

**What might Marie Curie, Charles Darwin,
Florence Nightingale and Adam Smith
think of Radiological Protection today?**

Wade Allison, Oxford University

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Scottish Nuclear Medicine Group

17 June 2013

The need to sound the alarm

▶ *Current knowledge of radiobiology is incompatible with world radiation safety based on ALARA and linearity (LNT)*

Pollycove and Feinendegen (2008)

▶ *What was a good intention years ago to protect workers from overexposure to ionizing radiation has been turned now to producing a widespread radiation phobia with disastrous global political and economic consequences..*

▶ *News 20 Feb 2013:*

Chaos in Bulgarian energy

An energy crisis has triggered mass demonstrations, the resignation of the Bulgarian government and cyber attacks on electricity distributor CEZ. A long-running failure to maintain generating capacity underlies the country's problems.

Trillion-euro cost of German energy transition

Germany's plan to transform its energy system to one reliant on renewable power as it phases out nuclear energy could cost up to €1 trillion, German energy and environment minister Peter Altmaier has publicly admitted.

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Policy Statement of the International Organization for Medical Physics

William R. Hendee, PhD
International Organization for Medical Physics

Editor's Note: We are pleased to reprint an editorial by William R. Hendee, PhD, editor of *Medical Physics*, on the policy statement on radiation risks recently adopted by the International Organization for Medical

porting documents and additional readings). Now the International Organization for Medical Physics, representing 80 national and six regional medical physics organizations and 18000 medical physicists worldwide, has developed its own policy statement which is reproduced below. One can only hope that the policy statements issued by these knowledgeable organizations will have some deterrent influence on the continued propagation of unsupportable cancer risk estimates related to medical imaging procedures conducted with minimum doses of radiation consistent with high quality studies.

—WILLIAM R. HENDEE, PhD
EDITOR, *MEDICAL PHYSICS*

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¹From the International Organization for Medical Physics, York, England; and *Medical Physics*, Medical College of Wisconsin, Milwaukee, Wis (W.R.H.). Address correspondence to W.R.H. (e-mail: whendee@mcw.edu).

How high might those safety limits be?

As High As Relatively Safe (AHARS) instead of
As Low As Reasonably Achievable (ALARA)

How might public trust in radiation at lesser doses be established?

Marie Sklodowska-Curie 1867-1934

Physicist, chemist, radiologist

= *“Nothing in life is to be feared. It is to be understood.”*



Charles Darwin 1809-1882

student of divinity, naturalist, biologist, geologist,



Florence Nightingale 1820-1910

Nurse and pioneering statistician

= *“How very little can be done under the spirit of fear”*



Adam Smith 1723-1790

Economist and philosopher

= *“Science is the great antidote to the poison of enthusiasm and superstition”*



When Radiological Safety meets Industrial Safety

(1) Two comments on the balance between them by Howard Iskayn 20 May 2013, on LinkedIn Nuclear Safety Group

I worked on the design of a FOAKE plant that was regulated/controlled by a European Nuclear Regulator. There was a real hazard of death by the escape of hot gas. The Regulator stated that he was not concerned with death by anything other than nuclear exposure. For the nuclear regulatory "death by hot gas was satisfactory so long as the body could be buried without radiation restrictions". Accordingly, the design stressed radiation ALARA and had almost no concern about the hazard of hot gas.

While working at a DOE remediation site in the USA, I remember the acceptability for U-238 given in terms of rem/volume whereas the most serious danger from that isotope was its toxicity as a heavy metal. Admittedly, nuclear and industrial safety culture should have a great deal in common, but my view is the regulators have not always applied them in a reasonable manner.

(2) An unsolicited email (Dec 2012) from Ken Chaplin, a senior long-time inspector in the nuclear industry

“... four of us were working in a relatively high temperature environment in lead jackets and plastic lined suits. The radiological hazards were insignificant, but two of us almost passed out from the heat in a very difficult to access location.

I had staff climbing ladders attached to walls, with very little space to get their feet on the ladder rungs... required to wear steel toed shoes, inside rubber "one size fits all" boots, inside paper booties.... in the name of contamination control; however, I am far more concerned about people falling 8 metres onto piping.

Staff are increasingly worried and this results in much lower productivity and higher stress levels ... by the entire organization pursuing ALARA, without accompanying health benefits.

I am watching as radiological protection dogma, in particular ALARA, stops the nuclear industry dead in its tracks. It is hard to prevent this, but I am trying.”

ALARA safety restrictions, intended to allay fears, achieve the opposite. Regulation and worker stress drive up costs, bring no benefit and are economically damaging.

Fear of radiation

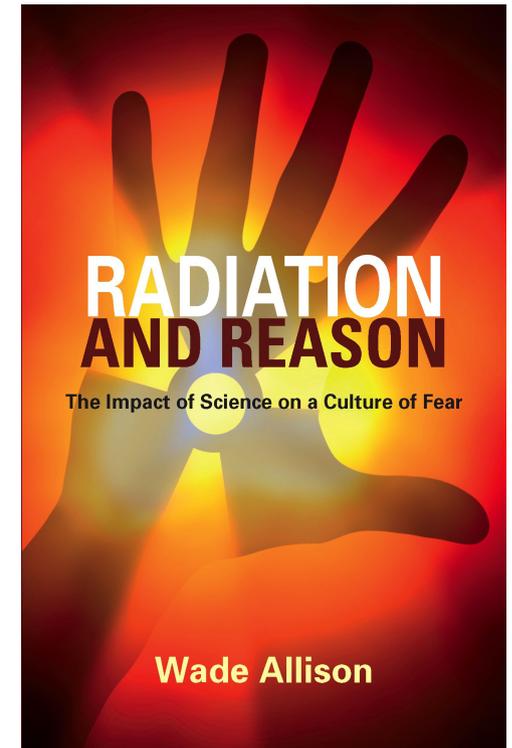
Why?



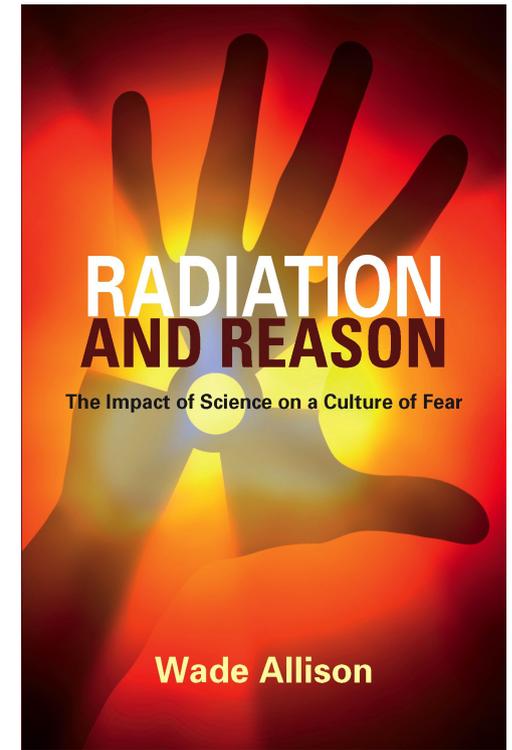
1. Fear of the aftermath of a nuclear holocaust.
An effective Cold War message that frightened everybody at the time.
2. Cannot feel nuclear radiation.
 - OK, get a detector, a smoke detector
 - Even better, the cells of your body can feel - repair the damage, too.
3. The international regulations (ICRP) designed to keep lid on public opinion by promising no more than background levels, 1 mSv per year.
As Low As Reasonably Achievable (ALARA)



“Science is the great antidote to the poison of enthusiasm and superstition”



**Increased fear,
increased regulations,
increased costs and prices,
economic damage **STOP!****

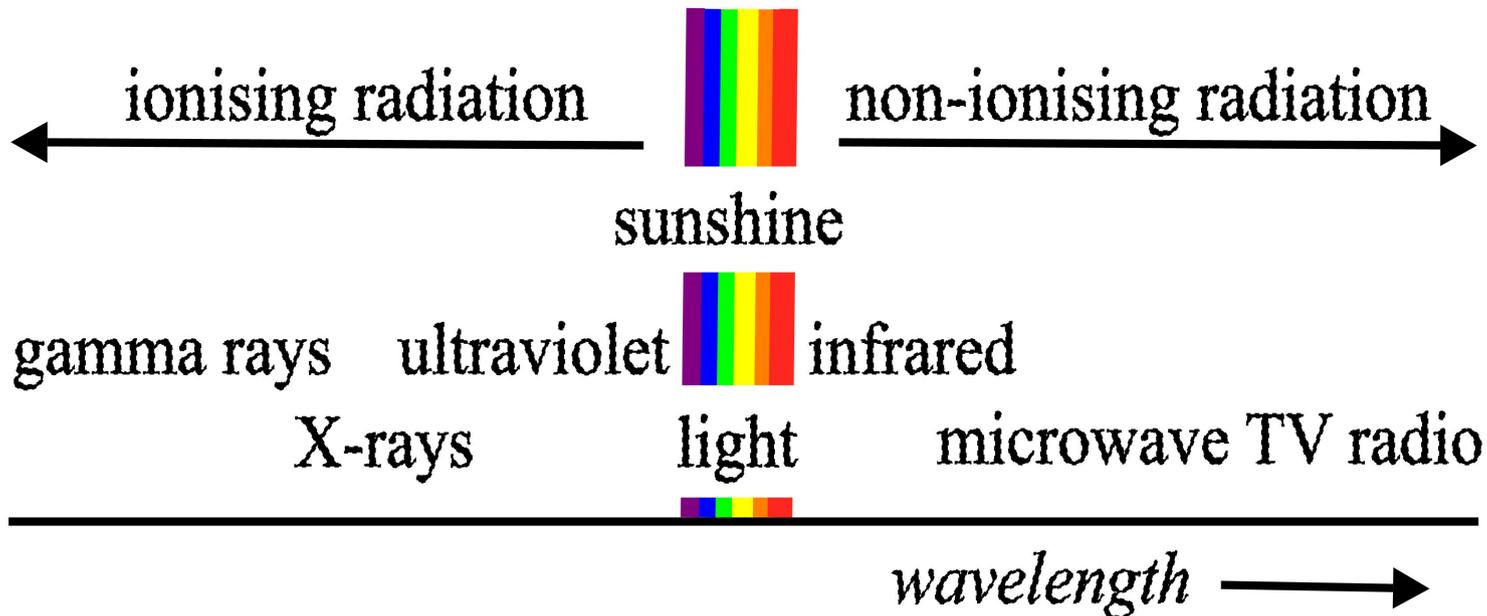


Reassurance from the physical science of nuclei?

Radiation energy deposited

	Energy J kg ⁻¹	Duration	Joules kg ⁻¹ day ⁻¹	Joules kg ⁻¹ month ⁻¹
1 kg food in microwave	rate 500 watts	single 30 mins	10 ⁶	10 ⁶
Radiotherapy (tumour)	2 Sv (or Gy or J kg ⁻¹) day ⁻¹	30 days	2	60
Radiotherapy (peripheral)	1 Sv (or Gy or J kg ⁻¹) day ⁻¹	30 days	1	30
ALARA As High As Reasonably Safe	100 mSv month ⁻¹	any/every month	0.003	0.1
CT scan	10 mSv	single, acute	0.01	0.01
PET/SPECT scan	10 mSv	single, in a few hrs	0.01	0.01
Average environmental radioactivity	2.5 mSv yr ⁻¹ (2.5 mJ yr ⁻¹)	Chronic	0.000 06	0.000 2
ALARA As Low As Reasonably Achievable	1 mSv yr ⁻¹ (1 mJ yr ⁻¹)	any/every year	0.000 03	0.000 1

The radiation spectrum (photon)

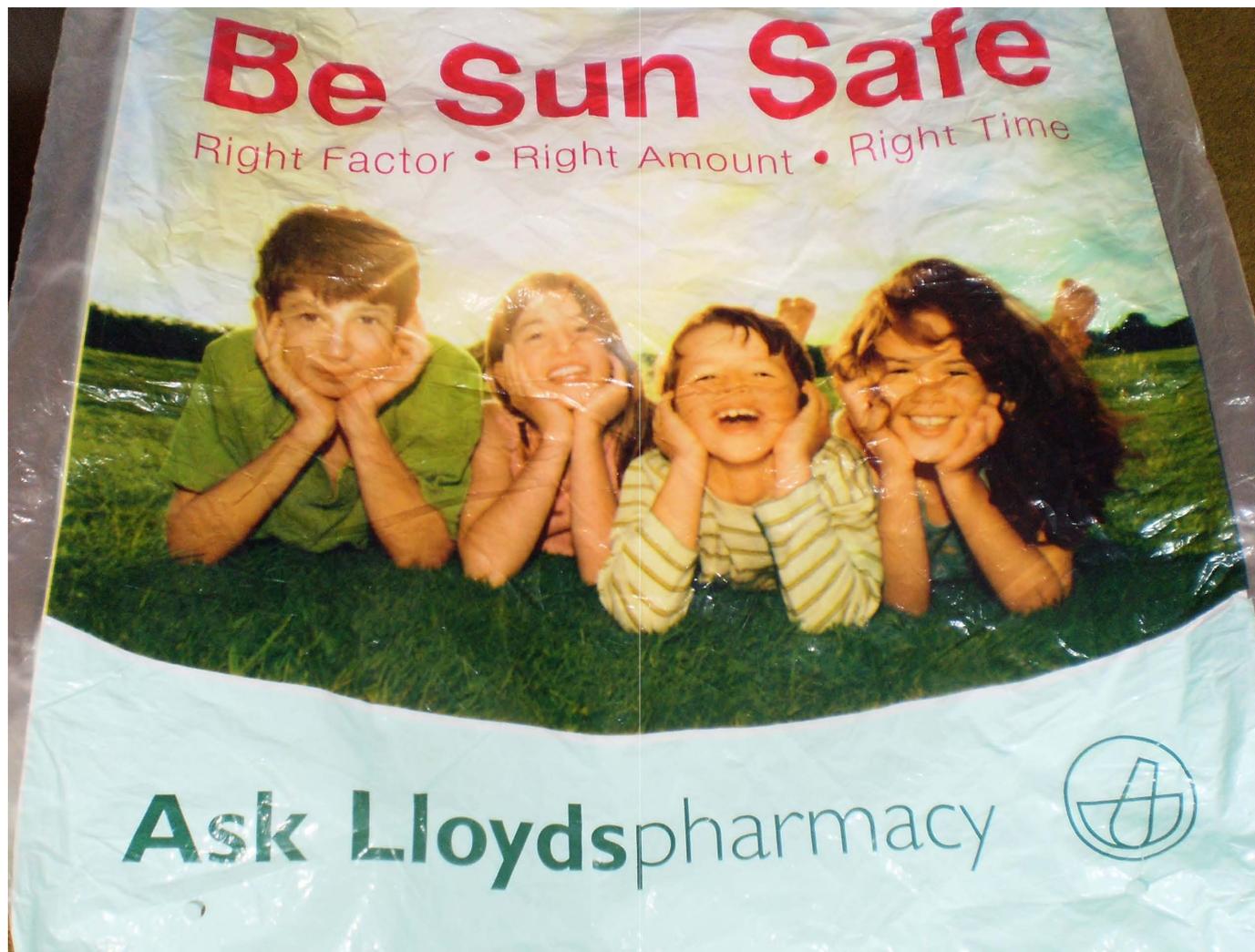


Effects

Ionising radiation (incl UV)	Cell death DNA damage	Acute Radiation Syndrome Cancer
Non-ionising radiation	Thermal heating	Cooking

A plastic carrier bag giving simple accessible advice about personal responsibility for safety from ionising radiation (ultraviolet in sunshine).

This advice engages with the enjoyment of life and common sense, not imposed safety regulations emanating from an international committee. Just the local pharmacy telling Mum and Dad -- what a breath of fresh air!



What happened at Fukushima?

Problem: Major earthquake and tsunami driven by **natural** radioactivity heating the Earth

Result: physical destruction and 18,800 deaths

Problem: Three destroyed nuclear reactors with some leakage of **artificial** radioactivity

Result: no casualties, none expected in future

Problem: Worldwide panic driven by, excessively cautious radiation regulation and lack of education

Result: displaced people (1000 deaths), condemned food, power stations turned off, imported fossil fuel, economy hit, reduced trust in society, science and medicine

26 March 2011 Last updated at 12:50

18K Share



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 Chernobyl? [The latest UN report](#) published on 28 February confirms the known death toll - 28 fatalities among emergency workers, plus 15 fatal cases of child thyroid cancer - which would have been avoided if iodine [tablets](#) had been taken (as they have now in Japan). And in each case the numbers are minute compared with the 3,800 at Bhopal in 1984, who died as a result of a leak of chemicals from the Union Carbide pesticide plant.

So what of the radioactivity released at Fukushima? How does it compare with that at Chernobyl? Let's look at the measured count rates. The [highest rate reported, at 1900 on 22 March, for any Japanese prefecture](#) was 12 kBq per sq m (for the radioactive isotope of caesium, caesium-137).

A [map](#) of Chernobyl in the UN report shows regions shaded according to rate, up to 3,700 kBq per sq m - areas with less than 37 kBq per sq m are not shaded at all. In round terms, this suggests that the radioactive fallout at Fukushima is less than 1% of that at Chernobyl.



Modern reactors are better designed than those at Fukushima - tomorrow's may be better still

Becquerels and Sieverts

■ A becquerel (Bq), named after French physicist Henri Becquerel, is a measure of radioactivity

A quantity of radioactive material has an activity of 1Bq if one nucleus decays per second - and 1kBq if 1,000 nuclei decay per second

■ A sievert (Sv) is a measure of radiation absorbed by a person, named after Swedish [medical](#) physicist Rolf Sievert

■ A milli-sievert (mSv) is a 1,000th of a Sievert

[Q&A: Health effects of radiation](#)

Allison
26 Mar 2011
15 days

And later in the article I wrote

"Unfortunately, public authorities react by providing over-cautious guidance - and this simply escalates public concern."

No rise in cancer rates after Fukushima disaster - UN

Cancer rates are not expected to rise as a result of the Fukushima nuclear disaster in Japan, UN scientists say.

The evacuation of thousands of people shortly after the [accident](#) in 2011 sharply lowered their exposure to radiation, a draft report concluded.

The World Health Organisation has said local residents have a slightly higher risk of developing certain cancers.

Reactors at the Fukushima nuclear plant were crippled by an earthquake and tsunami that killed some 19,000 people.

It was the world's worst nuclear incident since Chernobyl in 1986.

'No radiation-related deaths'

The findings of the [draft](#) report were presented by the UN Scientific Committee on the Effects of Atomic Radiation (Unscear) in the Austrian capital, Vienna.

Committee member Wolfgang Weiss said the decision by the Japanese authorities to evacuate large numbers of people had proved to be the right one.

"If that had not been the case, we might have seen the cancer rates rising and other health problems emerging over the next several decades," he added.

Unscear's report also stated that "no radiation-related deaths have been observed among nearly 25,000 workers involved at the accident site".

Studies after Chernobyl linked cases of thyroid cancer to radioactive iodine that contaminated milk. But Mr Weiss said that had not been the case in Japan.

The report was prepared by 80 scientists from 18 countries and will be published in full later this year.

The findings contradicted a report published by the WHO in February, which said the risk of cancer for those living near the nuclear plant had risen.



The Fukushima nuclear plant was crippled by the deadly earthquake and tsunami on 11 March 2011

Related Stories

[Fukushima radioactive water 'leak'](#)

[Fukushima cooling system restored](#)

[Rat linked to Fukushima power](#)

UNSCEAR
31 May 2013
2+ years

"It is this upheaval to people's lives that has brought real health effects, and these will need "special attention" in coming years," said Carl-Magnus Larsson, chair of UNSCEAR.

"Families are suffering and people have been uprooted and are concerned about their livelihoods and futures, the health of their children... it is these issues that will be the long-lasting fallout of the accident."

Food Regulation at Fukushima

July 2011. Less than 500 Bq/kg = 0.008 mSv per kg.

Then one CT scan (8 mSv) equivalent to eating
 $8/0.008 = 1000 \text{ kg} = 1 \text{ tonne}$ in 3 months.

But in April 2012 regulation tightened to 100 Bq/kg.

Then one CT scan equivalent to 5 tonnes in 3 months.

Water released

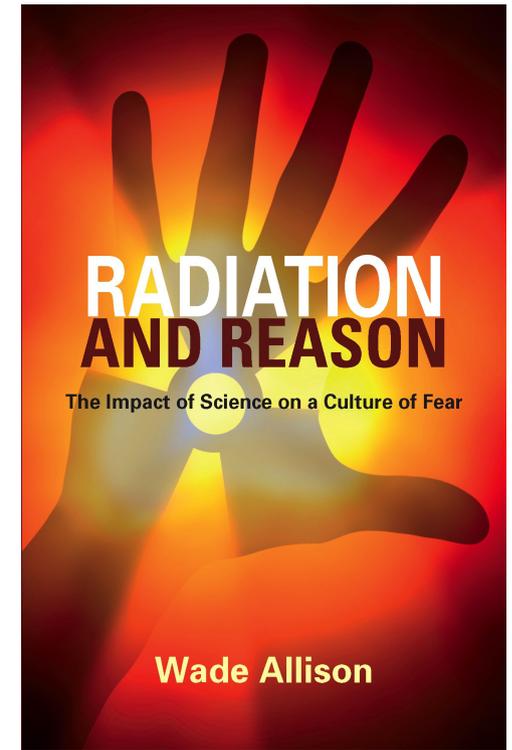
April 2011. 11,500 tonnes release into sea, intentionally.

Stated to be a) 100 times regulation limit. b) “Quite safe”.

Both statements true!!

Inept regulation created a guaranteed massive loss of confidence.

(2 CT scan equivalent to drinking a litre a day for 3 months)



Why are there no casualties at Fukushima?

A billion years of evolution

- For protection against threats that do not change
- For all cellular life incl. plants/animals without brain
- For all DNA damage, radiation and chemical oxidation
- By static design
many individuals, many cells each with complete DNA copy, double stranded DNA, steady cell renewal by cycle, steady individual renewal by birth-sex-death cycle
- By dynamic reaction
by antioxidants, by inter-cellular signalling, by apoptosis, by DNA repairs, by cell cycle suspension, by immune reaction
- By progressive stimulated change
extra antioxidants, added repair enzymes, adaptive immune system

Typical stabilised reaction

as in engineering or electronics **never LINEAR**

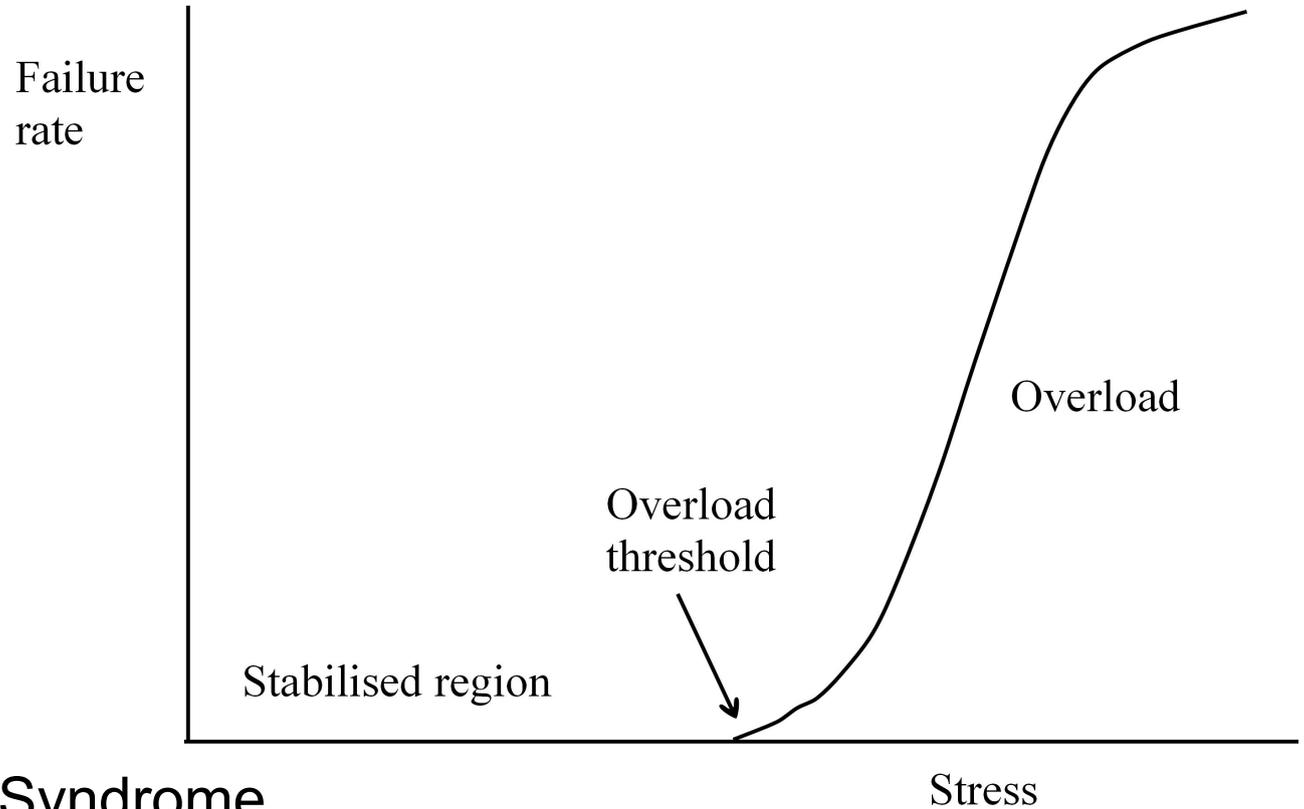
Stabilisation **time**
hours to weeks

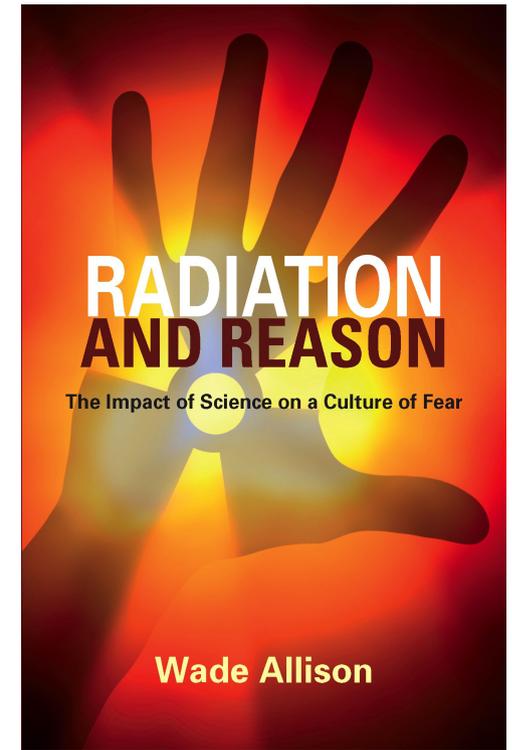
Stress:
Chronic/protracted
(mGy per month)

OR
Acute (mGy)

Failure:
Early, Acute Radiation Syndrome
OR
Late, immune failure and cancer

With **adaption**, threshold can increase,
through the stimulation of extra resources.





How might Florence Nightingale have established trust in radiation?

Action plan, Nightingale style

1. Evidence. Measure thresholds

Get factors of 10 right, ignore factors of 2 Ignore small samples or tiny doses

Chernobyl Fire Fighters	Acute	ARS
Goiania	incl internal	ARS and cancer
Hiroshima & Nagasaki	Acute	Cancer
Dial Painters	Chronic	Cancer
Radiotherapy fractionation (Animal experiments	Protracted Chronic	Secondary cancer Cancer)

2. Draw pictures of statistical data for authorities

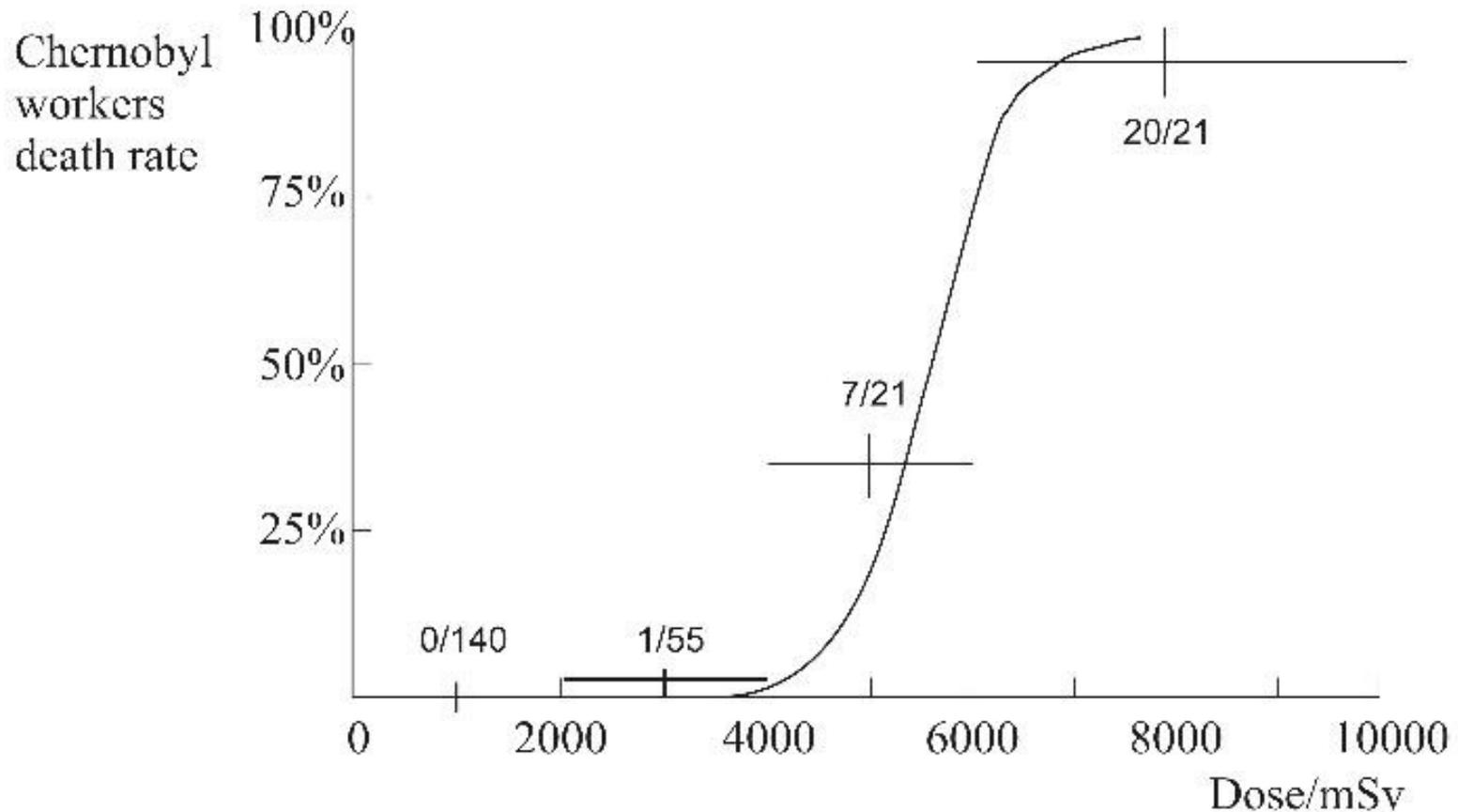
3. Connect with public. Contrast familiar beneficial high clinical doses and tiny Fukushima doses

4. Lobby to end ALARA/LNT safety levels at UN. damage to social health, the world economy, the environment, normal industrial safety

Chernobyl early firefighters

Crosses show the mortality (curve is for rats).

The numbers show the number who died/total in each dose range.



Above 4,000 mSv 27/42 died from ARS in 2/3 weeks.

Below 2,000 mSv zero out of 195 died.

Acute threshold about 2000 mSv (ARS)

Internal Caesium-137, Accident in Goiania

Source 1988 IAEA publication 815

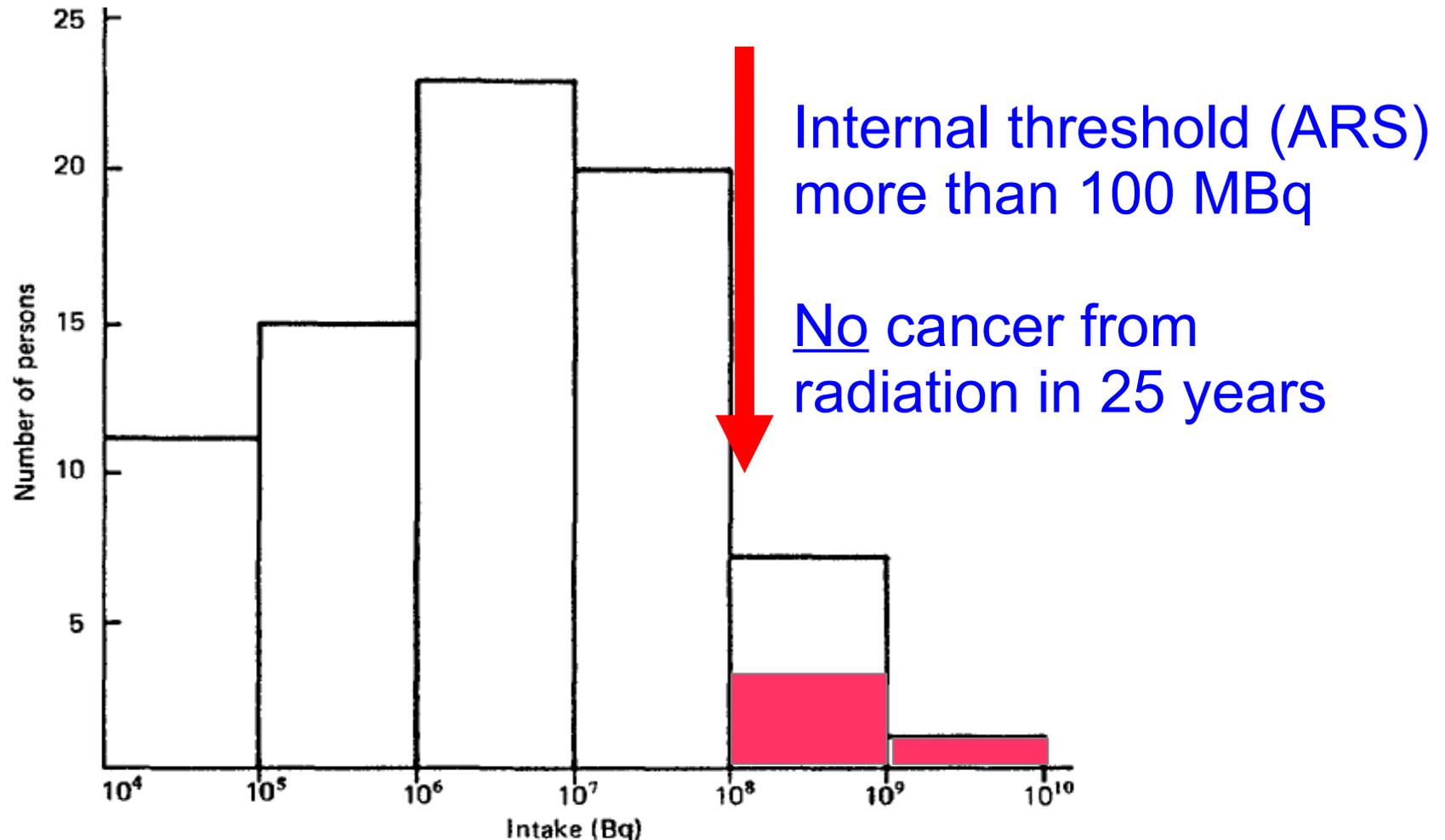


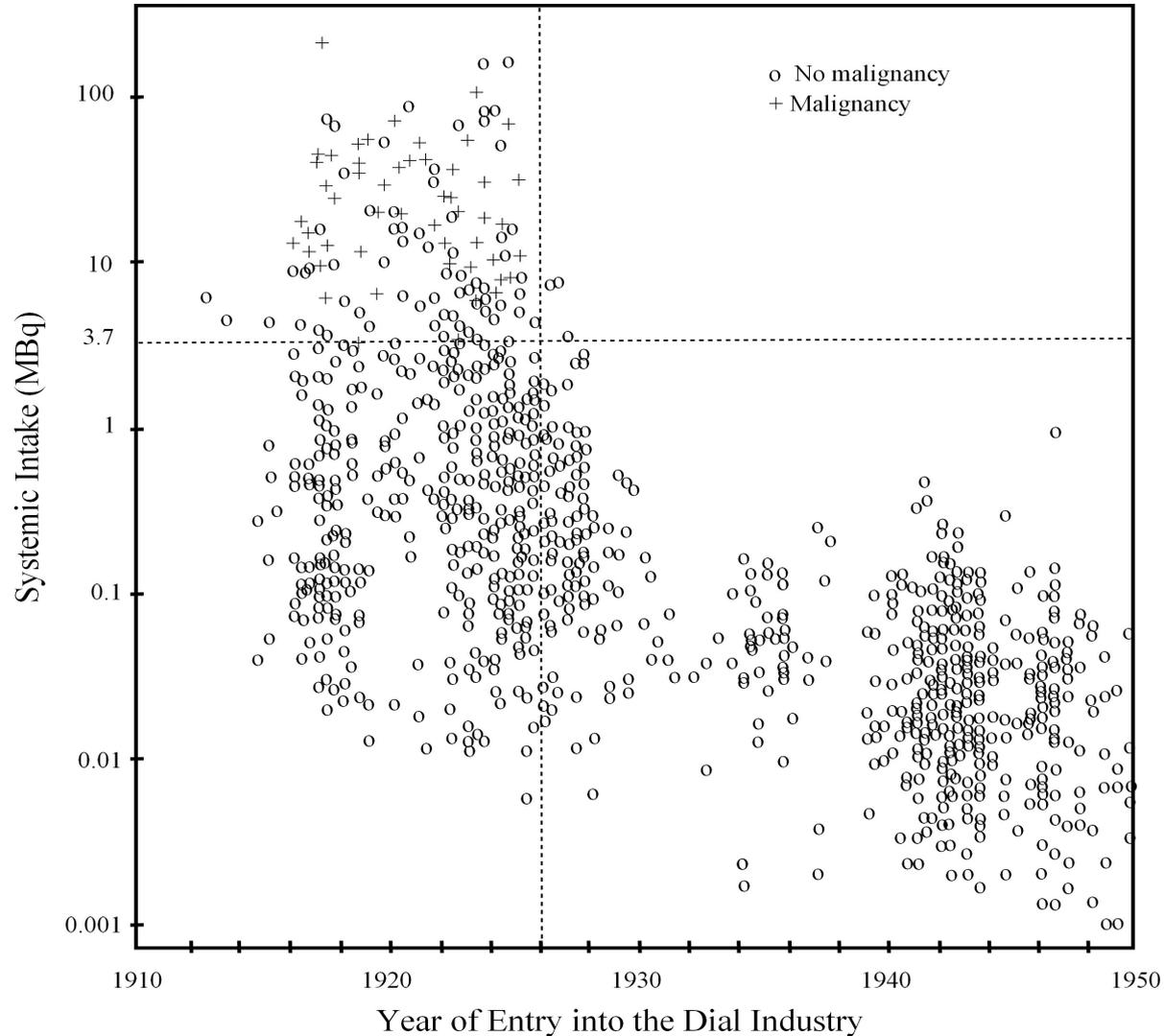
FIG 13. Histogram of the frequency distribution of estimated radioactivity of intakes of persons contaminated. number of individuals versus radioactivity in becquerels

Whole body internal radioactivity in kBq, Cs-137 and others

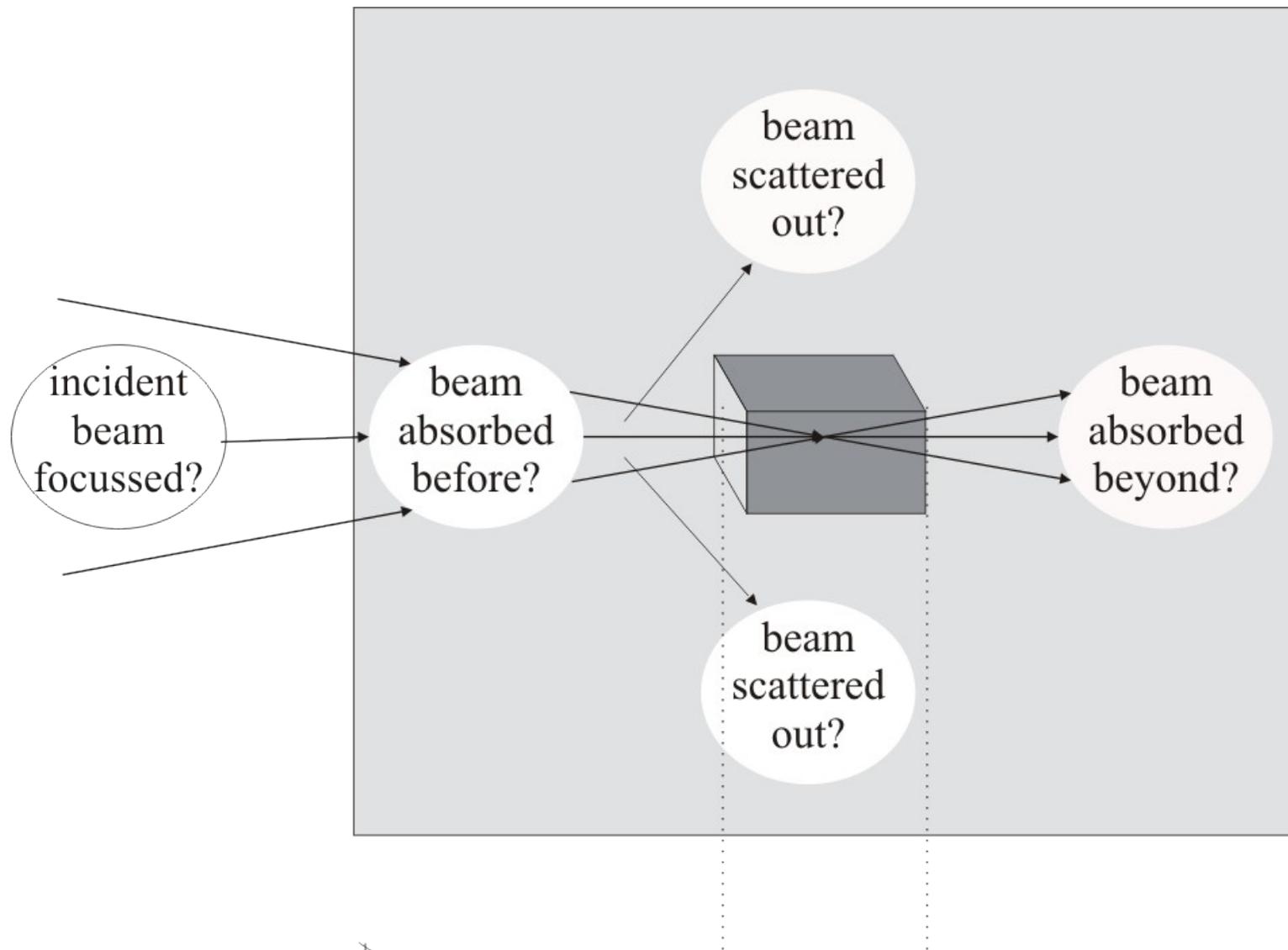
			Number of people	Deaths
Goiania	Cs-137	above 1,000,000 kBq	1	ARS
<i>Litvinenko</i>	<i>Po-210</i>	<i>100,000-300,000 kBq</i>	<i>1</i>	<i>ARS</i>
Goiania	Cs-137	100,000-1,000,000 kBq	7	3 ARS
<i>Radium Dial Painters</i>	<i>Ra-226</i>	<i>Above 3,700 kBq</i>	<i>191</i>	<i>46 cancer</i>
<i>Radium Dial Painters</i>	<i>Ra-226</i>	<i>Below 3,700 kBq</i>	1339	<i>nil</i>
Goiania	Cs-137	10,000-100,000 kBq	20	nil
	Cs-137	1,000-10,000 kBq	23	nil
	Cs-137	100-1,000 kBq	15	nil
	Cs-137	10-100 kBq	11	nil
	Cs-137	all below 12 kBq,	32,811	NIL
	<i>K-40</i>	<i>4.4 kBq</i>	<i>all</i>	<i>nil</i>
	Cs-137	all below 1.4 kBq Nov 2011- Feb 2012	1,494	NIL

Radium Dial painters death from bone cancers (+) and otherwise (o),
According to absorbed activity and year of entry.

Horizontal dashed line is activity threshold for bone cancer 3.7 MBq,
about 1300 mGy per year or **chronic threshold at least 100 mGy per month
(cancer)**

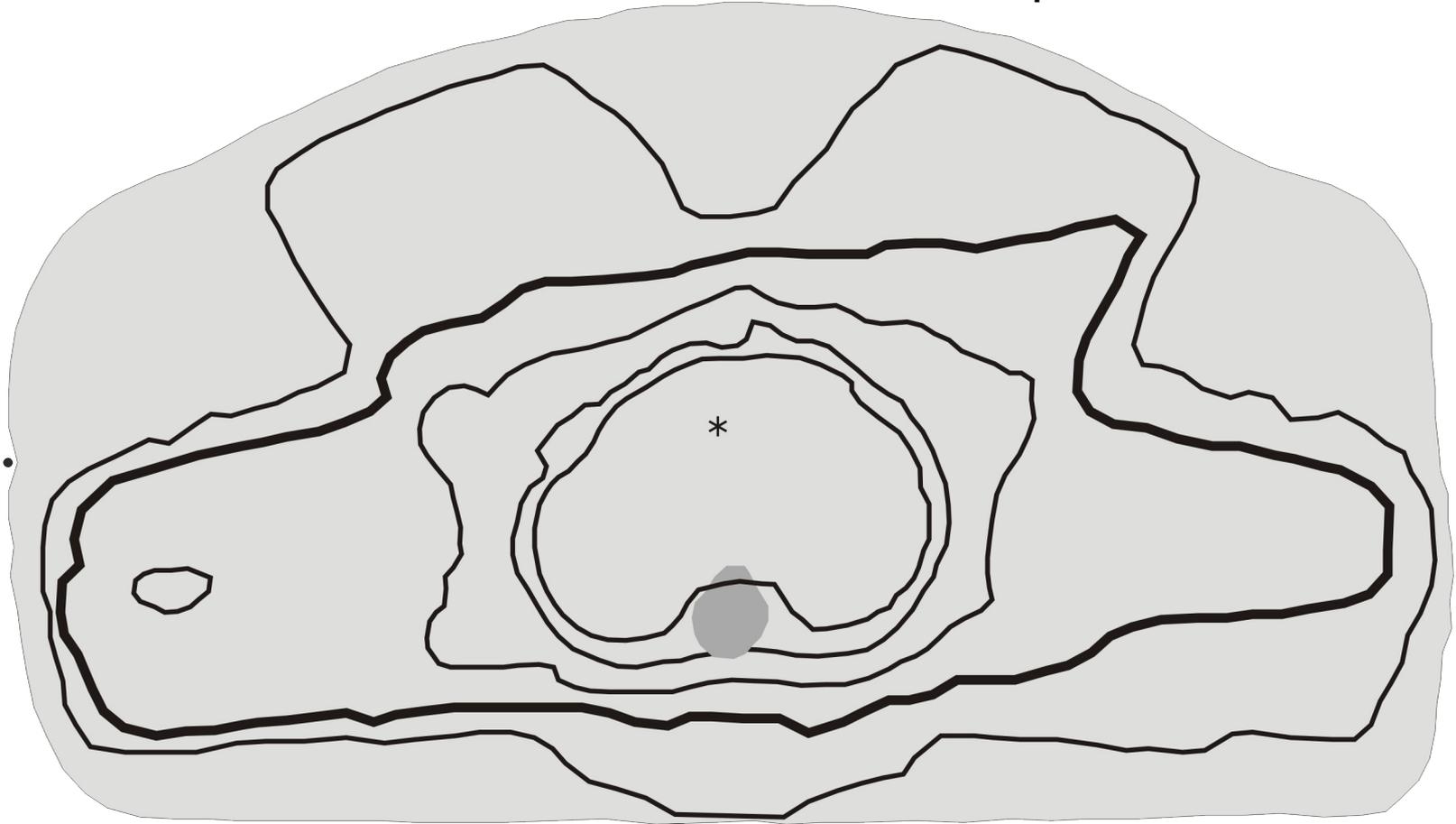


Getting the radiation through the body into the tumour (schematic)



Radiotherapy dose contours of a prostate cancer treatment.

Section of lower abdomen perpendicular to the spine. Rectum shown shaded.
Contours at 97, 90, 70, **50**, 30% of peak dose



[From an image by kind permission of Medical Physics and
Clinical Engineering, Oxford Radcliffe NHS Trust.]

Radiotherapy doses (to tumour) recommended by Royal College of Radiologists

[Doses are usually given in gray where 1000 mSv = 1 gray, for gammas.]

tumour	fractions	total dose	interval
bladder		60000 mSv	5 times a week
breast	16 x 2750 mSv	44000 mSv	5 times a week
arm pit	15 x 2700 mSv	40500 mSv	5 times a week
glioma	30 x 2000 mSv	60000 mSv	5 times a week
cervical	25 x 1800 mSv	45000 mSv	5 times a week
lung	36 x 1800 mSv	64800 mSv	over 12 weeks
prostate	39 x 2000 mSv	78000 mSv	5 times a week

Without fractionation or with linear response (LNT)
Would be fatal to peripheral tissue

Is local dose or wholebody dose the important measure?

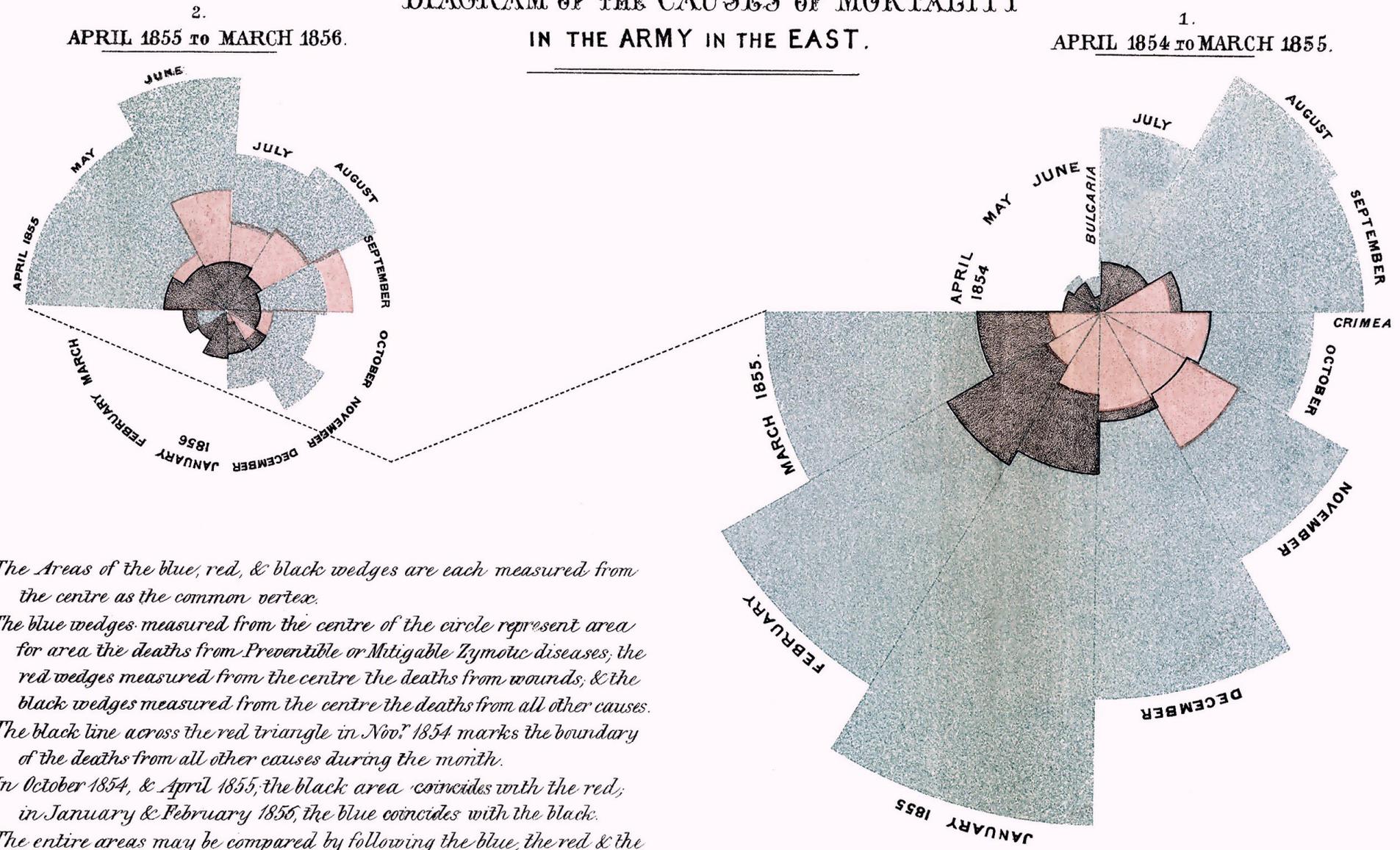
1. The initial energy loss is local (LET)
2. The early cell damage is local except for some spread by ROS migration/ the Bystander Effect
3. It is granted that the **same** local dose when applied over a larger volume should have an incidence of disease proportional to that volume.
4. In Radiotherapy it is the local radiation dose that kills the cells, not the wholebody dose, otherwise directing the dose would be pointless
5. Secondary cancers usually occur in the irradiated region.
6. Sites of initial carcinogenesis are relatively local to the causative radiation site: eg skin cancers are on the exposed skin, smoking gives mainly lung cancer, excess drinking gives mainly liver cancer not lung or skin cancers, etc Most precisely, radio-iodine is trapped by the thyroid and causes thyroid cancer, not another cancer.)
7. Only when the cancer metastasises does it migrate elsewhere
8. The idea that wholebody dose is the appropriate measure comes from the LNTH which would validate dose averaging, as it would for a whole population (as in use of man-sievert).

Statistics, graphics and public persuasion

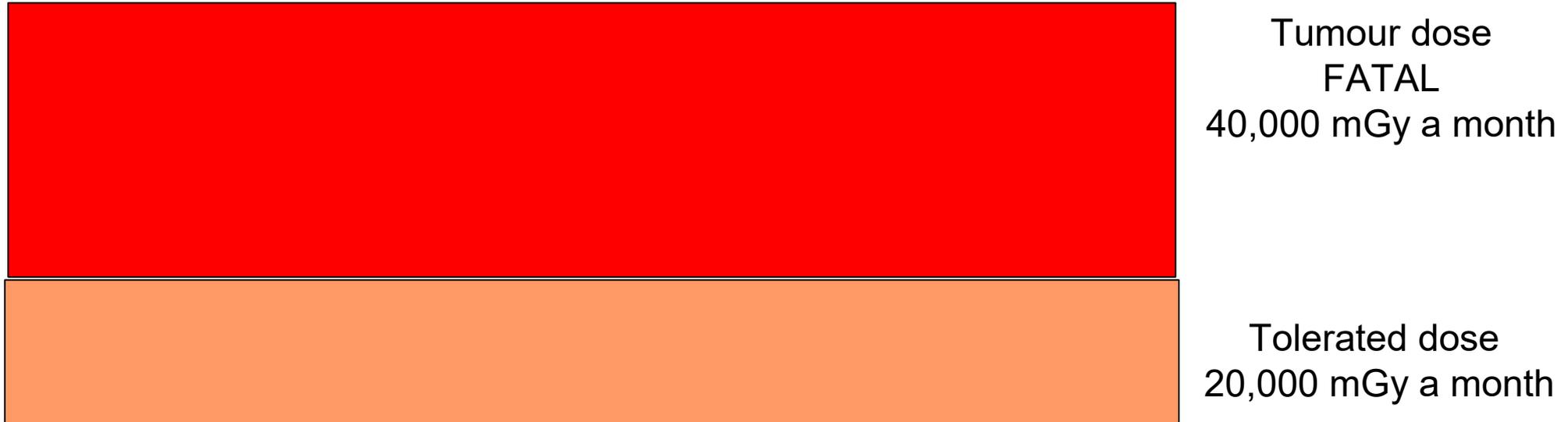
Florence Nightingale

DIAGRAM OF THE CAUSES OF MORTALITY

IN THE ARMY IN THE EAST.



Monthly doses depicted as areas



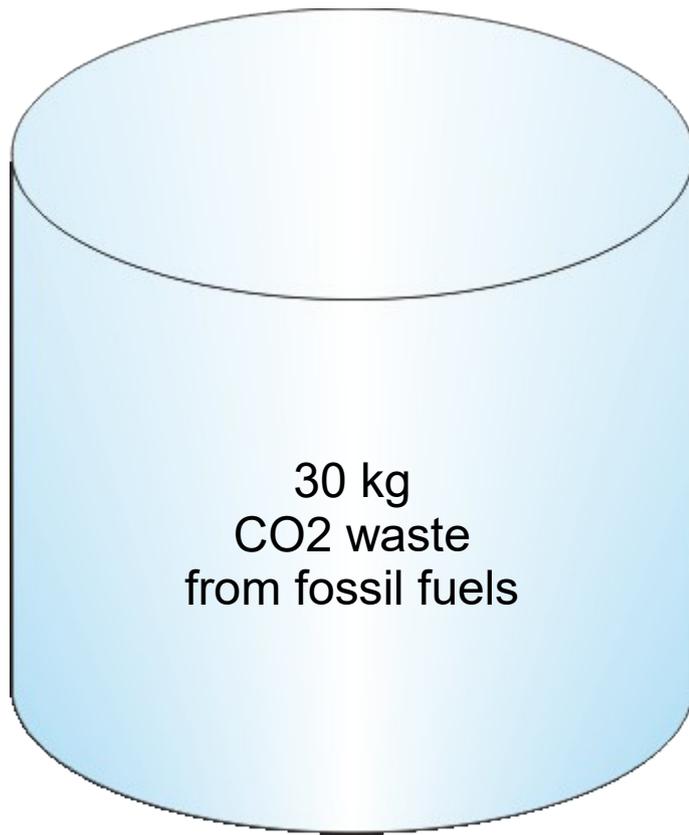
■ A **conservative safe dose** (AHARS). Less than Dial Painter threshold.
100 mGy per month. [Also max 5000 mGy per lifetime, for the present]

→ Current public “safe” dose (ALARA). Small addition to natural Background
0.1 mGy per month, [or 1 mGy per yr]

As High As Relatively Safe (AHARS)
would be a relaxation by **about 1000 times** over
As Low As Reasonably Achievable (ALARA) .

Waste per person fossil/biological/nuclear

Canister volumes showing weight of waste per person per day (UK figures)



CO2 and burning: Waste released directly into the air and driving climate change. Out of control fires (thermal chain reaction) cause thousands of deaths each year



Faeces and disease: Waste released directly into the environment (water). Uncontrolled disease (biological chain reaction) causes millions of deaths

Nuclear waste: Contained and suitable for safe burial. 1/4000 kg [↗] No increase outside a working nuclear reactor. high level nuclear waste [↘] 50 years only 50 deaths (Chernobyl).

Conclusions

1. Radiation is a **modest local danger**, not a global threat like:
climate change,
political & economic instability,
population, water and food
2. Relax **safety levels** by ~1000 times, AHARS As High As Relatively Safe
No extra risk, major cost reduction, less bureaucracy, ditch LNT
Say 100mGy single acute dose, and
100mGy/month chronic/protracted dose rate, and
5000mGy whole-of-life,
3. **Education** to remove stigma of nuclear,
to spread trust in science and trust in society
and to explain radiation in simple terms
4. **Nuclear technology** for individual health, for
power, for fresh water, for food preservation,
for the health of the planet.

Books and articles/lecture/interviews (free download)

www.radiationandreason.com

Books on sale at £12

17 June 2013

Scottish Nuclear Medicine Group

