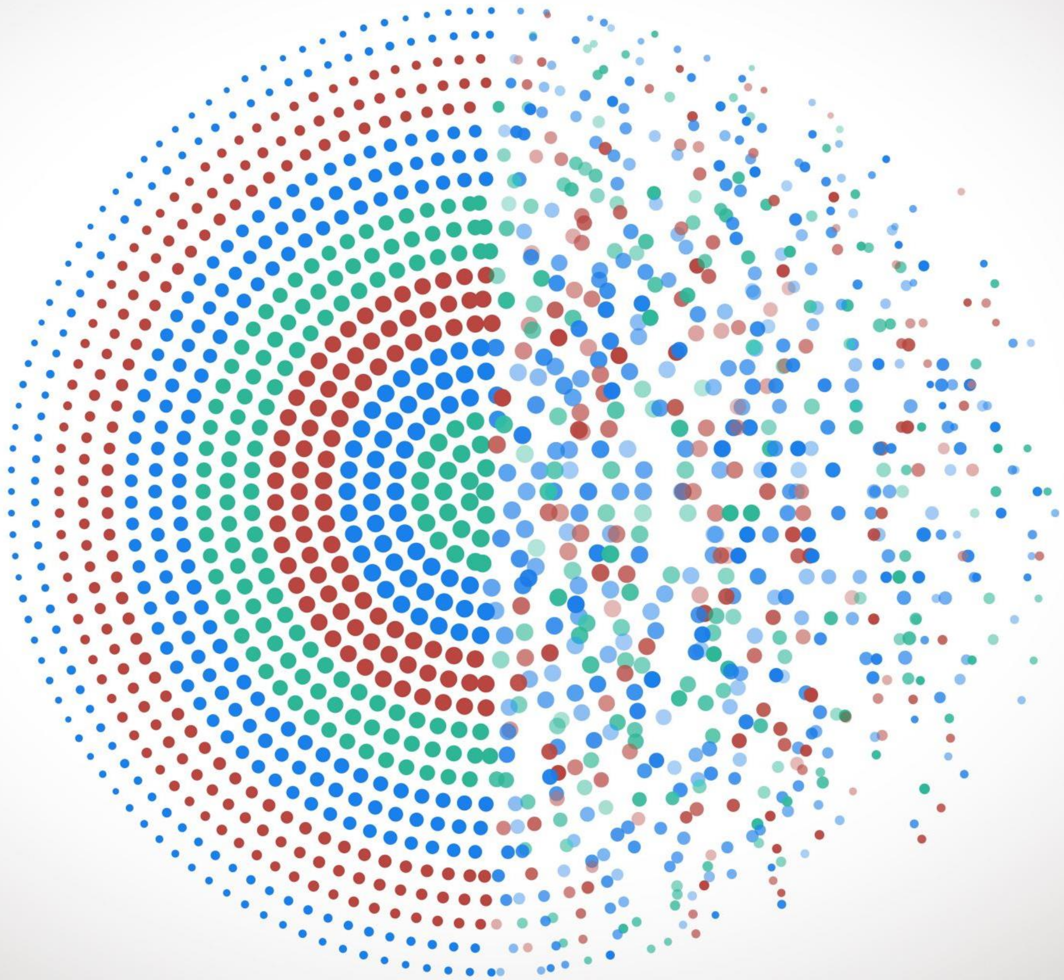
Fallout and environmental consequences

Tone D. Bergan



A closer look at the radionuclides and the contamination

- Investigations from nuclear test sites
- Hiroshima and Nagasaki
- Experiences from global fallout from atmospheric testing of nuclear weapons
- Nuclear accidents

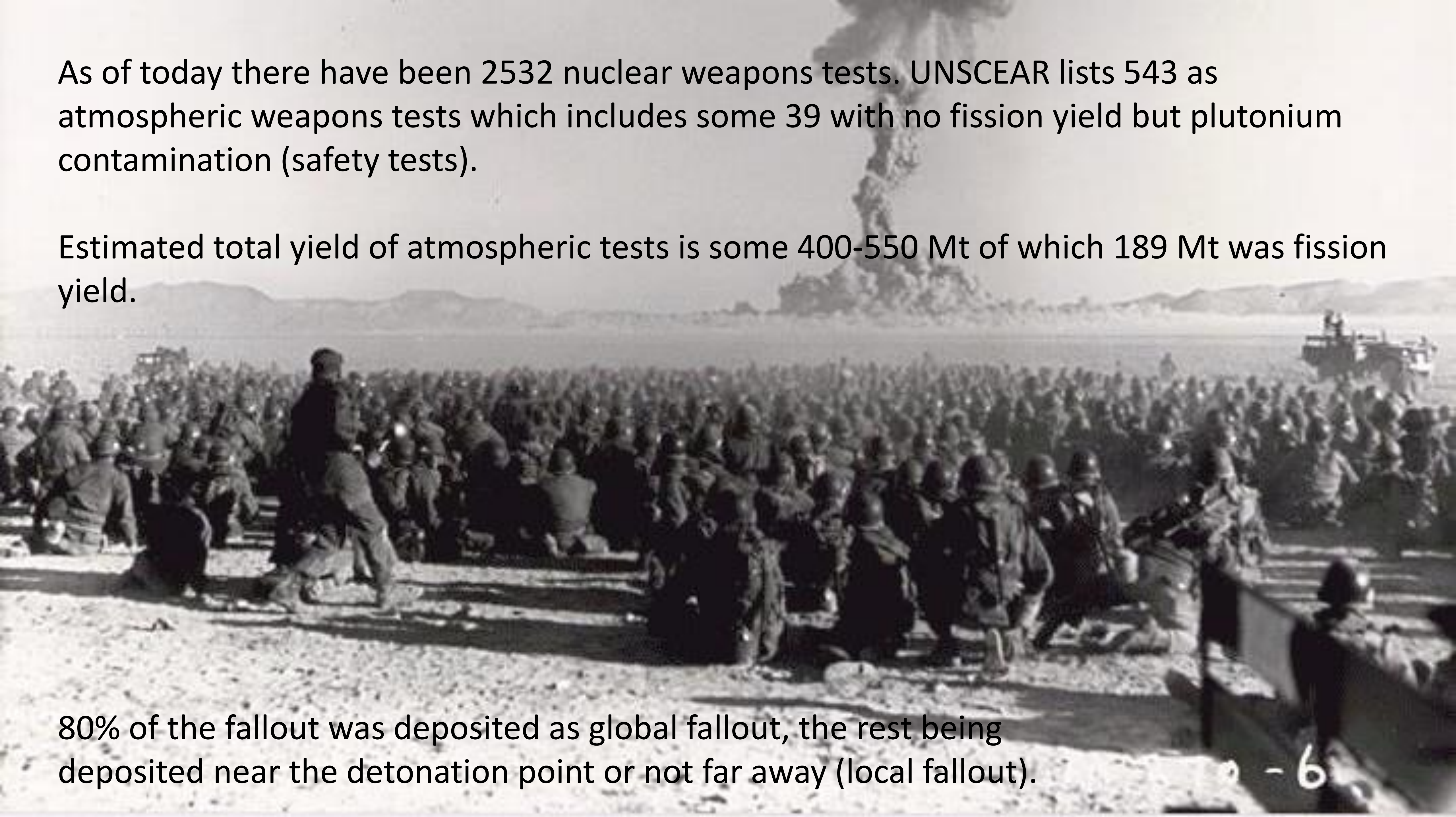
Simulation of a nuclear blast in a major city

It is unhealthy to be near a nuclear detonation

The weapon will kill you in three possible ways:

- The ball of plasma – a fireball that will evaporate everything in its way
- The shock wave and fire storms
- The radiation

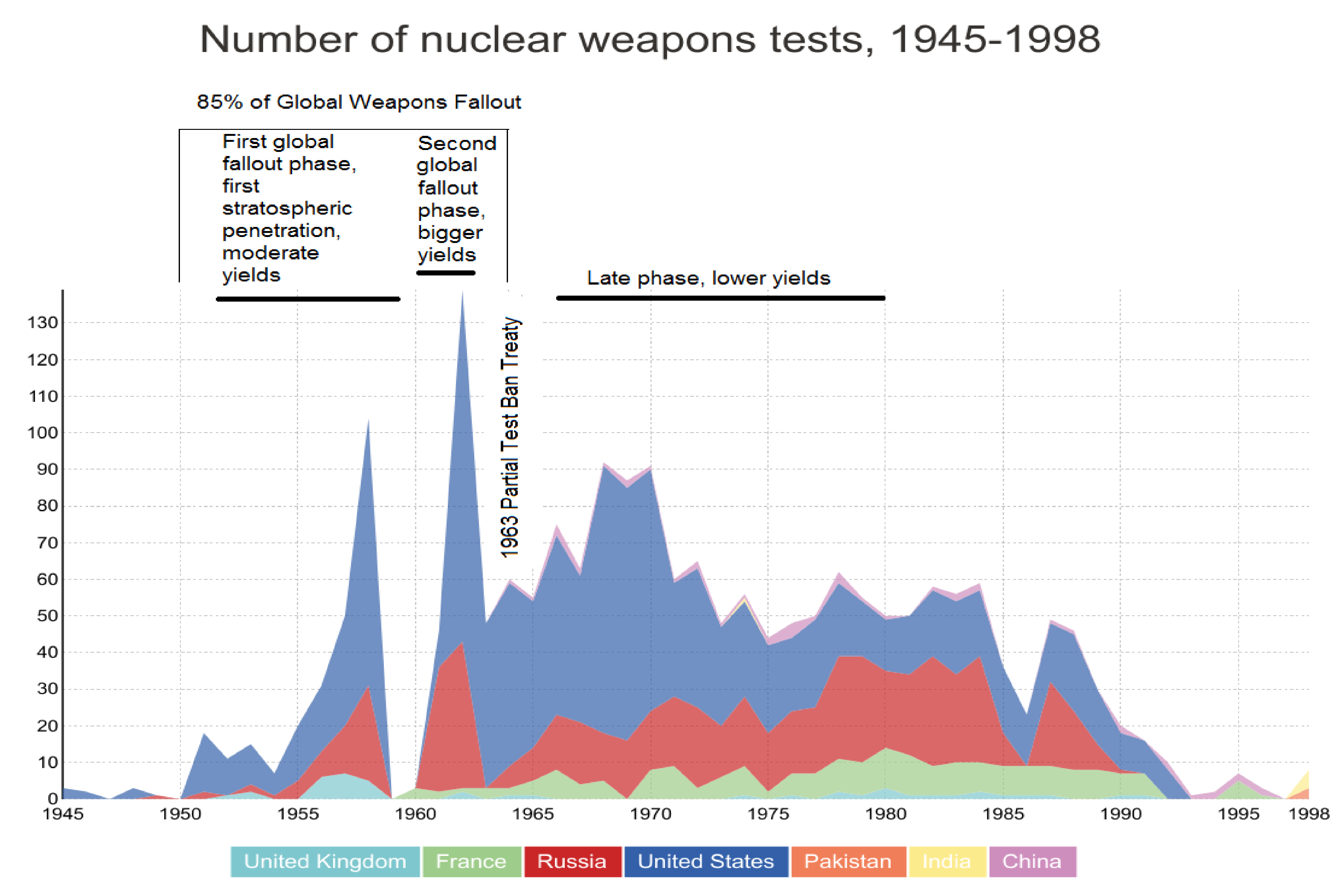
- Neil Halloran in collaboration with the Nobel Peace prize – [Research and information]



As of today there have been 2532 nuclear weapons tests. UNSCEAR lists 543 as atmospheric weapons tests which includes some 39 with no fission yield but plutonium contamination (safety tests).

Estimated total yield of atmospheric tests is some 400-550 Mt of which 189 Mt was fission yield.

80% of the fallout was deposited as global fallout, the rest being deposited near the detonation point or not far away (local fallout).



Number of nuclear weapons tests, 1945-1998
85% of Global Weapons Fallout
First global fallout phase, first stratospheric penetration, moderate yields
Second global fallout phase, bigger yields
Late phase, lower yields
1963 Partial Test Ban Treaty
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
1998
United Kingdom
France
Russia
United States
Pakistan
India
China

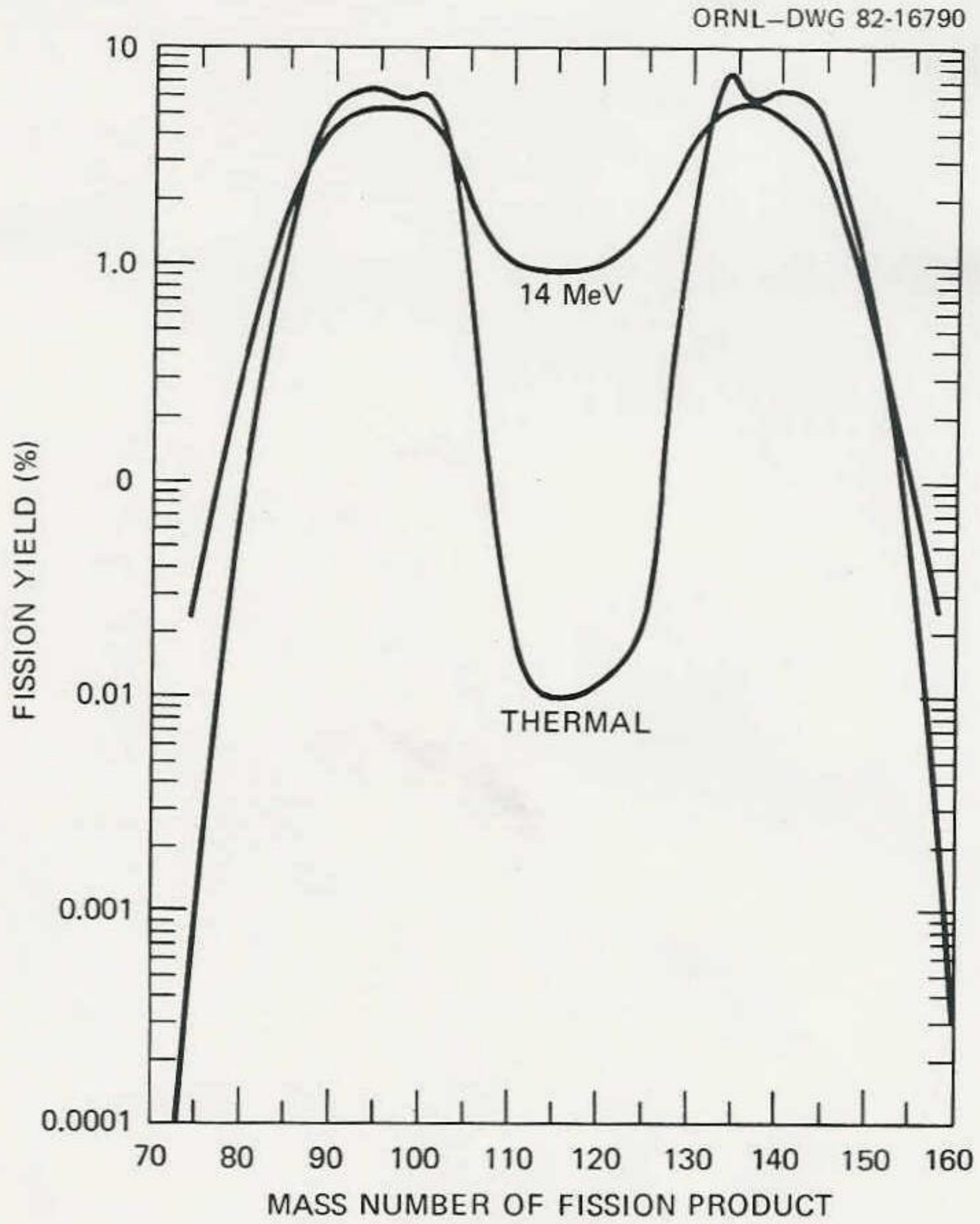
The physics in a detonation

Around 300 isotopes based on 36 elements - $3{\cdot}10^{23}$ fissions atoms per kilotonnes

1 kt amounts to 10^{21} desintegrations per second one minute after detonation. After 24 h, the radioactivity is reduced by a factor 2000.

Hydrogenbombs – thermonuclear bombs – fission-fusion-fission bombs: Using ^{2}H (tritium) and ^{3}H (deuterium). The radioactive yield is around 50% less than from a fission bomb. Fast neutrons (typically ~14 MeV) produces a different yield.

USA detonated its first H-bomb in 1952, the Soviet Union in 1954.


ORNL–DWG 82-16790
FISSION YIELD (%)
10
1.0
0
0.01
0.001
0.0001
14 MeV
THERMAL
70
80
90
100
110
120
130
140
150
160
MASS NUMBER OF FISSION PRODUCT

Relevant radioisotopes in a nuclear detonation

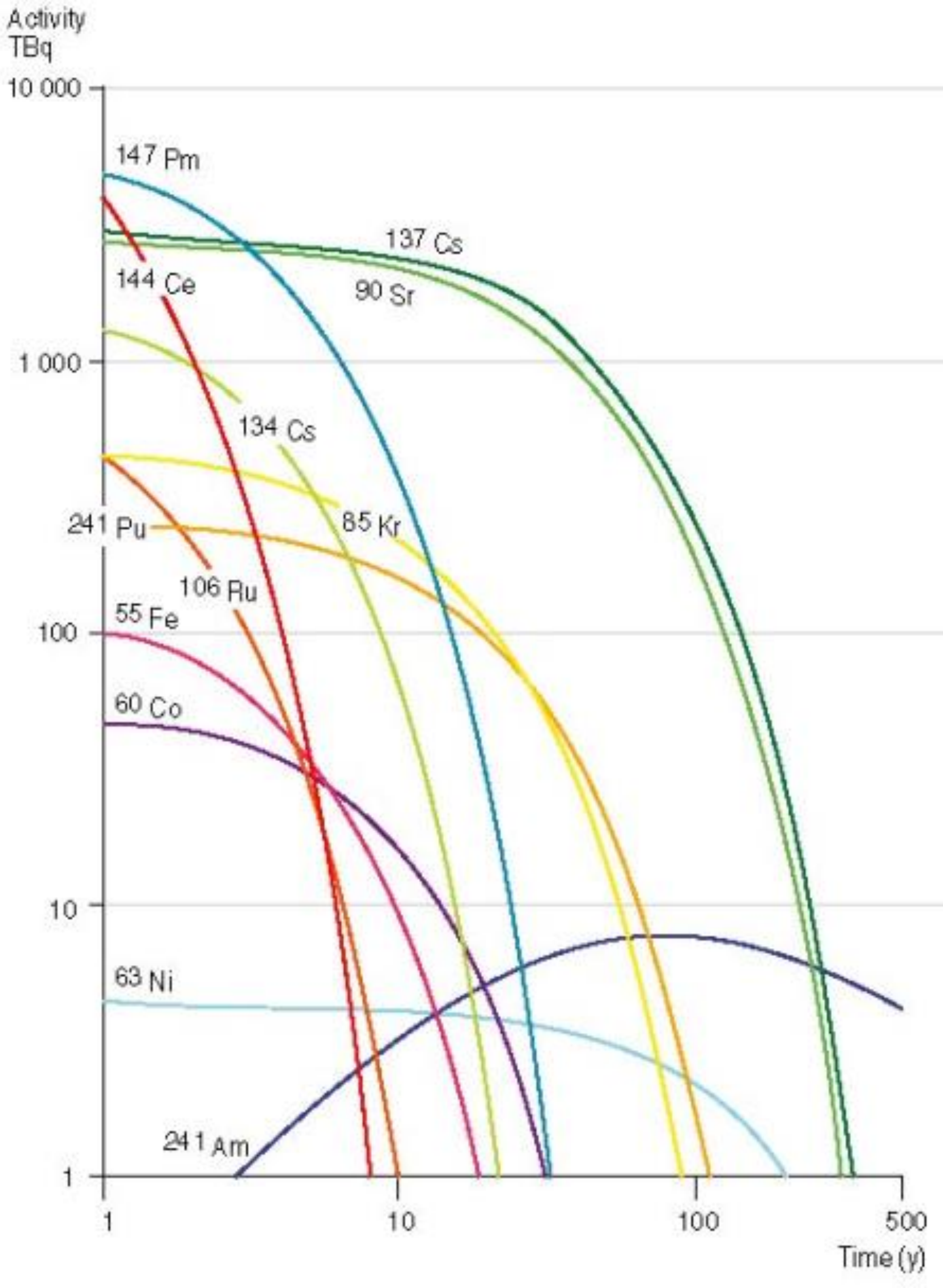
Nuclide	Half-life	Yield (TBq/kt) 1 h
Cs-137	30.2 y	0,70
Sr-90	28.6 y	0,25
Kr-85	11 y	0,05
Eu-155	4.7 y	0,44
Sb-125	2.7 y	0,08
Pm-147	2.6 y	-
Ru-106	1.0 y	21
Ce-144	290 d	12,6
Sn-123	131 d	0,74
Te-127m	90 d	0,11
Zr-95	63 d	74
Y-91	58 d	1,9
Sr-89	54 d	34,4
Cd-115m	43 d	0,11
Ru-103	41 d	181
Te-129m	33 d	3,7
Ce-141	32 d	15,5
Eu-156	15.4 d	2,1
Pr-143	13.7 d	5,9
Cs-136	13.0 d	48,1
Ba-140	12.8 d	444
Nd-147	11.1 d	203
Sn-125	9.4 d	8,5
I-131	8.0 d	322
Ag-111	7.6 d	111
Tb-161	7.0 d	2,2
Xe-133	5.3 d	24
Sb-127	3.9 d	52
Te-132	3.2 d	1 702

… and the list goes on……

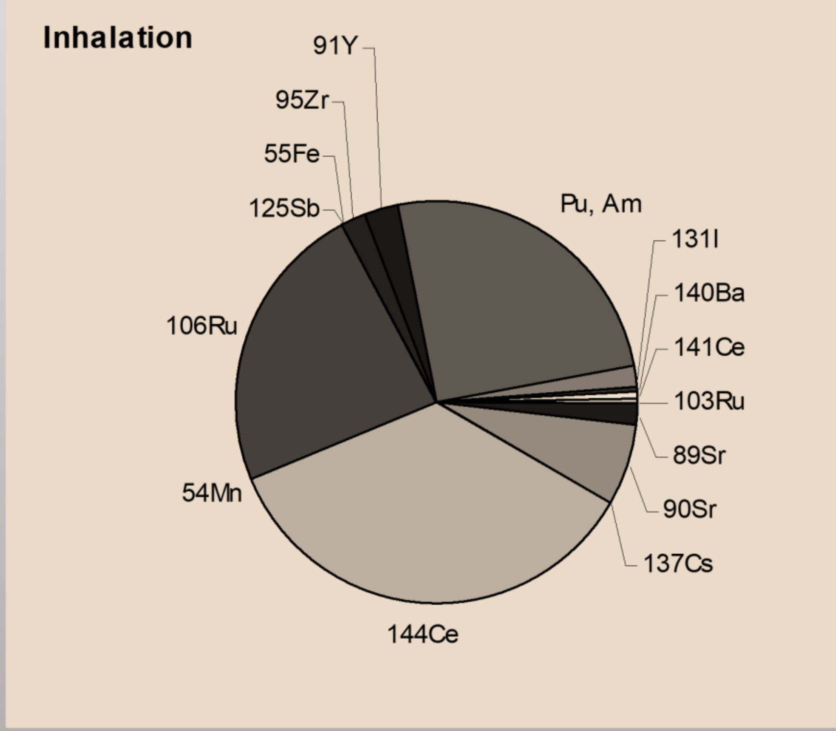
Mo-99	67 h	2 479
Pm-149	56 h	21
Cd-115m	53 h	28
Sm-153	47 h	277
La-140	40.2 h	37
As-77	38.8 h	14
Rh-105	36.5 h	4 070
Ce-143	32.0 h	2 627
Te-131m	30.0 h	444
Sn-121	27.5 h	63
Pm-151	27.5 h	814
Pd-112	21.0 h	185
I-133	20.8 h	4 810
Gd-159	18.0 h	70
Zr-97	17.0 h	8 510
Eu-157	15.4 h	204
Pd-109	13.6 h	4 070
Y-93	10.0 h	9 250
Sm-156	10.0 h	444
Sr-91	9.7 h	6 290
Te-127	9.3 h	31
Xe-136	9.2 h	4 440
Sb-128	9.0 h	481
I-135	6.7 h	19 240
Tc-99m	6.0 h	-
Pr-145	6.0 h	12 580
Ag-113	5.3 h	444
Sb-129	4.6 h	13 320
Ru-105	4.4 h	27 380
Kr-85m	3.7 h	3 626
La-141	3.6 h	25 530
Y-92	2.8 h	4 440
Kr-88	2.7 h	9 250
Sr-92	2.4 h	22 570
Br-82	2.4 h	3 034
I-132	2.0 h	3 071
Nd-149	2.0 h	14 430
Kr-83m	1.5 h	888
Sn-127	1.4 h	2 183
Ba-139	1.3 h	74 000
Kr-77	1.2 h	13 690
La-142	1.2 h	51 800
Nb-97	1.2 h	3 700
Te-177	1.2 h	5 920

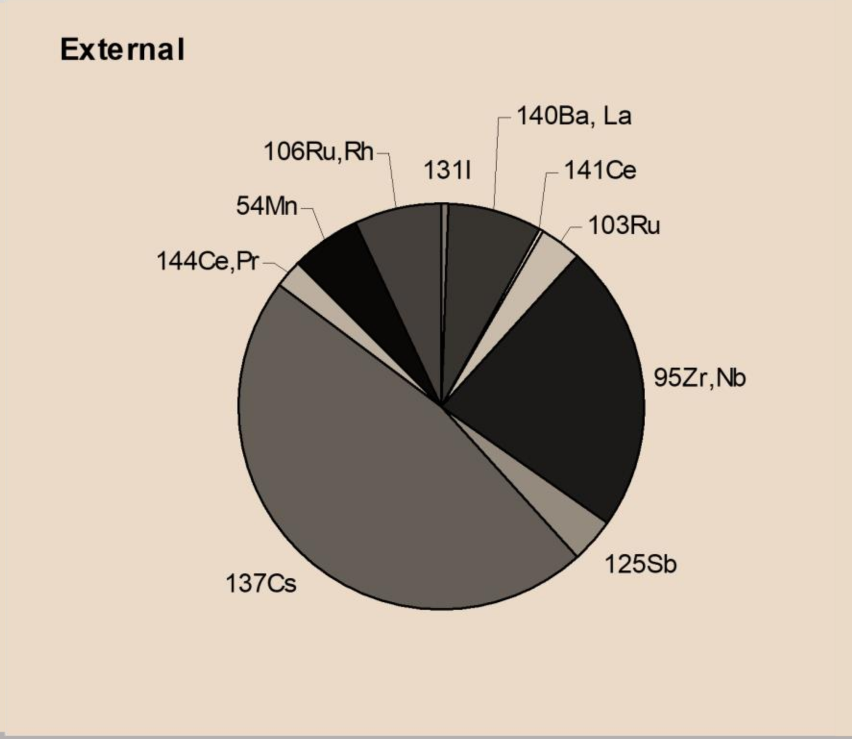
The half-lives

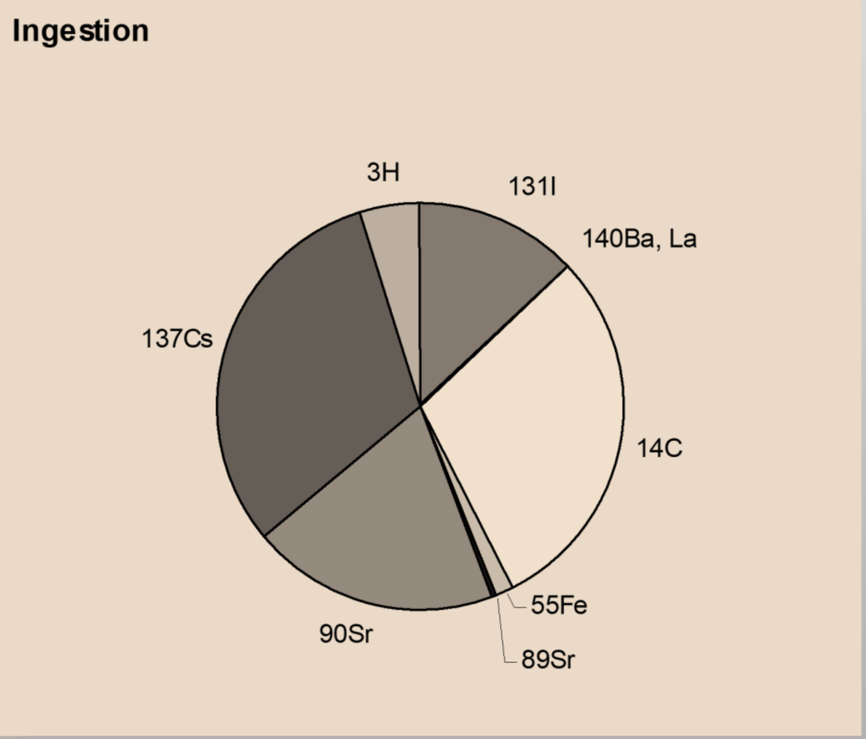
Nuclide	Physical half-life	Biological half-life	Organ
^{134}Cs	2,1 y	60-120 days	Whole body
^{137}Cs	30,2 y	60-120 days	Whole body
^{131}I	8,04 days	11-80 days	Thyroid
^{90}Sr	28,5 y	50 d – 30 y	Sceleton



Exposure pathways and radiation doses







Data from UNSCEAR 2000

Radionuclides of concern

Radionuclide	Inhalation	External	Ingestion
^{3}H			X
^{131}I	X	X	X
$^{140}Ba/La$	X	X	X
^{137}Cs	X	X	X
^{90}Sr, ^{89}Sr	X	X	X
^{55}Fe	X		X
Pu & Am	X		X
^{141}Ce, ^{144}Ce	X	X	
^{103}Ru, ^{106}Ru	X	X	
^{54}Mn	X	X	
^{125}Sb	X	X	
$^{95}Zr/Nb$	X	X	
^{91}Y	X		
^{14}C			X

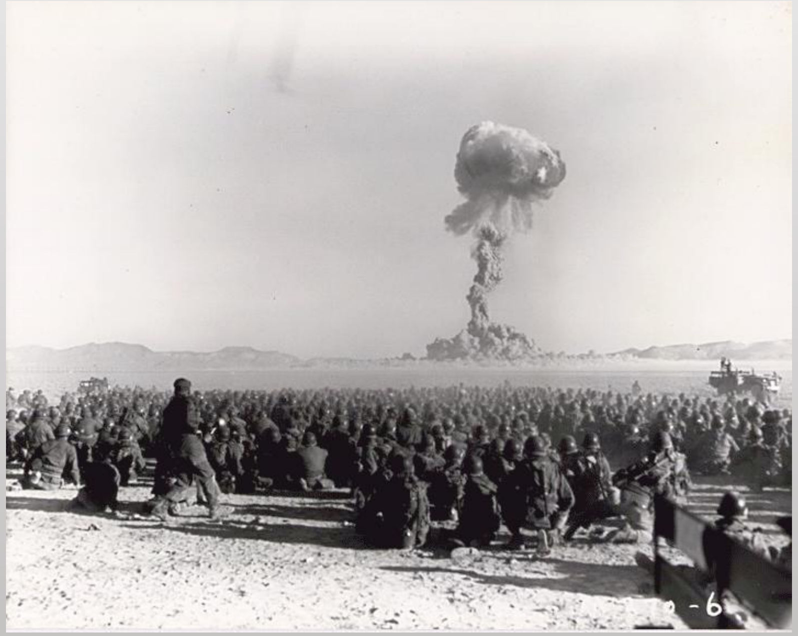
Neutrons

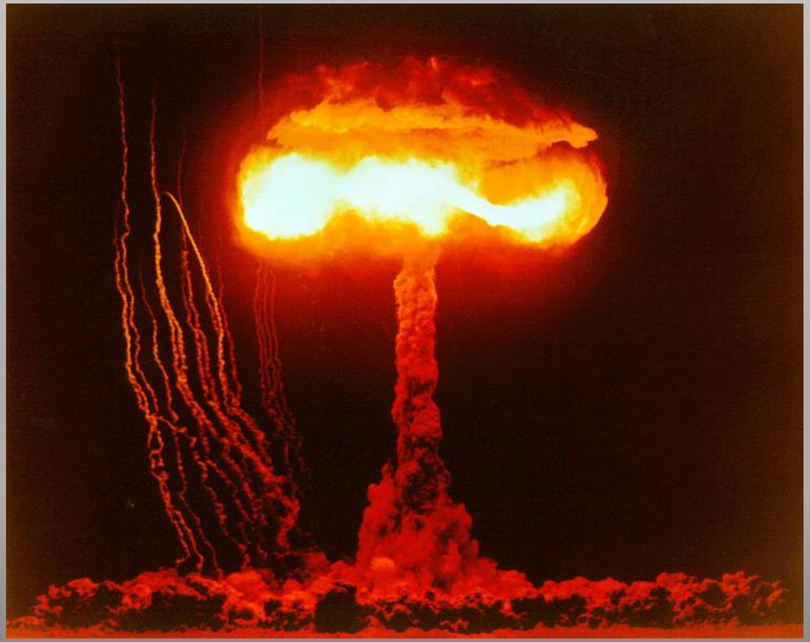
Mass of about 20% of an alpha particle, but much greater than a beta particle.

Produced in fission reaction but may also be produced by some isotopes (^{252}Cf, $^{241}Am/Be$).

The neutron has no charge.

Neutrons can undergo a number of interactions with nucleii – some of these interactions impart enough energy to the target nucleus to result in gamma ray emission.





Interactions with matter

Alpha particles:

+2 charge, 4 amu create a lot of ionisiation. In dry air approx. 50000 ion pairs per cm of distance travelled. A 4 MeV particle travels ca. 2.5 cm, taking electrons from its surroundings and stopping as a normal helium atom. Very damaging to the material they travel through.

Beta particles:

+1 charge, 5.4×10^{-4} amu cause less ionisation than alpha particles – 100 to 300 pairs per cm in dry air. Easily deflected, usually stop after 20 m or less. Can cause the emission of x-rays (Bremsstrahlung).

Gamma photons:

No charge, no mass. Lose energy in chunks as they undergo interaction. Three main interactions:

Photoelectric effect – all energy given to an orbiting electron, photon disappears,most important for low energy photons.

Compton effect – some of the gamma energy transferred to the electron, gamma energy can then undergo another interaction, while the compton electron can cause ionisation more important for high energy photons.

Pair Production – for photons with E greater than 1.02 MeV. Occurs near the nucleus and interction of the photon with the nuclear electric field produces an electron and the anti-particle positron. The positron then interacts with an electron and forms two annihalation photons of 511 keV each. The original gamma photon vanishes.

Interaction with water

Water – radiation interactions are important as tissue/cells are mostly water.

Ionising radiation produces secondary electrons in water with energies < 100 eV which can change water molecules to form radicals that can be biologically toxic.

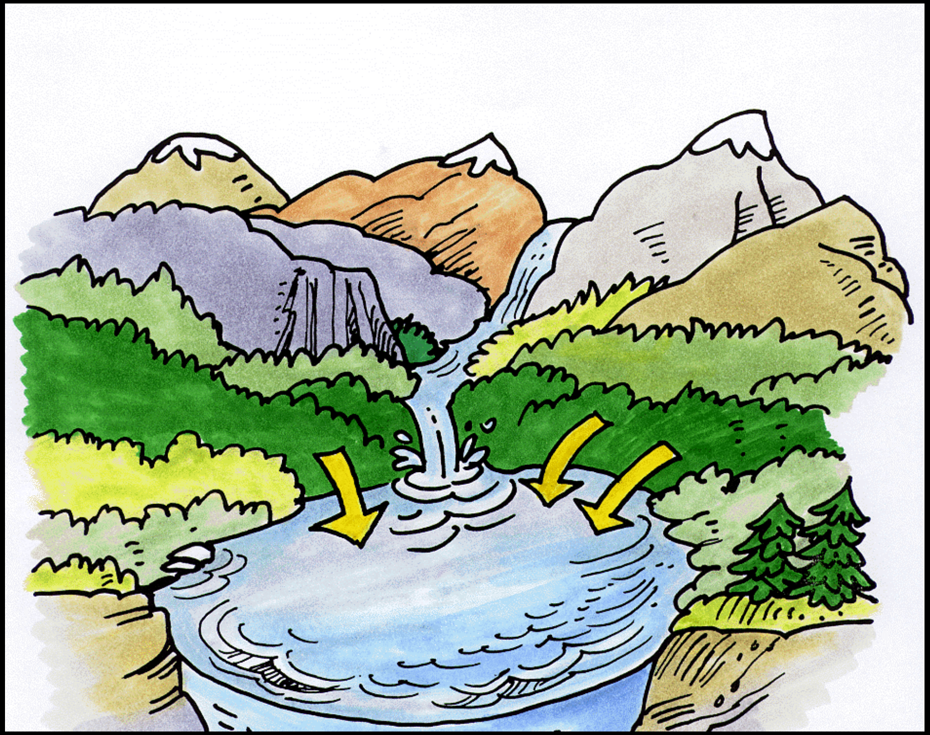
H_2O can become H_2O^+ or excited H_2O^* . The H_2O^+ can dissociate to form H^+ and OH or it can react with more water to form hydronium ions H_3O^+ and an hydroxyl radical OH^-. H_2O^* can similarily go on to form radical species.

OH can go on to form H_2O_2 which is also very damaging to cells.

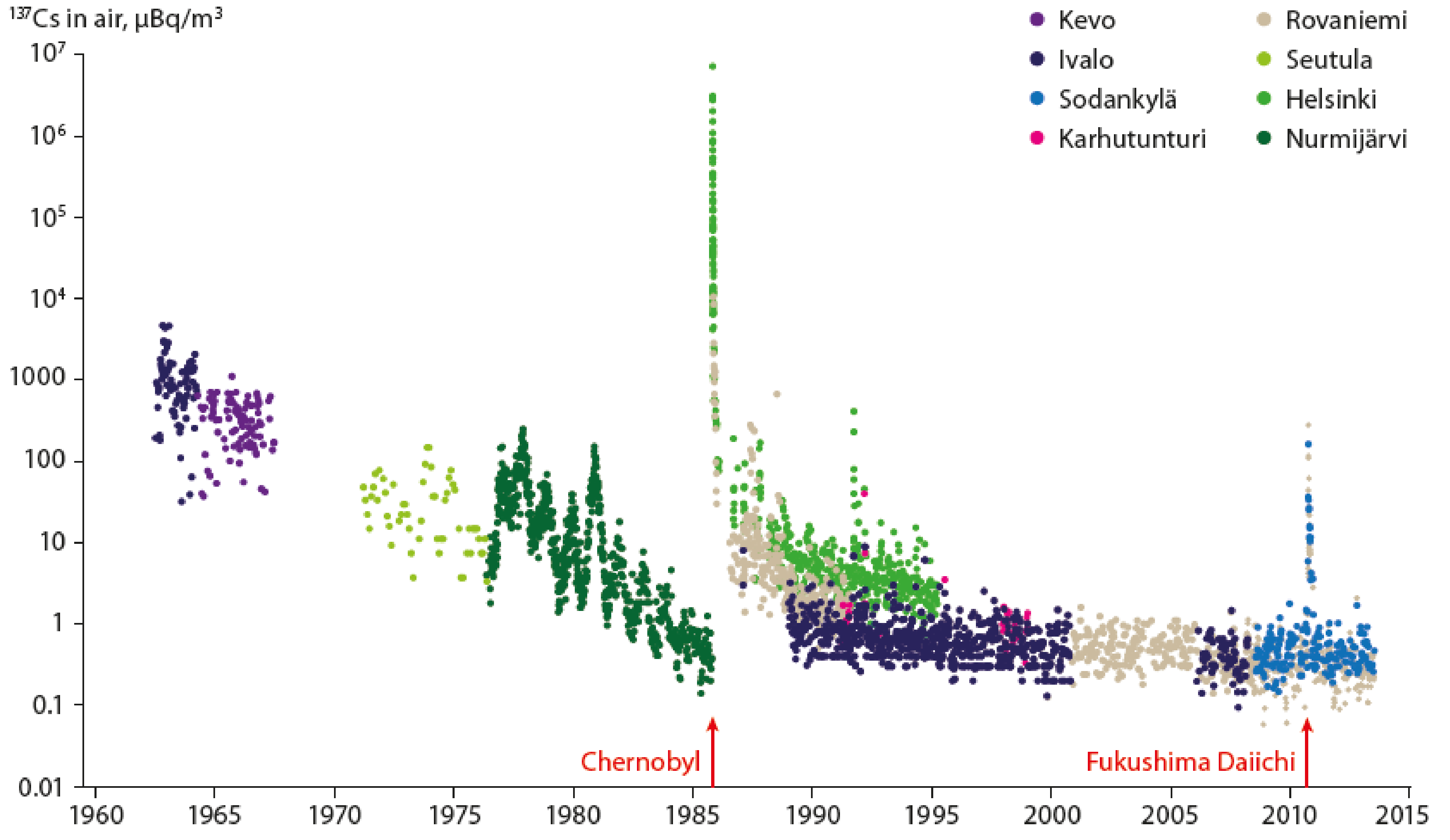
The formation of radical species in water is perhaps the most critical effect of cells or tissue being exposed to radiation.

Drinking water and milk

- Radioactivity in milk and water will be an immediate problem. Runoff from surrounding areas will increase concentration in fresh water



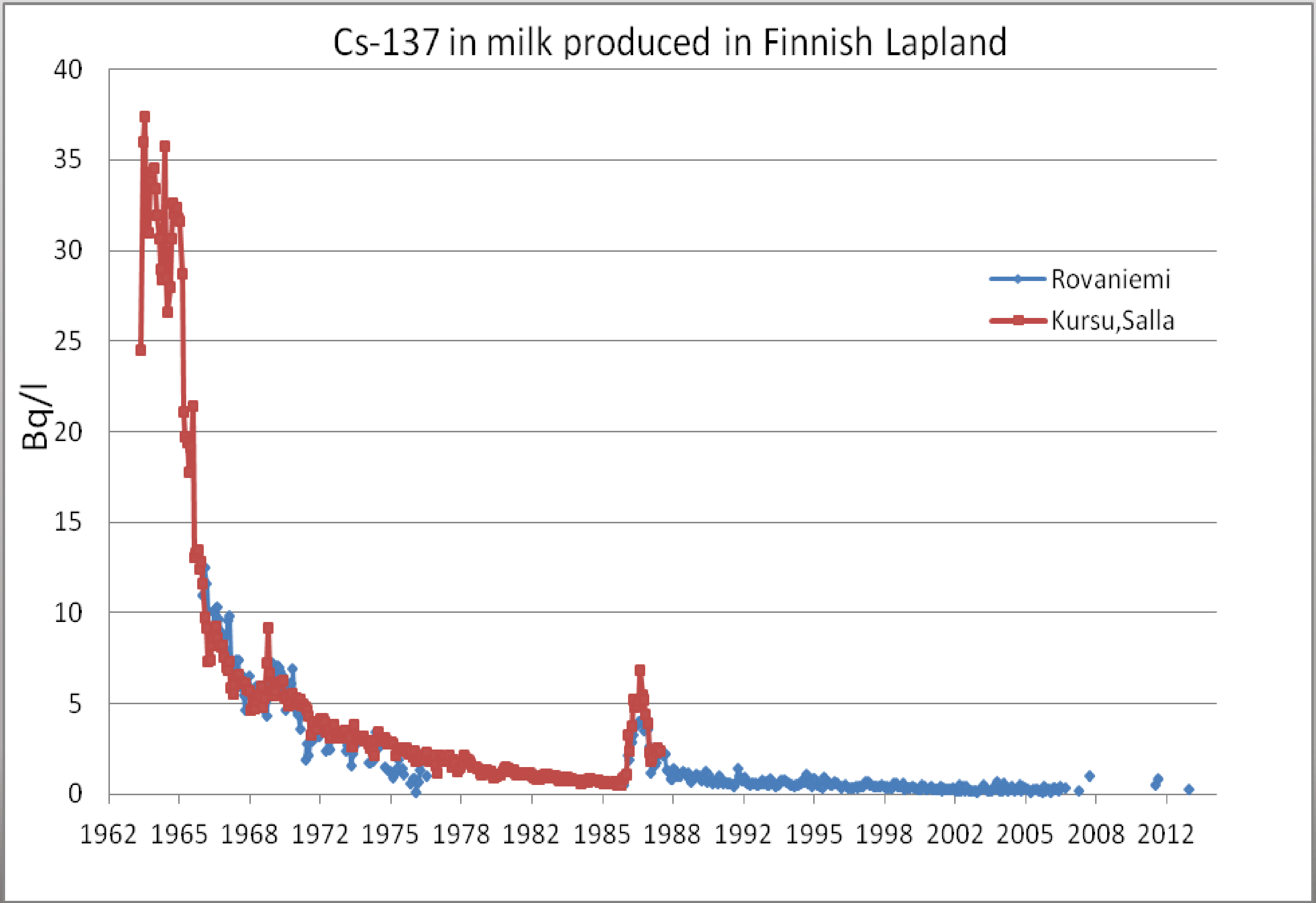
Long timeseries, concentration in Air



Activity concentrations of ^{137}Cs in ground level air at various sites across Finland since the early 1960s.

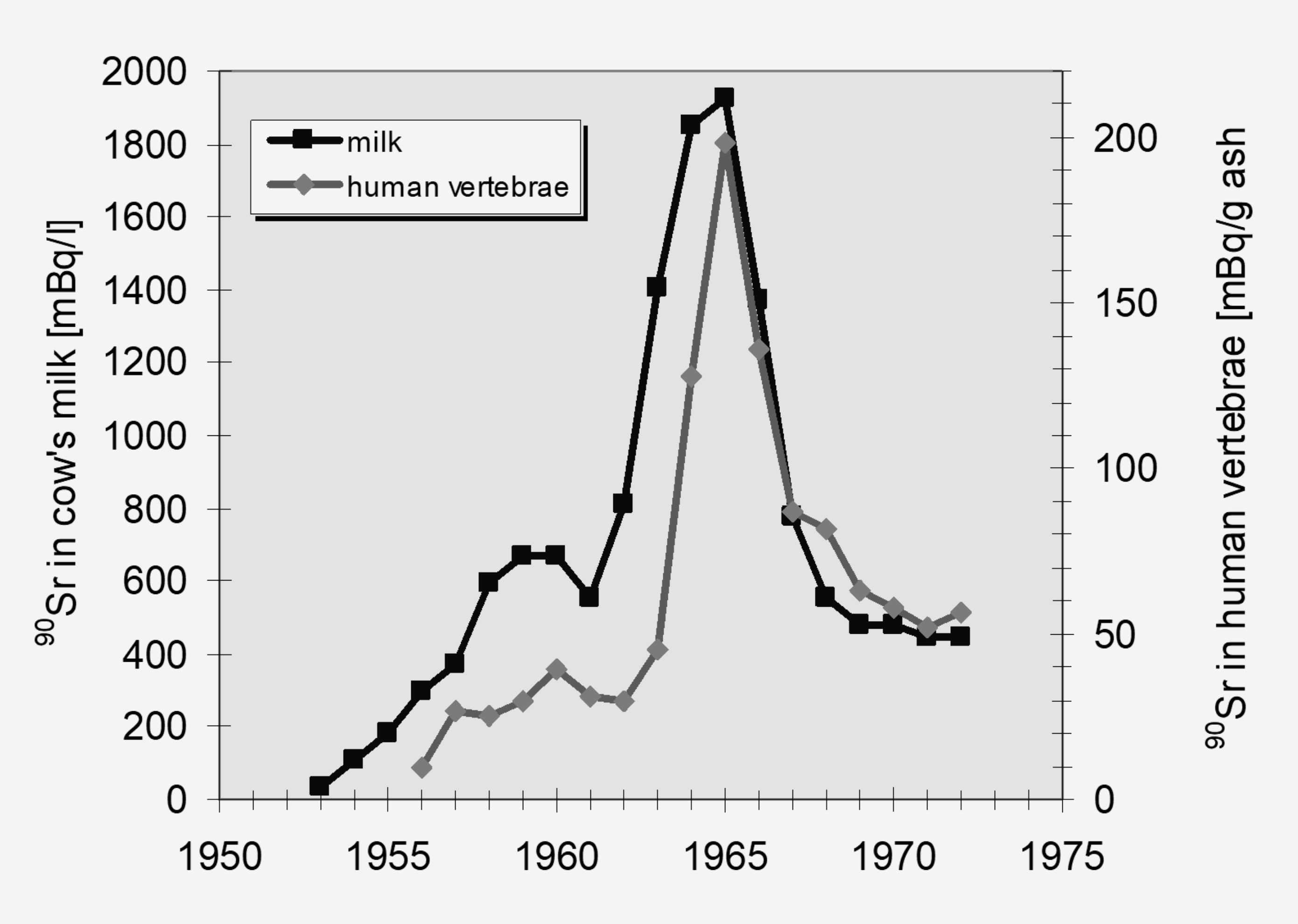
Source: AMAP

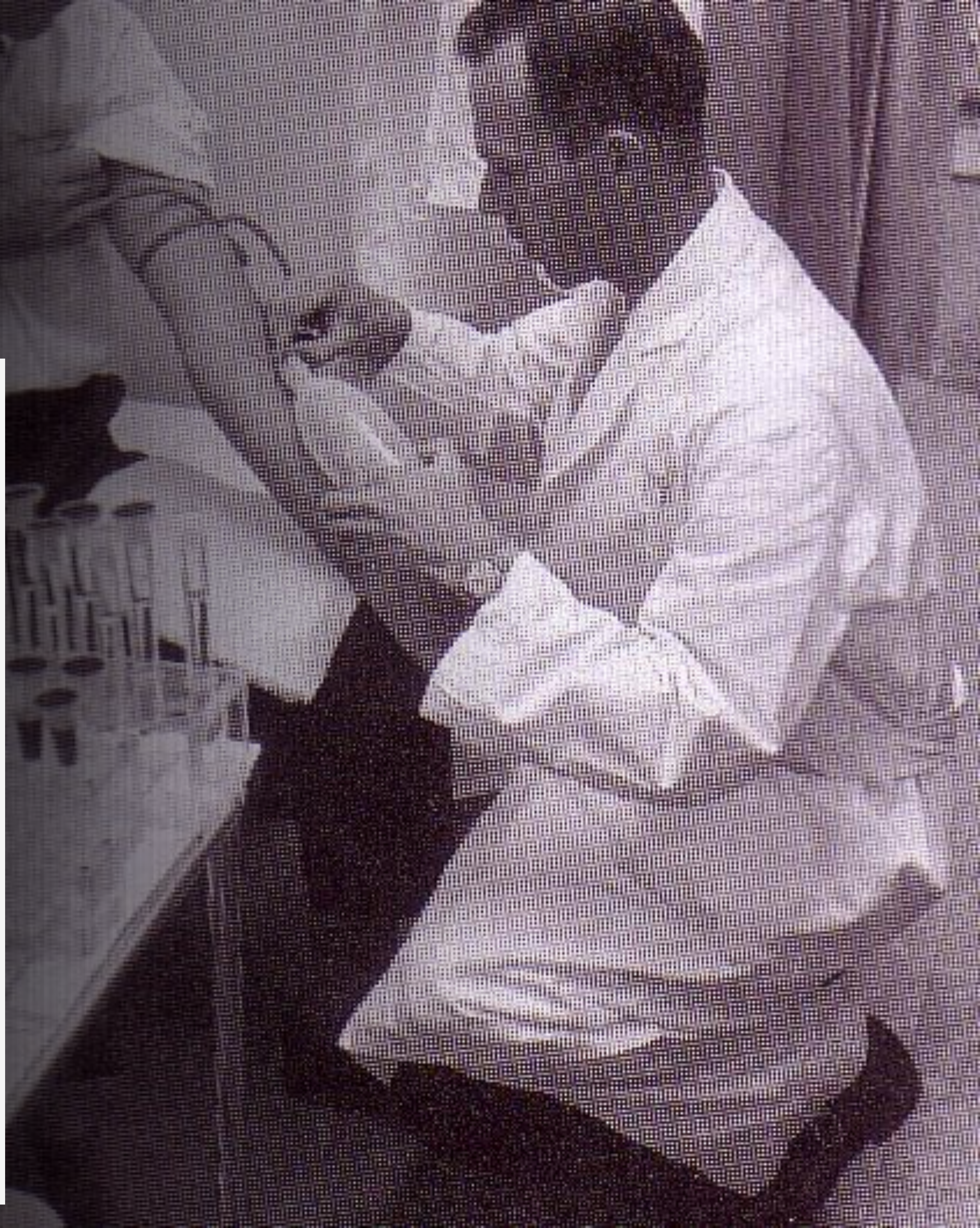
Levels in the Terrestrial Environment



Source: AMAP

^{90}Sr in 1-5 years old children





2014: Almost 30 y after the Chernobyl accident

Radioactive Reindeer! Is the Bizarre Situation Not Improving?

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By Brian Stallard

Oct 06, 2014 07:23 PM EDT

Even nearly three decades after the meltdown of the Chernobyl nuclear power plant, grazing animals in Norway are still feeling the effects. Reindeer in particular have seen a stunning amount of radioactive contamination, boasting disturbing and inordinate levels of the radioactive substance Caesium-137. Alarmingly, this most current season had led to surprisingly high levels of radioactive concentration. (Photo : Pixabay)

Even nearly three decades after the meltdown of the Chernobyl nuclear power plant, grazing animals in Norway are still feeling the effects. Reindeer in particular have seen a stunning amount of radioactive contamination, boasting disturbing and inordinate levels of the radioactive substance Caesium-137.

Decontamination

- Many types of activities – depending on the situation

Decontamination & countermeasures

Different types of measures:

Advice on staying indoors

Orders relating to evacuation measures

Orders on evaluation of population for effects

Advice on seeking nuclear shelter

Advice on using iodine tablets

Advice on securing areas that are or can be contaminated

Orders regarding decontamination of people

Advice on diet

Advice on short term restrictions on agricultrual produce

Advice on dose reduction measures

Mapping, monitoring, assessing areas


NEVER TRUST AN ATOM
They Make Up Everything

Hereditary Effects

Hereditary effects – effects observed in offspring born after one or both parents had received a radiation dose <u>prior to conception</u>.

Radiation exposure serves to increase the occurrence of spontaneous mutations in the cells.

31,150 children of parents who were within 2 km of the hypocenter of the Nagasaki/Hiroshima bombs were compared with a control grouping of 41,066 children – no statistically significant modified indicators recorded.

Due to absence of statistically valid information in humans, hereditary risk factors are derived from experimentally exposed animals.