National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Radioactivity measurements in 'negative ion' consumer products

This is a translation of an RIVM letter report that was published earlier in Dutch under letter report number 2021-0239.

This report contains two errata
d.d. 02-08-2022 on page 33
d.d. 05-11-2024 on page 35

RIVM letter report 2022-0052
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Synopsis

Radioactivity measurement in ‘negative ion’ consumer products

This is a translation of an RIVM letter report that was published earlier in Dutch under report number 2021-0239.

Sellers of ‘negative ion’ consumer products, such as jewellery and eye masks, state that these products improve your health. But these products can contain radioactive substances that emit so-called ionising radiation. This radiation can damage tissue and DNA, which is bad for your health. The wearer of the jewellery is exposed to this radiation. In the United States of America it is no longer allowed to sell these products.

The ANVS asked RIVM to investigate 10 negative ion consumer products. The reason was that a Dutch citizen had alerted the ANVS that negative ion products can contain radioactive substances. RIVM assessed if this was the case, and what the radiation dose for the skin would be for someone wearing the products.

All 10 products contain more radioactivity than legally permitted. The skin of the wearer of the products is exposed to an added radiation dose. Effects like redness of the skin at the site where the product is worn cannot be ruled out.

The law states that radioactivity in consumer products is not allowed, unless it is deemed justified. For the investigated products this is not the case. Justification means that exposure to ionizing radiation is only allowed if the advantages outweigh the possible health detriment.

Keywords: negative ions, radiation, consumer products, ANVS

Publiekssamenvatting

Radioactiviteitsmetingen aan 'negatieve ionen'-consumentenproducten

Dit is een vertaling van een RIVM briefrapport dat eerder in het Nederlands is uitgebracht onder rapportnummer 2021-0239.

Van producten met 'negatieve ionen', zoals sieraden en slaapmaskers, zeggen verkopers dat ze de gezondheid verbeteren. Maar deze producten kunnen radioactieve stoffen bevatten die zogeheten ioniserende straling uitzenden. Deze straling kan weefsel en DNA beschadigen, wat schadelijk is voor de gezondheid. De drager van de sieraden staat aan deze straling bloot. In de Verenigde Staten mogen deze producten daarom inmiddels niet meer worden verkocht.

Op verzoek van de ANVS heeft het RIVM onderzoek gedaan aan 10 negatieve ionen-producten. De aanleiding was een signaal van een inwoner van Nederland dat negatieve ionen-producten radioactieve stoffen kunnen bevatten. Het RIVM heeft uitgezocht of dit echt zo was, en aan welke stralingsdosis de huid blootstaat als iemand het product draagt.

Alle 10 producten bevatten meer radioactiviteit dan volgens de wet is toegestaan. De drager van de producten staat hierdoor via de huid bloot aan een extra dosis straling. Ook kan niet worden uitgesloten dat bijvoorbeeld de huid rood wordt op de plek waar het product wordt gedragen.

In de wet staat dat er geen radioactiviteit in consumentenproducten mag zitten, tenzij daarvoor een rechtvaardiging is afgegeven. Dat is niet het geval voor deze producten. Rechtvaardiging betekent dat blootstelling aan ioniserende straling alleen is toegestaan als de voordelen opwegen tegen de mogelijke gezondheidsschade.

Kernwoorden: negatieve ionen, straling, consumentenproducten, ANVS

Contents

Summary

On behalf of the inspectorate of the Authority for Nuclear Safety and Radiation Protection (ANVS), an investigation was conducted into radioactive substances in 'negative ion' consumer products sold over the Internet and in other places. The websites where the products are sold claim that 'negative ions' have a positive effect on health.

The ANVS inspectorate was alerted to the existence of these products by a private individual and a number of American YouTube videos that show that the 'negative ions' are generated by radioactive substances in the products. The ANVS inspectorate asked RIVM to find out whether a selection of 10 'negative ion' consumer products are actually radioactive, and if so, what substances they contain and in what quantities. We determined this using high-resolution gamma spectrometry. All of the products contain radioactive substances from natural decay chains. These are substances that slowly decay, through multiple stages, into a stable material. These radioactive substances and their decay products are called natural chains because they have been in the ground since the earth was formed. Decay products from the thorium-232 (Th-232) chain were found in all of the products, and 6 of the 10 products also contained nuclides from the uranium-238 (U-238) and uranium-235 (U-235) chains. The biggest contribution came from the daughter nuclides of the Th-232 chain: the activity concentration was between 6.4 ± 0.6 and 74 ± 8 Bq g^{-1} and the total activity was between 5.9 ± 0.4 and 780 ± 80 Bq per item.

The local skin equivalent dose was also calculated, a measure for deterministic effects such as skin burns. Based on the assumption that the products would be worn for 24 hours a day, this resulted in a local skin equivalent dose for the various products of between 12 and 50 mSv per year. The dose limit for the local skin equivalent dose was 50 mSv per year. By way of comparison, the skin dose resulting from average radiation exposure in the Netherlands is 2.6 mSv per year.

The amount of radioactivity in the examined products was above the release limit of 1 Bq g^{-1} for Th-232. Even more important is the fact that the calculated local skin equivalent dose was in near or even equal to the skin dose limit.

Quality system

The Centre for Environmental Safety and Security of the National Institute for Public Health and the Environment (RIVM/VLH) is accredited by the Dutch Accreditation Council (RvA) for a number of tests in accordance with NEN-EN-ISO-17025 (registration number L153)[1]. These tests relate to measurements performed in the context of the monitoring program on nuclear facilities of nuclear facilities (ANVS), the National Radioactivity Monitoring Network and environmental monitoring in compliance with the EURATOM Treaty.

The measurements and analyses described in this report deviate from these standard operations and therefore do not fall under this accreditation. However, work was performed in accordance with the standard quality assurance procedures where possible, particularly with regard to administration of samples, measurements and validation of the quantitative aspects.

[1] The erratum dated November 5th, 2024, relates to this paragraph and is published on page 35 of this report.

1 Introduction

On 13 August 2020, the ANVS received a report of possible radioactivity in a necklace/pendant being sold online. The report was made by a private individual. Subsequently, on 12 February 2021, the ANVS received another report from a private individual of possible radioactivity in various products offered for sale on the Internet. It was claimed that the products emitted so-called ‘negative ions’. On the websites selling the products, a health claim was made that these ions would have a positive effect on the health of the wearer. The report made reference to videos on YouTube showing an investigation by a youtuber [YT21].

In response to these reports, the ANVS inspectorate expressed the view that radioactive substances could be present and initiated two investigations. To determine the risks posed by such products, the inspector concerned ordered 10 of these types of products, which were then presented to RIVM for further investigation.

In accordance with the engagement letters [ANVS20, ANVS21], the following investigation into these ‘negative ion’ consumer products was performed:

- Investigation into and sampling of the radioactive substances in the presented products;
- Gamma spectrometry analysis of the sample to determine what radioactive substances are present and in what quantities;
- Specification of the activity concentration and the total activity of the radionuclides in the products, based on the components that contain radioactive substances;
- Investigation into the risks for individual citizens resulting from the radiation dose (also from alpha and beta radiation) in the use of the products. In this regard, it was assumed that a wristband or necklace would be worn for 24 hours a day and the sleep mask for 8 hours a day.

The results of the two investigations are summarised in this letter report.

2 Method of measurement

A total of 10 items were supplied by the ANVS for investigation; a summary of these items is given in Table 1. The items were photographed (see Figure 1) and weighed. The net gamma dose rate at the surface and at a distance of 10 cm from the items was determined using a FLIR IdentiFinder R400. The results are set out in Table 2. Of all the items, at a distance of 10 cm only the sleep mask had a dose rate higher than the background value (net value of 0.03 μSv/h).

Table 1 Information about the 10 consumer products.

Number	Code	Description	Supplier
1	4708iXL	Fit & Slim silicone wristband, XL	Magnetix
2	4705iL	Sport boost wristband, turquoise	Magnetix
3	4720iM	Smiley Kids wristband	Magnetix
4	4657iXL	Magnetic necklace	Magnetix
5	609132886690	Black-and-white necklace	Energy Armour
6	-	Dog tag	Energy Armour
7	-	Black armband	Energy Armour
8	736211735560	Sleep mask	Energy Armour
9	SKU: IO.TIT.046	"Basic Nero" wristband	Ionira
10	-	Quantum Pendant	-

Table 2 The measured net gamma dose rates and weights of the whole items. The background value of the gamma dose rate is approximately 0.03 μSv/h.

Number	Weight of the whole item[a] [g]	Dose rate at the surface
1	9.10	0.02 μSv/h
2	17.96	0.02 μSv/h
3	5.64	0.01 μSv/h
4	4.98	0.01 μSv/h
5	11.13	0.04 μSv/h
6	4.41	0.01 μSv/h
7	9.22	Background
8	16.69	0.13 μSv/h
9	25.99	Background
10	20.66	0.065 μSv/h

[a] This is the weight of the entire item including the non-radioactive parts, excluding the packaging material.

Figure 1 Items 1 to 10 are shown in order from left to right and from top to bottom.

The whole of each of the consumer products was measured using high-resolution gamma spectrometry, in an n-type germanium semiconductor detector (Mirion; 40%; BE type), a pulse sorter (DSA-1000, Mirion) with 8,192 channels and the APEX gamma and Genie-2000 software packages (Mirion).

The spectra were analysed using Genie-2000 (Mirion). The counting efficiency of each measurement was calculated using Mirion's ISOCS software package [ISOCS], with a model of the measurement geometry being created for each measurement, including the dimensions, elemental composition and density of the objects. An example can be seen in Figure 2.

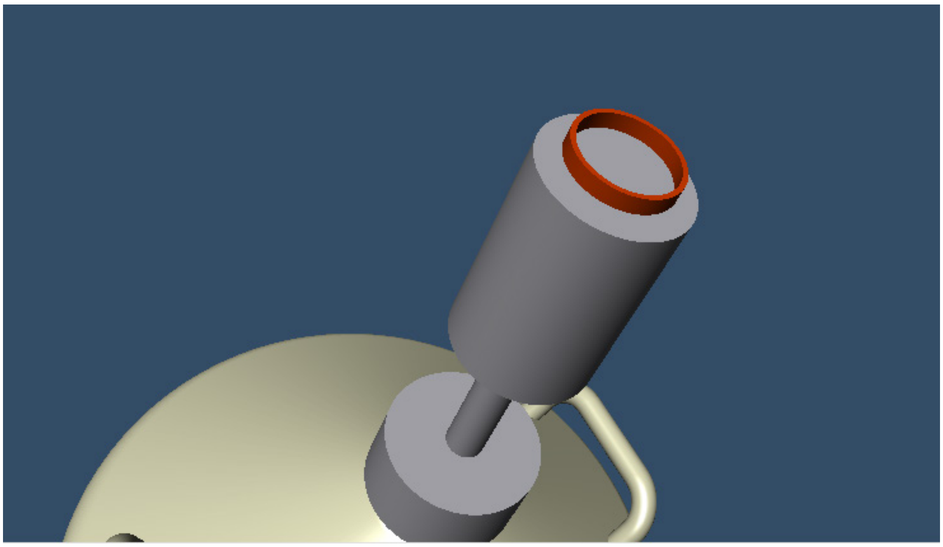

Figure 2 Example of model-based measurement geometry in ISOCS, used to calculate the counting efficiency.

Using a Victoreen model ASM 990 combined with a pancake probe type 498-110, we determined which parts of the items contained radioactive material. The pancake probe is mainly sensitive to beta and low-energy gamma radiation, which can be well shielded with 5 cm thick blocks of lead. Before using the probe, we checked whether a count rate higher than the background value was measured if the items were fully shielded with lead. This was not the case.

The items were examined by shielding a large part of the items with lead and leaving a small portion exposed. This exposed part was then measured with the pancake probe to determine whether it was radioactive. An example can be seen in Figure 3. The shielding was progressively moved along until the entire item had been "scanned". For a number of the items the radioactivity was found throughout the item, while in others it was in a specific component.

Figure 3 Method used to determine which components contained the radioactive substances, by shielding a large part of each item with lead and measuring a small part with a detector sensitive to beta radiation.

Table 3 lists the radioactive components of the items. For the items where the radioactivity was found in a specific component, these components were separated from the inactive components and measured again using gamma spectrometry in the same way as for the whole items.

Table 3 List of the radioactive components of the various items, determined using the Victoreen in combination with the pancake probe and 5 cm lead as shielding.

Sample No.	Radioactive component/part	Weight of radioactive part [g]
1	Whole wristband	9.104
2	Whole wristband	17.959
3	Whole wristband	5.644
4	Whole necklace	4.976
5	Silicone inside the necklace	5.6306
6	"Shield" bearing the logo in the centre of the dog tag	1.2774
7	Whole wristband	9.216
8	Silicone inside the sleep mask	10.572
9	The red and white dots on the links[a]	0.7292
10	Pendant	19.08

[a] Determined by detaching the links and measuring for each type using a germanium semiconductor detector.

3 Results

3.1 Gamma spectrometry

Daughter nuclides from the natural chains of Th-232, U-238 and U-235 were found in the items. The activity concentrations and activities of the natural chains found in the radioactive components are shown in Table 4. In a number of the items, the Th-232 chain was not in equilibrium. This suggests an operation during the production process in which radium was partially or entirely removed from the material. This related to all of the Magnetix items and one item from Energy Armour. The activity concentrations of the daughter nuclides are shown in Annex I.

Table 4 Activity concentrations [Bq·g^{-1}] and activities [Bq] determined using gamma spectrometry for the radioactive components of the items.

Sample No.	Chain/nuclide	Activity concentration [Bq·g^{-1}][a]	Activity [Bq][a,b]
1	Ac-228[d]	8.8 ± 0.9	80 ± 8
	Ra-224+[d]	12.4 ± 1.3	113 ± 12
2	Ac-228[d]	8.7 ± 0.9	157 ± 16
	Ra-224+[d]	12.3 ± 1.3	220 ± 20
3	Ac-228[d]	10.3 ± 1.0	58 ± 6
	Ra-224+[d]	14.7 ± 1.5	83 ± 9
4	Ac-228[d]	11.0 ± 1.1	55 ± 6
	Ra-224+[d]	16.0 ± 1.7	79 ± 8
5	Th-232sec[c]	21 ± 2	116 ± 12
	U-235sec[c]	0.22 ± 0.03	1.21 ± 0.17
	U-238sec[c]	3.7 ± 0.4	21 ± 2
6	Th-232sec[c]	18.7 ± 1.9	24 ± 2
	U-235sec[e]	N/Q	N/Q
	U-238sec[c]	1.78 ± 0.19	2.3 ± 0.2
7	Ac-228[d]	6.4 ± 0.6	59 ± 6
	Ra-224+[d]	7.5 ± 0.8	69 ± 7
	U-235sec[e]	N/Q	N/Q
	U-238sec[c]	0.37 ± 0.04	3.4 ± 0.3
8	Th-232sec[c]	74 ± 8	780 ± 80
	U-235sec[e]	N/Q	N/Q
	U-238sec[c]	6.8 ± 0.8	72 ± 8
9	Th-232sec[c]	16.2 ± 1.1	5.9 ± 0.4
	U-235sec[e]	N/Q	N/Q
	U-238sec[c]	3.08 ± 0.2	1.13 ± 0.09
	K-40	0.7 ± 0.3	0.27 ± 0.10
10	Th-232sec[c]	8.0 ± 0.4	153 ± 8
	U-235sec[c]	0.068 ± 0.006	1.29 ± 0.10
	U-238sec[c]	1.02 ± 0.05	19.4 ± 1.0

[a] The stated uncertainties are based on one standard uncertainty.
[b] Total activity based on the weight of the radioactive part of the item.
[c] Chain in equilibrium (assumed) based on the daughter nuclide results.
[d] Nuclides from the Th-232 chain. In these samples this chain was not in equilibrium.
[e] The chain was present in the spectrum but could not be reliably quantified.

3.2 Local skin equivalent dose from wearing the items

The items emit gamma radiation as well as alpha and beta radiation. Alpha and beta radiation consist of particles: alpha radiation consists of helium nuclei and beta radiation consists of electrons. Gamma radiation is electromagnetic radiation, similar to light. How deeply the different types of radiation can penetrate various materials depends on what type of radiation it is and the energy of the radiation. Alpha radiation is stopped by a sheet of paper. Beta radiation can pass through paper, but is stopped by a thin sheet of metal. Gamma radiation will always partially pass through a material, but the thicker and heavier the material that is in the way, the less gamma radiation will pass through.

You need a heavy material to effectively attenuate gamma radiation, such as a thick lead plate or a concrete wall (see Figure 4).

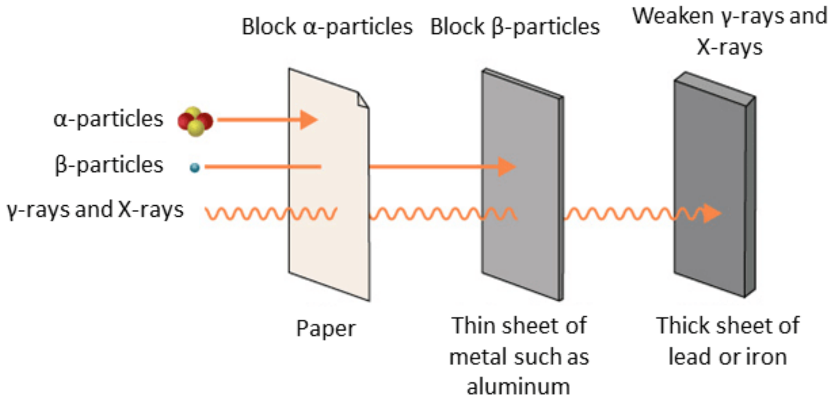

Figure 4 The penetration power of the main types of radiation. Adapted from "BOOKLET to Provide Basic Information Regarding Health Effects of Radiation", Ministry for the Environment, Japan.

Accordingly, the majority of the alpha radiation will not be released from the items or will be absorbed by the dead skin layer. This means the alpha radiation will make no significant contribution to the dose received by the skin or other sensitive organs. However, the beta and gamma radiation will contribute to the local skin equivalent dose applicable to the most exposed cm^2 of skin. This skin dose is calculated using the dose conversion coefficients (DCCs) from Table 7.1 in the document *Berechnungsgrundlage für die Ermittlung von Körper-Äquivalentdosen bei äußerer Strahlenexposition* [SSK2017]. A DCC tells you the dose you will receive if you are exposed to a specific amount of radioactivity. The DCCs used apply to the direct contamination of an unshielded surface (namely the skin). Since the items in this investigation have a certain thickness, we also need to correct for self-absorption of beta particles in the items themselves. There are various methods of arriving at an answer, based on different assumptions. We have calculated the skin dose using a method inspired by Dalton and Kunaish [Dalton64]. Self-shielding leads to a reduction in counting efficiency, and in our method we have assumed that the counting efficiency is the same as the dose efficiency. In addition to self-shielding two of the items feature a fabric cover, which shields the radioactive components. We took this into account by correcting the skin dose by a Clothing Shielding Factor, described in the report "Assessment of Skin Doses" by the NRPB [NRPB97]. It was assumed that all of the gamma radiation would pass through the items[2].
Since a number of assumptions were made (such as the length of time for which the items would be worn) to calculate the dose, the results specify the order of magnitude of the actual skin dose. The actual dose may deviate by up to several dozen percent from the reported value. For a number of the items, the results of this calculation were verified using

[2] 84% of gamma radiation with an energy of 200 keV passes through the entire thickness of the pendant. Th-232sec only has a few gamma's with energy below 200 keV, and these also have a low yield. Therefore, the assumption that all gamma's pass through the objects unhindered is a good assumption, that can only give a minor overestimation of the gamma skin dose.

the VARSKIN 6 program created by the United States Nuclear Regulatory Commission [NRC21].

The dose received by the wearer of the items over the course of a year depends on the number of hours per day the person wears the item. The most conservative approach is to assume that the items would be worn directly against the skin for 24 hours a day, 7 days a week. This is not realistic for the sleep mask, and it was assumed that this would be worn for 8 hours a day, 7 days a week. For these lengths of time, the total local skin equivalent dose resulting from wearing the various items varies between approximately 12 and 50 mSv per year, with the contribution resulting from beta radiation being between 10 and 44 mSv per year and the contribution from gamma radiation being between 2 and 10 mSv per year (see Table 5). By way of comparison, normal average radiation exposure in the Netherlands is 2.6 mSv per year [RIVM18]. The associated expected local skin equivalent dose is also 2.6 mSv per year. The skin dose resulting from the use of the examined ‘negative ion’ consumer products is far above this limit.

Table 5 The total local skin equivalent dose for the most exposed cm² of skin, and the contributions from the beta and gamma radiation to this skin dose. Corrections were made for self-shielding and for any shielding from fabric covers.

Sample No.	Total skin dose (mSv)	Beta radiation contribution (mSv)	Gamma radiation contribution (mSv)	Time worn each day (h)
1	19	14	6	24
2	34	25	9	24
3	34	30	5	24
4	18	17	2	24
5	13	10	2	24
6	50	44	6	24
7	20	17	3	24
8	47	44	3	8
9	25	22	4	24
10	32	20	12	24

4 Findings and conclusions

In this report, we demonstrated that the examined 'negative ion' consumer products contain daughter nuclides from the natural chains of Th-232, U-238 and U-235.

In the items in which the Th-232 chain was in equilibrium (sample numbers 5, 6, 8, 9 and 10), the activity concentration of Th-232sec in the radioactive components varied between 8.0 ± 0.4 and 74 ± 8 Bq g^{-1}, while the total activity was between 5.9 ± 0.4 and 780 ± 80 Bq per item.

In the items in which the Th-232 chain was not in equilibrium (sample numbers 1 to 4 and 7), the activity concentration of Th-232 daughter nuclides in the radioactive components varied between 6.4 ± 0.6 and 16.0 ± 1.7 Bq g^{-1}, while the total activity was between 55 ± 0.4 and 220 ± 20 Bq per item.

In the items in which the U-238sec chain was present (sample numbers 5 to 10), the activity concentration in the radioactive components varied between 0.37 ± 0.04 and 6.8 ± 0.8 Bq g^{-1}, while the total activity was between 1.13 ± 0.09 and 72 ± 8 Bq per item.

The U-235 chain was detected in the items with sample numbers 5 to 10, but was only able to be quantified in two items (sample numbers 5 and 10). It was assumed that the U-235 chain was in equilibrium in these items, since the U-238 chain was in equilibrium. The activity concentration of U-235sec in sample number 5 was 0.22 ± 0.03 Bq g^{-1} and the total activity was 1.21 ± 0.17 Bq. The activity concentration of U-235sec in sample number 10 was (0.068 ± 0.006 Bq g^{-1}) and the total activity was (1.29 ± 0.10 Bq).

The amount of radioactivity in the examined products is above the Dutch clearance level of 1 Bq g^{-1} for Th-232, as specified in Dutch law ('Besluit basisveiligheidsnormen stralingsbescherming', Bbs). Clearance levels are used to assess whether a permit or registration is required for products on radiological grounds.

In addition to the activity and the activity concentration in the items, the local skin equivalent dose resulting from wearing the items was also calculated for the most exposed cm^2 of skin. The maximum local skin equivalent dose from wearing the items for 24 hours a day, 7 days a week for one year is between 12 and 50 mSv, assuming that the person wears the objects directly against the skin. For the sleep mask, it was assumed that it would be worn for 8 hours a day, 7 days a week. This would result in a local skin equivalent dose of 47 mSv/year. The local skin equivalent dose resulting from the use of the examined 'negative ion' consumer products is far above the skin dose resulting from normal average radiation exposure in the Netherlands, and is even near or just as high as the dose limit of 50 mSv/year [Bbs21].

5 References

[ANVS20] ANVS engagement letter with the reference "Holmes-480860-01-3TU" of 4 November 2020

[ANVS21] ANVS engagement letter with the reference "ANVS-2021/2983" of 15 March 2021

[YT21] https://youtu.be/C7TwBUxxICO from 18 February 2020 and https://youtu.be/3BA5bw1EV5I from 19 January 2021

[ISOCS] In Situ Object Counting System (ISOCS), Mirion; https://www.mirion.com/products/s573-isocs-calibration-software

[SSK17] Berechnungsgrundlage für die Ermittlung von Körper-Äquivalentdosen bei äußerer Strahlenexposition, Geschäftsstelle der Strahlenschutzkommission beim Bundesamt für Strahlenschutz (2017)

[Dalton64] G.R. Dalton and H.H. Kunaish, The beta self-shielding correction for 2π geometries, Int. J. Appl. Radiat. Isot., 15, pp 301-307 (1964)

[NRPB97] Assessment of Skin Doses, Documents of the NRPB Vol. 8 No. 3, National Radiological Protection Board (1997)

[RIVM18] RIVM Infographic "Blootstelling aan straling" (Exposure to radiation); https://www.rivm.nl/straling/infographics-over-straling (2018)

[Bbs21] Besluit basisveiligheidsnormen stralingsbescherming; https://wetten.overheid.nl/BWBR0040179/2021-07-01, Article 9.1.3b

Annex I – Daughter nuclide data

Daughter nuclides measured in Sample 1.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	11.8 ± 1.3
	Bi-212	12.8 ± 1.4
	Pb-212	12.5 ± 1.5
	Ra-224	13.1 ± 1.7
	Ac-228	8.8 ± 0.9

[a] The stated uncertainties are based on one standard uncertainty.

Daughter nuclides measured in Sample 2.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	12.1 ± 1.3
	Bi-212	12.1 ± 1.3
	Pb-212	12.9 ± 1.5
	Ra-224	13.4 ± 1.7
	Ac-228	8.7 ± 0.9

[a] The stated uncertainties are based on one standard uncertainty.

Daughter nuclides measured in Sample 3.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	14.3 ± 1.5
	Bi-212	14.8 ± 1.6
	Pb-212	14.9 ± 1.7
	Ra-224	16 ± 2
	Ac-228	10.3 ± 1.0

[a] The stated uncertainties are based on one standard uncertainty.

Daughter nuclides measured in Sample 4.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	16.0 ± 1.7
	Bi-212	16.3 ± 1.8
	Pb-212	15.5 ± 1.8
	Ra-224	16 ± 2
	Ac-228	11.0 ± 1.1

[a] The stated uncertainties are based on one standard uncertainty.

Daughter nuclides measured in Sample 5.

Decay chain	Radionuclide	Activity concentration [$Bq \cdot g^{-1}$][a]
Th-232	Tl-208	21 ± 2
	Bi-212	22 ± 2
	Pb-212	19 ± 2
	Ra-224	21 ± 3
	Ac-228	20 ± 2
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231	<MDA
	Th-231	<MDA
	U-235	0.22 ± 0.03
U-238	Pb-210	3.1 ± 0.6
	Bi-214	3.7 ± 0.4
	Pb-214	3.8 ± 0.4
	Ra-226	3.9 ± 0.6
	Th-230	5 ± 2
	U-234	<MDA
	Th-234	3.1 ± 0.4
	Pa-234m[b]	N/Q
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Daughter nuclides measured in Sample 6.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	19 ± 2
	Bi-212	20 ± 2
	Pb-212	17 ± 2
	Ra-224	20 ± 3
	Ac-228	18.5 ± 1.9
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231	<MDA
	Th-231	<MDA
	U-235[b]	N/Q
U-238	Pb-210	1.8 ± 0.3
	Bi-214	1.80 ± 0.19
	Pb-214	1.8 ± 0.2
	Ra-226	<MDA
	Th-230	<MDA
	U-234	<MDA
	Th-234	1.5 ± 0.2
	Pa-234m[b]	N/Q
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Daughter nuclides measured in Sample 7.

Decay chain	Radionuclide	Activity concentration [$Bq \cdot g^{-1}$][a]
Th-232	Tl-208	7.2 ± 0.8
	Bi-212	7.6 ± 0.8
	Pb-212	7.4 ± 0.9
	Ra-224	7.9 ± 1.0
	Ac-228	6.4 ± 0.6
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231[b]	N/Q
	Th-231	<MDA
	U-235[b]	N/Q
U-238	Pb-210	0.34 ± 0.06
	Bi-214	0.35 ± 0.04
	Pb-214	0.40 ± 0.05
	Ra-226	0.29 ± 0.08
	Th-230[b]	N/Q
	U-234	<MDA
	Th-234	0.52 ± 0.07
	Pa-234m[b]	N/Q
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Daughter nuclides measured in Sample 8.

Decay chain	Radionuclide	Activity concentration [$Bq \cdot g^{-1}$][a]
Th-232	Tl-208	75 ± 9
	Bi-212	73 ± 8
	Pb-212	71 ± 8
	Ra-224	78 ± 10
	Ac-228	74 ± 8
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231	<MDA
	Th-231	<MDA
	U-235[b]	N/Q
U-238	Pb-210	6.6 ± 1.6
	Bi-214	6.7 ± 0.8
	Pb-214	6.5 ± 1.0
	Ra-226	14 ± 3
	Th-230	<MDA
	U-234	<MDA
	Th-234	6.7 ± 1.1
	Pa-234m	<MDA
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Daughter nuclides measured in Sample 9.

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
Th-232	Tl-208	0.26 ± 0.03
	Bi-212	0.29 ± 0.03
	Pb-212	0.29 ± 0.04
	Ra-224	0.33 ± 0.04
	Ac-228	0.27 ± 0.03
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231	<MDA
	Th-231[b]	N/Q
	U-235[b]	N/Q
U-238	Pb-210	0.23 ± 0.06
	Bi-214	0.047 ± 0.005
	Pb-214	0.054 ± 0.008
	Ra-226	0.070 ± 0.019
	Th-230	<MDA
	U-234	<MDA
	Th-234	0.034 ± 0.010
	Pa-234m	<MDA
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Daughter nuclides measured in Sample 10.

Decay chain	**Radionuclide**	**Activity concentration [Bq·g^{-1}][a]**
U-235+	Bi-211[b]	N/Q
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223[b]	N/Q
	Th-227	<MDA
	Pa-231	0.083 ± 0.011
	Th-231	0.054 ± 0.013
	U-235	0.066 ± 0.006
U-238+	Pb-210[b]	N/Q
	Bi-214	1.03 ± 0.05
	Pb-214	0.83 ± 0.08
	Ra-226	1.1 ± 0.2
	Th-230[b]	N/Q
	U-234	<MDA
	Th-234	<MDA
	Pa-234m[b]	N/Q
	U-238	<MDA
Th-232+	Tl-208	8.5 ± 0.5
	Bi-212	8.5 ± 0.5
	Pb-212	7.6 ± 0.6
	Ra-224	8.8 ± 0.8
	Ac-228	7.8 ± 0.4

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

Erratum 1 letter report 2022-0052

Radioactivity measurements in 'negative ion' consumer products

Bilthoven: 02 August 2022
Subject: Erratum to report 2022-0052

In Table 4 on page 20 of the RIVM report 2022-0052 entitled Radioactivity measurements in 'negative ion' consumer products a few corrections should be made. The activity concentrations of sample number 9 were not reported correctly.

The reported numbers should be:

Sample No.	Chain/nuclide	Activity concentration [$Bq \cdot g^{-1}$]	Activity [Bq]
9	Th-232sec	8.1 ± 0.6	5.9 ± 0.4
	U-235sec	N/Q	N/Q
	U-238sec	1.54 ± 0.12	1.13 ± 0.09
	K-40	0.70 ± 0.15	0.27 ± 0.10

In Annex I on page 31 a few corrections should be made. The activity concentrations of sample number 9 were not reported correctly.

The reported numbers should be:

Decay chain	Radionuclide	Activity concentration [$Bq \cdot g^{-1}$][a]
Th-232	Tl-208	8.4 ± 0.6
	Bi-212	8.4 ± 0.7
	Pb-212	8.1 ± 0.7
	Ra-224	9.4 ± 0.9
	Ac-228	8.0 ± 0.6
	Th-232	<MDA
U-235	Bi-211	<MDA
	Pb-211	<MDA
	Rn-219	<MDA
	Ra-223	<MDA
	Th-227	<MDA
	Pa-231	<MDA
	Th-231[b]	n.q.
	U-235[b]	n.q.
U-238	Pb-210	3.2 ± 0.5
	Bi-214	1.54 ± 0.12
	Pb-214	1.45 ± 0.14
	Ra-226	<MDA
	Th-230	<MDA

Decay chain	Radionuclide	Activity concentration [Bq·g^{-1}][a]
	U-234	<MDA
	Th-234	<MDA
	Pa-234m	<MDA
	U-238	<MDA

[a] The stated uncertainties are based on one standard uncertainty.
[b] The nuclide was present in the spectrum but could not be reliably quantified.

P.N. Brandhoff

Erratum 2 letter report 2022-0052

Radioactivity measurements in 'negative ion' consumer products

Bilthoven: November 5th, 2024
Subject: Erratum on report 2022-0052

RIVM report 2022-0052 with the title Radioactivity measurements in 'negative ion' consumer products contains errors.

The text on page 11 on the subject of quality system contains inaccuracies. The erratum is textual and has no impact on the correctness of the earlier reported results. The full text of this paragraph should be replaced with the following text:

The measurements as described in this report have been carried out with measurement instruments that are used, maintained and calibrated according to a quality system based on NEN-EN-ISO-17025 and are within the scope of ISO-9001 certification of RIVM.

P.N. Brandhoff

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