Plutonium-239

A couple of statements about plutonium-239 have become de rigueur memes during recent years. As with most memes, there are elements of truth intermixed with disingenuous hyperbole.

"Plutonium-239 is one of the most toxic/dangerous substances on earth."

Plutonium is certainly hazardous if inhaled into the lungs, and to a lesser extent, if ingested. But if it is in a sealed container and stays outside the body, plutonium is relatively harmless, being principally an alpha-emitter and low energy gamma-emitter that is easily shielded. The radiotoxicity of Pu-239, if inhaled, is certainly one of the more radiotoxic alpha-emitters, though is comparable to more common naturally occurring alpha-emitting radionuclides in uncontaminated soil.

The following table presents NRC airborne concentrations limits for the public (in μCi/mL) that if inhaled over the course of one year would give a total lifetime dose of 50 millirem,[1] together with EPA-measured background threshold values (BTV) in soil for SSFL (in pCi/g).[2] Common naturally occurring uranium-238, thorium-232, radium-226 and polonium-210 have concentrations in soil at least 100 to 200 times higher than plutonium-239 from weapons test fallout yet have comparable airborne (inhalation) limits. Thorium-232 actually has an airborne limit 5-times lower that plutonium-239, and a background threshold value 200-times higher than plutonium-239. This indicates that inhaling airborne dust from uncontaminated background soil gives a thorium-232 dose and risk of 5 x 200 = 1,000-times greater than from plutonium-239.

Radionuclide	**Airborne (Inhalation) Limit (μCi/mL)**	**Background Threshold Value (BTV) in Soil (pCi/g)**
Plutonium-239	2×10^{-14}	0.0142
Uranium-238	6×10^{-14}	1.68
Thorium-232	4×10^{-15}	2.95
Radium-226	9×10^{-13}	1.88
Polonium-210	9×10^{-13}	2.09

[1] Nuclear Regulatory Commission. 10 CFR 20, Appendix B. Table 2. "Effluent Concentrations." https://www.ecfr.gov/current/title-10/chapter-I/part-20/appendix-Appendix%20B%20to%20Part%2020

[2] Environmental Protection Agency. "EPA Radiological Characterization Study Results." November 2012. https://www.boeing.com/content/dam/boeing/boeingdotcom/principles/environment/pdf/EPA_November_2012_Factsheet.pdf

"A few millionths of an ounce of plutonium-239, if inhaled, will cause lung cancer with a virtual 100% statistical certainty."

Source of Statement

This statement appeared in various documents related to the PSR-LA litigation.[3],[4] and on PASSFL's website.[5] It is a rephrasing of a statement from a 1990 report, "The Hazard from Plutonium Dispersal by Nuclear Warhead Accidents."[6] The original statement on page 4 reads,

> "… it is estimated from experimental data on beagle dogs that the risk of death from pulmonary neoplasia (a cancer) would be approximately 100 percent for the inhalation by a human adult of more than 0.08 milligrams of WgPu (weapons grade plutonium) …"

0.08 milligrams converts to 0.0000028 ounces or "a few millionths of an ounce."[7] Note that the original statement refers to cancer fatality risk (CFR) whereas the CBG and PASSFL statements implicitly but mistakenly refers to cancer incidence risk (CIR) due to the omission of the word "death." BEIR VII states that cancer incidence risk (CIR) is 0.00114 per rem and the cancer fatality risk (CFR) is 0.00057 per rem (average of estimates from Table 1).[8]

Source Report's Objective

The source report's objective was to estimate the effects of plutonium-fueled nuclear warheads involved in accidents (e.g. plane crashes or non-nuclear explosions) and PuO_2 aerosols being subsequently dispersed to the environment following explosion of chemical high explosives (HE). Notwithstanding the long-term cancer effects of inhaling plutonium-239, it is worth noting

[3] Committee to Bridge the Gap (CBG). "Demolition of Radioactive Structures and the Disposal and Recycling of the Debris from the SSFL and the Role Played by the California DTSC and the California DPH." August 5, 2013. https://www.philrutherford.com/SSFL/boeing_building_demolition/SSFLDemolitionAndDisposalStudy.pdf

[4] PSR-LA, SCFS, CBG & Consumer Watchdog. "Appellants' Opening Brief." Californian Appeals Court. Case No. C088821. June 28, 2022. https://www.dtsc-ssfl.com/files/lib_physocrespvsdtsc/courtdocuments/69832_Appellants_Opening_Brief_Final.pdf

[5] PASSFL website. Accessed October 23, 2026. https://parentsagainstssfl.com/radioactive

[6] Steve Fetter and Frank von Hippel. "The Hazard from Plutonium Dispersal by Nuclear Warhead Accidents." Science and Global Security. Vol. 2, No. 1 (1990). https://philrutherford.com/SSFL/Pu-239/Hazard_from_plutonium_dispersal_by_nuclear_warhead_accidents.pdf

[7] Note that CBG mistakenly reported 0.08 milligrams as 0.08 micrograms and wrote the incorrect conversion of 0.08 micrograms = ~3 millionths of an ounce. PASSFL likewise used the same incorrect conversion.

[8] NAS BEIR VII. "Biological Effects of Ionizing Radiation: Health Risks from Exposure to Low Levels of Ionizing Radiation." Report Summary. June 2005. https://philrutherford.com/Radiation_Risk/11340rb.pdf

that the 1990 report also reaches the following conclusions about short-term and long-term effects of being exposed to 10 kg of plutonium-239 (Table 5) dispersed following a HE non-nuclear explosion of a nuclear weapon.

- *"An accident involving the dispersal of kilogram-quantities of plutonium in aerosol form might, in a worst case (for example, an accident at Bangor Naval Base with the wind blowing toward Seattle with low wind speed and deposition velocity), cause a few thousand cancer deaths during the subsequent decades* ***with a probably undetectable increase in the resulting regional cancer rate. Even under worst-case conditions, no early deaths due to high doses would be expected.****"* (page 12)

- *"A maximum dose approaching 0.08 milligrams—the lowest dose likely to cause threshold effects— occurs only at close ranges (< 500 meters) and low wind speeds (≤ 1 meter per second). Therefore* ***doses exceeding 0.08 milligrams are highly unlikely*** *to occur anywhere near civilian populations."* (page 17)

- *"Even if the surrounding population was not evacuated and the land was not decontaminated for long periods of time (conditions that are highly unlikely), the maximum off-site dose would exceed 0.08 milligrams only under a very limited set of weather conditions combined with a very low cloud height.* ***Therefore, for all practical purposes, threshold health effects from such accidents can be ignored****."* (page 18)

Given these conclusions regarding dispersal of the 10 kg of plutonium-239 contents of a nuclear weapon, concerns over hypothetical dispersal of non-existent Pu-239 from decommissioned building 4055, that has been surveyed clean by Rockwell, the Nuclear Regulatory Commission and the Environmental Protection Agency, appear to be contrived.

Beagle Dog Experimentation

The report (pages 13-14) refers to experiments performed on beagle dogs that inhaled varying quantities of aerosolized plutonium, were observed over an extended periods of time, and diagnosed with pulmonary fibrosis and/or pulmonary neoplasia (cancer) until death ensued. Correlation between plutonium effects on beagle lung tissue and human lung tissue enabled the 0.08 milligram figured to be computed.

Comparison of Risks from Pu-239 to Other Naturally Occurring Alpha Emitters

The small *"few millionths of an ounce"* appears alarming at first, however this is an artifact of using mass units instead of the more conventional units of radioactivity (Ci. μCi, pCi) and a result of the relatively high specific activity of plutonium-239 of 0.062 Ci/g.

To determine whether *"a few millionths of an ounce"* is unusual, we will look at some other common alpha-emitting radionuclides. The detailed spreadsheet[9] below calculates two separate scenarios …

1. the **cancer fatality risk (CFR) of inhalation mass** of a few millionths of an ounce of plutonium-239 in addition to common naturally occurring alpha emitters, uranium-238, thorium-232, radium-226 and polonium-210, and

2. the cancer incidence risk (CIR) from **inhaling dust-containing air from background radionuclides in soil** including uranium-238, thorium-232, radium-226, polonium-210 and plutonium-239.

1. Cancer Fatality Risk from Inhalation of 0.08 Milligrams of Radionuclides

Using NRC regulatory standards for airborne effluent release to the public, EPA's standard inhalation rate, BEIR VII cancer fatality risk factors, and established radionuclide specific activities, the cancer fatality risk (CFR) for inhaling a few (~3E-6 oz) is confirmed to be 97%, essentially 100%.

Although the inputs to the calculations were all available in 1990, the time the source report was written, the fact that the results of the beagle experiments, together with the extrapolation to predicted human results, should agree so closely to the relatively simple calculation in the spreadsheet below, is surprising.

In review of the first portion of the spreadsheet below, the only two radionuclide-specific parameters are the NRC airborne limits and the specific activities. The relative differences of these two parameters effect the differences in cancer risks from the "inhalation mass."

Identical parallel calculations were done for inhalation of 0.08 milligrams of uranium-238, thorium-232, radium-226 and polonium-210. Uranium-238 and thorium-232 had very small risks. However radium-226 had a relatively large risk at 34%. The reason for this is that radium-226 has a relatively large specific activity of 0.99 Ci/g compared to plutonium-239 specific activity of 0.062 Ci/g. Perhaps similar concerns should be voiced for potential release of naturally occurring radium-226 that is in all soil and rock and building materials during building demolition?

However, polonium-210 blows away plutonium-239 with a cancer fatality risk of 1,557. The reason for this is that polonium-210 has a very large specific activity of 4,490 Ci/g which dwarfs the plutonium-239 specific activity of 0.062 Ci/g. Of course, 1,557 is a meaningless value for

[9] Rutherford. "Pu-239_inhalation_cancer_risk.xlsx." Excel Spreadsheet. October 23, 2026. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fphilrutherford.com%2FSSFL%2FPu-239%2FPu-239_inhalation_cancer_risk.xlsx&wdOrigin=BROWSELINK

probability. Probability (or individual risk) can only have a value between 0 and 1. Therefore we can ratio the inhalation mass of ~3E-6 ounce by 1,557 = ~2 billionths of an ounce. That is the inhaled mass of polonium-210 that will give a cancer fatality risk of 100%. Perhaps similar concerns should be voiced for potential release of naturally occurring polonium-210 that is in all soil and rock and building materials during building demolition?

Linear-No-Threshold Theory of Radiation Risk: All health physicists are familiar with the linear-no-threshold theory of radiation risk and will recognize the problems with some of the high doses and high risks discussed in the above paragraphs. BEIR VII derived cancer risk factors for low-dose radiation, which BEIR VII itself defines as less than 10 rem (or 10,000 mrem). LNT enables a direct linear correlation between dose and risk, all the way down to zero dose and zero risk. LNT is a simple, convenient way to compute risk from dose, and is principally used in the range of 0 to 100 rem. Therefore the cancer incidence risk (CIR) for 10 rem is 10 x 0.00114 = 0.0114 or about 1%. EPA's acceptable CIR range is 10^{-6} to 10^{-4}. This translates into a dose range of approximately 1 to 100 mrem. Superfund remedies will usually seek to achieve cleanup goals within this risk range for a 26-year exposure duration. This translates to a dose range of approximately 0.04 to 4 mrem/y. These are clearly small risks and small dose rates. In contrast, the doses and risks resulting from the hypothetical inhalation of 0.08 milligrams or 3E-6 ounces of plutonium-239 are large and typically outside that range at which LNT computations are made. The plutonium-239 dose to achieve a ~100% long-term cancer fatality risk (CFR) is 1,698 rem. At this dose, the concern is not long-term cancer. The concern is acute radiation syndrome (ARS) in which death would be certain within a few weeks following exposure. Although the dose following inhalation of 0.08 milligrams of plutonium-239 into the lung will not result in an instantaneous dose of 1,698 rem, the exposure rate is likely to be sufficiently high to achieve a cumulative dose of 1,698 rem over a relatively short time period. For these reasons, the original and current 100% estimates of cancer risk should be viewed with caution.

2. Annual Cancer Incidence Risk from Inhalation of Dust-containing Air With Background Radionuclides

The second portion of the spreadsheet below calculates the relative cancer incidence risk (CIR) per year for naturally occurring alpha emitters, uranium-238, thorium-232, radium-226 and polonium-210, and anthropogenic plutonium-239, from inhalation of dust-laden air. The EPA uses 0.0001 gram per cubic meter as a dust resuspension factor (airborne dust loading) in its Preliminary Remediation Goal Calculator. Using this together with the EPA measured background threshold values (BTV) for SSFL soil and the NRC airborne effluent limits for the public, we can calculate annual CIR for inhalation of dust from background levels of radionuclides in soil.

All naturally occurring alpha-emitting radionuclides in soil have BTVs between 1.5 and 3 pCi/g. In contrast plutonium-239 from nuclear weapons test fallout has much smaller concentration at 0.0142 pCi/g.

The only two radionuclide-specific parameters in this calculation that impact the result are the BTVs and the NRC airborne limits.

All radionuclides have relatively small annual CIRs. The NRC airborne limit for thorium-232 is 4E-15 μCi/mL, that is a factor of 5-times lower than the plutonium-239 limit of 2E-14 μCi/mL. This implies that, from a radiological point of view, thorium-232 is 5-times more hazardous than plutonium-239 for the same quantity of activity. As we have seen above, if quantities are expressed in terms of mass units rather than radioactivity units, the reverse may be true, if specific activities are significantly different. However, in this case, specific activity does not enter into the calculation.

The BTV for thorium-232 of 2.95 pCi/g is a factor of ~200-times larger than the BTV for plutonium-239 of 0.0142 pCi/g. Both these two factors mean that the annual CIR for thorium-232 is approximately 5 x 200 = 1,000 larger than the annual CIR for plutonium-239. The annual CIR for thorium-232 is 4.2E-6 and the annual CIR for plutonium-239 is 4.0E-9. The 1,000-fold difference is independent of assumed dust resuspension rate.

Plutonium-239 Inhalation Cancer Risk

Verification that *"a few millionths of an ounce of Pu-239. if inhaled, will result in cancer (fatality) with a virtual 100% statistcal certainty"*		Units	Naturally occurring alpha-emitting radionuclides			
	Pu-239		**U-238**	**Th-232**	**Ra-226**	**Po-210**
EPA inhalation rate	**20**	**m^3 per day**	**20**	**20**	**20**	**20**
Conversion factor	365	days per year	365	365	365	365
Conversion factor	1,000,000	mL per m^3	1,000,000	1,000,000	1,000,000	1,000,000
Annual inhalation volume	7.30E+09	mL per year	7.30E+09	7.30E+09	7.30E+09	7.30E+09
Derived Airborne Concentration (DAC) for the public (10CFR20, Appendix B)	**2.0E-14**	**µCi per mL**	**6.0E-14**	**4.0E-15**	**9.0E-13**	**9.0E-13**
Annual inhaled activity at DAC	1.5E-04	µCi per year	4.4E-04	2.9E-05	6.6E-03	6.6E-03
Specific activity	**6.2E-02**	**Ci per gram**	**3.4E-07**	**1.1E-07**	**9.9E-01**	**4.49E+03**
Conversion factor	1.0E+06	µCi per Ci	1.0E+06	1.0E+06	1.0E+06	1.0E+06
Specific activity	6.2E+04	µCi per gram	3.4E-01	1.1E-01	9.9E+05	4.49E+09
Annual inhaled mass at DAC	2.4E-09	gram per year	1.3E-03	2.7E-04	6.6E-09	1.5E-12
Conversion factor	0.0353	ounce per gram	0.0353	0.0353	0.0353	0.0353
Annual inhaled mass at DAC	8.3E-11	ounce per year	4.5E-05	9.4E-06	2.3E-10	5.2E-14
Total annual NRC dose limit at DAC	50	mrem per year	50	50	50	50
Dose per ounce of radionuclide inhaled	6.0E+11	mrem per ounce	1.1E+06	5.3E+06	2.1E+11	9.7E+14
Fetter & von Hippel mass of Pu-239 inhaled for 100% cancer fatality	**0.08**	**milligram**	**0.08**	**0.08**	**0.08**	**0.08**
Fetter & von Hippel activity of Pu-239 inhaled for 100% cancer fatality	5.0E+06	picocurie	27.2	8.8	7.9E+07	3.6E+11
Conversion factor	3.53E-05	ounce per milligram	3.53E-05	3.53E-05	3.53E-05	3.53E-05
Quantify "few millionths of ounce"	3E-06	ounce	3E-06	3E-06	3E-06	3E-06
Dose from ~3E-6 oz of inhaled radionuclide	1,697,514	mrem	3.10	15.1	602,344	2.73E+09
BEIR VII theoretical radiation cancer fataiity risk (CFR)	**5.7E-07**	**CFR per mrem**	**5.7E-07**	**5.7E-07**	**5.7E-07**	**5.7E-07**
Theoretical cancer fatality risk (CFR) from inhalation of 3E-6 oz of radionuclide	**0.97**	**CFR**	**1.8E-06**	**8.6E-06**	**0.34**	**1557**

Cancer incidence risk from inhaling soil-generated dust containing background radionuclides		Units	Naturally occurring alpha-emitting radionuclides			
	Pu-239		**U-238**	**Th-232**	**Ra-226**	**Po-210**
EPA SSFL background threshold value (BTV) for soil	**0.0142**	**pCi per gram**	**1.68**	**2.95**	**1.88**	**2.09**
EPA PRG dust resuspension factor (airborne dust loading)	**0.0001**	**gram per m^3**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Airborne conentration	1.42E-06	pCi per m^3	1.68E-04	2.95E-04	1.88E-04	2.09E-04
Conversion factor	1.00E+06	pCi per µCi	1.00E+06	1.00E+06	1.00E+06	1.00E+06
Conversion factor	1.00E+06	mL per m^3	1.00E+06	1.00E+06	1.00E+06	1.00E+06
Airborne conentration	1.42E-18	µCi per mL	1.68E-16	2.95E-16	1.88E-16	2.09E-16
Derived Airborne Concentration (DAC) for the public (10CFR20, Appendix B)	**2.0E-14**	**µCi per mL**	**6.0E-14**	**4.0E-15**	**9.0E-13**	**9.0E-13**
Total annual dose at DAC	50	mrem per year	50.00	50.00	50.00	50.00
Annual dose breathing dust-containing air with soil radionuclide BTVs	0.0036	mrem per year	0.14	3.69	0.01	0.01
BEIR VII theoretical radiation cancer incidence risk (CIR)	**1.14E-06**	**CIR per mrem**	**1.14E-06**	**1.14E-06**	**1.14E-06**	**1.14E-06**
Theoretical annual cancer incidence risk (CIR) from breathing air containing radionuclides	**4.0E-09**	**CIR per year**	**1.6E-07**	**4.2E-06**	**1.2E-08**	**1.3E-08**

Bold represents input data

Unbolded represents conversion factors and calculated values

Blue bold represents final results

Yellow shaded represents key comparisons to Pu-239