# Assessing the Probability of a Specific Cancers among Veterans of UK Atomic Weapons Tests

Richard Bramhall, George Carr-Hill and Roy Carr-Hill

[Written in Response to a Request for 'Statistical' Help from the Low Radiation Campaign]

**BACKGROUND**

The background to this note is the Appeals of twelve men in the First-Tier Tribunal against the MoD refusal to award war service pensions.[6] These were heard in the High Court 13 to 30 June 2016. Seven of the appellants had cancer. The Appeal of another man, who also suffered from pancreatic cancer had succeeded in 2013, but he had been part of the same original group and it was these four men whose medical history led the appellants' representatives to suggest that there was a significant discrepancy between the numbers of pancreatic cancers in the appeal group and the number that would have been expected on the basis of the rate in the general population.

This particular note is about designing a statistical answer for this case. The total number of people who took part in the UK's atomic weapon testing programmes i.e. those who had been sent to the nuclear test sites (not those who had worked at Atomic Weapons establishments) was more than 22,000. The tests took place between 1952 and 1958, so most of the veterans would, if alive, now be in their 80s or 90s. The 13 were among the veterans (many hundreds of them) who (1) were sick and (2) blamed their illness on their exposure at the test sites and (3) therefore applied for war pensions and (4) had been refused pensions and (5) had individually lodged appeals against the refusal decisions. The men in this group of 12 were those whose separate applications had reached a particular stage when the MoD decided to make them into a collective group: seven of them were cancer sufferers; four of them were pancreatic cancers. [we need to know the overall size and the overall characteristics of the group (age, length of

[6] WPAFCC References ENT/00203/2015; ENT/00202/2015; ENT/00258/2015; ENT/00200/2015; ENT/00254/2015; ENT/00201/2015; ENT/00258/2015; ENT/00199/2015; ENT/00253/2015; ENT/00204/2015; ENT/00250/2015; ENT/00251/2015

working life on programme) from which these 16 (12) are drawn because, of course 7 itself is a large proportion having any kind of cancer]

A relatively small part of the veterans' case was that cancer of the pancreas is 2% of all cancers so it was unlikely that there would be so many in a 'random' group of seven. This, it was said, suggested that their common experience at the contaminated test sites was causative (bearing in mind that the standard of proof needed before these tribunals is only "reasonable doubt", so the argument would add to the reasonableness of finding in the veterans' favour). The question we have to find an answer to is "Exactly how unlikely is it?" - i.e. "What is the probability of this event?".

Last year (2016) the plaintiffs were dismayed to find that the Tribunal (judges etc.) were far from numerate, so in addition to a statistical argument, we need a version for the person on the Clapham Omnibus. For example, "Imagine a roulette wheel with 50 slots. You throw 7 balls into the wheel and you win a prize if 4 of them end up in any single slot. The probability of winning is ?????"

**OUR RESPONSE**

First, we needed to find out the basic 'facts' about pancreatic cancer and its possible links to exposure to radiation.

Second, we needed to search for a method of demonstrating the probabilities in a way that even the under-schooled male on a Clapham omnibus – such as a judge at a Pension's Tribunal - could understand.

**CANCER PROBABILITIES AND POTETIAL IMPACT OF RADIATION**

**Pancreatic Cancer among all Cancers**

In the UK TO COME

**Likelihood of Radiation affecting Condition**

Thirty five years after their exposure to radiation at the testing sites, the National Radiological Protection Board (NRPB) between 1986 and 1993 had identified 22,347 participants and a similar number of controls. Mortality and cancer incidence were reported, comparing rates between the study and control groups, with data cut off at 1991. The results are skewed as the analysts disregarded cancers diagnosed within 10 years of the veterans' attendance at the test sites on the questionable assumption that they occurred too soon to have been caused by the exposure. About 3,000 are still alive. That should mean, given their age, that around 40 should have experienced pancreatic cancer.

In fact, at that time, only three of them had reported cancer of the pancreas. The fourth, Trevor Butler, was claiming on a range of non-carcinogenic conditions. He developed pancreatic cancer later and his widow is now claiming a widow's pension. We have no reason to suppose that the men in this group colluded or even knew each other; it is possible but it is hard to see how the possibility that they knew each other could have influenced the MoD's decision to make them into a group. But the MoD's expert witness in last year's case, Richard Haylock, dismissed out of hand any possibility that the group was random. It was put to him in writing before the hearings began (see pancreatic prob.pdf attached) but he didn't respond. From the witness box he said it was "not a sensible thing to ask for" (see "transcript Haylock refuses to answer.doc" attached). The MoD's barrister confirmed that Haylock had not given a written answer. Haylock then said he had done a different calculation based on the probability of pancreatic cancer in 20,000 men. He outlined it verbally and that account was pasted from the court transcript into the Determination (decision document) at paragraph 509. There is no possibility of checking his calculation as we don't have the data. So the probability issue was lost inside a smear on the honesty of the veterans and the probity of their representatives, ignoring the fact that it was the MoD who decided to have those cases heard as a group.

We therefore have to consider the possibility that finding 4 pancreatic cancers among a group of 7 all-cause cancers was indeed a chance occurrence and tell the Tribunal, in vernacular language, just how unlikely that is. It would then be for the MoD to make a counterproposal. The point is that we only have to show a reasonable doubt that the radiation exposure could have caused the disease. It's not the criminal burden of proof that guilt must be established beyond reasonable doubt. The MoD is well aware that when these cases are determined in the veterans' favour, there are consequences for nuclear weapons policy[7] and they defend savagely, exploiting any perceived weakness in the veterans' case.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470418/NRPB-W27.pdf

[7] Although such considerations do not seem to have bothered the US Department of State or its nuclear weapons policy, who have acquiesced in the setting up of the Radiation Exposure Compensation Programme (see immediately below).

Determination para. 509. *Dr Haylock {previously worked at the NRPB}had however done a calculation of the probability of developing pancreatic cancer in a population of people born in 1939, alive in 1959 and who were now 70 years old*[8]*. He calculated that 0.5% will die from pancreatic cancer and so, in a group of 20,000 test veterans, one would expect 100 cases of pancreatic cancer irrespective of radiation exposures. In 1998 there were 77 such cases. The fact that four such people made war pensions claims tells us nothing about causative possibility.*

**Radiation Exposure Compensation Program**

The Radiation Exposure Compensation Program is administered by the US Department of Justice. It provides payments to 3 groups of people (uranium miners, miller and transporters; onsite participants and downwinders).

For Onsite participants

People (including military personnel) who were present onsite during above-ground nuclear tests (at the Nevada, Trinity, Pacific, or South Atlantic test sites) and who later develop certain medical conditions may be entitled to a payment of $75,000. (Military personnel exposed to radiation at Hiroshima or Nagasaki are not eligible.)

The eligible conditions include cancers of the lung, thyroid, breast, esophagus, stomach, pharynx (throat), small intestine, pancreas, bile ducts, gallbladder, salivary gland, urinary bladder, brain, colon, ovary, and liver (unless related to cirrhosis or hepatitis B). Other cancers covered include leukemia (other than chronic lymphocytic leukemia), non-Hodgkin lymphoma, and multiple myeloma.

**Possible Presentations of Arguiment**

Confidence Interval Approach

There are 9,000+ new case of pancreatic cancers a year among c. 360,000 all cancers, so pancreatic cancers are 2.5% of all new cancers. The formula would be sqrt (0.025*0.975/7) = sqrt (0.0036) =

[8] The dates don't make any sense: if they were born in 1939, then in 1998 they would have been 59 not 70; the 77 cases are in NRPB report.

c.0.06. That would give a 95% confidence interval of -9.5% to 14.5% which still puts 4/7 = c.57% way out of range of even a 99% confidence interval of -15.5% to 20.5%. But we couldn't see anyone explaining negative percentages of dead people to a bunch of judges.

<u>Probability Approach</u>

Looking at the probabilities of n = 0,1,2... cases out of 7:

P(0) = (1 - 0.025)**7 = 0.975**7 = 0.838
P(1) = 7 x 0.975**6 x 0.025 = 0.150 P(0,1) = 0.988
P(2) = 21 x 0.975**5 x 0.025**2 = 0.011 P(0,1,2) = 0.999
P(3) = 35* 0.975**4 x 0.025**3 = 0.000494 P (0, 1 ,2 , 3) =0.9995

Hence P(n greater than 1) = 0.012 i.e. over 80 to 1 against
and P(n greater than 2) = 0.001 i.e. 1000 to 1 against
and P (n greater than 3) = 0.0005 i.e. 2000 to1 against

This could also be used for sensitivity analysis. i.e., using 0.1 rather than 0.025 as a possible extreme figure (4 times the observed rate):

P(0) =(1-0.1)**7 = 0.9**7 = 0.4783; P(1)= 7*0.1x0.9**6 =0.3720;
giving P(0,1,2) = 0.9743 i.e. P(n greater than 2) = 0.0257 - about 39 to 1 against;
and P(0,1,2,3) = 0.9973 i.e. P(n greater than 3) = 0.0027 - about 370 to 1 against.

I think it is more appropriate to use the lifetime risk - rather than age-specific rates - of pancreatic cancer; hence my suggested figure of 2.5% at about the time (early 1990s) the veterans were exposed (see Annex).

**Proposed Letter to the Tribunal**

UK Cancer Research data tell us that pancreatic cancer is now (2014) 3% of all cancers whilst the incidence rate has increased by 14% since the early 1990s compared to an overall increase in the incidence of cancer of 12% so the suggested figure of 2.5% is quite close to what one might have expected in early 1990s (as 2.5*14/12 = 2.9%).

Given the presumed rate of 2.5%, we imagine a roulette wheel with 40 holes where one and only one of them is the pancreatic cancer hole. We have seven balls representing the seven men and throw them into the wheel: what are the chances of different numbers of the 7 balls landing in the pancreatic cancer hole. The statistical calculations for this rate of 2.5% and for the 'sensitivity analysis' with a rate of 10% (i.e. for 4 times greater) are in the Annex.

Probability of NO case out of 7 (0 balls landing in the specific hole out of 40) is 0.838.
Probability of exactly ONE case out of 7 (exactly 1 ball landing in that specific hole) is 0.150
Probability of exactly TWO cases out of7 (exactly 2 balls landing in that specific hole) is 0.011
Probability of exactly THREE cases out of 7 (exactly 3 balls landing in that specific hole) is 0.000494

Hence probability of 0 or 1 or 2 or 3 balls landing in that specific hole (adding up the specific probabilities) = 0.9995, which means that the probability of there being 4 or 5 or 6 or 7 cases is 1-0.9995 = 0.0005 i.e. 2,000 to 1 against.

With the sensitivity analysis the probabilities of 0, exactly 1, exactly 2, and exactly 3 cases are respectively P(0)= 0.4783; P(1) = 0.3720 with P(0,1) = 0.8503; P(2) = 0.1240 with P(0,1, 2) = 9743; and P(3) = 0.0230 with P (0, 1 ,2 , 3) =0.9973

Hence, P(n greater than 1) = 1-P(0,1) = 0.15 a little less than 7 to 1 against;
and P(n greater than 2) = 1-P(0,1,2) = 0.026 i.e. nearly 40 to 1 against;
and P (n greater than 3) = 1-P(0,1,2,3) = 0.0027 i.e. 370 to 1 against

P.S. It is also interesting to note that in NRPB-W27:

- Table 6.10, comparing observed deaths among participants and controls based on national population SMRs, that the risk of pancreatic cancer among test participants relative to controls is1.04 with a one-sided probability of 0.44, which means that the balance of probabilities (I think that is the criterion in tribunal cases) is in favour of the appellants
- Table 6.11 compares observed deaths directly between test participants and controls and the relative risk is1.08 with a one-sided probability of 0.36, and the same conclusion

**ANNEX I**

Using 2.5%, we have the following:

P(0) = (1 - 0.025)**7 = 0.975**7 = 0.838

P(1) = 7 x 0.975**6 x 0.025 = 0.150     P(0,1) = 0.988

P(2) = 21 x 0.975**5 x 0.025**2 = 0.011     P(0,1,2) = 0.999

P(3) = 35* 0.975**4 x 0.025**3 = 0.000494  P (0, 1 ,2 , 3) =0.9995

Hence P(n greater than 1) = (1-P,0,1) = 0.012  i.e. over 80 to 1 against
and P(n greater than 2) = 0.001  i.e. 1000 to 1 against
and P (n greater than 3) = 0.0005   i.e. 2000 to 1 against

To our analysis, we could also add, what is called sensitivity analysis by supposing that the rate among veteran is 4 times higher than the usual national rate, i.e. 10% rather than 2.5%.

P(0) = (1 - 0.1)**7 = 0.9**7 = 0.4783
P(1) = 7 x 0.9**6 x 0.1 =0.3720  P(0,1) = 0.8503
P(2) = 21 x 0.9**5 x 0.1**2 =0.1240  P(0,1,2) = 0.9743
P(3) = 35* 0.9**4 x 0.1**3 = 0.0230  P (0, 1 ,2 , 3) =0.9973

Hence  P(n greater than 1) = 0.15 a little less than 7 to 1 against
and P(n greater than 2) = 0.026  i.e. nearly 40 to 1 against
and P (n greater than 3) = 0.0027    i.e. 370 to 1 against

Well beyond reasonable doubt even if we assume rate is 4 (four) times amongst veterans than amongst the average population

Even in the studies done by the National Radiological Protection Board, which stopped short of 1990, there were gaps as the younger men where almost all National Servicemen, many of whom were lost to the follow-up.

## ANNEX II: Literature in US and elsewhere

*Evidence of a dose-response relationship (strongest evidence)*

**Pancreatic Cancer and Exposure to Ionizing Radiation**

**Summary***:* Some evidence has been recorded of a possible connection between cancers of the pancreas and exposure to ionizing radiation. This possible connection is supported by evidence from studies conducted at Los Alamos National Laboratory and other studies of nuclear workers at other sites who have been exposed to ionizing radiation. The National Research Council's, on the other hand, has determined that the pancreas is relatively insensitive to ionizing radiation.

Pancreatic cancers are designated as "specified" cancers under the Energy Employees Occupational Illness Compensation Program Act. Historically, incidence of pancreatic cancer in Los Alamos County is in the middle of New Mexico county rates. Incidence in Rio Arriba County is among the ten highest county rates. Incidence means new cases of cancer, while mortality means deaths due to cancer.

***Studies of Los Alamos National Laboratory (LANL) Workers***.

- Female Lab Employees Study: An increase in pancreatic cancer deaths was found in women who were employed at the Lab from 1943 to 1981, assuming a 25-year latent period.* But this was based on only one case, who had a cumulative dose of 690 mrem (a measure of radiation dose).

- Zia Study (unpublished): Possible increasing rates of pancreatic cancer deaths were observed with increasing doses of external radiation in males employed between 1946 and 1978. 15

***Studies of Other Nuclear Workers in the United States***

There were other studies: by Mancuso () at Hanford in Pittsburg where there were increasing rates of death due to pancreatic cancer with increasing doses of external radiation in workers who were employed for at least six months from 1945 to 1986; in Mallinckrodt, St. Louis, Missouri, where increased rates of pancreatic cancer deaths were found in a study of 2,514 men who were employed in uranium processing between 1942 and 1966, and followed through 1993; in Oak Ridge Y-12, where increased rates in pancreatic cancer deaths were found in a study of 8,116 men and women who were employed between 1947 and 1972, and then followed through 1990; in Savannah River Site, where an increase in pancreatic cancer deaths was observed in white male hourly and long-term (15+ years) workers who were employed before 1955; and in West Chicago (Kerr-McGee) Thorium Plant, where an increase in pancreatic cancer deaths was found in a study of 1,446 men who were first employed between 1955 and 1969, and then followed through 1976.

***Studies of Other Nuclear Workers World-Wide***

In Sellafield, England, compared to non-radiation workers, a possible increase in pancreatic cancer deaths was seen in a study of 5,203 plutonium workers who were employed between 1947 and 1975, and then followed through 1992. A possible increase in the incidence of pancreatic cancer was found in plutonium workers who were employed between 1971 and 1986, and then followed through 1992. 3

**Atomic Bomb Survivors:** In studies performed to date there is no reported evidence of increased rates of pancreatic cancer in A-bomb survivors.

**Other Literature**

Watanabe et al (1995) studied whether Navy veterans who had participated in an atmospheric nuclear test in 1958 were at increased risk of death from certain cancers. The cancer mortality risk of 8554 Navy veterans who participated in an atmospheric nuclear test in the Pacific was compared with that of 14,625 Navy veterans who did not participate in any test. Radiation dosage information was obtained from film badges for 88% of the test participants. The median radiation dose for the test participants was 388 mrem (3.88 millisieverts [mSv]). Among participants who received the highest radiation dose (> 1000 mrem, or 10 mSv), an increased mortality risk for all causes (relative risk [RR] = 1.23; 95% confidence interval [CI] = 1.04, 1.45), all cancers (RR = 1.42; 95% CI = 1.03, 1.96), and liver cancer (RR = 6.42; 95% CI = 1.17, 35.3) was observed. The risk for cancer of the digestive organs was elevated among test participants (rate ratio = 1.47; 95% CI = 1.06, 2.04) but with no significant dose-response trend. Many of the cancers of a priori interest were not significantly elevated in the overall test participant group or in the group that received the highest radiation dose.

**ANNEX III: Cancer Compensation Programs for People Exposed to Radiation as Part of Nuclear Weapons Testing**

Between 1945 and 1962, the United States tested nuclear weapons in the open air. Several other countries began above-ground nuclear testing during this time as well, with some continuing these tests up until 1980.

Most of the above-ground tests in the United States were done in the South Pacific and at the Nevada testing grounds, with a small number being done at the Trinity (New Mexico) and South Atlantic testing sites. Military maneuvers involving about 200,000 people were conducted as part of many of these tests. The tests exposed these people, as well as many others living in nearby areas, to different amounts of radiation. In addition, tens of thousands of uranium miners and workers at several nuclear weapons plant sites were exposed to radiation and other toxic substances.

There is little doubt that radiation exposure can cause cancer. This has become clear from studies of groups such as the survivors of the atomic blasts in Japan, where the risks of certain cancers such as leukemias and thyroid cancers were higher than normal, as well as from studies of people exposed to medical radiation and in some workplace settings. But it's often hard to estimate the likelihood that a person exposed to radiation will develop cancer as a result of being exposed. Many factors influence this risk, including the type, amount, and route of radiation exposure. For example, people can be exposed to radioactive elements internally if they inhale or ingest them, as well as being exposed to external radiation sources. In addition, when exposures have occurred many years in the past, it's often hard to know how much or what types of radiation exposure a person had.

**Compensation for people who have been exposed to radiation**

The US government has passed several laws to compensate military veterans, people who worked in the nuclear industry, and others exposed to radiation as part of nuclear testing programs who later develop certain types of cancer or other diseases.

The United States conducted nearly 200 atmospheric nuclear weapons development tests from 1945 to 1962. Essential to the nation's nuclear weapons development was uranium mining and processing, which was carried out by tens of thousands of workers. Following the tests' cessation in 1962 many of these workers filed class action lawsuits alleging exposure to known radiation hazards. These suits were dismissed by the appellate courts. Congress responded by devising a program allowing partial restitution to individuals who developed serious illnesses after exposure to radiation released during the atmospheric nuclear tests or after employment in the uranium industry: the Radiation Exposure Compensation Act was passed on October 5, 1990. The Act's scope of coverage was broadened in 2000.

**Radiation Exposure Compensation Program**

The Radiation Exposure Compensation Program is administered by the US Department of Justice. The DOJ promulgated regulations for carrying out the program that permit use of existing records so claims can be resolved reliably, objectively, and non-adversarially, with little administrative cost to either the individual filing the RECA claim or the United States government. The initial 1992 regulations were updated in 1997 and revised on March 23, 2004.

This unique statute was designed to serve as an expeditious, low-cost alternative to litigation. Significantly, RECA does not require claimants to establish causation. Rather, claimants qualify for compensation by establishing the diagnosis of a listed compensable disease after working or residing in a designated location for a specific period of time.

It provides payments to 3 groups of people:

**Uranium miners, millers, and transporters**

People who worked in these industries between 1942 and 1971 and who develop lung cancer, kidney cancer (in millers or transporters), or certain other conditions may be eligible for a lump sum payment of $100,000.

**Onsite participants**

People (including military personnel) who were present onsite during above-ground nuclear tests (at the Nevada, Trinity, Pacific, or South Atlantic test sites) and who later develop certain medical conditions may be entitled to a payment of $75,000. (Military personnel exposed to radiation at Hiroshima or Nagasaki are not eligible.)

The eligible conditions include cancers of the lung, thyroid, breast, esophagus, stomach, pharynx (throat), small intestine, pancreas, bile ducts, gallbladder, salivary gland, urinary bladder, brain, colon, ovary, and liver (unless related to cirrhosis or hepatitis B). Other cancers covered include leukemia (other than chronic lymphocytic leukemia), non-Hodgkin lymphoma, and multiple myeloma.

**[Downwinders**

People who lived or worked downwind of above-ground nuclear tests in certain counties in Utah, Nevada, and Arizona for at least 2 years during certain periods between 1951 and 1962 and who later develop certain medical conditions may be entitled to a payment of $50,000. The eligible cancers are the same as those for onsite participants.

For a more complete list of eligibility requirements and information on how to file a claim, contact the Department of Justice Radiation Exposure Compensation Program at 1-800-729-7327 (1-800-729-RECP) or visit their website at www.justice.gov/civil/common/reca.html

## REFERENCES

Haylock Determination, para599

Kneale GW, Mancuso TF, *et al.* (1981) "Hanford Radiation Study: A Cohort Study of the Cancer Risks from Radiation to Workers at Hanford (1944-77 Deaths) by the Method of Regression Models in Life Tables." *British Journal of Industrial Medicine* 38(2): 156-166. )

C R Muirhead, C.R., Kendall, G.M., Darby, S.C., Doll, R., Haylock, R.G.E., O'Hagan, J.A., Berridge, G.L.C., Phillipson, M.A. and Hunter, N. (2004) Epidemiological studies of UK test veterans: II. Mortality and cancer incidence, *J. Radiol. Prot. 24* 219–241

US Department of Justice (2000) Radiation Exposure Compensation Program www.justice.gov/civil/common/reca.html

US National Research Council BEIR IV Committee

Watanabe KK, Kang HK, Dalager NA. (1995) Cancer mortality risk among military participants of a 1958 atmospheric nuclear weapons test, Am. J. Public Health 1995; 85(4): 523-527.