Radiological Implications of Selected Fertilizers (0-0-60)

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1. Purpose:

Fertilizers play a major role in improvement of plants growth and enhancement of crop yields. One of the essential elements, potassium, helps in root growth and drought resistance of plants. Potash fertilizers are derived from potash rocks cored from earth's crust and consist of trace quantities of Naturally Occurring Radioactive Materials (NORM). With an intent of increasing concentration of potassium, manufacturers increase percentage of potash and this results in enhancement of radioactive concentrations (specifically K-40) in fertilizers.

The state of Mississippi is one of the agriculture based states in the U.S. and ~20% of its workforce are directly or indirectly involved with farming industry and may be handling fertilizers as part of their job. It is vital that fertilizers are evaluated for radioactivity levels as potassium enriched fertilizers may contain elevated levels of NORM and can pose health hazards to farm workers.

2. Methodology:

2.1. Sample collection and preparation: Fifteen bags of 0-0-60 fertilizer were collected from local market. 1- 2 kg of fertilizer was scooped from each bag and was transferred to individual aluminum pans and then dried at 110^0 C for 24 hours. Each sample was then filled into 0.5 L Marinelli beaker, weighed and hermetically sealed with parafilm. Sealed fertilizer samples were kept aside for 28 days to attain secular equilibrium between Rn-222 (Radon) and its daughters.

The radioactivity measurement of soil samples was conducted using a High Purity Germanium detector (HPGe detector), manufactured by Canberra, USA. The detector was interfaced with the digital spectrum analyzer (DSA-1000) (Multi-Channel Analyzer (MCA)) and operates via the Genie-2000 gamma spectroscopy software.

Prior to sample analysis, the germanium detector was calibrated for energy and efficiency using a National Institute of Standards and Technology (NIST) traceable multi-nuclide gamma standard source manufactured by Eckert & Ziegler, Atlanta, USA. Background measurements were performed by placing an empty sealed Marinelli beaker and counted for 24 hours. The specific activity of Ra-226 was derived from the photo peak 609.3 keV of Bi-214 and the photo peak 911.1 keV of Ac-228 was used to determine Th-232. K-40 was measured directly by its own photo peak at 1460.8 keV.

2.2. Theoretical Estimation of K-40

Fraction of K in K2O = 0.83

Percent of K in 50 lb (22.68kg) = 0.498

Mass of K in one bag = 11.294kg

Natural abundance of K-40 in K is 0.0117%

Mass of K-40 in one bag = 1.32 $x10^{-3}$ kg

Number of K-40 atoms (N) = 1.98 x 10^{22} atoms

Half-life ($T_{1/2}$) of K-40= 4 x 10^{16} s and Decay constant (λ) = $\frac{0.693}{T1/2}$

K-40 activity in 50 lb (22.68kg) = λ N = 3.4 $x10^{5}$ Bq

K-40 activity per one kg of (0-0-60) fertilizer = 1.5 $x10^{4}$ Bq kg^{-1}

2.3. Calculation of Absorbed Dose (D): The outdoor absorbed gamma dose rate in the air at 1 m height from the ground for the samples was estimated in $nGyh^{-1}$ using the equation below (UNSCEAR, 2008):

$$\mathrm{D(nGyh^{-1}) = 0.0417SA_k + 0.462\ SA_{Ra} + 0.604\ SA_{Th}}$$

Where D is the absorbed dose in nGy h^{-1}; SA_K,S A_{Ra}, and SA_{Th} are the specific activities of K-40, Ra-226, and Th-232 in (Bq kg^{-1}), respectively, in the fertilizers. To comply with the safety standards, the estimated dose values should be less than 59 nGy y^{-1} (UNSCEAR, 2000).

2.4. Calculation of Annual Effective Dose Rate (AEDR): The annual effective dose rate due to external exposure was estimated from outdoor absorbed gamma dose rate considering the conversion factor for adults (0.7 x 10^{-3} Sv Gy^{-1}). Individuals spend 80% of the time indoors and 20% of the time outdoors. The annual effective dose rate was estimated in μSvy^{-1} by using the following formula (UNSCEAR, 2008).

$$AEDR(\mu Svy^{-1}) = AGDR \times (0.7 \times 10^{-3}) \times (8766 \times 0.2)$$

$$AEDR(\mu Svy^{-1}) = D \times (0.7 \times 10^{-3}) \times (8766 \times 0.2)$$

World-wide average of AEDR in soils reported by UNSCEAR, 2008 is 70 μSvy^{-1}.

3. Results & Discussion:

A set of 15 samples of 0-0-60 (potash) fertilizers were analyzed for specific activities of Ra-226, h-232, and K-40 using a high purity germanium detector. Also, specific activity of K-40 was estimated considering half-life, number of atoms, and molar mass of K-40. In addition, other key isotopic activities in fertilizers (Ra-226 and Th-232) are provided in Table 1. Fig 1 provides a comparison of experimental and theoretical activities of K-40.

Table 1: Specific Activities of Key Isotopes

Specific Activity	Ra-226 (Bq kg^{-1})	Th-232 (Bq kg^{-1})	K-40 (Bq kg^{-1})
Theoretical	NA	NA	15,000± 122
Experimental	1.1 ± 0.13	0.43 ± 0.08	15,162± 962

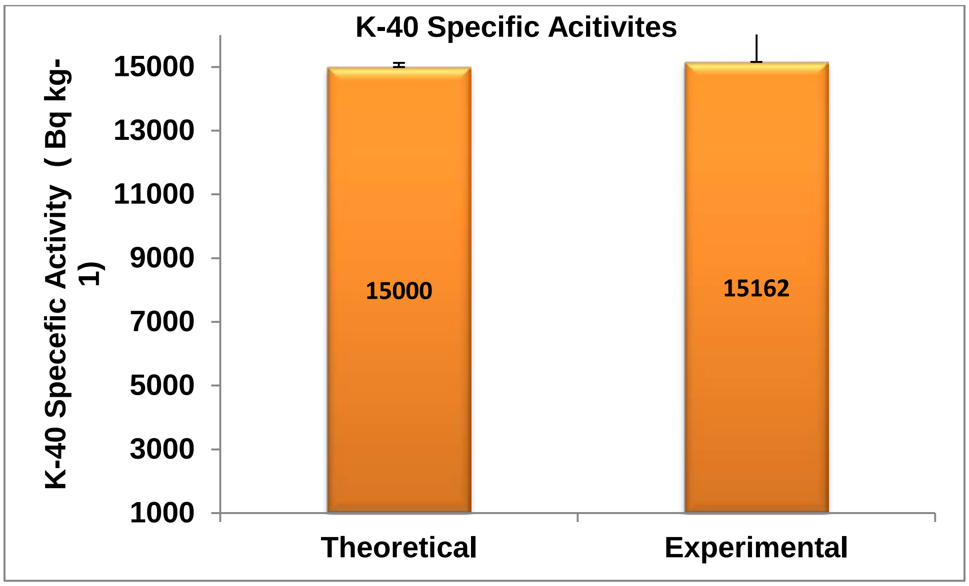

Figure 1: Theoretical and Experimental Specific Activities of K-40

Based on the obtained Ra-226, Th-232, and K-40 specific activities, radiological health hazard indicating parameters are calculated and are provided in Table 2. Also, comparison of world-wide average values of these parameters with results obtained in this study is provided in Figures 2 and 3.

Table 2: Comparison of Calculated Health Hazard Indicating Parameters with World-wide Averages

	Acceptable Limit/World-wide Average	Experimental Values
Annual Effective Dose Rate (AEDR)	70 μSvy^{-1}	776 μSvy^{-1}
Absorbed Gamma Dose Rate	59 nGy y^{-1}	633 nGy y^{-1}

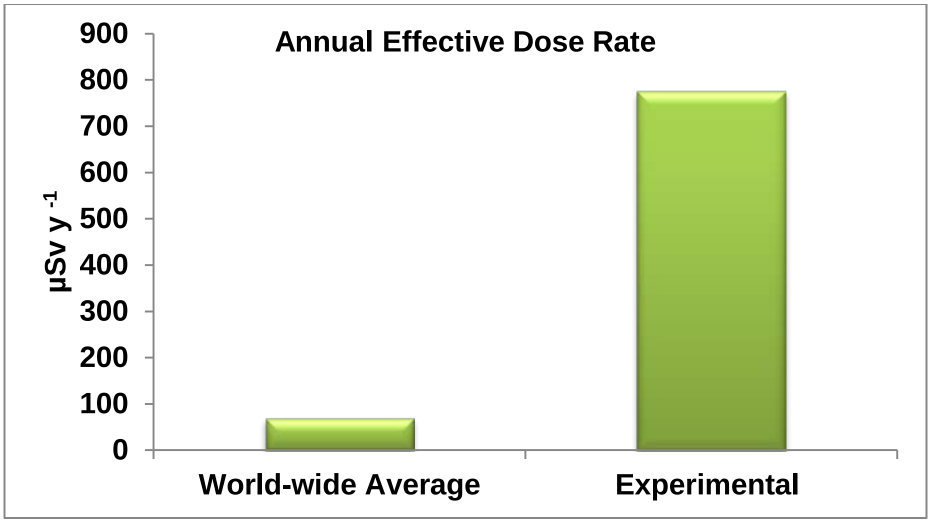

Figure 2: Comparison of Annual Effective Dose Rate (AEDR)

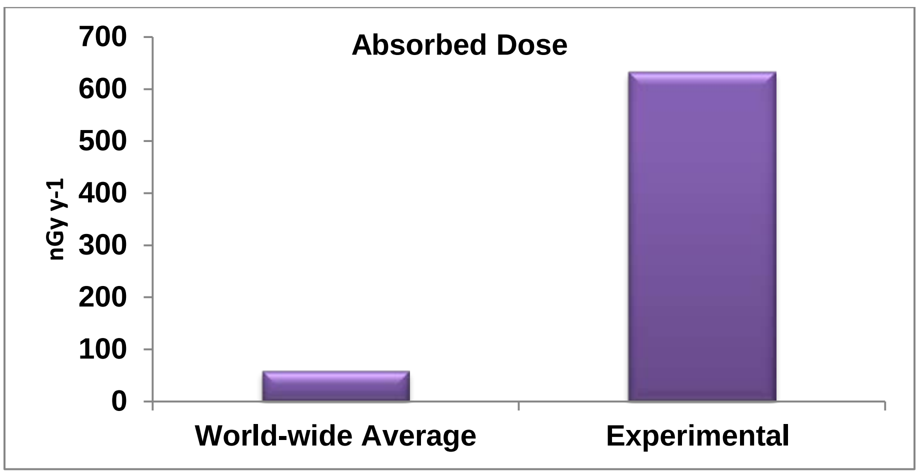

Figure 3: Comparison of Absorbed Dose Rate

4. Conclusions:

Radioactivity measurements were performed on selected fertilizers (0-0-60) and based on the obtained results, radiological health hazard indicating parameters were calculated. Obtained results suggest that fertilizers considered in this study exceed the safety limit. As fertilizers are not regulated, it is imperative that regulators provide stringent recommendations/guidelines with respect to safe handling of these NORM enhanced materials.

5. Relevance to CIRMS:

This work is performed by a high-school student (9th grader) as part of his summer internship. This work is in alignment with CIRMS mission as it focuses on assessment of workers safety from radioactivity found in the environment. Also, it is suggested that some additional guidance/recommendations must be provided to workers who are handling NORM enriched fertilizers. The first author would like to pursue degree in Health Physics/Nuclear Engineering and take-up research position in a National Laboratory.

References:

1. UNSCEAR 2000 Radiation Sources and effects of ionizing radiation New York: United Nations Scientific Committee on the Effect of Atomic Radiation

2. UNSCEAR 2008 Radiation Sources and effects of ionizing radiation New York: United Nations Scientific Committee on the Effect of Atomic Radiation