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Evaluation of the Justification for Using Consumer Products and Geological Samples Containing Radioactive Substances

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ABSTRACT

A strategy was developed at the Jožef Stefan Institute to evaluate the justification for using consumer products containing radioactive substances and geological samples (rocks and minerals) that contain naturally occurring radioisotopes [1]. Some commercially available products can contain radioactive material and are freely available to individuals without any control by administrative authorities; such products are referred to as consumer products [2]. It is necessary for the authority to evaluate whether there is a valid justification for their continued use when these products are on the market or if they are already in use.

1 INTRODUCTION

It can happen that, for example, at the post office, an alarm goes off due to increased radioactivity detected in one of the parcels. The Regulatory Authorities (SNSA) and authorized experts are activated. Usually, it turns out that the source of the radioactivity is either a geological sample or a consumer product containing radioactive substances in the parcel.

A similar situation may occur at an airport or at a nearby flea market, where the radioactivity symbol might be spotted, or someone familiar with such objects might recognize, for example, a watch with a radioactive dial.

Finding such an object and realizing it is radioactive can raise questions about its danger to the public. What are the criteria for something to be harmful, and what does the legislation say about them? What are the radiological properties and radiotoxicity of such products? What methodology should be used for exposure calculation? Who will take action? Who is responsible, and how will they act?

All of these are valid questions, and it turns out that in most countries, the answers are not clearly defined or provided by Authorities. For this purpose, the SNSA founded a project to establish the criteria and conditions for the safe use of consumer products.

2 CONSUMER PRODUCTS

Some commercially available products can contain deliberately incorporated radioactive material and are freely available to individuals without any control by administrative authorities; such products are referred to as consumer products.

For greater clarity and ease of management, consumer products were divided into groups based on their intended use and radioactive properties:

a – Products with added H-3 as a light source (jewellery, watches, key chains, self-luminous tubes...)

b – Products with added Ra-226 (watches, products with dials...)

c – Glassware, antique or other kitchen accessories with yellow or green colour with elevated uranium concentrations (glass, glaze...)

d – Gas mantles with Th-232

e – Static discharge devices with Po-210

f – Welding electrodes with added Th-232

g – Precious or semi-precious stones whose properties have been improved by irradiation

h – Various electronic components (laser rangefinder, bulbs, starter, spark plugs...)

i – Various historical items (documents and tokens) containing C-14 and Pm-147

j – Miscellaneous (linen, blankets, clothes, bracelets, necklaces, "bioenergy" cards...) containing natural radionuclides

k – Geological samples (samples containing radioactive elements of the uranium and thorium decay series are, e.g. sandstone, orlite, monazite, sand, scooterudite, torbernite, uranium thorianite, uranophane, uranium and thorium ore, etc.).

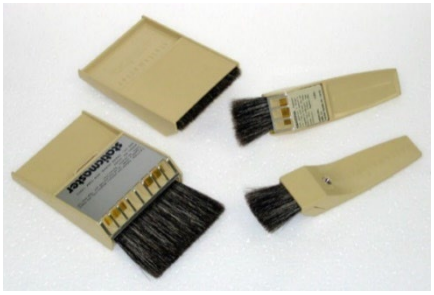
The last group – geological samples – are not consumer products but are treated as such for the sake of this project since they can be easily found in different markets. For illustration, photos of some examples of product groups are presented below.

a – Products with added H-3

b – Products with added Ra-226

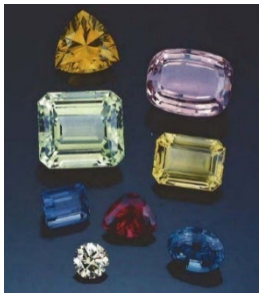
c – Kitchen accessories containing U-238

d – Gas mantles containing Th-232



e – Static discharge devices containing Po-210

f – Welding electrodes containing Th-232



g – Irradiated precious or semi-precious stones

h – Various electronic components

j – Products containing natural radionuclides

k – Geological samples

3 THE METHODOLOGY

3.1 Generic criteria / Acceptability criteria when using consumer products

According to national legislation [2, 3] and international guidelines [4, 5], the annual effective dose due to the use of consumer products should not exceed the order of magnitude of 10 μSv. For this study, this value was set as the generic criteria. Since they contain naturally occurring radionuclides, less stringent criteria of 1 mSv per year were used for geological samples. Additional criteria for skin dose were adopted, with 50 mSv for geological samples and 0.5 mSv for consumer products.

Table 1: Generic criteria for the effective annual dose (E_{GC}) and the annual skin equivalent dose (H_{GC})

	E_{GC} [mSv]	H_{GC} [mSv]
Consumer products	0.01	0.5
Geological samples	1	50

To calculate accepted doses, one must know all the radiological properties of the consumer product (including the typical activity of certain products) and the way the consumer product might be used. Different scenarios were prepared for the modes of use based on scenarios proposed by RP65 [6].

3.2 Scenarios Description

RP-65 [6] describes 15 scenarios, intended for professional use of radioactive sources (e.g. in a laboratory or industry), but we have selected and adapted them for the use of consumer products among the population. We considered only the most relevant five scenarios described below. Additionally, the scenario for the exposure to radon due to the exhalation of radon from samples was considered.
We used modified parameters for the scenarios assumed in RP-65 [6]. They include exposure times, the fraction of the consumed or inhaled activity, the probability of an accident, the fire release fraction, the assumed volume of the room in which the fire starts or in which radon is released, the concentration of dust in the air, etc.
Scenarios for dose assessment were divided into normal use, accidents and disposal of the consumer products and are as follows:

Normal use of consumer products

B1.1: External exposure due to a point source at a distance of 1 m
Use of the products in the home environment, e.g., on a table or shelf in the apartment.

B1.2: External exposure due to source handling
Touching or handling the source, attaching it to the wrist, or keeping it in the pocket.

R1: Inhalation dose due to radon progeny during exhalation of radon from objects into the room
The scenario was considered for objects containing Ra-226+ or U-238N. The methodology for estimating the average net exhalation from the material is based on E. Stranden [7].

Accidents when using a consumer product

B2.4: Spillage and ingestion from hands
Hand contamination can also occur for other reasons, such as breaking a source.

B2.8: Fire and inhalation of radionuclide dust or volatiles

Disposal of consumer product

When calculating the doses, disposal at the landfill or around the house is taken into account, for example, burying them in the garden.

B3.2: Inhalation of dusty undiluted or diluted deposited source

In this scenario, two scenarios are considered, of which only the higher of the two doses is considered. By default, the doses for both scenarios are the same.

The first scenario takes into account a resident who walks at the site of a disposed source and accidentally inhales radioactive dust from an undiluted source. The second scenario considers a resident who lives near a disposed source and inhales radioactive dust diluted in soil over a long period of time. The second scenario – unlike the first one – is not an accident.

B3.3: Equivalent skin dose from handling a deposited source

A resident finds a deposited source, picks it up, and keeps it in his pocket or hand for the next 8 hours.

3.3 Operational intervention levels

According to the scenarios, for each found or recognized object with a known radionuclide and activity (A) within each group of products, the total annual effective dose (E) and the total annual equivalent skin dose (H) were calculated as the sum of all doses of individual relevant scenarios.

We do not always have an item with known activity and other radiological parameters. Often, we have a product about which we know very little or almost nothing. It can be challenging to measure or estimate the activity of such items, especially in the field. Therefore, we need more straightforward operational values (measurements) that can be used to justify the everyday use of consumer products.

This is why we calculated the maximum permissible activity A_{OIL} (operational intervention level for activity) from the generic criteria (E_{GC}) for effective dose (Table 1) for an example of consumer product from each group:

$$E_{GC} \xrightarrow{\text{Scenarios}} A_{OIL} \xrightarrow{\text{Conversion factors}} DR_{OIL}, R_{OIL}$$

From the A_{OIL}, we estimated the predicted dose rate (DR_{OIL}, μSv/h) and the response of the contamination probe (R_{OIL}, cps beta) to such activity via conversion factors. The conversion factors for dose rates are listed [6]. For the response of the contamination probe R_{OIL}, the average conversion factor was estimated from the average of the yields of the beta radiation probes that we use daily in our lab. The values should be used with caution since they were calculated by neglecting self-absorption in the object.

4 REMINDERS FOR CONSUMER PRODUCTS AND GEOLOGICAL SAMPLES

For authorized experts in the field or for administrative authorities (inspectors), we have prepared reminders with a summary of calculations and assessments for each group of consumer products in the appendix.

The reminders contain a description of the product or geological samples, radiological data, the intended mode of use, a statement on the justification of use, conditions, and termination of use (disposal). The reminders include examples of typical activities and dose rates for items of general use and estimated OILs (activity, dose rate, and response of the contamination probe). For the sake of traceability, unrounded values are recorded for OILs, but they should be used as orders of magnitude of individual quantities, as uncertainties in estimations can be considerable. Each reminder's second page describes the scenarios, calculation equations and parameter values used.

Group b – Products with added radium (Ra-226)

Description: Watches and other objects with radioactive luminescent dials. Objects are pocket watches, wristwatches, alarm clocks, etc.
Radiological data: Radium (Ra-226+) is an alpha/beta/gamma emitter with a measurable dose rate. Ra-226+ can be detected with portable beta/gamma contamination monitors. The daughter of Ra-226 is Rn-222, which can exhale from an object as a noble gas and increase the inhalation dose even in a mechanically flawless (undamaged) object.

Figure 1: Example of the reminder for consumer products with added radium

Expected radionuclide	Exemption level A_{EL}	Typical values *		Activity range*
		A	$HD_{@10cm}$	
Ra-226+	10^4 Bq	**$6 \cdot 10^4$ Bq**	1,7 µSv/h	$2 \cdot 10^2 – 6 \cdot 10^4$ Bq

* Vrednosti so lahko izmerjene vrednosti ali vrednosti, najdene v literaturi.

Intended mode of use: Objects are worn on the wrist (wristwatches) or directly on the body (pocket watches) daily. They can also be used as home exhibits that are stored on shelves. Operational intervention levels (OILs) are calculated for wearing a watch on the wrist/body (**use**). **Limited use** assumes only occasional handling of the object, which lies on a shelf most of the time.

	Use			**Limited use**	**Disposal**		
	Activity A_{OIL} [Bq]	**Dose rate DR_{OIL}** (10 cm) [µSv/h]	**Response of cont. probe R_{OIL}** [cps beta]	**Activity $A_{OIL\text{-}limited}$** [Bq]	**Activity $A_{OIR\text{-}disposal}$** [Bq]	**Dose rate $DR_{OIL\text{-}disposal}$** (10 cm) [µSv/h]	**Response of cont. probe $R_{OIL\text{-}disposal}$** [cps beta]
H_{GC} = 0,5 mSv:	**45**	**< 0,1**	**~10**	$1{,}7 \cdot 10^6$	$1{,}7 \cdot 10^6$	-	-
E_{GC} = 10 µSv:	$2{,}7 \cdot 10^3$	-	-	**$3{,}8 \cdot 10^3$**	**$1{,}6 \cdot 10^5$**	**~3**	**$\sim 4 \cdot 10^4$**

Table explanation: OILs are reference values (e.g., activities, dose rates) at which the dose reaches the generic criterion for the annual effective (E_{GC}) or skin equivalent dose (H_{GC}). A_{OIL} is the total activity of objects to which an individual is exposed. It is calculated as: $A_{OIL} = (A/E) \cdot E_{GC}$ or $A_{OIL} = (A/H) \cdot H_{GC}$., where A is the activity of the source and E or H is the corresponding dose recalculated according to the scenarios below for this activity. The dose rate HD_{OIL} and the response of the contamination probe R_{OIL} are estimated from the lower of the two A_{OIL}, which is more restrictive. Due to traceability, the calculation results are unrounded, and the uncertainty is significant, so they should be used as orders of magnitude. HD_{OIL} and R_{OIL} are estimated assuming a point source. The actual response of the contamination probe will be significantly lower in most of the cases.

Justification statement: The unlimited use of such an object is **not** radiologically **justified**, as the A_{OIL} for skin dose is exceeded even at very low activities (45 Bq). The limited use of the item is conditionally justified, in which the item is not worn on the wrist or next to the body but is stored as a home exhibit. **Removable contamination must not be present!**

Conditions of use: **Unlimited use is not allowed.** Adults can use objects that do not exceed $A_{OIL\text{-}limited}$, but only as home exhibits. It is recommended to store such objects in display cases or other closed cabinets. We advise that children do not come into contact with such objects. The room where such objects are stored should be regularly ventilated to reduce the impact of radon. In the event of mechanical damage to the object, surface contamination may occur, so we recommend discontinuing use. After handling a damaged object, the user should wash their hands.

Disposal: Objects can be disposed of at a municipal landfill without restrictions if the total activity of the objects is lower than the order of magnitude of $A_{OIL\text{-}disposal}$. **A source with the activity of $A_{OIL\text{-}disposal}$ can trigger a portal monitor.**

5 CONCLUSION

The methodology was developed to assist the inspectors or authorized experts in determining whether consumer products can be freely used by simple radiological measurements and comparison of measured values with operational intervention levels.

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