Nuclear Safety and Public Understanding

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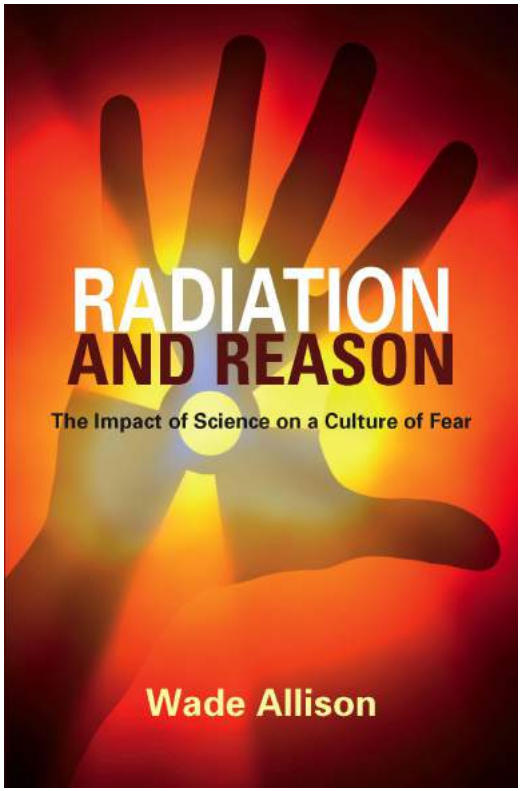
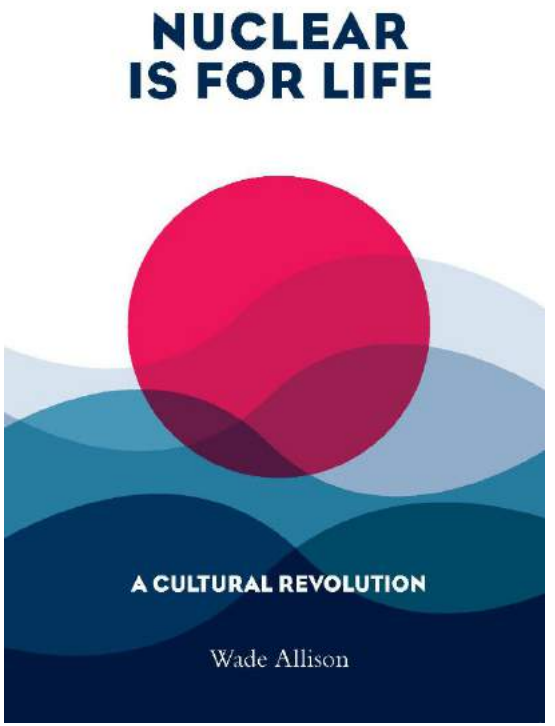




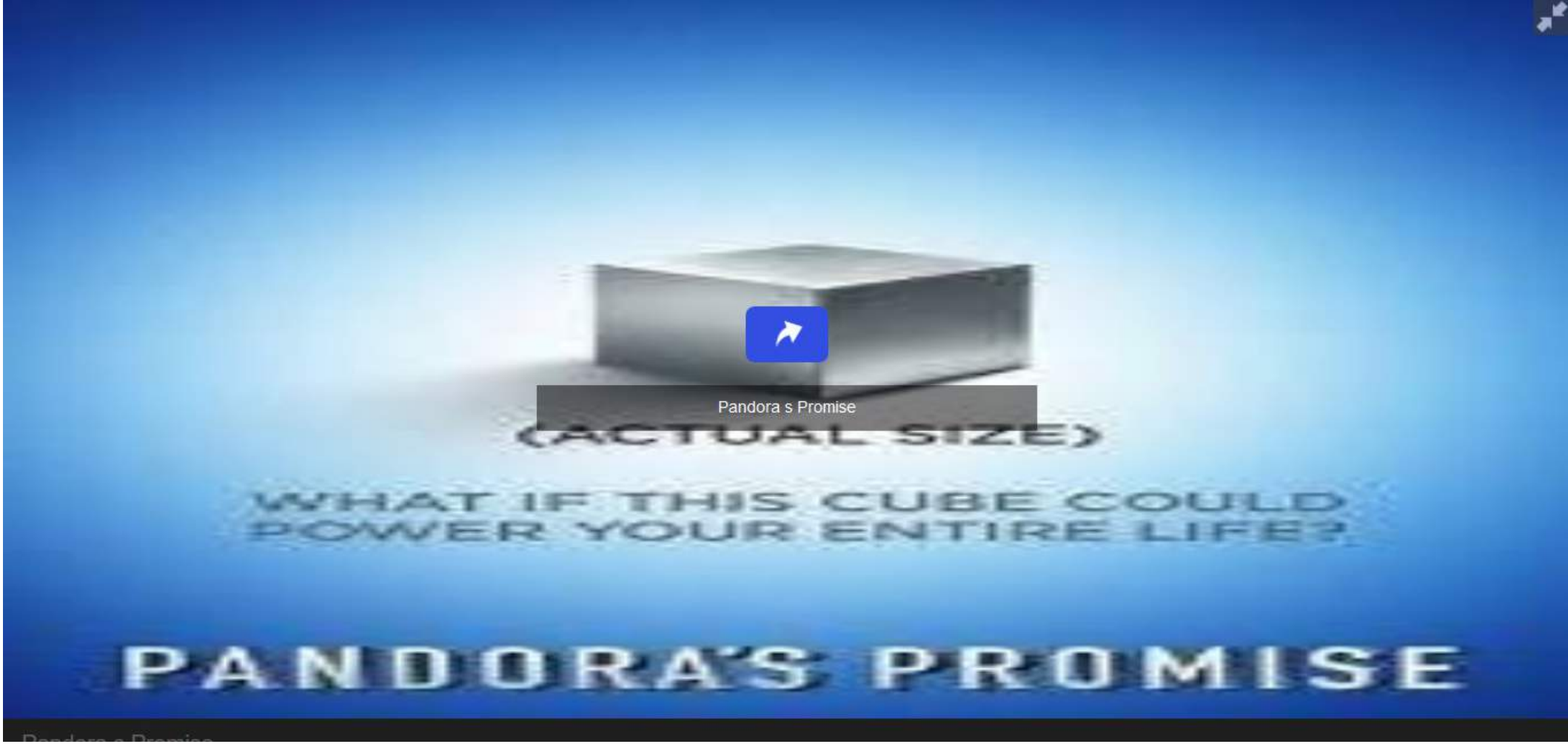
It is a great honour to be invited half way round the world to address you.

I was 13 years old when by chance I visited the exhibition “Atoms for Peace” in Geneva. That was in 1954 the year CERN was founded.

I resolved to study Mathematics and Science, and in 1963 I was back at CERN as an Oxford PhD student. The discipline and rigour of mathematics and particle physics are a great education for making sense of the world and of other sciences.

I want to share with you a clear picture of the evidence that confirms the extraordinary safety of nuclear technology. Surprisingly, it is not so much about reactor safety, but about biology and its resilience to nuclear (ionising) radiation.

The last part of the story is the extraordinary mistakes made in my lifetime. We owe it to future generations that they should not suffer the distorted view that has been built up since 1945. The story is not technically difficult but the politics of misunderstandings is always a challenge.



If you have not seen the movie PANDORA'S PROMISE, then see it now.
My message is more scientific but closely related:

> **"Much of what we were invited to treat as understood about nuclear safety is mistaken. We need the evidence to trust and understand the case for a complete change of culture."**

Plan of the lectures

The objectives of evidence-based radiation protection should include

1/ Protection in clinical medicine, without scaring the patient away from receiving life-saving treatment;

2/ Protection in the socio-economic environment, while avoiding unnecessary disorder and suffering;

3/ Protection while using the resources of nature for the common good, specifically electric power generation.

The solution should be to educate but not dictate to public how they need to engage with nuclear technology to survive.

In the first part I will minimise the use of mathematics in order to emphasise how it is possible to engage and reassure the widest public audience. Later on I will add in more technical details

I begin by describing Eight Truths that everyone in society should understand about nuclear technology and radiation

Eight truths that everyone should understand

1. nuclear radiation and radioactivity are natural processes
2. long ago life evolved protection against the harmful effects of radiation
3. radioactivity is not contagious
4. radiation is used to diagnose and cure cancers
5. radiation is safer than fire
6. waste is not a major problem
7. history and the media suggest a story of risks that may be exciting but does not fit the evidence
8. authorities have unsuccessfully tried to reassure the public by appeasing their fears

Truth 1. Nuclear radiation and radioactivity are natural processes

Nuclear radiation, like light, radio and sound carries energy.

That energy has a frequency, like pitch or colour, that fixes how the radiation is emitted and absorbed.

Radioactive atoms are ones that have the surplus energy to release radiation of a particular frequency when they **decay**

This nuclear energy per atom is a million times larger than the equivalent for an electronic atom (and chemical energies). This is why **nuclear is about a million times more powerful than carbon per kg** of fuel (or waste)

The **radioactivity** of a material is the number of decays per second (Bq, becquerel)

The total radiation energy that it emits per second (in watts) is the number of Bq times the particular energy of that decay process

Once a radioactive atom has released its radiation, it cannot do that again.

So radioactivity and the watts of radiated power decay away as time goes by.

a brief history of radioactivity

1. after the Big Bang 13.8 Gyr ago there remained mostly hydrogen, a little helium and much radiation of all sorts
2. after the earliest stars exploded more than 6 Gyr ago there remained all the other elements too, the stable ones and the radioactive ones, some of which are still decaying today [we are all nuclear waste!]
3. after the formation of the Earth and solar system 5.5 Gyr ago the only nuclear activity on Earth was this decay. Only one nucleus in a million has changed since that time because they are **completely isolated** by electrical forces
4. today the inside of the Earth is heated by the “decay heat” that powers volcanic and seismic activity near the surface
5. in 2011 it powered the tsunami in Japan with loss of 18,000 lives, but the world **did not** panic
6. the tsunami caused the Fukushima accident with the loss of 0 lives, but the world **did** panic

holidays in the sun...

Only if radiation energy is absorbed in living tissue does it have a temporary effect on life, welcomed as beneficial in sunbathing.

Light and UV lie next to Xrays and gamma rays in the radiation spectrum. They can have similar effects

Light and UV come from the Sun, a nuclear reactor essential to life

Too much, sunburn, cells killed, skin peals, but complete recovery in days. Some adaptation.

Any residual effects kept in check by the immune system. The immune system may fail in later years giving possible skin cancer in the region affected.

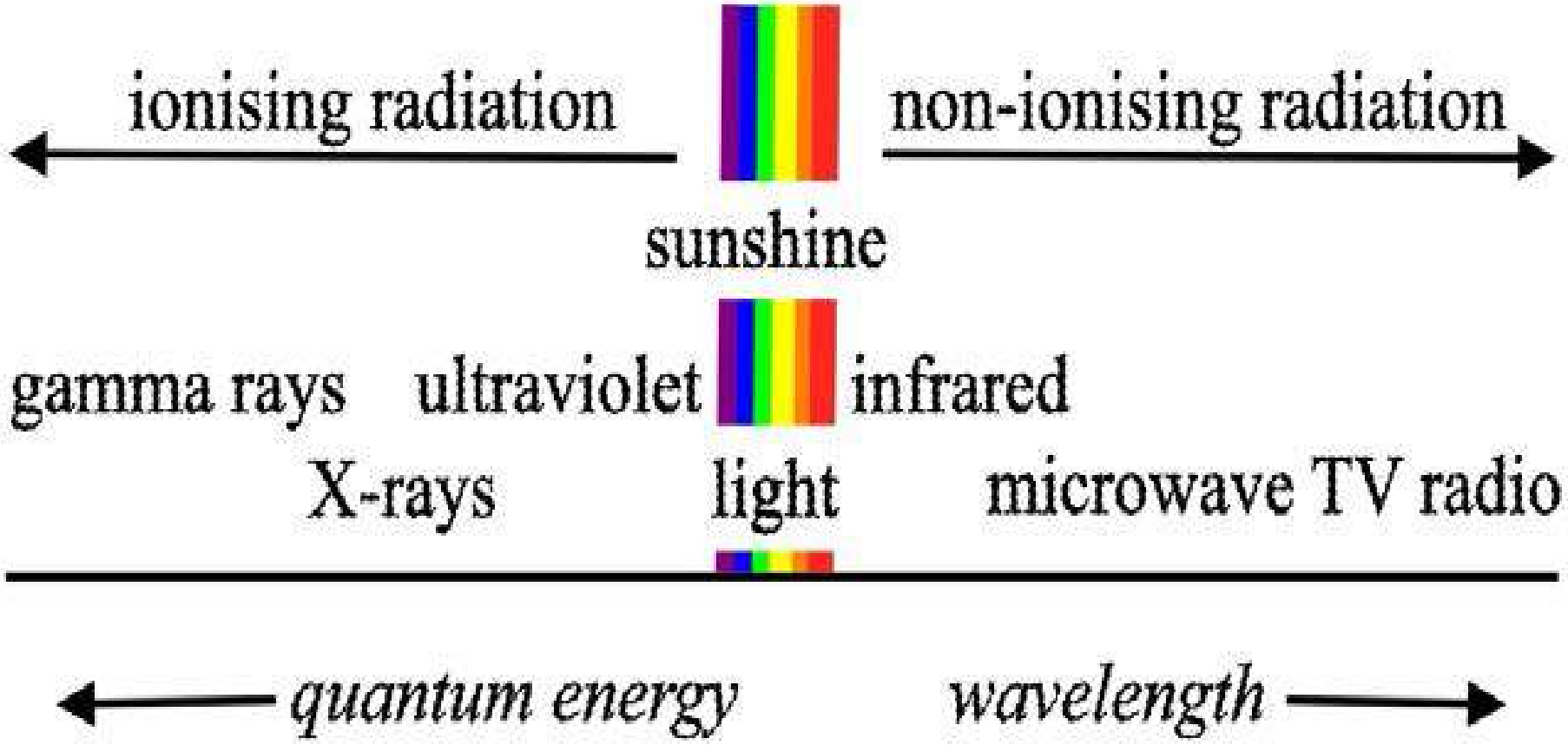
9000 skin cancer deaths per yr in USA.

Very like the effect of X-rays and nuclear radiation (the numbers are different)

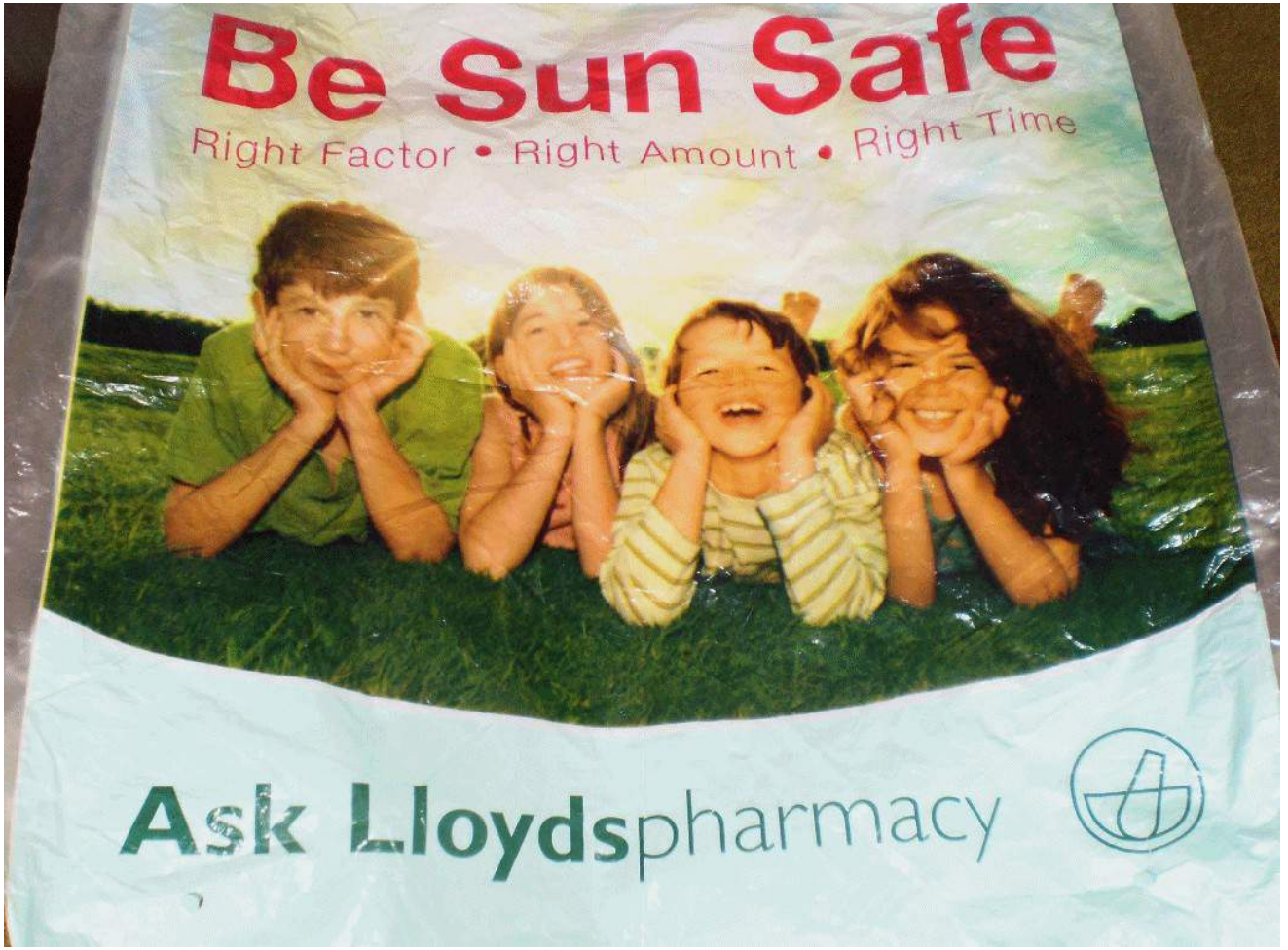
More protection from UV is needed but we learn to live and enjoy life

[is UV or light ionising radiation? Einstein, yes! - though less efficiently]

The radiation spectrum (EM)



Living, loving and laughing with UV radiation



a positive image with a sensible public safety message on a free carrier bag from a high street pharmacy

Truth 2. Long ago life evolved protection against the harmful effects of radiation

Darwinian evolution of life forms – to survive.

Think about competition between two evolving life forms (eg bacteria and humans, or two different tribes) one or the other will survive. Uncertain outcome

Think about battle between an evolving life form and changeless threat (eg cellular life and physical/chemical agent). Given enough time, life will always win by trial and error, however weak the life form and however strong the agent.

In this way life has been shaped to survive the similar disruption of molecules by oxygen and radiation ("oxidation").

It has had 3 billion years to find an almost perfect way to do it. Most living organisms today have been shaped in this way

look at the surprising evidence

Radiation in nature

no evidence of extra cancer in regions with high radiation, for instance from radon gas

Chernobyl, the worst imaginable nuclear accident.

Less than 50 deaths, but look at the animal life!

Thriving since humans moved out, in spite of being radioactive

Fukushima, “equal to Chernobyl”,

plant destroyed but no effect on human health at all though the avoidable socioeconomic effects were/are severe. More later

Goiania (1987), nuclear waste taken into the home and ingested!

Four dead but no cancer, even after 25 years. Story to follow

Presence of man spoiled the environment at Chernobyl far more than radiation!

bbc.co.uk/news/science-e …

Fukushima, prediction after two weeks

26 March 2011 BBC World Service

Viewpoint: We should stop running away from radiation

By Wade Allison University of Oxford

More than 10,000 people have died in the Japanese tsunami and the survivors are cold and hungry. But the media concentrate on nuclear radiation from which no-one has died - and is unlikely to.

Nuclear radiation at very high levels is dangerous, but the scale of concern that it evokes is misplaced. Nuclear technology cures countless cancer patients every day - and a radiation dose given for radiotherapy in hospital is no different in principle to a similar dose received in the environment.

What of Three Mile Island? There were no known deaths there.

and so on

http://www.bbc.co.uk/news/world-12860842

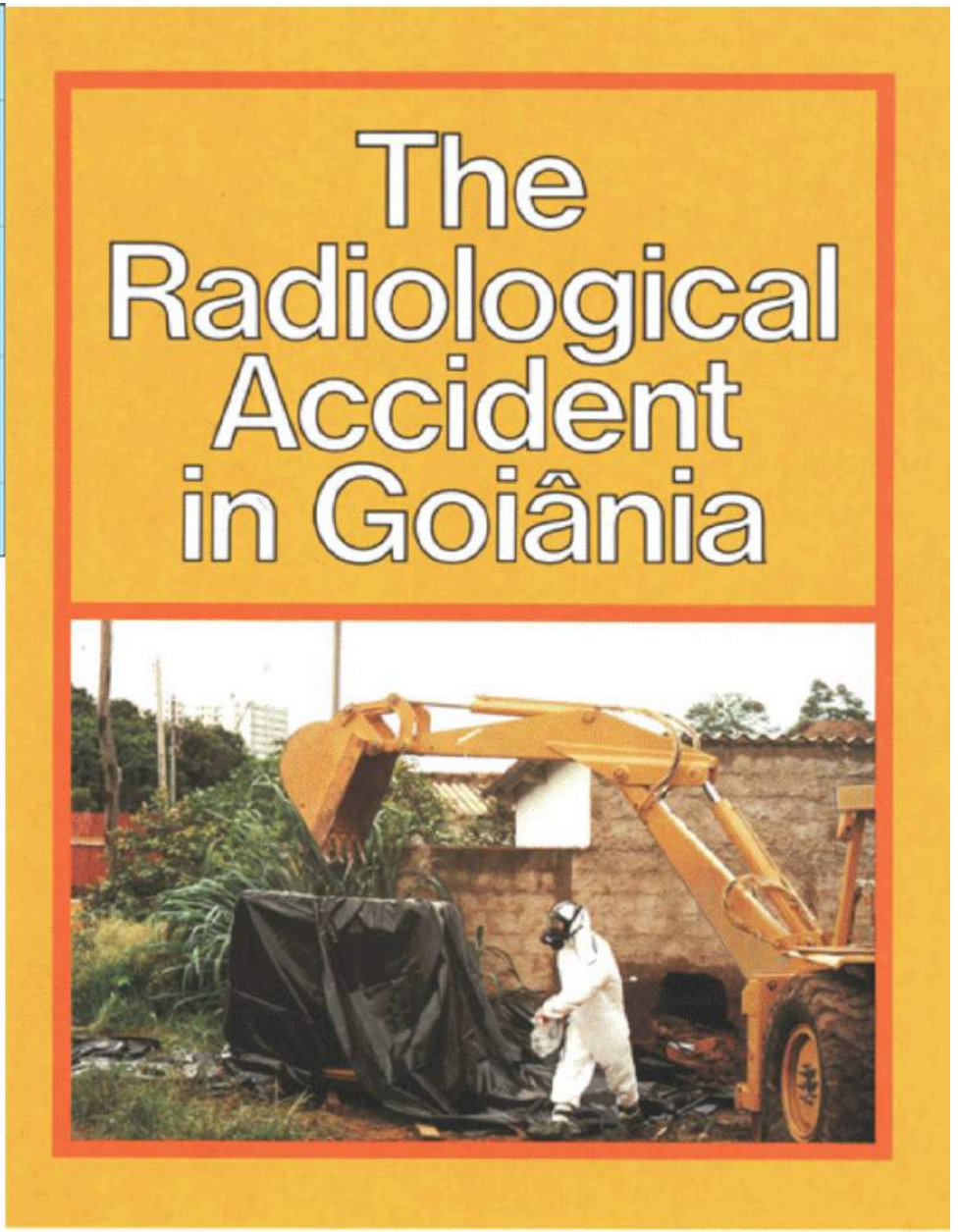

Visit to Chernobyl Sept 2011

Schoolmasters, doctors, community leaders Sept 2011


Discussion with radiation doctors
Minamisoma General Hospital Sept 2011
移植

Mobile whole-body contamination scanner
Minamisoma General Hospital Sept 2011

"On 13 September 1987, a shielded, strongly radioactive caesium-137 source (50.9 TBq, or 1375 Ci, at the time) was removed from its protective housing in a teletherapy machine in an abandoned clinic in Goiania, Brazil, and subsequently ruptured....." (IAEA)



Goiania, Brazil (1987)

Therapy source taken home by scrap merchant and split open.

The radiation gave a pretty blue glow in the air!

Children played with it in the kitchen, it got on their skin and in their food.

They invited the neighbours in to see what they had found – then sold it to another family.

249 people significantly contaminated, over 50 internally.

4 died in a few weeks. 28 had operations for burns. 0 cases of cancer due to radiation in following 25 years.

Many cases of mental health, alcoholism, depression from the label “irradiated”

Significant cases of internal contamination more than 10,000 times the highest measured for any member of the public at Fukushima.

Two successful births to women contaminated.

Details later.

Truth 3. Radioactivity is not contagious

Fire is contagious; it can spread and multiply.

Disease can spread and multiply.

Chemical contamination can spread but does not multiply or decay away.

When nuclear radiation is absorbed by any material the initial damage is chemical and biological. Materials **cannot** be made radioactive by radiation (except by neutrons inside a working reactor core or in a research lab).

Radioactivity decays away. It can only be spread out, not multiply.
It is **not** contagious.

Awful inhuman behaviour towards people from contaminated areas.
This happened after Hiroshima, Nagasaki, Chernobyl, Fukushima.
Even in hospitals

This is completely avoidable with a little public education.

This simple addition to public information does not seem to be given.
Public education is needed BEFORE any incident.
You cannot teach people during an incident!

Truth 4. Radiation is used to diagnose and cure cancers

Radiation used in clinics is **the same** as found in the environment and accidents.

- Natural radiation in the environment is a **low dose rate**.
- Radiation doses and dose rates are **moderate** if they never cause harm that can be demonstrated.
- **High** doses and dose rates have been shown to harm occasionally.

Where are the boundaries? I will discuss this again later in more detail.

Early death from **Acute Radiation Syndrome** occurs in the range 4000-7000 mGy, as at Goiania (4) and Chernobyl (28).

If the dose is protracted over a period cells have time for repair, replacement and adaptation. Then greater doses can be tolerated.

In a diagnostic radiation scan (CT/SPECT/PET) a single acute dose of 10 mGy is received. This is very small compared to the beneficial dose received by a patient who is a member of the public on a course of radiotherapy treatment.

Radiation has been used to treat cancers for over 100 years (radiotherapy).
It is not new or untried.
There is no need for the **precautionary attitude** that may be appropriate for a new technology.

The doses used in such radiotherapy are **high**, but everybody has a friend or relative who has received such therapy and lived to say “thanks”.

In a typical treatment tumour cells receive 30 daily doses of 2000 mSv to kill them.

Nearby healthy tissue then gets 30 daily doses of 1000 mSv and needs to survive by cell repair, replacement and adaptation -- that 30,000 mSv is to be compared to the official low dose rate recommended limit of 1 mSv per year.

If the treatment dose were more dangerous than the original cancer,
the oncologists would reduce the dose.
If it were very much less dangerous,
the oncologists would increase the dose to reduce the chance that the cancer survives.

Compromise: chance of triggering a new cancer, a few %; chance of curing the original cancer, perhaps 90%. All depending on details.

Truth 5. radiation is safer than fire

We all make decisions on the basis of 1) fear, 2) obedience, or 3) the use our own judgement and knowledge.

Wild animals are motivated largely by habit and fear.

Pets, small children and everybody else to an important extent are motivated by obedience to laws and the views of others.
But this can lead to serious (or stupid) errors, as exemplified by:
- the disaster of the Battle of the Somme;
- the Charge of the Light Brigade;
- the story of King Canute;
- Hans Christian Anderson's story of the Emperor's New Clothes.

As in the past it is essential to human survival on Earth that teenagers and adults learn to study nature, apply science and think for themselves whenever they can.

If nobody thinks, the wrong decisions may be made.

Understanding more effective than following the crowd

As the story of King Canute relates the tide ignored the King's command

Science and the laws of nature are deaf to the authority of governments, to the UN, to any legal decisions, majority votes and the influence of money

Safety without study may lead to the wrong answer

The final confrontation with the Environmental Anti Fire Party, half a million years ago, perhaps

A story *with the benefit of a little historical imagination:*

Out of fear and obedience alone we would never have accepted fire!

We would have listened to the environmentalists of the day.

Those environmentalists were **right** to worry about the dangers of fire
(though they did not yet know of the effect of its waste on the environment)

Yet they were wrong to oppose fire at that time.
Modern life could not have developed without it.
hot cooked food, warm dry houses, good health, transport...

Those who objected to fire went home cold and hungry, and then died out.

But today's environmentalists are **wrong** to oppose nuclear technology.
- Nuclear is not dangerous, as the record shows.
- Its waste has no impact on the environment.
- It provides a unique opportunity to avoid the use of fire, as their forebears urged.

Who is going home to die this time?
Just for lack of study? VOTE NUCLEAR!

Truth 6. Radioactive waste is not a major problem

Much less of a problem than personal waste:

Children trained from a very early age;

Vast quantity 1-2 kg/person/day;

Usually discharged into the environment;

Encourages contagious disease to spread and multiply;

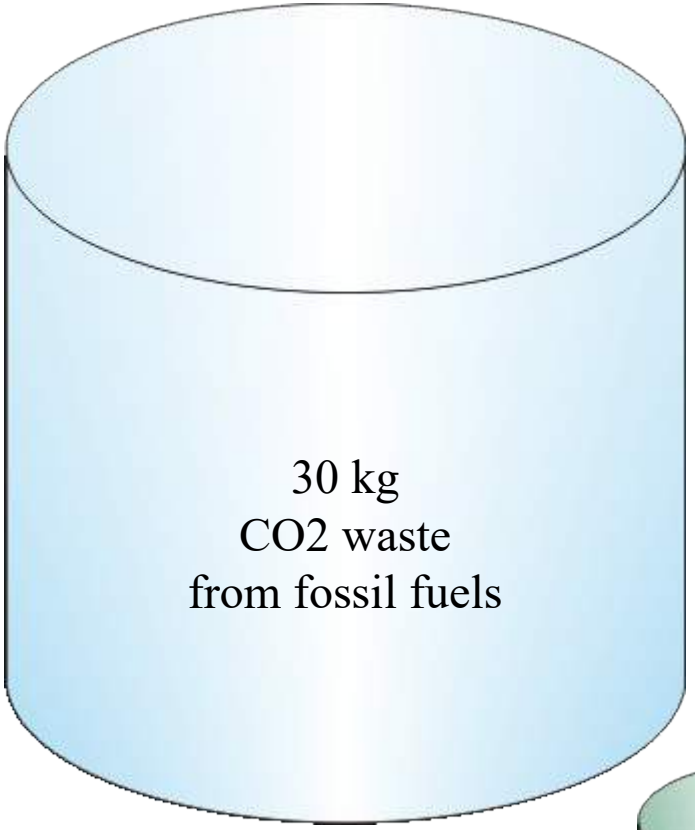
Worldwide death toll every year from contaminated water in millions;

But a valuable waste product that can be recycled as fertiliser.

Nuclear waste can be recycled too.

Waste per person per day (UK)

weight pictured as volume of a canister



<u>CO2 and burning</u>:
Waste directly into air driving climate change.
Thermal **chain reaction** drives burning
-- many hundred thousand of deaths a year

<u>Faeces and disease</u>:
Direct to environment or reprocess
Biological **chain reaction** supports
disease -- millions of deaths a year

1/4000 kg
high level nuclear waste

<u>Nuclear waste</u>: Small, can be contained and reprocessed
No chain reaction except within a working reactor.
Less than 50 deaths in 50 years (Chernobyl).

Truth 7. History and the media. A story of risks that may be exciting but does not fit the evidence

1945 Hiroshima and Nagasaki. At a low point the world learns of nuclear energy

1954 The large Bikini nuclear test and the *Lucky Dragon* (with compensation)

1955 Russell-Einstein Manifesto against testing with 10 Nobel Laureates

1956 BEIR1 report rules against a threshold and in favour of LNT

1957 Novel *On the Beach*

1958 Pauling petition to UN with 11,000 signatures
1958-1962 Worldwide antinuclear demonstrations.

1962 Personal telegram from Pauling to Kennedy (with invalid claims)

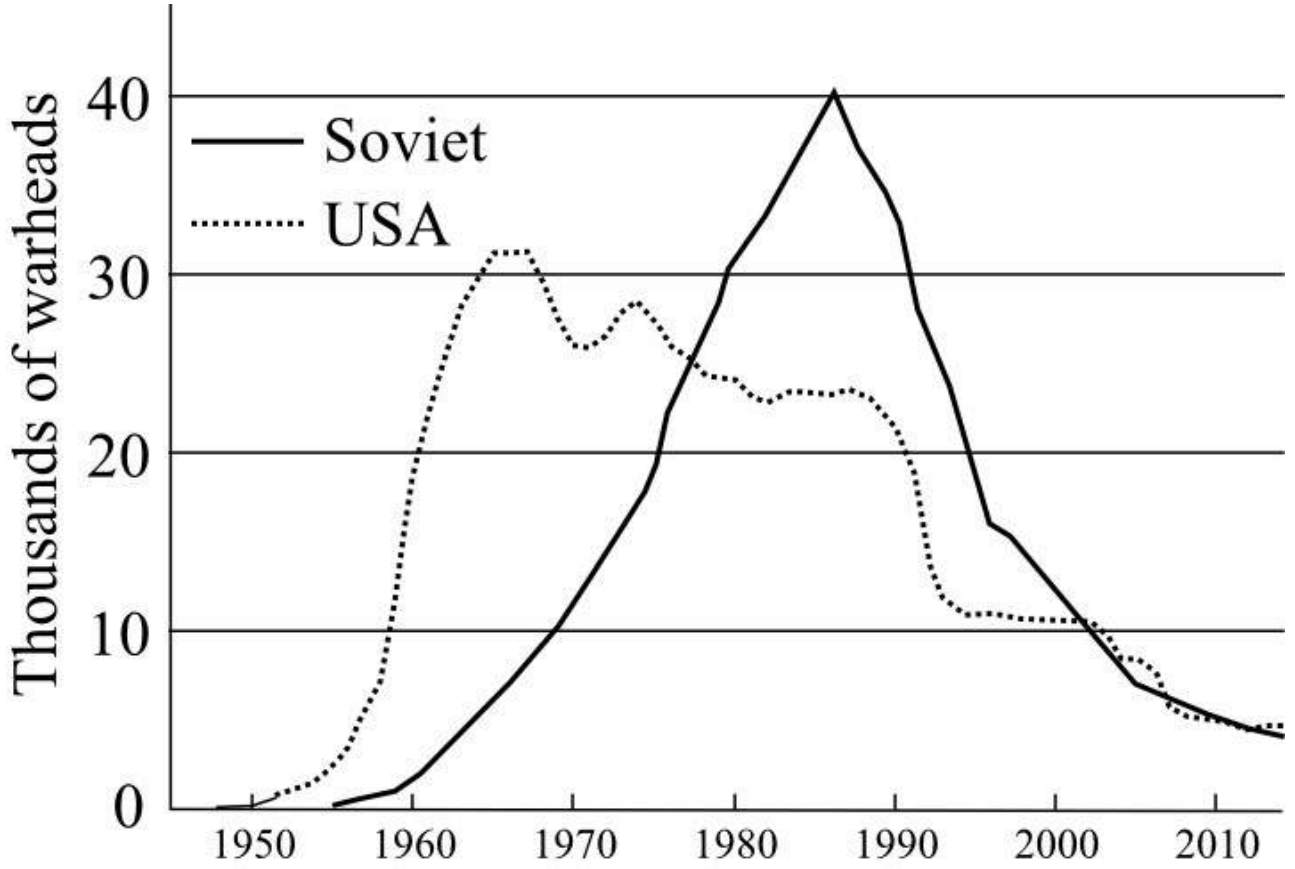
1962 Cuban Missile Crisis. *Would we wake up next day?*

1963 Partial Test Ban Treaty

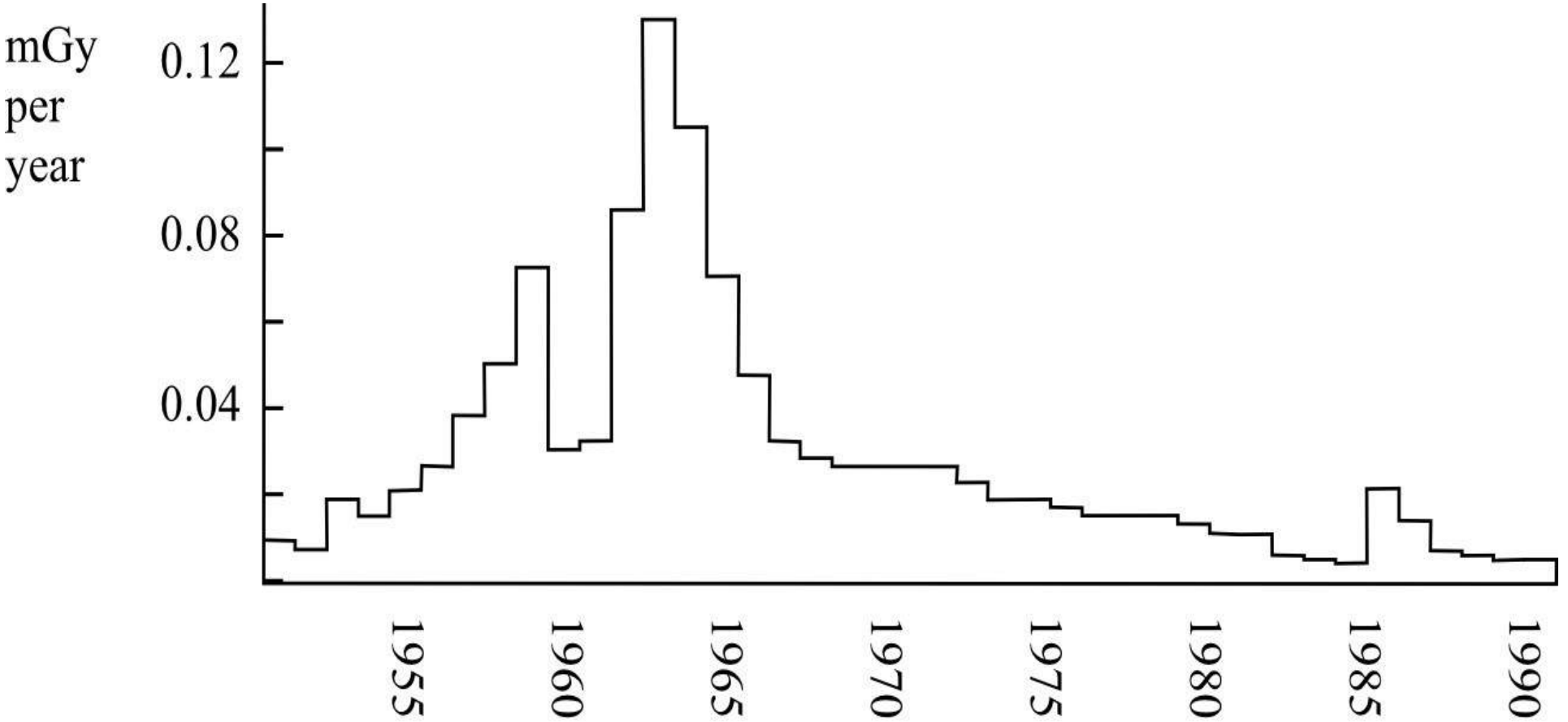
2004 Joint Report by the French Academies comes out against LNT

2015 Three petitions to US NRC and other initiatives to overturn LNT

Nuclear arms race of the 20th Century with policy of mutually assured destruction

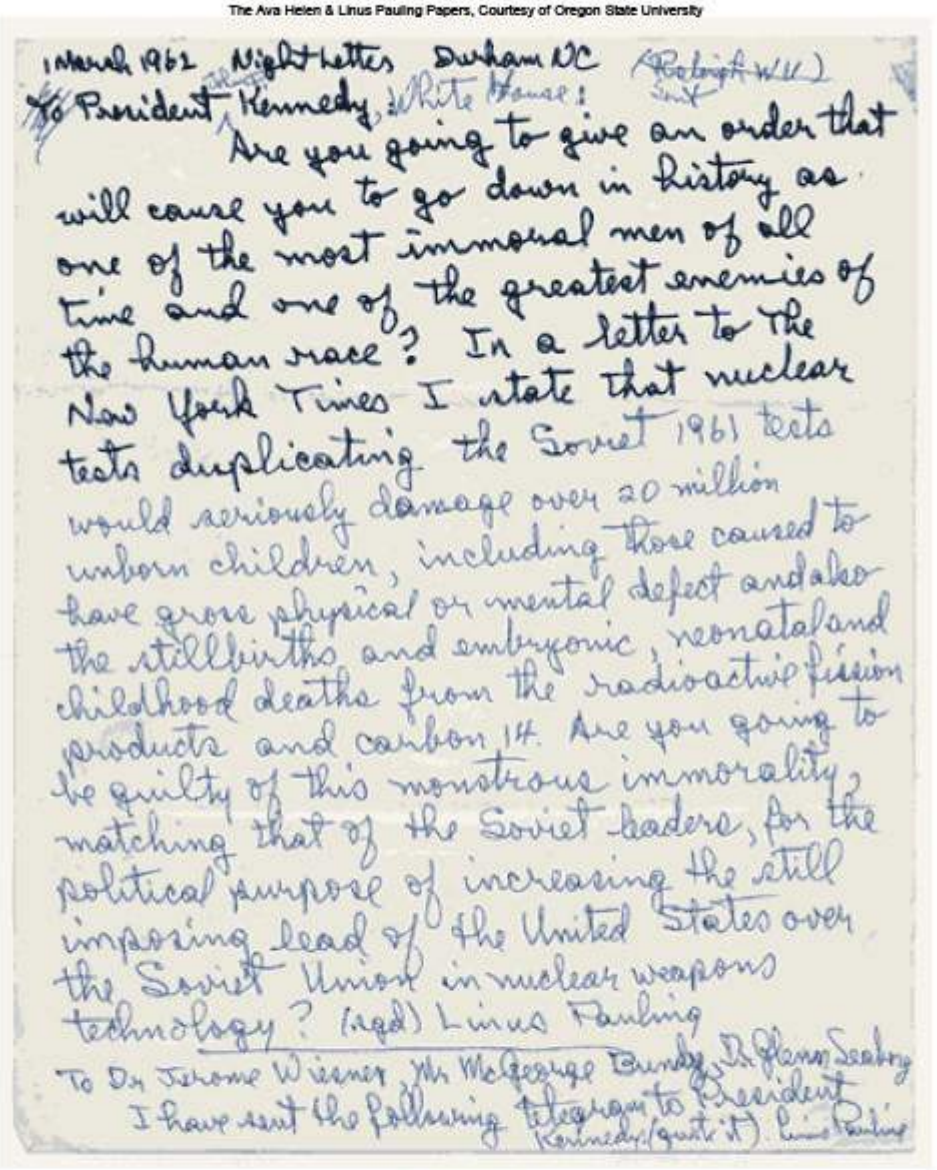


Fallout from nuclear weapon testing (and Chernobyl 1986) as measured in the UK



The letter sent to Kennedy by Linus Pauling.

The human genetic inheritance risks that it speaks of are not valid, as now agreed by all authorities.



The Ava Helen & Linus Pauling Papers, Courtesy of Oregon State University

1 March 1962 Night Letter Durham NC (Raleigh NC)
To President Kennedy, White House:
Are you going to give an order that will cause you to go down in history as one of the most immoral men of all time and one of the greatest enemies of the human race? In a letter to the New York Times I state that nuclear tests duplicating the Soviet 1961 tests would seriously damage over 20 million unborn children, including those caused to have grave physical or mental defect and also the stillbirths and embryonic, neonatal and childhood deaths from the radioactive fission products and carbon 14. Are you going to be guilty of this monstrous immorality, matching that of the Soviet leaders, for the political purpose of increasing the still imposing lead of the United States over the Soviet Union in nuclear weapons technology? (sgd) Linus Pauling
To Dr Jerome Wiesner, Mr McGeorge Bundy, Dr Glenn Seaborg
I have sent the following telegram to President Kennedy (quote it) Linus Pauling

Pauling sent this telegram to President Kennedy in 1962.

Truth 8. Authorities have tried, unsuccessfully, to reassure the public by appeasement

1926 dial painters: radium causes cancer - becomes a matter for US litigation!

1934 Limit set at 734 mGy/yr, see next slides.

1943/4 Plutonium safety? Scale up by 10^9, no info, no time, urgent, secret!
"most dangerous in the world" ever since, but OK for Queen Elizabeth

1945 public introduced to nuclear by Hiroshima/Nagasaki. Shock learnin

1954 appeasement "even the smallest dose is dangerous"
Linear No-Threshold idea LNT, without evidence
Precautionary Principle "you cannot be too safe"
Regulations "As Low As Reasonably Achievable" ALARA, 1 mSv/yr
explicitly ignoring nature's repair mechanisms "to be conservative"
driven by fear of litigation (esp US), not science of nature

1979 and after. Three Mile Island, Chernobyl, Fukushima Regulations driven by public fear not by evidence. Absurd cost of physical/engineering "solutions"

Today. Distortion of the nuclear solution to replacing carbon energy technologies

Comment from a distinguished scientist that remains valid today

Lauriston Taylor (1902-2004), a physicist. Charter member of ICRP 1928. Founder of NCRP and chairman for 48 years.

In a 1980 lecture he said:

Today [1980] we know about all we need to know for adequate protection against ionizing radiation. Therefore, I find myself charged to ask: why is there a radiation problem and where does it lie?

No one has been identifiably injured by radiation while working within the first numerical standards [equivalent to 734 mGy/yr] *set by the NCRP and then the ICRP in 1934.*

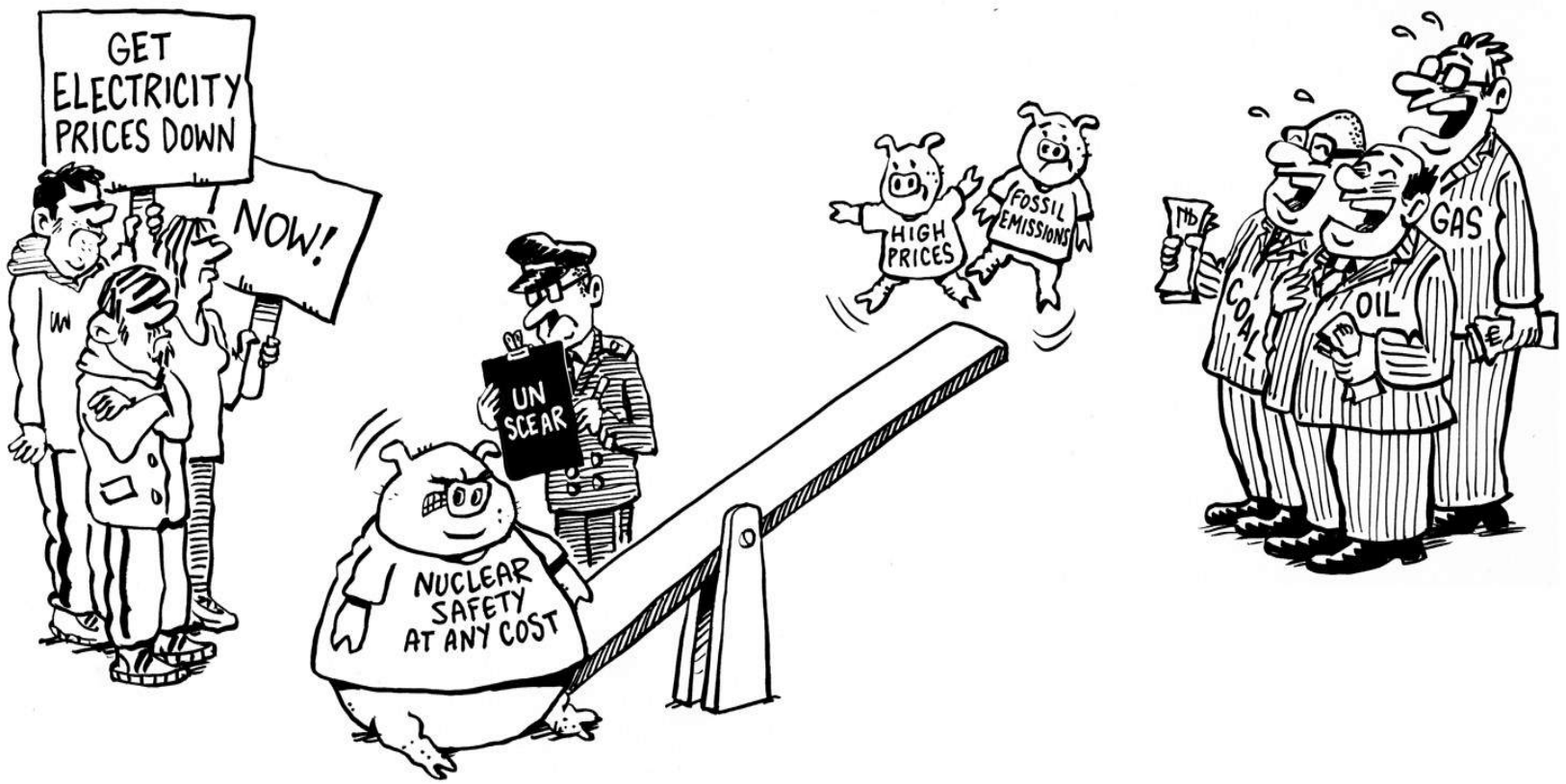
An equally mischievous use of the numbers game is that of calculating the number of people who will die as a result of having been subjected to diagnostic X-ray procedures. An example of such calculations are those based on a literal application of the linear non-threshold dose-effect relationship, treating the concept as a fact rather than a theory. ... These are deeply immoral uses of our scientific knowledge.

Protection and safety by Darwinian evolution? or the deliberations of a UN committee?

As Aesop's Fable of the Tortoise and the Hare illustrates

The natural protection of life, eg from ionising radiation, provided by slow evolution wins easily against regulation determined by committee

Regulations recommended by UNSCEAR
Not based on science,
1000X too restrictive and at an unjustifiable price



'The narrow obsession of international authorities with nuclear safety has distorted the market and is now hitting consumer prices and the environment

Policy: what changes are needed to achieve public acceptance?

1. Address psychological effects - even though not matters of physical safety.
   Accept that, like heights, large energies may create a tingle of fear.
   Size matters. (try standing at the foot of a tall hydroelectric dam!)
   Nuclear installations would be better small, underground and without towers

2. Similarly avoid using unnecessary protective equipment (eg next slide).
   It may impress but obstructs trust.

3. Familiarise the population with frequent discussion and practice in schools from a young age, like with fires and fire practice, also for earthquakes (in Japan).

4. Ensure plenty of “hands on” experience with detectors and natural sources.
   Study how the smoke detector works – it is a cheap radiation sensor

5. Combine with existing awareness of UV safety

6. Encourage the study of natural science plus medicine and engineering

7. Emphasise publicly the medical benefits of nuclear technology

Officials in protective gear may impress, but an open neck shirt and personal contact would reassure better! This shows a public relations failure:

Engage the aspirations of young people

Science, knowledge of the world is exciting.

We owe it to our children that they should study interesting questions like

"What is the chance that there is life out there to receive a signal that we might send them?"

The answer may be "quite large" but they should worry about the answer to related questions like

"What is the chance that civilisation will still be here when their answer arrives back, may be centuries later?"

The answer is probably "very small".
By then our environment will probably have become uninhabitable.
There will be nobody here to hear the answer to the first question.

Young people should be encouraged to work on the problems of survival, in particular the need for energy and trust – trust in society and natural science

Addressing older generations

1. Few are listening to logical argument or have enough time to read
2. The older generation and those less educated are not ready to accept change
3. Clever environmentalists are prepared to reconsider their views, and many have. See the video "Pandora's Promise"
4. Many professionals stand together to defend status quo, appealing to their corporate authority

Battle, fear against science, is not resolved by votes or laws

Max Planck: *A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die.*

Many think they already know and their minds are made up

Tolstoy: *The most difficult subjects can be explained to the most slow witted man if he has not formed any idea of them already; but the simplest thing cannot be made clear to the most intelligent man if he is firmly persuaded that he knows already, without a shadow of doubt, what is laid before him.*

Others are in employment that depends on the status quo

Upton Sinclair: *It is difficult to get a man to understand something when his salary depends on his not understanding it.*

Expanding on some important points

1. Units, doses, dose rates, ALARA and LNT
2. More on Chernobyl
3. More on Fukushima
4. More on Goiania
5. Cancer caused by radiation
6. Lifelong chronic data on dogs
7. Lifelong human data: Dial Painters
8. AHARS to replace ALARA/LNT

1. Units, doses, dose rates, ALARA, LNT

Absorbed energy breaks molecules, the initial oxidative damage,
and then the tissue responds – its alive!

Generally molecules are very weak so oxidation is quite indiscriminate
Oxidation is linear in joules per kg, Gray (Gy).
So 1 Gy/sec = 1 watt per kg, similar to limit for MRI and ultrasound.

Mean dose rate to healthy tissue in radiotherapy:
1 Gy/day = 1/(24x60x60) = 12×10^{-6} watt per kg

Background dose rate 1 mGy/yr = 32×10^{-12} watt per kg

UV dose rate in full sun (roughly)
1% of 1000 watt per sq m = 10 watt per sq m

UV is less effective at oxidising biological molecules,
but the difference in energy flux is huge
so that UV is more dangerous then most nuclear sources.

But then there is the effect of tissue recovery
this depends on the resources that are locally available to cells.

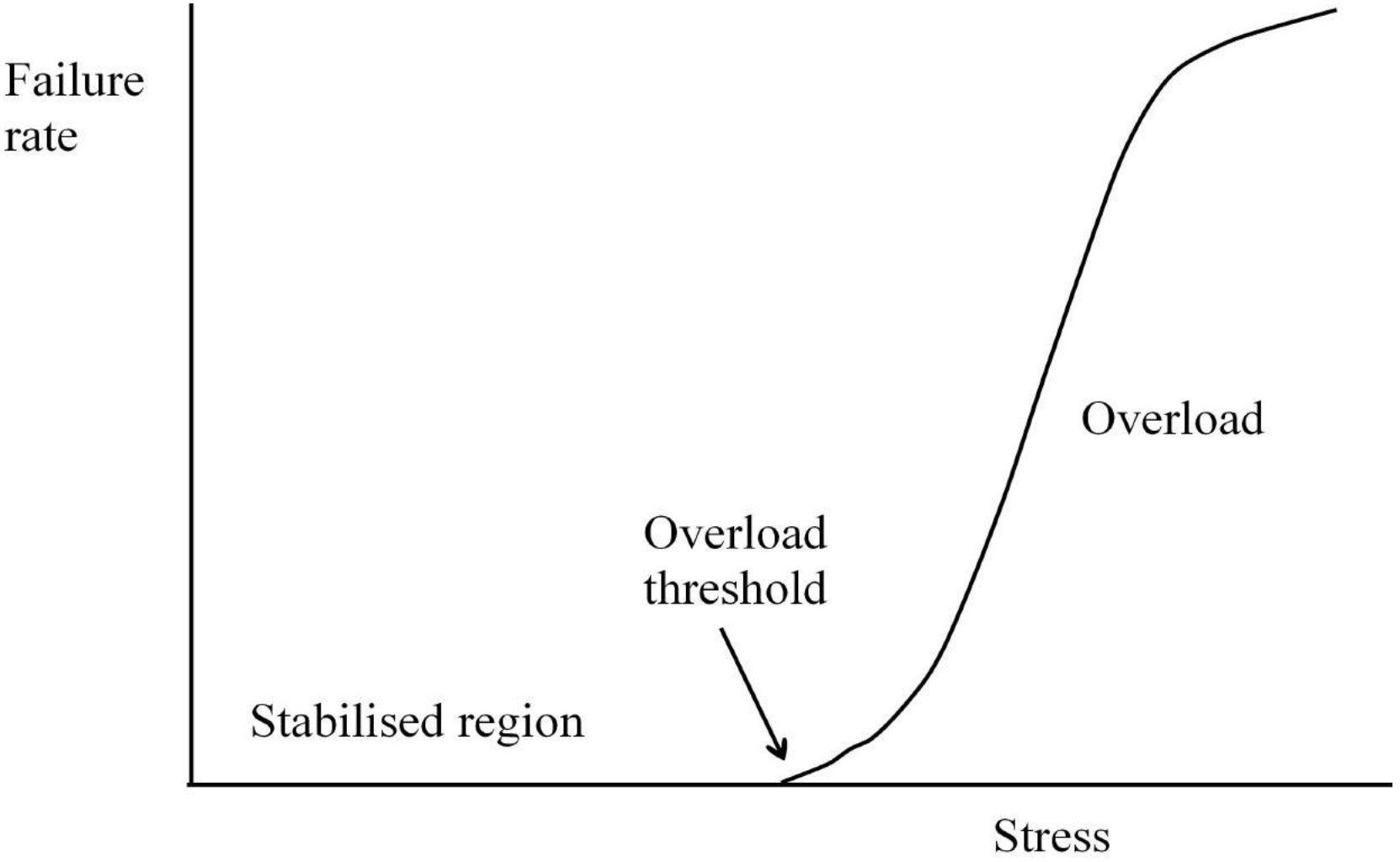
If the microscopic energy density is high ("high LET") then the incidence of multiply damaged DNA (DSBs etc) inhibits good repair. Otherwise the nature of the incident radiation does not matter much.

LNT accepts this by weighting High LET radiation with factors *w*. Thus *w*(alpha)=20; *w*(neutron)=5-20; otherwise *w*(beta,gamma)=1. The result is called sievert(Sv). In practice this does not make any difference and 1 Gy = 1 Sv (except for alpha). Better use Gy.

LNT completely ignores time by adding up all the dose at any time and to any body. This collective dose is not biologically meaningful. LNT tries to patch up with a rate-dependent factor DDREF. However that does not make good the fallacy.

If LNT were correct, Radiotherapy dose fractionation would not work. Radiotherapy could be deliverable in one treatment but patients would die.

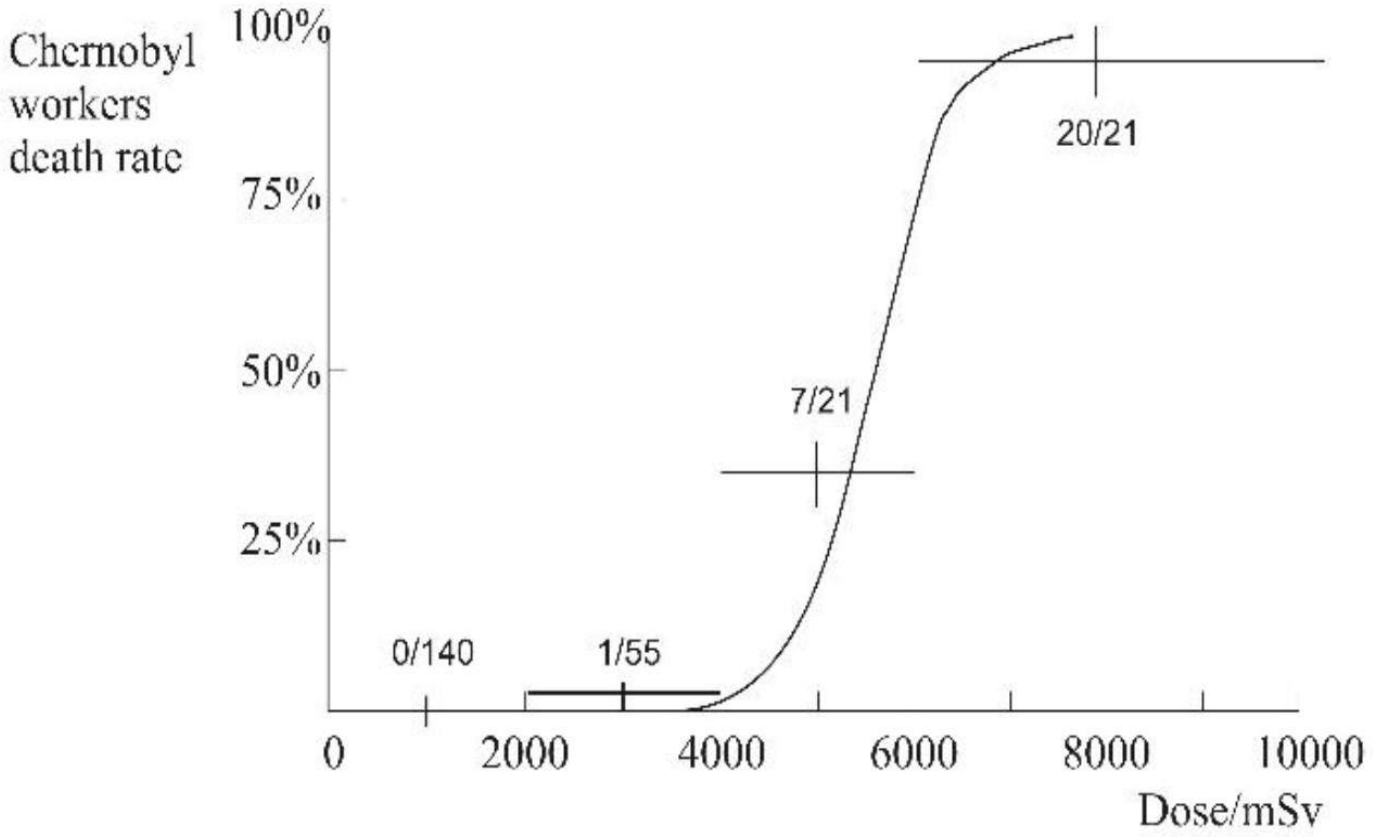
Failure and stability of a system with resource limited repair/replacement



where stress is dose RATE within a recovery time (a day? less than a month)
BUT NOTE repair/replacement can adapt too! As in getting fit

2. More on Chernobyl

Major loss of life, 28 early firefighters.
Crosses show their mortality (curve is for rats).
The numbers show died/total in each dose range.
Acute Radiation Syndrome in a few weeks.



Since that time there have been:
- no further deaths among these early firefighters linked to radiation;
- no clear evidence of later deaths, either identifiable or statistical, linked to radiation.
  eg cancer from caesium-137.

Exception: iodine-131 deaths 15, avoidable but controversial.

Health effects were summarised by WHO in 2006 and updated in a draft UNSCEAR report on 28 Feb 2011, not read by anyone in Japan, it would seem. The important lessons on social and mental health learnt at Chernobyl went unheeded in Japan.

There was a victim culture of hopelessness, born of ignorance, but sustained by financial payouts, especially in Japan. This led to alcoholism, family breakup and general mental health problems at Chernobyl acknowledged by WHO as identifiable and more serious than any possible unidentified direct effect of the radiation.

Artifically increased abortions rates in Greece are discussed in *Nuclear is for Life.*

The admission of unnecessary food restrictions are discussed in *Radiation and Reason.*

3. More on Fukushima

1. Major earthquake and tsunami

Cause (natural) radioactivity heating the Earth.

Physical destruction & 18,800 deaths. **Natural disaster**

2. Three destroyed nuclear reactors

at Fukushima Daiichi with release of (artificial) radioactivity.

No casualties, none expected in future. **No disaster**

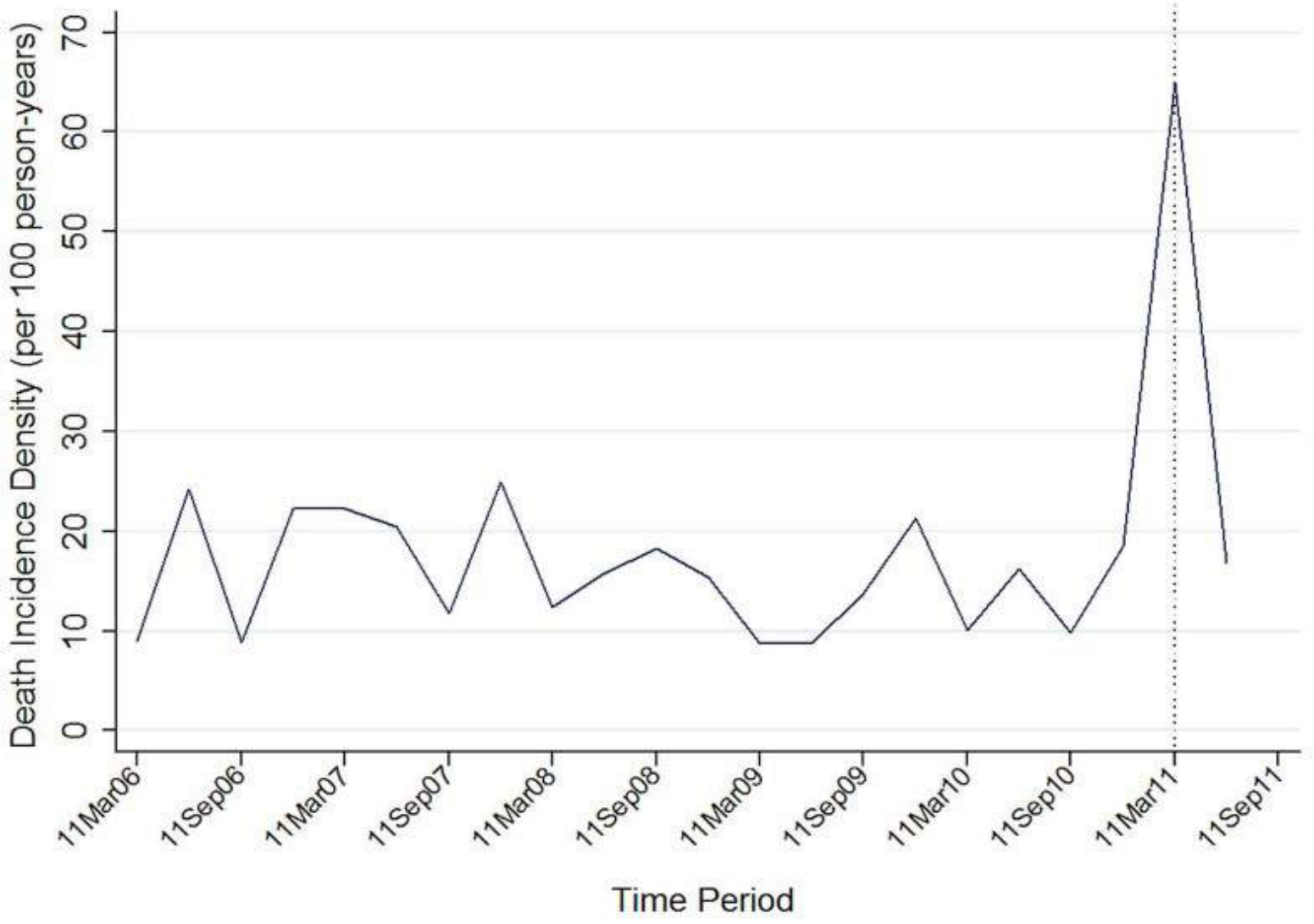
3. Local and worldwide panic

caused by excessively cautious safety, lack of plan / education

Displaced people (1600 extra deaths), condemned food,
power stations turned off, imported fossil fuel,
severe economic damage,
reduced trust in society, science and medicine

Self inflicted education failure, not due to radiation

Death rate in homes for elderly



4. More on Goiania Whole-body internal Cs-137 activity compared to Fukushima and K-40

No	Whole body activity	Persons	Deaths	Relative activity
Goiania Cs137	Above 1000 MBq	1	1 ARS death	>100,000
Goiania Cs137	100 to 1000 MBq	7	3 ARS death	>10,000
Goiania Cs137	10 to 100 MBq	20	No deaths or cancers in 25 years	>1,000
Goiania Cs137	1 to 10 MBq	23		>100
Goiania Cs137	1/10 to 1 MBq	15		>10
Goiania Cs137	1/100 to 1/10 MBq	11		>1
Fukushima adults Cs137	At or below 1/100 MBq	32811	Not expected	Less than 1
Everybody natural K40	4/1000 MBq	all	--	
Fukushima children Cs137	All below 2/1000 MBq	1491	Not expected	

5. cancer caused by radiation

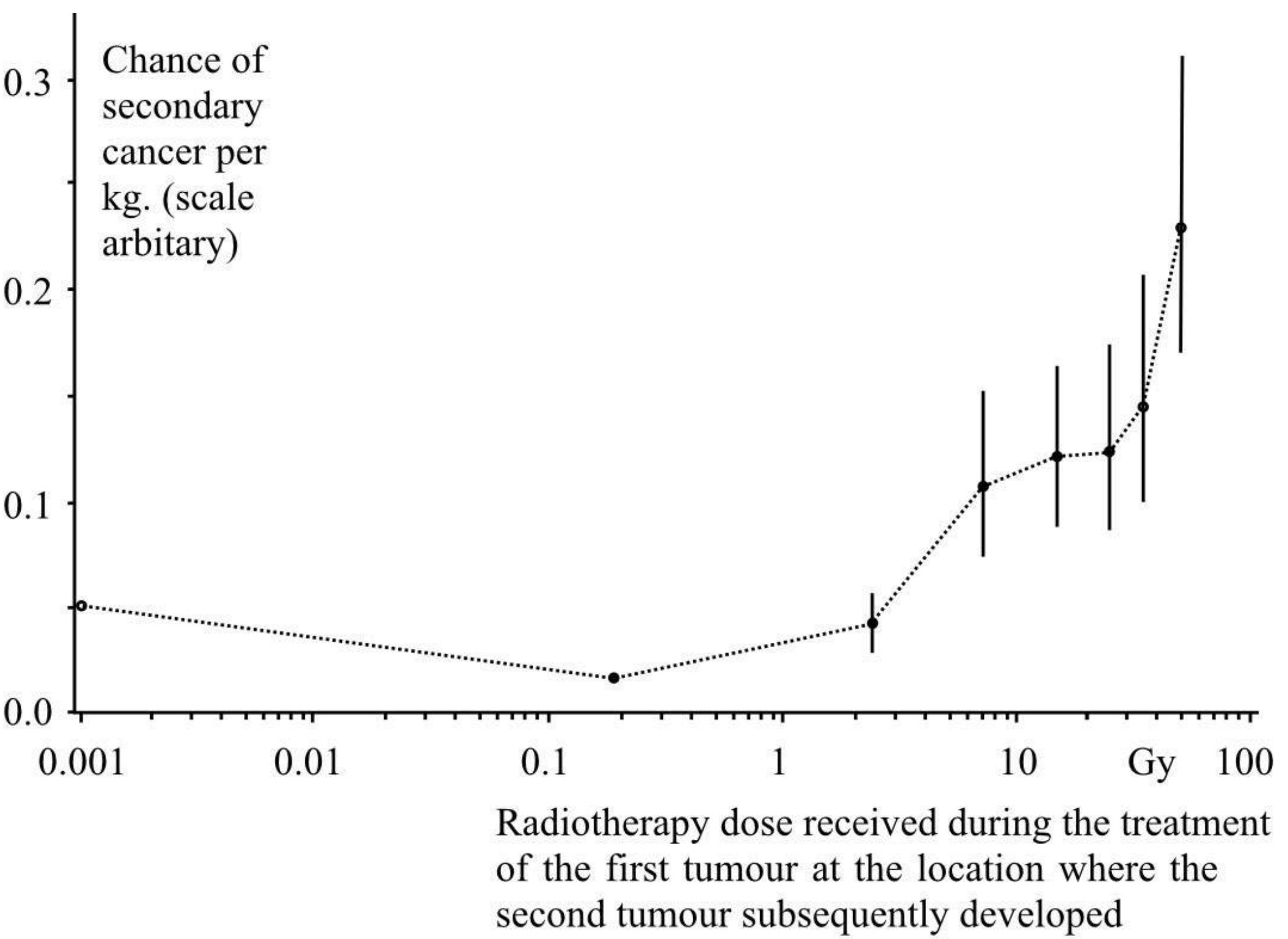
A new method of assessing the dose-carcinogenic effect ... Tubiana M Health Phys 100, 296 (2011)
http://www.ncbi.nlm.nih.gov/pubmed/21595074

UK/France 5000 survivors of childhood cancers followed for av 29 years
369 second primary cancers 7.4%.

No evidence of any new primary cancer caused by a radiation dose less than about 5 Gy, that is 5,000 mGy;

• for doses in the range 5 to 40 Gy the risk of a second cancer increases progressively at higher dose – this is evidence for a late response to a very high protracted dose;

• there is evidence of a beneficial suppression of cancer incidence for radiation doses around 0.5 Gy, that is 500 mGy


Chance of secondary cancer per kg. (scale arbitary)
0.3
0.2
0.1
0.0
0.001
0.01
0.1
1
10
Gy
100
Radiotherapy dose received during the treatment of the first tumour at the location where the second tumour subsequently developed

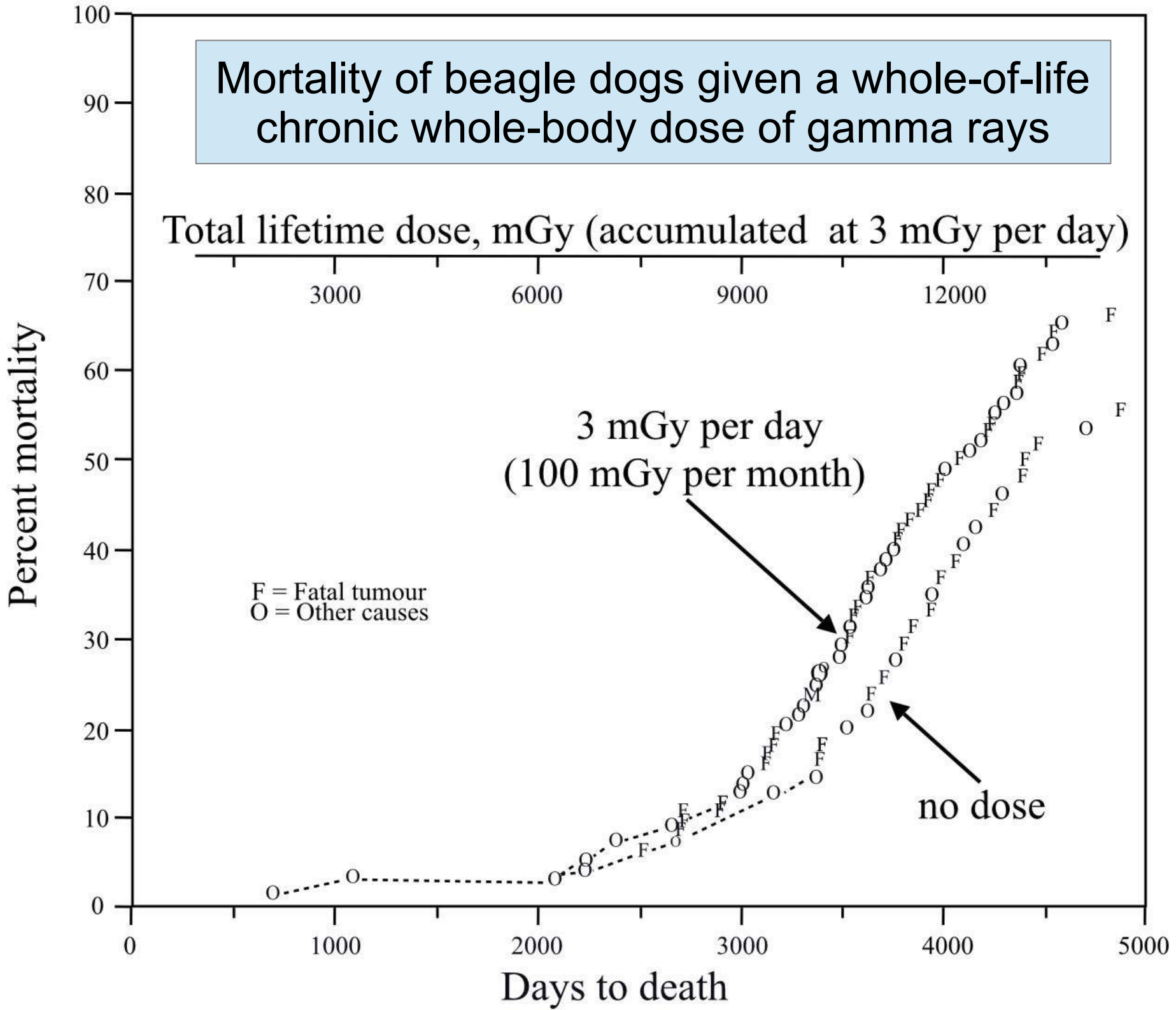
6. Lifelong chronic data on dogs

There is good data on mice given a chronic radiation dose rate throughout life including in utero. They do not show serious effects but their lives are so short and metabolic rates so different to humans that comparison is difficult.

Dogs are more similar to humans. Their mortality of those on 3 mGy per day (90 mGy per month) chronic dose rate is the same as unirradiated dogs up to about 9000 mGy whole-of-life dose at which point their mortality increases.

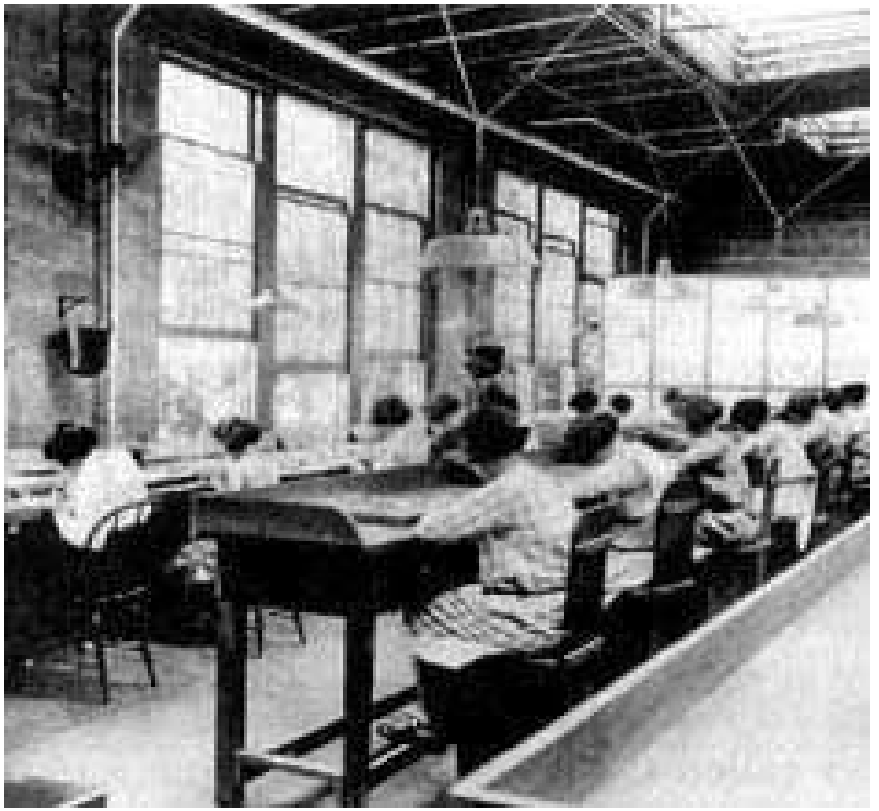
The extra mortality is not markedly tumour related.

For whole-of-life mortality and the effect of chronic dose we take this as a useful measure to be compared with the human data on child second cancers and the dial painters.


Mortality of beagle dogs given a whole-of-life chronic whole-body dose of gamma rays
Total lifetime dose, mGy (accumulated at 3 mGy per day)
3000
6000
9000
12000
Percent mortality
3 mGy per day
(100 mGy per month)
F = Fatal tumour
O = Other causes
no dose
Days to death
0
1000
2000
3000
4000
5000
0
10
20
30
40
50
60
70
80
90
100

7. Lifelong human data: Dial Painters

luminous watches and dials painted with radium paint



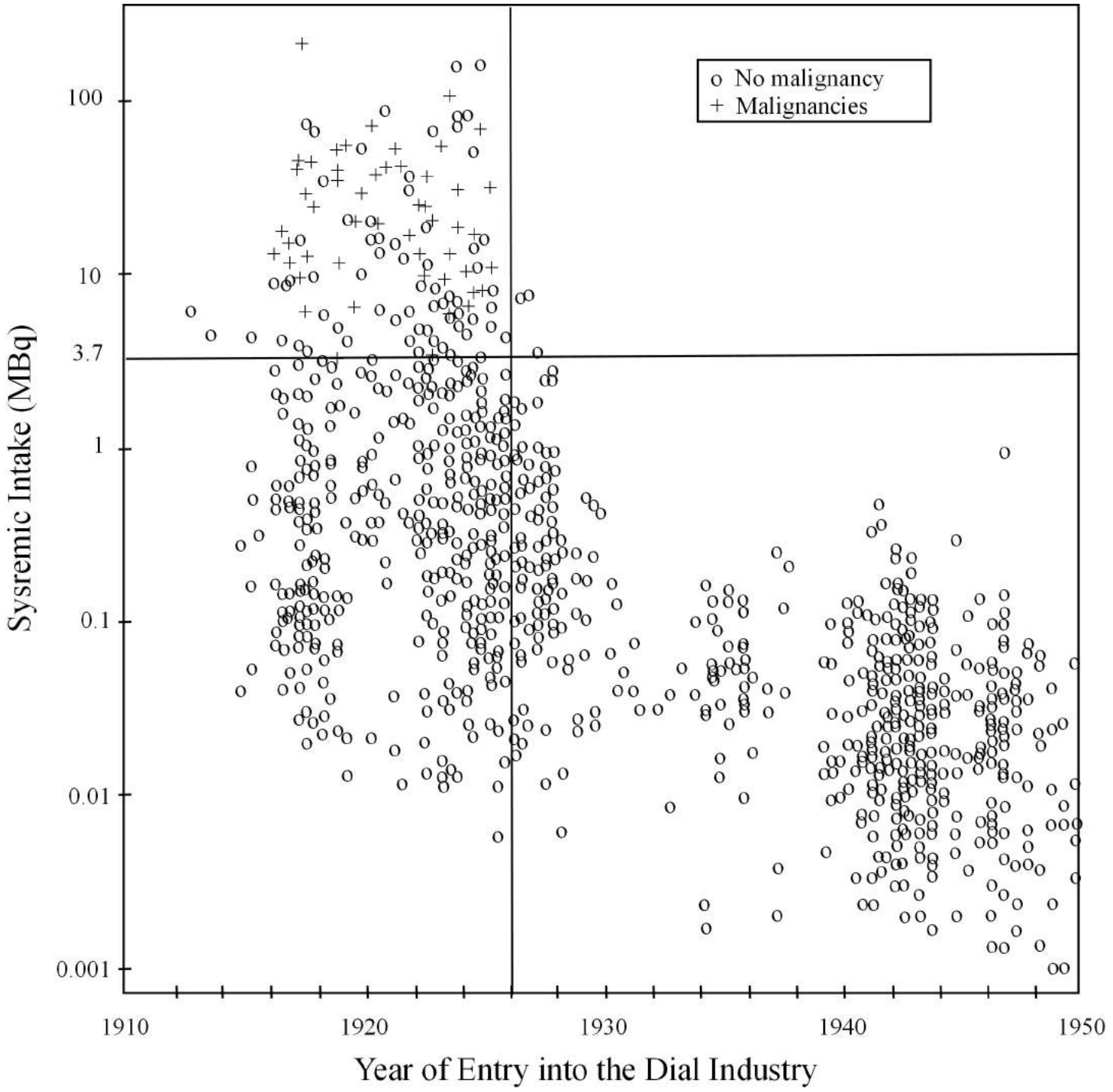
Bone cancer usually 1/400. Evidence for threshold: (Rowland 1997)

1339 painters with less than 10,000mGy, 0 cases [3 expected]

191 painters with more than 10,000mGy, 46 cases. [<1 expected]

No malignancies after 1926 when practices changed.

No malignancies with less than 3.7 MBq



8. How AHARS safety should replace ALARA/LNT

As High As Relatively Safe (AHARS).
The value of parameters that suggested here for the safety of radiation exposures. Questions answered by evidence, here and elsewhere

What is the threshold for an acute dose? **100 mGy (mSv), fairly well agreed**

What is the repair time? **Varies, roughly between a day and a month. Not agreed by those who do not acknowledge the question!**

What is the threshold for a chronic dose rate? **Between 60-100 mGy per month, as in 1934. Not agreed by those who deny the role of repair.**

What is the whole-of-life limit? **About 10,000 mGy but may be more. Those who deny repair quote numbers like 100 mGy!**

What should replace the International Nuclear Event Scale (INES)? **Nothing! There is no such scale as INES for other accident types**

How can we make such a political change? **Teach from the bottom. Go to the top. Follow the guidance of those who have made such changes before...**

Follow the example of Florence Nightingale (1858):

- get the data
- draw a good coloured diagram
- explain it to everybody
- insist and leave no doubt

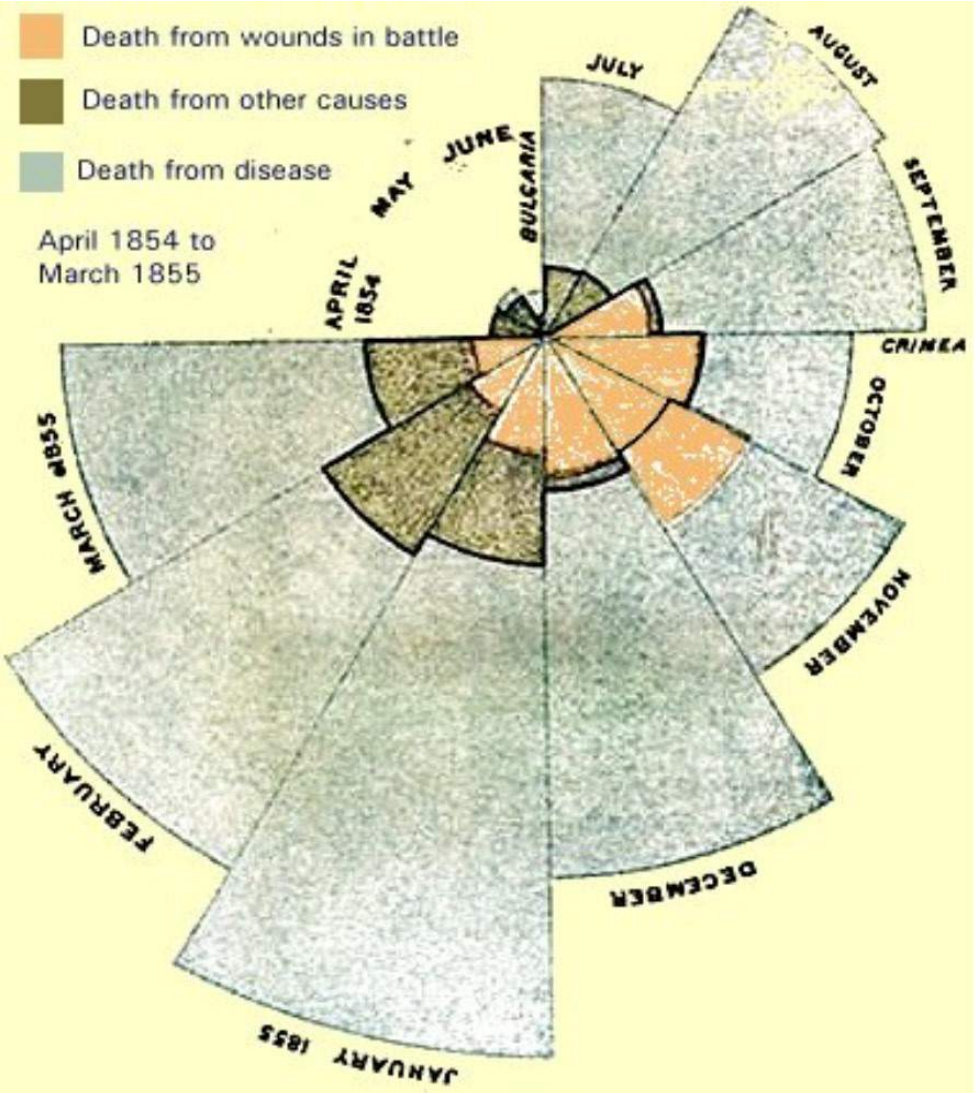
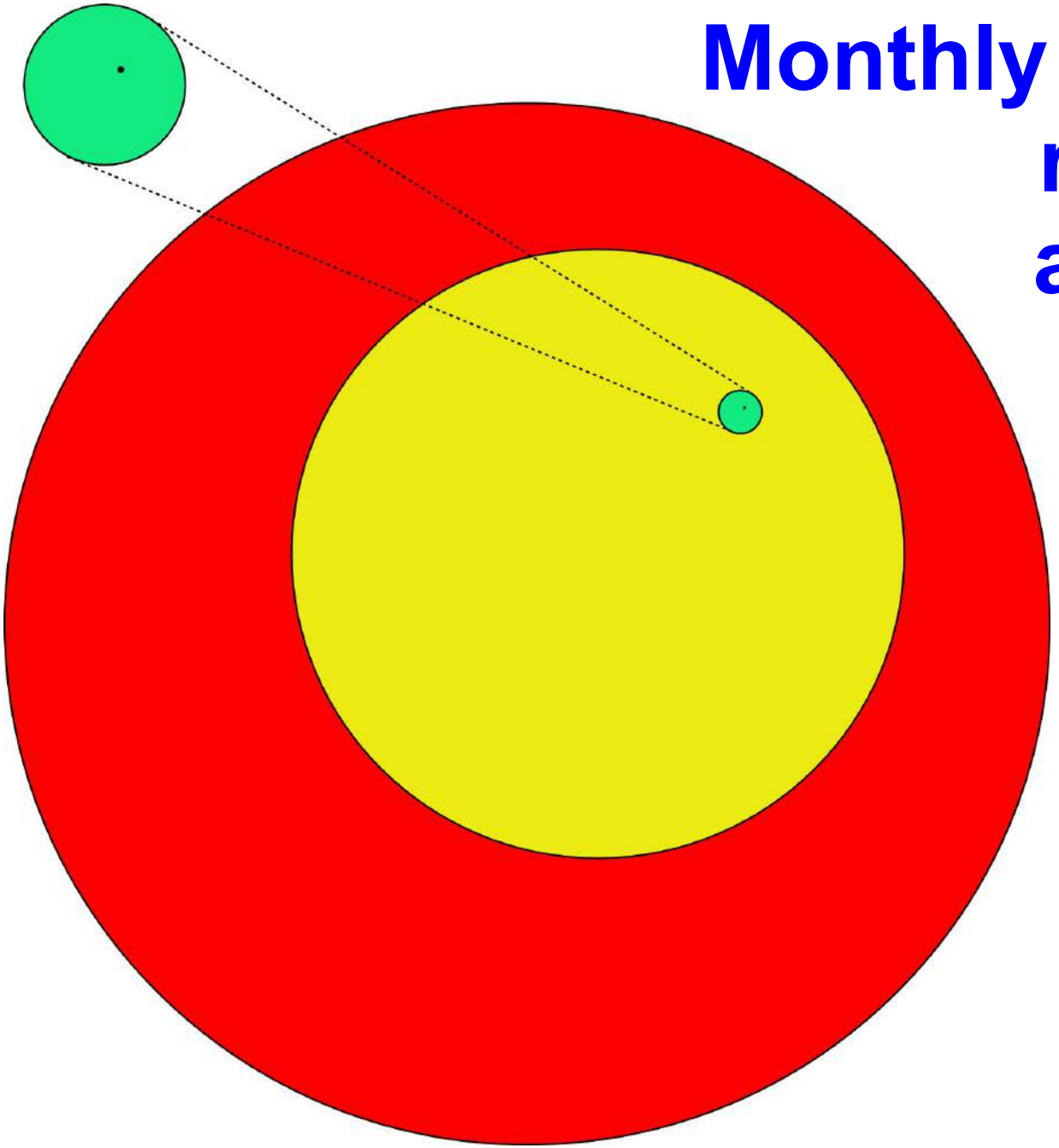


Illustration 35.

Nightingale F. "Notes on Matters Affecting the Health, Efficiency, and Hospital Administration of the British Army Founded Chiefly on the Experience of the Late War."

Presented by Request to the Secretary of State for War.

Privately printed for Miss Nightingale. Harrison and Sons. 1858.



Monthly radiation dose rates shown as areas of circles

Red circle, 40,000 mGy per month, less than a radiotherapy dose rate that kills a tumour

Yellow circle 20,000 mGy a month, a survivable therapy dose rate to healthy tissue near a treated tumour

Green circle 100 mGy per month, a conservatively safe dose rate, As High As Relatively Safe (AHARS)

Small black dot 0.08 mGy per month, [1 mSv per year] an unreasonably cautious rate, As Low As Reasonably Achievable (ALARA)

Conclusions

- Build a future on nuclear technology with a total change of culture so that carbon technology is discontinued
- Re-base Radiation Protection on a dose-rate threshold, AHARS. Inspire public confidence with the positive life-saving uses of radiation for health
- Follow Florence Nightingale and explain to people the evidence, simply and graphically
- Teach familiarity with radiation in schools, as the Japanese do with earthquakes and tsunamis and everybody does with fire safety
- Concentrate more resources on education and less on regulation, and get cheaper electricity for more competitive industry and better public acceptance
- Teach that nature and its laws can over-ride man-made legislation!

The Pedascope

CERTIFICATE

SHOE-FITTING TEST DATA FOR _____

1. **ANKLE ROLL** GOOD ☐ FAIR ☐ POOR ☐

2. **WEIGHT DISTRIBUTION**

RIGHT WAY

LEFT RIGHT

____% BALL ____%

____% OUTER ____%

____% HEEL ____%

WRONG WAY

3. **X-RAY FITTING TEST**

RIGHT WAY

LEFT RIGHT

☐ GOOD ☐

☐ FAIR ☐

☐ POOR ☐

WRONG WAY

This scientific way of approaching the problem of poorly-fitted shoes eliminates guesswork. Now you can see for yourself!