Recent radiation epidemiology data for Rocky Flats

D. M. Wood, Emeritus Associate Professor
Department of Physics, Colorado School of Mines

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This document has been 'spun off' from others concerning dose and risk since it deals with fairly frequently occurring updates to internationally accepted epidemiological data.

In 2023 two important major update publications have become available. As we have noted elsewhere, there is a slow 'dance' between new epidemiological data and detailed information and recommendations from the International Commission on Radiological Protection (ICRP). It is important to note that both publications concern the effects of ionizing radiation on *nuclear plant workers*, not on members of the general public. On the other hand, we *can* apply the new data to doses computed elsewhere in a natural exposure environment as if relevant to the public.

1 *External radiation at relatively low dose*

The INWORKS consortium reports regularly on health data of nuclear industry workers in France, the United Kingdom, and the U.S. 'Solid' cancers due to 'external' (gamma ray) exposure for 309,932 workers followed long enough to produce 10.7 million person-years of monitoring were examined [1]. In this survey each country's follow-up period has been extended by 10 or more years. The focus was on 'low' cumulative doses, below 700 mGy total dose; all cancers were 'lagged' by 10 years (that is, the 'incubation time' for cancers was assumed to be 10 years). Chronic obstructive pulmonary disease is strongly associated with smoking but *not* with exposure to ionizing radiation, so was included in data below.

Since this study is entirely for gamma ray exposure and the 'relative biological effectiveness' for photons is by definition 1 within the ICRP framework, the dose in gray (Gy) is the same as the dose in sieverts (Sv).

category	ERR per Gy	90% CI
all cancer	0.53	0.30 to 0.77
solid cancer	0.52	0.27 to 0.77
non-lung solid cancer	0.46	0.18 to 0.76
COPD	0.12	-0.43 to 0.69

Table 1: Excess relative solid cancer death rate per Gy, INWORKS 2023. Doses were lagged by 10 years

The study also reports an analysis for cumulative doses below 100 mGy. Because of a poorly-explained choice to change methodologies

Traditionally doses below 100 mGy have been considered *low* and until roughly 2000 it was believed there were no health impacts below this cutoff.

below a cumulative dose of about 200 mGy, the full data range (0-700 mGy) and the low data range (0-200 mGy or so) have distinctly different slopes. This has already been noted in multiple news sources, for example here and here. I suspect the weak explanation will cause the authors no end of difficulties and possibly push-back from the ICRP and from exponents of radiation hormesis.

These results represent among the best indications to date that for whole-body (gamma radiation) doses to *nuclear workers* the linear no-threshold description appears satisfactory. On the other hand, it has almost no relevance to doses from Rocky Flats plutonium isotopes since these emit essentially no gamma rays, only alpha particles.

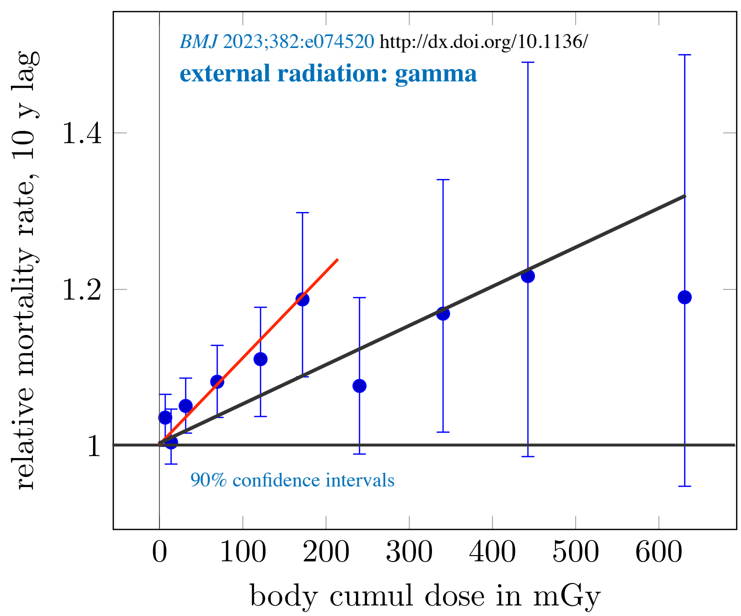

Figure 1: 2023 INWORKS results for gamma radiation low-dose range. The two line segments indicate reasonable linear fits for the entire dose range and for lower 0-170 mGy doses. The change in slope reflects a change in sampling methods over the small dose range.

2 *ICRP Publication 150 on Pu and U*

ICRP Publication 150 *Cancer risk from exposure to plutonium and uranium* [2] was approved in 2021. The report reviews all epidemiological worker studies to date but concerns only workers at nuclear plants, although it briefly discusses what is known about risks to the *public* from plutonium exposure. The report notes, “Individual annual exposure data, long duration of health surveillance in the cohort, and validation of the dosimetric models used for individual organ-/tissue-specific dose assessment were the major criteria considered for inclusion of a study in the analysis of lifetime risk.” The report’s most significant data comes from a cohort of workers at Mayak in the Russian Federation and another for Sellafield in the

United Kingdom.

The most remarkable finding is that "It is now possible to estimate the lifetime excess risk of lung cancer following inhalation of plutonium directly from epidemiological studies of plutonium workers."

The document's Table 2.6 summarizes 10 lung cancer studies for non-Mayak workers by year from 1999 through 2017, including Rocky Flats workers [3]. "A significant positive linear trend with internal lung dose was found for workers employed for 15–25 years ($P < 0.001$), but for those workers employed for <15 years or for >25 years, ORs [odds ratios] for most internal lung dose categories were <1.0 and none were significant."

For our purposes, the most important statements are that

1. The lifetime excess risk of lung cancer mortality from inhalation of insoluble PuO_2 (the form found in Rocky Flats soil) is about 1.4 per 10,000 persons per mGy of dose. For comparison, exposure to ^{222}Rn progeny (discussed in more detail in our documents on radon and thoron) due to exposure from age 18-64 is 1.6 per 10,000 per mGy of dose. Thus radon progeny and PuO_2 are very similar in their effects on lung cancer rates. It's important to observe that the lifetime *baseline* risk of lung cancer mortality reported in this publication is 631 per 10,000 persons for a 'Euro-American' male population.

2. "For radon, there is good evidence from studies of exposure in homes to suggest that the risk of lung cancer is consistent with that estimated from studies of miners exposed at low levels... In contrast, *epidemiological studies of environmental exposure to plutonium and uranium do not indicate increased risk of cancer overall...* [italics ours]. **In other words, there is no epidemiological evidence so far of any increased risk of cancer from plutonium or uranium in the environment.**

Principal other ICRP findings include

- "Results from the Mayak worker cohort also suggest an association between plutonium exposure and risks of liver and bone cancers, although data are limited. There is no consistent evidence of a positive dose–response relationship between the risk of leukemia and plutonium exposure."
- The report states "for the same absorbed dose to the lung and dose distribution, the risks from plutonium exposure are larger than those from external gamma exposure by a factor of approximately 16". Those who are already familiar with the 'relative biological effectiveness' (RBE) factor for alpha particles will recognize how close this is to the ICRP current 'official' RBE of 20 for alpha particles.
- "It was considered premature to quantify lifetime excess risks for bone and liver cancers, for which associations have also been demonstrated for plutonium"
- Autopsy data for Mayak workers showed larger retention of insoluble plutonium for smokers than for non-smokers.

DMW estimates therefore an excess lifetime relative risk of death from lung cancer due to PuO_2 inhalation of $1.4/631 \times 1000$ mGy/Gy = 2.22/Gy.

Lung cancer is the main cancer associated with (and expected for) inhalation of plutonium (PuO_2 for Rocky Flats). If we choose to apply the above data to exposure for a member of the public (*not officially correct*), we would proceed as follows.

1. Use the estimated yearly dose due to inhalation and ingestion of contaminated dirt for the eastern boundary of the Refuge, where soil Pu radioactivity is the highest. This is 1.9 microSv/year.

2. Compute, say, the dose for 50 years. This is 0.093 mSv, from the document Radiation and dose overview.

3. Since these doses were computed from 'dose coefficients', which relate the dose in sieverts to the activity in Bq, they are in Sv, so include a value of 20 for the relative biological effectiveness of alpha particles. However, the lifetime excess risk of lung cancer is given from the ICRP results above per (milli)gray of dose. Thus we need to divide the dose in Sv by 20 to find the (alpha) dose in Gy; this is 0.00465 mGy.

4. The lifetime excess risk of lung cancer therefore is approximately (see the remark in the margin) 2.22/Gy $\times 0.00465 \simeq 1.03 \times 10^{-5}$, a 1 in about 100,000 chance. (This sounds higher than I'd expect, but my estimate is quick-and-dirty.) Since the average Arvada yearly dose from *radon progeny* is about 4500 times larger *and* (as noted in the ICRP report) response to PuO_2 inhalation is very similar to that for radon, the lifetime excess risk of lung cancer due to radon inhalation over 50 years would be 4500 times larger than for plutonium, or about 0.05. So you have a 5% enhanced risk of lung cancer from average Arvada radon concentrations, according to this quick estimate. This will be amended when ICRP recommendations inhaled Pu for the *public* become available.

Reminder: green links below are clickable.

References

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