ACTIVITY CONCENTRATIONS OF ^{238}U, ^{232}Th, AND ^{40}K RADIONUCLIDES IN SOME SOUTH AFRICAN MEDICINAL HERBS AND THEIR EFFECTIVE INGESTION DOSES

by

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Measurements of ^{238}U, ^{232}Th, and ^{40}K activity concentrations in some commonly used medicinal plant parts have been performed for radiation hazard assessment and as baseline data for health risk monitoring in South Africa and other countries. The mean activity of ^{238}U, ^{232}Th, and ^{40}K was found to be 43.3 Bqkg^{-1}, 33.7 Bqkg^{-1}, and 180 Bqkg^{-1} in Sclerocarya birrea; 85.0 Bqkg^{-1}, 75.3 Bqkg^{-1}, and 316.7 Bqkg^{-1} in *Cymbopogon citratus*; 47.3 Bqkg^{-1}, 37.0 Bqkg^{-1}, and 773.3 Bqkg^{-1} in *Neorautanenia ficifolia*; 25.7 Bqkg^{-1}, 30.0 Bqkg^{-1}, and 510 Bqkg^{-1} in *Kigelia africana*, respectively. The estimated annual effective dose due to ingestion ranged from 0.013 mSv (*Kigelia africana*) to 0.032 mSv (*Cymbopogon citratus*), well within recommended limits for the members of the public. Although the values revealed no hazards from a radiological point of view, it represents a valuable database for regulatory functions.

Key words: effective dose, medicinal plant, radiation hazard, South Africa

INTRODUCTION

Medicinal plants are culturally and economically valuable resources for a large proportion of South Africa's population [1, 2]. They formed the basis of many modern drugs, nutraceuticals, and food supplements [3, 4]. Additionally, they are an abundant source of secondary metabolites (bioactive constituents) crucial to improving human health [1, 5]. Notably, over 50 % of drugs approved globally in the last 30 years are from natural products, with plants as the dominant source [6].

The therapeutic properties of the plants are partly due to active constituents formed by the inorganic mineral element composition in the plants [7]. These inorganic elements, including the unstable ones (radionuclides), accumulate in various parts of the plant's tissue through soil-water by root uptake and the aerial parts by direct deposition [8-10]. The radionuclides ultimately find their way into the human body through ingestion, representing an internal source of radiation exposure [8, 11, 12].

A medicinal plant or herbal preparation with high radioactive content compounded by its probable long-term usage can result in serious health effects such as chronic lung cancer and leukaemia [13-15]. Hence, the need to understand the distributions of natural radionuclides in the plants and their products to accurately assess the radiological health implications to consumers.

The considerable growth in traded plant material on traditional markets in various parts of South Africa and the sustained demand in their crude, unprocessed forms, including the potentiality that new remedies will be developed and commercialized in the future [15], has also increased interest in the radionuclides content.

Therefore, activity concentrations of naturally occurring radionuclides (^{238}U, ^{232}Th, and ^{40}K), in samples of medicinal plant materials within South Africa, were determined to evaluate the annual effective doses due to ingestion.

MATERIALS AND METHODS

Purchase and preparation of plant material

Medicinal plant materials, supplied within the KwaZulu-Natal province (South Africa) precinct and identified by a trader practising his trade at informal *muthi* markets in the Midlands region of the area, were collected for this study. The trader provides the names and samples of parts used to manage specific health conditions, tab. 1. These plants were recommended to patients who requested treatment following diagnosis by Western healthcare practitioners, or based on personal knowledge and experience from patients' complaints.

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Table 1. The local names, plant parts investigated, and the traditional use

Sample code	Traditional name	Species	Parts examined	Medicinal uses
MGA1 MGA2 MGA3	Umganu	*Sclerocarya birrea*	Stem bark	Relieve stomach discomfort Treatment of treats dysentery, diarrhoea, and rheumatism
SIG 4 SIG 5 SIG 6	Isiqunga	*Cymbopogon citratus*	Whole plant	Helpful in treating coughs, cuts, asthma, disorders, and flu
ISI 7 ISI 8 ISI 9	Isikhundla	*Neorautanenia ficifolia*	Root	Treatment of scabies, dysmenorrhea, and as an anticonvulsant
MVO 10 MVO 11 MVO 12	Umvongothi	*Kigelia africana*	Stem bark	For infertility, gynecological, and obstetric conditions

Impurities, including soil particles, were removed from the plant materials, and dried for several days at room temperature until there was no detectable change in mass. The dried samples were finely grounded, homogenized, weighed, and sealed in Marinelli beakers for about 40 days to allow radioactive equilibrium before gamma spectroscopy. Three replicates were prepared for representative sub-sampling and better determination of the medicinal plant's activity concentration with radiological health hazards.

Determination of radionuclides content

Activity concentration of radionuclides in the plants was determined from measurements by a broad energy high purity germanium (Canberra HPGE) detector, placed inside a lead shield to minimize the effects of background radiation. The gamma-ray detector, with 25 % relative efficiency, consisted of a DSA-1000 digital signal processing system interfaced with a multi-channel analyser with Genie2000 software for spectral analysis.

To facilitate accurate quantitative measurements, the system's energy-channels relationship and efficiency calibration was performed prior to sample analysis using IAEA certified reference standards.

The standard reference, with the same geometry as the investigated samples, were counted for 28 800 seconds, after which the net area under the corresponding daughter photopeak in the energy spectrum, corrected for background spectra, was used to compute the sample radionuclide activities [16, 17].

The activity concentrations were based on the gamma peaks of ^{234}Pa (1000 keV), ^{214}Pb (351.7 keV), and ^{214}Bi (1764.5 keV) for ^{238}U, ^{228}Ac (911.2 keV), and ^{208}Tl (538.19 keV) for ^{232}Th. The activity value of ^{40}K was determined directly from the single peak of 1460.5 keV.

RESULTS AND DISCUSSION

Activity concentrations of ^{238}U, ^{232}Th, and ^{40}K

The measured activity concentrations *A* of primordial radionuclides ^{238}U, ^{232}Th, and ^{40}K from the plant's samples are presented in tab. 2. The mean concentrations of the radionuclides in this study are considered representative as the standard deviation is relatively small in each sample analysed. According to the results, the concentrations varied widely in all plant samples, largely on the order ^{232}Th < ^{238}U < ^{40}K, except for the *Kigelia africana* with higher ^{232}Th concentrations than ^{238}U. The highest concentration of ^{40}K was found in *Neorautanenia* ficifolia with 773.3 Bqkg^{-1} and the lowest 180 Bqkg^{-1} in *Sclerocarya birrea*. The higher values observed for the potassium isotope (^{40}K) compared to other radionuclides (^{238}U and ^{232}Th) agrees with previous studies [13, 18, 19] and could be attributed to its ubiquitous nature with significant plants absorption and accumulation in the studied parts [13, 20].

Table 3 compares the activity concentration of the three radionuclides with values obtained by other investigators for medicinal plants from other countries. The range of values was comparable to the present study, except for studies from Bangladesh [19], Nigeria [22], and Serbia [23], with lower values for ^{238}U and ^{232}Th, respectively. Notably, from all the studies, the values reported for ^{40}K (67-70 Bqkg^{-1}) in Nigeria were considerably lower, possibly due to the characteristics of the study region being an oil and gas production field [24].

Annual effective dose from ingestion

The annual effective ingestion dose (*AED*) to the population due to radioactivity in the medicinal plants

Table 2. The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K [Bqkg^{-1}] in each plant part sample

Medicinal plants	Parameters	*A* [Bqkg^{-1}]		
		^{238}U	^{232}Th	^{40}K
Sclerocarya birrea	Range	31-56	24-42	130-230
	Mean	43.3	33.7	180
Cymbopogon citratus	Range	54-119	46-108	140-480
	Mean	85.0	75.3	316.7
Neorautanenia ficifolia	Range	44-51	34-42	730-830
	Mean	47.3	37.0	773.3
Kigelia africana	Range	24-29	25-33	480-570
	Mean	25.7	30.0	510

Table 3. Comparison of ^{238}U, ^{232}Th, and ^{40}K values in the medicinal plants and AED with some selected studies

Country (Plant studied)	*A* [Bgkg^{-1}]			*AED* [Bgkg^{-1}]	References
	^{238}U	^{232}Th	^{40}K		
South Africa (Sclerocarya birrea)	31-56	24-42	130-230		Present study
(Cymbopogon citratus)	54-119	46-108	140-480		
				0.013-0.032	
(Neorautanenia ficifolia)	44-51	34-42	730-830		
(Kigelia africana)	24-29	25-33	480-570		
Ghana	20-47	42-71	566-1093	0.009-0.014	[12]
India	15-84	15-74	145-354	0.015-0.077	[17]
Bangladesh	4.12-28.2	3.02-17.6	363 -1097	0.006-0.018	[18]
Egypt	<0.1-20.7	<0.71-29.3	172-1181	0.002-0.509	[21]
Nigeria	14.7-16.2	7.0-11.4	67-70	–	[22]
Serbia	0.6-8.2	1.7-15.1	126-1243	–	[23]

was computed from the mean activity concentrations A_i [Bqkg^{-1}] of the radionuclides by applying a dose conversion factor DC_i (mSvBq^{-1}) of 2.8 10^{-4}, 2.3 10^{-4}, and 6.2 10^{-6} mSvBq^{-1} for ^{238}U, ^{232}Th, and ^{40}K, respectively. The following expression was used for the calculation [25]

$$AED\ (\text{mSv})$$
$$(A_U DC_U \quad A_{\text{Th}} DC_{\text{Th}} \quad A_{\text{K}} DC_{\text{K}})U$$

where, U is the annual consumption rate of traditional medicine 0.75 (kg per year) in South Africa [15].

The *AED* varied from 0.013 mSv to 0.032 mSv, tab. 3, with an annual dose distribution of 0.013 mSv (*Kigelia africana*), 0.016 mSv (*Sclerocarya birrea*), 0.020 mSv (*Neorautanenia ficifolia*), and 0.032 mSv (*Cymbopogon citratus*). Figure 1 represents the *AED* by percentage due to the intake of the medicinal plants. Comparing these values with the world annual average dose (0.29 mSv) for ingestion of natural radionuclides in medicinal plants set by UNSCEAR [26] and those from other countries, tab. 3, it is observed that the values obtained are far lower than that given in the UNSCEAR report and within levels reported for most countries. This result indicates no significant radiological health effect to the public, nevertheless, sustained intake or the use of plants from areas with higher natural background radiation than examined can increase the internal exposure levels above the acceptable limit-consequently, the possibility of inducing damage.

CONCLUSION

The concentrations of natural radionuclides ^{238}U, ^{232}Th, and ^{40}K in some South African medicinal plants with the effective ingestion dose were evaluated to assess the radiation hazards for the people. The presented results suggest no health implications and a useful pedestal for monitoring and developing guidelines for managing natural radionuclides in medicinal plants and controlling public exposure.

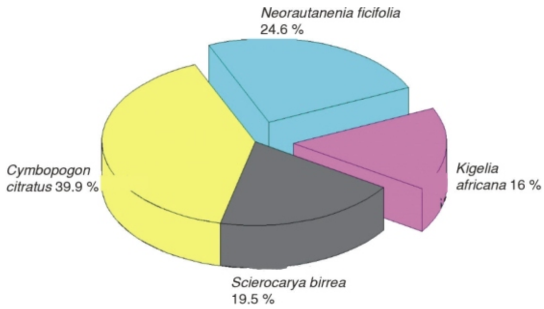

Figure 1. Average effective ingestion dose values for consumers in investigated plant samples

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AUTHORS CONTRIBUTIONS

All authors contributed to the study's conception and design. Funding acquisition, resources, and supervision were by N. Chetty. Material preparation, data collection, and analysis were performed by B. Adeleye. The first draft of the manuscript was written by B. Adeleye, and both authors read and approved the final version to be published.

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Бамисе АДЕЛЕЈЕ, Навен ЧЕТИ

КОНЦЕНТРАЦИЈЕ АКТИВНОСТИ ^{238}U, ^{232}Th И ^{40}K РАДИОНУКЛИДА У ЈУЖНОАФРИЧКОМ ЛЕКОВИТОМ БИЉУ И ЊИХОВЕ ЕФЕКТИВНЕ ДОЗЕ УСЛЕД ИНГЕСТИЈЕ

Мерења концентрација активности ^{238}U, ^{232}Th и ^{40}K у неким деловима лековитог биља које се најчешће користи вршена су ради процене опасности од зрачења и као основни подаци за праћење здравственог ризика у Јужној Африци и другим земљама. Утврђено је да су средње активности ^{238}U, ^{232}Th и ^{40}K: у *Sclerocarya birrea* 43.3, 33.7 и 180 Bqkg^{-1}, у *Cymbopogon citratus* 85.0, 75.3 и 316.7 Bqkg^{-1}, у *Neorautanenia ficifolia* 47.3, 37.0 и 773.3 Bqkg^{-1} и у *Kigelia africana* 25.7, 30.0 и 510 Bqkg^{-1}, респективно. Процењена годишња ефективна доза услед ингестије кретала се од 0.013 mSv (*Kigelia africana*) до 0.032 mSv (*Cymbopogon citratus*), што је сасвим у границама препорученим за становништво. Иако вредности нису откриле никакве опасности са радиолошке тачке гледишта, оне представљају вредну базу података за регулаторне функције.

Кључне речи: ефективна доза, лековита биљка, опасност од зрачења, Јужна Африка