The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2257-2

Joint ICTP-IAEA School of Nuclear Energy Management

8 - 26 August 2011

Nuclear Power and Radiation Risk

Pier Roberto Danesi

Istituto Universitario di Studi Superiori
Pavia
Italy

Strada Costiera 11, 34151 Trieste, Italy - Tel.+39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it

The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

Joint IAEA/ICTP School of Nuclear Energy Management

8-26 August 2011

NUCLEAR POWER and RADIATION RISK: MYTHS and SCIENTIFIC REALITIES

P.R. Danesi

e-mail: piero@danesi.at

Istituto Universitario di Studi Superiori - University of Pavia

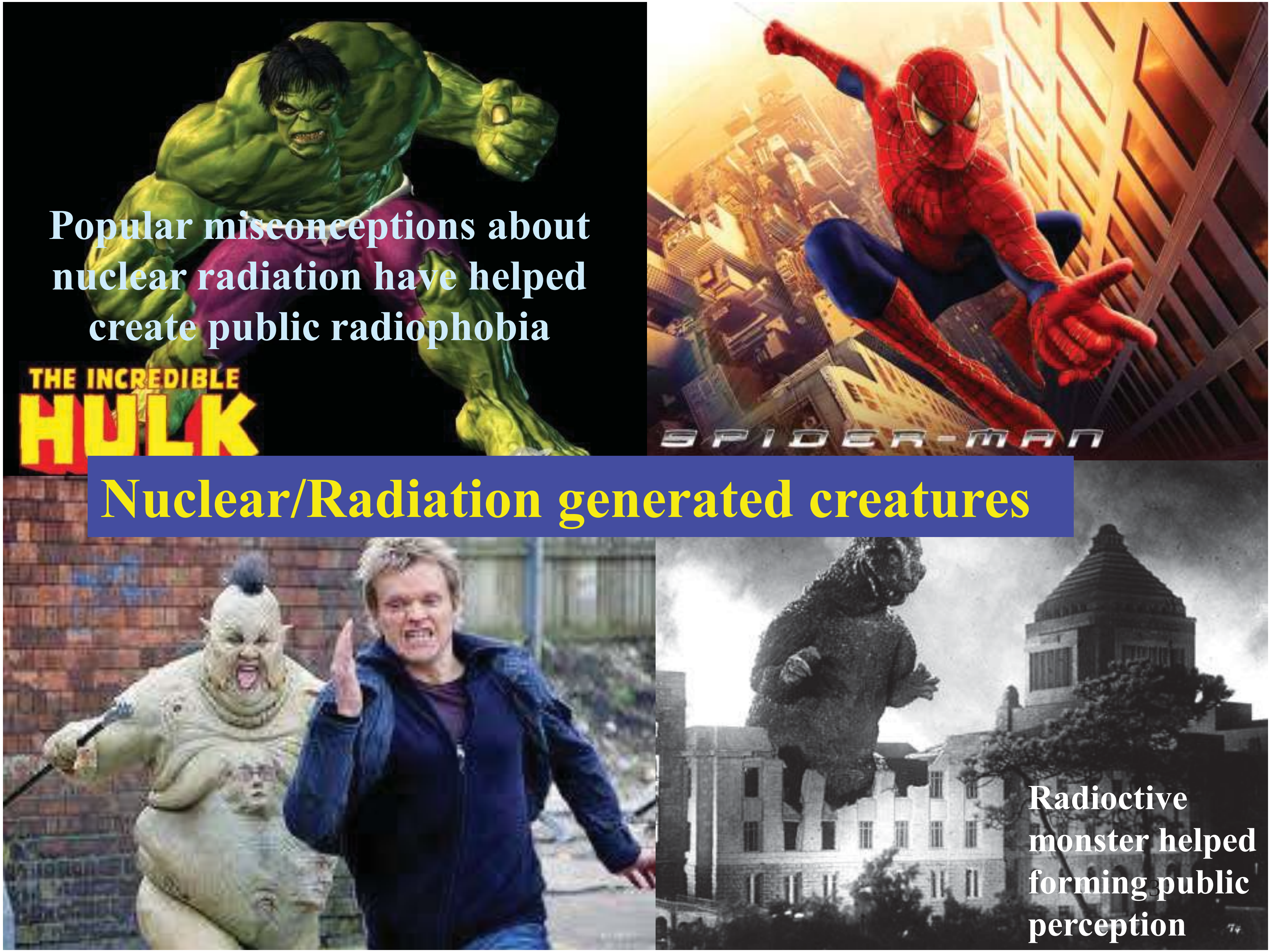
former Director (1986-2002) IAEA´s Laboratories (Seibersdorf and Vienna)

Often science-fiction movies, the literature and occasionally also the media, have attributed to *radiation* the creation of mutants having either supernatural powers, such as The Incredible Hulk and Spiderman, or monstrous creatures, such as Godzilla or the violent Zombies.

This, together with the memory of the atomic bombs dropped on Hiroshima and Nagasaki in 1945 that killed more than 100,000 people, has created in the mind of many people a negative meaning of the words *atomic or nuclear*.

Therefore in the popular imagery the words *atomic*, *nuclear and radiation* are often considered negative terms and anything related to them is perceived as dangerous and, consequently, to be avoided.

In this way also beneficial non-power applications of radiation (for example the use of radiation to treat cancer or sterilize food) or the use of nuclear energy to reduce environmental pollution and the emission of green-house gases, have encountered in many countries problems in public acceptance.


Popular misconceptions about nuclear radiation have helped create public radiophobia
THE INCREDIBLE
HULK
SPIDER-MAN
Nuclear/Radiation generated creatures
Radioctive monster helped forming public perception

Major Public Perceptions About Atomic Energy

Answering deeply rooted public concerns about nuclear energy means challenging three wide spread myths

1. Nuclear waste disposal is an insoluble problem
2. Radiation is deadly. So any technology involving radiation is inherently dangerous
3. Nuclear energy fosters nuclear weapons proliferation

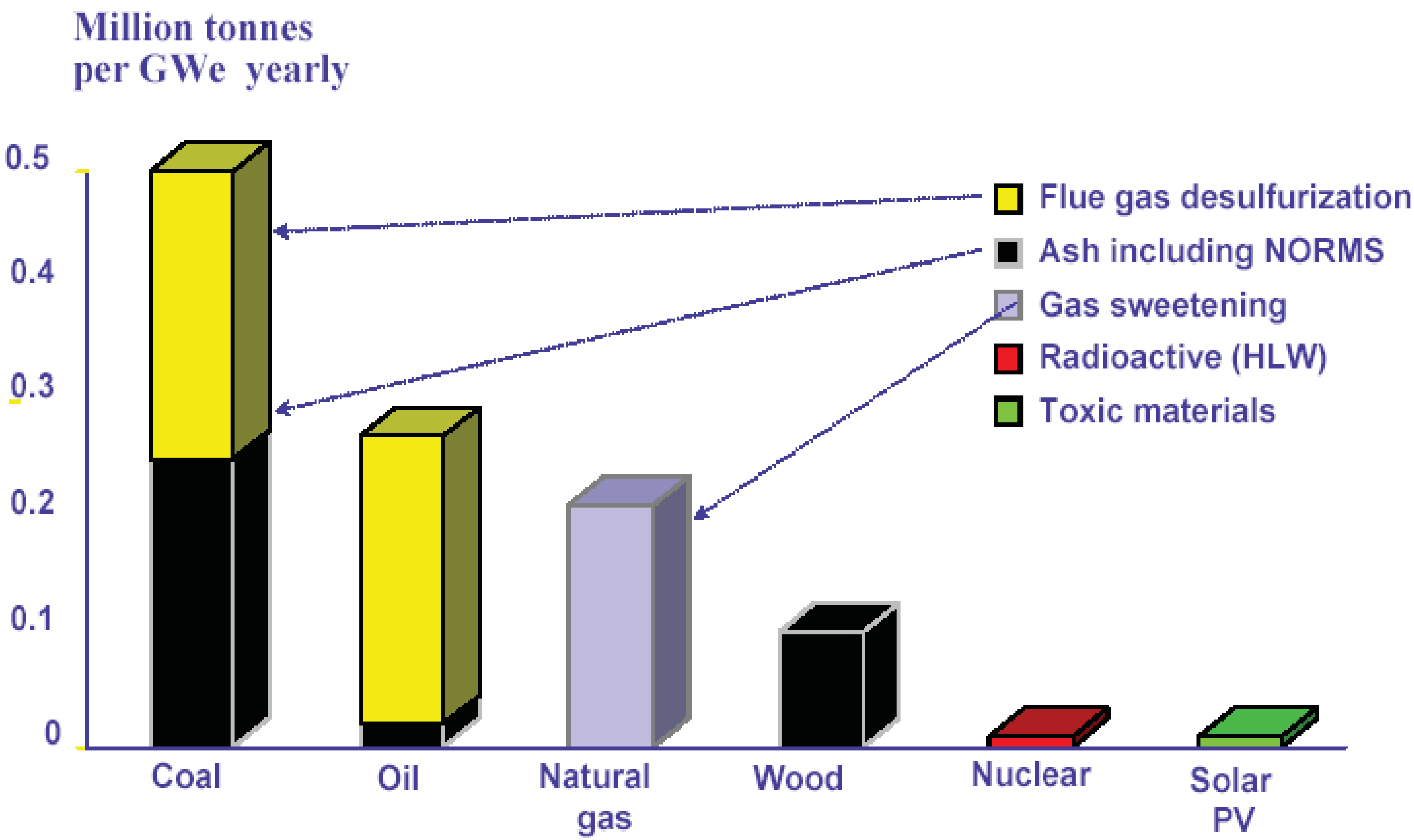
The technology to dispose for very long times and safely low, intermediate and high level nuclear waste is well developed.

Nevertheless in some countries this disposal has not been possible because of public opposition.

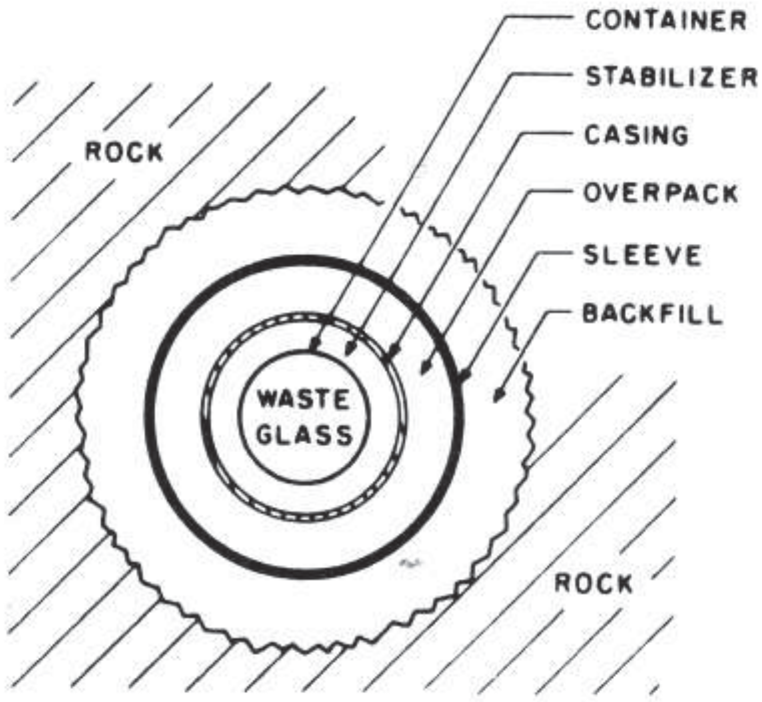
The following figures show that

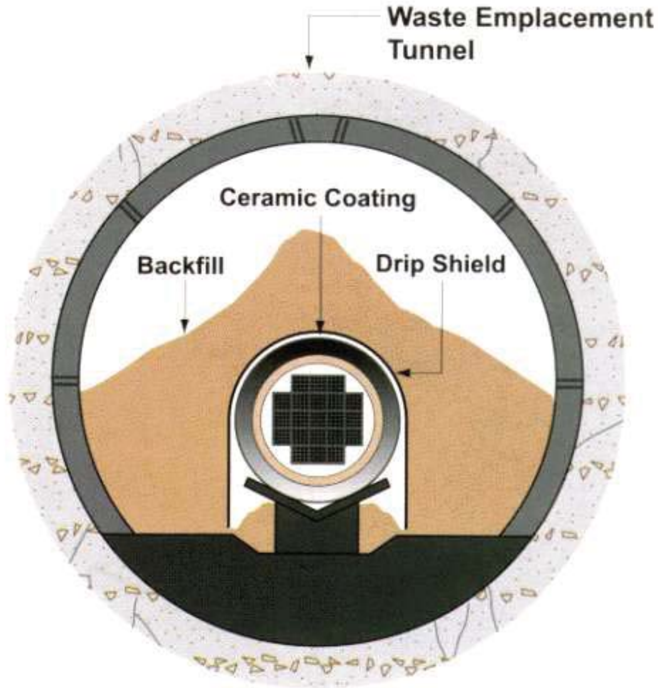
- the volume of nuclear waste is very small in comparison to those of wastes produced by other forms of energy,
- a schematic description of the available disposal technologies,
- what is called a nuclear waste in reality contains material that can be still utilized to produce energy,
- plutonium is not more toxic than other poisons mankind has learned to handle safely.

Wastes in Fuel Preparation and Plant Operation



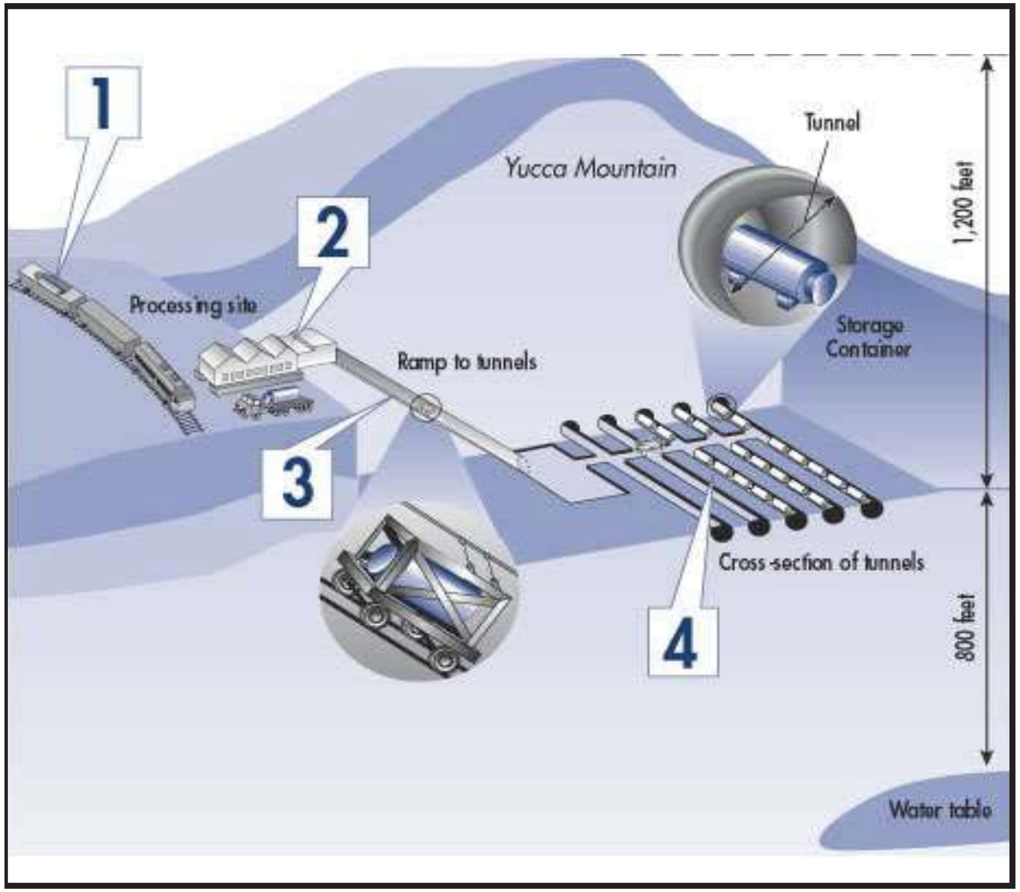
International Atomic Energy Agency

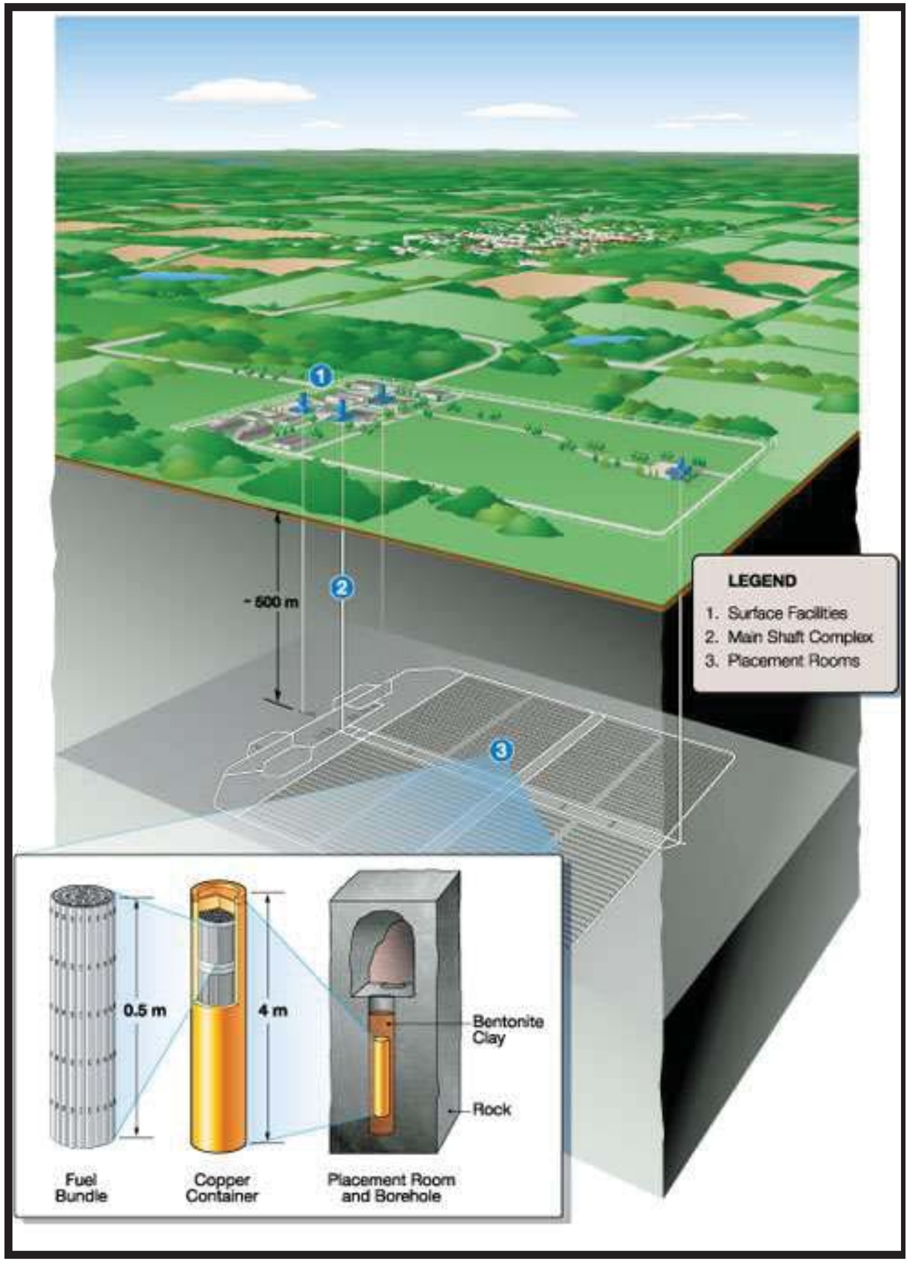




Schematic diagram of **buried waste package**. Components are as follows: **waste glass-the waste itself**, converted into a glass: **container-stainless steel can** in which glass is originally cast; **stabilizer-filler material** to improve physical and chemical stability of the waste; **casing-special material** highly resistant to corrosion by intruding water; **overpack**-provides additional corrosion resistance and structural stability; **sleeve-liner** for hole gives structural support; **backfill-material** to fill space between waste package and rock, swells when wet to keep water out; if waste becomes dissolved, backfill absorbs it out of the escaping water.

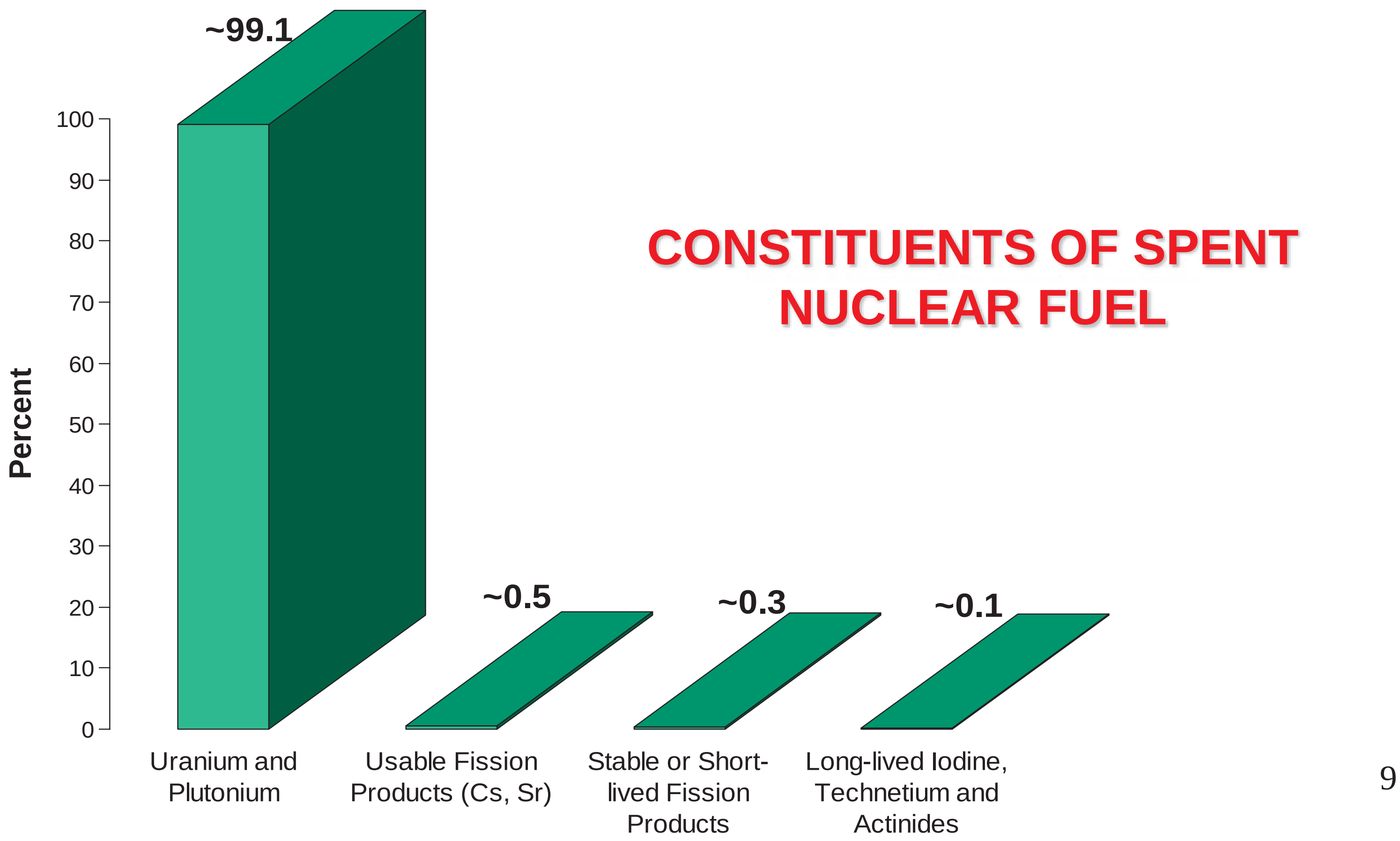
THE NUCLEAR ENERGY OPTION; B. Cohen, Plenum Press 1990


1
2
3
4
Yucca Mountain
Tunnel
Processing site
Storage Container
Ramp to tunnels
Cross-section of tunnels
1,200 feet
800 feet
Water table


LEGEND
1. Surface Facilities
2. Main Shaft Complex
3. Placement Rooms
~500 m
0.5 m
4 m
Bentonite Clay
Rock
Fuel Bundle
Copper Container
Placement Room and Borehole

Used nuclear fuel is "waste."

Fact: Used fuel assemblies from commercial nuclear reactors are energy-rich resources that contain 95 percent of their original potential energy. By recycling the used fuel to make new fuel (as done in a number of countries), the remaining energy can be put to use. If the used nuclear fuel currently in storage were recycled using existing technologies, it could power the existing nuclear power plants for more than 30 years with no new uranium required



Radioactive Wastes-Myths and Realities (updated May 2009)

World Nuclear Association

www.world-nuclear.org/info/inf103.html

There are a number of pervasive myths regarding both radiation and radioactive wastes.

Some lead to regulation and actions which are counterproductive to human health and safety

Over the years, many views and concerns have been expressed in the media, by the public and other interested groups in relation to the nuclear industry and in particular its waste.

(next slides)

Plutonium is the most dangerous material in the world

Plutonium has been stated to be 'the most toxic substance on earth' and so hazardous that 'a speck can kill'. Plutonium is indeed toxic and therefore must be handled in a responsible manner. Its hazard is principally associated with the ionising radiation it emits. However, it is primarily hazardous if inhaled in small particles.

Comparisons between toxic substances are not straightforward since the effect of plutonium inhalation would be to increase the probability of a cancer in several years time, whilst most other toxins lead to immediate death.

Best comparisons indicate that, gram for gram, toxins such as ricin and some snake venoms and cyanide are significantly more toxic.

Also all the cleaning products that we have in our kitchen are toxic if we absorb them, whilst some of the products that are spread onto crops are toxic as well.

Nuclear Power Stations do not emit dangerous levels of radiation during their normal operation.

Moreover, in comparison with many other activities, living in the proximity of a nuclear power station implies a risk that is much lower than that incurred in many other activities normally considered as safe.

The situation may however change in case of a severe accident at the nuclear power station.

Later, using as an example the accident that occurred in Japan in March 2011 at the Fukushima Dai-ichi NPP, it will be shown to which extent this risk may have increased.

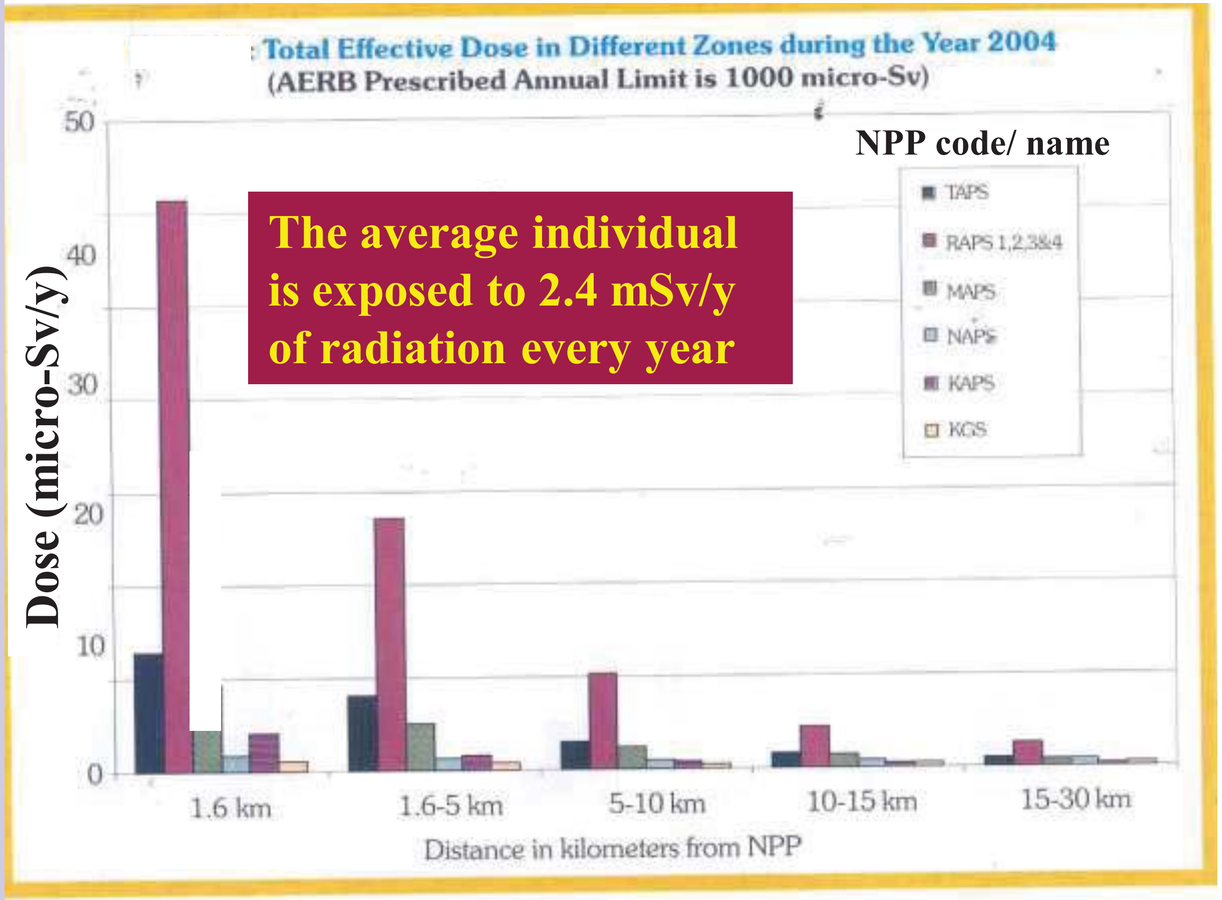
Nuclear plants emit dangerous amounts of radiation.

RADIATION

Fact: Nuclear power plants have controlled and monitored emissions of radiation, but the amount is extremely small and poses no threat to the public or the environment.

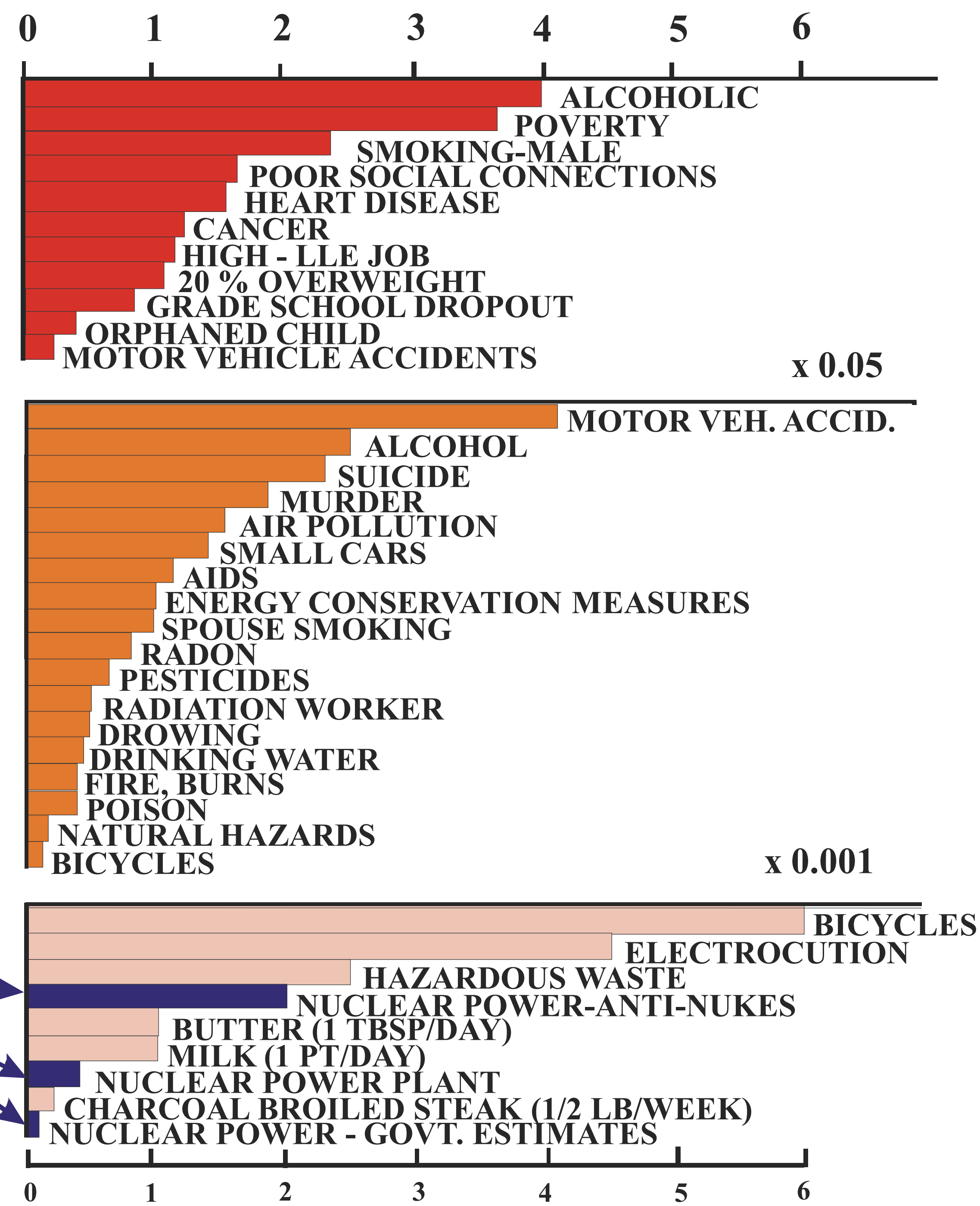
People living close to a nuclear power plant receive, at most, few additional 0.01 mSv/y of radiation exposure, i.e. one thousandth of the radiation exposure from a single whole-body CT scan.

After several thousands reactor years of operation, there is no medical evidence that shows anyone in the western world has been harmed by the radiation from any commercial nuclear energy facilities.



LOSS OF LIFE EXPECTANCY
(thousands of days)

Nuclear Power radiation risks



Other factors contributing to the lack of public acceptance of nuclear energy are the fears that

• NPPs can be vulnerable to attacks by terrorist groups

and/or

• the concern that nuclear energy can favor the proliferation of nuclear weapons

Safety , Security, Proliferation

Nuclear plants are vulnerable to cyber-attacks.

Fact: There has never been a successful cyberattack to a nuclear plant. Unlike industries for which two-way data flow is critical (e.g. banking), nuclear power plants do not require incoming data flow. None of a plant's safety and control systems are connected to the Internet.

Terrorists can use commercial reactor fuel to make nuclear weapons.

Fact: It is impossible to make a nuclear weapon with the low-enriched uranium contained in commercial nuclear reactor fuel. Only through extremely complex and expensive reprocessing could the plutonium in used nuclear fuel be isolated for use in a nuclear weapon. This requires a very large industrial complex that would take years and hundreds of millions of dollars to construct-far beyond the capability of any terrorist organization.

Nuclear energy leads to the proliferation of nuclear weapons.

Fact: The technology to make highly concentrated uranium and plutonium for nuclear weapons is completely independent of nuclear power plant technology. It is impossible to make a nuclear weapon with the low-enriched uranium contained in commercial nuclear reactor fuel.

MYTHS & FACTS ABOUT NUCLEAR ENERGY, Synopses of Common Myths About Nuclear Energy and Corresponding Facts That Refute Them, NEI - NUCLEAR ENERGY INSTIUTE, Oct. 2010

Other issues to be considered in respect to public acceptance of nuclear power are:

•lack of knowledge by the general public, the media and the politicians

•lack of trust in the public and private authorities,

and

•radiophobia

LACK OF KNOWLEDGE

The level of public knowledge about nuclear technology is low

For example surveys have found that:

the best known fact about nuclear power was that uranium was its fuel (31% of respondents)

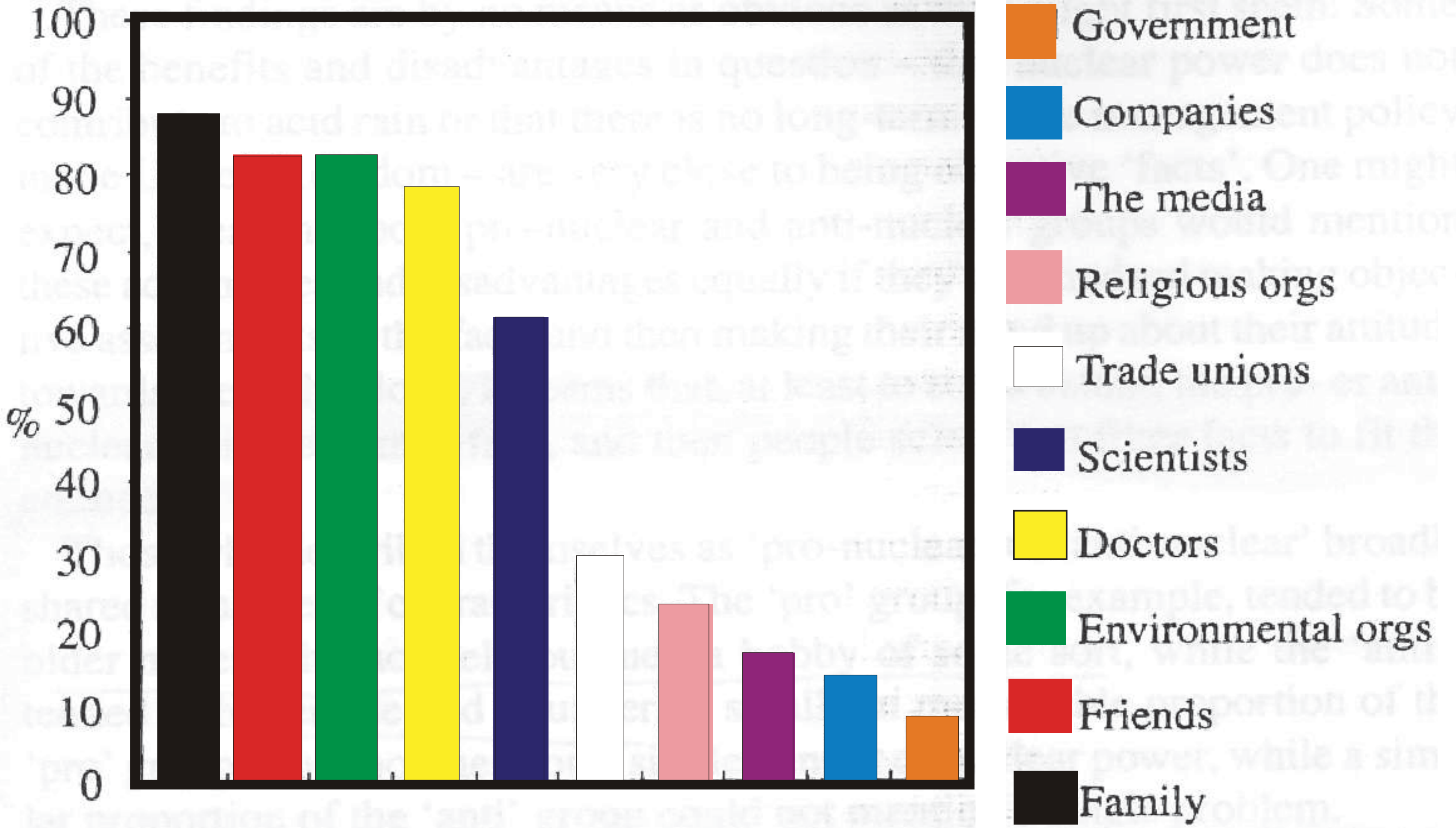
about 59% of people believed nuclear power to be responsible for acid rain

only 13% were aware that radiation can come from both natural and man-made sources

M.C. Grimston and P. Beck "Double or Quits? The Global Future of Civil Nuclear Energy" Earthscan Publications Ltd, London, 2002

LACK OF TRUST

Percentage of respondents often or always trusting institutions to tell the truth



The "Decline of Deference"

NUCLEAR ENERGY ACCEPTANCE

PROBLEMS ENCOUNTERED IN SOME DEMOCRATIC COUNTRIES

- **Positive statements about Nuclear Energy are believed only when made by institutions enjoying high credibility with the public**

- **In some countries the credibility of politicians, the private sector and the media has become low**

To reverse this situation is difficult, it will take a long time and may require considerable changes in important sectors of the society

RADIOPHOBIA

the irrational fear that any level of ionising radiation is dangerous

major causes

- Psychological reaction to the devastation and loss of life caused by the atomic bombs of Hiroshima and Nagasaki
- Psychological warfare during the cold war
- Lobbying by fossil fuel industries
- Interest of some radiation protection lobbies striving for recognition and budget
- Interest of news media that profit by inducing public fear
- The assumption of a linear, no-threshold relationship between radiation dose and biological effects

EFFECTS OF RADIATION

Our knowledge of radiation effects derives primarily from groups of people who have received high doses.

The risk associated with large radiation doses is relatively well established.

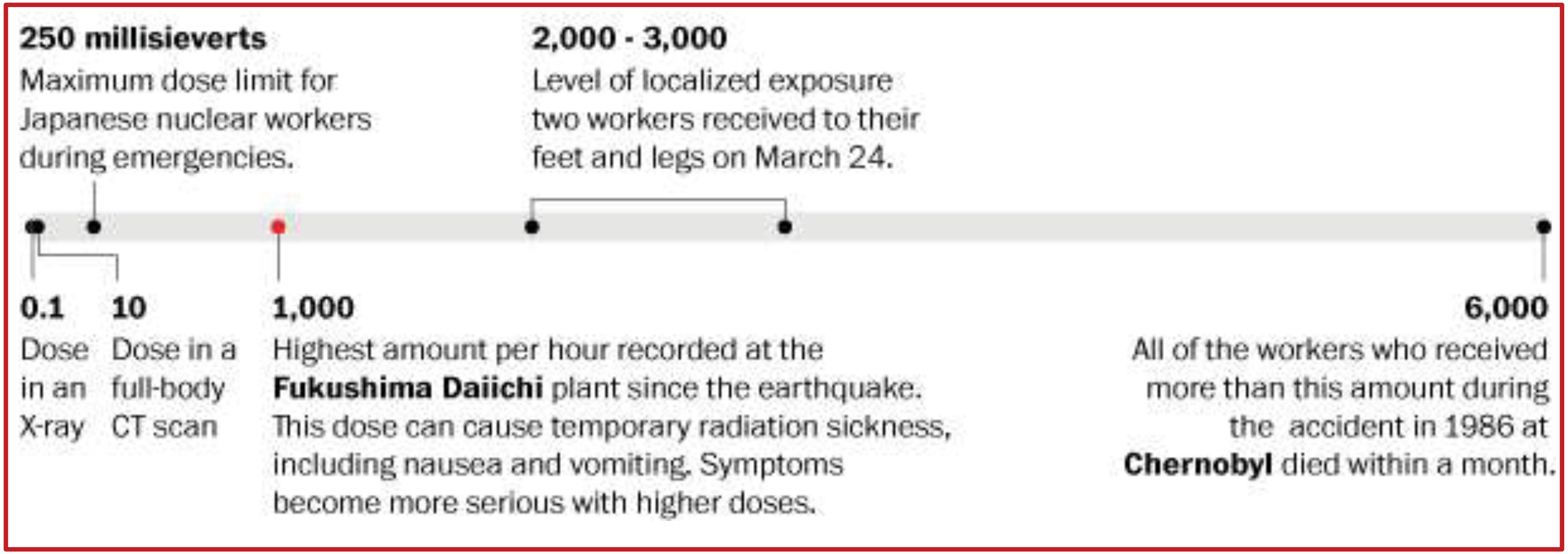
However, the risks associated with doses under about 200 mSv are less obvious because of the large underlying incidence of cancer caused by other factors.

Radiation protection standards assume that any dose of radiation, no matter how small, involves a possible risk to human health.

However, available scientific evidence does not indicate any cancer risk or immediate effects at doses below ~ 100 mSv a year.

At low levels of exposure, the body's natural repair mechanisms seem to be adequate to repair radiation damage to cells soon after it occurs.

How dangerous is ionising radiation?

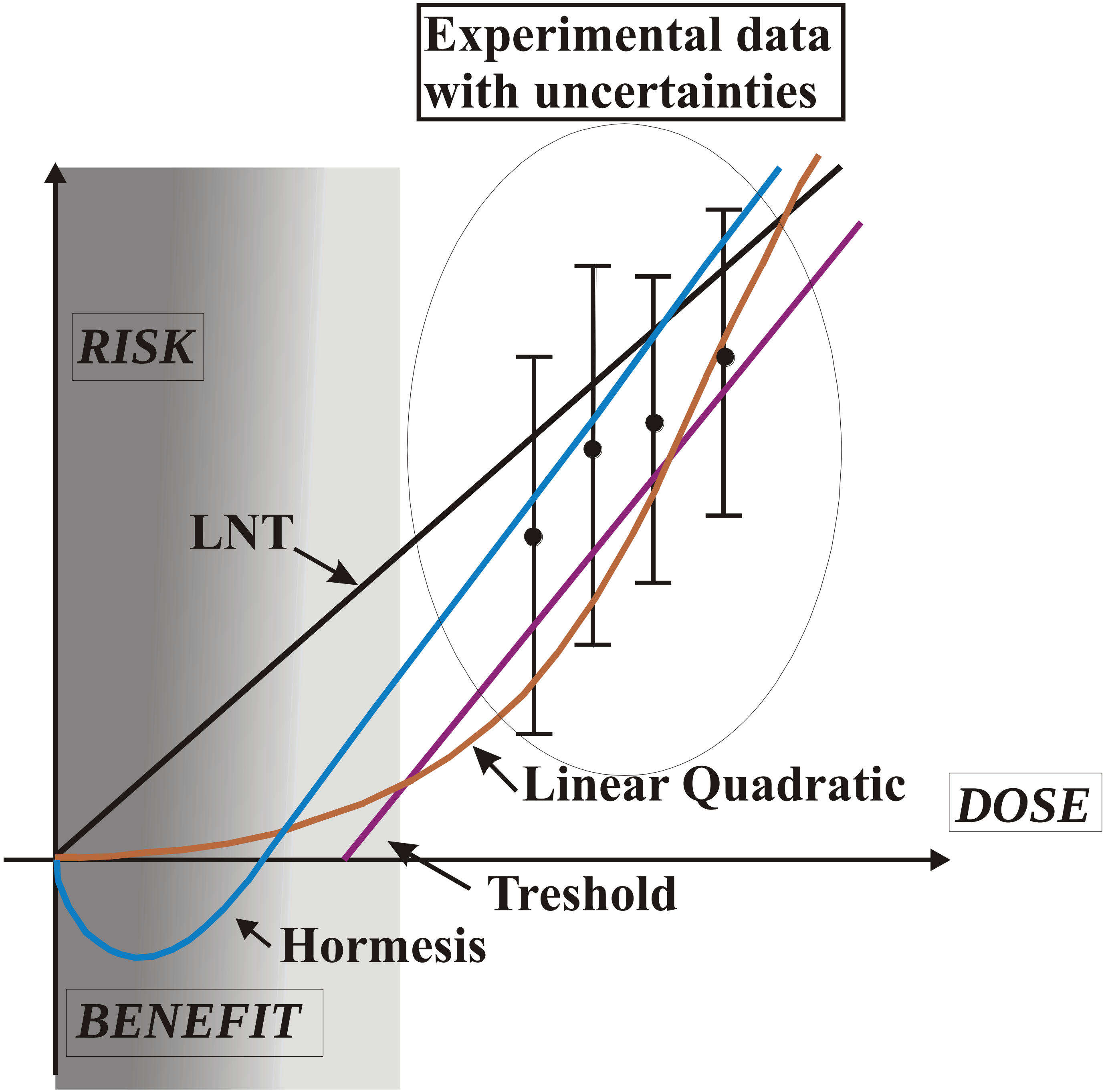


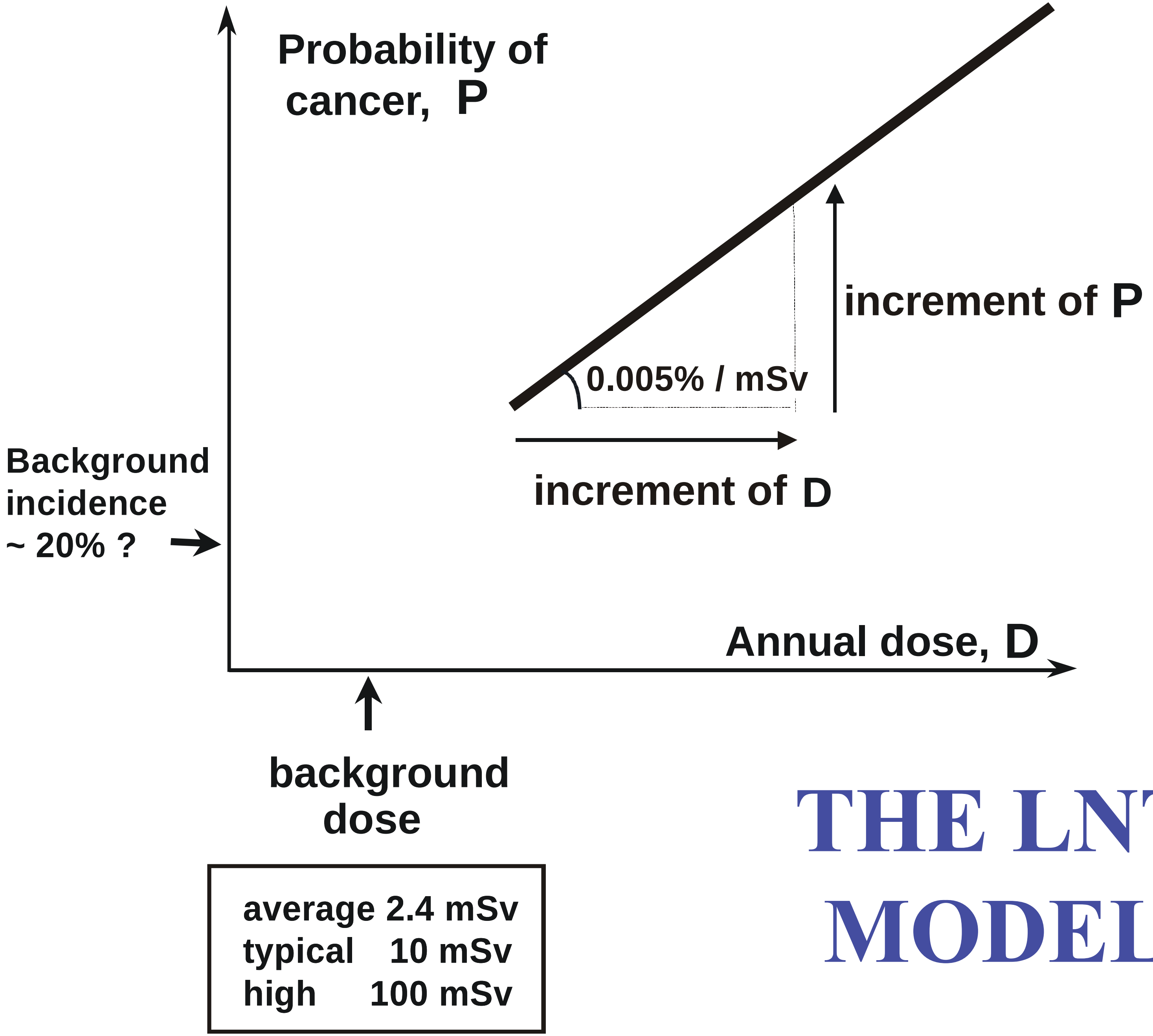
Radiation Effects

Very high doses received instantaneoulsy produce immediately observable symptoms

The damage from low doses (less than 100 mSv) can appear after decades or not show up at all

A short discussion of the Linear-No-Threshold hypothesis and other possible behaviors of the Risk vs. Dose curves at low radiation doses


Experimental data
with uncertainties
RISK
LNT
Linear Quadratic
DOSE
Treshold
Hormesis
BENEFIT



THE LNT MODEL

Arguments based on epidemiology and radiobiolooly contradicting the validity of the linear no-threshold hypothesis at low radiation doses (less than 100-200 mSv) delivered at low dose-rates

There are scientific arguments against the validity of the LNT model at low level of radiation based both on

- **EPIDEMIOLOGICAL**

and

- **RADIOBIOLOGICAL**

data

EPIDEMIOLOGY

Radiogenic health effects (primarily excess cancers) are observed in human epidemiology studies only at doses in excess of ~ 100 - 200 mSv delivered at high dose rates. Consequently, estimation of adverse health effects at lower doses is mainly speculative.

Natural High Background Areas Around The World

Country	Area	Dose * $mSv.y^{-1}$	Remarks
Brazil	Guarapari	24.5	Monazite sands
China	Yangjiang	3.2	Monazite particles
India	Kerala	15.7	Monazite sand
Iran	Ramsar	7 - 35	Spring water
Italy	Orvieto town	4.9	Volcanic soil

*** Average values are given, except for Iran**

*** UNSCEAR, 2000**

EFFECTS OF LOW RADIATION DOSES

•In Yangjiang, Guandong province of China,
150,000 peasants with the same genetic background
were examined. 50 % lived in a region where they received a threefold higher radiation dose (5.4 mSv/y) than the control group (2 mSv/y).

•No difference was found for the total mortality for cancers and leukemia between the studied group and the control population.

•Cancer mortality (except leukemia) for the age group 40-70 years was statistical lower than in the control group.

•Hereditary diseases and congenital deformities in children were the same as on the control area

EFFECTS OF LOW RADIATION DOSES DUE TO RADON AND RADON-DAUGHTERS

In Kerala (India) a population of more than 100,000 receives doses averaging 15.7 mSv/y (up to 33 mSv/y). Extensive studies have shown that there are no statistical significant biological effects on the population in comparison with the control group (2 mSv/y)

In Badgastein (Asustria) there are the most extensively studied hot springs in the world. They were known more than 600 years ago. 20 thermal springs originate in the center of the town. 5 million liters of water (35 ^{o}C to 40 ^{o}C) with a Rn-222 concentration of ~ 1,500 kBq/m^3 are utilized each day

All epidemiological data obtained so far have never detected any statistically meaningful radiation effects on the populations living in these areas (or in visitors)

RADIOBIOLOGY

- **The LNT is frequently extrapolated to doses as low as 1/10,000 of those for which there is direct evidence of cancer induction by radiation. This means the assumption that a single particle of radiation interacting with a single DNA molecule can initiate cancer.**

- **Experimental investigations have shown that DNA damage occurs all the time in our bodies. Each human cell averages more than 200,000 damage events every day and reparative biochemical mechanisms continually mend this damage.**

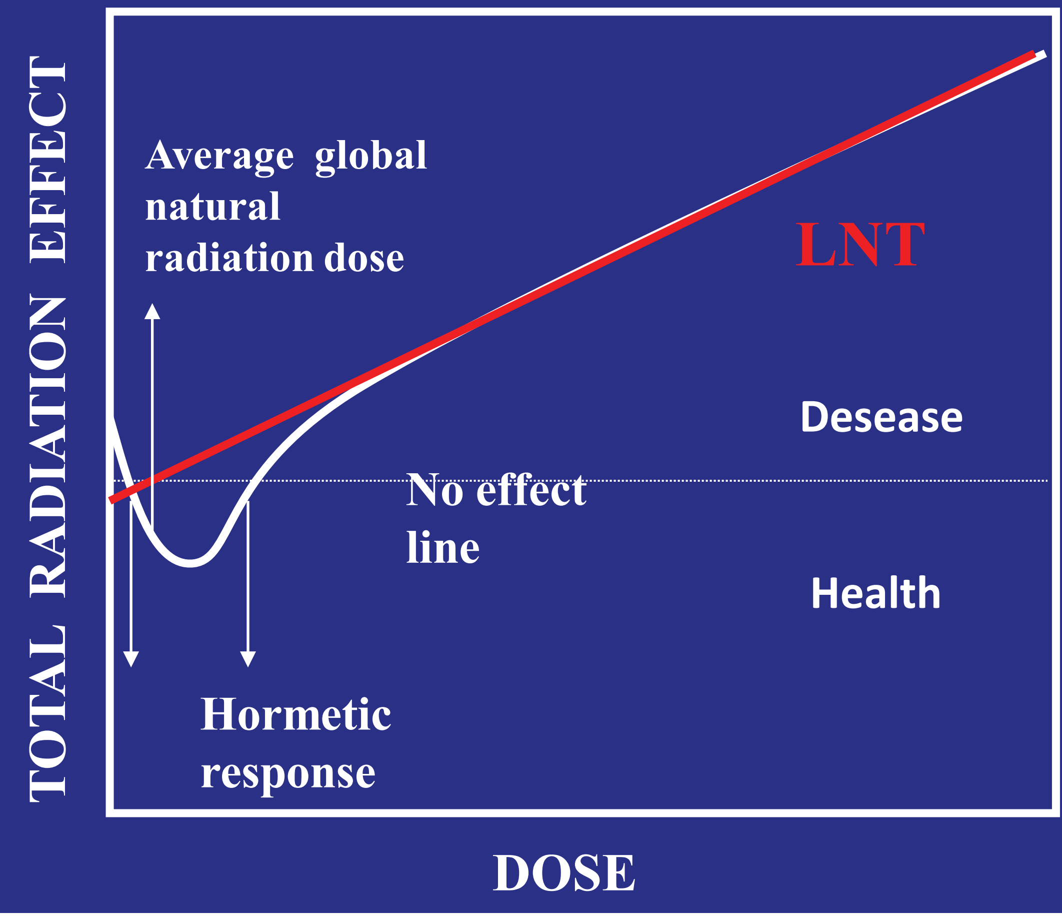
- **There is scientific evidence, collected through *in vitro* and *in-vivo* experiments on various types of cells, showing that exposure to low level radiation substantially reduces the number of chromosome aberrations from subsequent exposure to large radiation doses.**
- **This effect is ascribed to stimulated production of repair enzymes by low level radiation, supporting the claim that low level radiation stimulates the biological defence mechanisms.**

- **Many scientists claim that there is now substantial scientific evidence that the LNT model represents an oversimplification of the biological mechanisms involved.**

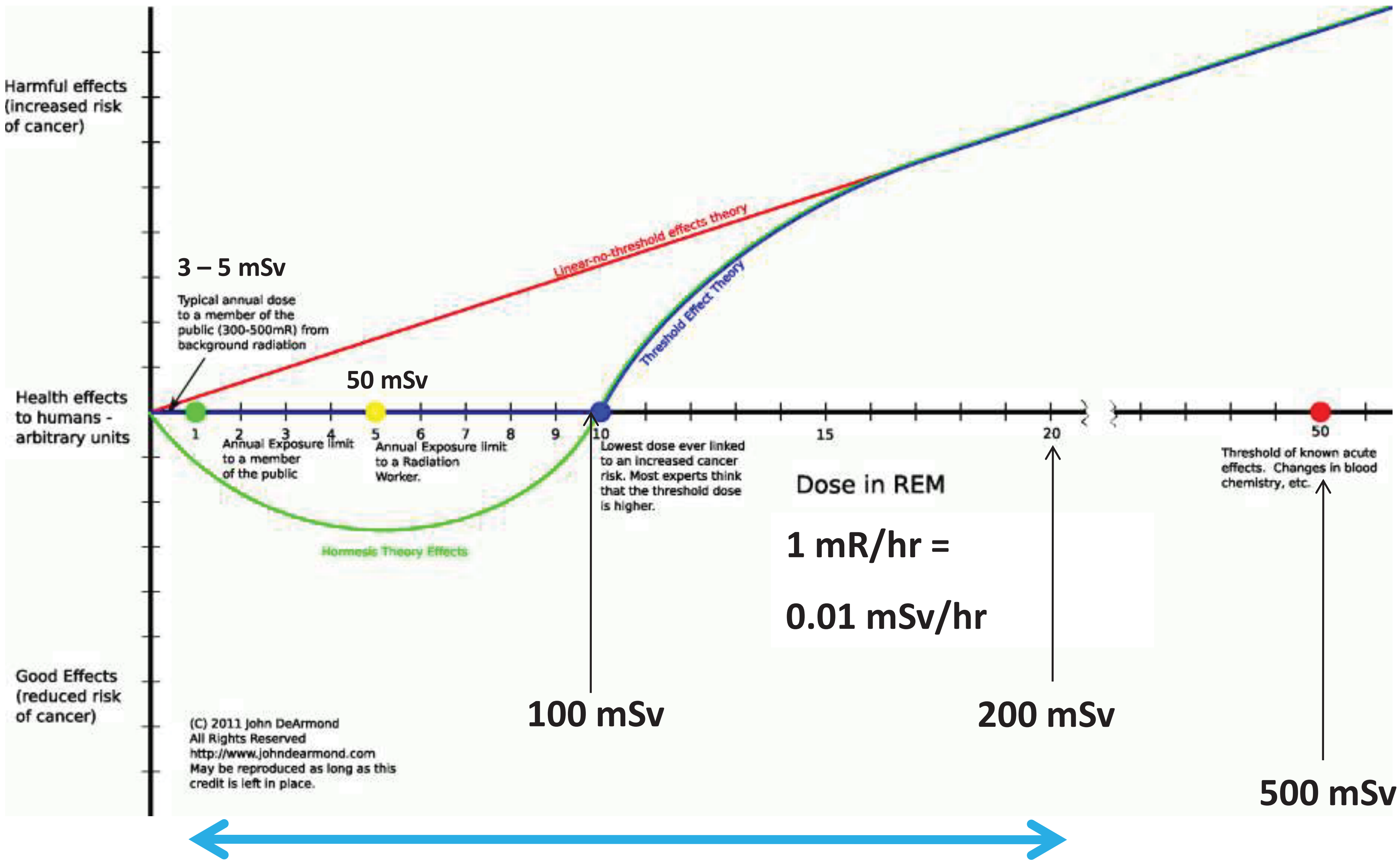
- **Therefore the health risk in the low dose range is overestimated and consequently a huge and totally unjustified financial and social price is paid by society**

In conclusion,

at the light of the present scientific knowledge a more reasonable functional dependence of the total radiation effect (health detriment) on the radiation dose should be of the type:



Graphic representation of different hypothesis of the Risk vs. Radiation Dose curves at low radiation doses



Many scientists believe that doses in this range, received at low rates, are not harmful to people

SOME EXAMPLES OF THE

CONSEQUENCES

OF THE USE OF THE

LNT MODEL

AT LOW RADIATION DOSES

Present radiation protection standards based on the exposure limit for the public of 1 mSv/year save one life/year at a cost of US $ 50,000,000/year.

If a person is protected for 50 years, each human life hypothetically saved by implementation of the present radiation protection regulations will cost about 2.5 billion US $.

In order to arrive at more rational decisions on the acceptability or not of nuclear power and nuclear technologies in general, radiation risk should be considered in a broader context and compared with other risks we consider acceptable.

In the following figures the concept of statistical risk is introduced and comparison among different types of risks are presented

A MORE RATIONAL APPROACH

1. Quantification of risk

Historical risks

- relatively frequent occurrence
- statistical data are available

Risks calculated from event trees

- very rarely occurring
- a model is often necessary

2. Comparative risk assessment

[3. Benefit-cost-risk analysis]

Risk Acceptability

A MORE RATIONAL APPROACH

1. **Quantification of risk**
2. **Comparative risk assessment**

$$R = P \times C$$

Mathematical Definition of Risk

R = risk

P = probability of occurrence

C = seriousness of the consequence

P = 1, certainty

C = 1, case of death

RISK ASSESSMENT

Risk assessment is in general the process of identification of:

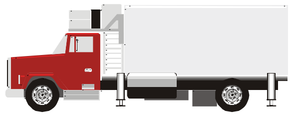
- **the source of risk (be it an industrial installation, a motor car or a toxic substance);**
- **the possible adverse biological consequences of exposure to the source;**
- **the quantitative relationship between the degree of harm and the exposure (dose-response and dose-effect);**
- **quantification and characterization of other types of harm such as economic losses;**
- **at least qualitative characterization of non-quantifiable harm such as social impairment and anxiety.**

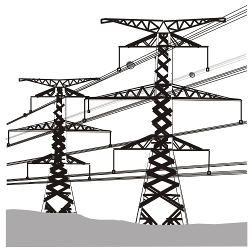
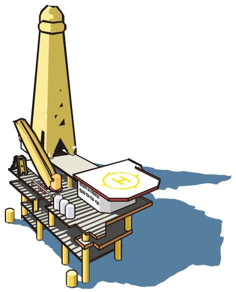
Risks are usually assessed for a specific purpose, namely to improve the basis for decision making

Different Professions have different risks







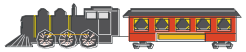



PROFESSION	Microrisk/year
Office employees	2
Trade	10
Factory workers	10-100
Transportation	400
Coal mining	800
Construction of high power transmission lines	1200
Work at deep sea oil wells	1500

Examples of activities involving the same death risk of 1 microrisk R= 1 x 10^{-6}

R = C x P   (C = 1, i.e. death)

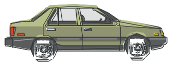
Travelling 2500 km by train
(accident)



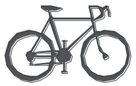
Flying 10,000 km by plane
(cancer from cosmic radiation)

Travelling 80 km by bus
(accident)

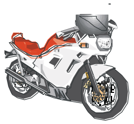
Driving a car for 65 km
(accident)



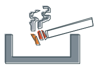
Bicycling for 12 km
(accident)



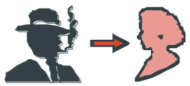
Riding a motorcycle for 3 km
(accident)



Smoking a cigarette
(cancer and heart desease)



Living 2 weeks with a smoker
(cancer and heart desease)



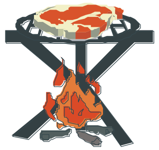
Drinking half a liter of wine
(cirrhosis of the liver)

Normal consumption of tap water for 1 year
(cancer from chloroform)

Drinking 30 cans of diet soda
(cancer from saccharin)

Eating 40 tablespoons of peanut butter
(liver cancer from aflatoxin B)

Eating 100 charcoal broiled steaks
(cancer from benzopyrene)



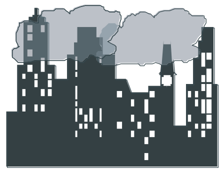
Living in a brick house for 10 days
(cancer from radon)

Living 2 months in high mountains
(cancer from cosmic radiation)

Living 5 years next to a nuclear power plant
(cancer from ionising radiation)

Living 50 years within 5 miles of a nuclear power plant
(accident)

Breathing in a polluted city for 3 days
(air pollution)



Spending 1 hour in a coal mine
(black lung desease)

Spending 3 hours in a coal mine
(accident)

RISKS CAN BE EXPRESSED IN TERMS OF LOSS OF LIFE-EXPECTANCY (LLE)

General Considerations

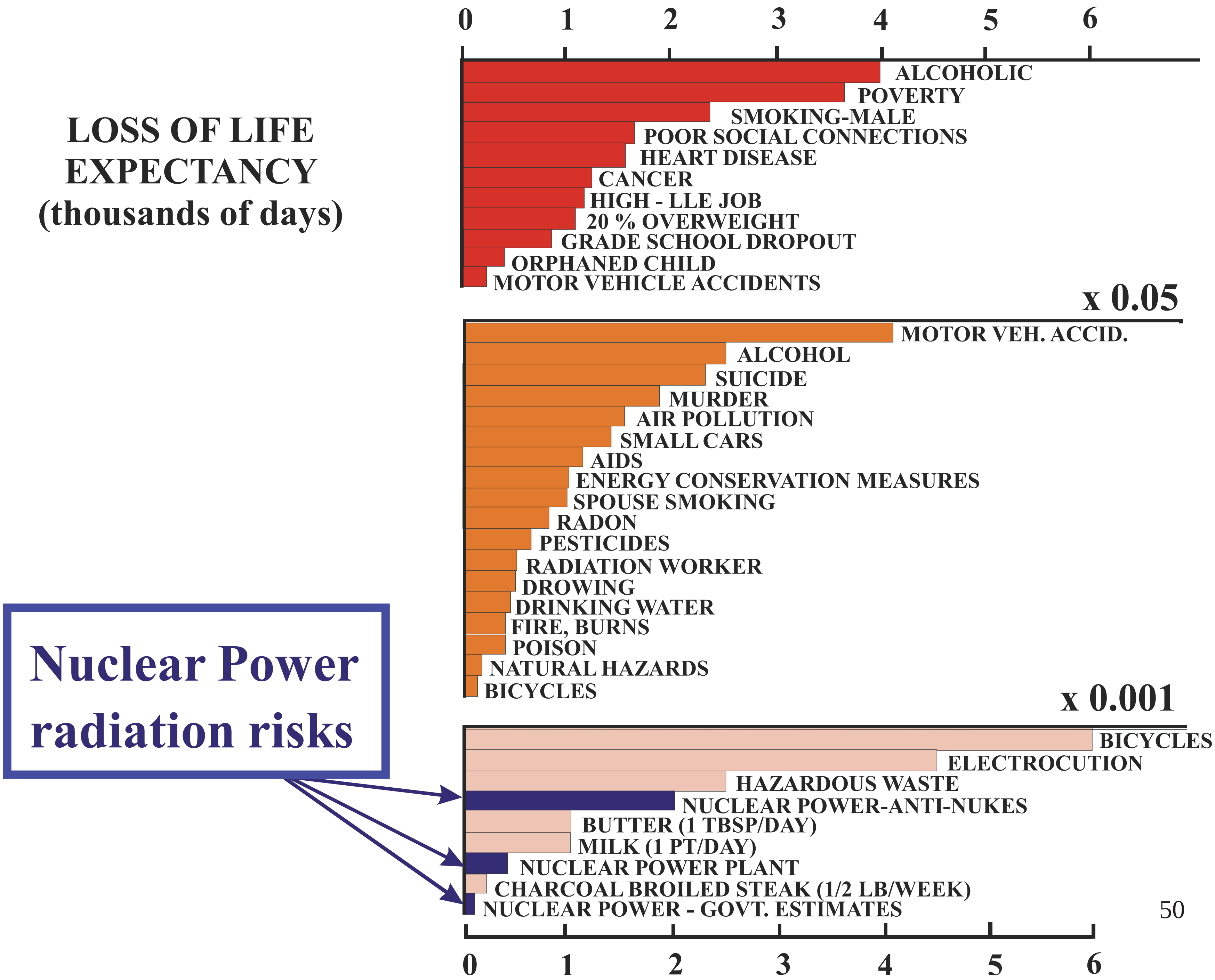
- **The general public is often confused when receiving information on risk**
- **One of the reasons is that risks are not generally expressed in understandable terms**
- **They are usually given as annual mortality rates, which are nearly always smaller than 10^{-3}, whereas there is good evidence that the public recognizes little difference between an annual risk of 10^{-3} and 10^{-6} and 10^{-9}**
- **To overcome this problem it has been tried to express risk in terms of days of life expectancy lost or loss of life expectancy (LLE)** ***(B.Cohen et al. "Health Physics", 1979, 1981, 1991)***
- **LLE can be calculated for various age ranges. Therefore the premature death of an elderly person is less regrettable than the death of a young person**

LOSS OF LIFE EXPECTANCY (LLE) HAS BEEN CALCULATED FOR:

- accidents - occupational risks - unemployment - overweight - social connections - small vs large cars - passive smoking - air pollution - other environ. pollutants	- carcinogens in natural food - sports - geographical location - epidemics - natural hazards - socio-economic factors - exposure to radiation

Cohen17.cdr

LOSS OF LIFE EXPECTANCY (thousands of days)

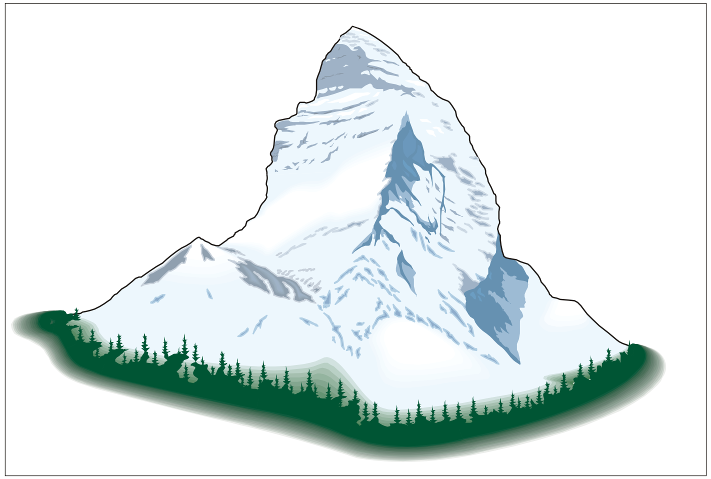


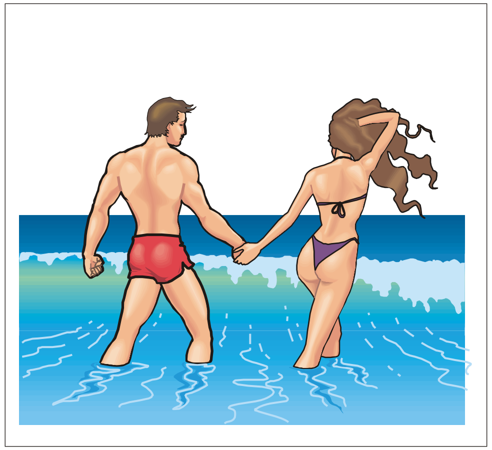
Some observations

Influence of geographical location (USA)

Areas at high elevation have substantially lower mortality rates than areas near sea level

Here you live longer than here



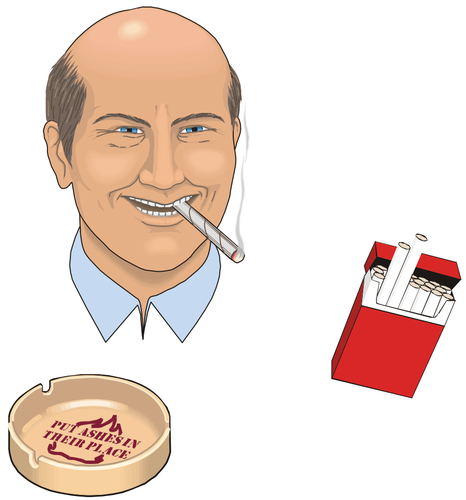


The correlations are especially strong for cancer, but they are also significant for cardiovascular diseases

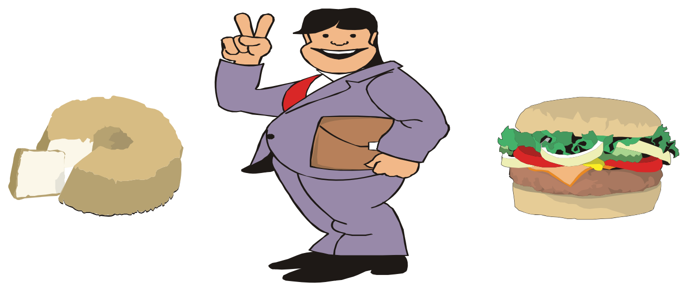
Some risk comparisons

From the catalogue of risk it is possible to compare the amount of exposures giving the same risk

Living one year near a NPP gives a LLE= 0.05 days.
Smoking one pack (20) of cigarettes/day gives a LLE= 2250 days.
Smoking 1 cigarette/day gives a LLE= 112 days = 0.308 years
LLE of 0.05 days (NPP) corresponds then to 0.162 cigarettes/year or 1 extra cigarette every 6 years



Being 20% overweight for one year (14 kg over 70 kg) gives a LLE of 1200 days.
LLE of 0.05 days (NPP) corresponds to a weight increase of 0.05x14/1200= 0.6 g



Cohen20.cdr

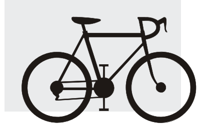
In industrial countries the risk of dying from cancer (not caused by anthropogenic radioactivity) ranges from 200,000 to 250,000 microrisks

If the LNT hypohesis was valid (?) the risk due to an equivalent dose of 1 mSv, would be

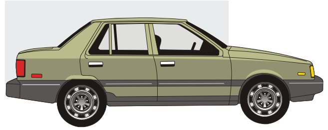
50 microrisks

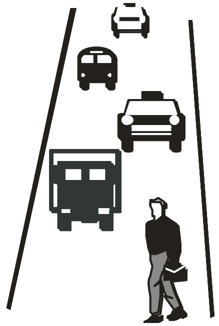
i.e. 50 lethal cancers by 1 million people exposed to the risk

bicycling for 600 km



driving for 3250 km

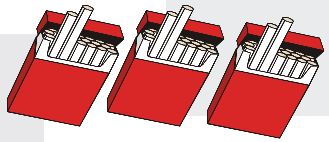


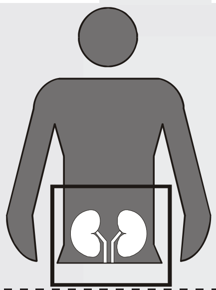


crossing a busy road twice a day for 1 year

drinking a glass of wine (0.125 l) per day for 1 year

smoking 2.5 packets of cigarettes





being X-rayed for kidney metabolism

Finally, we will present some information about the accident that occurred at the Fukushima Dai-ichi NPP in March of 2011 and its radiological consequences.

It will be shown that on the basis of preliminary considerations the accident, although catastrophic in terms of economic and technological consequences for the nuclear industry, so far appear to have had only a minor radiological impact on the civil population of Japan.

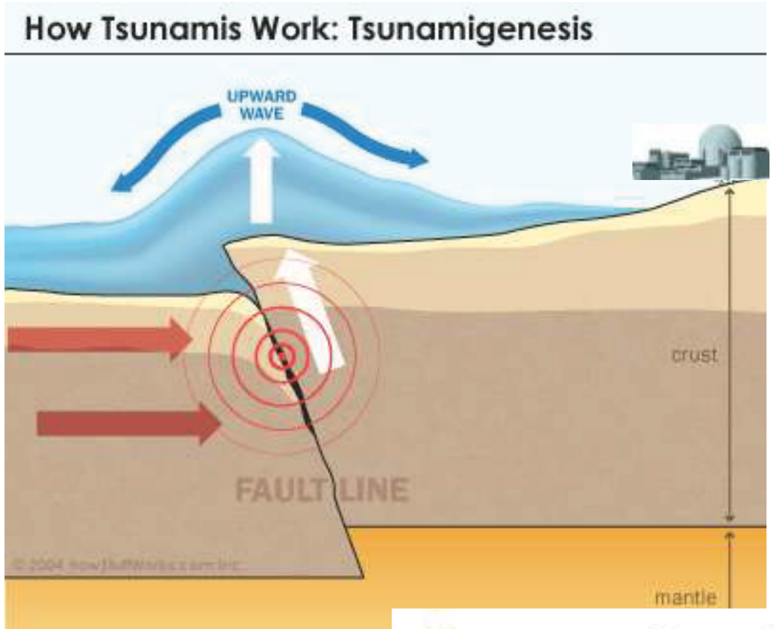
This was due to the prompt evacuation of the population residing in the vicinity of the NPP, which took place according to the emergency plans, and other precautions (such as sheltering and restrictions on consumption of contaminated food and water) put in place by the Japanese authorities.

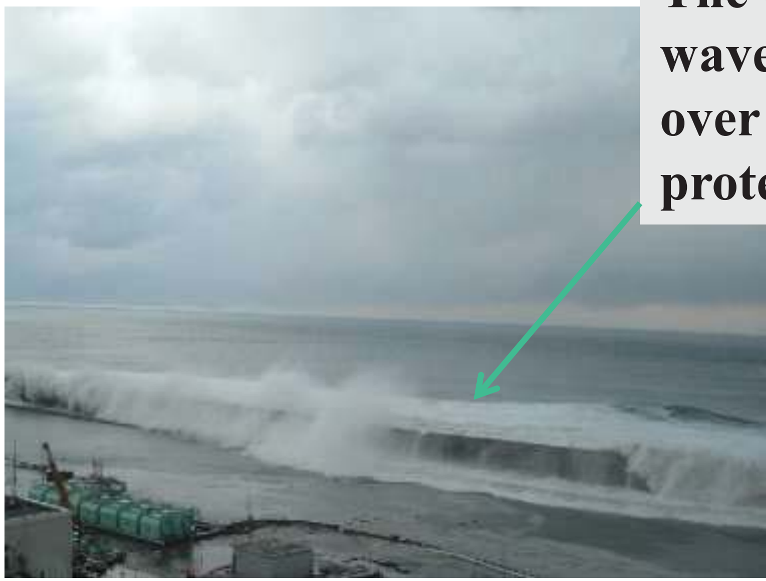
Only one small area outside the 30 km zone (Iiitate Village, with a population of about 7000) received radiation doses amounting to several tents of mSv. To prevent this population from receiving higher doses, this was evacuated on 15 May 2011.

Has the situation changed after the nuclear accident of March 2011 at the Fukushima Dai-ichi NPP?

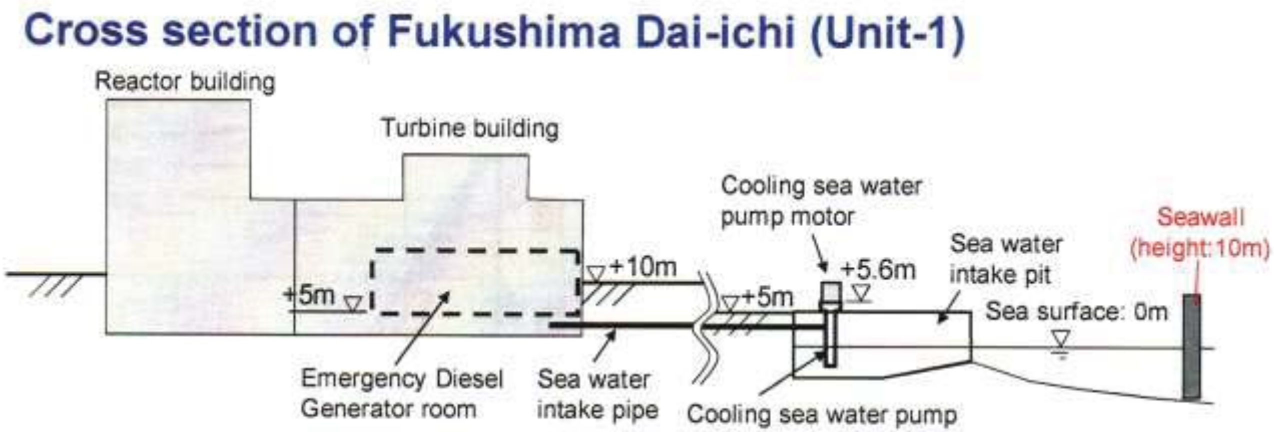
The Nuclear Accident at the Fukushima Dai-ichi NPP

A short summary of the accident and temporal sequence of the radioactive releases

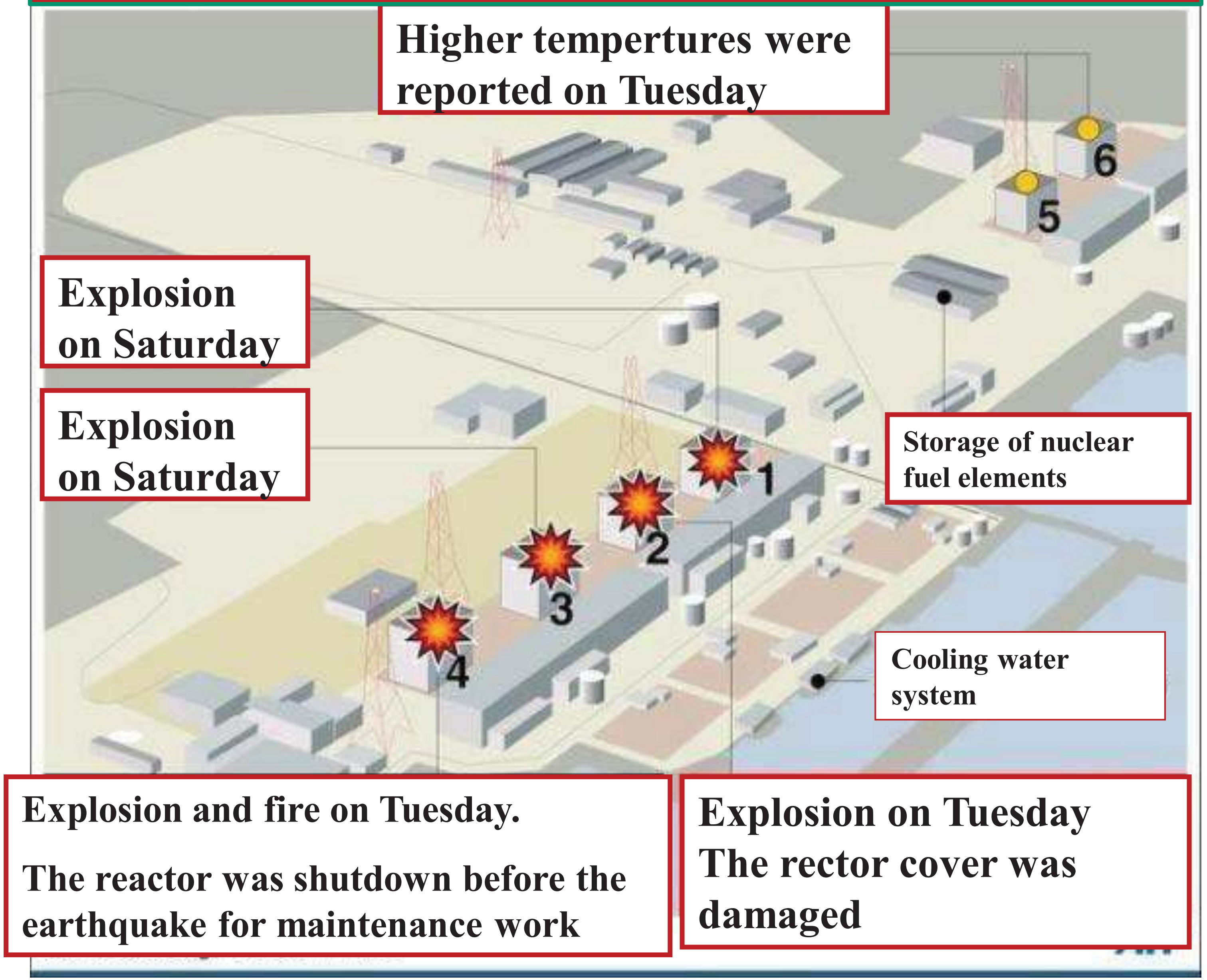




The tsunami wave passing over the protection wall



Nuclear Power Plants at Fukushima 1



Most population potentially exposed was evacuated by 15 March 2011 (before the major radioactivity releases took place)

EVACUATION

11 March, Evacuation of an estimated 1,864 people within a distance of 2 km from the plant. This was extended to 3 kilometres and 5,800 people at 21:23 , together with instructions for residents within 10 kilometres of the plant to stay indoors.

12 March The evacuation was expanded to a 10 kilometres radius at 5:44, and then to 20 kilometres (12 mi) at 18:25. The residents of the Fukushima area were advised "to stay inside, close doors and windows and turn off air conditioning. They were also advised to cover their mouths with masks, towels or handkerchiefs" as well as not to drink tap water. Over 50,000 people were evacuated.

13 March The figure increased to 170,000–200,000 people, after officials voiced the possibility of a meltdown.

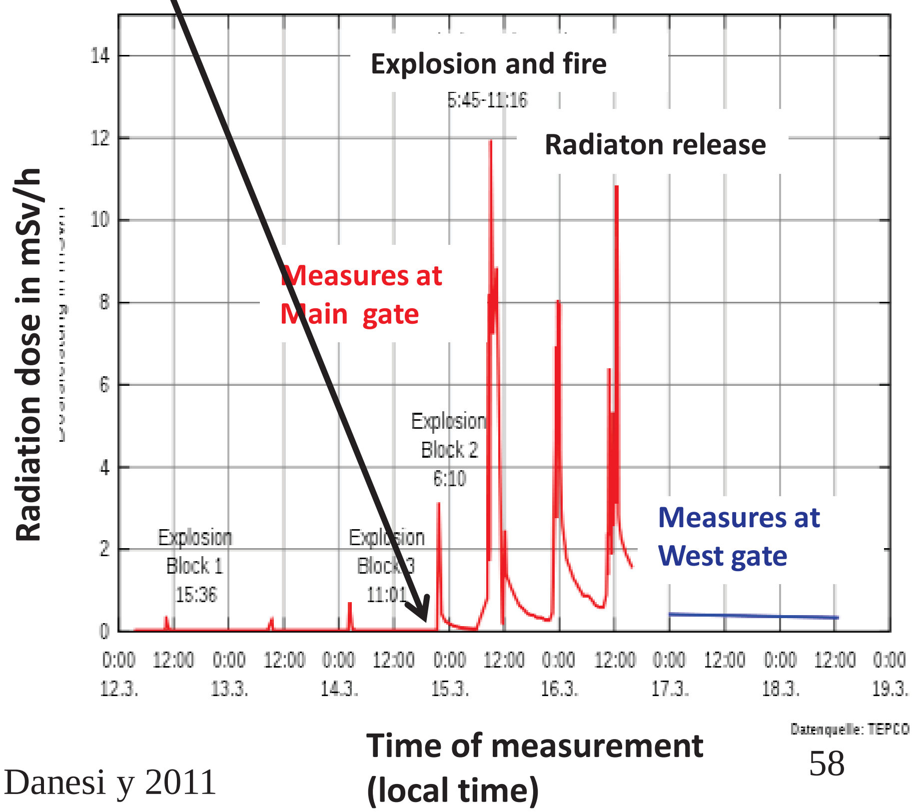
---

15 March The evacuation area was extended. Instructions were issued that any remaining people within a 20 km (12 mile) zone around the plant must leave, and urged that those living between 20 km and 30 km from the site should stay indoors.

22 April, It was officially announced that the evacuation zone would be extended to an irregular zone extending northwest of the Fukushima site.

15 May The Japanese government began evacuating people from outside the official exclusion zones, including the village of Iitate, where high levels of radiation had been repeatedly measured.

Temporal sequence of the explosions and radioactivity



P.R Danesi y 2011

First Consequence

Destruction of the Nuclear Reactor

Huge financial, image and trust damage

Second Consequence

Radiocative contamination of part of the Japanese territory and of the the oceanic waters

Risk to population exposed to radiation

Immediate deaths? Letal leukemias and cancers?

Major Radionuclides Released into the Environment

^{132}Te ($t_{1/2}$ = 3.2 d) [practically disappeared after 1 month]

and isotopes of noble gases such as Xe e Ar

^{131}I ($t_{1/2}$ = 8.04 d) [practically disappeared after 3 month]

^{137}Cs ($t_{1/2}$ = 30.2 y)

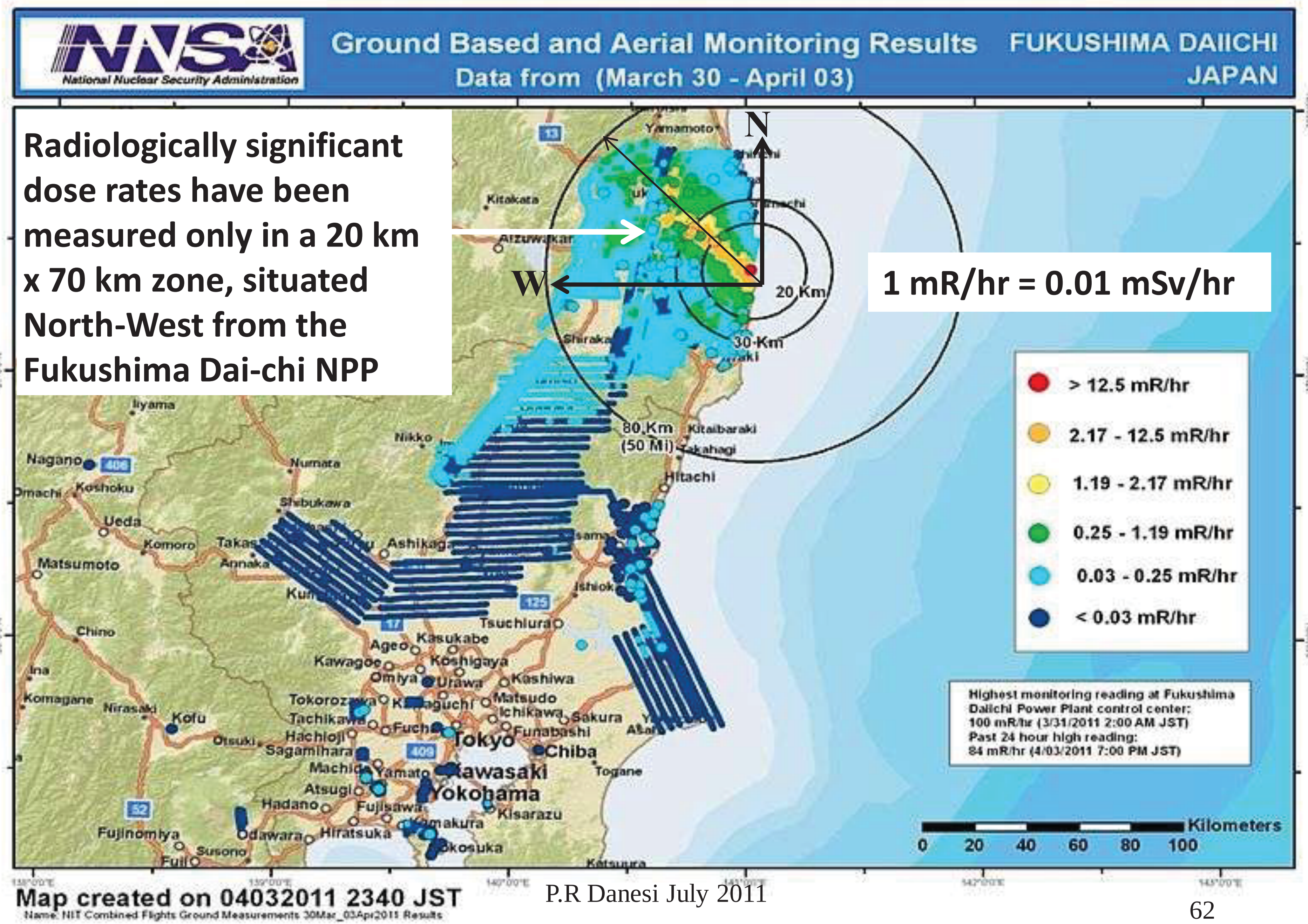
^{134}Cs ($t_{1/2}$ = 745 d)

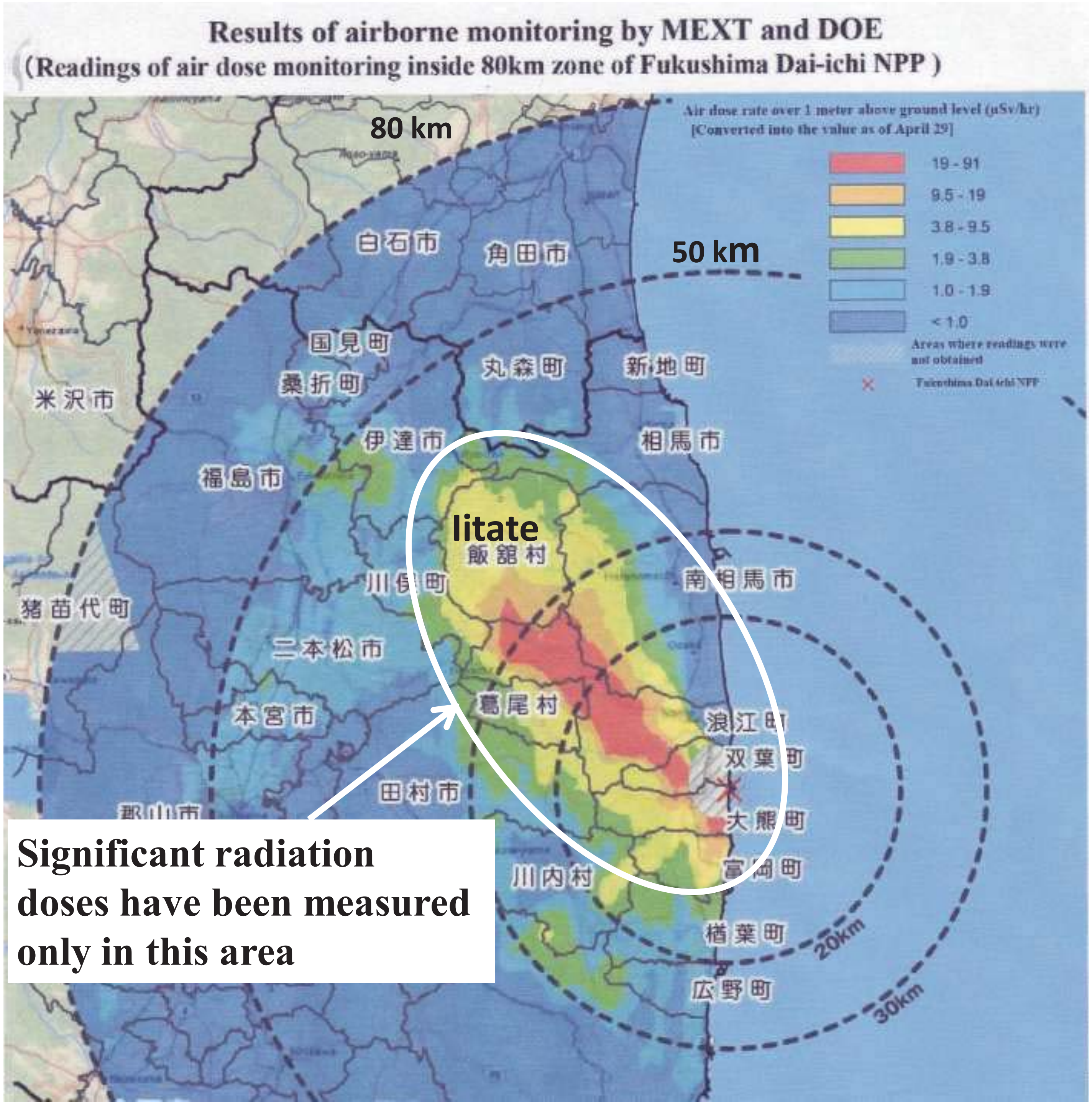
The following contamination and dose maps were obtained by aerial surveys conducted by the US National Nuclear Security Administration (NNSA), the US DoE (Department of Energy) and the Japanese Authorities.

The data indicate that significant radiation contamination has occurred mainly in a 20 km x 70 km zone located NW with respect to the Fukushima Dai-ichi NPP.

Radiologically significant dose rates have been measured only in a 20 km x 70 km zone, situated North-West from the Fukushima Dai-chi NPP

1 mR/hr = 0.01 mSv/hr



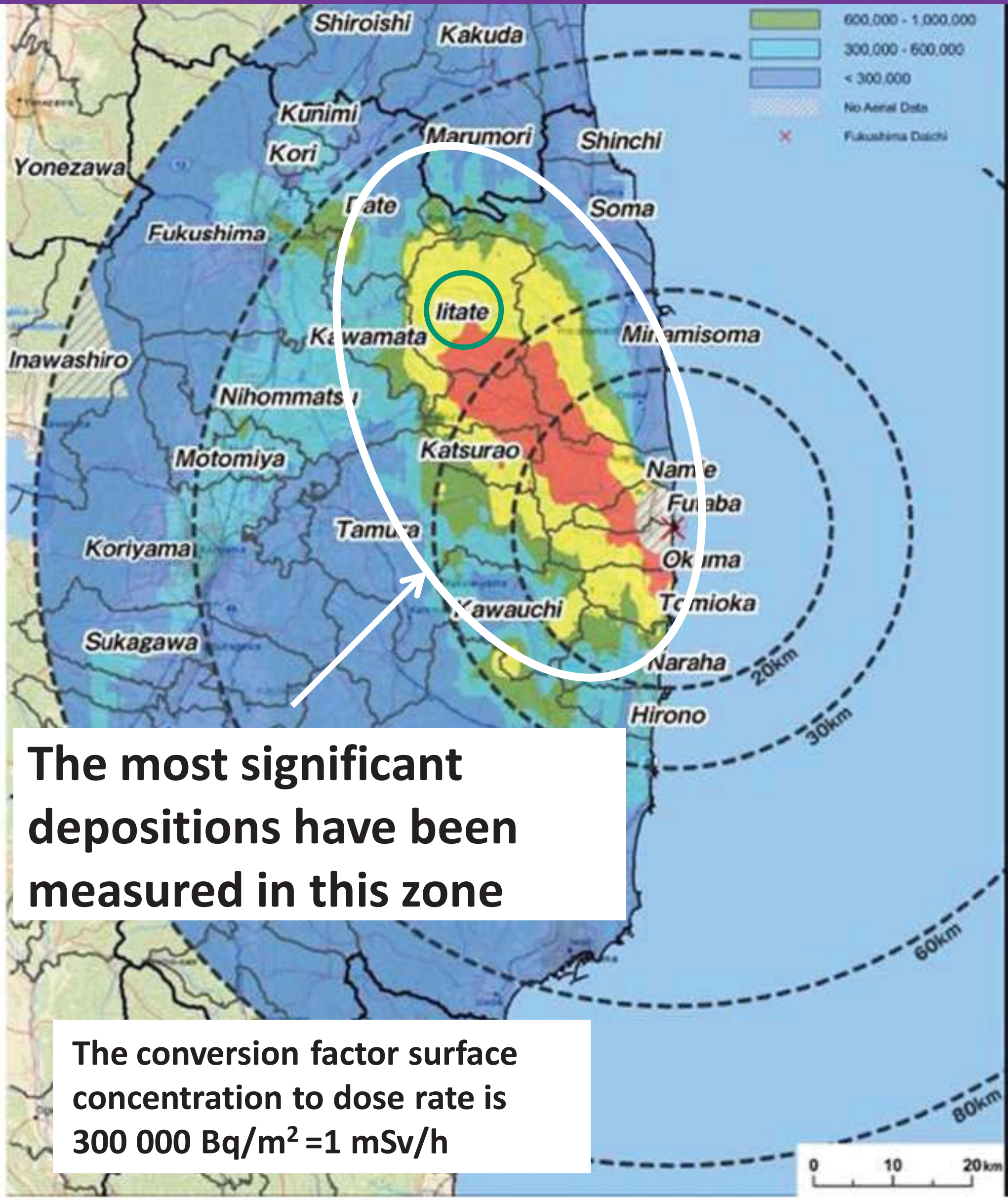


Radiation dose rates at 1 meter above ground in μSv/h normalized at 29[th] April 2011

- 19 – 91
- 9.5 – 19
- 3.8 – 9.5
- 1.9 – 3.8
- 1.0 – 1.9
- < 1.0

P.R Danesi July 2011

Deposition map of Cs-137 + Cs-134 (Japanese – USA aerial survey) with indication of the most contaminated areas



The most significant depositions have been measured in this zone

The conversion factor surface concentration to dose rate is 300 000 Bq/m² =1 mSv/h

The values represent the sum of Cs-134 and Cs-137.

Blue: deposition between 0.3 and 0.6 MBq/m²

Light blue: deposition between 0.3 and 0.6 MBq/m²

Green: deposition between 0.6 and 1 MBq/m².

Yelllow: deposition between 1 and 3 MBq/m².

Red: deposition between 3 and 30 MBq/m².

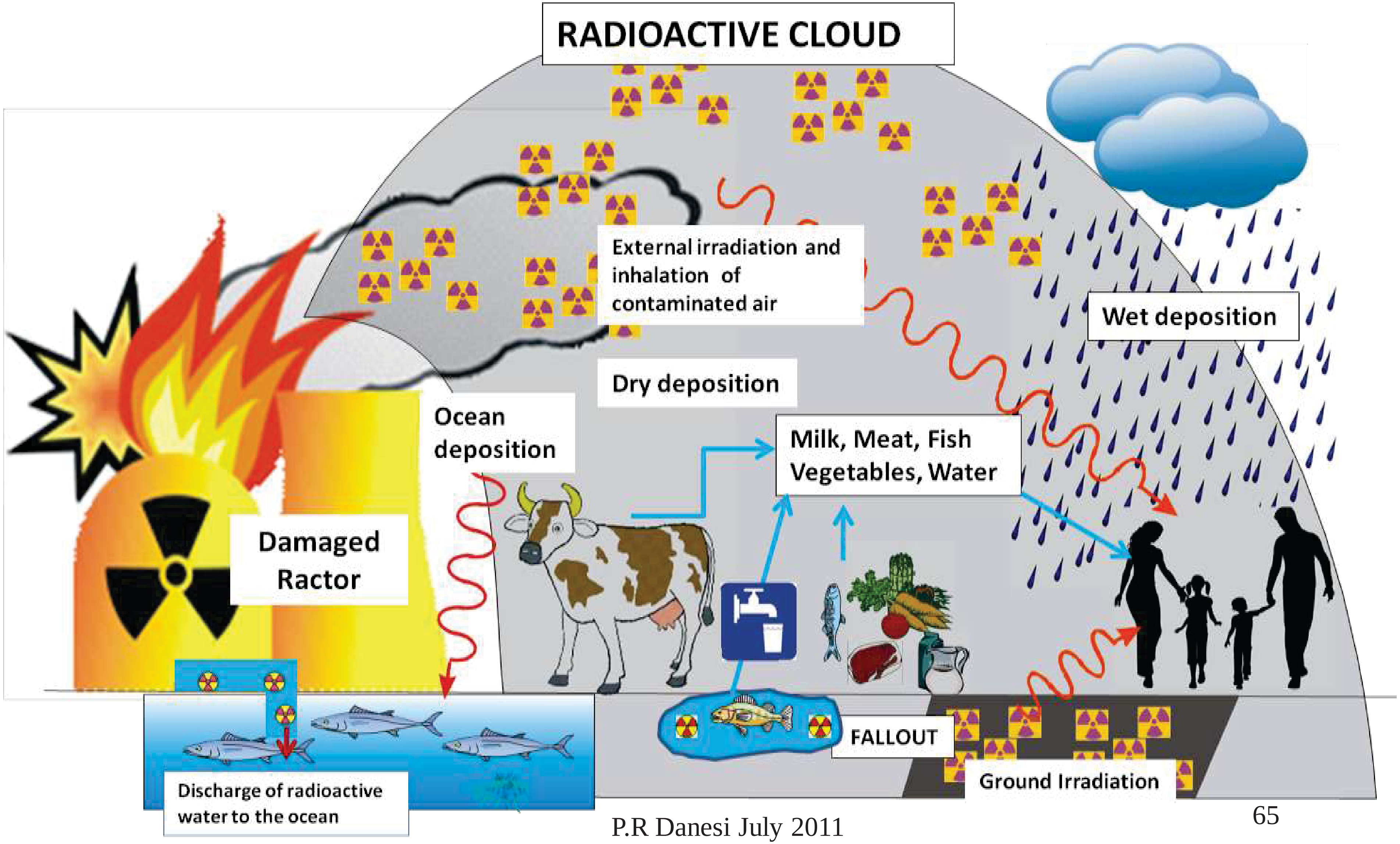
Dati normalizzati al 29 April 2011.

Deposition of radiocaesium.ppt from IAEA web-site of 20 May 2011

P.R Danesi July 2011

Fukushima Dai-chi Accident

Different irradiation paths to be considered for calculating the radiation doses received by the exposed populations



P.R Danesi July 2011

As foreseen by the emergency plan all residents of the potentially affected area were evacuated before any radiation from the damaged nuclear reactors arrived

The only exception was the 7000 inhabitants of the Itate Village zone (outside the 30 km area) evacuated on 15 May 2011

A fraction of this population (how many?) may have received a dose of about 50 mSv before being evacuated

QUESTION

May these people run the risk of developing cancers or leukemias in the future because of this dose?

Estimate of the number of lethal cancers which could occur in the Iitate population (about 7000), in addition to those expected without the nuclear accident, due to the radiation dose received by the Fukushima Dai-ichi accident

According to the LNT model (Linear-No-Threshold model) generally used in radioprotection (which according to many scientists over-estimates the risk at low radiation doses, i.e. less than about 100 mSv), the increased probability to develop a lethal cancer during the entire life is 5/100,000 = 5×10^{-5} for each mSv received.

Therefore in a population of 7000 (Iitate illage) receiving a radiation dose of 50 mSv, the number of individuals which could die from a lethal cancer in the next 20 years (assuming no additional dose is received) is 17 (different types of lethal cancer have latencies ranging from 7 to 25 years).

In a population of 7000 (such as Iitate) each year (before the Fukushima Dai-ichi accident) 18 died of "natural cancers ". Therefore the deaths caused by natural cancers foreseen in the next 20 years are 360 (18x 20)

17 additional deaths could occur due to the radiation received by the Fukushima Dai-ichi accident.

These deaths will be spread over a period of 20 years

Then in the worste case the total number of deaths by cancer could increase from 360 to 377 (+ 17), i.e. of about 4.7 %

However it is practically impossible that epidemiological studies will ever detect this increase because of annual fluctuations and statistical uncertainties

PRELIMINARY CONCLUSIONS

So far the number of deaths in the civil population due to the radiation received has been zero

Presently, the number of people that may have received significantly high radiation doses to legitimate forecasting the insurgence of lethal cancers (doses higher than 100 mSv) also appears to be zero

By arbitrarily using the Linear No-Threshold hypothesis also for people that received 50 mSv we can try to forecast the future insurgence of lethal cancers in the Iitate Village population

The number of people in the Iitate Village which could suffer from a lethal cancer in the next 20 years could increase form 360 to 377 (4.7 %), namely from an average of 64 to an average of 64.85 per year (statistically insignificant)

MAIN UNCERTAINTIES

The inhalation dose that may have been received in the period 16-17 March (plume) and the ingestion dose that may have been received by the consumption of contaminated food and water has not been yet considered

→ (higher number of lethal cancers)

The individuals affected could be less than 7000

→ (fewer lethal cancers)

The LNT (Linear No Threshold Model) largely over-estimates the effects at low doses or even does not apply at all

→ (fewer lethal cancers)

The Japanese radiometric data have not been subjected to external quality control and to an independent evaluation

The radiation doses received in Iitate in perspective

Annual natural (background) radiation doses to the inhabitants of some areas of the world and comparison with the doses which may have been received in Iitate (Japan) because of the Fukushima

Dai-ichi nuclear accident

Country	Area	Approx. population	Annual radiation exposure (mSv)
Brazil	**Guarapari**	**73 000**	**175**
Iran	**Ramsar**	**2 000**	**260**
India	**Kerala**	**100 000**	**70**
Iitate Village	***Japan***	***7000***	***50 (in 2011)***

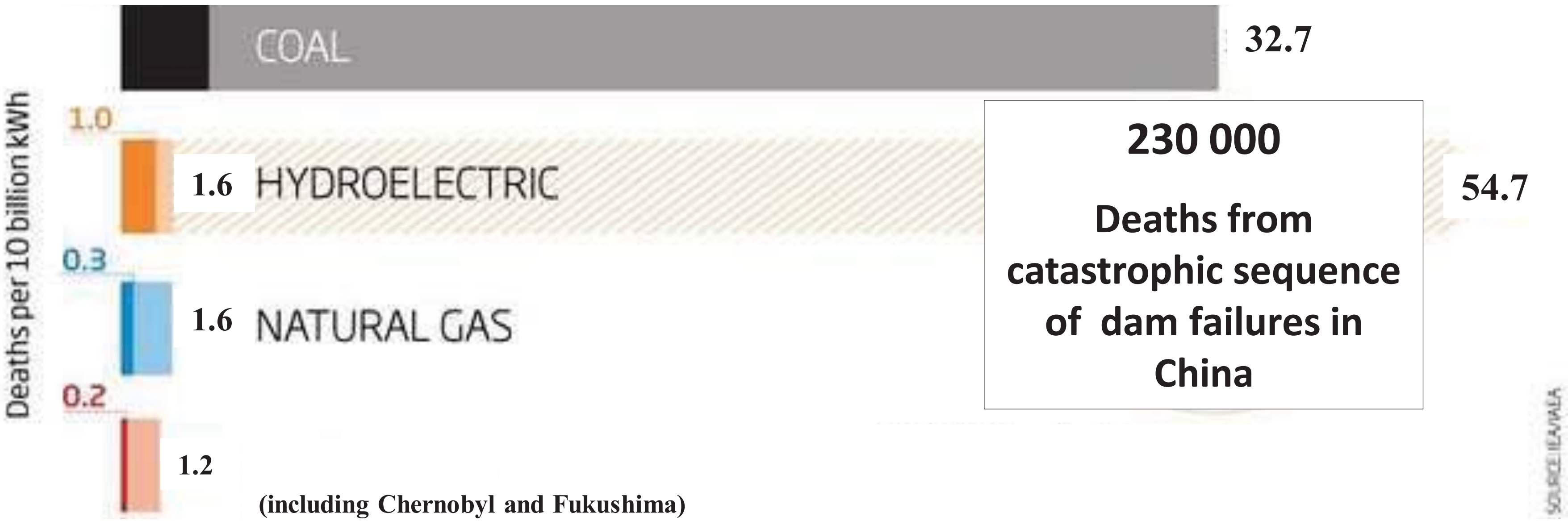
How much we die by producing energy

NewScientist Issue 2805, 23 March 2011 by P. McKenna

POWER RISK

For each unit of electricity produced, nuclear power is nowhere near as deadly as coal

The ranges for each power source indicates estimates from different studies (IEA-Paris)



The figures indicate that fossil fuels are responsible for the largest number of deaths

Estimated costs (dollars per megawatt-hour) for new energy generation (2016)

296.1 solar PV,

256.6 solar thermal,

191.1 wind offshore,

149.3 wind on land,

129.2 coal with carbon capture storage (CCS),

119.9 hydro,

119.0 nuclear,

115.7 geothermal,

113.3 natural gas with CCS,

100.4 coal conventional,

83.1 natural gas conventional.

Thank you for your attention

Any question?

For clarifications or further information you can write or phone to:

Pier Roberto Danesi

e-mail: piero@danesi.at

Tel. +43-1-7968936