Health and safety around Rocky Flats

Executive summary for potential homeowners, revised 2023

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(Lives on southern Refuge boundary)

Figure 1: Google Books N-gram historical hits on Rocky Flats. The peak was due to the FBI/EPA plant raid in 1989.

tl;dr:The well-known Superfund cleanup of the industrial area of Rocky Flats resulted in measured soil levels of plutonium far below the agreed-upon criterion. The current Refuge is even less contaminated, making it entirely safe for full-time National Wildlife Service employees, visitors, and those living around it. There is no published scientific evidence of health problems around Rocky Flats. The only route to exposure is via inhalation or swallowing dust, but soil plutonium from the nuclear plant amounts to less than 1% of total soil radioactivity (2.5% of soil alpha particle emissions). Careful epidemiology since the 1980s has never found increased leukemia or other cancer rates downwind of (or clustering of cases near) the former plant. Anti-nuclear groups cannot be trusted for non-historical information since they have no expertise, an anti-nuclear agenda, and are completely unfamiliar with the scientific literature.

Note: Green text is a clickable link. Most graphics are suitable for serious zooming to read them better. This document is best viewed with a PDF viewer, not printed.

This document is intended for people (potential home buyers or realtors) interested in or concerned about living around the Rocky Flats National Wildlife Refuge. It is a very brief overview of Vast Quantities of detailed information from the (strictly non-commercial) website I set up in early 2018, radically updated in 2023. Other documents on the website are much more quantitative and have extensive citations directly to the scientific literature and to government reports (from the U.S., Europe, the U.K., and other countries). Apart from addressing common concerns for newcomers, this document will focus on what is *true* rather than refuting what is *false*. Life is short.

I wish it were about the charms of the area and the attractions of the Wildlife Refuge–birds, elk, deer, curious vegetation, even Preble's meadow jumping mouse, but you can get that somewhere else.

- *Under no circumstances* should you believe anything you read below until you have verified my credentials (see the website), maybe by taking a deep dive into a topic about which you already know something.
- Quantitative diagrams below come from the National Institutes

It makes my skin crawl to make unsubstantiated statements not directly backed up with citations to the published scientific literature, but that is the **intent** for this document (only).

of Standards and Technology, my own measurements, or my own independent calculations using internationally-accepted guidelines from the International Commission for Radiological Protection (ICRP). These in turn come from decades of careful epidemiological studies of atomic bomb survivors, nuclear plant workers, and the public. As you will discover from the website, these are in good to excellent agreement with what you can read from the DOE, Fish&Wildlife, and the CDPHE [links at end of document].

Note: Reliable information may be found from the U.S. Department of Energy and the Colorado Department of Public Health and Environment. The added value of *this* document is that I will express strong opinions about the reliability and motives of some groups opposed to living around or using the Refuge. Some of the questions you might have include

I am surprised how definite and clear my opinions are now in comparison with how I felt when doing 'due diligence' before buying a lot in Candelas in 2014. This is because I invested a great deal of time in educating myself and then writing documentation so that no one else would have to go through the uncertainties we faced in 2013, when there were few accessible resources, only nonsense on social media. As a result the situation is now very clear to me: there are *no health risks* associated with living where we do. Lots of careful epidemiology in the 1980s through 2002 or so strongly indicates that no effects will *ever* be measured.

- What's the possible concern? (Radiation and cancer.)
- What is the *data*? Show it to me!
- Whom should I trust for information (or *not*)? (The authorities, not social media or conspiracy-theory groups.)
- What is the scientific opinion about the safety of living around the Refuge and recreating on the Refuge? (There are no health risks associated with living around the Refuge or using any part of the Refuge.)
- How successful was the Superfund cleanup? The scientific opinion is that it was so well done that it is considered exemplary and used as a model for ongoing cleanups, especially because of its effective use of financial incentives. The negotiated cleanup target (50 pCi due to plutonium per gram of soil) was negotiated before it was appreciated that *actual* values were much lower.

For other questions, consult the FAQ or use the website search window to find relevant documents. Links to some of these documents are below.

We will not talk about history (such as the Superfund cleanup)–it is not relevant to those living in the newer housing developments around the Refuge.

Anti-Refuge activists dwell almost exclusively on the history with occasional forays into pseudo-science.

1 *Radiation and health concerns*

The Rocky Flats plant produced plutonium parts for nuclear weapons and did some research on other radioisotopes. Standards for handling waste products were sloppier in the 1950s-1980s than they

are now, and accidents such as fires apparently cannot be avoided at such plants (American, European, Soviet, Russian, European, Japanese, Australian). The result was that plutonium, in the very insoluble form PuO_2, was dispersed over areas downwind of the plant (mostly east and some southeast).

Industrial solvents also were poorly handled and are present in soil in some areas around the plant. The region immediately around the plant was subject to a Superfund cleanup finished in 2005. Radiation releases from Rocky Flats are shown in Fig. 2. After about 1977 the principal source of exposure is from soil contamination dispersed as dust in the air. (This is fully accounted for in the dose diagram below.) Thus the concerns for those living nearby were the small concentrations of (radioactive) plutonium left in soil around Rocky Flats and the possible health effects. Appendix A briefly reviews ionizing radiation.

Many people do not 'get' radiation—it is invisble and potentially scary. So in this document we pay no attention to the *units* of radioactivity or dose and instead *compare* doses, allowing you to decide for yourself whether a given radiation dose is large or small with respect to, for example, background doses, which you can do nothing about.

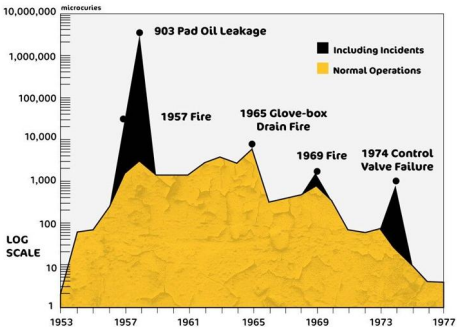


Figure 2: Historical releases of radiation due to accidents, fires, and operations. These dropped to very low levels around 1977 [from a 1992 ChemRisk report].

1.1 *Plutonium*

Plutonium is very much like other natural alpha-particle emitters in the soil except that it does not produce a significant whole body' dose since it emits very few (penetrating) gamma rays. Large doses of *ingested* or *inhaled* plutonium, historically from accidents at plutonium processing plants, can migrate to the surfaces of bones and to the liver. The range of alpha particles is a couple inches in air and *much less* in tissue (which is very similar to water). As a result it is only if it is inhaled or swallowed that a potential health risk occurs. The working assumption around Rocky Flats is that Pu remains in the dust from contaminated soil.

Two sets of *measured* data are extremely important:

1. Plutonium (Pu) isotopes (Fig. 3) account for less than 1% of total soil radioactivity. This is less than 'fallout isotopes' such as ^{137}Cs, left over from weapons testing in the 1950s through 1970s. Pu isotopes account for about 2.5% of total alpha particle radioactivity (smaller pie chart).

2. The radiation dose (Fig. 4, evaluated on the eastern Refuge boundary where it is most concentrated) from plutonium in dust (inhaled, ingested, and in the form of 'hot particles') in total is thou-

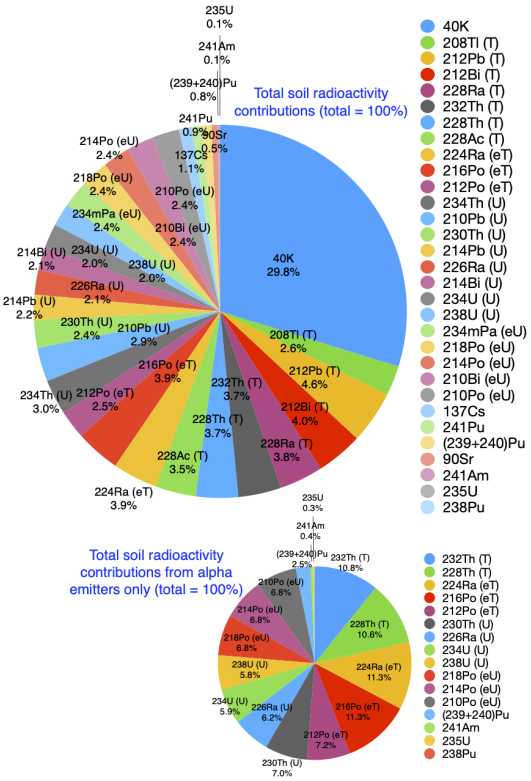


Figure 3: Radioisotopes in Rocky Flats soil from National Institute of Standards and Technology measurements, upper ie chart. Lower: same but for alpha particle emitters.

sands of times smaller than background radiation, and is based on 2019 measurements.

2 *Cancer rates around Rocky Flats*

The mistaken (and continuing) belief in elevated cancer rates around Rocky Flats was 'bookended' by two Jefferson County Public Health directors, both MDs, both named Johnson. Work of the first, Carl Johnson, predicted sensationally high cancer rates downwind of Rocky Flats. It was discredited within a couple of years and no such excess rates have ever been found. The second, Mark Johnson, with 30 years to read the scientific and epidemiological literature about Rocky Flats, did not and joined forces with anti-Refuge conspiracy theorists.

2.1 *Example of reliable epidemiology*

Rapidly reproducing tissue is the most sensitive to ionizing radiation. Leukemias (cancers of the blood produced by the cells which produce short-lived blood cells) are among the first to appear if there *is* a radiation problem, emerging within 3-4 years of exposure–see Fig. 5.

As noted above, plutonium (PuO_2) can only give a radiation dose if inhaled or ingested. Thus lung cancer is the most plausible to be produced from Pu, provided smoking is 'controlled for' (by subtracting smoking-caused case from all cases). Given the incubation times shown, from Fig. 2 by 1987 plenty of 'solid cancers' (tumors) should have emerged from public exposure to plutonium and leukemias from chronic ongoing exposure, provided the radiation doses were high enough.

A complication for careful epidemiology, especially along the Front Range, is a strong place-to-place variation of population *density*, as shown, for example, in Fig. 6. For a cancer of well-known incidence (number of cases per 100,000 population, say) there will be many more cases in areas of high population density than low.

Displaying cancer cases by where they occur on a map is thus naive and very misleading—they will appear to cluster in regions of high population density. One clear tool for compensating for this is called a *cartogram*, which is a deliberate distortion of a geographical region so that all areas have the *same* population density, while retaining the ability to measure distances and statistics. Then randomly occurring disease events will appear randomly distributed on the cartogram. If they are due to proximity to, say, a radiation source, they will cluster nearby. Fig. 7 shows the results of careful work in 1988. The area surveyed for disease had very non-uniform popula-

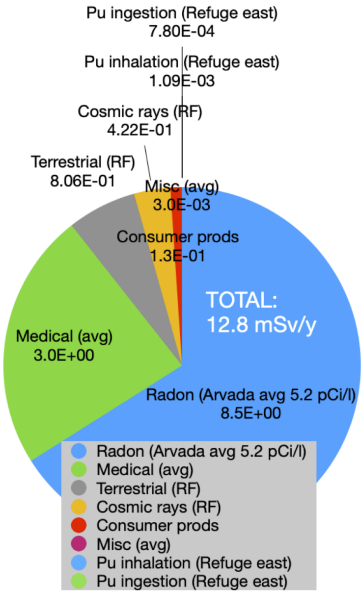
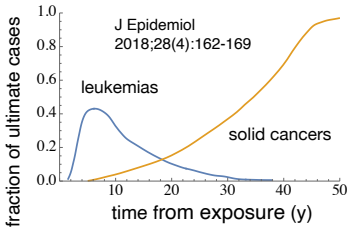


Figure 4: Yearly radiation dose for person living on the eastern Refuge boundary (there are none). Terrestrial and cosmic ray doses are measured, radon estimated for Arvada.



Japanese Legacy Cohorts: The Life Span Study Atomic Bomb Survivor Cohort and Survivors' Offspring

Figure 5: Incubation times for leukemias and solid cancers, from atomic bomb survivors.

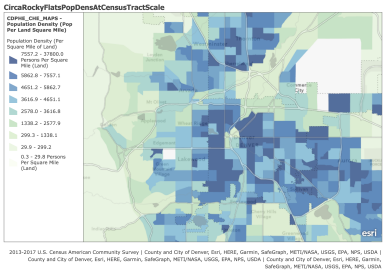


Figure 6: Population density around Rocky Flats. Note only that it varies widely.

tion density: in Fig. 6. The shape of the cartogram shows how strong are the distortions of the map needed to make the population density uniform. On the other hand, there is *no evidence* of clustering of cases near Rocky Flats—cases appear randomly scattered (and this can be tested carefully). Be warned that sloppy pseudo-science workers, blissfully unaware of huge variations of population density, will display cases of any disease they blame on Rocky Flats on an ordinary map.

3 *Inside the Refuge*

The area that became the Refuge was carefully characterized before being handed over to the Fish&Wildlife Service from the Department of Energy. It was not affected by the Superfund cleanup because plutonium levels were already low.

The 2336 samples taken before and after the cleanup are shown in the upper panel of Fig. 8. There are many thousands of other samples (water, air, soil) for other radionuclides or other contaminants; the claim that 'not enough is known about Rocky Flats' reflects ignorance, not fact. The distribution of Pu in soil is quite non-uniform, with a few high-level samples dominating the mean (average), as for a dataset like (.01,.012,.006,.04, 200.) (fictitious). The mean of 40.01 for this example is completely dominated by a single point. In the bottom panel of Fig. 8 is shown the 'cumulative distribution function' (CDF) for $^{239+240}$Pu in the soil, measured in picoCuries per gram of soil (pCi/g), an archaic unit which is the same as the units shown in the pie charts already discussed. The CDF is the answer to the question, 'What fraction of samples had a measured pCi/g below x, where x runs over the range of 0 to 10 pCi/g. For example, half of the 2208 samples in the range had a concentration under 0.096 pCi/g, 82% below 1 pCi/g, and 95% under 10 pCi/g.

As noted in a July 2006 U.S. Government Accountability Office publication, "DOE collaborated with the community in determining the level of remediation the cleanup would achieve... Working with local governments and members of the public, DOE and the regulatory agencies ultimately agreed on a soil action level of 50 picocuries of plutonium per gram (pCi/g) of surface soil (i.e., the top 3 feet of soil), meaning that a remedial action would be triggered by a soil sample indicating the existence of plutonium in excess of 50 pCi/g. A plutonium level of 50 pCi/g translates to a risk level of 1 in 500,000 (that is, this level of contamination could result in one more case of cancer than otherwise would have been expected in every 500,000 persons)." It is clear that with 95% of samples having under 10 pCi/g (much lower in the Refuge) the cleanup was very, very successful.

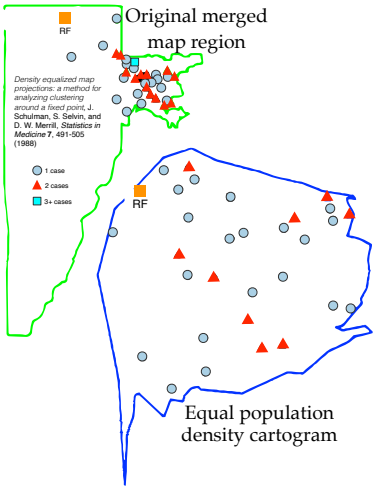
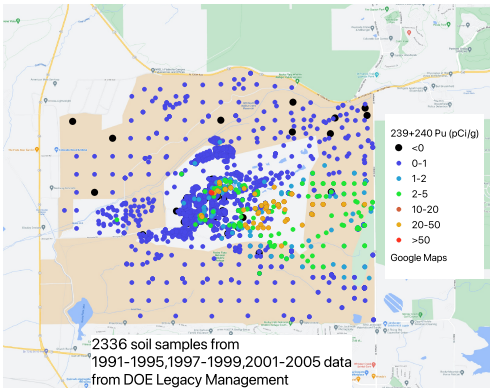
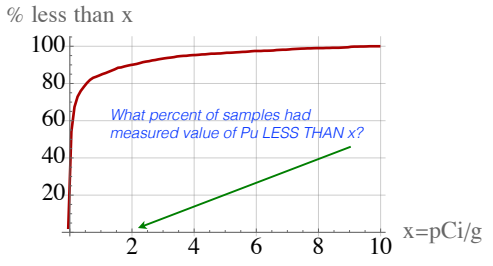


Figure 7: Upper left: original map region with lung cancer cases and very nonuniform population density. Lower right: cartogram with uniform population density and location of same cases. Rocky Flats site shown as orange square.





radionuclide	NIST value	no. samp	mean	median	70% pctl
$^{239+240}$Pu	0.45	2208	2.00	0.0960	0.31

Figure 8: QGIS export of DOE sampling points inside the Refuge, top panel. Lower panel: 'cumulative distribution function' for measured plutonium levels. The was due to the FBI/EPA plant raid in 1989.

The fat dots are to make it easier to see the color of each sample. Large black dots gave negative concentrations which are physically meaningless but can occur in real measurements. In the Refuge the highest concentrations lie in the 'Windblown Area' due east of where the plant's external storage areas had been before 1969.

4 *Whom should I trust for information?*

4.1 *Whom you should* **not** *believe*

Anti-Refuge groups evolved from Cold War era anti-nuclear groups and from grave suspicion of the Department of Energy during the period before and after the plant closed in 1989. They now blame their illnesses on proximity to Rocky Flats, despite *no evidence* of this (and plenty of epidemiology back in the 1980s). These groups are reflexively anti-nuclear and pretend to be concerned about the health of people living nearby. Here's why they are unreliable.

- Most of the information they pass on is incorrect; some is only misleading. Never is it backed up by citations outside of their ancient sources.
- They are essentially conspiracy theory groups, relying mostly on information from the 1970s which has been discredited.
- They are entirely unfamiliar with the scientific literature on Rocky Flats, radiation, and epidemiology.
- They have no technical expertise and almost no acquaintance with science. Thus they believe that it is possible for the Department of Energy to hide information and bribe the CDPHE to cover up facts.

What to avoid:

- Social media (Facebook, Reddit, Twitter/X). These are by far the most common way that misinformation gets passed around and becomes part of Rocky Flats urban myth.
- Rocky Flats Downwinders ('purveyors of fine misinformation'). Their mission appears to be to blame many illnesses in the metro area on Rocky Flats; their 2016 health survey was a publicity stunt which violated all precepts of epidemiology.
- The Rocky Mountain Peace and Justice Center (Boulder): funds the rest, and is a repository of outdated information from the 1970s when its founder was still paying attention
- Hangers-on websites: Physicians for Social Responsibility Colorado; Candelas Glows; Rocky Flats Glows. . . and so do the surrounding neighborhoods. . . .

4.2 *Reliable sources*

All of these are reliable, but some are definitive but technical. These are listed in order of readability.

- The Colorado Department of Public Health and Environment Generally very readable: see the menu at the left of the web page for FAQ and 'facts at a glance'.
- The Rocky Flats Stewardship Council. The ongoing work of the Council is mostly related to oversight. What is there tends to be fairly readable but not recent (pre-cleanup).
- Rocky Flats National Wildlife Refuge, maintained by the U.S. Fish & Wildlife Service. The left sidebar has links to a small library. A great deal of work was done in characterizing what is now the Refuge even before the cleanup (which included only the plant area) was completed.
- DOE Office of Legacy Management definitive, extremely complete, mostly tedious.
- *Do* read Wikipedia, which has decent coverage of Rocky Flats and can be trusted for technical information about radiation, plutonium, and other nuclear topics.

5 *Takeaways*

- There has *never* been a health risk from living around Rocky Flats. The quantities of Pu in soil are simply *too small*.
- There is *no evidence* from careful epidemiological studies of the populations around Rocky Flats since the mid-1980s that there are excess cancer risks. The Pu doses are so small that this is likely to remain true indefinitely.
- The Superfund cleanup of the former industial area (within the off-limits DOE-controlled part of the Refuge) was exceptionally effective, and is used as an example of success.
- Anti-Refuge groups who oppose its use and warn against living around it have a strict anti-nuclear agenda and are at this point believers in a conspiracy theory that the 'truth' is being hidden and only 'experts' from the 1970s can be trusted. Some of their materials qualify as medical misinformation, but none of them take responsibility for this their own nonsense.
- Since the NIST data about radioisotopes in Rocky Flats has been available since 1984, it is shameful that so much time and money has been wasted fighting misinformation that could have been dismissed out of hand almost four decades ago.

Appendix A: Everything you need to know about (ionizing) radiation

This is all you need to know:

- (Ionizing) *radiation*: the emission of charged alpha and beta particles and gamma rays (high-energy light) by unstable isotopes (called radioisotopes) of atoms when they 'decay' (spontaneously convert into a more stable isotope). Ionizing radiation has enough energy to break bonds in water and in biological molecules such as DNA.

  Alpha particles can be stopped by a sheet of paper, beta particles by a thin metal sheet, and gamma rays are very penetrating.

- *Radioactivity*: The (presence of or) number of such decays per second.

- Radiation *dose*: the amount of energy deposited by the radiation in the whole body (only possible for gamma rays) or into particular organs (such as the lungs or liver or bones) by targeted gamma rays or alpha and beta particles. It is this energy that does biological damage, in some cases leading to cancer or genetic damage.

  Large doses of nuclear radiation are much more likely to *kill* cells than to cause mutations or cancer; typically 14% or fewer of cancer survivors treated by radiation therapy develop a secondary cancer in the therapy volume as a result, at a rate of about 1% per year (higher for breast cancer). The working description of risk vs. dose is the 'linear no threshold' model: risk of cancer is directly proportional to dose.

- "The dose makes the poison", a maxim attributed to the German Renaissance physician and alchemist Paracelsus. Small radiation doses stimulate the immune system; some organisms fail to thrive without ordinary levels of ('background') radiation. All radiation doses from Pu expected anywhere around or inside the Refuge are *very small* in comparison to background radiation. Since background radiation has (with very few exceptions globally) not been shown to produce health effects, the extra dose from Pu is almost definitely negligible. See Fig. 4 below.

  Cancer rates even for Rocky Flats plant workers were actually below normal, probably due to the relatively small number of workers and a healthy work force.

The *measurement* of radiation is straightforward and precise. The calculation of *dose* is a geometrical problem (given the type and intensity of the radiation, the distribution of the sources, the duration of the exposure, and the nature of the target (skin for ultraviolet light, or the tissue type in general). The calculation of *health effects* is the trickiest part since they are 'stochastic' (the emission of radiation is strictly random) and so *must* be analyzed statistically. Emission of radiation is a random process and so are the effects on tissue except at very high radiation doses. Health effects must be assessed for very large groups of people via epidemiology.

Both radiation and soil contamination levels can be measured to levels that millions of times lower than would present a danger to health. Living with Pu is not qualitatively different than living with water contaminated with, say, benzene. We know it's not good, we can measure its concentration very accurately, and its levels are regulated and monitored.

Appendix B: Nonsense

These don't need addressing; they're all wrong. The presence of any such statement tells you what you're dealing with.

- People living around the Refuge are not permitted to eat produce they grow. It *is* true that ordinary soil around this area is poor enough that it has generally been enriched with topsoil.
- Since ^{239}Pu has a half-life of 24,100 years, you should not take chances. Oh yeah? *Short* half-lives provide more intense radioactivity. ^{40}K, more than 40 times more plentiful in soil than Pu, has a half-life of 1.25 billion years.
- Inhaling a single hot particle will cause cancer. Several Rocky Flats workers inhaled more than 10,000 hot particles in an accident; 10 years later none had developed cancer.
- Candelas is built on a Superfund site.
- You can't drink the water. See Arvada annual water report. Read where water comes from here

Read our FAQ and True/False pages.