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A Study to Determine Clearance Levels of Radioactive Wastes in Kenya

Zaphania O. Mukaka[a]*, Sung Il Kim[b]
[a]Department of Nuclear and Quantum Engineering, KAIST, Yuseong-gu, Daejeon 305-701, Republic of Korea
[b]KINS, 62 Gwahak-ro, Yuseong-gu, Daejeon 305-338, Republic of Korea
*corresponding author: mukakazaphs@kaist.ac.kr

1. Introduction

Radiation sources have been in use in Kenya since colonial times. The first radiation protection law in the country was established in 1948 and was called "Radiological Protection Ordinance-1948." Under this law, the Radiological Protection Board was established to regulate the use of radiation sources in the then British Protectorate. In post-independence Kenya, the Radiation Protection Act (Cap 243 of the Laws of Kenya) came into force on 1st November, 1984 after being passed by Parliament on 29th December, 1982. On 25th November, 1986, the Radiation Protection Board was established to regulate all radiation-related activities in the country [1].

In the 50 years since, key radiation sources have found usage in medical, industrial, agricultural and research applications in Kenya according to records from the Radiation Protection Board and Ministry of Health [2].

Once radioactive sources have outlived their usefulness in their respective applications, they transition to radioactive waste. Such waste has to be stored or disposed according to the regulatory body's regulations and in conformity with the As low As Reasonably Achievable (ALARA) principle. Due to lack of a radioactive waste disposal facility in Kenya, radioactive wastes are stored in a bonded warehouse until such a time when their activity is low and they meet the criterion for clearance.

The International Atomic Energy Agency (IAEA) has established activity concentrations of radionuclides to act as a universal guideline or standard for clearance in member countries. Radioactive wastes whose activity would yield a trivial risk to the people and environment, i.e. with an annual dose below 10 μSv are usually cleared from regulatory control with no further regulatory control mechanisms being taken [3].

The Radiation Protection Board currently depends on the IAEA's generic clearance level activity concentrations for purposes of clearing the radiation wastes within its inventory. However, the IAEA's standard generic clearance level values give globally accepted reference values, and, as such do not include a particular country's site-specific parameters.

This study aims to determine activity concentrations of radionuclides in the Kenyan inventory that correspond to the clearance level dose of 10 μSv/a as set by the IAEA. The RESidual RADioactivity (RESRAD) computer code, an important tool developed in 1989 to aid in evaluation of sites with radioactive contamination, will aid in modeling these clearance level values using a pathways analysis method and available site-specific data from Kenya.

Afterwards, the obtained clearance level values will be compared with the IAEA's generic clearance level values of the corresponding radionuclides.

2. Methods

Radionuclides under review in this study are Am-241, Cd-109, Cf-252, Co-60, Cs-137, Fe-55, Ir-192, Mn-54, Na-22, Ni-63, Pu-238, Pu-239, and Zn-65, which are currently found in the Kenyan inventory [2]. The activity of radionuclides under review is set to the basic radiation dose limit of 10 μSv/a, which corresponds to the clearance level dose, and 1 Becquerel per gram (Bq/g) is used as the arbitrary value of activity for each radionuclide.

In addition, the 'Resident Farmer Scenario' of the RESRAD code is used, wherein all pathways contribute to the determination of the clearance levels of the radionuclides under review, as seen in Figure 1

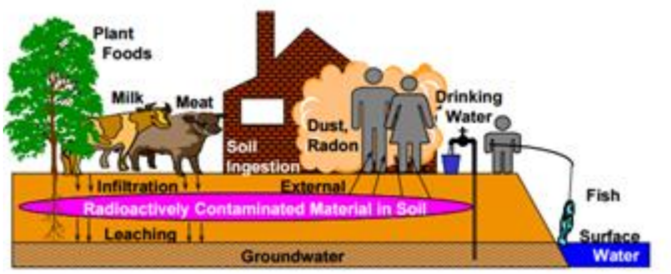

Figure 1. A schematic of pathways in the RESRAD code

All RESRAD code parameters are kept in the default mode except for those listed below that apply to the Kenyan situation.

A) Calculation times: 1 and 1,000 years.
B) Contaminated zone thickness: 3 meters.
C) Cover depth of contaminated hydrological data: 0.5 meters.
D) Fruits, vegetables and grain consumption: 800 kg per year.
E) Leafy vegetable consumption: 70 kg per year.
F) Milk consumption: 365 liters per year.
G) Meat and poultry consumption: 150 kg per year.
H) Fish consumption: 15 kg per year.
I) Other sea food consumption: 0.9 kg per year.
J) Soil ingestion: 150 g per year.
K) Drinking water intake: 800 liters per year.

Afterwards, the software is run and the output is displayed. The Single Radionuclide Soil Guideline G (i, t) corresponds to the clearance level value for each radionuclide at a time t. The clearance level value corresponds to G (i, t) when t = 0 years.

The above process is repeated till all radionuclides under consideration have been covered [4].

3. Results

Modeling of clearance level values for various radionuclides was done using the RESRAD computer code. Corresponding IAEA generic clearance level values were also tabulated against the resultant RESRAD code modeled values as shown in Table I[5].

Table I. Clearance level values of radionuclides modeled using the RESRAD code and corresponding IAEA generic clearance level values for respective radionuclides.

Radionuclides	**RESRAD code Study result [Bq/g]**	**IAEA generic clearance level values [Bq/g]**
Am-241	2.542E-1	0.1
Cd-109	1.48E-1	1
Cf-252	4.957E-1	1
Co-60	1.321E-1	0.1
Cs-137	6.227E-2	0.1
Fe-55	1.429E+2	1000
Ir-192	1.016E00	1
Mn-54	3.296E-1	0.1
Na-22	1.226E-1	0.1
Ni-63	4.397E00	100
Pu-238	2.271E-1	0.1
Pu-239	2.055E-1	0.1
Zn-65	2.778E-2	0.1

The values in Table I demonstrate that the clearance level values of radionuclides can also be modeled using the RESRAD computer code. For most of the radionuclides under study, the result falls within the acceptable limit of between a tenth and ten (10) times the IAEA's generic clearance level value i.e.

$$0.1n < n < 10n$$

where n is the IAEA's generic clearance level value for a given radionuclide under the study.

This is true for all radionuclides except Ni-63 which is less than 10% of the IAEA's generic clearance level value for Ni-63. The variance in the results of the study is due to the assumption that all parameters have equal significance to each of the radionuclides.

Figure 2 gives a schematic assessment of this study's (RESRAD code modeled values) and the IAEA's generic clearance level values for respective radionuclides.

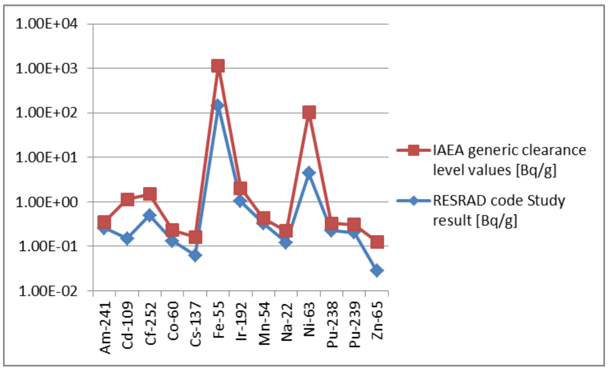

Figure 2. A schematic summary of the RESRAD code results and IAEA generic clearance level values for the given radionuclides.

4. Discussion and Conclusion

The results modeled using the RESRAD code are conservative. For most of the radionuclides in the Kenyan inventory, the values do correspond with the IAEA standard generic clearance level values, albeit with minor differences. For most of the radionuclides, the difference is within the acceptable uncertainty limit. Apart from the 10 μSv per year effective dose to individual's criterion, the IAEA model takes into account the low probability events that result in high radiation doses. For these low probability events the effective dose resulting from them should not exceed 1 mSv per year. Thus, consideration was given to doses to the skin and an equivalent dose to the skin of 50 mSv per year was duly used in estimating the clearance level activities. The RESRAD computer code model largely depends on numerous default values of the pathway analysis method based on the US geographical background. This could be the major reason as to why there exists some deviation between RESRAD code study results and the IAEA's generic clearance level values.

In addition, in the execution of the file some parameters such as aspects of hydrology, meteorology and geology were not conclusive, thus the execution had to be carried out using the default values of the RESRAD computer code. If data on these three parameters was conclusive, there is a high probability that a true reflection of the clearance levels of the given radionuclides would be formulated. This might have been achieved with a lot of certainty because a true scenario of the clearance levels depicting Kenya's landscape would be achieved. Since the IAEA does not also incorporate site-specific data to each and every region and country, and due to the fact that these parameters vary from region to region, disparities in the values from this study (based on the RESRAD computer code) and the IAEA's generic clearance level values are expected.

In conclusion, the RESRAD computer code can also be used to model clearance levels of radioactive wastes for states when conclusive hydrological, meteorological and geological data is available. This being an initial step in modeling clearance levels applicable to the Kenyan situation, when up to date hydrological, meteorological and geologic data is available, the results can be refined to yield true conclusive clearance level values of radionuclides in the Kenyan inventory.

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