

RADIOACTIVE QUACKERY

Bringing the light inside the body

Carl Willis

Zoom, February 4, 2021

Personal introduction



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- NE faculty and Chief Reactor Supervisor at University of New Mexico
- Sr. Research Engineer at Verus Research
- Collector of radioactive quack remedies (& other hot stuff)

THE WHITE HOUSE

WASHINGTON

“Suppose that we hit the body with a tremendous, whether it's ultraviolet or just very powerful light [...] supposing you **brought the light inside the body**, which you can do either through the skin or in some other way.”

-Donald Trump, April 23, 2020



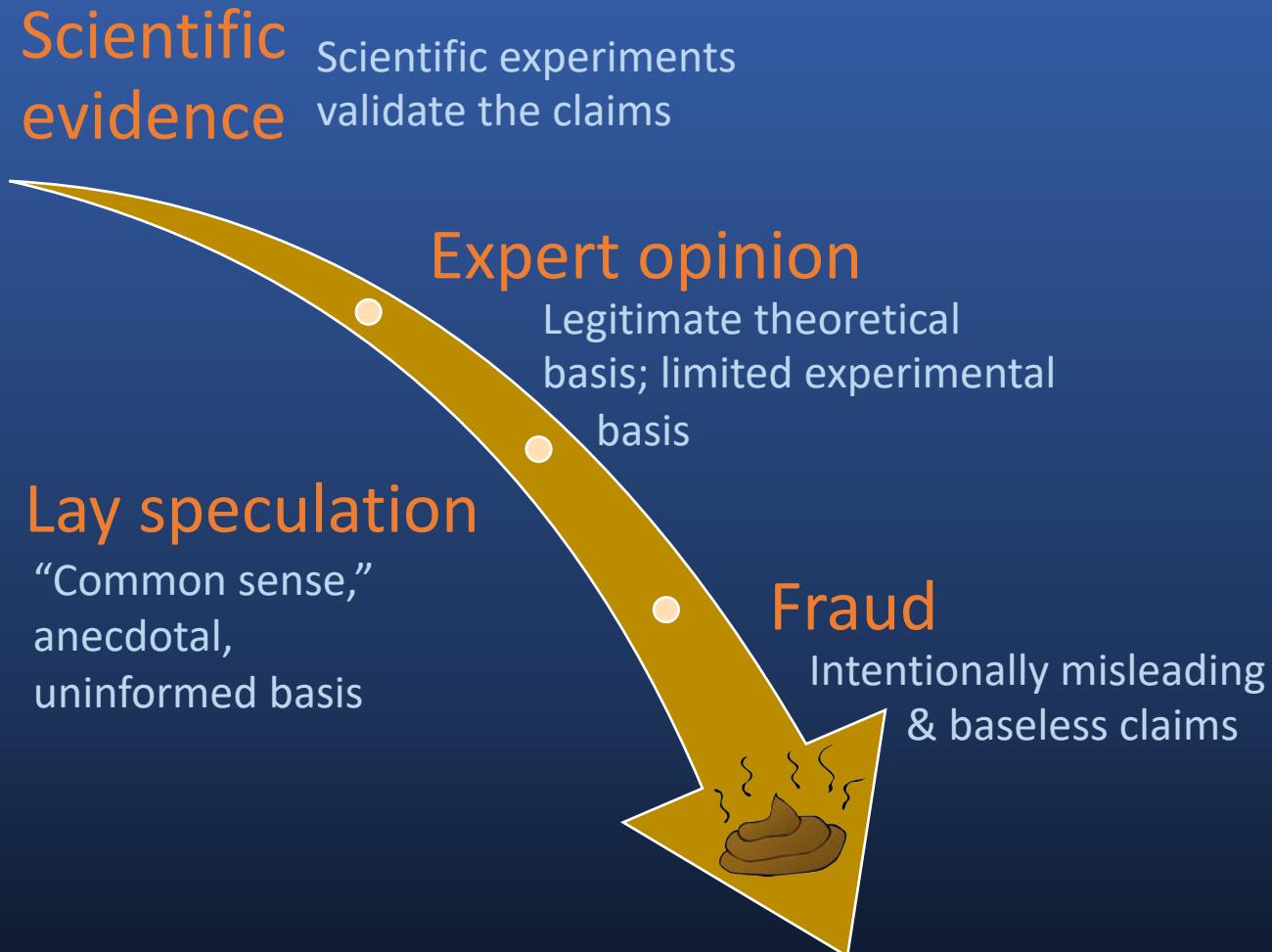
Outline

- Part I: The classic radium cure era (1900-1932)
 - Regular medicine and quackery: a demarcation problem
 - “Mild radium therapy”: motivations, techniques, and business opportunities
 - Rogue’s gallery of classic quack cures and claims
 - Lessons learned
- Part II: The modern era
 - How has radiation been reinterpreted in modern quack paradigms?
 - A modern rad-quackery rogue’s gallery
 - Current challenges in the regulatory landscape
 - A closer look at hormesis and the legacy of classic radium cures

The big picture

- Radium “quack” remedies were distributed through partnerships with regular medicine providers and had varying degrees of support within the regular medical and scientific establishments. Many remedies that are lumped under the umbrella of “quackery” today are better regarded as mainstream medicine in the context of their day.
- Some remedies had well-documented fatal consequences, but the vast majority of people using such products suffered no discernable detriment.
- Internal dose response models in use today are informed by data from exposures during the classic radium remedy era.
- The cultural relationship with radiation has changed dramatically in the last century, but radioactive quackery has not disappeared—it’s just marketed in different ways today.

Quackery and the hierarchy of evidence



- Quackery, by etymology, refers to promotion (specifically, overpromotion).
- Quackwatch definition: "*the promotion of unsubstantiated methods that lack a scientifically plausible rationale.*" [1]
- We will look at a variety of radioactive remedies whose justifications fall in various places along the hierarchy of evidence.
Most are not fraud!

Signs of quackery

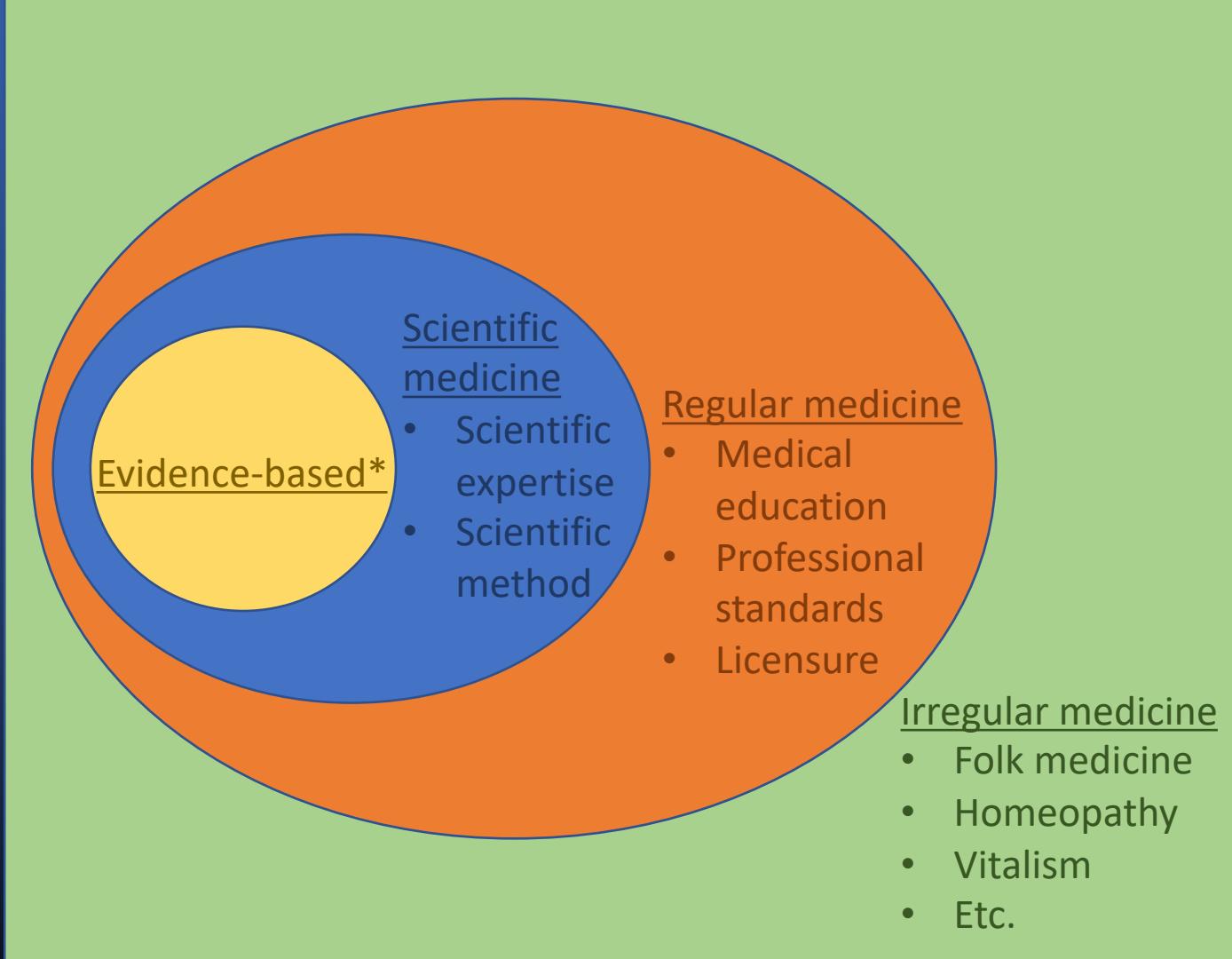
- Claims lack specificity, are difficult to define or test
- Often target challenging conditions & promise miraculous results
- Speculative justification (for which safety and effectiveness are not demonstrated)
- Don't tell the whole story (no risk-benefit analysis)
- Inexpert origins
- Expert endorsers have financial conflicts of interest
- Kickbacks to doctors
- Claims that appeal to nature
- Claims rooted in anecdote, *fads*
- Anti-intellectual / anti-establishment claims



PART I

The Classic Radium Cure Era, 1900-1932

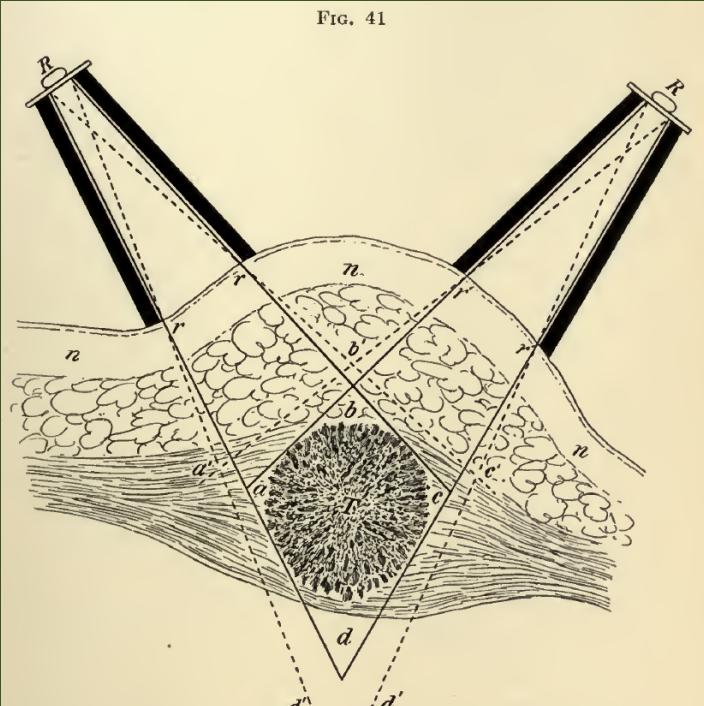
Medical authority in the classic radium cure era



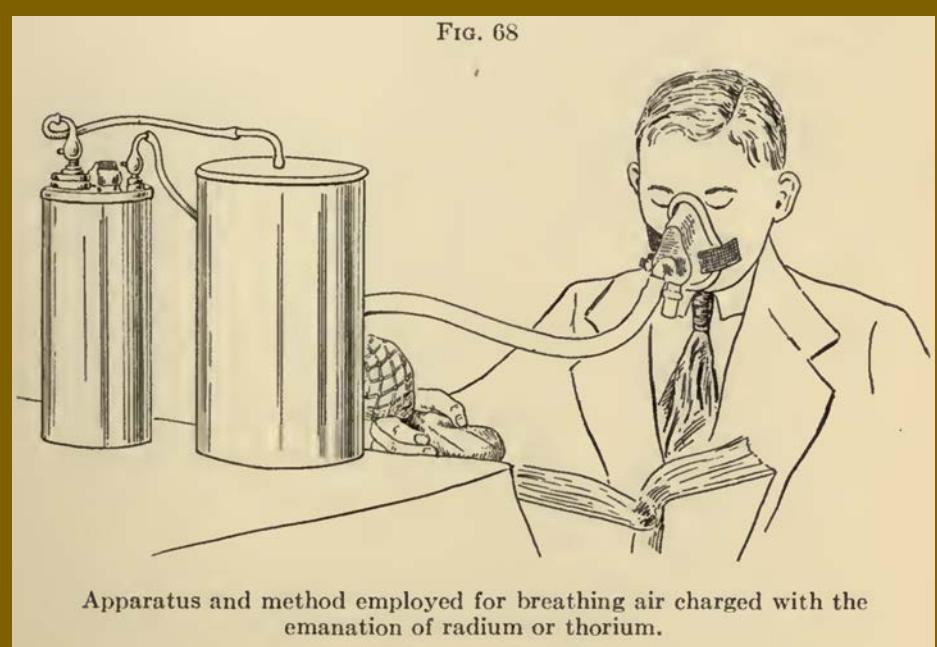
- Medical education in transition: many schools, minimal standards, low levels of rigor. The Flexner Report (1910) motivates changes toward the present structure of the medical establishment in the United States.
- Pre-Food, Drug & Cosmetics Act (1938): minimal regulation of safety and effectiveness of drugs and devices
- Quackery often practiced and / or prescribed by regular doctors

Radium in regular medicine

Evidence-based use:
external radiation
therapy for tumors



"Cross-fire." R, the radium mounted upon a cone of lead covered with gauze; T, the tumor; the area a, b, c, d receives the full amount of radiation while a', b', c', d' and the area between the radium received only a partial radiation. The remaining portions, n, are entirely protected.



Speculative use (based on a range of lay and expert opinions): "mild radium therapies," emanotherapy

- Both figures at left from Newcomet, a 1914 scholarly text [2]
- Little distinction made between use cases with strong scientific support and those with weak or no support.

The nexus of quackery and regular medicine

THE COUNCIL ON PHARMACY AND CHEMISTRY OF THE AMERICAN MEDICAL ASSOCIATION HAS ACCEPTED FOR INCLUSION WITH NEW AND NON-OFFICIAL REMEDIES THE FOLLOWING PRODUCTS OF THE STANDARD CHEMICAL COMPANY OF PITTSBURGH, PENNSYLVANIA:

Radium Bromide
Radium Chloride
Radium Sulfate
Radium Carbonate

"Standard" Radium Solution for Drinking
"Standard" Radium Solution for Bathing
"Standard" Radium Compress
"Standard" Radium Earth

For Literature Address

RADIUM CHEMICAL COMPANY
Forbes and Meyran Avenues, Pittsburgh, Pa.

You are cordially invited to visit our exhibit at the annual meeting of the Illinois State Medical Society, Springfield, Illinois, May 18th, 19th and 20th, 1915, Masonic Temple. Booth Number 18.

"STANDARD"
RADIUM
PREPARATIONS

"Standard" Radium Solution for Drinking
Each bottle contains two micrograms radium element in 60 cc. aqua dist.

Maximum equilibrium constant of radium emanation, 5400 mache units.

"Standard" Radium Solution for Intravenous Use.
In Ampules of 2 cc. N. P. S. S. containing 5, 10, 25, 50, or 100 micrograms radium element.
PERMANENT

"Standard" Radium Compress
A means of applying radium locally for the relief of pain.

A flexible pad of standardized, guaranteed radium element content.

PERMANENT RADIO-ACTIVITY

INDICATIONS
Subacute and Chronic Joint and Muscular Conditions.
High Blood Pressure. Nephritis.
The Simple and Pernicious Anemias.

"The value of radium is unquestionably established in chronic and subacute arthritis of all kinds (lactic and tuberculous excepted) acute, subacute and chronic joint and muscular rheumatism (so called) in gout, sciatica, neuralgia, polyneuritis, lumbago and the lancinating pain of tabes."—Rowntree and Baetjer, Journal A. M. A. Oct. 18, 1913.

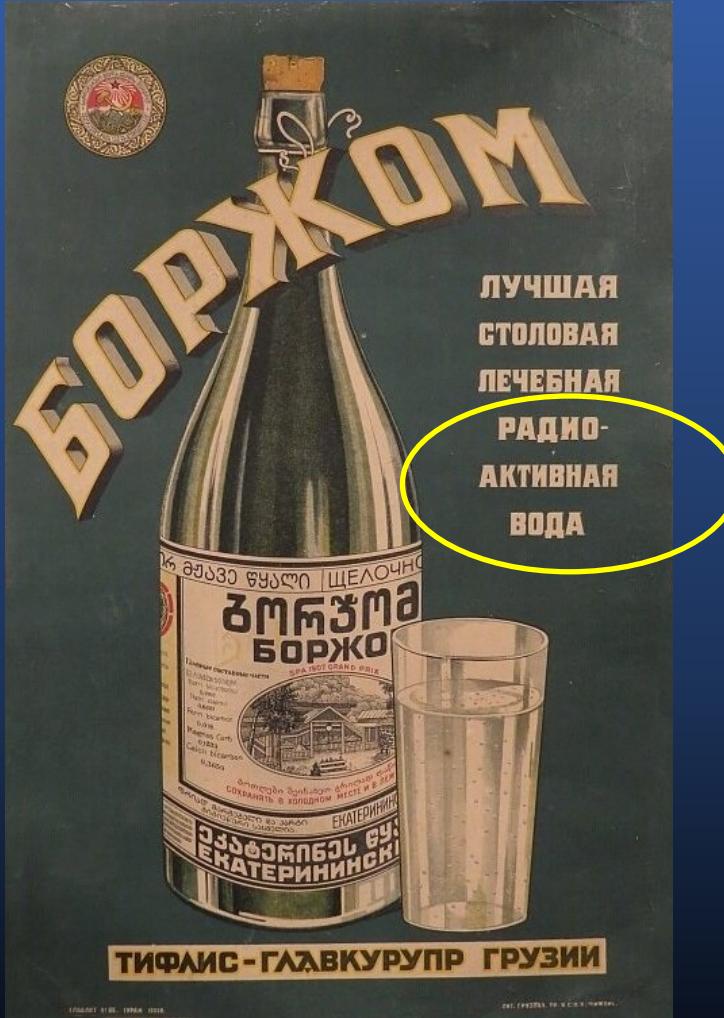
For Descriptive and Clinical Literature Address.

New York Chicago
C. Everett Field, M. D. G. W. Hanford, M. D.
50 E. 11st St. 719 1st Nat'l Bank Bidg.

Boston San Francisco
Samuel Delano, M. D. Fred J. Lachenbach
29 Newbury St. Biologic Depot
 505 Butler Blvd

- Both Radium Chemical Company ads at left from journal *Radium* in 1915-1916 [3]
- Radium for speculative uses: drinking, bathing, compresses, injection
- Note the AMA's position on these radium drugs
- Journal positions itself as scholarly, editors are M.D.s, but actually work for Radium Chemical Company and are paid to develop market for radium

The foundations of “mild radium therapy”
arose in speculation about benefits of natural mineral waters and sunlight...



“Mild radium therapy”: emanators

Endorsed by many mainstream physicians, clinically studied...but fad-prone

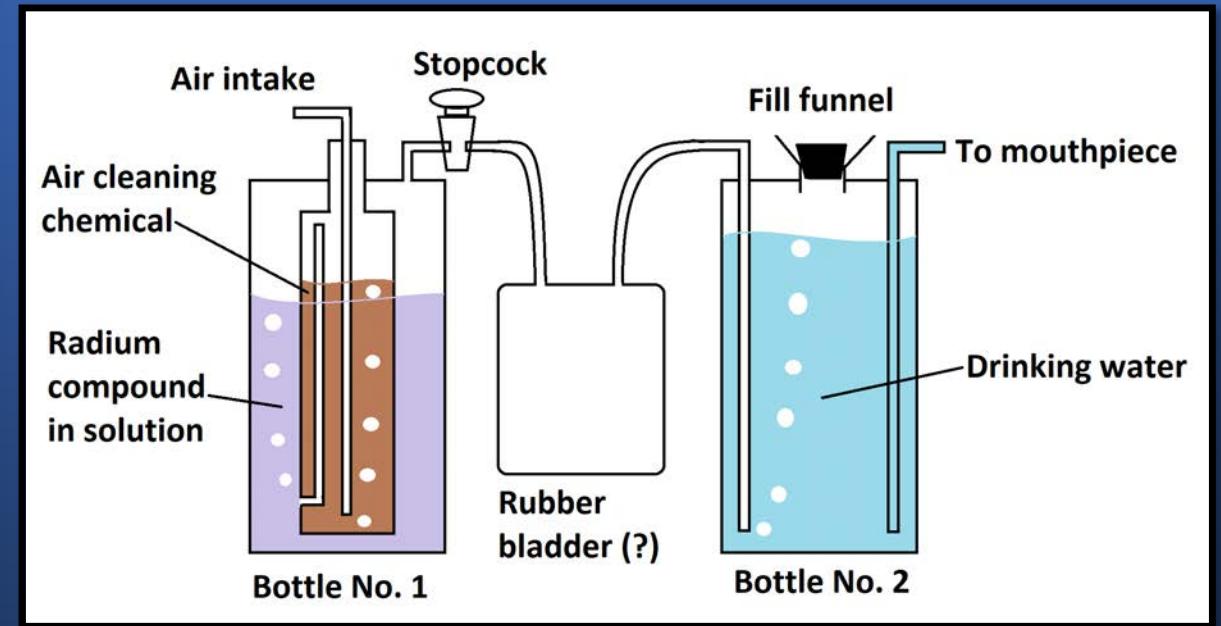


“Sadera” emanator, France, ca. 1929 contains ~40 µCi Ra-226



“Radium das Leben” emanator, Germany, ca. 1930 contains ~10 µCi Ra-226

An American emanator (ca. 1919-1924)



"Radiumizer" by the Rocky Mountain Radium Products Company. Contains $\sim 110 \mu\text{Ci}$ Ra-226 (radiation from which has colorized the glass).

This company also made radium suppositories.

Video: <https://www.youtube.com/watch?v=gEKHP2fnWOk>

Revigators (1924-1930)

American radium ore crocks made in great quantity, still easy to find.

Inventor Ralph Thomas was a stock trader.



WHY YOUR DRINKING WATER SHOULD ALWAYS BE RADIO-ACTIVE

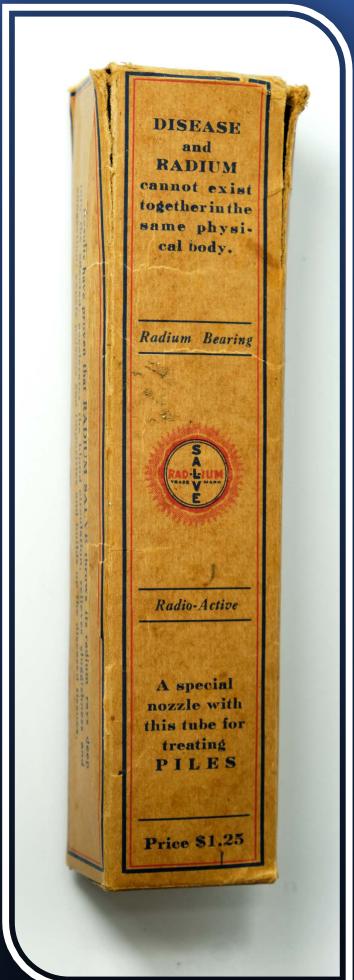
IMPORTANT

Radio-active water has no case to prove. Don't adopt it with the attitude that you are trying something new and untried. Accept it as the blessing it is, for the famous health springs of the world, such as Gastein, Germany; Bath, England; Hot Springs, Ark.; Vichy, France, have performed health miracles for centuries. And it is now accepted by authorities, who actually practice at the springs, that this is due to the high radio-activity of the water. The Revigator truly duplicates the radio-activity of these springs.

Only those doubt the efficacy of the Revigator who are not familiar with the wonderful health benefits derived from radio-active water in health springs strength at the really famous health springs of the world.

Klein's Radium Salve (ca. 1929)

You were directed to squeeze this up your keister. (~ 1 microcurie Ra-226)



"A special nozzle [...] for treating PILES"

A New Medicine For The World
Klein's Radium Salve
It Works Fast

Radium Salve has achieved its greatest triumph in coping with disease from the mildest form to that of the most stubborn kind. Use Radium Salve for Chronic Ulcers, Eczema, Sores and PILES. Especially good for sore golf feet, poison oak, ringworm, pimples, facial blemishes and sores and skin diseases of various kinds.

IT WORKS FAST.

It Smoothes the Skin Quickly.

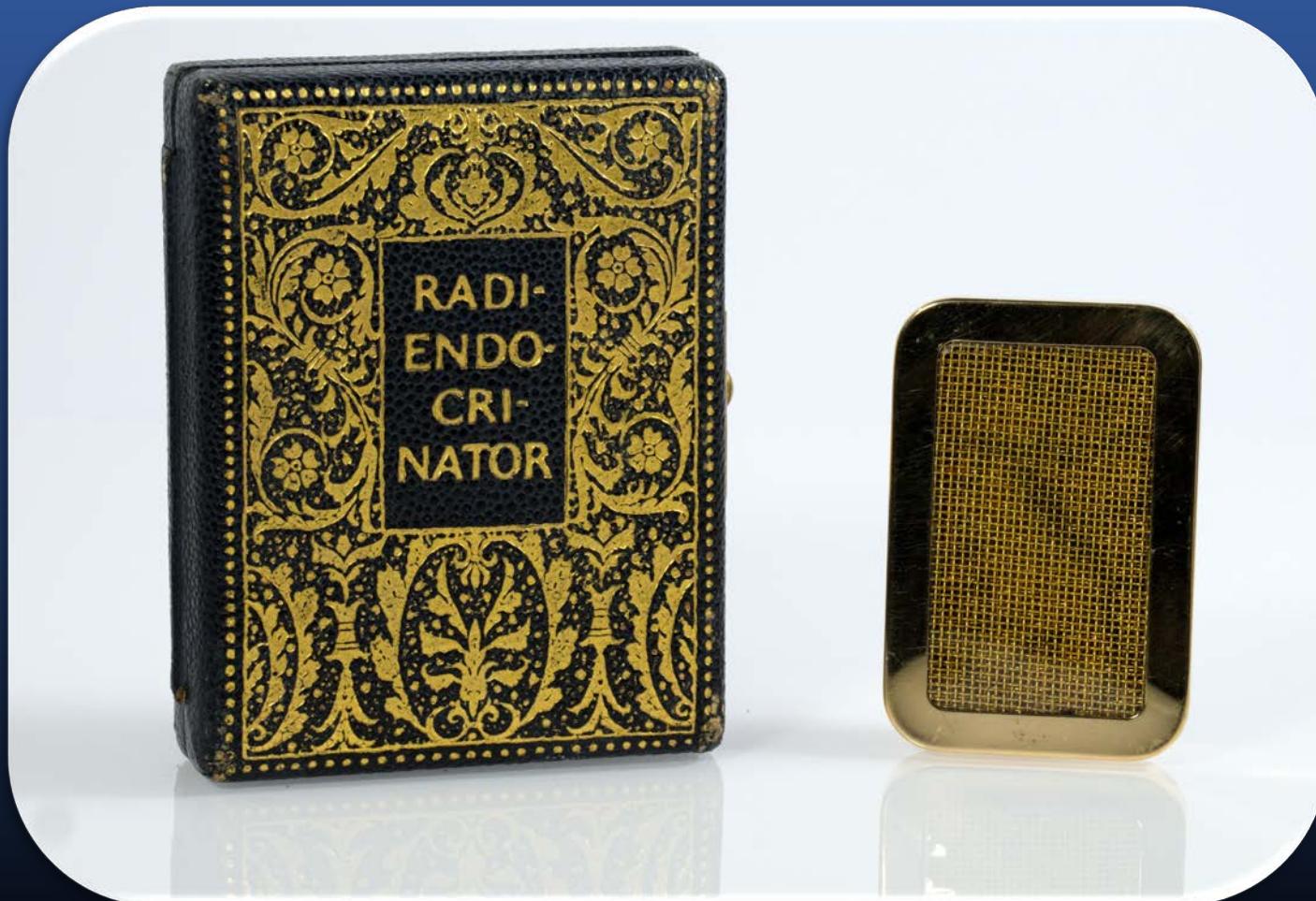
BUY A TUBE TODAY AND STOP YOUR SUFFERING

For sale at Krueger's Drug Stores and all other drug stores in Victoria. If your druggist cannot supply you, write the Radium Salve Corporation of America, 306 West Seventh Street, Little Rock, Arkansas.

Ellis-Jones and Van Vleet-Ellis, Memphis, Tenn.
McKesson-Lincoln, Little Rock, Ark.
Wholesale Distributors

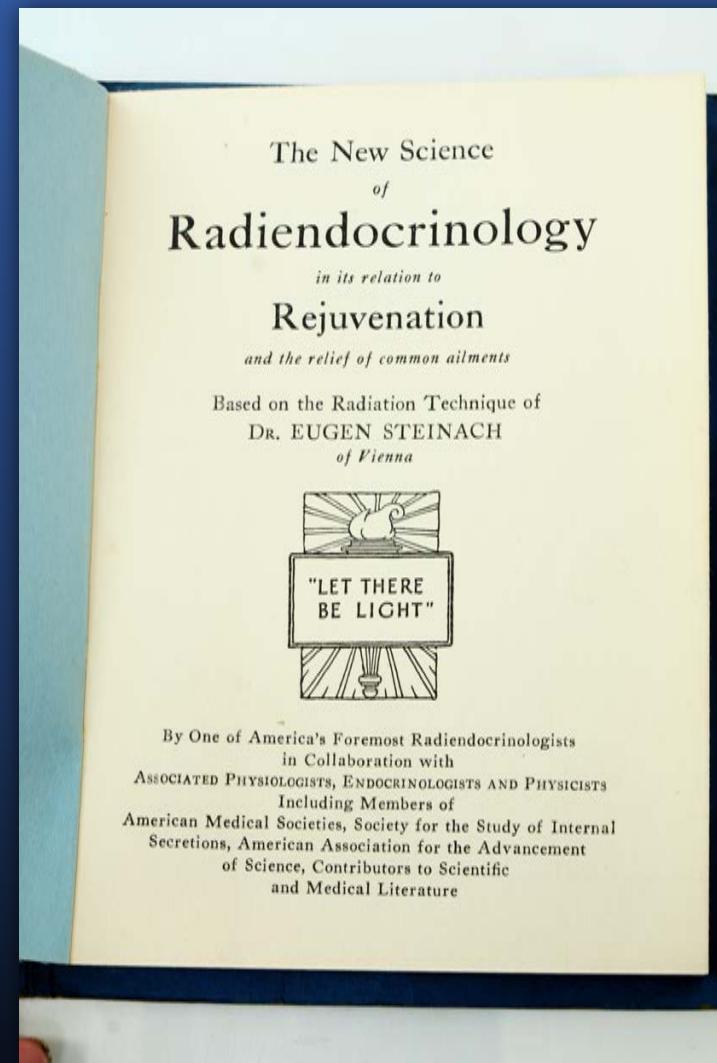
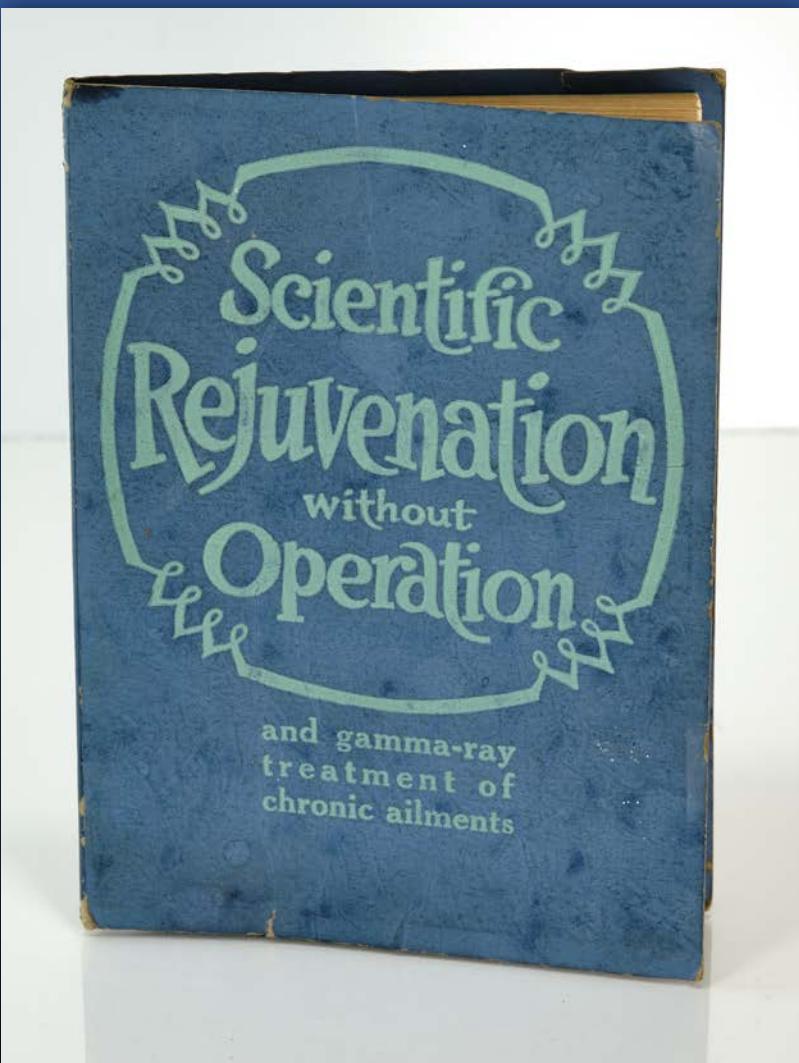
Radiendocrinator (1924-1929)

A radioactive jockstrap by William Bailey. (100 microcuries Ra-226, 150 microcuries Ra-228)



- “Radiate as directed”: 91 mGy/h scrotal skin dose rate at peak activity (3.5 years old), per VARSIN model
- Possibility of skin erythema (radiation burns) after several nights of use

Radiendocrinator promotional literature



“The Radiendocrinator is built up of radioactive materials which send forth from the instruments an unending stream of powerful ray-charges that penetrate the endocrines and ionize them [...] One may liken it to a powerful beam of sunshine turned into the dark interior recesses of the body [...]”

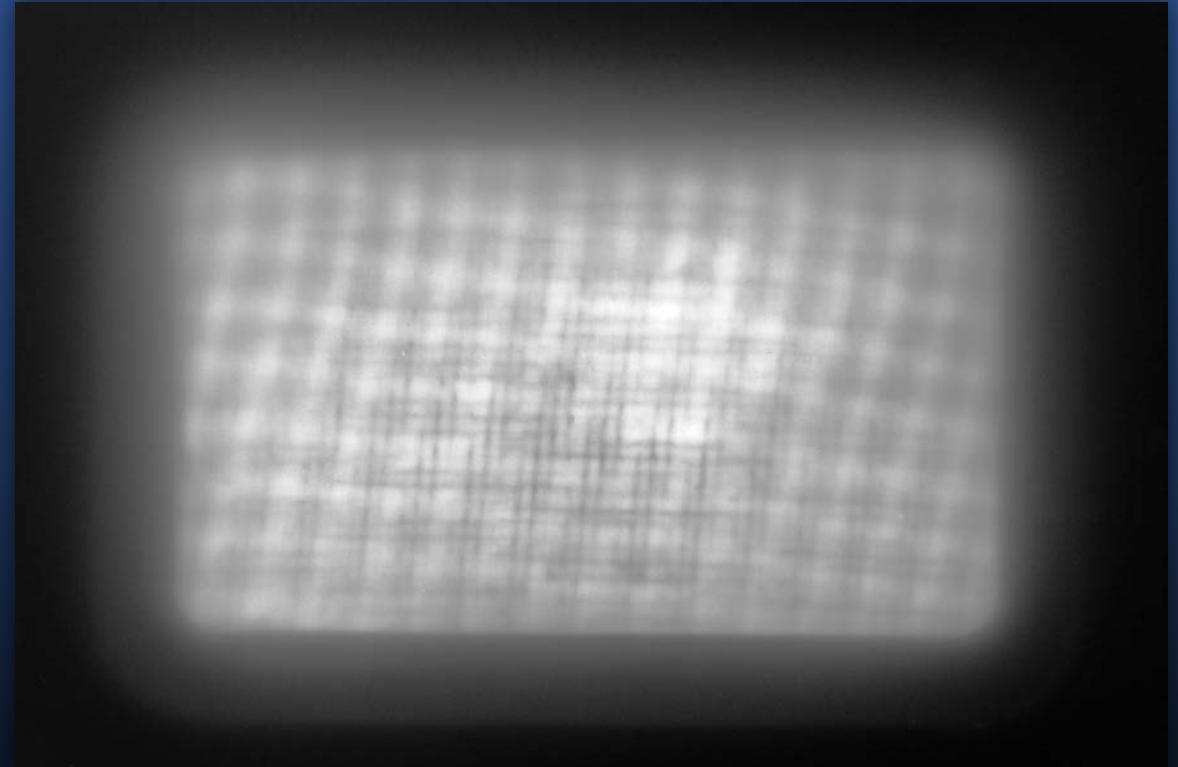
Radiendocrinator measurements

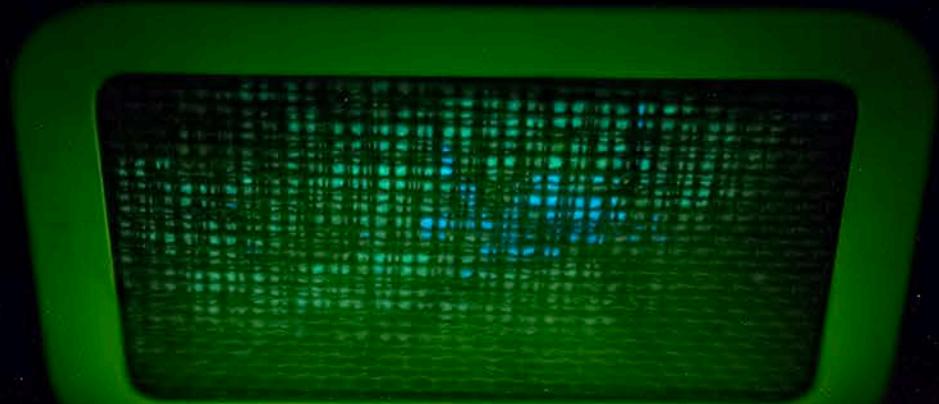


- Contact exposure rate in an air ionization chamber survey instrument is $\sim 40 \text{ mR/h}$.
- Inverse-square measurement confirms about 95 microcuries Ra-226
- Ra-228 is completely decayed.

Radiendocrinator autoradiographs

Autoradiographs can be made on Ilford HP5+ film (standard processing) in about an hour.





Radiendocrinator on an x-ray fluoroscope screen (20-minute exposure)

Radiendocrinator storage



1" lead box, lead
bricks in unoccupied
outbuilding

Strategy is to limit radon spread and unwanted exposure to external radiation.



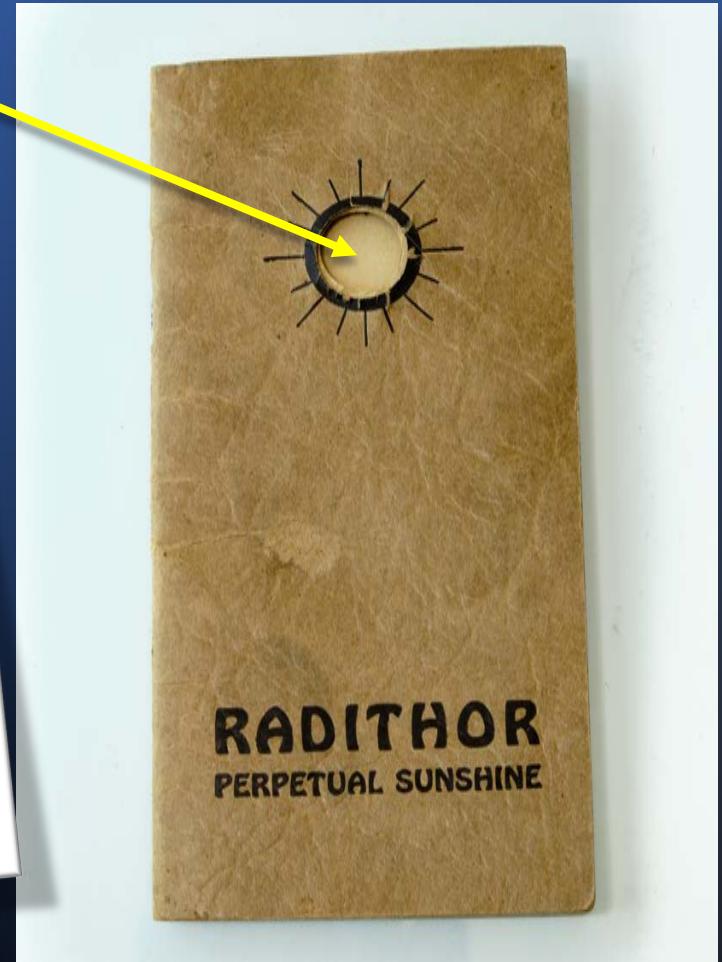
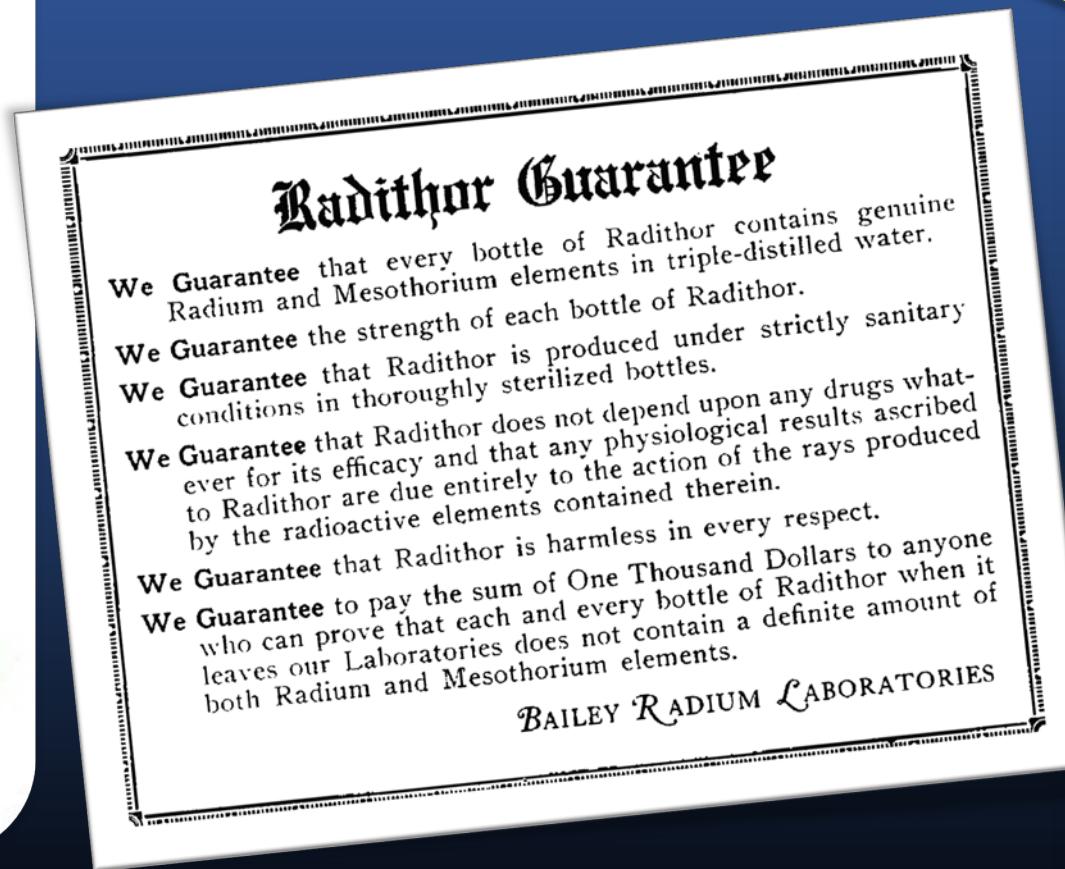
Sealed plastic bag;
Case stored
separately

Sealed inner
container

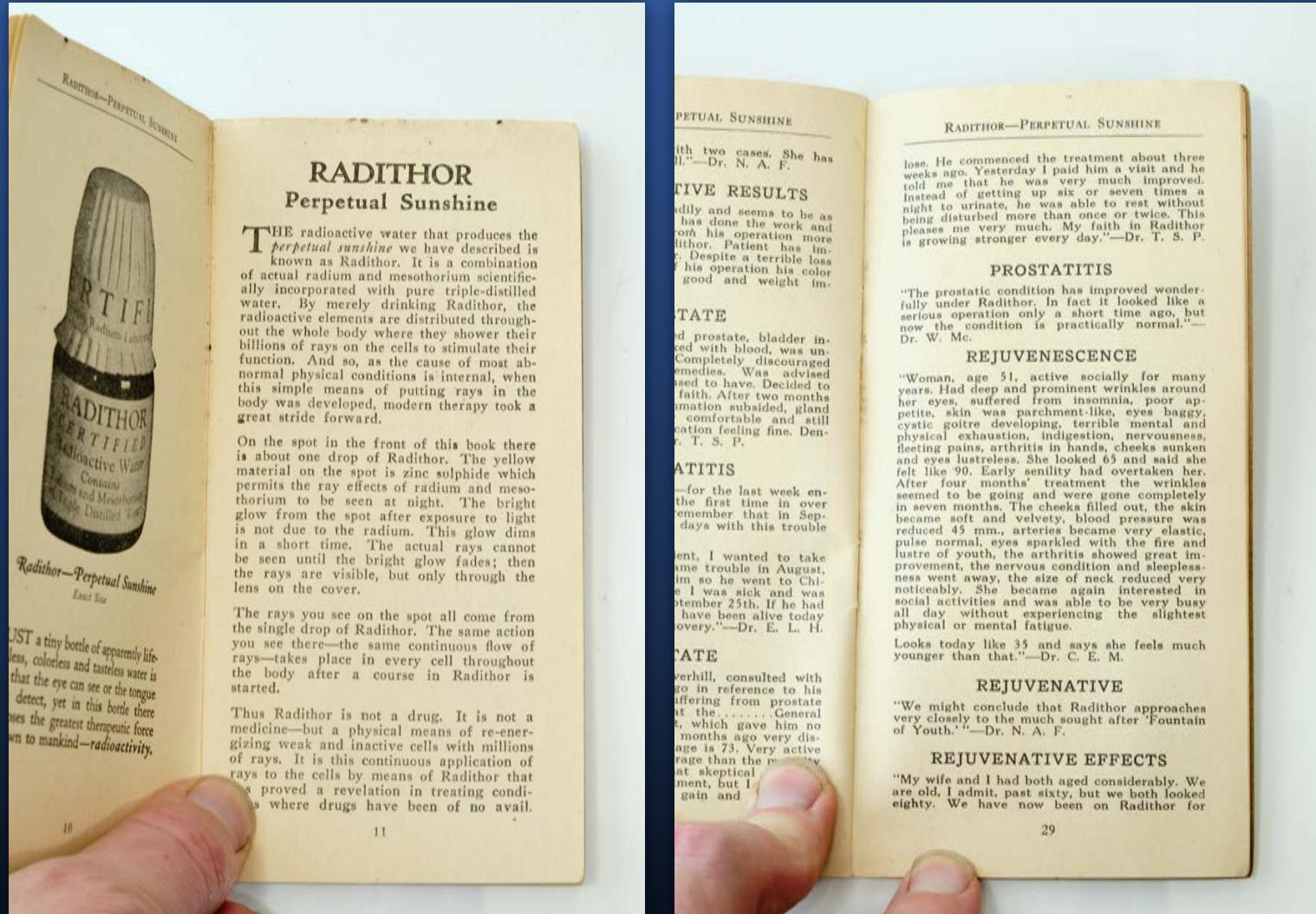


Radithor (1918-1931)

Most infamous of all the radium quack cures. (1 microcurie Ra-226, 1 microcurie Ra-228)



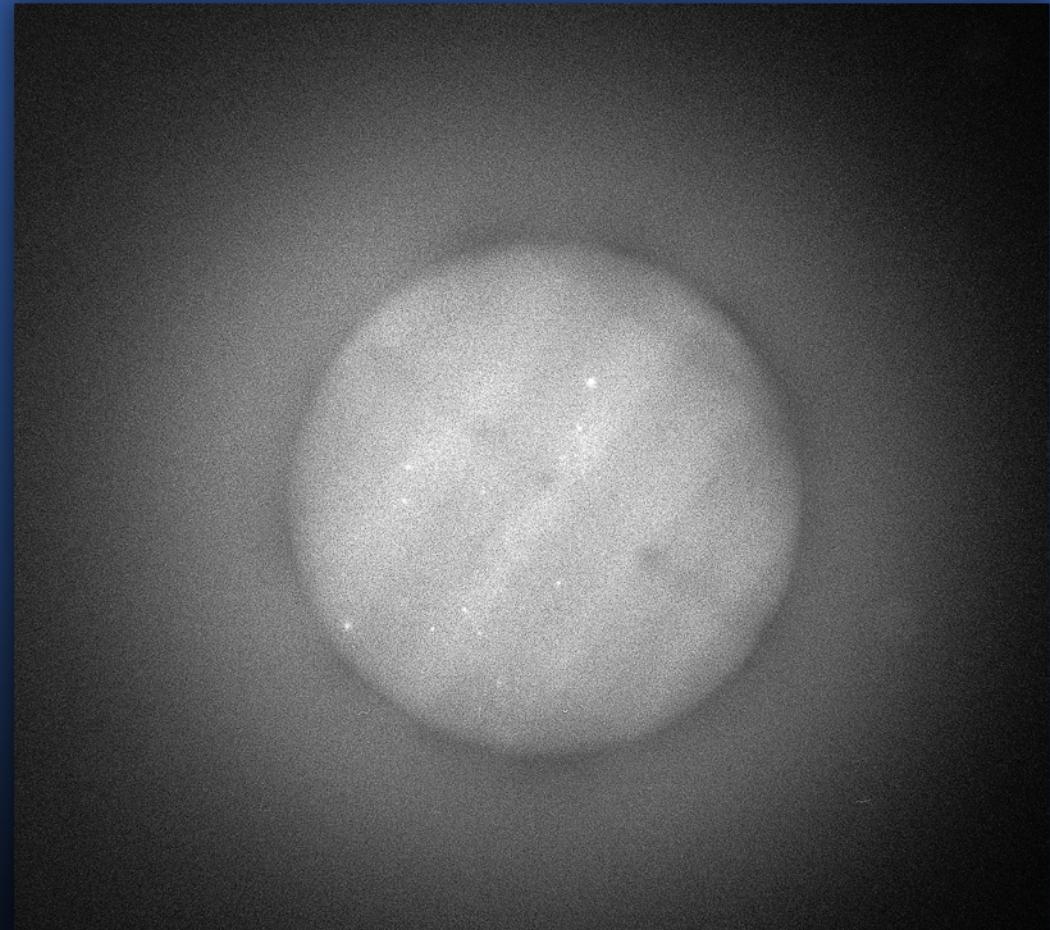
Promotional literature: “Perpetual Sunshine”



“By merely drinking Radithor, the radioactive elements are distributed throughout the whole body where they shower their billions of rays on the cells to stimulate their function.”

Radithor autoradiographs

Most original Radithor corks are sufficiently contaminated with radium to produce an image on film in several days.



Radithor as “fee-splitting quackery”

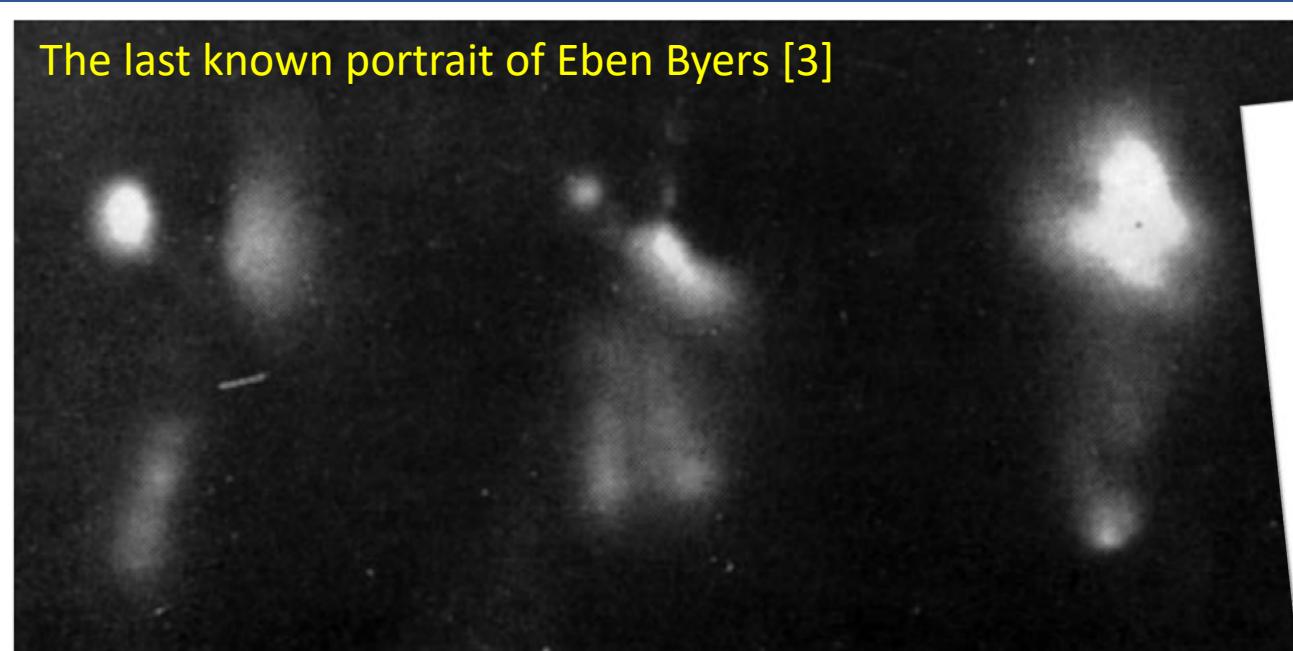


- Doctors got \$5 kickback from William Bailey for every \$30 case of 30 Radithor bottles prescribed [4]
- Explicit kickbacks not outlawed at the federal level until 1972 in the US (Anti-Kickback Statute)

Radithor and the end of the classic era

“Radithor is one of the few radioactive quack cures that can be unambiguously linked to someone's death.” [5]

The last known portrait of Eben Byers [3]



INVISIBLE RAYS from Byers's teeth left these eerie images on photographic film during the forensic examination that followed his gruesome death. Decades later a reexamination of the teeth and bones of Byers, Bailey and other consumers of Radithor showed significant levels of residual radioactivity.

Although many individuals had quickly succumbed, some—including Bailey—managed to reach a ripe age, often without suffering any ill effects that could be attributed clearly to the radiation. This extraordinary variation in the effects of long-term radiation remains unexplained.

The Radium Water Worked Fine Until His Jaw Came Off

Cancer Researcher Unearthed
A Bizarre Tale of Medicine
And Roaring '20s Society

By RON WINSLOW

EBEN M. BYERS DIES OF RADIUM POISONING

Noted Sportsman, 51, Had Drunk a Patented Water for a Long Period.

CRIMINAL INQUIRY BEGUN

Pittsburgh and New York Steel Man Won Amateur Golf Title—Was Prominent on Turf.

Moral of the story: *don't kill rich golfers!*

Radithor's unintended benefit to science



**William J. A.
Bailey**

ANL Case #
01-567

1884-1949
(died age 64)

Known for: quackery

Radium intake: 158.7 µCi Ra-226 +
140.6 µCi Ra-228

Skeletal dose: 27.3 Gy

Cause of death: bladder cancer



**Ebenezer
Byers**

ANL Case #
01-434

1880-1932
(died age 51)

Known for: hitting ball with stick

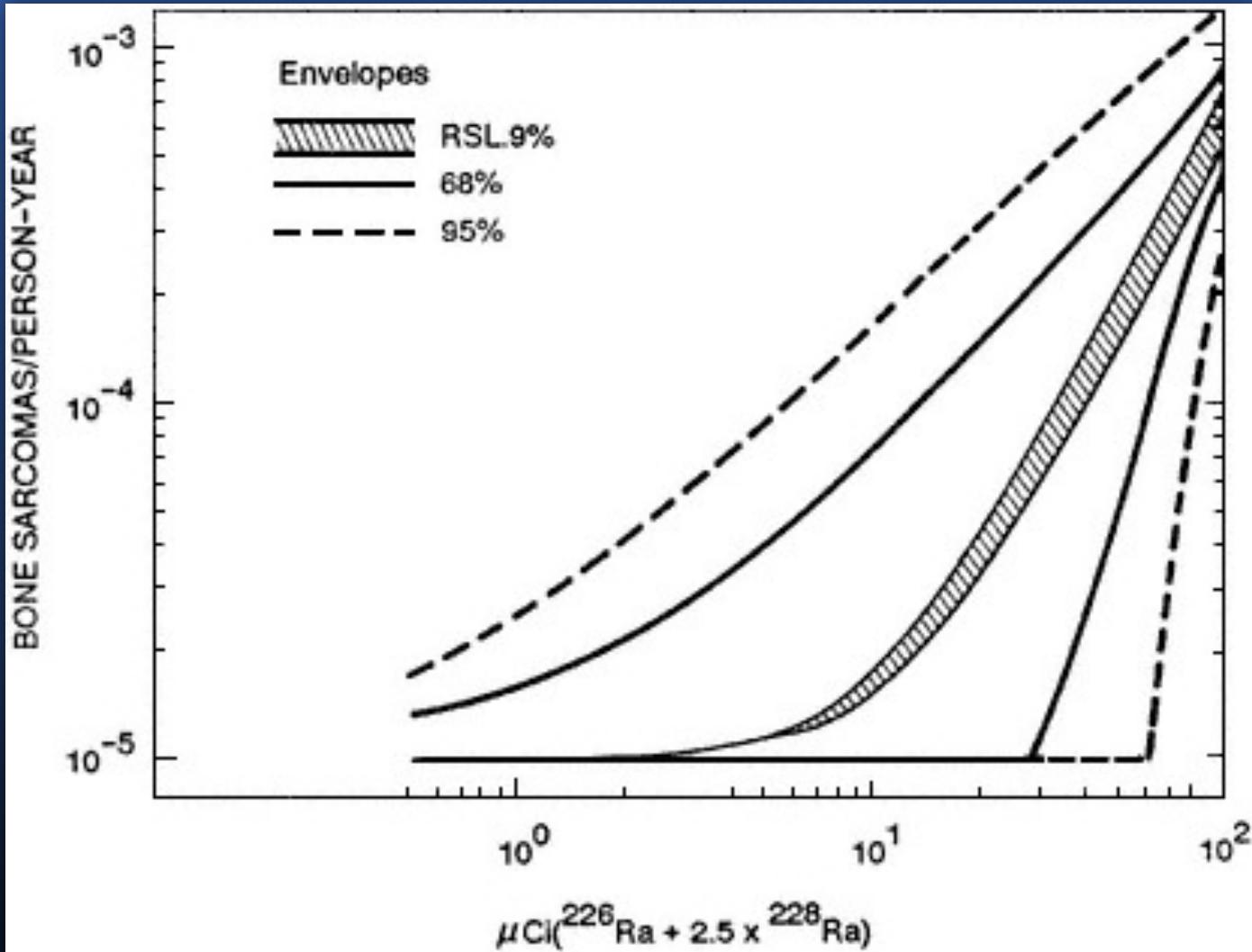
Radium intake: 348.8 µCi Ra-226 +
599.9 µCi Ra-228

Skeletal dose: 25.5 Gy

Cause of death: bone cancers

- Argonne Radium Studies [3]: the largest body of data on health consequences of internally-deposited radionuclides
- Subjects: radium dial painters, Radithor and other radium water users, people injected with radium
- Skeletal doses are reconstructed
- Highest dose recorded from Radithor: 112 Gy, Case #01-005

Radithor's unintended benefit to science



- Dose response for bone sarcoma appears to follow a threshold, non-linear trend
- Below a skeletal dose of about 1 kGy, there is no apparent response
- “[t]he great majority of exposed individuals went through life with no recognizable consequences of their exposures. They lived as long as, and apparently in as good health as, their unexposed neighbors.” [3]

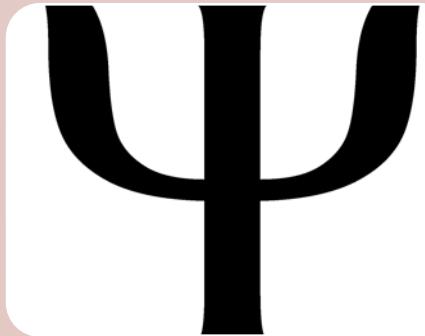
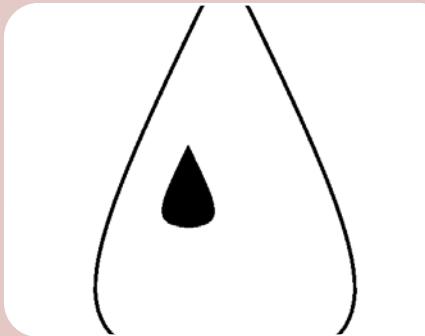
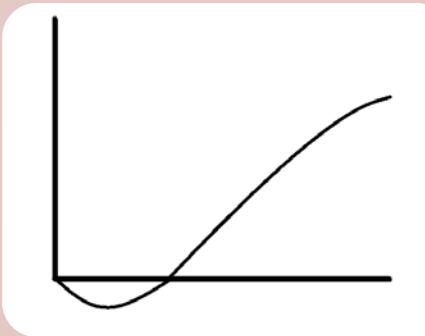
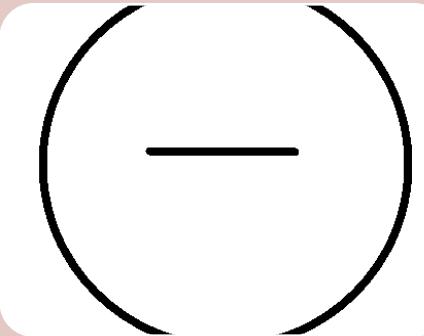
PART II

Radioactive Quackery

in the Modern Era

Modern rad quackery claims

generally fall into one or more of these categories:



Negative ions

- Purify air
- Rebalance qi (chi), prana
- Improve mood, mental health
- “Detoxify”

Hormesis

- Improve general wellbeing and function due to hormesis effects of low doses of radiation

Homeopathy

- Water memory
- Law-of-similars cures

Quantum woo

- The kind of pseudoscientific word salad peddled by Deepak Chopra

Quantum pendant (ca. 2000 – present)

Quantum woo + negative ions, jewelry, variable thorium content

IEMA

Illinois Emergency Management Agency

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IEMA Informs Consumers about Pendants Containing Trace Amounts of Radioactive Material

May 15, 2018

Continuous wear may result in radiation exposure to skin

SPRINGFIELD – The Illinois Emergency Management Agency (IEMA) is informing consumers that some pendants using negative ion technology contain trace amounts of naturally occurring radioactive materials. While the pendants do not pose an immediate health and safety concern, continuous wear over long periods of time may result in a slightly elevated skin exposure to radiation.

Negative ion technology embeds negative ions in personal products and is currently being advertised as a means to maintain health and improve emotional well-being. Products using this technology include pendants, colorful silicone wristbands and athletic tape. The pendants using negative ion technology are often advertised as Quantum Pendants and Scalar Energy Pendants.

"We are committed to protecting the public from unnecessary exposure to ionizing radiation," said IEMA Acting Director William P. Robertson. "While the radiation levels in these pendants are very low, we believe consumers have the right to know they are being exposed to radiation. They can then make an informed decision about whether or not to continue wearing the pendant and, if so, how to reduce exposure."

In response to an inquiry by an Illinois consumer, the agency analyzed a pendant in its radiochemistry laboratory and determined it contained naturally occurring radioactive materials, namely thorium and uranium. The source of the naturally occurring radioactive materials in the pendants appears to be from volcanic rock or monazite sands.

IEMA recommends anyone who chooses to continue wearing the pendants should take steps to reduce exposure to the limited radiation present. Those steps include limiting the time you are in contact with the pendant and wearing the pendant over clothing instead of directly on the skin. Consumers who discontinue wearing the pendants can safely dispose of them in the trash.

IEMA and the U.S. Nuclear Regulatory Commission (NRC) have determined some pendants being distributed and sold nationally and internationally contain enough naturally occurring radioactive material to warrant increased regulatory controls. IEMA and the NRC will be working with distributors of the pendants in the U.S. to ensure proper controls are implemented.

Product Images



These have been subject to import bans, seizures, and other regulatory controls.

Mine measures ~1500 CPM on a pancake Geiger counter.



Nano wand (?? – present)

Made in China, claims vary by retailer. Contains thorium.

Mine measure ~600 CPM on a pancake Geiger counter.

Available on Amazon.

The screenshot shows an Amazon product page for a QiQibaby New Zero Point Energy Nano Wand Beauty Pen. The product is described as a "Health Stick in Leather Pouch". It has a price of \$19.48 with FREE Shipping. The item has been purchased 2 times. The listing includes a short description, a bulleted list of benefits, and purchase options like "Add to Cart" and "Buy Now".

QiQibaby New Zero Point Energy Nano Wand Beauty Pen Health Stick in Leather Pouch

Price: \$19.48 (\$0.19 / Count) & FREE Shipping

- Pain or discomfort in the fields of light and activating your body to reduce or close to rotate the press EWand
- Remind of youthful appearance, rotate Available areas
- Unclear blockages stagnant flow for improve mind
- Water liquid cream energize right away
- Our wands are made up of a special combination of granulated minerals, fused together inside of a magnetic casing to access zero point energy

Report incorrect product information.



Greenfield Harmonizer (2010 – present)



Measures ~1700 CPM on a pancake Geiger counter.

Claims to structure water (a homeopathic doctrine).

Contains high-activity uranium ore.

Intended usage:
externally irradiate
water used for
drinking or crop
irrigation.

Japanese negative ion sources

Measures ~1600 CPM on a pancake Geiger counter.



Typically contain Th-232. Claims made for negative ions:

- Improve mood
- Purify air and water
- Destroy odors
- Denature nicotine (claimed by Wellrich card)

Measures ~900 CPM on a pancake Geiger counter.



Doses from some modern radquackery

Table 4. Radiation dose measured by TLD100 crystals during 91.6 h in contact with a bracelet and during 167.8 h in the centre of the phantom, when the bracelet was mounted on a cylindrical water phantom.

	Crystal position	Measured dose [mGy]	Dose rate [$\mu\text{Gy h}^{-1}$]	Yearly dose [mGy y^{-1}]
On the bracelet	1	0.319	3.48	30.53
	2	0.344	3.76	32.94
	3	0.396	4.33	37.89
	4	0.376	4.11	36.00
	5	0.423	4.62	40.47
	6	0.287	3.14	27.50
	Average	0.36 ± 0.05	3.91 ± 0.55	34.22 ± 4.82
At phantom centre	7	0.402	2.40 ± 0.24	21.02

Negative ion bracelet found in Israel [8]

- Modern devices are often not known to be radioactive by their users.
- Modern devices are often intended to be worn, slept on, breathed through, or carried on the person, so potential doses can be rather high.

Doses from some modern radquackery

Table 2 Concentration of radioactivities and main other elements in the radioactive consumer products.

No	RCP Name	Concentration (Bq g^{-1}) ^{*1} ^{232}Th	Concentration (Bq g^{-1}) ^{*1} ^{238}U	Main other elements ^{*2}
1	Jell-1	$(4.1\pm 0.3)\times 10^1$	$(1.5\pm 0.01)\times 10^1$	Ce, Zr, Yb, Eu, Hf
2	Liquid (red)	$(2.1\pm 0.01)\times 10^1$	$(3.9\pm 0.3)\times 10^0$	-
3	Cream	$(2.0\pm 0.07)\times 10^1$	$(7.1\pm 0.2)\times 10^0$	Zr, Ce, Hf, Yb
4	Face powder	$(6.8\pm 0.01)\times 10^1$	$(1.3\pm 0.01)\times 10^1$	Ce,
5	Jell-2	$(4.1\pm 0.3)\times 10^1$	$(1.5\pm 0.01)\times 10^1$	Ce, Zr, Yb, Eu, Hf
6	Body lotion	$(1.8\pm 0.2)\times 10^{-3}$	-	Ce, Hf
7	Mascara	$(1.1\pm 0.1)\times 10^{-1}$	$(5.6\pm 1.2)\times 10^{-1}$	Fe, Zn
8	Bedrock-bath; red	$(1.3\pm 0.07)\times 10^3$	$(1.9\pm 0.04)\times 10^2$	Fe, Ce, Mn, Zn
9	Bedrock-bath; white	$(1.3\pm 0.02)\times 10^3$	$(2.1\pm 0.1)\times 10^2$	Ce, Zn, Zr, Yb, Hf
10	Bakelite	$(5.4\pm 0.04)\times 10^3$	$(8.6\pm 0.3)\times 10^1$	-
11	Ra powder	$(2.6\pm 0.1)\times 10^{-1}$	$(2.1\pm 0.2)\times 10^{-1}$	Ca, Mn, Ce, Hf
12	Ra brick	ND	$(6.3\pm 0.09)\times 10^1$	-
13	Gas lantern mantle	$(1.7\pm 0.1)\times 10^2$	$(4.2\pm 0.1)\times 10^0$	Mg, Pb, K, Al, Y
14		$(2.9\pm 0.1)\times 10^2$	$(5.8\pm 0.1)\times 10^0$	Mg, Al, Na, Si, Ce
15	Mileage improvement	$(1.6\pm 0.1)\times 10^0$	$(3.7\pm 0.5)\times 10^0$	-
16		$(4.1\pm 0.04)\times 10^2$	$(7.3\pm 0.2)\times 10^1$	-
17	Deodorant	$(1.6\pm 0.1)\times 10^3$	$(3.0\pm 0.05)\times 10^2$	Ce, Zr, Zn, Cr, Tb
18		$(1.6\pm 0.07)\times 10^2$	$(2.3\pm 0.07)\times 10^2$	-
19	Pillow	$(1.2\pm 0.05)\times 10^2$	$(1.8\pm 0.4)\times 10^1$	Ce, Zn, Zr, Cr
20	Wall paper	$(4.4\pm 0.01)\times 10^0$	$(9.9\pm 1.2)\times 10^{-1}$	Fe, Zn, Zr, Hf
21	Optical microscope	$(2.7\pm 0.1)\times 10^2$	ND	-
22	Under wear	$(1.1\pm 0.01)\times 10^0$	$(1.3\pm 0.01)\times 10^0$	Zr, Ce, Hf
23	T-shirt	$(1.4\pm 0.1)\times 10^{-2}$	$(1.6\pm 0.01)\times 10^{-2}$	-
24	Wide stomach band	$(2.1\pm 0.1)\times 10^{-2}$	$(9.5\pm 0.01)\times 10^{-3}$	-
25	Monaz-bracelet	$(8.2\pm 0.1)\times 10^2$	$(1.3\pm 0.2)\times 10^2$	Ce, Zr, Zn, Tb
26	Sports bracelet	$(5.0\pm 0.6)\times 10^2$	$(1.0\pm 0.02)\times 10^2$	-
27	Eye-mask (Japan)	$(2.3\pm 0.2)\times 10^1$	$(9.8\pm 0.3)\times 10^1$	-
28	Eye-mask (Korea)	$(4.2\pm 0.3)\times 10^1$	$(6.8\pm 0.9)\times 10^0$	-

Radioactive consumer products in Japan (not all are quackery) [9]

- A good reference here is the lantern mantle, 200-300 Bq/g Th-232
- Quack items described as “deodorant”, bracelets, bath additives among those that are more radioactive than the lantern mantle.

Doses from some modern radquackery

Table 1 Inspected quantities and dose evaluation results for the 11 kinds of products

Product type	Number of inspection sample	Number of annual effective dose exceeding 1 mSv	^{220}Rn conc. (Bq/m^3)	^{222}Rn conc. (Bq/m^3)	Internal dose (mSv/year)	External dose (mSv/year)
Mattress	20	8	0–11,550	18–215	0–78	0–0.5
Quilt	14	3	4–986	7–60	0.01–7	0–1
Pillow	9	4	9–21,760	7–89	0.07–144	0–0.1
Mask	4	3	11–19,140	25–258	0.01–9	0–0.002
Eye mask	2	2	100–2860	34–122	11–20	0.03–0.04
Scarf	1	1	175	17	4	0.11
Carpet	1	1	93	11	2	0.5
Shawl	1	1	372	21	10	0.2
Protective gear	2	0	13–19	6–11	0.006–0.4	0–0.02
Water cup	4	0	10–27	3–16	0–0.4	0–0.04
Kettle	1	0	14	10	0.02	0

Up to 144 mSv/y from quack items (including pillows, mattresses) sold in Taiwan [10], exceeding occupational dose limits

Emergent challenges with radioactive quackery

- Internet-based direct-import distribution creates challenges interdicting modern quack products.
- The Internet also provides a fertile growth medium for anti-establishment views, pseudoscience, quack promotions and fads.
- The words “radioactive” and “radiation” are taboo, and many users of these products today are unaware that they are radioactive. New descriptive language makes little denotative sense and the presence of a radioactive material can be difficult to infer.
- It is unlikely that the current quackery will contribute meaningfully to our understanding of radiobiology.

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