distribution of receptors within the study area. The initial year records the highest dose of 1.6 x 10^{-1} mSv/yr at the fence boundary, gradually decreasing to 7.82 x 10^{-2} mSv/yr at the nearest residence.

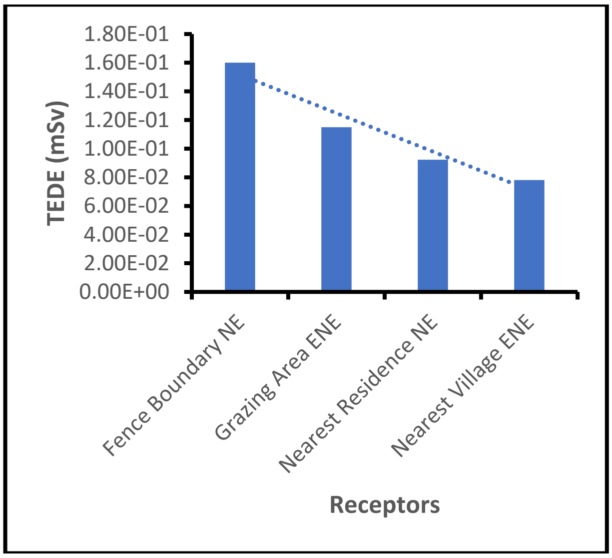

Figure 4 illustrates the decline in radiation impact as distances from the source increase. The fence boundary NE, the closest receptor, received the highest TEDE, while the nearest village ENE received the lowest TEDE dose.

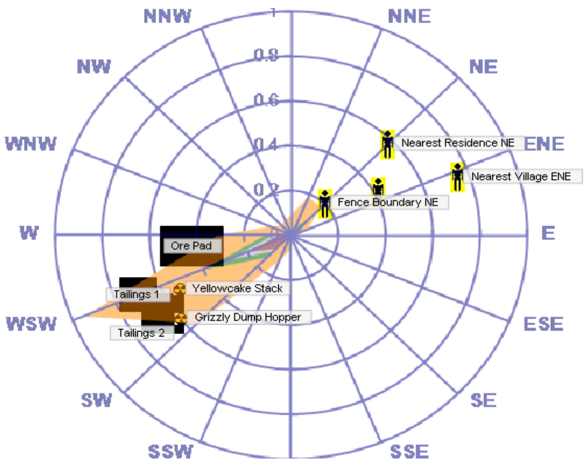

Figure 5 provides a comprehensive overview of the source term locations, the dominant west-southwest wind direction, and surrounding receptors around Mika.

4. Conclusion

Surface mining operations have a significant impact on the environment due to the substantial amount of waste rock produced compared to the extracted ore. This high ratio of waste rock to ore results in a large surface footprint. It's important to note that this waste rock can pose radiological concerns as a secondary source. Waste rock contributes to radiological concerns through various pathways. Firstly, it can directly generate dust and release radon, which is a radioactive gas. Additionally, waste rock can indirectly contribute to the dispersion of radionuclides. This can occur through releases to surface water and groundwater, which may then distribute these radionuclides to surrounding areas. Overall, waste rock from surface mining operations can have direct and indirect implications for radiation exposure. The management and mitigation of radiological risks associated with waste rock are important considerations in ensuring environmental and public safety.

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