Public Dose Evaluation from Frequent Usage of Consumer Products Containing Naturally Occurring Radioactive Materials

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Introduction

- Several consumer products containing small amounts of incorporated radionuclides are generally accessible for public use worldwide.
- However, frequent use of these products exposes the public to risk of unjustified radiation exposure which is against the standard of radiation protection.
- Recent ICRP recommendations are based on the reasonable assumption that there is no safe level of radiation exposure, and that even the least amount of exposure might generate stochastic effects like cancer.

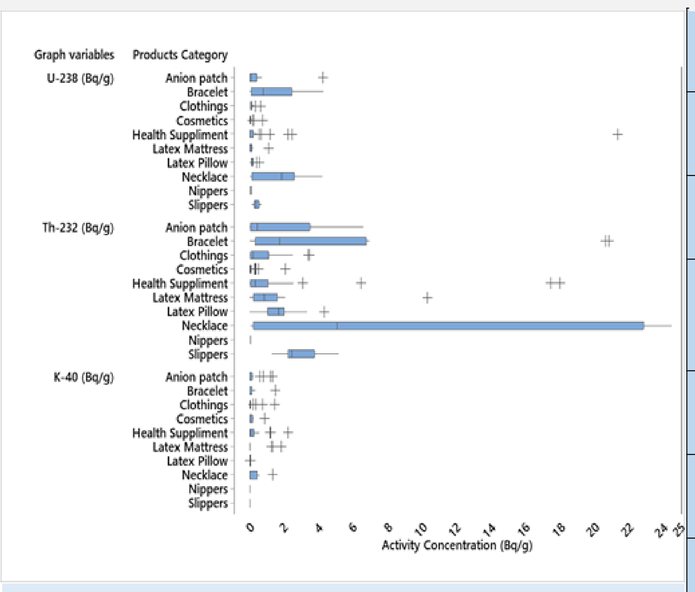
Objective

The objective of this study is to assess public exposure dose from widespread use of consumer products containing naturally occurring radioactive materials (NORMs) under various usage conditions. External and Internal doses as well as age-dependent TEDE was evaluated.

Methodology

Activity Concentration Data

- Data obtained were analyzed using Boxplot
- The lower, median and upper whiskers were used as input to reduce the outliers in data
- Normalized value was used for dose evaluation.



Computer code comparison

Code	Models	Assumptions	Calculation	Scope
Microshield	ANSI/ANS-6.1.1-1977 standards	Point Kernel	Gamma-ray shielding and dose prediction.	External Dose
IMBA	Dosimetric Biokinetic	ICRP Publications 60 and 68, 26 and 30 or 10CFR 835	Dosimetric Bioassay	Internal Dose

Hypothetical Usage Scenario

Estimations for usage location, average normal usage time and exposure pathways were made for various consumer products incorporating NORMs as shown in table 1

Product Categories	Usage Location	Usage Time /day	Exposure Pathways
Pillows	Head, neck	7h 50min	Inhalation
Latex Mattress	Whole body	7h 50min	Inhalation
Clothing	Depending on usage	24h	Inhalation
Necklace	Neck	8h 7 min	Inhalation
Bracelets	Hand	8h 7 min	Inhalation
Amnion Patch	Body for wound covering	8h 7 min	Inhalation and Ingestion
Cosmetics	Face and Body	8h 7min	Ingestion
Dippers	Depending on usage	20 min	Inhalation
Slippers	Foot wares	5h 1 min	Inhalation
Health Supplements	Waist, abdomen	5h 1 min	External Inhalation

Age Dependent Dose Coefficients

- Age-dependent effective dose coefficient values from ICRP 119 are shown in Table 2 .
- External radiation exposure and inhalation rate were calculated from ICRP 144 and ICRP 1975.

Nuclide	Absorption Type	1 Year	10-Year	Adult
Effective Dose Coefficient for Inhalation (Sv/Bq)				
^{238}U	F	1.3×10^{-6}	7.3×10^{-4}	5.0×10^{-7}
	M	9.4×10^{-6}	4.0×10^{-4}	2.9×10^{-6}
	S	2.5×10^{-6}	1.0×10^{-4}	8.0×10^{-6}
^{232}Th	F	2.2×10^{-6}	1.3×10^{-4}	1.1×10^{-4}
	M	8.1×10^{-5}	5.0×10^{-5}	4.5×10^{-5}
	S	5.0×10^{-5}	2.6×10^{-5}	2.5×10^{-5}
^{40}K	F	1.7×10^{-8}	4.5×10^{-9}	2.1×10^{-9}
Effective Dose Coefficient for Ingestion (Sv/Bq)				
^{238}U	-	1.2×10^{-7}	6.8×10^{-8}	4.5×10^{-8}
^{232}Th	-	4.5×10^{-7}	2.9×10^{-7}	2.3×10^{-7}
^{40}K	-	4.2×10^{-8}	1.3×10^{-8}	6.2×10^{-9}
Effective Dose Coefficient for External Exposure extracted and calculated from ICRP 144) (Sv/h per Bq/g).				
^{238}U		1.48×10^{-16}	1.15×10^{-16}	9.44×10^{-17}
^{232}Th		5.06×10^{-16}	4.02×10^{-16}	3.37×10^{-16}
^{40}K		4.39×10^{-13}	3.79×10^{-13}	3.46×10^{-13}
Inhalation rate extracted from ICRP recommendations 1975, 2004.				
1 m3/h or 24 m3/d equivalents to 1225 g/h				
m^3/d		5.1	15.2	22.2
m^3/h		0.2125	0.63	0.925
g/h		260	775	1331.13

Total Effective Dose Equivalents

- Analytical method was employed in calculating TEDE
- The $TEDE_{total}$ (mSv/y) can be expressed mathematically as:

$$\boldsymbol{TEDE_{total} = D_{ext.} + D_{int(inh)} + D_{int(ing)}} \quad (1)$$

$\boldsymbol{TEDE_{total}}$ The total effective dose equivalent (mSv/y)

$\boldsymbol{D_{ext.}}$ External dose from direct gamma radiation

$\boldsymbol{D_{int(inh)}}$ Internal dose due to inhalation pathway

$\boldsymbol{D_{int(ing)}}$ Internal dose due to ingestion pathway

The annual effective dose from inhalation ($\boldsymbol{D_{int(inh)}}$) and ingestion ($\boldsymbol{D_{int(ing)}}$) can be calculated using the expression

$$D_{int(inh)} = D_R \times I_R \times H_t \times DC_{inh} \quad (2)$$

$$D_{int(ing)} = D_R \times I_R \times I_T \times DC_{ing} \quad (3)$$

where:

$\mathbf{D_R}$ Is the measured activity concentration of inhaled or ingested radionuclide (Bq/g)

$\boldsymbol{I_R}$ Inhalation and ingestion rate (g/h)

$\boldsymbol{H_t}$ Exposure time to contaminated air (h/y)

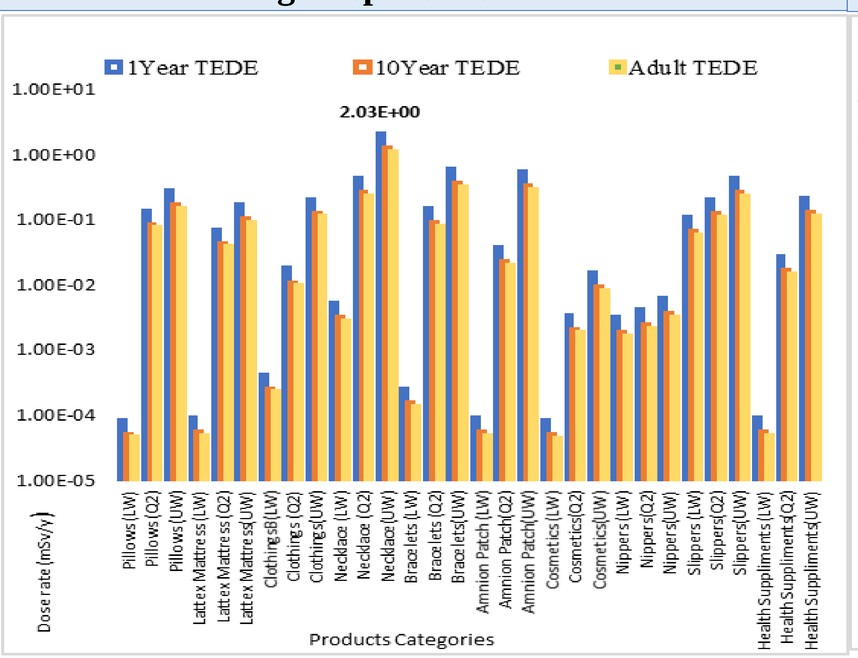
$\boldsymbol{I_T}$ Time of Ingestion rate (h/y)

$\mathbf{DC_{inh}}$ Inhalation dose coefficient (Sv/Bq)

$\mathbf{DC_{ing}}$ Ingestion dose coefficient (Sv/Bq)

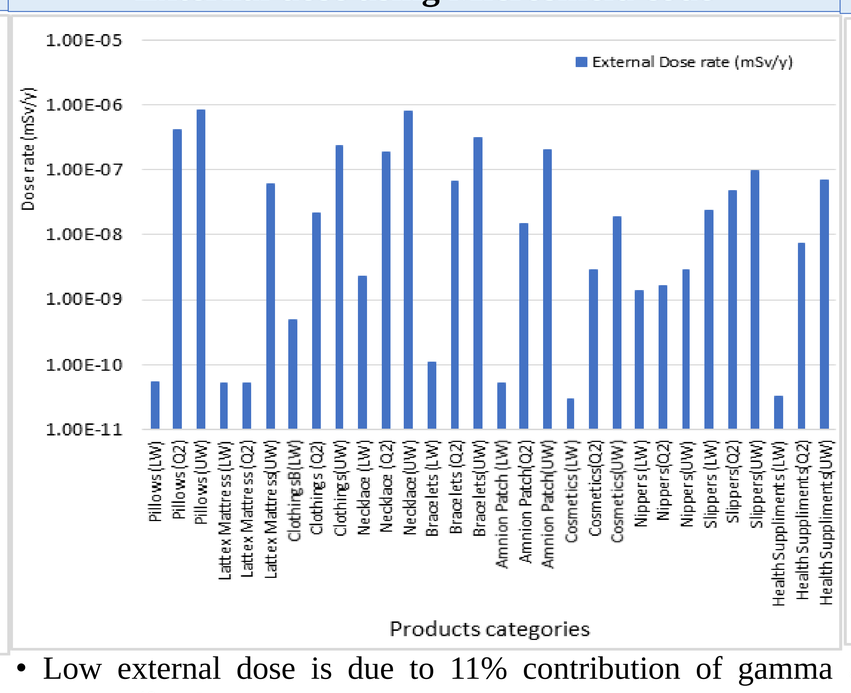
Results

Age Dependent TEDE



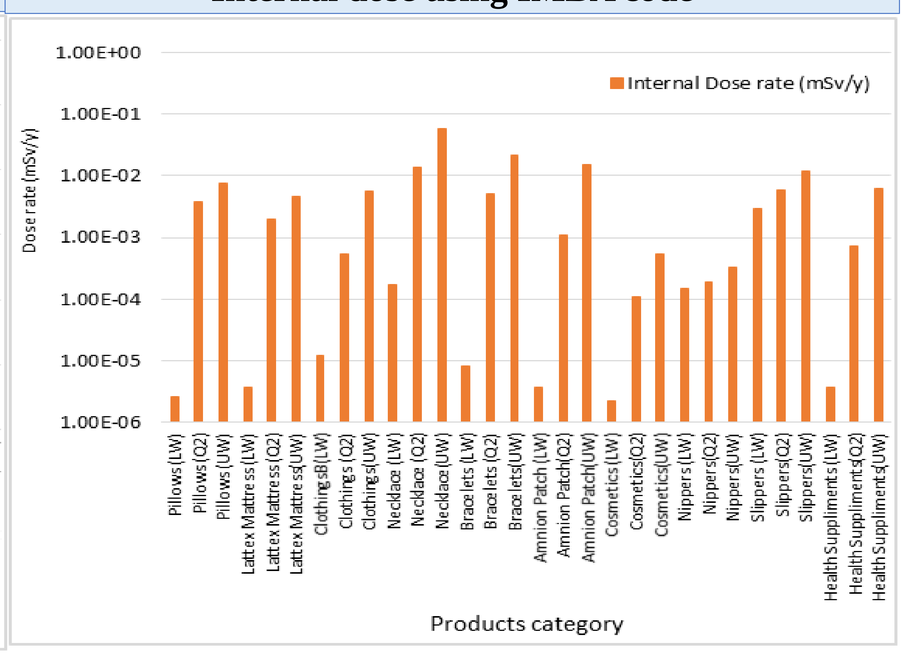
- The TEDE reported at the upper whisker of necklace are all above the recommended ICRP public dose limit of 1 mSv/y.
- TEDE is high in infants than 10 years old children and adults due to sensitivity of tissue.

External dose using Microshield code



- Low external dose is due to 11% contribution of gamma during ^{40}K decay.
- The external doses are all below the ICRP dose limit of 1 mSv/y.

Internal dose using IMBA code



- High internal dose is attributed to inhalation of radon and thoron during decay of ^{238}U and ^{232}Th.
- The internal doses are all below the ICRP public dose limit of 1 mSv/y.

Conclusion

- The ICRP dose limits are intended to act as a boundary conditions, preventing deterministic consequences while reducing stochastic impacts.
- If the public dose is greater than 1 mSv/y, public safety measures must be implemented.
- Results using analytical calculation show highest TEDE received from necklace products for various age groups, all above the recommended dose limit.
- External and internal exposure doses evaluated using Microshield and IMBA codes are all below the recommended public dose limit of 1 mSv/y.