ISSN 2796-9916

MEMORIA TÉCNICA ARN 2022

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Origins and Future of Radiation Protection

González, A.J.

Presentado en: Evento del FORO sobre Retos Presentes y Futuros de la Protección Radiológica y la Seguridad Nuclear, durante la 66º Conferencia General del OIEA.
Viena, Austria, el 28 de septiembre de 2022

Foro Iberoamericano de Organismos Reguladores Radiológicos y Nucleares

Evento Informativo: **25 años del Foro**

Retos Presentes y Futuros de la Protección Radiológica y la Seguridad Nuclear.

Conferencia General del OIEA, Vienna International Center, 28/9/2022

Origins and Future of Radiation Protection

Orígenes y futuro de la protección radiológica

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Content

PART 1

GENESIS

The starting point:

Discovery of

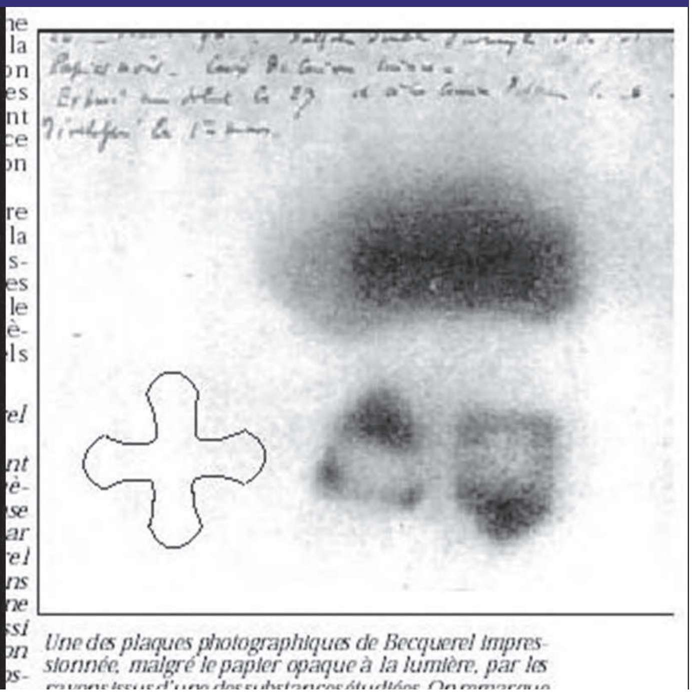
ionizing radiation

&

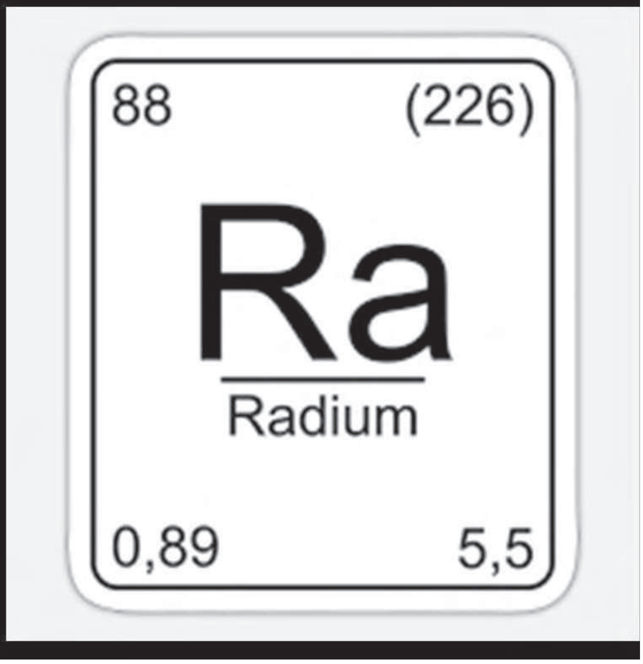
radioactivity

8 November 1895, Wilhelm Röntgen discovers “A New Kind of Rays” (Über eine neue Art von Strahlen)

February 24, 1896: Henri Becquerel discovers radioactivity



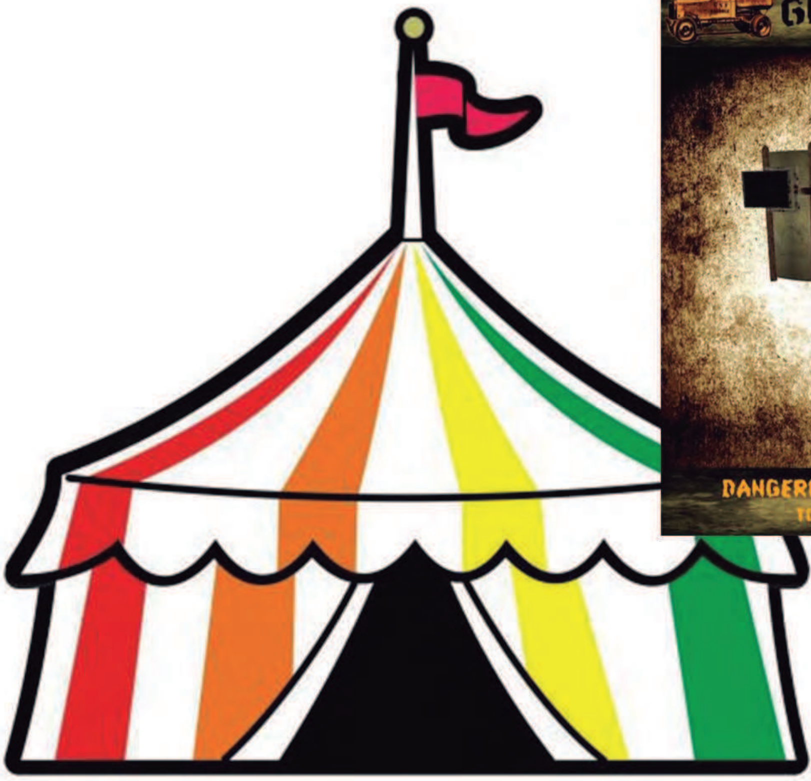
December 21, 1898, Madame Marie Skłodowska Curie discover radium



‘Magic’ phenomena

↓

Sudden increase in uses




GNF SALVAGE
DANGEROUS OLD X-RAY MACHINE
TOUCH ON/OFF SCRIPTED
MOD
COPY
TRANS


MIMI GARNEAU
Scview
www.delcampe.net


Radium Cosmetiques
NOTHING LIKE THEM IN U. S.
Face Lifting Without Plastic Surgery
Aimeray Radium Cosmetiques
507 5th Ave., New York City, N. Y.


Do You Not Know?
The Eyetome
Invented by Dr. Francis King, well-known Ocular Muscle Specialist. Is relieving all forms of Eye Troubles and doing away with glasses in great numbers of cases. Call or write 709 Grant Bldg., Los Angeles. VA. 3346.


154
MÉTHODE
THO-RADIA
EMBELLISSANTE PARCE QUE CURATIVE
DENTIFRICE
THO-RADIA
A BASE DE SELS DE THORIUM
FORMULE
du Docteur Alfred CURIE
Astringent et bactéricide, il stérilise la cavité buccale, évite et combat les gingivites, prévient la carie et les pyorrhées alvéolaires. Il assainit les dents, laisse dans la bouche une délicieuse impression de fraîcheur, conserve l'éclat, la blancheur et l'intégrité de la dentition.
Le grand tube :
6 francs
Pas de joli sourire sans de jolies dents
CHEZ LES PHARMACIENS EXCLUSIVEMENT

RADIUM THERAPY

The only scientific apparatus for the preparation of radio-active water in the hospital or in the patient's own home.

This apparatus gives a high and measured dosage of radio-active drinking water for the treatment of gout, rheumatism, arthritis, neuralgia, sciatica, tabes dorsalis, catarrh of the antrum and frontal sinus, arterio-sclerosis, diabetes and glycosuria, and nephritis, as described in Dr. Saubermann's lecture before the Roentgen Society, printed in this number of the "Archives."

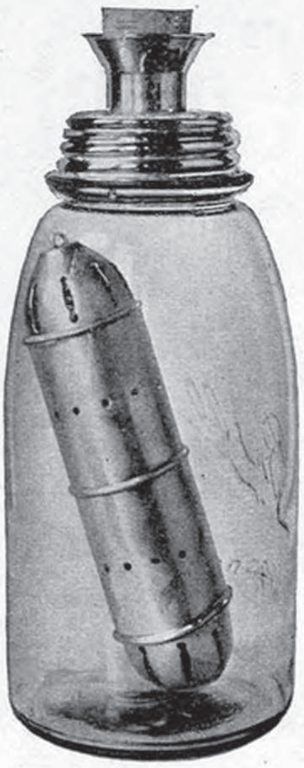
DESCRIPTION.

The perforated earthenware "activator" in the glass jar contains an insoluble preparation impregnated with radium. It continuously emits radium emanation at a fixed rate, and keeps the water in the jar always charged to a fixed and measureable strength, from 5,000 to 10,000 Maché units per litre per diem.

SUPPLIED BY

RADIUM LIMITED,

93, MORTIMER STREET, LONDON, W.



RADIUM
EMANATION WATER
Drives Out Uric Acid

Suffering from too much uric acid and diseases caused by faulty elimination—**Rheumatism, Gout, Periodical Headaches, Neuralgia, Constipation, Neurasthenia, Auto-Intoxication and Lack of Bodily Vigor**—quickly relieved in a natural way without drugs or chemicals by our new discovery

THE WAY TO MAKE RADIUM WATER IN YOUR OWN HOME

with our Rayode. A little device containing Radium enough to supply 2,700 Mache Units of Radio-activity, in two quarts of water every twenty-four hours, for less than 10c a day. The Rayode will last a lifetime.

SEND FOR FREE LITERATURE

Tells how you can buy or rent a Rayode to make Radium Water in your own home, with your own ordinary drinking water. Address:

THE COLORADO RADIUM PRODUCTS COMPANY

635 First National Bank Building Denver, Colo

Radium fountain in Bad Elster (1924)

All these uses should certainly have generated a lot of harm,….

…particularly, among the workers producing such products

Radiation protection was not there!

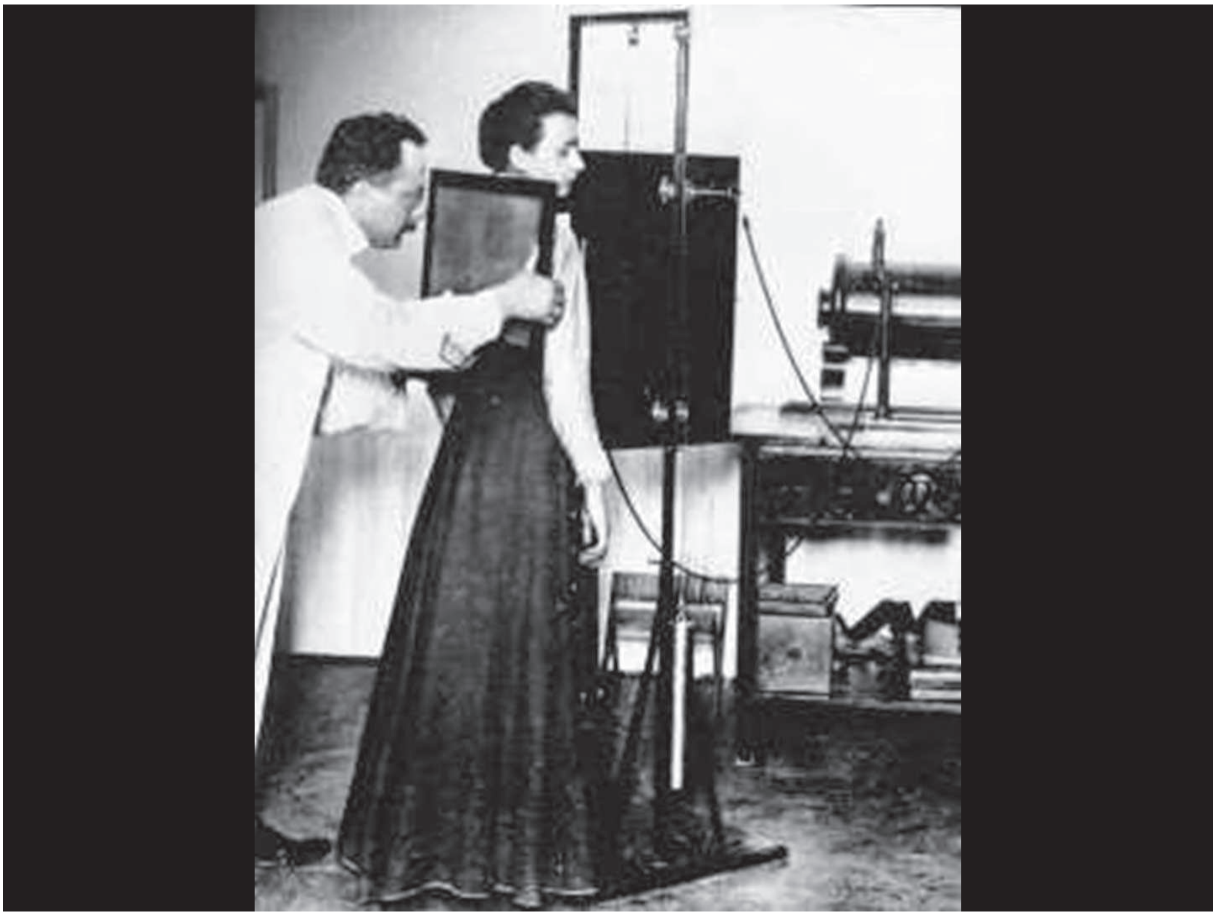
The 'radium girls'

Female factory workers who suffered serious radiation effects from painting watch dials with self-luminous paint at three different factories in USA 1917 - 1920s.

Concern for protection finally aroused from the newly created profession of

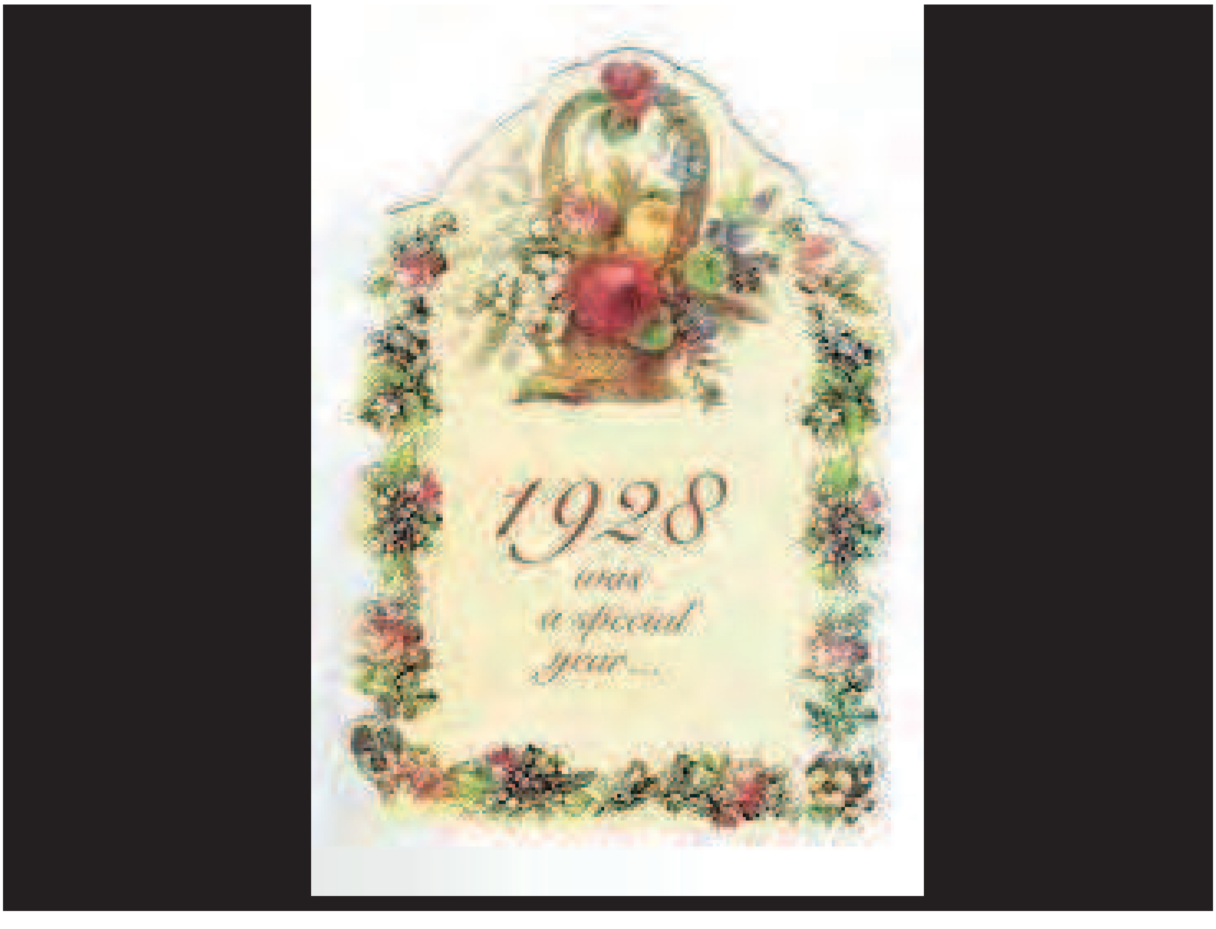
radiologists!


RONTGEN X-RAY LABORATORY
MEDICO-CHIRURGICAL-COLL. HOSP.




Day 9
Day 11
Day 16
Day 24

Radiation harm was obvious and radiologist become concerned for themselves



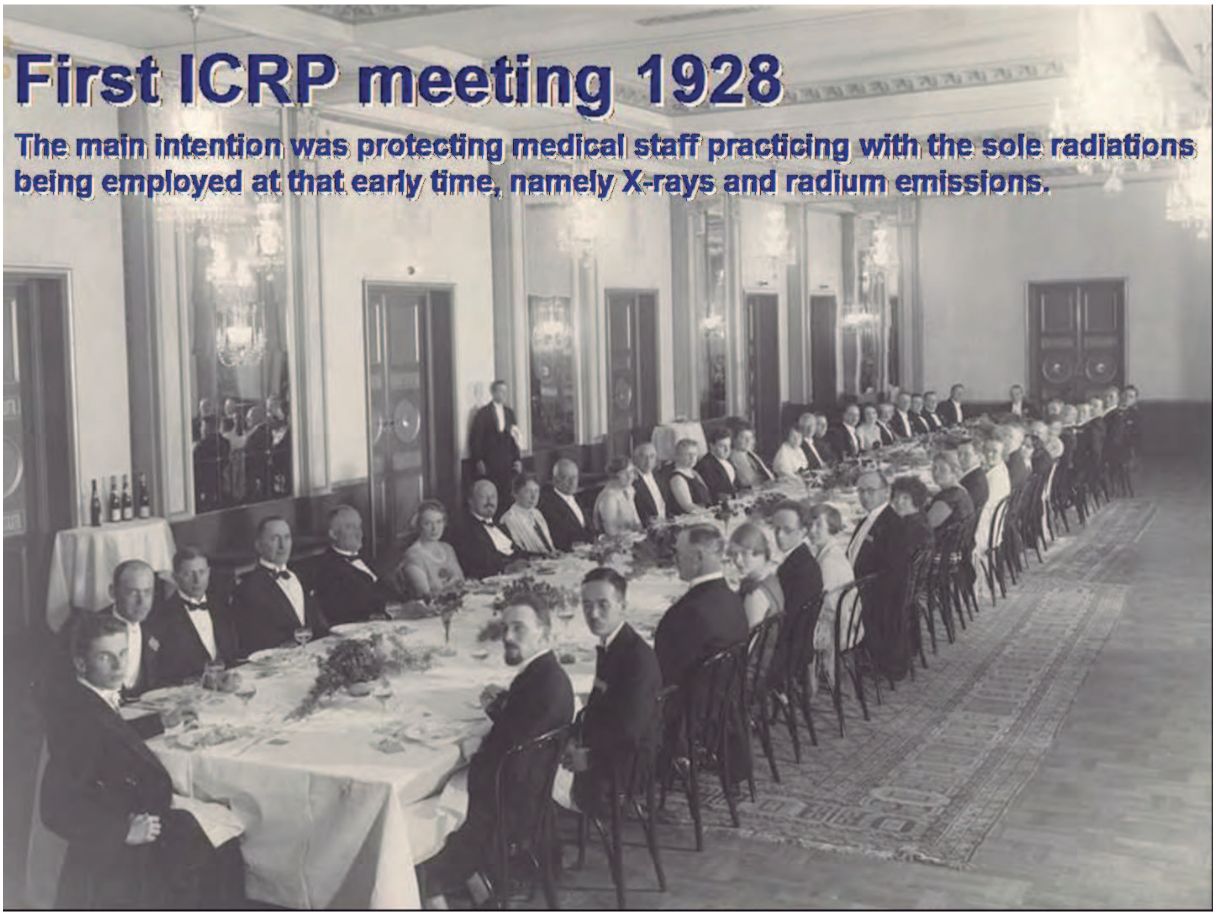
During the Second Congress of Radiology, in Stockholm, in 1928, radiologists created a Committee to produce recommendations for protecting themselves

They established the
International X-ray and Radium Protection Committee

Main motivation?...
occupational radiation protection (of radiologists)

ICRP

28 September, 2022



INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

on the proposal of the Radio-Physics Section adopted by the Second International Congress of Radiology in Stockholm, July 27th, 1928

Main recommendations

- Adequate protection and suitable working conditions should be provided!
- Those in charge of X ray and radium departments should ensure such conditions for their personnel.

The recommendations also reflected the wide ignorance at the time

- ‘All rooms should be provided with:
  - windows affording good natural lighting and ready facilities for admitting sunshine and fresh air whenever possible!
  - adequate exhaust ventilation capable of renewing the air of the room not less than 10 times an hour!
  - air inlets and outlets arranged to afford cross-wise ventilation’!
- ‘All rooms should preferably be decorated in light colours’!

Thus…in its genesis…

1. ..'radiation protection' was created for ***occupational protection*** purposes only, and..
2. …for the '***practices***' of ***radiology*** & ***radium-therapy***.

   (the term '*practice*' will become applied to any endeavour, and would evolve to the concept of '*planned exposure situations*')
3. Background natural radiation was ignored

PART 2

EVOLUTION

Governmental regulation:

The initial event

1937

First legislation establishing governmental regulation for radiation protection….

….was established in Iberoamerica!...

…precisely, in Uruguay!

Law No. 9744 of Uruguay

- **Promulgation: 12/17/1937**
- **National Registry of Laws and Decrees:**

  Volume 1; Year: 1937; Page: 894

1937 Law No. 9744 of Uruguay

- **Article 3**

The Executive, through the Ministry of Public Health, will designate a Commission to study and regulate the protection and safety conditions of the personnel who handle X-rays and Radium, ….as well as the prophylaxis measures to avoid the professional injuries.

1955-1960

The momentous lustrum!

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

was established by the General Assembly of the United Nations

UNSCEAR's functions

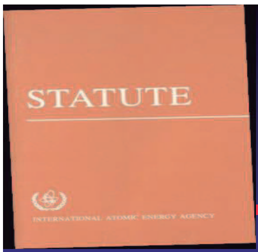
Provides a scientific

international consensus on

the levels of ionizing radiation,

and their health effects

IAEA



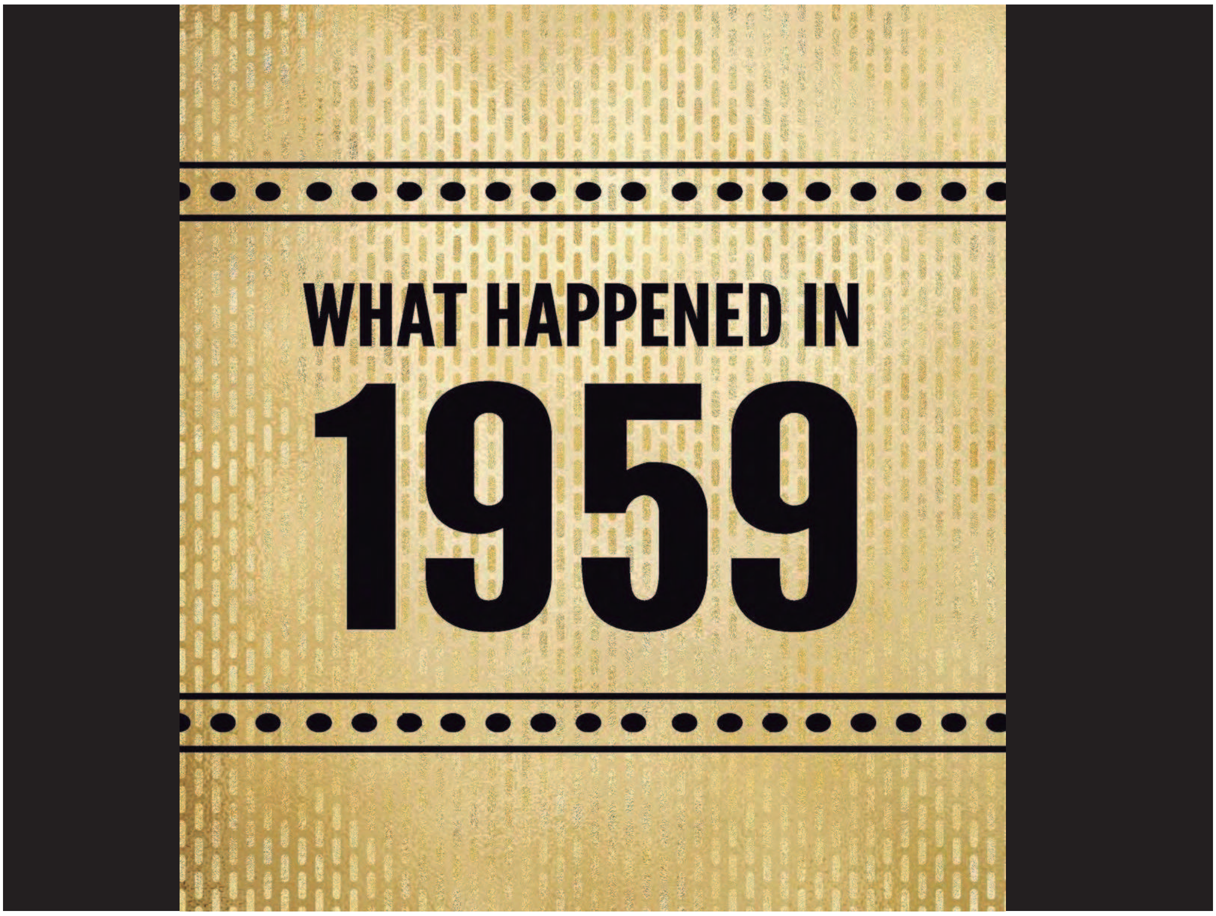
IAEA Statutory Functions

Under Article III.A.6 of its Statute, it is authorized:

"To establish…standards of safety for protection of health…and to provide for the application of these standards,

at the request of a State, to any of that State's activities in the field of atomic energy."

(in collaboration with the competent organs of the United Nations and with the specialized agencies concerned)

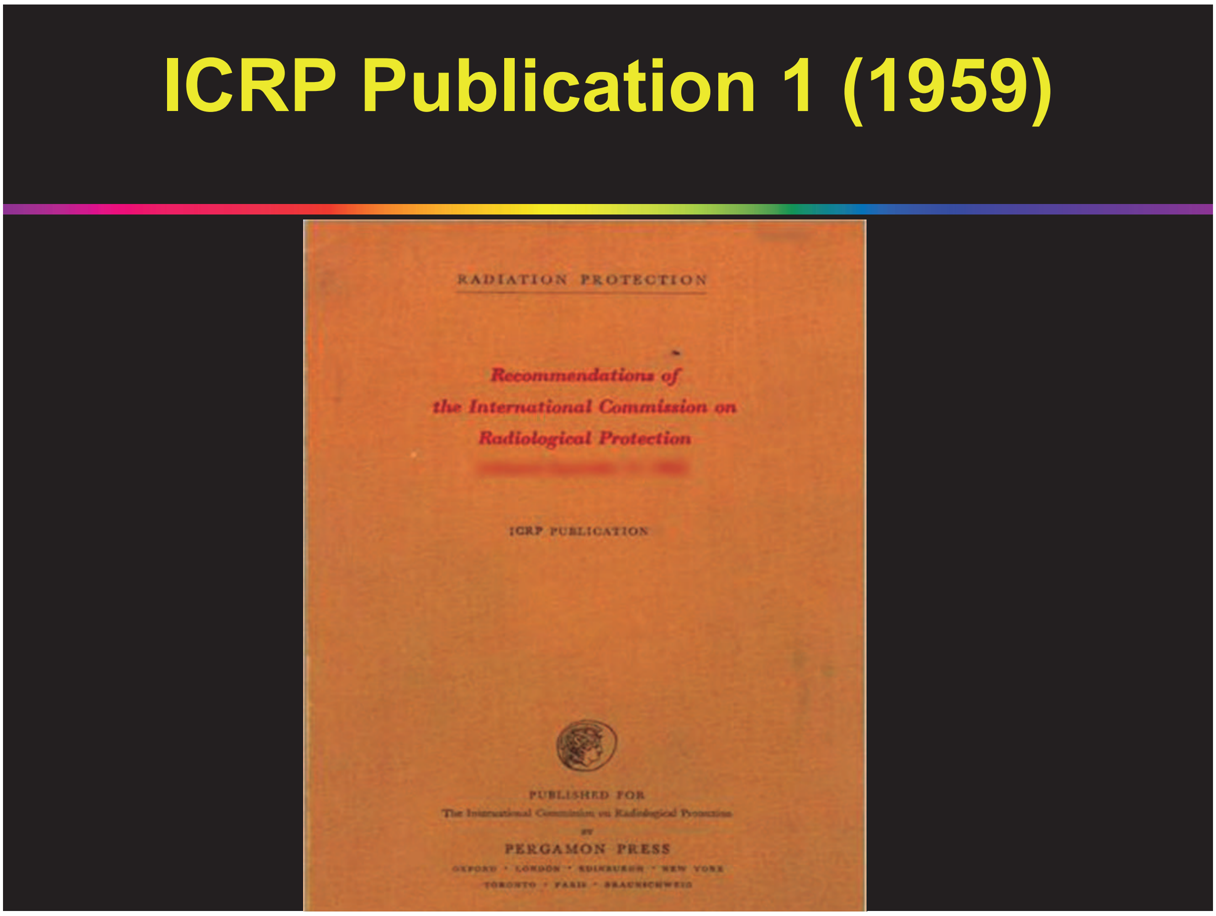


ICRP

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

First recommendations of ICRP,

following a restructure in its current form



1960:International Labour Organization adopts the *Radiation Protection Convention*

First international Legally Binding Obligation

Each Member of ILO which ratifies the Convention undertakes to give effect thereto by means of

- laws or regulations,
- codes of practice or
- other appropriate means.

ILO Radiation Protection Convention No. 115 (1960)
Date of entry into force: 17.6.1962
Ratifications:

- Argentina 15.6.1978
- Azerbaijan 19.5.1992
- Barbados 8.5.1967
- Belarus 26.2.1968
- Belgium2.7.1965
- Beliz 15.12.1983
- Brazil 5.9.1966
- Chile 14.10.1994
- Czech Rep. 1.1.1993
- Denmark 7.2.1974
- Djibouti 3.8.1978
- Ecuador 9.3.1970
- Egypt 18.3.1964
- Finland 16.10.1978
- France 18.11.1971
- Germany 26.9.1973
- Ghana 7.11.1961
- Greece 4.6.1982
- Guinea 12.12.1966
- Guyana 8.6.1966
- Hungary 8.6.1968
- India 17.11.1975
- Iraq 26.10.1962
- Italy 5.5.1971
- Japan 31.7.1973
- Kyrgyzstan 31.3.1992
- Latvia 8.3.1993
- Lebanon 6.12.1977
- Luxembourg 8.4.2008
- Mexico 19.10.1983
- Netherlands 29.11.1966
- Nicaragua 1.10.1981
- Norway 17.6.1961
- Paraguay 10.7.1967
- Poland 23.12.1964
- Portugal 17.3.1994
- Russian Fed. 22.9.1967
- Slovakia 1.1.1993
- Spain 17.7.1962
- Sri Lanka 18.6.1986
- Sweden 12.4.1961
- Switzerland 29.5.1963
- Syrian A. R. 15.1.1964
- Tajikistan 26.11.1993
- Turkey 15.11.1968
- Ukraine 19.6.1968
- U.K. 9.3.1962
- Uruguay 22.9.1992

PART 3

FOLLOW UP

ACHIEVEMENTS

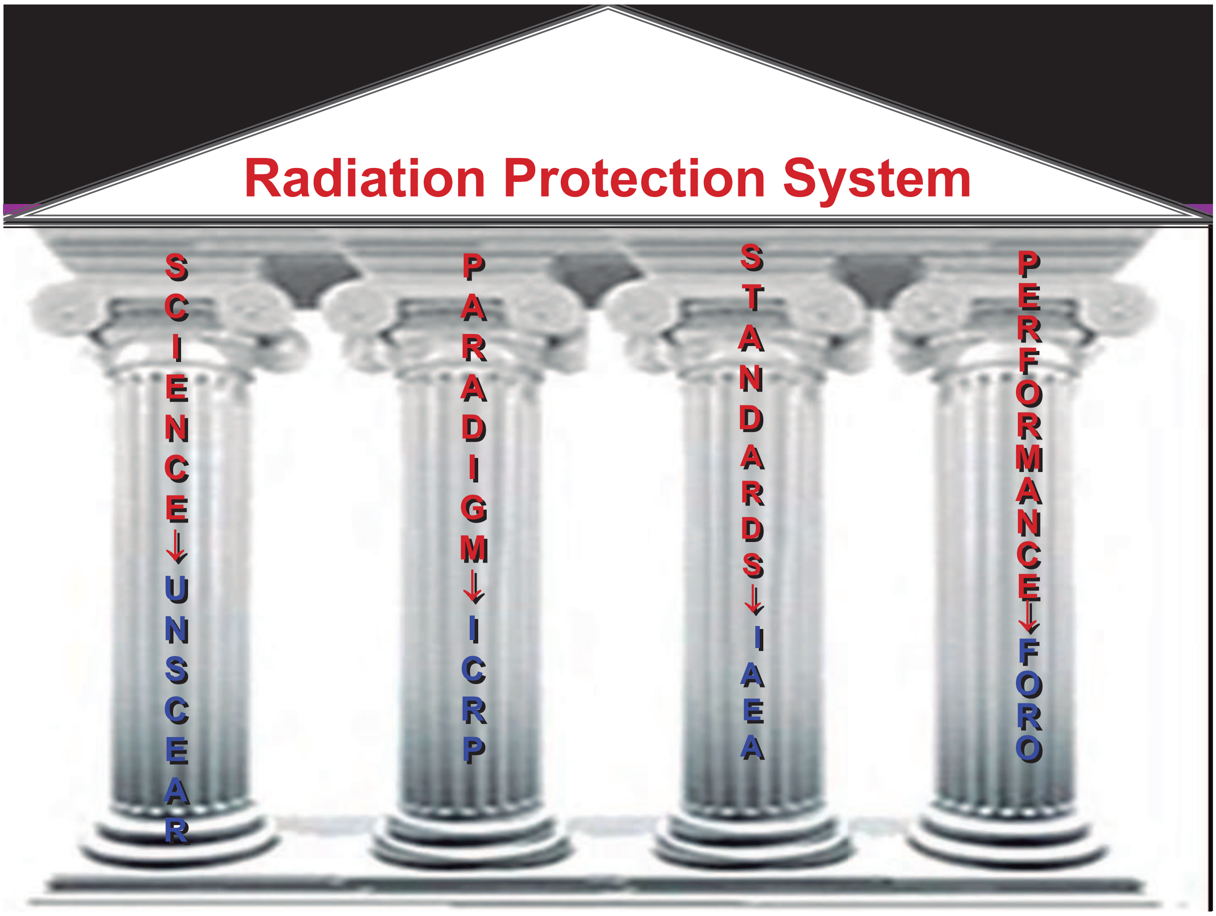
There was a intensive follow up and a unique achievement

An International and

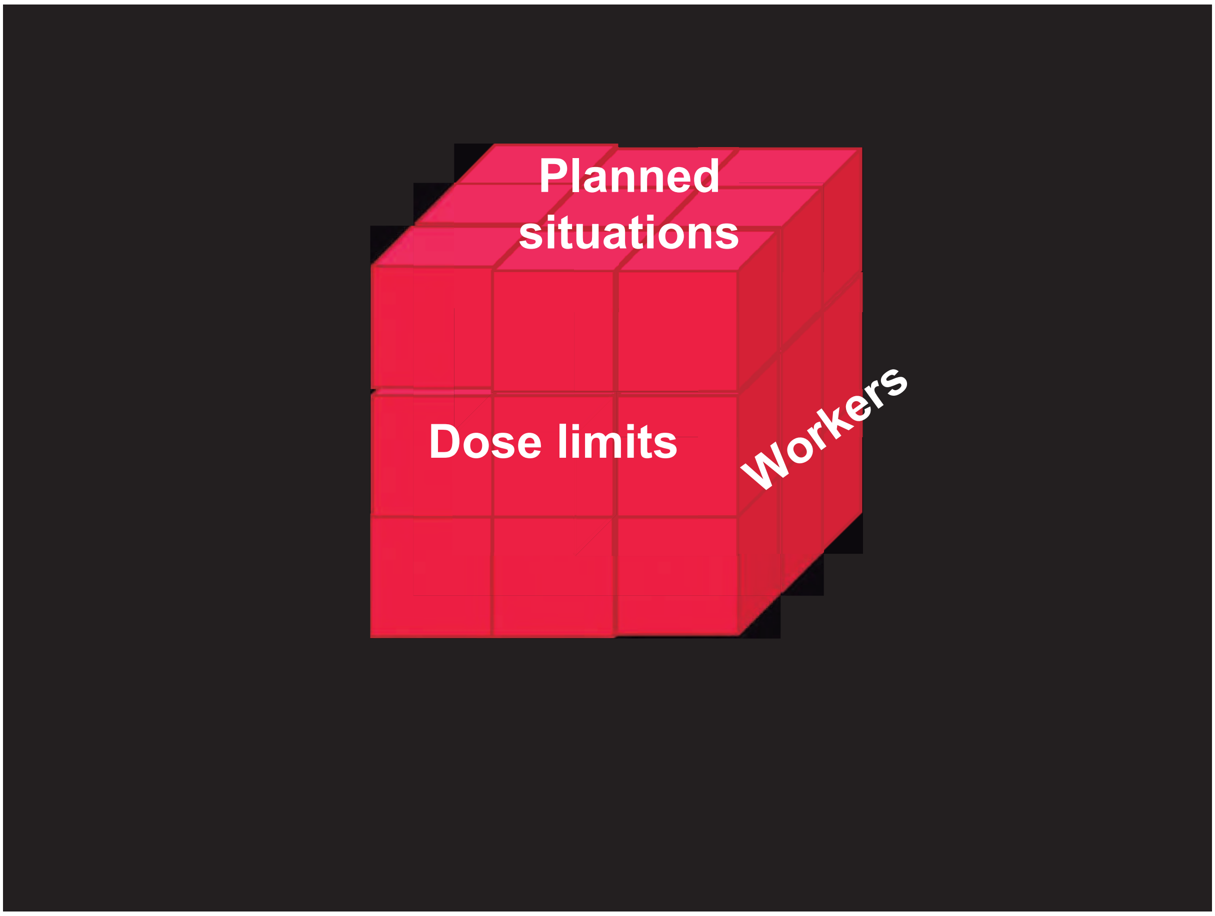
Intergovernmental Regime of

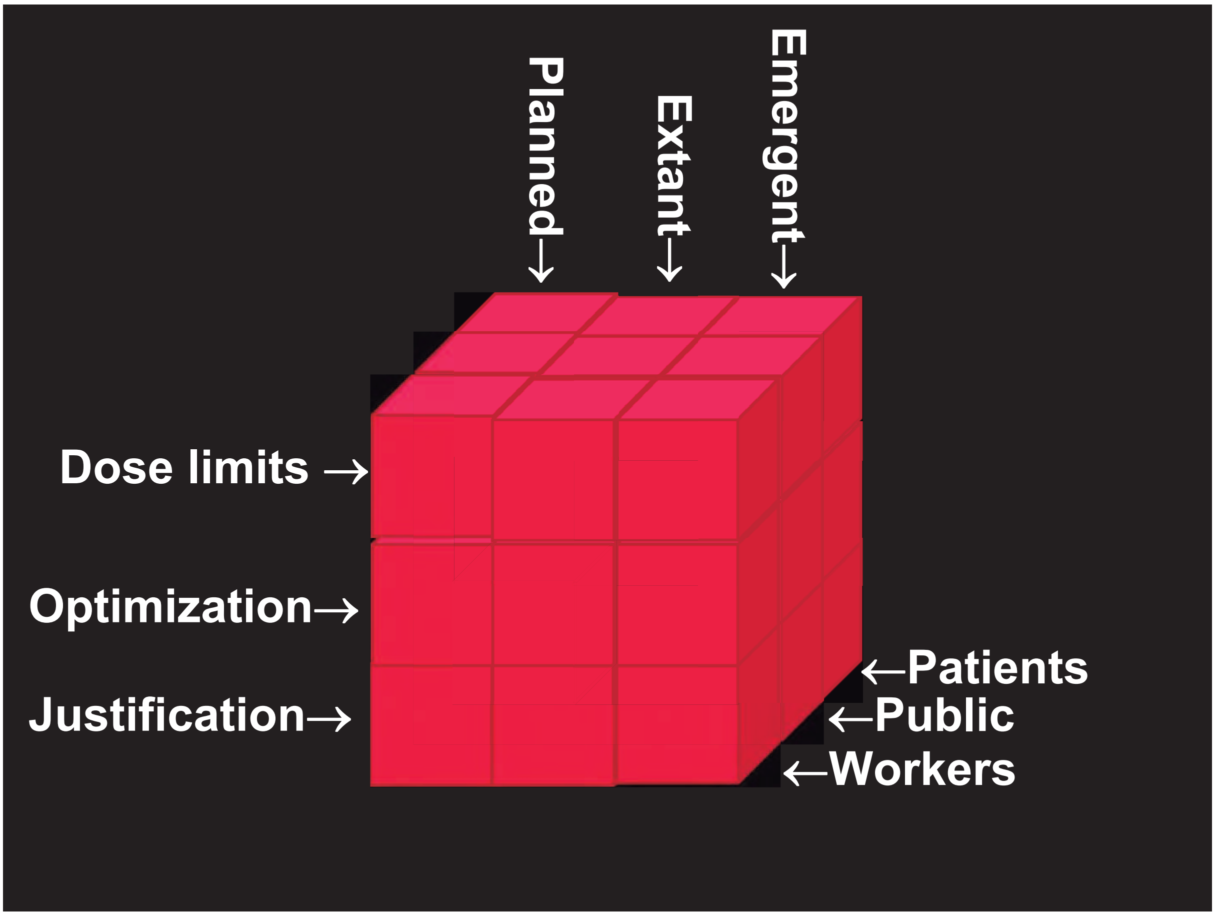
Radiation Protection


Radiation Protection System
SCIENCE
PARADIGM
STANDARDS
PERFORMANCE


Radiation Protection System
SCIENCE↓UNSCEAR
PARADIGM↓ICRP
STANDARDS↓IAEA
PERFORMANCE↓FORO


Radiation Protection System
UNSCEAR
ICRP
IAEA
FORO


Planned situations
Dose limits
Workers



PART 4

CHALLENGES

The system presents many challenges

- Some of these challenges are particularly important for Iberoamerican countries.
- They could be addressed by the FORO
- Hereinafter, few examples are presented

First challenge

What is the precise meaning of *occupational exposure*?

BSS 105

- All exposures of workers incurred in the course of their work, with the exception of exposures excluded from the Standards and exposures from practices or sources exempted by the Standards.

ICRP 103

- All exposure incurred by workers in the course of their work, with the exception of:
  - excluded exposures and exposures from exempt activities involving radiation or exempt sources;
  - any medical exposure; and
  - the *normal local* natural background radiation.

IAEA Glossary

- All exposure of workers incurred in the course of their work, with the *exception* of *excluded exposures* and *exposures* from exempt *practices* or *exempt sources*.

New BSS

- Exposure of workers incurred in the course of their work.

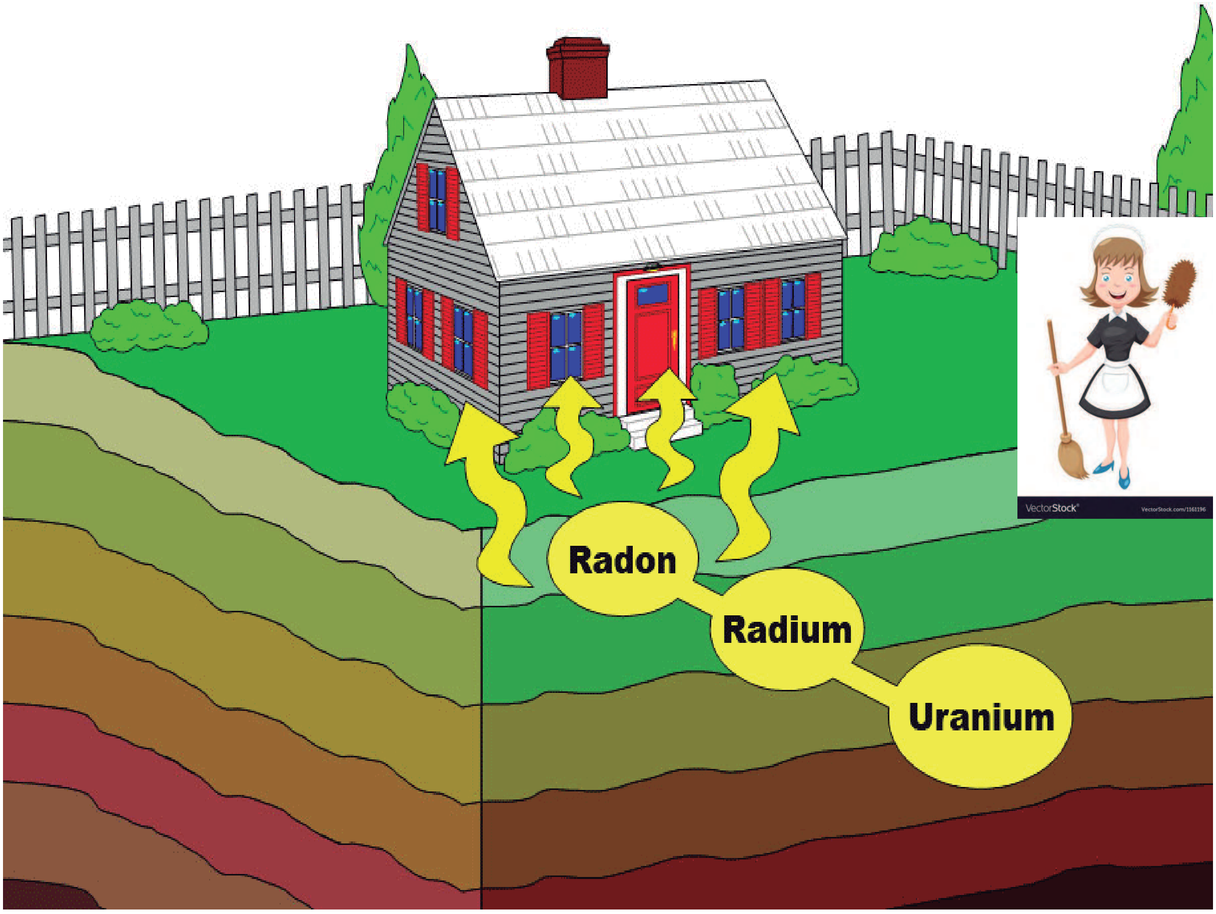
New EC Directives

- Exposure of workers, apprentices and students, incurred in the course of their work.

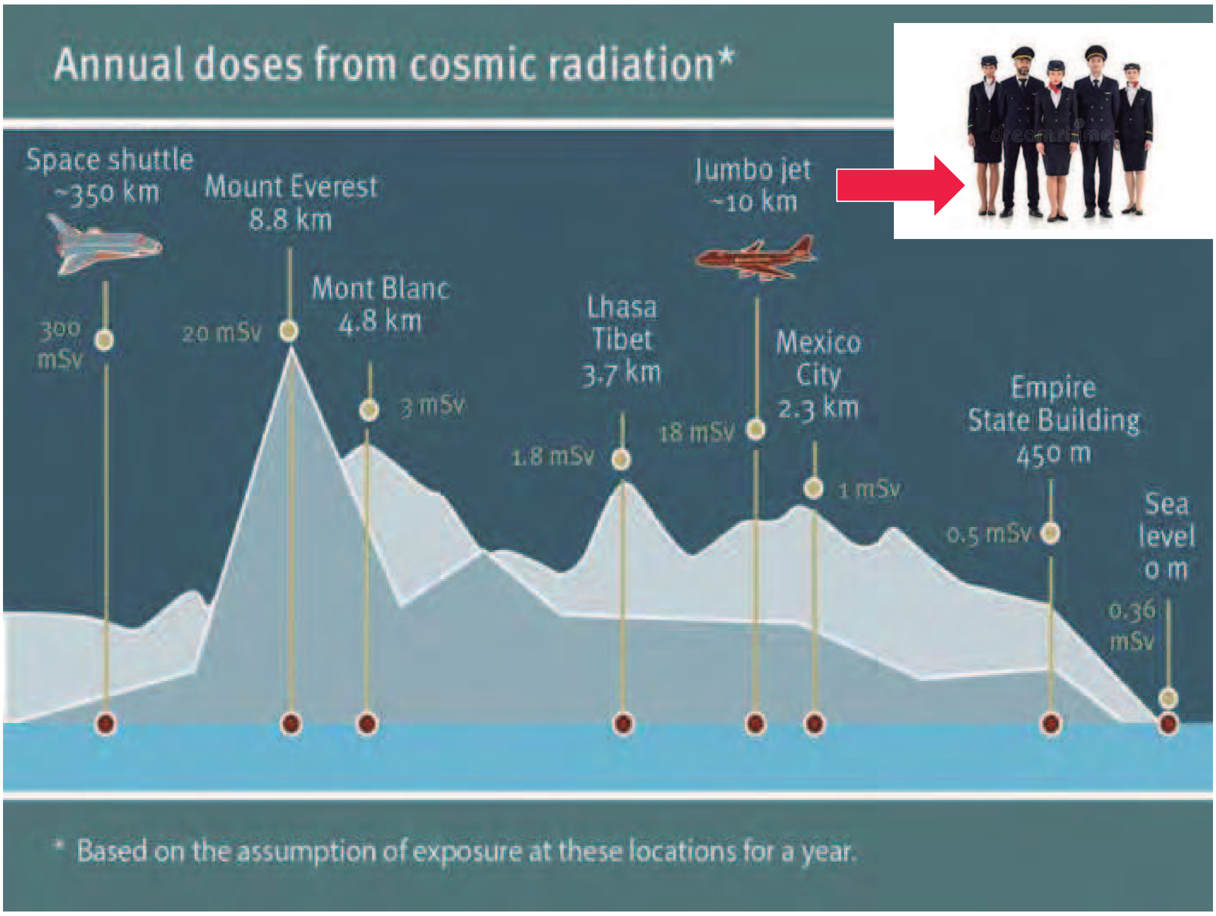
ILO Convention

- *'…applies to all activities involving exposure of workers to ionising radiations in the course of their work.'*

Is it applicable to a ‘worker’ living in a low background area but employed in a working place located in a high background area?



Is it applicable to aircrews?



Is it applicable to spas workers?

Why is this relevant for the FORO?

Because in Iberoamerica there are many areas with high background levels!

Second challenge

Should the proven chances of incurring radiation health effects be equated to conjectures of potential effects?

SOURCES, EFFECTS AND RISKS OF IONIZING RADIATION

United Nations Scientific Committee on the Effects of Atomic Radiation

UNSCEAR 2012
Report to the General Assembly
with Scientific Annexes

ANNEX A

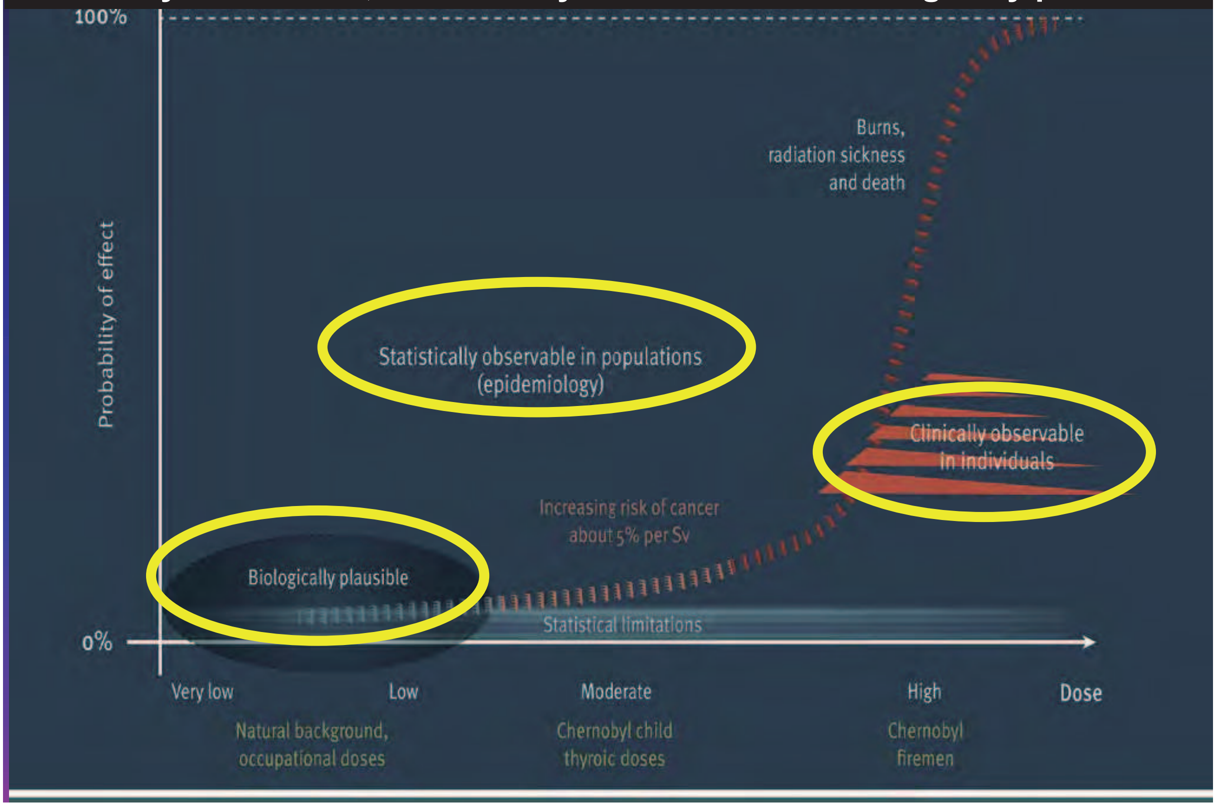
ATTRIBUTING HEALTH EFFECTS TO IONIZING RADIATION EXPOSURE AND INFERRING RISKS

How radiation effects are distinguished?

71

A clear distinction between effects:

clinically observable, statistically observable and biologically plausible



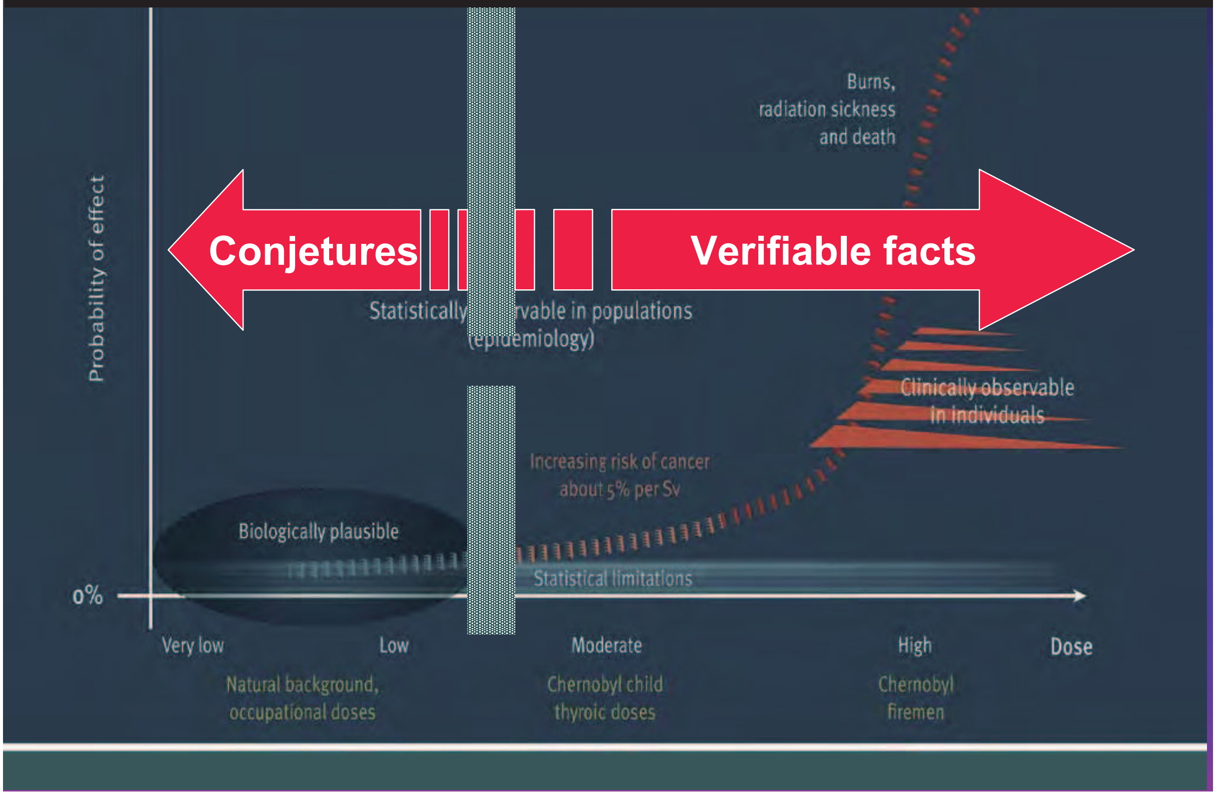
objective verifiable facts

vis-à-vis

subjective conjectures

73

At high doses the effects are verifiable facts, but at low doses they are subjective conjectures



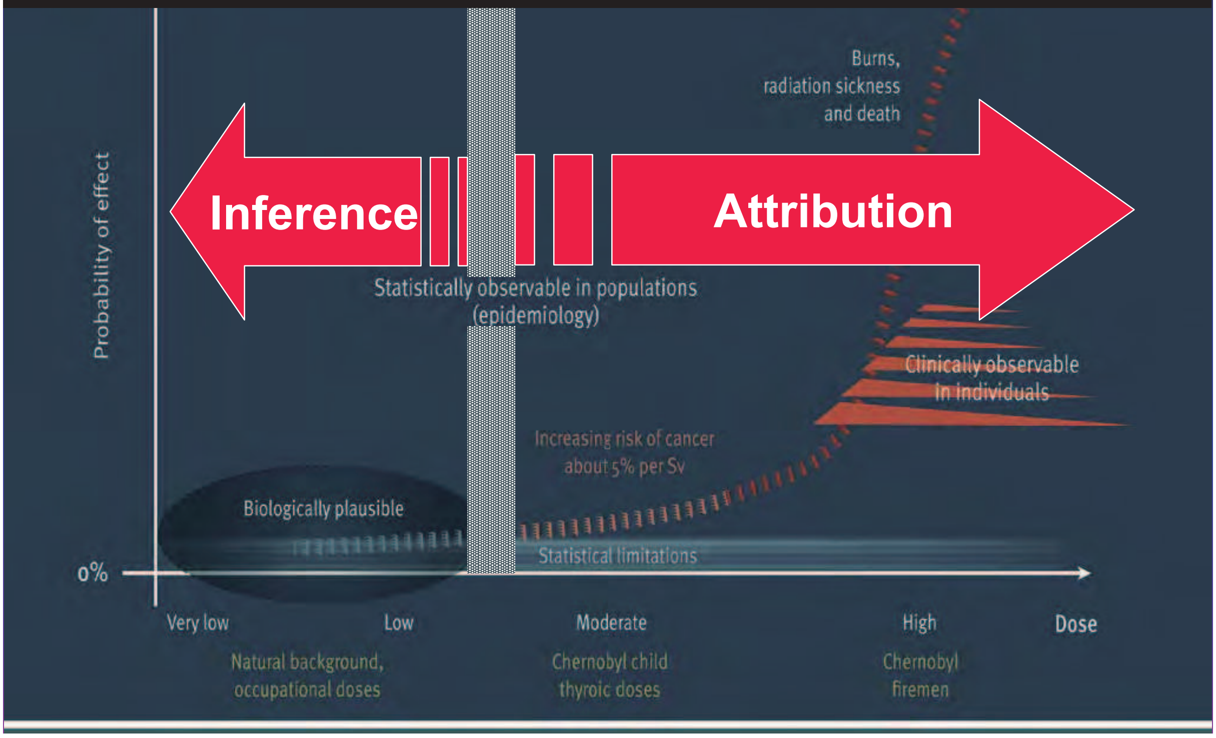
Attribution

vis-à-vis

inference

75

At high doses the effects are *attributable* to the exposure, but at low doses there is just a subjective *inference* of radiation risk



The fundamental epistemological issue is the following:

5%/Sievert = 0.005%/milliSievert,

mathematically….

….but….

…conceptually…

5%/Sievert ≠ 0.005%/milliSievert

77

IAEA | Preprint Repository

Preprint

Attribution of Radiation Health Effects and Inference of Radiation Risks: Consideration for Application of the IAEA Safety Standards

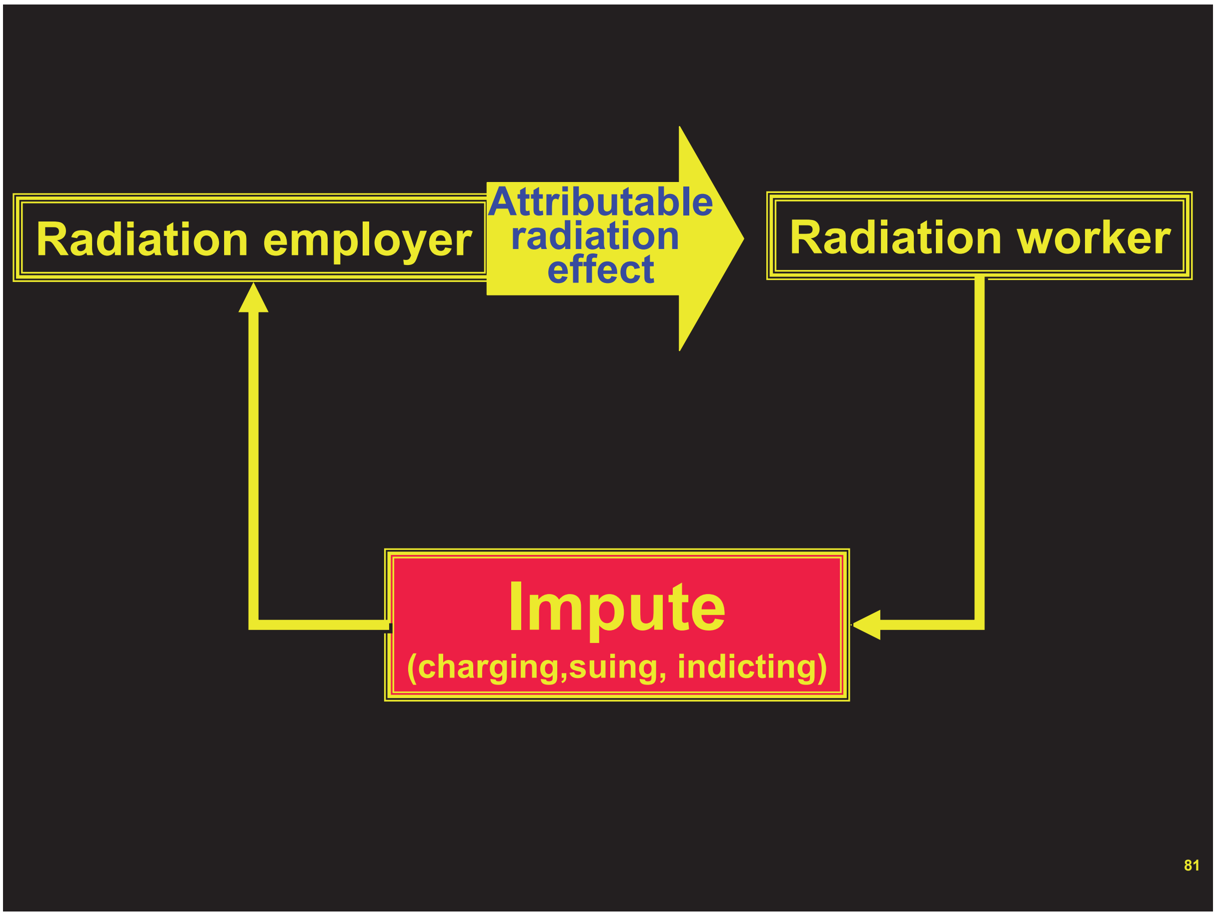
Third challenge

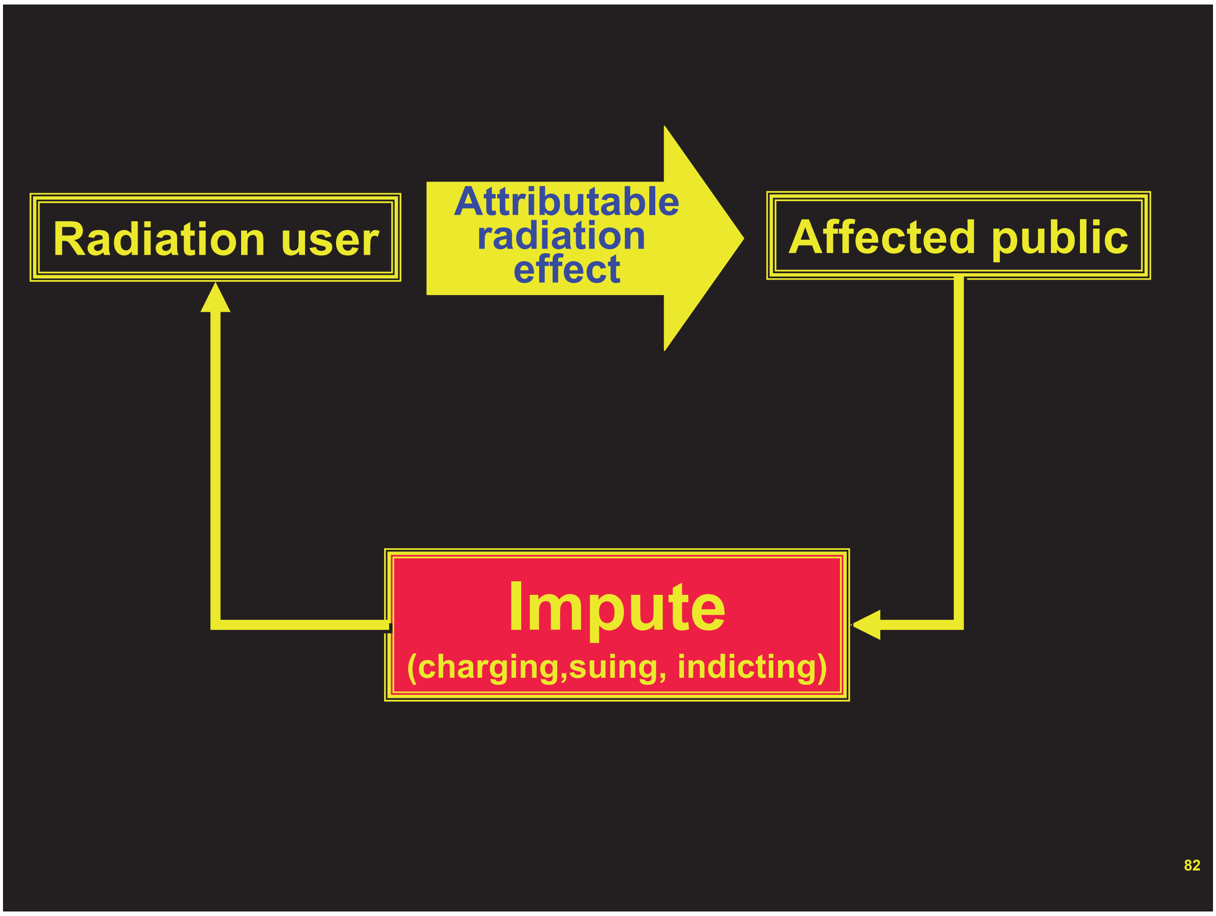
Legal imputation of occupational harm

Imputation

Actions based on law for assigning radiation harm to employers responsible of radiation exposure situations.

Precursor of the derivative concepts of *charging,suing, indicting, prosecuting* and *judging*


Radiation employer
Attributable radiation effect
Radiation worker
Impute
(charging,suing, indicting)
81


Radiation user
Attributable radiation effect
Affected public
Impute
(charging,suing, indicting)
82

Expert witness

Who are the experts who may attest?:

- Pathologists
- Epidemiologists
- Radioprotectionists

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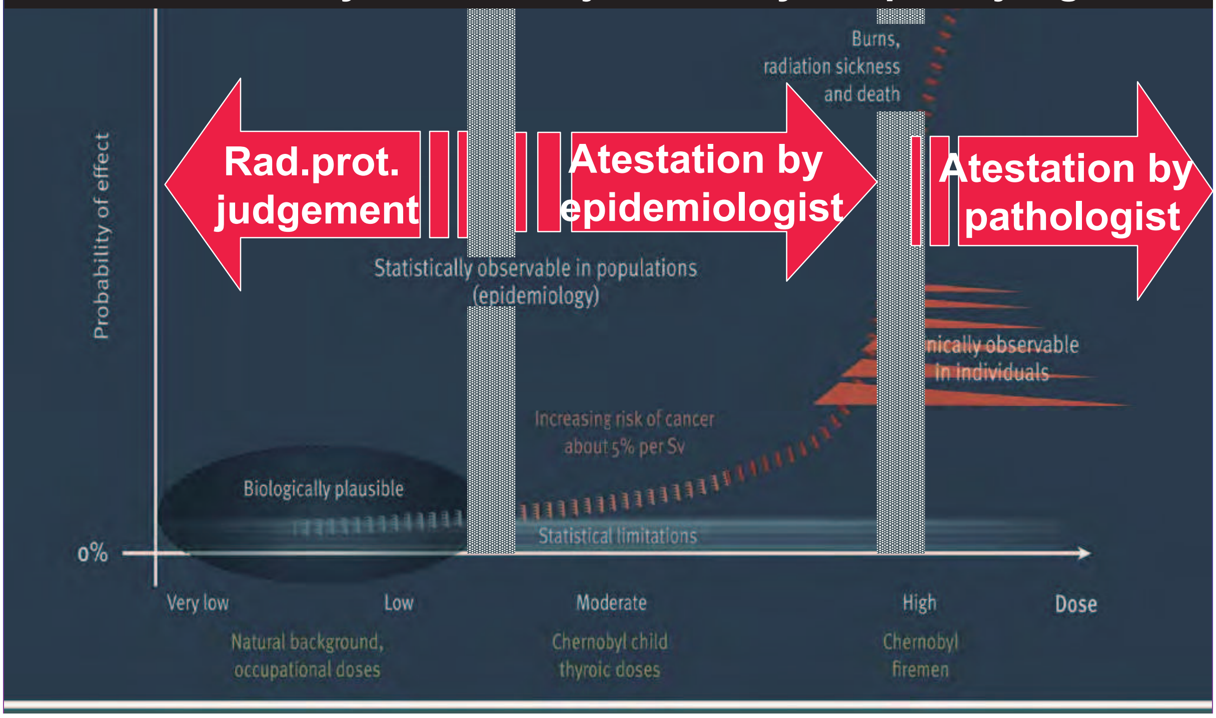
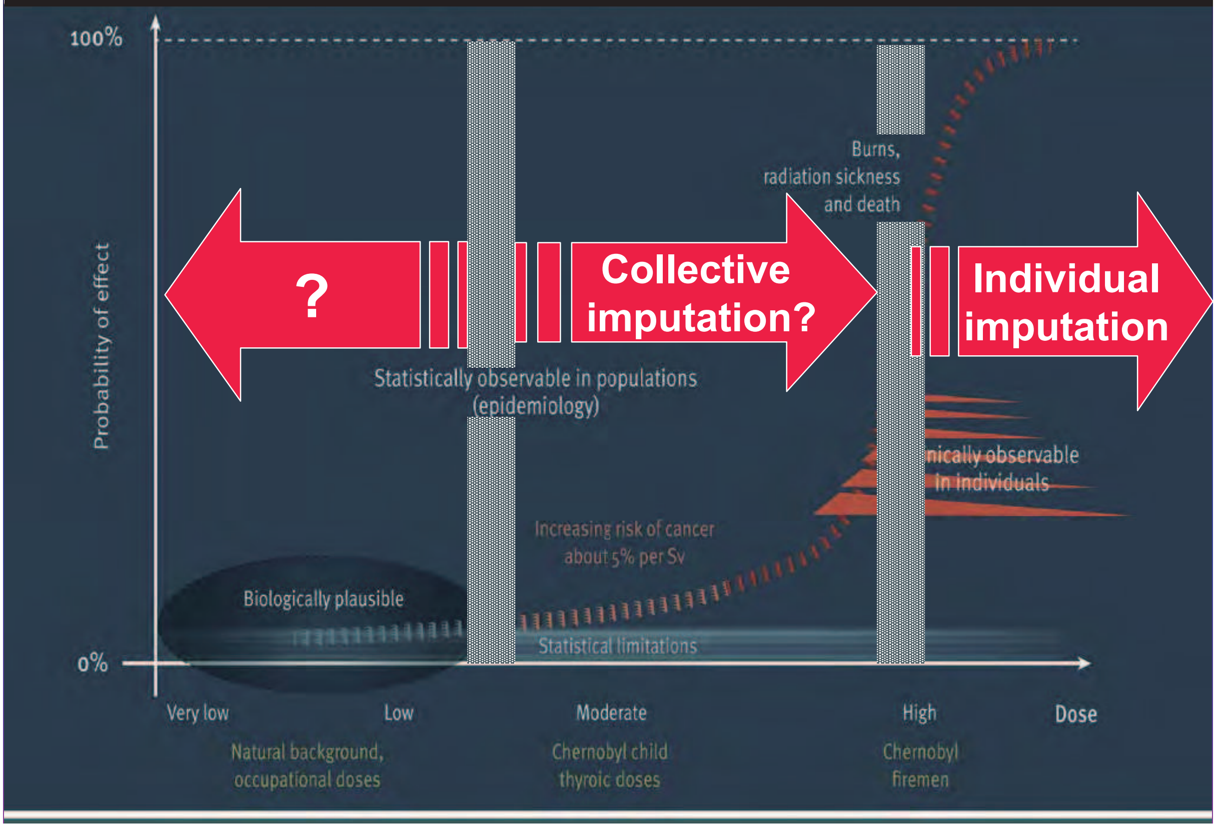
At high doses individual effects can be attested by pathologists, at moderate doses collective effects can be attested by epidemiologists, at low doses risks can not be attested but they can be conjectured by rad.prot.' judgment

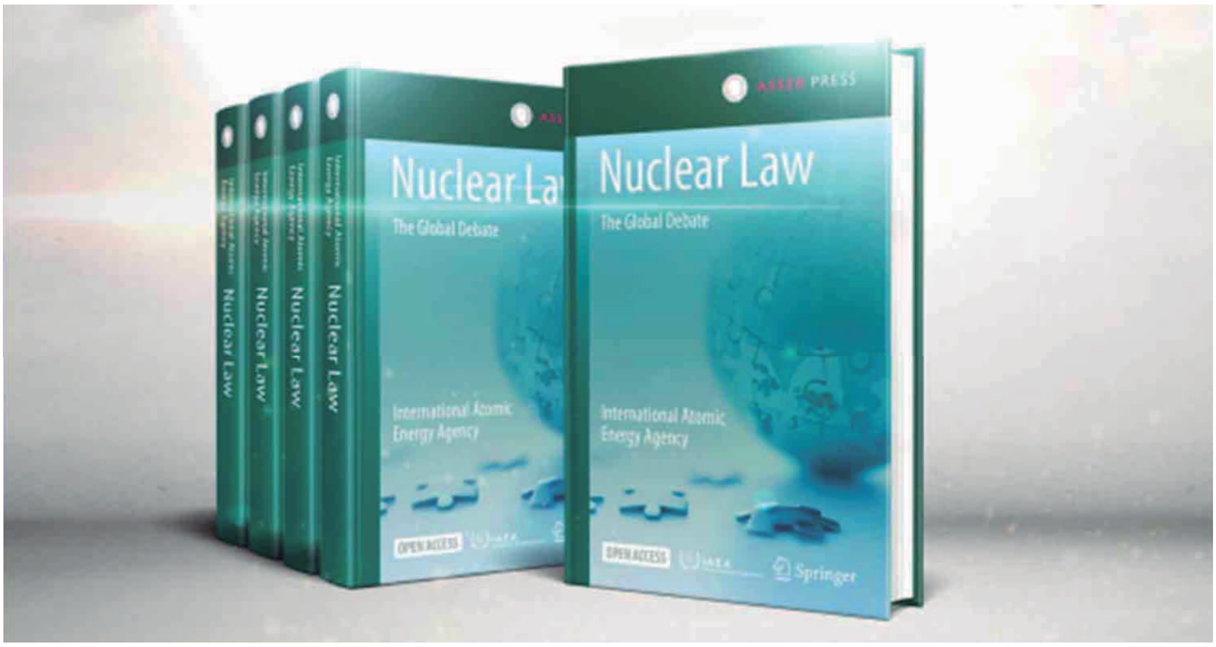


Imputing



Why is this relevant for the FORO?

Because Iberoamerica shares a similar codified legal system that is not tailored to handle probabilistic situations!



Chapter 7

Legal Imputation of Radiation Harm to Radiation Exposure Situations

Abel Julio González

Fourth challenge

Quantities and units for controlling workers' exposure

Quantities

- **Physical:** activity, absorbed dose.
- **Protection:** equivalent and effective dose.
- **Operational:** dose equivalent.
- **Recording:** various.
- **Extensive** (like heat): collective dose
- **Intensive** (like temperature): dose

Units

- Becquerels and curies
- Grays and rads
- Sieverts and rems
- Person.grays; person.rads;
- Person.sieverts; person.rems

Challenges

- **Traceability:** protection, operational vs. recording
- **Use of collective dose**

  collective dose per unit 'goodness'; how to measure 'goodness' in work?
- **Protection quantities**

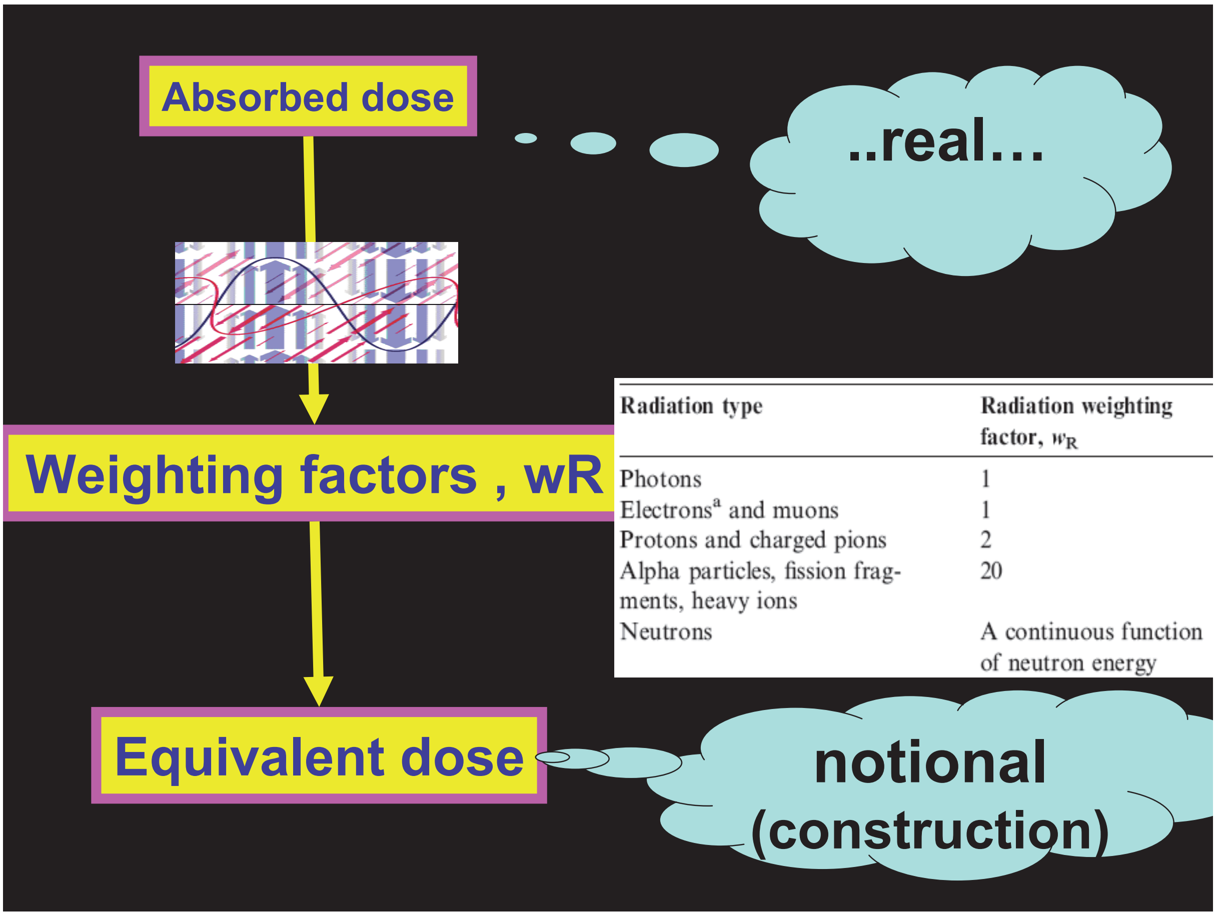
  defined for low doses with coefficients extrapolated from high doses
- **Applicability to accidents**
- **Effective dose for single organ exposure**

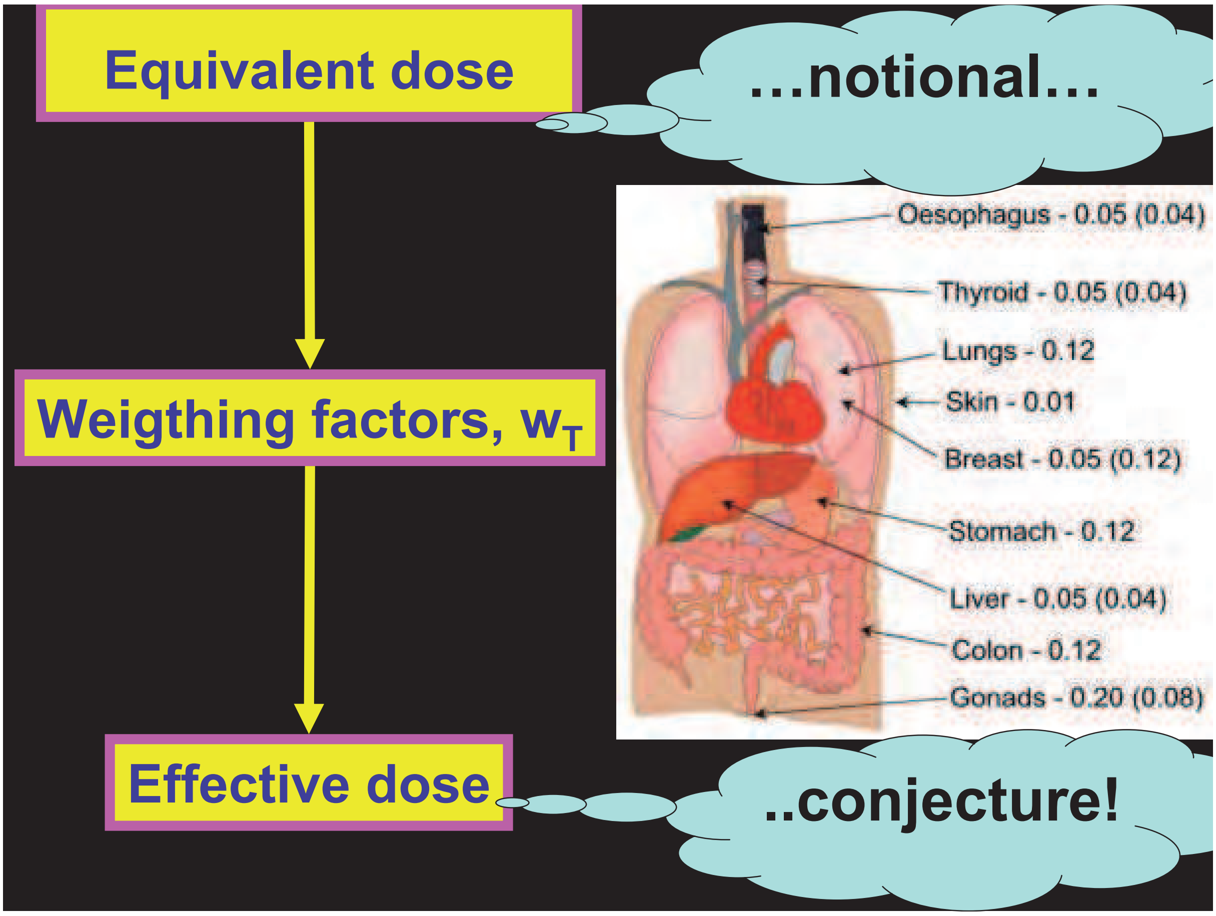
  the case of radon

The fundamental epistemological problem:

Shall the same quantity and unit (without any proviso) be used for:

- calculating ***health effects on workers*** that are ***attributable the employer***, and
- inferring ***conjectural risks of workers***?


Absorbed dose
..real…
Weighting factors , wR
Radiation type
Radiation weighting factor, w_R
Photons 1
Electrons[a] and muons 1
Protons and charged pions 2
Alpha particles, fission fragments, heavy ions 20
Neutrons A continuous function of neutron energy
Equivalent dose
notional (construction)


Equivalent dose
…notional…
Weigthing factors, w_T
Oesophagus - 0.05 (0.04)
Thyroid - 0.05 (0.04)
Lungs - 0.12
Skin - 0.01
Breast - 0.05 (0.12)
Stomach - 0.12
Liver - 0.05 (0.04)
Colon - 0.12
Gonads - 0.20 (0.08)
Effective dose
..conjecture!

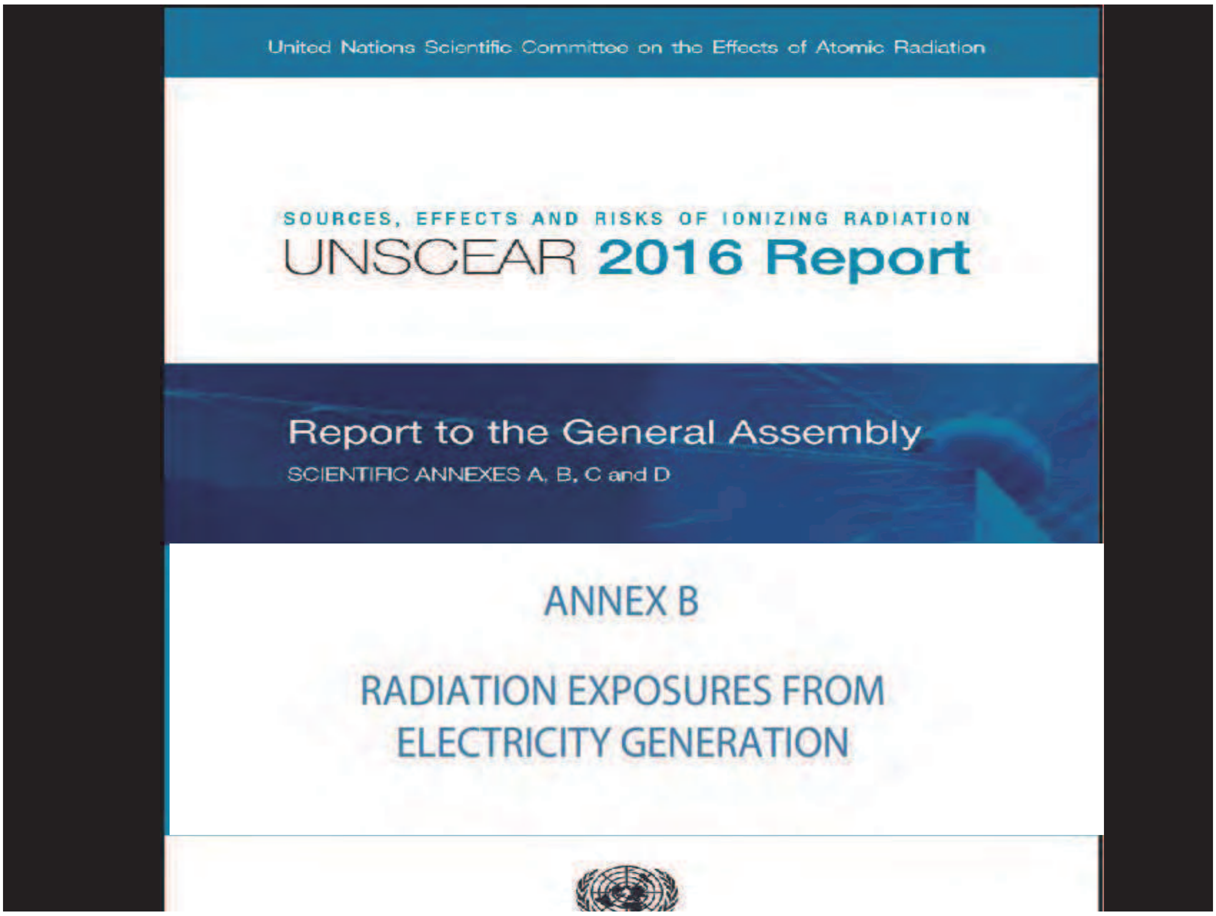
Why is this relevant for the FORO?

Because Iberoamerican countries had taking

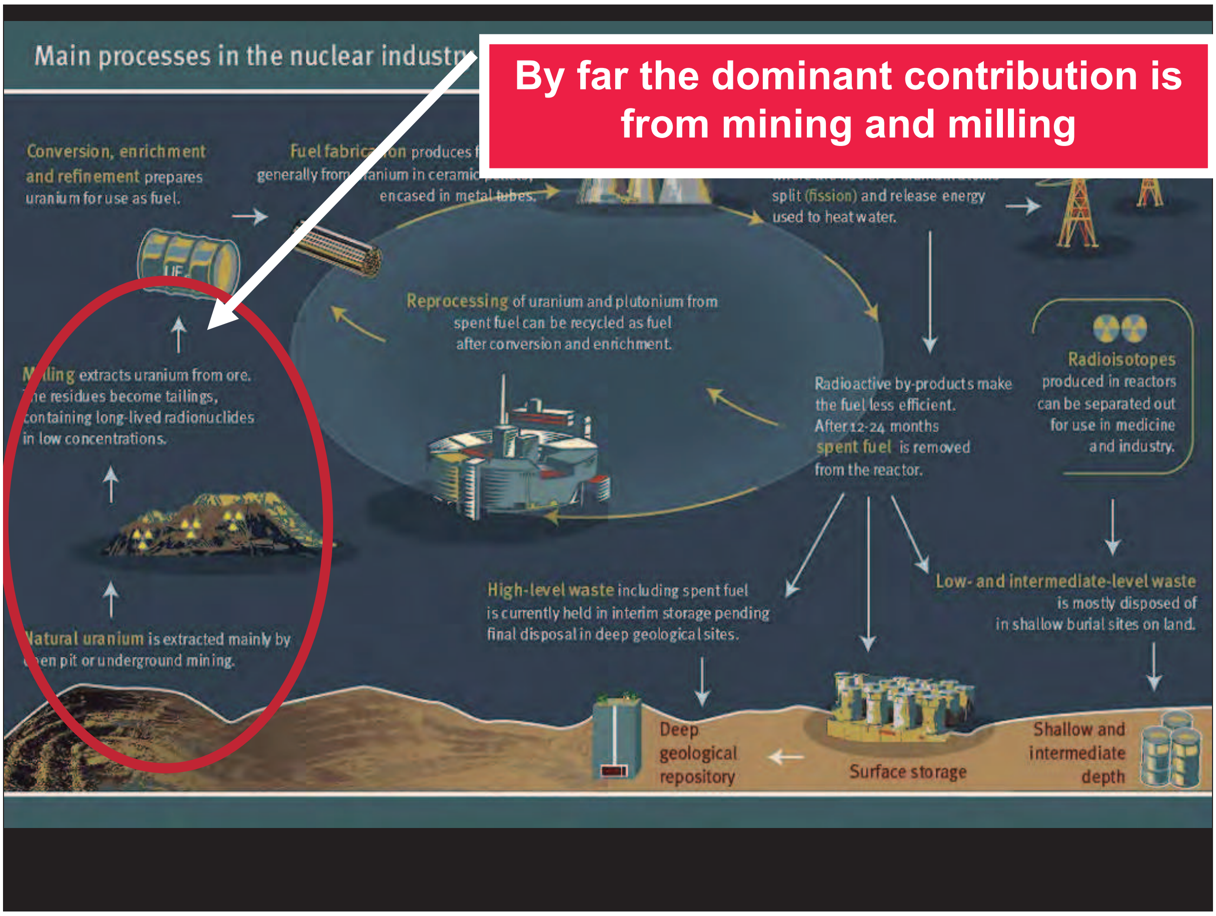
the initiative to address this issue!

Fifth challenge

A new paradigm for the protection of workers engaged in the production of electricity?



Today's focus:
Workers at nuclear power plants

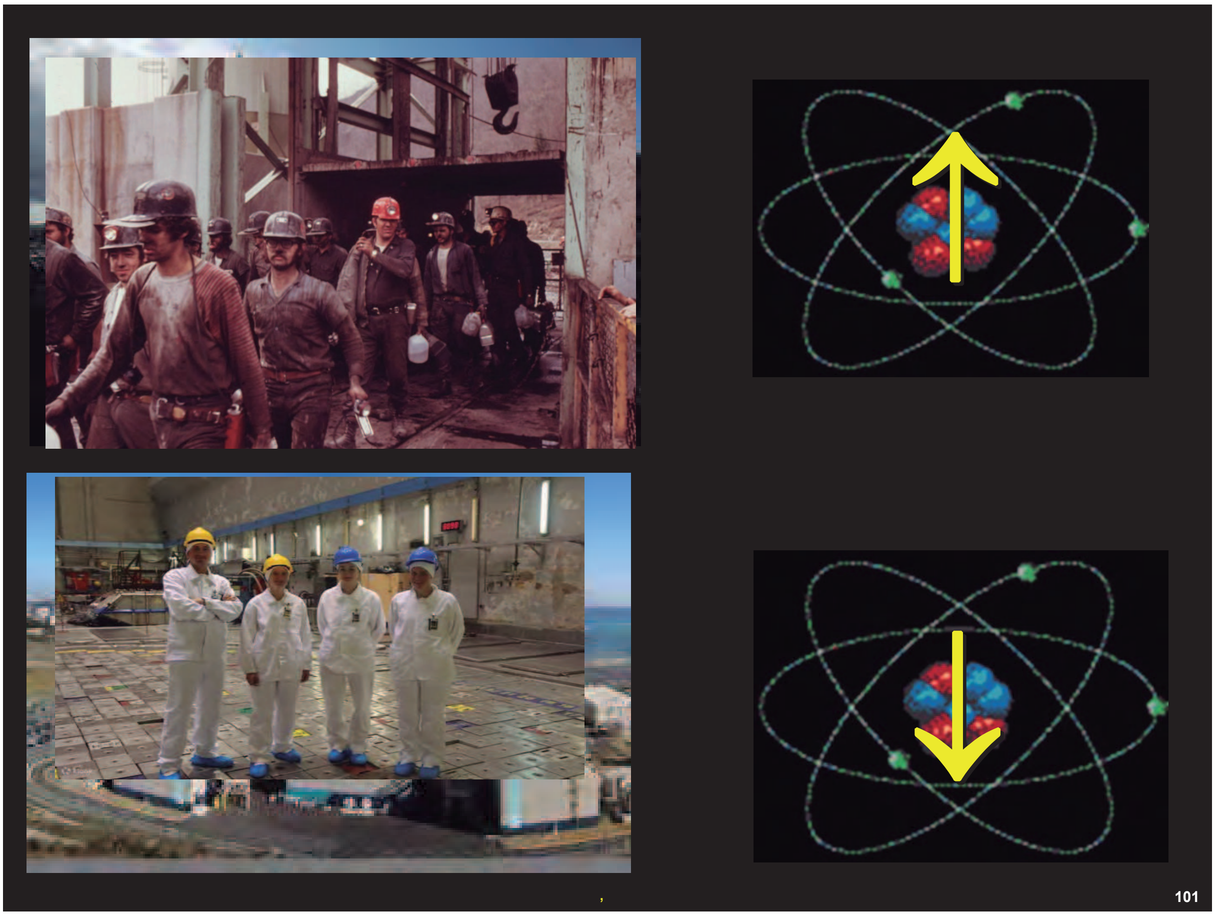


But, more important: a paradigm shift!

- **Among the various sources of energy for <u>generating electricity</u>, the source that delivers the highest radiation exposure to workers**

is not nuclear, <u>it is *coal!*</u>

100



- **Contribution from coal ~ 50%.**

(from operations and environmental discharges during coal mining and combustion at power plants and also from coal ash deposits)

- **Contribution from nuclear ~20%.**

(mainly due to uranium mining and milling, not to NPP operations)

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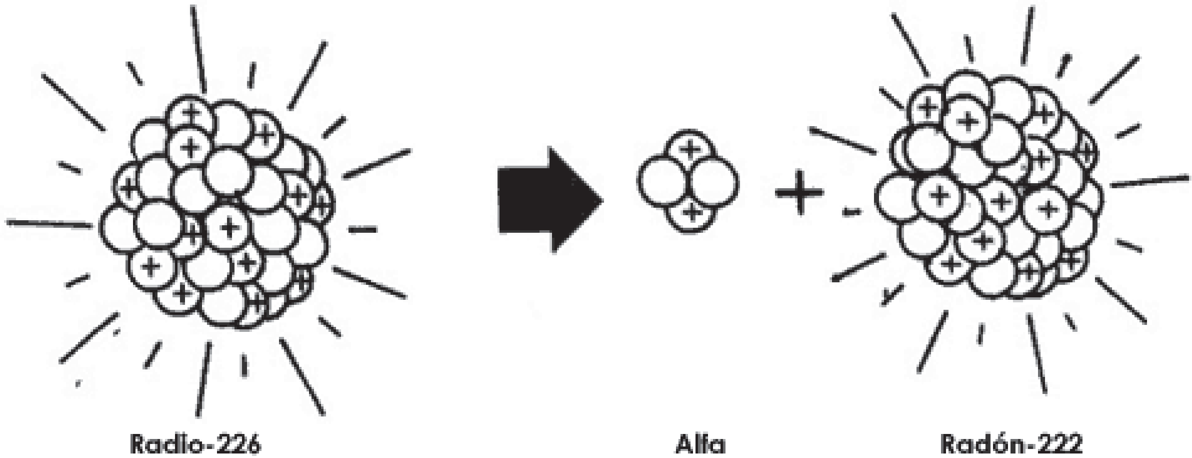
The great culprits: The natural radioactive elements *radium-226* and *radon-222*!



Moreover….!!!

- By far the largest radiation impact due to the

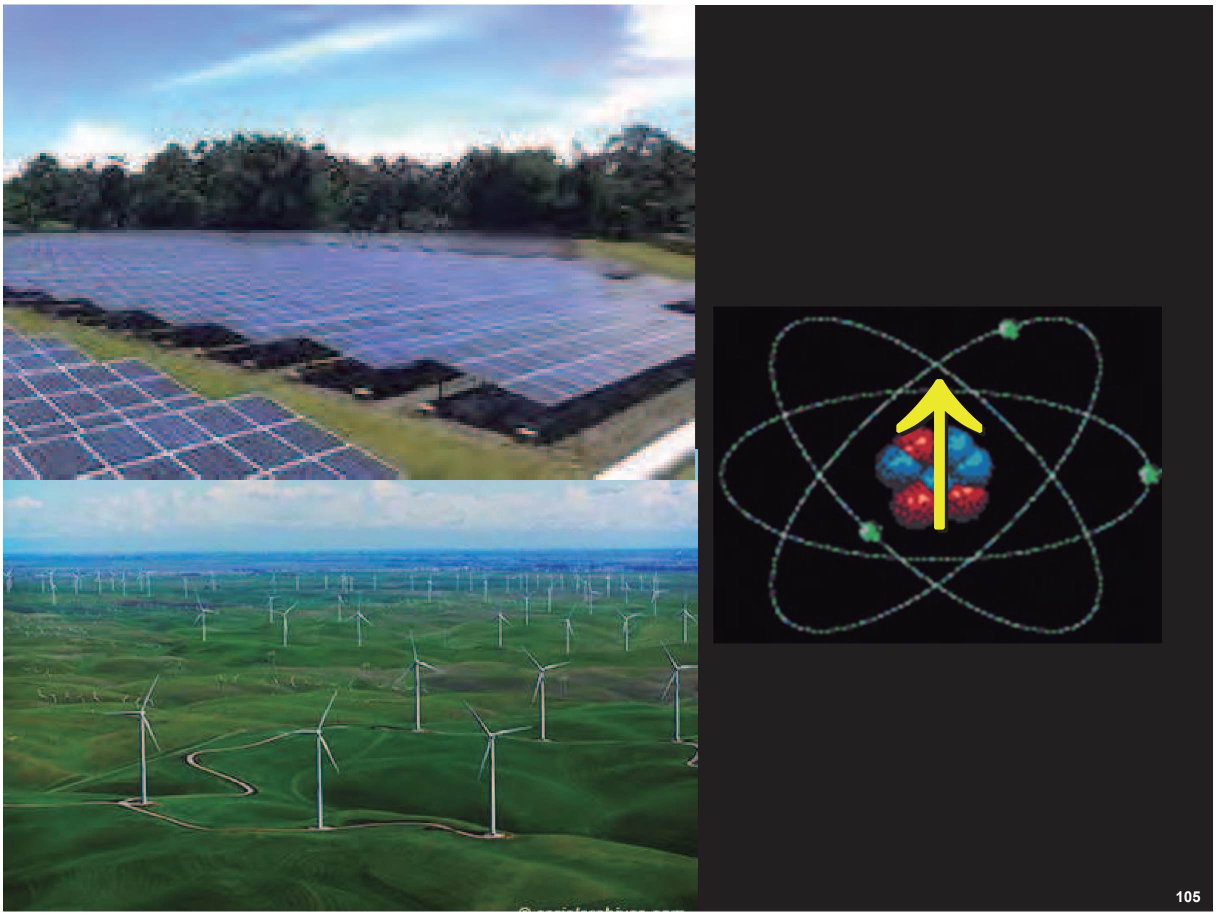
installation of <u>electrical power</u>

(construction of plants)

was found in

solar plants **followed by** ***wind plants*****.**

104



- The reason is that solar and wind require large amounts of ***rare earth metals***, and the mining of low grade ore produces large occupational radiation exposures.

Rare earths for solar cells

- Solar panels use, for example, *Tellurium*.
- *Tellurium* is three times rarer than gold.

Rare earths for wind generators

- *Neodymium* is used in wind turbine magnets

  (neodymium-iron-boron [NdFeB magnet powder is used to manufacture permanent wind turbine magnets)

Thus:

Dominant radiation exposures

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Why is this relevant for the FORO?

Because finding a logical paradigm for

natural radiation

is of particular importance for the

iberoamerican region!

Sixth challenge

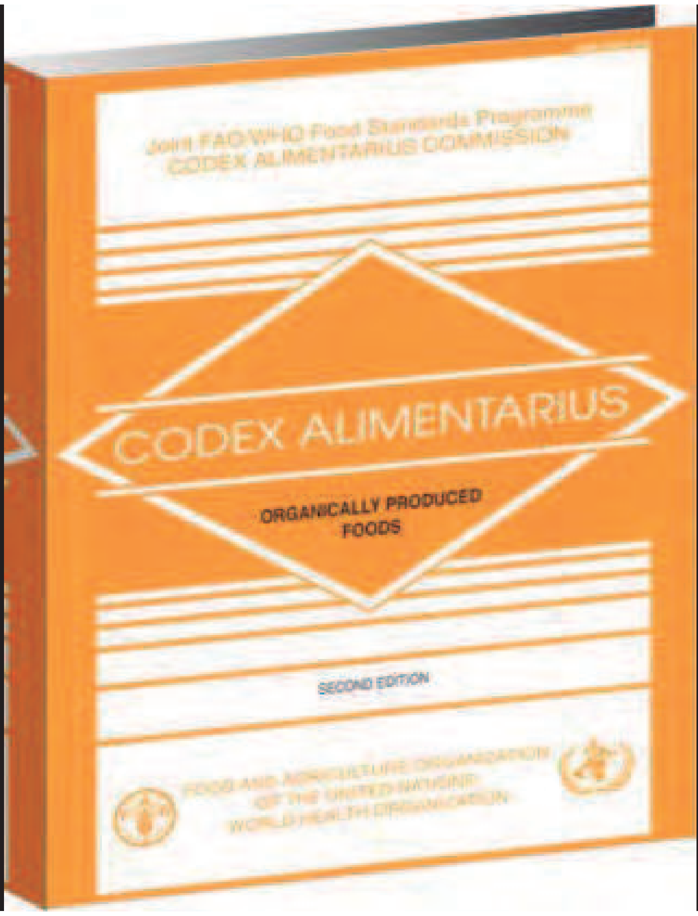
Internationally Harmonized Regulatory Framework for Controlling Radioactivity in Goods Supplied for Public Consumption or Use

Many consumer goods, such as

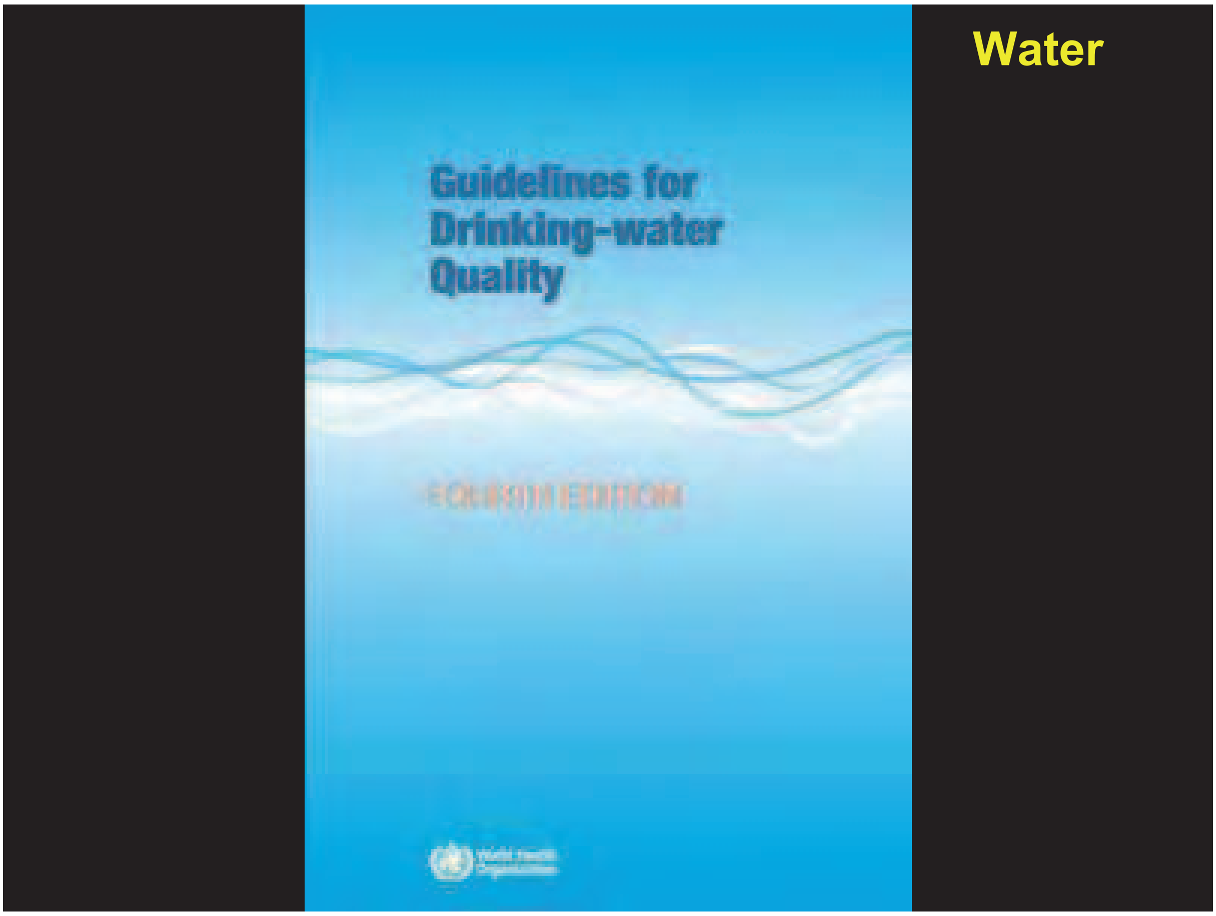
- foodstuffs,
- Drinking water and
- Non edible products,

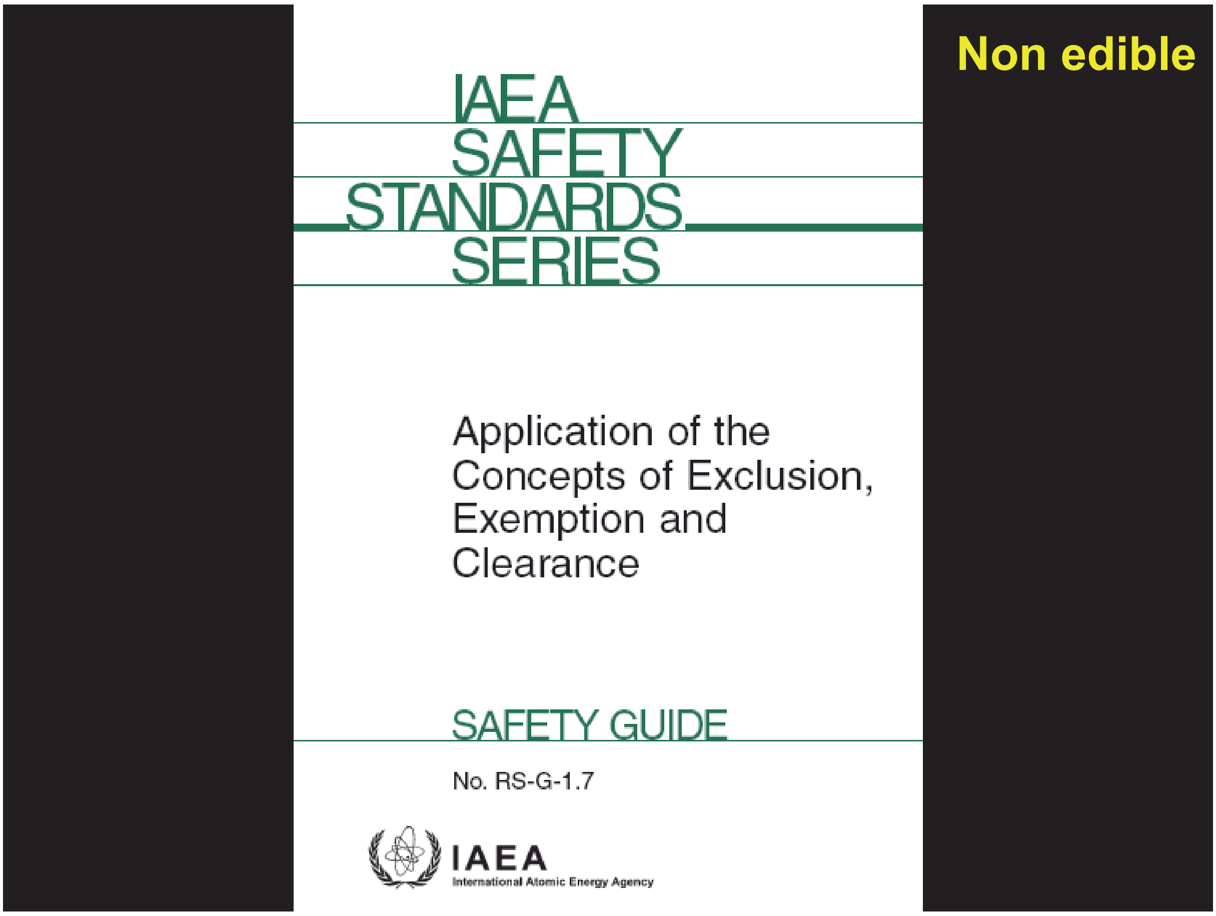
may present levels of radioactivity

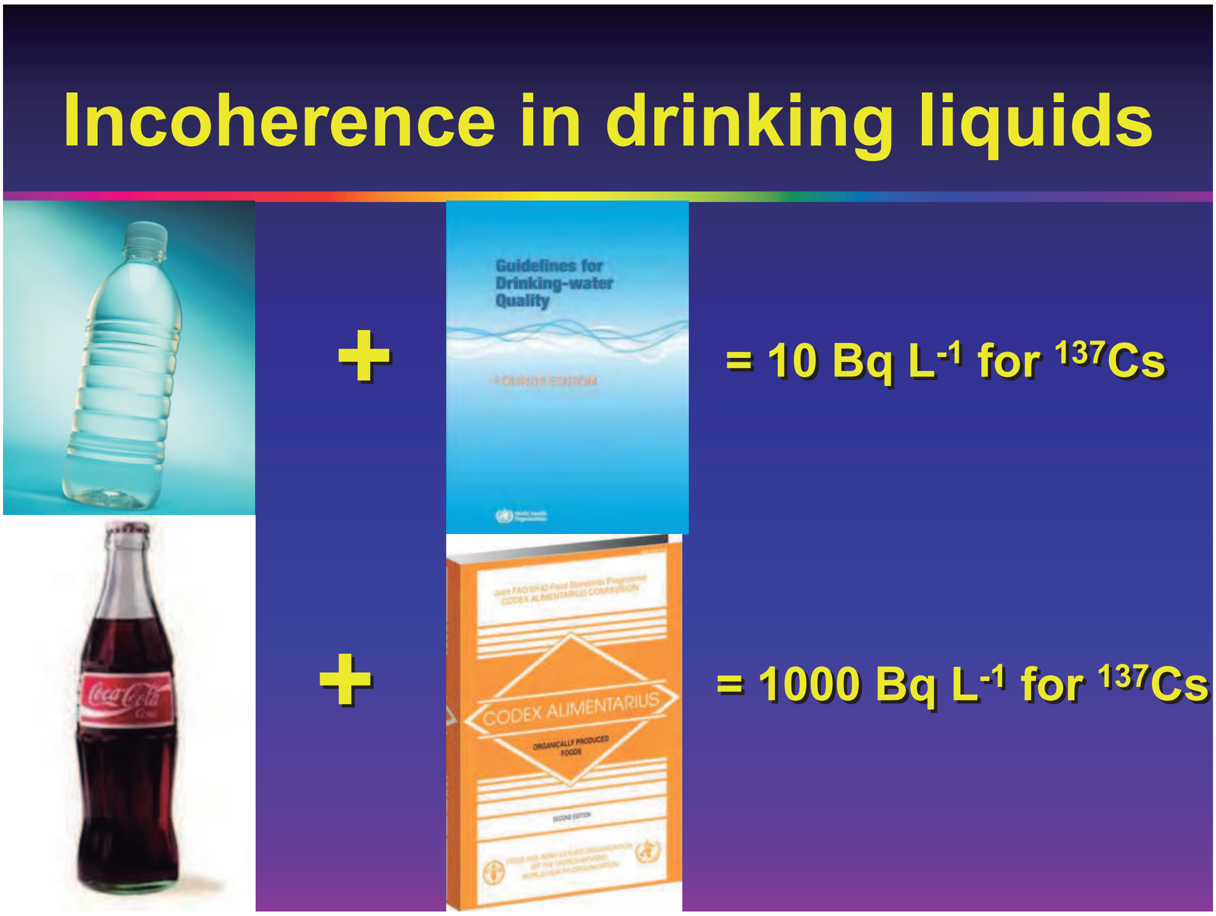
- **Their regulatory control is not straightforward**
- **Some international intergovernmental agreements exist but they are incoherent and inconsistent.**

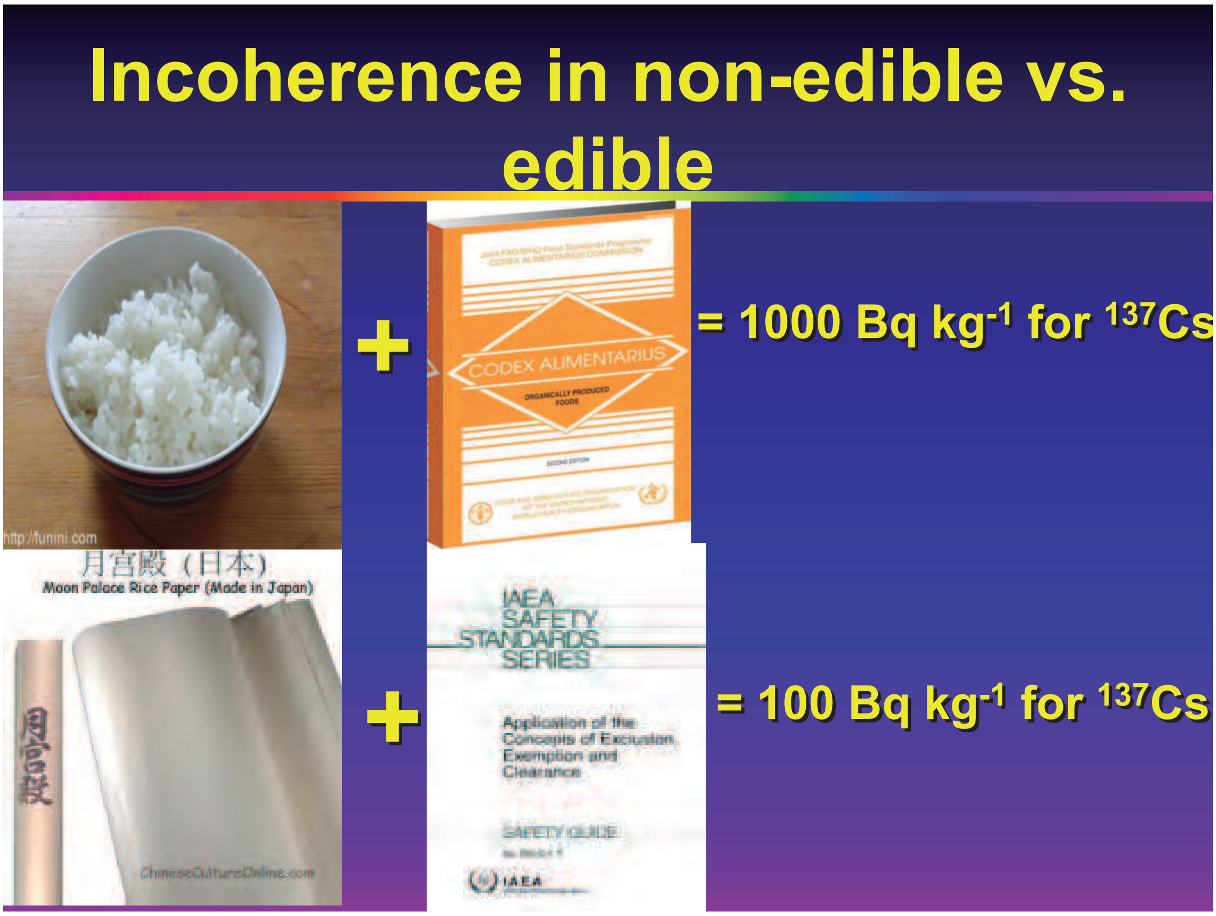


Foodstuff


Water
Guidelines for
Drinking-water
Quality


Non edible
IAEA
SAFETY
STANDARDS
SERIES
Application of the
Concepts of Exclusion,
Exemption and
Clearance
SAFETY GUIDE
No. RS-G-1.7
IAEA
International Atomic Energy Agency


Incoherence in drinking liquids
Guidelines for Drinking-water Quality
+
= 10 Bq L-1 for 137Cs
+
CODEX ALIMENTARIUS
= 1000 Bq L-1 for 137Cs


Incoherence in non-edible vs. edible
+
CODEX ALIMENTARIUS
= 1000 Bq kg-1 for 137Cs
http://funini.com
月宮殿（日本）
Moon Palace Rice Paper (Made in Japan)
ChineseCultureOnline.com
+
IAEA SAFETY STANDARDS SERIES
Application of the Concepts of Exclusion, Exemption and Clearance
SAFETY GUIDE
IAEA
= 100 Bq kg-1 for 137Cs

29 January 2019

Radioactivity in Goods Supplied for Public Consumption or Use:

Towards an Internationally Harmonized Regulatory Framework

A discussion document prepared jointly by the Autoridad Regulatoria Nuclear (ARN) of Argentina and the International Atomic Energy Agency

Why is this relevant for the FORO?

Because Iberoamerican countries are big producers and exporters of consumer goodsand can be discriminated on baseless radiological arguments!

Seventh challenge

Resolving the conundrum of the 'Denials of Shipment' (DoS)

Regulating

Safe Transport

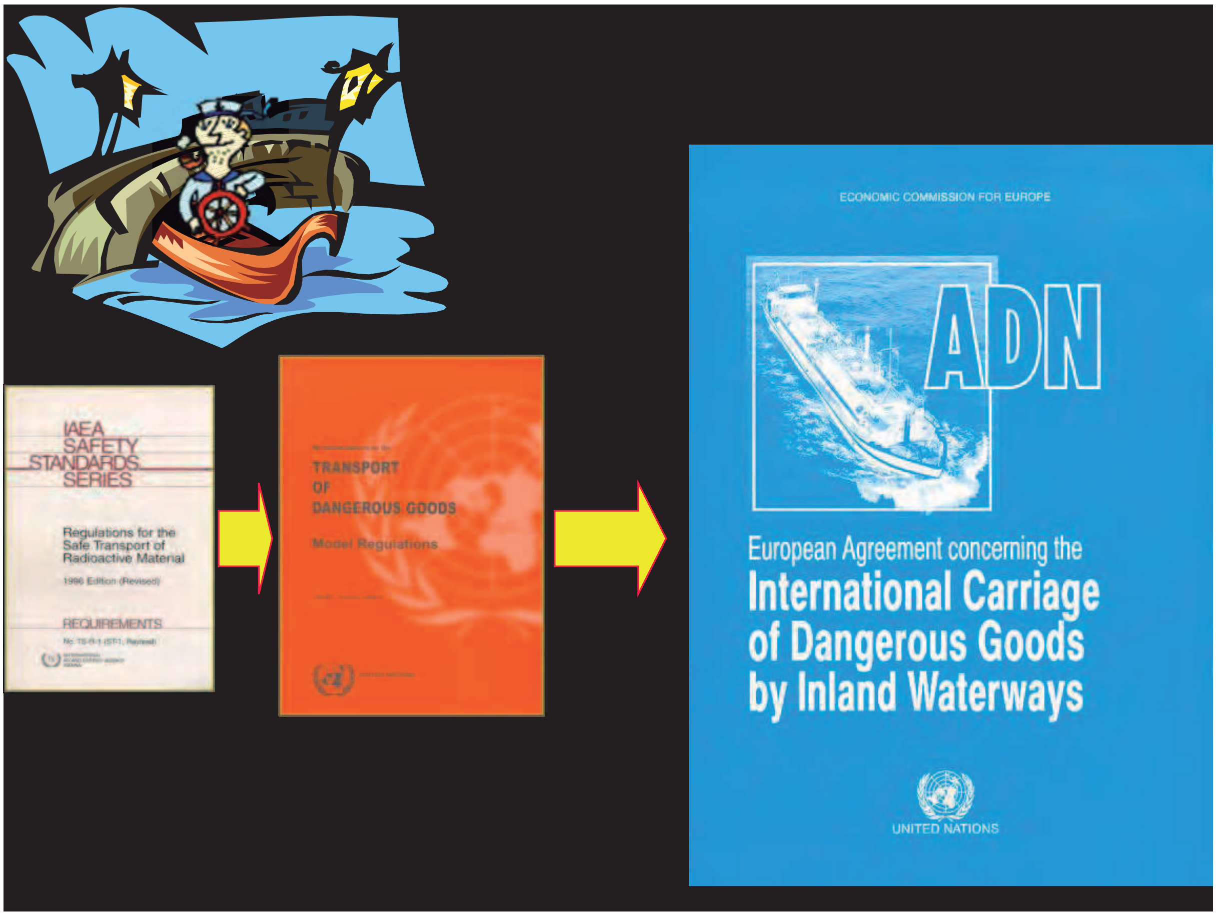

IAEA Safety Standards
for protecting people and the environment
Jointly sponsored by
Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO
Safety Fundamentals
No. SF-1
IAEA
International Atomic Energy Agency

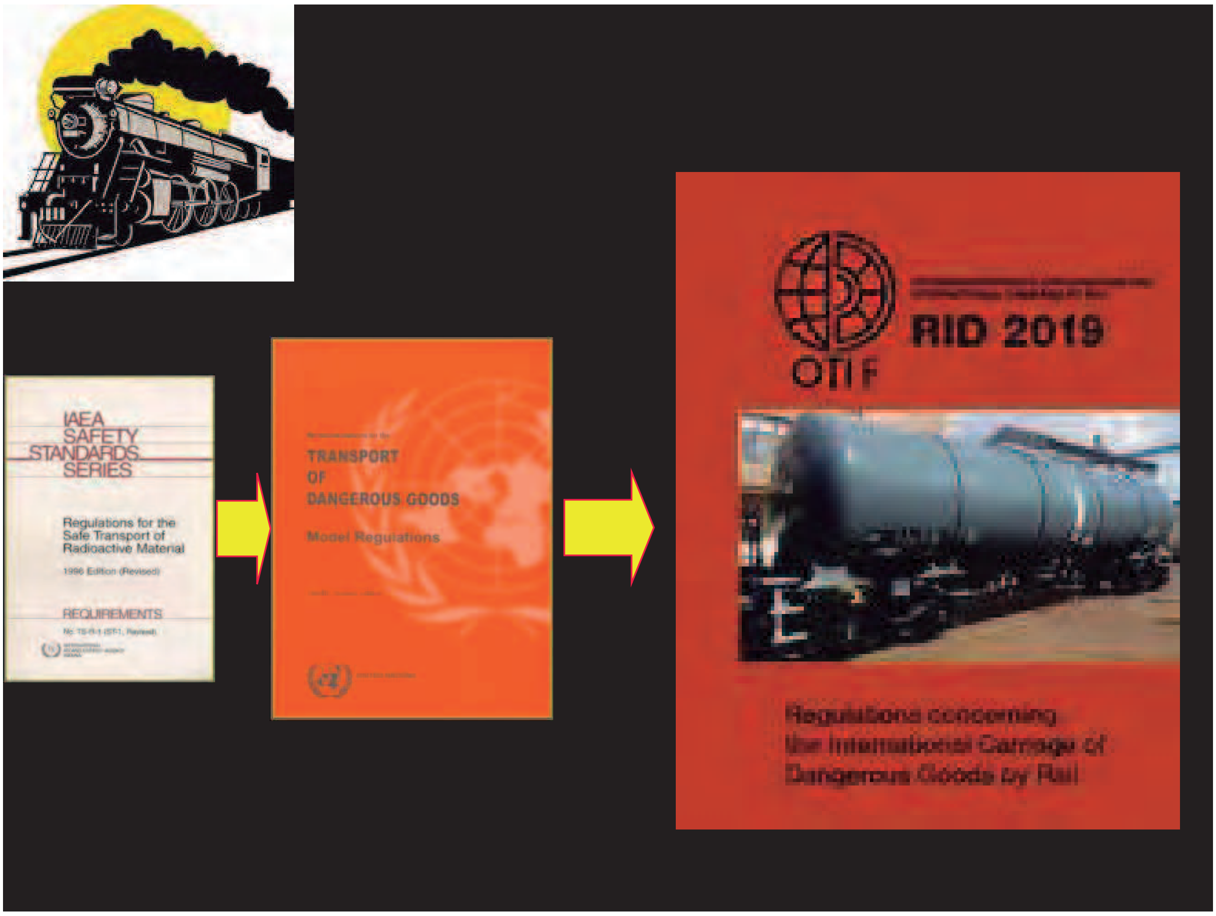

IAEA Safety Standards
for protecting people and the environment
Fundamental
Safety Principles
Safety Fundamentals
No. SF-1
IAEA
SAFETY STANDARDS
safety
series
IAEA Safety Standards
Radiation Protection and
Safety of Radiation Sources:
International Basic
Safety Standards
INTERIM EDITION
General Safety Requirements Part 3
No. GSR Part 3 (Interim)
IAEA
SAFETY
STANDARDS
SERIES
Regulations for the
Safe Transport of
Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
INTERNATIONAL
ATOMIC ENERGY AGENCY
VIENNA
124


IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA
to Geneva
Recommendations on the
TRANSPORT OF DANGEROUS GOODS
Model Regulations
UNITED NATIONS
28 September, 2022
125


IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
TRANSPORT OF DANGEROUS GOODS
Model Regulations
Technical Instructions for the Safe Transport of Dangerous Goods by Air
IATA
2003
Dangerous Goods Regulations
44th Edition
International Air Transport Association


IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT OF DANGEROUS GOODS
Model Regulations
IMDG Code 2000 Edition
International Maritime Dangerous Goods Code
1
INTERNATIONAL MARITIME ORGANIZATION


IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT OF DANGEROUS GOODS
Model Regulations
ECONOMIC COMMISSION FOR EUROPE
ADN
European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
UNITED NATIONS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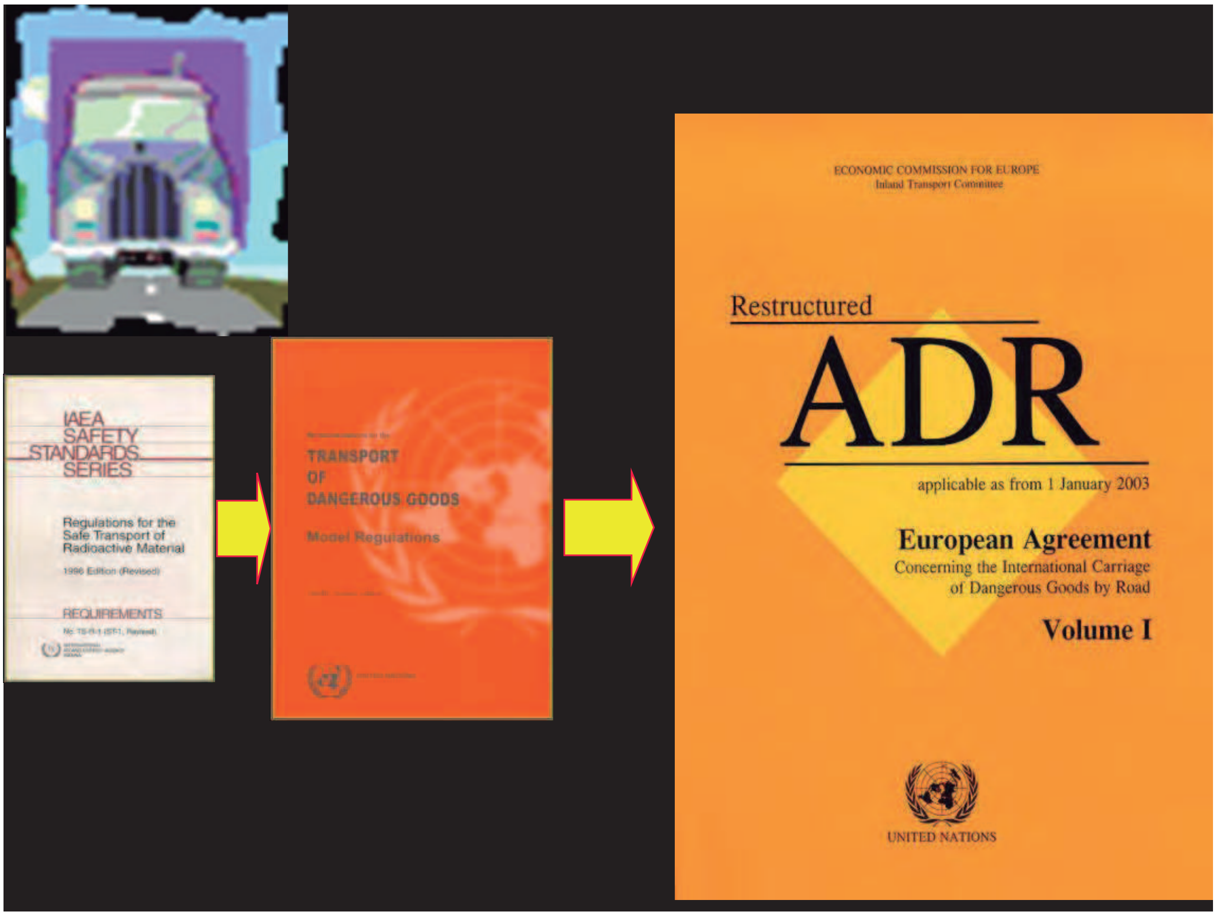
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT OF DANGEROUS GOODS
Model Regulations
OTIF
RID 2019
Regulations concerning the International Carriage of Dangerous Goods by Rail


IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT OF DANGEROUS GOODS
Model Regulations
ECONOMIC COMMISSION FOR EUROPE
Inland Transport Committee
Restructured
ADR
applicable as from 1 January 2003
European Agreement
Concerning the International Carriage of Dangerous Goods by Road
Volume I
UNITED NATIONS

In spite of this sophisticated system

↓

DoS

DOS can be described as follows:

DOS results from the cumulative effect of a policy of not accepting radioactive material by carriers, ports, airports, terminals, and/or handling facilities,

regardless that the materials be transported in compliance with international and intergovernmental safety standards.

The Potential Way Forward

Code of Conduct

What is a 'Code of Conduct'

A non mandatory commitment undertaken by States on:

behaviour, performance and accomplishment

It is not a legally binding undertaking for those States adhering to the Code.

Elements for a Code of Conduct

Preambular declarations…

…in which States describe their:

- awareness,
- desires, and
- affirmations; and….

….in which Sates affirm what they

- recognize,
- keep in mind, and
- take into account.

Pronouncements…

…in which States decide and declare the:

- norms,
- rules, and
- responsibilities

…they wish to undertake for facilitating the safe and secure transport of radioactive materials

Why is this relevant for the FORO?

Because Iberoamerican countries need easy safe transport of radioactive materials and have taking the initiative to address this issue!

EPILOGUE

In order to address these challenges,

the **FORO**,

may consider undertaking some action;

for instance, the following could be

explored:

Potential action 1

The **FORO**,

in co-operation with relevant international organizations

may consider to suggest a process for

reviewing and revising relevant Conventions;

e.g. ILO Convention.

Potential action 2

The FORO and the IAEA

may consider to initiate a joint process for convening a Diplomatic Conference to adopt a

Declaration on

Protection against Natural Radiation

Potential action 3

The FORO

in cosposorship with

IAEA

may consider to develop and establish

ad hoc **Codes of Conduct**

on unsolved issues

Responding to the Regulatory Safety Challenges for New Reactor Technologies

González, A.J.

Presentado en: International Conference on Topical Issues in Nuclear Installation Safety:
Strengthening Safety of Evolutionary and Innovative Reactor Designs del
Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 18 al 21 de octubre de 2022

RESPONDING TO THE REGULATORY SAFETY CHALLENGES FOR NEW REACTOR TECHNOLOGIES

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[1]Autoridad Regulatoria Nuclear, Ciudad de Buenos Aires, Argentina

Abstract

The paper presents some propositions for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs. Ir first summarize some aspects of the regulatory approach to nuclear reactor safety by the competent Argentine Nuclear Regulatory [ARN]. It then suggest to refresh the current international safety regime being developed under the aegis of the IAEA reinforcing it inter alia by strengthening the Convention of Nuclear Safety by fully applying the concepts for the safety of new reactors imbedded in the Vienna Declaration of Nuclear Safety, reviewing the so-called 'IAEA Safety Standards' and dissecting its 'standards' proper (which shall be fully applicable to the new designs) from its 'norms' proper (which shall be revised and tailored to the new designs), and inforcing the use of probabilistic safety criteria, fully coherent and consistent with the universally accepted radiation protection paradigm, all of which shall provide the safety framework for the new reactor design. Some specific challenges associated to the development of the SMR prototype CAREM, will also be discussed.

1) INTRODUCTION

This paper is aimed at presenting some propositions for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs.

As nuclear reactor technologies are maturing, plans to deploy them are being made elsewhere. The development, progress, novelty and modernization of the nuclear industry being associated to these changes is generating increased interest at a time when a nuclear renascence seems inevitable inter alia due to the need of facing up climate change and energy supply.

The family of evolutionary and innovative reactors is large and include a large variety of designs. They include (in alphabetical order) the following: the gas-cooled fast reactor (GFR), a helium-cooled reactor that convert fertile uranium and manages actinides; the high-temperature gas-cooled reactor (HTGR), a reactor operating at high temperature with pebble bed fuel; the lead-cooled fast reactor (LFR), which features a fast neutron spectrum and a molten lead or lead-bismuth eutectic coolant; the molten-salt reactor (MSR), where the primary coolant, or the fuel itself is a molten salt mixture; the sodium-cooled fast reactor (SFR), a fast neutron reactor cooled by liquid sodium; the supercritical-water-cooled reactor (SCWR), an epithermal reduced moderation water reactor; and, the very-high-temperature reactor (VHTR), which uses a graphite-moderated core with a once-through uranium fuel cycle, and helium or molten salt as a coolant. They also include a family of reactors agenerally identified with the acronym SMR. The acronym was firstly used at the International Atomic Energy Agency (IAEA) to denote small and medium nuclear reactors but now it is widely understood to describing a generic and still undefined concept termed 'small modular reactors'.

It is apparent that the substantive changes in reactor design, implicit in all these new technologies, will be triggering significant regulatory safety challenges. These issues are particularly relevant for Argentina as a pioneering country in the development of SMRs. Already in the early 80's the Argentine Atomic Energy National Commission (Comisión Nacional de Energía Atómica [CNEA]), , proposed a new reactor concept, eventually termed Central ARgentina de Elementos Modulares (CAREM), which was officially presented by CNEA at an IAEA Seminar in Lima, Perú, in 1984 [1.

The paper will summarize some aspects of the regulatory approach to nuclear reactor safety by the competent Argentine authority, the Nuclear Regulatory Authority (Autoridad Regulatoria Nuclear [ARN]). The aim is to help to solve the new challenges presented by evolutionary and innovative reactors design. It will also suggest some propositions vis-à-vis these challenges, which can be briefly described as follows:

- The current international safety regime being developed under the aegis of the IAEA may need some refreshment for confronting the new challenges. It may require to be reinforced inter alia by:
  - Strengthening the Convention of Nuclear Safety by fully applying the concepts for the

safety of new reactors imbedded in the Vienna Declaration of Nuclear Safety.

- Reviewing the so-called 'IAEA Safety Standards' and dissecting its 'standards' proper (which shall be fully applicable to the new designs) from its 'norms' proper (which shall be revised and tailored to the new designs)

• Enforcing the use of probabilistic safety criteria, fully coherent and consistent with the universally accepted radiation protection paradigm, which shall provide the safety framework for the new reactor design.

The position paper will also discuss some specific challenges associated to the development of CAREM, which have been very demanding for both its promoter and constructor, CNEA, and for the regulator.

2) ARN AND ITS APPROACH TO SAFETY

ARN is the inheritor of a long standing Argentine tradition for regulating radiation and nuclear endeavours. It starts with the country's first nuclear legal action, which took place three quarter of a century ago, in 1950. At those early times for nuclear energy, the Argentine Government issued the Decree of the National Executive Branch No. 10936/50 creating the National Atomic Energy Commission (CNEA) [2]. The relevance of this Decree for the discussions hereby is that it established that a specific function of CNEA would be to 'control the official and private atomistic [SIC] investigations that are carried out throughout the territory of the Nation'. It has been recognized however that the main original aim of CNEA was to provide a legal framework to the first nuclear project in Argentina, the failed Huemul project [3]. Nonetheless, that initial regulatory reference in 1950 was ratified in 1956 with the Decree Law 22,498/56 [4], ratified by the Congress by Law 14,156 in 1958 [5], and regulated in 1958 with Decree 842/58 [6], which extended regulatory control not only to governmental activities but also to external users.

CNEA exercised the above described evolving regulatory functions from 1950 to 1994. In 1994, the Argentine regulatory structure was updated by creating an administratively independent regulatory authority, the so-called National Nuclear Regulatory Entity, or ENREN, which would operate between 1994 and 1997). ENREN was again updated in 1997 by the National Law No. 24804 on the Nuclear Activity, which established the ARN [7]. Namely, the ARN is the successor of ENREN, which in turn was the successor of the regulatory branch of CNEA. Thus, after 72 years of regulatory experience, the Nuclear Regulatory Authority (ARN) is today an autarchic independent entity under the jurisdiction of the Presidency of the Nation.

The time evolution of the Argentine nuclear regulatory system is summarily described in Figure 1.

Figure 1: Summary description of the time evolution of the Argentine regulatory system

Over this long time, the Argentine regulator licensed three nuclear power plants, the PHWR types Atucha I and Atucha II and the Candu type Embalse, in addition to several research reactors and a large variety of nuclear and radiation installation, including a large factory of natural uranium fuel and a heavy water plant. In order to perform this work an ad hoc regulatory system was build up over the years. Its full description is available in the ARN official web-page https://www.argentina.gob.ar/arn

From its commencement, the Argentine regulatory approach considers, as a conditio-sine-qua-non for safety, a regulatory acceptable radiation and nuclear security. In ARN's view, any installation or endeavour involving radiation exposure, be that actual or potential exposures, cannot be safe if it is not secure, namely that protection of people and their environment can not se assured if relinquishing of control has not been prevented; conversely, a secured installation or endeavour does not necessarily ensure safety. Therefore, the Argentine approach considers nuclear security a fundamental and necessary condition for safety; but a condition that, however, is not sufficient for ensuring safety. This has been the traditional position of Argentina for promoting radiation and nuclear security. It should be recalled that the Argentina was the first country to promote security among regulators by convening the international conference of national regulators with competence on radiation and nuclear security to discuss the issue [8].

The Argentine regulatory approach is founded on a solid paradigm for protecting people and their environment against potential detrimental effects of radiation exposure, which was originally developed and recommended by the International Commission on Radiological Protection (ICRP) [9] and incorporated into the international fundamental safety principles [10]. The paradigm is based on unyielding ethical foundations [11]. The main principles are those recommended and established internationally, namely: the principle of justification of decisions that alters the radiation exposure situation; the principle of optimization of protection and safety, requiring the selection of the best protection and safety options under the prevailing circumstances (It is to be noted that the practical application of this principle firstly originated in Argentina[12]); the principle of individual exposure limitation for restricting possible inequitable outcomes of optimized safety of justified actions; and the implicit principle of intergenerational duty for the protection future generations and the habitat.

In Argentina there are governmental legal obligations on ethics. These obligations implicitly include ethics of the nuclear regulatory approaches [13], [14]. Thus, the fundamental principles governing the ARN decisions are based on central ethical doctrines, as follows: justification on teleology; optimization o utilitarianism; individual limitation on deontology; and, intergenerational duty on arête (or virtuosity) [11].

Moreover, the Argentine regulatory approach to safety is fully consistent and coherent with the international safety regime being developed under the aegis of the IAEA, including:

- The legally binding obligations established by all relevant Conventions, of which Argentina is a Contracting Party.
- The system of international safety standards being established under the aegis of the IAEA with the co-sponsorship of all relevant international and intergovernmental organizations.

Nonetheless, the ARN consider that adherence to the international safety regime is a necessary but not necessarily a sufficient condition for safety. Thus, additional requirements are added by the ARN system. Notably, in the ARN system, the fundamental safety principles described above are applied to ALL radiation exposure situations, namely, to exposures to actual radiation doses and also to exposures to potential radiation doses, e.g., those that may arise from accidents, namely those being mainly related to the safety and security of radiation and nuclear endeavours. For this purpose, since many years ago, Argentina uses safety criteria based on a probabilistic approach founded on the underlying principles described above [15]. A detailed description of this approach is presented hereinafter.

3) THE INTERNATIONAL SAFETY REGIME

There is a unique and solid international and intergovernmental regime governing nuclear safety, which is being built under the aegis of the IAEA. The international community and the IAEA should be proud of this singular achievement that is uncommon to most industries.

At the top of the international safety regime is a number of legally binding undertakings, such as the Conventions, and other type of national commitments, such as States' declarations at diplomatic conferences or Codes of Conduct, made by States in pursuing nuclear safety. At its basis are the so-called 'IAEA Safety Standards'.

However, it is not clear whether such a regime is fully tailored to the new issues being triggered by evolutionary and innovative reactors. Thus, for responding to the regulatory safety challenges presented by the new family of evolutionary and innovative reactors designs, it would be necessary to answer these straightforward questions:

• Are States' commitments on nuclear safety enough for satisfying the new safety challenges?;

• Are the 'IAEA Safety Standards' tailored for tackling the safety issues that are being triggered by the new family of evolutionary and innovative reactors designs?

Part of the discussion triggered by these questions is mutatis mutandi applicable also to fusion reactors as it has already been presented in the literature [16].

- **International Undertakings**

- *The Legally Binding Undertaking*

The main international legally binding undertaking on the safety of nuclear power plants is the Convention on Nuclear Safety (CNS) [17]. It apply to nuclear installations, which are defined as any land-based civil nuclear power plant under its jurisdiction including such storage, handling and treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant. This definition is fully applicable to the new family of evolutionary and innovative reactors designs and, therefore, ARN considers that the legally binding undertakings by the Contracting Parties of the CNS are mandatory for the development and operations of the new family of evolutionary and innovative reactors designs by any of the contracting parties.

The Argentine 2019 report to the CNS had e already informed on the compliance of the Argentine obligations in relation to the reactor CAREM [18]. Argentina informed that pre-licensing activities for CAREM have been initiated.

- *The Politically Binding Undertaking*

Following the Fukushima accident and a proposal by the Swiss Confederation to amend the CNS presented at the 6th Review Meeting of the CNS, States have adopted the Vienna Declaration on Nuclear Safety on principles for the implementation of the objective of the Convention on Nuclear Safety to prevent accidents with radiological consequences and mitigate such consequences should they occur [19]. The Vienna Declaration was adopted by the Contracting Parties of the CNS meeting at a Diplomatic Conference in Vienna, Austria, on 9 February, 2015. Argentina was a main promoteor of the adoption of the Vienna Declaration. The Diplomatic Conference was presided by the then IAEA's Argentine Ambassador and IAEA Governor, and now IAEA Director General, Ambassador Rafael Mariano Grossi. While the Declaration's principles reflect a consensus of all Contracting Parties, the Argentine headship was apparent.

The Declaration's principle applying to new family of evolutionary and innovative reactors designs declares that new nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions. There is also a subsidiary but important principle applying to these new reactors, which establishes that national requirements and regulations for addressing the above objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards.

The Declaration also establishes that its principles should be reflected in the actions of the CSN's Contracting Parties, in particular when preparing their reports on the implementation of the CNS.

Argentina, singularly, has declared at the meeting of the CSN's Contracting Parties adherence of new designs to the first principle of the Vienna declaration. She informed that its SMR prototype, the CAREM, is being designed and constructed complying with the principles of the Vienna Declaration. Moreover, Argentina declared that the development of CAREM is a 'practical example that illustrates the strong commitment that Argentina has with the Vienna Declaration'.

This should not be suppressing: over many years of regulatory activity, ARN and its preceding bodies have emphasized the importance of mitigation and not only prevention of accidents and the Vienna Declaration pursue identical purposes.

- **The 'IAEA Safety Standards'**

The origin of the 'IAEA Safety Standards' concept should be searched in the IAEA Statute. Article Ill of the IAEA Statute [20] establishes as a fundamental IAEA's function that the Agency is authorized to establish standards of safety for protection of health. This is to be performed in consultation and in collaboration with the competent organs of the United Nations and with the specialized agencies concerned.

Following such mandate the IAEA has established standards of safety that have been generally co-sponsored by relevant international organizations, particularly those within the United Nations family. It should be noted that in international language co-sponsoring indicates that the policy making organs of the co-sponsoring organizations are formally adopting the document concerned; this is an important difference with documents that are developed 'in cooperation with', which do not commit the cooperating organizations.

The IAEA Statute also establishes that the IAEA General Conference, consisting of representatives of all Member States, elects a Board of Governors with authority to carry out the functions of the Agency in accordance with the Statute, including the establishment of the standards of safety.

In sum:

• the 'IAEA Safety Standards' are standards of safety for the protection of health, namely they are not standards for protecting nuclear installations but rather for protecting health detriments that these installations might generate;

• while 'IAEA Safety Standards' are established under the aegis of the IAEA, they are co-sponsored by relevant international organizations, which converts them into international standards rather than just IAEA's standards; and,

• they are also intergovernmental, because they are approved by governments.

It seems that when reference is made to the 'IAEA Safety Standards', the precise denotation would be: international and intergovernmental standards of safety for the protection of health, established under the aegis of the IAEA.

The first standards of safety were approved by the IAEA Board of Governors, on 31 March 1960, under the name "The Agency's Safety Standards and Measures", reproduced in document INFCIRC/18) [21], which was revised in 1975 and approved by the IAEA Board of Governors in February 1976. Since then a vast corpus of safety standards have been established.

The IAEA Annual Report for 2021 [22] informs that: The Agency completed the review of the applicability of the safety standards to SMRs and non-water cooled reactors. The review confirmed the overall applicability of the Agency safety standards to these technologies, but also identified areas that require further work. The review included consideration of the life cycle of these technologies as well as the safety–security–safeguards considerations and challenges. This work was captured in a Safety Report on this topic, which will be published in 2022.

While the above are generally good news for the regulation of the new family of evolutionary and innovative reactors designs, ARN estimate that a deep general analysis of the situation is worthwhile and will be attempted hereinafter.

- *Standards* vis-a-vis *norms*.

There were subtle but important differences in the official translation of the English term 'standards' in the 'Agency's Safety Standards' phrase. It should be recalled that the IAEA documents shall be done in the

Chinese, English, French, Russian and Spanish languages, each being equally authentic. The translation discrepancy may be relevant for answering to the regulatory issues associated to the new family of evolutionary and innovative reactors designs.

The English term 'standard' has been translated as follows:

• into Spanish as norma, i.e., norm in English, and not as estándar, which is the Spanish term for the English term standard;

• into French, as norme, i.e., norm in English, (and not as estandar, which is the French term for the English term standard;

• into Russian as Нормы [normy], i.e., norm in English, and not as стандартный [standartnyy], which is the Russian term for the English term standard;

• into Arabic as معايير [maeayir, norm] (and not as القاعدة [alqaeida, base-standard]); and, conversely,

• into Chinesse as 标准 [Biā ozhǔ n], i.e., standard (and not as 规则 [guī zé], i.e., norm).

Therefore, it seems that translators have generally assumed that the terms standard and norm were interchangeable, namely that they would be quasi-synonyms.

But the denotations of the terms standard and norm are very different, as follows:

• Standard, which derives from an old expression denoting a flag on a pole as a rallying point, generally means a *level of attainment*, ideally represented by that flag. Namely, standard is a generic concept expressing general principles for achievement rather than detailed rules; it is a strategic rather than a tactic concept.

• Norm, on the other hand, directly derives from the Latin norma, which originates in the 'carpenter's square', and clearly denotes a *rule* or *precept*. The norms contain the tactics to achieve that strategic level of attainment contained in the standards

In sum, since level of attainment is not a synonym of rule or precept, then standard is not a synonym of norm.

The Agency's Safety Standards and Measures were reviewed by the IAEA Board of Governors and the revision was published as INFCIRC/18/Rev.1 [23]; this document contains some relevant definitions. It inter alia indicates that the name "standards" have a multiplicity of meanings, including standards, regulations, rules and codes of practice, namely that the word standard is used with a wide meaning.

It should therefore be concluded that, as identified by the IAEA Board of Governors, the 'IAEA Safety Standards" is a collection of standards proper, i.e., levels of attainments, and norms proper, i.e., regulations or rules, code of practice, namely precepts.

An internationally and intergovernmentally acknowledged level of safety attainment in a nuclear reactor should be a condition for acceptance whatever the type of reactor.

Therefore, the standards proper, within the 'IAEA Safety Standards', should apply to any reactor design, including new evolutionary and innovative reactors designs.

Notwithstanding, specific norms proper, i.e., rules and precepts, should in addition be required for achieving safety and those need be tailored to definite type of installations.

Therefore, the norms proper, within the 'IAEA Safety Standards', which have been developed for reactor designs other than the new evolutionary and innovative reactors designs, may not be applicable to these.

Thus, in summary:

• The STANDARDS PROPER, within the 'IAEA Safety Standards', DO APPLY TO NEW EVOLUTIONARY AND INNOVATIVE REACTORS DESIGNS.

• The NORMS PROPER, within the 'IAEA Safety Standards', are specific to each type of reactor and, therefore, DO NOT NECESSARILY APPLY TO NEW EVOLUTIONARY AND INNOVATIVE REACTORS DESIGNS. (Specific safety norms for these rectors will have to be developed).

The main levels of attainment, or standards proper, within the 'IAEA Safety Standards', are described in the so-called 'Fundamental Safety Principles' [10]. They account for ten primary principles described hereby, which may need some refreshments but for the time being should form the basis for the regulation of the new evolutionary and innovative reactors designs, as follows:

• Responsibility for safety: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

• Role of government: An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

• Leadership and management for safety: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

• Justification of facilities and activities: Facilities and activities that give rise to radiation risks must yield an overall benefit.

• Optimization of protection: Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

• Limitation of risks to individuals: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

• Protection of present and future generations: People and the environment, present and future, must be protected against radiation risks.

• Prevention of accidents: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

• Emergency preparedness and response: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.

• Protective actions to reduce existing or unregulated radiation risks: Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

The 'IAEA Safety Standards' also include Requirements and Guides. The first establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The second provide recommendations and guidance on how to comply with the safety requirements. Within the Requirements there are mainly standards but also some norms. Within the Guides there are mainly norms but also some standards. For instance, the Requirement for the Safety of Nuclear Power Plants: Design [24] establishes requirements for management of safety, for design, for quality, etc, which are de facto 'standards', i.e. levels of attainment. They are obviously applicable to new evolutionary and innovative reactors designs. However, some norms in the 'IAEA Safety Standards' are not tailored to them and therefore not applicable.

Separating standards proper and norms proper within the documents that constitute the 'IAEA Safety Standards' will be a very demanding but not an impossible challenge; but, it will clearly be absolutely necessary.

The IAEA has already made efforts to assess the applicability of the IAEA Safety Standards' design safety requirements to small modular reactor technologies intended for near term deployment [25], although until now there has been no discussion regarding the distinction between standards proper and norms proper.

It should be noted that the standards proper within the 'IAEA Safety Standards' are based on higher level primary standards on the science and the basic paradigm on which the standards proper within 'the IAEA Safety Standards' are based. The primary standards on the internationally consensual science on the levels and effects of radiation exposure are the remit of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which periodically submit its estimates to the United Nations General Assembly. The primary standard on the internationally accepted protection paradigm, including its ethical basis, has traditionally been the remit of the ICRP, the independent nongovernmental charity that develops radiation protection recommendations since the early days of ionizing radiation uses [26]; the IAEA Board of Governors had decided that the 'Agency Safety Standards' are to be drawn up in accordance with the provisions of Article III. A. 6 of the IAEA Statute and will be based, to the extent possible, on the recommendations of ICRP.

4) PROBABILISTIC CRITERIA

. Since many years ago, ARN has included compliance with a probabilistic criterion as a regulatory condition for licensing nuclear reactors. It therefore considers that licensing the new evolutionary and innovative reactors designs require full application of probabilistic criteria

The basic ARN approach is to require designers to use the available probabilistic tools, such as event and fault trees, for a priori overall safety analyses of the nuclear installation under consideration.

A comparison is, therefore, required to be performed between the probability of occurrence of a hypothetical chain of events leading to an unexpected human radiation exposure, along with its consequences—in terms of doses incurred— versus a probabilistic regulatory criterion based on the fundamental safety principles.

It must be emphasized that the Argentina approach of using probabilistic safety criteria is NOT aimed at performing a posteriori "confirmatory" study of the risk of the nuclear installation being considered; rather, the aim is to check a priori that the prevention of nuclear accidents is coherent and consistent with the fundamental safety principles. Probabilistic safety analyses of the installations and confirmation that those principles are met is therefore a pre-condition for licensing.

It must also be emphasized that this approach is in addition, and not in replacement, of international nuclear safety requirements, in particular it does not replace the determinist criteria for the prevention of accidents.

It should be also underlined that such a priori probabilistic analysis allows firmly grounded anticipation, when there is frequency data that allow classical statistical treatment, and (with the help of Bayes' theorem) some founded inference and subjective probabilities when only professional judgment is available.

Thus, such a probabilistic safety criterion was issued at a very early time, by the Argentine authorities. The main criterion was issued as Argentine Norm Number 3.1.3. [27] already in the year 1979 and it was further clarified by Norm Number 3.2.2. [28] in the year 1980. The novel approach was presented and discussed at various international scientific meetings on nuclear safety[29] [30]. The approach evolved over time and now it served as a basis for the current regulatory system, as those early norms were later endorsed by the ARN and formalized in the current normative for nuclear safety for the licensing of nuclear installations [31].

The aim of the ARN approach is: (i) requiring applicants for a nuclear installation license to identify the failure sequences which, in case of occurrence, will deliver a radiation dose to members of the public; and, (ii) making their probability of occurrence sufficiently low to be coherent and consistent with the basic safety principles. The probability of occurrence of each failure sequence, as well as the corresponding activity of released radionuclides, is to be assessed by using event and fault trees, while taking into account the following criteria:

• the failure analysis shall systematically encompass all foreseeable failures and failure sequences, including the common-mode failures, the failure combinations, and the situations exceeding the design basis (failure in this context means an aleatory event preventing a component from performing its safety function, as well as any other event which may additionally occur as a necessary consequence of such deficiency; failure sequence, on the other hand, means a sequential series of failures which can, although not necessarily, occur after an initiating event);

• a failure or a failure sequence may be selected as representative of a group of failures or of failure sequences (in such a case, the failure or failure sequence to be selected from the group shall be that delivering the worst consequences and the analysis shall take into account the sum of the probabilities of the failure or failure sequences in the group);

• the analysis shall consider that a protection function may have lost operativeness either before the occurrence of the failure or of the failure sequence or as a result of such occurrence;

• the analyses of failures, of failure sequences, or of any part thereof shall be based on experimental data as far as it is possible (if this cannot be done, the valuation methods must be validated through appropriate tests);

• the levels of failure rate assigned to the safe-related components, in the evaluation of the failure probability of systems, shall be justified; in case that justifiable values were not available for some of the components, the applicant shall use levels of failure rate prescribed by the licensing authority (if a given failure rate is justified on the basis of quality assurance, this must be specified in detail);

• the failure analyses shall consider the maintenance and testing procedures and the time interval between successive maintenance and testing actions; and,

• failure rates postulated for human actions shall be justified taking into account the complexity of the task, the stress involved, and any other factors which might influence that failure rate.

Thus, the doses on a notional critical group of people, which would result from the release of radionuclides due to a failure or failure sequence, shall be assessed by accepted methods. The annual probability of occurrence of any failure sequence, when plotted as a function of the resulting effective dose, shall result in compliance with a criterion that is coherent and consistent with the basic safety principles enounced above.

The implicit basic safety restriction is a risk limit derived from the ethical principles described above, particularly from deontological and arête ethical doctrines, These principles entail that the risk committed by individual sources should be low enough as to be automatically disregarded. The currently recommended limit implies an annual risk limit of around 10^{-5} for any individual, even for the highest exposed one, as a result of performing all practices involving radiation exposure. As it would be discussed hereinafter, since the limits relate to individuals, appropriate constraints should be selected for each source of radiation risk.

The constraint must be sufficiently lower than the relevant limit, so as to prevent individual exposure to risks due to several sources from exceeding such limit. In Argentina, the regulation implies a constraint of around 1/3 of the limit, but as optimization is an additional mandatory requirement in the Argentine regulations, in practice, the actual highest individual risk is far lower than the constraint. As a result, the de facto annual limit of individual risk would become lower than the overall limit of around 10^{-5}.

On the basis of the above limitation and taking into account the uncertainties usually involved in probabilistic safety assessments, the Argentine authority did consider that an annual risk limit for accidental exposures from nuclear installations should not exceed around 10−6.

It should be noted that accidental exposures may arise from a theoretically infinite number of accidental sequences, each one having a given probability of occurrence and delivering a given expected dose to the most exposed individual. The actual risk incurred by this individual will then result from the integration of the tail distribution of doses (i.e., the complement of the probability function of doses) times the probability of death provided the dose is incurred. The safety constraint should therefore be that the value of this integral be lower than 10^{-6} per annum. The assessment of all possible accidental sequences involving radiation exposure is extremely difficult and practically unfeasible. Therefore, the Argentine authority is satisfied if only ten of the most relevant sequences are identified and has assigned them an annual risk limit of 10^{-7}.

Since each sequence may result in different doses, a criterion curve was adopted, which is a relationship between the annual probability of sequence occurrence and the expected individual dose, each point of the curve representing a constant level of risk. The criterion curve enforced by the Argentine authority is shown in Figure 2.

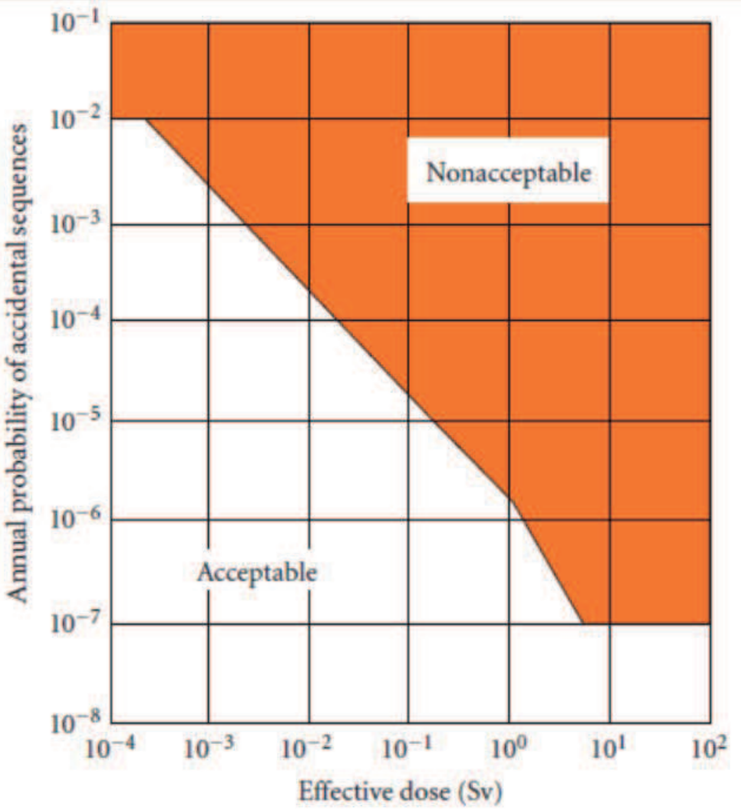

Figure 2: Criterion Curve

It is to be noted that failure of a point to be under the criterion curve does not necessarily mean that the risk constraint is not met, because even in this case, the integral of the tail distribution could be lower than 10^{-6} annum.

The logic behind the criterion curve is as follows. For the range of doses from which only stochastic effects of radiation can be incurred, the criterion curve must show a constant, negative, 45◦ slope in a—log annual probability versus log individual dose—coordinate axis plane. This would ensure that the annual probability of incurring the dose times the probability of death provided the dose is incurred (the latter being in the order of 10^{-2} per Sv) will be kept constant. One of the coordinate points in this part of the curve would obviously be the following: annual probability: ~ 10−7 annum−1; individual dose: 1 Sv, because the product 10^{-5} annum−1 × 1 Sv × 10^{-2} Sv^{-1} results in a second-order of stochasticity annual risk of 10^{-7} $annum^{-1}$. In the dose range where deterministic effects of radiation may occur (i.e., for individual doses higher than around 1 Sv), the slope of the curve should increase, in order to take into account the higher risks of death at these levels of dose. For doses higher than approximately ~6 Sv, the probability of death approaches unity. From this level to higher doses, the criterion curve should remain constant at an annual probability of 10^{-7} (because the exposed individual at such dose levels would inevitably die regardless the level of the dose). Between the coordinate points defined by nnual probability: 10−5 annum−1; individual dose: 1 Sv and annual probability: 10^{-7} $annum^{-1}$; individual dose: 6 Sv, the criterion curve should show a shape similar to that of the relationship between the individual dose and the frequency of death (which, at that range, is approximately S-shaped but, for the sake of simplification, the authority has decided to approximate these two points by means of a linear-shaped relationship). Finally, the criterion curve has been truncated at an annual probability level of 10^{-2}, because the occurrence of incidents having a higher annual probability (regardless the dose) is unacceptable for the authority.

It should be emphasized that the criterion curve is individual related; that is, it is intended to limit the risk rate on the individual incurring the highest risk, but it does not take into account the overall expected impact from accidental situations. The criterion assures a level of safety which is sufficient to ensure that an individual risk constraint, compatible with the safety principles, will not be exceeded. It fails, however, to answer positively the old question of the safety engineers, that is, Is such safety level safe enough as to preclude further safety improvements? An installation complying with the criterion would be equally considered whether it is imposing risks (lower than the "acceptable" one) to few individuals or if many individuals would incur such risks. If an accident does occur, however, the overall impact will be very different in each case, suggesting that the overall safety level might be lower in the second case than in the first one. The principle of optimization may require further safety improvements in the second case. This would allow for complementing the probabilistic criterion based on individual risk considerations alone.

International standards recommended the use of the concept of radiation detriment, namely, the mathematical expectation of harm, to quantify the impact from a source of radiation exposure. The detriment is an extensive quantity that estimates the combined impact of deleterious effects resulting from exposure to a given radiation source. It is defined as the expectation of the harm to be incurred, taking into account the expected frequency and severity of each type of deleterious effect. The detriment incurred by one individual receiving a dose in the range of stochastic effects is proportional to the effective dose incurred, the proportionality factor being the probability that the individual will incur a deleterious effect as a result of the exposure. Therefore, in cases of actual exposures to low levels of dose, the total detriment is proportional to the sum of all individual effective doses incurred, that is, is proportional to the collective dose commitment, a quantity resulting from the time integration of the collective dose rate, which, in turn, results from the integral of the population spectrum in terms of effective dose rate incurred). It was therefore tempting, and it was proposed, to use a similar concept for measuring the expected impact from accidental exposures [32]. For potential accidental exposures, the concept of detriment may keep its theoretical meaning although it would become a quantity of a second order of stochasticity. In such case, the probability of a given exposure, that is, the combined probabilities of both, an accidental release and an environmental condition (dispersion, deposition), should be introduced in the formulation and integrated over all possibilities. Then, if low doses were expected, the detriment should be proportional to the resulting mathematical expectation of the collective dose commitment. For higher doses, another component of the detriment should be added in order to take into account the non-stochastic effects of radiation. This idea of using the detriment of a second order of stochasticity, and the related mathematical expectation of collective dose commitment, for quantifying the impact from accidental exposures is appealing, as the concept would allow for optimizing safety, increasing it to a sufficiently high level that further improvement would not be worthwhile taking into account both the benefits achieved in terms of expected collective dose commitment reduction and the cost of obtaining such reduction. But it entails two serious difficulties. One is that is questionable if the concept of mathematical expectation, which was defined for frecuentist probabilities, continue to be valid for subjective probabilities. The second, more serious is that, unfortunately, it was demonstrated [33] that, at very low probabilities, the detriment will lose its usefulness as a basis for decision-making. In fact, in such cases the standard deviation of the result may be orders of magnitude higher than the actual expectation and the coefficient of variability would become very large. The detriment is then no longer a central measure of the distribution of harm, and, in addition, the uncertainty of the detriment becomes too large to make it meaningful, even if the probability as such could be estimated by safety assessments with an accurate degree of certainty. At very low failure probabilities, the inherent uncertainty of the product of probability and consequences makes the use of this quantity rather doubtful.

For all these reasons, ARN decided that, for potential accidental exposures, the principles of justification and optimization be implemented in a less quantitative manner. The value assigned to the variables follows a utility function of probability and consequence. The utility function usually gives more weight to larger accidents than would be implied by the direct product probability time consequence.

5) EXPERIENCES ON THE LICENSING OF A SMR PROTYPE

The CAREM concept for a SMR prototype was developed during the 90's, by INVAP S.E. (Argentinean nuclear vendor of R&D complex technological systems). The conceptual engineering and experimental facilities were developed under the supervision of the CNEA specialists and the basic engineering was then developed jointly by CNEA and INVAP during 1998-2000. Its main design characteristics are an integrated reactor with passive safety systems. The project has been widely described in the literature [34] [35] [36 [37] [38] [39].

The project was re-refreshed in 2006 under CNEA's management and, in 2007 an application was submitted for the issuing the Construction License for the prototype CAREM. ARN then defined an "ad hoc" licensing scheme based on the authorization of "non-routine practices". This licensing scheme foreseen the following authorizations:

- for use of site
- for construction,
- for fueling,
- for core subcritical testing,
- for initial criticality,
- for zero power tests,
- for power increase, and
- for full power tests.

ARN later updated and adapted taking into account particular requirements of ARN standards, in particular standard AR 0.0.1 on Licensing of Type I installations, and standard AR 3.7.1. on Documentation to be submitted to the Regulatory Authority prior to the commissioning of nuclear reactor, as well as on the experience gained in other projects. The scope of this modification will take place from the next licensing milestone, when the construction and preliminary tests are complete

As reported in the Argentine National Safety Reports to the Convention on Nuclear Safety, the design features of CAREM have an improved implementation of the Defense in Depth (DiD) concept and, therefore, it can be considered as an example of how the basic objective of the Vienna Declaration could be implemented in future projects.

In reference to the development of the licensing activities ARN follows a proactive, rather than retrospective, approach accompanying the project realization. As in other licensing projects review & assessment, inspections and audits are performed following a safety oriented graded approach.

ARN regulatory scientists have been describing ARN's experiences on licensing CAREM in submitting papers. For instance it has been described some of the ARN experience in the licensing of CAREM prototype reactor by, for instance, presenting a summary of basic design aspects of CAREM 25 Reactor in relation with DiD concept, as follows [40]:

• Level 1 of DiD eliminates some initiating events with potential to threaten the reactor integrity.

- The integrated primary, featuring natural circulation and self-pressurizing, implies eliminating events as large LOCAs, LOFA and control rod ejection.

• Level 2 of DiD identifies the specific systems that prevent the demand of Safety Systems and in general that reduce the occurrence of fault sequences, namely risk reduction systems.

• Level 3 of DiD prevents initiating events from escalating to a severe accident, and it is unfolded in:

- Sub-level 3A, with the goal of controlling PIEs plus single failure events within the Design Basis scenarios, accounts for both the short and the long term.

 The Controlled State, namely grace period, is achieved by means of Safety Systems featuring passive driving forces (require no Power Supply) and is extended up-to 36 hours without requirement of operator intervention.

 The second step, a Safe State is kept as long as necessary, by means of active systems actuated manually with no urgency, at any moment within the grace period.

- Sub-level 3B, with the goal of controlling multiple failures or extremely rare events, accounts for two conditions in which the additional failures can take place.

 For failures of the Safety Systems in Sub-level 3 A during step 1, the goal is Controlled State by means of diverse Safety Systems, also passive.

 For failures in the Safe State (Sub-level 3A during step 2), the goal is to extend the grace period beyond 36 hours, by means of Safety Related Systems. It allows the operator intervention to recover the availability of the Safe State Systems.

• Level 4 of DiD mitigates conditions of core damage by the preservation of the confinement function, preventing releases to the environment.

- Design features dealing with preventing high pressure failure of the RPV, hydrogen deflagrations and detonations, corium-concrete interaction, and Containment failure in the long term (pressure increase is prevented by sprinklers and a Suppression Pool cooling system).

The key issue of mission time in events trees for level one probabilistic safety analyses for the use of probabilistic criteria has also been described [41]. ARN have already requested the evaluation of a level 1 probabilistic safety assessment (L1 PSA), as a mandatory documentation. It also requested to focus on the analysis of the mission time used for the modelling of the initiating events postulated in the L1 PSA, considering its variation between active and passive systems. The particularity of this type of nuclear reactor is that the time for passive systems (it is termed the grace period for the CAREM reactor) is longer than for active systems. Therefore, specific regulatory criteria for the mission time has been requested for the sequences of the event trees of the L1 PSA for the CAREM.

Finally, ARN is conscious of the regulatory challenges that will be presented by deployment of future SMRs derived from the CAREM prototype and it is closely following international discussions on the subject [42], [43]. [44], [45].

6) SUMING UP

Some propositions for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs have been described. The ARN approach to the safe regulation of a SMR prototype, the CAREM, is an example on how these propositions can be used in practice. It starts with a full respect of the international safety regime. This includes the legally binding commitments, such as the Convention on Nuclear Safety and also politically binding commitments such as the Vienna Declaration on Nuclear Safety. It also includes full compliance with the standards proper within 'the Agency Safety Standards' and the proposal for developing norms proper within 'the Agency Safety Standards. In addition ARN fully implement probabilistic criteria that present a uniqueness: its coherence and consistency *vis-à-vis* the fundamental ethical principles governing radiation and nuclear safety for both actual and potential safety situations.

For all the above reasons, it is submitted that the ARN approach to nuclear safety, included the current international and intergovernmental regime, properly adjusted, could serve as a good basis for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs in general and with SMRs in particular.

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International Conference on Topical Issues in Nuclear Installation Safety: Strengthening Safety of Evolutionary and Innovative Reactor Designs

IAEA Headquarters Vienna, Austria 18–21 October 2022

A Response to the Regulatory Safety Challenges for New Reactor Technologies

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New Reactor Technologies

- the gas-cooled fast reactor (GFR);
- the high-temperature gas-cooled reactor (HTGR);
- the lead-cooled fast reactor (LFR);
- the molten-salt reactor (MSR);
- the sodium-cooled fast reactor (SFR);
- the supercritical-water-cooled reactor (SCWR);
- the very-high-temperature reactor (VHTR); and,…
- …a large variety of reactors known as SMR.

Content

1. The basic safety questions
2. Potential responses
   - Sufficiency of the States' commitments
     Suitability of the "IAEA Safety Standards"
3. Implementing the responses
   - On the *Vienna Declaration on Nuclear Safety.*
   - On the "IAEA Safety Standards"
4. Summing up

1.

Regulatory Challenge:

The basic safety questions

- Are States' formal commitments on nuclear safety sufficiently satisfactory for the new reactor technologies?
- Are the '*IAEA Safety Standards*' suitable for dealing with the new reactor technologies?

2.
Potential responses to the basic questions

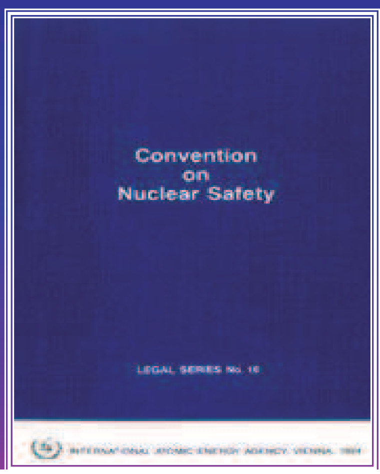
Responding to the first question

States' commitments
on
nuclear safety
for
the new reactor technologies

Legally binding undertaking

The Convention on Nuclear Safety

CNS



Are the undertakings in the CNS sufficient

to convince sceptic members of the public

of their representatives that States will

guarantee that the new reactor

technologies would be sufficiently safe?

After the Fukushima accident, concerns arose in many States on this contradiction:

- States had adopted the CNS '*aware of the importance to the international community of ensuring that the use of nuclear energy is safe…*'
- However, a catastrophic accident occurred

Had the Convention been violated? …or…

Are the States' obligations insufficient?

It seems that the current legally binding undertakings on nuclear safety are not sufficient for *ensuring that the use of nuclear energy [even with the new reactor technologies] is safe.*

Namely, the CNS seems to be insufficient!

Suitability of the “IAEA Safety Standards” for the new reactor technologies

Background
on the so-called
'IAEA Safety Standards'

Under its Statute the IAEA is authorized

- to establish standards of safety for the protection of life and property and
- to provide for their application at the request of a State.

INFCIRC/18*

For implementing the Statute

the Board of Governors approved

Agency's Health and Safety Measures

on **31 March 1960**

* IAEA, The Agency's Health and Safety Measures, INFCIRC/18, IAEA, Vienna (1960).

IAEA safety standards…

…shall mean safety standards promulgated by the IAEA:

- under the authority of the Board of Governors;
- harmonized with international organizations of recognized competence in the matter; and,
- designed to invite international acceptance.

A clarification

In compliance with the IAEA Statute the so-called 'IAEA Safety Standards' are developed under the aegis of the IAEA but they are :

1. **cosponsored and established by all relevant international Agencies**; and,
2. **endorsed by States representatives**

Namely, the "***IAEA Safety Standards***" are

international

(because they are co-sponsored by the international organizations)

and

intergovernmental

(because they are approved by governments)

Therefore

- The so called IAEA Safety Standards are

International

and

Intergovernmental

Radiation and Nuclear Safety Standards

INFCIRC/18/Rev.1*

- The Agency's Safety Standards and Measures were reviewed by the IAEA Board of Governors in 1976.
- The Board indicated that the name "standards" have a multiplicity of meanings, including standards, norms, ..etc.

* The Agency's Safety Standards and Measures, INFCIRC/18/Rev. 1, IAEA, Vienna (1976).

Confusing terminology

The English term *standard* has been translated

- into Spanish as *norma* (and not as *estándar*)
- into French as *norme* (and not as *estandar*)
- into Russian as *нормы [normy]* (and not as стандартный [*standartnyy*])
- into Arabic as معايير [maeayir, norm] (and not as القاعدة [*alqaeida*, standard])
- into Chinesse as 标准 [Biāozhǔn - standard] (and not as 规则 [guīzé - norma])

...but...

Standard

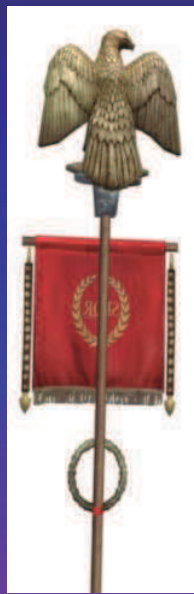
≠

Norm

Standard

= Level of attainment

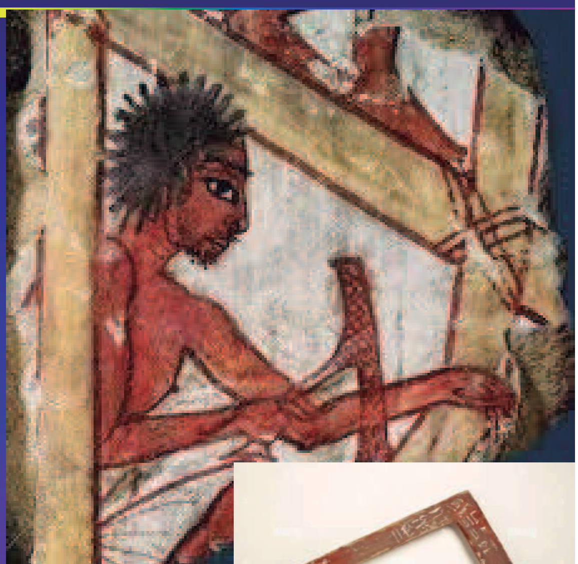
(From Latin *estendre* denoting a flag raised on a pole as a rallying point)



Norm

= Precept, rule

[from Latin *norma* , carpenter's square’]



Situation

Namely, the '*IAEA Safety Standards*'

become a concoction of

Standards & ***Norms***

The basic question can now be divided in two

- Are the ***standards*** within the 'IAEA Safety Standards' tailored to the new reactor technologies?
- Are the ***norms*** within the 'IAEA Safety Standards' tailored to the new reactor technologies?

The *levels of attainment* in nuclear safety should be acceptable for any nuclear reactor.

Therefore:

The *standards* (within the IAEA Safety Standards) should be aplicable to

New Reactor Technologies

But the safety prescriptions and rules shall be tailored to the specificity of each reactor type

Therefore:

Safety norms (with the ‘IAEA Safety Standards’) shall be developed for dealing with the specificity of new reactor technologies

3.
Implementing
the
responses

On the insufficiency of States' legally binding undertakings on nuclear safety for the new reactor technologies.

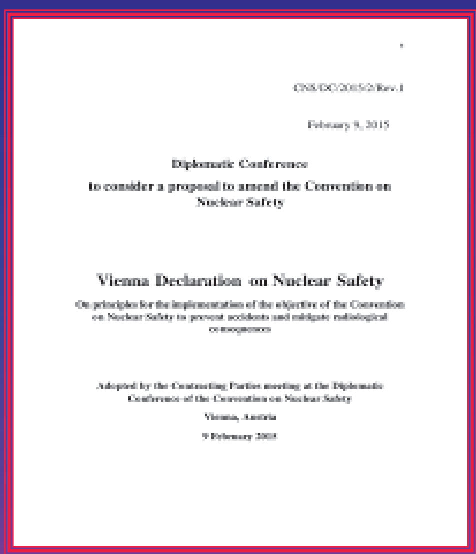
In response to concerns on such insufficiency,

the Vienna Declaration on Nuclear Safety

was adopted in 2015!

Political commitment

The Vienna Declaration on Nuclear Safety



CNS/DC/2015/2/Rev.1

February 9, 2015

Diplomatic Conference
to consider a proposal to amend the Convention on Nuclear Safety

Vienna Declaration on Nuclear Safety

On principles for the implementation of the objective of the Convention on Nuclear Safety to prevent accidents and mitigate radiological consequences

Adopted by the Contracting Parties meeting at the Diplomatic Conference of the Convention on Nuclear Safety

Vienna, Austria

9 February 2015

Thus, it is suggested that new reactors technology should obey the applicable principles of

the Vienna Declaration on Nuclear Safety, namely:

*'New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and **avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.**'*

'National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards'

"With immediate effect, these principles should be reflected in the actions of Contracting Parties, in particular when preparing their reports on the implementation of the CNS"

However, until now, Argentina is the only Contracting Party that has formally declared that its proposal for a New Reactor Technology, the CAREM, is in full compliance with the principles of the Vienna Declaration on Nuclear Safety

On the suitability of the “IAEA Safety Standards” to the new reactor technologies.

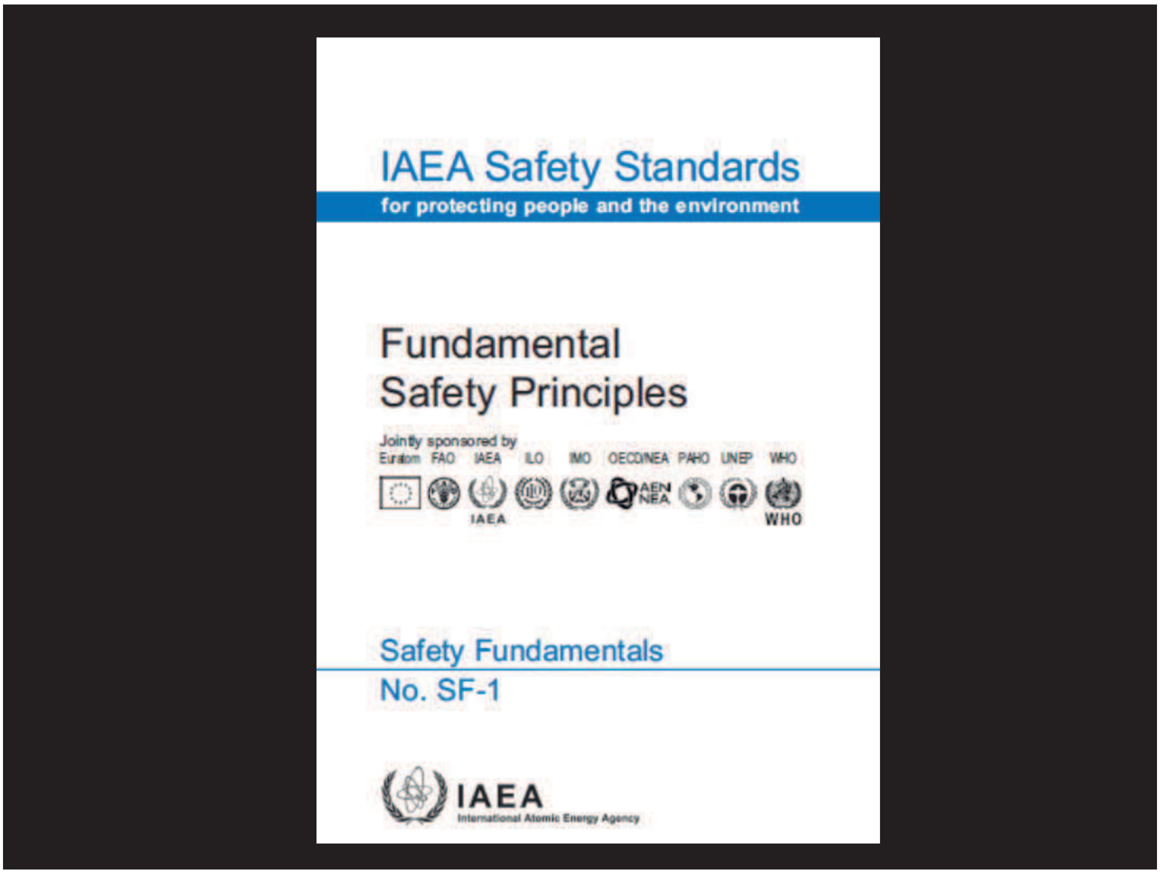
Challenges

1. Separate *standards* from *norms* within the corpus of the already existing ‘IAEA Safety Standards’.
2. Review the applicability of the existing *standards* (within the current corpus of ‘IAEA Safety Standards’) to the new reactor technologies and eventually revise their content.
3. Check the *norms* (within the current corpus of ‘IAEA Safety Standards’) that are applicable to the new reactor technologies
4. Develop and establish new *norms* (within the future corpus of ‘IAEA Safety Standards’) *ad hoc* to the particularities of new reactor technologies

Applicability of the existing *'standards'* proper

(within the current corpus of 'IAEA Safety Standards')

The main '*standard*' proper within the 'IAEA Safety Standards' are the *Fundamental Safety Principles*



Main 'standard': The fundamental principles

1. **Responsibility for safety:** The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
2. **Role of government:** An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.
3. **Leadership and management for safety:** Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
4. **Justification of facilities and activities:** Facilities and activities that give rise to radiation risks must yield an overall benefit.
5. **Optimization of protection:** Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
6. **Limitation of risks to individuals:** Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
7. **Protection of present and future generations:** People and the environment, present and future, must be protected against radiation risks.
8. **Prevention of accidents:** All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
9. **Emergency preparedness and response:** Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
10. **Protective actions to reduce existing or unregulated radiation risks:** Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

Optimization

Among the available protection and safety options, select the '*best under the prevailing circumstances*'.

Clear definition of such a 'best'!

Individual risk restriction

- Clear definition of 'risk' (in the IAEA Glossary there are 3 definitions, incompatible among them).
- If risk is defined as a probability, it should be made clear that it is a subjective probability rather than a probability based on factual frequencies.
- A consensual acceptability risk criterion would be needed

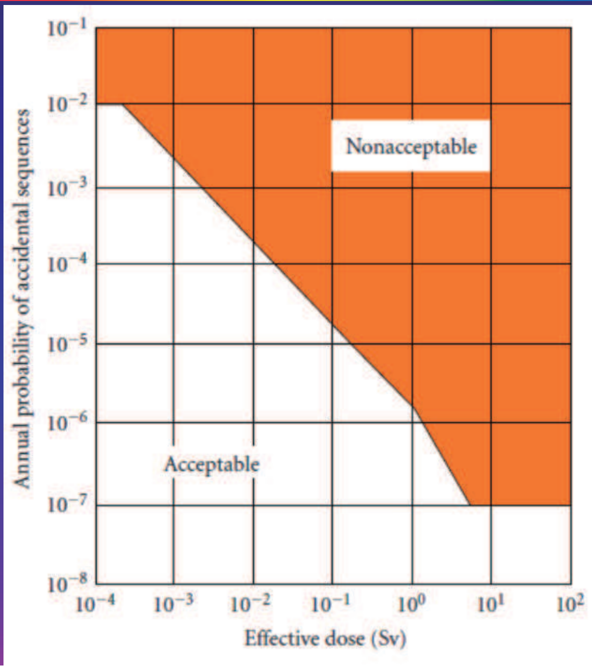
A suggested response

A PROBABILISTIC CRITERION

based on the internationally accepted radiation risks

- Since many years ago, the Argentine authority requests *a priori* safety analysis *vis-à-vis* such a probabilistic criterion.
- It therefore considers that licensing the new evolutionary and innovative reactors designs require full application of such probabilistic criterion.

Criterion compatible with the universal paradigm on acceptable dose limits



The logic behind the criterion

- For the range of doses from which only stochastic effects of radiation can be incurred, the criterion must show a constant, negative, slope in a—log annual probability versus log individual dose—coordinate axis plane, ensuring that the annual probability of incurring the dose X the probability of death (~10^{-2} per Sv) will be constant.
- In the dose range where deterministic effects may occur (i.e., doses >1 Sv), the slope of the curve increase, accounting the higher risks of death.
- For doses higher than approximately 6 Sv, the probability of death approaches unity. Above this level to higher doses, the criterion should remain constant at an annual probability of 10^{-7} . Below the criterion be S-shaped but, for the sake of simplification, is linear.
- Finally, the criterion is truncated at an annual probability of 10^{-2}, because incidents having a higher annual probability (regardless the dose) are considered unacceptable.

Warning about the criterion

Meaning of probability

- **Frequentist probability**: the limit of the relative frequency of occurrence of events in many trials
- **Subjective probability**: reasonable expectation of the occurrence of events quantified as a personal degree of belief of qualified experts representing the state of knowledge

Prospective versus retrospective Probabilistic versus deterministic

- The probabilistic criterion is aimed at a prospective detailed examination of the safety design, on the basis of a subjective quantification of the likelihood of situations that might happen.
- It is not aimed at replacing deterministic criteria, i.e. criteria aimed at preventing events and actions ultimately determined by causes regarded as external to the will and mitigating their consequences

Applicability of the existing *'norms'* proper

(within the current corpus of 'IAEA Safety Standards')

Areas for which new ‘norms’ (proper) may need to be developed

- for use of site,
- for construction,
- for fueling,
- for core subcritical testing,
- for initial criticality,
- for zero power tests,
- for power increase, and
- for full power tests.

Improved implementation of the Defense in Depth (DiD) concept

Integrated primary,

featuring natural circulation and self-pressurizing, implies eliminating events as large LOCAs, LOFA and control rod ejection.

Specific systems for

- preventing the demand of safety systems and reducing the occurrence of fault sequences
- preventing initiating events from escalating to a severe accident
- featuring passive driving forces (requiring no power supply) and extending the grace period without requiring operator intervention.
- mitigating conditions of core damage by the preservation of the confinement function.
- preventing high pressure failures, hydrogen deflagrations and detonations, corium-concrete interaction,
- prevetnting containment failure, e.g. by sprinklers and a cooling systems

4.

SUMING UP

Some propositions for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs have been described.

The approach suggested by the Argentine regulatory authority (being used for the CAREM reactor) is an example on how these propositions can be used, in two fronts:

- States' binding commitments, such as the Vienna Declaration on Nuclear Safety.
- full compliance with the *standards* proper within 'the Agency Safety Standards' and proposal for developing *norms* proper within 'the Agency Safety Standards'

For all the described reasons, it is submitted that the approach suggested could serve as a good basis for responding to the regulatory safety challenges associated with the new family of evolutionary and innovative reactors designs in general and with the so called SMRs in particular.

Radioactivity in Goods Supplied for Public Consumption or Use: Towards a Synthesis of an Internationally Harmonized Regulatory Framework

González, A.J.

Presentado en: Topical Session on Radiation Safety of Non Food Commodities del
Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 24 de noviembre de 2022

TOPICAL SESSION ON RADIATION SAFETY OF NON FOOD COMMODITIES

IAEA Vienna International Centre, Vienna, Room M3, 24 November 2022

Radioactivity in Goods Supplied for Public Consumption or Use: Towards a Synthesis of an Internationally Harmonized Regulatory Framework

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Member of the Commission of Safety Standards of the IAEA

Member of the Committee of Radiation Protection and Public Health of NEA (OECD)

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Few introductory reflections

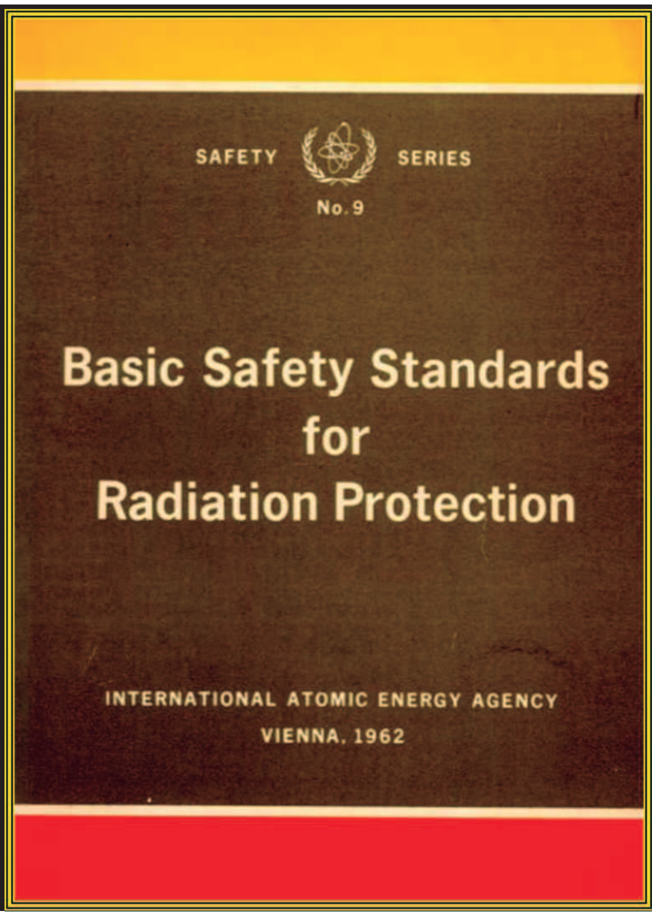
1.

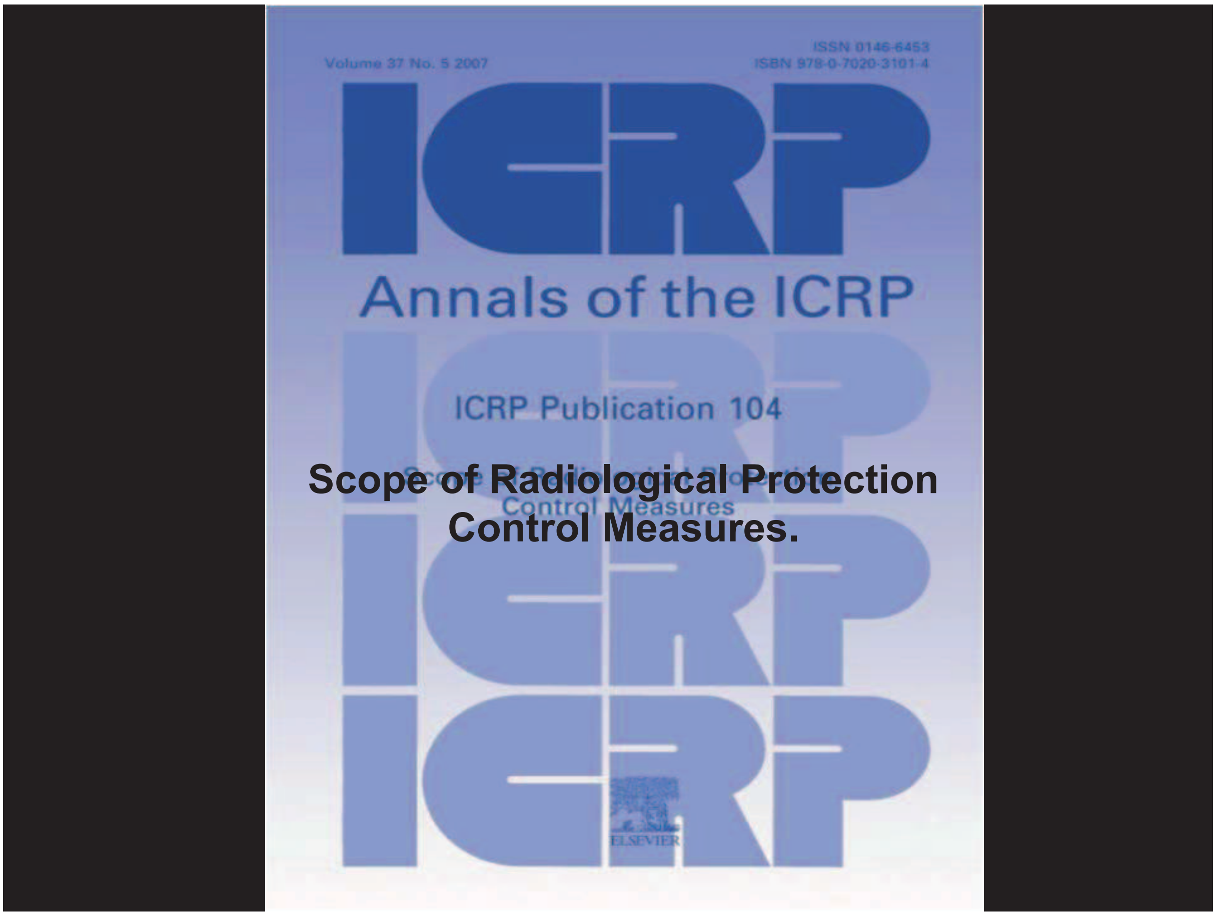
The regulatory *scope*,

namely the extent to which regulatory actions are relevant,

has not been a major concern for our radiation protection profession.

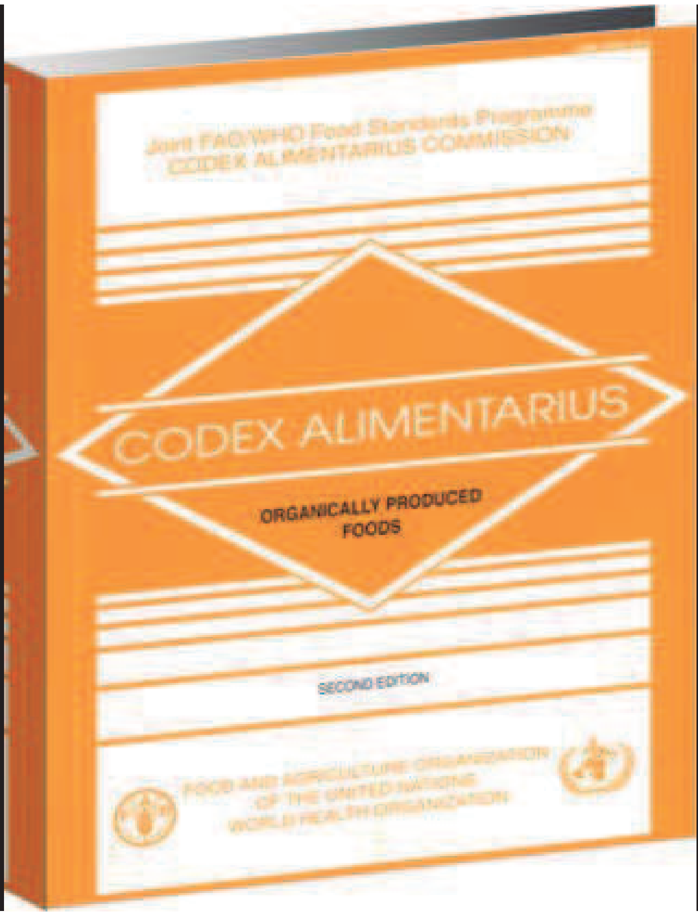
This was not always the case: the first radiation protection standards defined the regulatory scope very clear.



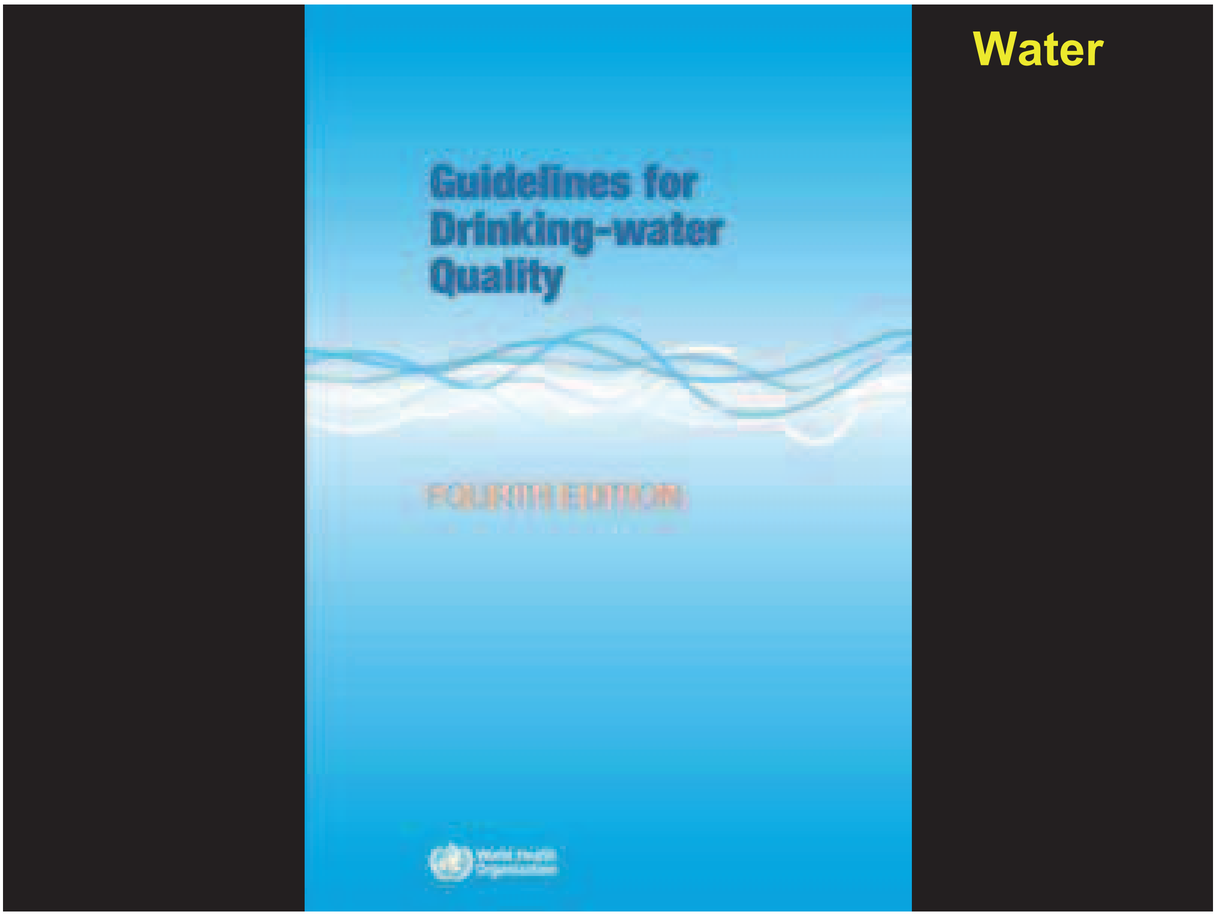


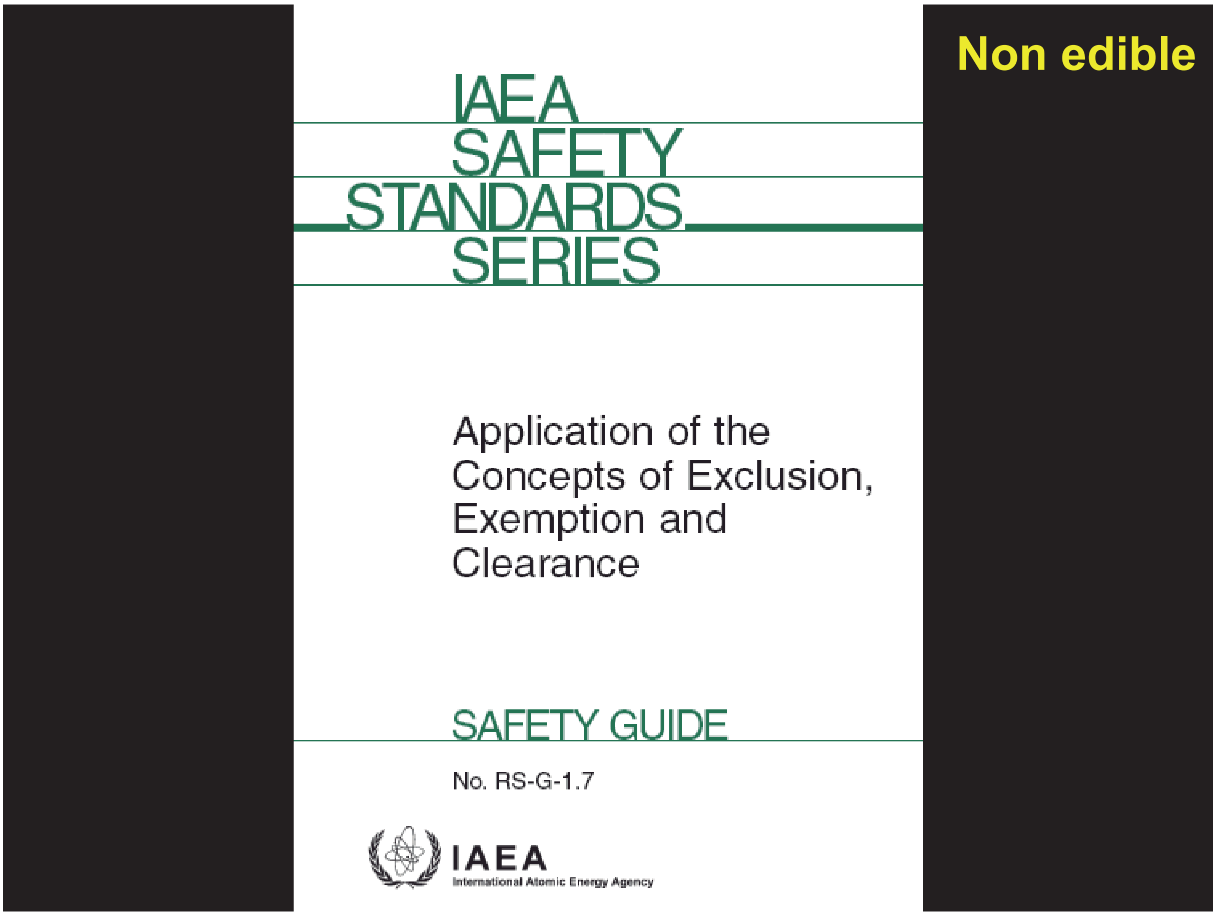
Current situation

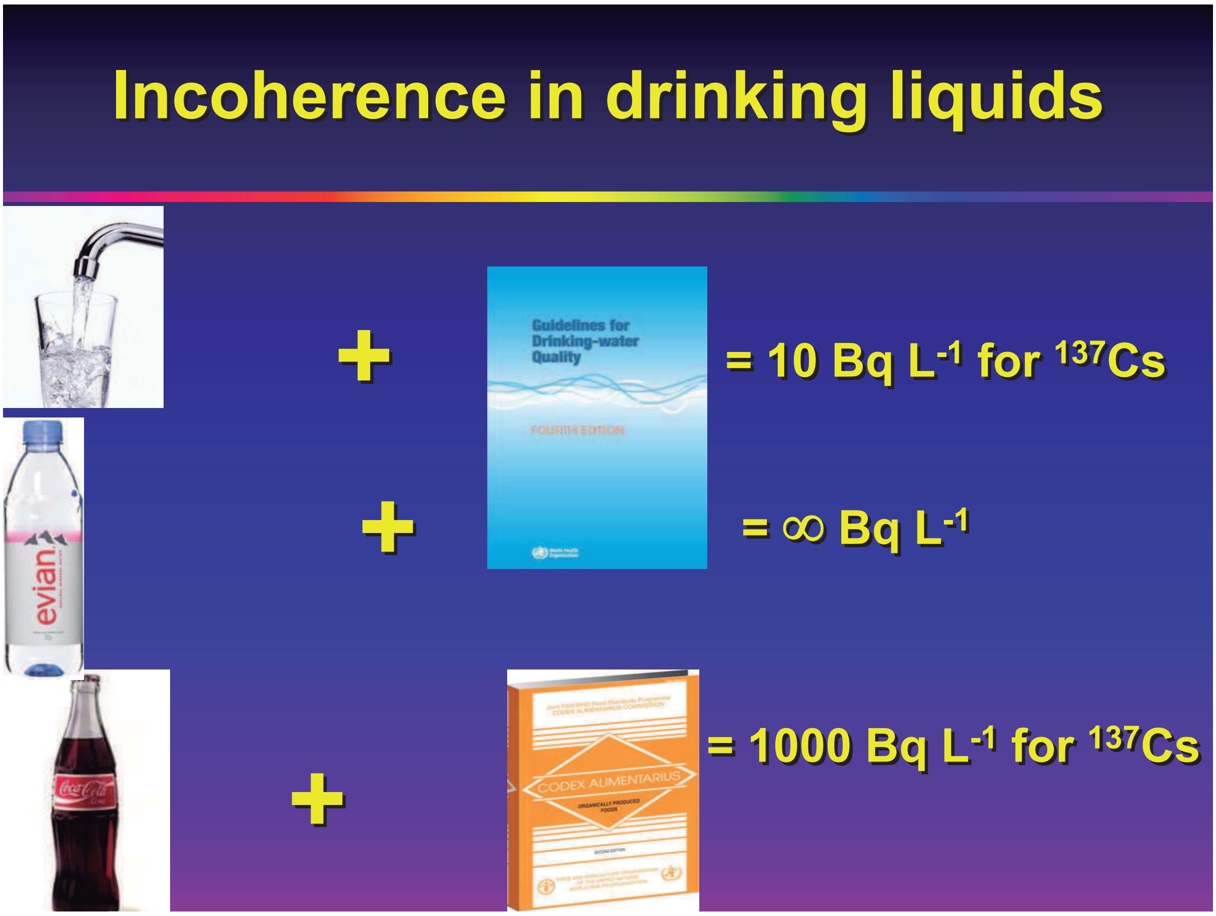
- Their regulatory control of radioactivity in consumer goods is not straightforward
- Some **international intergovernmental agreements exist** but they are incoherent and inconsistent.



Foodstuff


Water
Guidelines for Drinking-water Quality


Non edible
IAEA SAFETY STANDARDS SERIES
Application of the Concepts of Exclusion, Exemption and Clearance
SAFETY GUIDE
No. RS-G-1.7
IAEA
International Atomic Energy Agency


Incoherence in drinking liquids
+
Guidelines for Drinking-water Quality
FOURTH EDITION
= 10 Bq L^{-1} for ^{137}Cs
evian
+
= ∞ Bq L^{-1}
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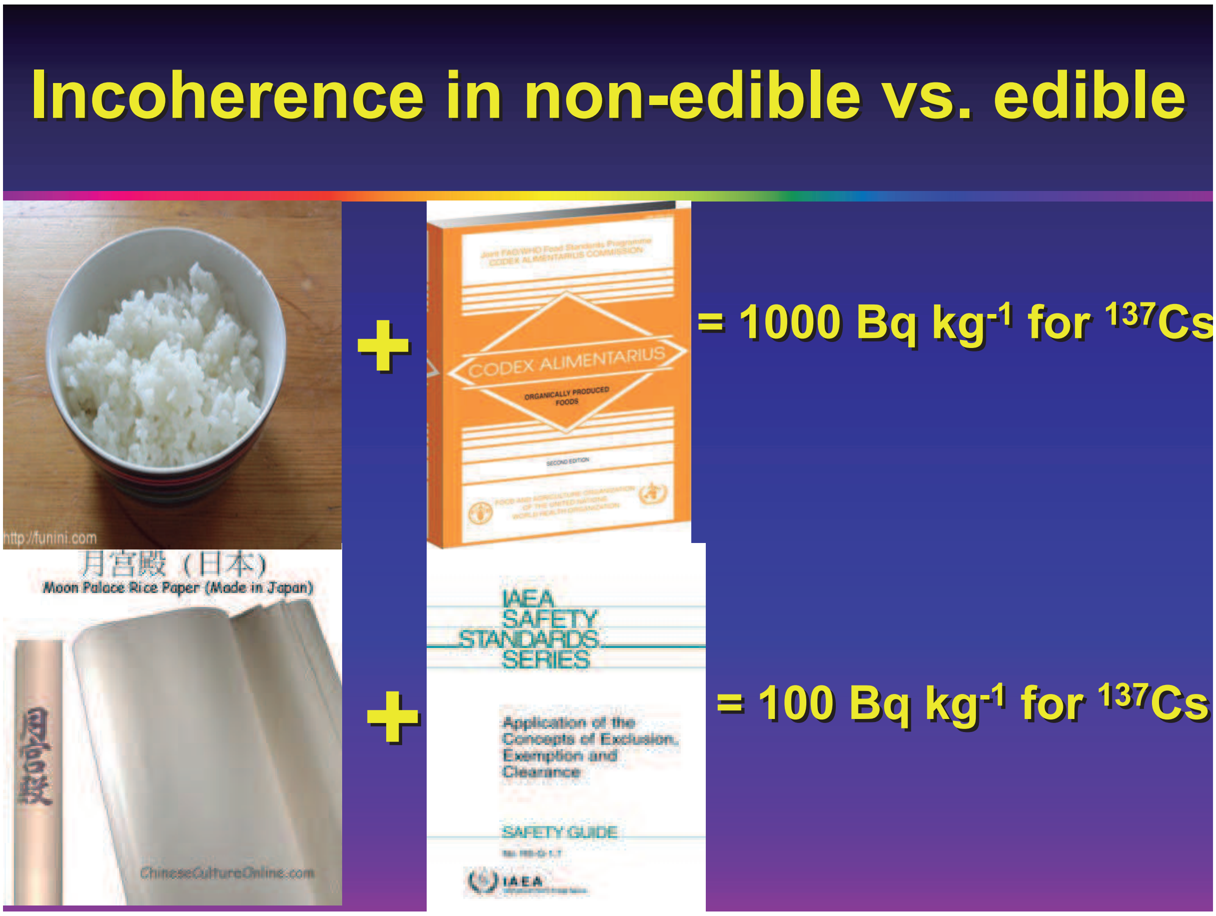
CODEX ALIMENTARIUS
ORGANICALLY PRODUCED FOODS
= 1000 Bq L^{-1} for ^{137}Cs


Incoherence in non-edible vs. edible
http://funini.com
+
CODEX ALIMENTARIUS
ORGANICALLY PRODUCED FOODS
= 1000 Bq kg^{-1} for ^{137}Cs
月宮殿（日本）
Moon Palace Rice Paper (Made in Japan)
ChineseCultureOnline.com
+
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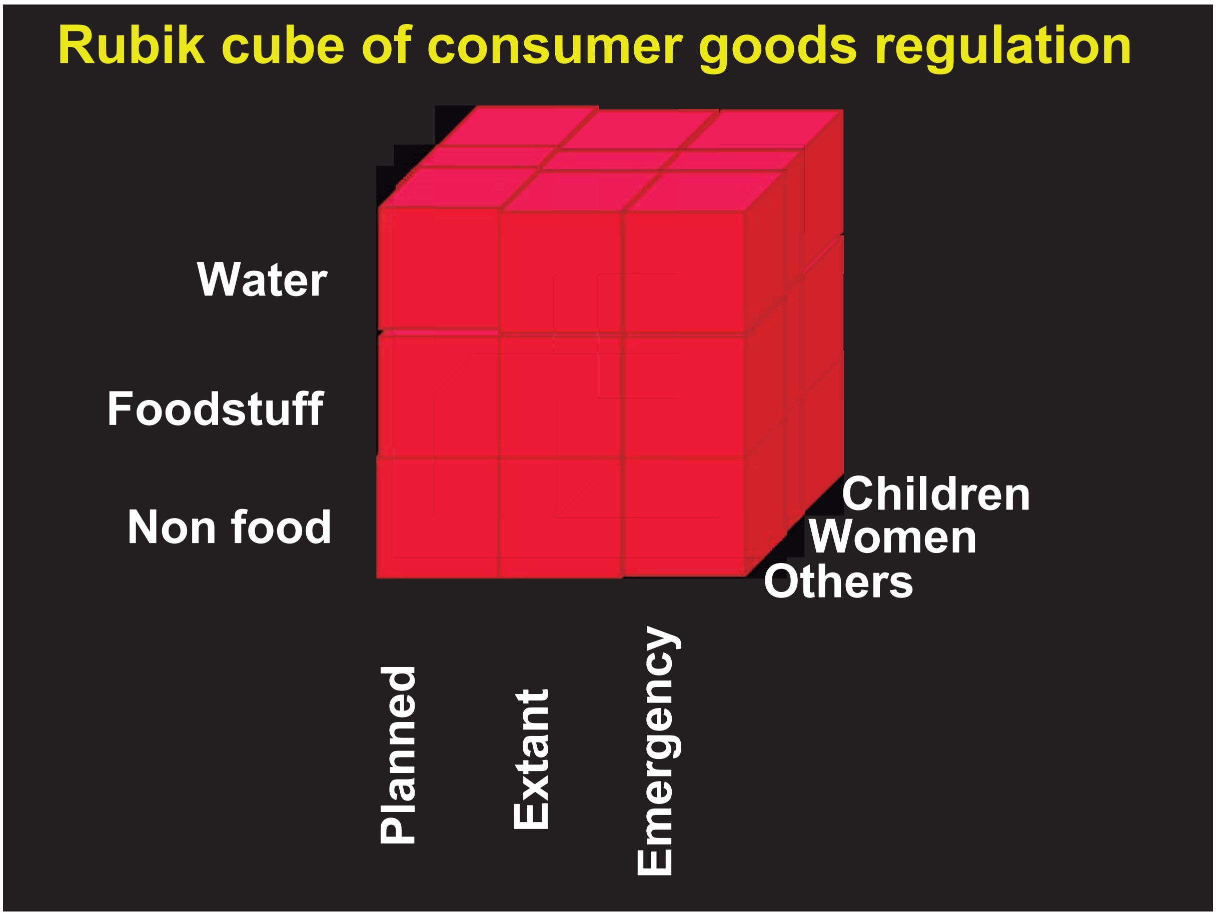
Application of the Concepts of Exclusion, Exemption and Clearance
SAFETY GUIDE
IAEA
= 100 Bq kg^{-1} for ^{137}Cs

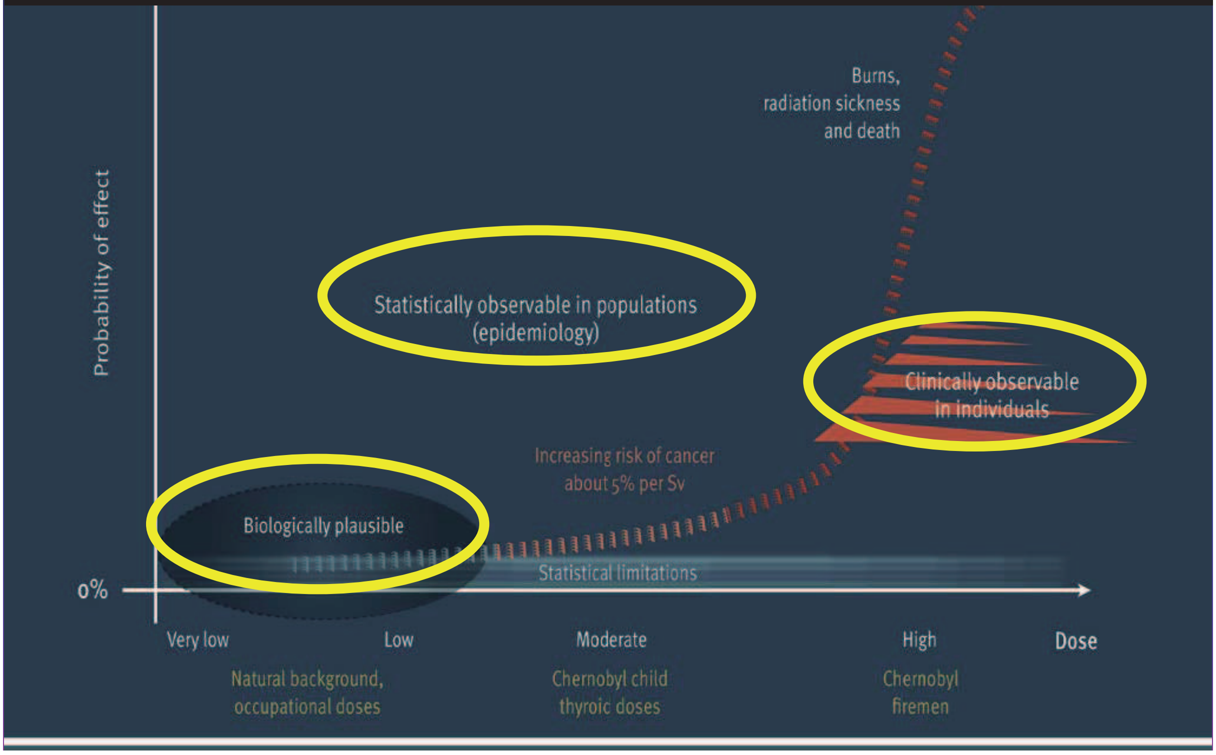


2.

We regulate without taking full account of the epistemological constraints of our basic knowledge

Regulators have been ignoring a clear warning from UNSCEAR: The distinction between effects:

clinically observable, statistically observable and biologically plausible



…and its epistemological consequence…

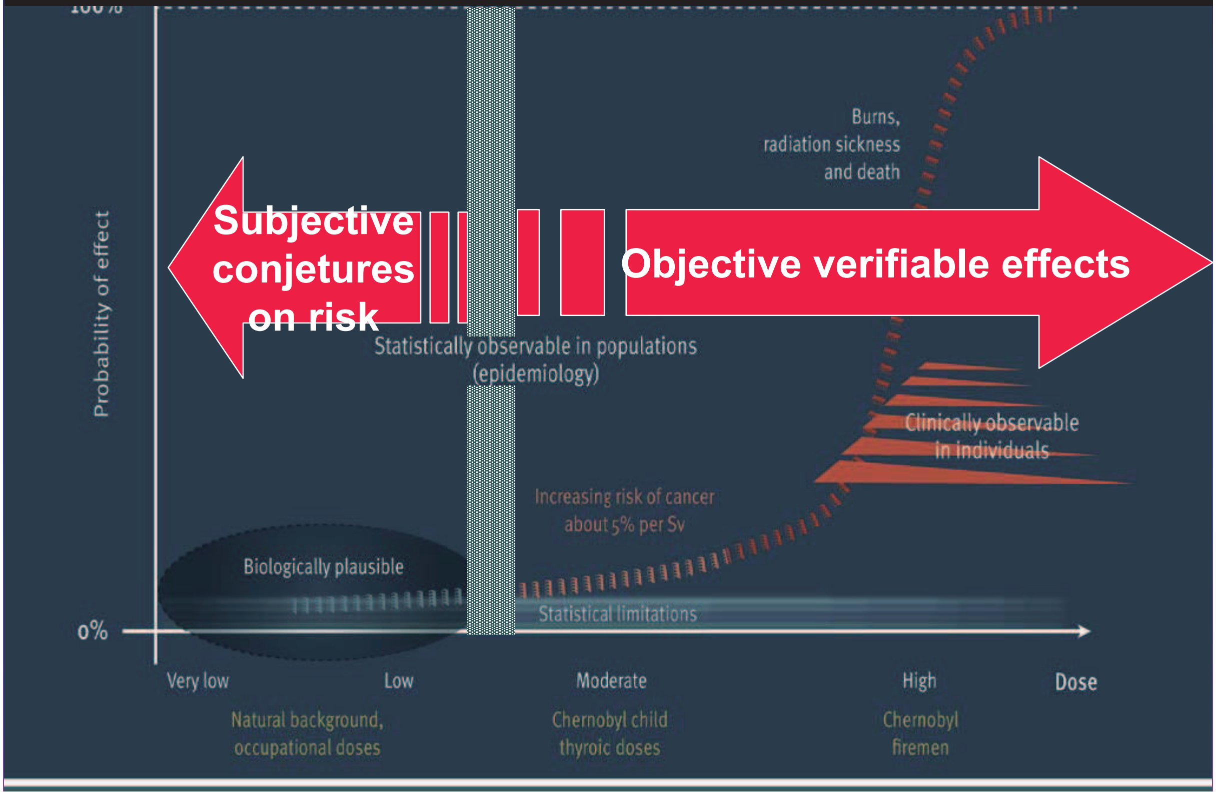
objective verifiable health effects

vis-à-vis

subjective conjectures on risks

16

Regulations do not distinguish objective verifiable health effects from subjective conjectures on risks



3.
Quantities

- We usually regulate on the basis of the so-called ‘protection quantities’, such as equivalent and effective dose, which are not real quantities.
- Rarely we use, as a basis, (real) quantities, such as activity and absorbed dose.

4. Some basic questions have not been answered

Should regulations differentiate between goods that…

- …contain radionuclides that
  - ✓are *artificial* versus those *natural?*
  - ✓are *artificially added* or incorporated due to *natural environmental processes?*;
- …are consumed and those that are used?;
- …are considered edible and those which are not?
- …are consumed or used by a given sex or age?
- …incorporate radionuclides from diverse initial exposure situations?

Suggestion for going forward and respond to the IAEA General Conference

Moving from analysis to synthesis in the regulations of consumer goods

A discussion document

jointly prepared by

the Autoridad Regulatoria Nuclear (ARN) of Argentina

and

the International Atomic Energy Agency

is presented for cosideration

CONTENT

1. Background
2. Semantics and terminology
3. Quantities
4. Exposure situations
5. Views from States
6. Recommendations
7. Epilogue

1. Background

A long saga

- For nearly half a century the international community has been requesting to the radiation protection professionals a simple answer to a simple question:

What are the radioactivity levels in consumer goods that made them unsuitable for consumption and use?

Analysis

Many diverse detailed examination were made of the elements of regulating consumer products separating them into its constituent elements!

- Water
- Commodities
- Food
- Non-food products
- etc

Synthesis

But, an international agreement combining those analysed components to form a simple, connected, coherent, and consistent whole, namely, a

synthesis

on how to regulate consumer goods

has been elusive.

- On 18 September 2015, the Nuclear Regulatory Authority of Argentina (ARN) and the International Atomic Energy Agency (IAEA) agreed on

‘*Practical Arrangements’ setting forth the framework for non-exclusive cooperation between the Parties in the area of radiation safety and monitoring*.

- A relevant activity agreed to be pursued was the

“development and publication of a harmonized approach for managing radionuclide activity concentrations in food, drinking water and non-food commodities.”

IAEA initiative

Miroslav Pinak
Initiator of the 'practical arrangements'

As a result of this arrangement a document was developed and published.

It contains concrete recommendations for an internationally harmonized regulatory framework for controlling radioactivity in goods supplied for public consumption or use.

It is freely available at

https://www.iaea.org/sites/default/files/19/02/iaea-arn_document_on_consumer_goods.pdf

29 January 2019

Radioactivity in Goods Supplied for Public Consumption or Use:

Towards an Internationally Harmonized Regulatory Framework

A discussion document prepared jointly by the
Autoridad Regulatoria Nuclear (ARN) of Argentina
and the
International Atomic Energy Agency

IAEA main co-author

Tony Colgan
Ex-Head, IAEA
Radiation
Protection Unit

ARN main co-author

Purposse of the IAEA-ARN document

Suggesting a synthetic simple approach for the regulatory control of radioactivity in goods supplied for public consumption and use.

The propossed way forward

1. Clarifying the basic concepts, including that of ‘*consumer goods*’.
2. Revising the basic control *quantity*.
3. Homogenizing the *exposure situations*.
4. Converging the current multiple approaches into a *simple criterion*

2. Semantics and terminology

Words that might confuse

- Commodities
- Consumer products
- Consumer goods
- Planned situations
- Emergency situations
- Existing situations
- Extant situations
- Drinking water
- Bottled water
- Mineral water
- Foodstuff
- Non food products
- Contamination

Commodities

- Common parlance: A raw material or primary agricultural product that can be bought and sold
- ICRP/IAEA defintion: Commodities are products generally used or consumed by the public that can contain radioactive substances.
- It is an untranslatable term - 'basic product'?.

Consumer products

- Common parlance: all everyday goods supplied for public consumption or use
- IAEA: "a device or manufactured item into which radionuclides have deliberately been incorporated or produced by activation, or which generates ionizing radiation, and which can be sold or made available to members of the public without special surveillance or regulatory control after sale".

Our proposal

- To use for our generic definition

consumer goods

➢ i.e., any article or substance, supplied for public consumption or use, which is manufactured or refined or produced during a natural, chemical, or manufacturing process, including, merchandises materials, goods and articles, which are consumed or used by the public at large.

How the consumer goods have been (artificially) divided

Water

Is '*drinking water*' water pure enough for drinking?

Why then *bottled water* and *mineral water* were treated separately of drinking water?

The meaning of ‘water’
(different regulations for various ‘waters’)

- **Drinking (?) water** (translated as ‘potable’ water)
- **Packaged drinking waters**

  (packed waters other than natural mineral waters, which may contain minerals, naturally occurring or intentionally added, and carbon dioxide, naturally occurring or intentionally added, but shall not contain sugars, sweeteners, flavourings or other foodstuffs)
- **Natural Mineral Waters**
  - naturally carbonated natural mineral water;
  - non-carbonated natural mineral water;
  - decarbonated natural mineral water;
  - natural mineral water fortified with carbon dioxide from the source; or
  - carbonated natural mineral water.

Foodstuff

- Is *food* any consumer good that be *edible*?...namely… fit to be ingestible?
- But *edibility* is a cultural issue, its definition changes among nations.

The meaning of 'edible'

- Does food include drinks?
- Is water as edible as food?....and, if so....
- ...why food and water are regulated differently?
- Should edibles that people eat for pleasure or vice (nor for nutrition) be out from food regulation?
- Understanding food has cultural connotations; substances that are edible in some cultures are considered inedible in others.

Contamination

Formally it means:

- the ***presence*** of radioactive substances on surfaces, or within solids, liquids or gases (including the human body), or
- the ***process*** giving rise to such *presence*.

It has a connotation that is not intended

(it gives no indication of the magnitude of the hazard involved)

Moreover, *contamination* …

- applied to food has a religious denotation
- conveys the idea of danger.
- causes public concern, as people perceive it as a binary situation, namely
  - either there is contamination, and some danger, or
  - there is not.

(The concept of 'low levels of contamination' is incomprehensible for many people)

These undertones cause anxiety to people and confusion to the authorities when dealing with or discussing radioactivity in consumer goods.

The use of the term *contamination* is particularly unhelpful for consumer goods in which, in general, the presence of radioactive substances is low.

The use of this term is discouraged!

3. Quantities

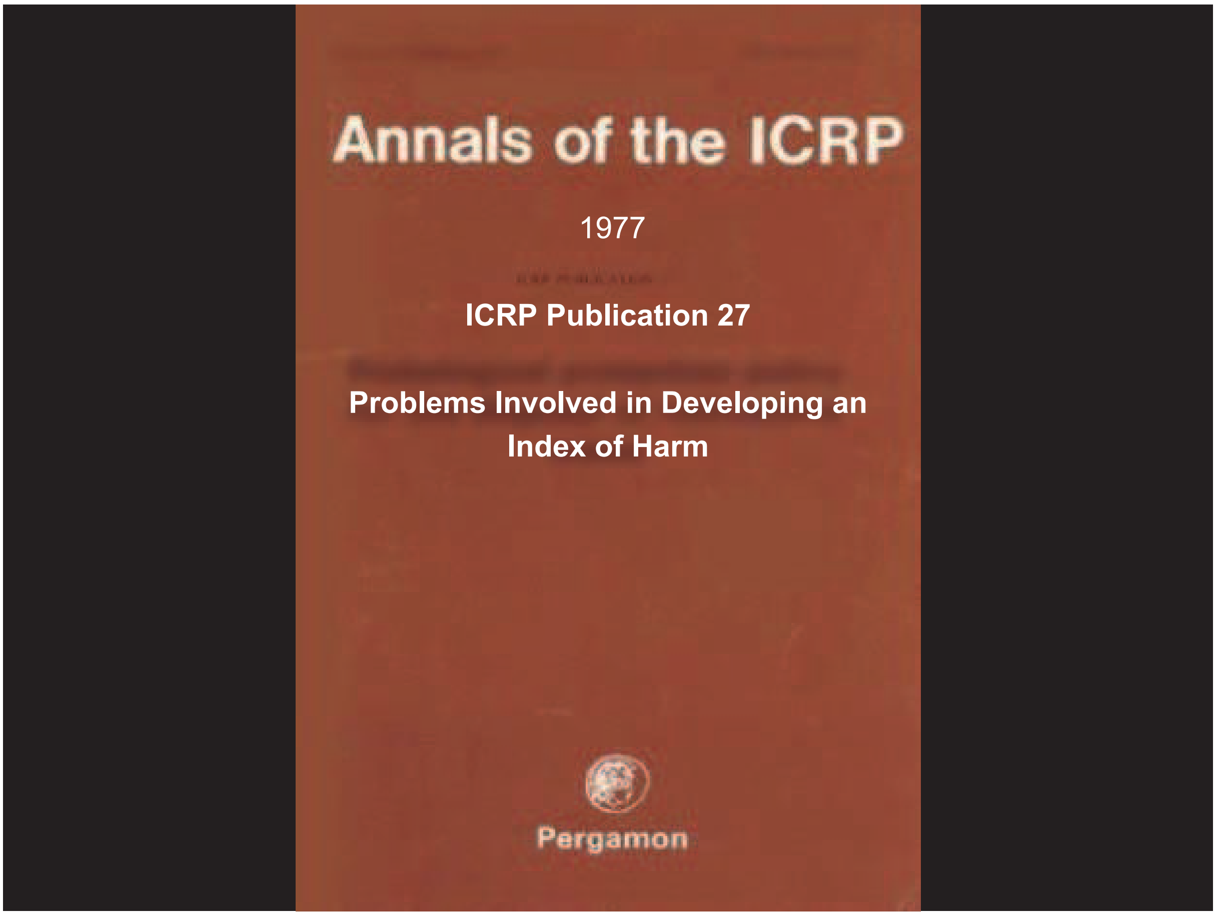
The temptation of basing the regulation of consumer goods on dose

Is it reasonable to use the RP system's dosimetric approach for the regulatory control of consumer goods?

Challenges

- Logic
- Measurability
- Controllability
- Traceability

The 1 mSv/year & 10 μSv/year 'magic numbers' and their logic



Index of Harm

TABLE 1. FATAL ACCIDENTS, MALES, U.K., 1971

Age groups	Manufacturing industries: No. employed (thousands)	Manufacturing industries: No. of deaths	Manufacturing industries: Deaths per million per year (±SE)	Construction: No. employed (thousands)	Construction: No. of deaths	Construction: Deaths per million per year (±SE)
15–	450	6	13±5	117	7	60±23
20–	1 330	36	27±4	340	45	132±20
30–	1 200	52	43±6	270	46	170±25
40–	1 300	62	48±6	240	26	108±21
50–	1 170	61	52±7	200	43	215±33
60–	460	23	49±10	90	16	180±45
65–	140	6	43±18	26	5	192±86
All ages	6 050	246	41±3	1 280	188	147±11
Mean age (years)	40.1	43.3		38.0	40.9	

Risk = 0.4 10^{-4}/y - 1.5 10^{-4}/y

First approach for judging the acceptability of radiation risk levels

Index of harm (workers)

+

(Hiroshima/Nagasaki)

risk factor 10^{-2} Sv^{-1}

↓

Occupational limit of 50mSv/year

Arbitrary limit for the public

Decision: 1/10 of the occupational limit

(The logic behind this decision was never clear)

↓

Limit of 5 mSv/a

↓

(used for many years for members of the public)

Change in Hiroshima & Nagasaki dosimetry

5 mSv/y

↓

Factor 5

↓

1 mSv/y

Value for exemption

1 mSv/a

↓

1 %

↓

10 μSv/a

Bequerels per unit mass

are factual, measurable and traceable,

and comparable to natural radioactivity!

They can be regulated!

μSv per year

are conjectural, neither measurable

nor traceable

They cannot be regulated

4. Exposure situations

Radionuclides in consumer goods could

- already be present in the environment and from there reach the goods (existing situation and extant situation), or
- be there due to an authorized discharge from a regulated activity (planed situation), or
- be the result of a non-anticipated situation (emergency situation).

Currently, these situations are subject to different regulatory approaches!

Radioactivity in consumer goods does not fall neatly into one of the exposure situations

Consumers and users of consumer goods are not interested in the exposure situation that originated the presence of radioactivity but on whether the product is safe to be consumed or used!

Therefore, the categorization into planned, emergency and existing exposure situations does not fit into the concept of controlling consumer goods.

It is suggested that this categorization should not be used when considering the need for controlling consumer goods!

4.

Views from States

IAEA organized several Workshop of States' representatives, to discuss the application of current international standards for managing radioactivity in consumer goods.

Decalogue of relevant views from States

1. Harmonize the international standards.
2. Do not differentiate between exposure situations.
3. Compare with natural values in the habitat for food, drinking water and non-edible goods.
4. Countries cannot comply with values lower than those in their natural environment.
5. Same criteria should apply to tap water, bottled water and natural mineral water.
6. Consider water as food.

7. Not use bands of values, since people and authorities usually believe that the minimum values are the safe ones.
8. Decide the status of any numbers that be finally established; namely, whether they are advisory, limits, upper bounds, lower bounds, action levels, trigger levels etc.
9. Situations should be avoided where goods that do not need to be regulated cannot be freely transported, and viceversa.
10. Control should be based on activity concentration rather than dose estimates.

5. Decalogue of recommendations

1. Terms being used, such as ‘commodities’ and ‘consumer products’ should be replaced by the term ***consumer goods***

Consumer goods do not include items to which radioactive substances are intentionally added, for which the existing term *radioactive consumer products* should be used.

2. The use of the term *contamination* should be avoided when referring to consumer goods.

Rather than referring to contaminated consumer goods, reference should be made to

- The ***presence*** of radionuclides in consumer goods

or

- The ***process*** making such presence possible.

3. The quantity to be used for regulating consumer goods is the (radio)activity, and its derivatives, e.g., activity per unit volume or per unit weight or per unit surface area of the relevant good.

- It is unreasonable, for practical and epistemological reasons, to use dosimetric quantities as the primary basis for controlling the presence of radioactivity in consumer goods.
- These quantities are generally not measurable in relation to the consumption or use of consumer goods and their estimation requires modelling, often with substantial subjective uncertainties.

4. The amount of natural radionuclides present in widely available consumer goods could serve as a good indicator of acceptable levels of radioactivity of any origin in consumer goods.

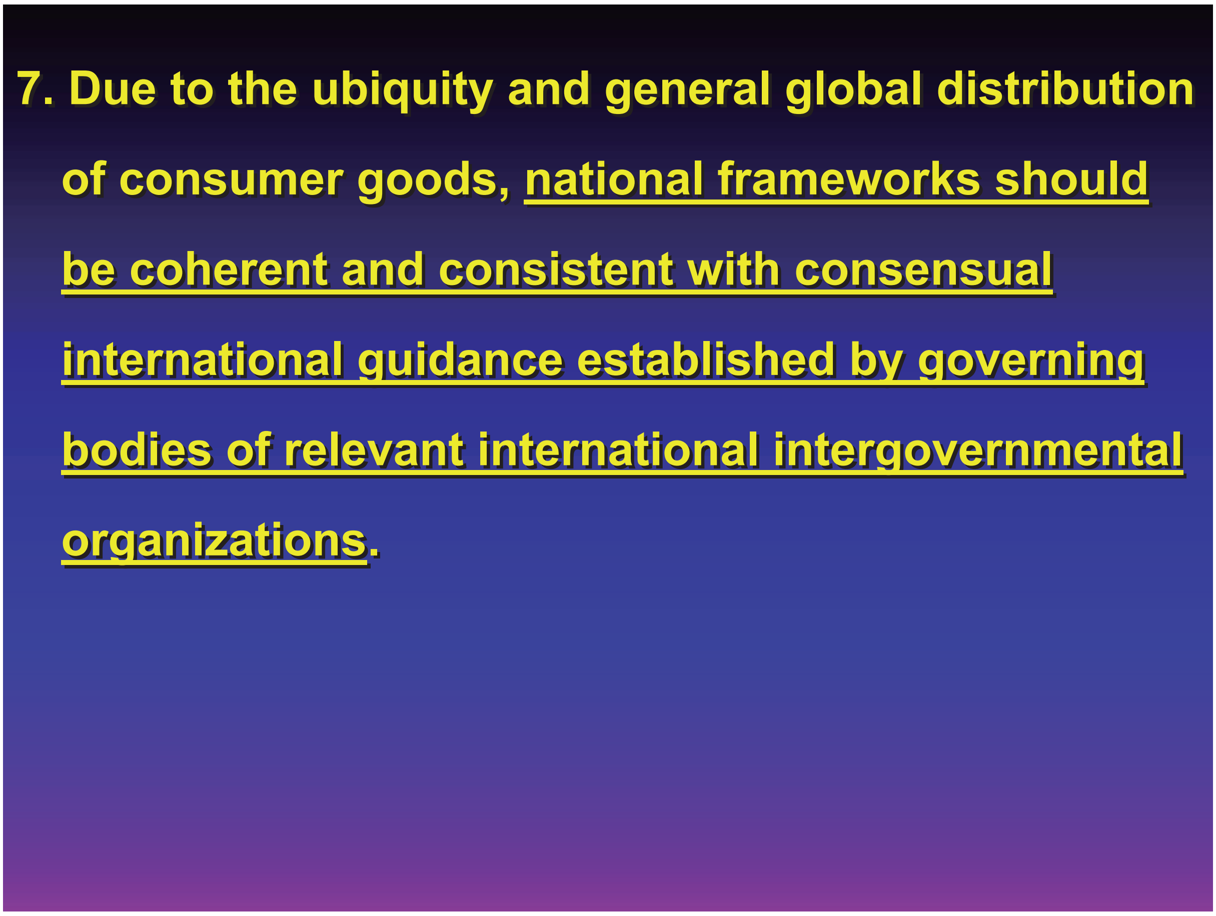
- It is important to establish the variability that exists in the concentrations of various radionuclides in consumer goods (including food and water currently freely available on the market.

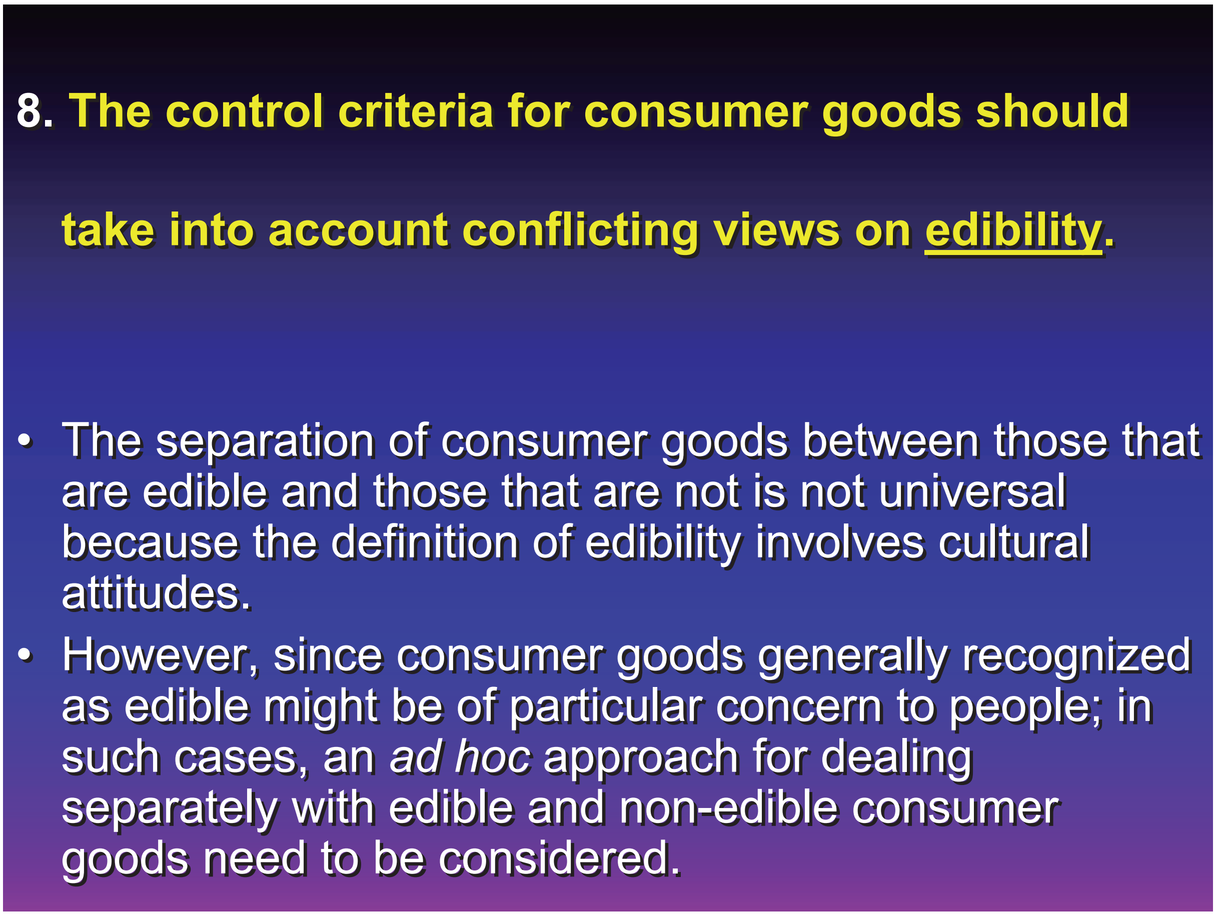
5. The presence of radionuclides in consumer goods should be regulated, regardless of the origin of the radionuclides, because radiation risks are independent of the origin of the activity; i.e., specifically, consumer goods containing naturally occurring radionuclides and those containing artificial radionuclides should be regulated using the same criteria and regulations.

- Notwithstanding the above, regulations may also take account of the amenability of control, and possibly also the social expectations of those affected.

6. The regulation of consumer goods should neither be based on the exposure situation from which they are derived (e.g., planned, emergency or existing) nor on the type of exposure being incurred (e.g., occupational or public); namely, all those affected by consumer goods should be considered members of the public undergoing an exposure situation without qualification.

- It is not always possible to identify exactly either the radiation exposure situation that has generated the presence of radioactivity in consumer goods.
- Additionally, for the consumer it is irrelevant which type of exposure situation has given rise to the presence of radioactivity in consumer goods.


7. Due to the ubiquity and general global distribution of consumer goods, national frameworks should be coherent and consistent with consensual international guidance established by governing bodies of relevant international intergovernmental organizations.

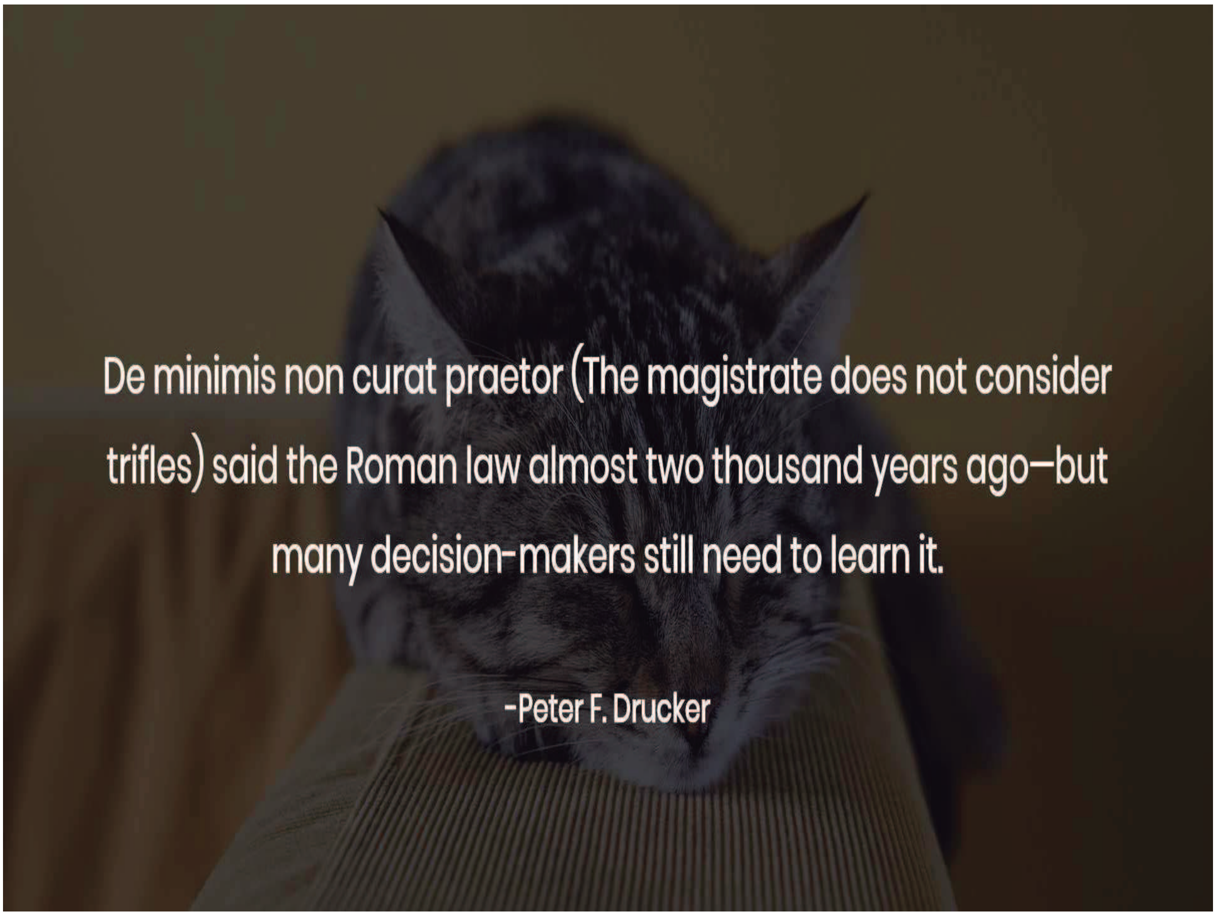

8. The control criteria for consumer goods should take into account conflicting views on edibility.
• The separation of consumer goods between those that are edible and those that are not is not universal because the definition of edibility involves cultural attitudes.
• However, since consumer goods generally recognized as edible might be of particular concern to people; in such cases, an ad hoc approach for dealing separately with edible and non-edible consumer goods need to be considered.

9. Activity levels in consumer goods that are considered safe for women and children should be used as the main criteria, which should be established based on consideration of a notional 'person' representative of those at higher risk.

- Criteria for controlling consumer goods that introduce differences among gender or age are difficult to implement in practice; and women and children are generally more sensitive to radiation than adult men.

10. National systems for controlling consumer goods could be framed on the following criteria:

- **Situations of radioactivity in consumer goods unamenable to be regulated should be excluded by legislation from the regulations**
- **Situations of radioactivity in consumer goods where protection can be considered already optimized should be exempted from regulation.**


De minimis non curat praetor (The magistrate does not consider trifles) said the Roman law almost two thousand years ago—but many decision-makers still need to learn it.
-Peter F. Drucker

6.

Epilogue

1. It is expected that the suggestions heretofore will be helpful for clarifying issues related to the control of radioactivity in consumer goods.
2. Until now, these issues have not been properly resolved and have been the subject of differing interpretations and confusion.
3. It is essential that the relevant intergovernmental international bodies address and resolve <u>in cosponsorship</u> the issues referred to heretofore.

Imputabilidad legal de daño en la salud por exposición a la radiación: Un desafío irresuelto

González, A.J.

Presentado en: Reunión Anual de la Asociación Argentina de Tecnología Nuclear (AATN).
Buenos Aires, Argentina, 19 al 22 de diciembre de 2022

Reunión anual de la Asociación Argentina de Tecnología Nuclear (AATN)

Salón Manuel Belgrano de la Cancillería, Buenos Aires; 19 de diciembre de 2022

Imputabilidad legal de daño en la salud por exposición a la radiación: Un desafío irresuelto

Abel J. González

Autoridad Regulatoria Nuclear; ✉ Av. del Libertador 8250; (1429) Buenos Aires; ☎ +54 1163231306;

Contenido

I. Amenazas al renacimiento nuclear.

II. Resumen del paradigma internacional sobre efectos en la salud de la exposición a la radiación.

III. Recomendaciones del Comité Científico de las Naciones Unidas para el Estudio de los Efectos de las Radiaciones Atómicas, adoptadas por la Asamblea General de las Naciones Unidas.

IV. Consecuencias para la imputabilidad de daño

V. Sugerencias

I

El renacimiento nuclear y sus amenazas

3

Aparentemente, las consecuencias asociadas a la guerra en Ucrania y los problemas con las energías eólica y solar podrían facilitar el devenir de un renacimiento nuclear.

4

Pero para que el renacimiento nuclear sea factible y sostenible hay varios desafíos a resolver.

5

- Desafíos económicos
- Desafíos tecnológicos
- Desafíos regulatorios

…y…particularmente…

- Desafíos legales asociados al némesis de la energía nuclear:

la radiación ionizante

Desafíos económicos

La energía nuclear se volvió no competitiva, fundamentalmente por el riego financiero que conlleva.

7

Desafíos tecnológicos

El mercado demanda centrales nucleares simples, baratas, repetibles y mas seguras, y estas no están disponibles.

8

Desafíos regulatorios

Gran parte del sistema regulatorio global es inhomogéneo, incoherente, inconsistente, y extremadamente complejo; otros emprendimiento humanos son regulados de manera mas simple y consensuada.

9

Desafíos legales

La energía nuclear enfrenta desafíos legales irresueltos relacionaos con los riesgos asociados a la radiación ionizante, a saber:

- responsabilidad civil por daños nucleares
- imputabilidad de efectos en la salud

10

La imputabilidad de los efectos en la salud asociados con la exposición a la radiación ionizante se ha transformado en una verdadera amenaza a la sustentabilidad financiera de la energía nuclear.

El 'negocio del juicio',

muy conocido en Argentina,

ha proliferado en centrales nucleares de todo el mundo con algunas pocas exepciones (Rusia, China)

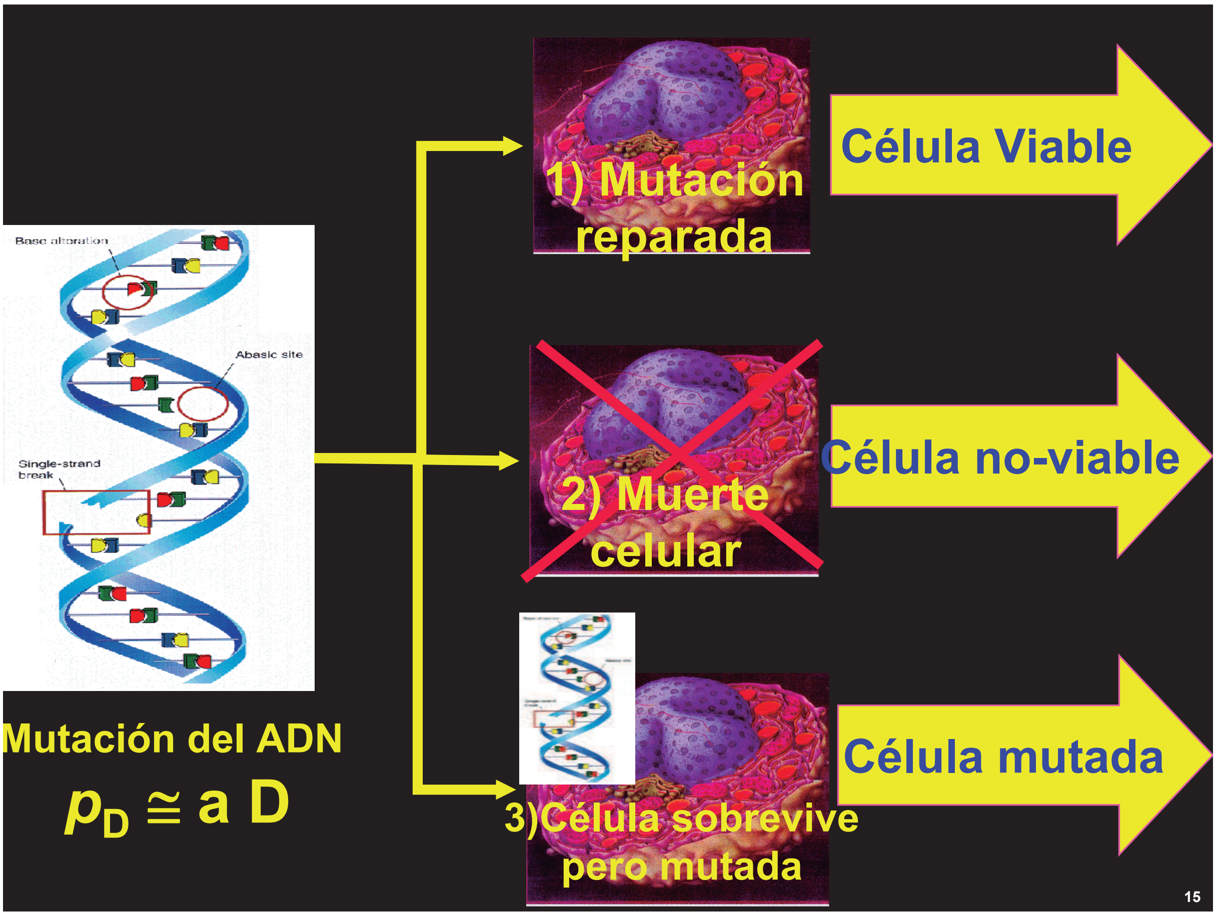
Las ciencias asociadas a la imputabilidad

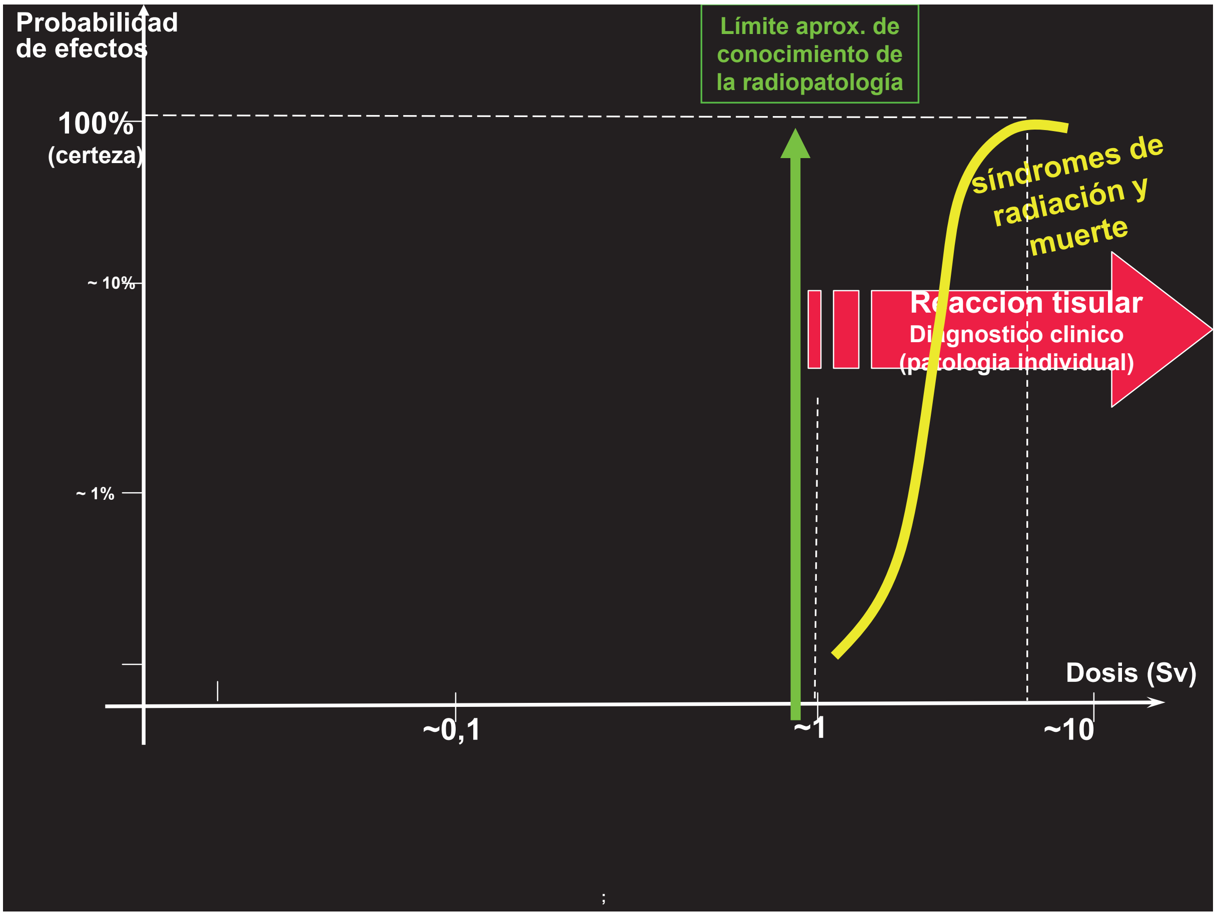
- Radiobiología
- Radiopatología
- Radioepidemiología
- Radioprotección

II.

Resumen del paradigma internacional actual sobre los efectos en la salud asociados a la exposición a las radiaciones ionizantes

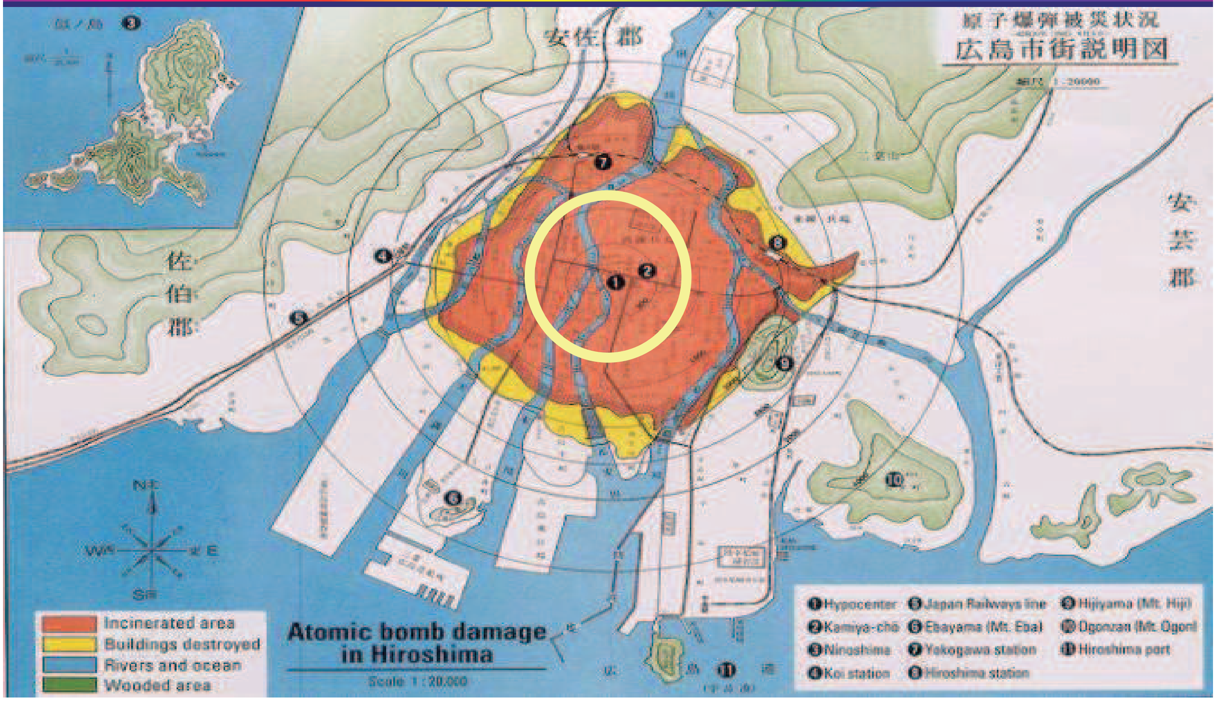
14


Base alteration
Abasic site
Single-strand break
1) Mutación reparada
Célula Viable
2) Muerte celular
Célula no-viable
Mutación del ADN
$p_D \cong a\ D$
3)Célula sobrevive pero mutada
Célula mutada
15


Probabilidad de efectos
100% (certeza)
~ 10%
~ 1%
Límite aprox. de conocimiento de la radiopatología
síndromes de radiación y muerte
Reaccion tisular
Diagnostico clinico
(patologia individual)
Dosis (Sv)
~0,1
~1
~10

Cohorte de Hiroshima y Nagasaki

Sobrevivientes: 86,500 individuos



Cohortes de Estudio de la RERF

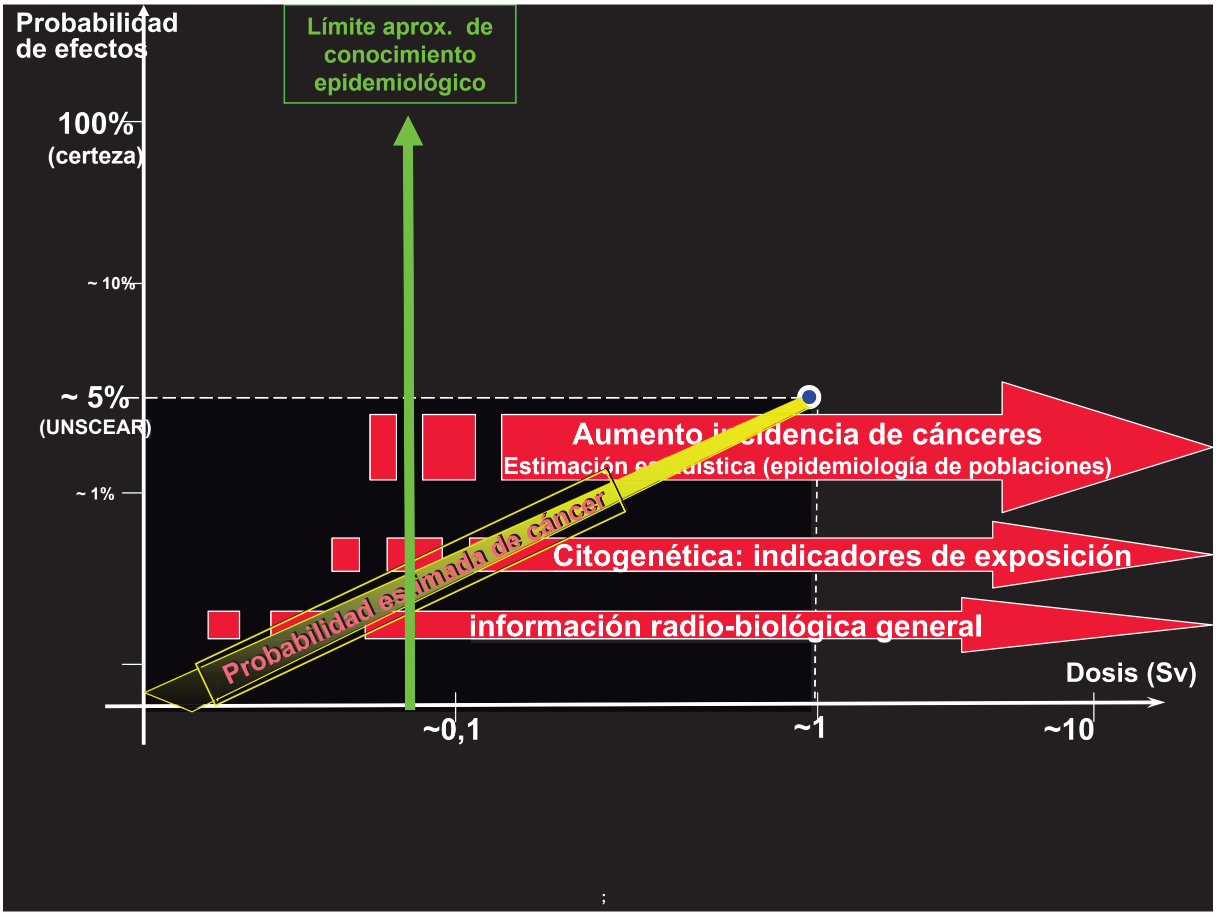
Life Span Study
(Estudio de Tiempo de Vida) (LSS)
120.000

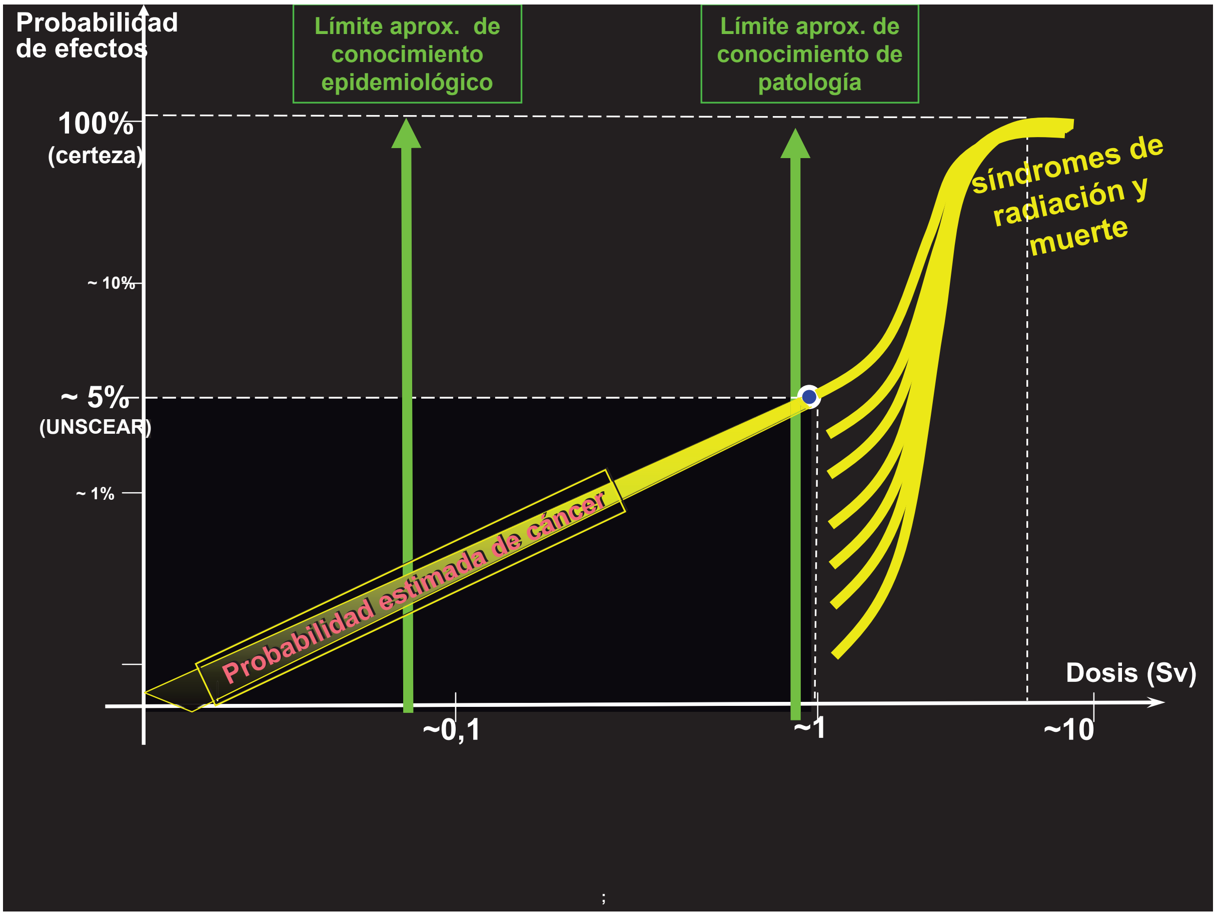
Estudio *In Utero*
3.600

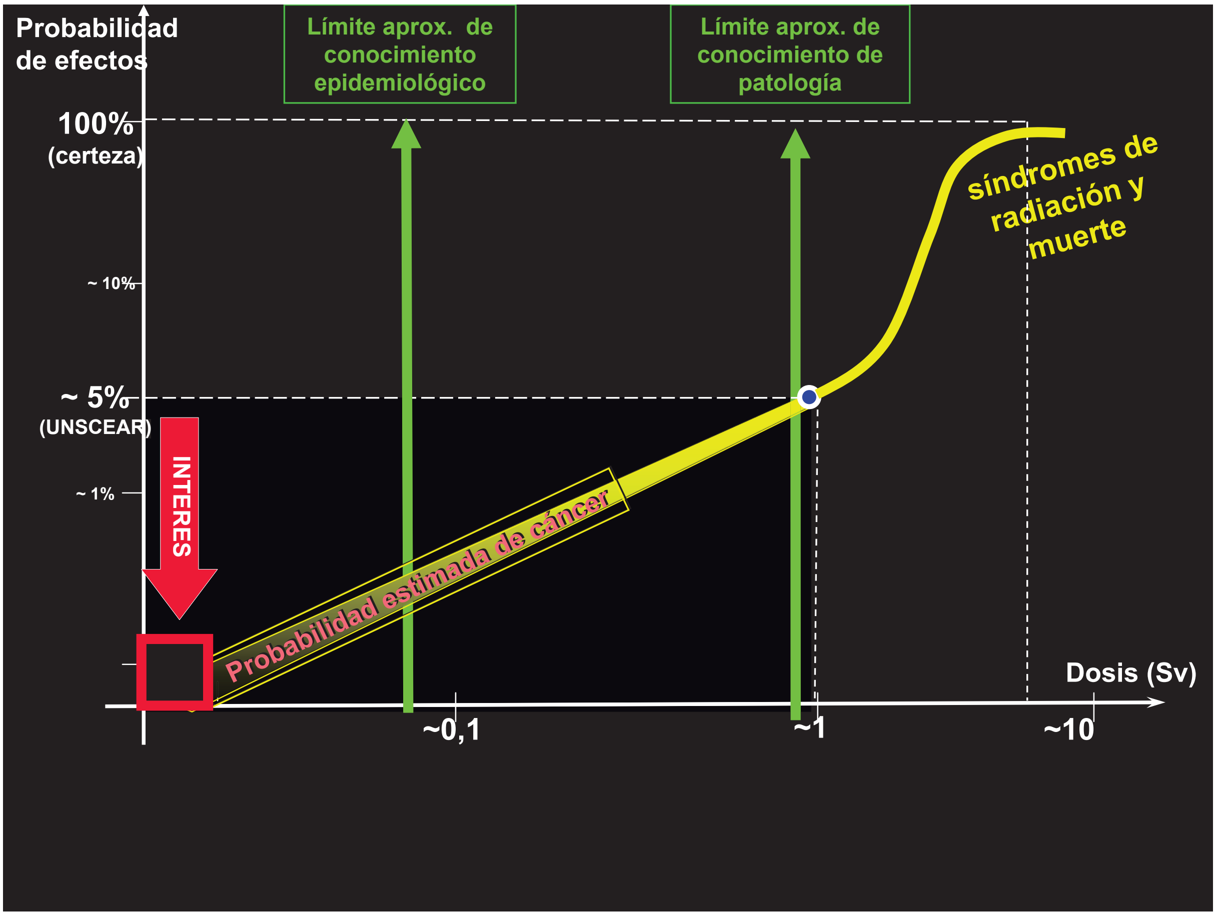
Estudio de niños supervivientes a la bomba atómica (F_1)
77.000

Adult Health Study
(Estudio sobre la Salud de Adultos)(AHS)
25.000
(1.000)

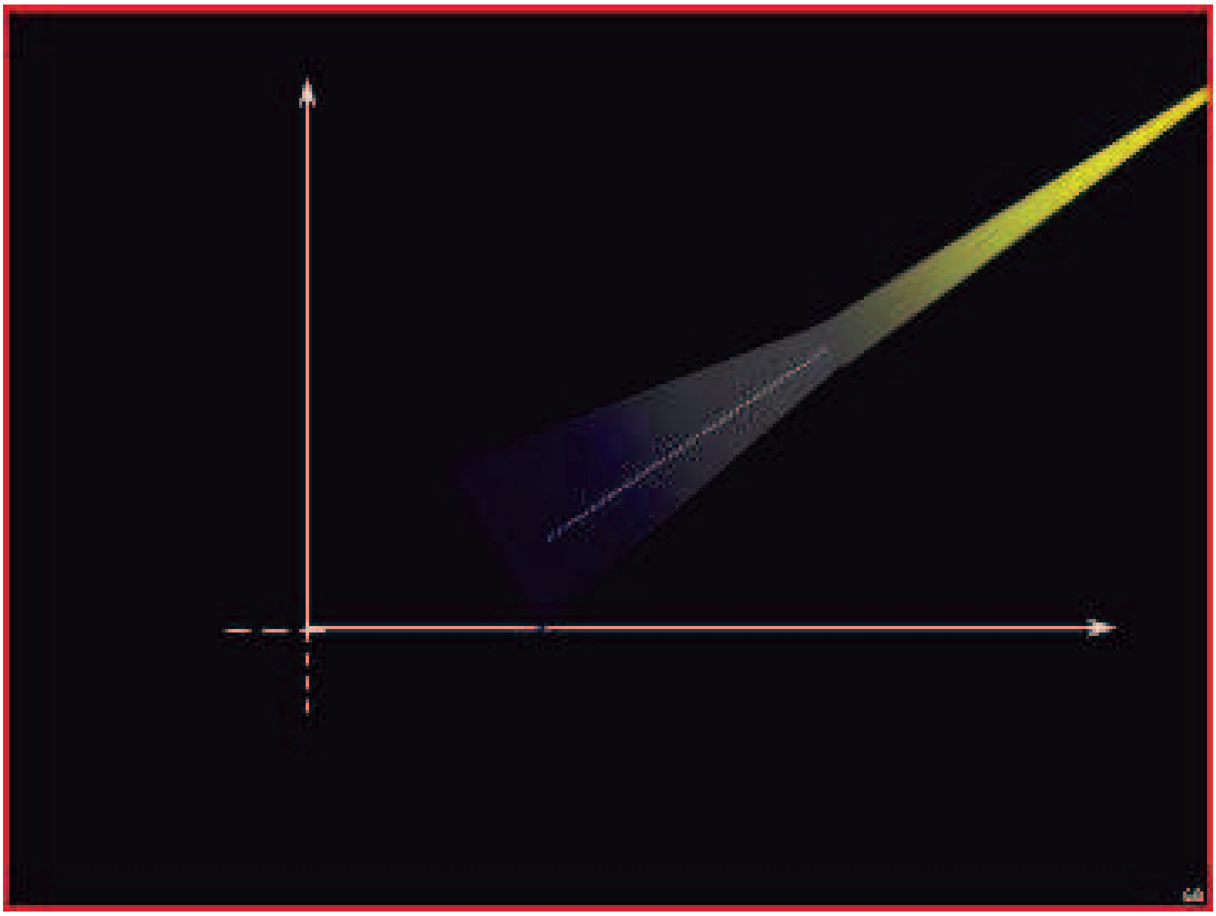
Estudio clínico de descendencia F1 de los supervivientes a la bomba atómica
12.000

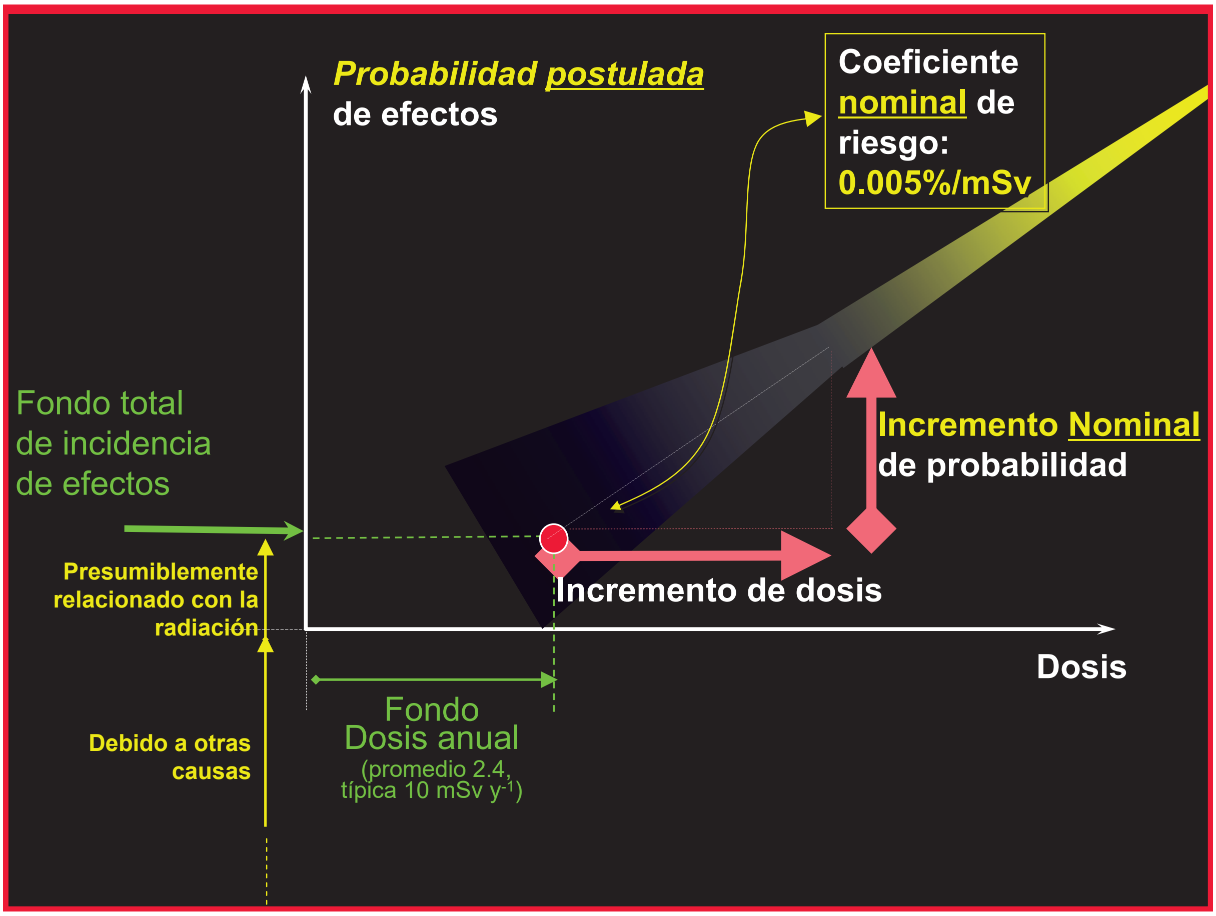

Probabilidad
de efectos
Límite aprox. de
conocimiento
epidemiológico
100%
(certeza)
~ 10%
~ 5%
(UNSCEAR)
~ 1%
Aumento incidencia de cánceres
Estimación estadística (epidemiología de poblaciones)
Citogenética: indicadores de exposición
información radio-biológica general
Probabilidad estimada de cáncer
Dosis (Sv)
~0,1
~1
~10


Probabilidad
de efectos
Límite aprox. de
conocimiento
epidemiológico
Límite aprox. de
conocimiento de
patología
100%
(certeza)
~ 10%
~ 5%
(UNSCEAR)
~ 1%
síndromes de
radiación y
muerte
Probabilidad estimada de cáncer
Dosis (Sv)
~0,1
~1
~10

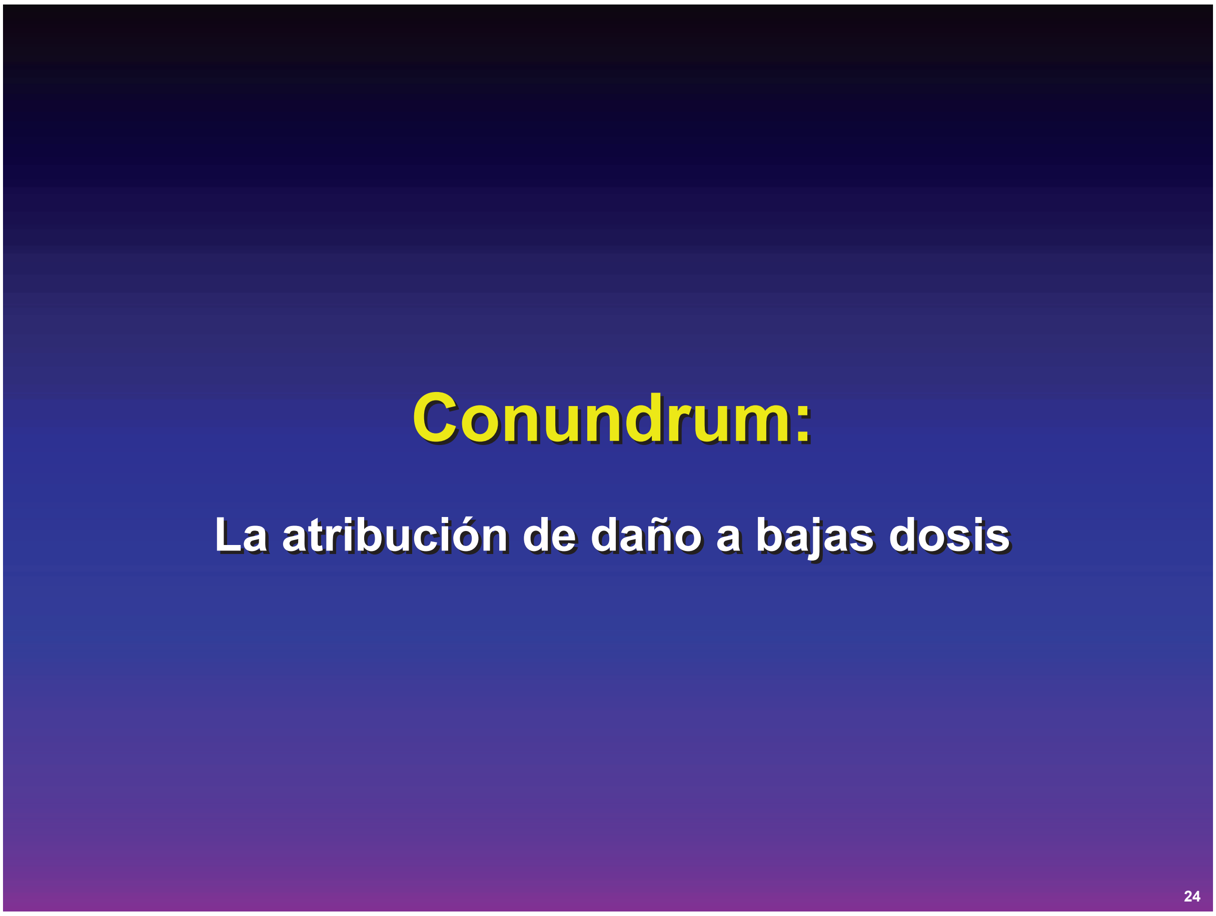


Probabilidad de efectos
Límite aprox. de conocimiento epidemiológico
Límite aprox. de conocimiento de patología
100% (certeza)
~ 10%
~ 5% (UNSCEAR)
~ 1%
INTERES
Probabilidad estimada de cáncer
síndromes de radiación y muerte
Dosis (Sv)
~0,1
~1
~10

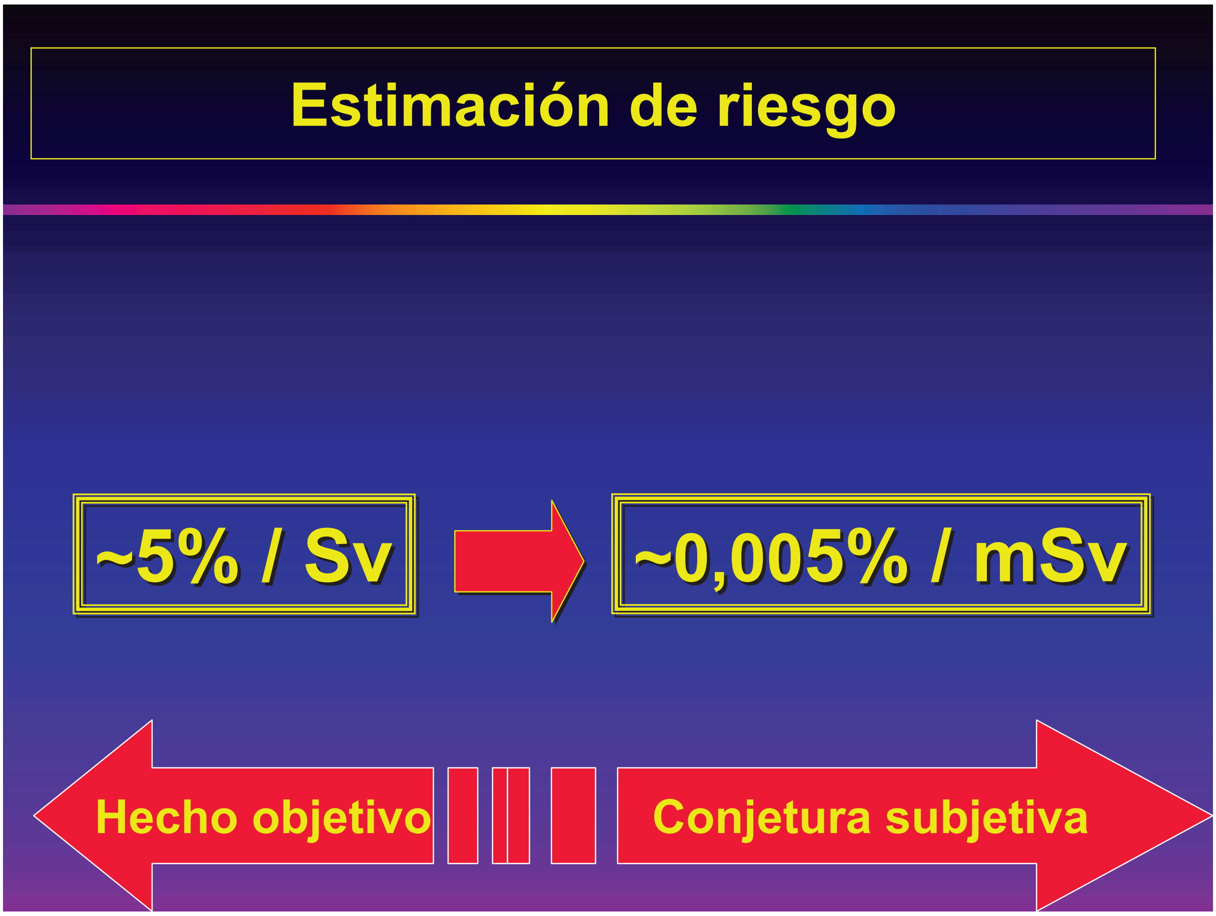


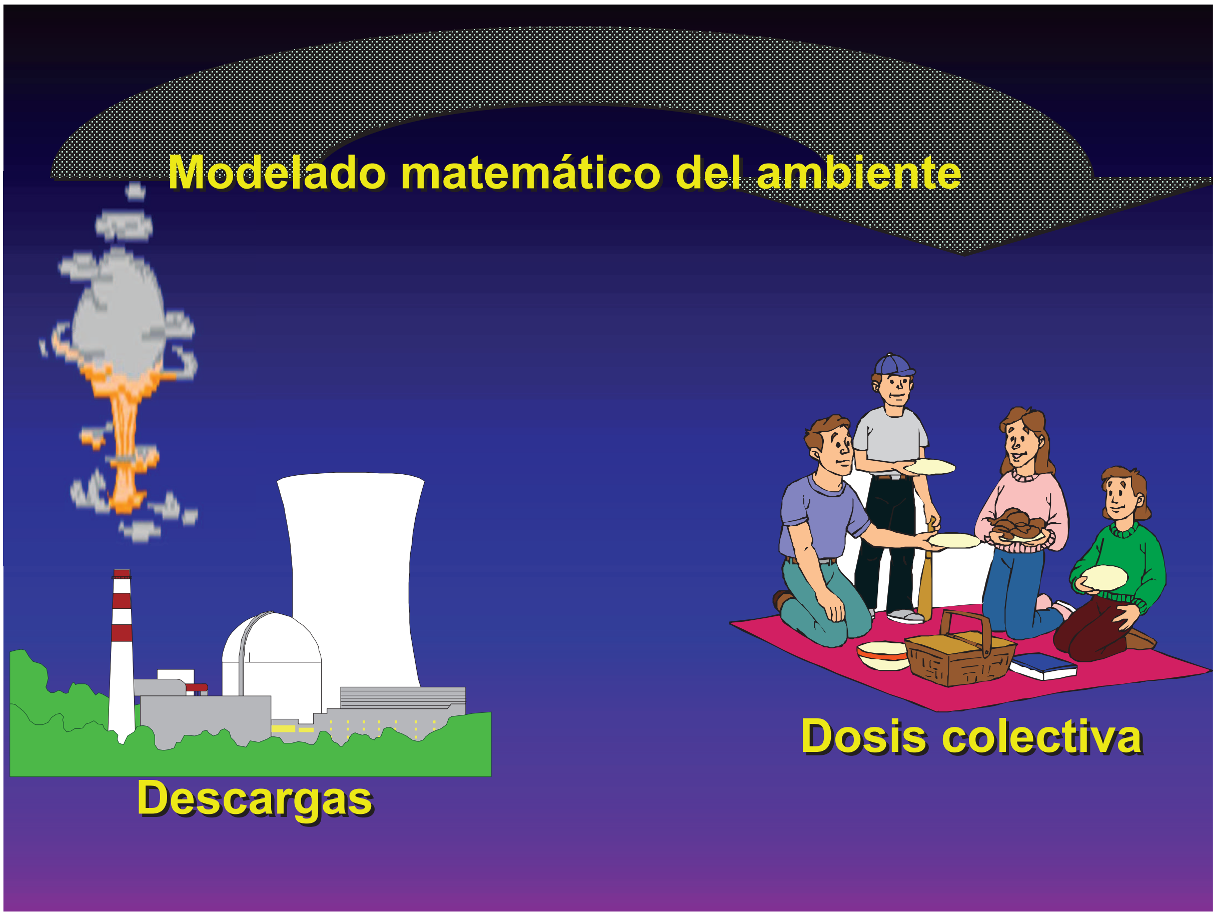


Probabilidad postulada
de efectos
Coeficiente nominal de riesgo: 0.005%/mSv
Fondo total de incidencia de efectos
Incremento Nominal de probabilidad
Presumiblemente relacionado con la radiación
Incremento de dosis
Dosis
Debido a otras causas
Fondo
Dosis anual
(promedio 2.4, típica 10 mSv y-1)



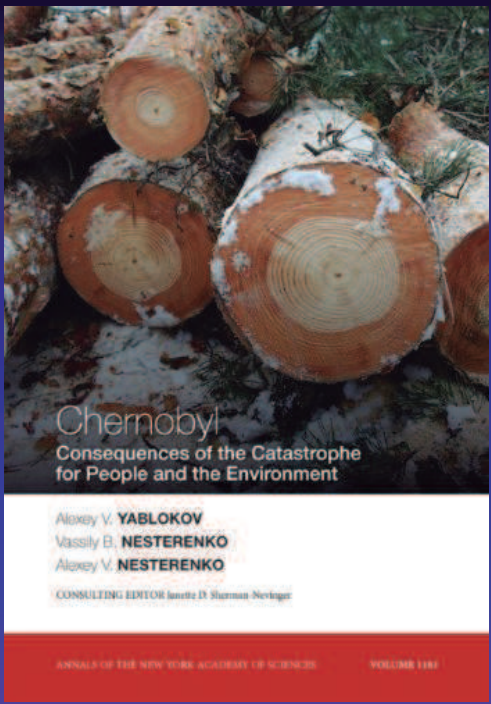
Conundrum:
La atribución de daño a bajas dosis
24


Estimación de riesgo
~5% / Sv
~0,005% / mSv
Hecho objetivo
Conjetura subjetiva


Modelado matemático del ambiente
Dosis colectiva
Descargas


Multiplicación por 0,005%/millisievert
dosis
colectiva
Número de muertos
27


¿Atribución?
X
Coeficiente
Nominal de
Riesgo
=
Dosis colectiva
Número personas muertas
Personas sievertx0,005 % mSv-1 = ¡Número personas muertas!
28



Chernobyl:

Consequences of the Catastrophe for People and the Environment

Annals of the New York Academy of Sciences

Alexey V. Yablokov (Editor),
Vassily B. Nesterenko (Editor),
Alexey V. Nesterenko (Editor),
Janette D. Sherman-Nevinger (Editor)

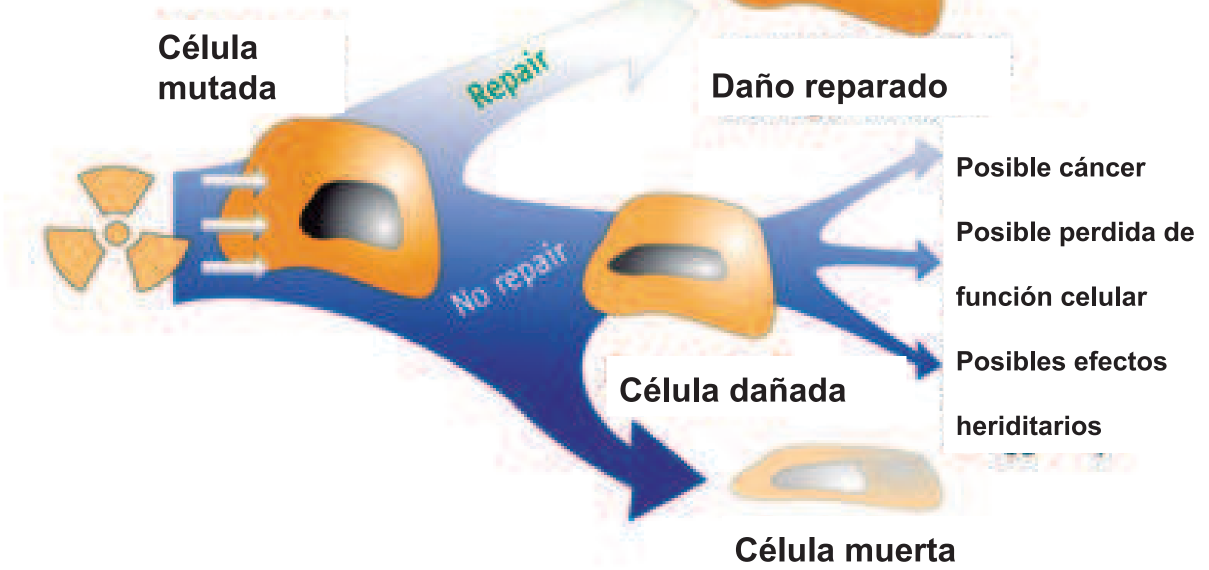
It concludes that based on records now available,
some <u>985,000</u> people died of cancer caused by the Chernobyl accident!

29

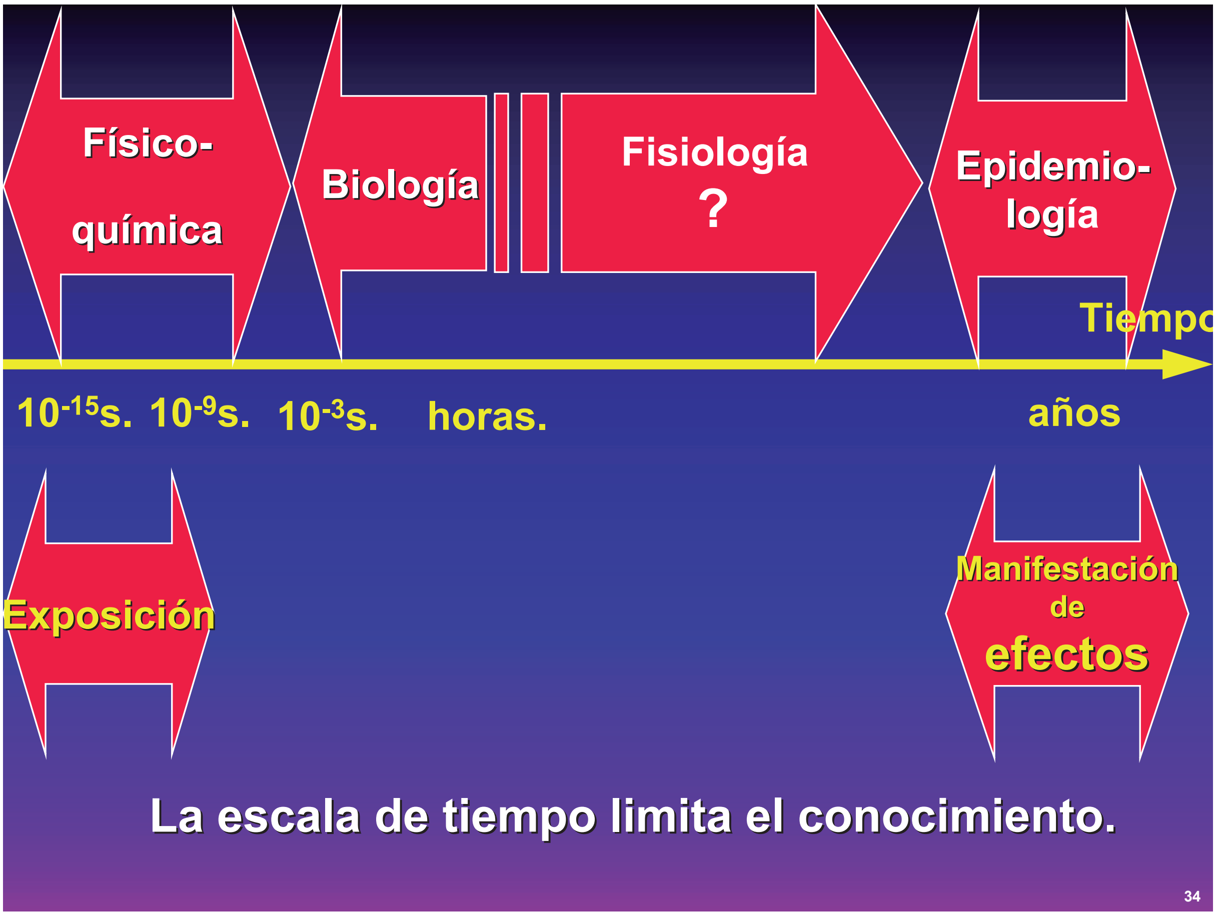
Estas imputaciones han causado daños muy serios, no conjeturales sino reales: serios efectos psicológicos y psiquiátricos en Chernobyl y en Fukushima

Las limitaciones epistemológicas de la radiobiología y la radioepidemiología

¿Son nuestras conjeturas biológicas un libro cerrado?



Célula mutada
Repair
Daño reparado
No repair
Posible cáncer
Posible perdida de
función celular
Posibles efectos
heriditarios
Célula dañada
Célula muerta

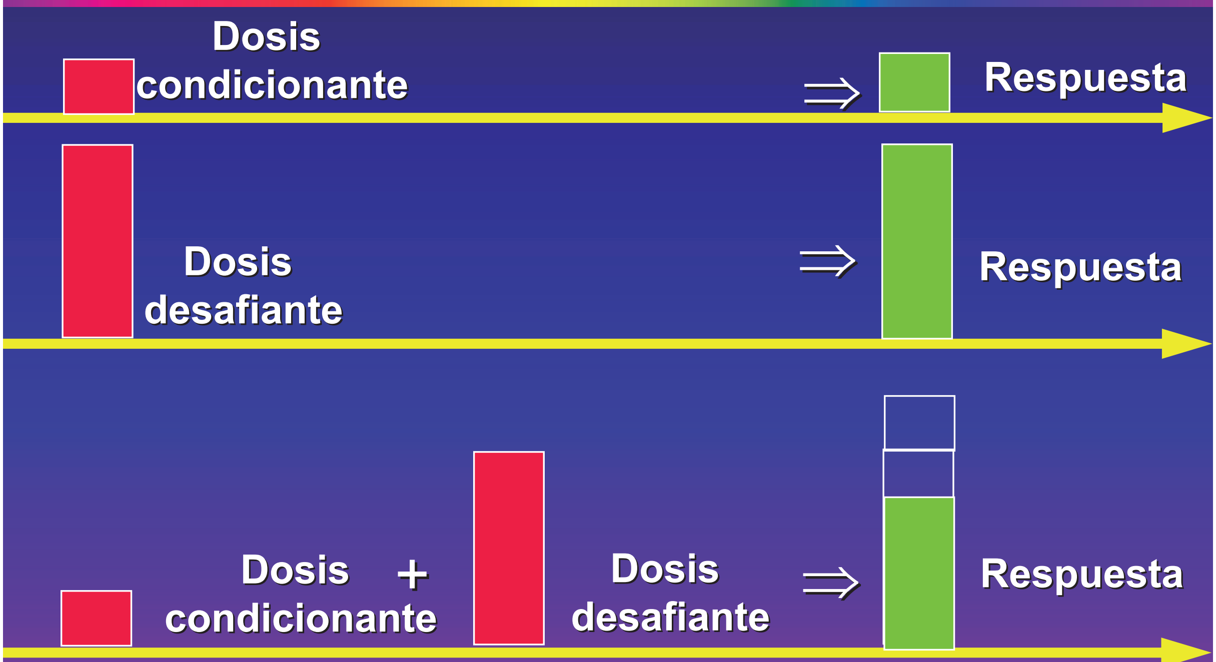


Físico-
química
Biología
Fisiología
?
Epidemio-
logía
Tiempo
10^{-15}s. 10^{-9}s. 10^{-3}s. horas.
años
Exposición
Manifestación
de
efectos
La escala de tiempo limita el conocimiento.
34

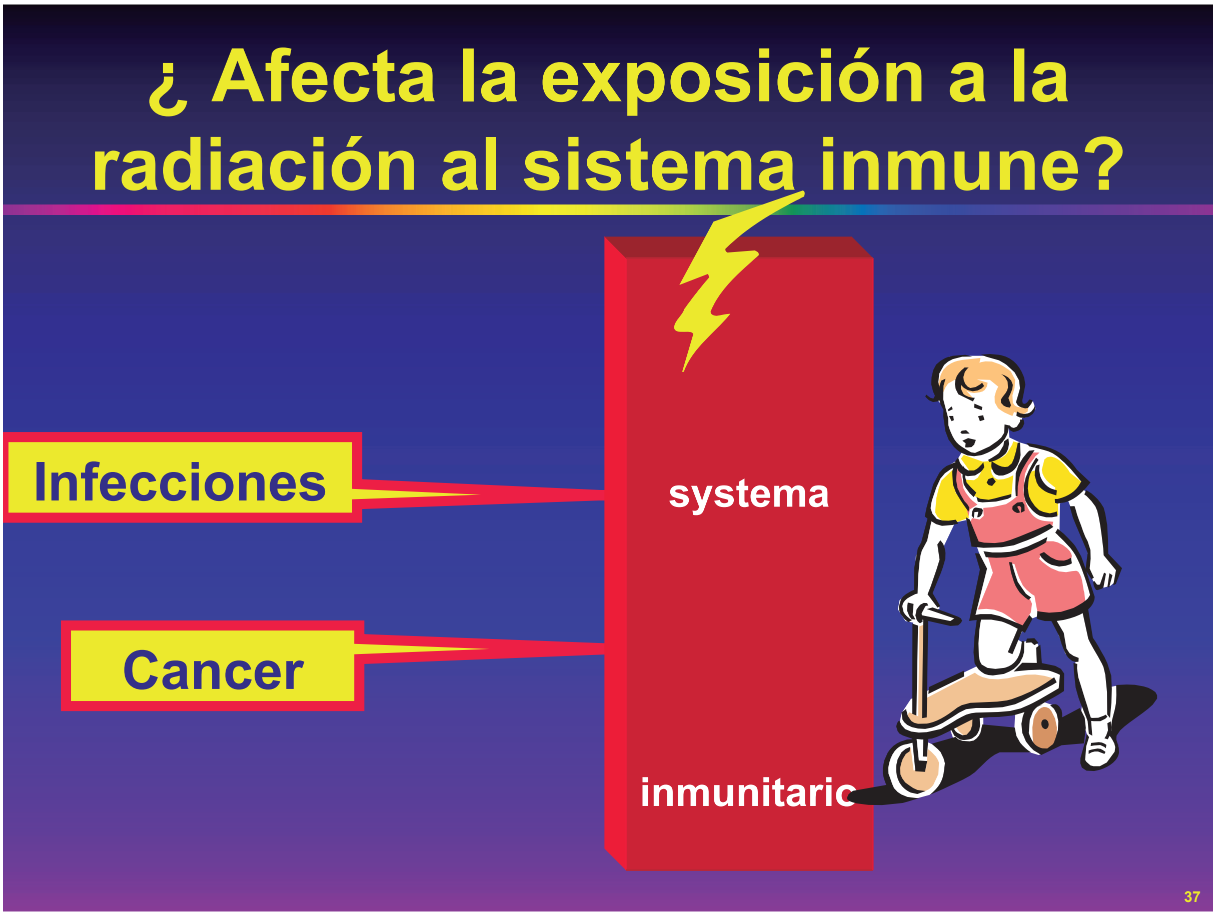
Posible influencia en el riesgo de daños fuera de la célula blanco y de otros fenómenos

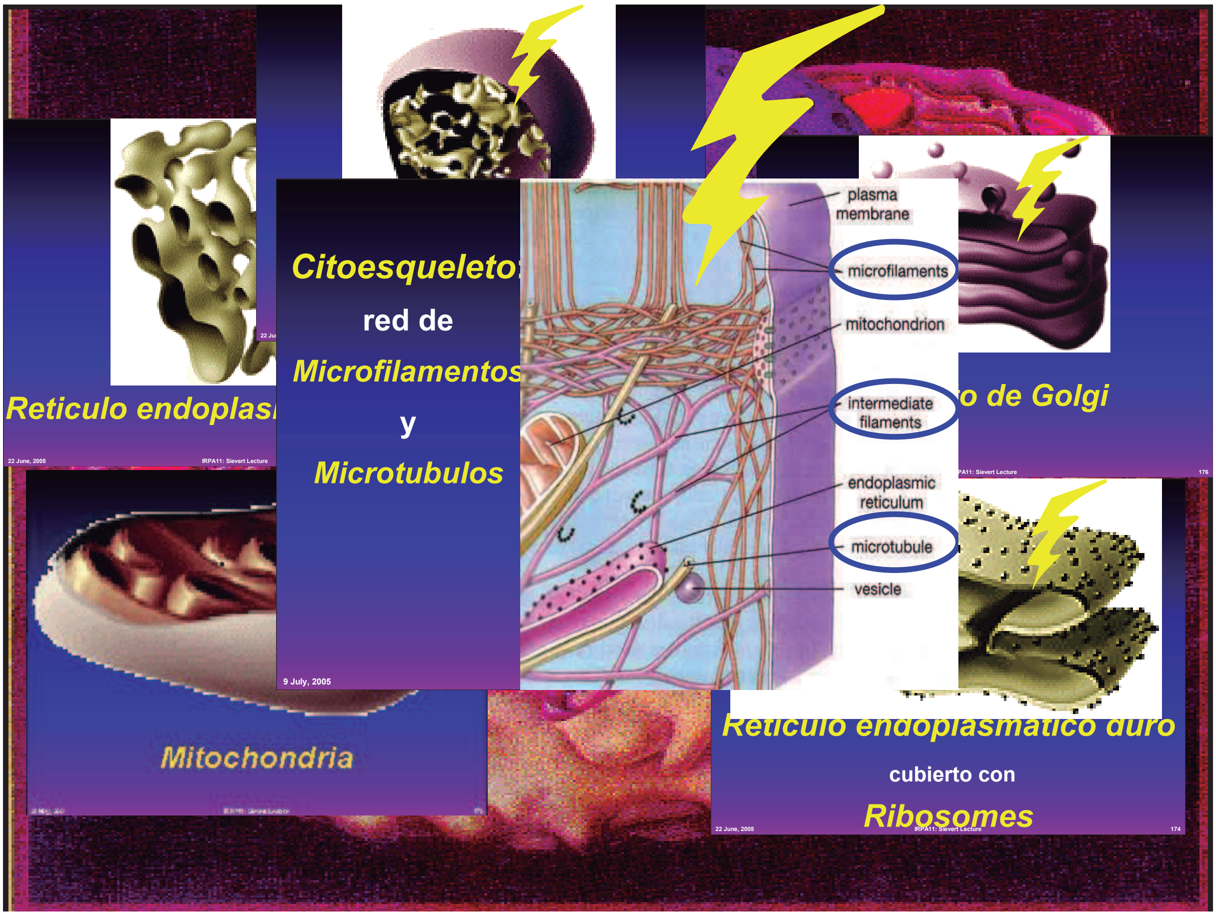
35

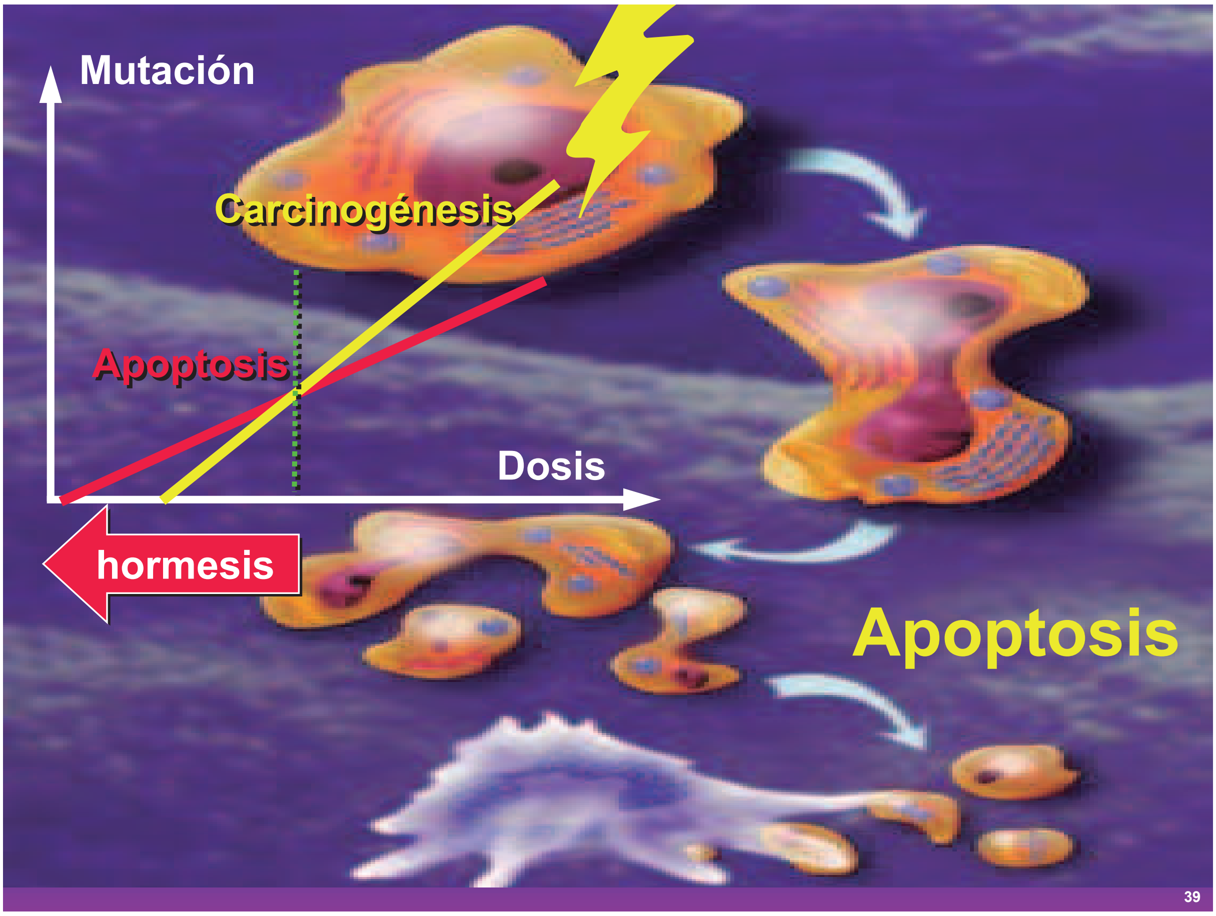
Respuesta Adaptiva



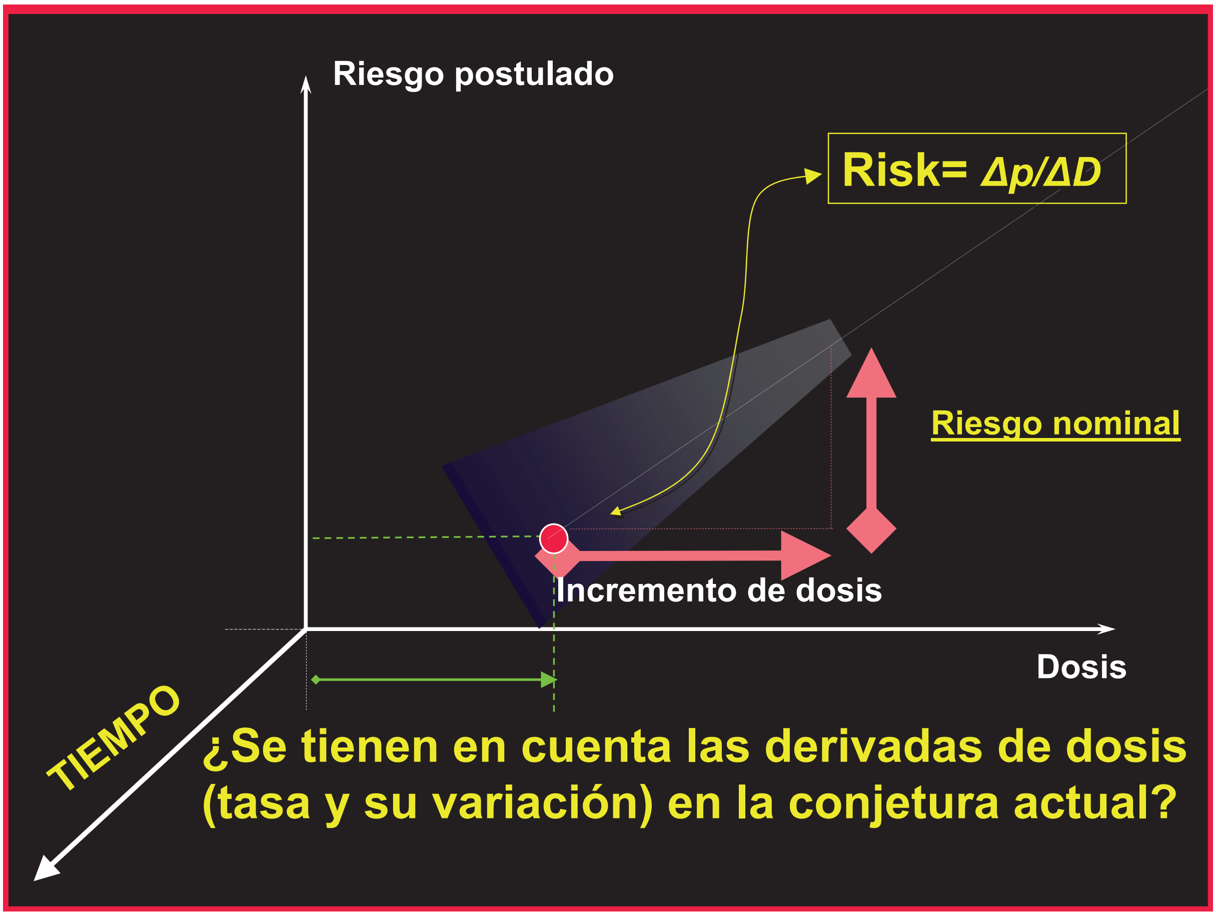
36


¿ Afecta la exposición a la radiación al sistema inmune?
Infecciones
Cancer
systema
inmunitaric
37


Reticulo endoplasi
Citoesqueleto:
red de
Microfilamentos
y
Microtubulos
plasma membrane
microfilaments
mitochondrion
intermediate filaments
endoplasmic reticulum
microtubule
vesicle
o de Golgi
Mitochondria
Reticulo endoplasmatico duro
cubierto con
Ribosomes



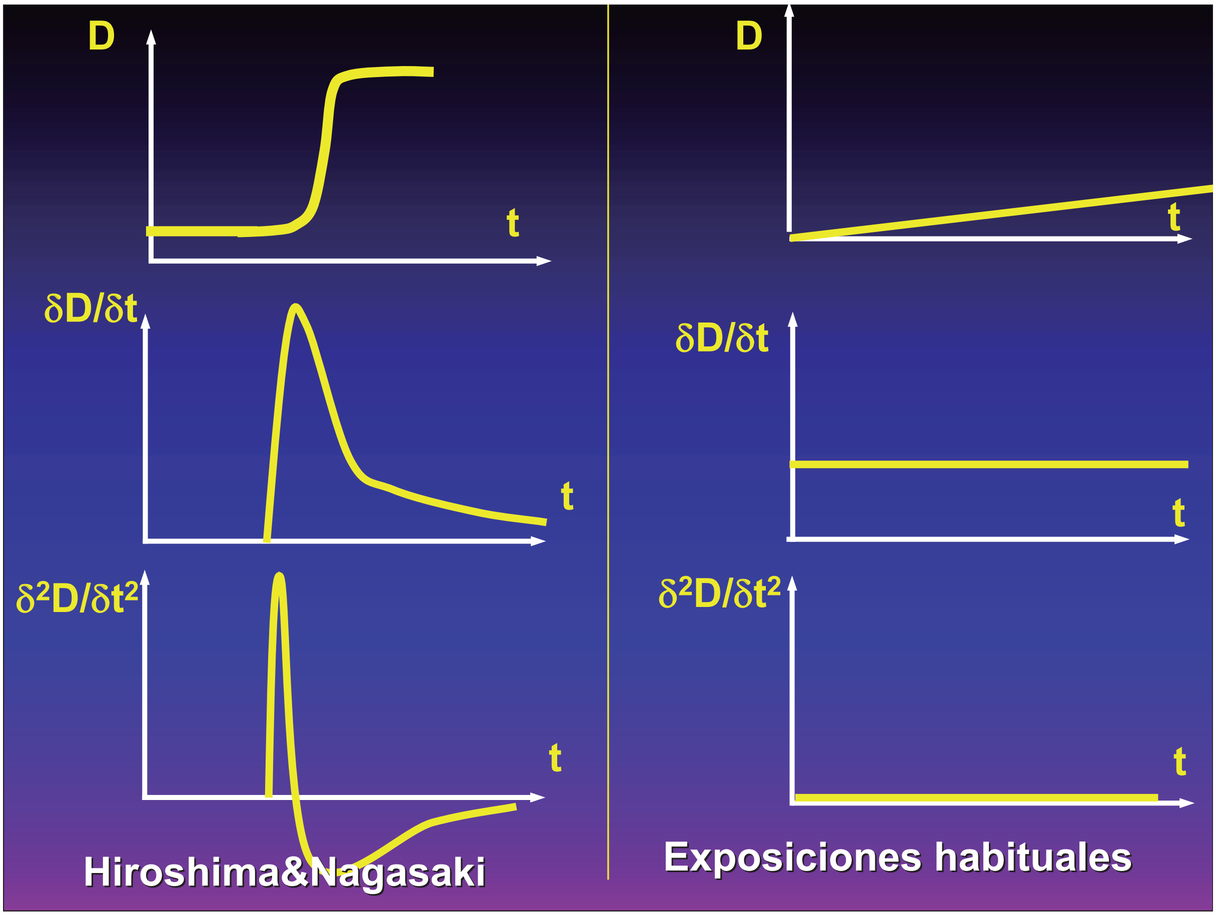
Mas aún, la dimensión del tiempo no se considera en la conjetura radiobiológica actual



¿Qué ocurre con el "cambio en la tasa de dosis", concretamente que implicancias tiene las variaciones en la segunda derivada de la dosis?

Si existe una respuesta adaptativa y su dinámica varía con la tasa de dosis

... ¿debería $\delta D^2/\delta t^2$ influenciar el riesgo, $\Delta p/\Delta D$?



RADIATION RESEARCH 173, 283–289 (2010)
0033-7587/10 $15.00
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DOI: 10.1667/RR2012.1

Cytogenetic Damage in Cells Exposed to Ionizing Radiation under Conditions of a Changing Dose Rate

Karl Brehwens,[a] Elina Staaf,[a] Siamak Haghdoost,[a] Abel J. González[b] and Andrzej Wojcik[a,c,1]

[a] *Centre for Radiation Protection Research, GMT Department, Stockholm University, 106 91 Stockholm, Sweden;* [b] *Argentine Nuclear Regulatory Authority, Buenos Aires, Argentina; and* [c] *Department of Radiobiology and Immunology, Institute of Biology, Jan Kochanowski University, 25-406 Kielce, Poland*

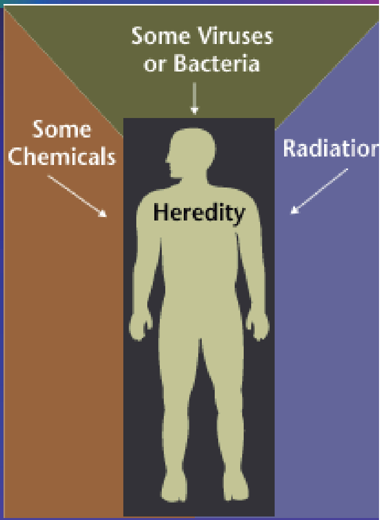
La radio-epidemiología es la palabra final.

¿Puede ayudar a convalidar la conjetura?

Límites de detectabilidad en radio-epidemiología

- Si la radiación a bajas dosis fuera carcinógena seria un débil cancerígeno.

- La incidencia de cáncer en general es muy alta.



- Es prácticamente imposible detectar canceres radioinducidos a dosis bajas.

Los estudios epidemiológicos adolecen de

incertidumbres

las que imponen límites epistemológicos.

Incertidumbres

- **Epistémicas:** que se deben a la caracterización incompleta de las cohortes.
- **Aleatorias:** que se deben a las variaciones estocásticas en las cohortes.

Algunas incertidumbres epistémicas

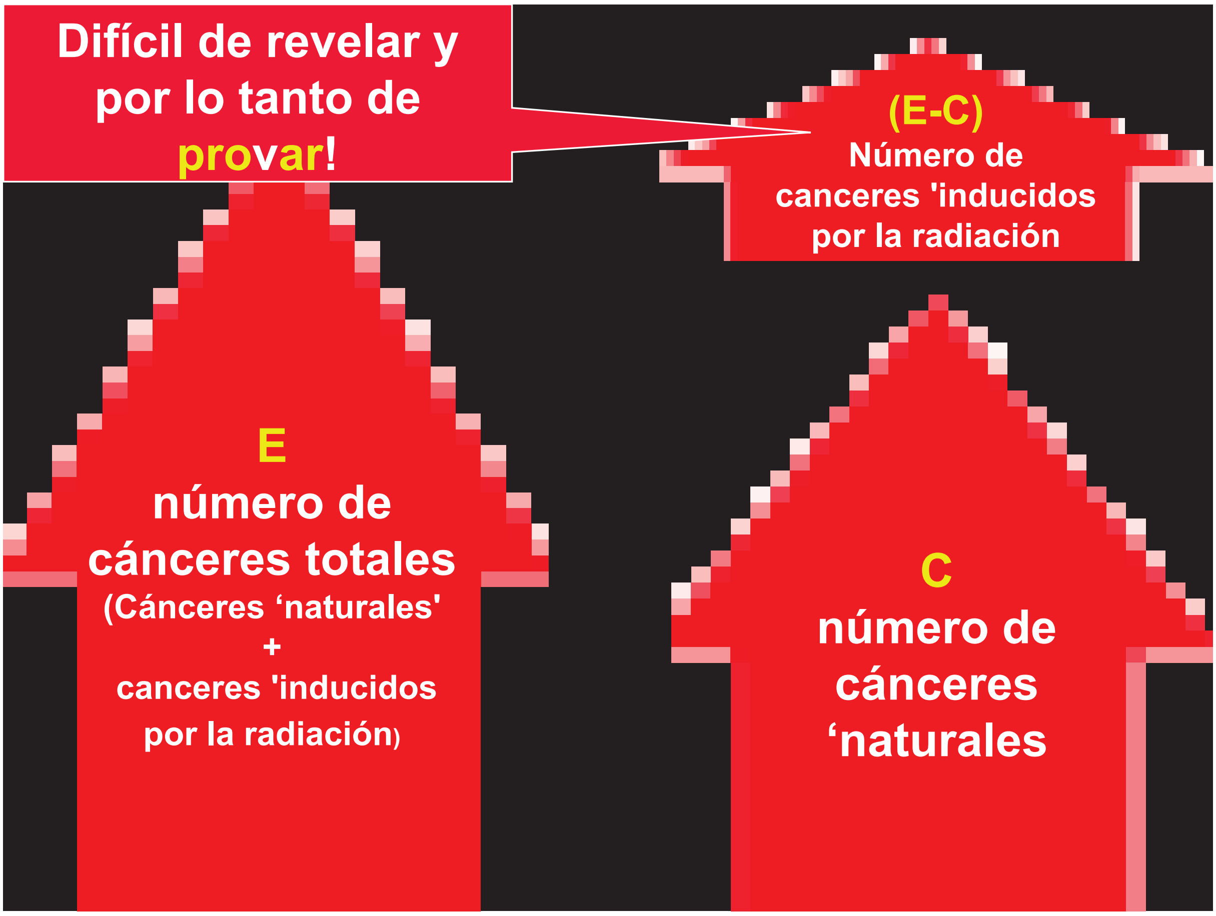
- Extrapolación entre dosis altas y dosis bajas.
- Extrapolación de entre dosis agudas y dosis crónicas
- Efecto de edad, latencia y el tiempo desde la exposición.
- Transferencia de datos entre poblaciones.
- Impacto de la susceptibilidad genética humana.
- Sesgos y prejuicios (biases):

  de verificación, de seguimiento, de selección.
- Posibilidad de un umbral de dosis.

Incertidumbres Aleatorias

(Impacto de la dosis en el poder estadístico y tamaño de la cohorte)


Grupo de control
"N" personas
"C" cánceres
"n" probabilidad de un cancer 'natural'
Grupo expuesto
"N" personas
"E" cánceres
"n" probabilidad de un cancer 'natural'
'p_D' probabilidad de un cancer de 'radiación'


Difícil de revelar y por lo tanto de provar!
(E-C)
Número de canceres 'inducidos por la radiación
E
número de cánceres totales
(Cánceres 'naturales'
+
canceres 'inducidos por la radiación)
C
número de cánceres 'naturales

Significado epidemiológico

- El número esperado de cánceres en el grupo de control será:

$$C = n\,N$$

- El número esperado de cánceres en el grupo expuesto será:

$$E = n\,N + p_d\,D\,N$$

- El número esperado de cánceres en exceso será

$$E - C$$

- La desviación estándard es

$$\sigma = \sqrt{2\,n\,N + p_d\,D\,N}$$

- Si el exceso de cánceres debe detectarse con una confianza estadística del 95%

$$E - C > 2\,\sigma$$

Operando algebraicamente y como n >> p_d D,

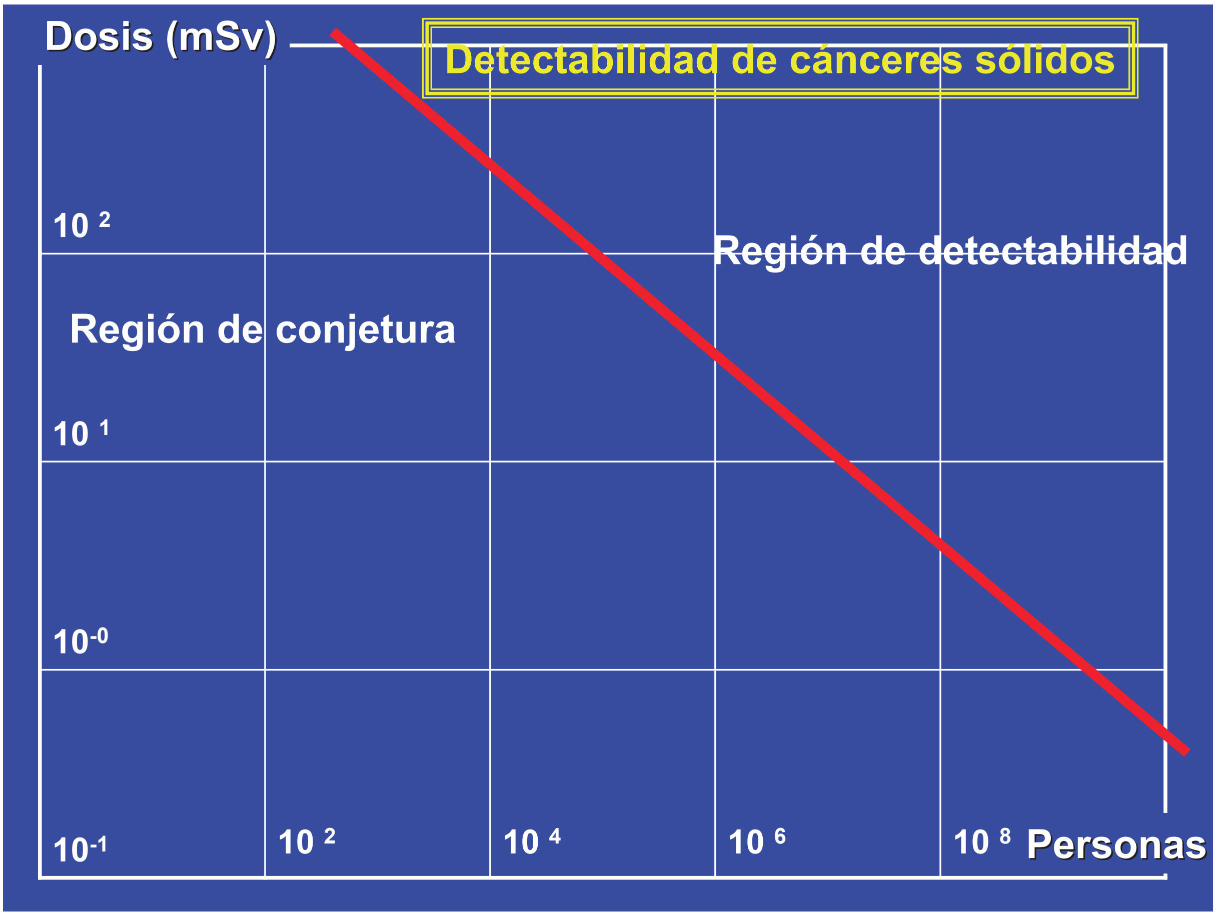
$$N > constante / D^2$$

que es la ecuación que da el número de personas, N, necesarias para detectar un exceso de cánceres en la dosis D.

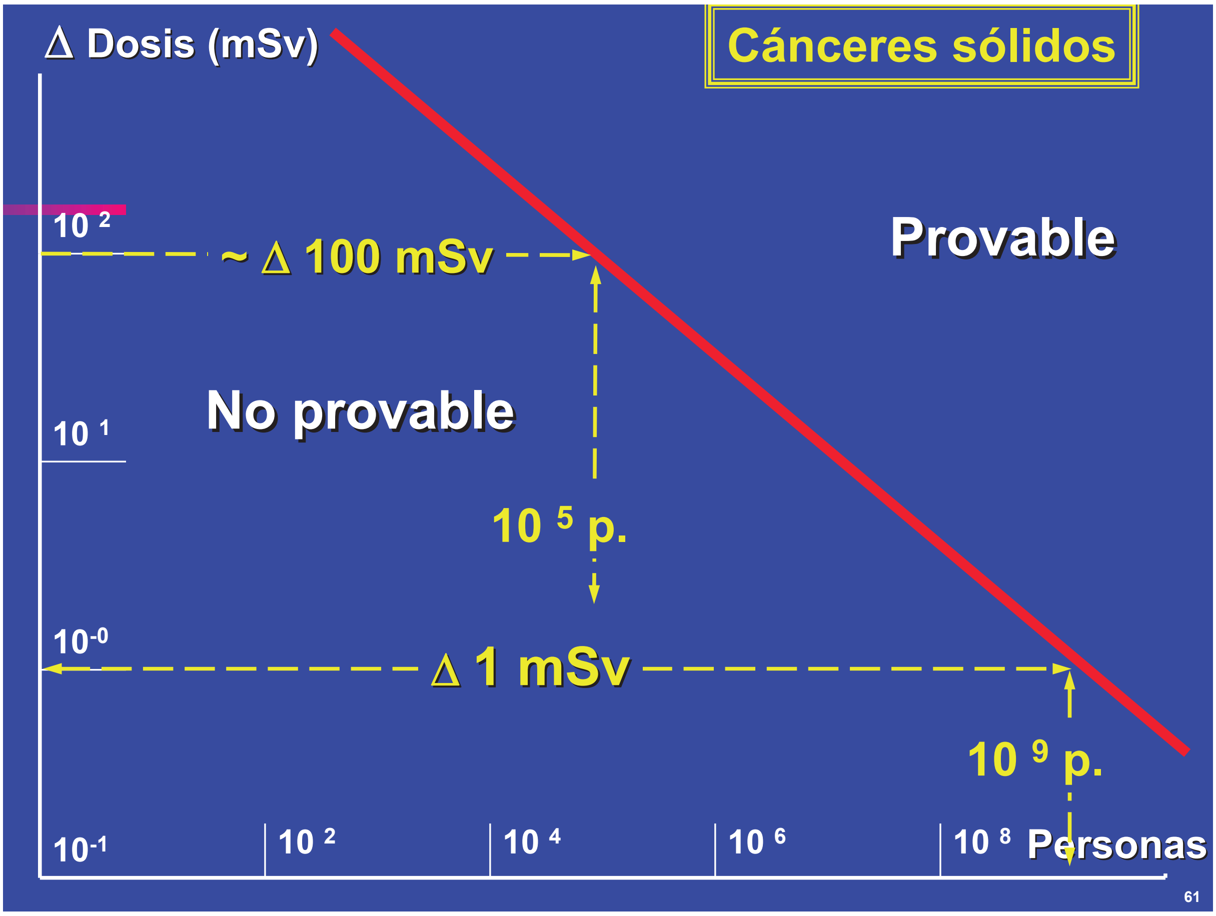
(Constante = 8 n / p_d^2)

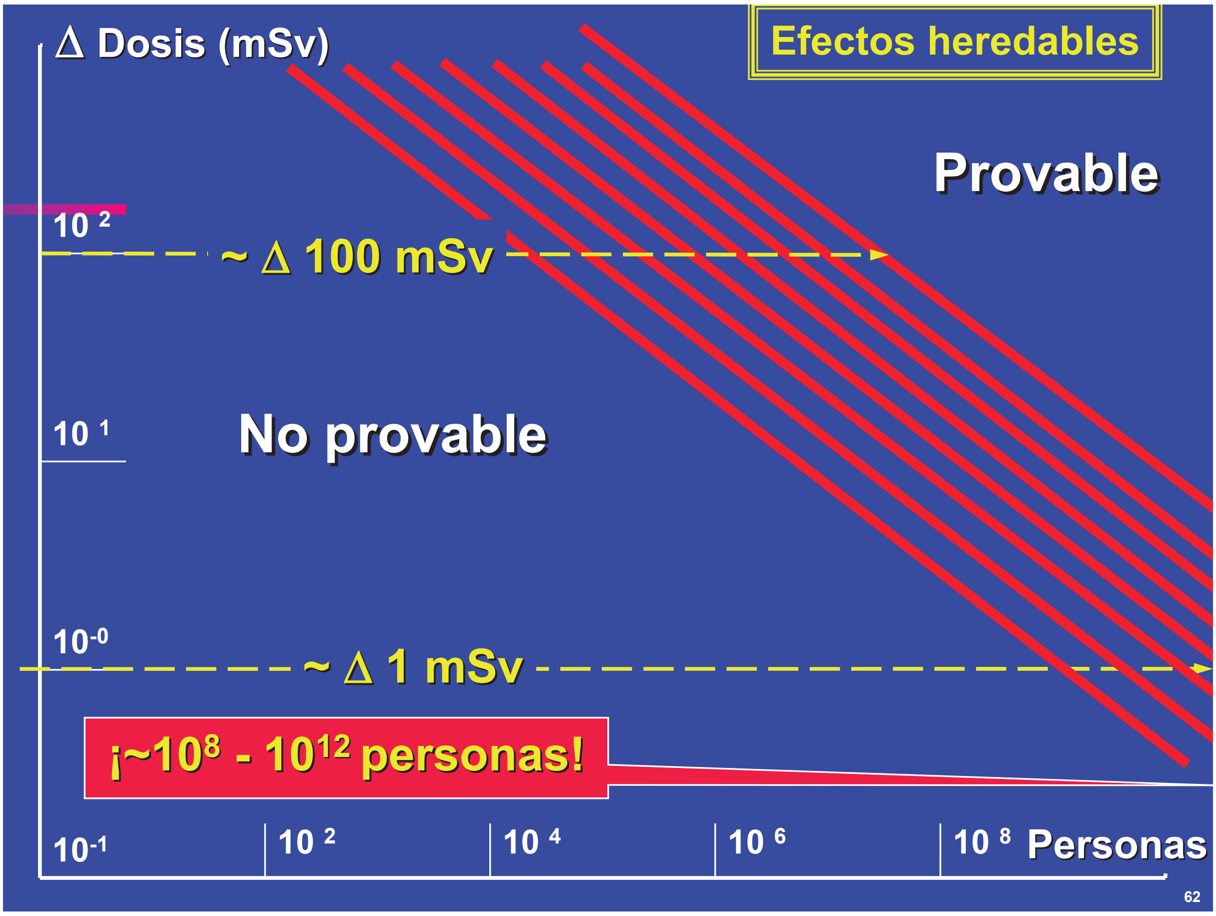
Límite de provabilidad epidemiológica

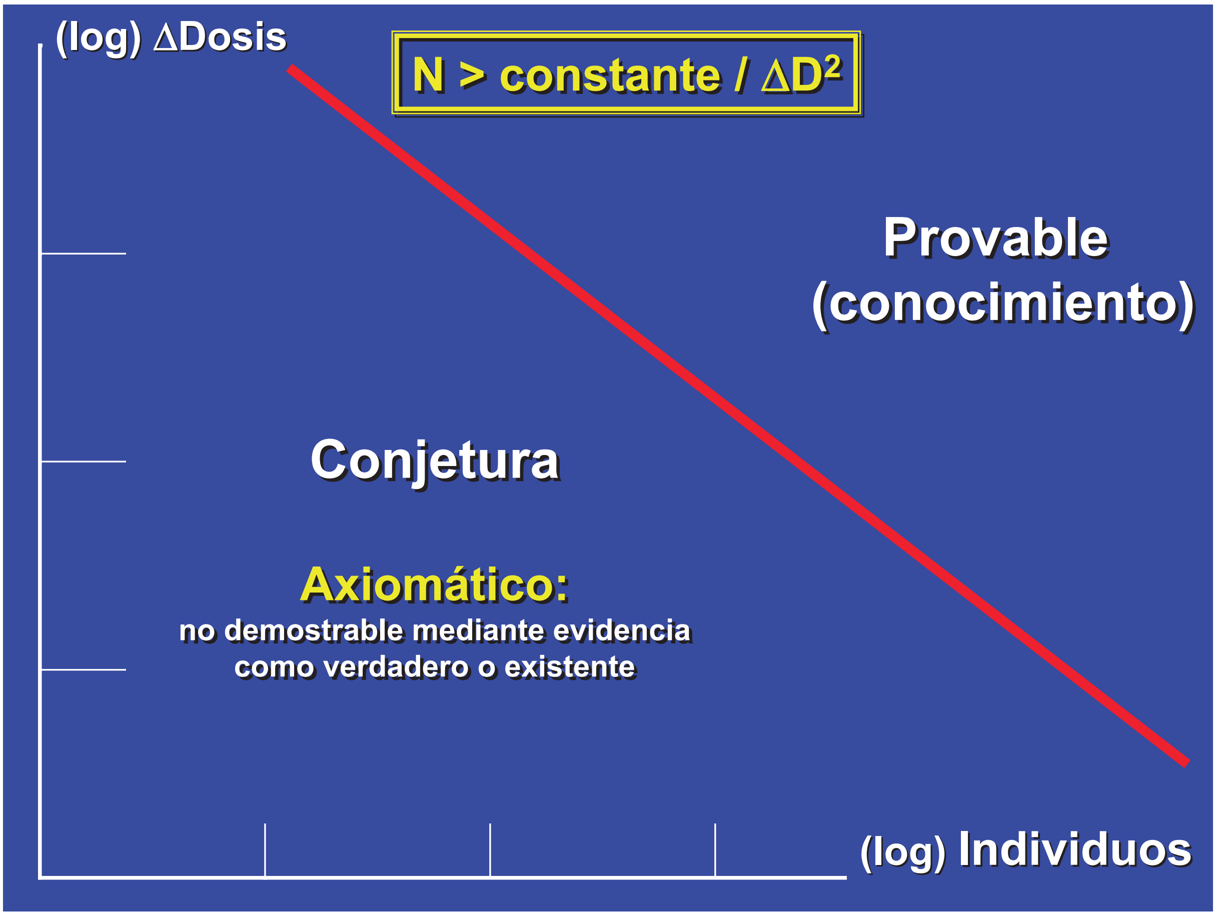
$$N > constante / \Delta D^2$$



Dosis, D (mSv)	~ Numero de personas, N
1	>1.000.000.000
10	>10.000.000
100	>100.000
1000	>1.000


Δ Dosis (mSv)
Cánceres sólidos
Provable
10 2
~ Δ 100 mSv
No provable
10 1
10 5 p.
10-0
Δ 1 mSv
10 9 p.
10-1
10 2
10 4
10 6
10 8
Personas
61


Δ Dosis (mSv)
Efectos heredables
Provable
10 2
~ Δ 100 mSv
10 1
No provable
10-0
~ Δ 1 mSv
¡~10⁸ - 10¹² personas!
10-1
10 2
10 4
10 6
10 8
Personas
62



En resumen

¿Conocen los legisladores y expertos legales estas limitaciones epistemológicas?

¿Comprenden que el ‘riesgo nominal’ de los estándares es una *conjetura subjetiva*?

¡Quizás no!

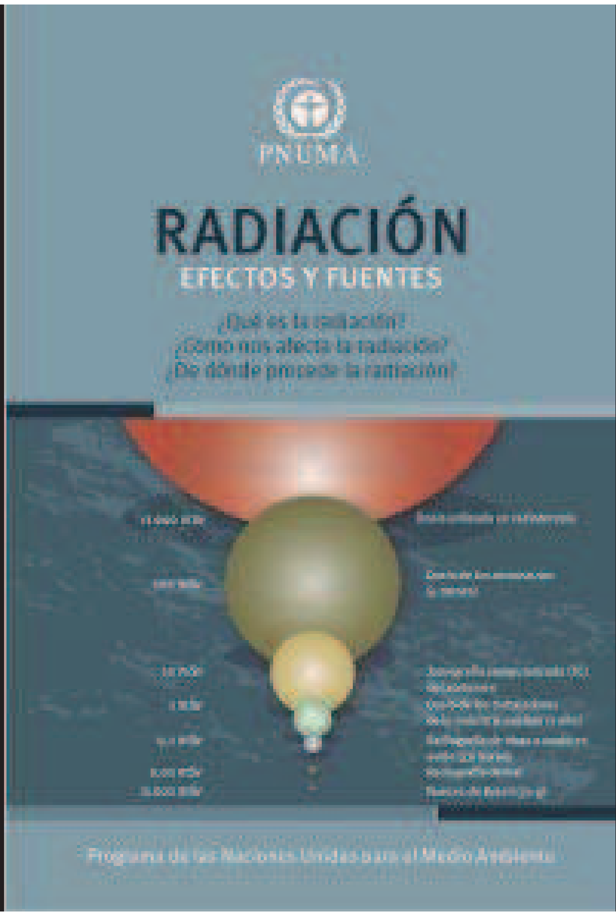
Comité Científico de las Naciones Unidas sobre los Efectos de la Radiación Atómica

Fue establecido por la Asamblea General de las Naciones Unidas en 1955. Su mandato en el sistema de las Naciones Unidas es para evaluar los niveles y efectos de la exposición a la radiación y que informe sobre este tema. Para los gobiernos y organizaciones de todo el mundo, las estimaciones de la Comisión proporcionan la base científica que les permitan evaluar los riesgos de radiación y establecer las medidas de seguridad

III.

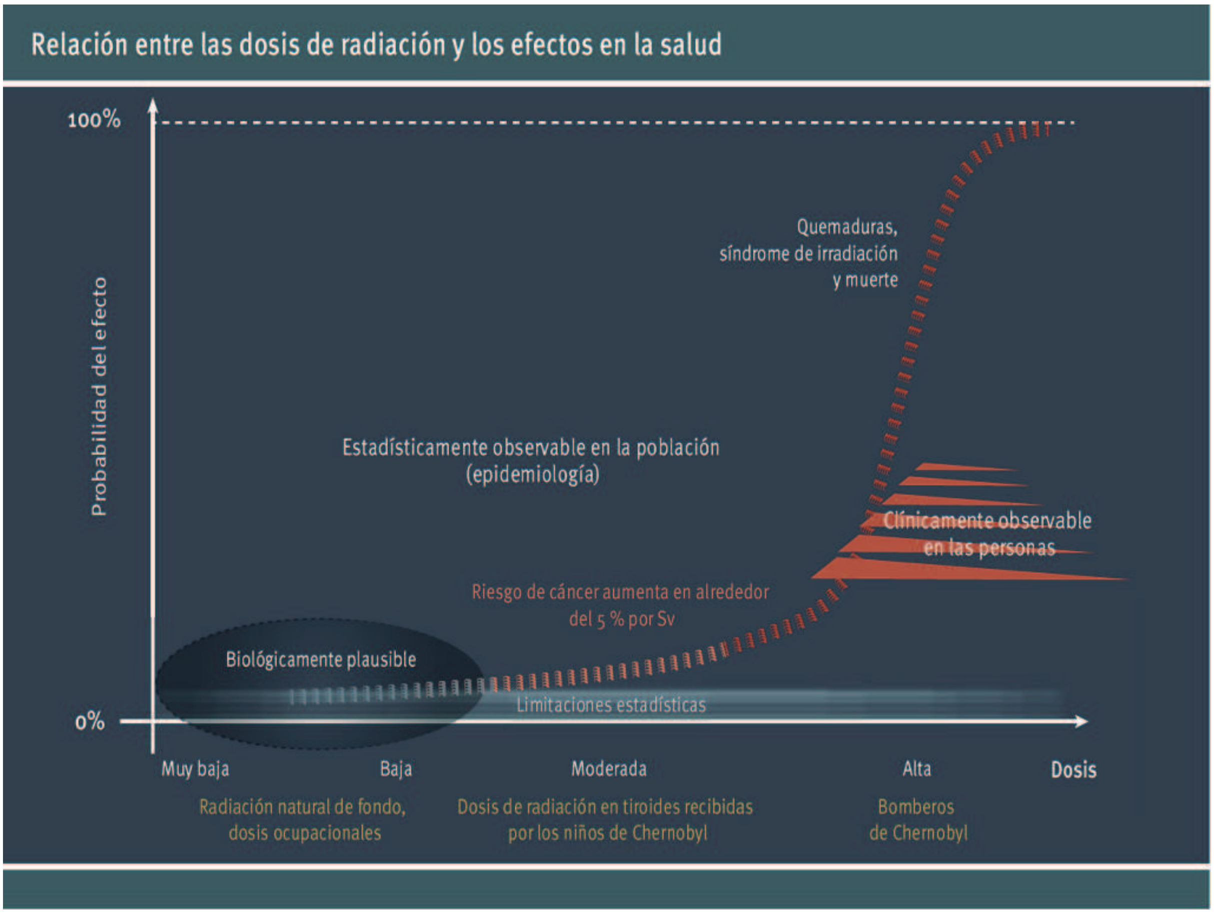
Precisiones del Comité Científico de las Naciones Unidas para el Estudio de los Efectos de las Radiaciones Atómicas, adoptadas por la Asamblea General de las Naciones Unidas.

66



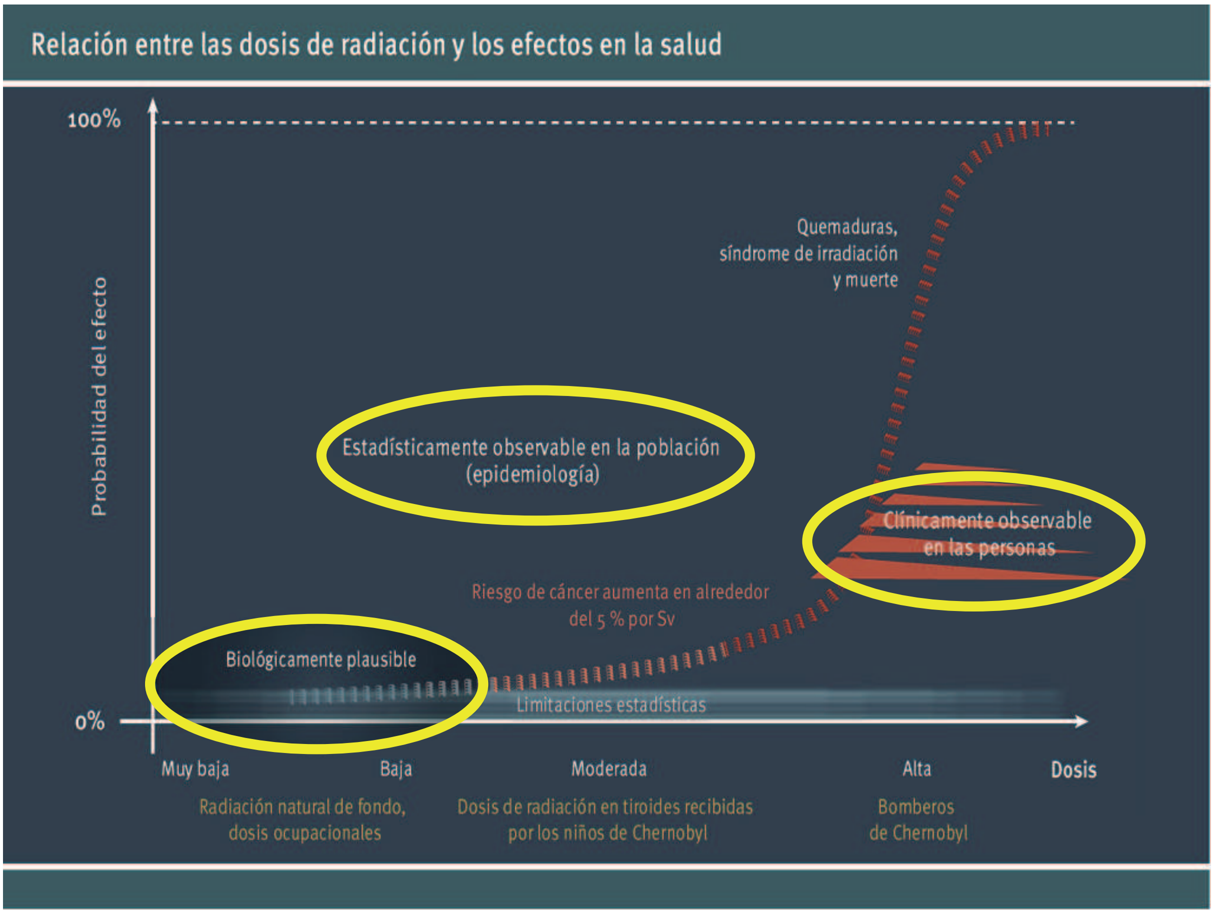
Relación dosis-respuesta

68



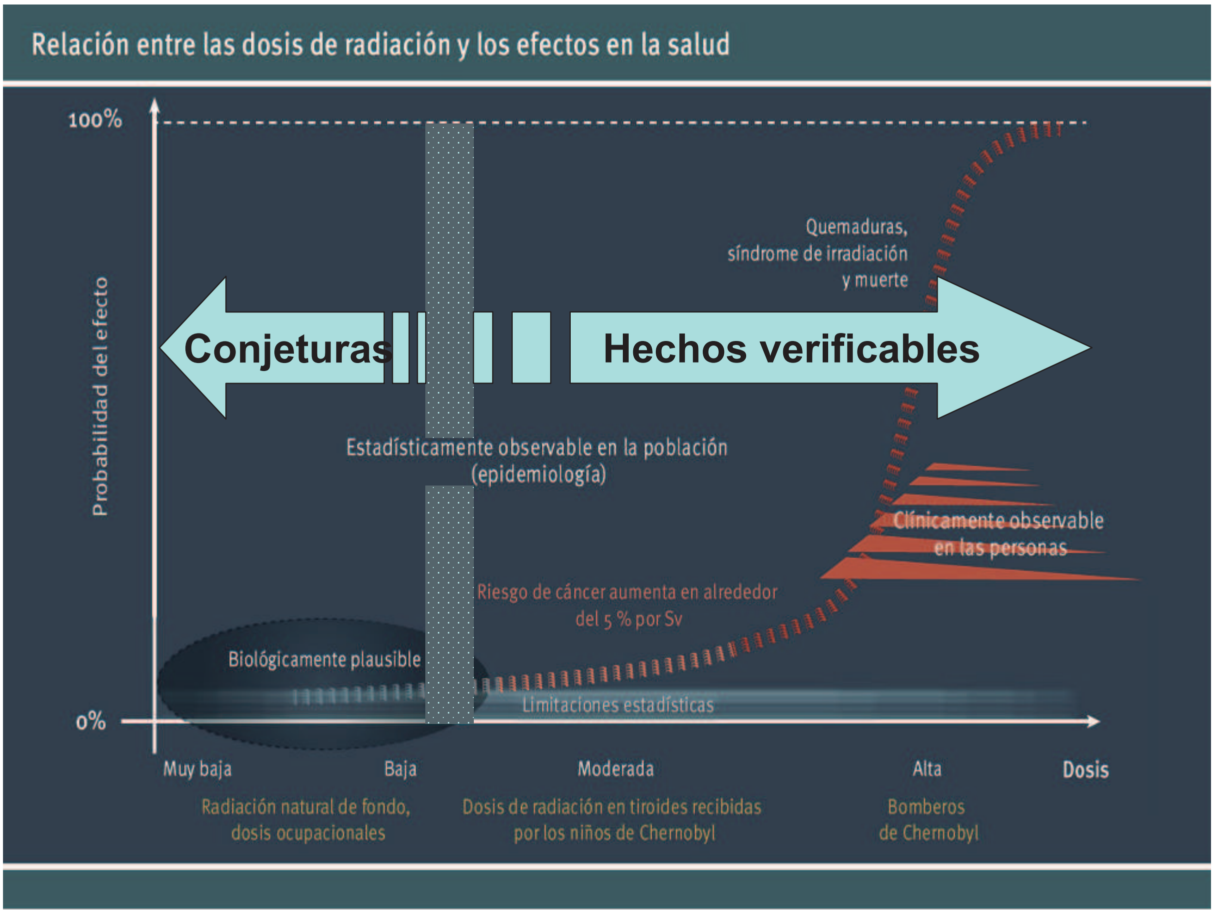
Observación de efectos

70



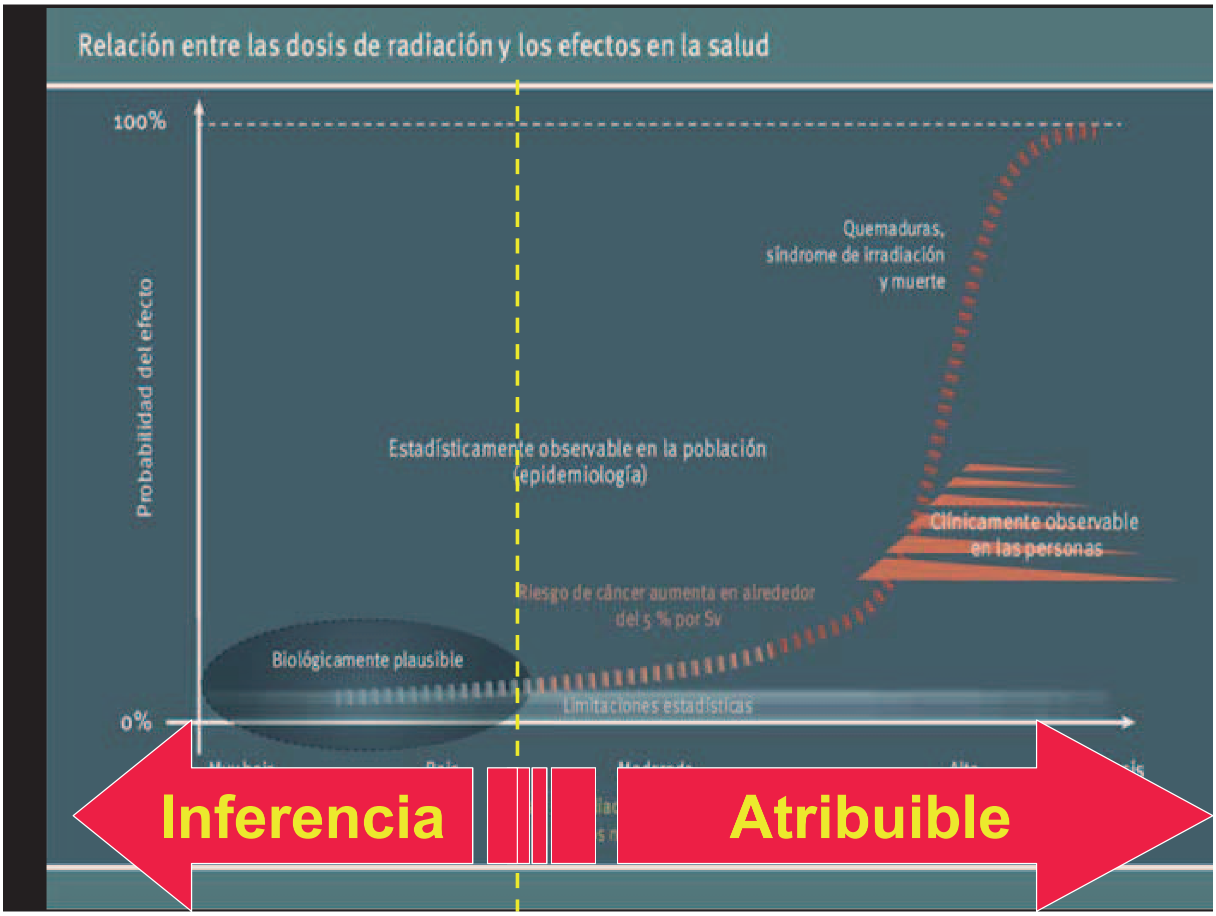
Hechos *versus* Conjeturas

72



Atribución *versus* Inferencia

74



Diagnóstico individual

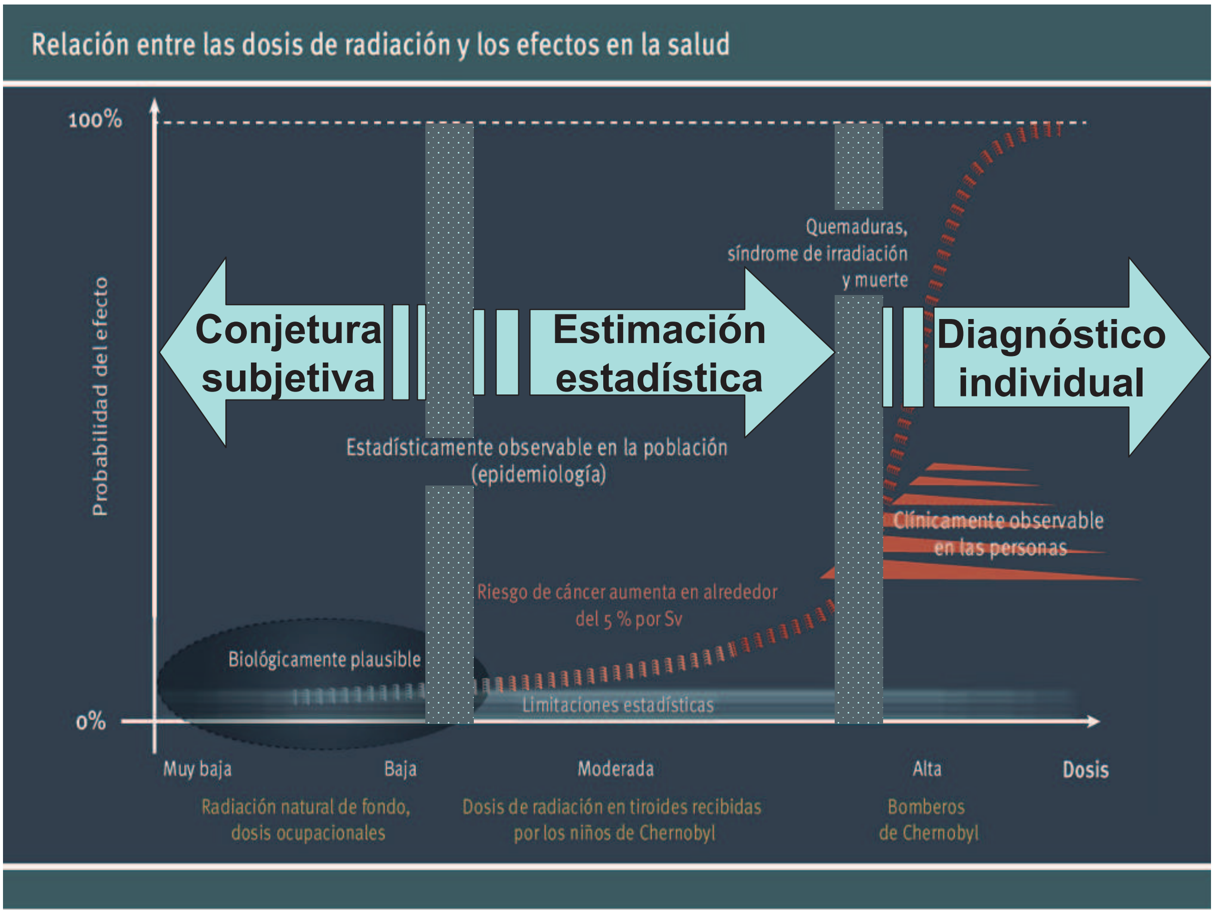
versus

Estimación estadística

versus

Conjetura subjetiva

76



Atribución individual

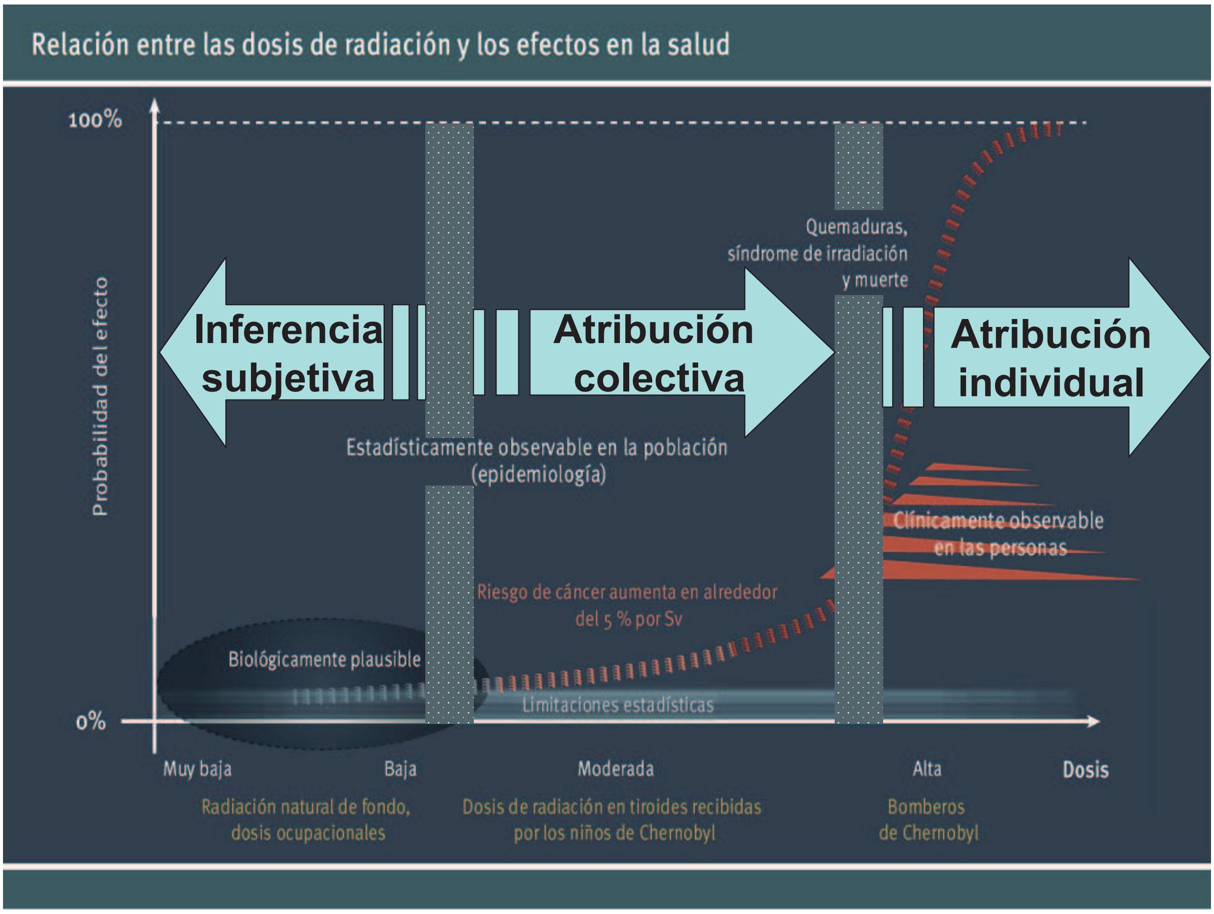
versus

Atribución colectiva

versus

Inferencia

78



Atestación patológica

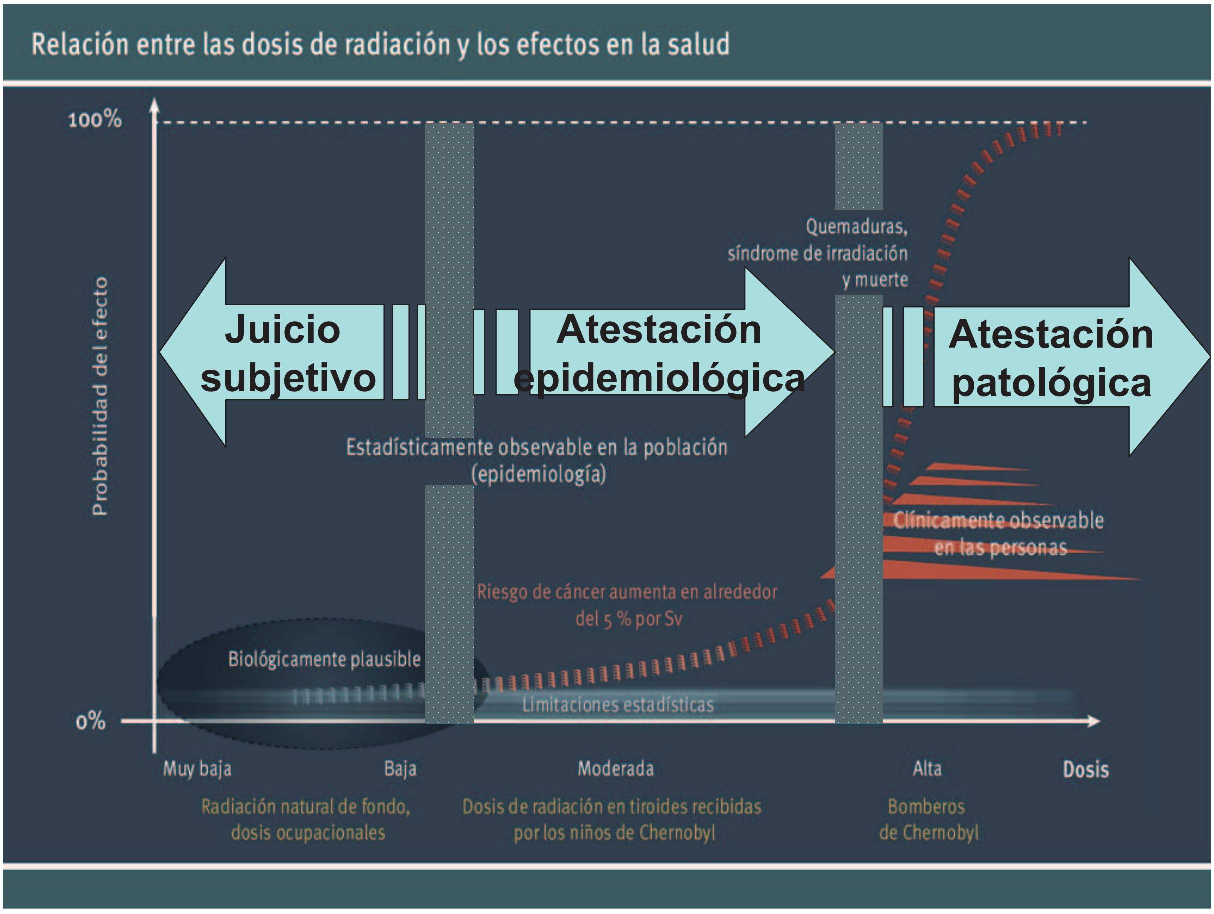
versus

Atestación epidemiológica

versus

Juicio subjetivo

80



IV

Consecunecias para la imputabilidad de daño

82

Legislación

- La legislación internacional referida a la **atribución de efectos** a la salud, la **inferencia de riesgo** y, en particular, a la **imputación de daño**, es **inhomogénea, incoherente e inconsistente.**
- Una distinción importante resulta de comparar:
  - la *legislación jurisprudencial ('caso-por-caso')* *versus,*
  - la *legislación codificada.*

Legislación 'caso-por-caso'

84

‘Caso por caso’

La legislación ‘caso por caso’ sobre la imputación

- se distingue de la legislación codificada por su flexibilidad.
- es mas maleable para interpretar situaciones probabilísticas tales como las del riesgo inferido de la exposición a la radiación a dosis moderadas, bajas y muy bajas.

Ejemplo

- En países donde prima la legislación caso-por-caso, se utiliza normalmente el concepto de ‘*participación asignada*’ (o *assigned share* en Inglés) para dirimir casos de imputación por daño a la radiación debidos a efectos estocásticos.

Legislación codificada

87

Codificación

- La legislación argentina , y en general la Iberoamericana, tiene como común denominador que es 'codificada'.
- El sistema legal codificado impide la arbitrariedad y discriminación, pero es un sistema fundamentalmente determínistico.

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Codificación

- El sistema es ideal para tratar situaciones de efectos determinísticos, dado que existen umbrales de dosis que definen si un efecto ocurrió o no, si es imputable o no.
- Los efectos pueden ser atestados sin ambigüedad por un experto patólogo competente.

89

Codificación

- Pero el sistema no es ideal para lidiar con situaciones probabilísticas, sobre todo situaciones con probabilidades subjetivas.
- La legislación codificada por lo tanto es problemática para resolver casos de imputación de efectos estocásticos.

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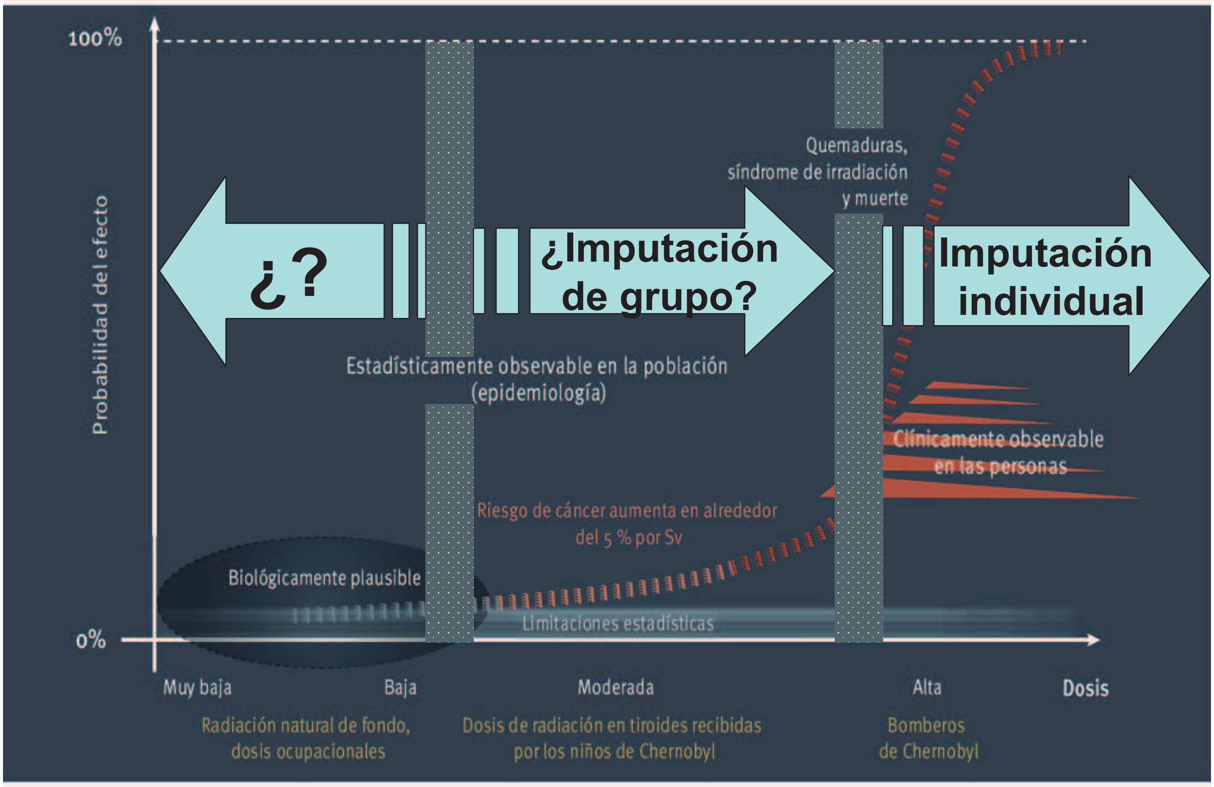
¿Alternativas de imputación en la legislación codificada?

91

Relación entre las dosis de radiación y los efectos en la salud



Legislación argentina relevante

- Constitución Nacional: artículos 41/42/43
- Ley 17557. Normas para rayos x.
- Ley N° 24.804 – Ley de la Actividad Nuclear
- Ley N° 25.886 – Código Penal Art 189 bis
- Ley N° 25.675 – Ley General del Ambiente
- Ley N° 24.051 – Ley de Residuos Peligrosos
- Decreto 1.390/98 Reglamentación-Ley 24.804
- Normas Regulatorias de la ARN y de M.de Salud
- 31 LEYES PROVINCIALES

Ejemplo:

LEY 4966 DE LA PROVINCIA DE MENDOZA

Artículo 1º- Establécese a partir de la vigencia de la presente Ley, el siguiente régimen para el personal que maneja ‘rayos ionizantes’ [SIC]:

- a) Jornadas: cuatro horas diarias;
- b) Licencias: treinta días/cinco meses;
- c) Control sanitario (hematológico) /seis meses

V

Sugerencias

95

Invitación…

…a los expertos legales de las instituciones relevantes (CNEA, ARN, NASA, INVAP, etc), a constituir una mesa informal para:

- discutir el tema y proponer soluciones compatibles con la legislación argentina; y
- explorar la factibilidad de un acuerdo iberoamericano.

- Dadas las similitudes culturales y sobre todo legislativas entre los países Iberoamericanos, hemos sugerido que se promueva un proyecto Iberoamericano relacionado con la atribución de efectos, la inferencia de riesgos y la imputabilidad.
- El proyecto tendría dos objetivos fundamentales, a saber:

97

Objetivo 1

- Promulgar una política interpretativa común, referida a la atribución de efectos a la salud, la inferencia de riesgo y, en particular, a la imputación de daño, relacionados con las situaciones de exposición a la radiación ionizante.

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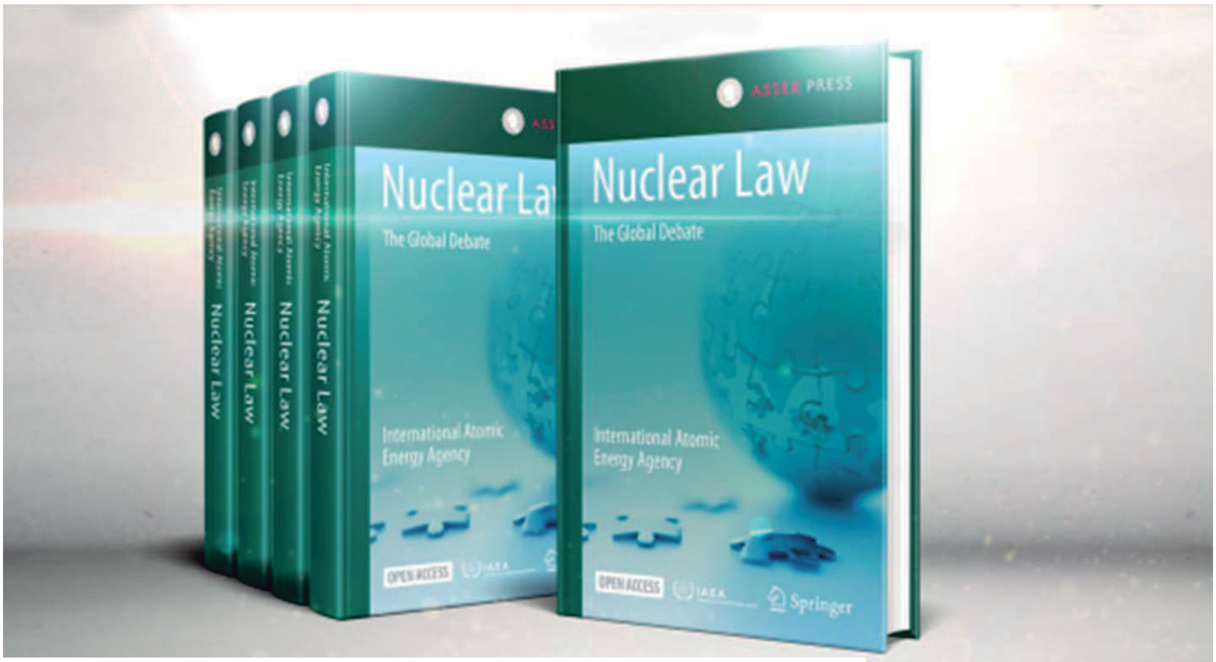
Objetivo 2

- Consensuar una **codificación legislativa común** para regular la aplicación de la ley en situaciones de exposición a la radiación ionizante, que sirva de base para las distintas legislaturas nacionales y provinciales.

99



Chapter 7
Legal Imputation of Radiation Harm to Radiation Exposure Situations

Abel Julio González

Radiation Concepts

González, A.J.

Clase dictada en el Curso del Summer Institute 2022 de la Universidad Nuclear Mundial, llevado a cabo en la Universitat Politècnica de València (UPV), en Valencia, España, del 19 al 25 de junio de 2022

World Nuclear University
Sumer Institute – 2022
Valencia-España-24/6/2022

Radiation Concepts

Abel J. González

UNSCEAR Representative, IAEA' CSS Member

Autoridad Regulatoria Nuclear

✉Av. Del Libertador 8250; (1429)Buenos Aires,Argentina ☎+54 1163231758

Reasons for this presentation

1. *Radiation* is the *nemesis* of nuclear energy.
2. The renascence of nuclear energy would be much easier, should *radiation* not be there.
3. Therefore, you, as future nuclear managers need to be aware of *radiation*; its levels and effects.

Content

1. What is radiation?
2. Where does radiation come from?
3. What does radiation do to us?
4. Epilogue:

Factual radiation health effects *vis-à-vis* conjectures on risk

3

First Part

What is radiation?

4

Confusion

Radioactivity ≠ Radiation

5

What is radioactivity?

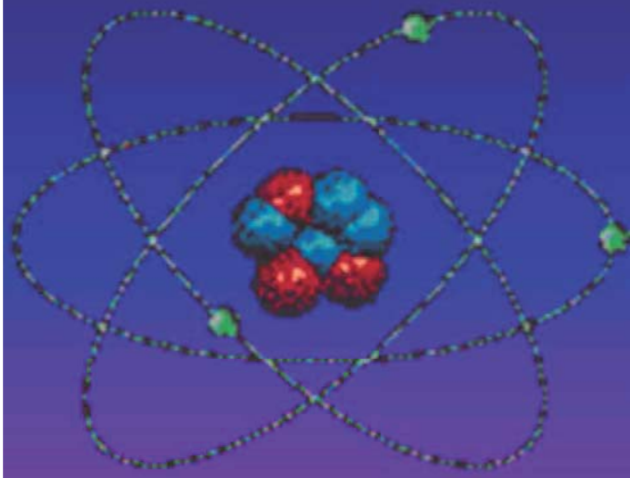
6

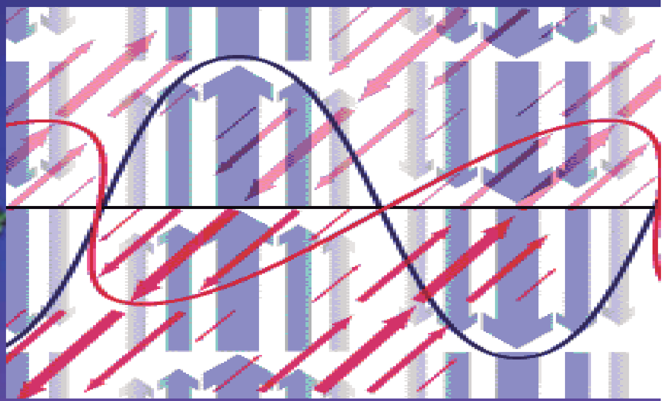
Radioactivity

Property of atoms of emitting energy as *radiation.*

Measured in *becquerels* (Bq); 1Bq = 1 emission/second

(but also in *curies* (Ci); 1 Ci = radioactivity in 1g of radium)



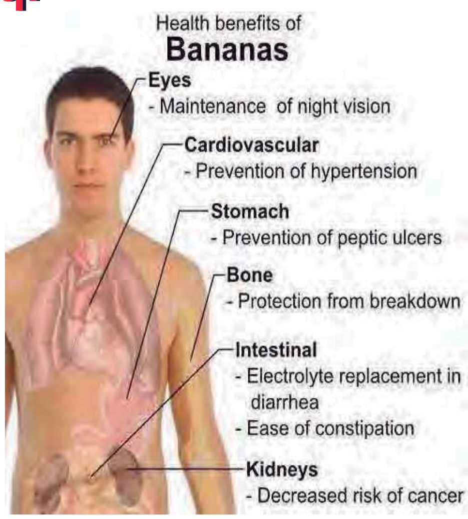


7

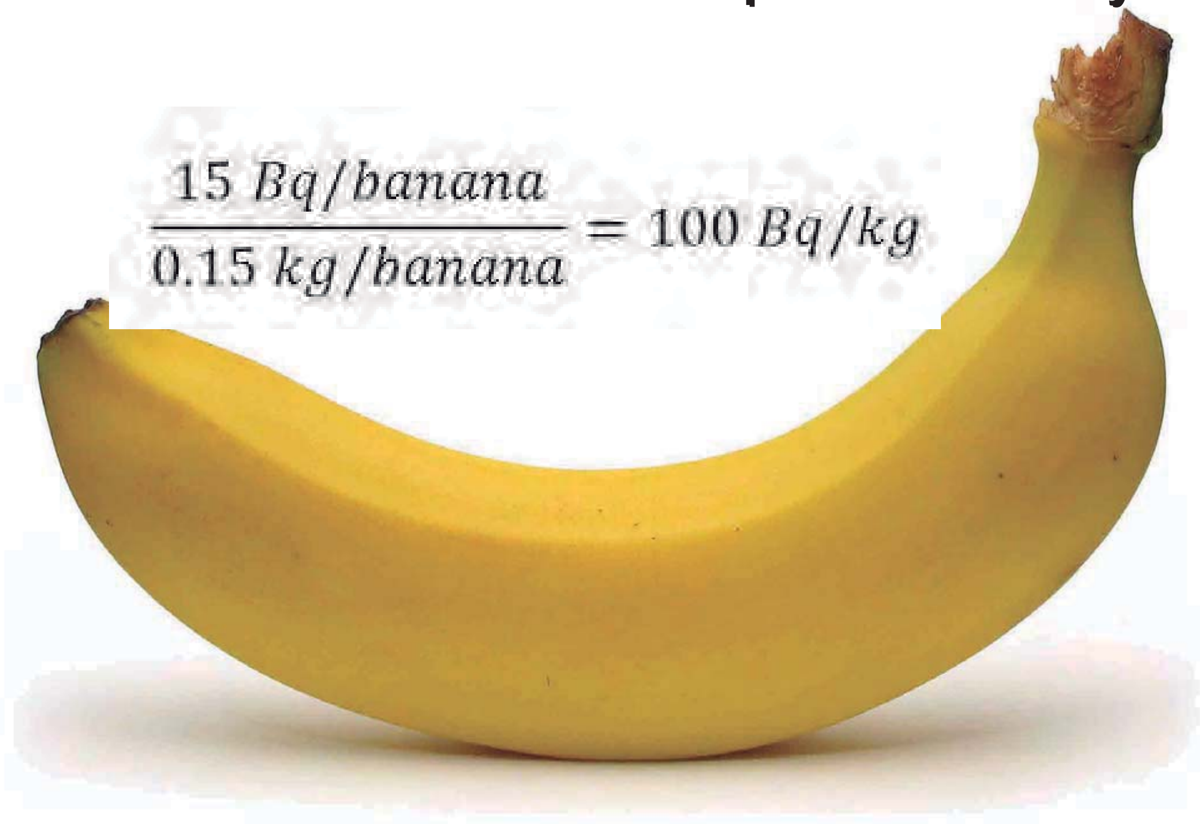
One becquerel is a very small amount of radioactivity

- **The amount of radioactivity in**

  a 70-kg person is about 5,000 Bq.

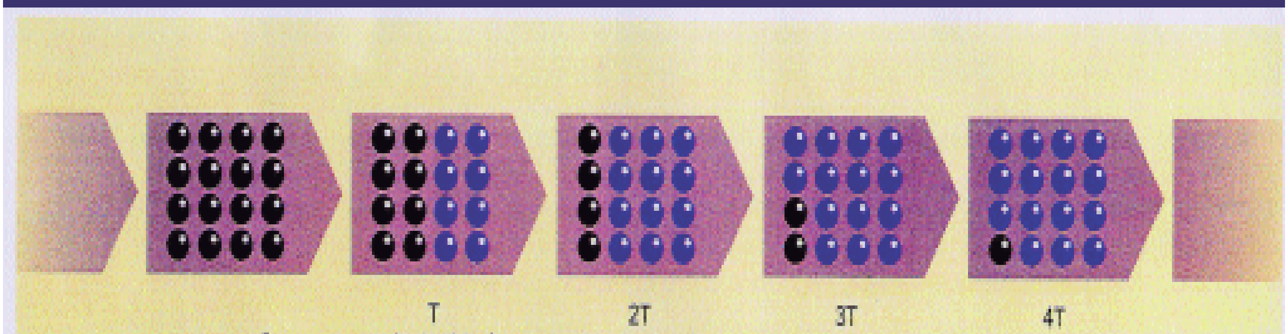


One banana contains 15 Bq of radioactivity!



$$\frac{15\ Bq/banana}{0.15\ kg/banana} = 100\ Bq/kg$$

Radioactivity decays



After 4 periods of semi-disintegration, radioactivity decays to 1/16

For instance: ^{131}Iodine (8 days), after 1 month, 100 Bq becomes 6 Bq

10

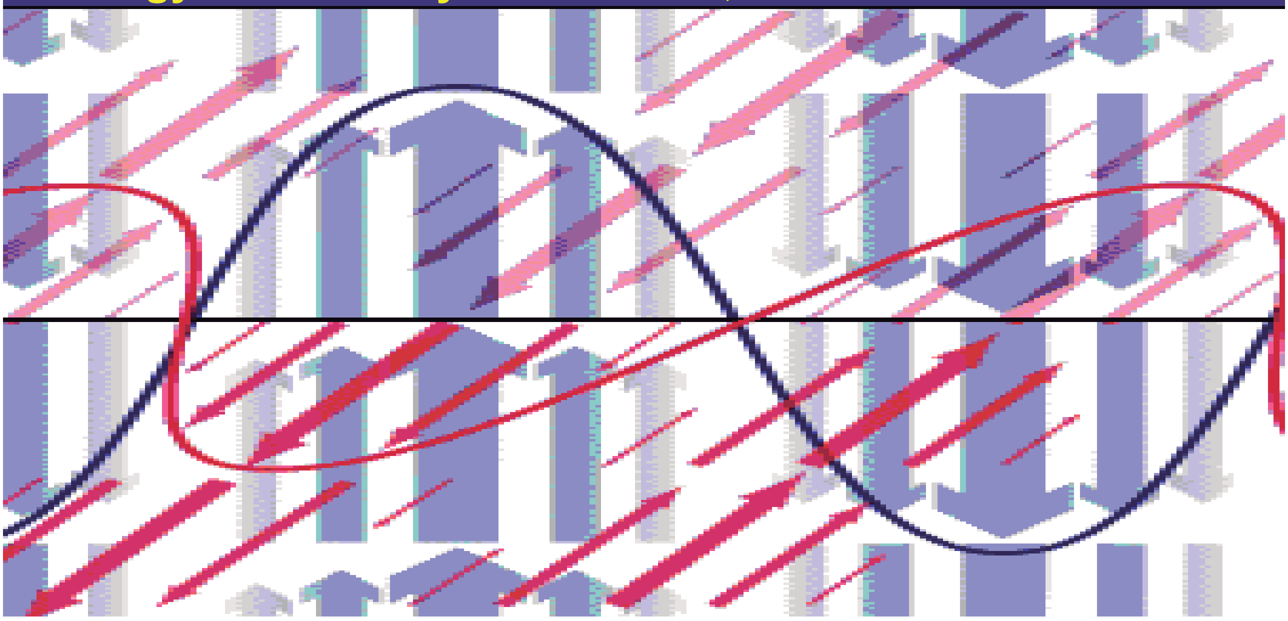
What is radiation?

11

Radiation

Energy transmitted in finite packages (quanta) that behave as a wave and as a particle

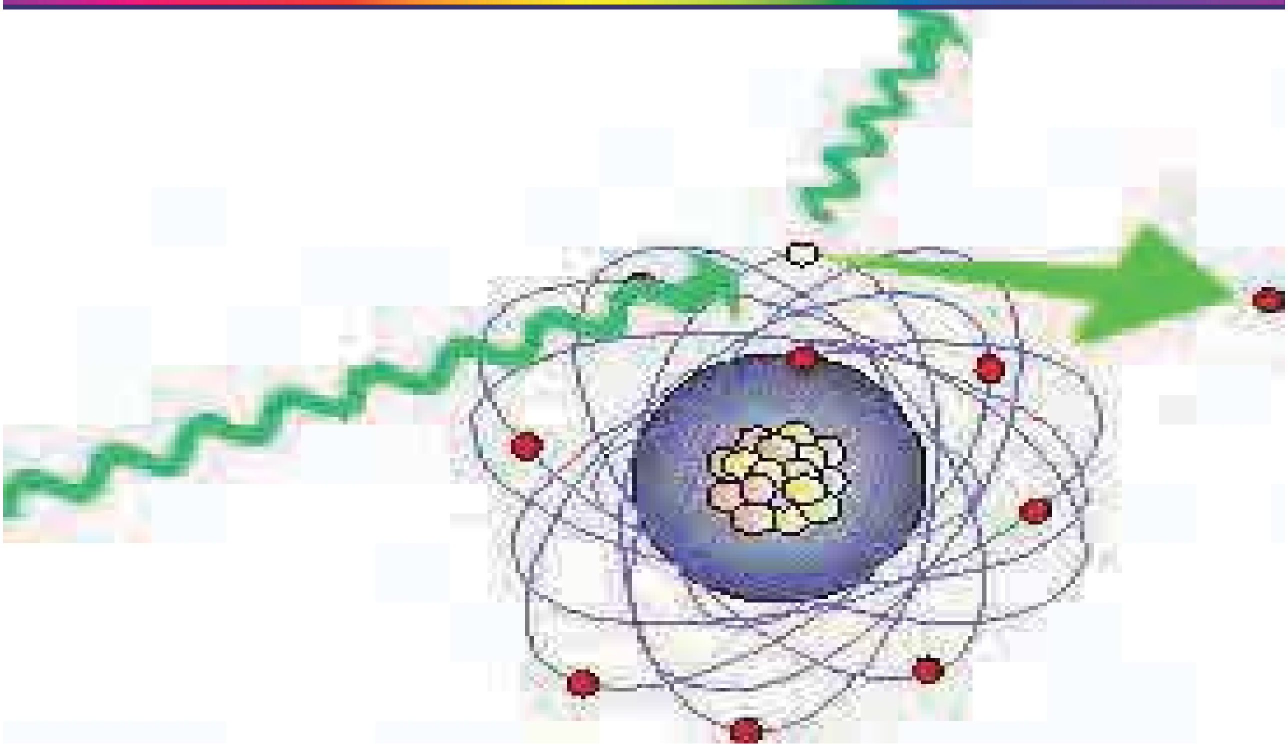
The effect of radiation in matter is measured by the radiation energy absorbed by unit of mass, which is termed ‘*dose*’



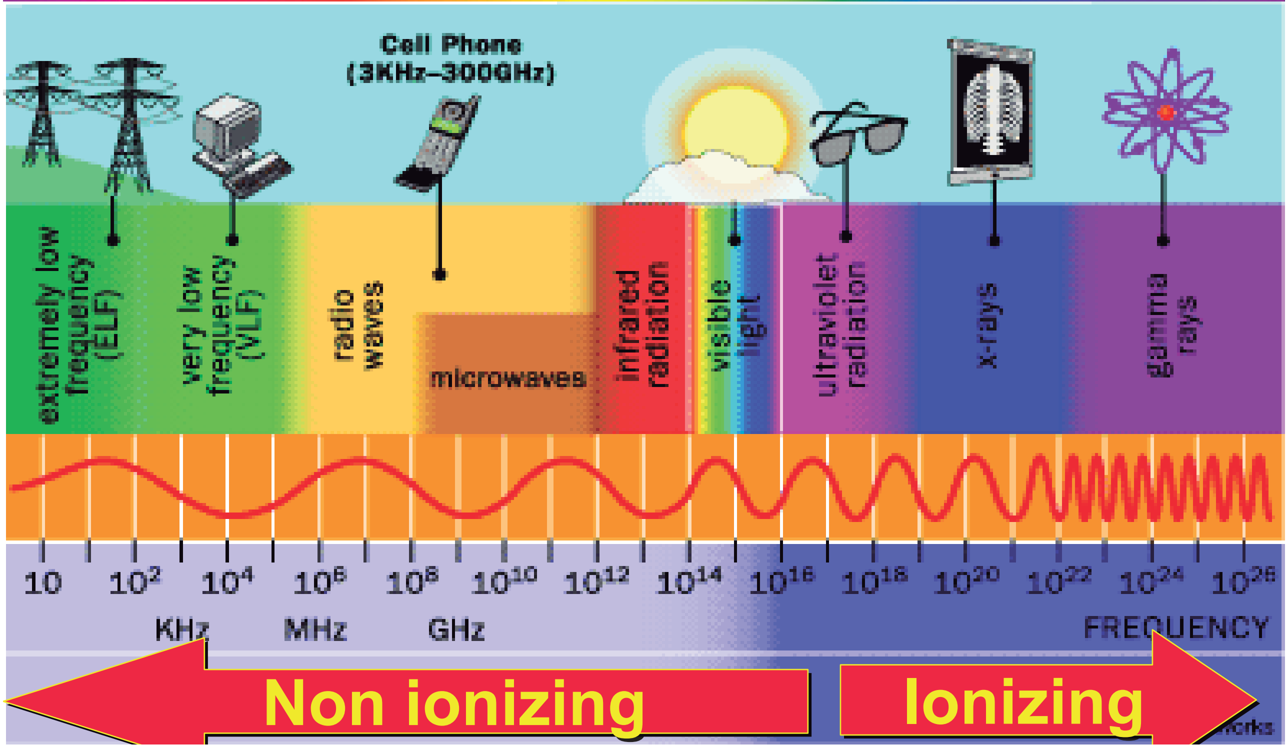
What is *ionizing* radiation?

13

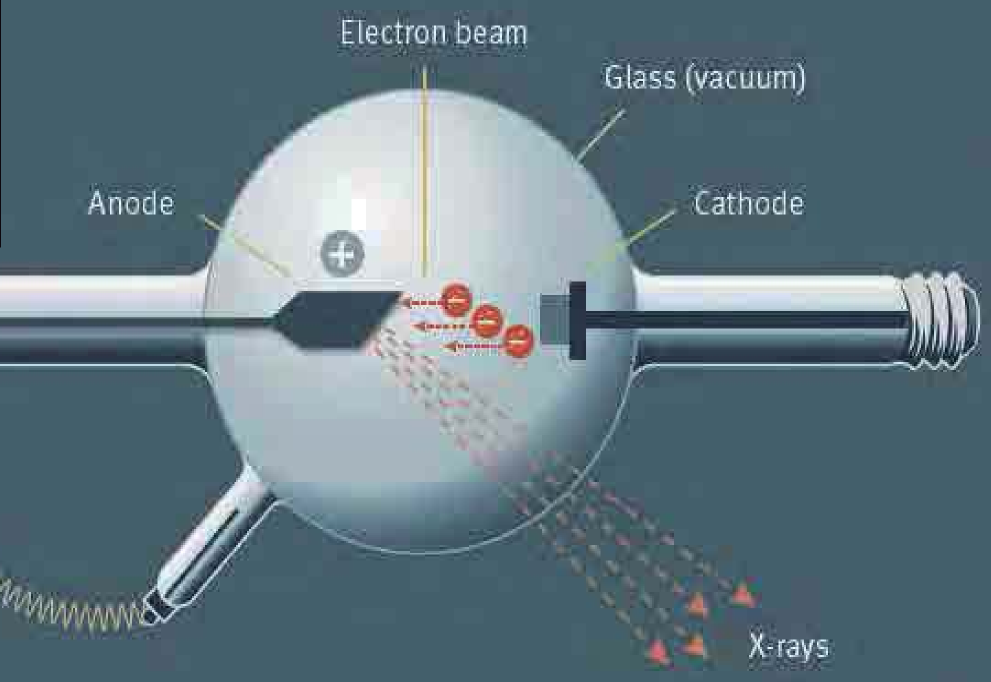
Ionizing radiation is radiation carrying enough energy to ionize an atom



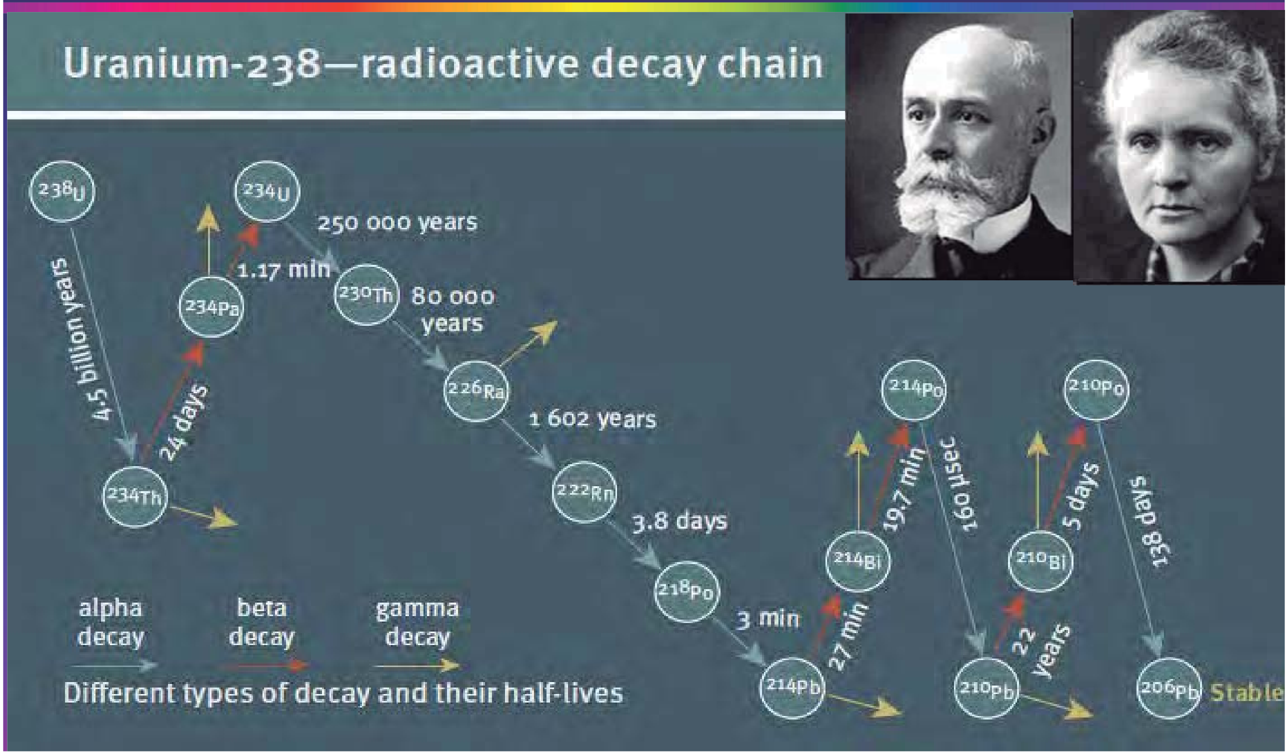
Radiation spectrum

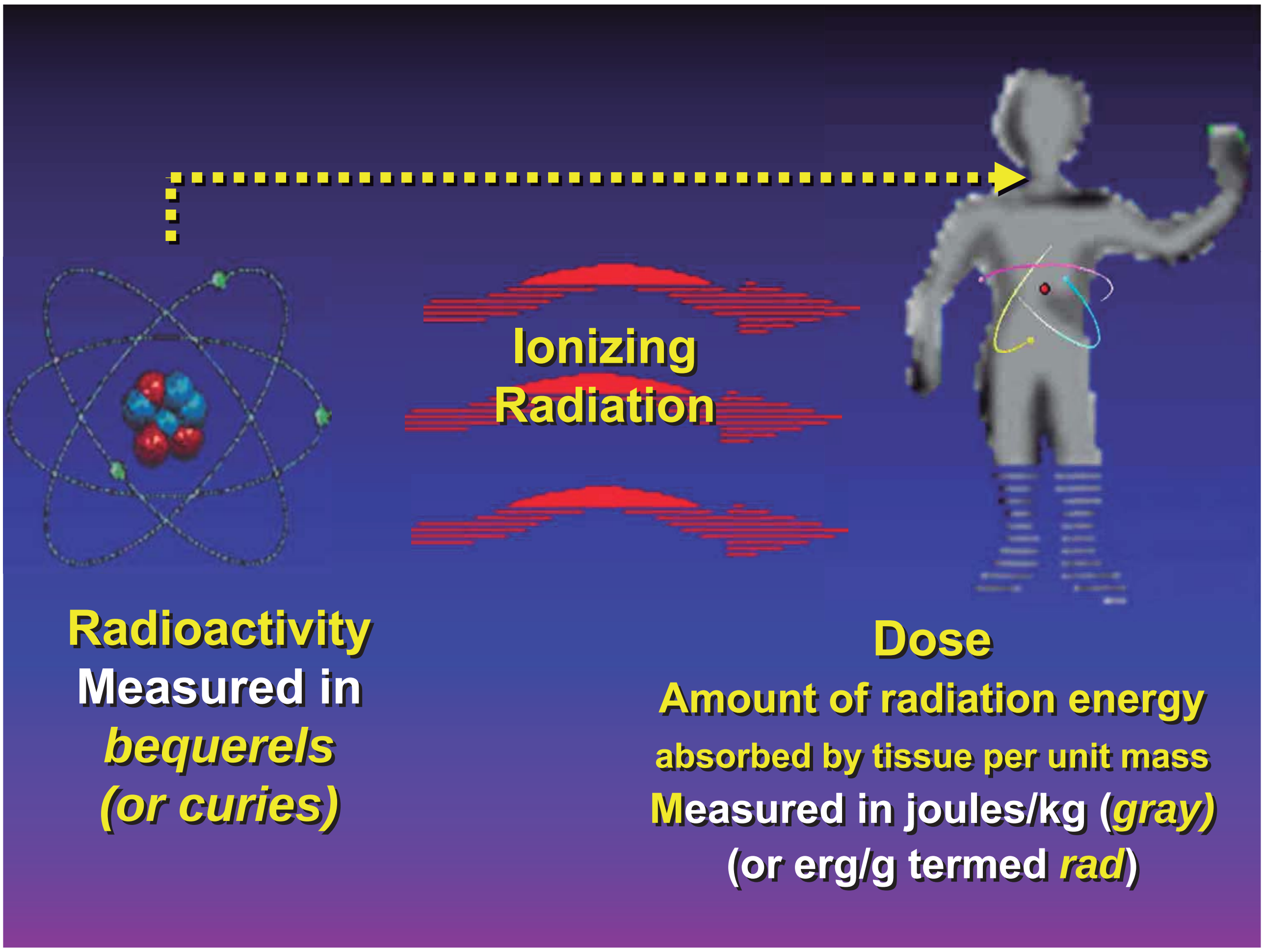


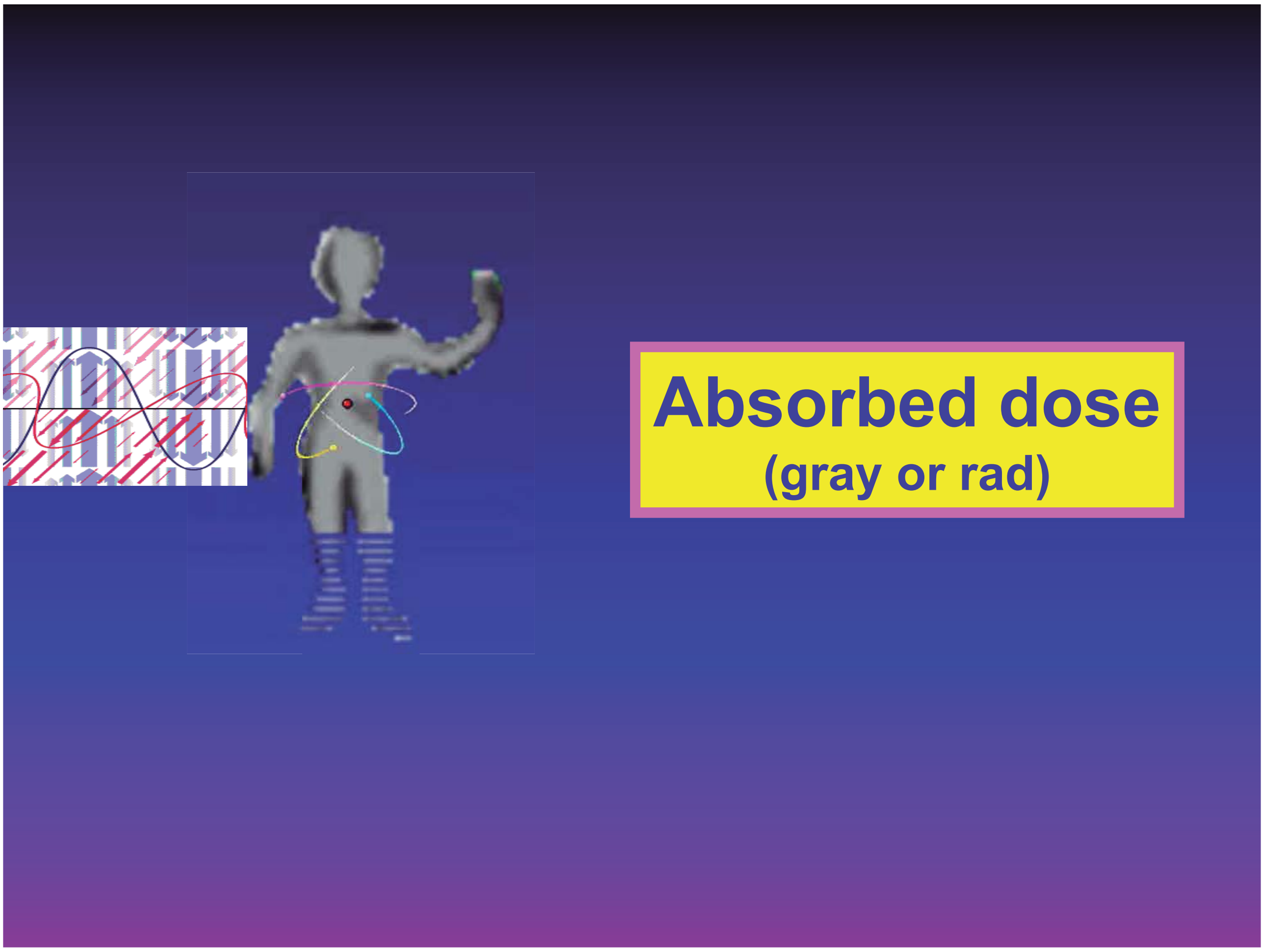
First ionizing radiation discovered: those emitted by a X-ray tube….

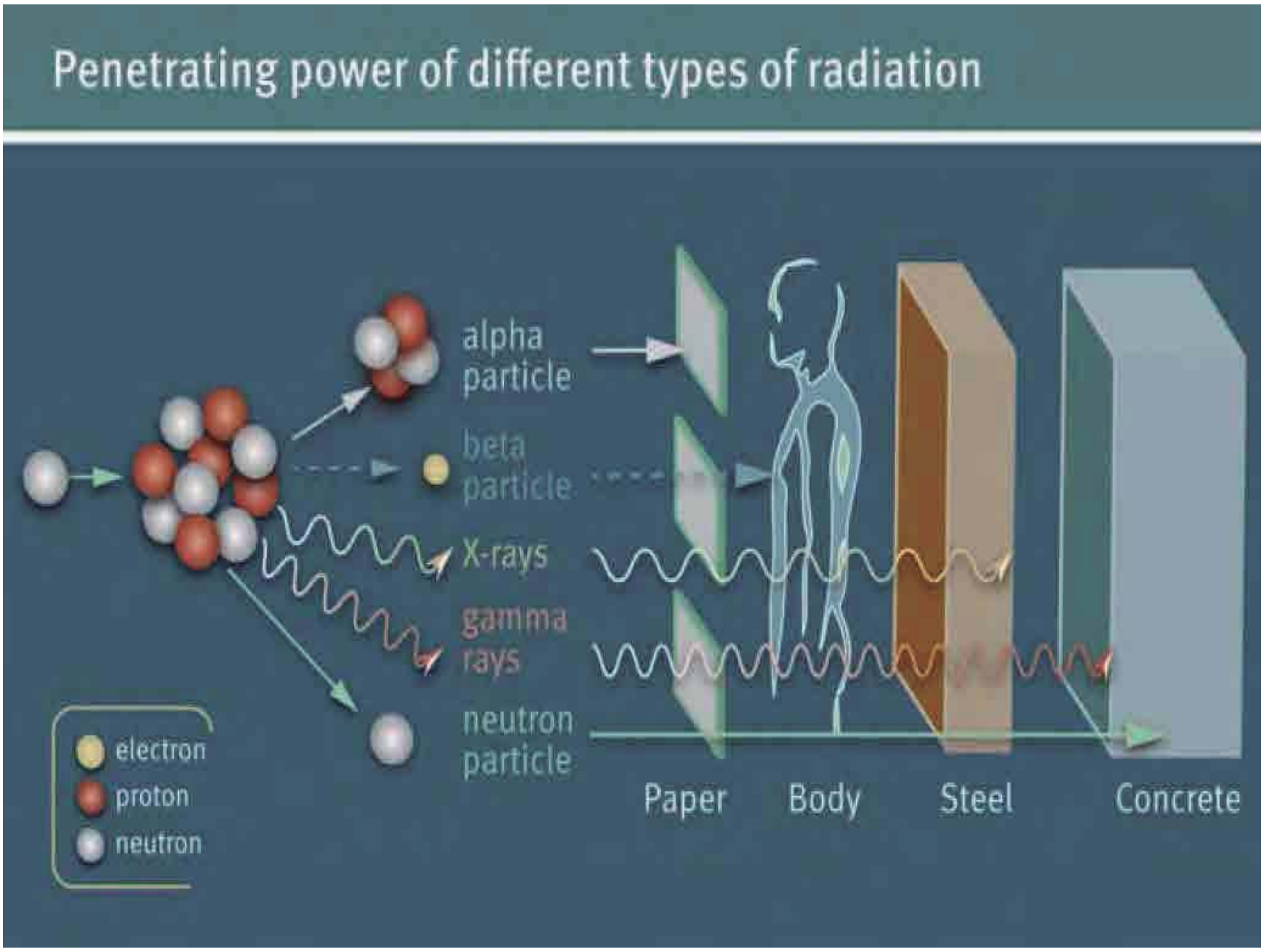


…and then, by radioactive substances

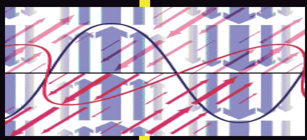





Absorbed dose
(gray or rad)


Penetrating power of different types of radiation
alpha particle
beta particle
X-rays
gamma rays
neutron particle
Paper
Body
Steel
Concrete
electron
proton
neutron

Absorbed dose (in tissues)
(gray or rad)



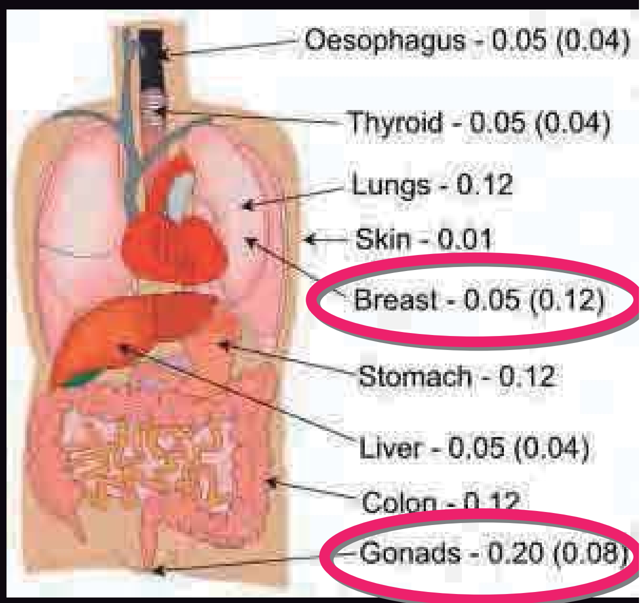
Radiation weighting factor, w_R

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons[a] and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy

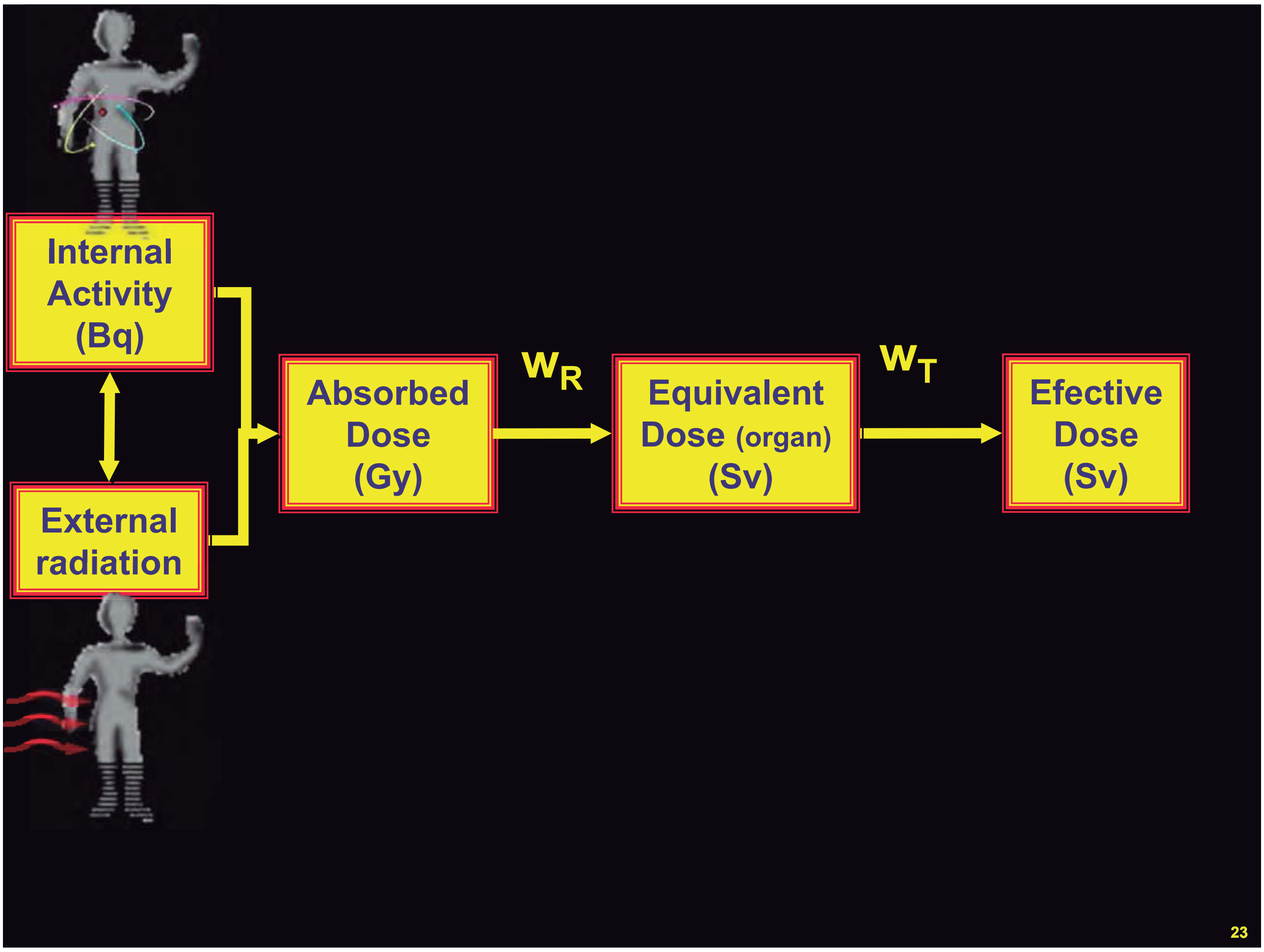
Equivalent dose
(sievert or rem)

Equivalent dose
(sievert or rem)

Tissue weighting factor), w_T



Effective dose
(sievert or rem)



The unit of effective dose is the Sievert [Sv]
(0.001 Sv = 1 milliSievert [mSv])

How much is a mSv?

- 1 year of natural radiation, around 1–10 mSv
- 1 computed tomography, around 10 mSv
- 1 chest floroscopy, around 1 mSv
- 1 chest radiography, around 0.1 mSv
- 1 dental radiography, around 0.01 mSv

24

Take away points

25

- Radioactivity → Activity → bequerel (curie)

- Radiation → Dose → sievert (rem)

  (1 milliieverts, mSv = 1/1000 sievert)

26

Radiation quantities

Physical quantity	
Activity	The number of nuclear transformations of energy per unit of time. It is measured as decays per second and expressed in becquerels (Bq).
Absorbed dose	The amount of energy deposited by radiation in a unit mass of material, such as a tissue or organ. It is expressed in grays (Gy), which corresponds to joules per kilogram.
Calculated quantity	
Equivalent dose	The absorbed dose multiplied by a radiation factor (w_R) that takes into account the way different types of radiation cause biological harm in a tissue or organ. It is expressed in sieverts (Sv), which corresponds to joules per kilogram.
Effective dose	The equivalent dose multiplied by organ factors (w_T) that take into account the susceptibility to harm of different tissues and organs. It is expressed in sieverts (Sv), which corresponds to joules per kilogram.
Collective effective dose	Sum of all effective doses of a population or group of people exposed to radiation. It is expressed in man-sieverts (man Sv).

Second Part

Where does radiation come from?

28

Where does radiation come from?

- **Natural sources**
  - Cosmic sources
  - Terrestrial sources
  - Food and drink
- **Artificial sources**
  - Medical applications
  - Ilitary aplications
  - Electricity generation (not only Nuclear Power Plants)
  - Industrial and other applications

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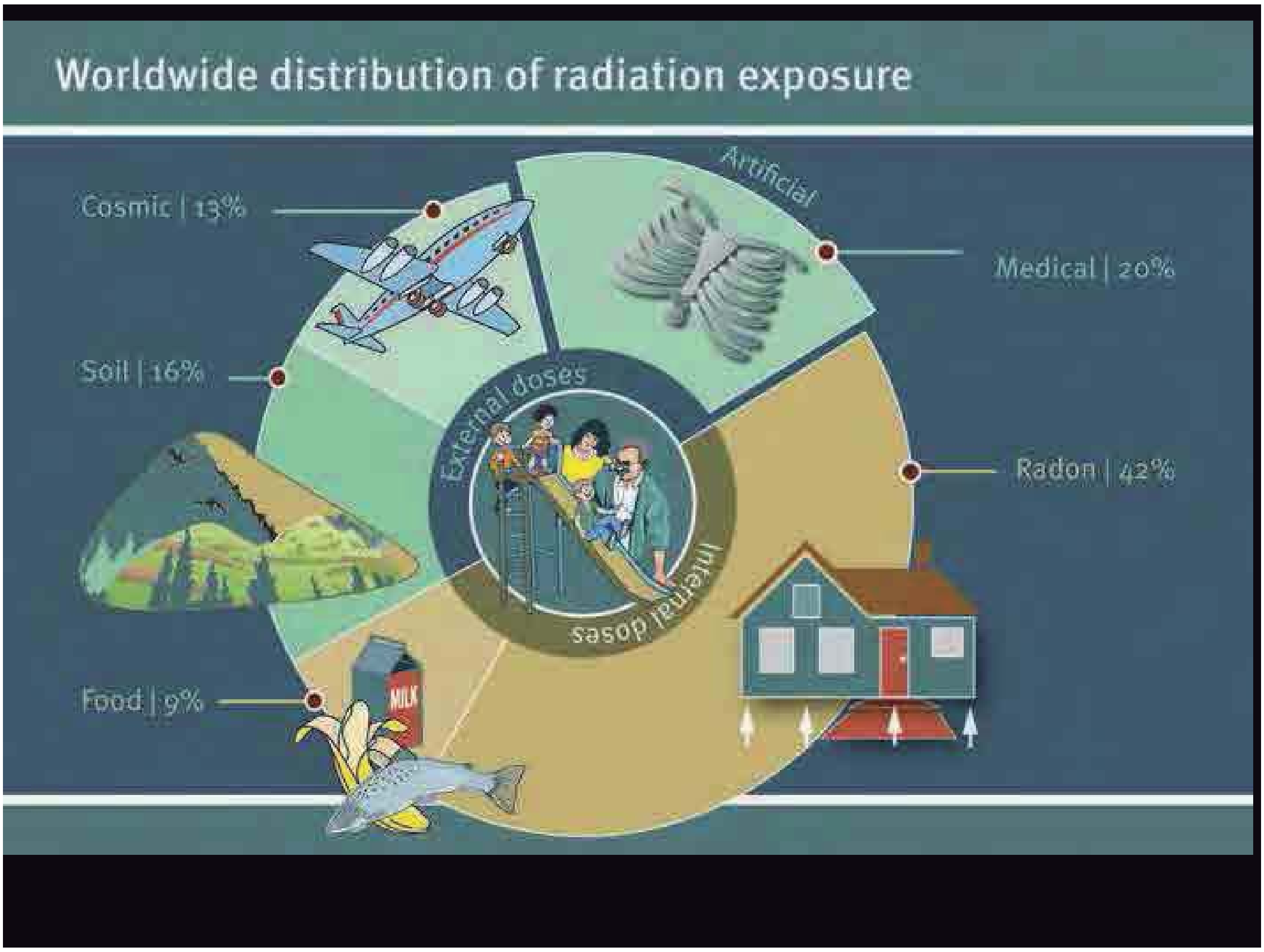
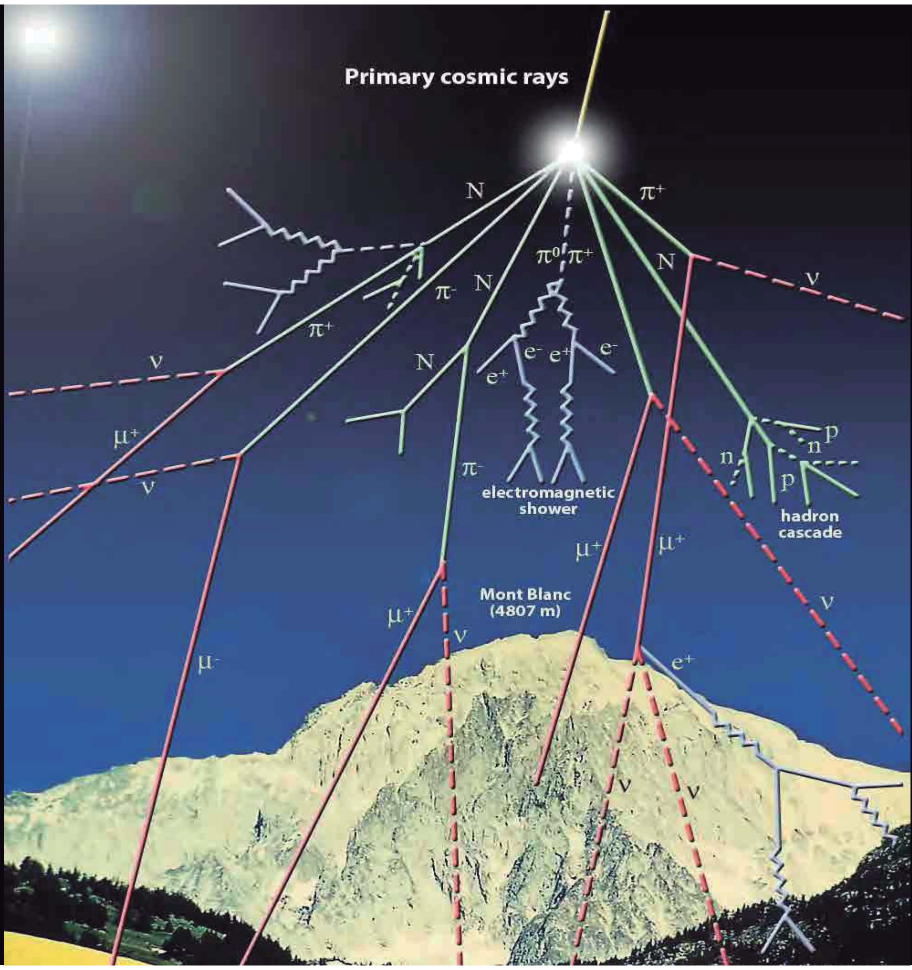
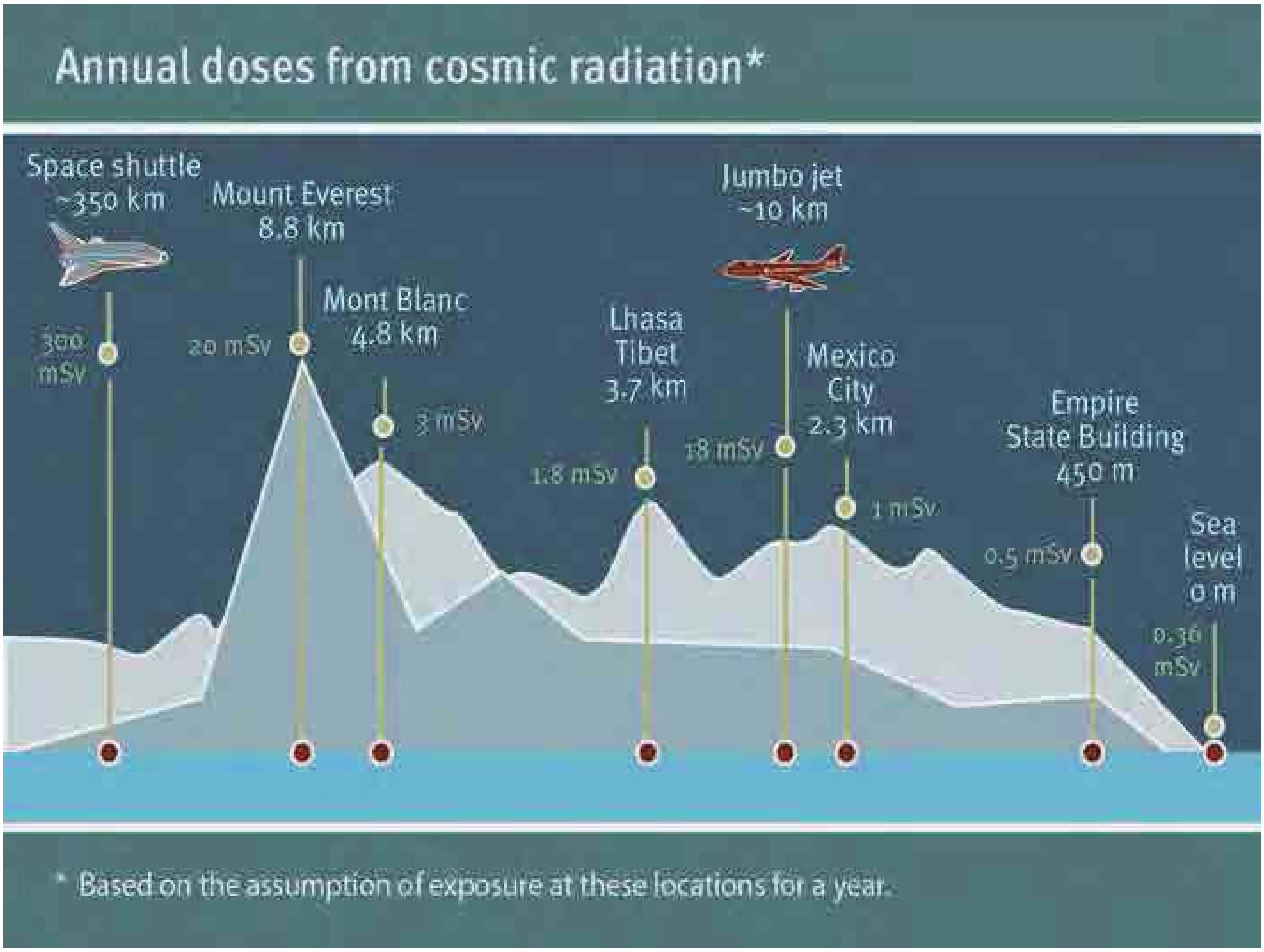
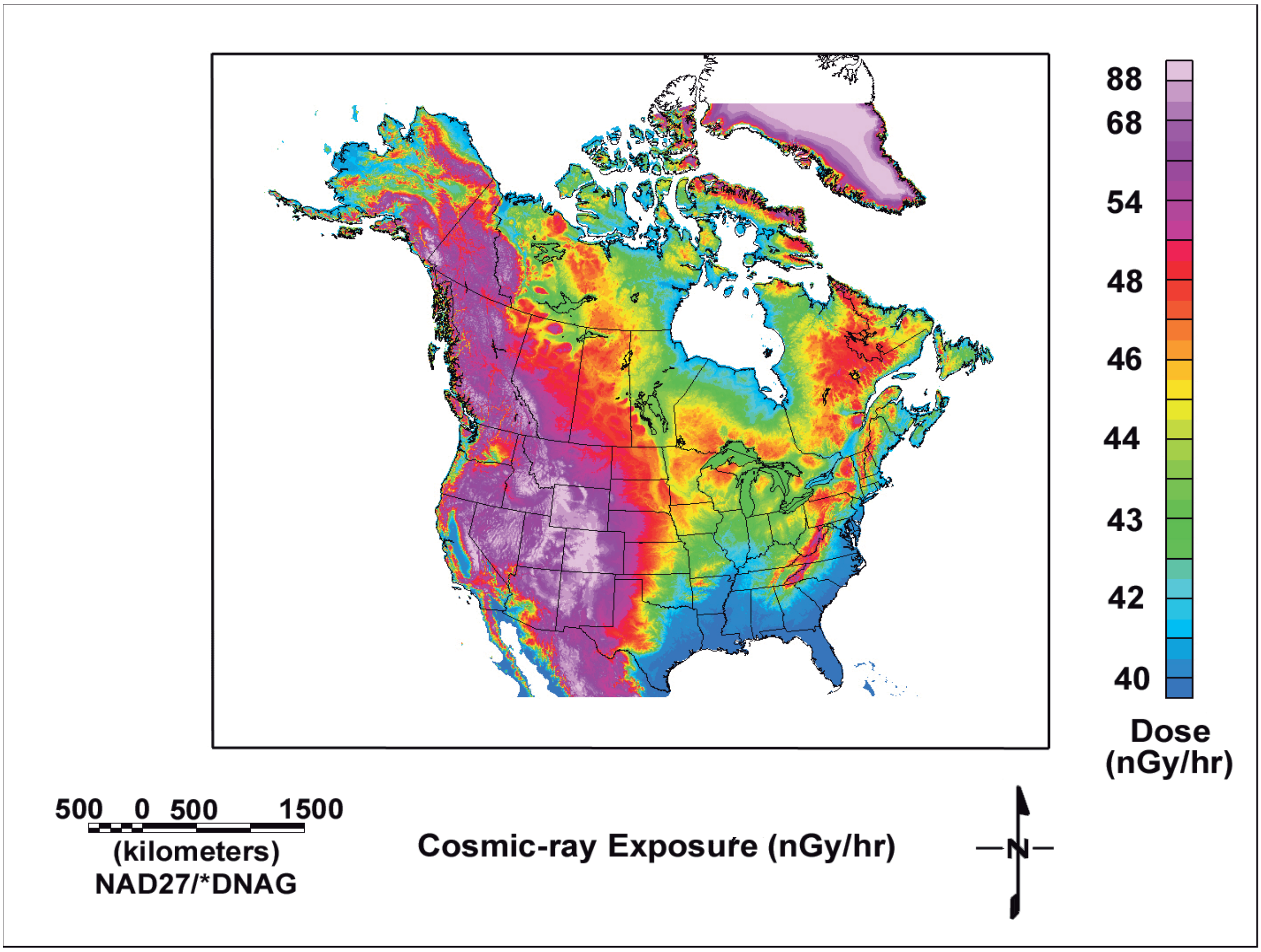


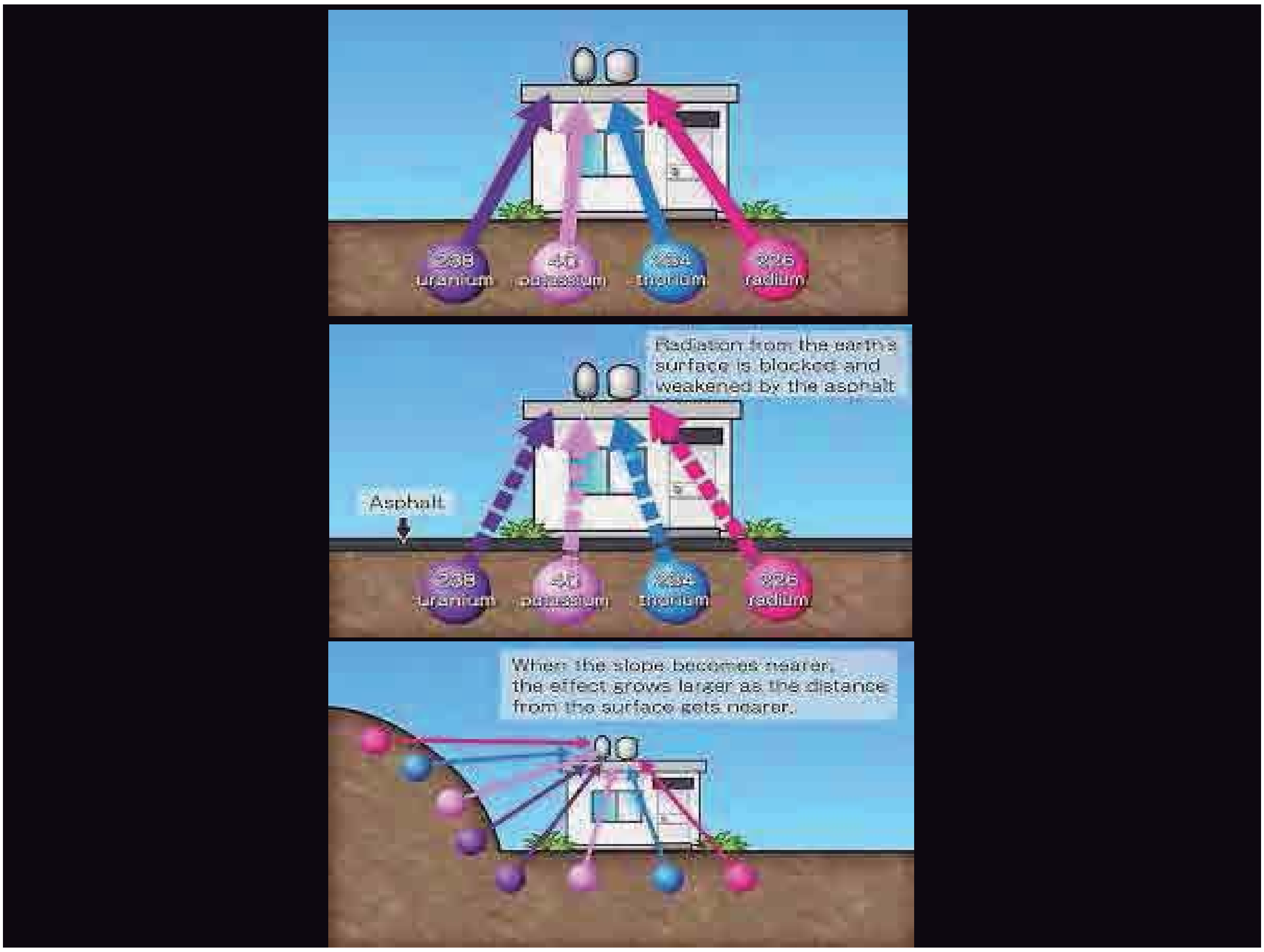
Natural sources

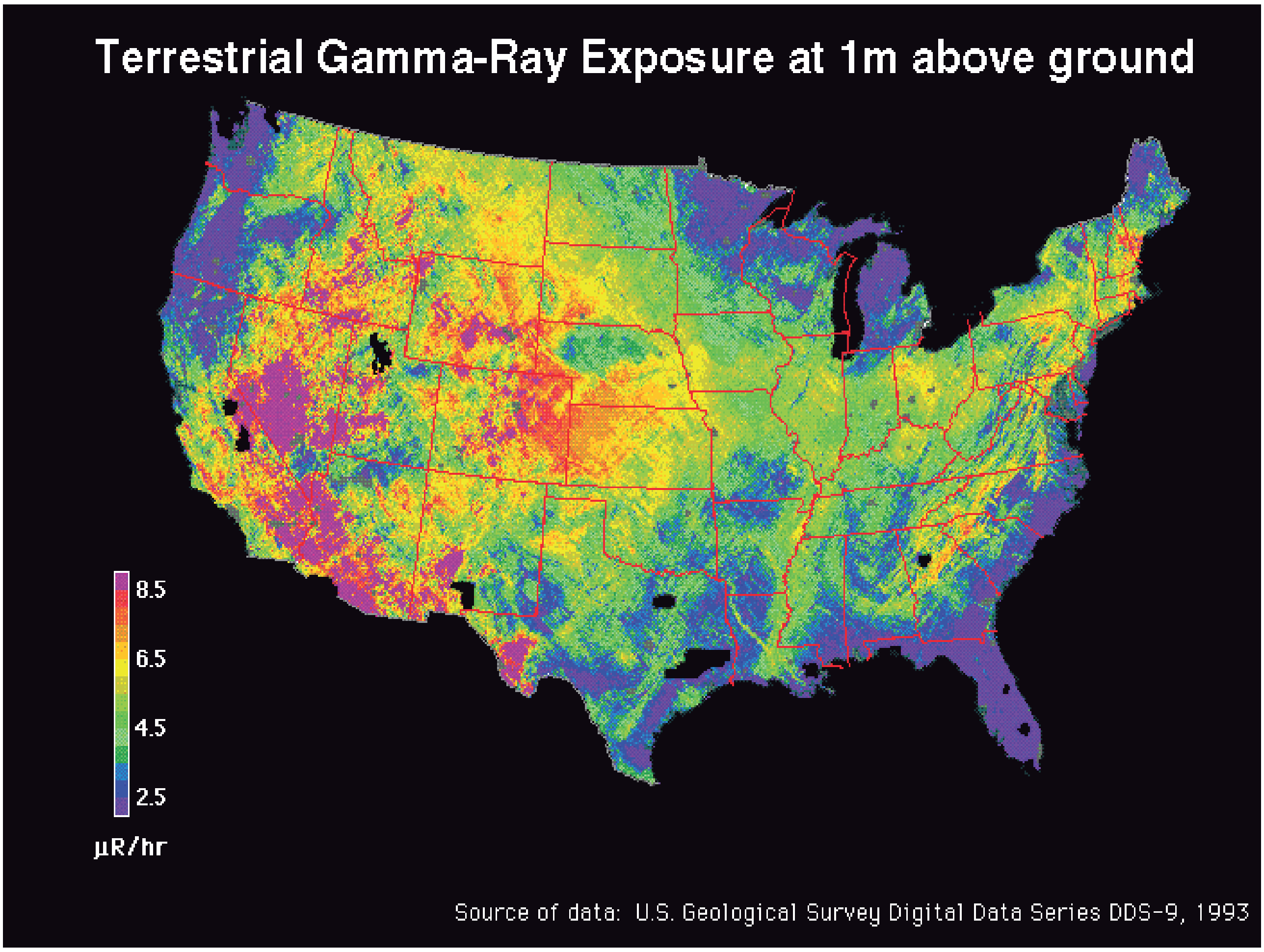
31

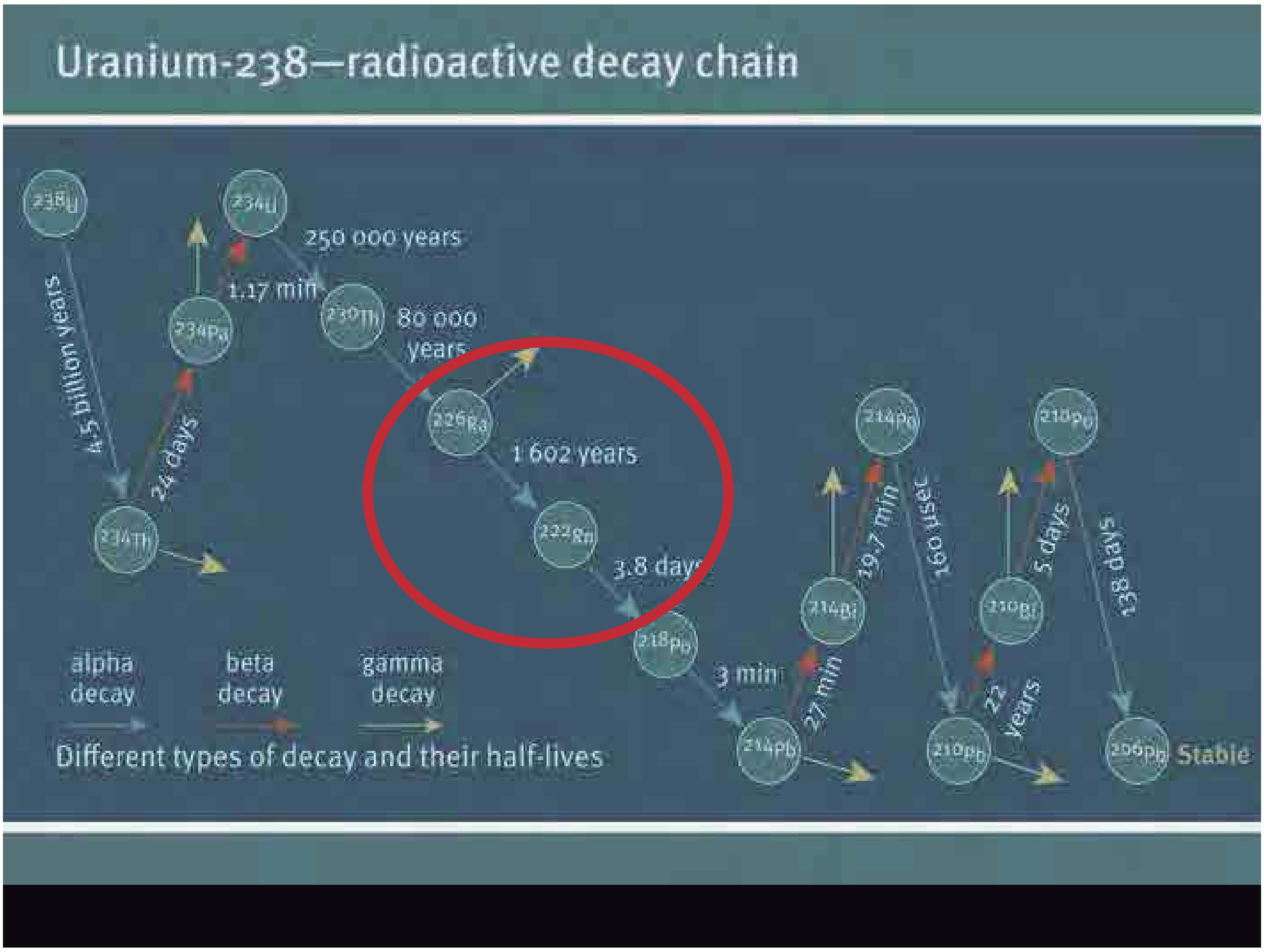


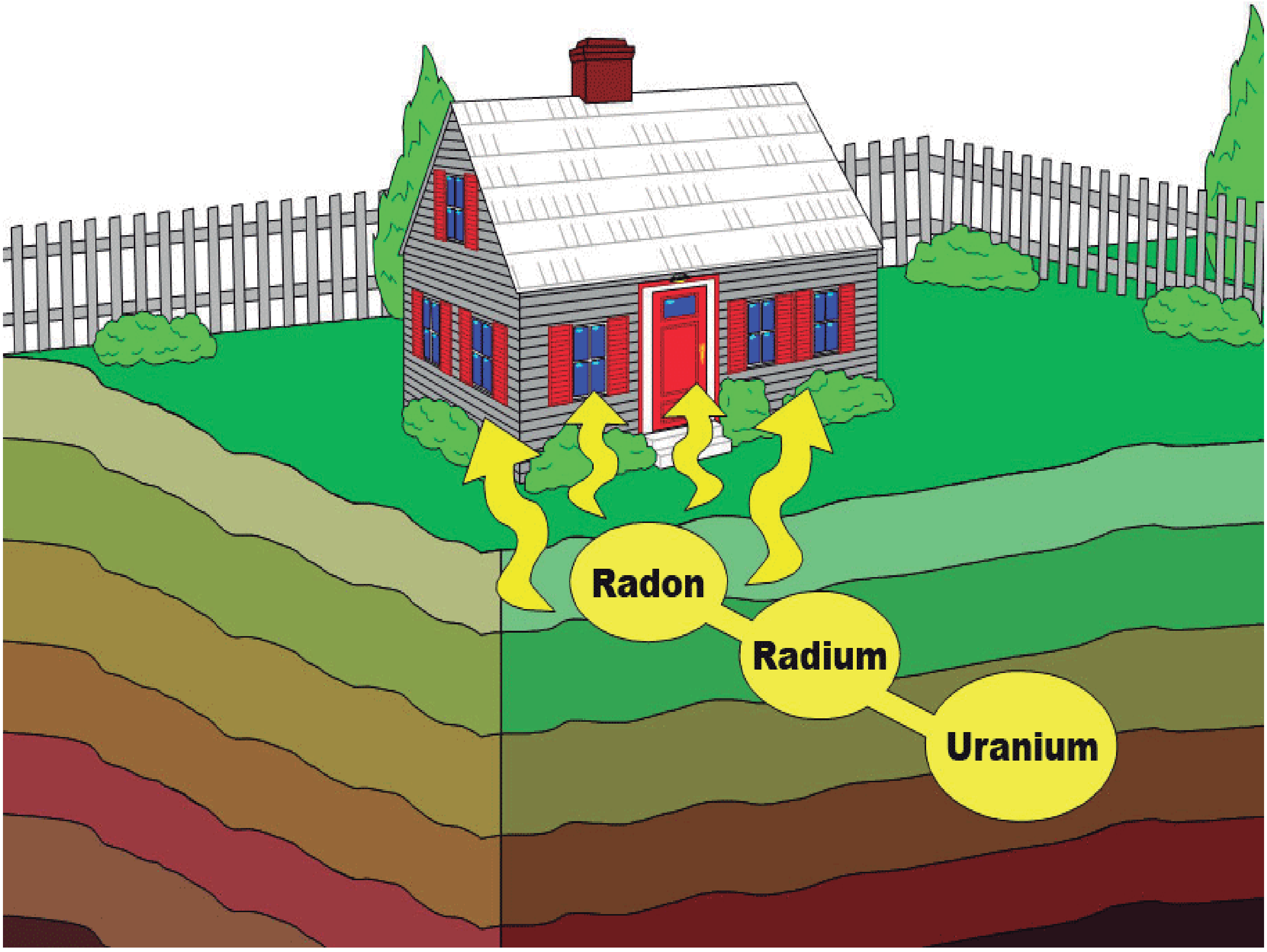

Annual doses from cosmic radiation*
Space shuttle ~350 km
300 mSv
Mount Everest 8.8 km
20 mSv
Mont Blanc 4.8 km
3 mSv
Lhasa Tibet 3.7 km
1.8 mSv
Jumbo jet ~10 km
18 mSv
Mexico City 2.3 km
1 mSv
Empire State Building 450 m
0.5 mSv
Sea level 0 m
0.36 mSv
* Based on the assumption of exposure at these locations for a year.

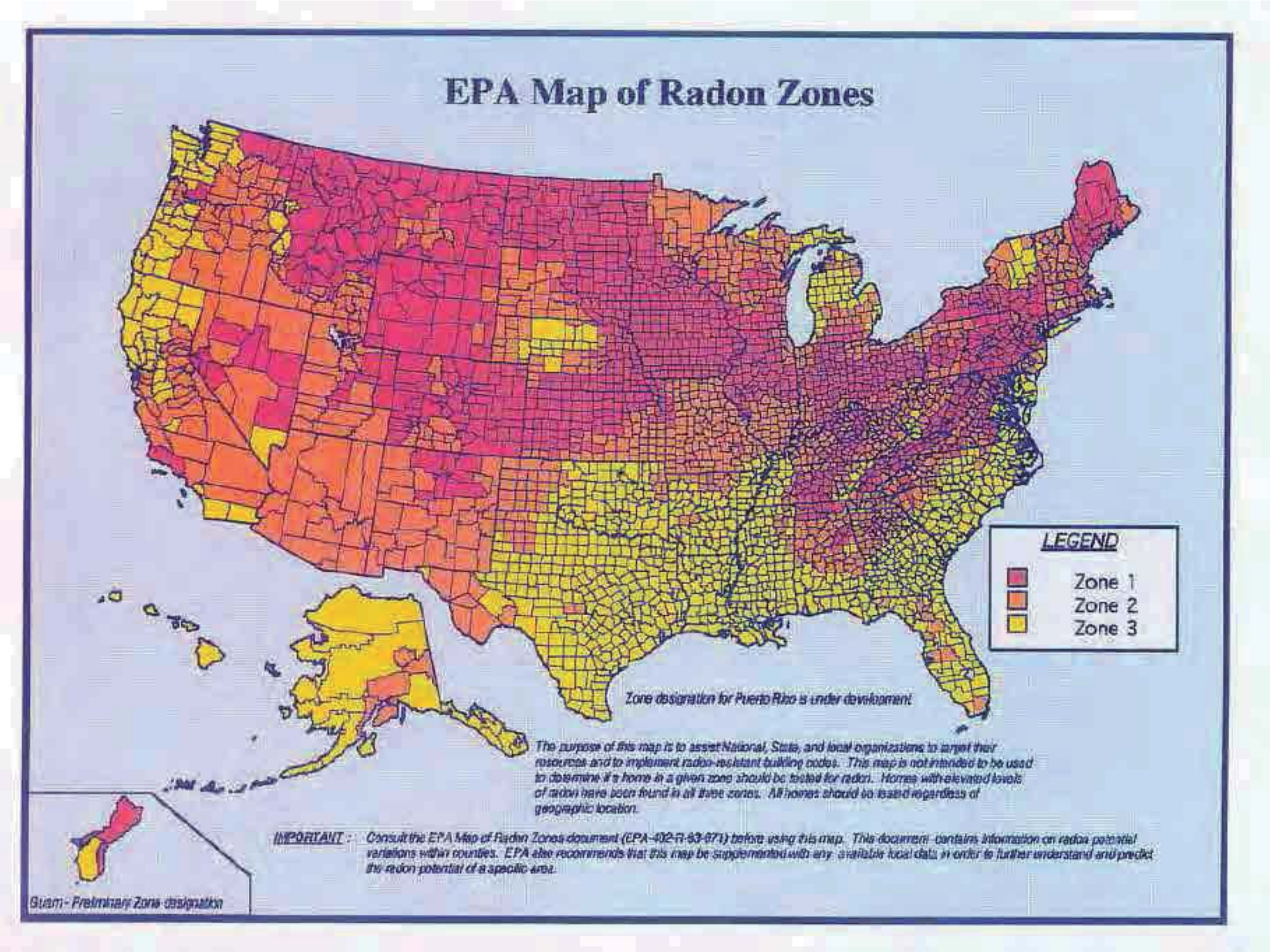

88
68
54
48
46
44
43
42
40
Dose (nGy/hr)
500 0 500 1500
(kilometers)
NAD27/*DNAG
Cosmic-ray Exposure (nGy/hr)
N

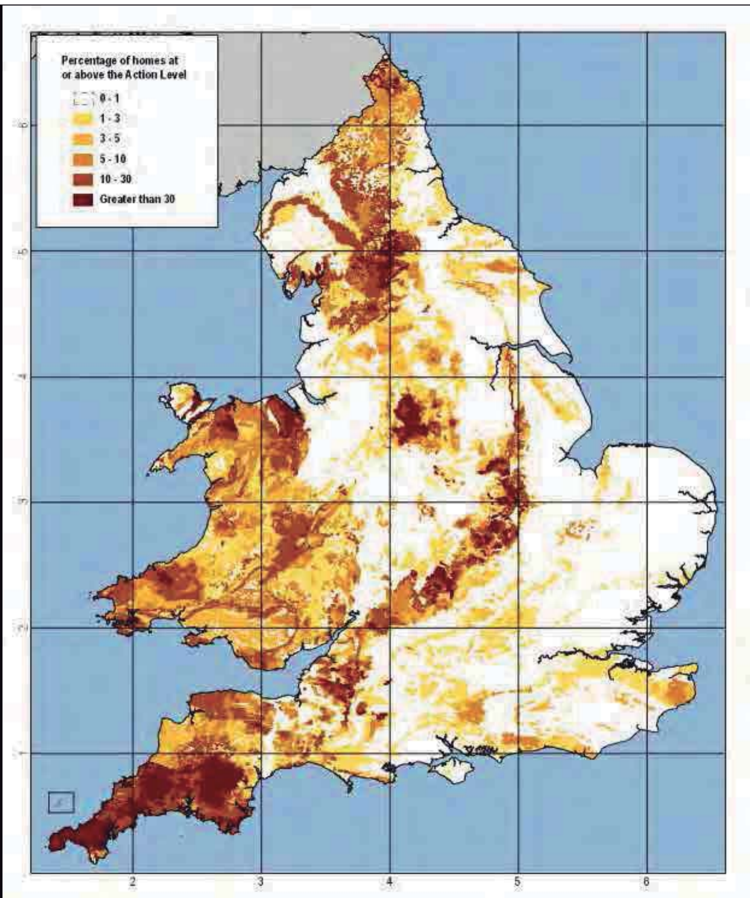

238 uranium
40 potassium
234 thorium
226 radium
Radiation from the earth's surface is blocked and weakened by the asphalt
Asphalt
When the slope becomes nearer, the effect grows larger as the distance from the surface gets nearer.


Terrestrial Gamma-Ray Exposure at 1m above ground
8.5
6.5
4.5
2.5
µR/hr
Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993


Uranium-238—radioactive decay chain
238U
4.5 billion years
234Th
24 days
234Pa
1.17 min
234U
250 000 years
230Th
80 000 years
226Ra
1 602 years
222Rn
3.8 days
218Po
3 min
214Pb
27 min
214Bi
19.7 min
214Po
160 µsec
210Pb
22 years
210Bi
5 days
210Po
138 days
206Pb Stable
alpha decay
beta decay
gamma decay
Different types of decay and their half-lives

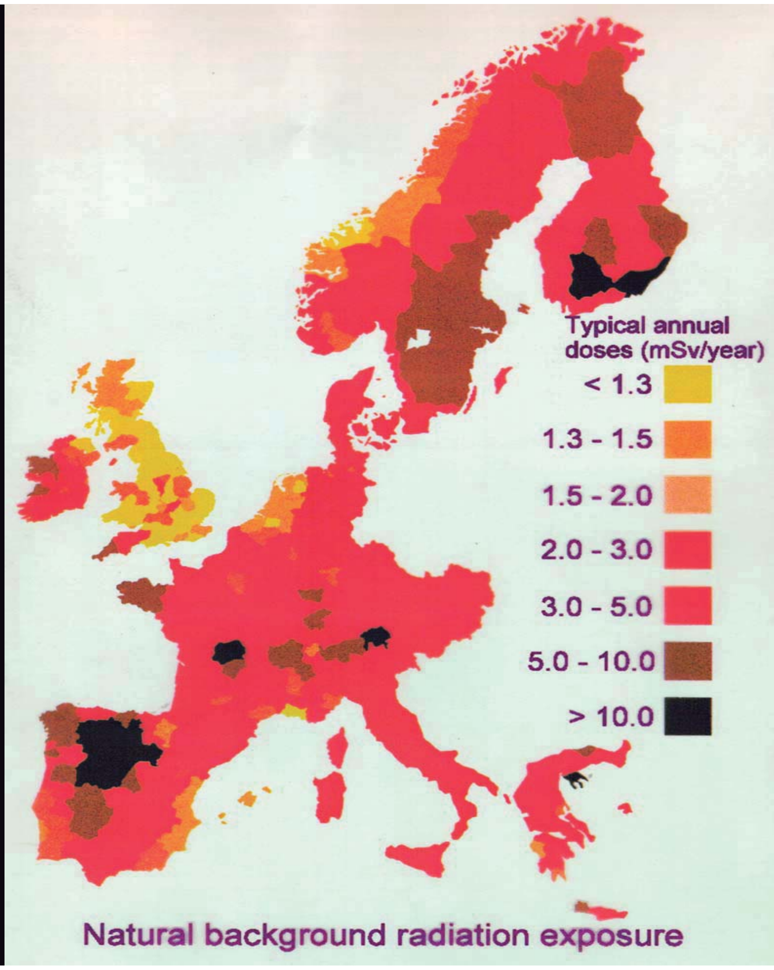

Radon
Radium
Uranium



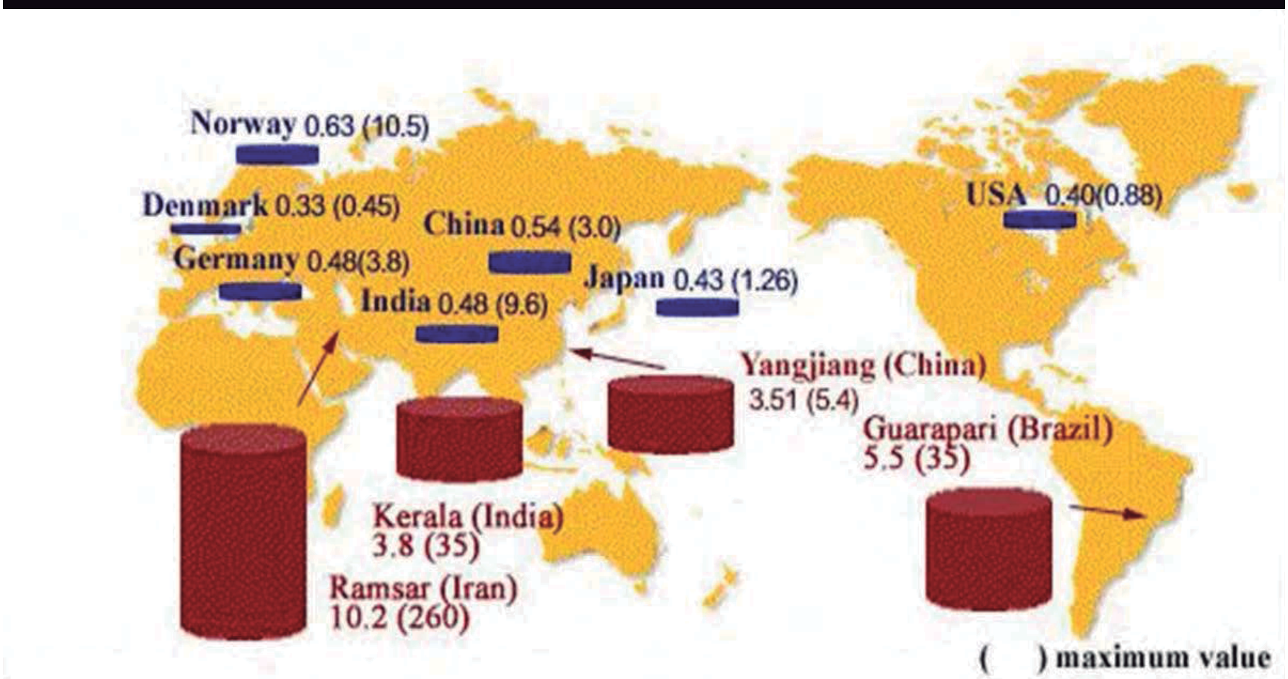


Overall map of radon Affected Areas in England and Wales (axis numbers are the 100-km coordinates of the national grid)

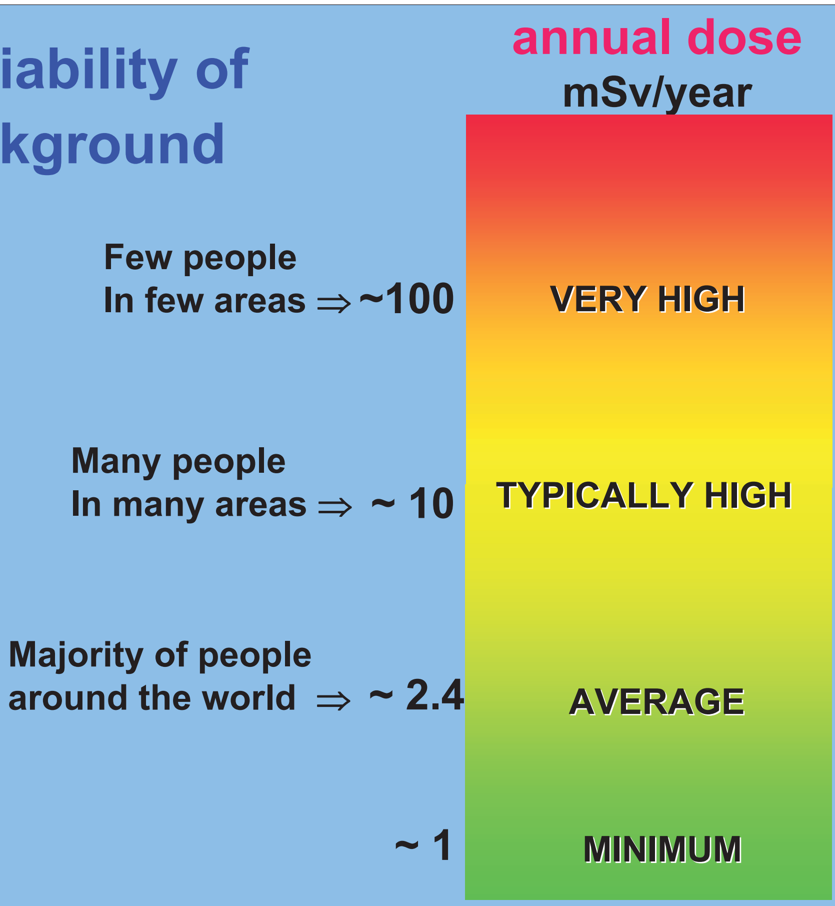
© Crown copyright. All rights reserved [Health Protection Agency][100016969][2007]
Radon potential classification © Health Protection Agency and British Geological Survey copyright [2007]


Typical annual doses (mSv/year)
< 1.3
1.3 - 1.5
1.5 - 2.0
2.0 - 3.0
3.0 - 5.0
5.0 - 10.0
> 10.0
Natural background radiation exposure

41

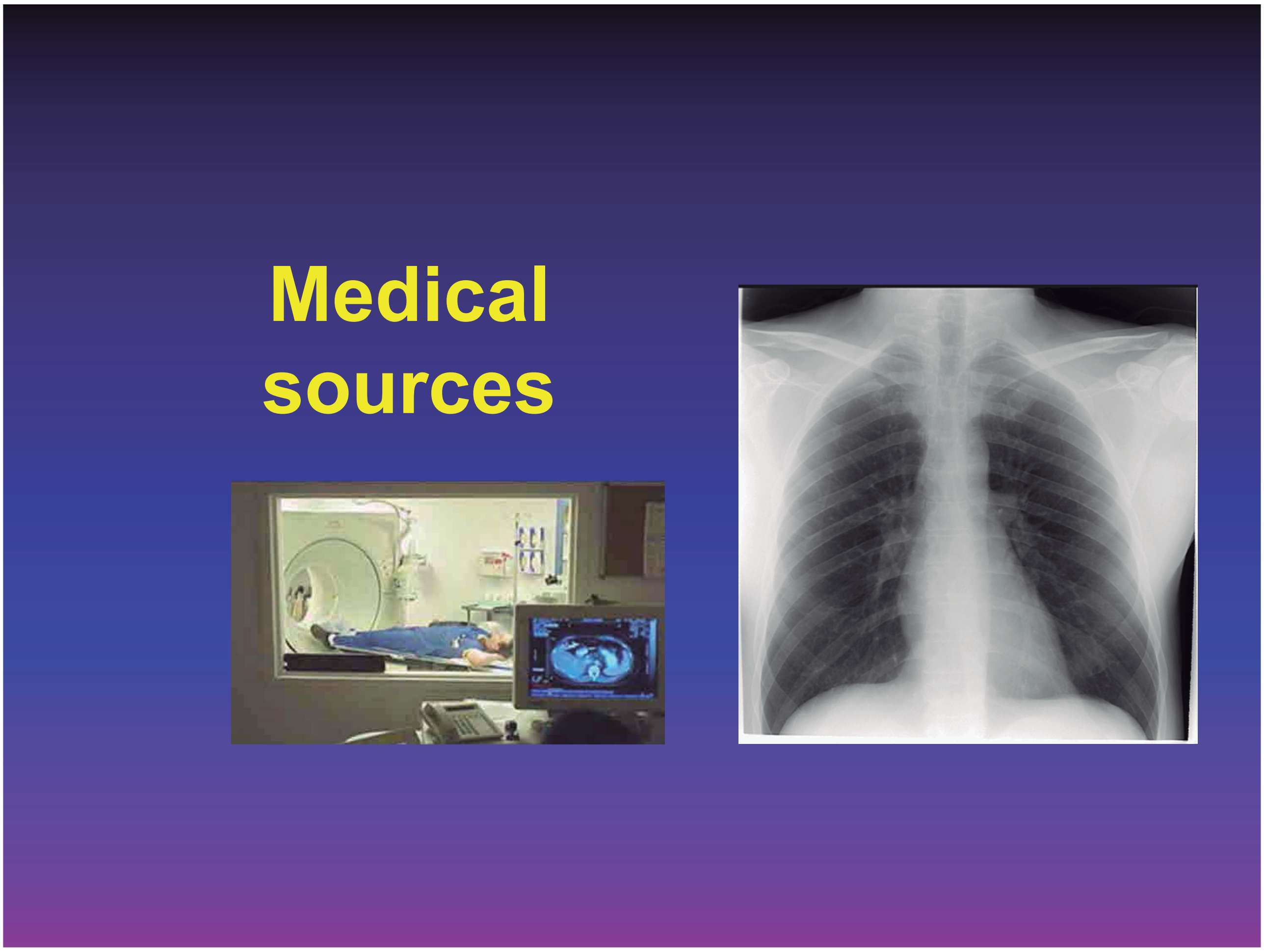

Norway 0.63 (10.5)
Denmark 0.33 (0.45)
China 0.54 (3.0)
Germany 0.48(3.8)
Japan 0.43 (1.26)
India 0.48 (9.6)
USA 0.40(0.88)
Yangjiang (China) 3.51 (5.4)
Guarapari (Brazil) 5.5 (35)
Kerala (India) 3.8 (35)
Ramsar (Iran) 10.2 (260)
( ) maximum value

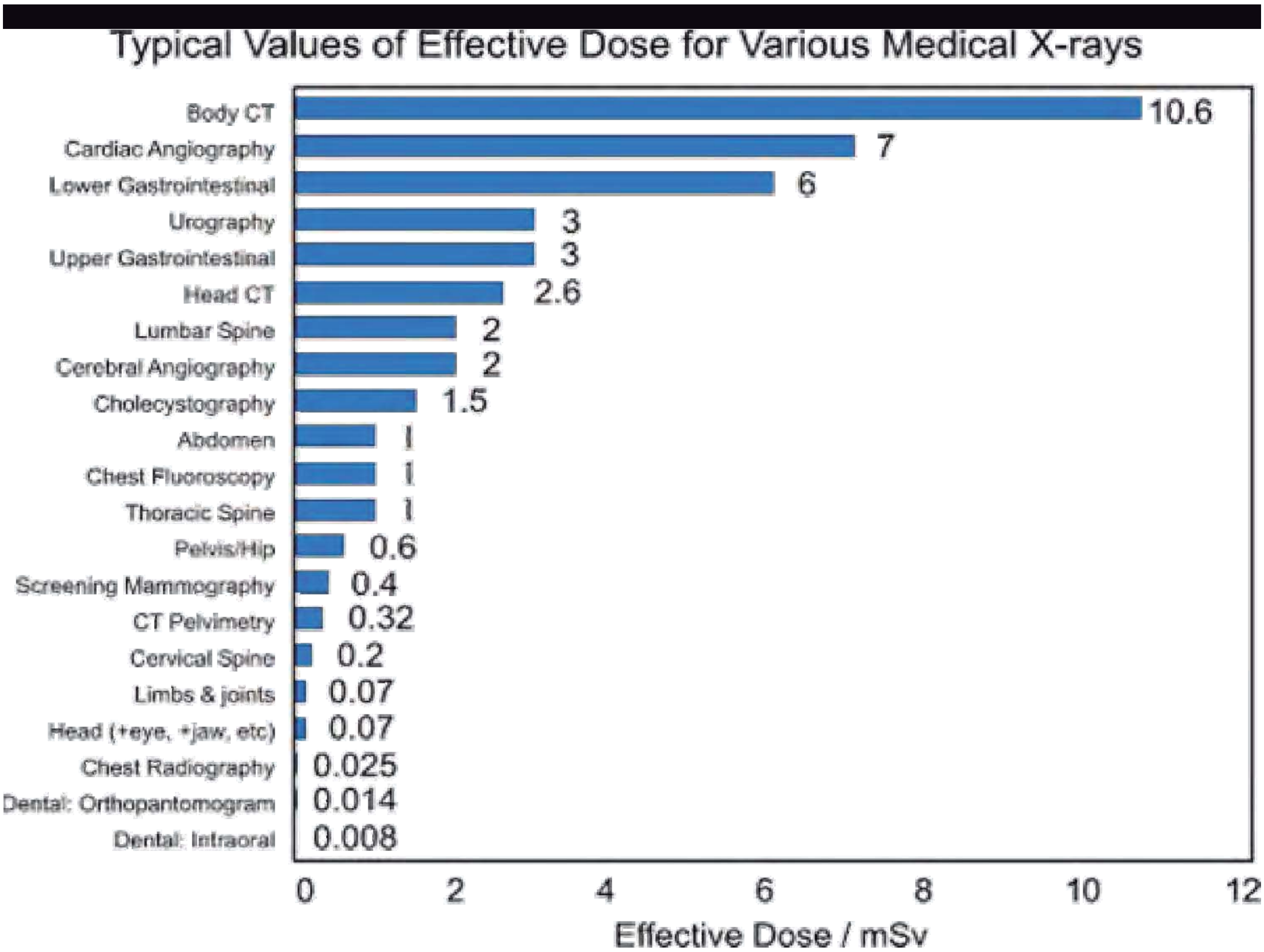
Extreme variability of natural background

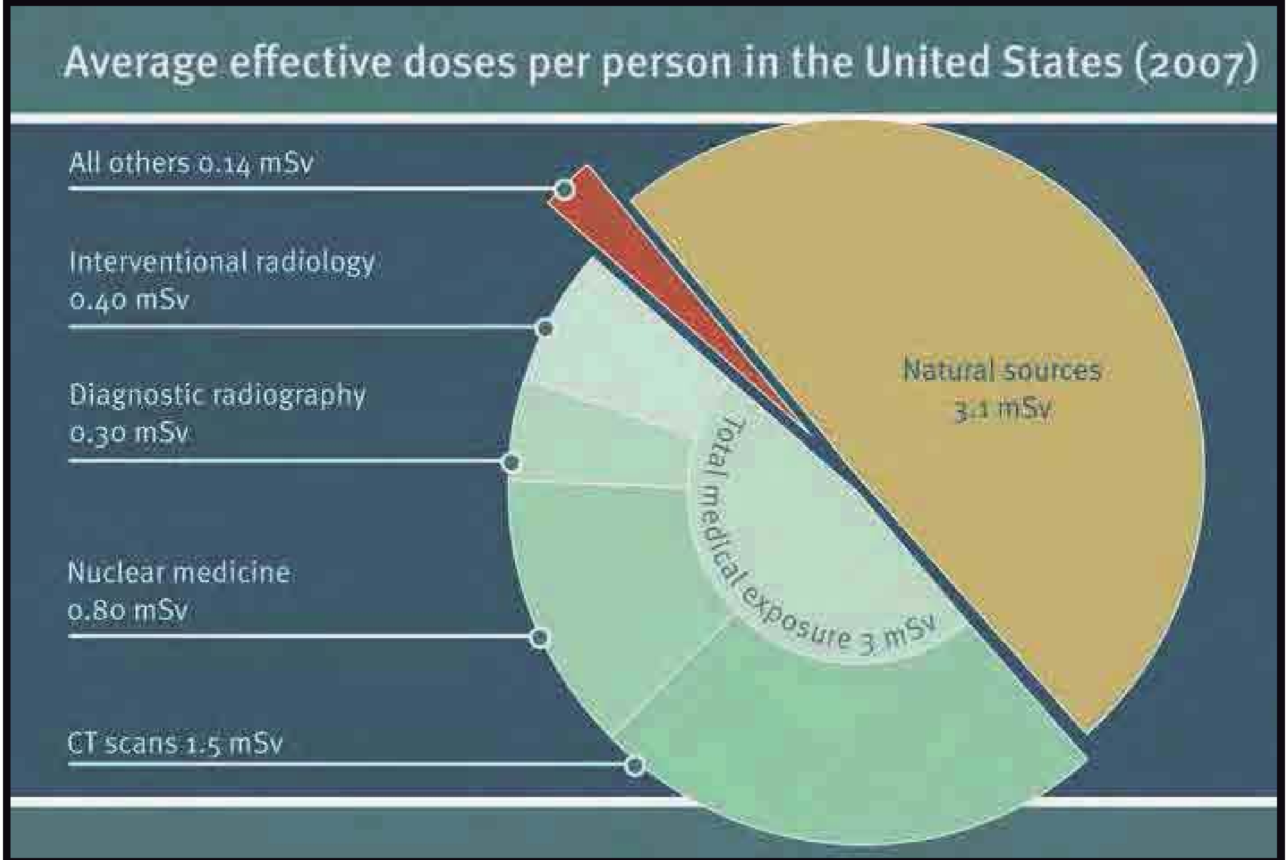


Artificial sources

44

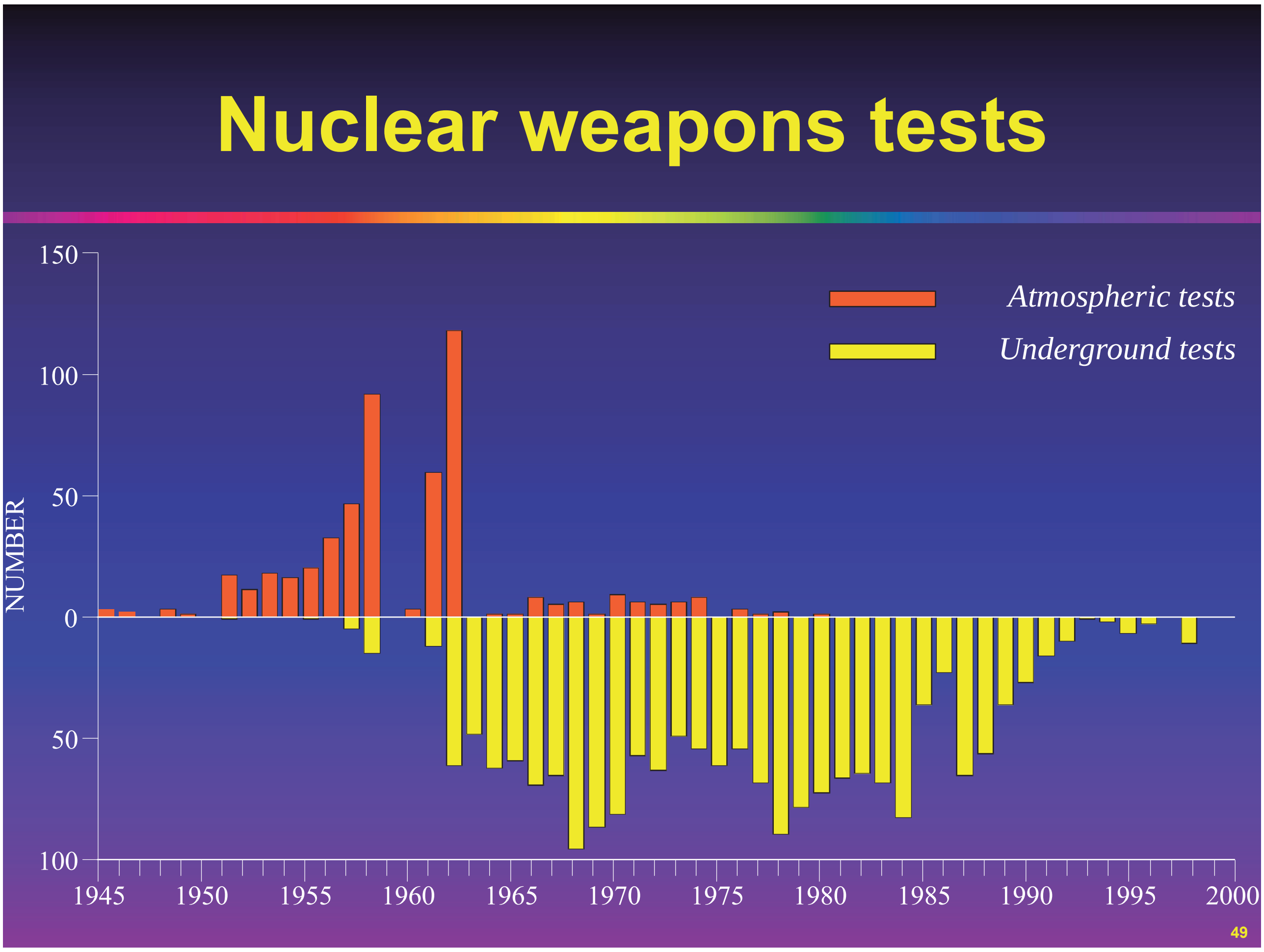

Medical
sources

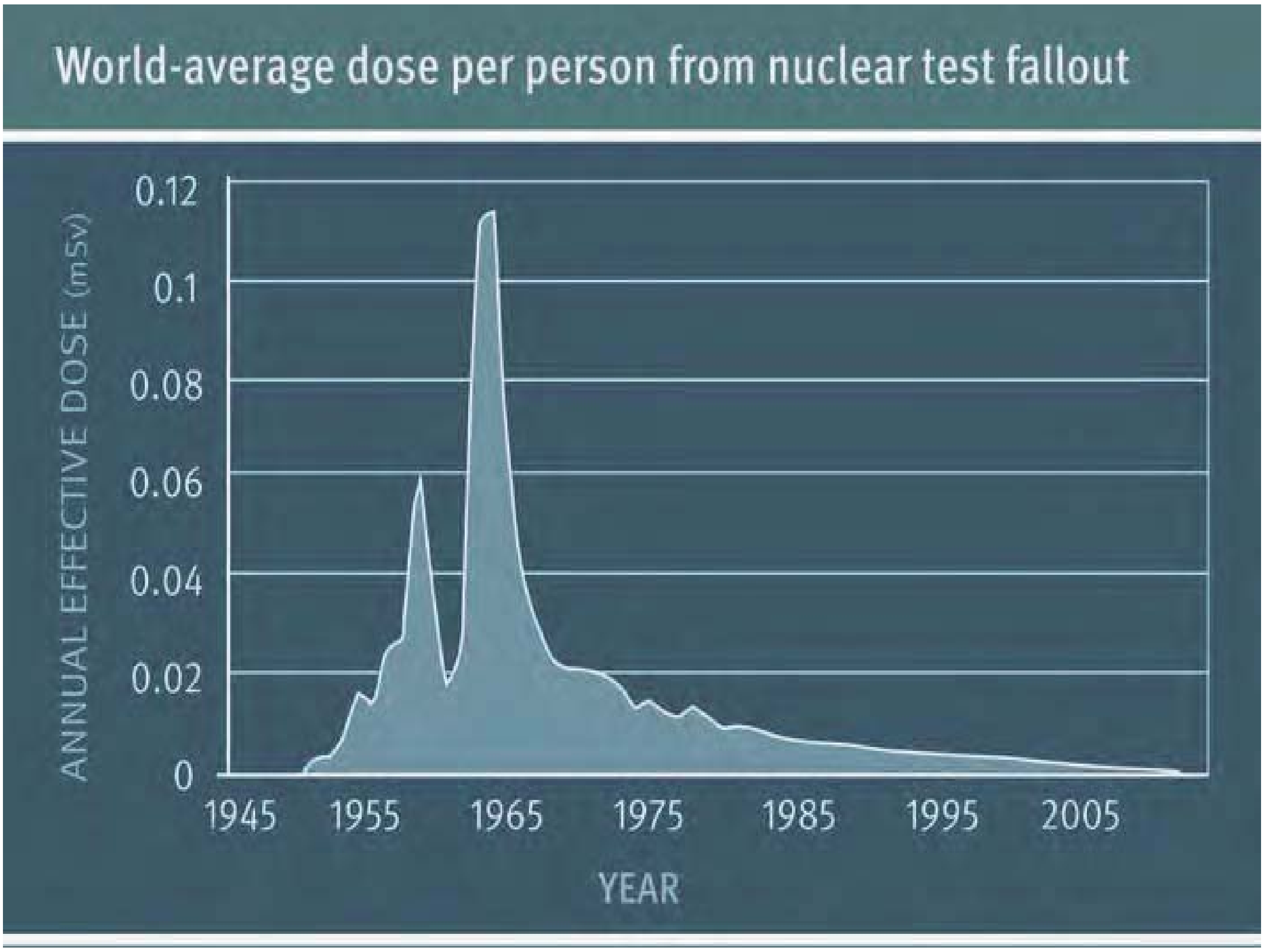

Typical Values of Effective Dose for Various Medical X-rays
Body CT
Cardiac Angiography
Lower Gastrointestinal
Urography
Upper Gastrointestinal
Head CT
Lumbar Spine
Cerebral Angiography
Cholecystography
Abdomen
Chest Fluoroscopy
Thoracic Spine
Pelvis/Hip
Screening Mammography
CT Pelvimetry
Cervical Spine
Limbs & joints
Head (+eye, +jaw, etc)
Chest Radiography
Dental: Orthopantomogram
Dental: Intraoral
10.6
7
6
3
3
2.6
2
2
1.5
1
1
1
0.6
0.4
0.32
0.2
0.07
0.07
0.025
0.014
0.008
0
2
4
6
8
10
12
Effective Dose / mSv



Military activities

48


Nuclear weapons tests
Atmospheric tests
Underground tests
NUMBER
150
100
50
0
50
100
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
49


World-average dose per person from nuclear test fallout
ANNUAL EFFECTIVE DOSE (mSv)
0.12
0.1
0.08
0.06
0.04
0.02
0
1945
1955
1965
1975
1985
1995
2005
YEAR

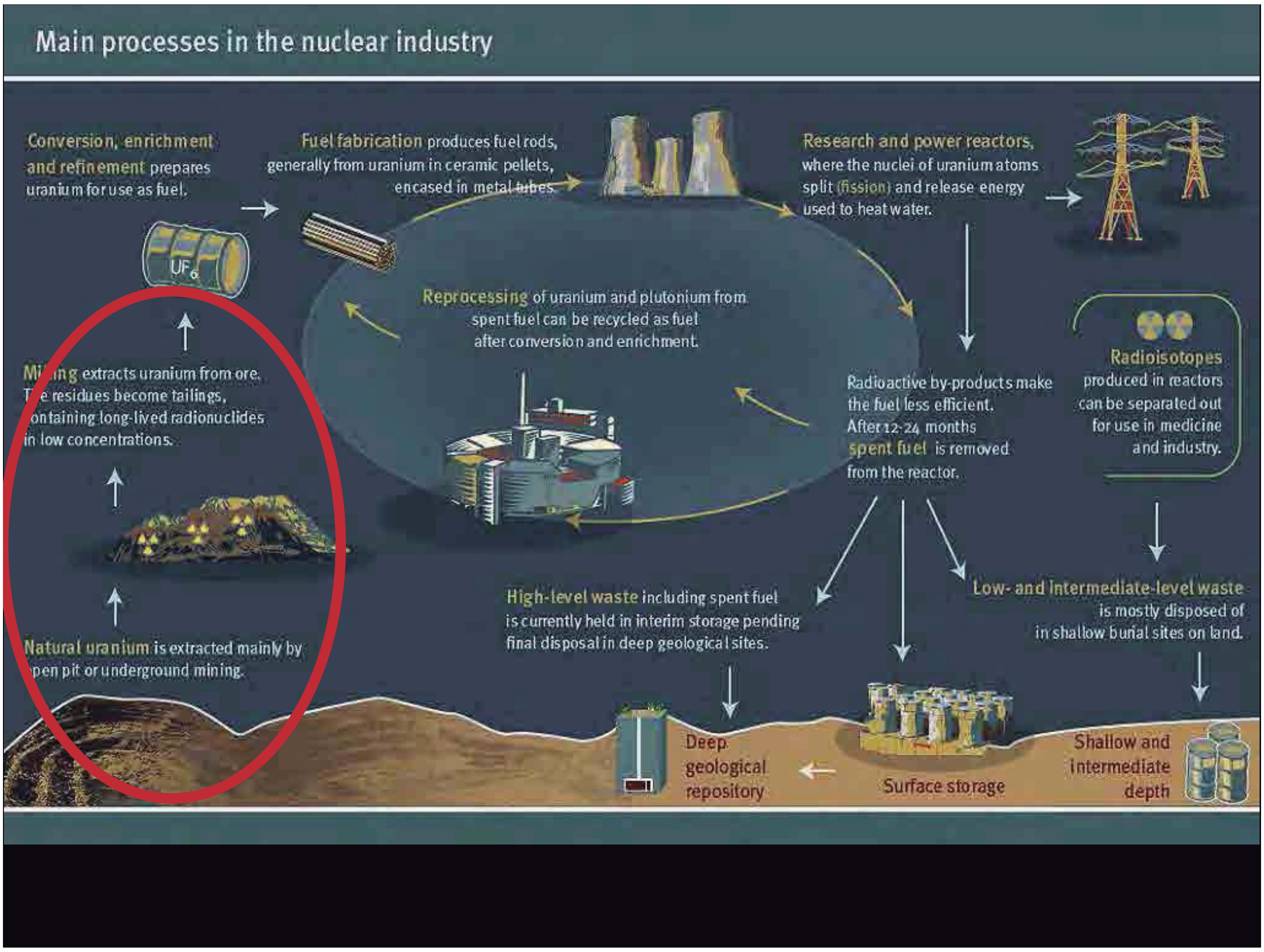
Electricity generation
(including Nuclear Power Plants)

51

Civil nuclear power

In comparison, basically zero contribution!

52



UNSCEAR Report to the UN General Assembly

Radiation exposure due to (nuclear and other sources used for) the generation of electricity

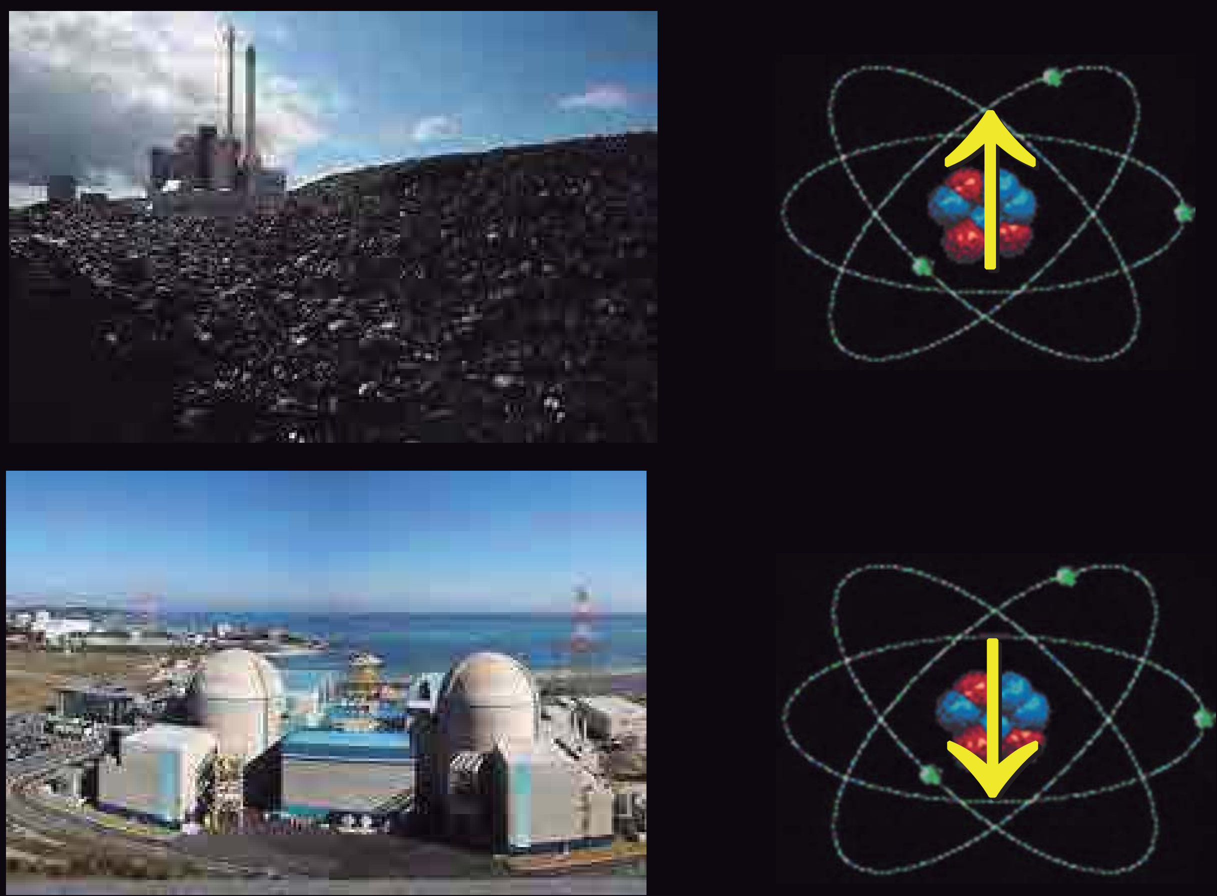
54

First surprise

- Among the various sources of energy for generating electricity, the source that delivers the highest radiation exposure to people

is not nuclear energy, <u>it is *coal!*</u>

55



56

- Contribution from coal ~ 50%.

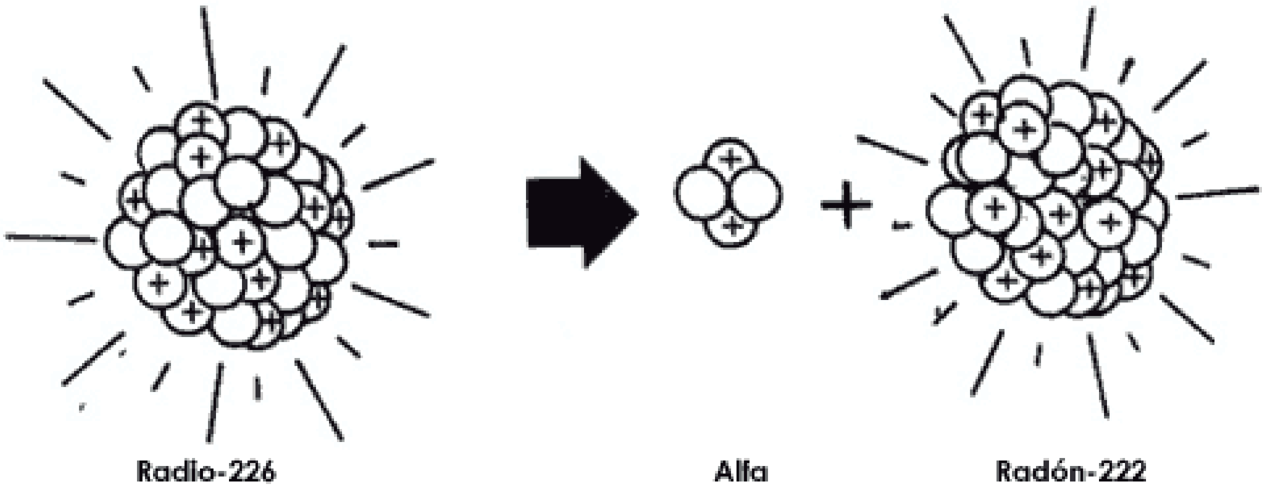
(from operations and environmental discharges during coal mining and combustion at power plants and also from coal ash deposits)

- Contribution from nuclear ~20%.

(mainly due to uranium mining and milling, not to NPP operations)

57

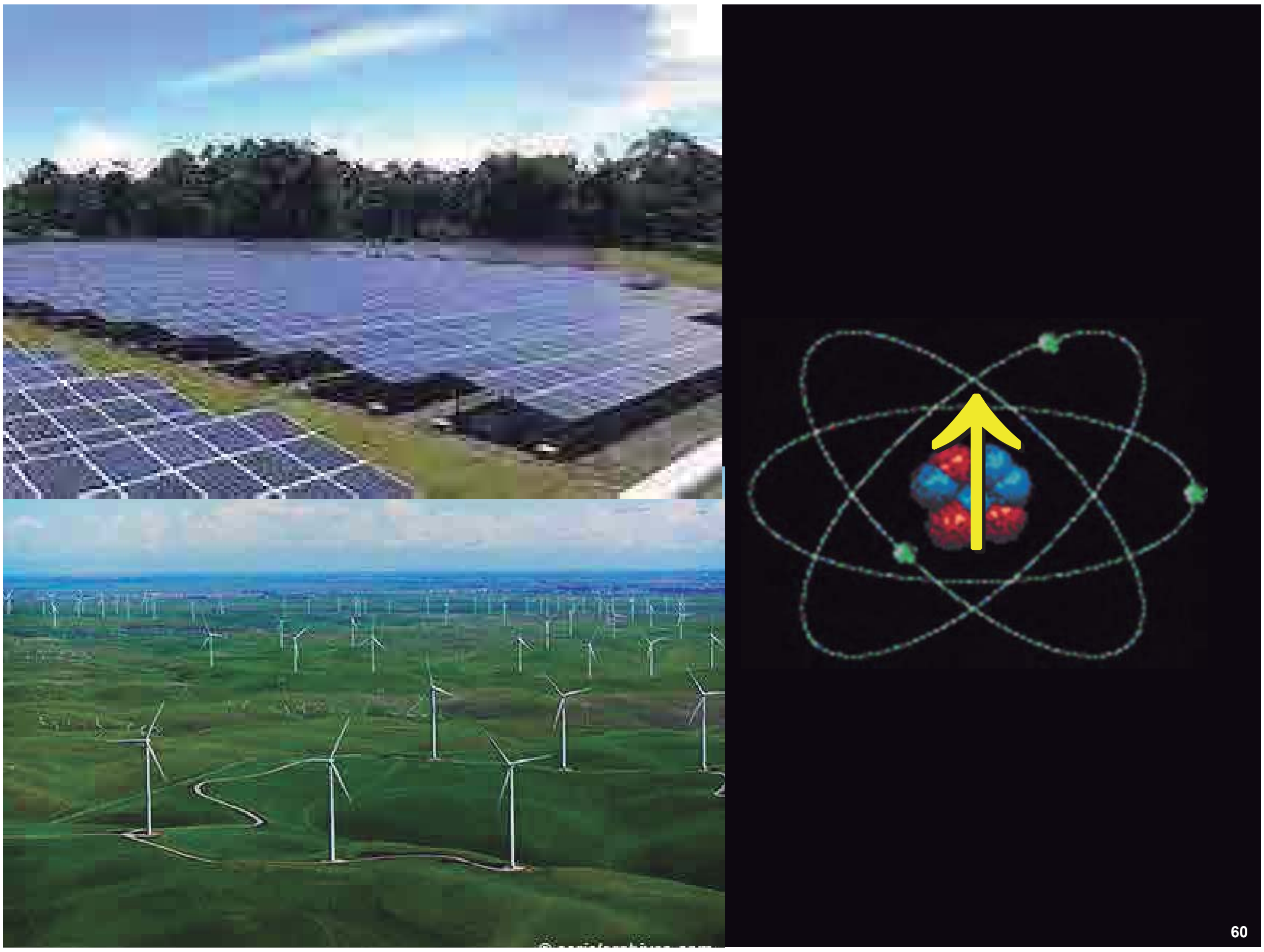
The great culprits: The natural radioactive elements *radium-226* and *radon-222*!



Second surprise

- **By far the largest radiation impact by electrical power installed** (i.e., due to the *construction* of plants) **was found in *solar plants* followed by *wind plants*.**

59



- The reason is that solar and wind require large amounts of *rare earth metals*, and the mining of low-grade ore produces large radiation exposures.

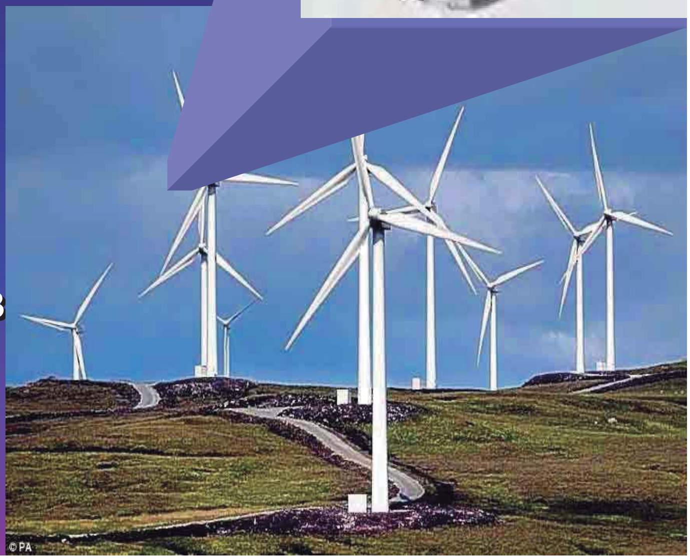
Rare earths for solar cells

- Solar panels use, for example, *Tellurium*.
- *Tellurium* is three times rarer than gold.

Rare earths for wind generators

- *Neodymium* is used in wind turbine magnets

(neodymium-iron-boron [NdFeB magnet powder is used to manufacture permanent wind turbine magnets)



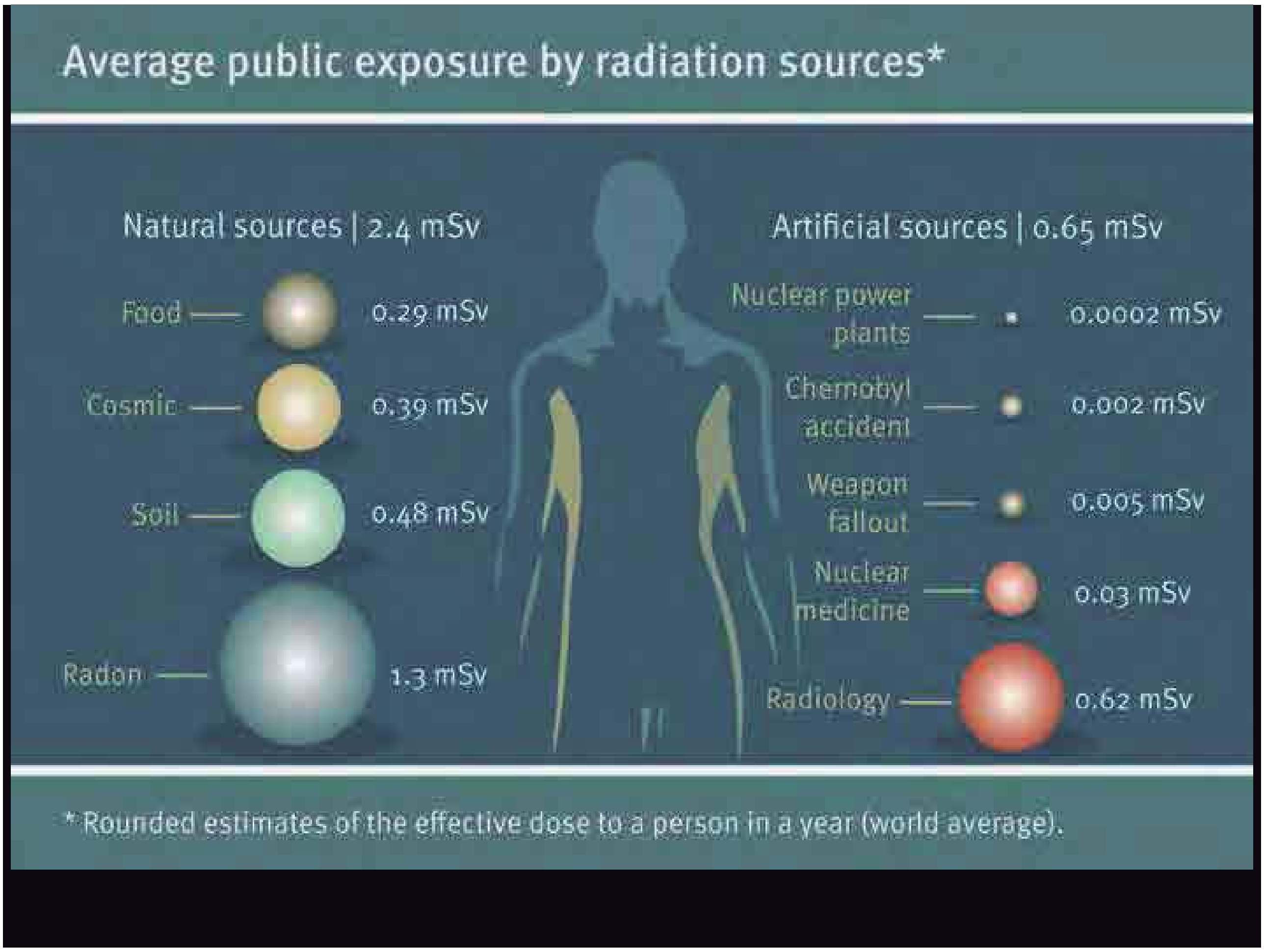
Average radiation exposure to workers and members of the public

64

Occupational exposures

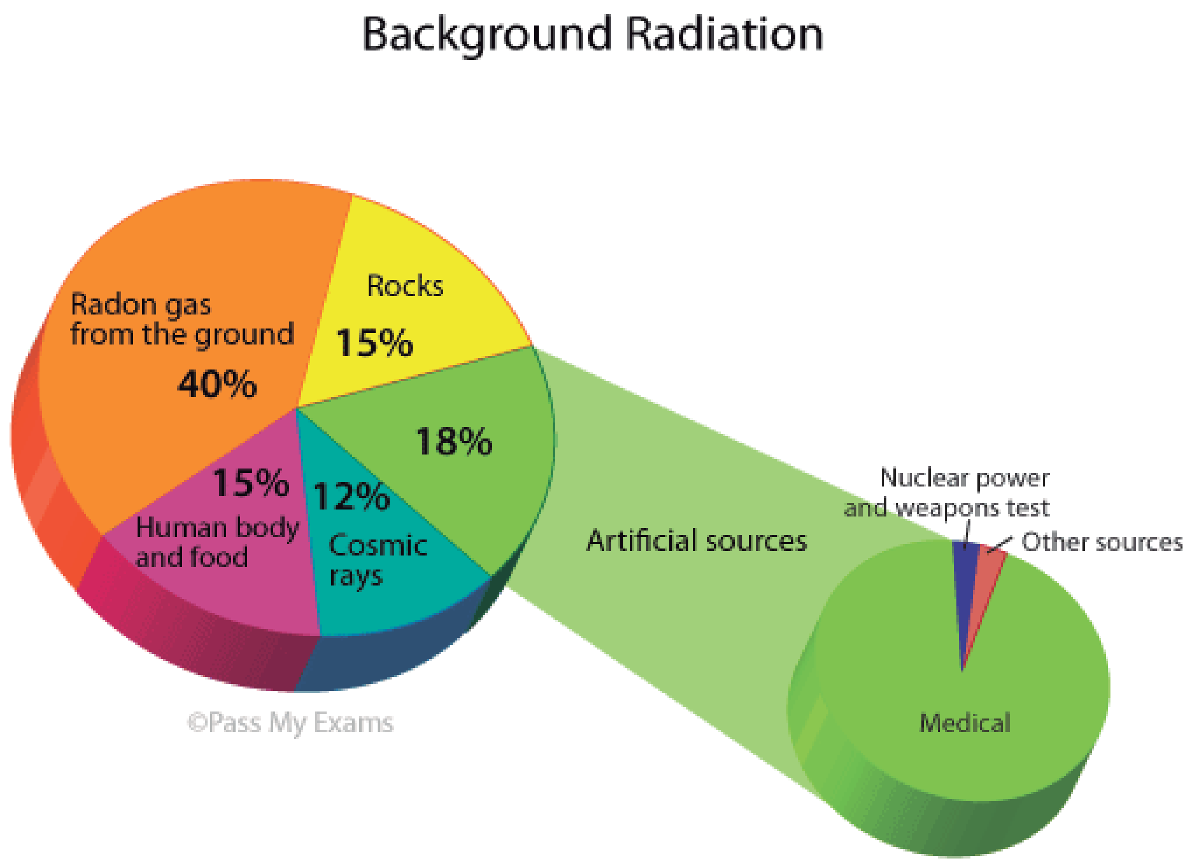
65

Trends in global radiological exposure of workers (mSv)*				
Decades	1970s	1980s	1990s	2000s
Natural sources				
Aircrew	—	3.0	3.0	3.0
Coal mining	—	0.9	0.7	2.4
Other mining**	—	1.0	2.7	3.0
Miscellaneous	—	6.0	4.8	4.8
Total	—	1.7	1.8	2.9
Artificial sources				
Medical uses	0.8	0.6	0.3	0.5
Nuclear industry	4.4	3.7	1.8	1.0
Other industries	1.6	1.4	0.5	0.3
Miscellaneous	1.1	0.6	0.2	0.1
Total	1.7	1.4	0.6	0.5



Summary of global doses

68



...but.... what about nuclear accidents?

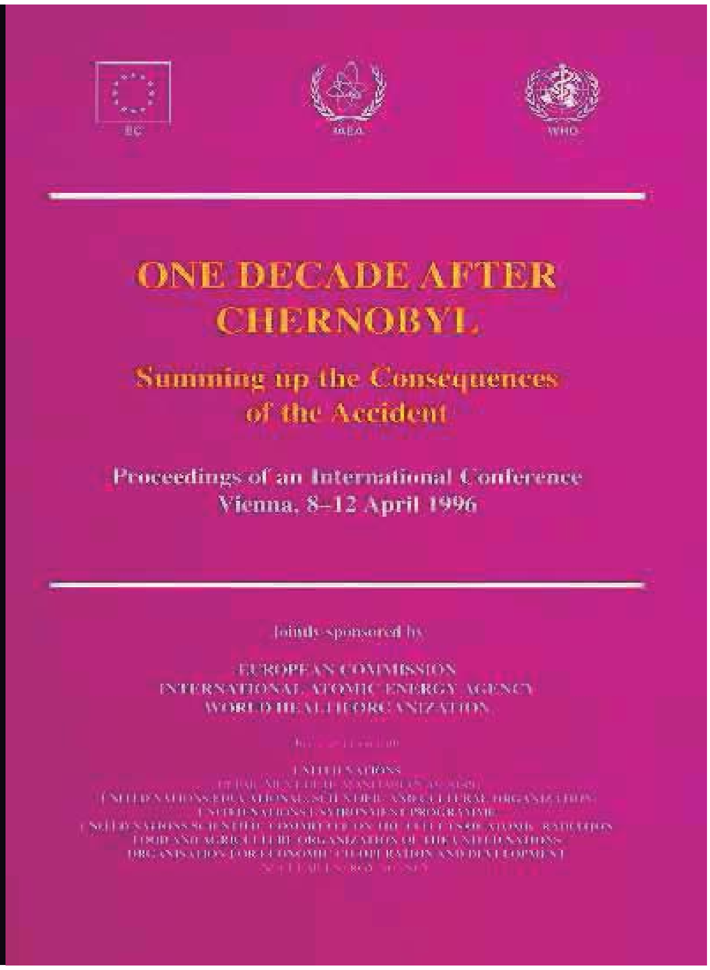
70

Chernobyl

- 28 dead workers
- 138 workers with acute radiation syndrome
- ~ 7000 non-lethal pediatric cancers
- Dose to the public = 1 tomography
- Political, social and economic catastrophe

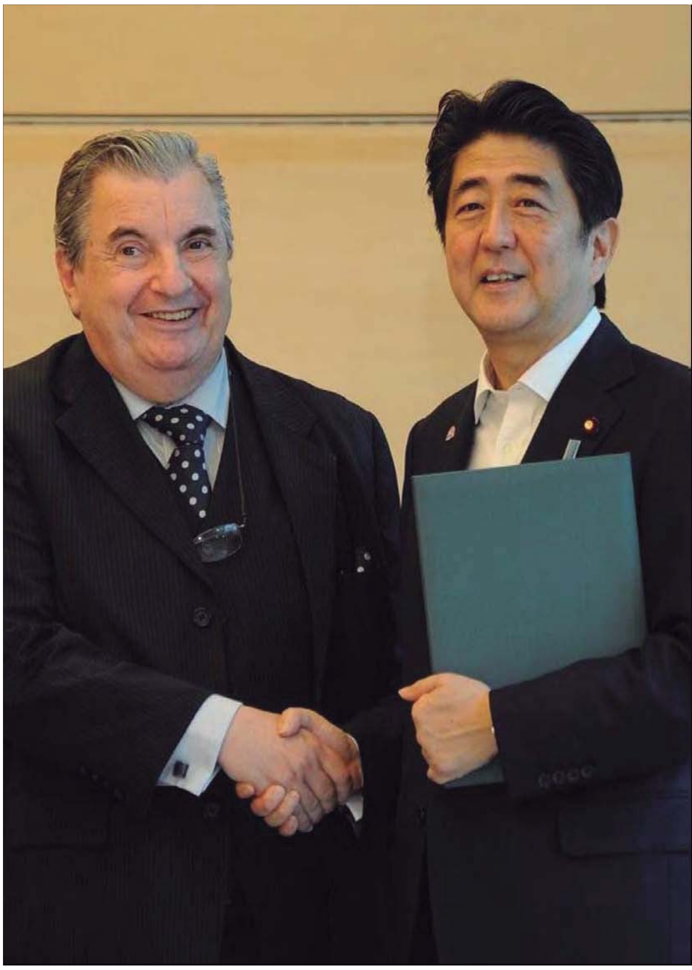
71

President of the Conference:
Angela Merkel



Fukushima

- Low radiation doses
- No health effects attributable to radiation, neither in workers nor in the public.
- Serious psychological effects.
- Political, social and economic catastrophe.
- Legal nightmare

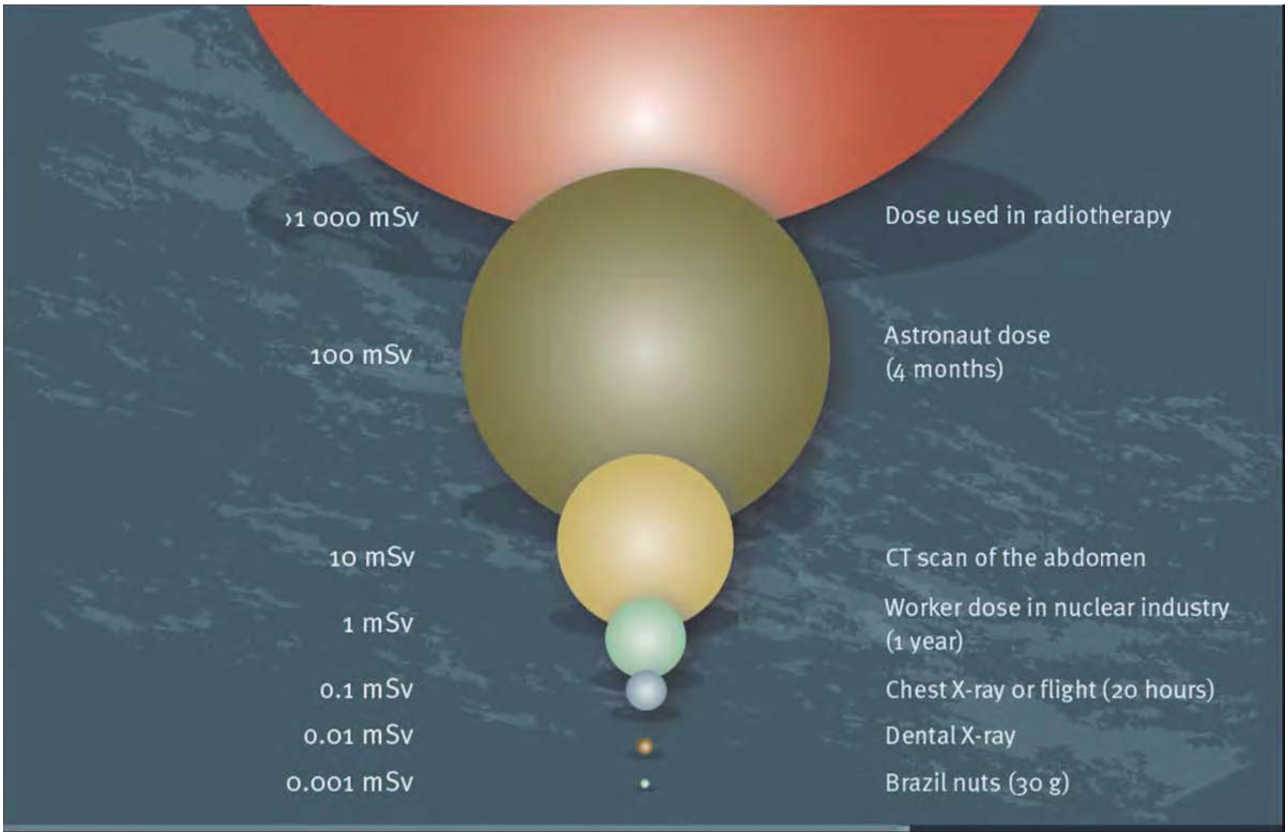


Take away points

75

- Background → 2.4 mSv/y (up to above 100 mSv)
- Medical ↑↑↑
- Nuclear ↓↓↓

76



Third Part

What does radiation do to us?

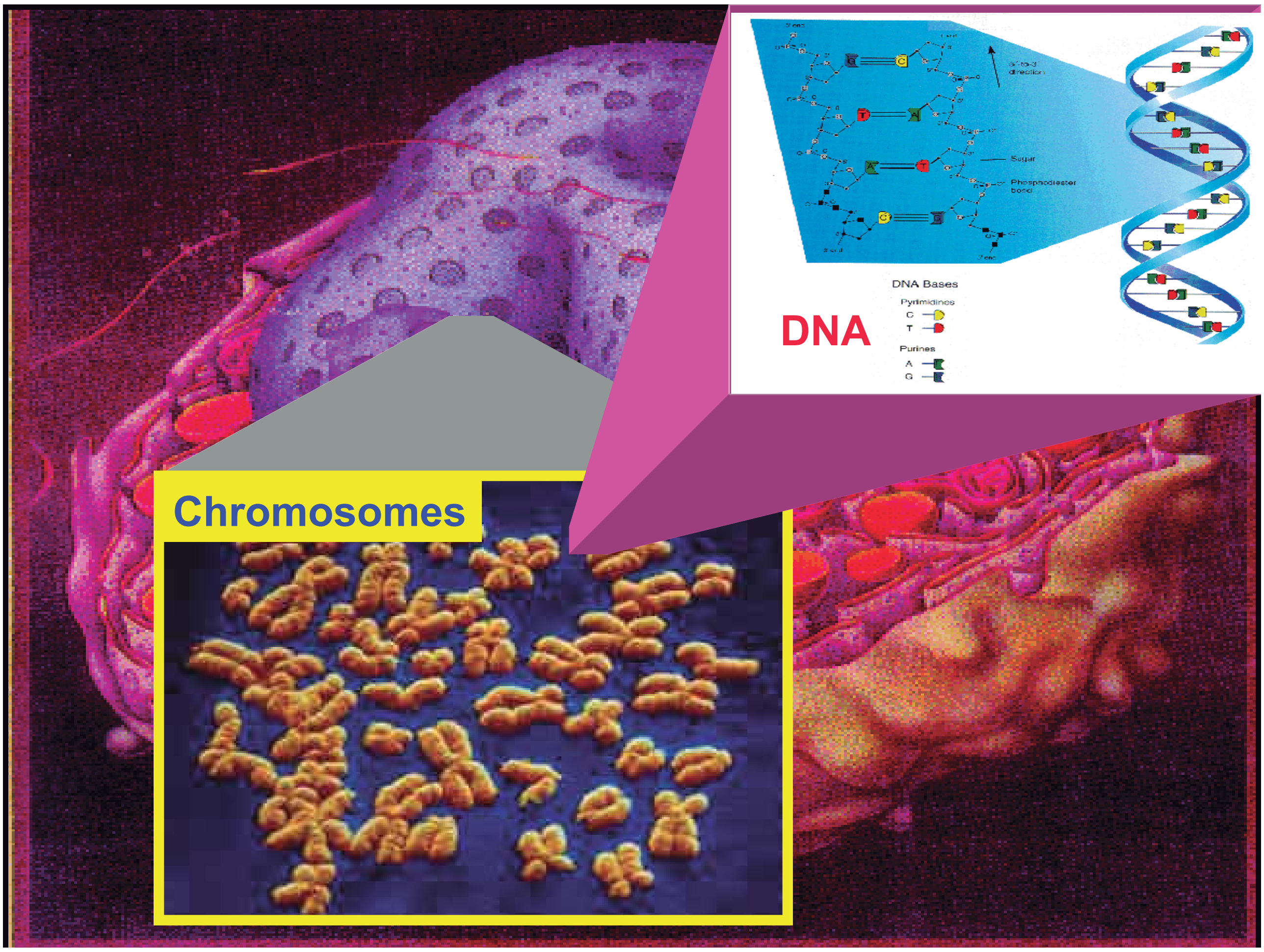
78

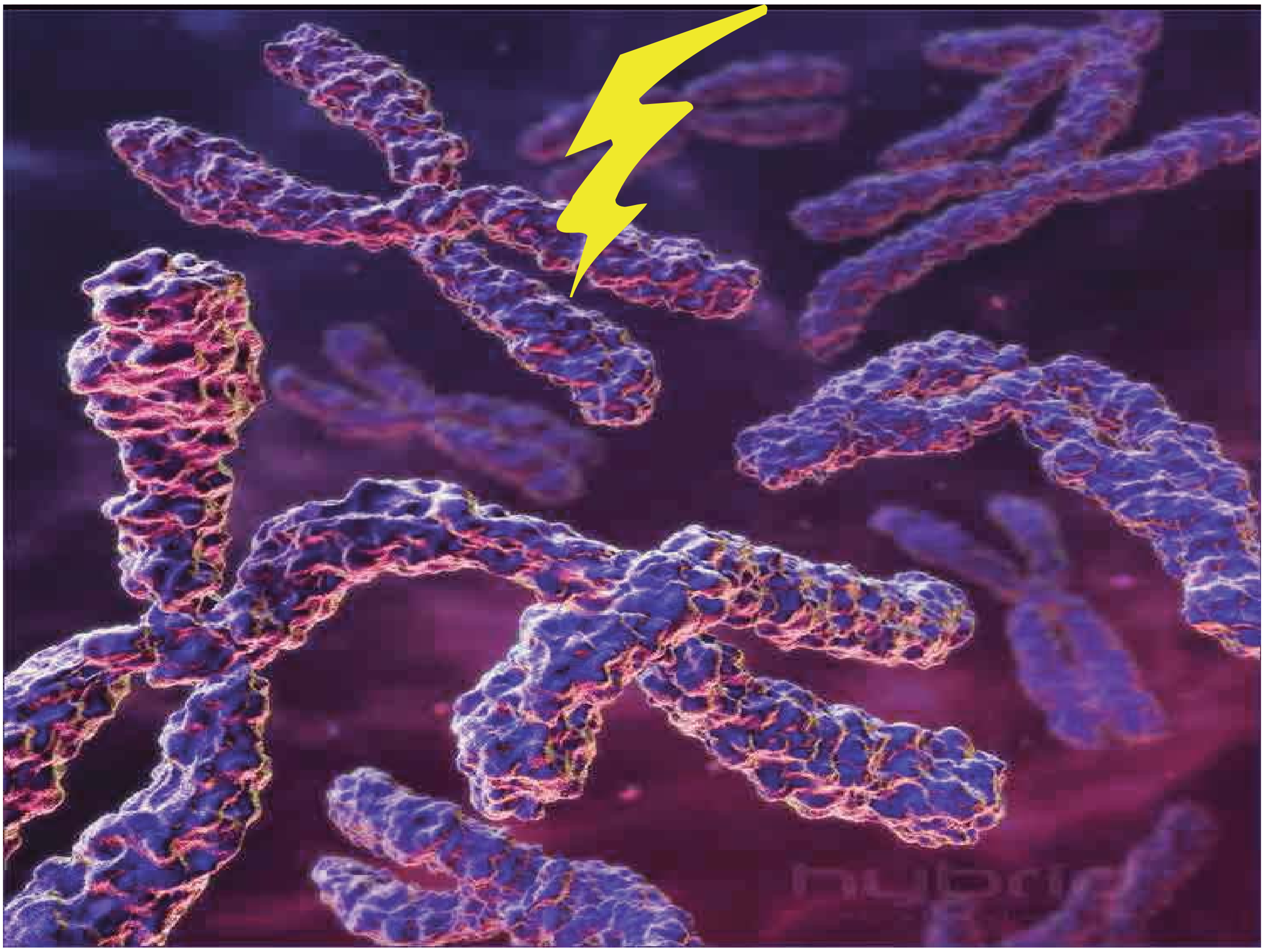
What does radiation do to us?

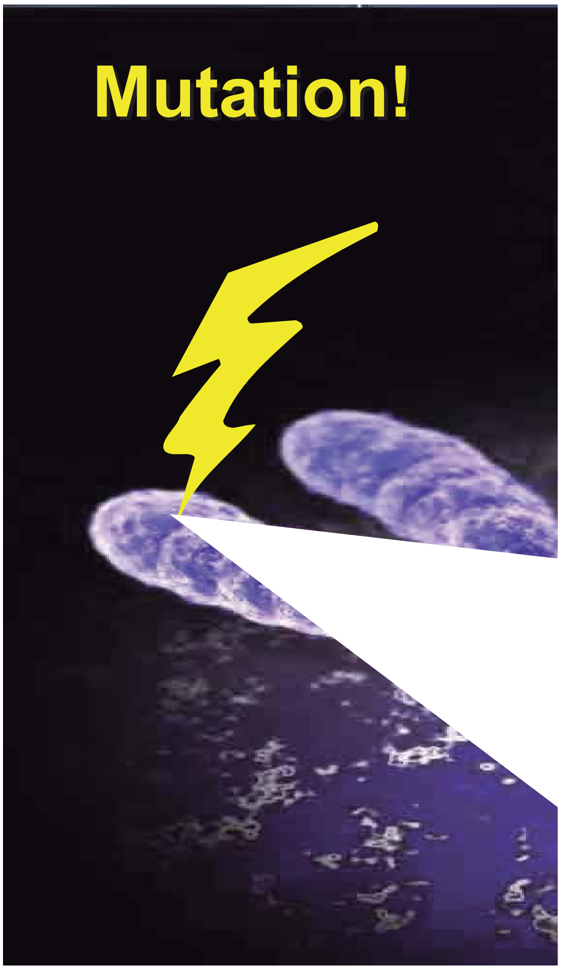
- Effects on humans
  - Early health effects
  - Delayed health effects
  - Effects on offspring
- Effects on animals and plants
- Relationship of radiation doses and effects

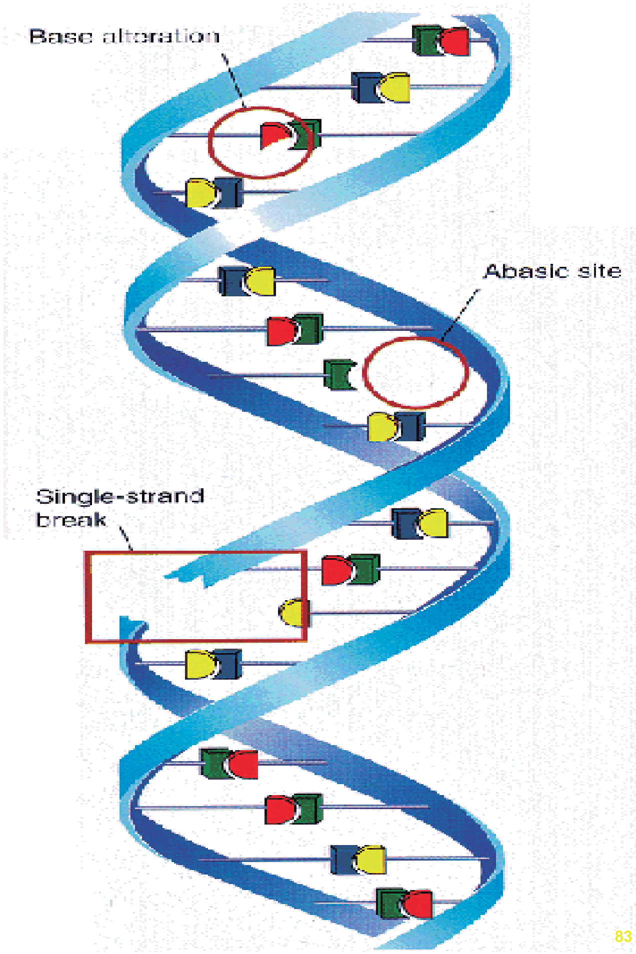
79

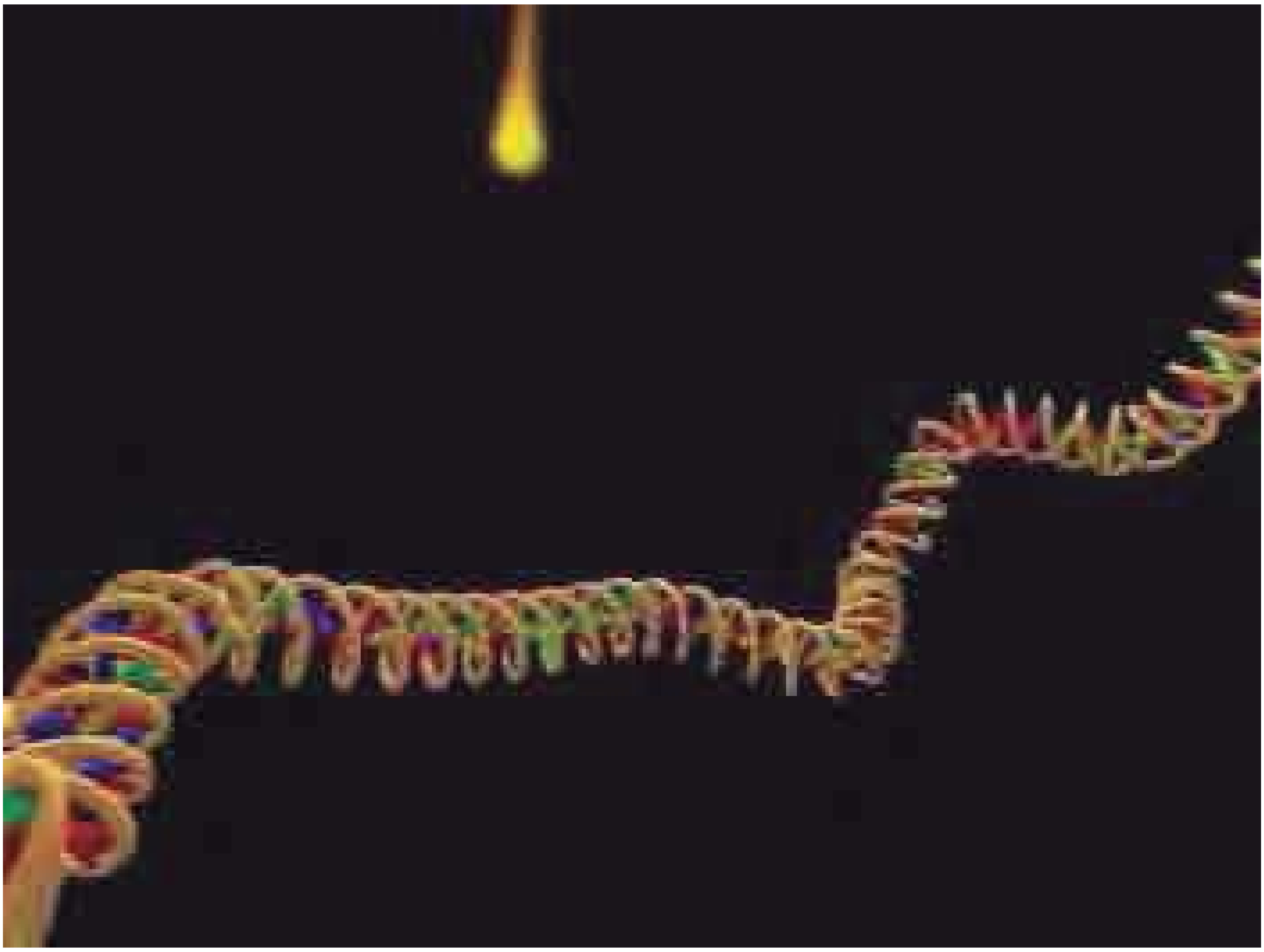
Effects on humans

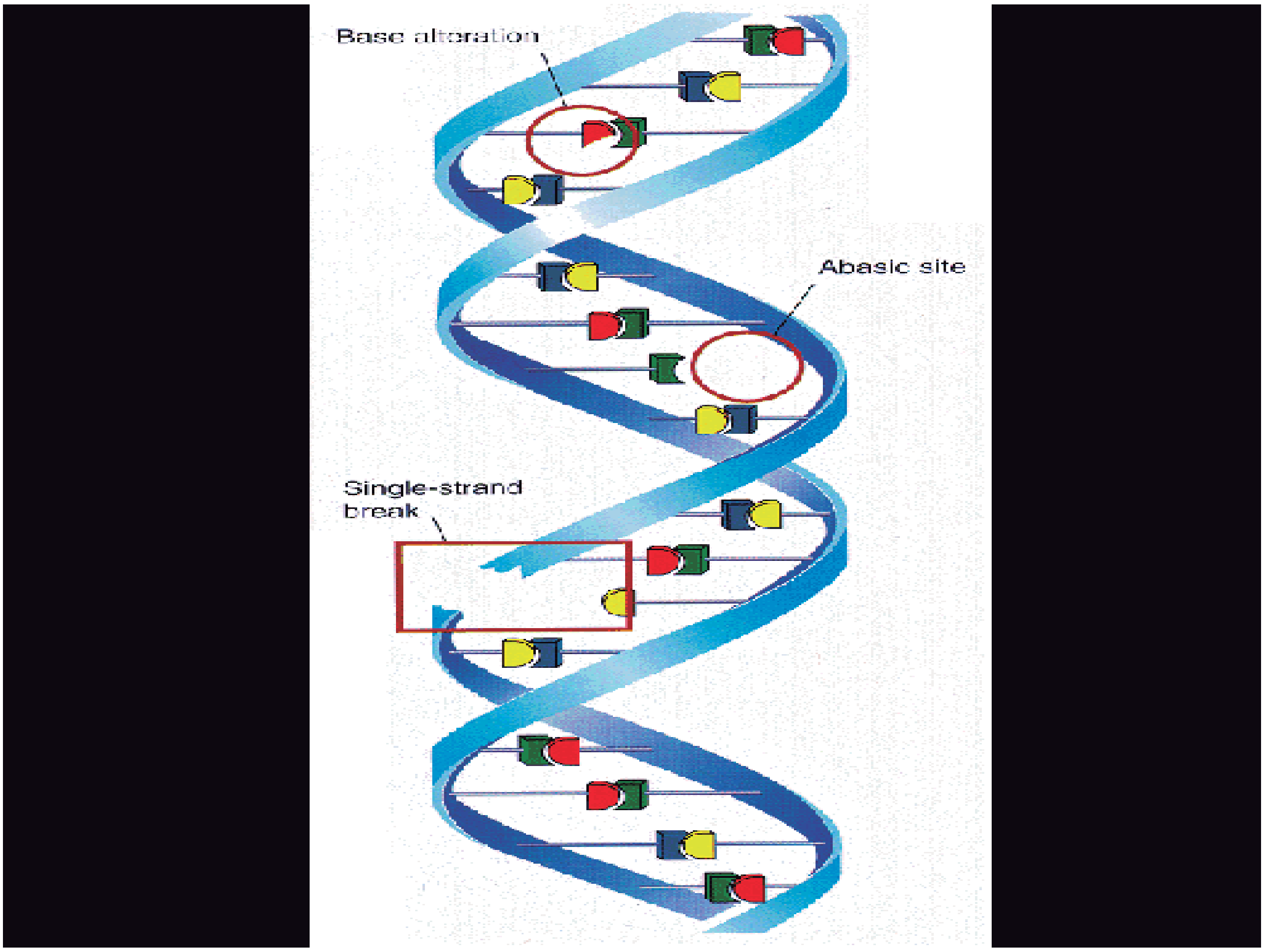

DNA
DNA Bases
Pyrimidines
Purines
Chromosomes

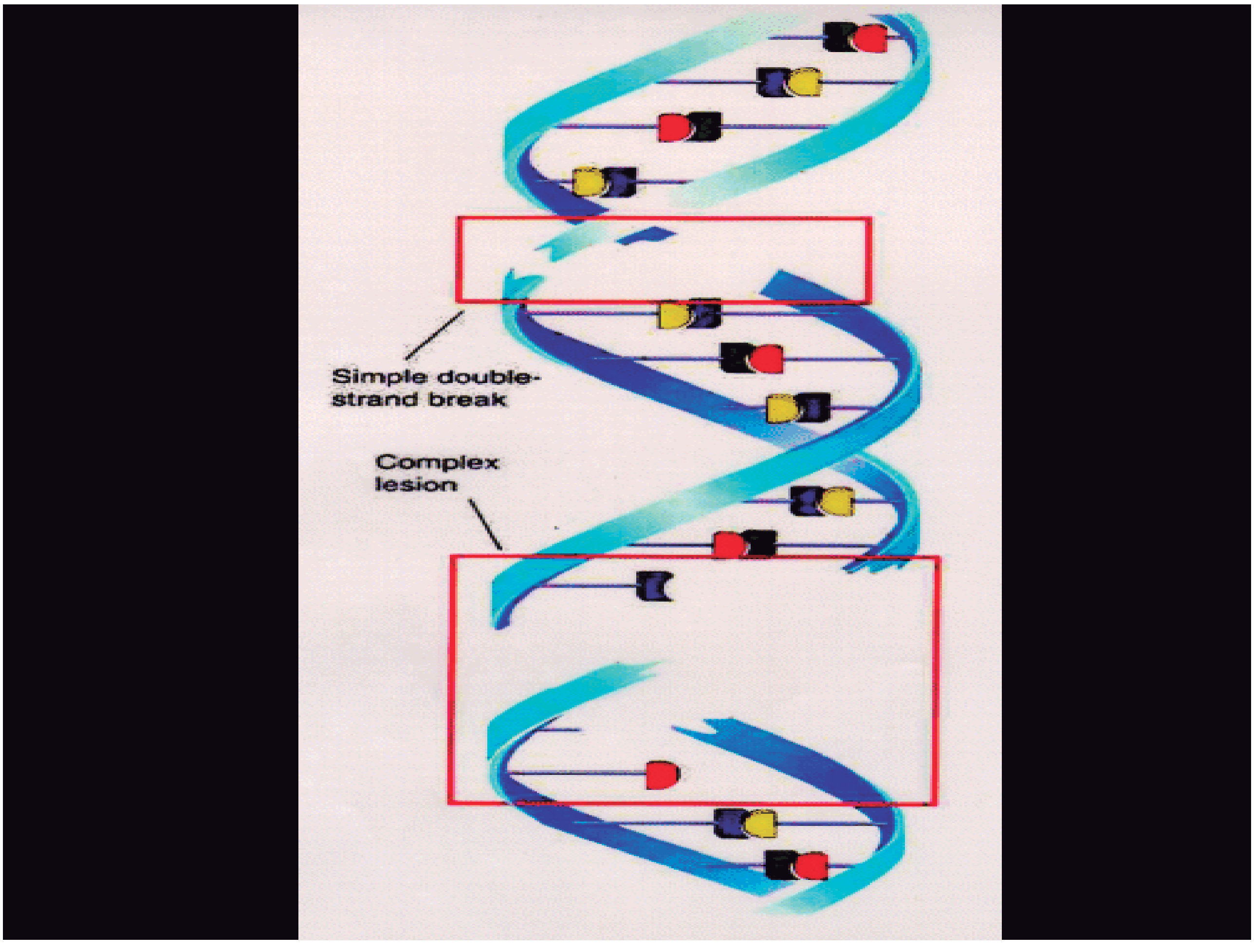


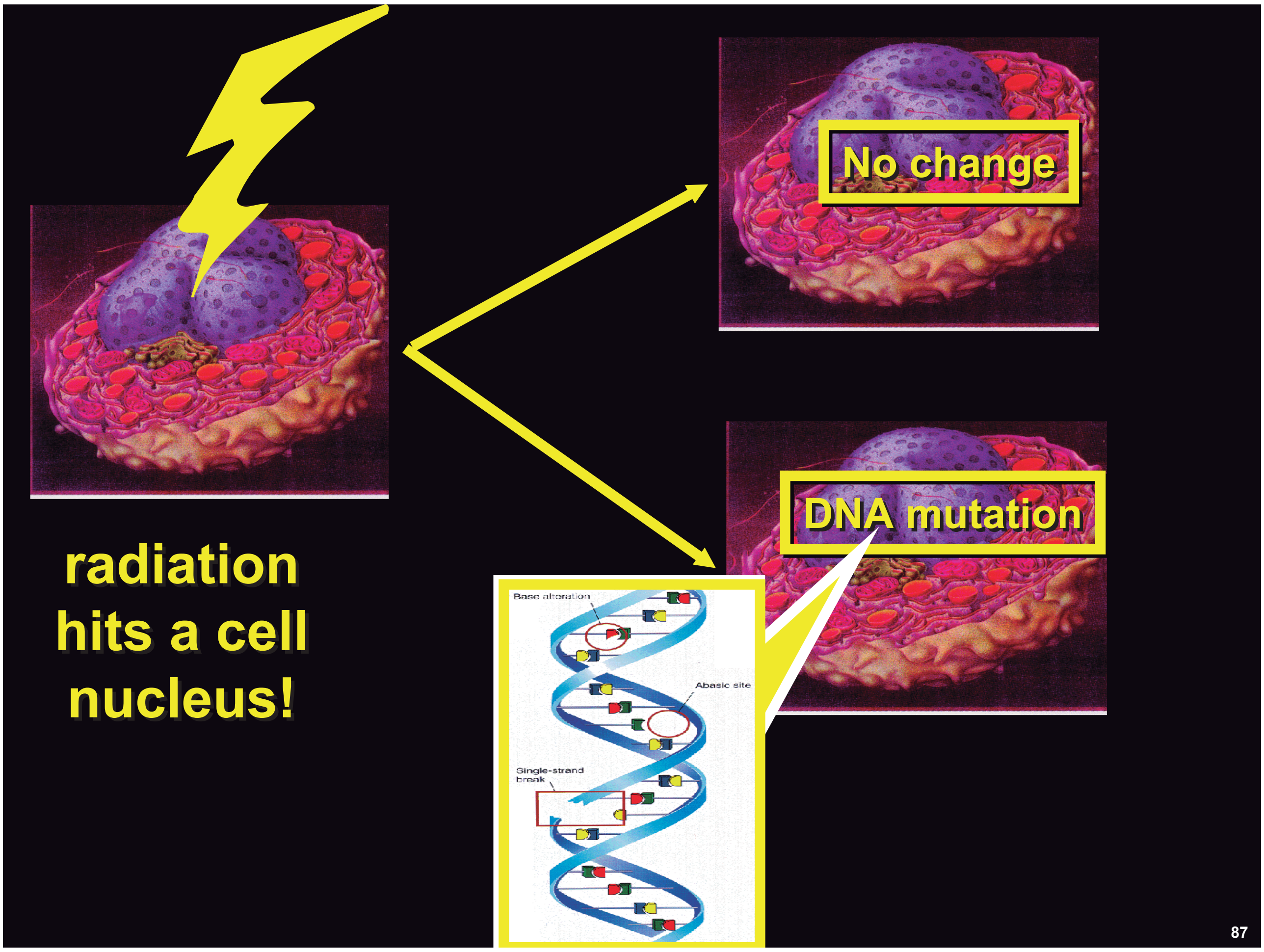

Mutation!

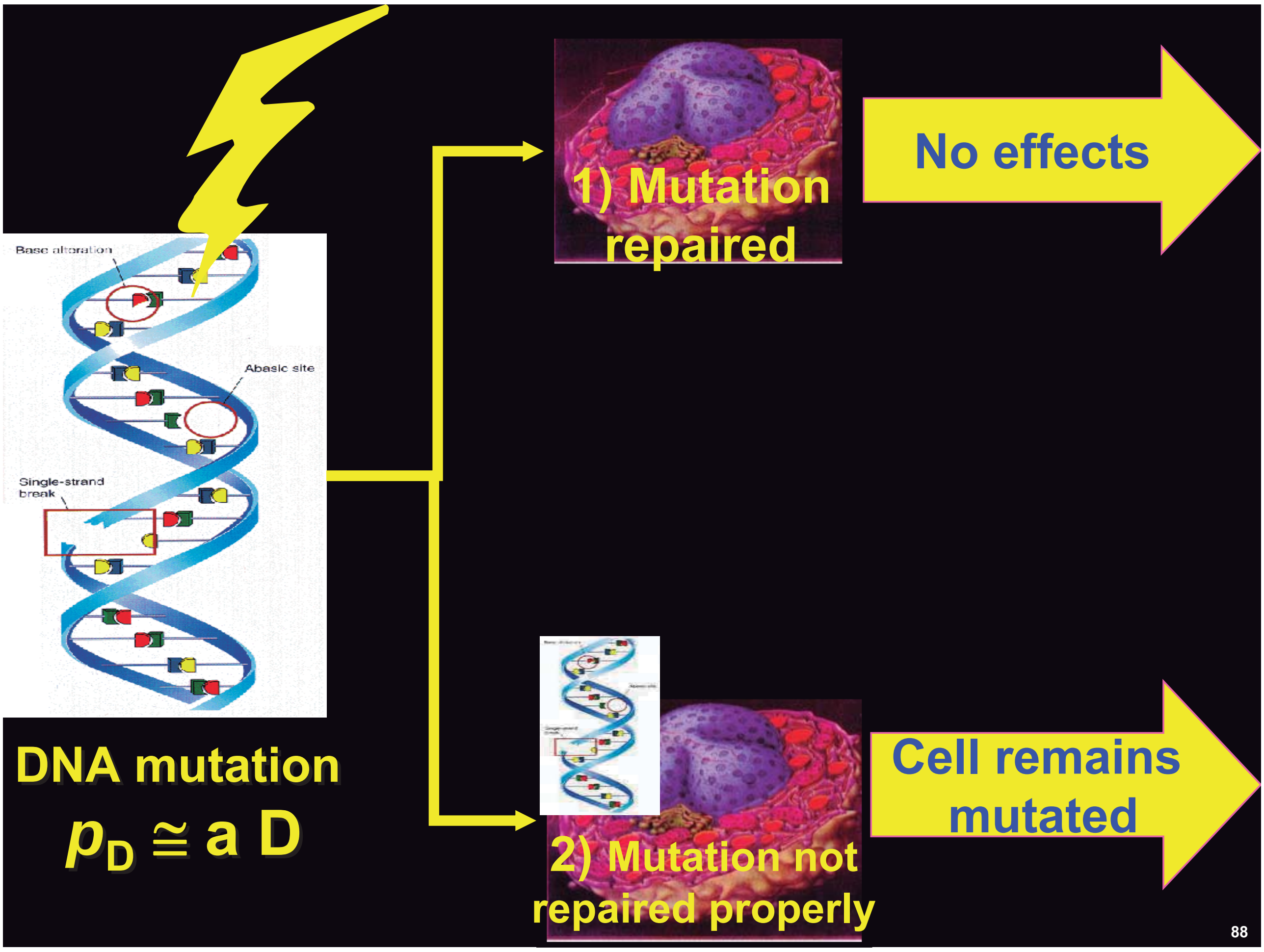

Base alteration
Abasic site
Single-strand break
83

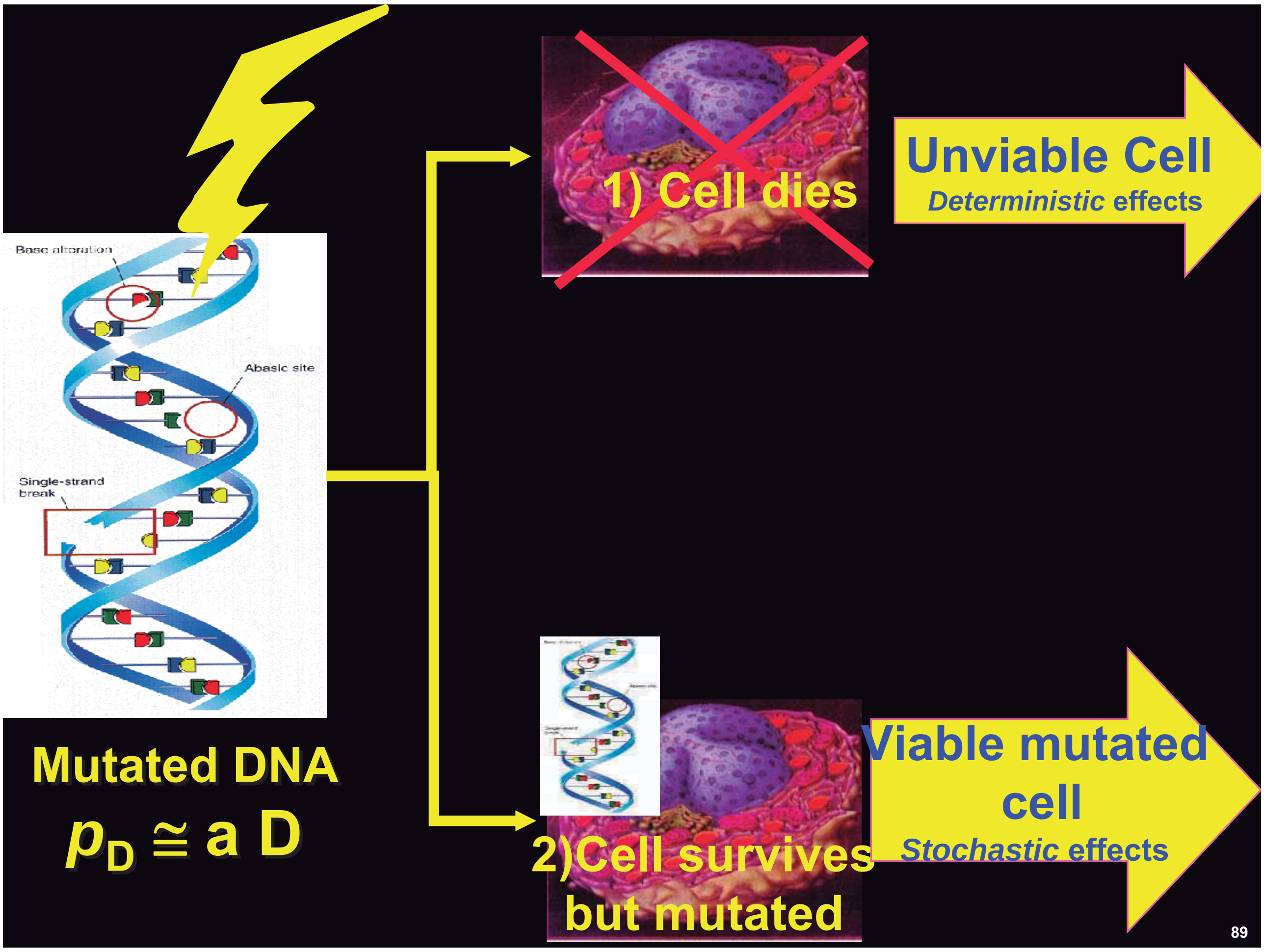


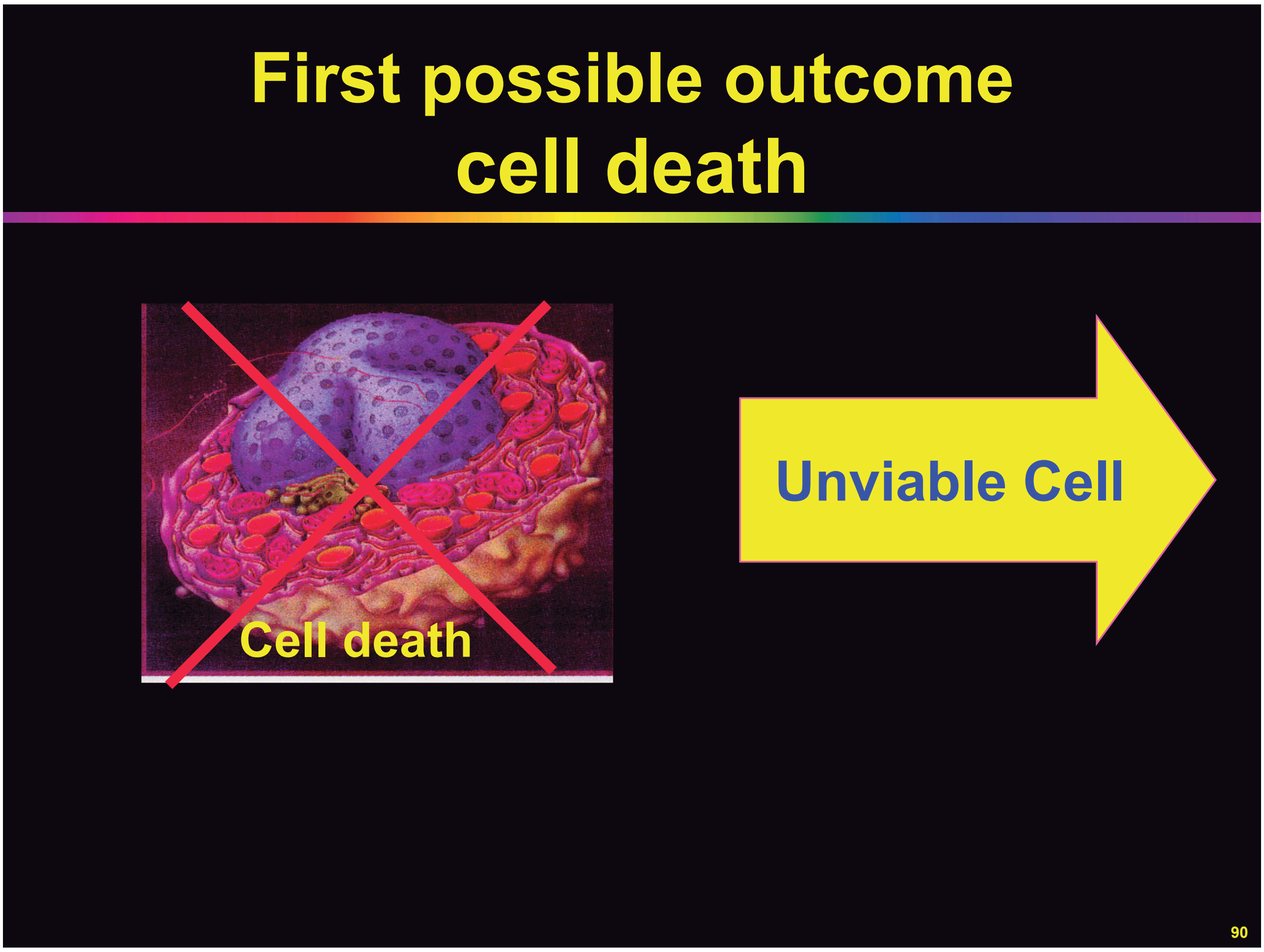

Base alteration
Abasic site
Single-strand
break


Simple double-
strand break
Complex
lesion

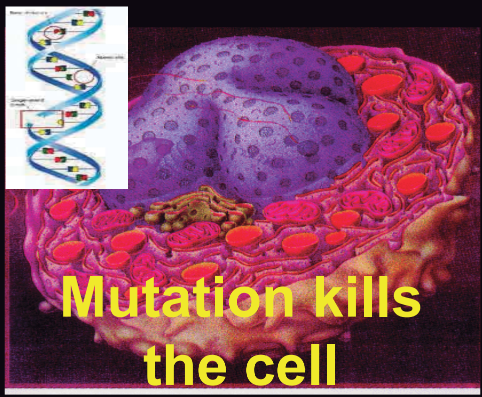

No change
DNA mutation
Base alteration
Abasic site
Single-strand break
radiation hits a cell nucleus!
87


1) Mutation repaired
No effects
Base alteration
Abasic site
Single-strand break
DNA mutation
$p_D \cong a\,D$
2) Mutation not repaired properly
Cell remains mutated
88


Base alteration
Abasic site
Single-strand break
Mutated DNA
$p_D \cong a\,D$
1) Cell dies
Unviable Cell
Deterministic effects
2)Cell survives
but mutated
Viable mutated
cell
Stochastic effects
89


First possible outcome
cell death
Cell death
Unviable Cell
90

Massive cell killing may generate prompt ‘*deterministic*’ health effects



Deterministic effects

91

Early health effects

Potential *deterministic* effects

- Tissue reactions
- Burns
- Organ failure
- Death

93

The occurrence of deterministic effects in exposed individuals is diagnosed by

radio-pathologists.

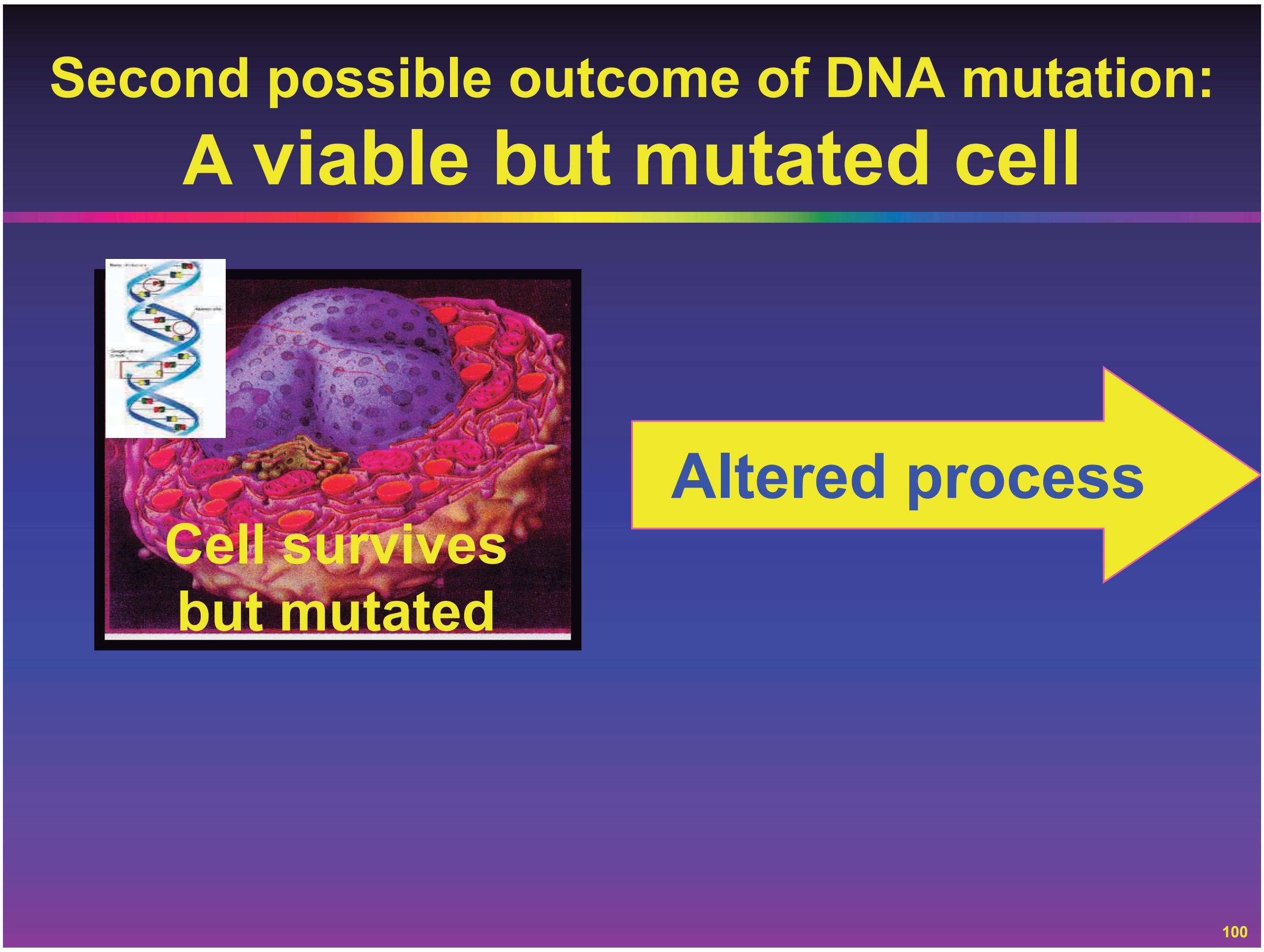
94


1
OAF

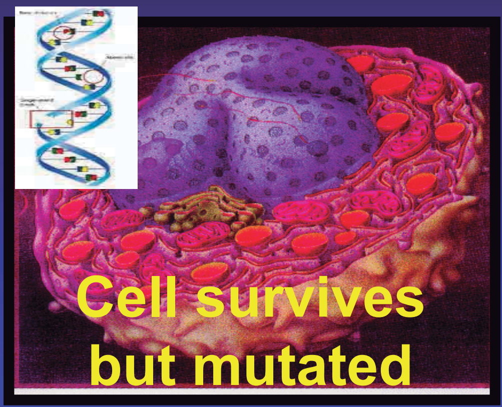

96

97

98


Second possible outcome of DNA mutation:
A viable but mutated cell
Cell survives
but mutated
Altered process
100

The altered process may generate late ‘*stochastic*’ health effects



Stochastic effects

101

Delayed health effects

potential *stochastic* effects

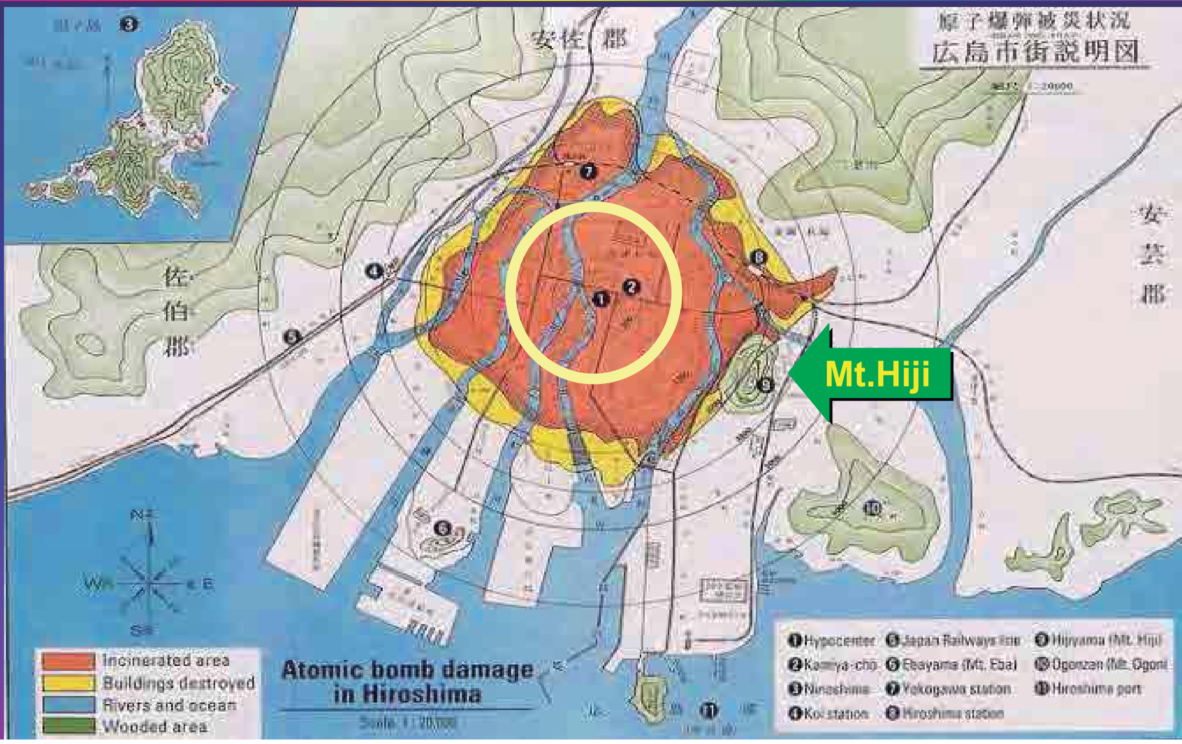
- Cancer
- Hereditable
- Antenatal

103

The prevalence of stochastic effects in an exposed population is estimated by radio-epidemiologists.

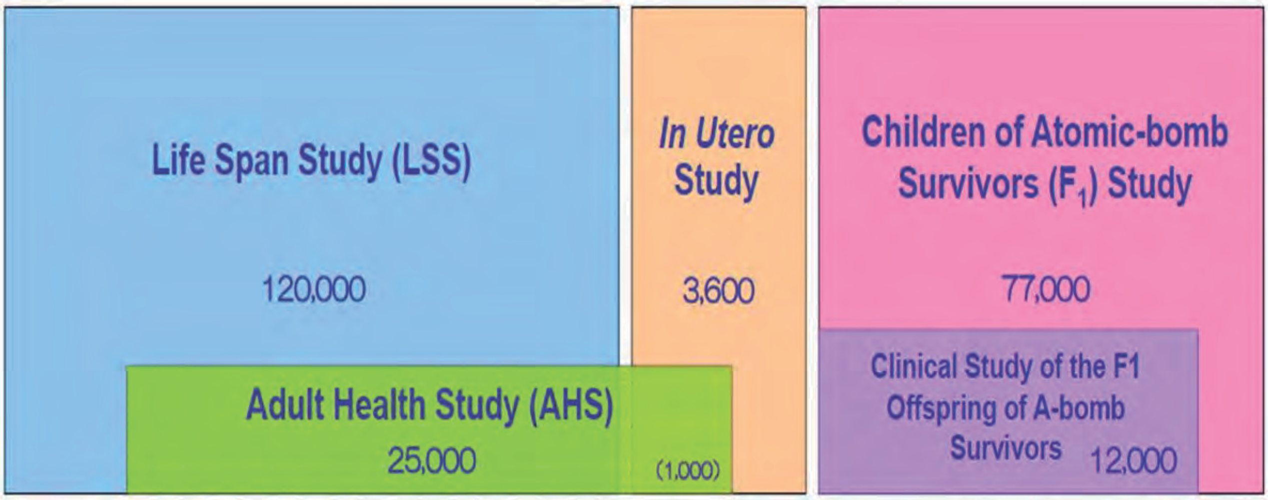
104

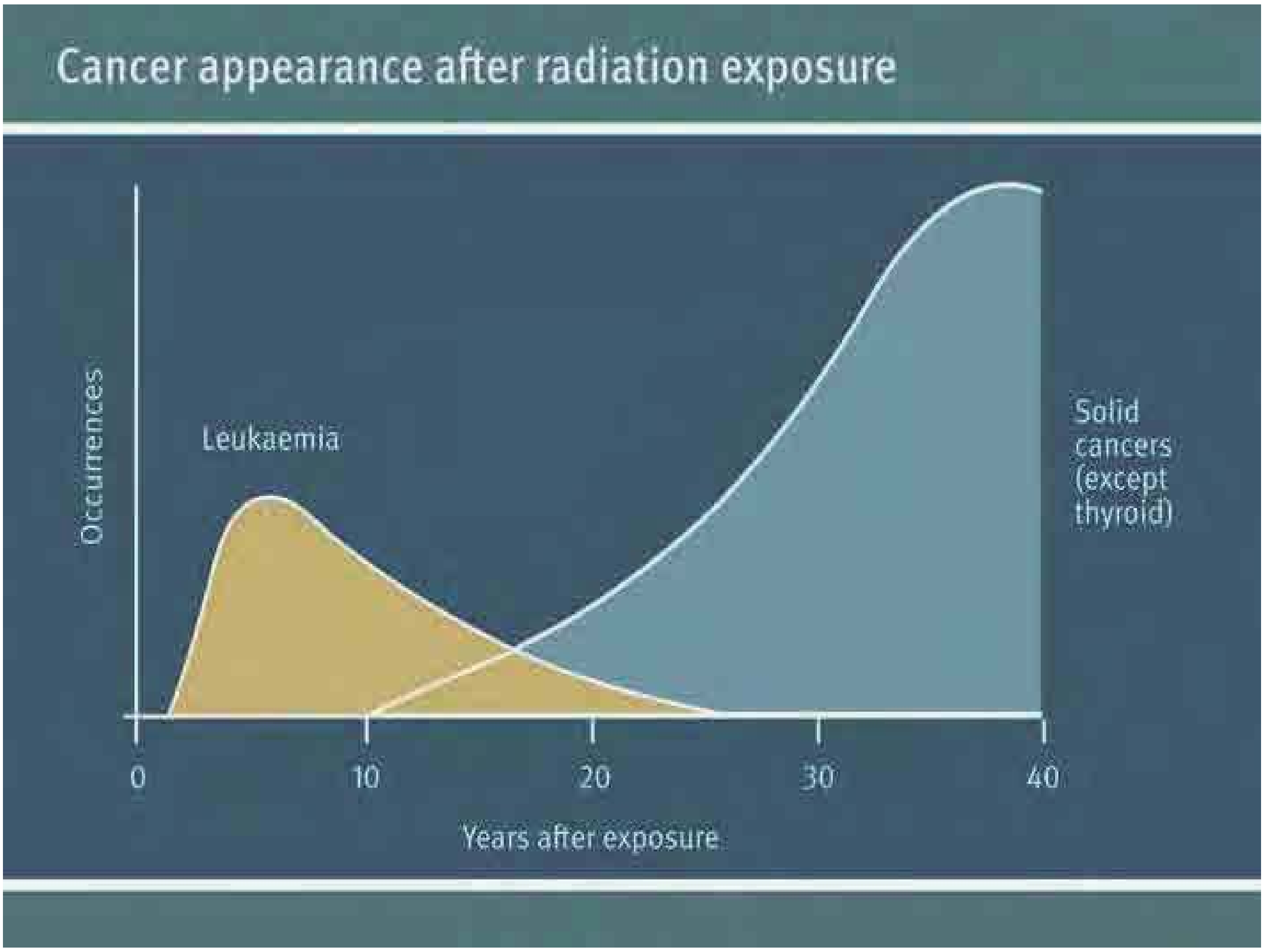
Cohort of Hiroshima & Nagasaki
(LIFE SPAN STUDY, LSS)



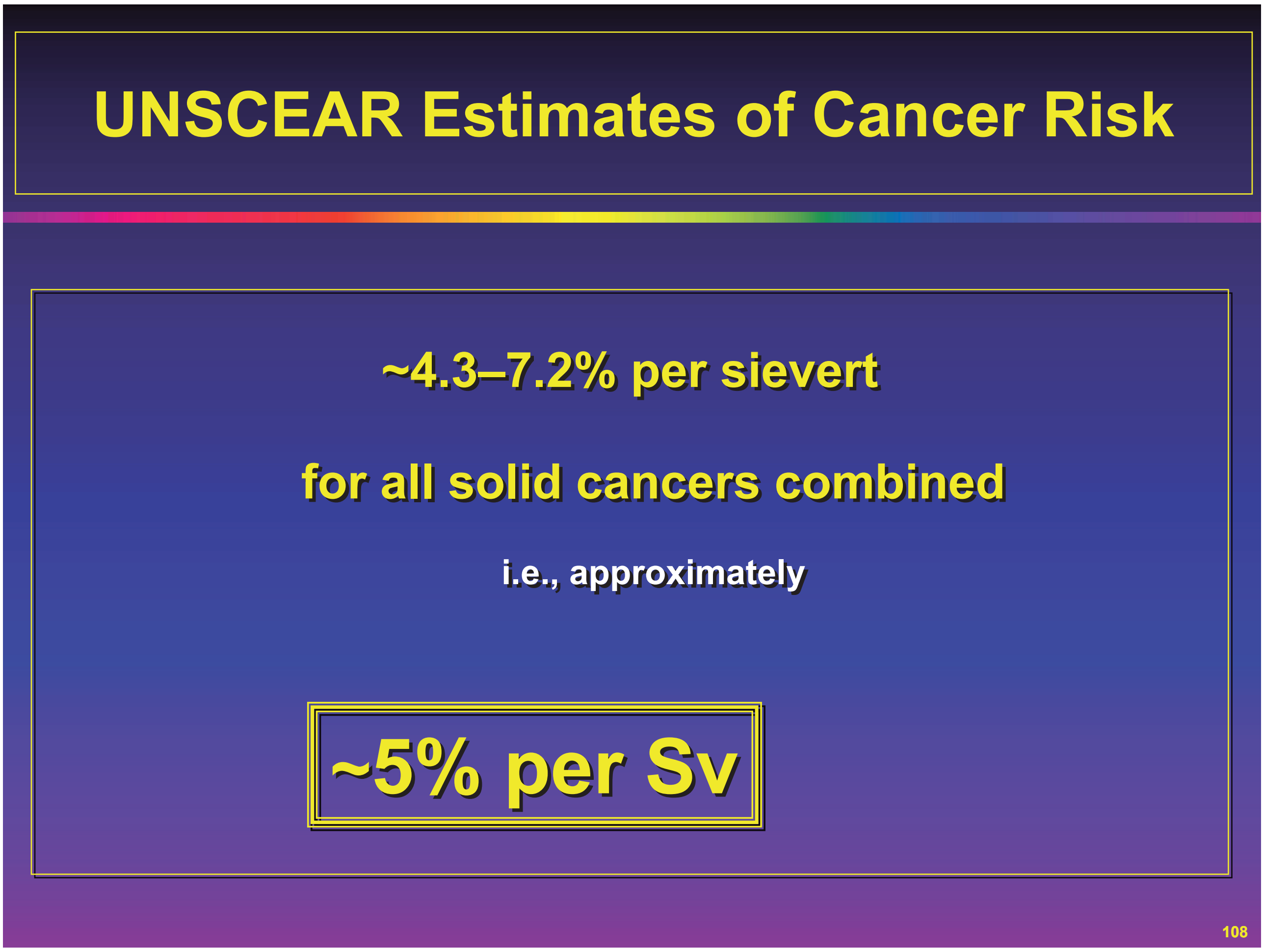
105

RERF Study Cohorts





Cancer appearance after radiation exposure
Occurrences
Leukaemia
Solid cancers (except thyroid)
0
10
20
30
40
Years after exposure



UNSCEAR Estimates of Cancer Risk
~4.3–7.2% per sievert
for all solid cancers combined
i.e., approximately
~5% per Sv
108

Limitations of epidemiology

109

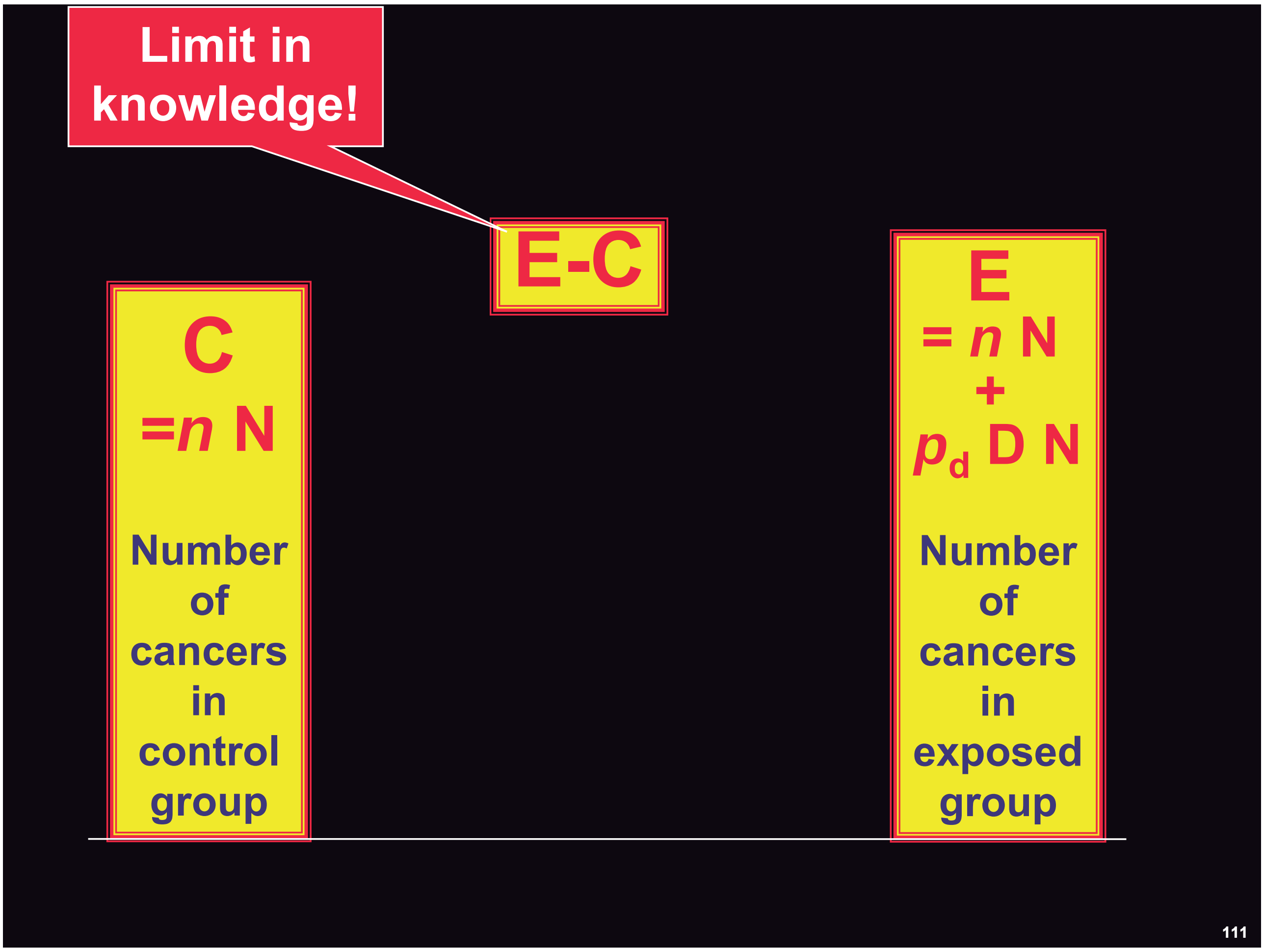
Control group

"N" people
"C" effects
"*n*" probability of 'natural' effect

Exposed group

"N" people
"E" effects
"*n*" probability of 'natural' effect
'p_D' probability of 'radiation' effect

110

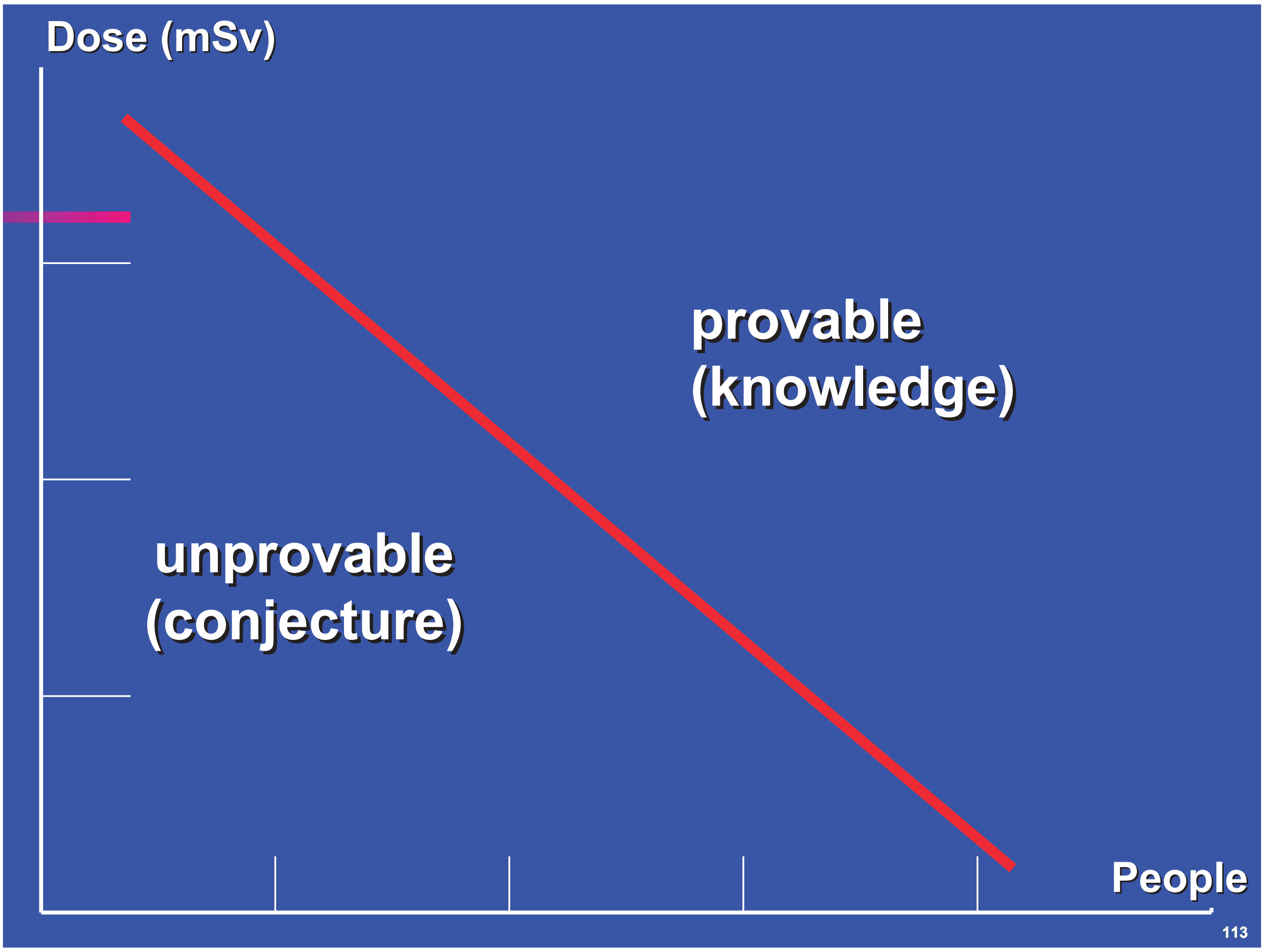


Statistical limits

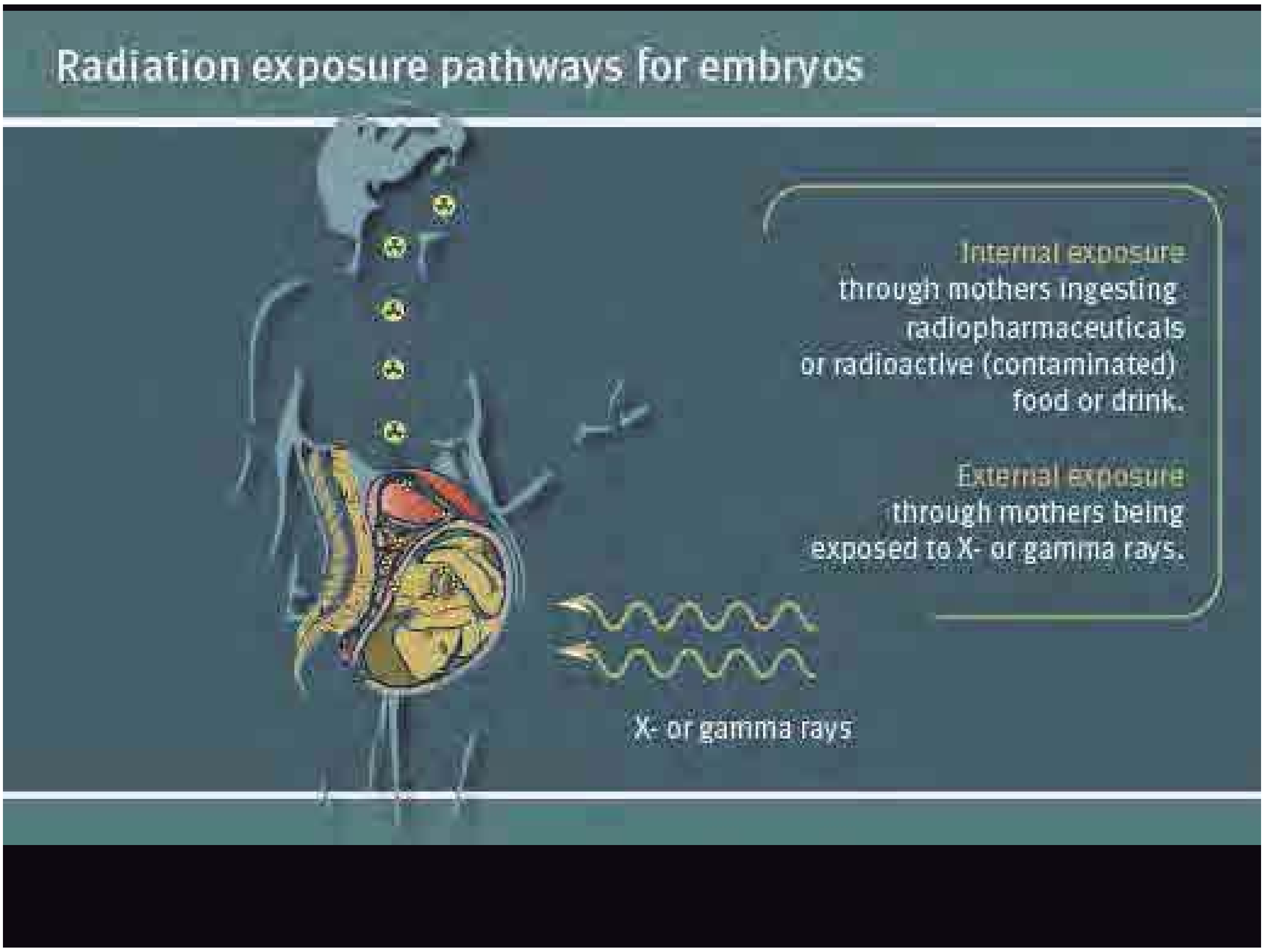
$$N > constant / D^2$$

which is the equation giving the number of people, **N**, needed for proving excess cancers at dose **D**.

112



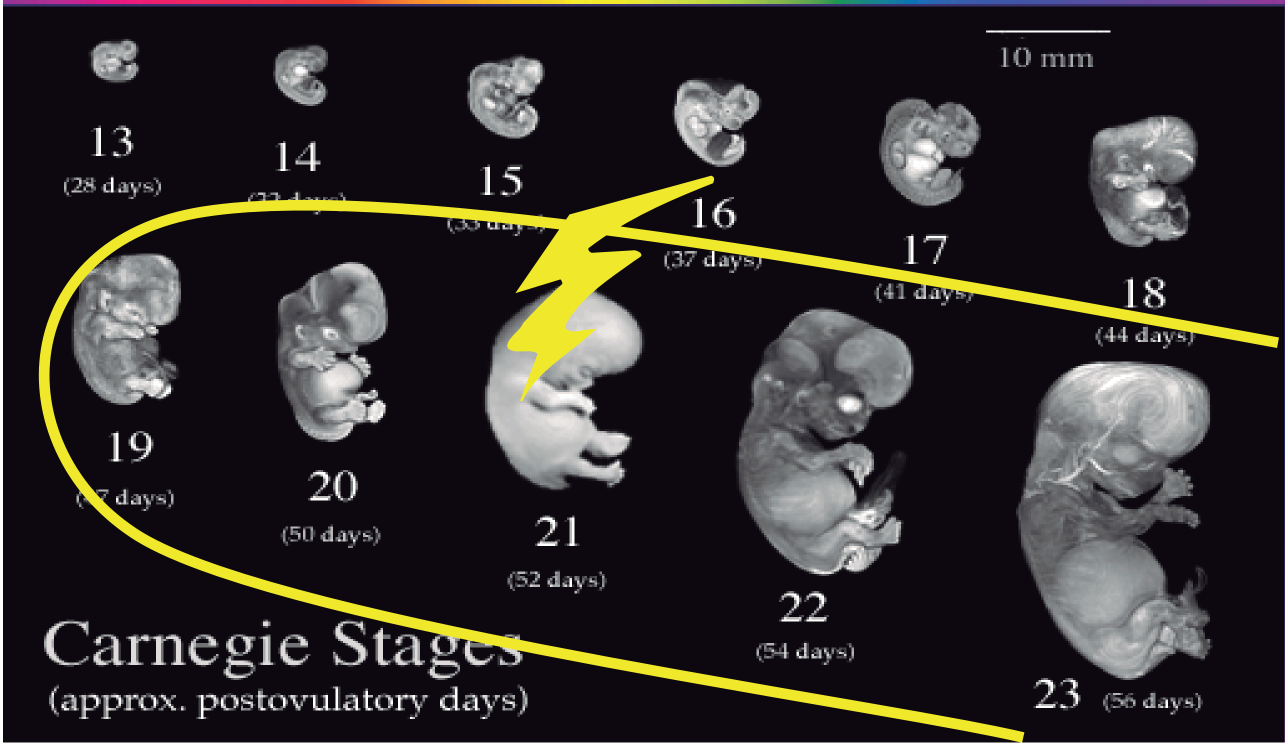
Effects on offspring



Antenatal Effects

116

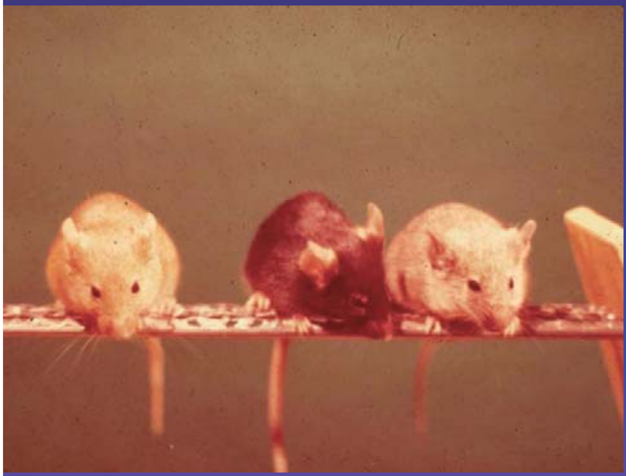
Antenatal Effects



Hereditable Effects

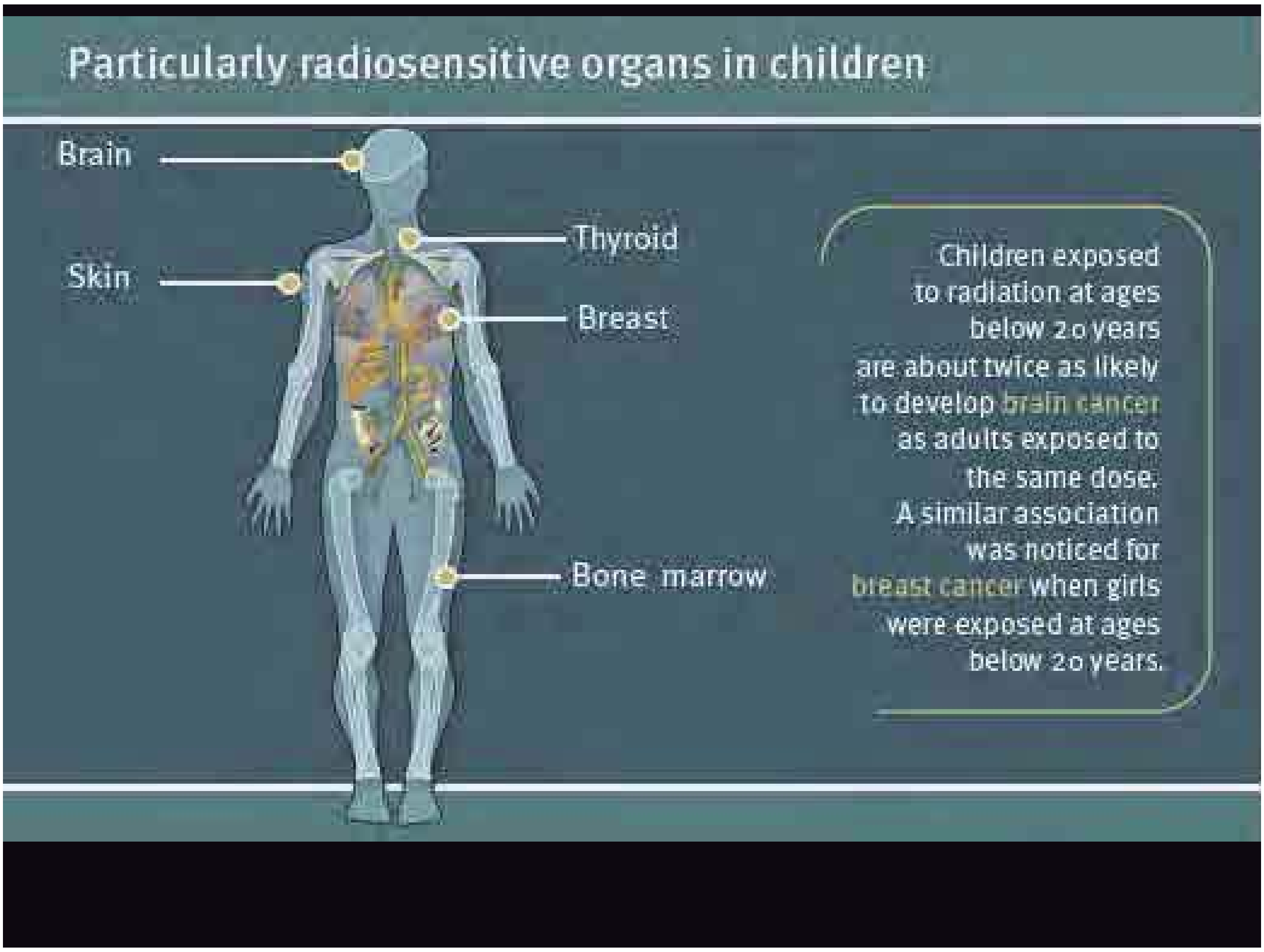
118

No hereditary effects have been observed in humans exposed to radiation: suspicions are based on animal studies



119

Effects in children



Take away points

122

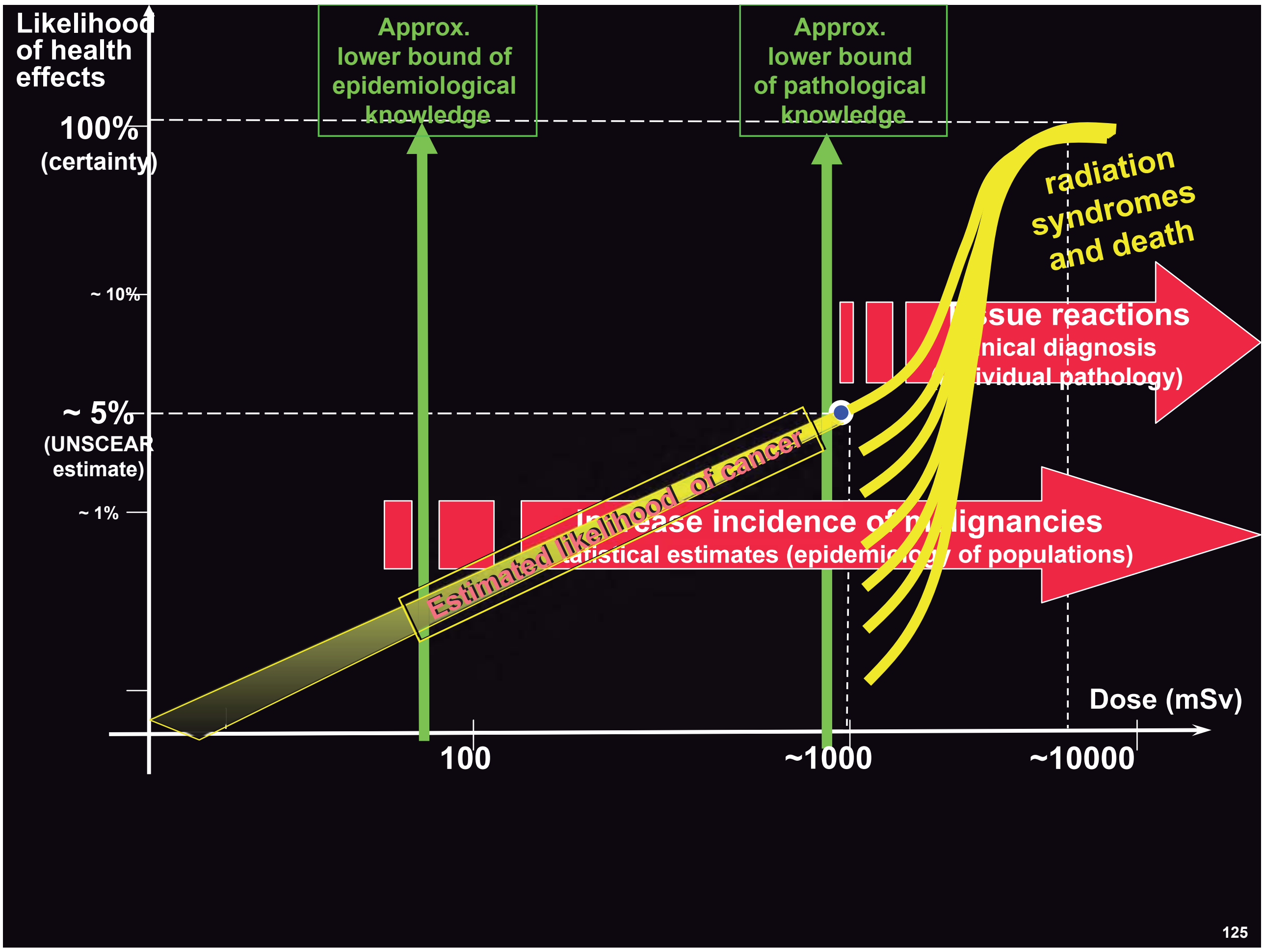
1. Radiation exposure at high acute levels, e.g. above several thousand of millisieverts is very dangerous.

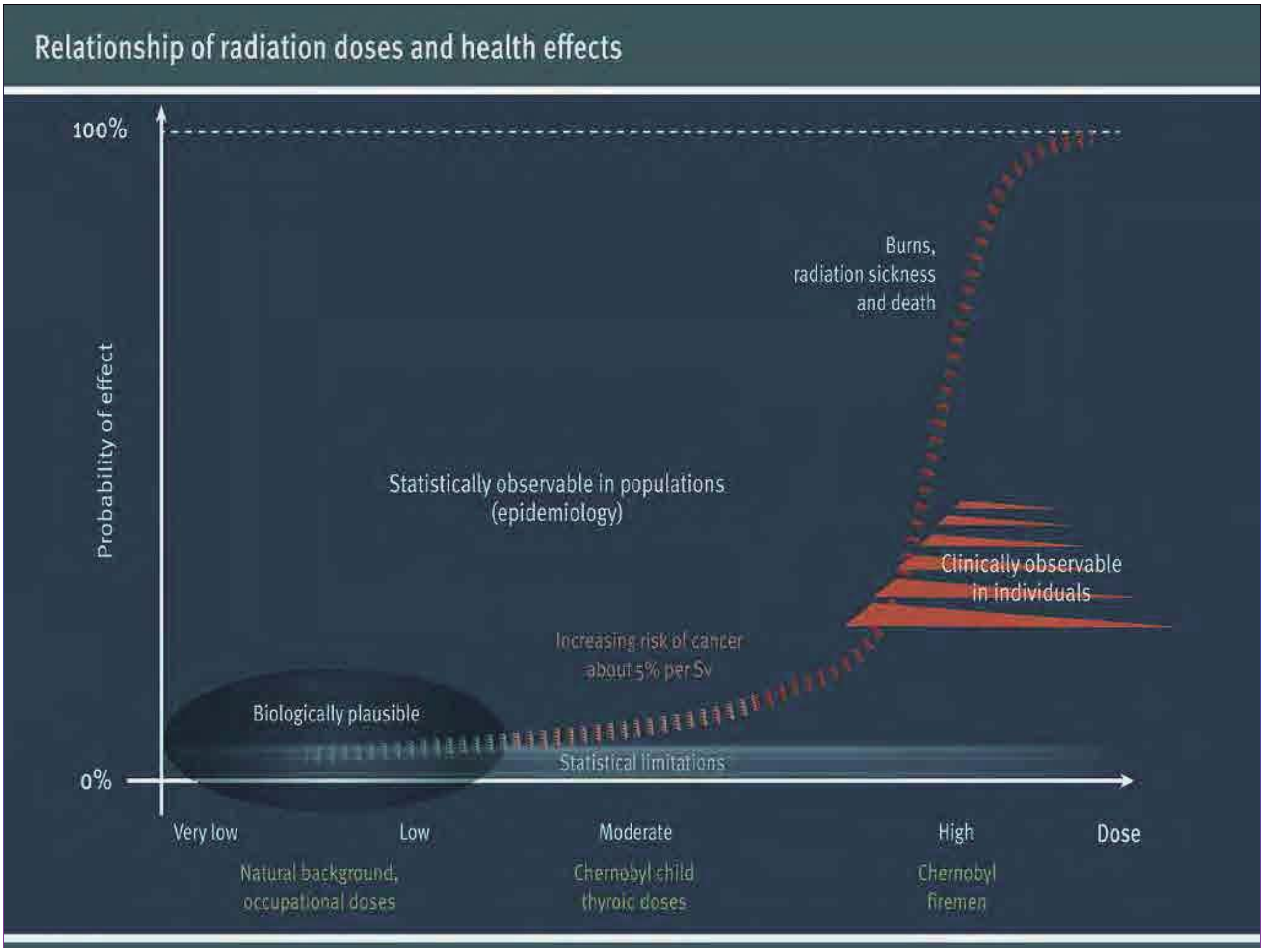
2. Radiation exposure at low chronic levels, e.g. towards tens of millisieverts per year, presents an extremely low risk.

3. Radiation exposure at very low chronic levels, e.g. < 1 millisievert per year, is not an individual health issue.

123

Relationship of radiation doses and effects


Likelihood of health effects
Approx. lower bound of epidemiological knowledge
Approx. lower bound of pathological knowledge
100% (certainty)
~ 10%
~ 5% (UNSCEAR estimate)
~ 1%
radiation syndromes and death
Estimated likelihood of cancer
Dose (mSv)
100
~1000
~10000
125


Relationship of radiation doses and health effects
100%
0%
Probability of effect
Burns, radiation sickness and death
Statistically observable in populations (epidemiology)
Clinically observable in individuals
Increasing risk of cancer about 5% per Sv
Biologically plausible
Statistical limitations
Very low
Low
Moderate
High
Dose
Natural background, occupational doses
Chernobyl child thyroid doses
Chernobyl firemen

Epilogue

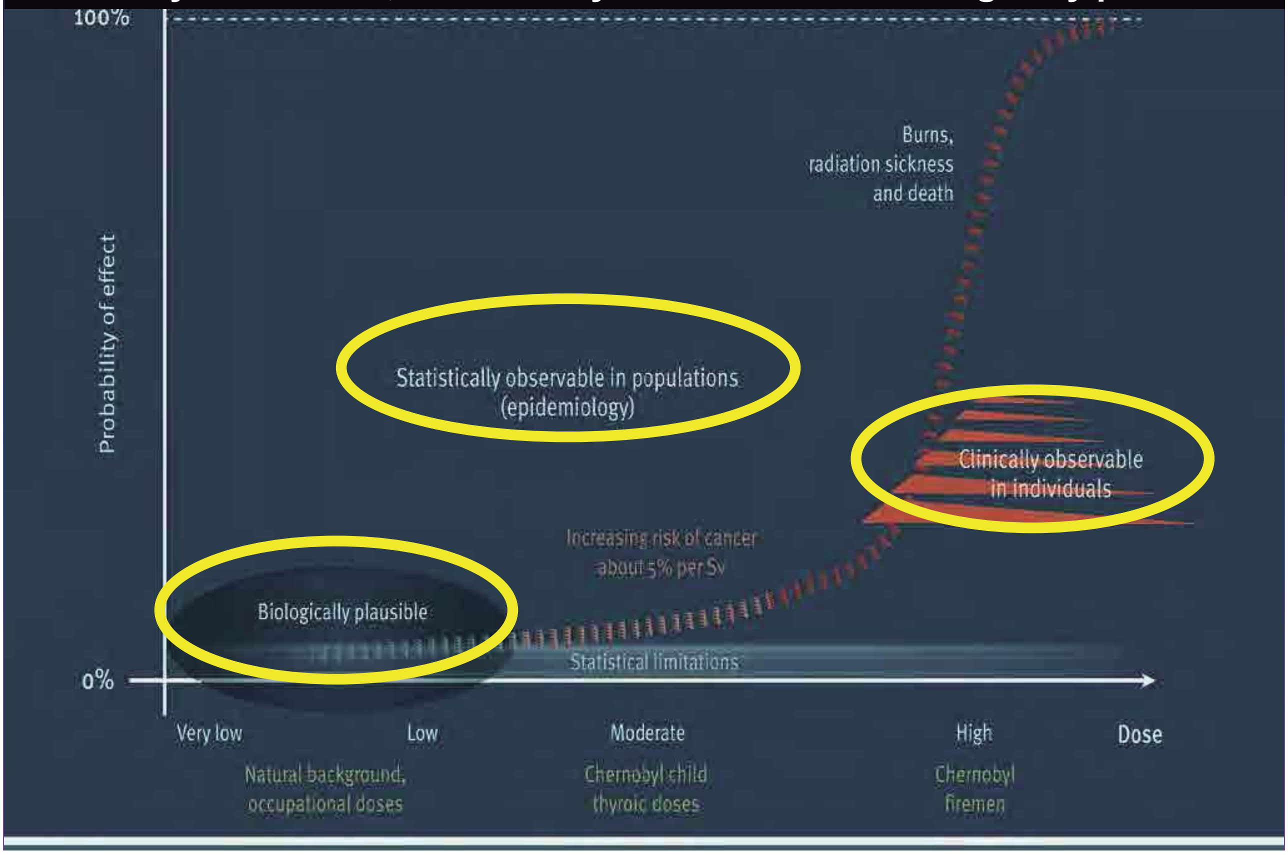
How radiation effects are distinguished?

(see presentation on attribution vis-à-vis inference)

127

A clear distinction between effects:

clinically observable, statistically observable and biologically plausible



Attribution of Effects vis-à-vis Inference of Risk

González, A.J.

Clase dictada en el Curso del Summer Institute 2022 de la Universidad Nuclear Mundial, llevado a cabo en la Universitat Politècnica de València (UPV), en Valencia, España, del 19 al 25 de junio de 2022

World Nuclear University
Sumer Institute – 2022
Valencia-España-24/6/2022

Attribution of Effects vis-à-vis Inference of Risk

Abel J. González
UNSCEAR Representative, IAEA' CSS Member
Autoridad Regulatoria Nuclear
✉Av. Del Libertador 8250; (1429)Buenos Aires,Argentina ☎+54 1163231758

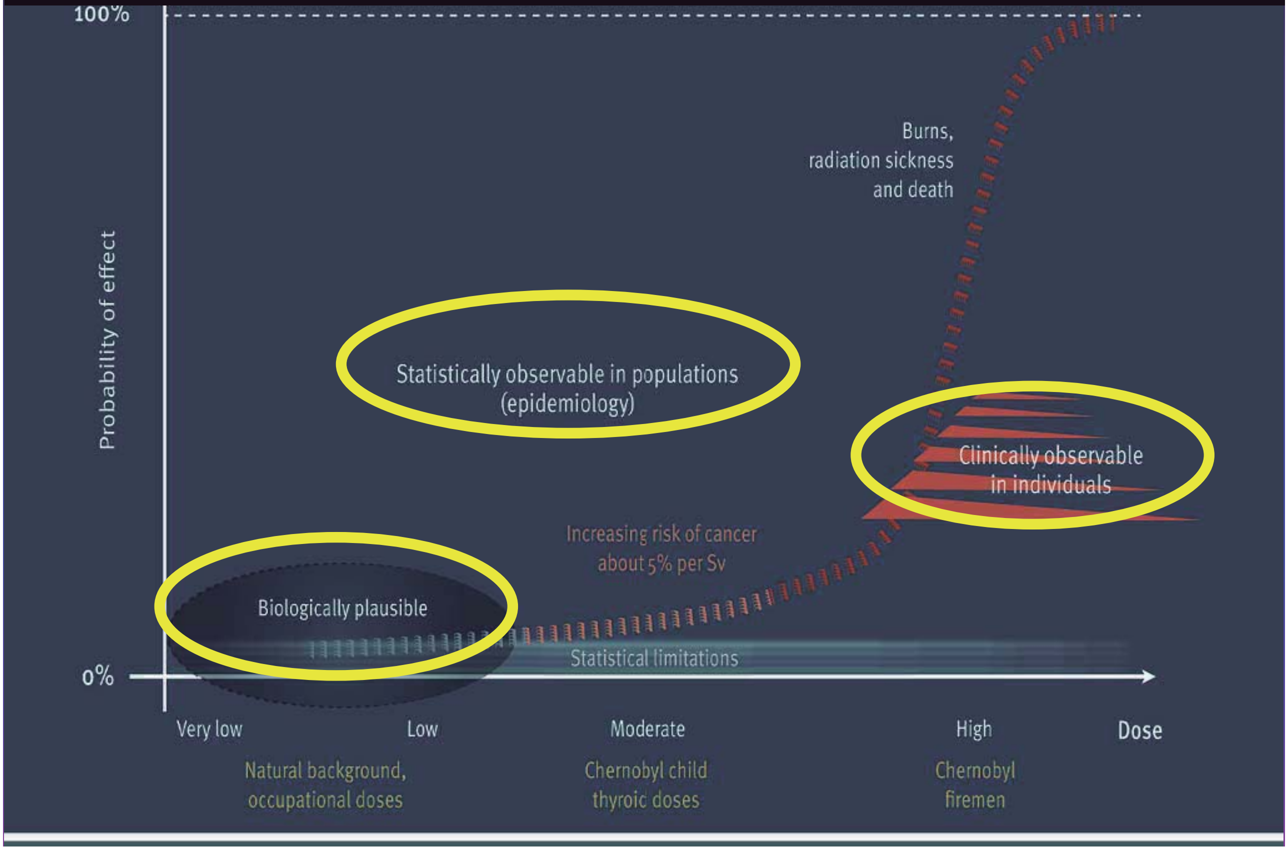
1

How radiation effects are distinguished?

2

A clear distinction between effects:

clinically observable, statistically observable and biologically plausible

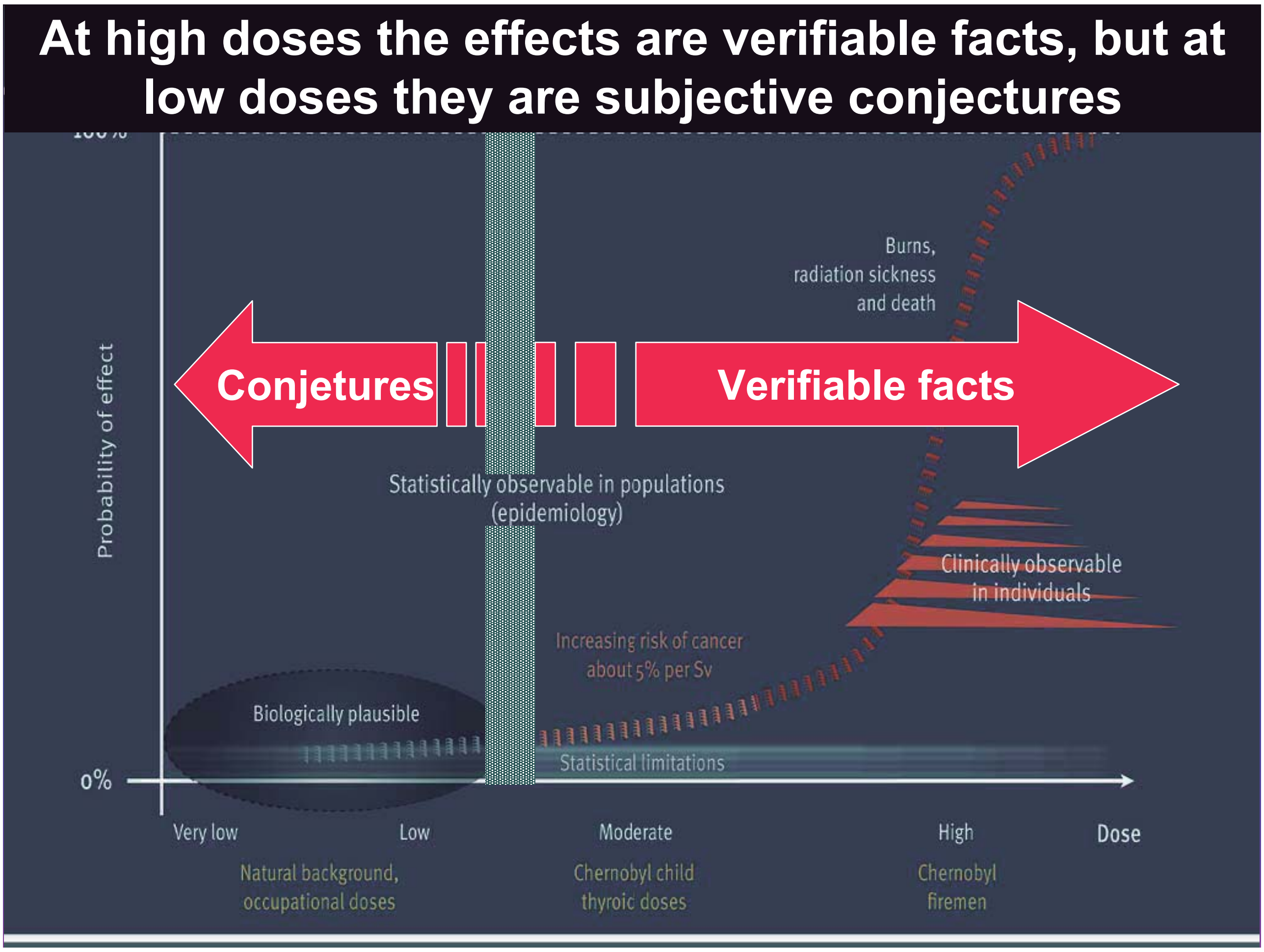


objective verifiable facts

vis-à-vis

subjective conjectures

4



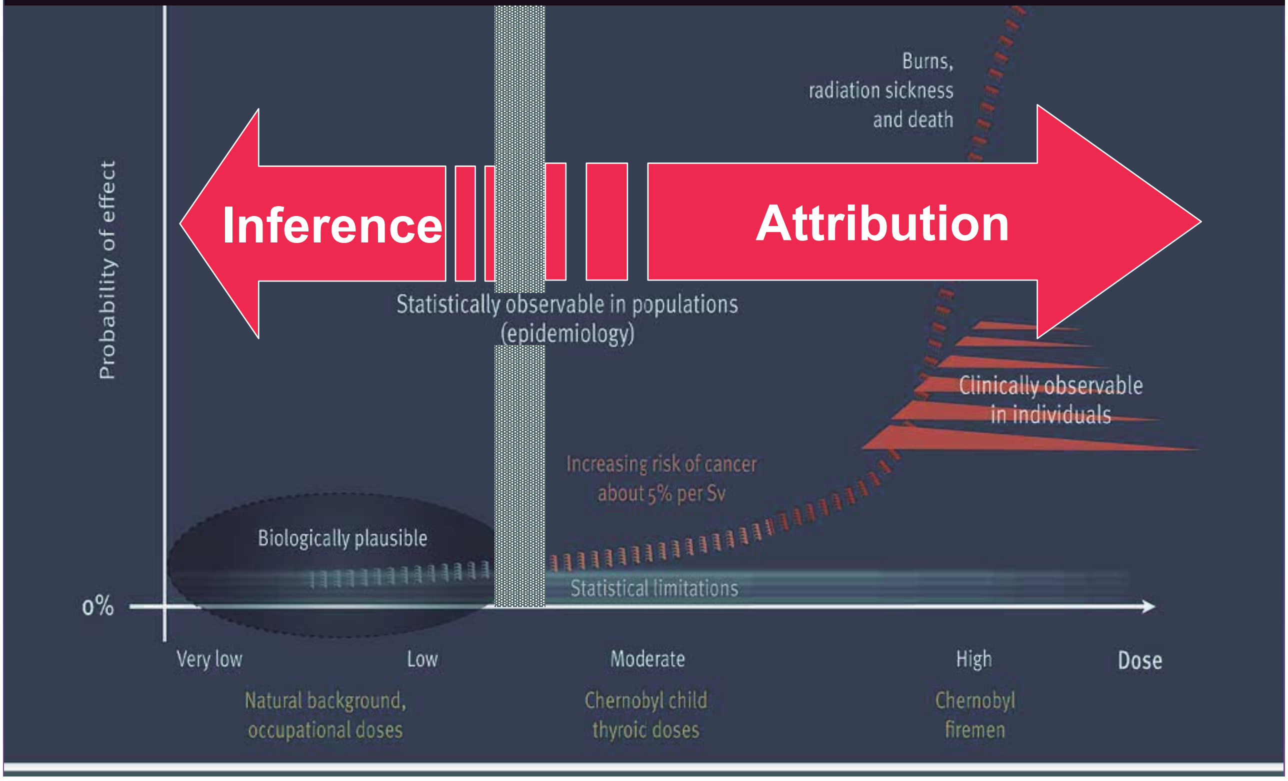
Attribution

vis-à-vis

inference

6

At high doses the effects are *attributable* to the exposure, but at low doses there is just a subjective *inference* of radiation risk



The fundamental issue:

Mathematically:

5%/Sievert = 0.005%/milliSievert

….but….

Epistemiologically:

5%/Sievert ≠ 0.005%/milliSievert

8

Individual diagnosis

vis-à-vis

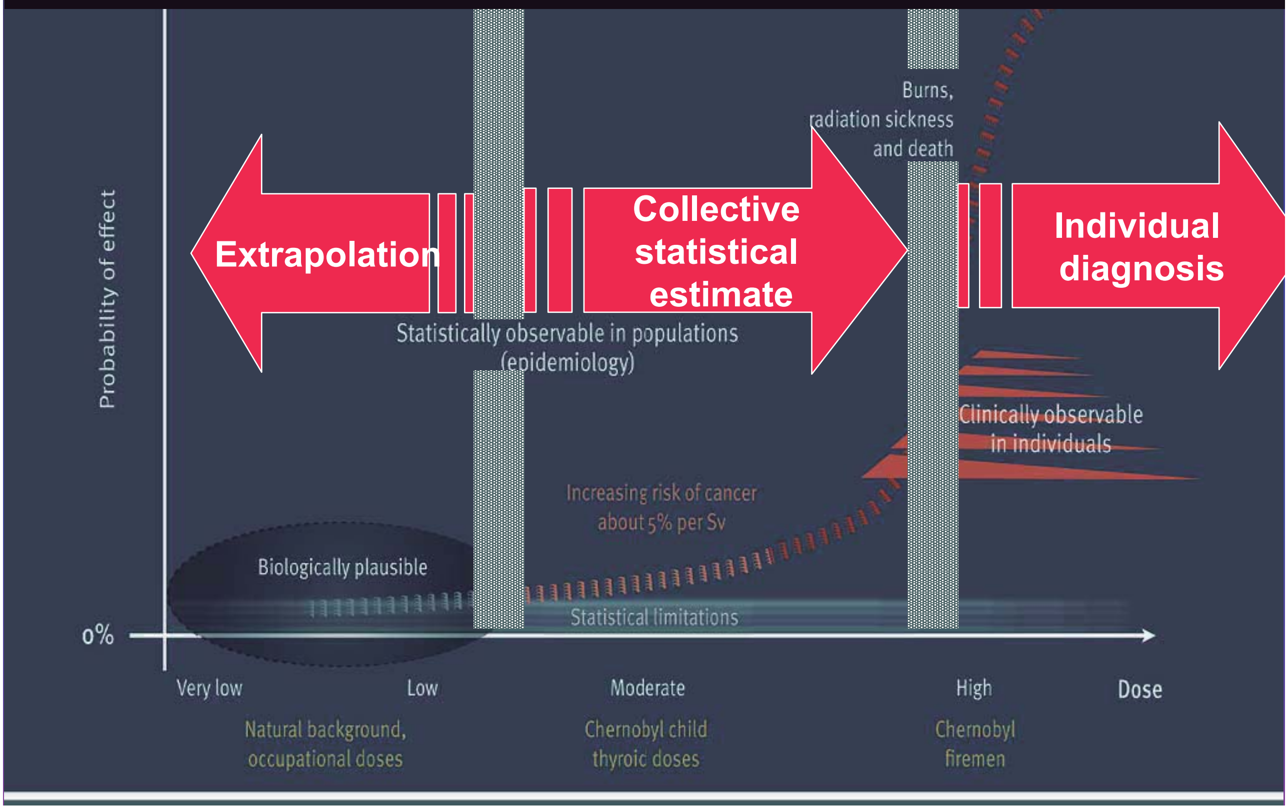
collective estimate

vis-à-vis

subjective extrapolation

9

At very high doses the effects are diagnosable in the exposed individual, at moderate doses they can be collectible estimated, at low doses they are just extrapolable



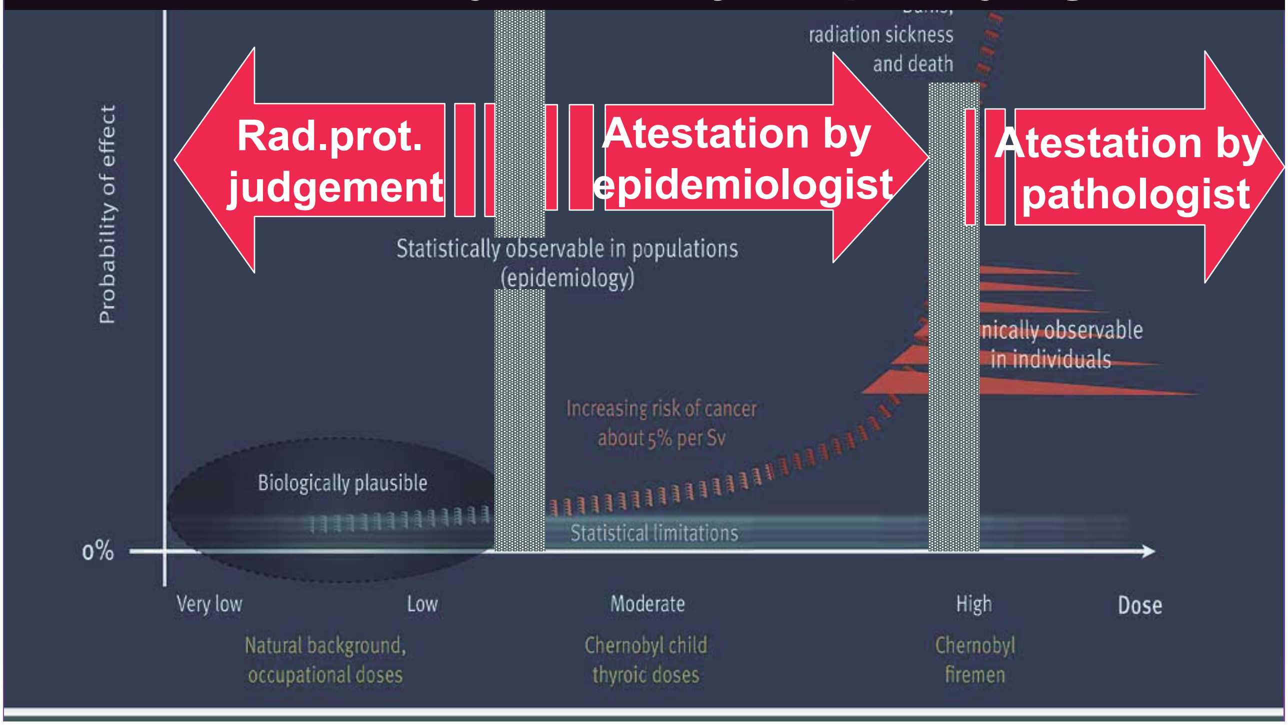
The dilemma of attestation

Who are the experts who may attest?:

- Pathologists
- Epidemiologists
- Radioprotectionists

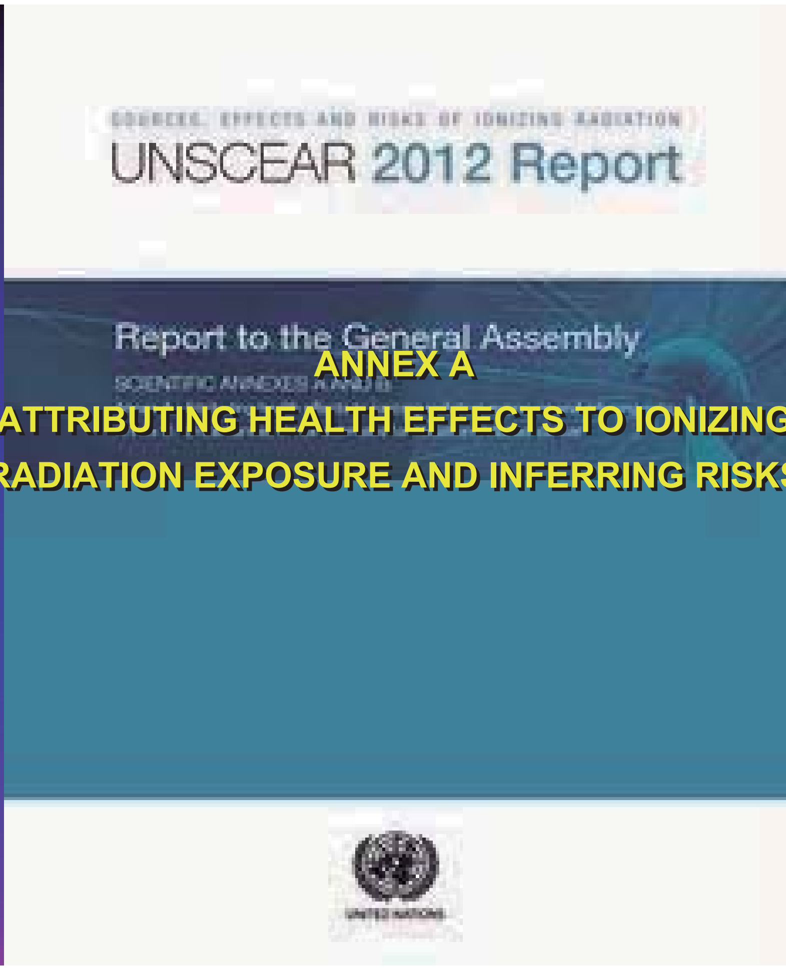
11

At high doses individual effects can be attested by pathologists, at moderate doses collective effects can be attested by epidemiologists, at low doses risks can be conjectured by rad.prot.' judgment



UNSCEAR
Report to the UN General Assembly

13



ANNEX A
ATTRIBUTING HEALTH EFFECTS TO IONIZING RADIATION EXPOSURE AND INFERRING RISKS

- *Increases in the incidence of health effects in populations cannot be attributed reliably to chronic exposure to radiation at levels that are typical of the global average background levels of radiation.*

- *An increase in the incidence of hereditary effects in human populations cannot at present be attributed to radiation exposure.*

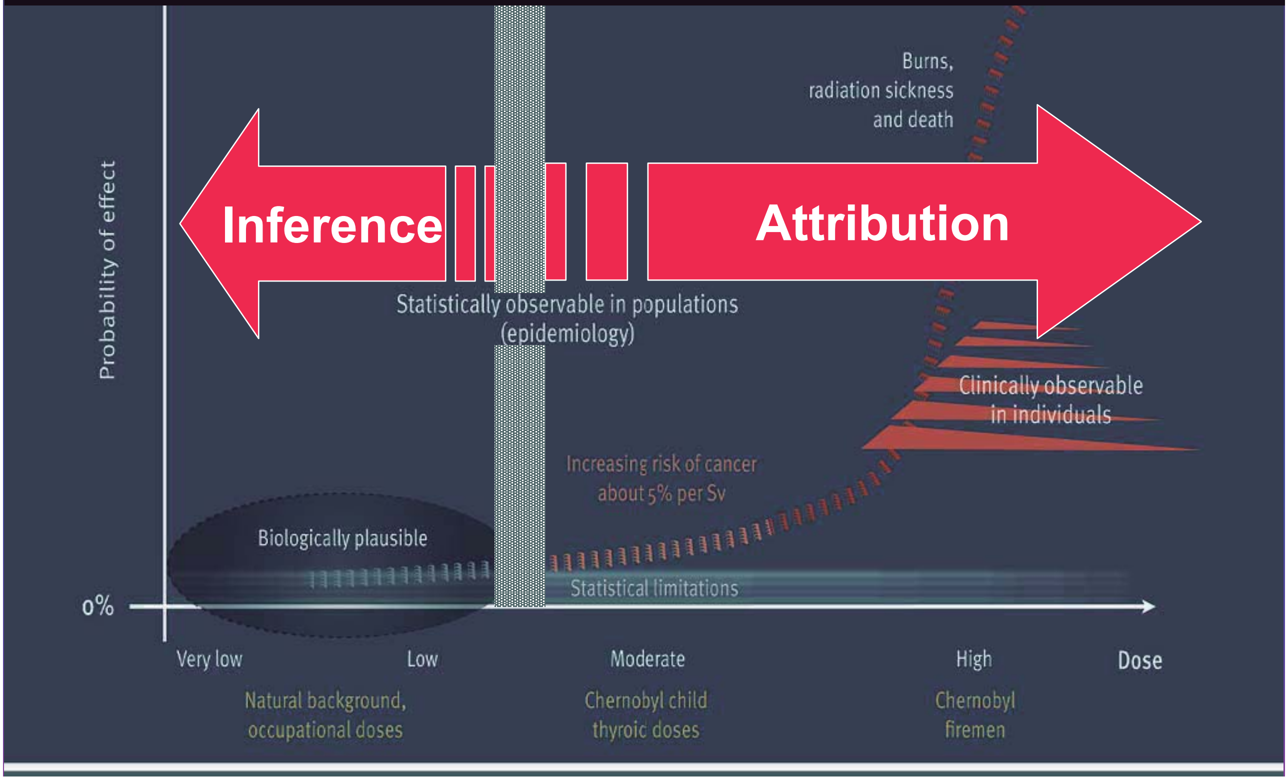
Potential legal consequences

17

Potential legal actions

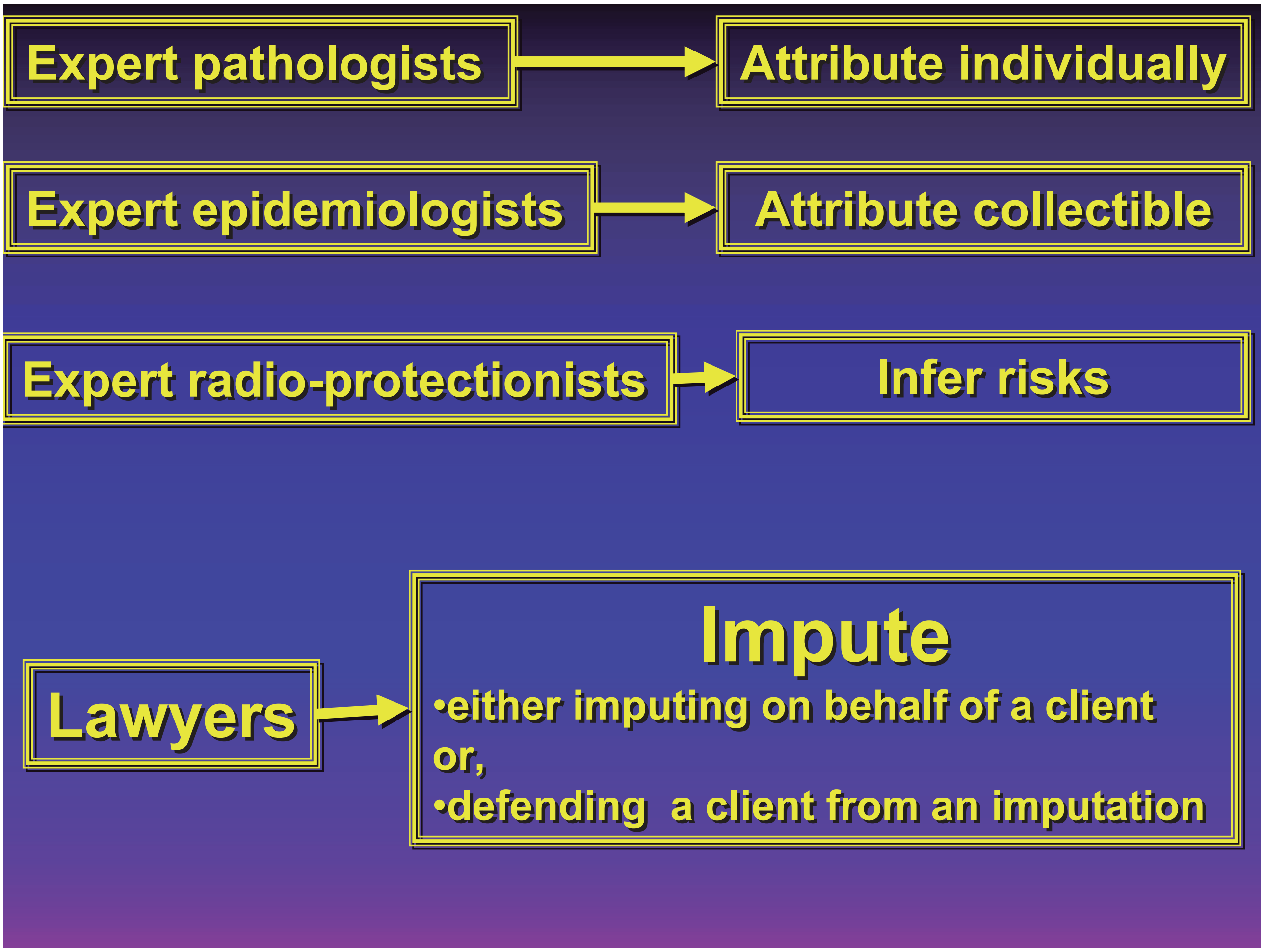
- **Impute:** ascribe responsibility for effects of radiation exposure.
- **Sue or prosecute :** institute legal proceedings.
- **Charge:** formally accuse of a law offence; e.g. violating radiation protection regulations
- **Indict:** formally accuse of a crime; e.g killing a person with radiation.

At high doses the effects are *attributable* to the exposure, but at low doses there is just a subjective *inference* of radiation risk



to *impute*
is different than
to *attribute*
or
to *infer*

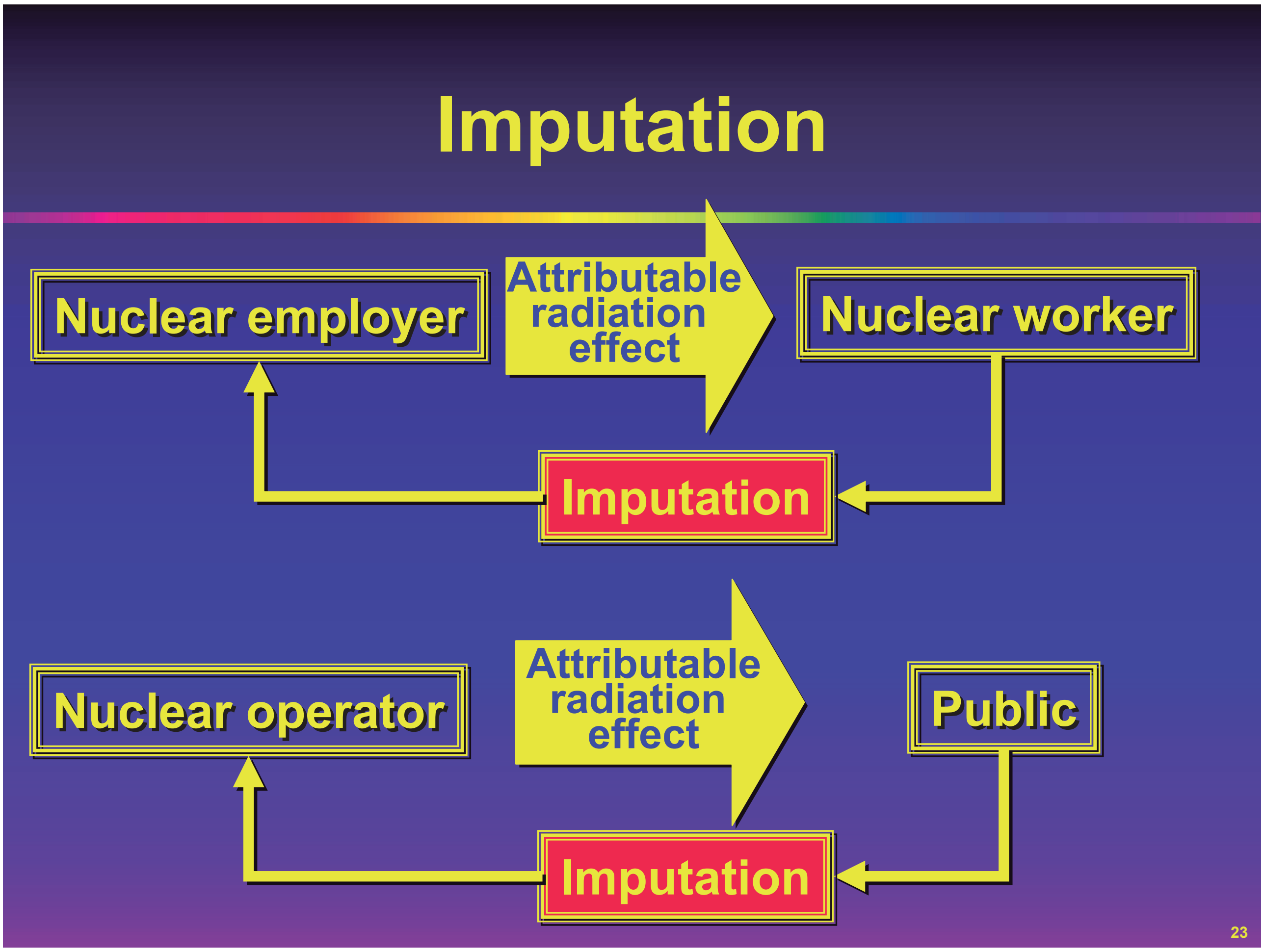
20

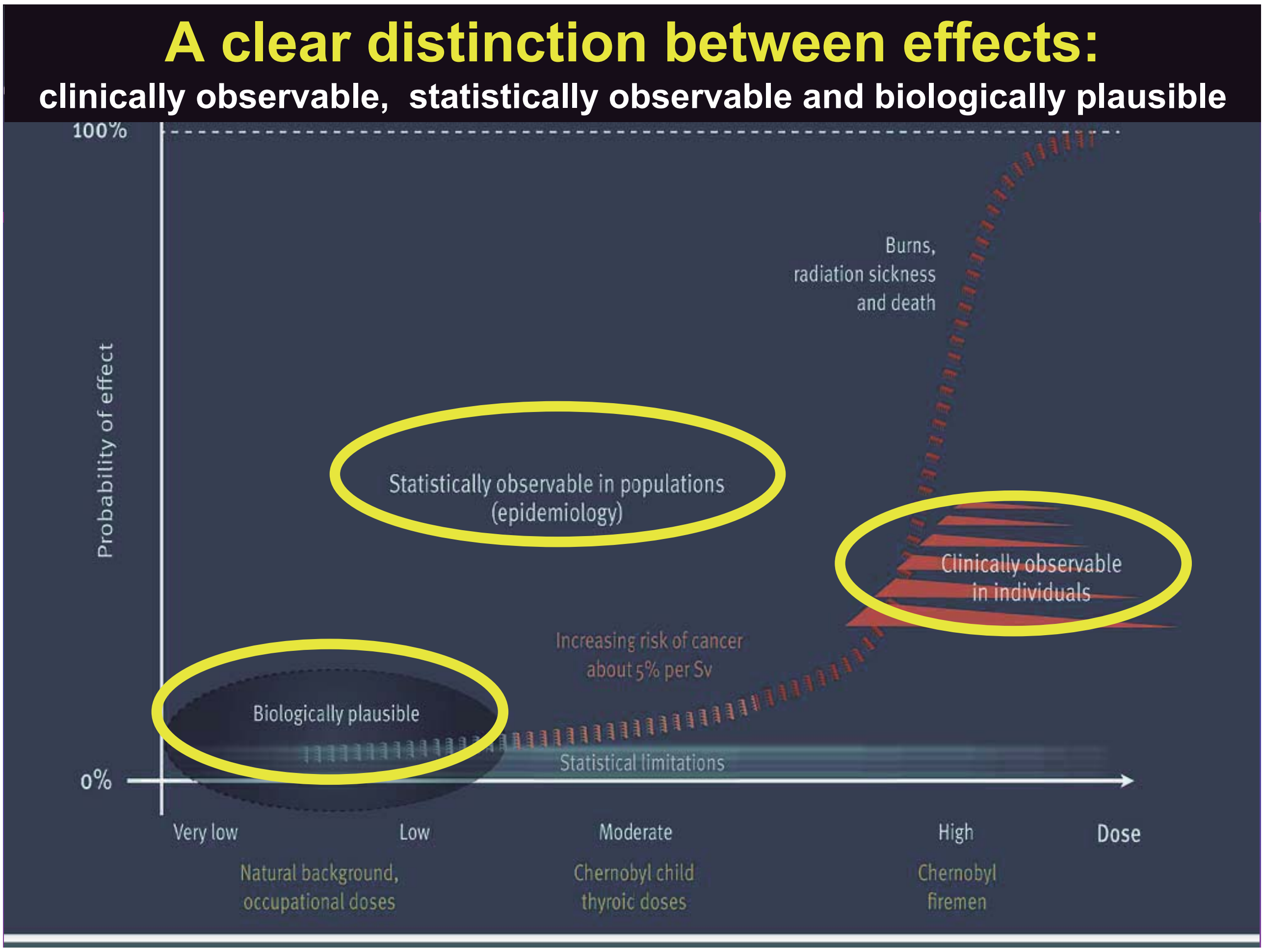


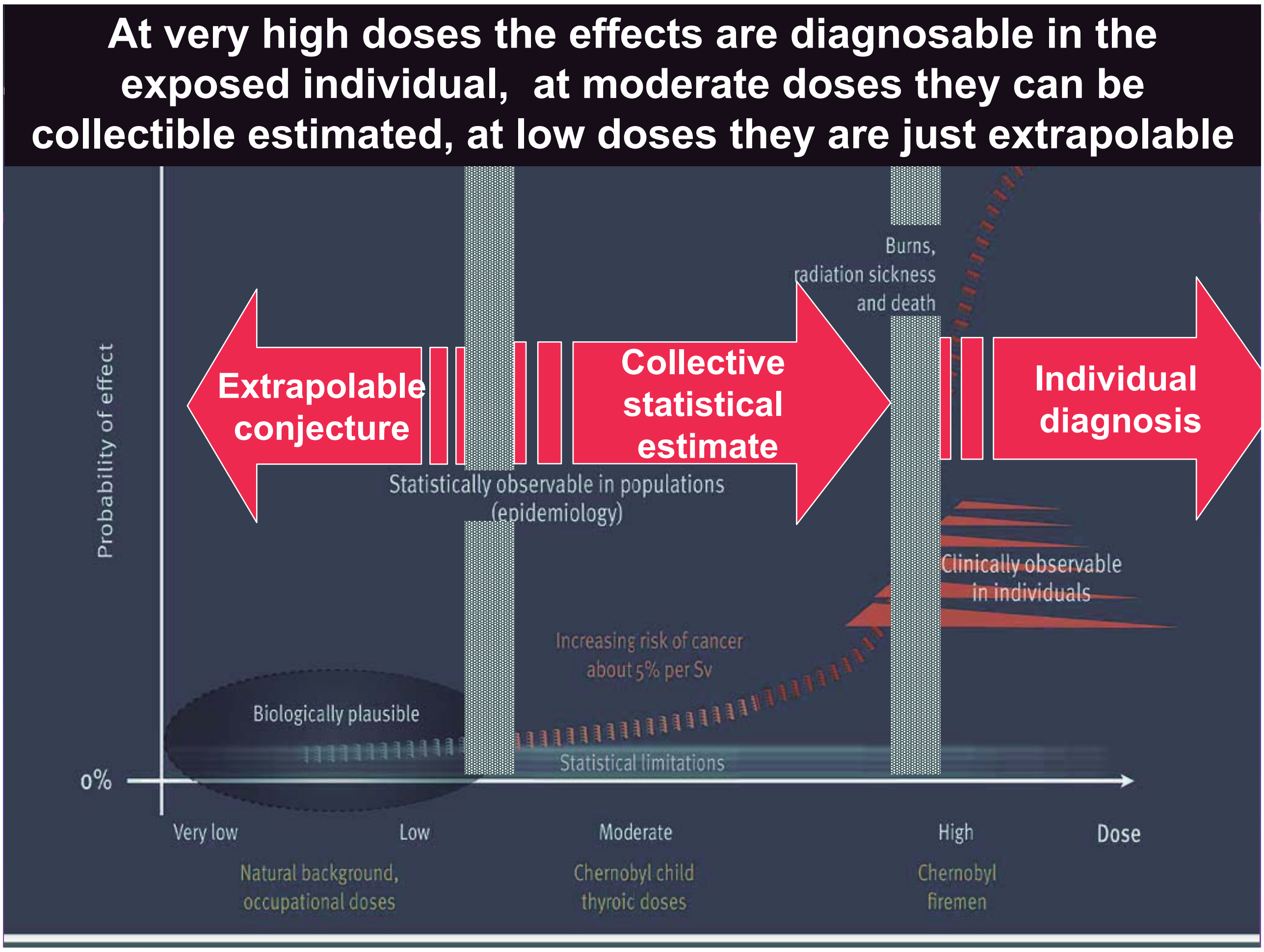
- Can you impute on behalf of a client?
- Can you defend your client from an imputation?

S

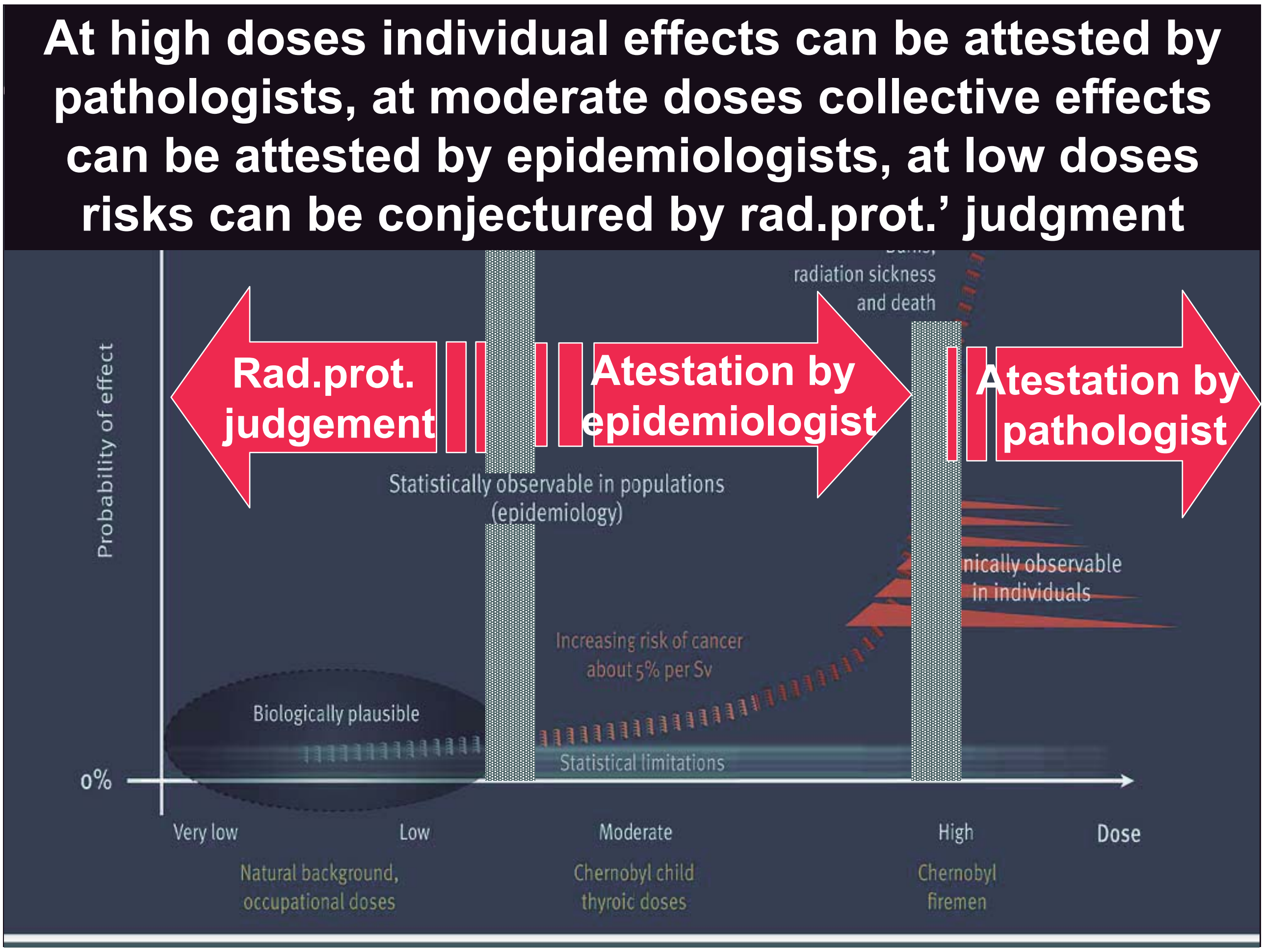
22


Imputation
Nuclear employer
Attributable radiation effect
Nuclear worker
Imputation
Nuclear operator
Attributable radiation effect
Public
Imputation
23


A clear distinction between effects:
clinically observable, statistically observable and biologically plausible
100%
Probability of effect
Burns, radiation sickness and death
Statistically observable in populations (epidemiology)
Clinically observable in individuals
Increasing risk of cancer about 5% per Sv
Biologically plausible
Statistical limitations
0%
Very low
Low
Moderate
High
Dose
Natural background, occupational doses
Chernobyl child thyroic doses
Chernobyl firemen

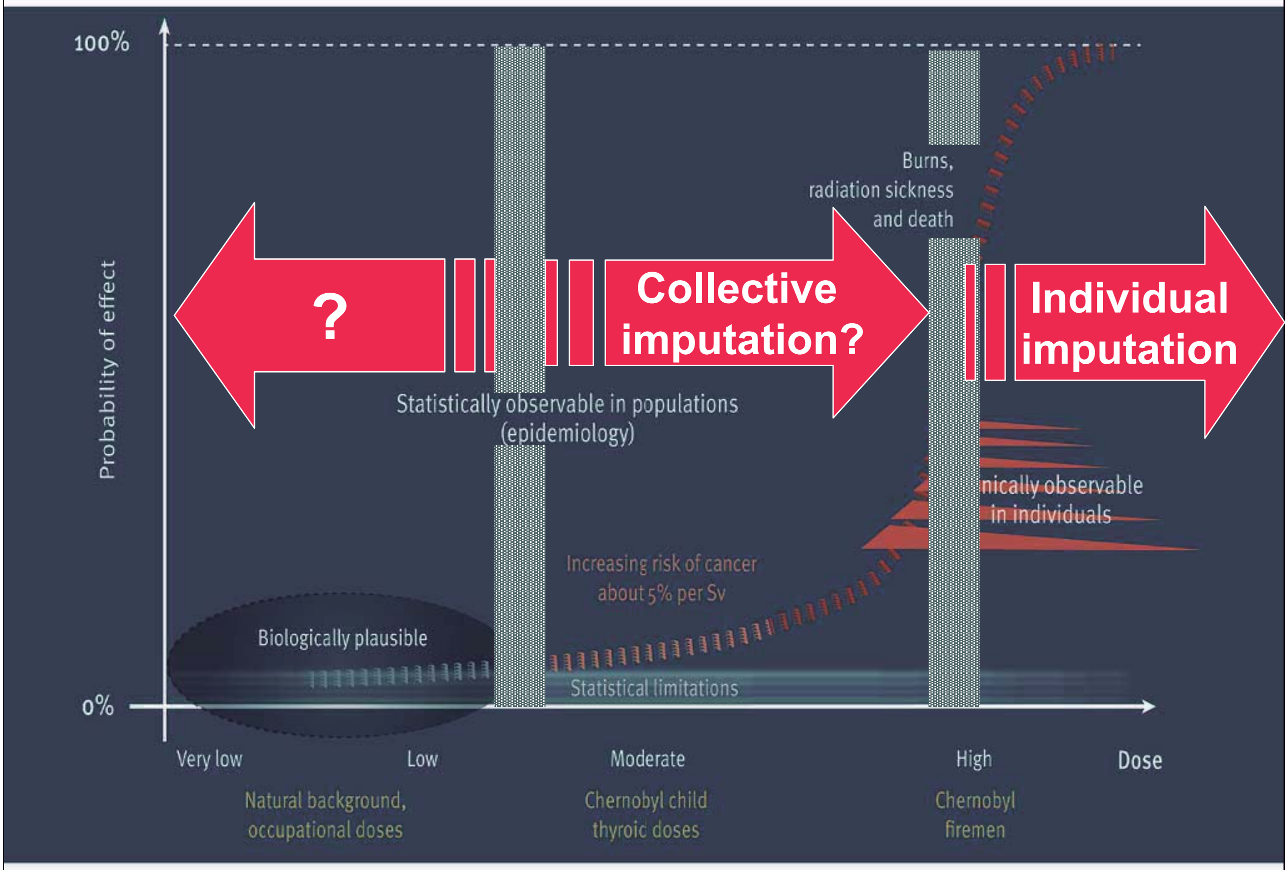


At very high doses the effects are diagnosable in the exposed individual, at moderate doses they can be collectible estimated, at low doses they are just extrapolable
Probability of effect
Extrapolable conjecture
Collective statistical estimate
Individual diagnosis
Burns, radiation sickness and death
Statistically observable in populations (epidemiology)
Clinically observable in individuals
Increasing risk of cancer about 5% per Sv
Biologically plausible
Statistical limitations
0%
Very low
Low
Moderate
High
Dose
Natural background, occupational doses
Chernobyl child thyroic doses
Chernobyl firemen



At high doses individual effects can be attested by pathologists, at moderate doses collective effects can be attested by epidemiologists, at low doses risks can be conjectured by rad.prot.' judgment
Probability of effect
radiation sickness and death
Rad.prot. judgement
Atestation by epidemiologist
Atestation by pathologist
Statistically observable in populations (epidemiology)
in individuals
Increasing risk of cancer about 5% per Sv
Biologically plausible
Statistical limitations
0%
Very low
Low
Moderate
High
Dose
Natural background, occupational doses
Chernobyl child thyroic doses
Chernobyl firemen

How to impute (or reject an imputation)



Imputation of effects on an individual

(for high doses)

- Classic case……

………nothing new!

Imputation of effects on a population

(for moderate doses)

- Through a *class action*, a type of lawsuit where one of the parties is a group of people who are represented collectively by a member of that group.
- It has been predominantly a U.S. phenomenon, but other countries are introducing similar actions (e.g. consumer organizations to bring claims on behalf of consumers).

Imputation of inferred risks

(at low doses)

?

However, legal cases involving low doses continue to occur in real life!

Fukushima nuclear disaster: Worker sues Tepco over cancer

2 February 2017 **BBC**

Fukushima nuclear disaster

AFP

The case of a man who developed leukaemia after working as a welder at the Fukushima nuclear site

- The plaintiff, 42, was the first person to be recognised by labour authorities as having an illness linked to clean-up work at the plant.
- He sued Tokyo Electric Power Company.
- The man was a welder for a sub-contractor.
- He spent six months working at Genkai and Fukushima No 2 nuclear plants before moving to the Fukushima No 1 plant, where he build scaffolding for repair work at the No 4 reactor building.

- His cumulative radiation exposure was **19.78 mSv**.
- Official limits in Japan currently allows workers at the plant to accumulate 100 mSv over five years.
- But in October 2015, a health ministry panel ruled that the man's illness was workplace-related and that he was eligible for compensation. "**While the causal link between his exposure to radiation and his illness is unclear, we certified him from the standpoint of worker compensation**", a health ministry official said at the time.

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Japan confirms first Fukushima worker death from radiation

5 September 2018

Fukushima nuclear disaster

AFP/GETTY IMAGES

Japan has announced for the first time that a worker at the Fukushima nuclear power plant died after suffering radiation exposure.

- The man, who was in his 50s, died from lung cancer that was diagnosed in 2016.
- Japan's government had previously agreed that radiation caused illness in four workers but this is the first acknowledged death.
- The employee who died had worked at atomic power stations since 1980 and was in charge of measuring radiation at Fukushima plant shortly after its meltdown.
- He worked there at least twice after it was damaged, and had worn a face mask and protective suit, Japan's Ministry of Health, Labour and Welfare said.
- After hearing opinions from a panel of radiologists and other experts, the ministry ruled that the man's family should be paid compensation.

36

Cases that do not even involve radiation exposure

- Though people were not exposed to radiation, plant operator Tokyo Electric Power Company (Tepco) is facing several compensation claims.

37

Profesional negligence

- More than 40 patients were evacuated from a hospital in the area and later died, while other deaths have been linked to the trauma suffered by those who lost their homes and loved ones.
- Former Tepco executives went on trial charged with professional negligence linked to the hospital evacuation.

38

Psychological consequences of Fukushima

A Japanese court has ordered the operator of the Fukushima nuclear plant to pay damages to the family of an evacuee who killed herself.

- Tokyo Electric Power Company (Tepco) will pay the family of Hamako Watanabe 49 million yen (£284,000, $472,000).
- Ms Watanabe killed herself after she was forced to leave her home due to radioactive contamination.
- The case could open the way for many others to sue Tepco for compensation

40

- In June 2011, three months after the plant's failure, Mrs Watanabe and her husband Mikio were forced to evacuate their home because of radioactive contamination. Their home in Kawamata town was about 40km from the plant.
- The family moved to an apartment in Fukushima city. Weeks later Mrs Watanabe, 58, doused herself in kerosene and set herself on fire.
- Her husband and three children sued Tepco for 91 million yen.
- They claimed the evacuation was responsible for a deterioration of Mrs Watanabe's mental state because she did not know when she could return home, according to Kyodo news agency.

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Epilogue

In sum:

- dealing with the imputation of effects to high, moderate, and low radiation doses;
- addressing open legal issues arising from the aftermath of nuclear accidents……..

…are just some of the many challenges that are waiting for you!

International safety Regime

González, A.J.

Clase dictada en el Curso del Summer Institute 2022 de la Universidad Nuclear Mundial, llevado a cabo en la Universitat Politècnica de València (UPV), en Valencia, España, del 19 al 25 de junio de 2022

WORLD NUCLEAR UNIVERSITY
SUMMER INSTITUTE 2022

World Nuclear University
Summer Institute – 2022
Valencia-España-24/6/2022

International Safety Regime

Abel J. González

UNSCEAR Representative, IAEA' CSS Member

Autoridad Regulatoria Nuclear

✉Av. Del Libertador 8250; (1429)Buenos Aires,Argentina☎+54 1163231758

1

SCIENCE

Epistemology of radiation

Method, validity and scope of the scientific knowledge about radiation

↓

PROTECTION PARADIGM

Conceptual ideal for keeping people protected

↓

INTERNATIONAL & INTERGOVERNMENTAL SAFETY REGIME

Establishing global safety undertakings and standards and providing for their application

UNSCEAR

ICRP

Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO

2

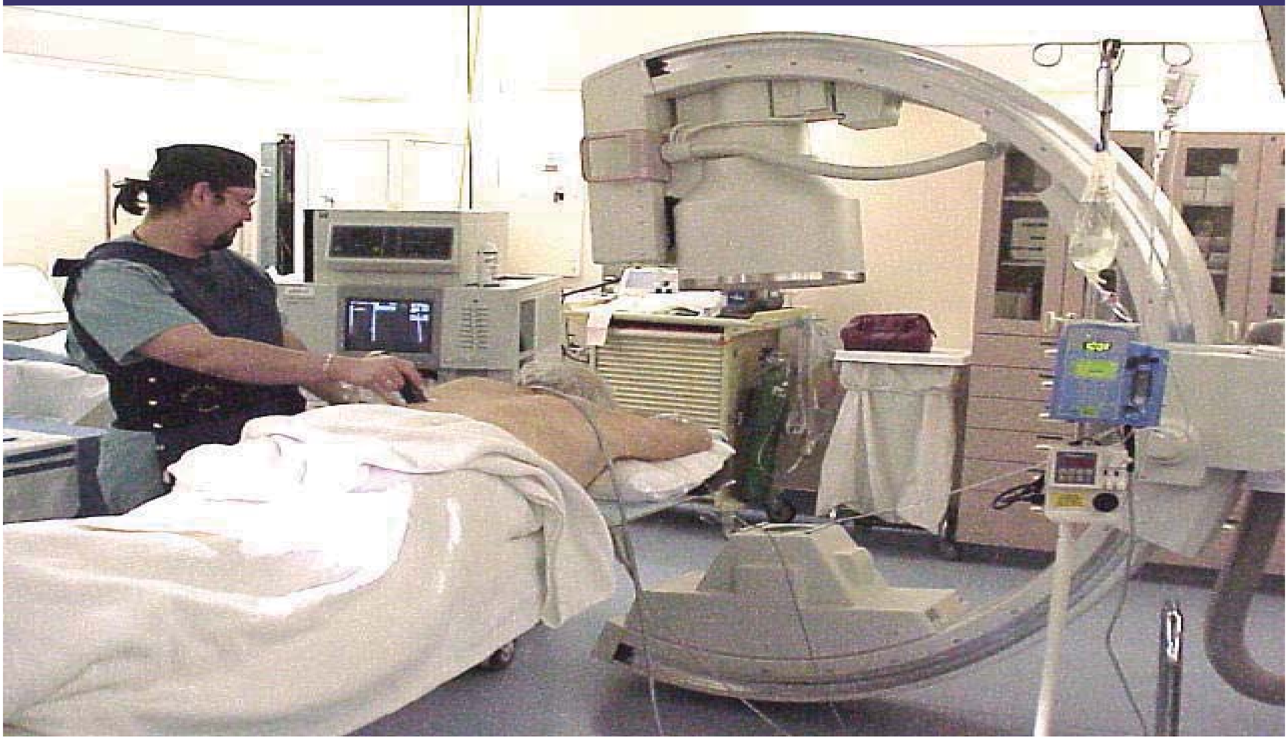
Paradigm

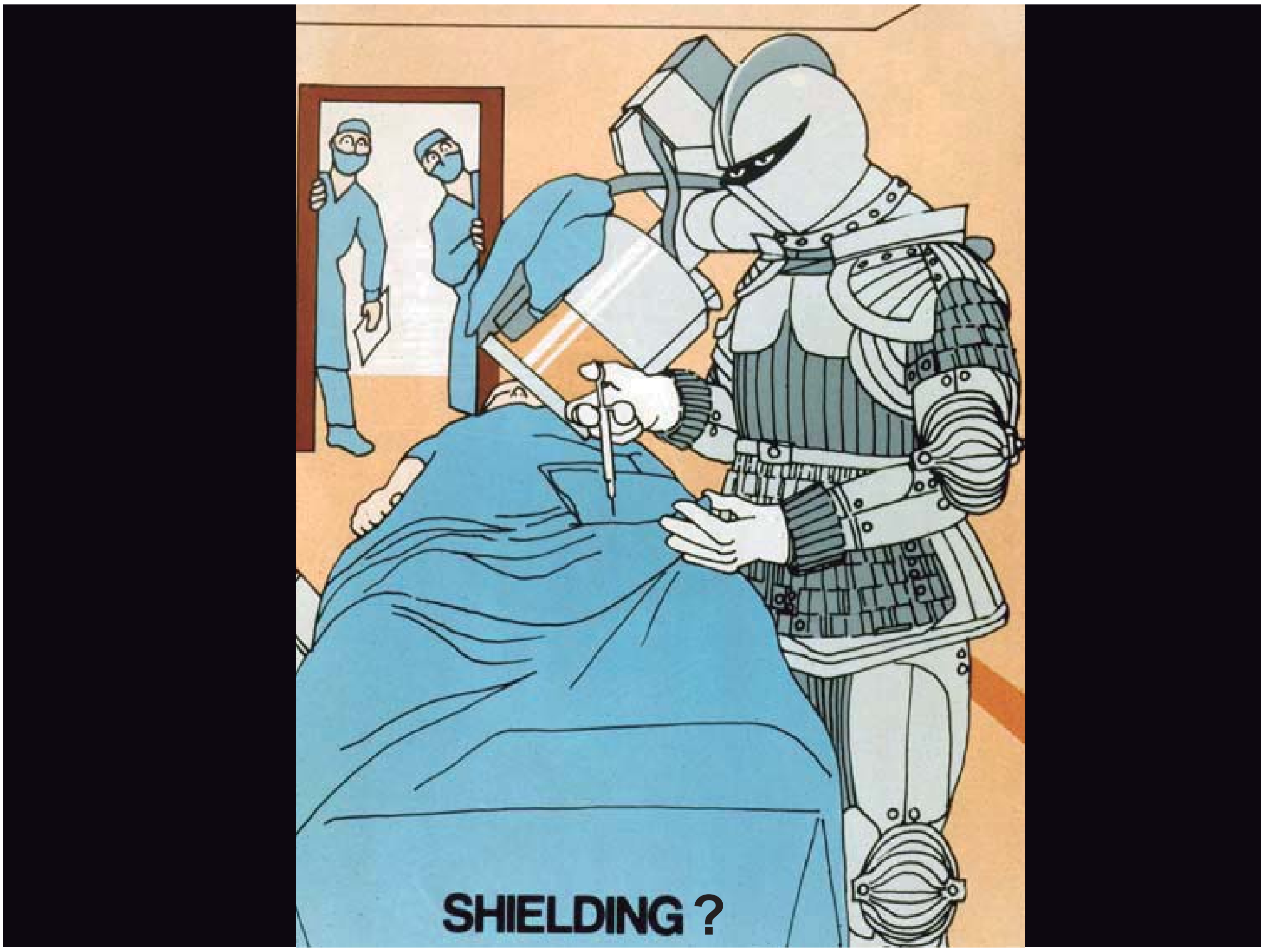
3

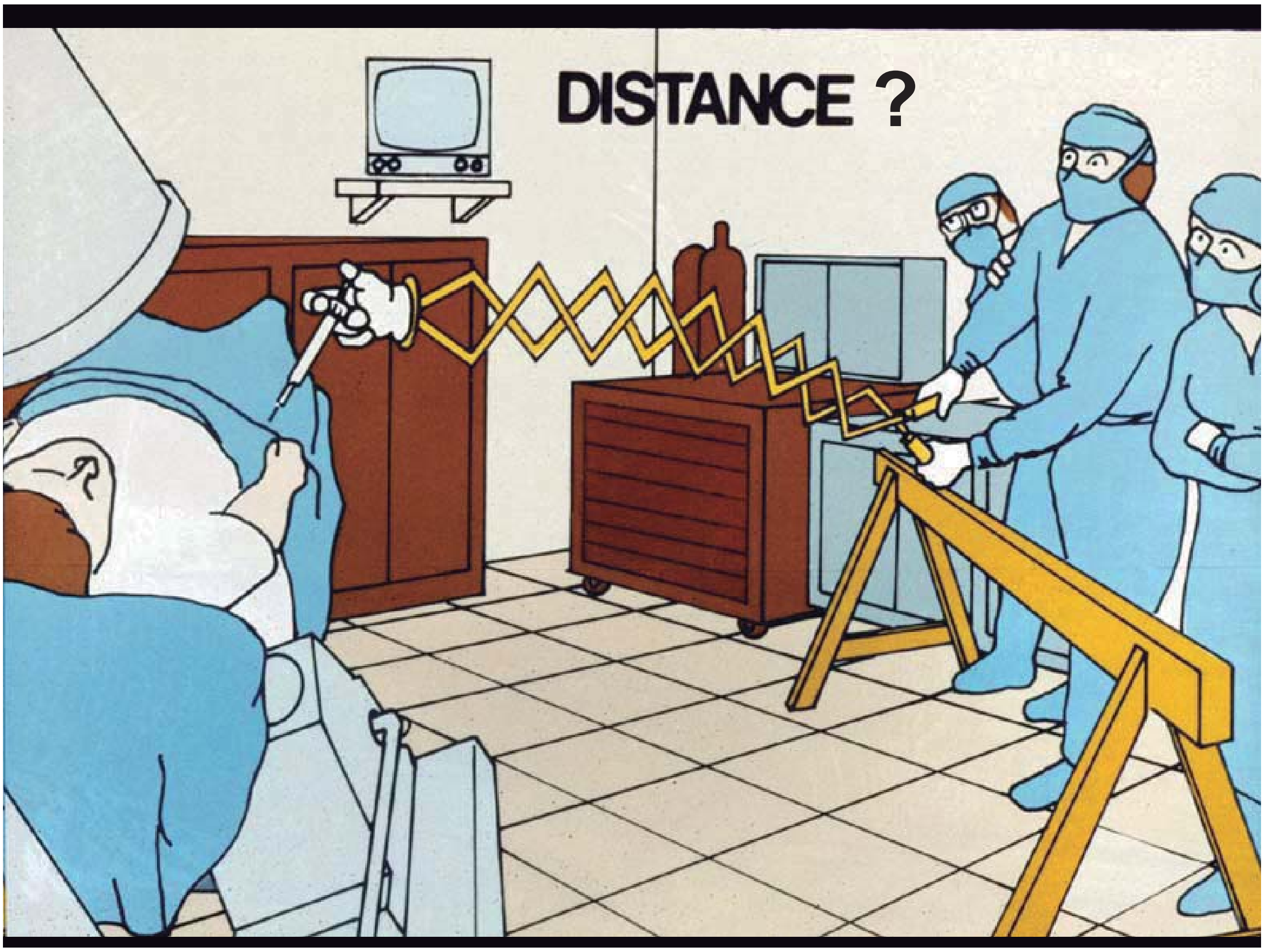
Protection → basic dogma

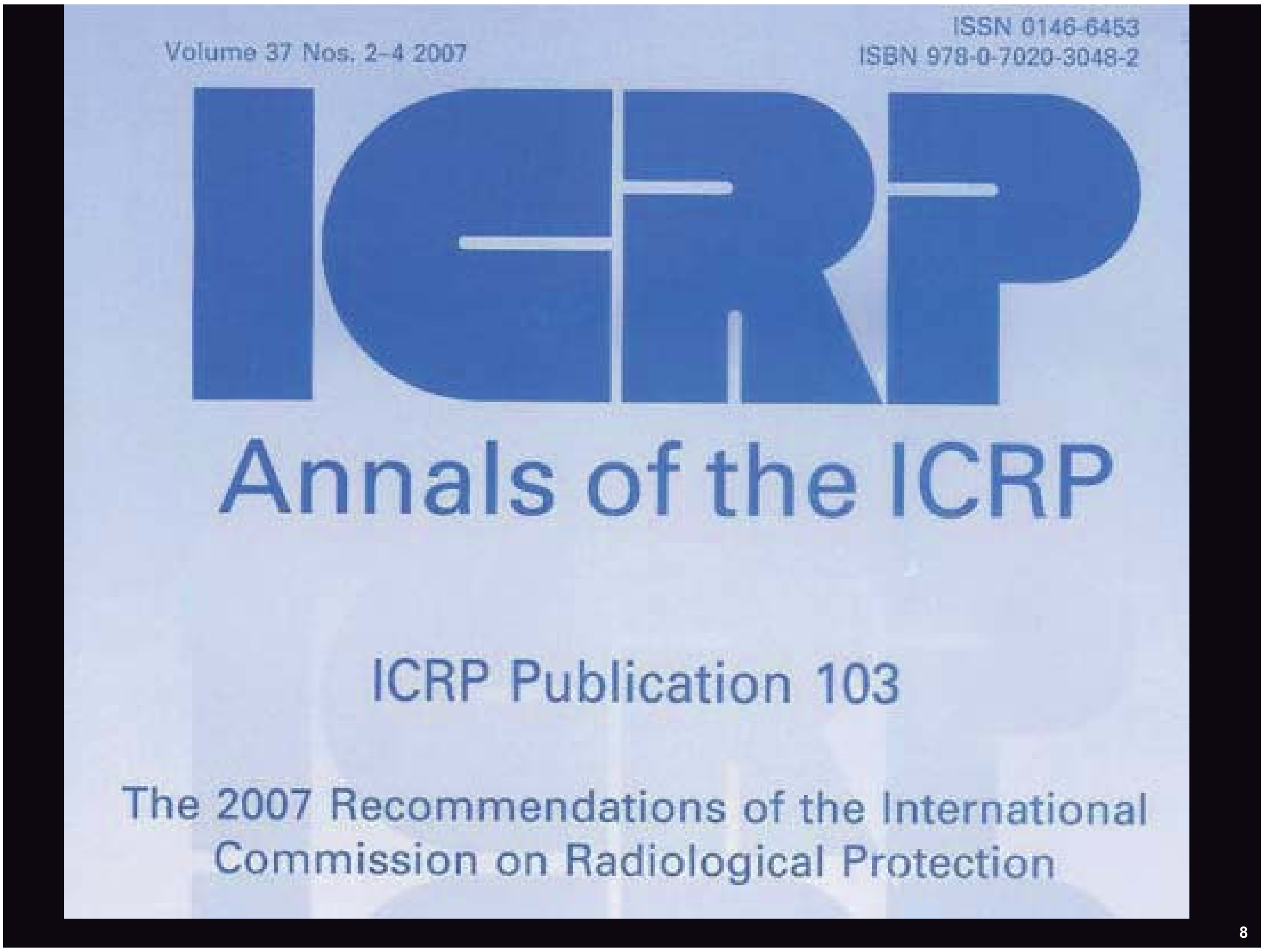
- Time
- Shielding
- Distance

Time?



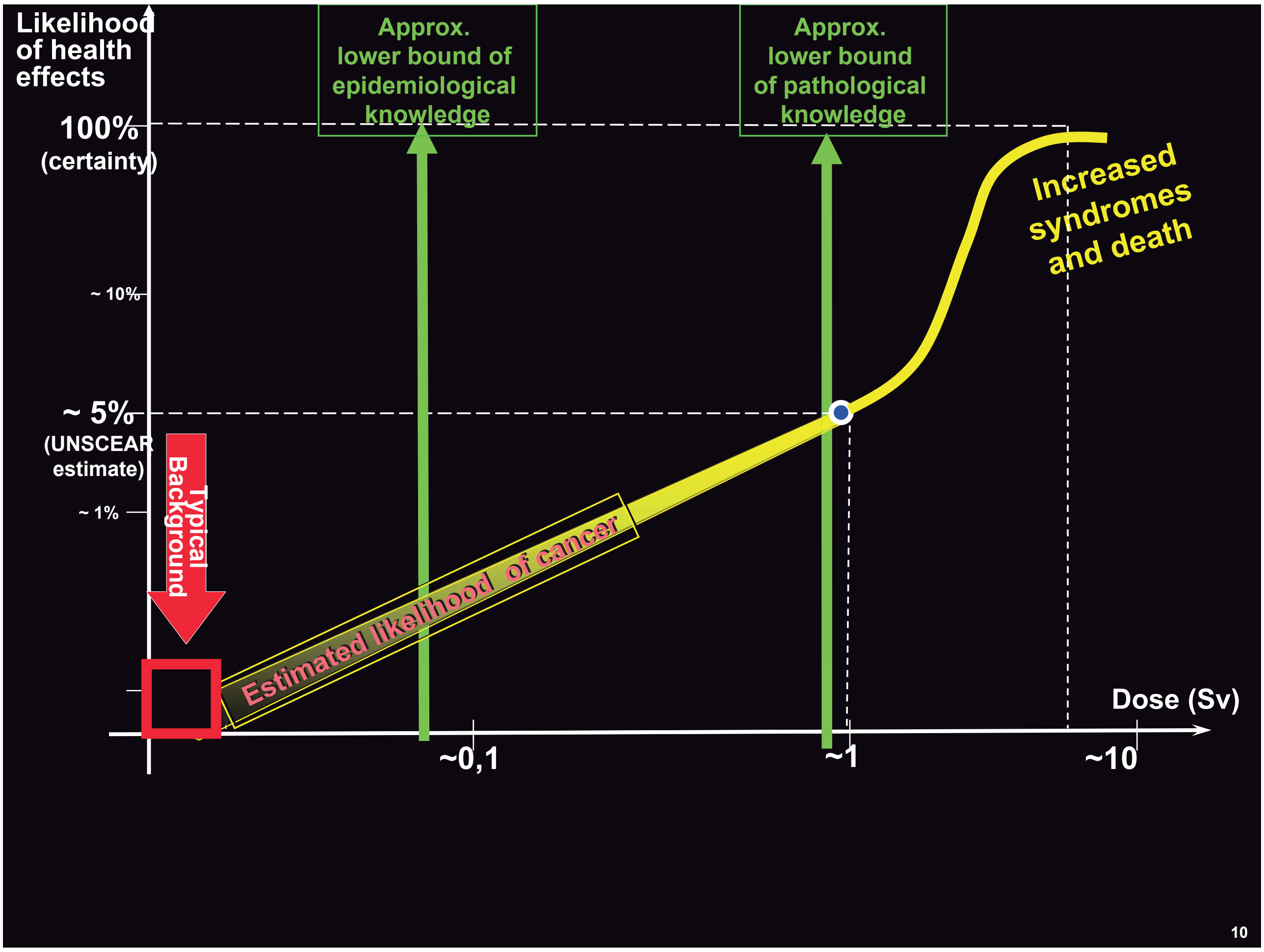


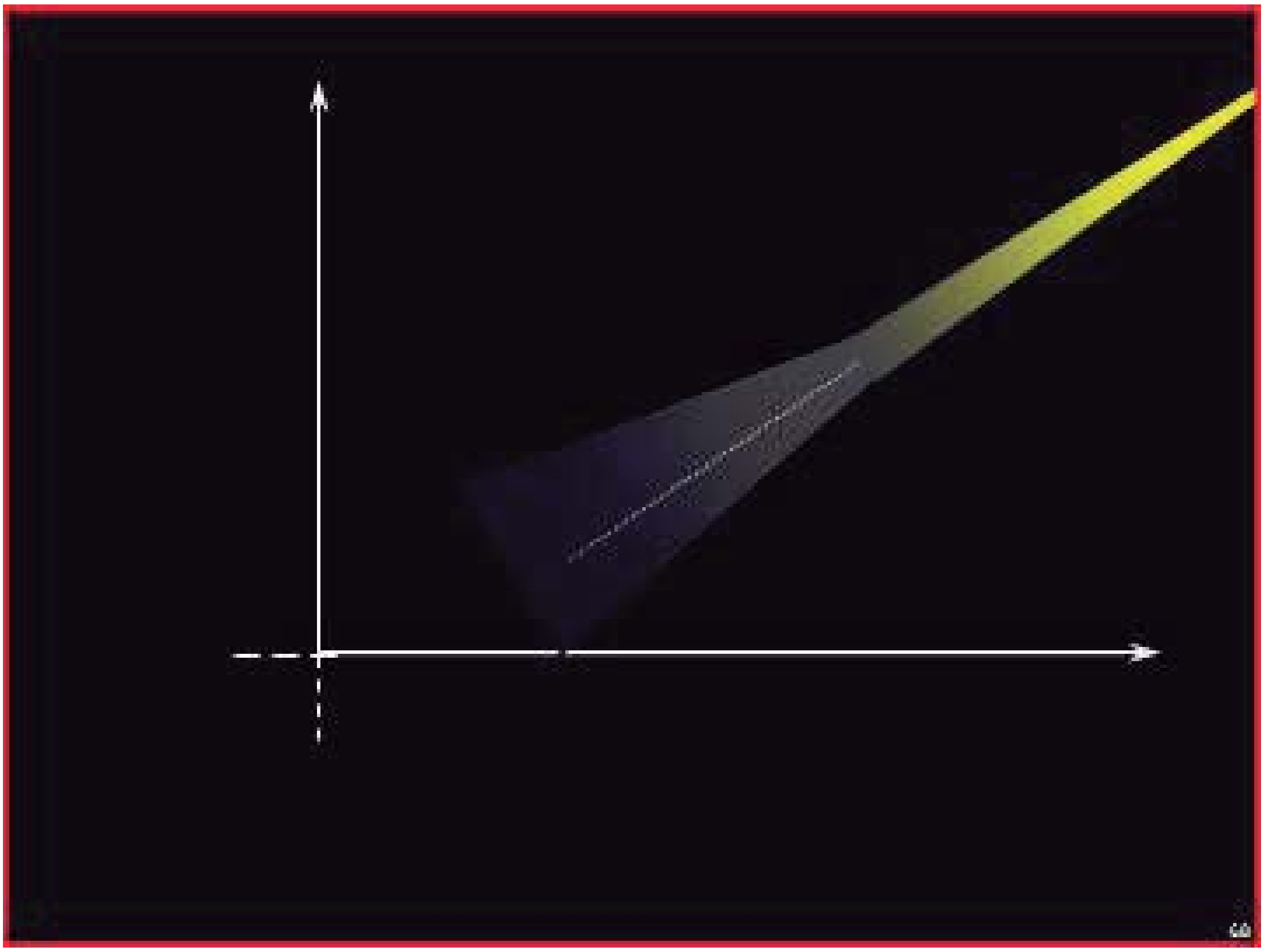

DISTANCE ?

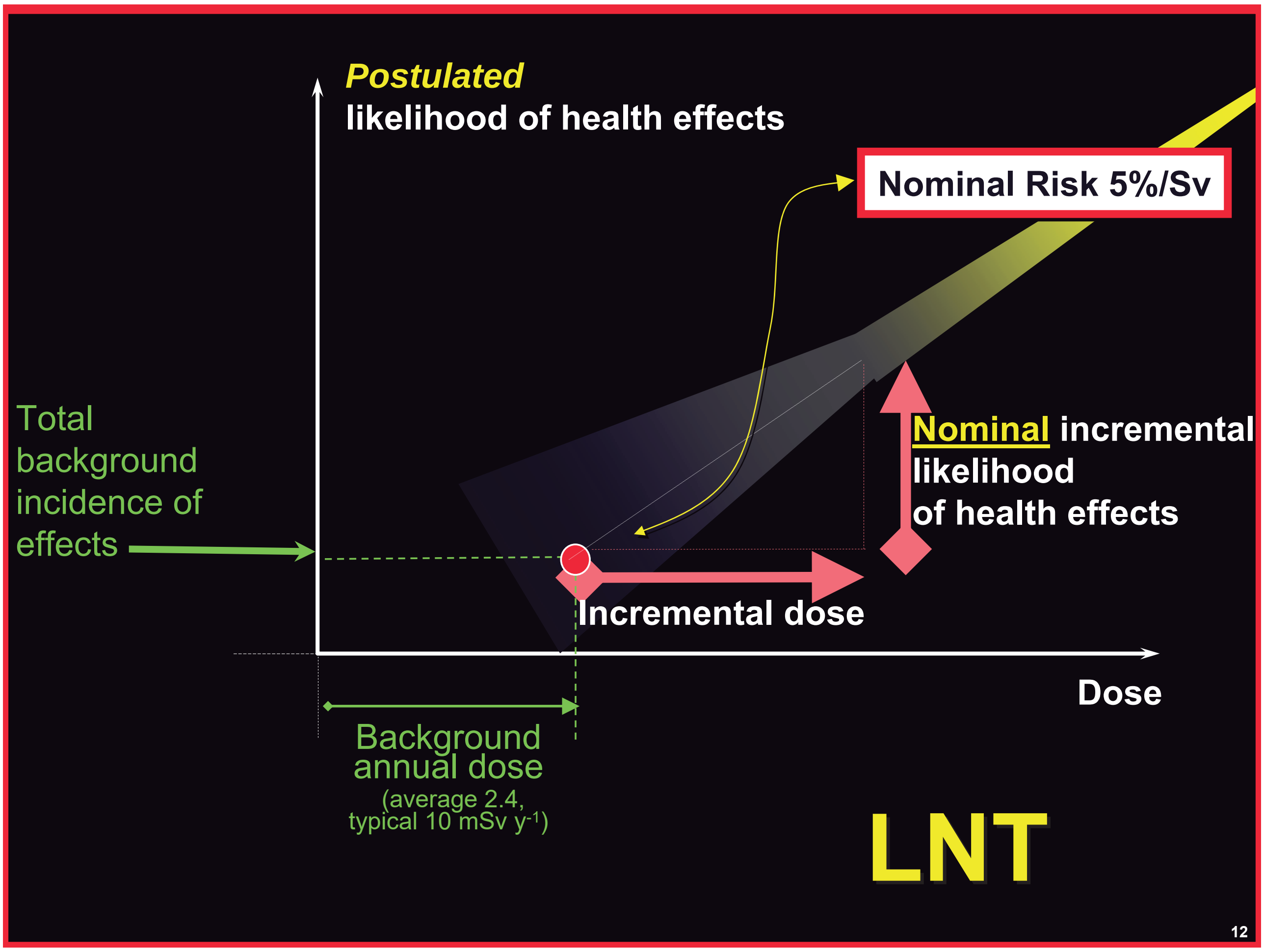

Volume 37 Nos. 2–4 2007
ISSN 0146-6453
ISBN 978-0-7020-3048-2
ICRP
Annals of the ICRP
ICRP Publication 103
The 2007 Recommendations of the International
Commission on Radiological Protection
8

Basic model

9

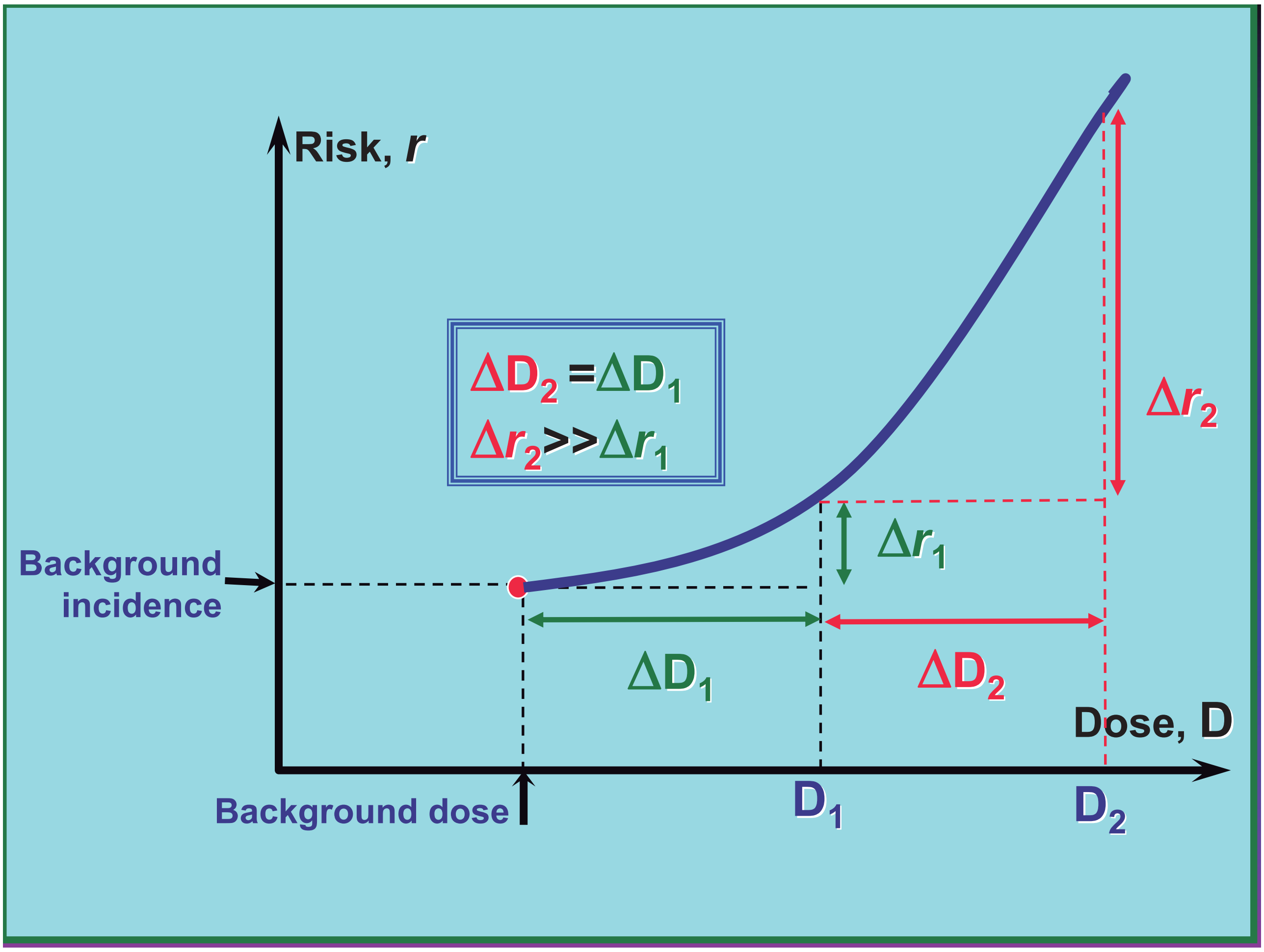






Postulated
likelihood of health effects
Nominal Risk 5%/Sv
Total background incidence of effects
Nominal incremental likelihood of health effects
Incremental dose
Dose
Background annual dose
(average 2.4, typical 10 mSv y-1)
LNT
12

- LNT is not a biological hypothesis but a *model for radiation protection purposes*
- LNT ‘provide the basis for the summation of doses from external sources of radiation and from intakes of radionuclides’.



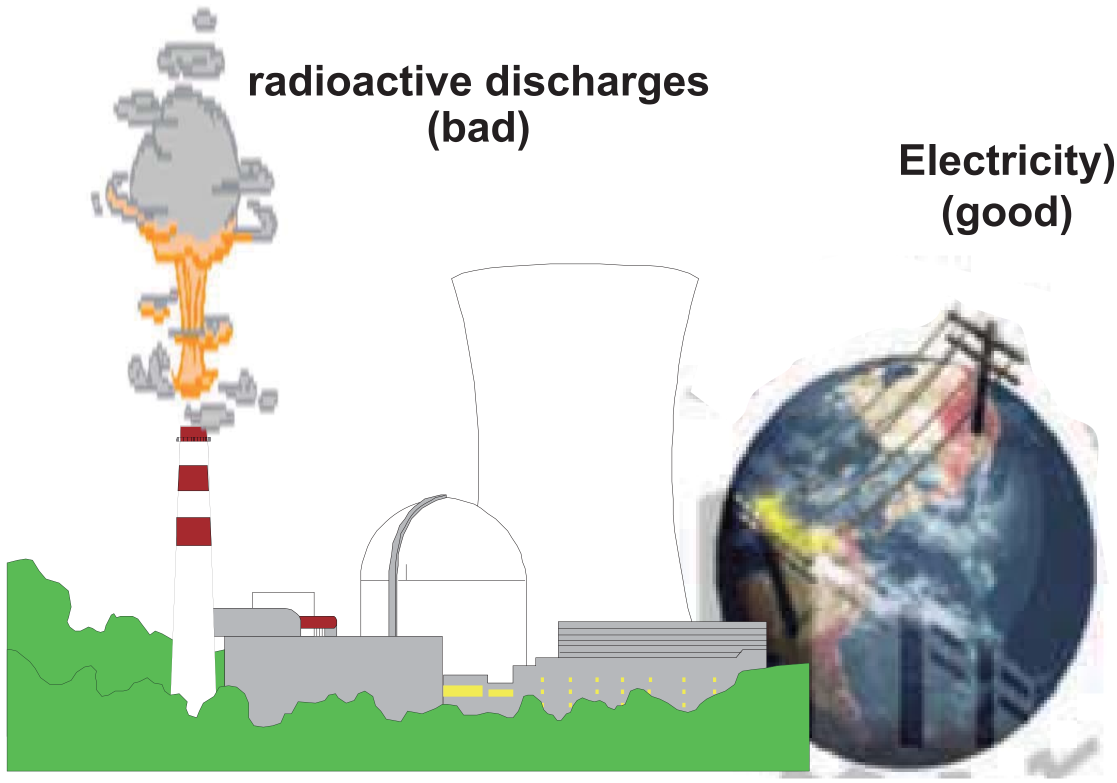
Main basic principles

- Justification of Decisions
- Optimization of Protection and Safety
- Restrictions on Individual Exposures

- Protect Future Generations/Environment

Justification of decisions

- Any decision that alters people's exposure should do more good than harm.



Is the installation justied?

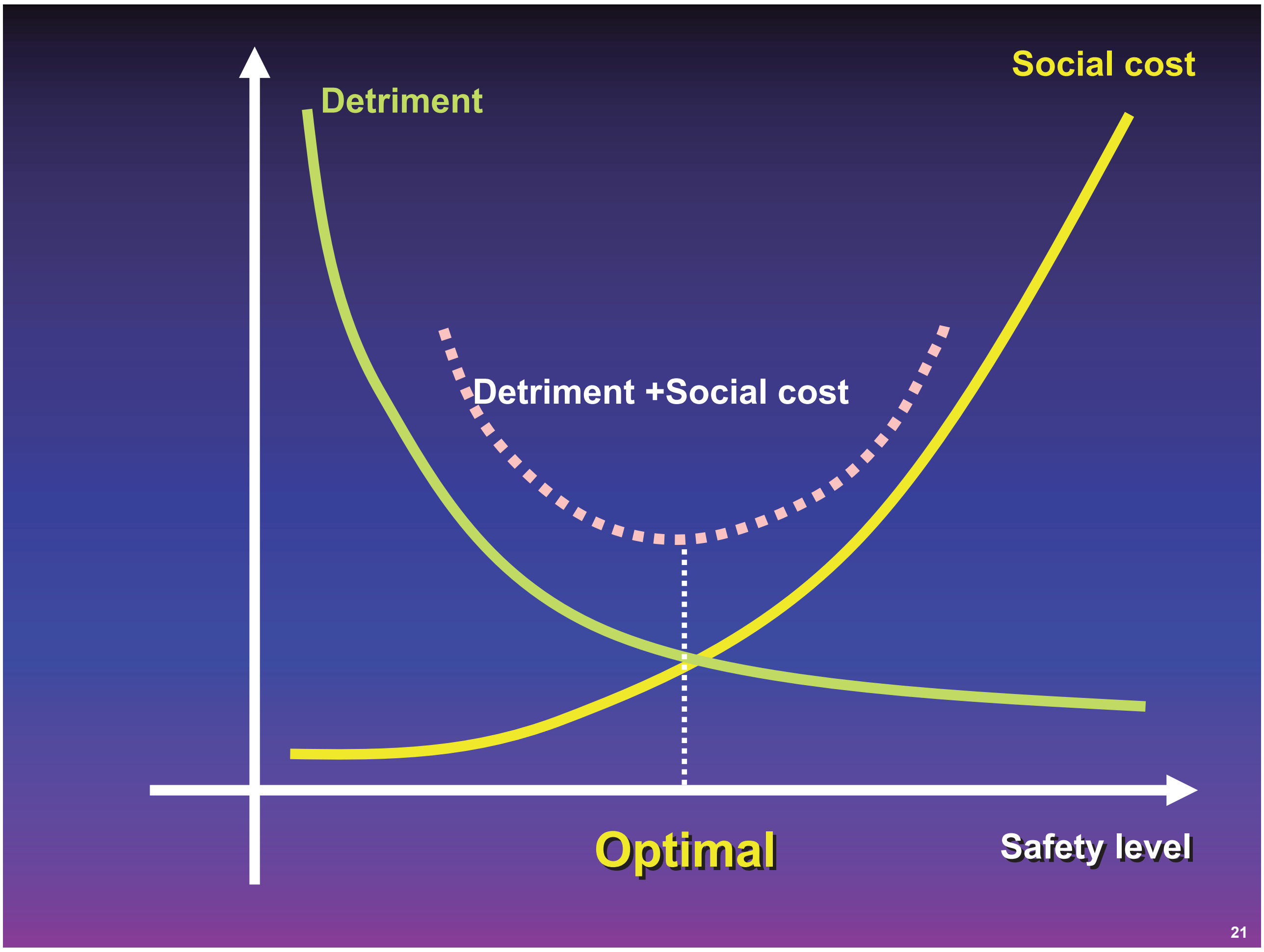
good > bad?

Is evacuation justified?

Optimization

- Select best protection and safety options……

…under the prevailing circumstances.



Individual Exposure Restrictions

(Dose and risk Limitation)

- **The total dose and risk to any individual should be restricted** (with *limits*, *constraints* or *reference levels*).

Future generations and the environment

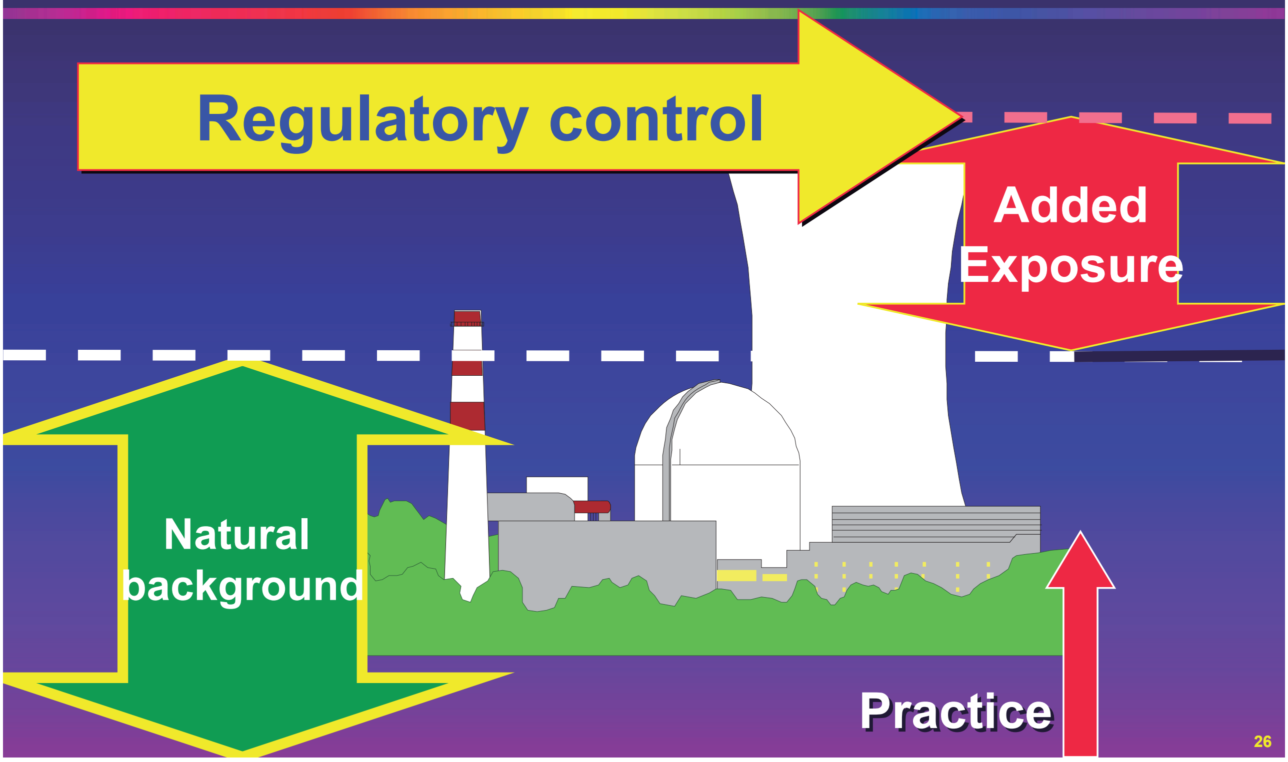
- Future generations must be protected.
- The environment must also be protected for:
  - maintaining biological diversity,
  - ensuring the conservation of species, and
  - protecting the health and status of natural habitats, communities, and ecosystems

23

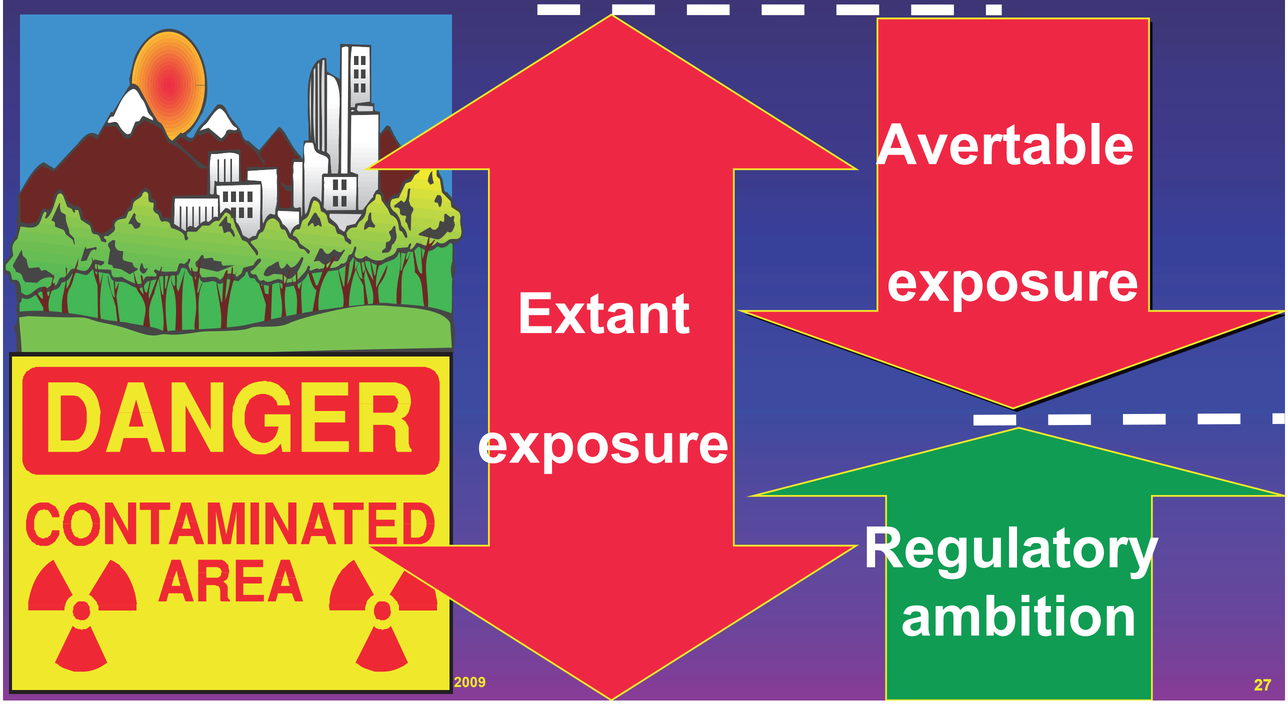
Types of situations

- **Planned** situations
- **Existing** (extant) situations
- **Emergency** situations

Planned situation



Emergency situations
Existing situations



Categories of exposure

3 systems

homogeneous, coherent and consistent….but distinct

- Patients
- Workers
- Public

29

Workers

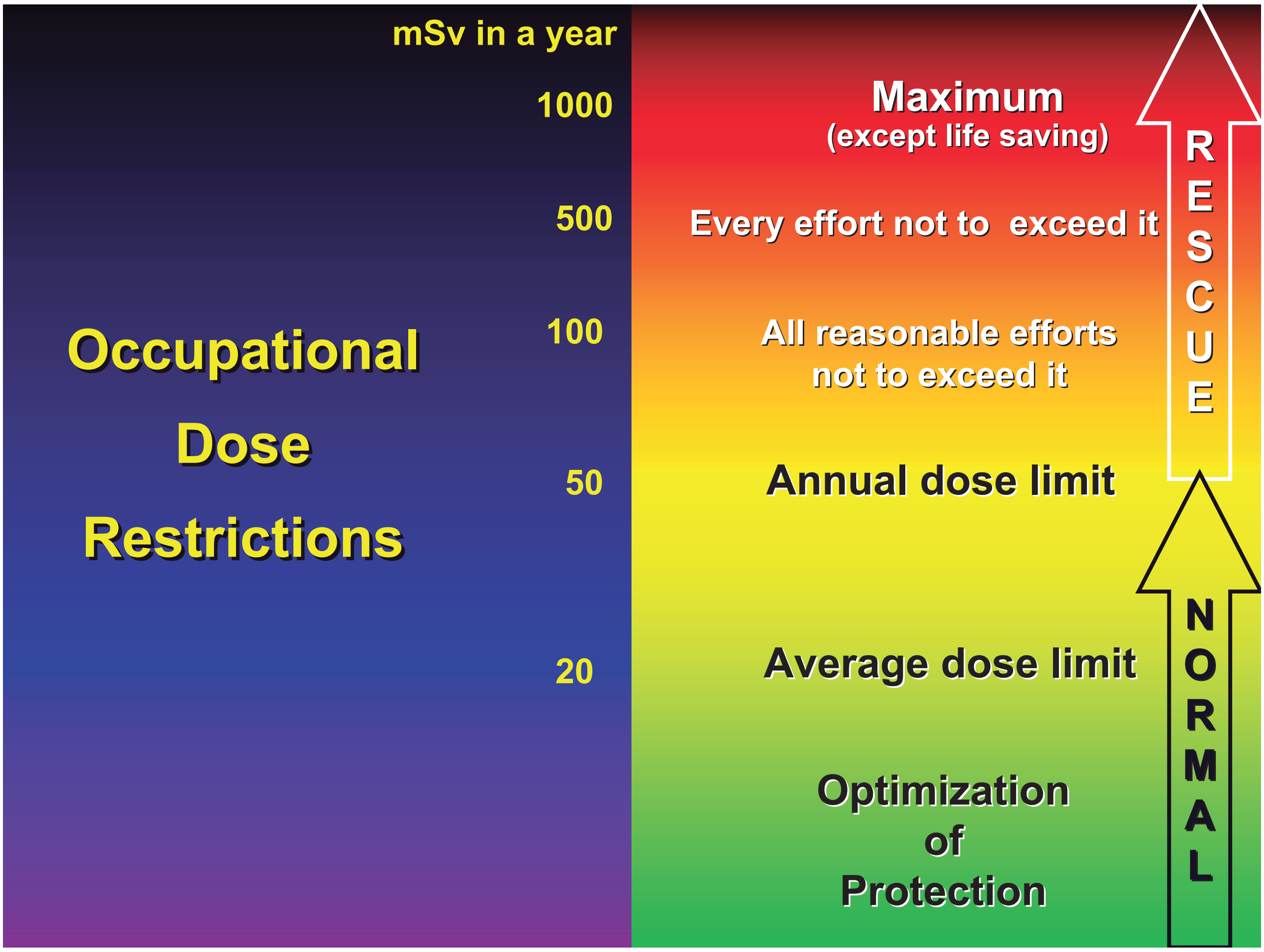
(voluntary and individually monitored exposure)

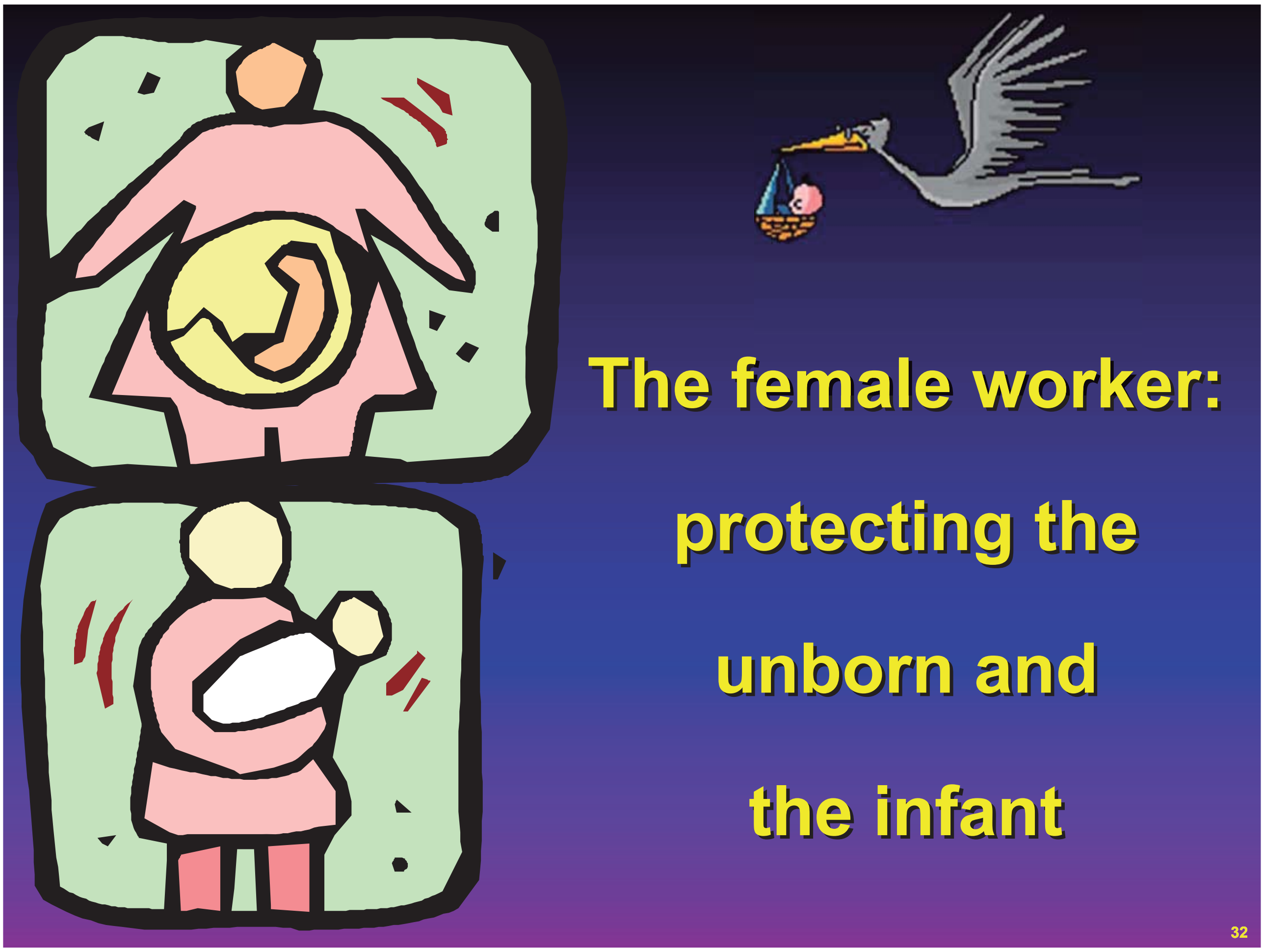
Monitored worker

Occupational exposure:

ALL exposure of workers incurred in the course of their work.

30


mSv in a year
1000
500
100
50
20
Occupational
Dose
Restrictions
Maximum
(except life saving)
Every effort not to exceed it
All reasonable efforts
not to exceed it
Annual dose limit
Average dose limit
Optimization
of
Protection
RESCUE
NORMAL


The female worker:
protecting the
unborn and
the infant
32

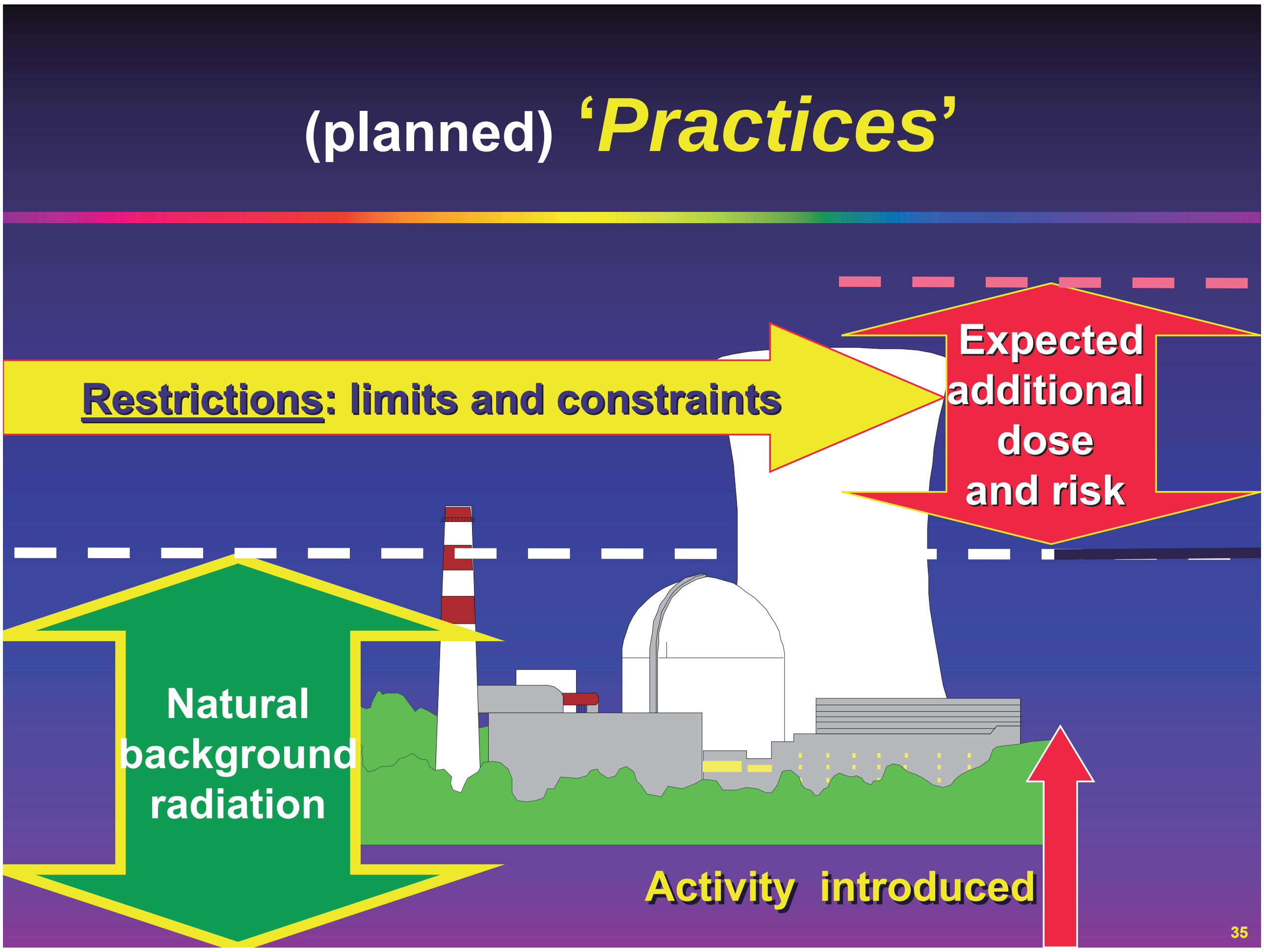
Members of the Public

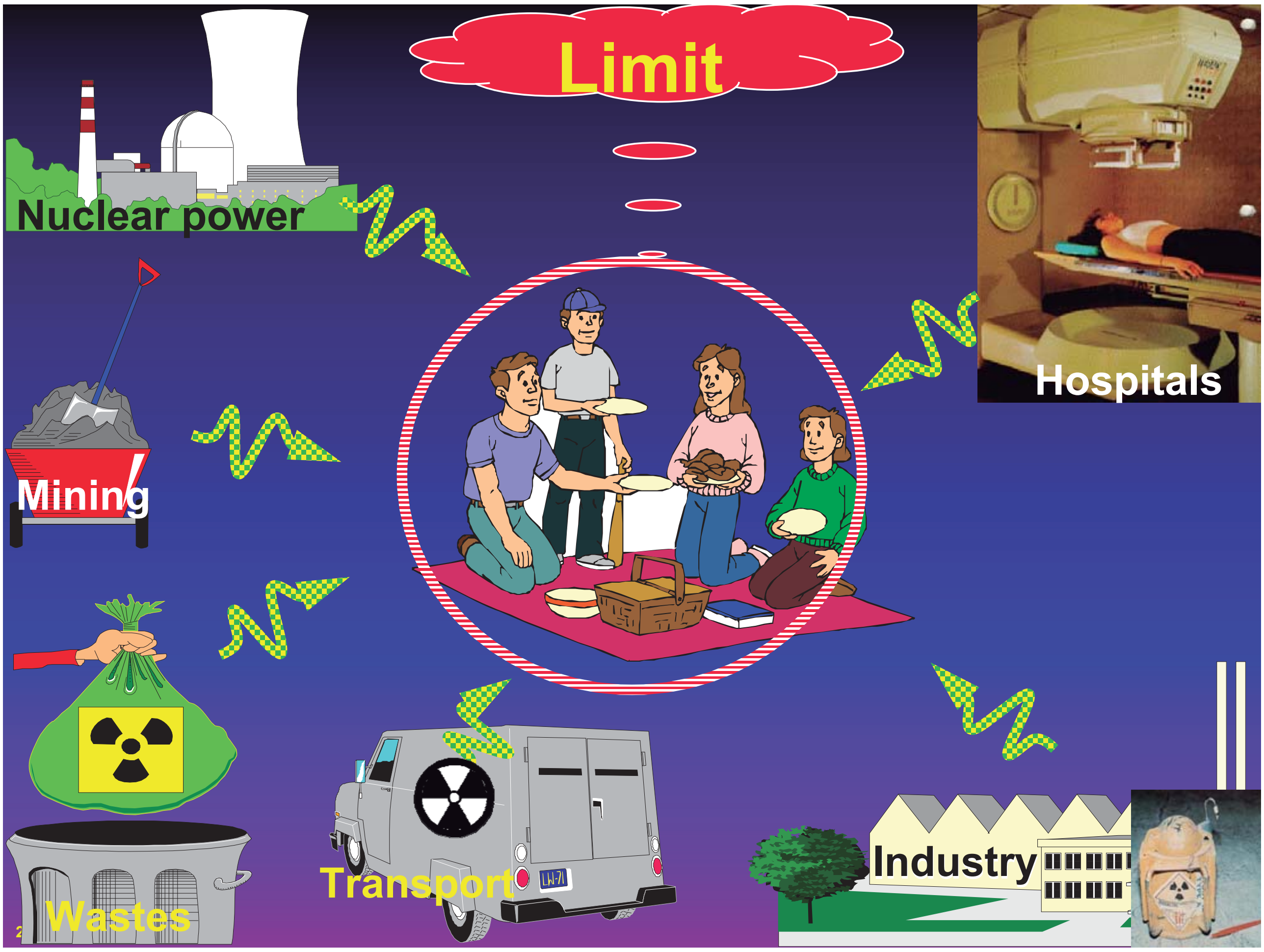
(involuntary no-individually monitored exposure)

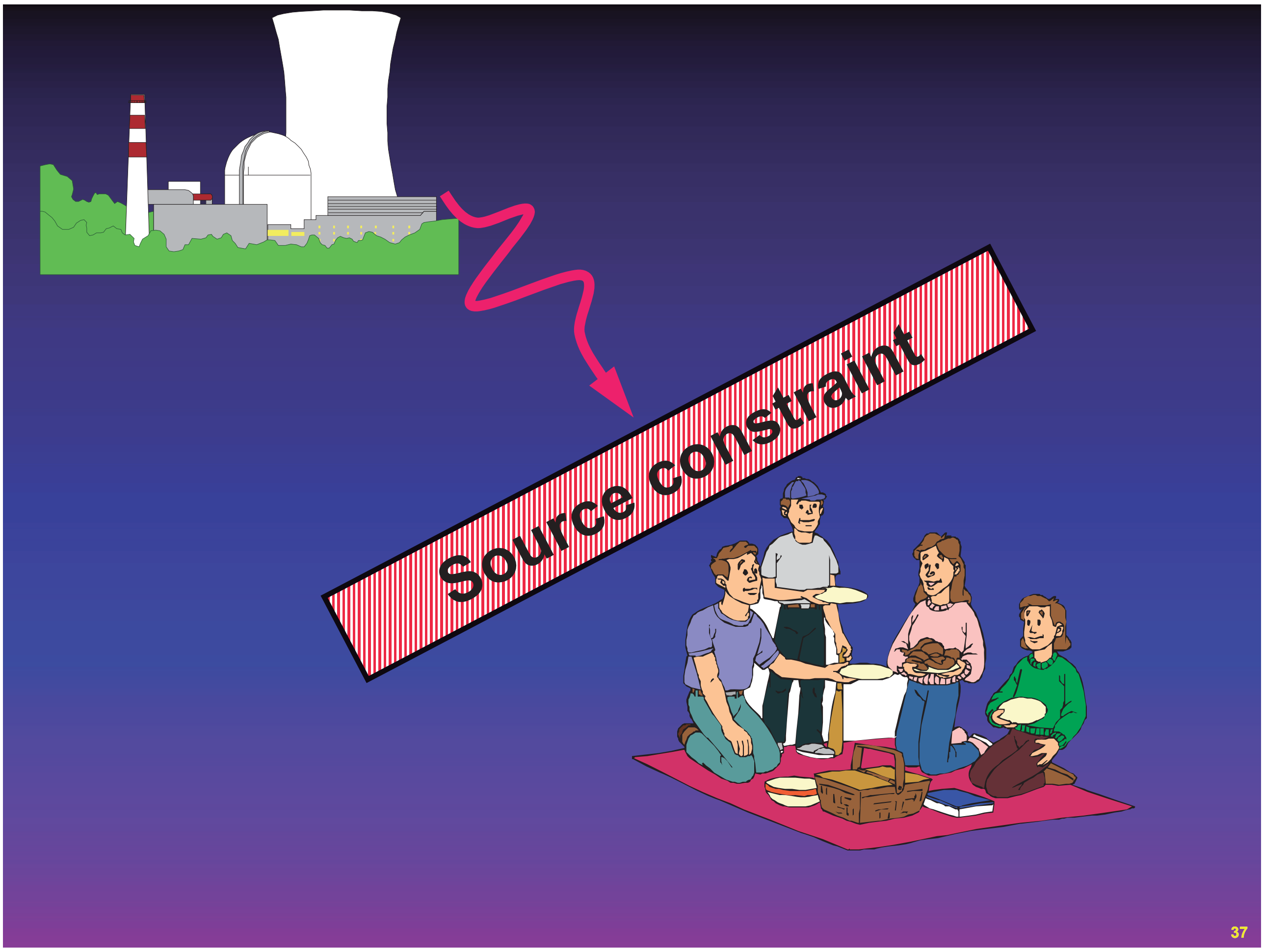
33

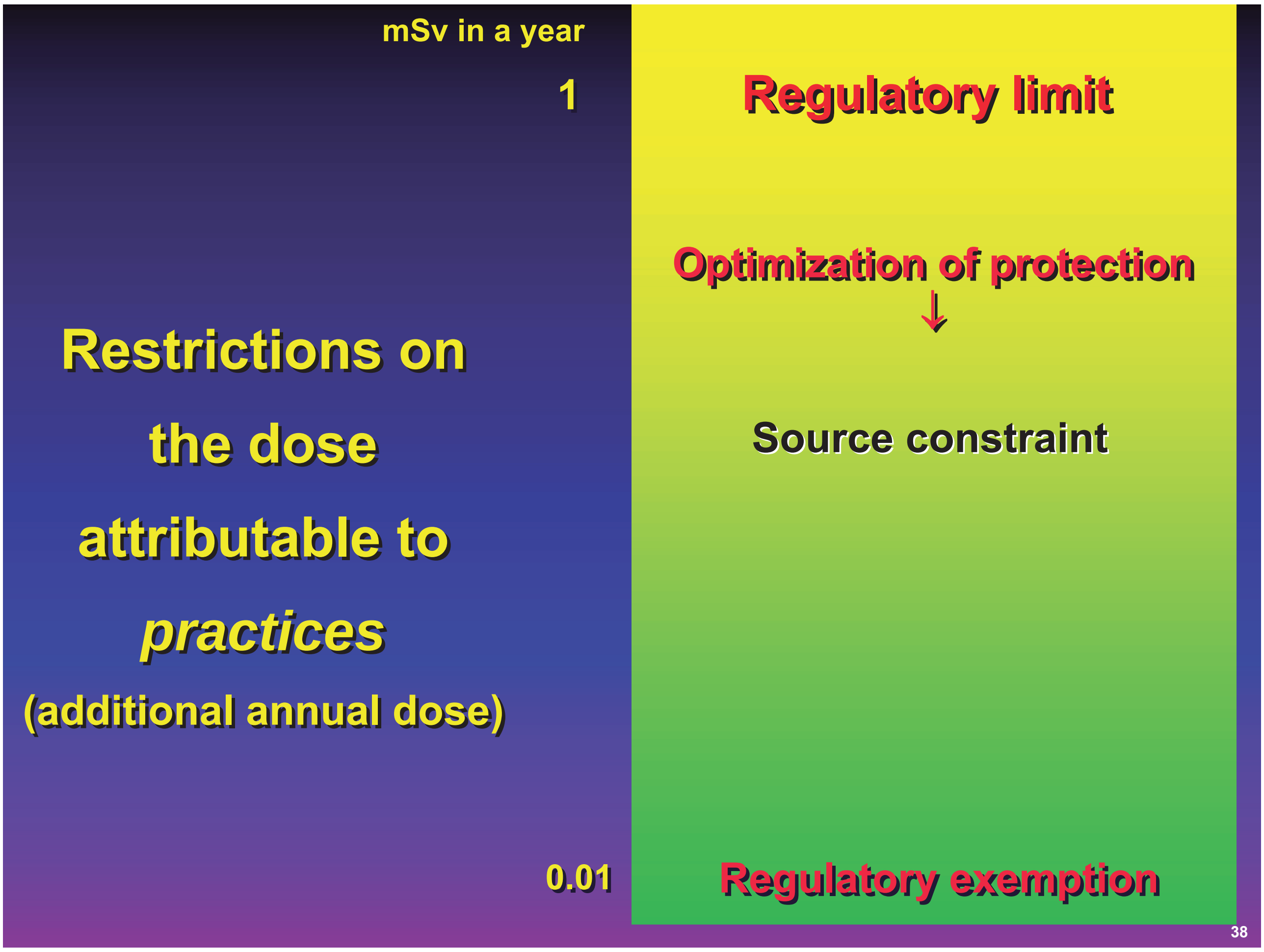
Planned Exposure Situations

(‘*Practices*’)


(planned) 'Practices'
Restrictions: limits and constraints
Expected additional dose and risk
Natural background radiation
Activity introduced
35


Limit
Nuclear power
Hospitals
Mining
Wastes
Transport
Industry


Source constraint
37


mSv in a year
1
0.01
Restrictions on
the dose
attributable to
practices
(additional annual dose)
Regulatory limit
Optimization of protection
↓
Source constraint
Regulatory exemption
38

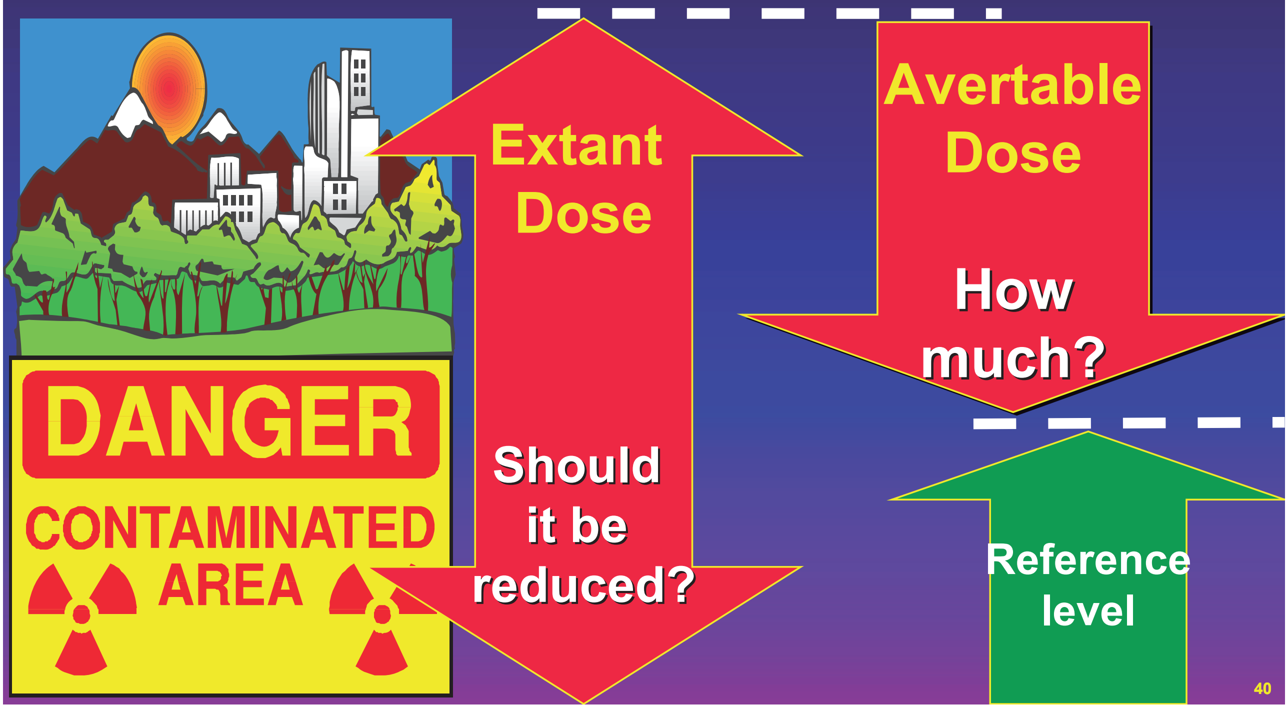
Existing and emergency situations

('Interventions')

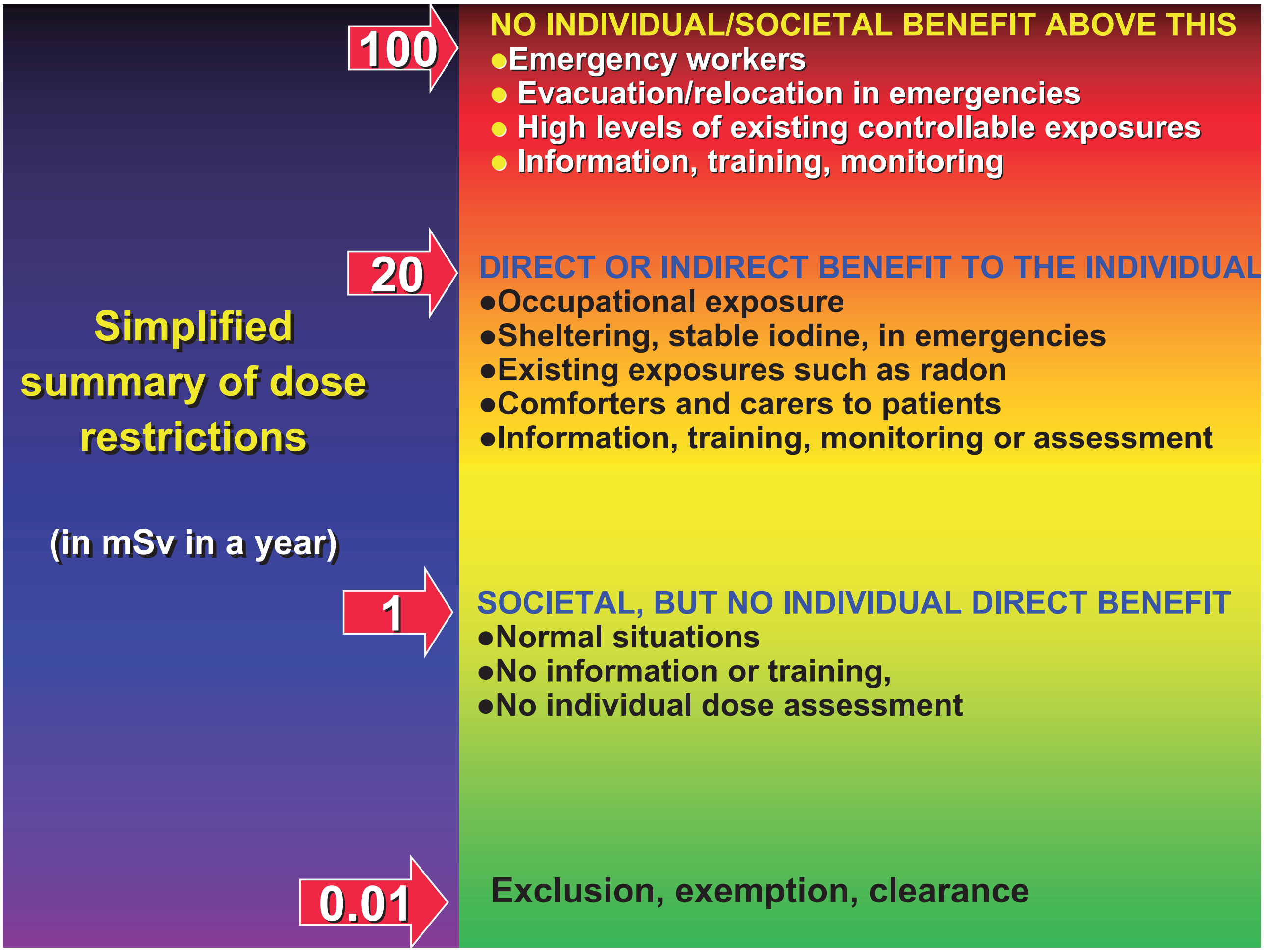
39

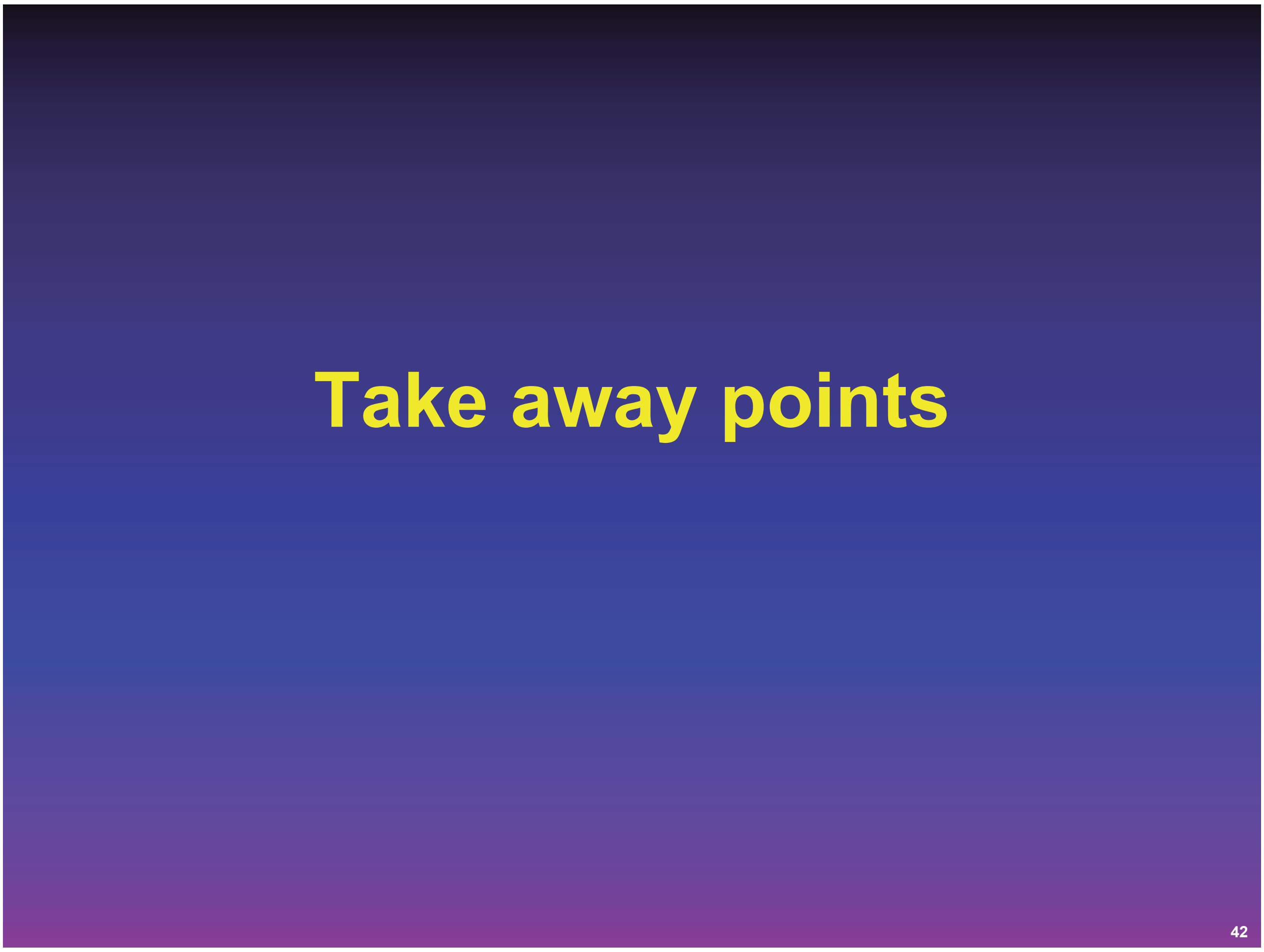
'Interventions'

(in existing and emergency situations)

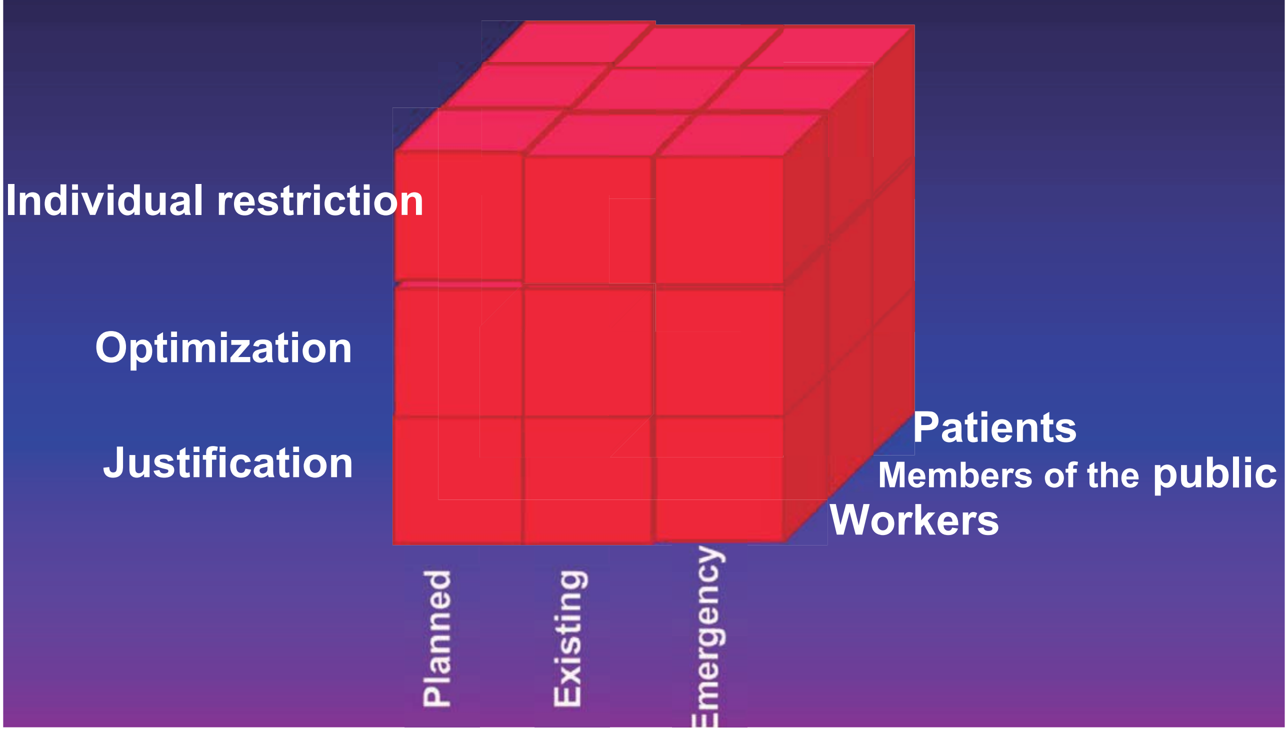


40


100
NO INDIVIDUAL/SOCIETAL BENEFIT ABOVE THIS
●Emergency workers
● Evacuation/relocation in emergencies
● High levels of existing controllable exposures
● Information, training, monitoring
20
DIRECT OR INDIRECT BENEFIT TO THE INDIVIDUAL
●Occupational exposure
●Sheltering, stable iodine, in emergencies
●Existing exposures such as radon
●Comforters and carers to patients
●Information, training, monitoring or assessment
Simplified summary of dose restrictions
(in mSv in a year)
1
SOCIETAL, BUT NO INDIVIDUAL DIRECT BENEFIT
●Normal situations
●No information or training,
●No individual dose assessment
0.01
Exclusion, exemption, clearance

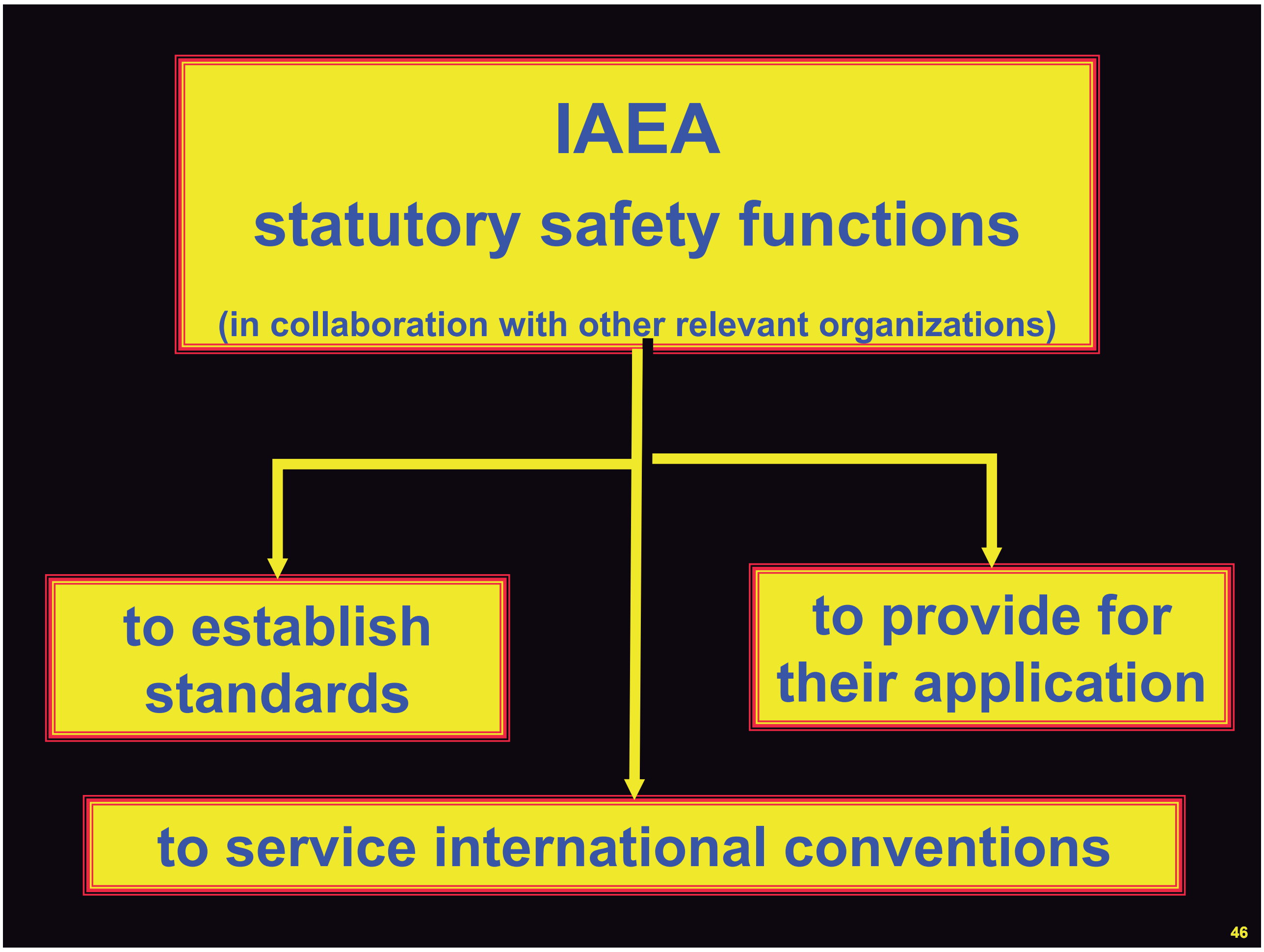

Take away points
42

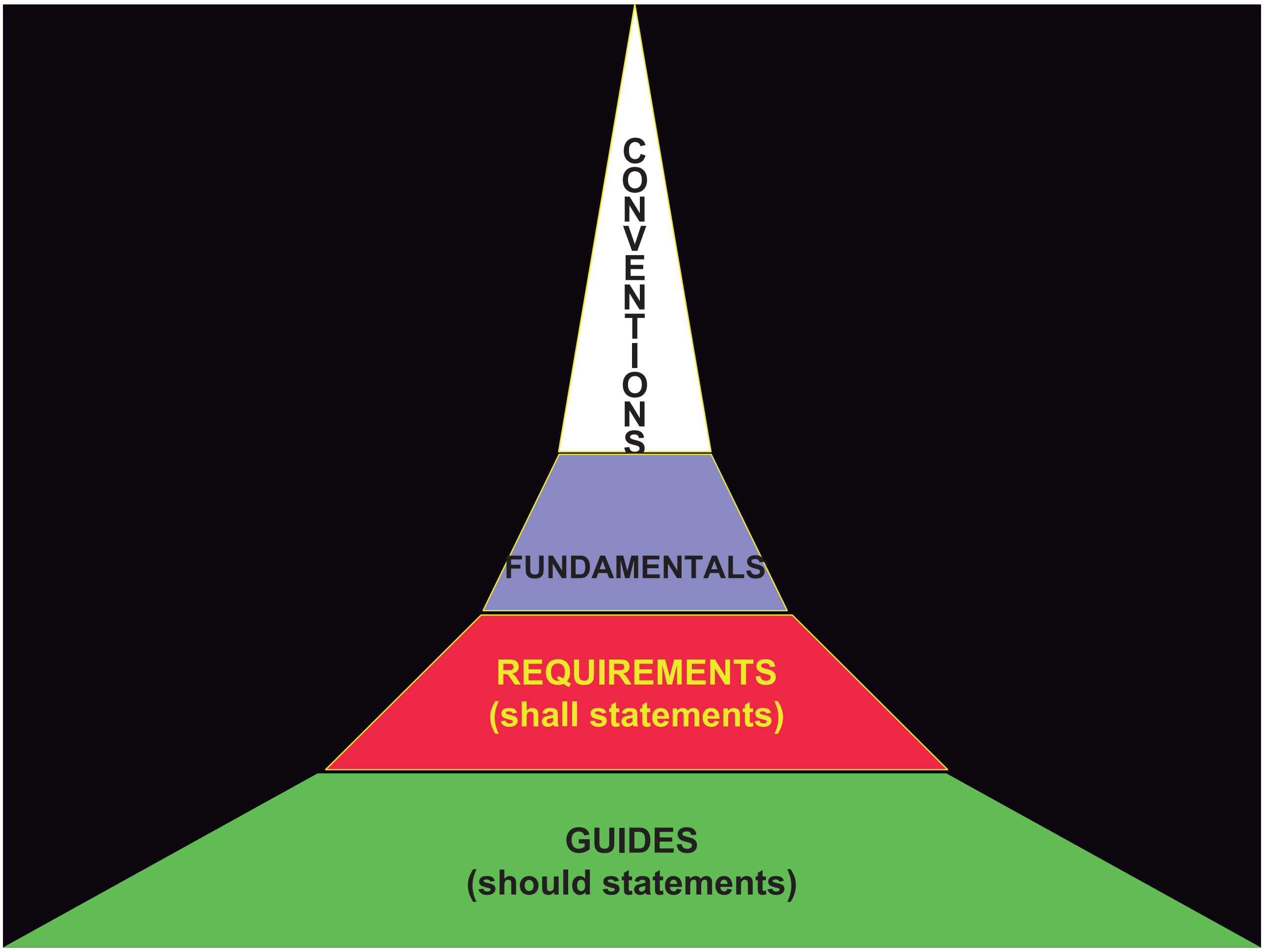
Key Elements of the Paradigm



1. Additional doses to members of the public should not exceed **1 millisievert in a year**
2. Total doses to workers should not exceed **20 millisievert in a year**, except for emergency workers (↑) and pregnant workers (↓)
3. Existing doses to members of the public of **several tens of millisieverts**, e.g. following an accident, will justify intervention with special protective measures, but if the doses are around millisieverts intervention may not be justifiable.


The international safety regime
45


IAEA
statutory safety functions
(in collaboration with other relevant organizations)
to establish standards
to provide for their application
to service international conventions
46



Legally Binding

Conventions

Convention on Early Notification of a Nuclear Accident

INF

International Atomic Energy Agency
INFORMATION CIRCULAR

INFCIRC/335
18 November 1986

GENERAL Distr.

Original: ARABIC, CHINESE, ENGLISH, FRENCH, RUSSIAN and SPANIS

CONVENTION ON EARLY NOTIFICATION OF A NUCLEAR ACCIDENT

1. The Convention on Early Notification of a Nuclear Accident was adopted by the General Conference at its special session, 24-26 September 1986, and was opened for signature at Vienna on 26 September 1986 and at New York on 6 October 1986. It entered into force on 27 October 1986, i.e. thirty days after the date (26 September 1986) on which three States expressed their consent to be bound by the Convention, as required under Article 12 thereof.

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency

INF

International Atomic Energy Agency
INFORMATION CIRCULAR

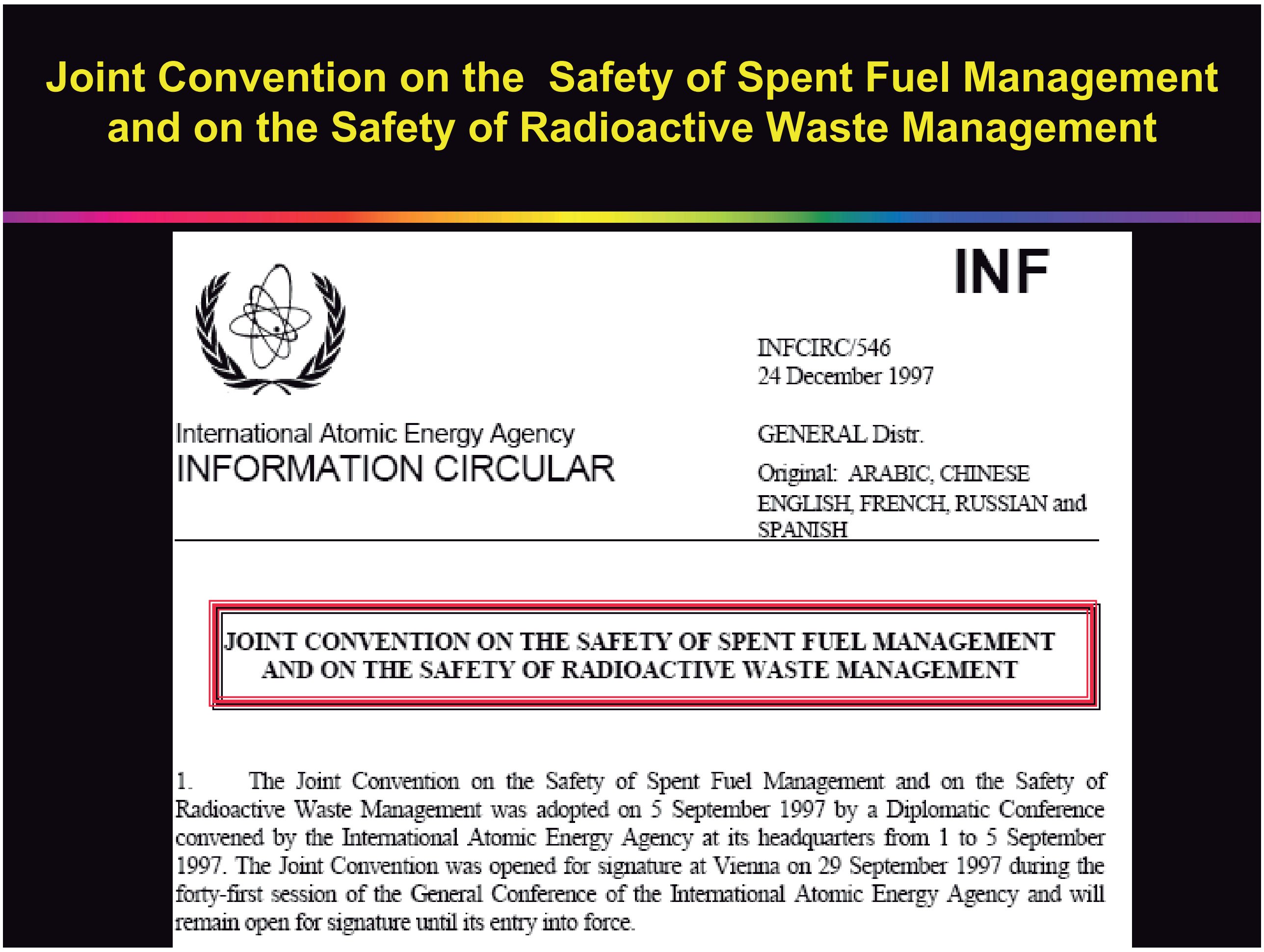
INFCIRC/336
18 November 1986

GENERAL Distr.

Original: ARABIC, CHINESE, ENGLISH, FRENCH, RUSSIAN and SPANISH

CONVENTION ON ASSISTANCE IN THE CASE OF A NUCLEAR ACCIDENT OR RADIOLOGICAL EMERGENCY

1. The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency was adopted by the General Conference at its special session, 24-26 September 1986, and was opened for signature at Vienna on 26 September 1986 and at New York on 6 October 1986.*/



Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

INF

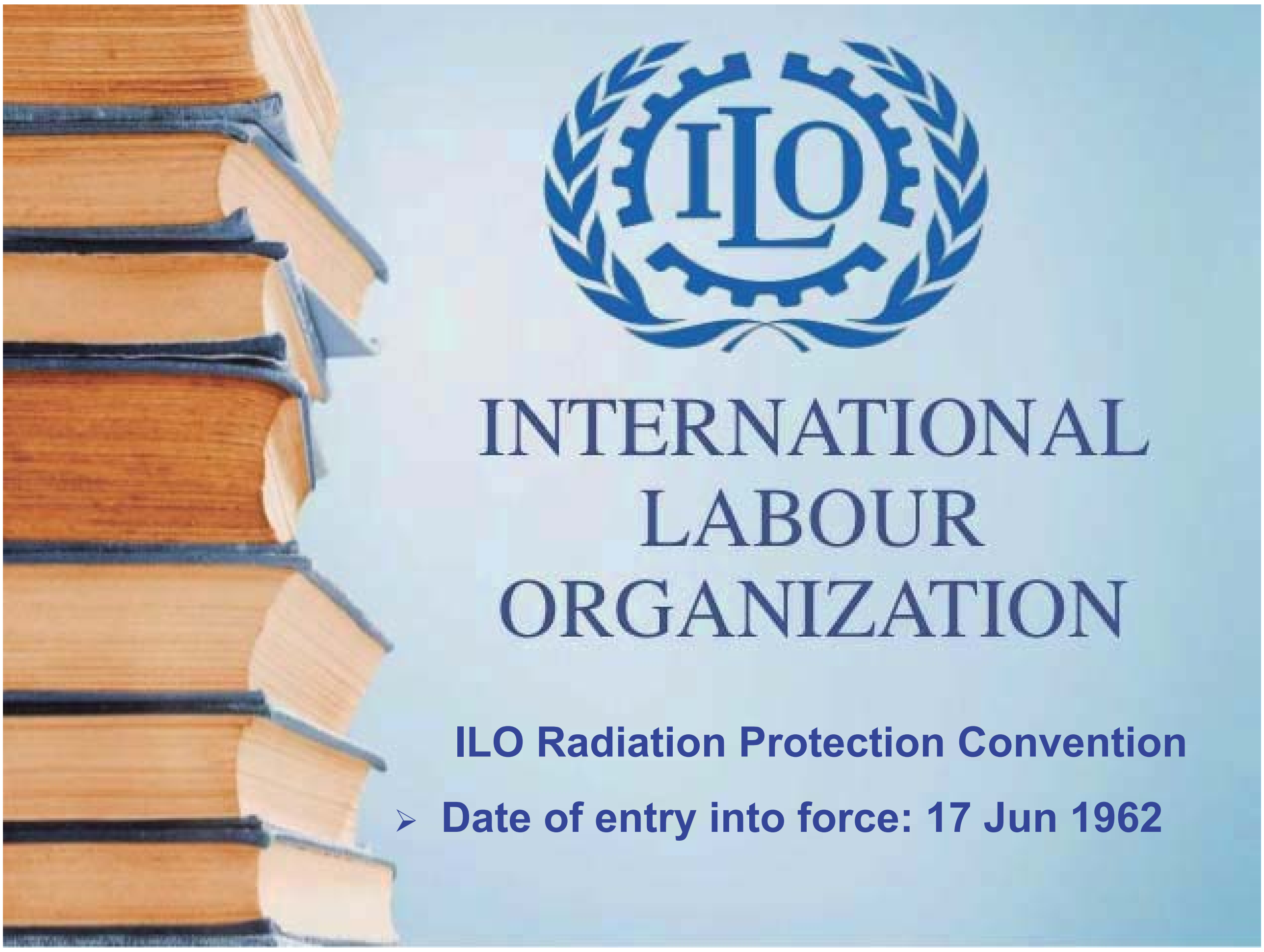
International Atomic Energy Agency
INFORMATION CIRCULAR

INFCIRC/546
24 December 1997

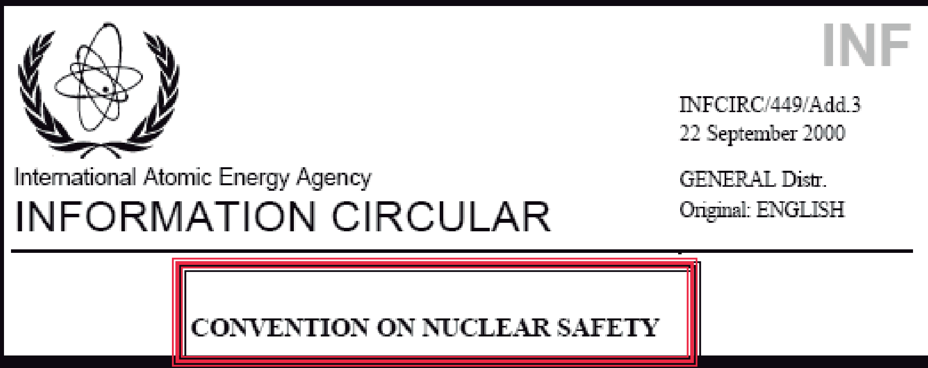
GENERAL Distr.
Original: ARABIC, CHINESE ENGLISH, FRENCH, RUSSIAN and SPANISH

JOINT CONVENTION ON THE SAFETY OF SPENT FUEL MANAGEMENT AND ON THE SAFETY OF RADIOACTIVE WASTE MANAGEMENT

1. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was adopted on 5 September 1997 by a Diplomatic Conference convened by the International Atomic Energy Agency at its headquarters from 1 to 5 September 1997. The Joint Convention was opened for signature at Vienna on 29 September 1997 during the forty-first session of the General Conference of the International Atomic Energy Agency and will remain open for signature until its entry into force.



Convention on Nuclear Safety


INF

International Atomic Energy Agency

INFORMATION CIRCULAR

INFCIRC/449/Add.3
22 September 2000

GENERAL Distr.
Original: ENGLISH

CONVENTION ON NUCLEAR SAFETY

Lesson from Fukushima

New development

Strengthening States' Undertakings on Nuclear Safety

54

Vienna Declaration on Nuclear Safety

On principles for the implementation of the objective of the Convention on Nuclear Safety to prevent accidents and mitigate radiological consequences

Principle 1

- New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions.

Principle 2

- Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner.

Principle 3

- National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified *inter alia* in the Review Meetings of the Convention on Nuclear Safety.

International

Safety

Standards

24 September, 2022

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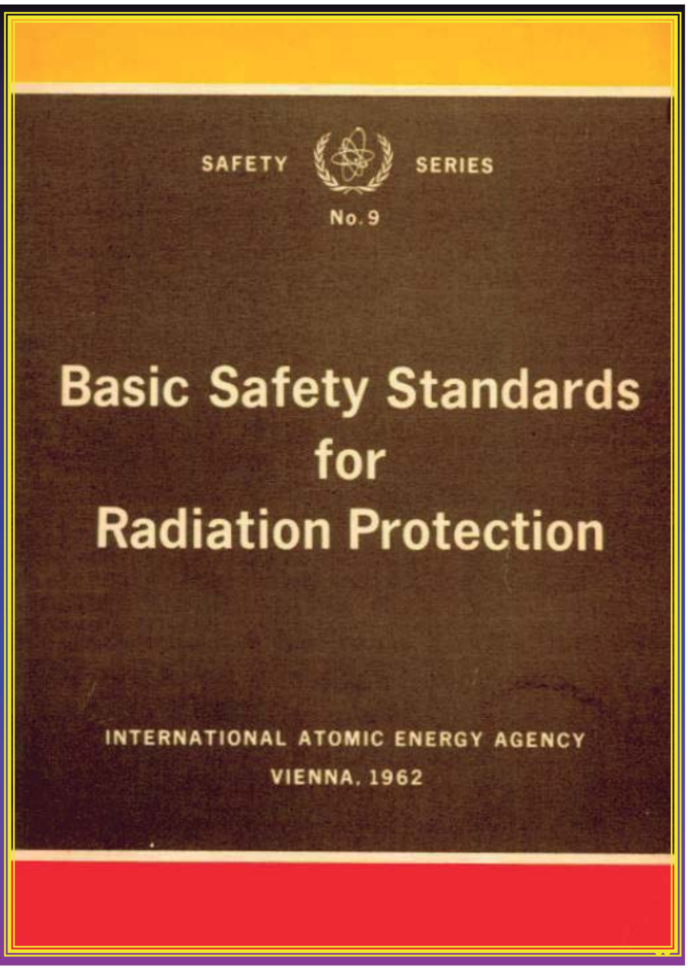
Long experience

1962: first

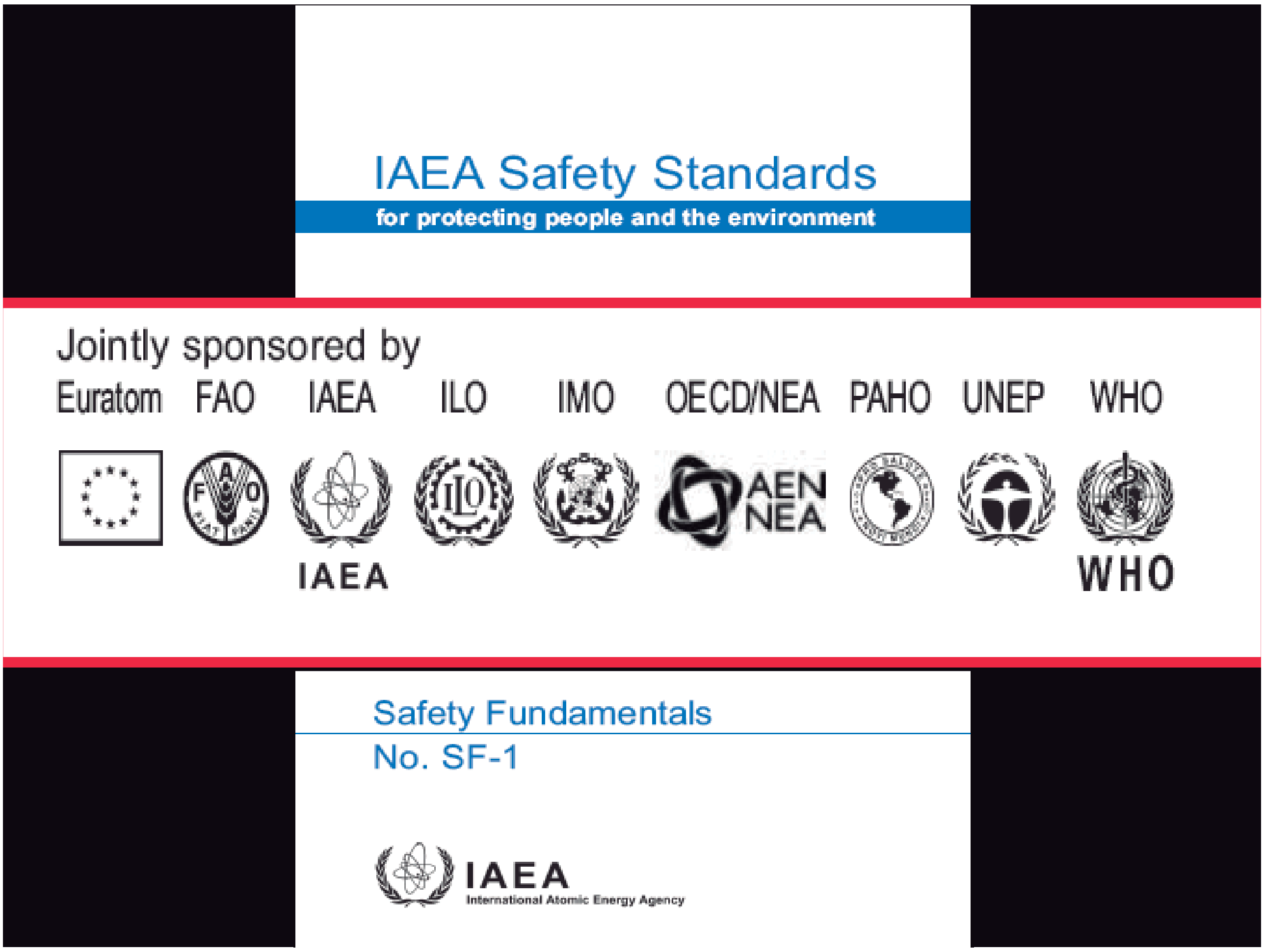
international

standards.



24 September, 2022


Safety Standards Hierarchy
Safety Fundamentals
Safety Requirements
Safety Guides
24 September, 2022
61


IAEA Safety Standards
for protecting people and the environment
Jointly sponsored by
Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO
AEN NEA
IAEA
WHO
Safety Fundamentals
No. SF-1
IAEA
International Atomic Energy Agency

Safety Principles

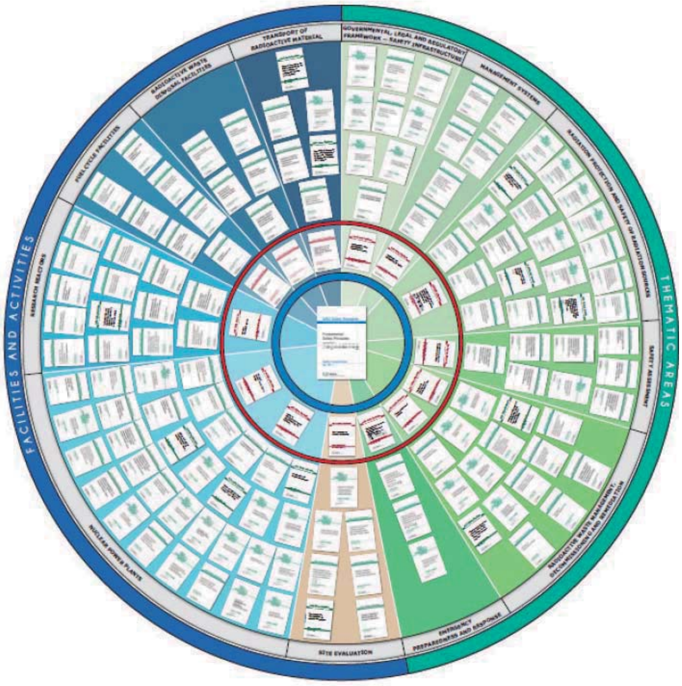
- 1: Responsibility for safety
- 2: Role of government
- 3: Leadership and management for safety
- 4: Justification of facilities and activities
- 5: Optimization of protection
- 6: Limitation of risks to individuals
- 7: Protection of present and future generations
- 8: Prevention of accidents
- 9: Emergency preparedness and response
- 10: Protective actions to reduce existing or unregulated radiation risks

A large corpus

of International

Safety Standards

is available



Example on how the system works:

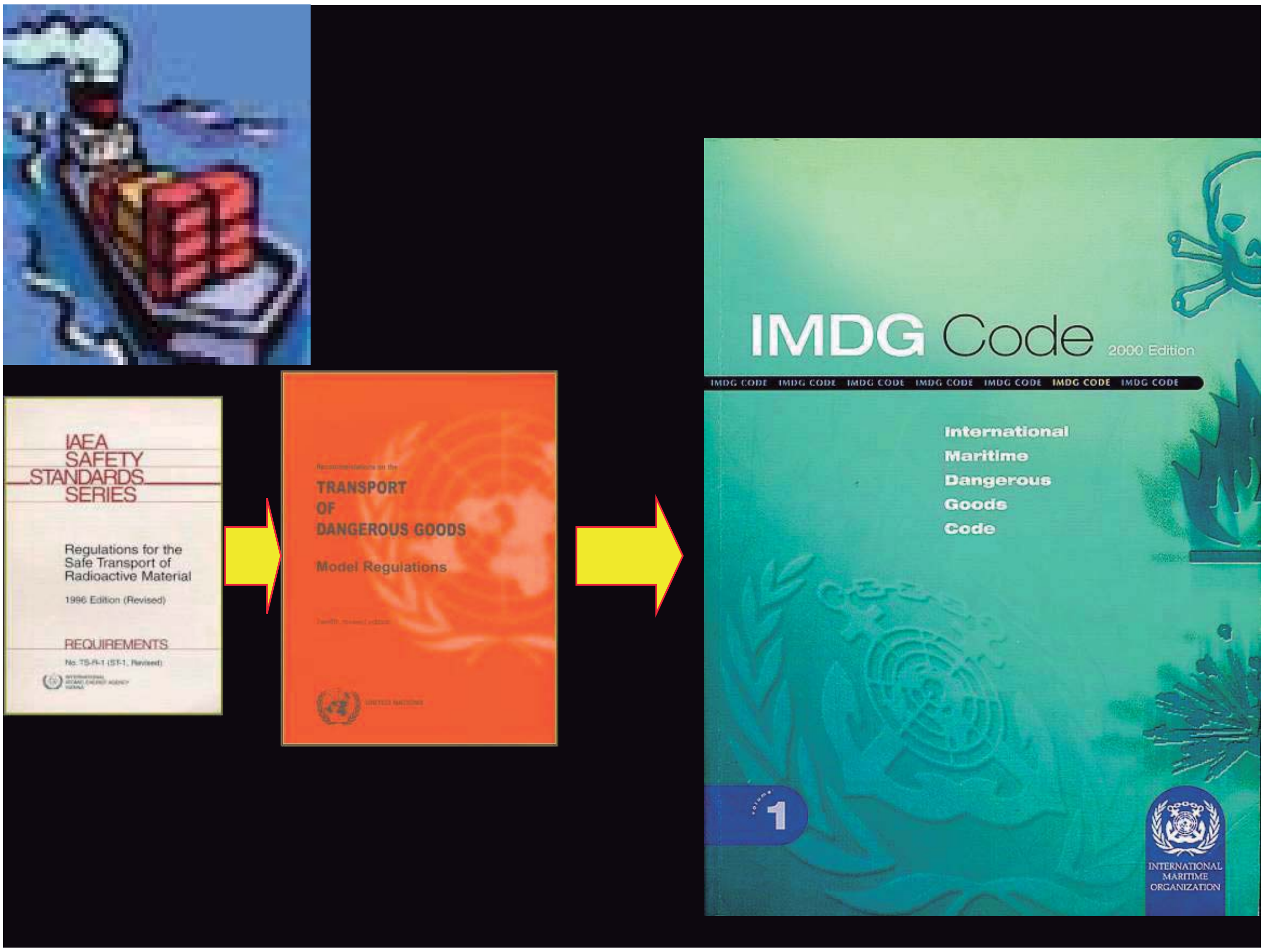
The Regulations for Safe Transport

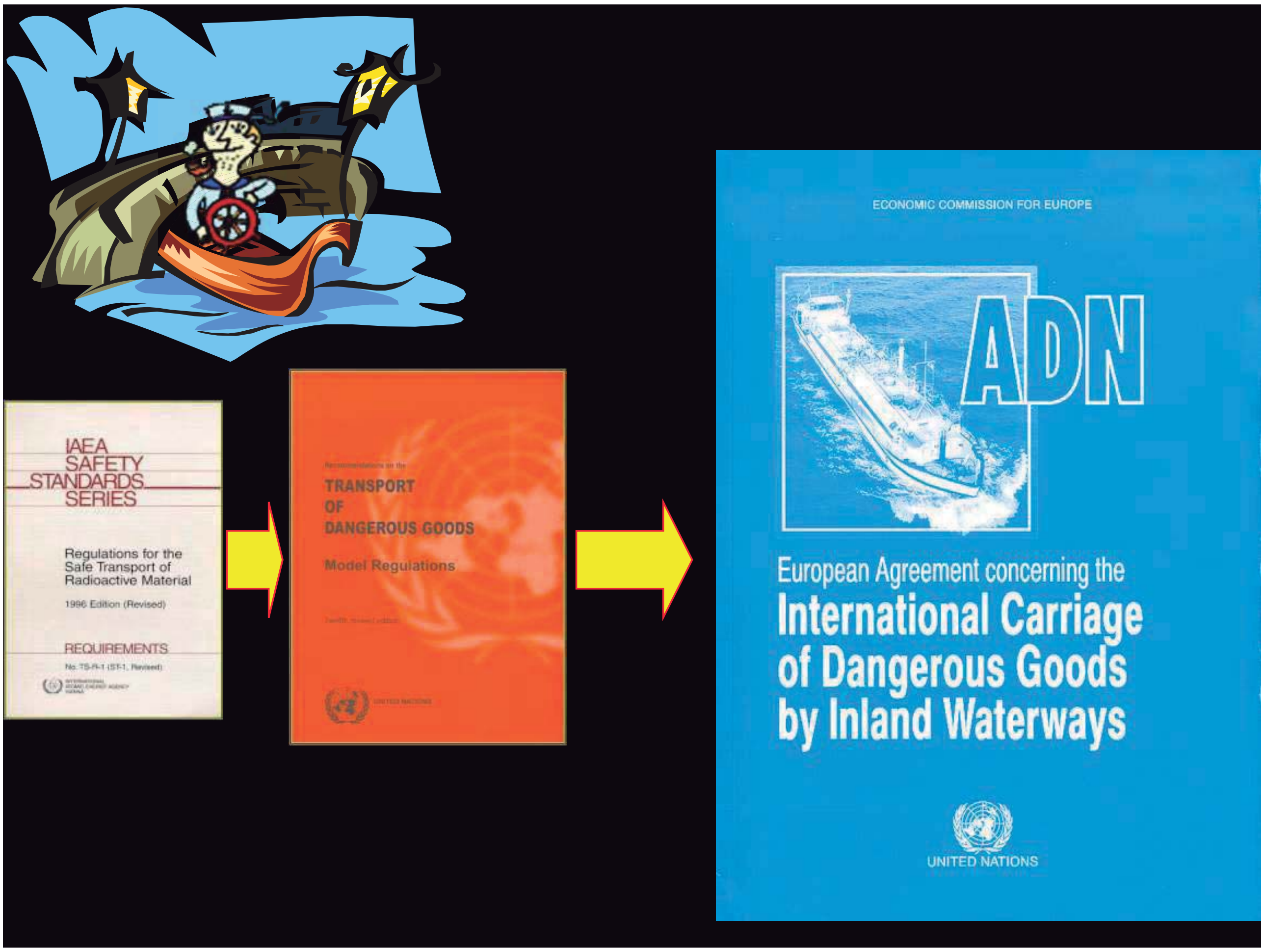

IAEA Safety Standards
for protecting people and the environment
Fundamental Safety Principles
Jointly sponsored by
Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO
Safety Fundamentals
No. SF-1
IAEA
International Atomic Energy Agency
SAFETY STANDARDS
safety series
International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources
IAEA Safety Standards
for protecting people and the environment
Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
INTERIM EDITION
General Safety Requirements Part 3
No. GSR Part 3 (Interim)
IAEA
IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA
67

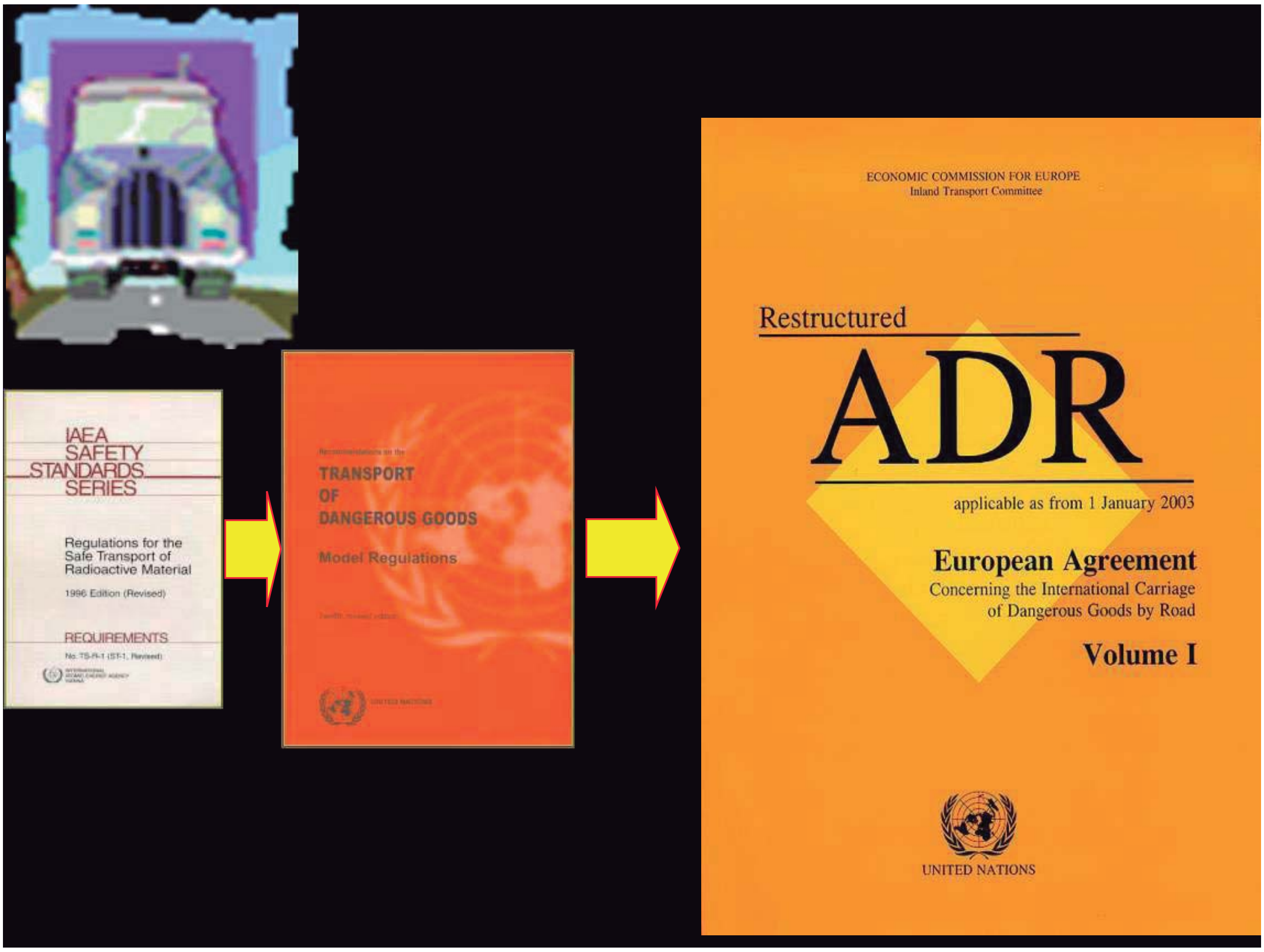

IAEA SAFETY STANDARDS SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA
to Geneva
Recommendations on the
TRANSPORT OF DANGEROUS GOODS
Model Regulations
RADIOACTIVE
CORROSIVE
UNITED NATIONS
24 September, 2022
68

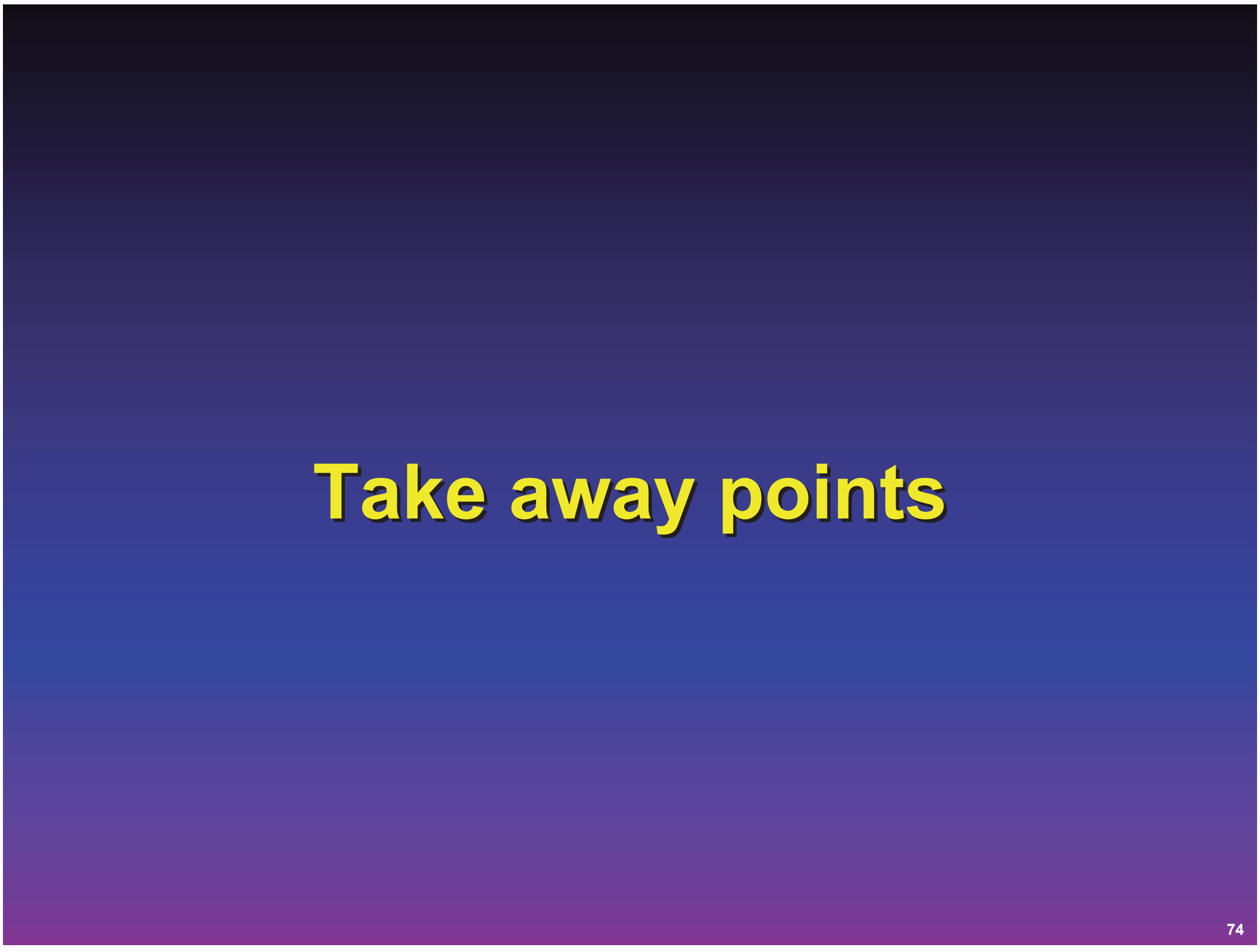

1.1
1
Non-flammable gas
2
Flammable liquid
3
Flammable solid
4
Oxidizer
5.1
Toxic
6
RADIOACTIVE III
7
CORROSIVE
8
9


IAEA
SAFETY
STANDARDS
SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
Recommendations on the
TRANSPORT OF DANGEROUS GOODS
Model Regulations
IATA
2003
Dangerous Goods Regulations
44th Edition
International Air Transport Association

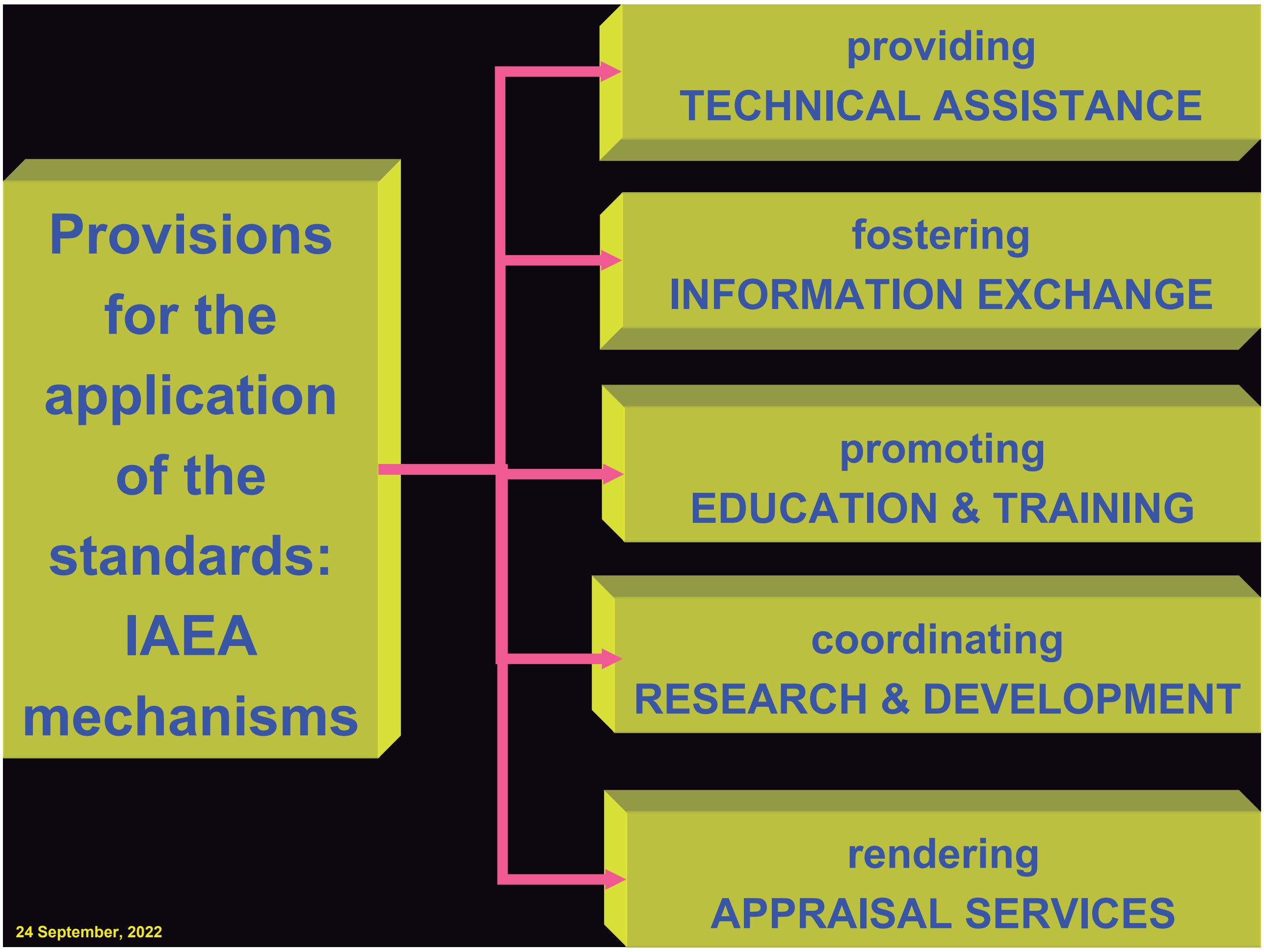

IAEA
SAFETY
STANDARDS
SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT
OF
DANGEROUS GOODS
Model Regulations
IMDG Code 2000 Edition
International
Maritime
Dangerous
Goods
Code
1
INTERNATIONAL MARITIME ORGANIZATION


IAEA
SAFETY
STANDARDS
SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
TRANSPORT
OF
DANGEROUS GOODS
Model Regulations
ECONOMIC COMMISSION FOR EUROPE
ADN
European Agreement concerning the
International Carriage
of Dangerous Goods
by Inland Waterways
UNITED NATIONS


IAEA
SAFETY
STANDARDS
SERIES
Regulations for the Safe Transport of Radioactive Material
1996 Edition (Revised)
REQUIREMENTS
No. TS-R-1 (ST-1, Revised)
TRANSPORT
OF
DANGEROUS GOODS
Model Regulations
ECONOMIC COMMISSION FOR EUROPE
Inland Transport Committee
Restructured
ADR
applicable as from 1 January 2003
European Agreement
Concerning the International Carriage
of Dangerous Goods by Road
Volume I
UNITED NATIONS


Take away points
74

1. There is a growing international safety regime
2. Obey the international conventions
3. Comply with the international requirements
4. Follow the international guides
5. Use the IAEA application mechanisms



Accidents

González, A.J.

Clase dictada en el Curso del Summer Institute 2022 de la Universidad Nuclear Mundial, llevado a cabo en la Universitat Politècnica de València (UPV), en Valencia, España, del 19 al 25 de junio de 2022

World Nuclear University
Sumer Institute – 2022
Valencia-España-24/6/2022

Accidents

Abel J. González
UNSCEAR Representative, IAEA' CSS Member
Autoridad Regulatoria Nuclear
✉Av. Del Libertador 8250; (1429)Buenos Aires,Argentina ☎+54 1163231758

1

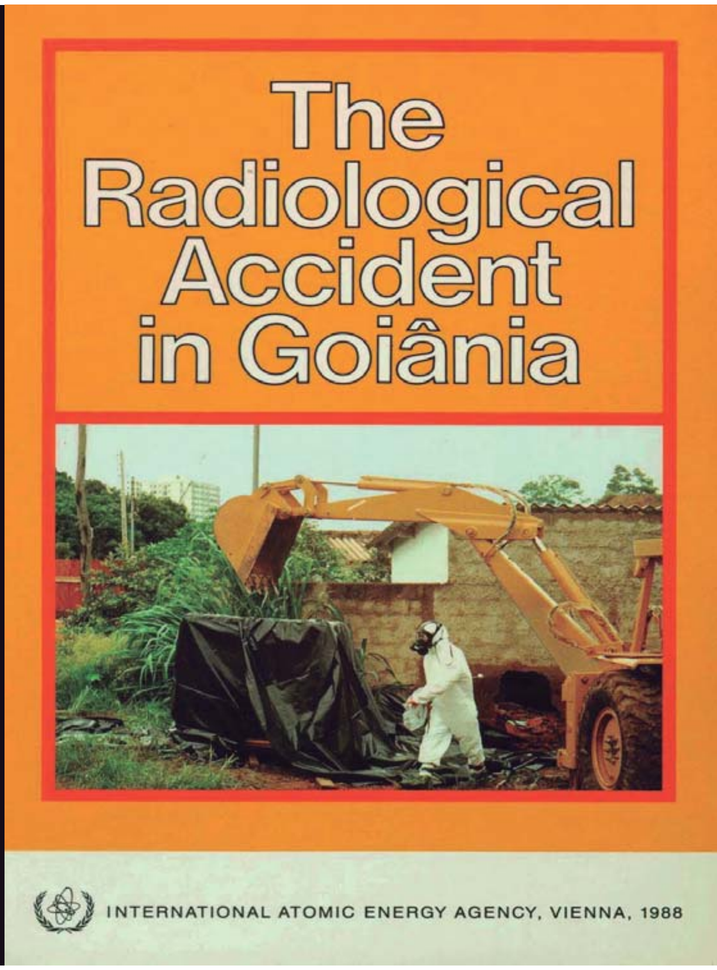
Accidents

- Radiation accidents are common in the medical, industrial and military applications of radiation.
- Nuclear accidents: 3 mayor accidents:
  - Three Mile Islands
  - Chernobyl
  - Fukushima
- Only Chernobyl had a measurable health impact.

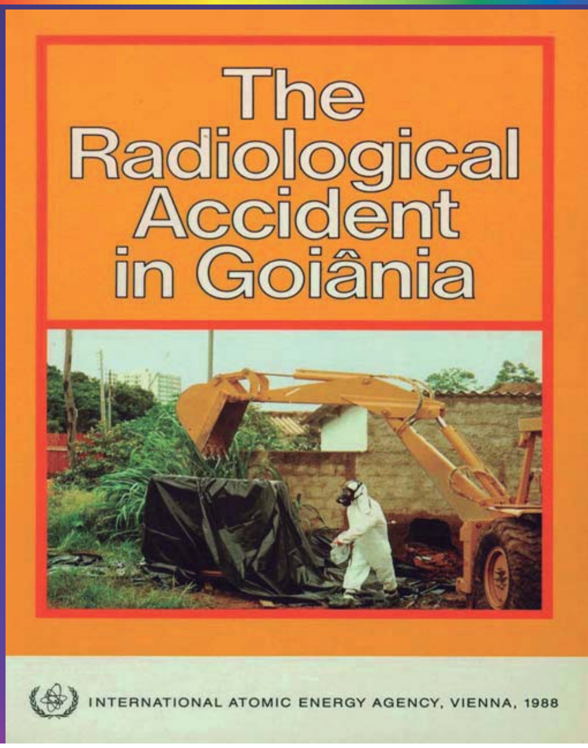
Part 1:

Radiation Accidents

The First Recorded International Experience



Revisiting Goiânia



6

Revisiting Goiânia

- ✓ Unsecured caesium 137 source in radiological clinic.
- ✓ Scrap scavengers break in, steal and move it to junkyard.
- ✓ Source capsule rupture: dispersible and soluble CsCl.
- ✓ City contaminated.
- ✓ 14 people overexposed; 4 died within 4 weeks.
- ✓ 112 000 people monitored; 249 contaminated.
- ✓ 85 houses contaminated; hundreds of people evacuated.
- ✓ >5000 m^3 of radioactive wastes.

Preparing to demolish the contaminated houses

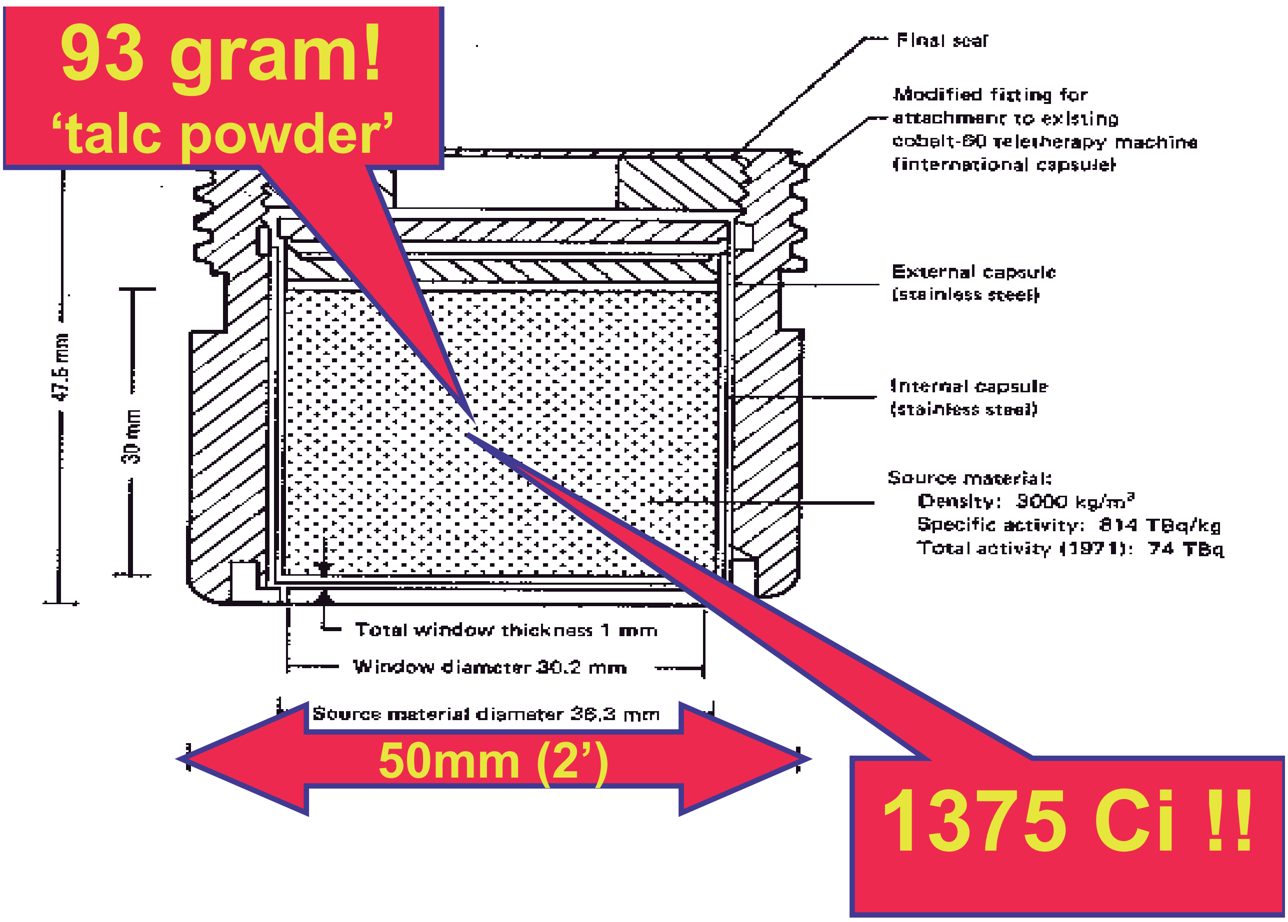
Demolishing work: dose rates up to 0.5 Sv/h

Contaminated rubble from a house

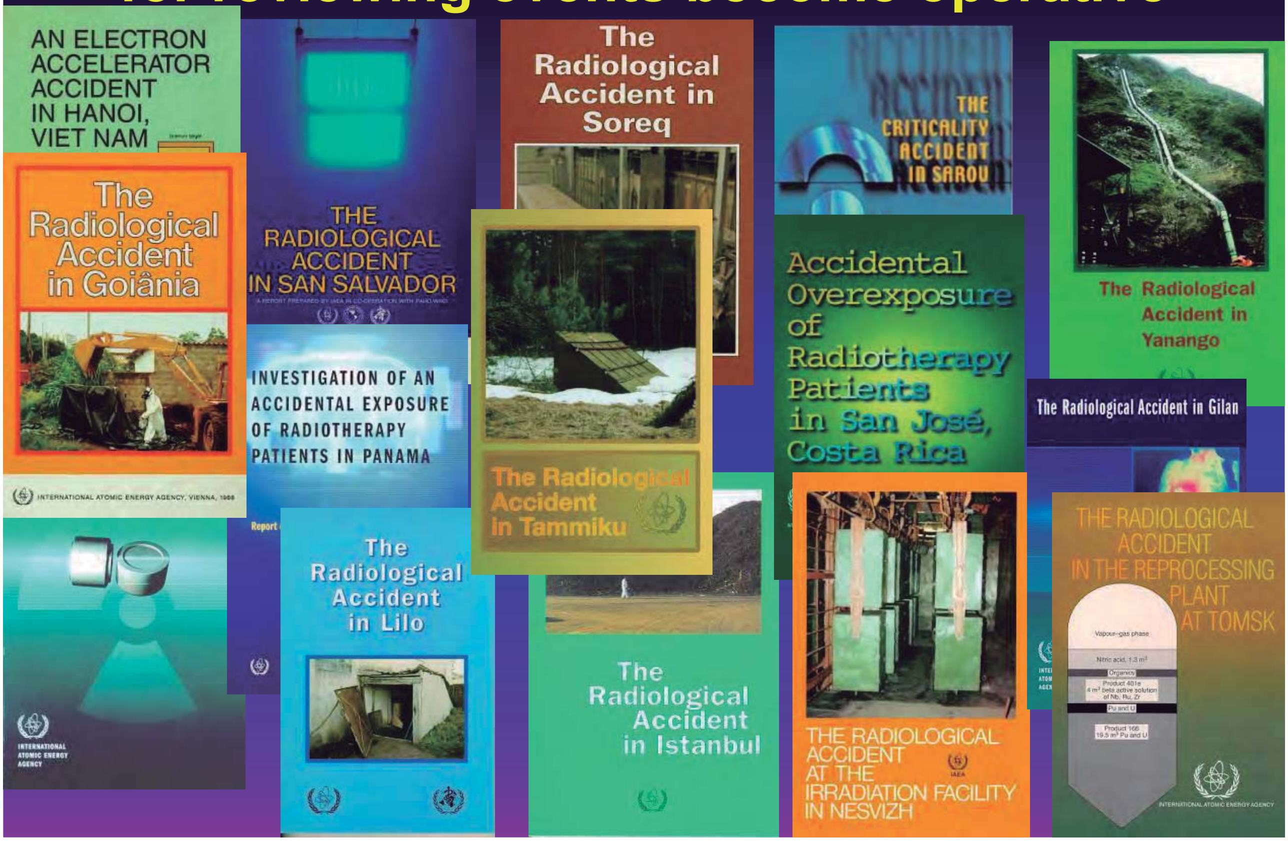
Restoration after removing the contaminated rubble

Stacking radioactive waste containers

Temporary radioactive waste repository



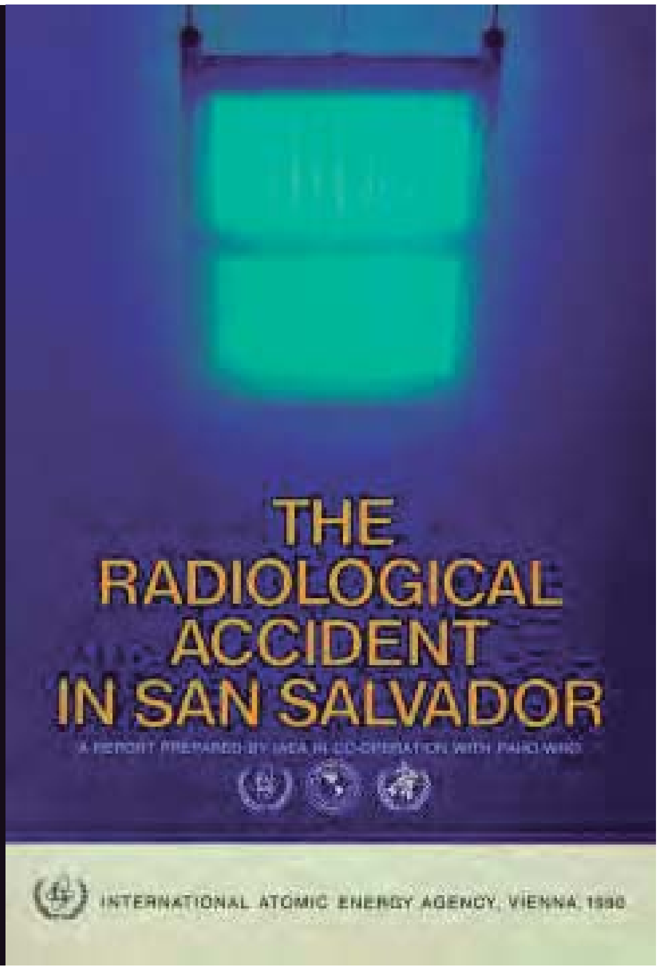
Following Goiânia, an international system for reviewing events become operative



Some industrial

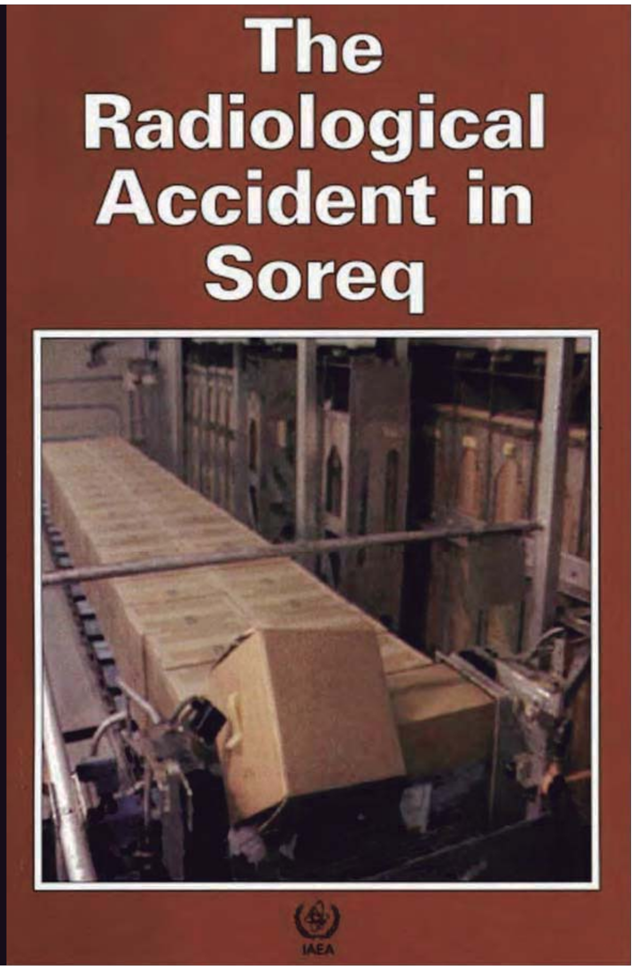
radiation accidents

- 5 February 1989
- industrial irradiation facility
- San Salvador, El Salvador
- cobalt-60 source in a movable source rack
- source rack became stuck in the irradiation position
- operator bypassed the irradiator's already degraded safety systems
- entered the radiation room with two other workers to free the source rack manually

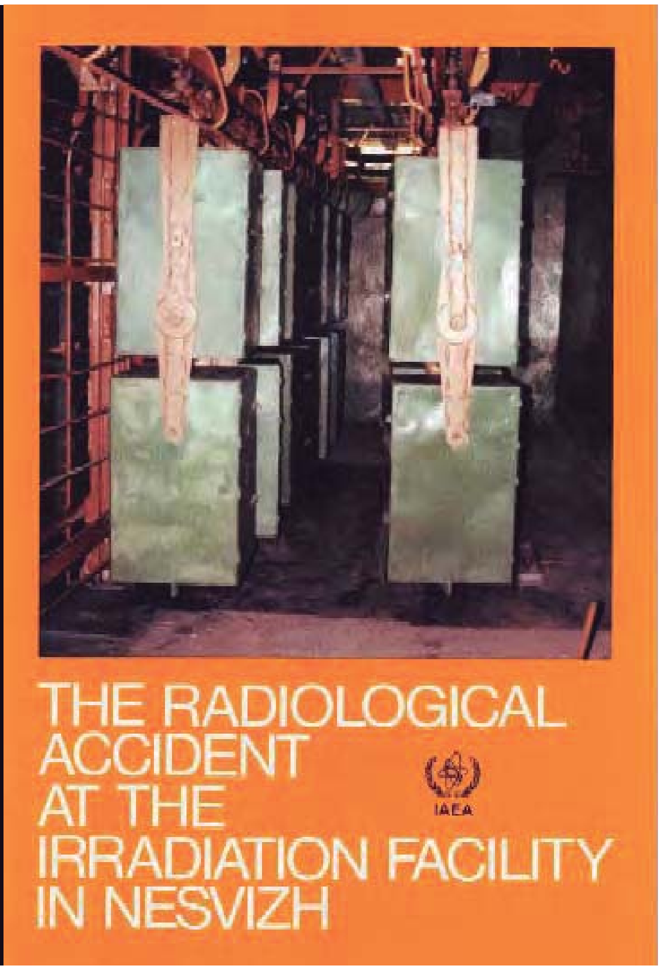


- 21 June 1990
- Soreq, Israel,
- radioactive cobalt-60 source in a movable source rack.
- source rack became stuck in the irradiation position owing to obstruction by cartons on the internal conveyor.
- The operator,
  - misinterpreted two conflicting warning signals,
  - bypassed installed safety systems and
  - contravened procedures
  - enter the irradiation room to free the blockage.

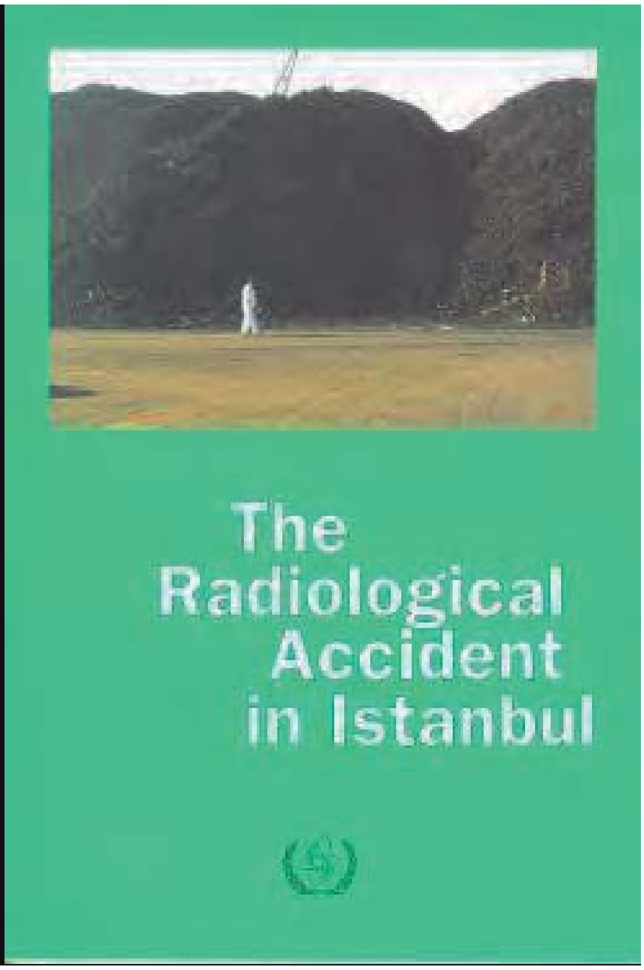
24 de septiembre de 2022



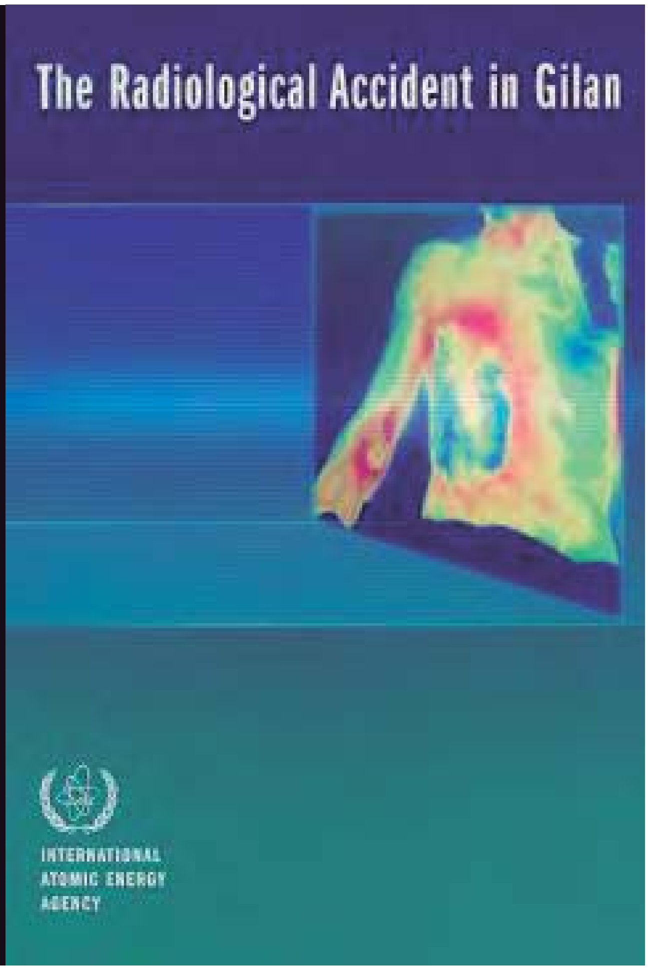
- 26 October 1991,
- irradiation facility in Nesvizh, Belarus.
- agricultural and medical products being sterilized
- ^{60}Co source in a moveable rack.
- jam in the product transport system
- the operator
  - entered the facility to clear the fault,
  - bypassing a number of safety features.



- In 1993, in Ankara, Turkey
- Importer loaded three spent radiotherapy sources in preparation for returning them to USA.
- The packages were not send but stored in Ankara from 1993 until 1998,
- In February 1998 the two packages transported to Istanbul, stored, and then moved, and after nine months, transferred
- Purchaser unaware of the radiation hazard.
- Broke open the shielded containers,
- This occurred in the residential area of Ikitelli in the Kuciikekmece district of Istanbul on 10 December 1998.
- On 13 December 1998, a total of ten persons fell ill and six of them began to vomit.
- The cause of the illness was not recognized until almost four weeks later (on 8 January 1999).

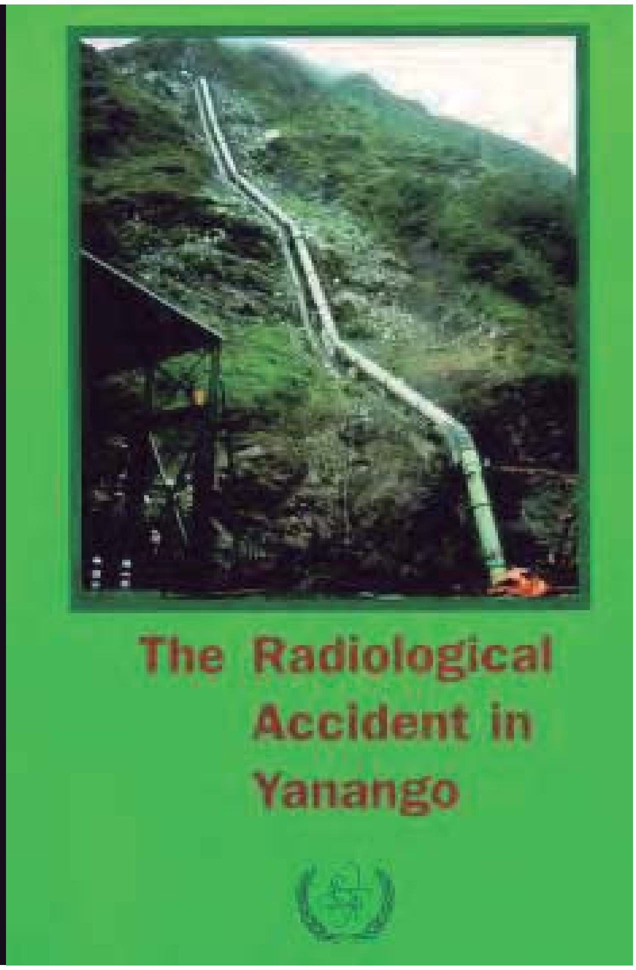


- On 24 July 1996
- Gilan, Islamic Republic of Iran.
- A worker picked up a ^{192}Ir industrial radiography source and put it in his chest pocket, where it remained for approximately 1.5 h.



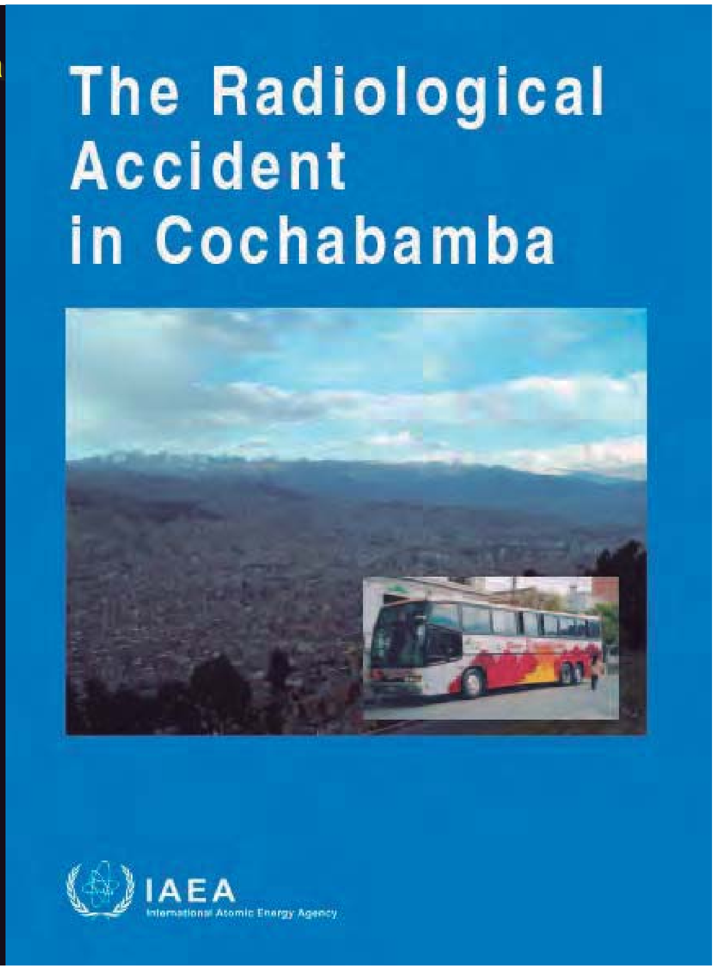
24 de septiembre de 2022

- 20 February 1999
- Yanango hydroelectric power plant in Peru.
- A welder picked up an ^{192}Ir industrial radiography source and put it in his pocket.
- Necessitated the amputation of one leg.
- His wife and children were also exposed.

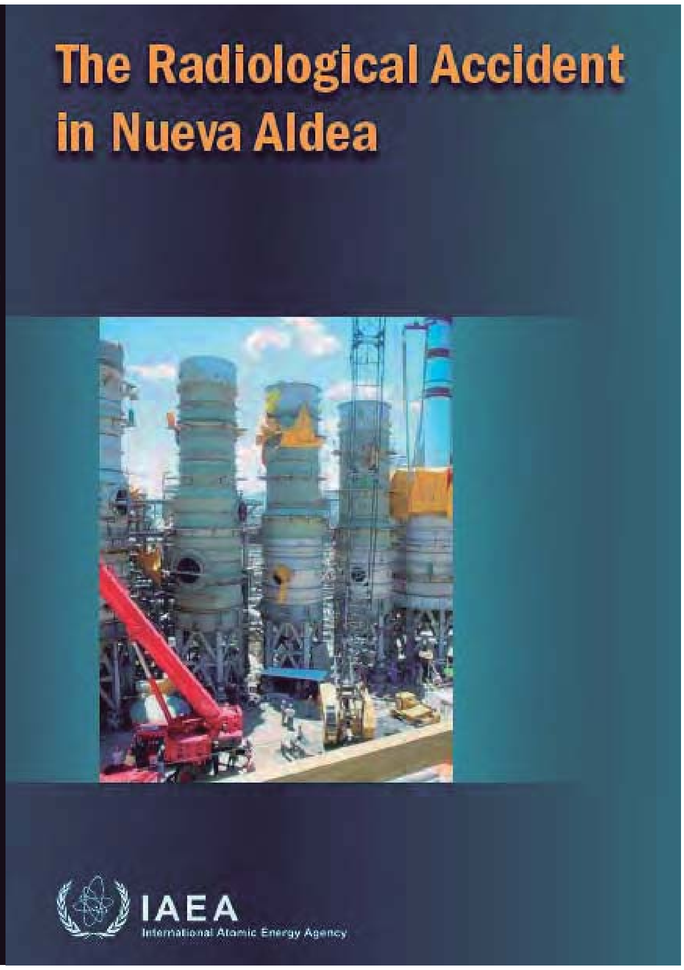


24 de septiembre de 2022

- April 2002 Cochabamba, Bolivia
- ^{192}Ir source, in a remote exposure container, remained exposed within a guide tube
- The container and the guide tube were returned from Cochabamba to La Paz as cargo on a passenger bus, which carried a full load of passengers for the journey of about eight hours.

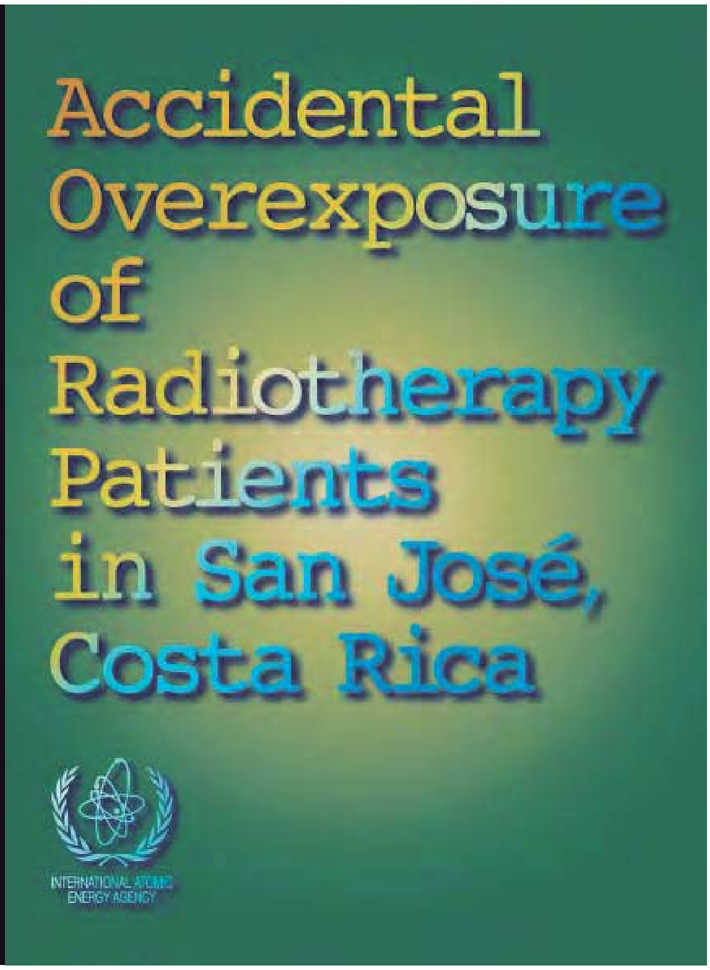


- 14 December 2005
- cellulose plant under construction in Nueva Aldea, Concepción, Chile.
- After completing radiography, a radiographer dismantled the radiography equipment, not noticing that the source had fallen out on to the tower platform.



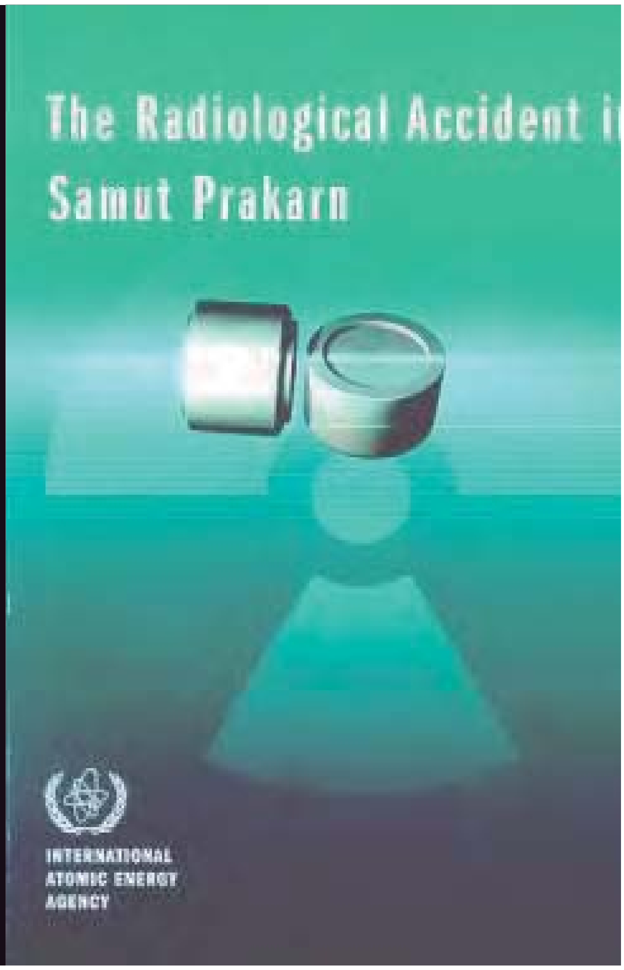
Some medical radiation accidents

- 22 August 1996
- San Juan de Dios Hospital in San José, Costa Rica
- ^{60}Co radiation therapy source was replaced and wrongly calibrated.
- The error resulted in the administration to patients of significantly higher radiation doses than those prescribed.
- This was a major radiation accident: 115 patients were affected.

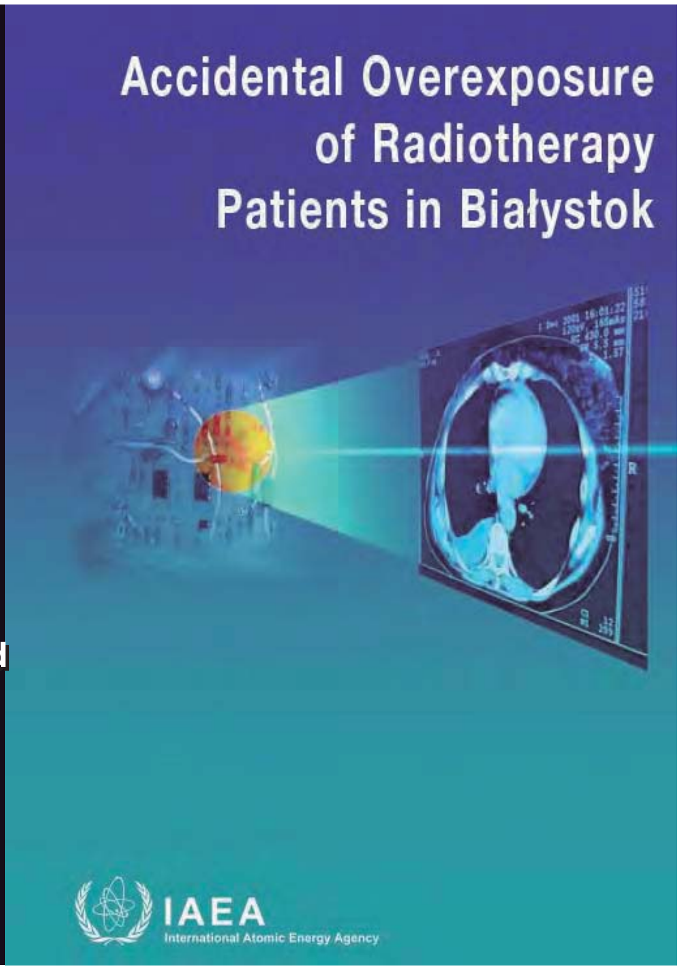


24 de septiembre de 2022

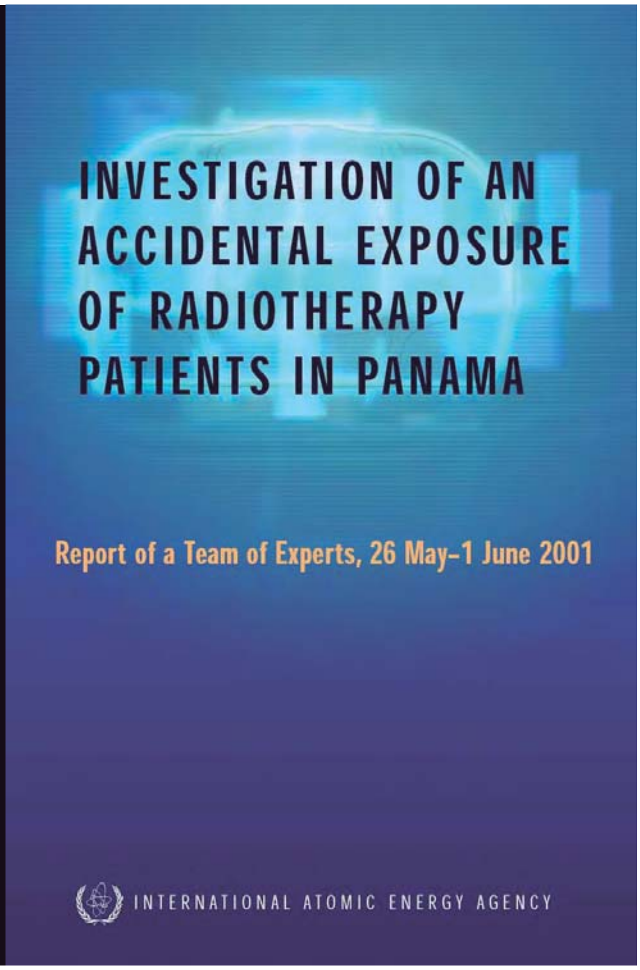
- In the 90's a company based in Bangkok, Thailand, possessed several teletherapy devices without authorization
- In late January 2000, a teletherapy head partially disassembled.
- On 1 February 2000, the device was moved to a junkyard in Samut Prakarn, Thailand.
- By the middle of February 2000, several individuals had begun to feel ill and sought medical assistance.



- 27 February 2001,
- Oncology Centre in Białystok, Poland
- patients undergoing radiotherapy were given significantly higher doses than intended and, as a result, developed radiation induced injuries.



- A computerized treatment planning system (TPS) was used by the Instituto Oncológico Nacional, in Panama, to calculate doses and determine treatment times.
- In August 2000 the method of digitizing shielding blocks was changed.
- As a result, the computer output indicated a treatment time substantially longer.
- The modified treatment protocol delivered a proportionately higher dose to 28 patients.

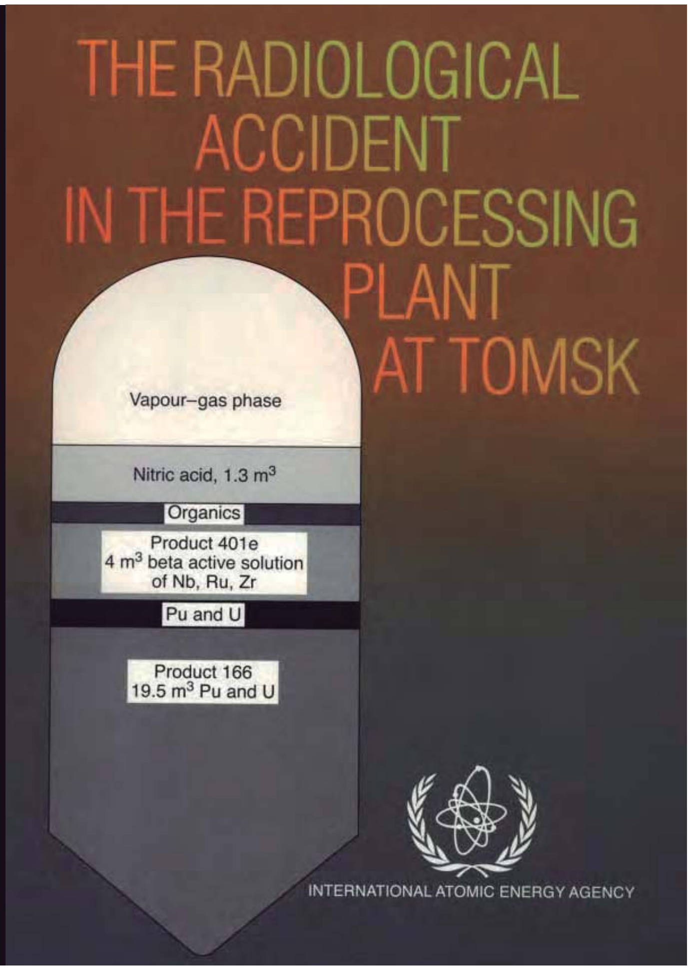


Some

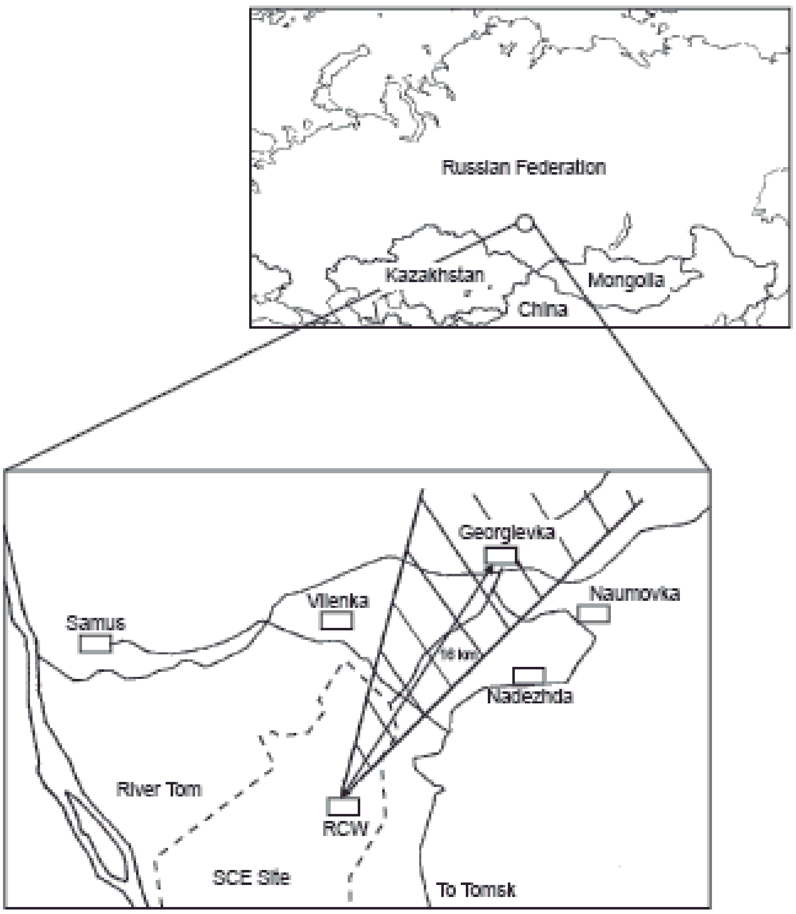
radiation accidents in the

military complex

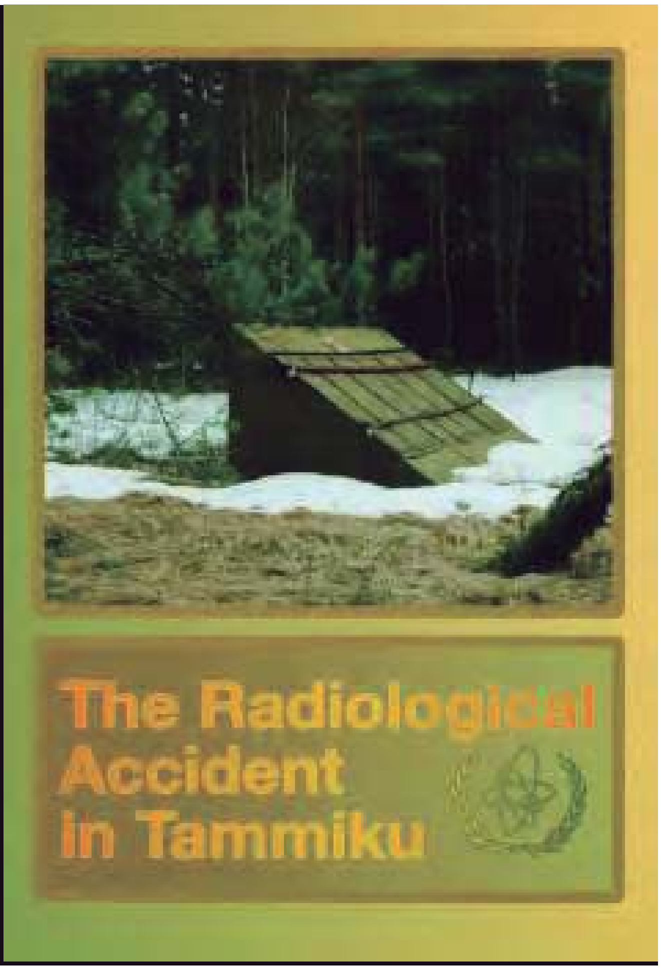
- On 6 April 1993
- Siberian Chemical Enterprises (SCE) facility near Tomsk. Russian Federation.
- The accident resulted in the release of about 30 TBq of beta and gamma emitting radionuclides and about 6 GBq of ^{239}Pu.
- The SCE site and the surrounding countryside to the north, including the village of Georgievka, were contaminated.



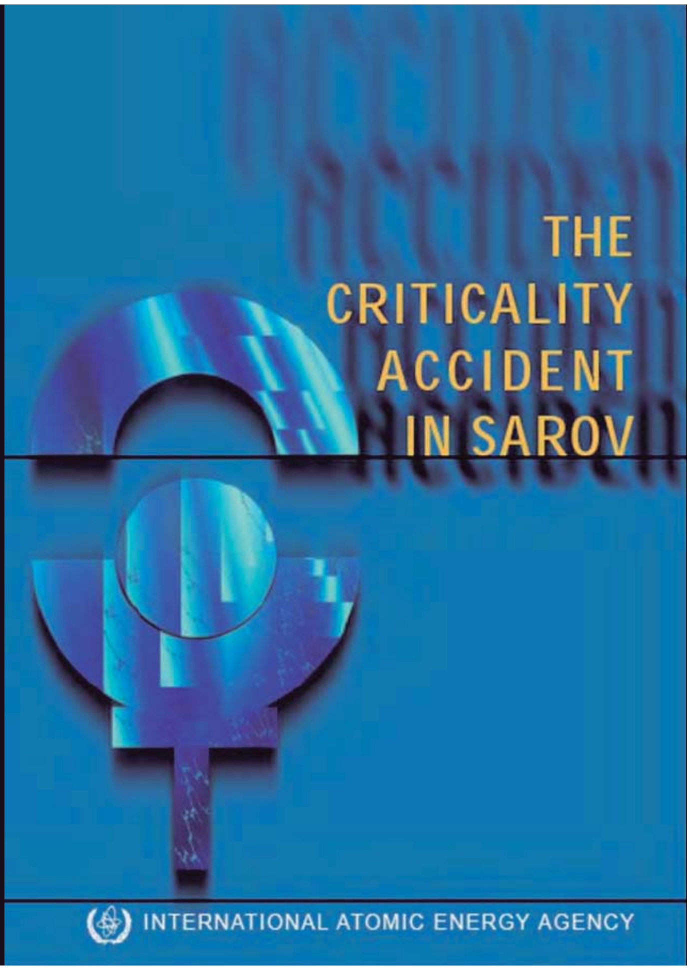
24 de septiembre de 2022



- On 21 October 1994,
- waste repository at Tammiku, Estonia,
- a metal container enclosing a caesium-137 source removed.
- source fell to the ground, it was picked up and placed it in a pocket and carried at home in the nearby village of Kiisa.



- On 17 June 1997
- Russian Federal Nuclear Centre (formerly known as Arzamas 16) in the town of Sarov, near Nizhnij Novgorod, Russian Federation.
- Routine manipulation of the components of a critical assembly.
- Criticality accident
- Overexposed skilled technician, died 66 h later.

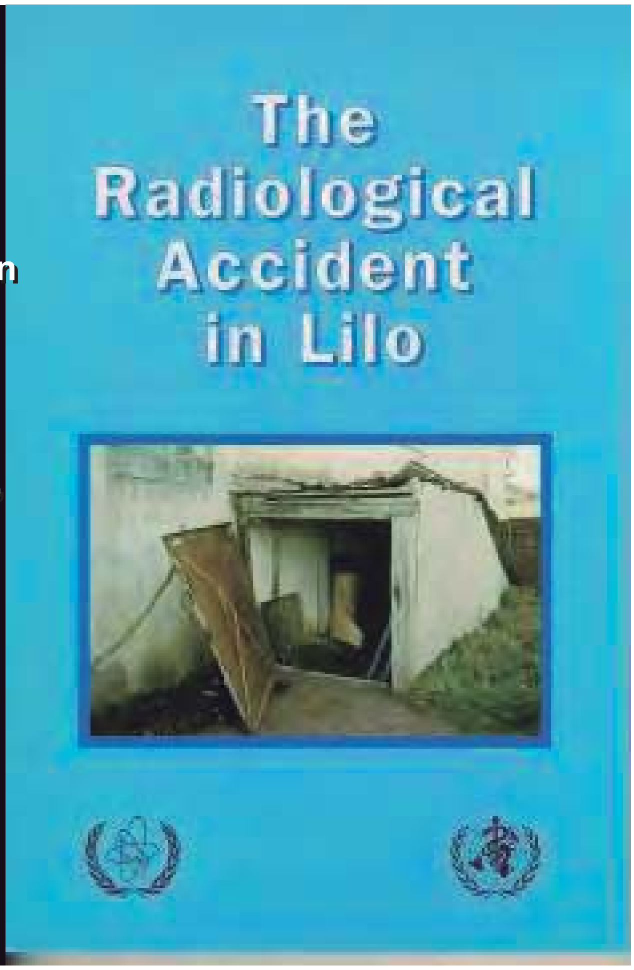


24 de septiembre de 2022

● 9 October 1997, Lilo, Georgia

●Servicemen of the Lilo Training Detachment of Frontier Troops developed local radiation induced skin diseases on various parts of their bodies.

●A large number of radiation sources, namely 12 137Cs sources, one 60Co source and 200 226Ra sources, were found abandoned in the premises, which previously had been used as barracks for troops from the USSR.

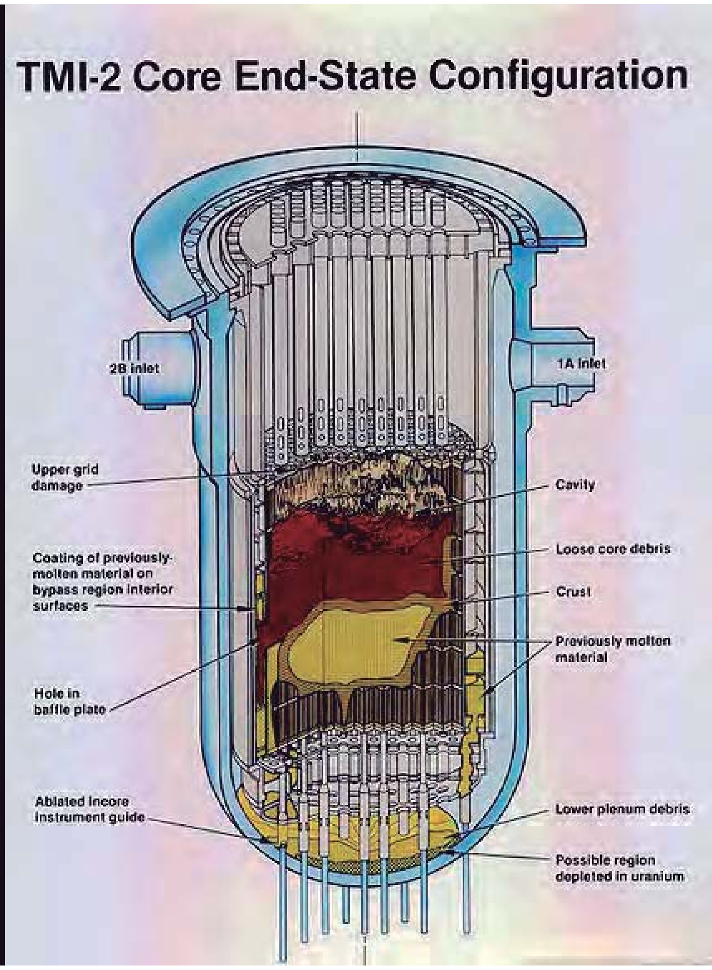


Part 2:

Nuclear accidents

- 3 nuclear accidents with public radiation exposure:
  - Three Mile Islands
  - Chernobyl
  - Fukushima
- Only Chernobyl had a measurable radiation health impact.

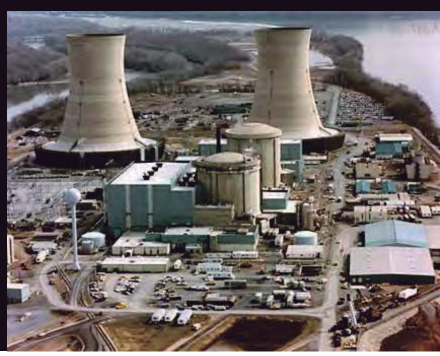
Three Mile Island NPP accident



Releases

$6\ 10^{16}$ Bq, of noble gases
(Chernobyl: 7,0 10^{18}Bq)

$5\ 10^{11}$ Bq, of iodine-131
(Chernobyl: 3,2 10^{18} Bq)

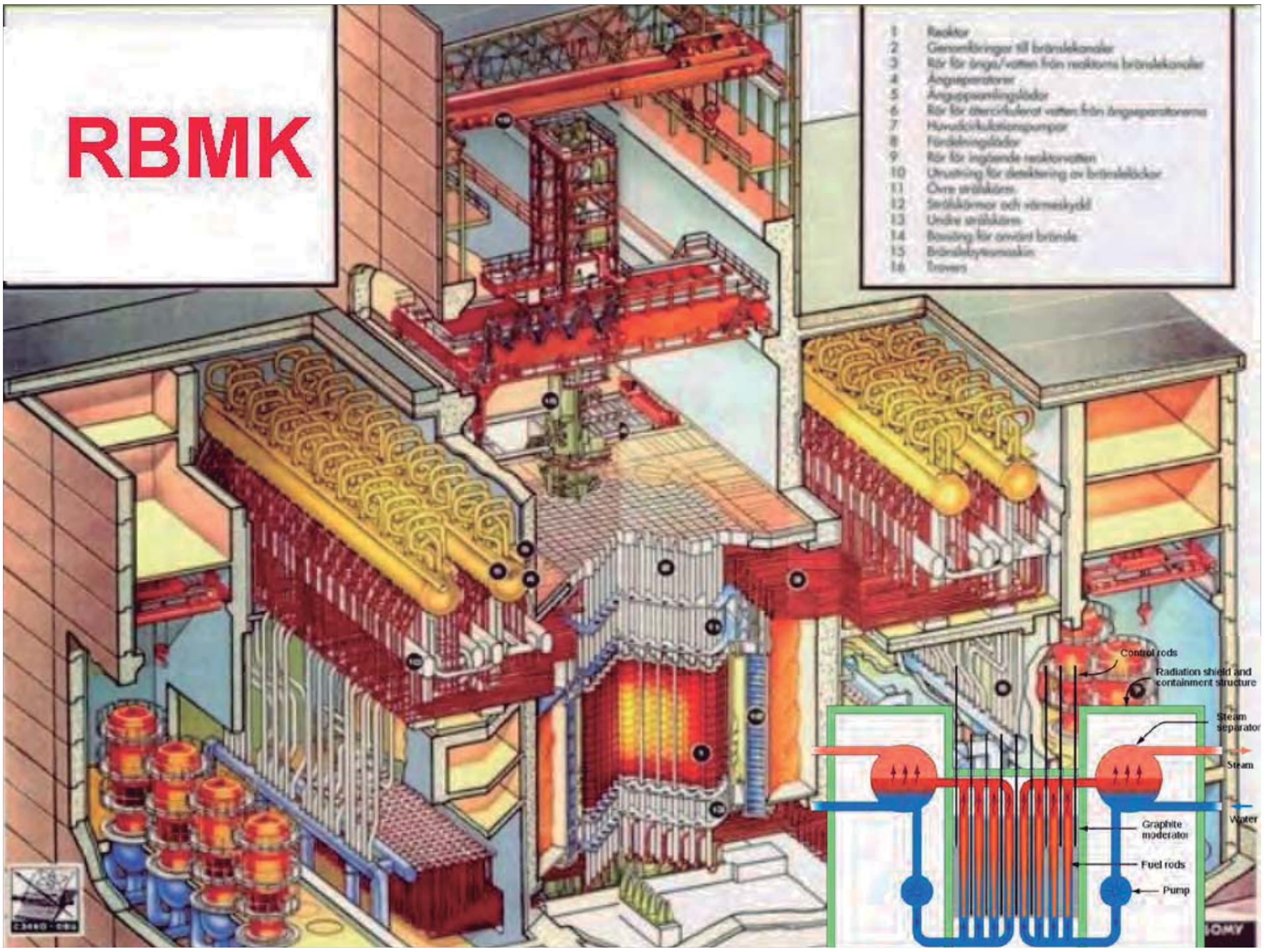


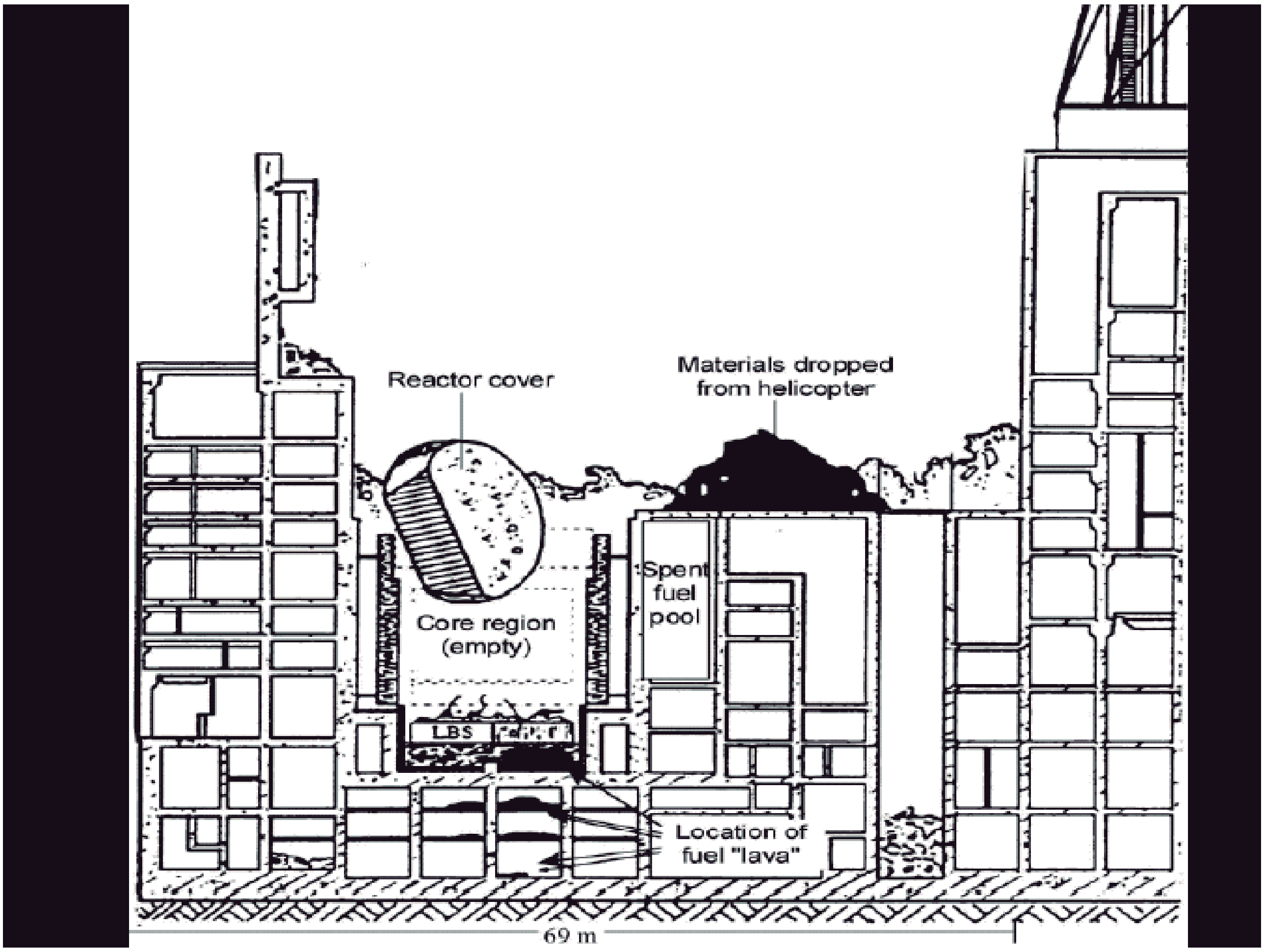
Consequences

- The dose to residents was much lower than the limits for normal operation.
- But, pregnant women and children in the county were evacuated (!?)
- People fell into panic.

41

Chernobyl Nuclear Power Plant Accident


RBMK
1 Reaktor
2 Genomföringar till bränslekanaler
3 Rör för ånga/vatten från reaktorns bränslekanaler
4 Ångseparatorer
5 Ånguppsamlingslådor
6 Rör för återcirkulerat vatten från ångseparatorerna
7 Huvudcirkulationspumpar
8 Fördelningslådor
9 Rör för ingående reaktorvatten
10 Utrustning för detektering av bränsleläckor
11 Övre strålskärm
12 Strålskärmar och värmeskydd
13 Undre strålskärm
14 Bassäng för använt bränsle
15 Bränslebytesmaskin
16 Travers
Control rods
Radiation shield and containment structure
Steam separator
Steam
Water
Graphite moderator
Fuel rods
Pump


Reactor cover
Materials dropped from helicopter
Spent fuel pool
Core region (empty)
LBS
Location of fuel "lava"
69 m

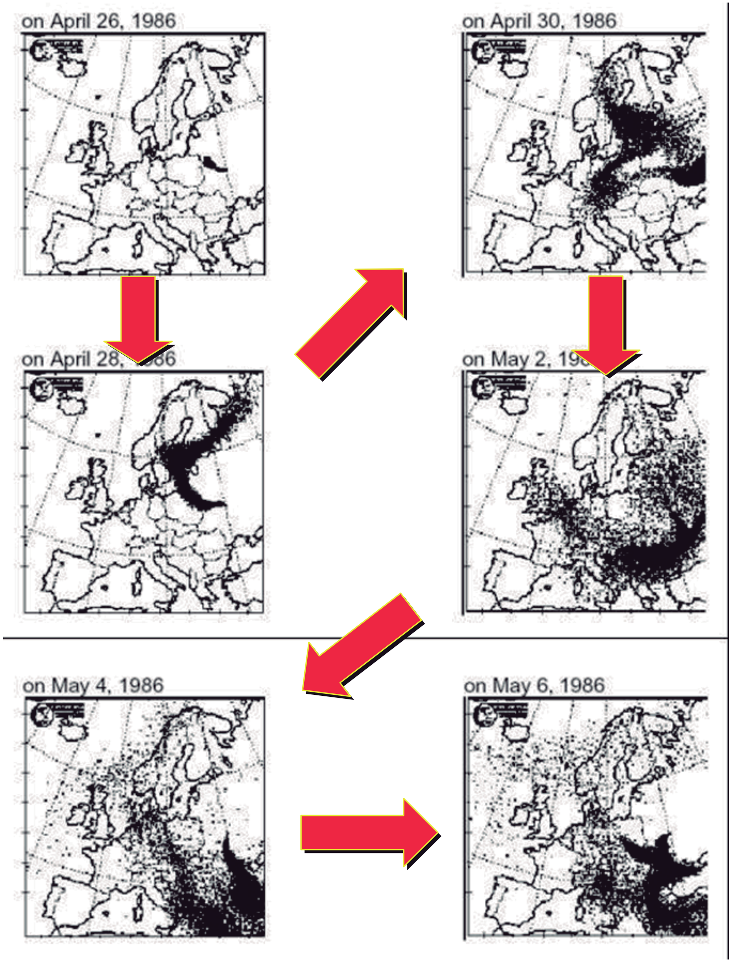
Radioactive discharge

$1.2\ 10^{19}$ Bq

^{131}I	55%	(50 000 000 Ci)	$3{,}2\ 10^{18}$ Bq
$^{134,137}Cs$	33%		$4{,}0\ 10^{17}$ Bq
Noble gases:	100%		$7{,}0\ 10^{18}$ Bq

46

Atmospheric dispersion



- The radioactive cloud dispersed over the entire northern hemisphere and deposited substantial amounts of radioactive material over large areas, contaminating land, water and biota and causing particularly serious social and economic disruption in Belarus, the Russian Federation and Ukraine.

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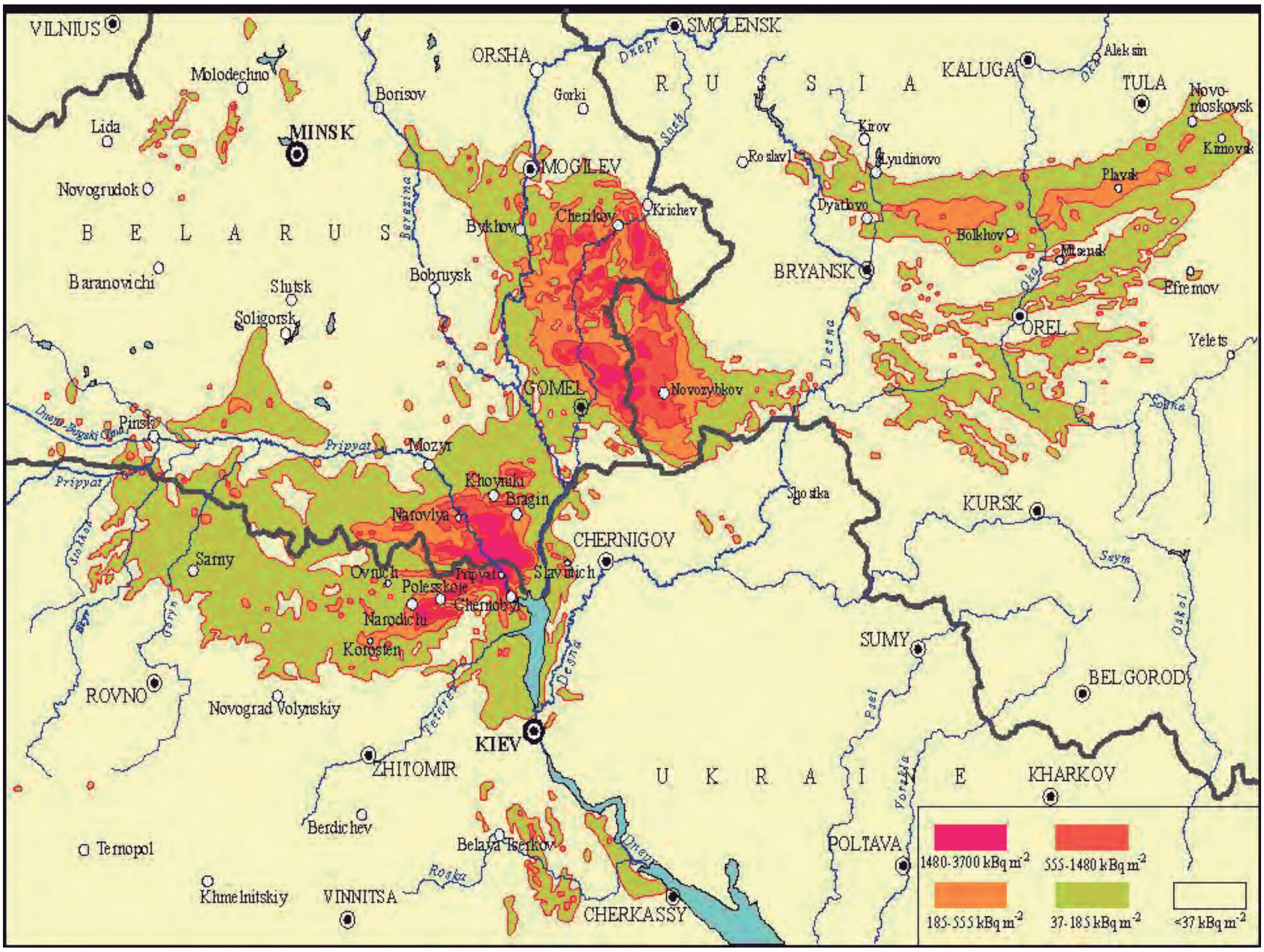
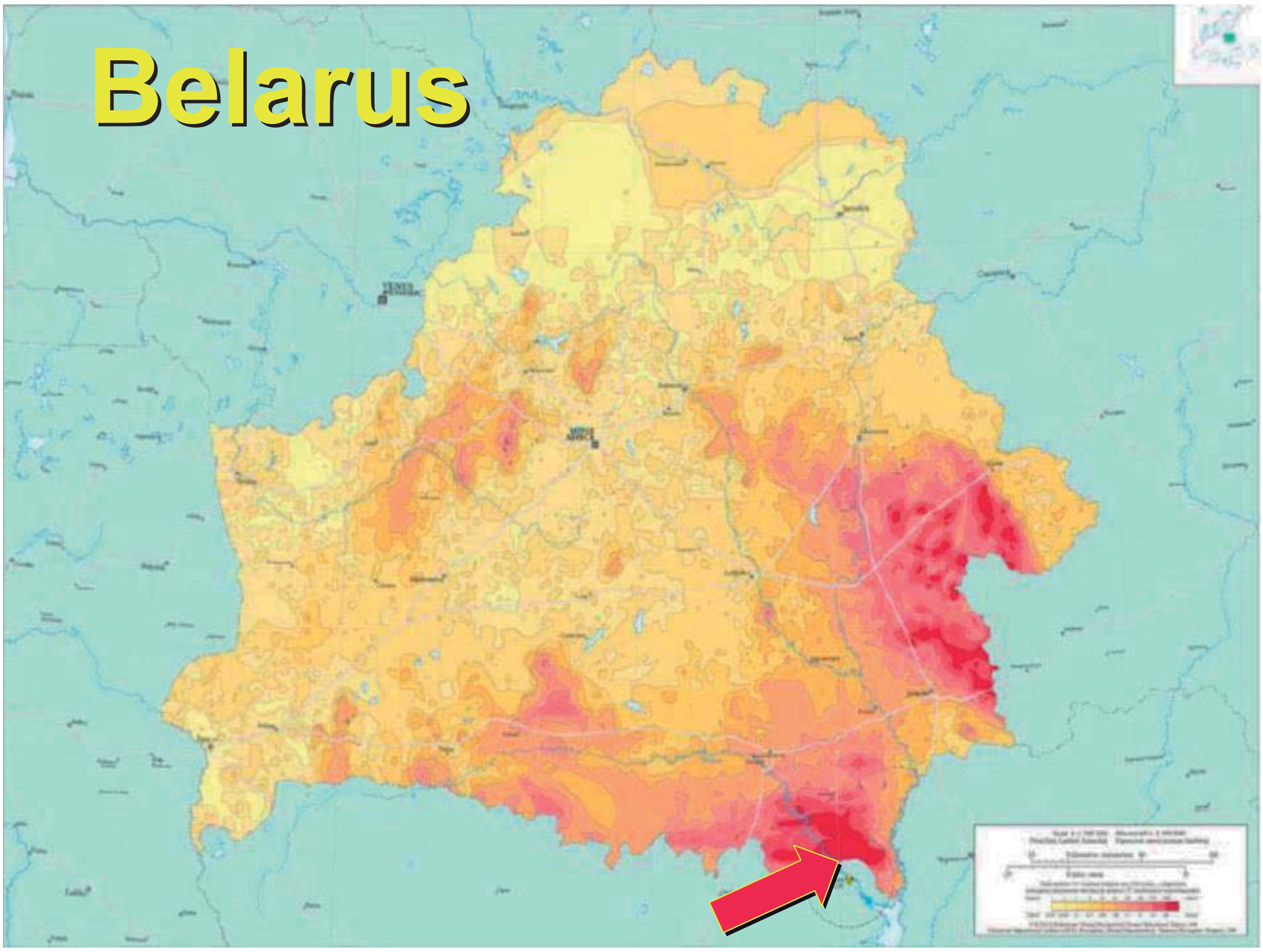

VILNIUS
SMOLENSK
ORSHA
Molodechno
Borisov
Gorki
R U S S I A
KALUGA
Aleksin
TULA
Novo-moskovsk
Lida
MINSK
Kirov
Novogrudok
MOGILEV
Roslavl
Lyudinovo
Kimovsk
Plavsk
B E L A R U S
Bykhov
Cherikov
Krichev
Dyatkovo
Bolkhov
Mtsensk
Baranovichi
Slutsk
Bobruysk
BRYANSK
Efremov
Soligorsk
OREL
Yelets
GOMEL
Novozybkov
Pinsk
Pripyat
Mozyr
Khoyniki
Bragin
Shostka
KURSK
Narovlya
CHERNIGOV
Sarny
Ovruch
Pripyat
Slavutich
Polesskoje
Chernobyl
Narodichi
Korosten
SUMY
ROVNO
BELGOROD
Novograd Volynskiy
KIEV
ZHITOMIR
U K R A I N E
KHARKOV
Berdichev
Ternopol
Belaya Tserkov
POLTAVA
Khmelnitskiy
VINNITSA
CHERKASSY
Dnepr
Desna
Berezina
Sozh
Oka
Seym
Psel
Vorskla
Oskol
Teterev
Ros
1480-3700 kBq m⁻²
555-1480 kBq m⁻²
185-555 kBq m⁻²
37-185 kBq m⁻²
<37 kBq m⁻²


Belarus


Ukraine
Black Sea
Sea of Azov


Europe
Arctic Ocean
Ocean
kBq/m²
Ci/km²
1480
185
40
10
2
40
5
1.08
0.27
0.054
Norway
Sweden
Finland
Ireland
UK
Russia
Moscow
Minsk
Belarus
Chernobyl
Kiev
Ukraine
Germany
Poland
France
Austria
Romania
Spain

Radiation Health Effects of the Chernobyl Accident

- ✓ 30 rescuers died
  (28 with acute radiation syndrome)
- ✓ Few 100 rescuers were injured
- ✓ Around 7000 children-thyroid cancers reported
  (in Belarus, the Russian Federation, and Ukraine)
- ✓ No detectable increases of other cancers
  (incidence or mortality),
  which can be attributed to radiation from Chernobyl.

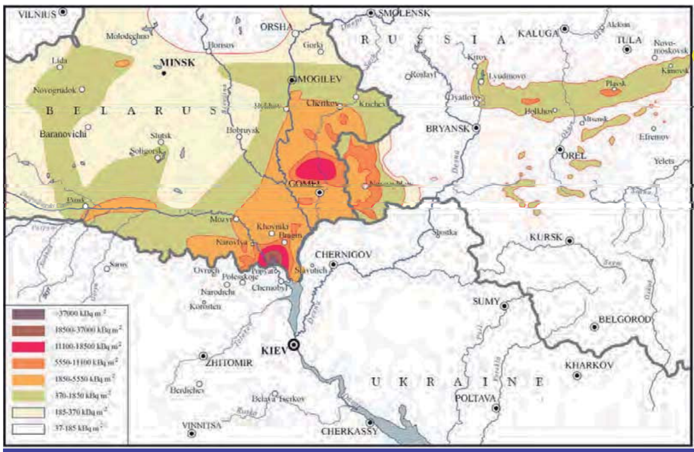
53

Essentially, the Chernobyl's victims were:

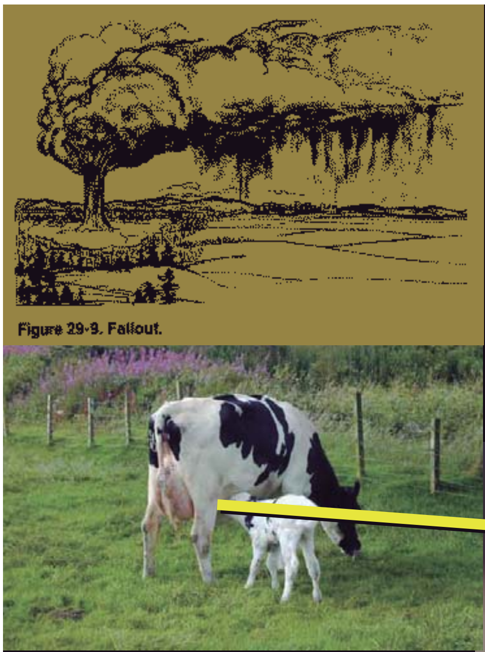
1. children exposed to radioiodine and
2. the emergency workers

1. Children

Thyroid cancers



- A substantial increase in thyroid cancer incidence among persons exposed to the accident-related radiation as children or adolescents in 1986 has been observed in Belarus, Ukraine and four of the more affected regions of the Russian Federation.



For the period 1991-2005, more than 6,000 cases were reported, of which a substantial portion could be attributed to drinking milk in 1986 contaminated with iodine-131.

high doses

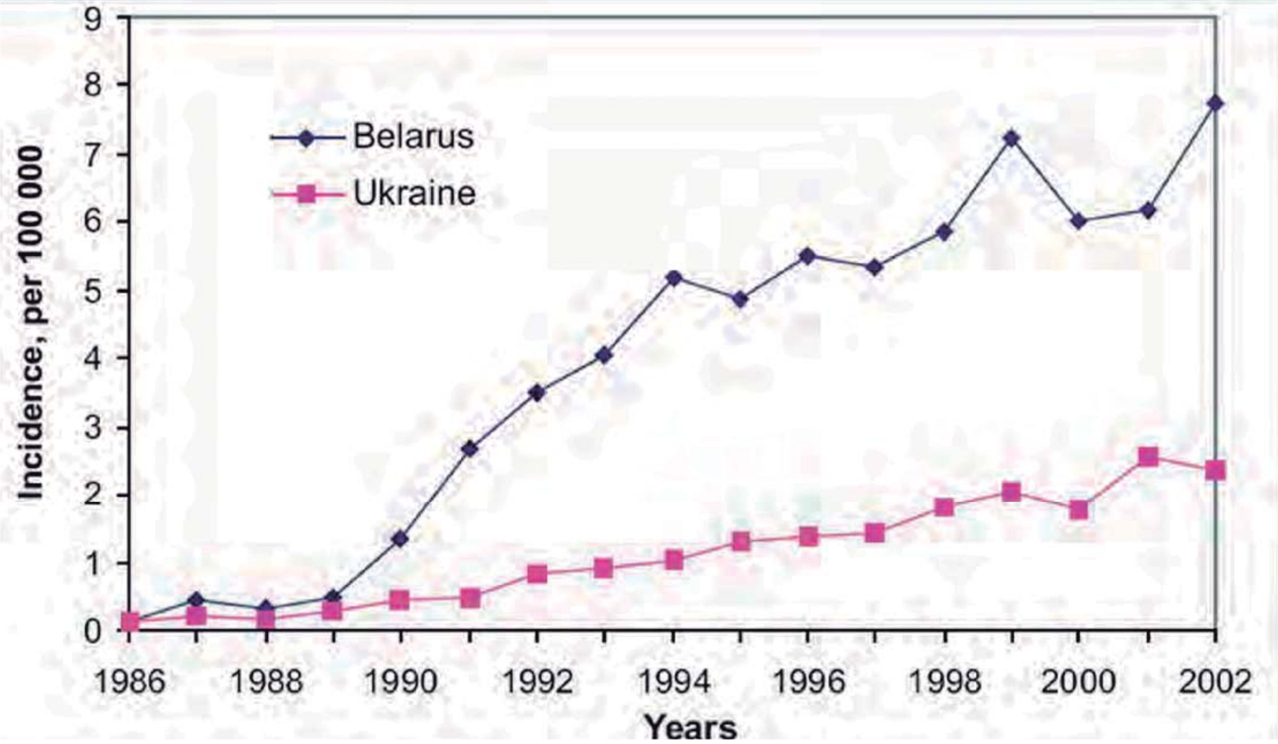
?

- - Average — 300 mSv ?
- – Higher — 10000 mSv ?

more?

58

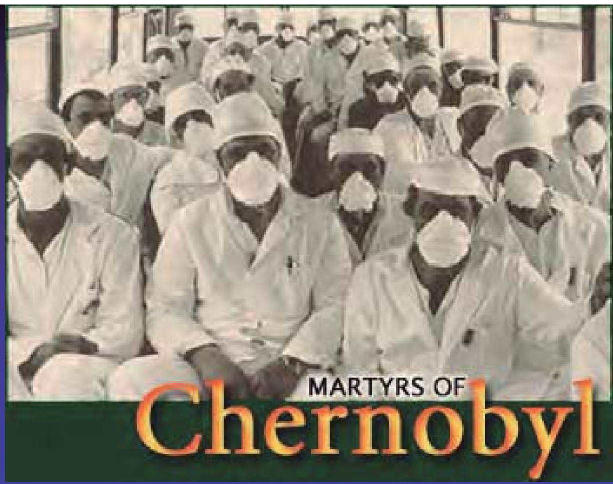
Although several thousands of extra thyroid cancer cases occurred only 15 were fatal



Incidence rate of thyroid cancer in children and adolescents exposed to 131I as a result of the Chernobyl accident (after Jacob et al., 2005)

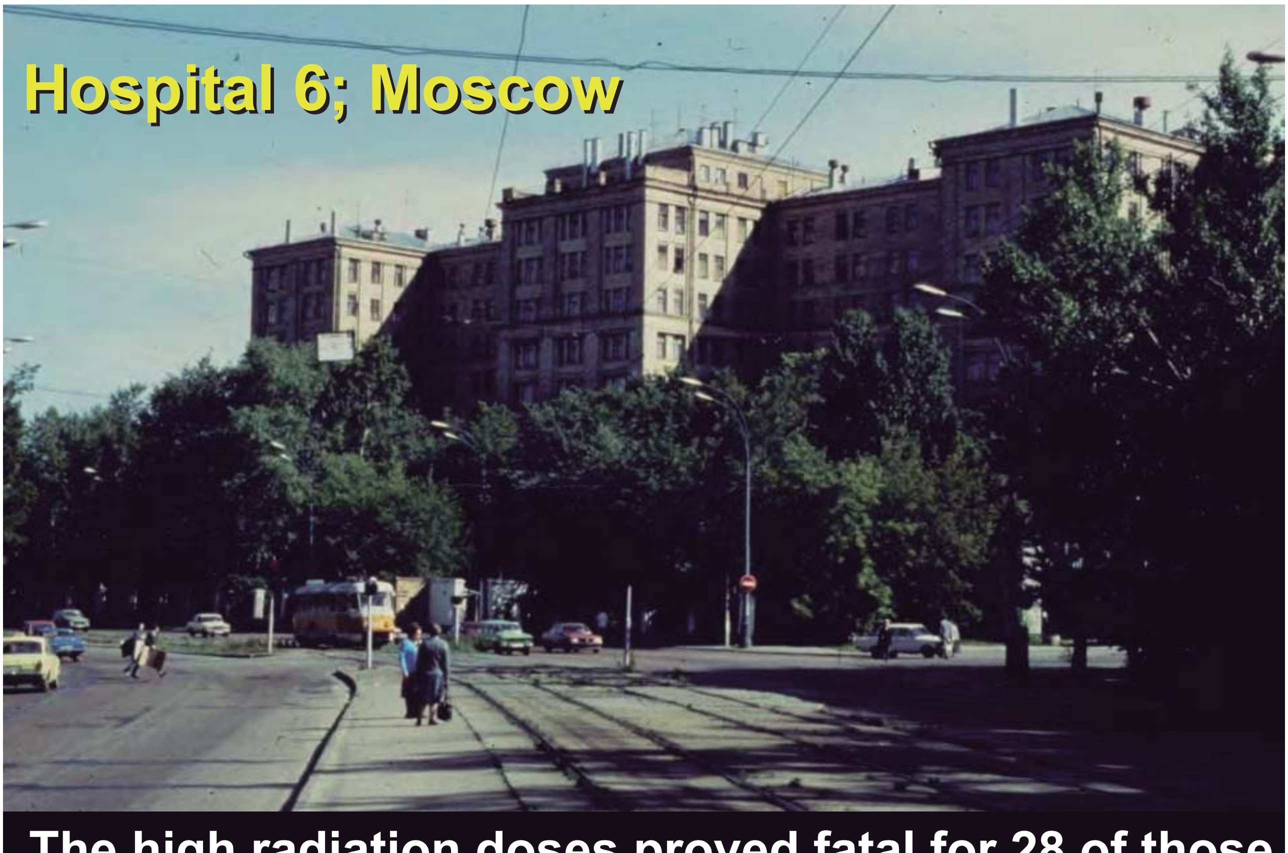
2. Workers

Two workers died in the immediate aftermath, and 134 plant staff and emergency personnel suffered acute radiation syndrome, which proved fatal for 28 of them.



admitted in hospital : 237

diagnosed with ‘acute radiation syndrome :134

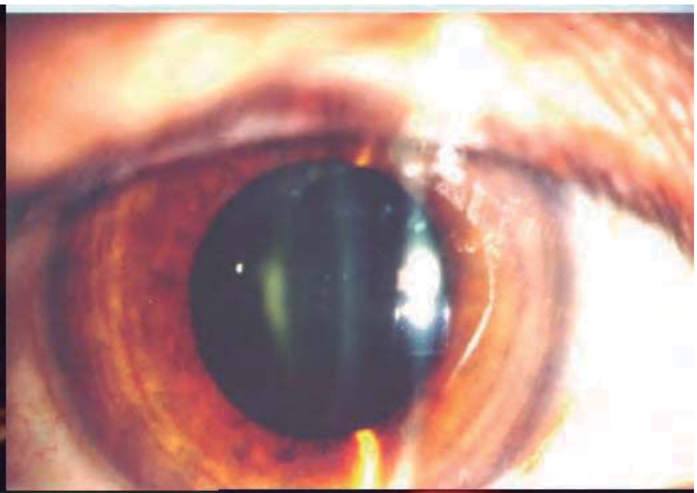


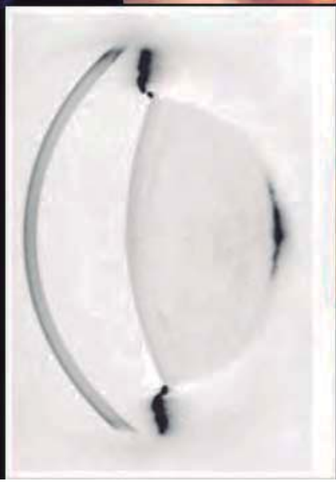
The high radiation doses proved fatal for 28 of those people in the first few months following the accident.

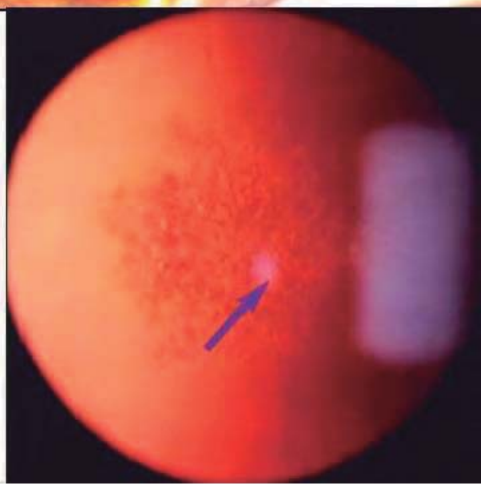

65

Skin injuries and radiation-related cataracts were among the main sequelæ of ARS survivors;

18. *Patient A (Day 26): burns to the legs and feet.*







Several hundred thousand workers were subsequently involved in recovery operations.

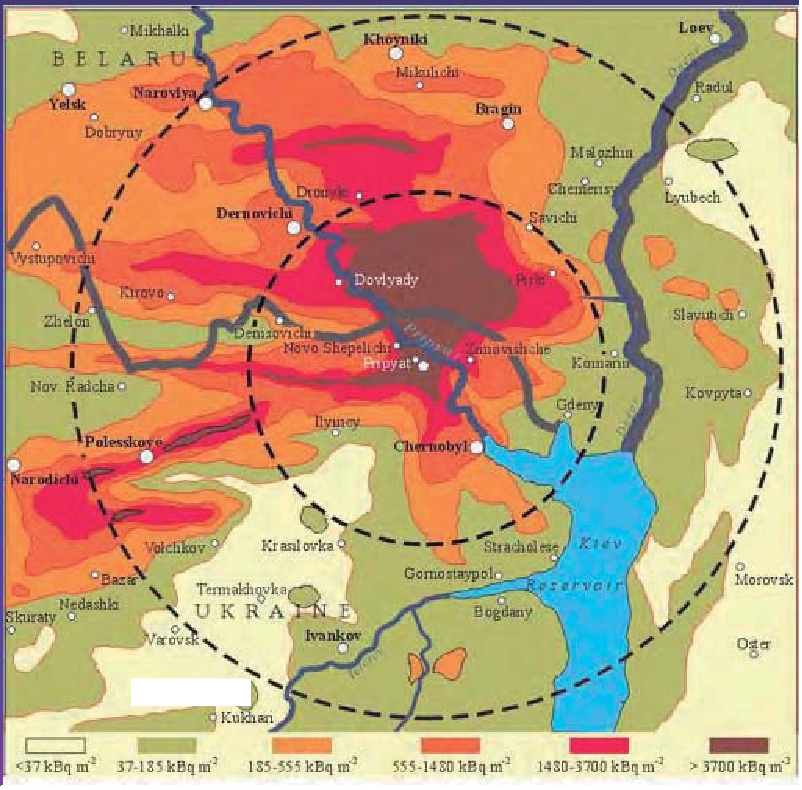
Among the several hundred thousand people were involved in recovery operations there is no evidence of health effects that can be attributed to radiation exposure.

Public exposure

Evacuation and resettlement

How many?

Ucrania	91,406
Belarus	24,725
Russia	186
Total	**116,317**




Энергетик

Most area residents were exposed to low-level radiation comparable to or a few times higher than the annual natural background radiation levels.

Long-term public radiation doses

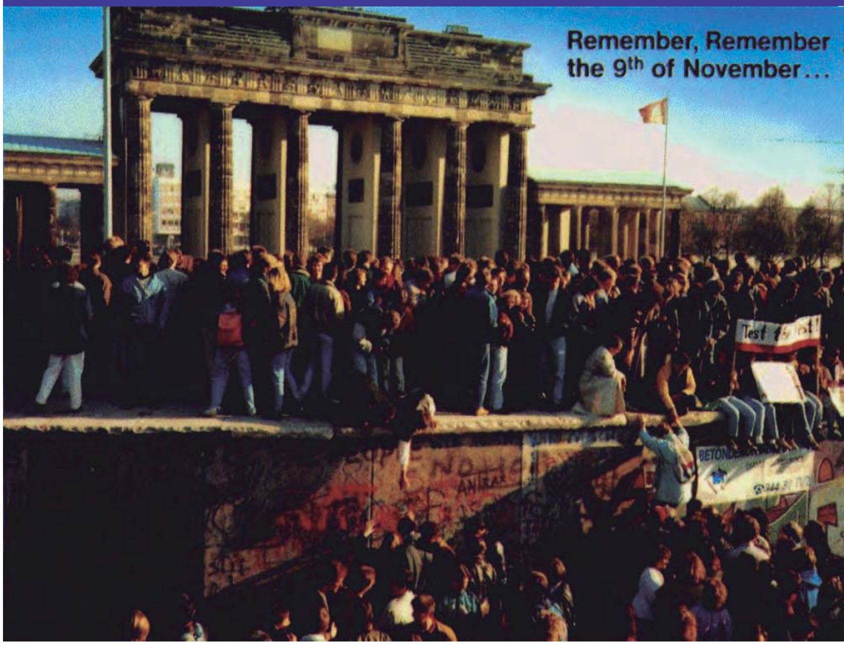
- The long-term radiation doses were low.
- The average additional dose over all the period 1986-2005 was 9 mSv.
- This is approximately equivalent to that from a CT.

84

No evidence of any health effect that can be attributed to radiation exposure.

1. These conclusions should not be construed to underplay the Chernobyl tragedy.
2. It should be underlined that the Chernobyl accident is also responsible for:

A political cataclysm



A social tragedy

88

The economic collapse of the region

Serious psychological effects

In suma: Chernobyl

- 28 dead workers
- 138 workers with acute radiation syndrome
- ~ 7000 non-lethal pediatric cancers
- However, low doses to the public = 1 tomography
- High political, social and economic impact

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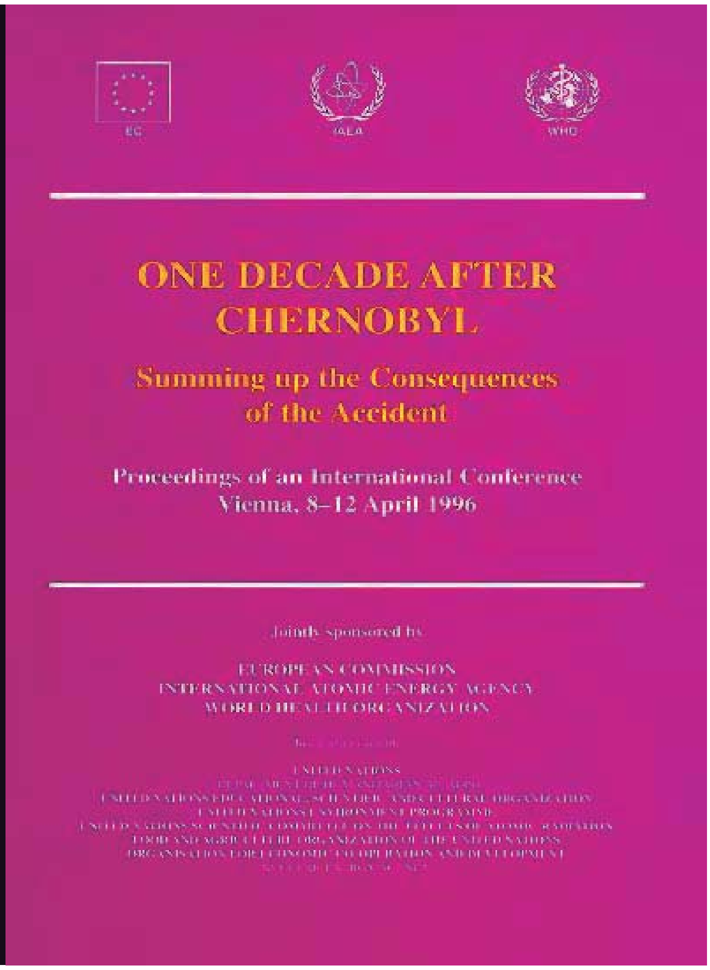
President of the Conference:
Angela Merkel



EC IAEA WHO

ONE DECADE AFTER CHERNOBYL

Summing up the Consequences of the Accident

Proceedings of an International Conference
Vienna, 8–12 April 1996

Jointly sponsored by

EUROPEAN COMMISSION
INTERNATIONAL ATOMIC ENERGY AGENCY
WORLD HEALTH ORGANIZATION

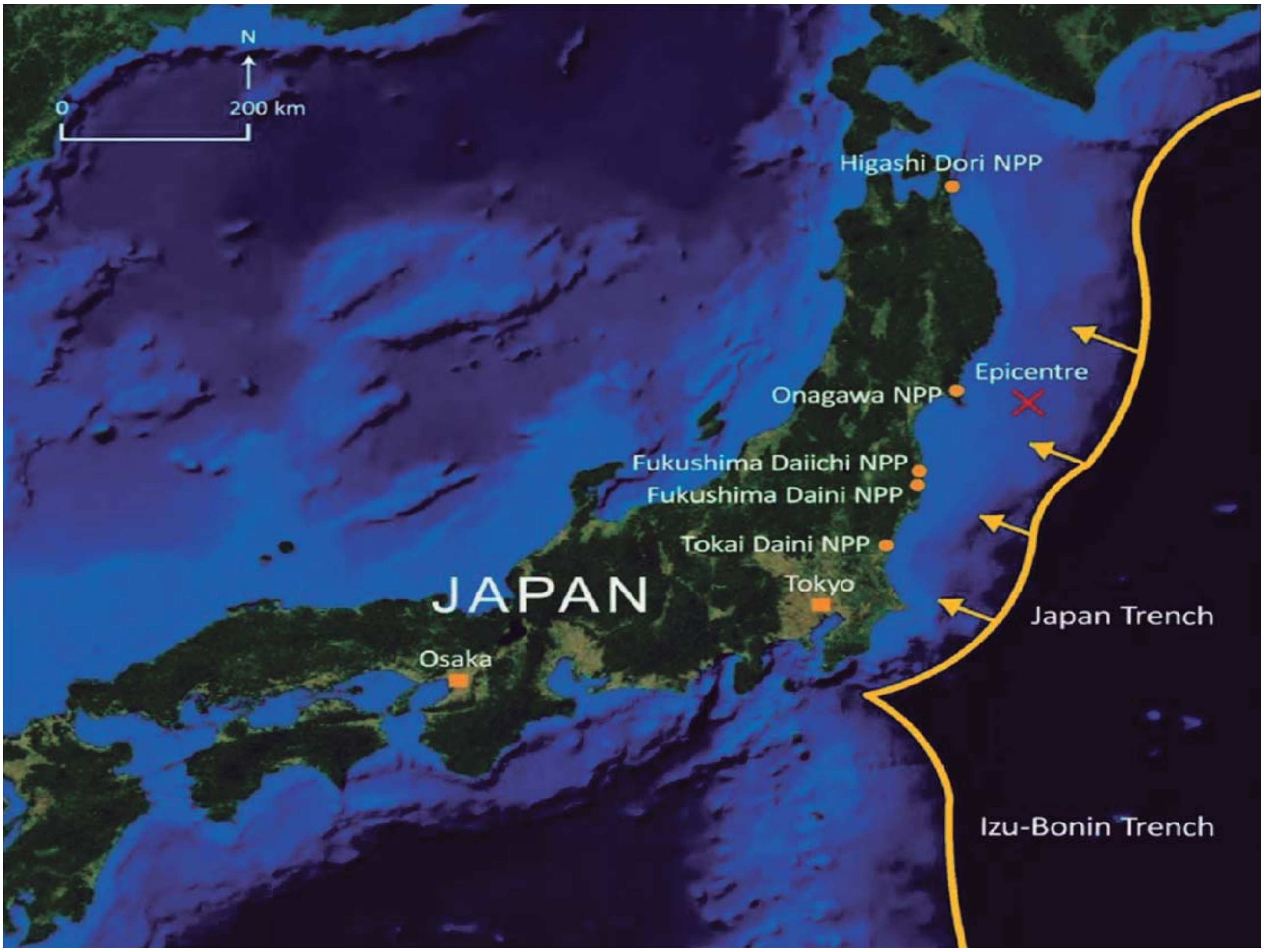
Fukushima Nuclear Power Plant Accident

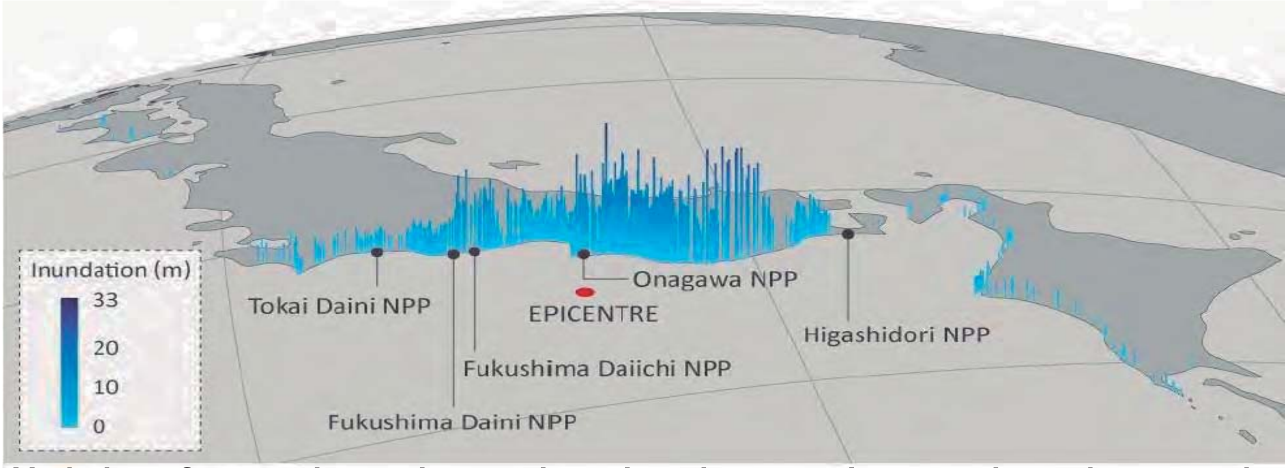
93

Fukushima Dai-ichi NPP

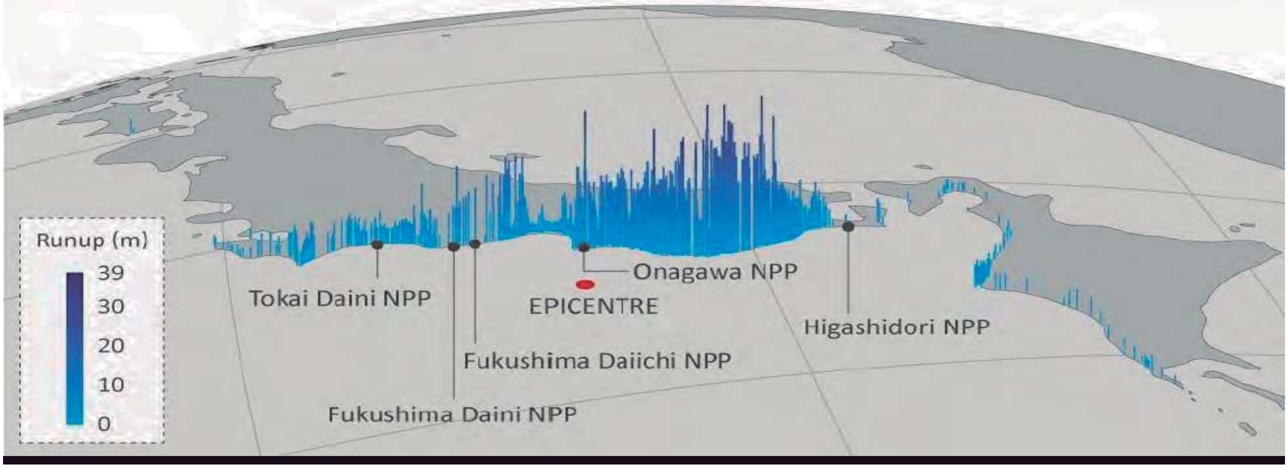
What happened?

95



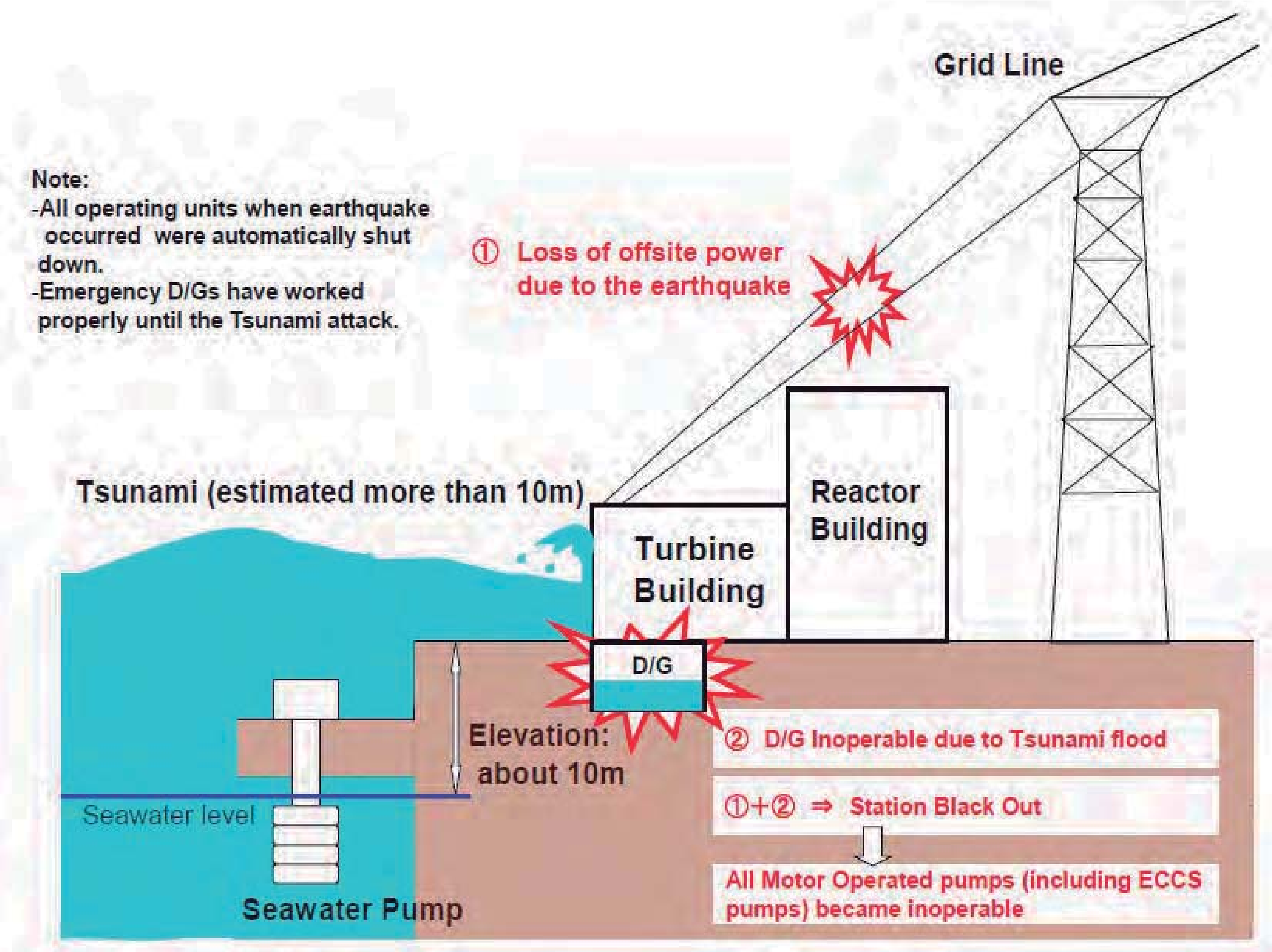


Variation of tsunami wave impact, based on the coastal geography and topography



The earthquake and subsequent tsunami, which flooded over 500 square kilometres of land, resulted in the loss of more than 20,000 lives and destroyed property, infrastructure and natural resources.


プール水サージタン
500KL



Consequences

- Part of the reactor fuel was melted down.
- The containment was inadequate, and large amounts of radioactive materials were released into the environment.

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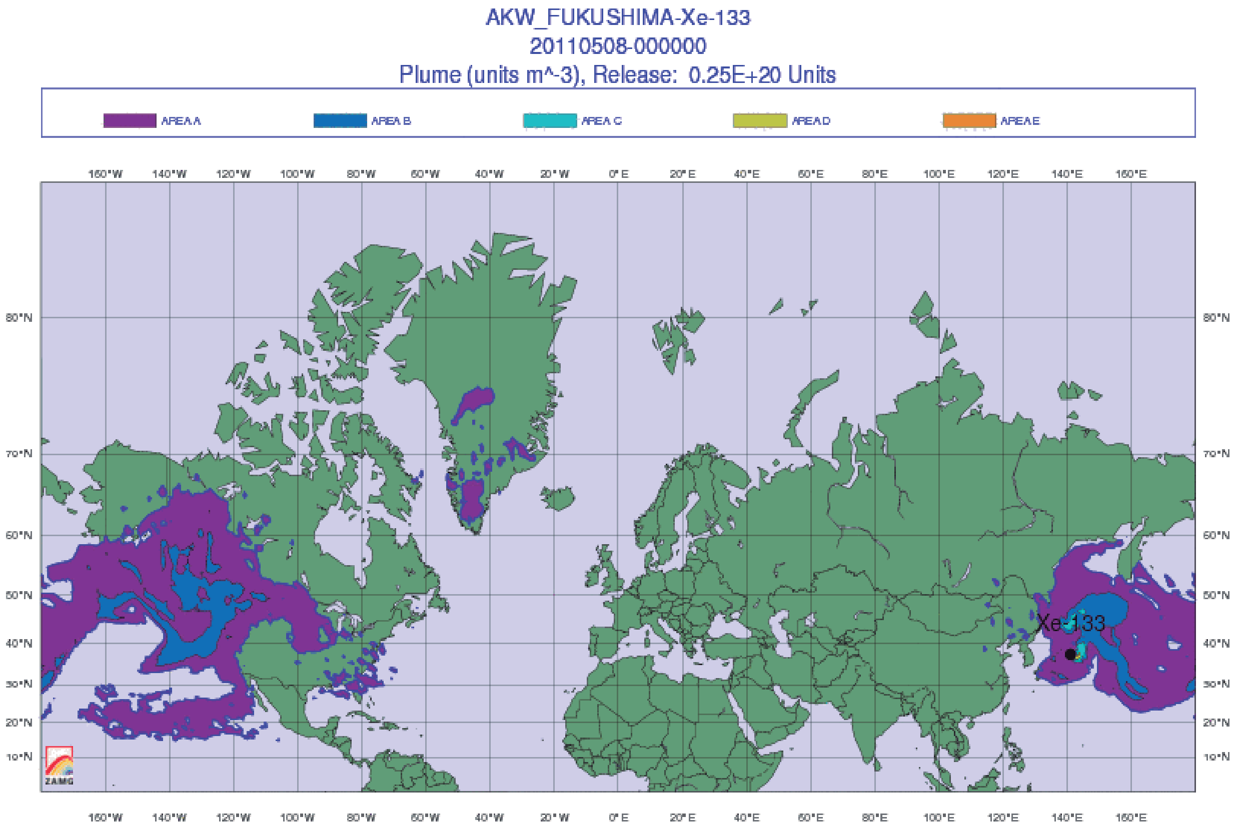
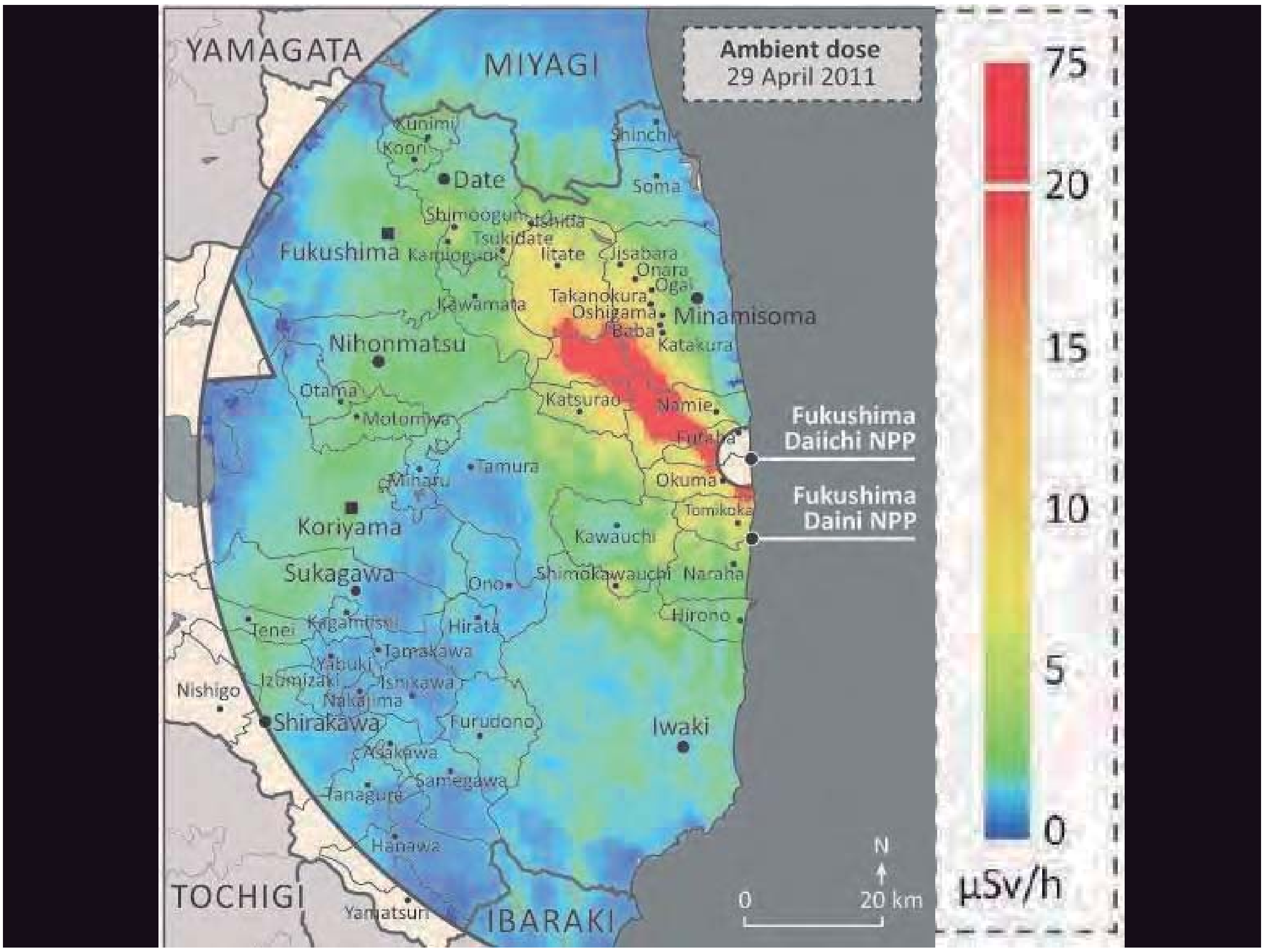
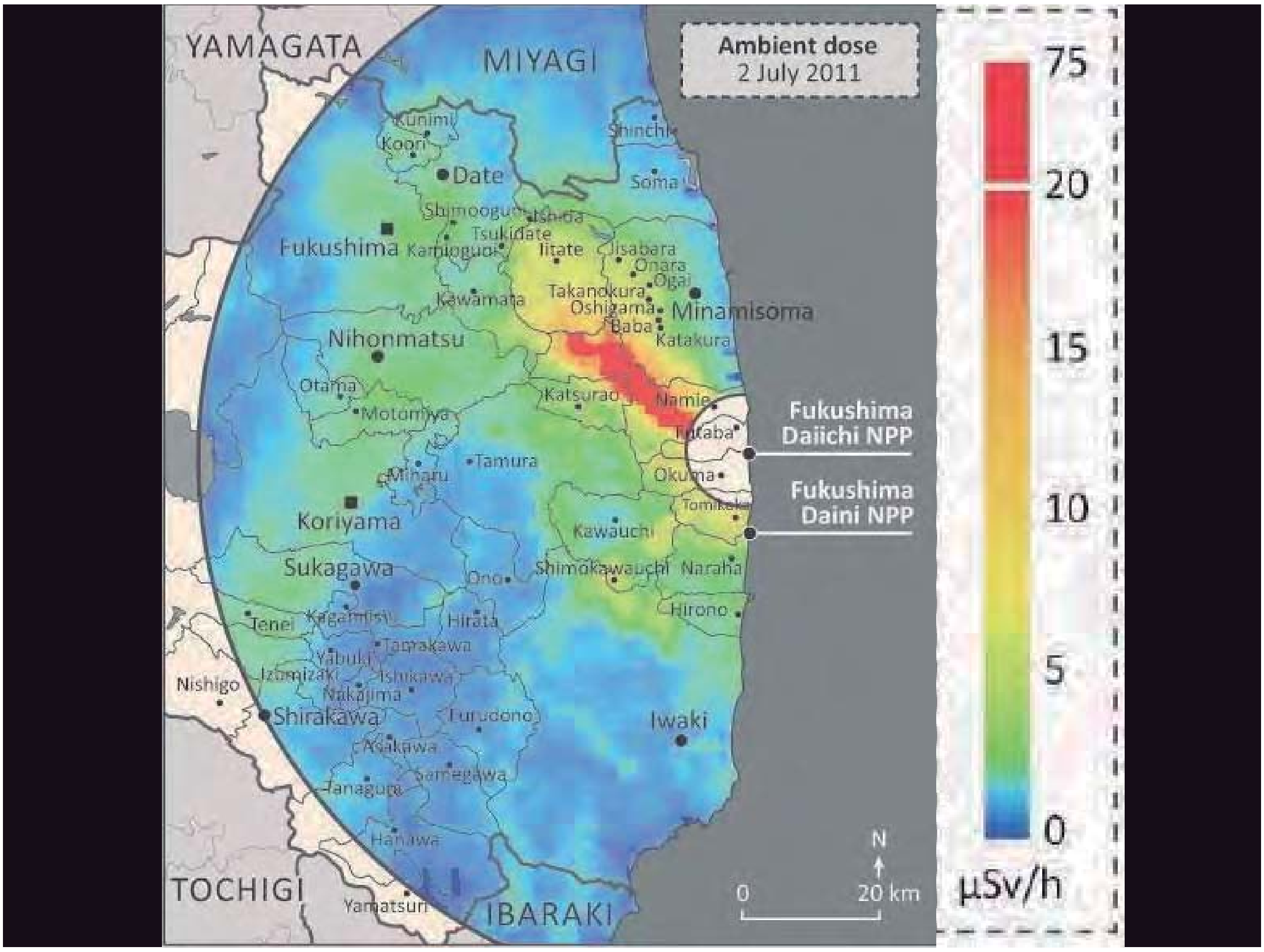
Inadequate
containment

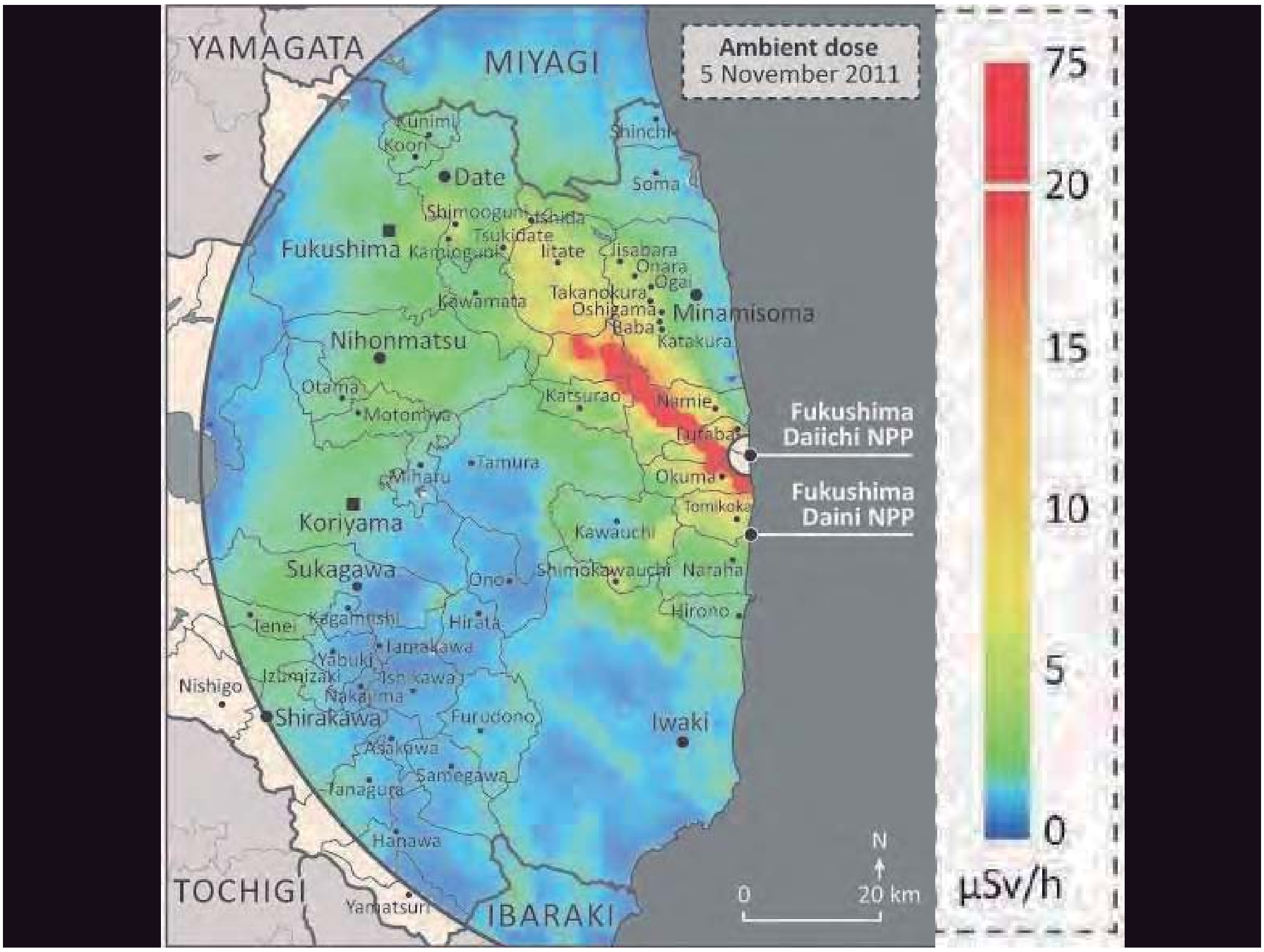

AKW_FUKUSHIMA-Xe-133
20110508-000000
Plume (units m^-3), Release: 0.25E+20 Units
AREA A
AREA B
AREA C
AREA D
AREA E
160°W 140°W 120°W 100°W 80°W 60°W 40°W 20°W 0°E 20°E 40°E 60°E 80°E 100°E 120°E 140°E 160°E
80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N
Xe-133
ZAMG

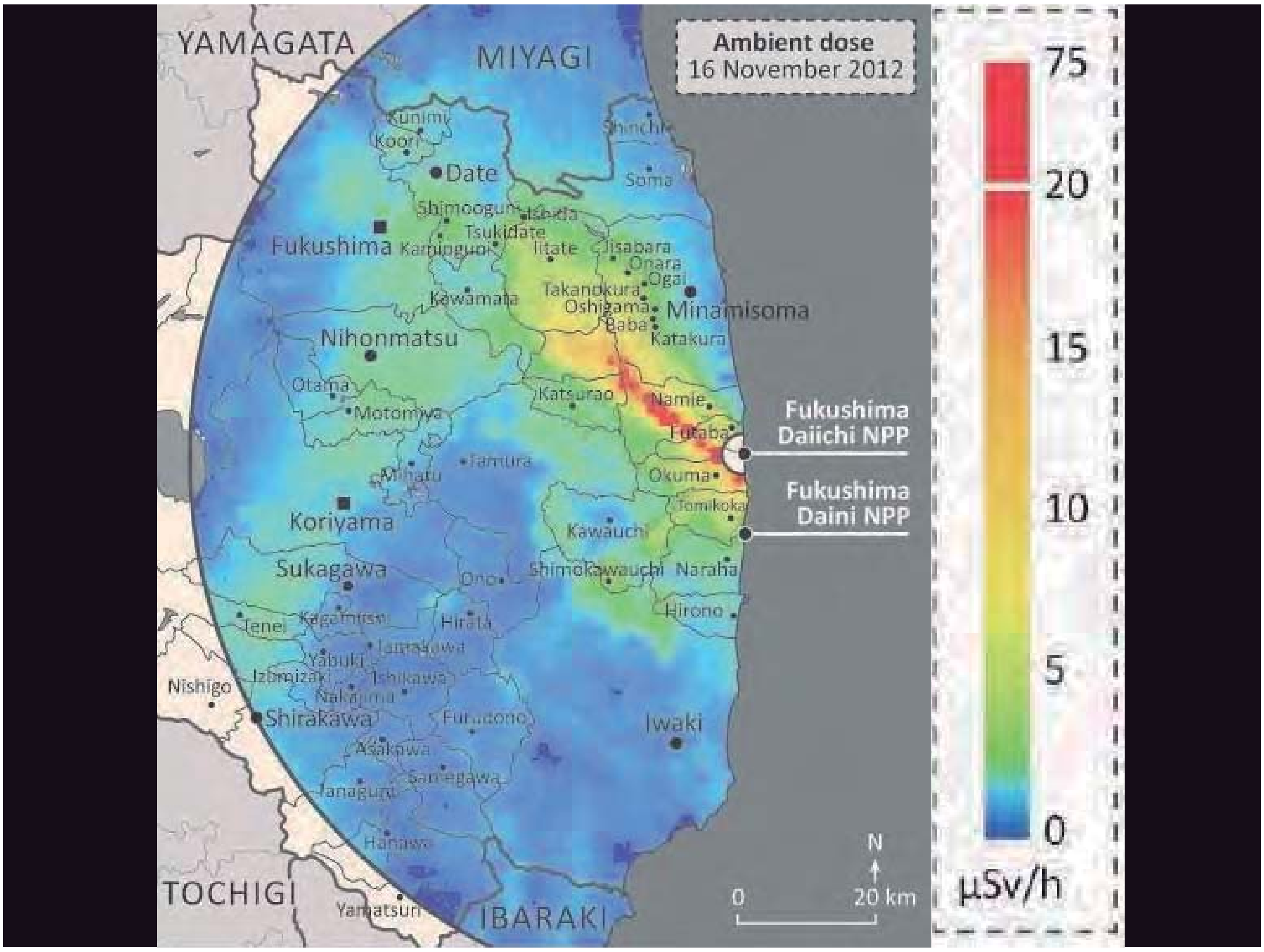


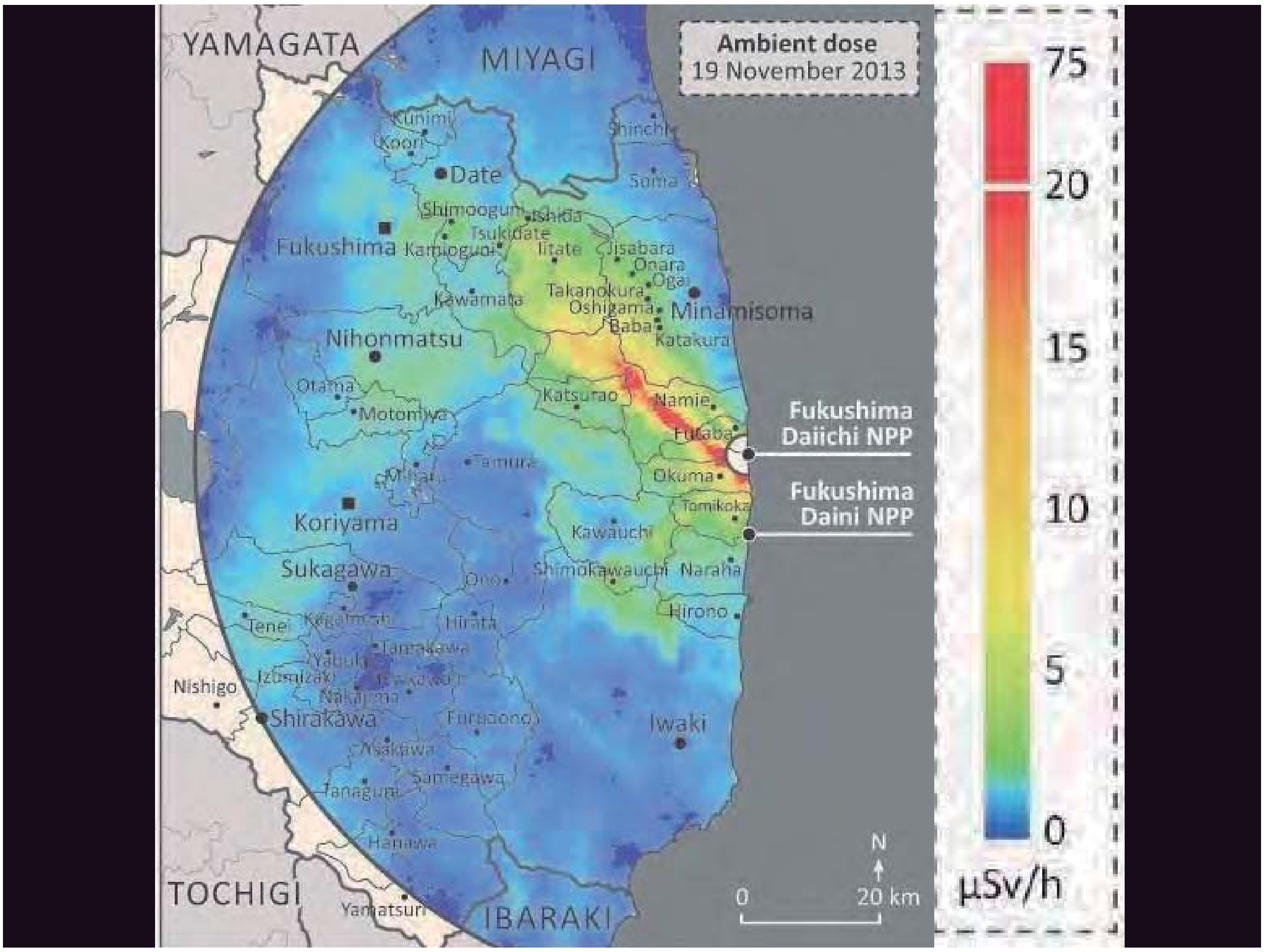
YAMAGATA
MIYAGI
Ambient dose
29 April 2011
Fukushima
Date
Minamisoma
Nihonmatsu
Fukushima Daiichi NPP
Fukushima Daini NPP
Koriyama
Sukagawa
Shirakawa
Iwaki
TOCHIGI
IBARAKI
0
20 km
75
20
15
10
5
0
µSv/h

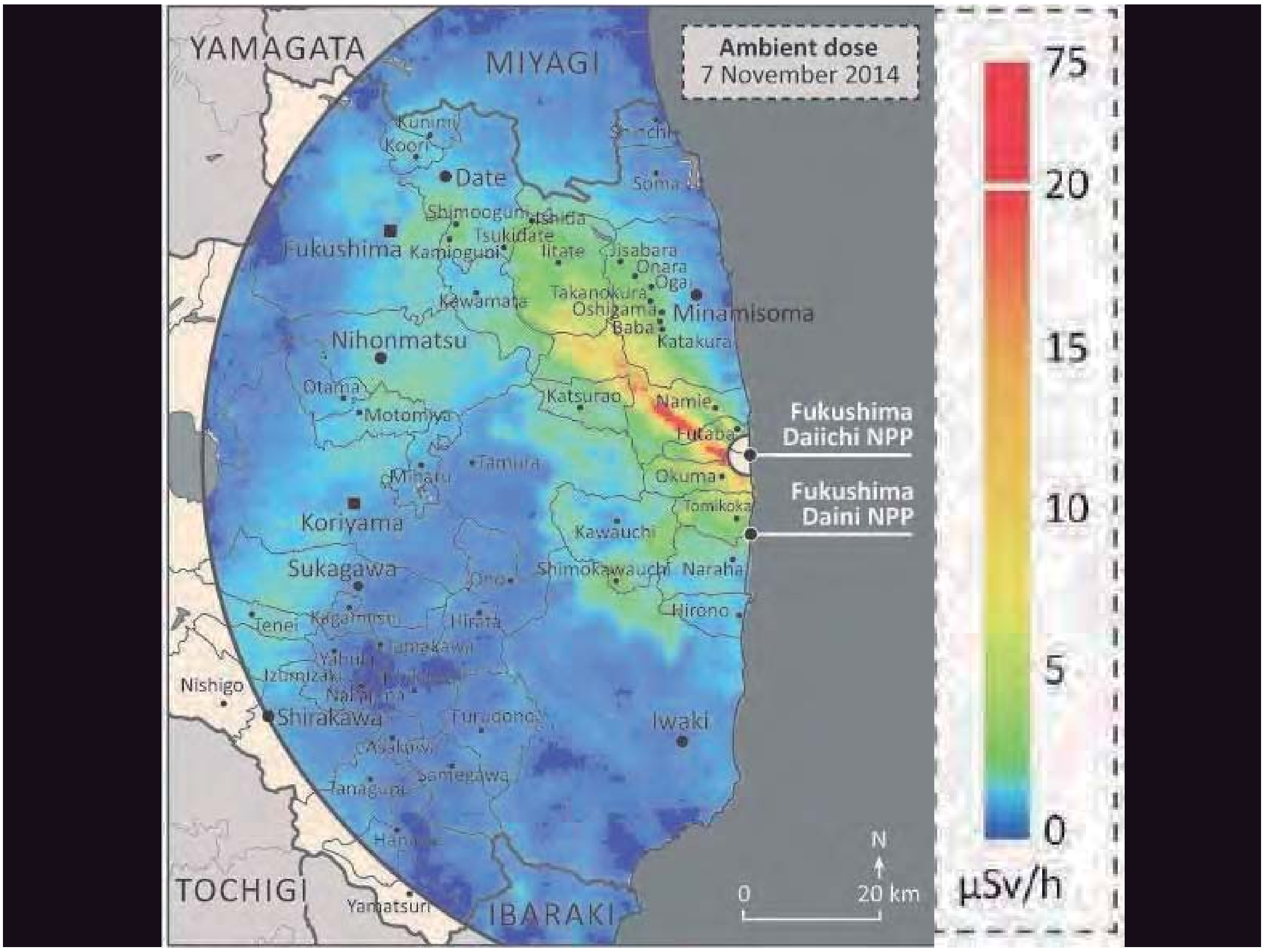


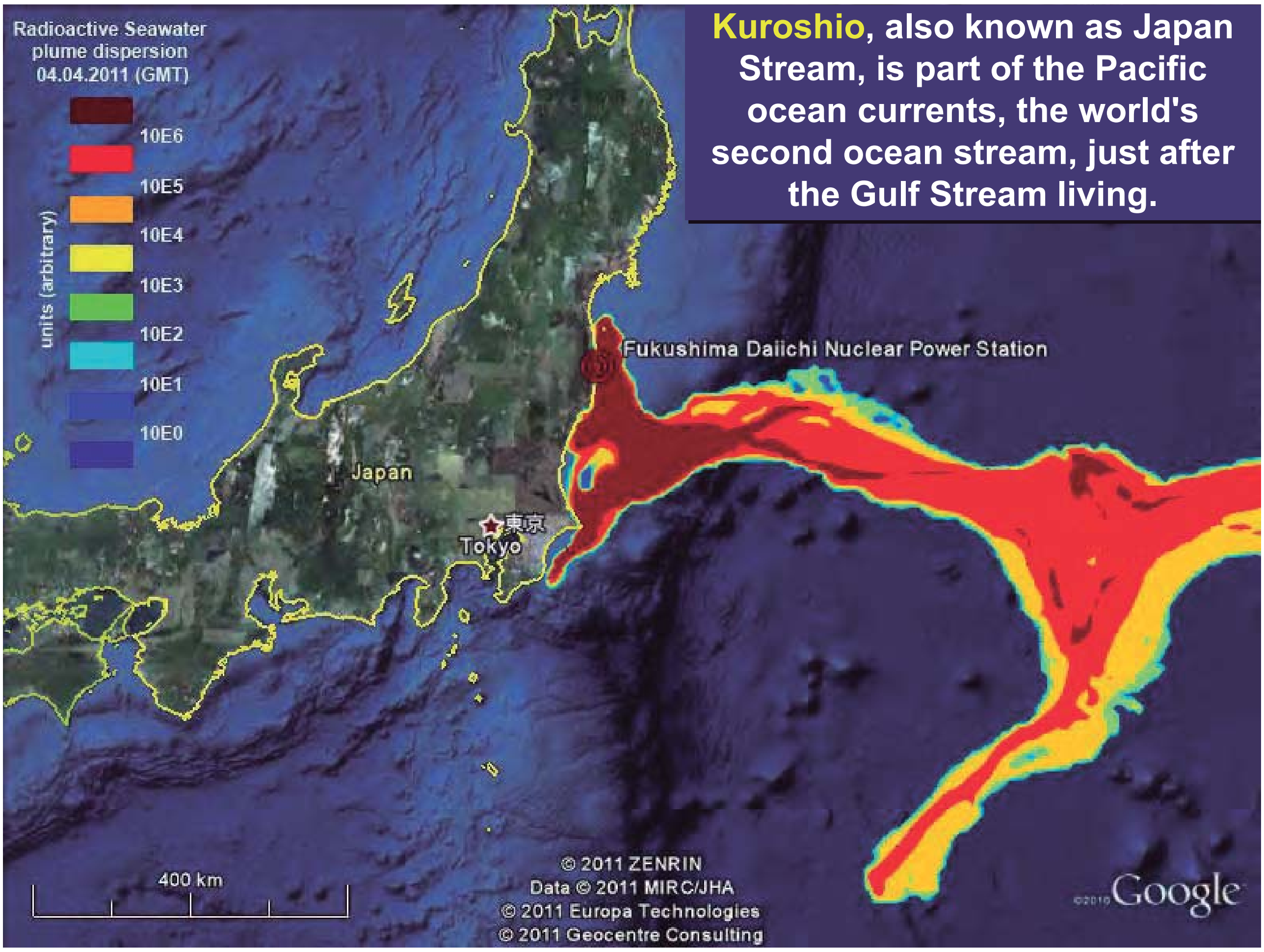
YAMAGATA
MIYAGI
Ambient dose
2 July 2011
Fukushima
Date
Minamisoma
Nihonmatsu
Fukushima Daiichi NPP
Fukushima Daini NPP
Koriyama
Sukagawa
Shirakawa
Iwaki
TOCHIGI
IBARAKI
0
20 km
75
20
15
10
5
0
µSv/h

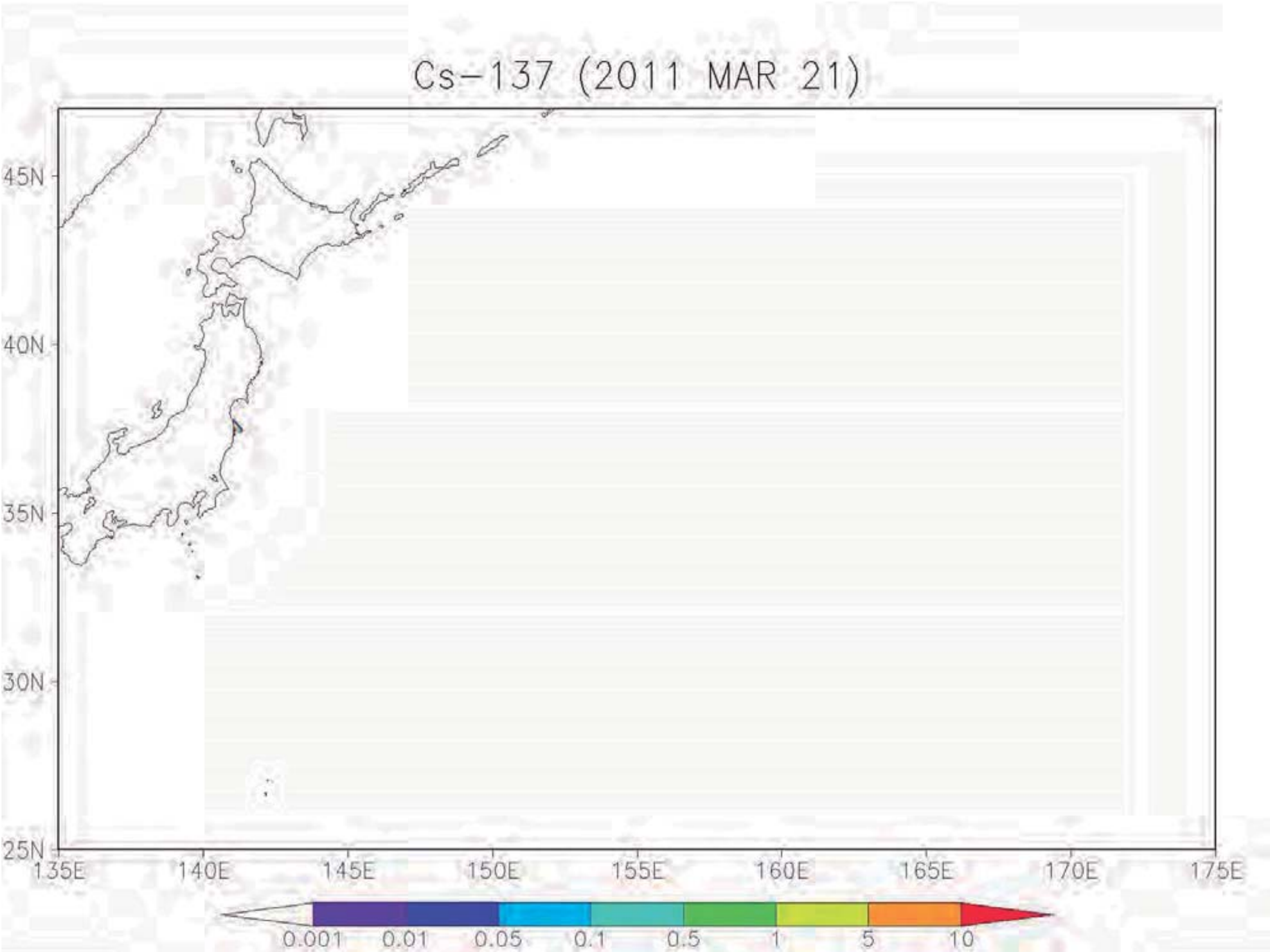

Ambient dose
5 November 2011
YAMAGATA
MIYAGI
Fukushima
Date
Minamisoma
Nihonmatsu
Koriyama
Sukagawa
Shirakawa
Iwaki
Fukushima
Daiichi NPP
Fukushima
Daini NPP
TOCHIGI
IBARAKI
0
20 km
N
75
20
15
10
5
0
µSv/h

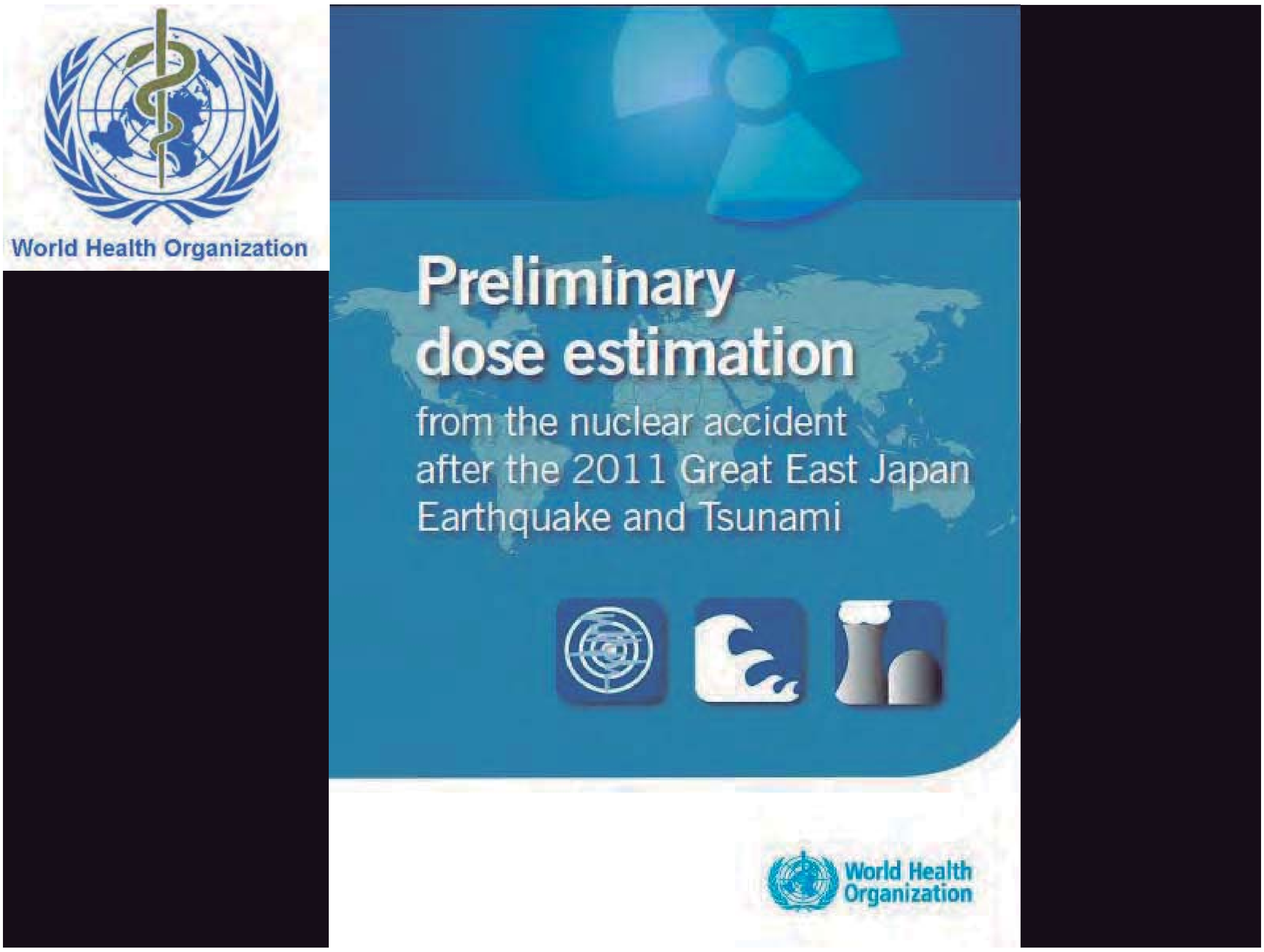

Ambient dose
16 November 2012
YAMAGATA
MIYAGI
Fukushima
Date
Minamisoma
Nihonmatsu
Koriyama
Sukagawa
Shirakawa
Iwaki
Fukushima
Daiichi NPP
Fukushima
Daini NPP
TOCHIGI
IBARAKI
0
20 km
N
75
20
15
10
5
0
µSv/h

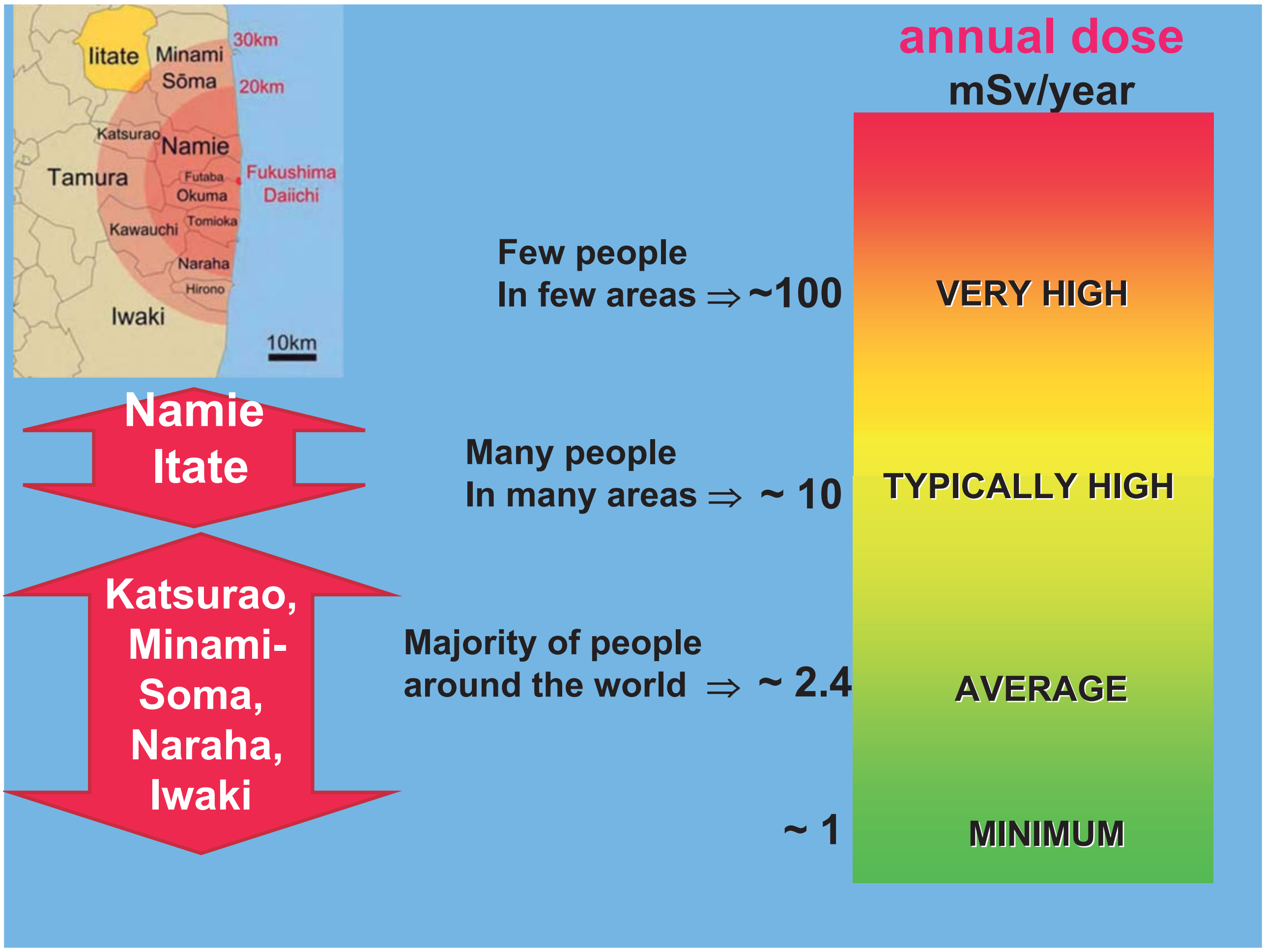

YAMAGATA
MIYAGI
Ambient dose
19 November 2013
75
20
15
10
5
0
µSv/h
Kunimi
Koori
Date
Shinchi
Soma
Shimoogum
Ishida
Tsukidate
Fukushima
Kamioguni
Iitate
Jisabara
Onara
Ogai
Kawamata
Takanokura
Oshigama
Minamisoma
Baba
Katakura
Nihonmatsu
Otama
Motomiya
Katsurao
Namie
Futaba
Fukushima
Daiichi NPP
Tamura
Okuma
Miharu
Tomioka
Fukushima
Daini NPP
Koriyama
Kawauchi
Sukagawa
Ono
Shimokawauchi
Naraha
Tenei
Hirata
Hirono
Tamakawa
Yabuki
Nishigo
Izumizaki
Nakajima
Shirakawa
Furudono
Iwaki
Asakawa
Samegawa
Tanagura
Hanawa
N
TOCHIGI
Yamatsuri
IBARAKI
0
20 km

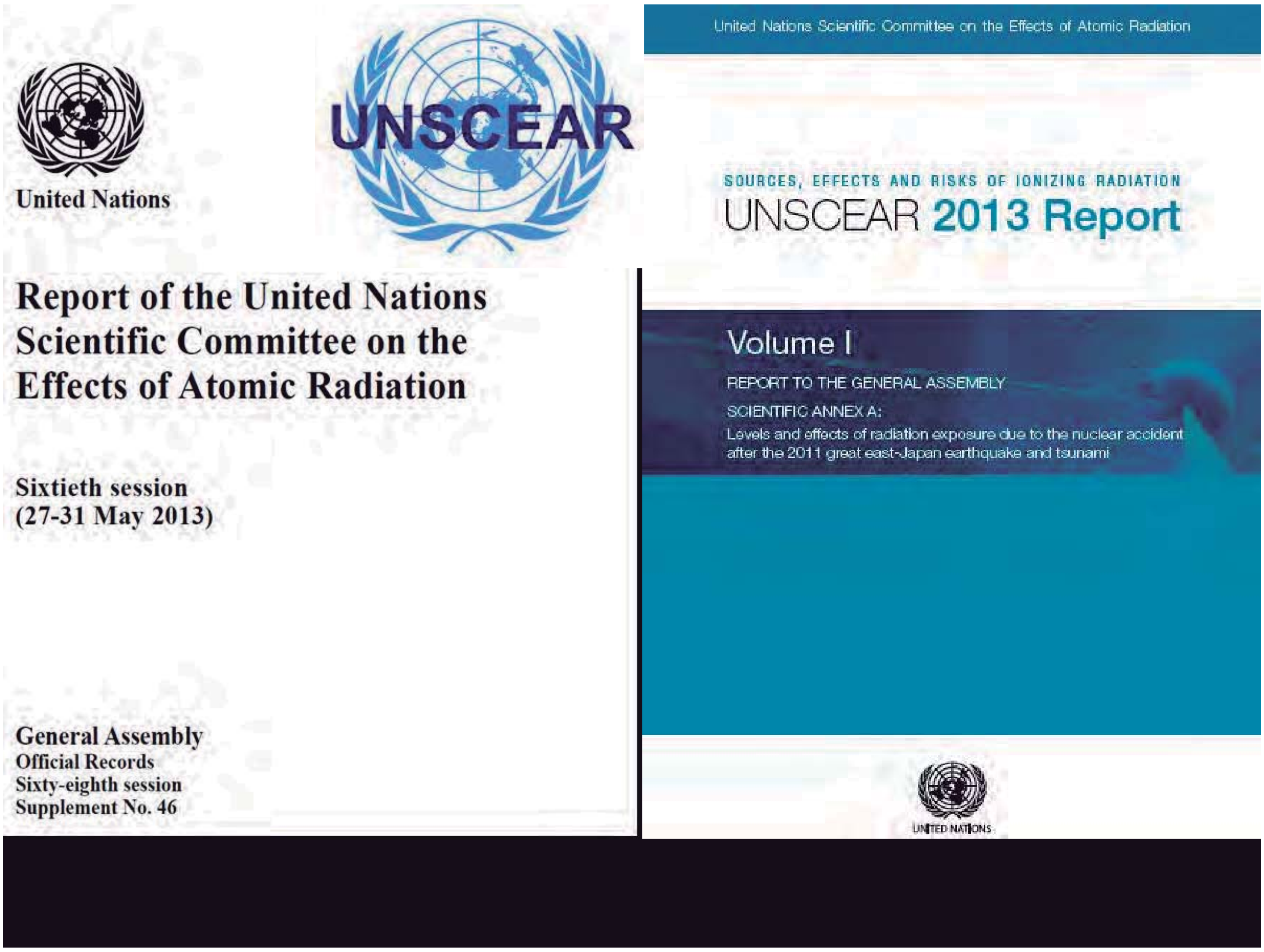

YAMAGATA
MIYAGI
Ambient dose
7 November 2014
75
20
15
10
5
0
µSv/h
Kunimi
Koori
Date
Soma
Shimoogum
Ishida
Tsukidate
Fukushima
Kamioguni
Iitate
Jisabara
Onara
Ogai
Kawamata
Takanokura
Oshigama
Minamisoma
Baba
Katakura
Nihonmatsu
Otama
Motomiya
Katsurao
Namie
Futaba
Fukushima
Daiichi NPP
Tamura
Okuma
Miharu
Tomioka
Fukushima
Daini NPP
Koriyama
Kawauchi
Sukagawa
Ono
Shimokawauchi
Naraha
Tenei
Hirata
Hirono
Tamakawa
Yabuki
Nishigo
Izumizaki
Shirakawa
Furudono
Iwaki
Asakawa
Samegawa
Tanagura
N
TOCHIGI
Yamatsuri
IBARAKI
0
20 km

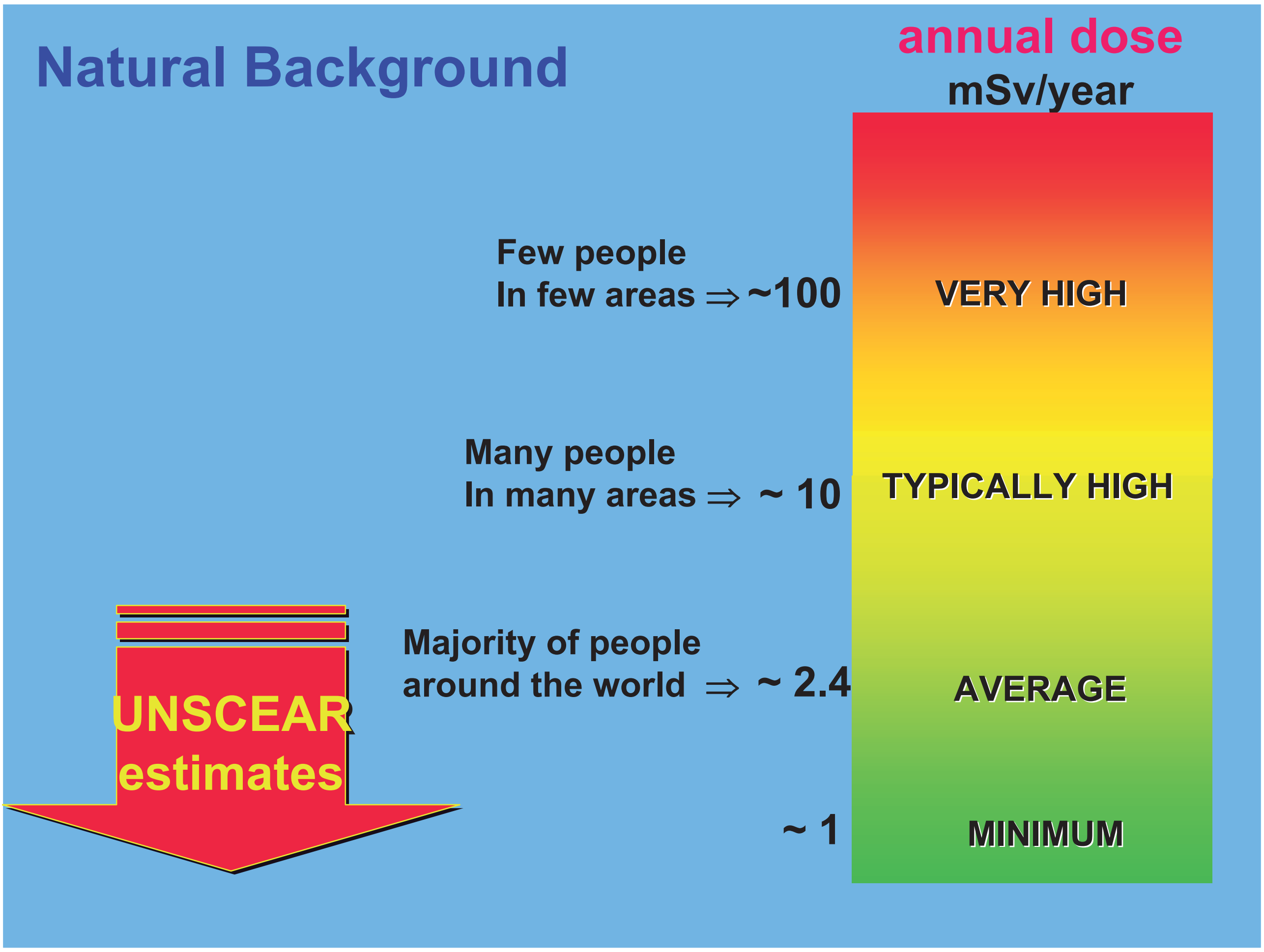

Radioactive Seawater
plume dispersion
04.04.2011 (GMT)
10E6
10E5
10E4
10E3
10E2
10E1
10E0
units (arbitrary)
Kuroshio, also known as Japan Stream, is part of the Pacific ocean currents, the world's second ocean stream, just after the Gulf Stream living.
Fukushima Daiichi Nuclear Power Station
Japan
東京
Tokyo
400 km
© 2011 ZENRIN
Data © 2011 MIRC/JHA
© 2011 Europa Technologies
© 2011 Geocentre Consulting
Google

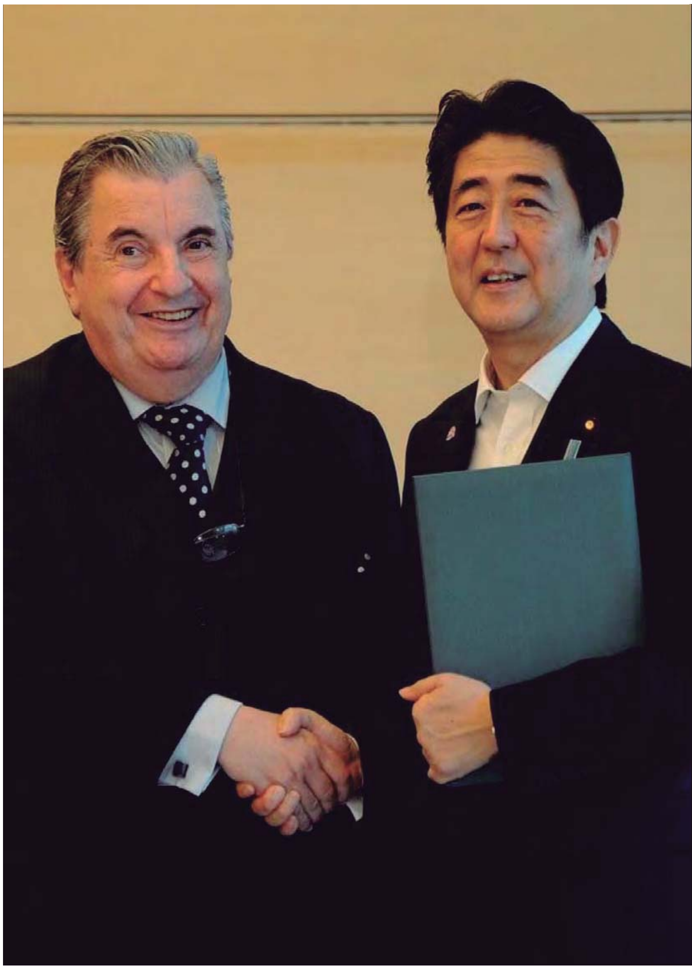

Cs−137 (2011 MAR 21)
45N
40N
35N
30N
25N
135E
140E
145E
150E
155E
160E
165E
170E
175E
0.001
0.01
0.05
0.1
0.5
1
5
10

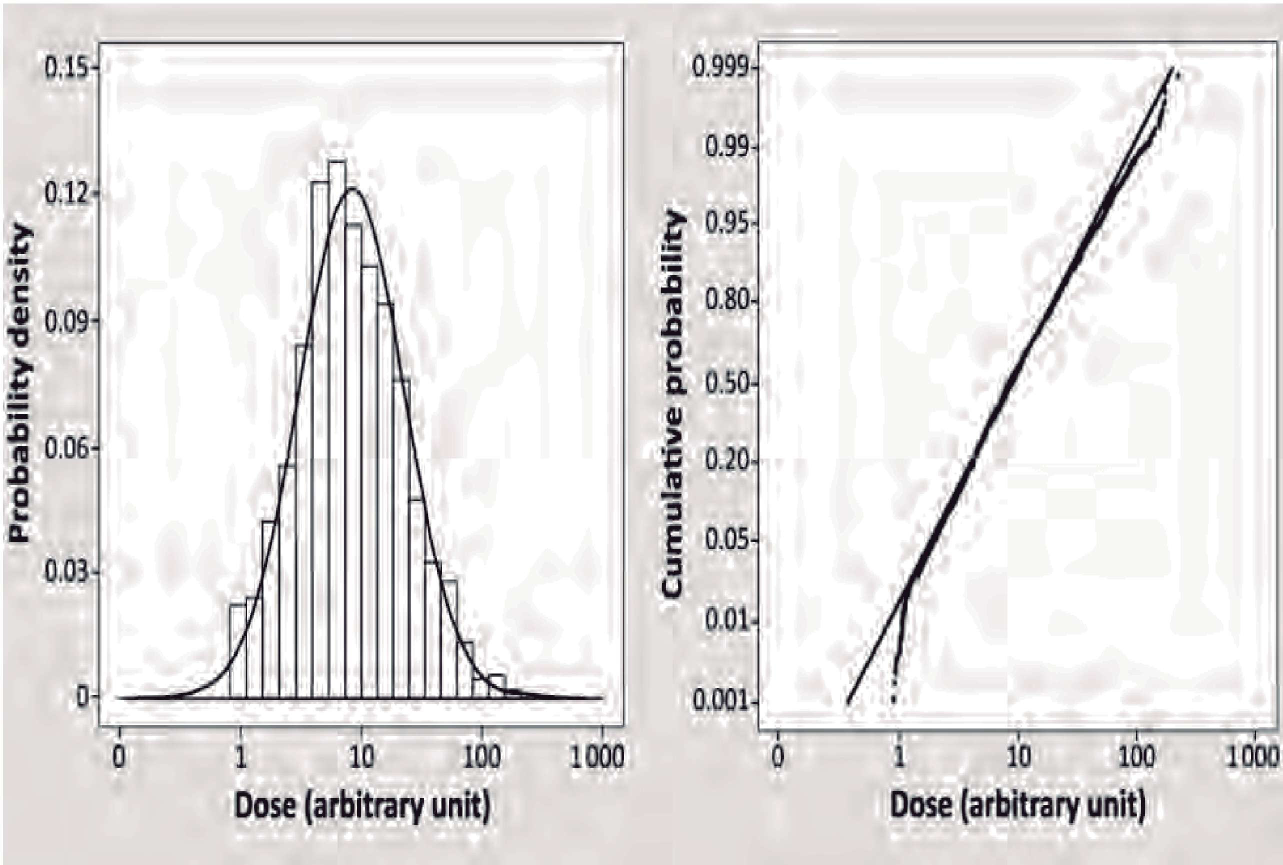

World Health Organization
Preliminary dose estimation
from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami
World Health Organization


Iitate
Minami Sōma
30km
20km
Katsurao
Namie
Tamura
Futaba
Okuma
Fukushima Daiichi
Tomioka
Kawauchi
Naraha
Hirono
Iwaki
10km
Namie Itate
Katsurao, Minami-Soma, Naraha, Iwaki
annual dose
mSv/year
Few people In few areas ⇒ ~100
VERY HIGH
Many people In many areas ⇒ ~ 10
TYPICALLY HIGH
Majority of people around the world ⇒ ~ 2.4
AVERAGE
~ 1
MINIMUM

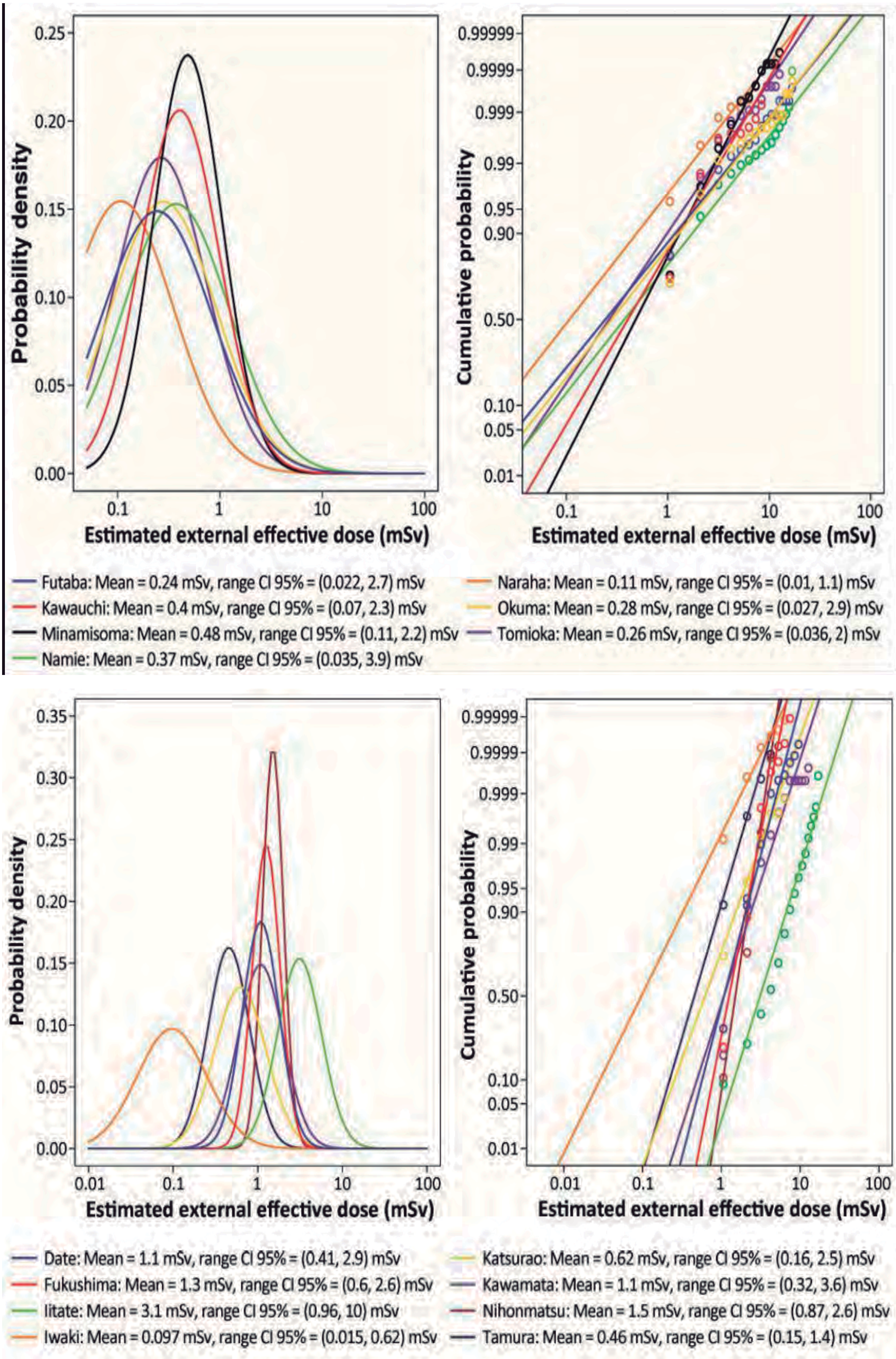

United Nations
UNSCEAR
Report of the United Nations Scientific Committee on the Effects of Atomic Radiation
Sixtieth session
(27-31 May 2013)
General Assembly
Official Records
Sixty-eighth session
Supplement No. 46
United Nations Scientific Committee on the Effects of Atomic Radiation
SOURCES, EFFECTS AND RISKS OF IONIZING RADIATION
UNSCEAR 2013 Report
Volume I
REPORT TO THE GENERAL ASSEMBLY
SCIENTIFIC ANNEX A:
Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami
UNITED NATIONS


Natural Background
annual dose
mSv/year
Few people
In few areas ⇒ ~100
VERY HIGH
Many people
In many areas ⇒ ~ 10
TYPICALLY HIGH
Majority of people
around the world ⇒ ~ 2.4
AVERAGE
~ 1
MINIMUM
UNSCEAR
estimates





Statistical analysis of estimated and measured data


Probability density
Estimated external effective dose (mSv)
Cumulative probability
Estimated external effective dose (mSv)
Futaba: Mean = 0.24 mSv, range CI 95% = (0.022, 2.7) mSv
Kawauchi: Mean = 0.4 mSv, range CI 95% = (0.07, 2.3) mSv
Minamisoma: Mean = 0.48 mSv, range CI 95% = (0.11, 2.2) mSv
Namie: Mean = 0.37 mSv, range CI 95% = (0.035, 3.9) mSv
Naraha: Mean = 0.11 mSv, range CI 95% = (0.01, 1.1) mSv
Okuma: Mean = 0.28 mSv, range CI 95% = (0.027, 2.9) mSv
Tomioka: Mean = 0.26 mSv, range CI 95% = (0.036, 2) mSv
Probability density
Estimated external effective dose (mSv)
Cumulative probability
Estimated external effective dose (mSv)
Date: Mean = 1.1 mSv, range CI 95% = (0.41, 2.9) mSv
Fukushima: Mean = 1.3 mSv, range CI 95% = (0.6, 2.6) mSv
Iitate: Mean = 3.1 mSv, range CI 95% = (0.96, 10) mSv
Iwaki: Mean = 0.097 mSv, range CI 95% = (0.015, 0.62) mSv
Katsurao: Mean = 0.62 mSv, range CI 95% = (0.16, 2.5) mSv
Kawamata: Mean = 1.1 mSv, range CI 95% = (0.32, 3.6) mSv
Nihonmatsu: Mean = 1.5 mSv, range CI 95% = (0.87, 2.6) mSv
Tamura: Mean = 0.46 mSv, range CI 95% = (0.15, 1.4) mSv

No radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident

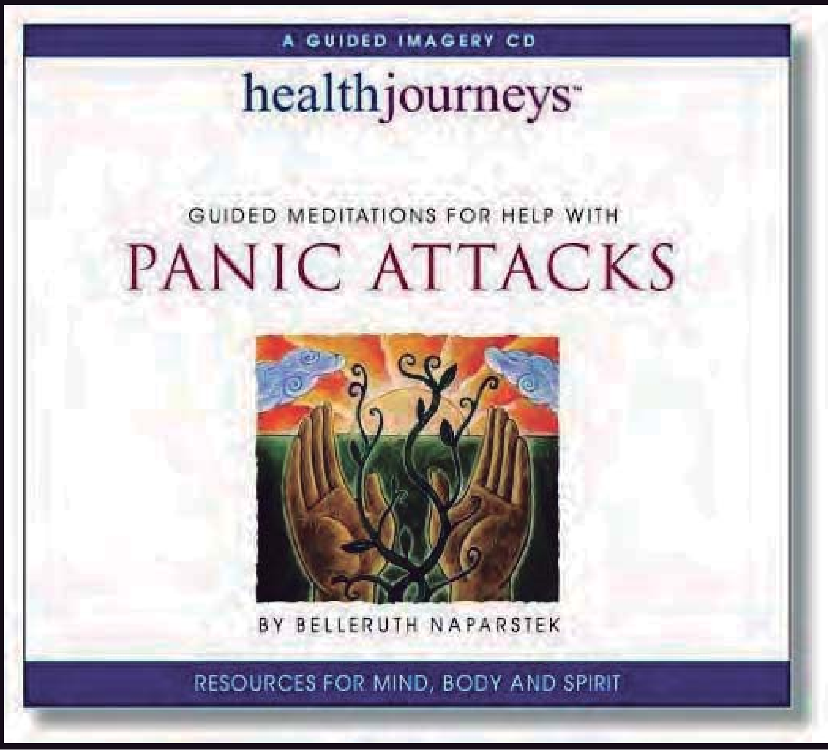
.

Psychological consequences

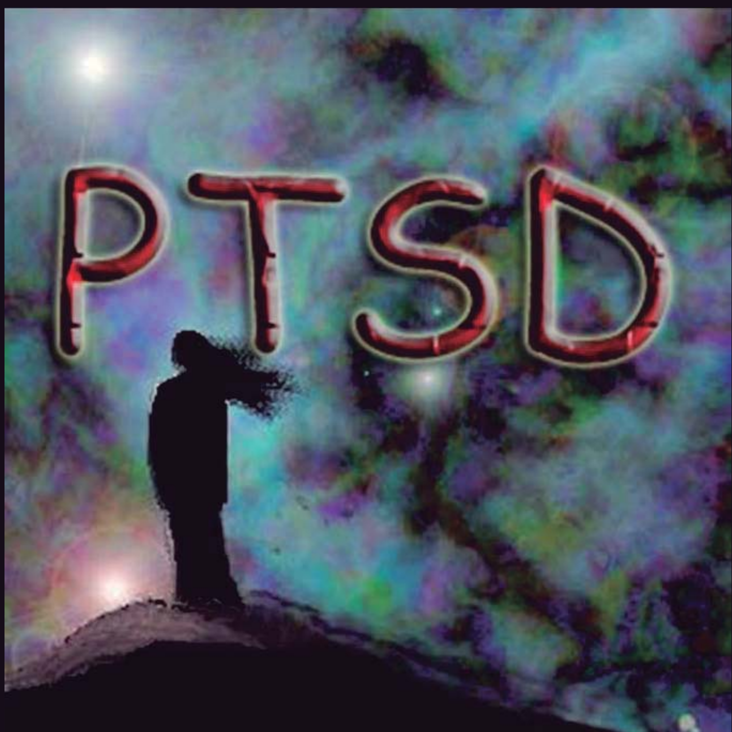
Depression

Grieving

Chronic anxiety



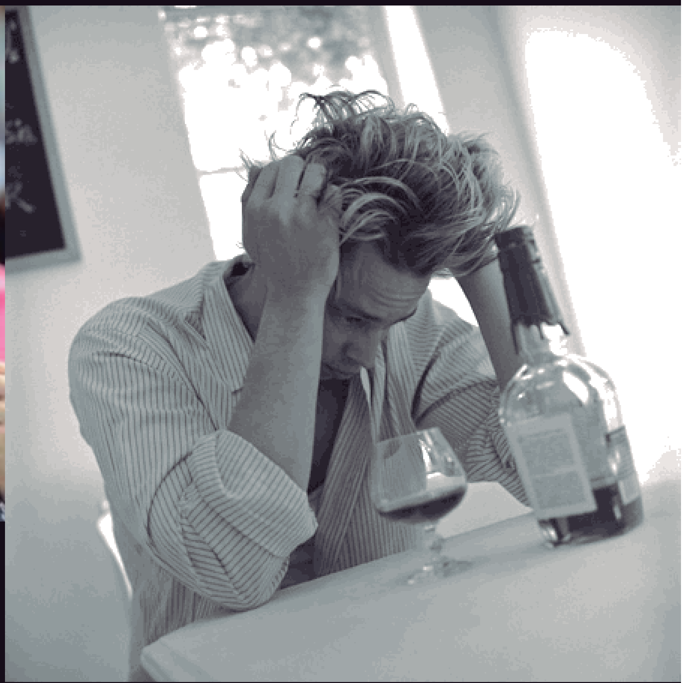
Postraumatic Stress Disorder



Insomnia

Severe headaches

Smoking y alcoholism



Anger

Desperation

Paternal Anguish


Stigma


Lesson:
Is evacuation justified when doses are low?

In sum: Fukushima

- Low radiation doses
- No health effects attributable to radiation, neither in workers nor in the public.
- Psychological effects.
- Political, social and economic impact

Epilogue

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1. Radiation from nuclear power is insignificant even taken into account accidents.
2. The real enemy of nuclear is not radiation but the fear to radiation.
3. In order to protect people against radiation we should concentrate on natural and medical radiation rather than on nuclear power.
4. For electricity, coal and renewables deliver more radiation than nuclear power.

Health Risks of Ionizing Radiation

González, A.J.

Clase dictada en el Curso de la Escuela Internacional de Derecho Nuclear,
organizada por la Universidad de Montpellier y la Agencia de Energía Nuclear de la OECD,
llevada a cabo en la Universidad de Montpellier, Francia, del 21 al 23 de agosto de 2022.

Nuclear Energy Agency of OECD-University of Montpellier

International School of Nuclear Law

22 August to 2 September, 2022

Nuclear Fuel Cycle/Radiation Protection;23 August 2022

HEALTH RISKS OF IONIZING RADIATION

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Why *radiation* is in the ISNL programme?

1. *Radiation* is the *nemesis* of nuclear energy.
2. Should *radiation* not be there, *nuclear law* would be much simpler,.
3. Therefore, you, as nuclear law specialists need to be aware of *radiation,* its levels and its effects.

Content

1. What is radiation?
2. Where does radiation come from?
3. What does radiation do to us?
4. What is the legal challenge:
   Attributing factual health effects *vis-à-vis* Inferring conjectured risks for
   imputing (legally charging) radiation harm
5. Epilogue: Potential legal challenges

3

First Part

What is radiation?

4

Confusion

Radioactivity *vis-à-vis* Radiation

5

What is radioactivity?

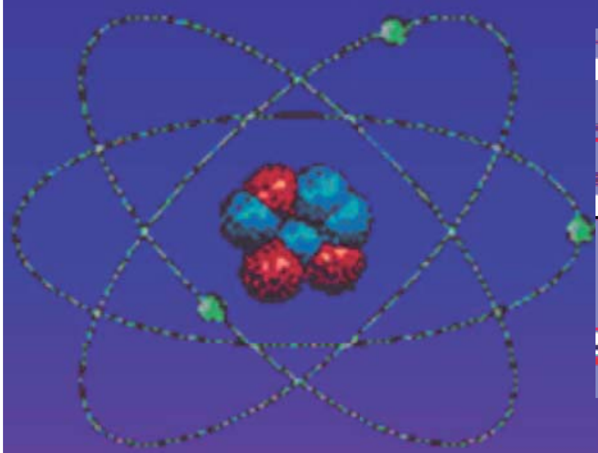
6

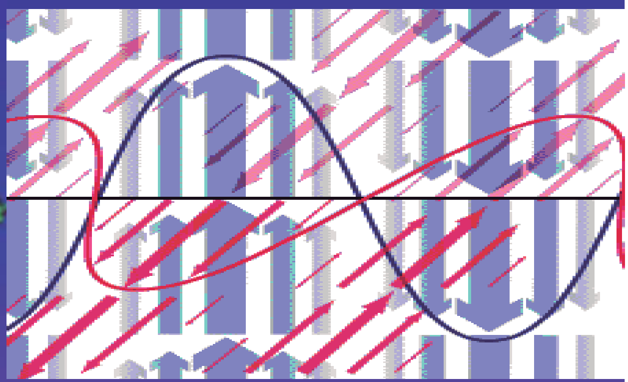
Radioactivity

Property of atoms of emitting energy as *radiation.*

Measured in *becquerels* (Bq); 1Bq = 1 emission/second

(but also in *curies* (Ci)! ;1 Ci= radioactivity in 1g of radium)





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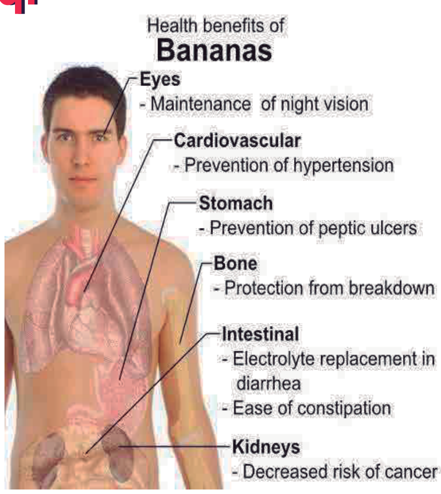
One becquerel is a very small amount of radioactivity

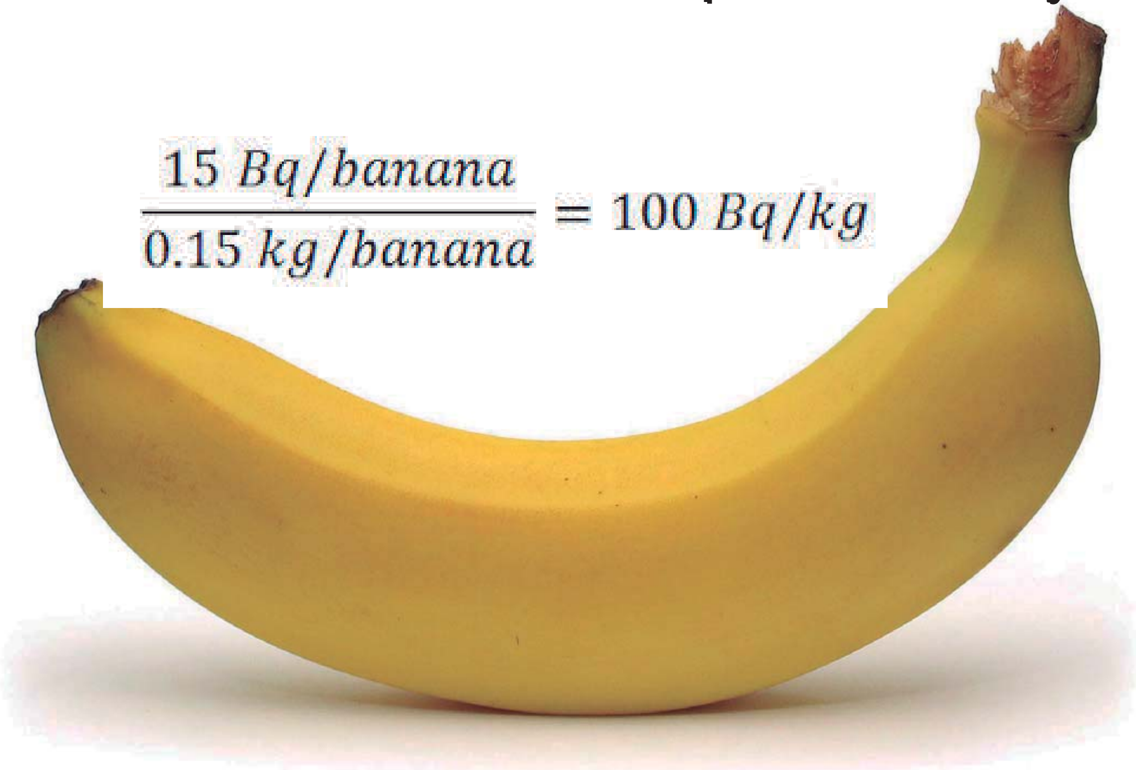
- **The amount of radioactivity in**

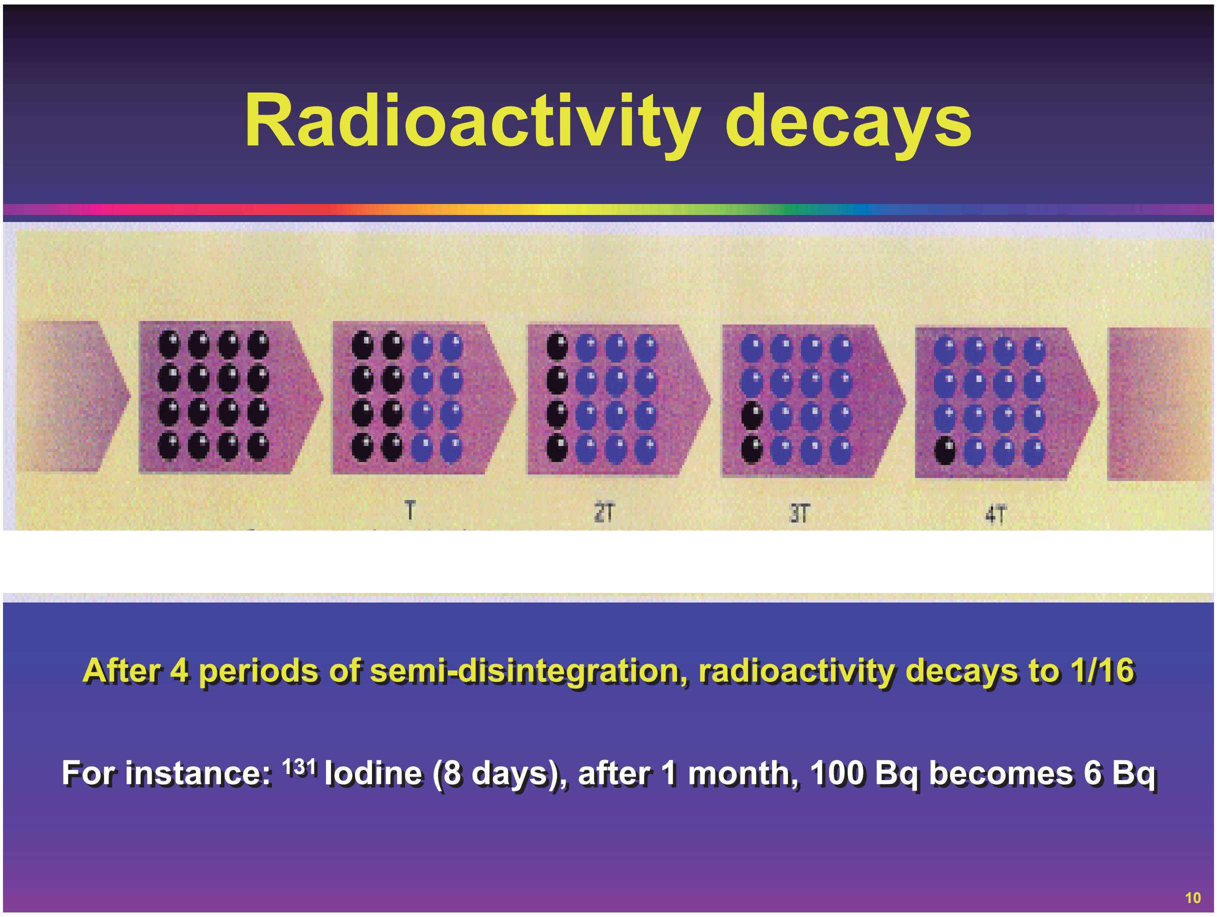
  a 70-kg person is about 5,000 Bq.



One banana contains 15 Bq of radioactivity!

$$\frac{15\ Bq/banana}{0.15\ kg/banana} = 100\ Bq/kg$$





What is radiation?

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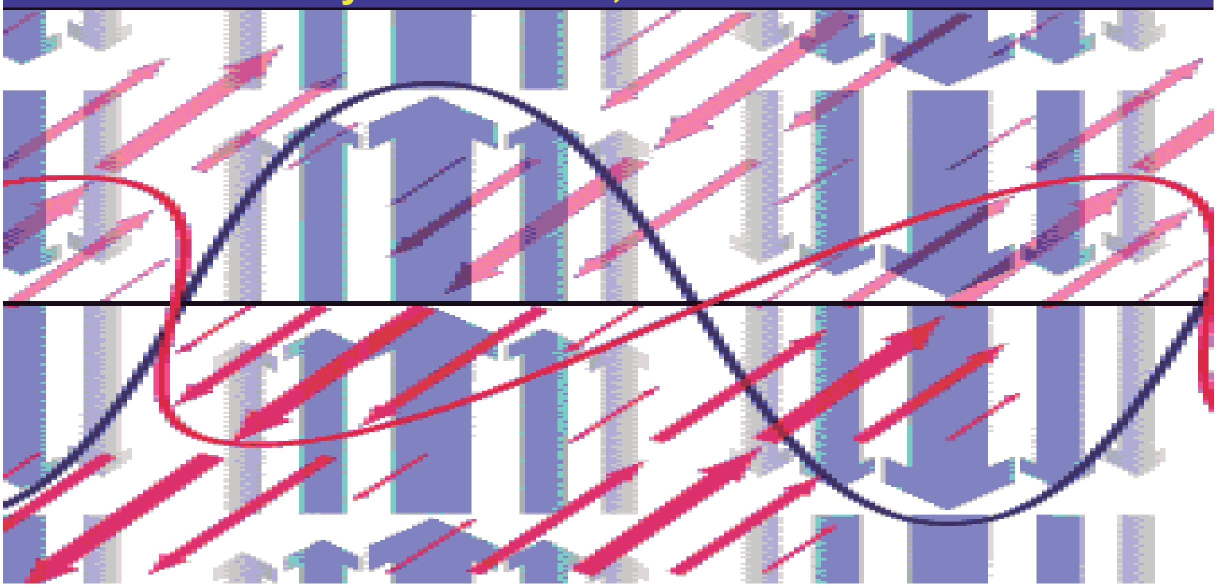
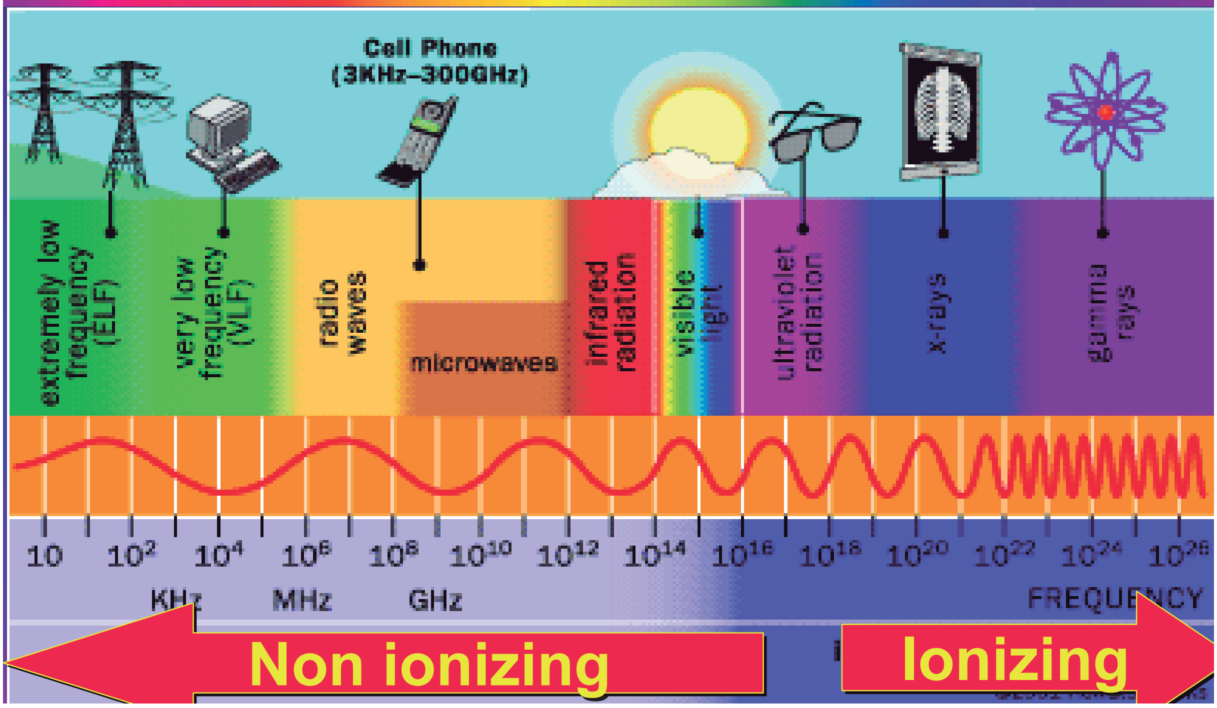
Radiation

Energy transmitted in finite packages (quanta) that behave as a wave or as a particle

The effect of radiation in matter is measured with the energy absorbed by unit of mass, which is termed '*dose*'



Radiation spectrum



What is *ionizing* radiation?

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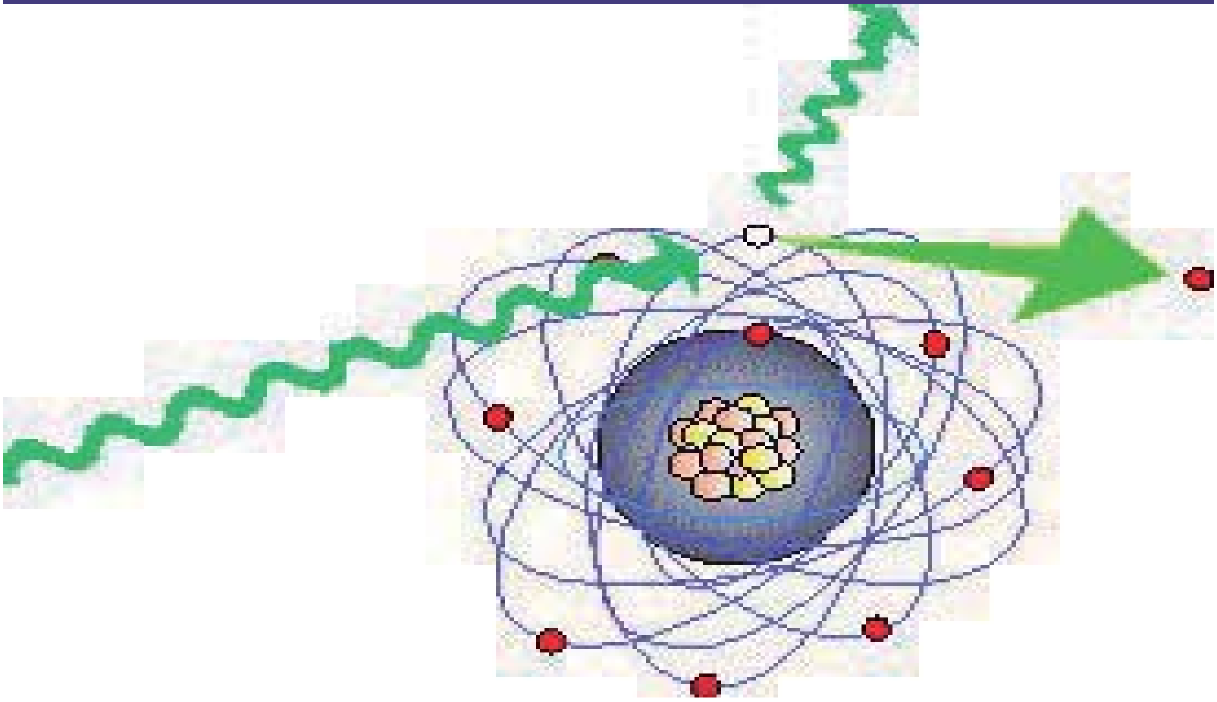
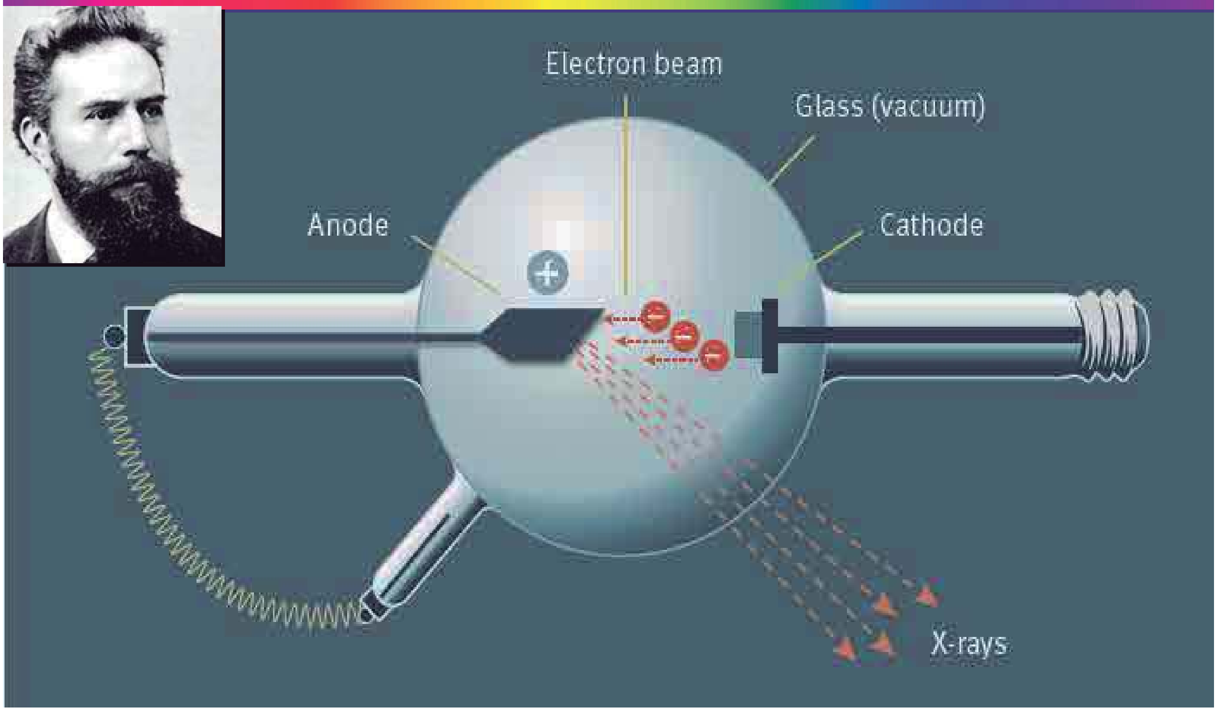
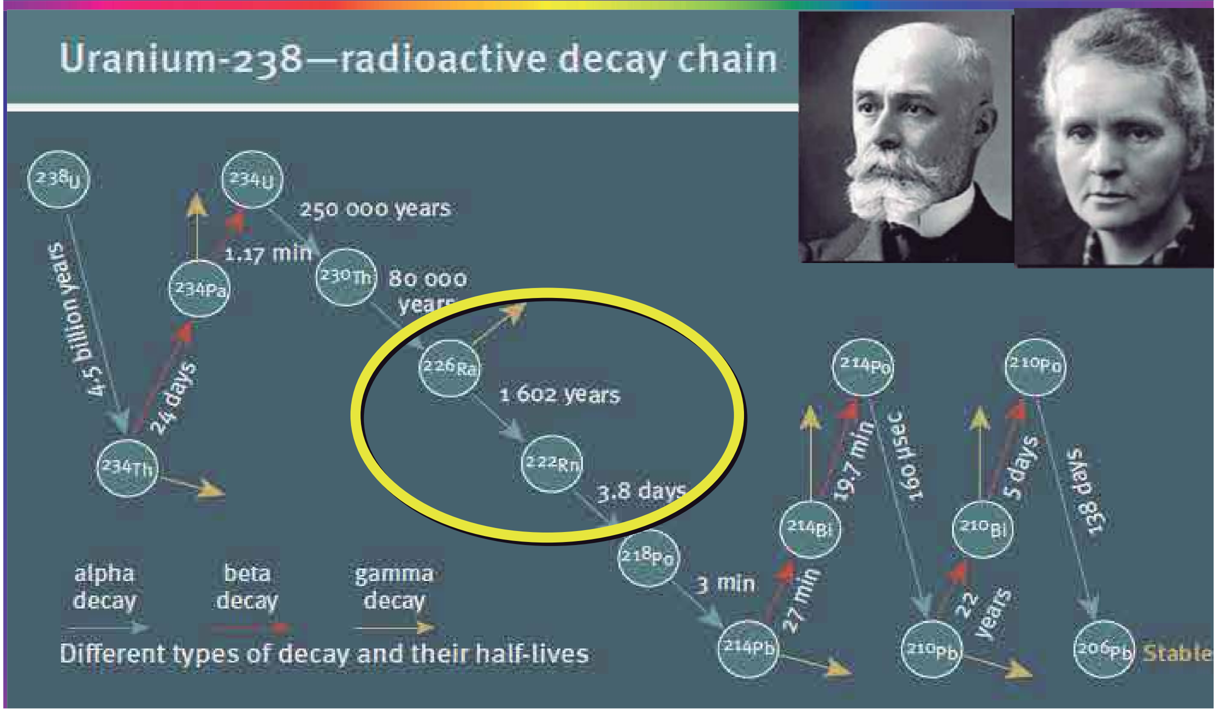
Radiation carrying enough energy to ionize an atom



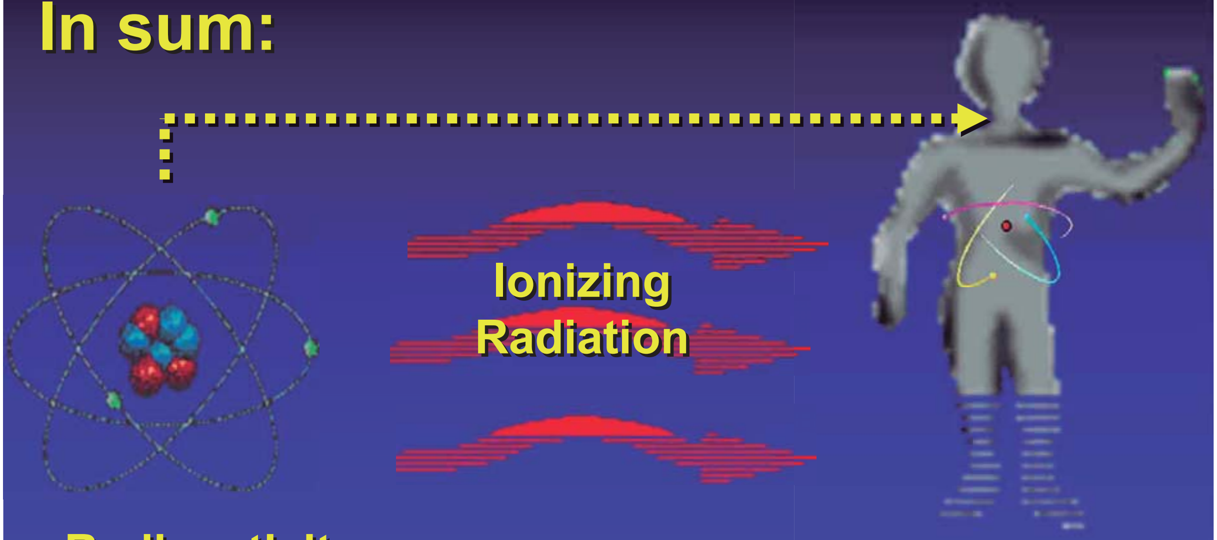
First ionizing radiation discovered: those emitted by a X-ray tube….



…or by radioactive substances

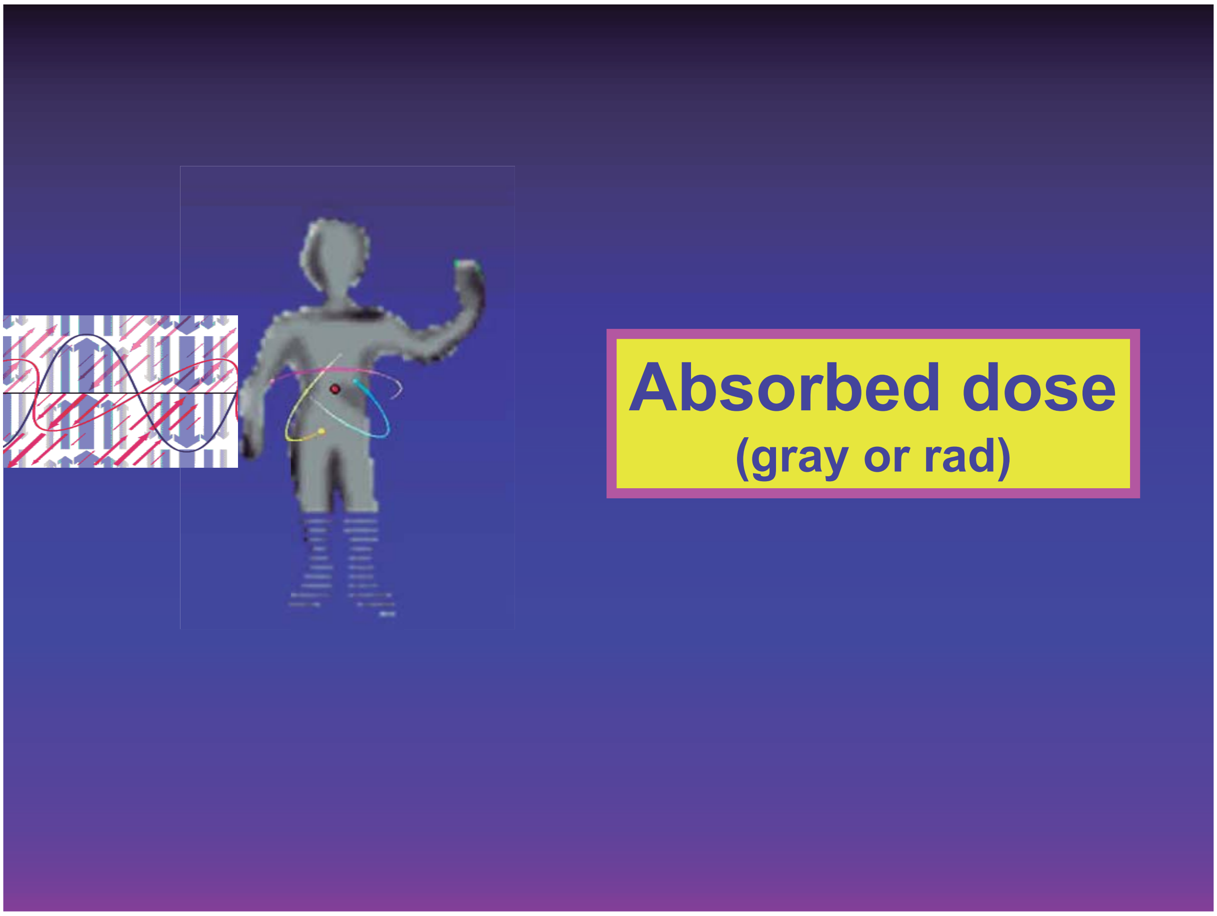


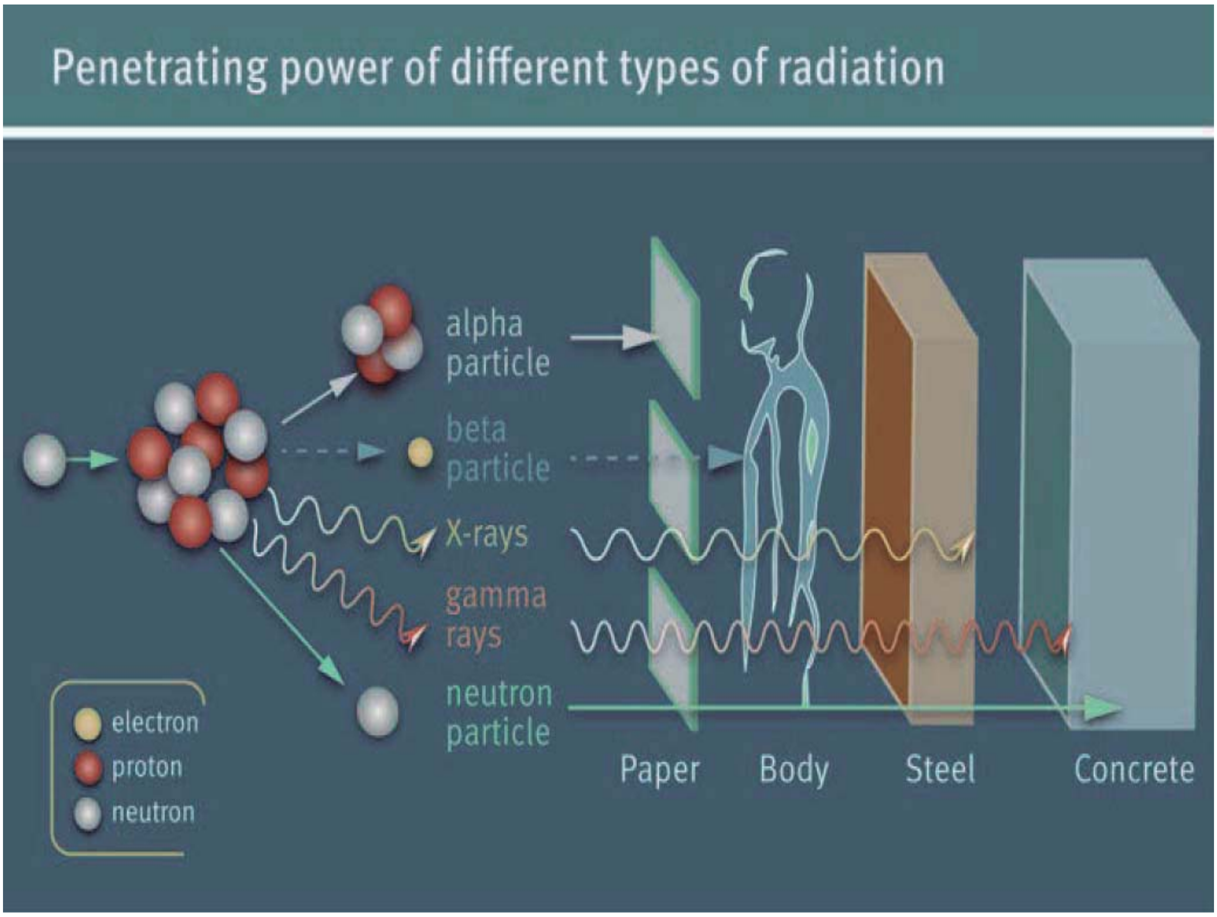
In sum:



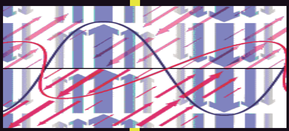
Radioactivity
Measured in
bequerels
(or curies)

Dose
Amount of radiation energy
absorbed by tissue per unit mass
Measured in joules/kg (*gray*)
(or erg/g termed *rad*)


Absorbed dose
(gray or rad)


Penetrating power of different types of radiation
alpha particle
beta particle
X-rays
gamma rays
neutron particle
electron
proton
neutron
Paper
Body
Steel
Concrete

Absorbed dose (in tissues)
(gray or rad)



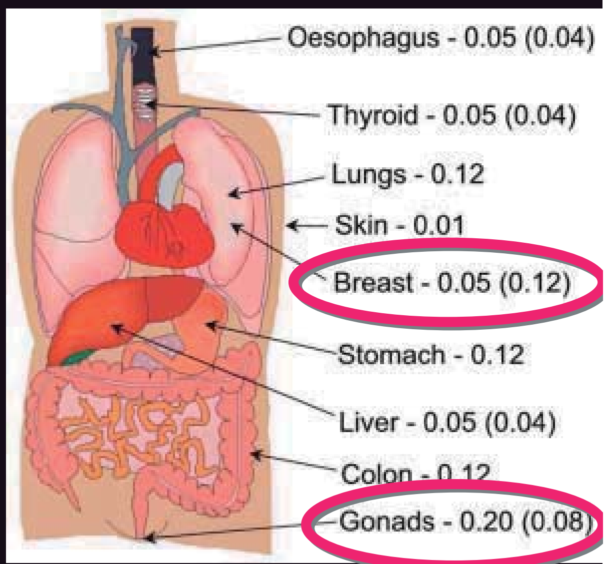
Radiation weighting factor, w_R

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons[a] and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy

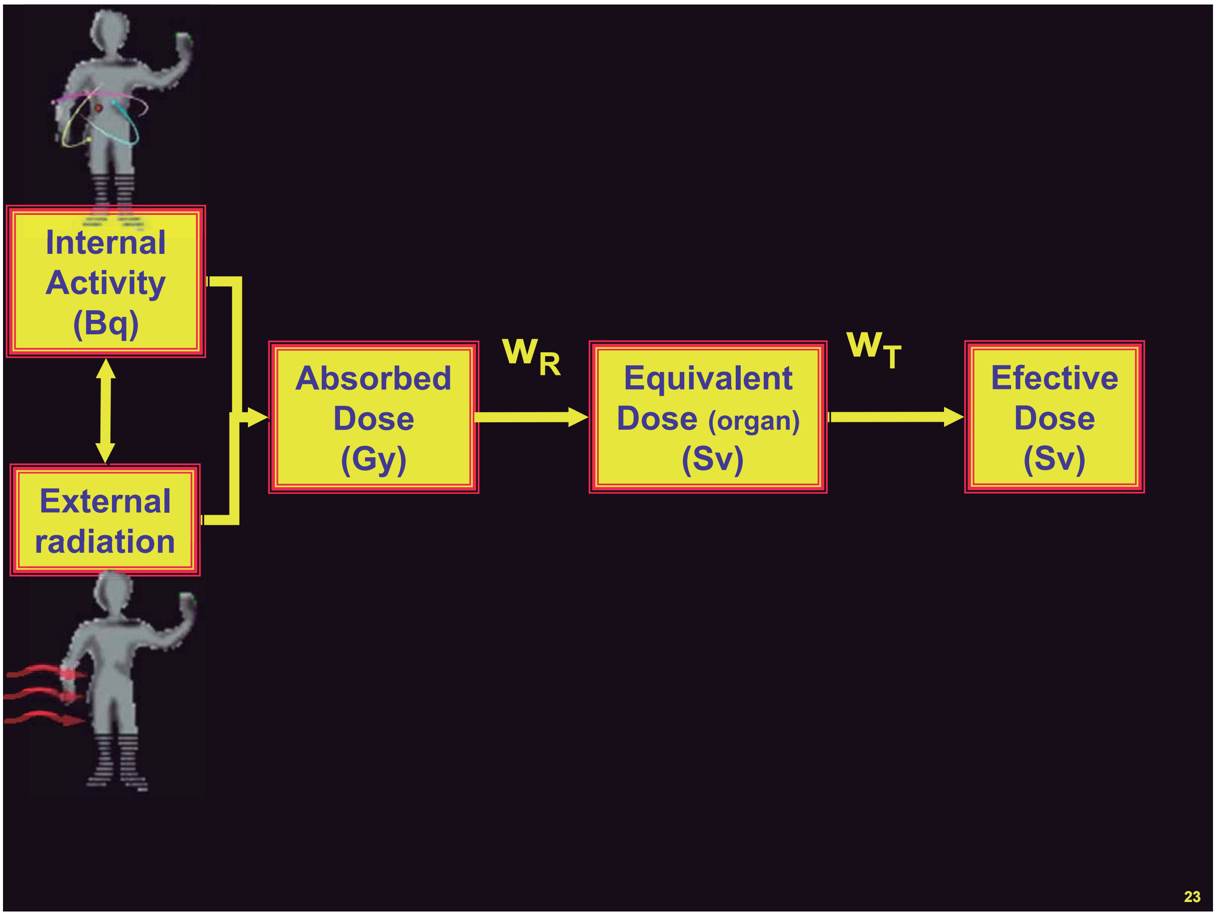
Equivalent dose
(sievert or rem)

Equivalent dose
(sievert or rem)

Tissue weighting factor), w_T



Effective dose
(sievert or rem)



The unit of effective dose is the Sievert [Sv]

....but normally it is used 0.001 Sv = 1 milliSievert [mSv]

How much is a mSv?

- 1 year of natural radiation, around 1–10 mSv
- 1 computed tomography, around 10 mSv
- 1 chest floroscopy, around 1 mSv
- 1 chest radiography, around 0.1 mSv
- 1 dental radiography, around 0.01 mSv

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Take away points

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- Radioactivity → Activity → bequerel (curie)
- Radiation → Dose → sievert (rem)

(1 milliieverts, mSv = 1/1000 sievert)

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Radiation quantities

Physical quantity	
Activity	The number of nuclear transformations of energy per unit of time. It is measured as decays per second and expressed in becquerels (Bq).
Absorbed dose	The amount of energy deposited by radiation in a unit mass of material, such as a tissue or organ. It is expressed in grays (Gy), which corresponds to joules per kilogram.
Calculated quantity	
Equivalent dose	The absorbed dose multiplied by a radiation factor (w_R) that takes into account the way different types of radiation cause biological harm in a tissue or organ. It is expressed in sieverts (Sv), which corresponds to joules per kilogram.
Effective dose	The equivalent dose multiplied by organ factors (w_T) that take into account the susceptibility to harm of different tissues and organs. It is expressed in sieverts (Sv), which corresponds to joules per kilogram.
Collective effective dose	Sum of all effective doses of a population or group of people exposed to radiation. It is expressed in man-sieverts (man Sv).

Second Part

Where does radiation come from?

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Where does radiation come from?

- **Natural sources**
  - **Cosmic sources**
  - **Terrestrial sources**
  - **Sources in food and drink**
- **Artificial sources**
  - **Medical applications**
  - **Nuclear weapons**
  - **Electricity generation (including Nuclear Power Plants)**
  - **Industrial and other applications**
- **Average radiation exposure to public and workers**

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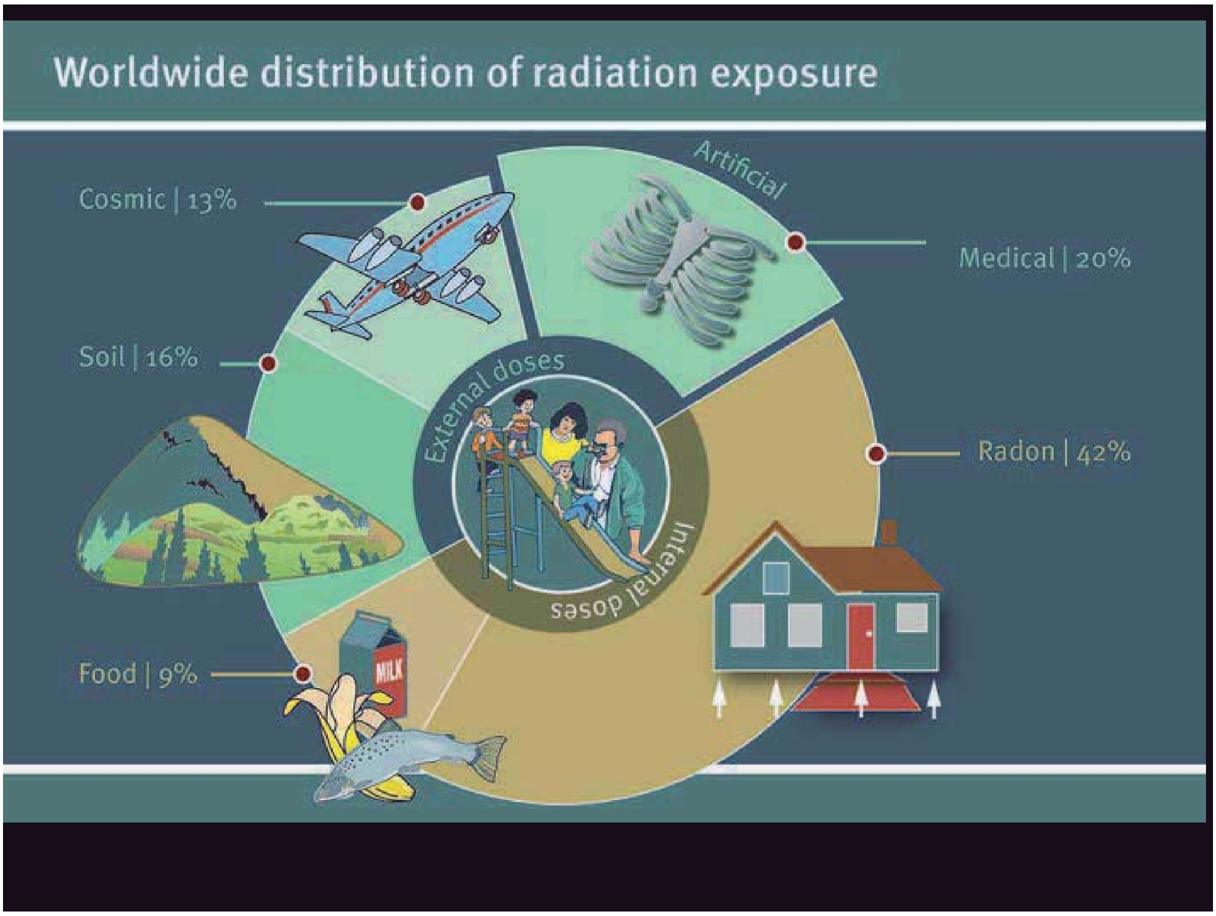

Sources of exposure

- Natural
  - Cosmic rays
  - Terrestrial
  - Inhalation [radon]
- Artificial
  - Medical
  - Military
  - Nuclear Power
  - Occupational
  - Accidents

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Natural sources

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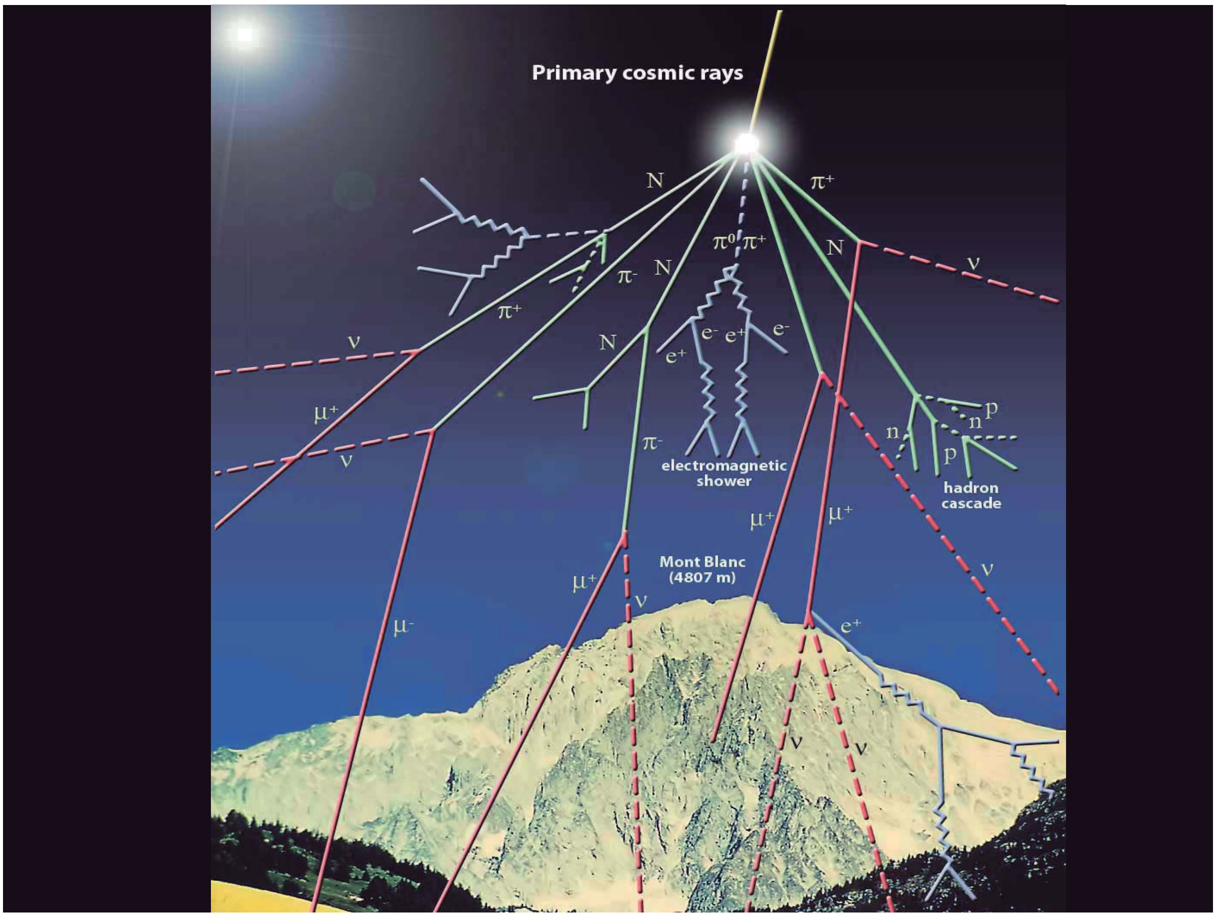
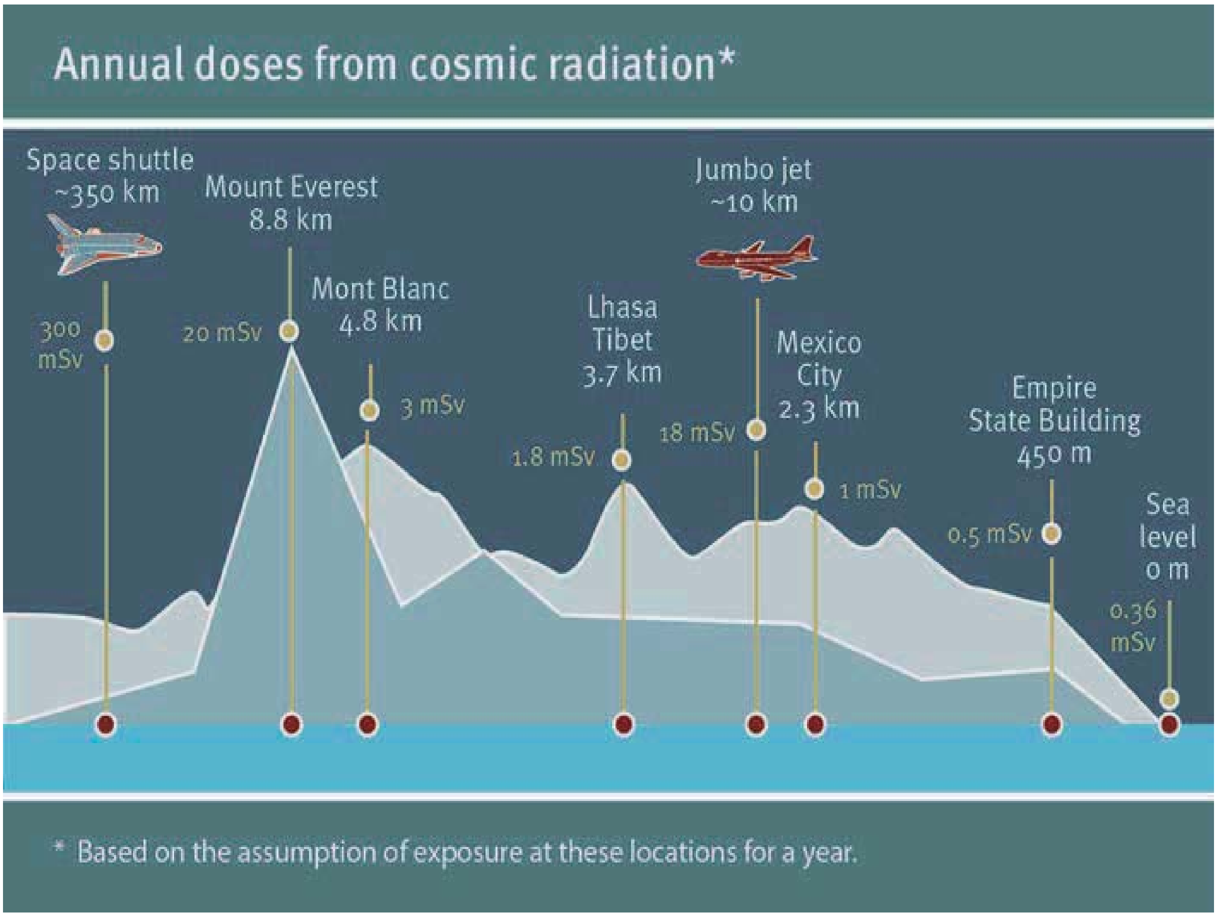
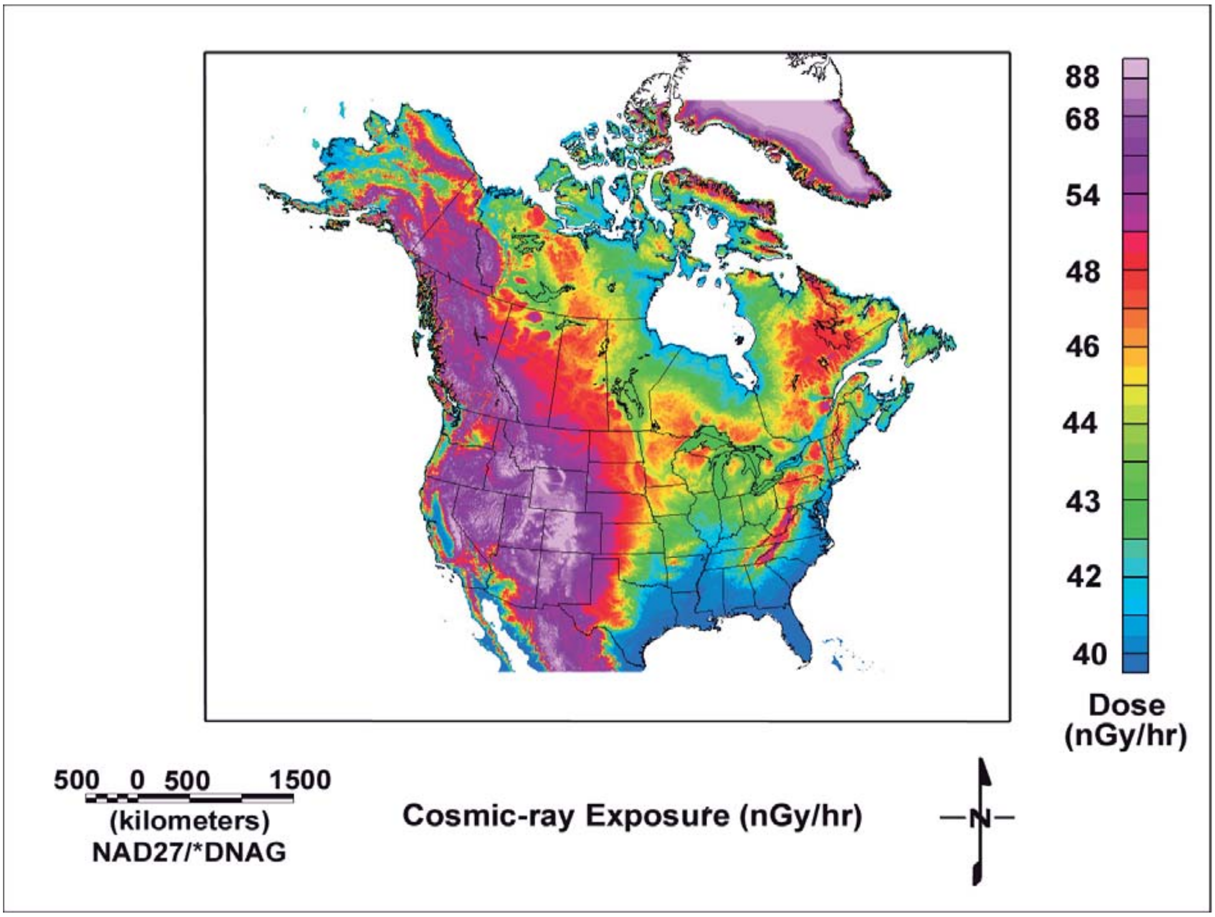
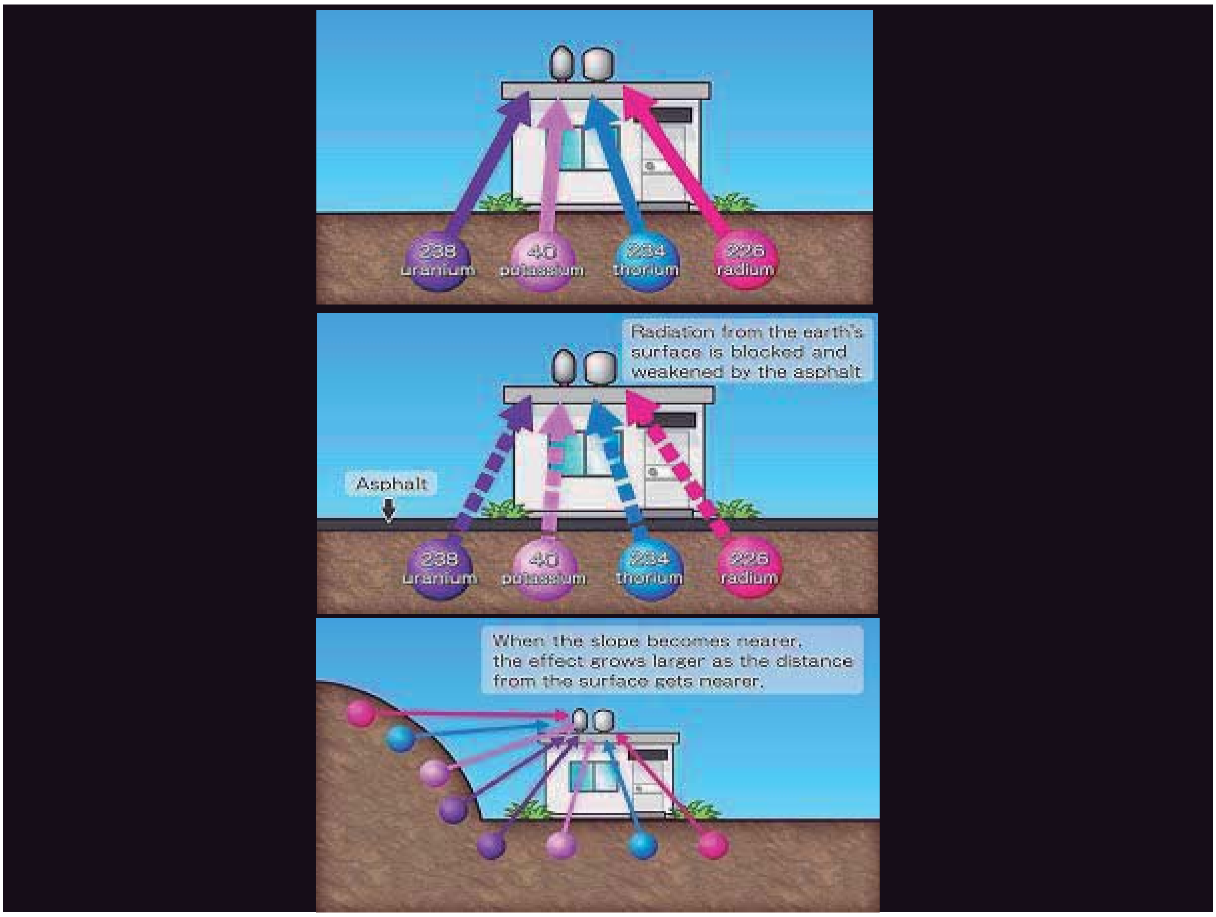
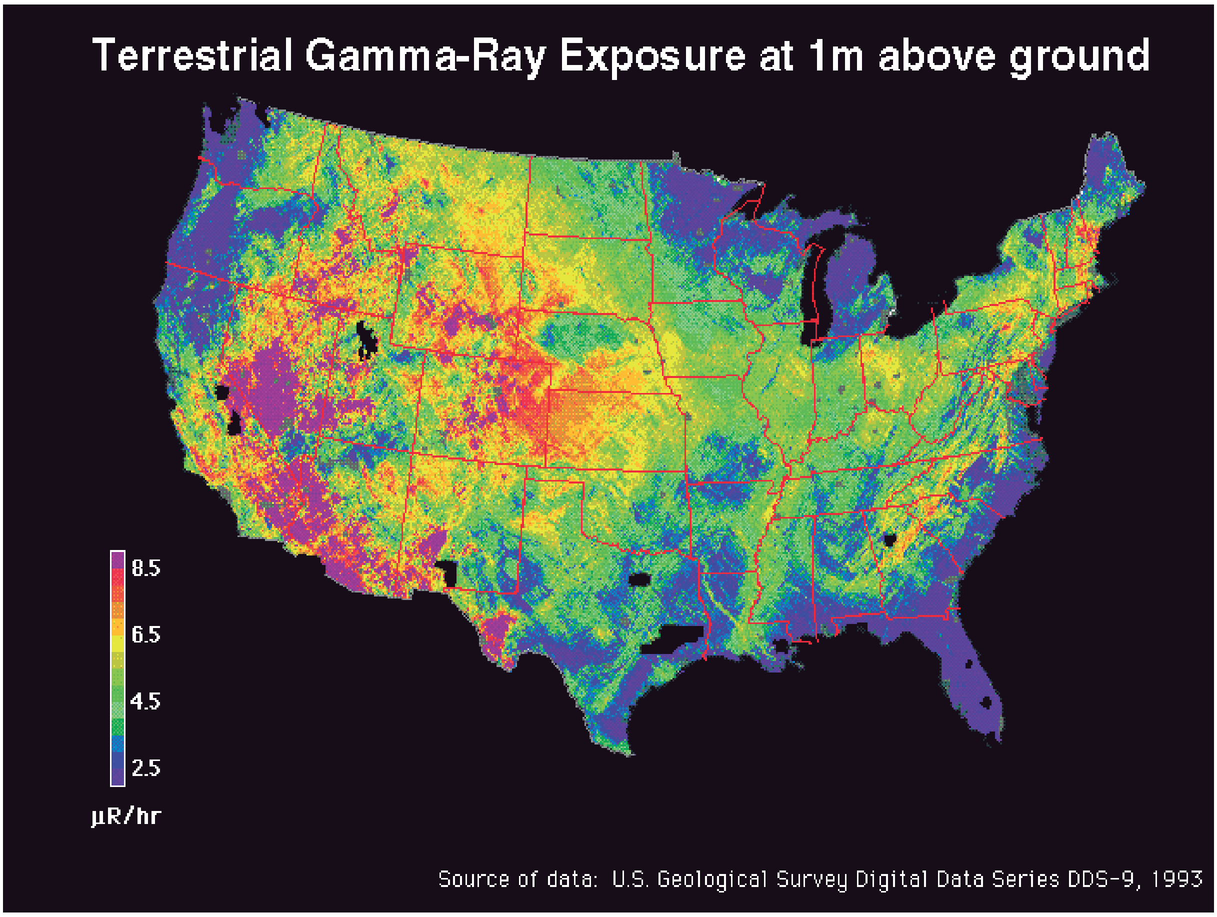
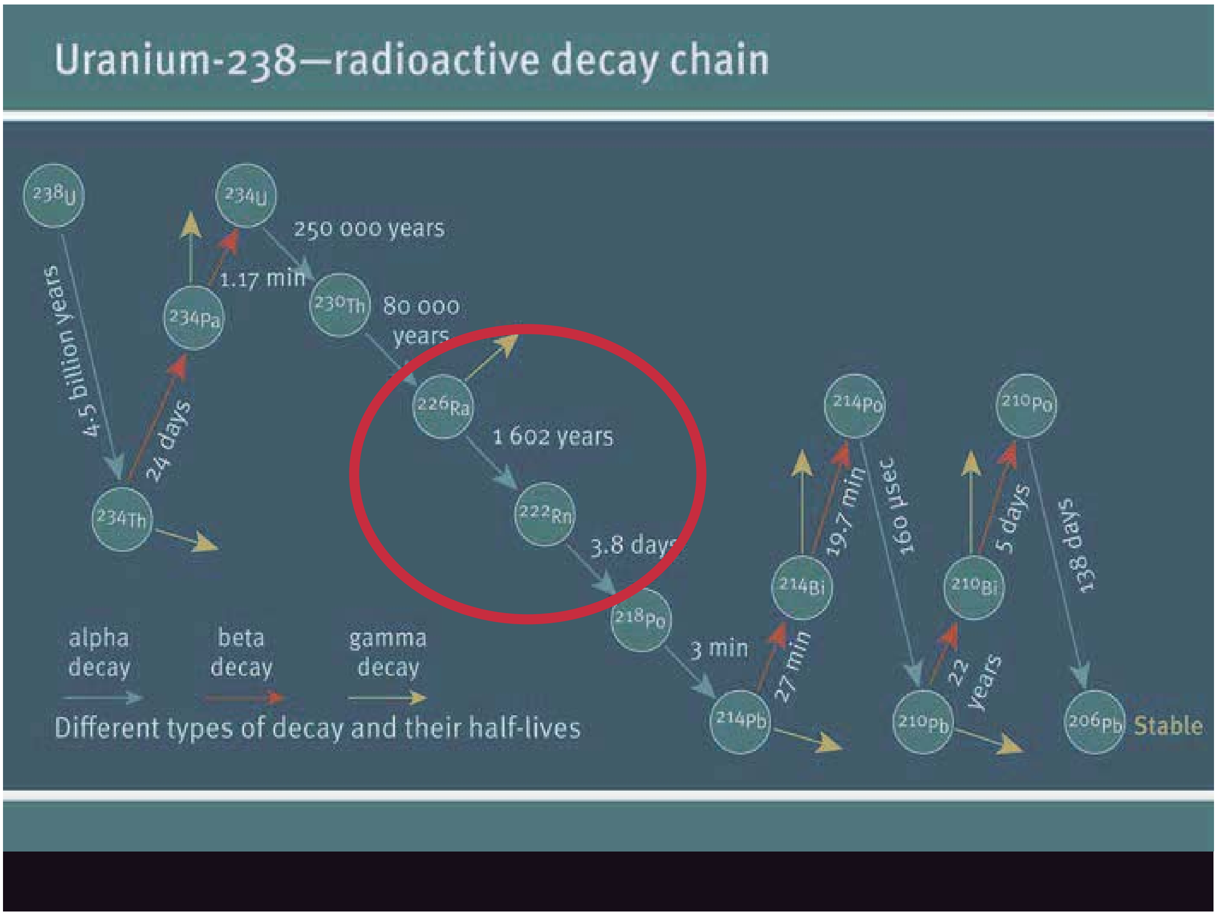

Primary cosmic rays
N
π⁺
π⁰ π⁺
π⁻
e⁻ e⁺
e⁻
e⁺
ν
μ⁺
μ⁻
n
p
electromagnetic shower
hadron cascade
Mont Blanc (4807 m)

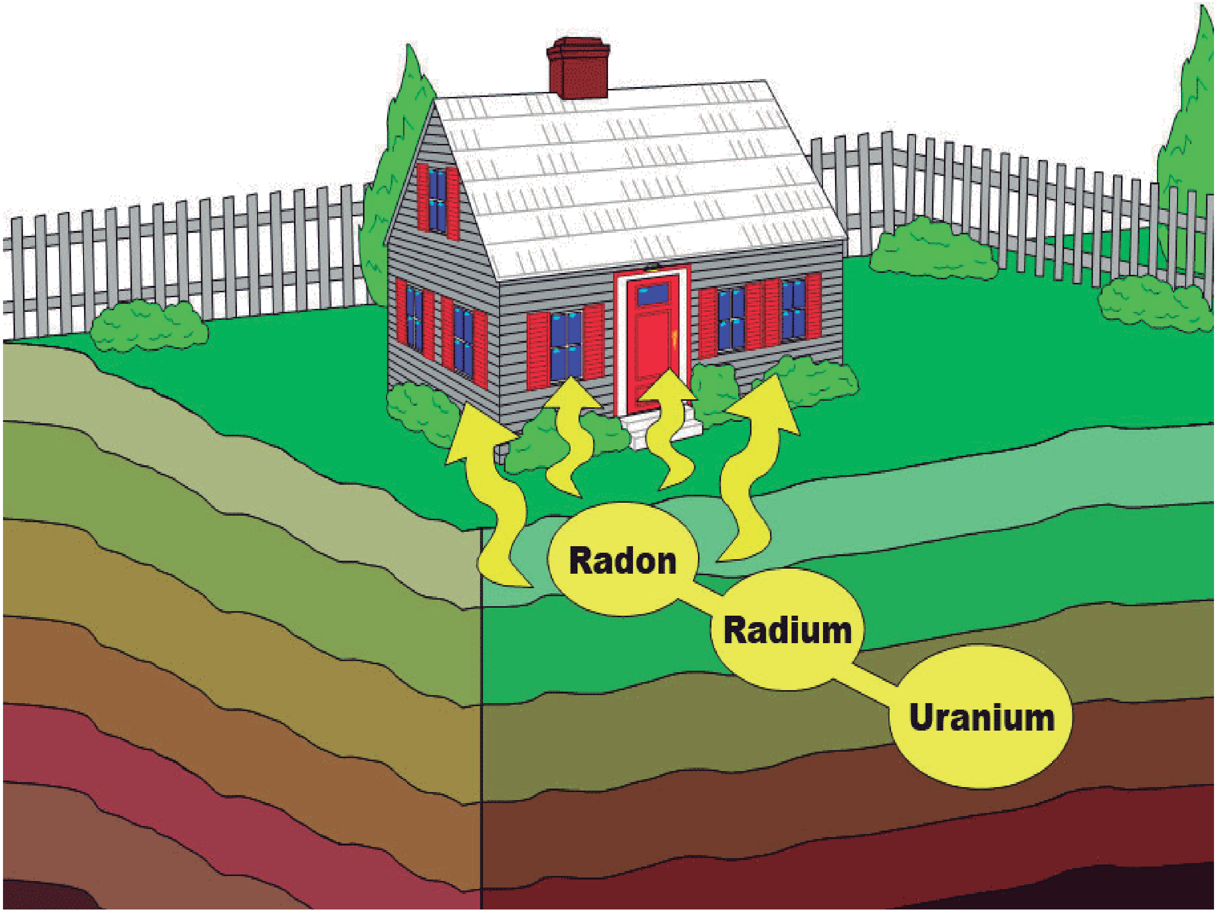

Annual doses from cosmic radiation*
Space shuttle ~350 km
300 mSv
Mount Everest 8.8 km
20 mSv
Mont Blanc 4.8 km
3 mSv
Lhasa Tibet 3.7 km
1.8 mSv
Jumbo jet ~10 km
18 mSv
Mexico City 2.3 km
1 mSv
Empire State Building 450 m
0.5 mSv
Sea level 0 m
0.36 mSv
* Based on the assumption of exposure at these locations for a year.

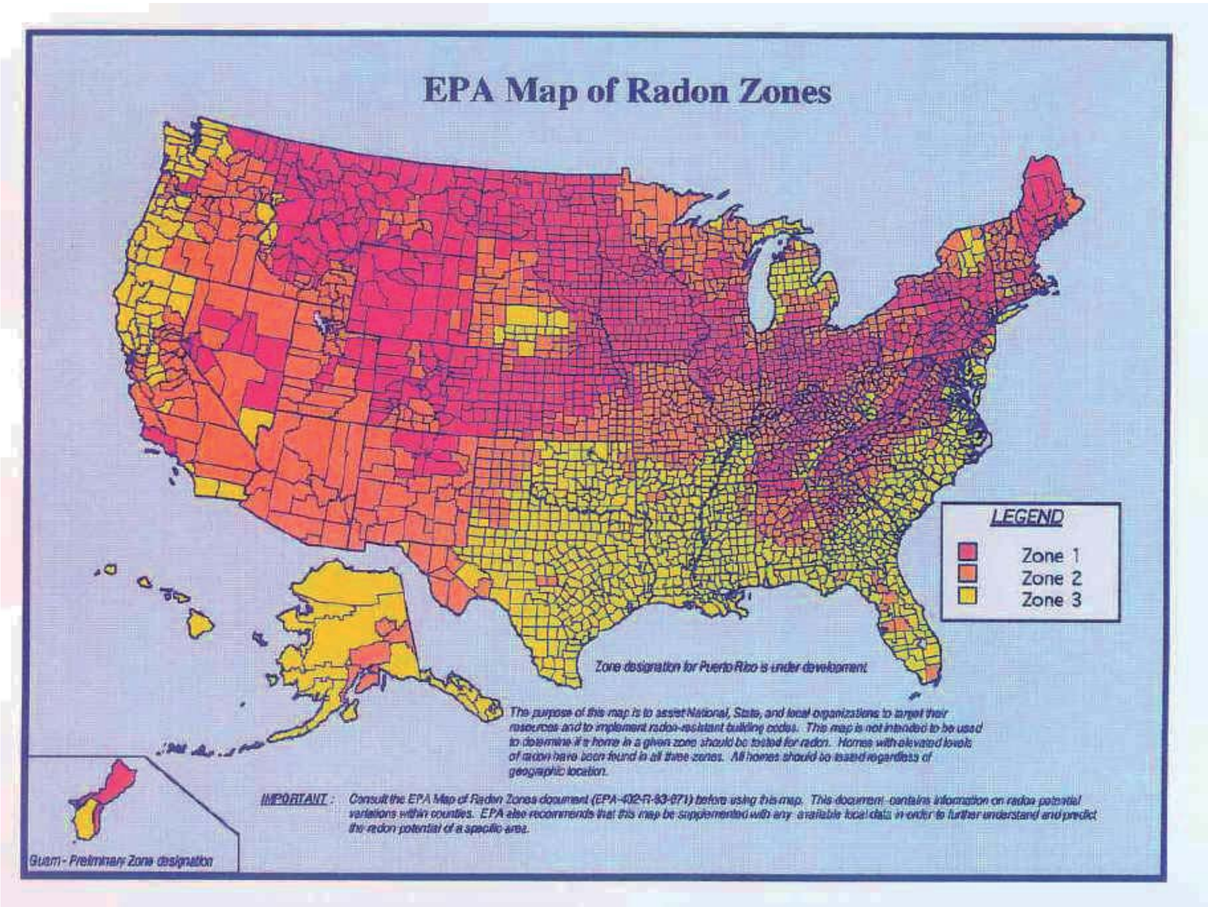

88
68
54
48
46
44
43
42
40
Dose (nGy/hr)
500 0 500 1500
(kilometers)
NAD27/*DNAG
Cosmic-ray Exposure (nGy/hr)
N

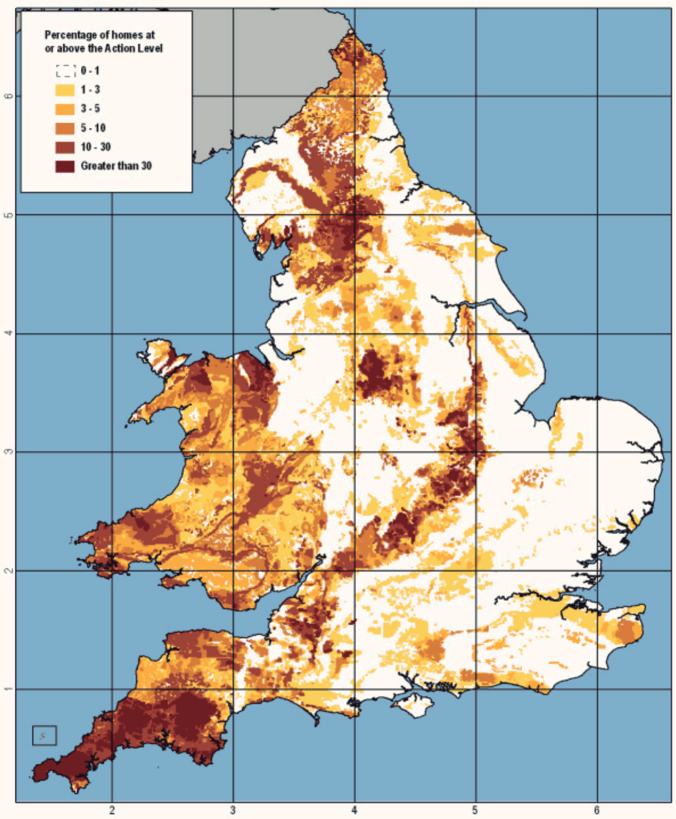

238 uranium
40 potassium
234 thorium
226 radium
Radiation from the earth's surface is blocked and weakened by the asphalt
Asphalt
238 uranium
40 potassium
234 thorium
226 radium
When the slope becomes nearer, the effect grows larger as the distance from the surface gets nearer.


Terrestrial Gamma-Ray Exposure at 1m above ground
8.5
6.5
4.5
2.5
µR/hr
Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993


Uranium-238—radioactive decay chain
238U
4.5 billion years
234Th
24 days
234Pa
1.17 min
234U
250 000 years
230Th
80 000 years
226Ra
1 602 years
222Rn
3.8 days
218Po
3 min
214Pb
27 min
214Bi
19.7 min
214Po
160 µsec
210Pb
22 years
210Bi
5 days
210Po
138 days
206Pb
Stable
alpha decay
beta decay
gamma decay
Different types of decay and their half-lives

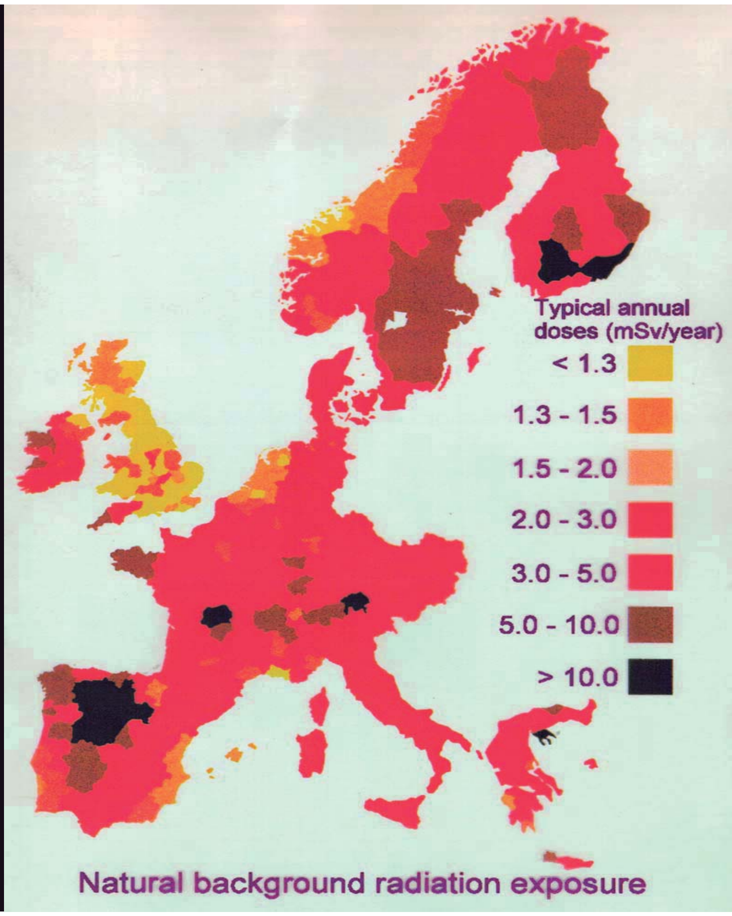

Radon
Radium
Uranium


EPA Map of Radon Zones
LEGEND
Zone 1
Zone 2
Zone 3
Zone designation for Puerto Rico is under development
The purpose of this map is to assist National, State, and local organizations to target their resources and to implement radon-resistant building codes. This map is not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. All homes should be tested regardless of geographic location.
IMPORTANT: Consult the EPA Map of Radon Zones document (EPA-402-R-93-071) before using this map. This document contains information on radon potential variations within counties. EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.
Guam - Preliminary Zone designation



Overall map of radon Affected Areas in England and Wales (axis numbers are the 100-km coordinates of the national grid)

© Crown copyright. All rights reserved [Health Protection Agency][100016969][2007]
Radon potential classification © Health Protection Agency and British Geological Survey copyright [2007]



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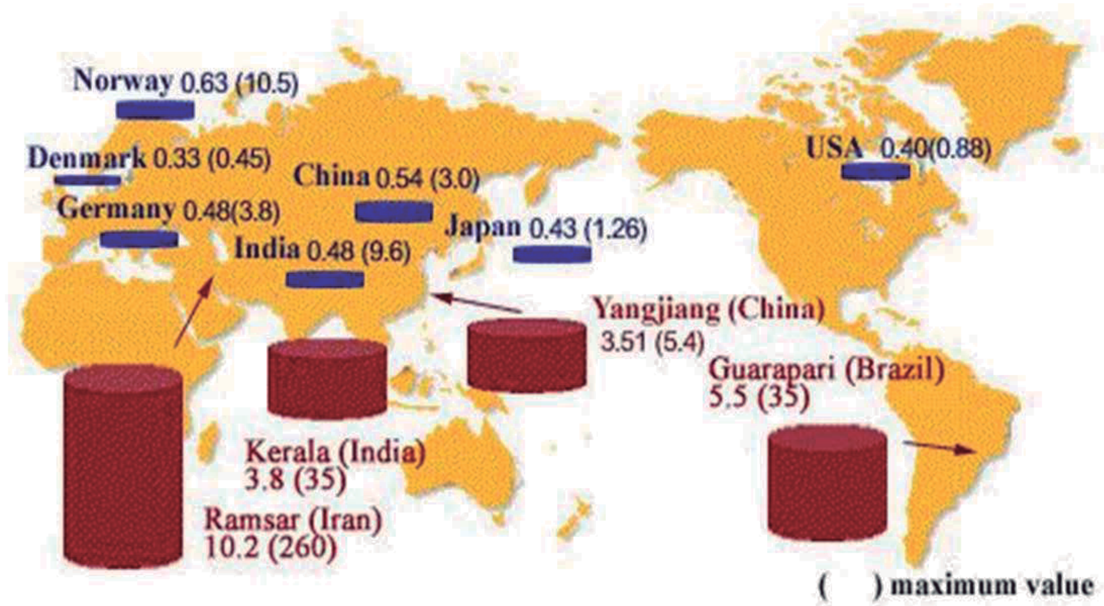
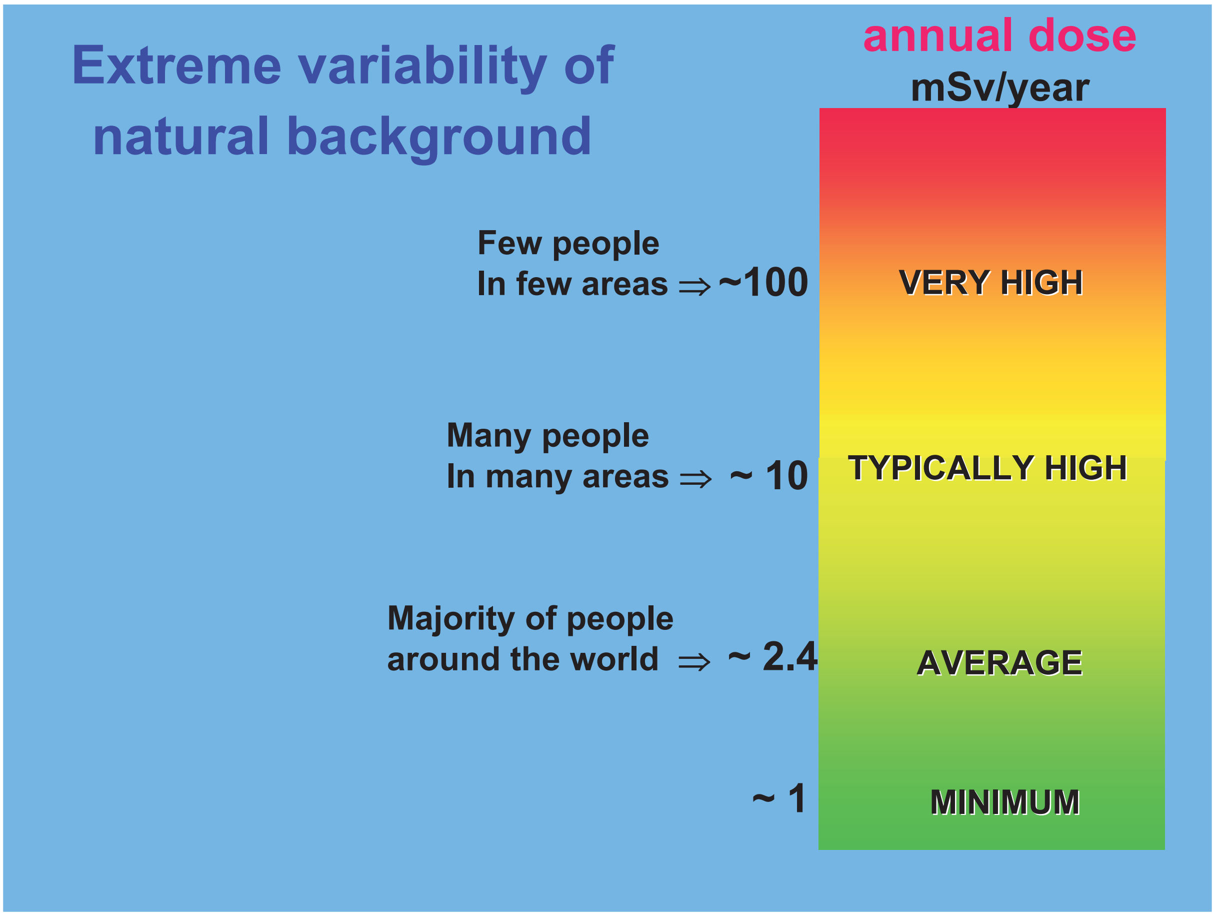
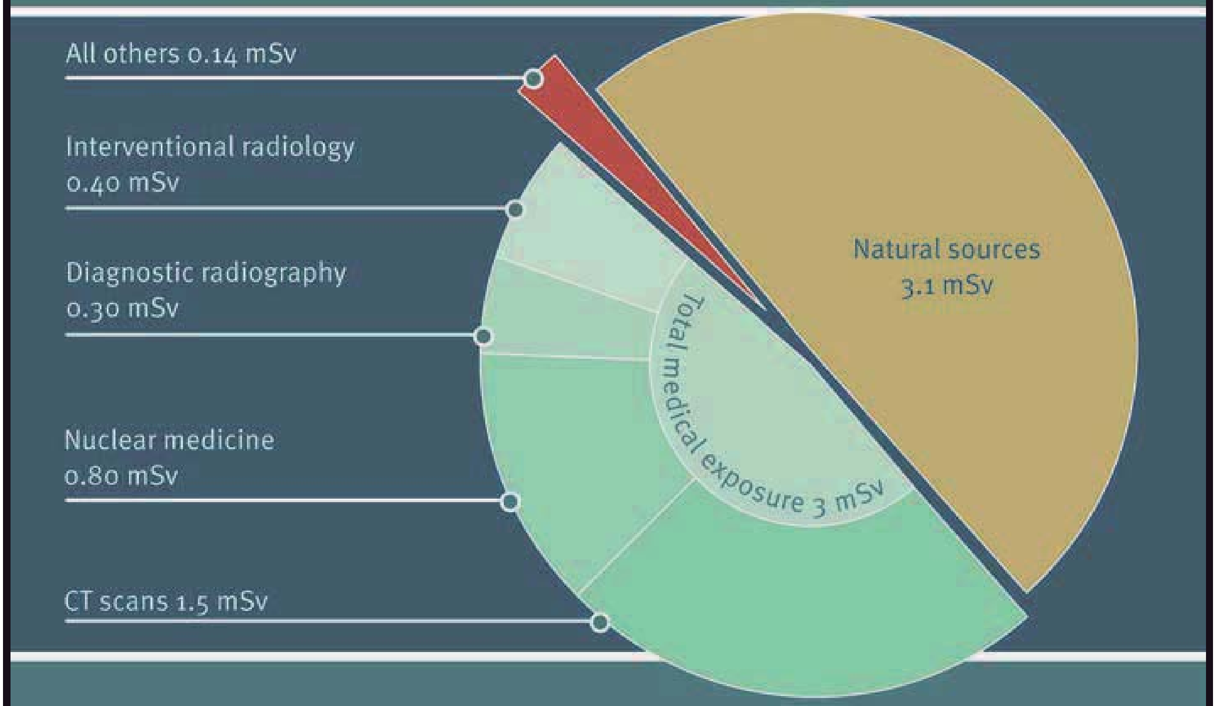

Norway 0.63 (10.5)
Denmark 0.33 (0.45)
Germany 0.48(3.8)
China 0.54 (3.0)
India 0.48 (9.6)
Japan 0.43 (1.26)
USA 0.40(0.88)
Yangjiang (China)
3.51 (5.4)
Guarapari (Brazil)
5.5 (35)
Kerala (India)
3.8 (35)
Ramsar (Iran)
10.2 (260)
( ) maximum value


Extreme variability of natural background
annual dose
mSv/year
Few people
In few areas ⇒ ~100
VERY HIGH
Many people
In many areas ⇒ ~ 10
TYPICALLY HIGH
Majority of people
around the world ⇒ ~ 2.4
AVERAGE
~ 1
MINIMUM

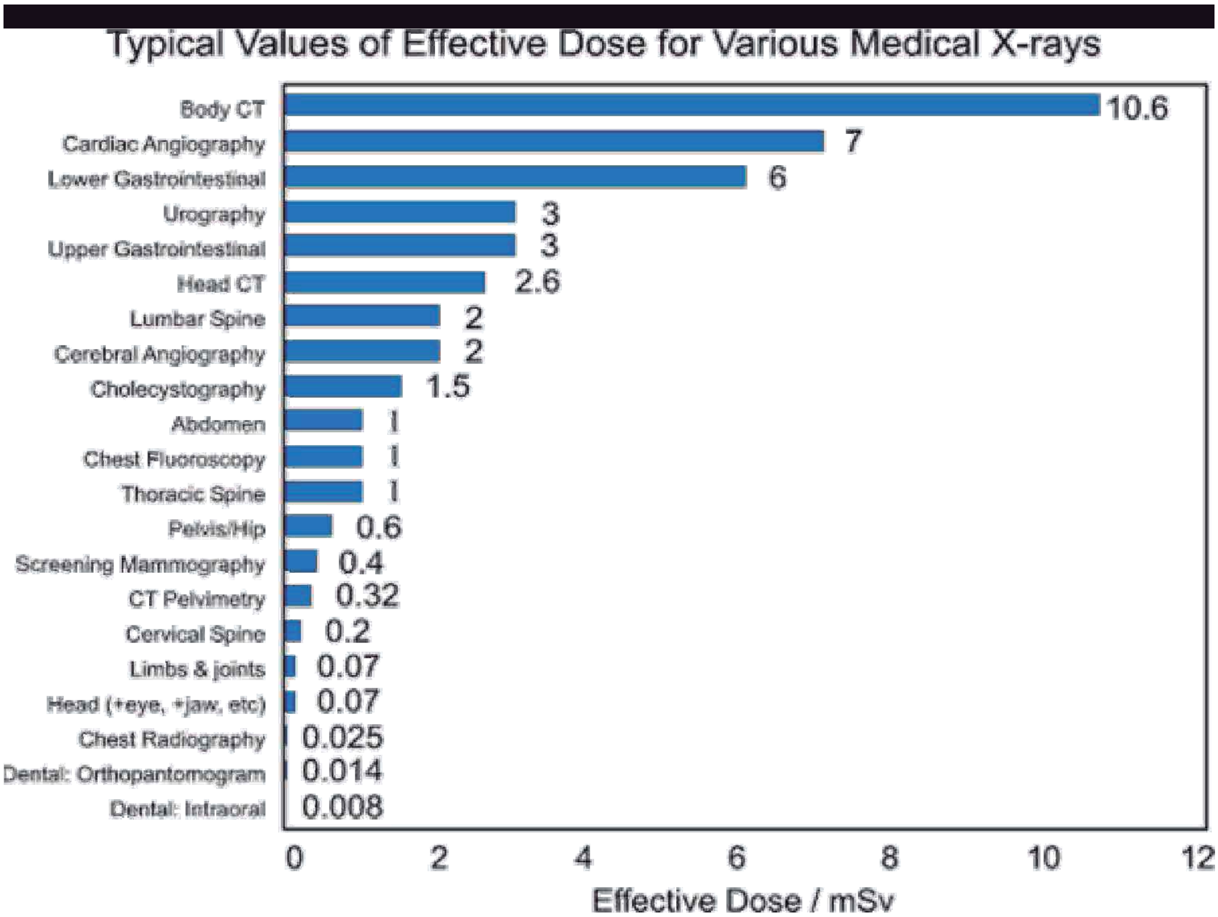
Artificial sources

45

Average effective doses per person in the United States (2007)



Medical sources



Military activities

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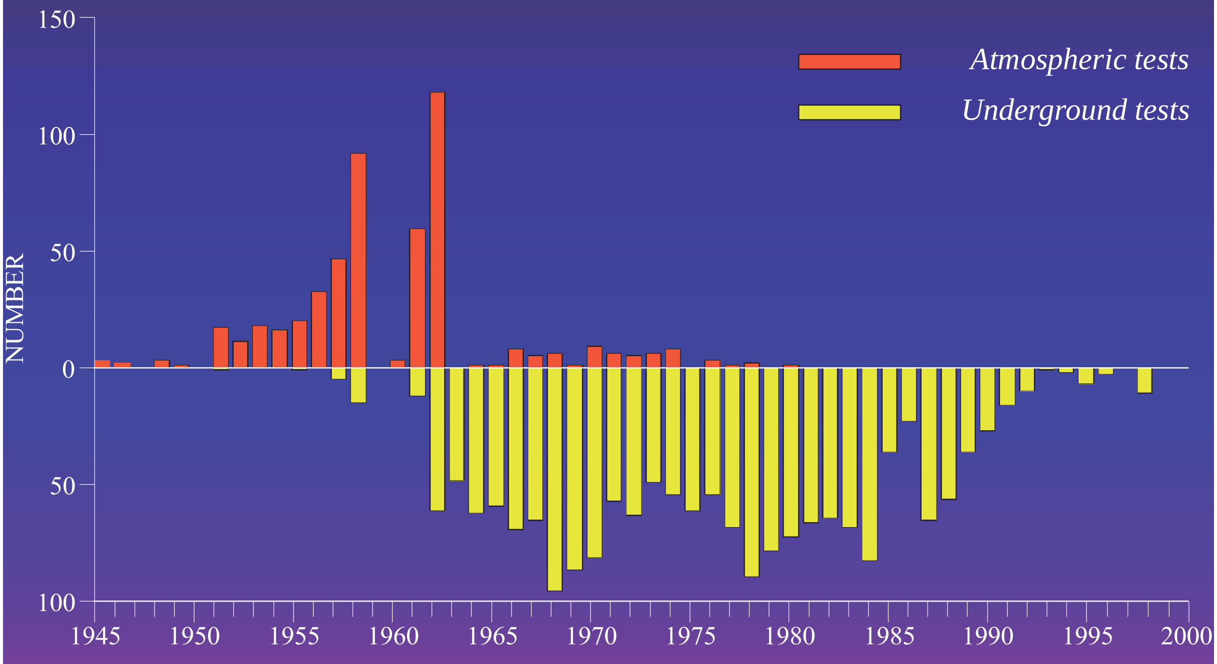
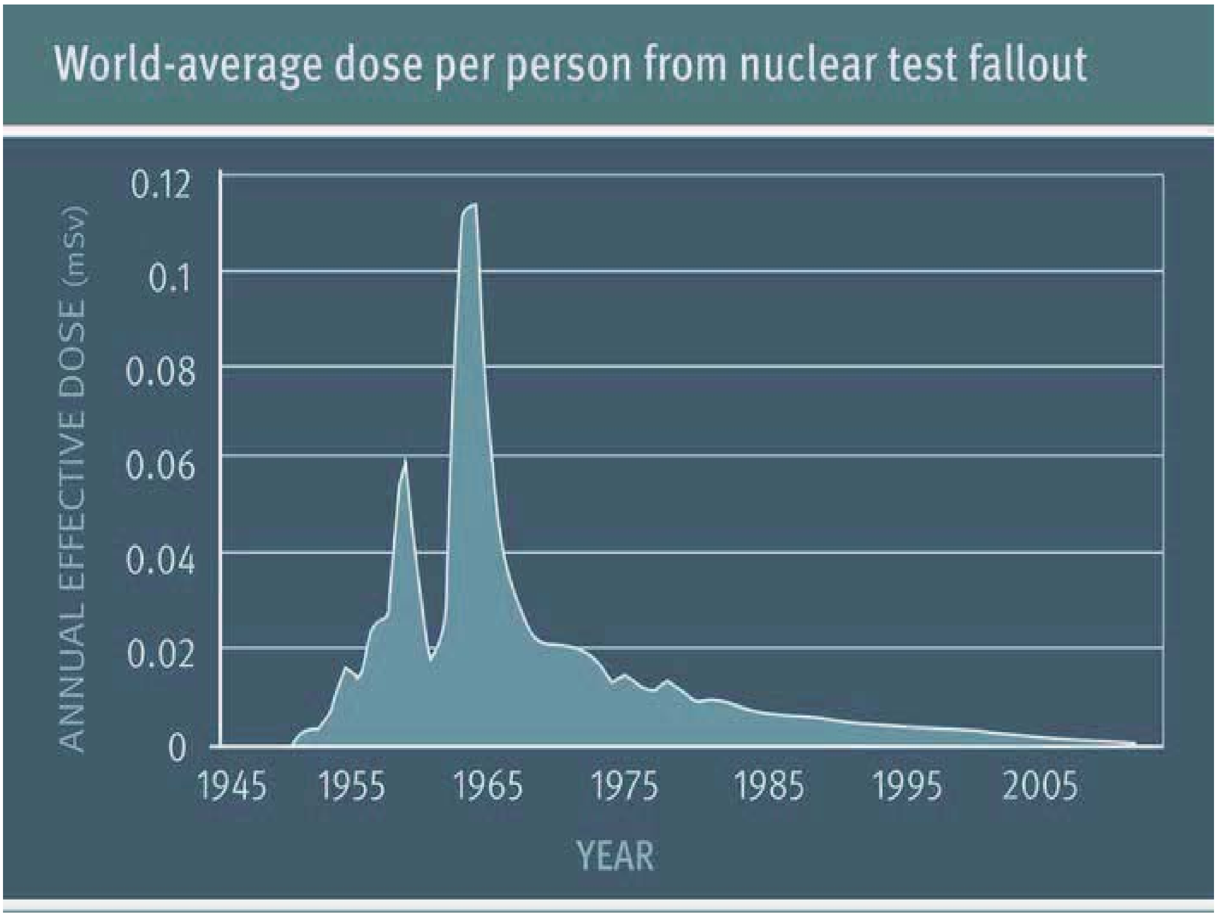
Nuclear weapons tests



50



Electricity generation

(including Nuclear Power Plants)

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Civil nuclear power

In comparison, basically zero contribution!

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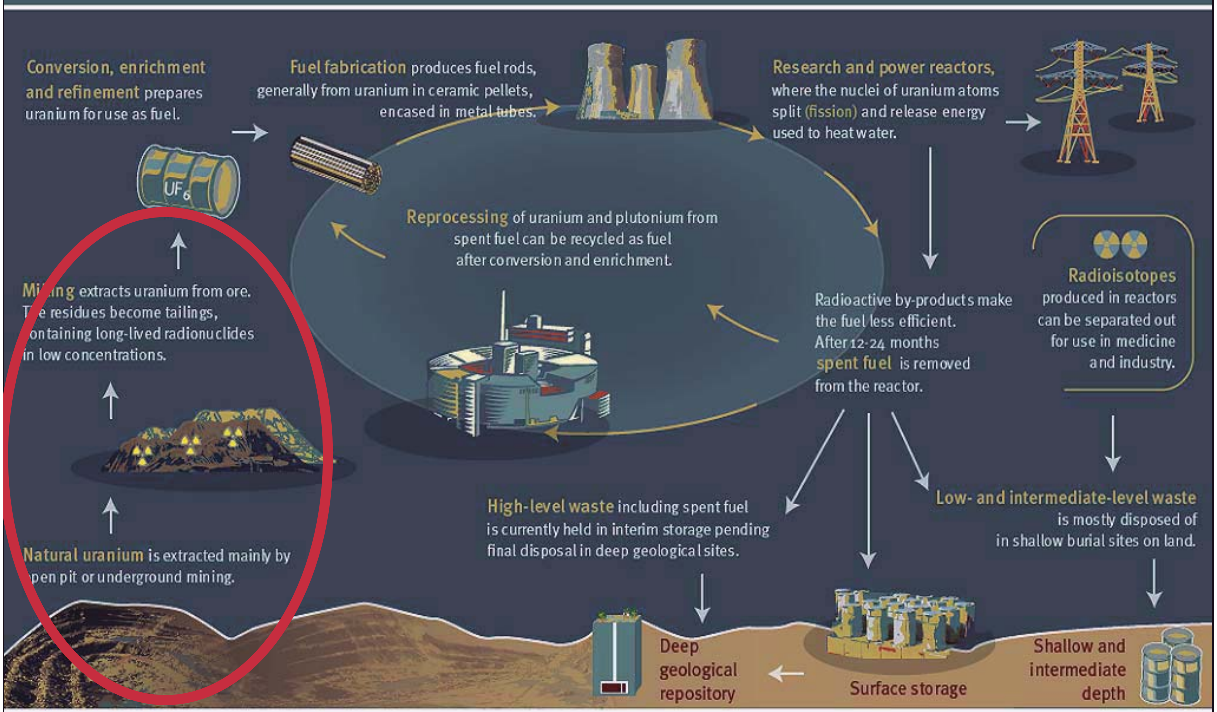
Main processes in the nuclear industry



However UNSCEAR, in a

Report to the UN General Assembly assessed:

Radiation exposure due to the generation of electricity (nuclear and other sources)

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First surprise

- Among the various sources of energy for **generating electricity**, the source that delivers the highest radiation exposure to people

is not nuclear, *it is coal!*

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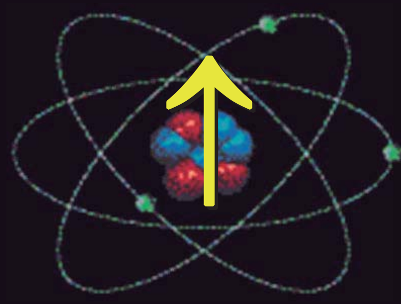

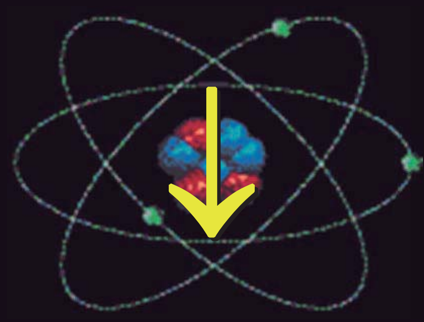

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- **Contribution from coal ~ 50%.**

  (from operations and environmental discharges during coal mining and combustion at power plants and also from coal ash deposits)

- **Contribution from nuclear ~20%.**

  (mainly due to uranium mining and milling, not to NPP operations)

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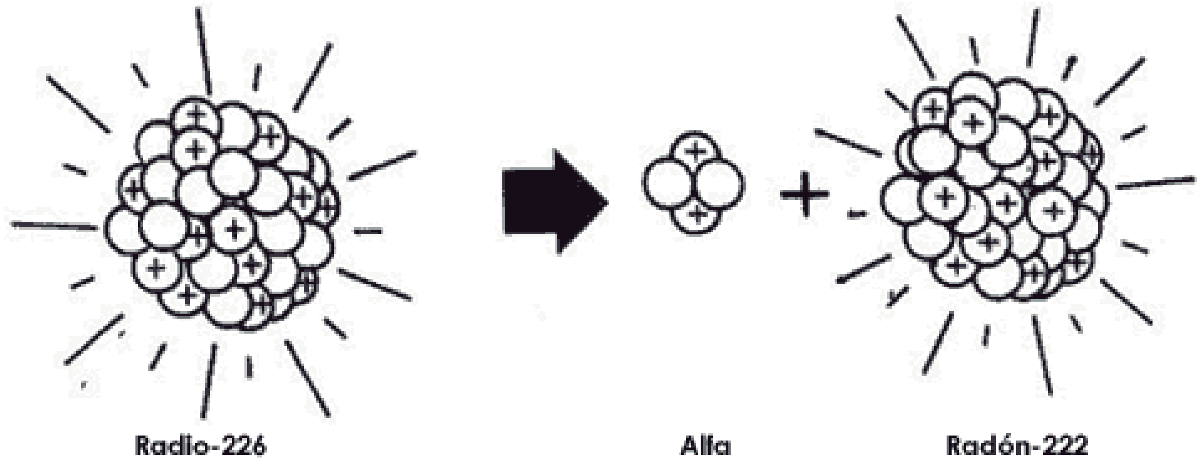
The great culprits:
The natural radioactive elements *radium-226* and *radon-222*!



Second surprise

- By far the largest radiation impact due to the

installation of electrical power

(construction of plants)

was found in

solar plants followed by *wind plants*.

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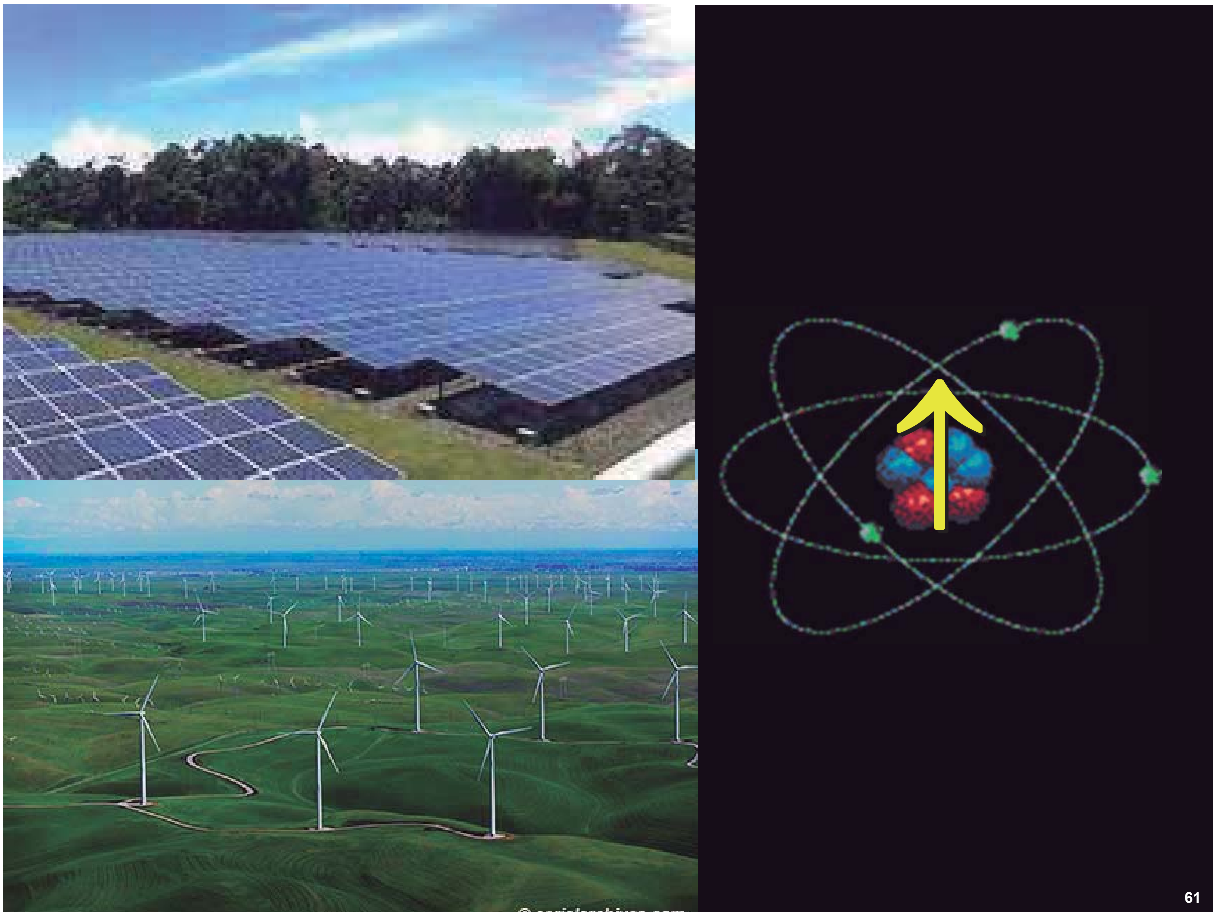

- The reason is that solar and wind require large amounts of ***rare earth metals***, and the mining of low-grade ore produces large radiation exposures.

Rare earths for solar cells

- Solar panels use, for example, *Tellurium*.
- *Tellurium* is three times rarer than gold.

Rare earths for wind generators

- *Neodymium* is used in wind turbine magnets

  (neodymium-iron-boron [NdFeB magnet powder is used to manufacture permanent wind turbine magnets)

Average radiation exposure to workers and members of the public

65

Occupational exposures

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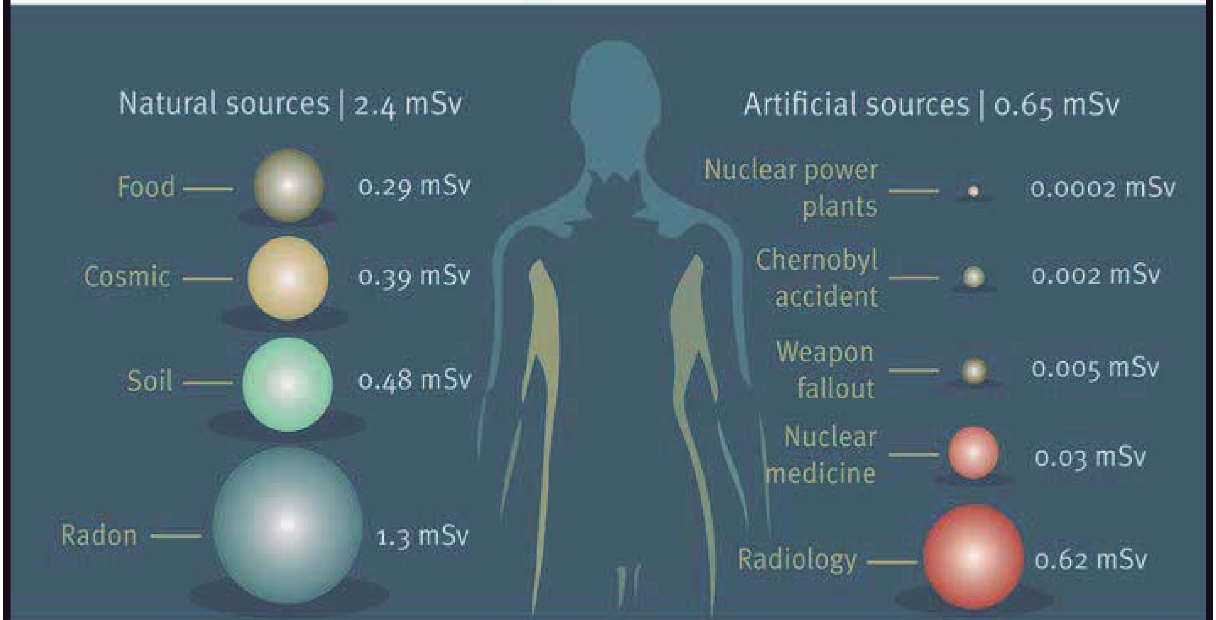
Trends in global radiological exposure of workers (mSv)*

Decades	1970s	1980s	1990s	2000s
Natural sources				
Aircrew	—	3.0	3.0	3.0
Coal mining	—	0.9	0.7	2.4
Other mining**	—	1.0	2.7	3.0
Miscellaneous	—	6.0	4.8	4.8
Total	—	1.7	1.8	2.9
Artificial sources				
Medical uses	0.8	0.6	0.3	0.5
Nuclear industry	4.4	3.7	1.8	1.0
Other industries	1.6	1.4	0.5	0.3
Miscellaneous	1.1	0.6	0.2	0.1
Total	1.7	1.4	0.6	0.5

Average public exposure by radiation sources*



* Rounded estimates of the effective dose to a person in a year (world average).

Summary of global doses

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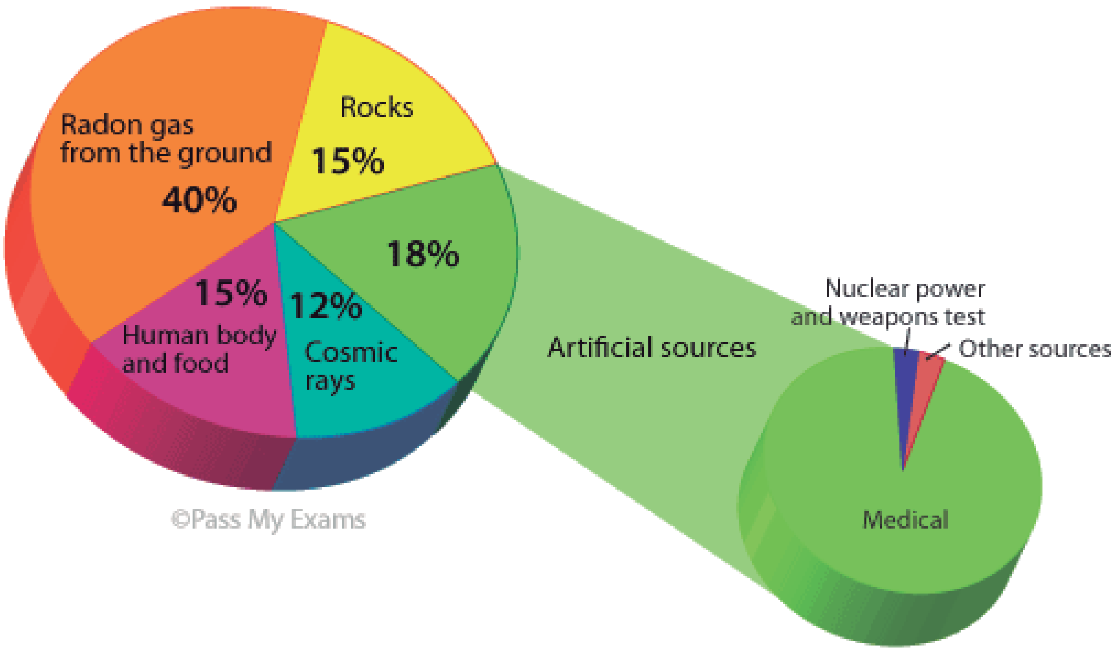
Background Radiation



…but…. what about nuclear accidents?

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Chernobyl

- 28 dead workers
- 138 workers with acute radiation syndrome
- ~ 7000 non-lethal pediatric cancers
- Dose to the public = 1 tomography
- Political, social and economic catastrophe

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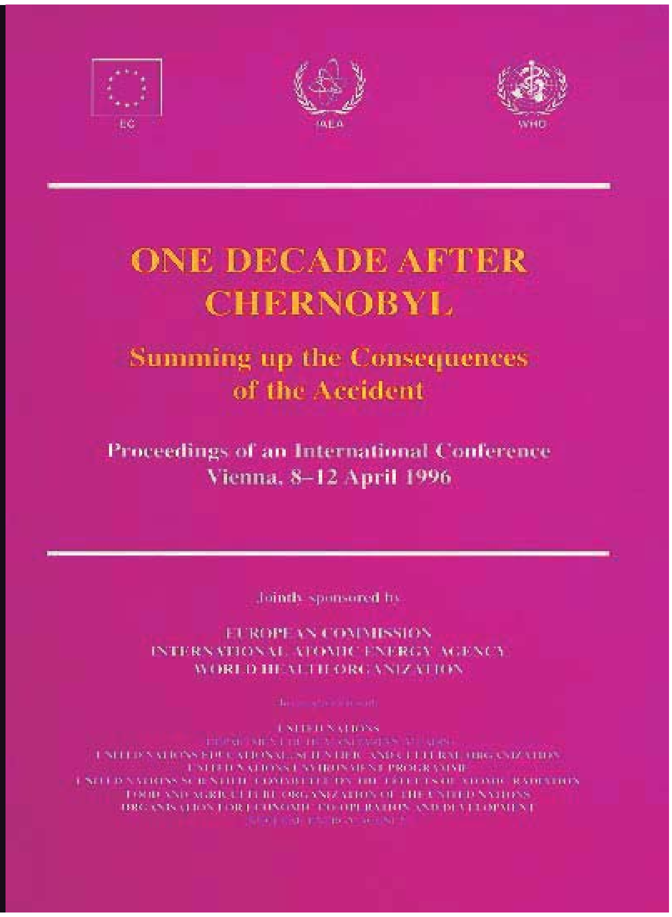
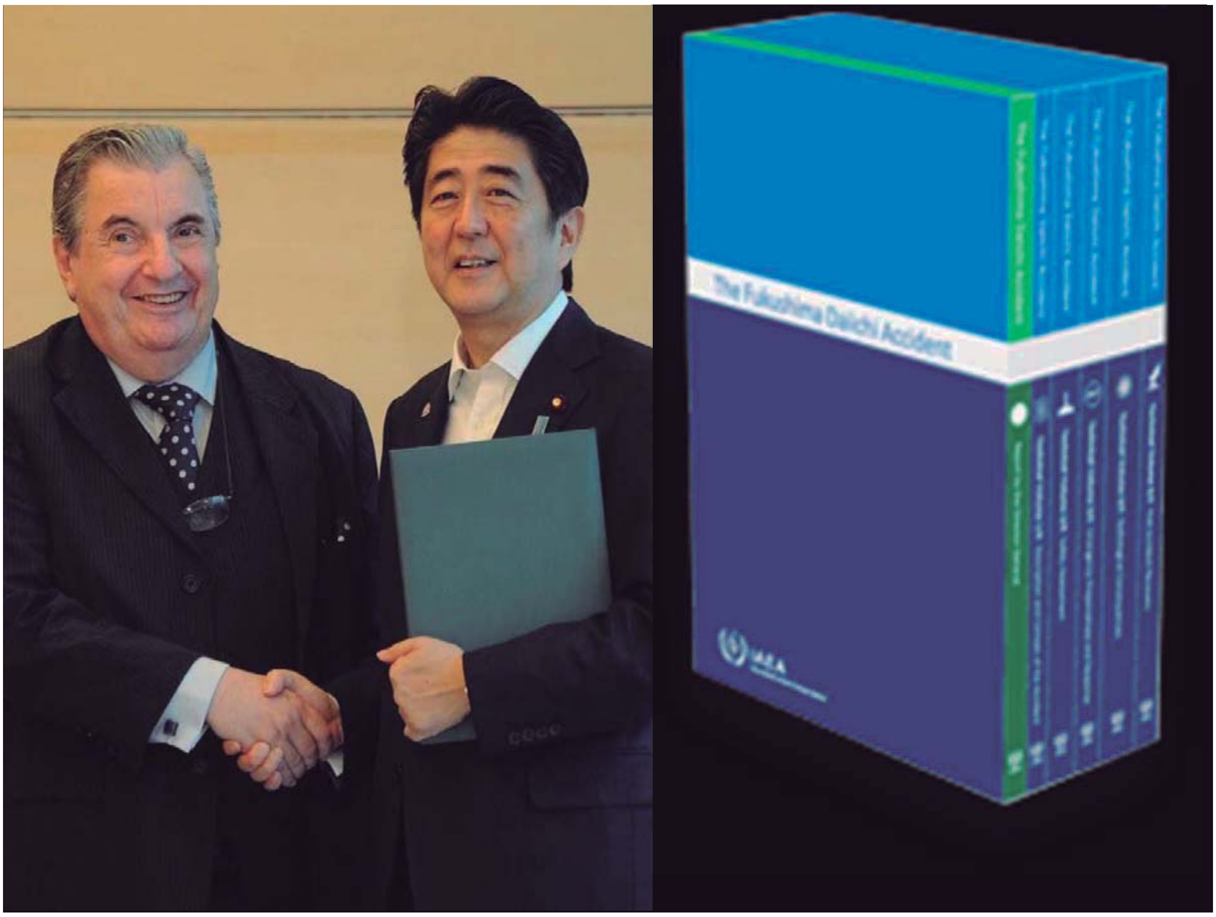
President of the Conference:

Angela Merkel



Fukushima

- Low radiation doses
- No health effects attributable to radiation, neither in workers nor in the public.
- Serious psychological effects.
- Political, social and economic catastrophe.
- Legal nightmare



Take away points

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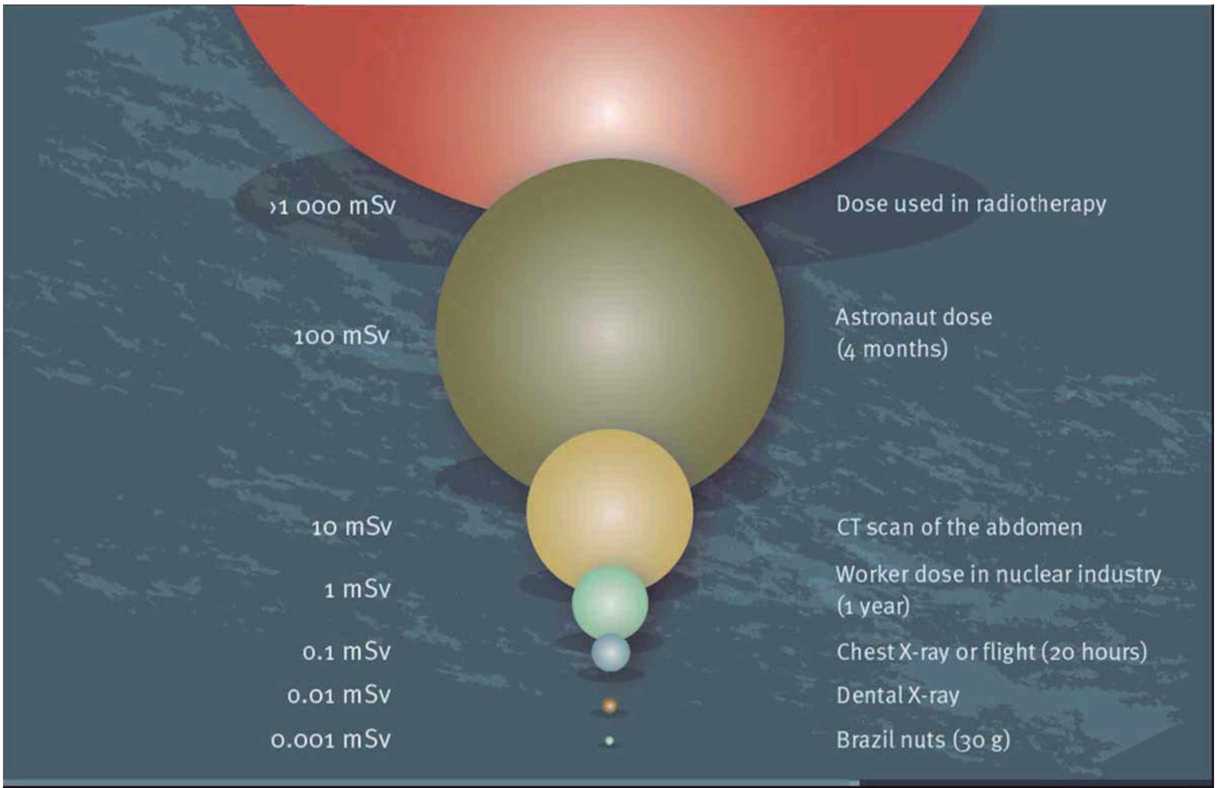
- Background → 2.4 mSv/y (up to above 100 mSv)
- Medical ↑↑↑
- Electricity via coal, solar and wind ↑↑↑
- Nuclear ↓↓↓

77



78

Third Part

What does radiation do to us?

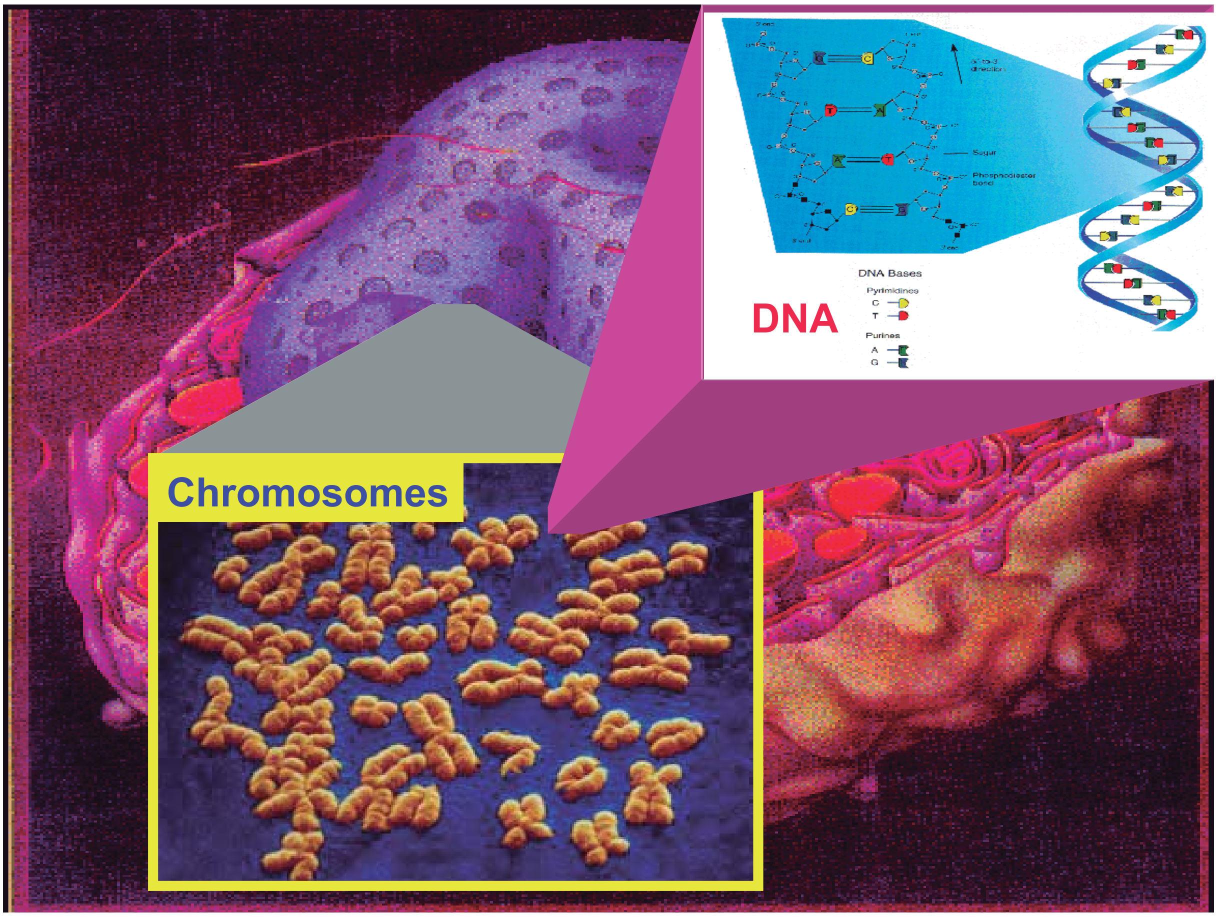
79

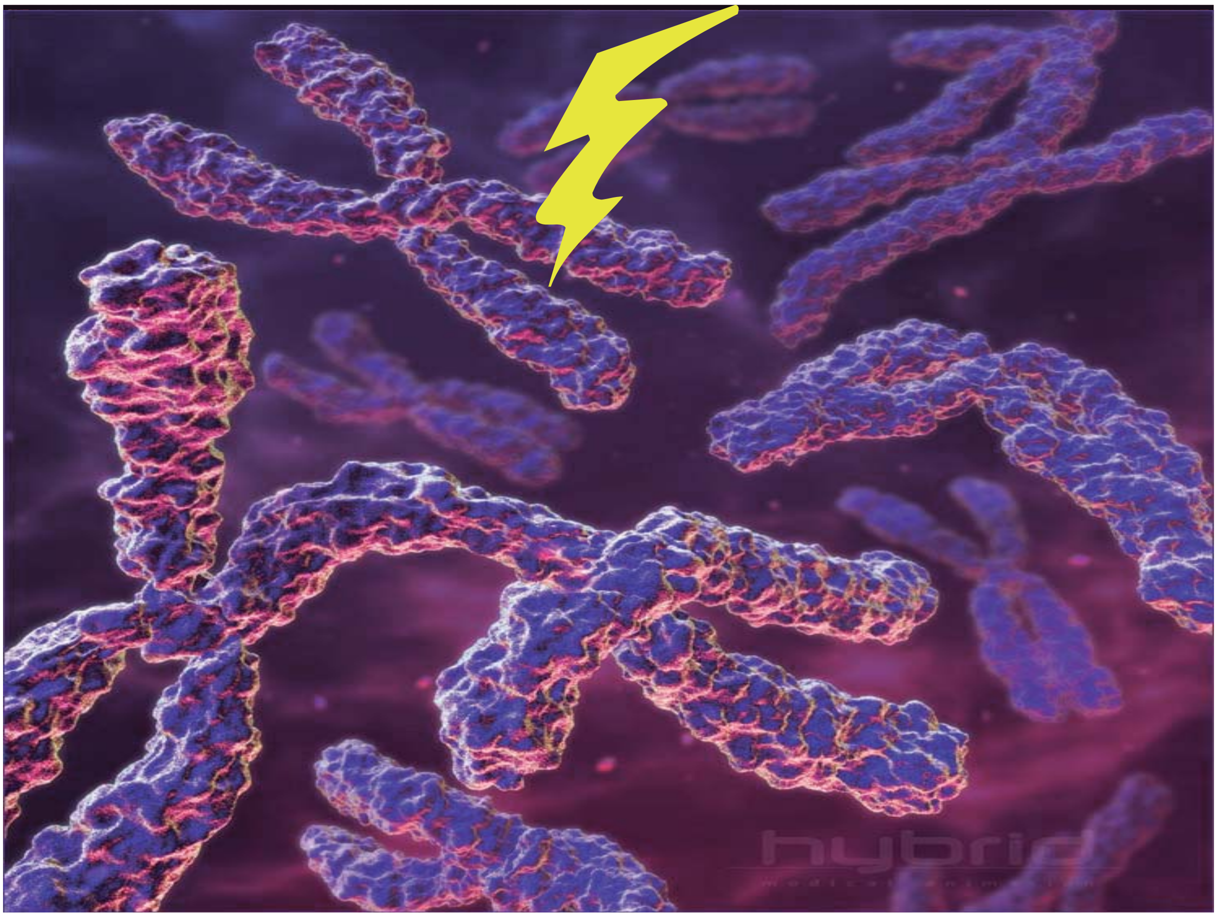
What does radiation do to us?

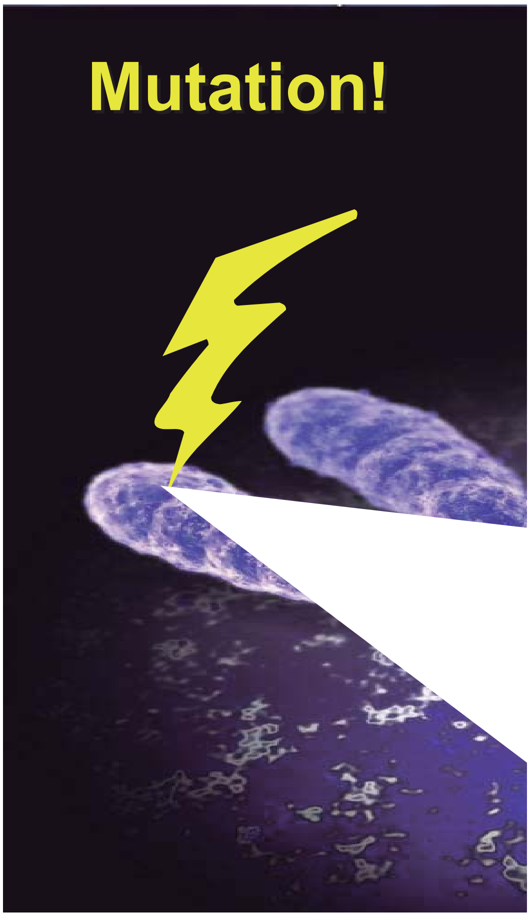
- Effects on humans
  - Early health effects
  - Delayed health effects
  - Effects on offspring
- Effects on animals and plants
- Relationship of radiation doses and effects

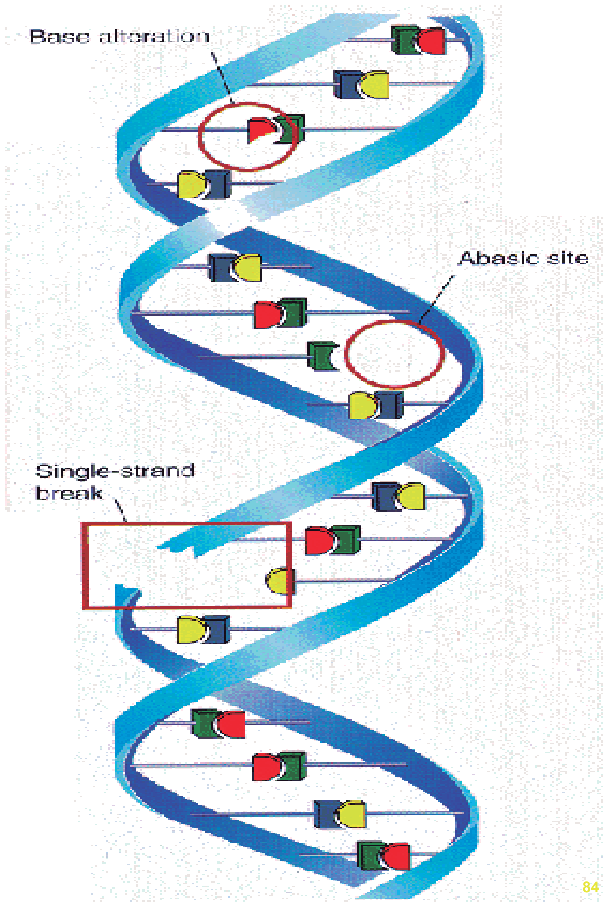
80

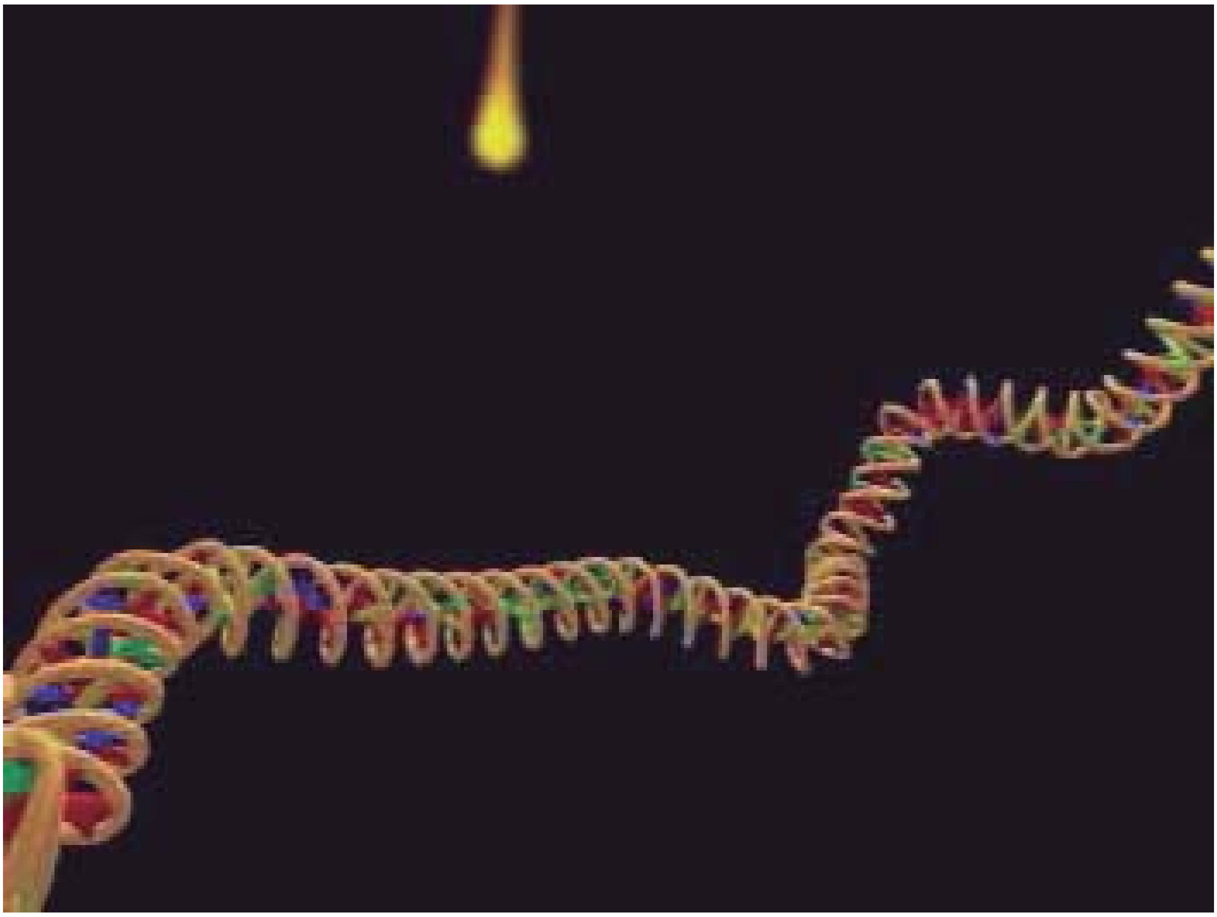
Effects on humans

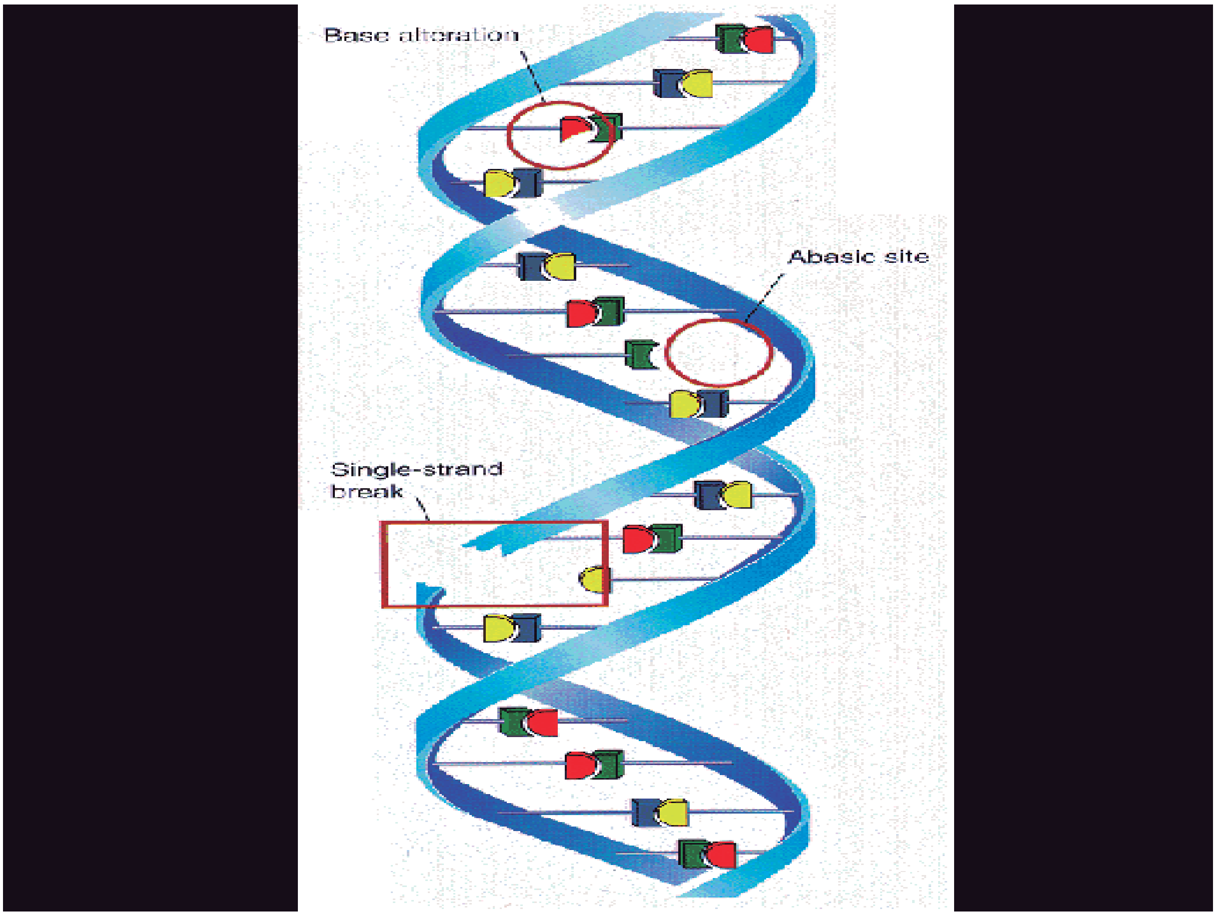


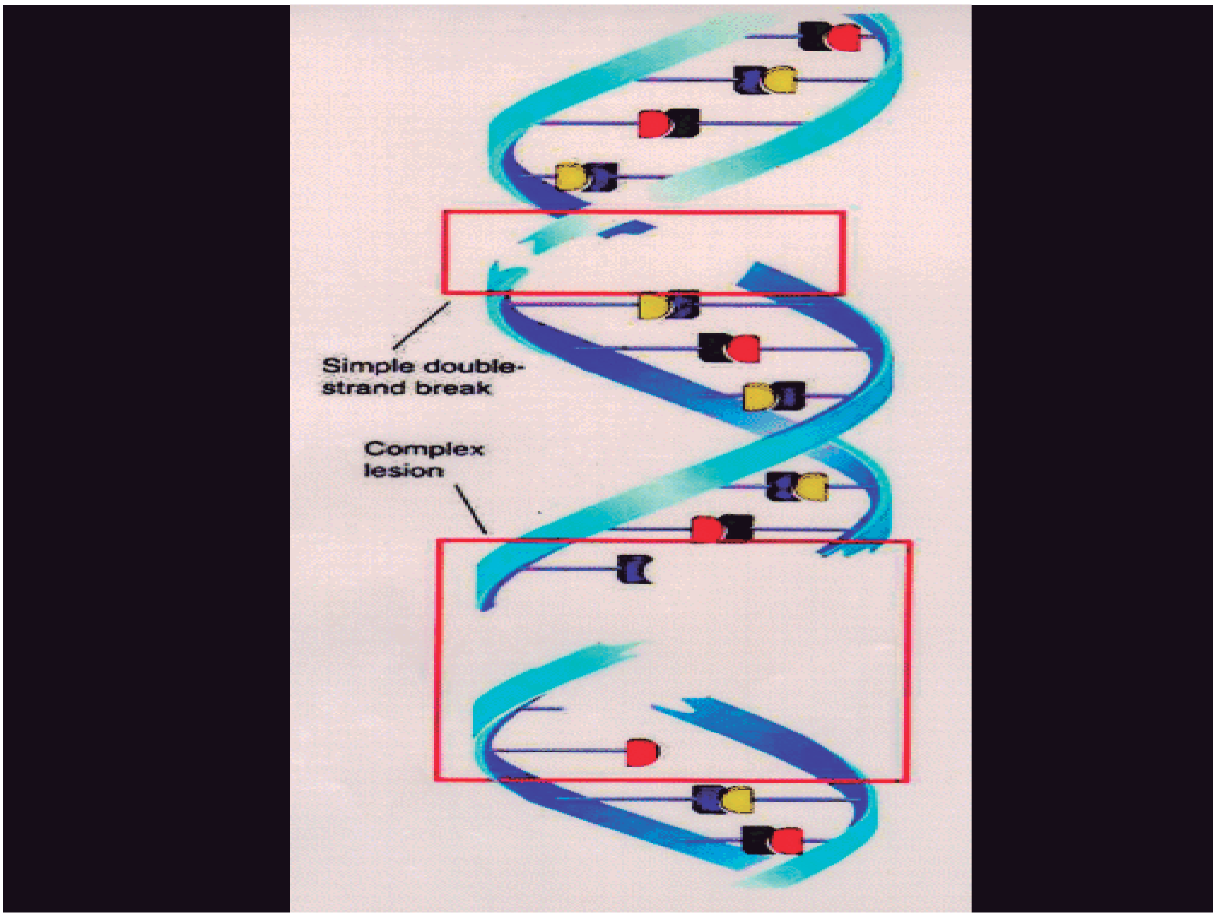


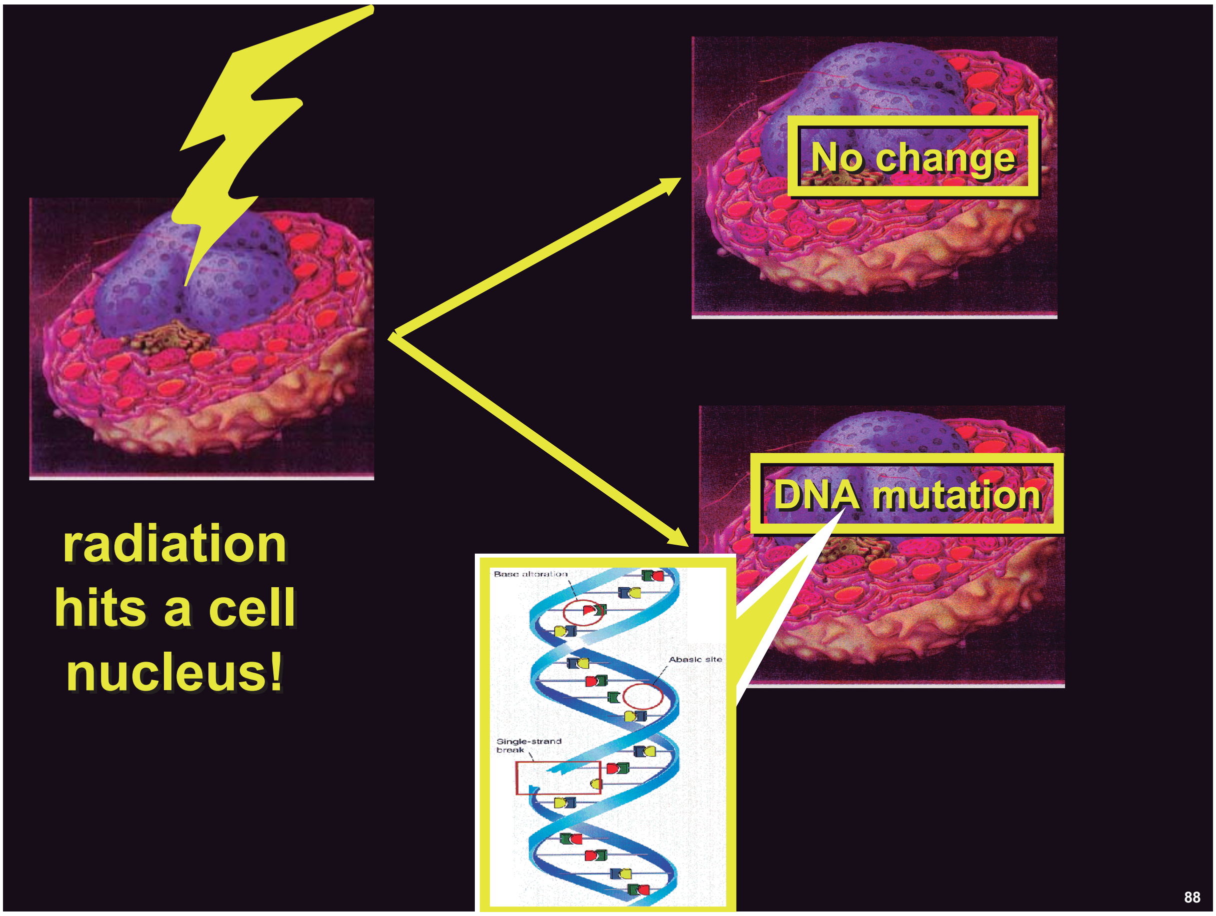

Mutation!

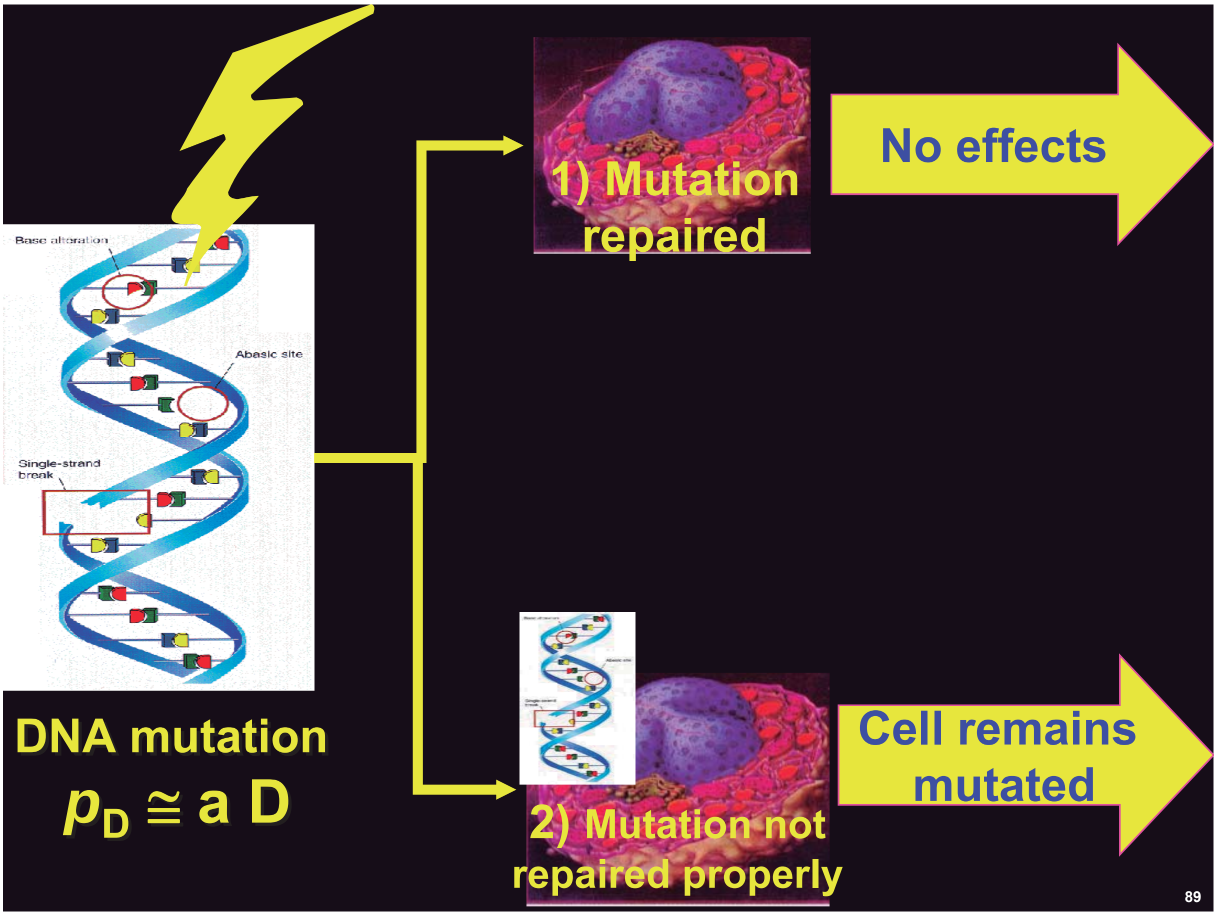

Base alteration
Abasic site
Single-strand
break

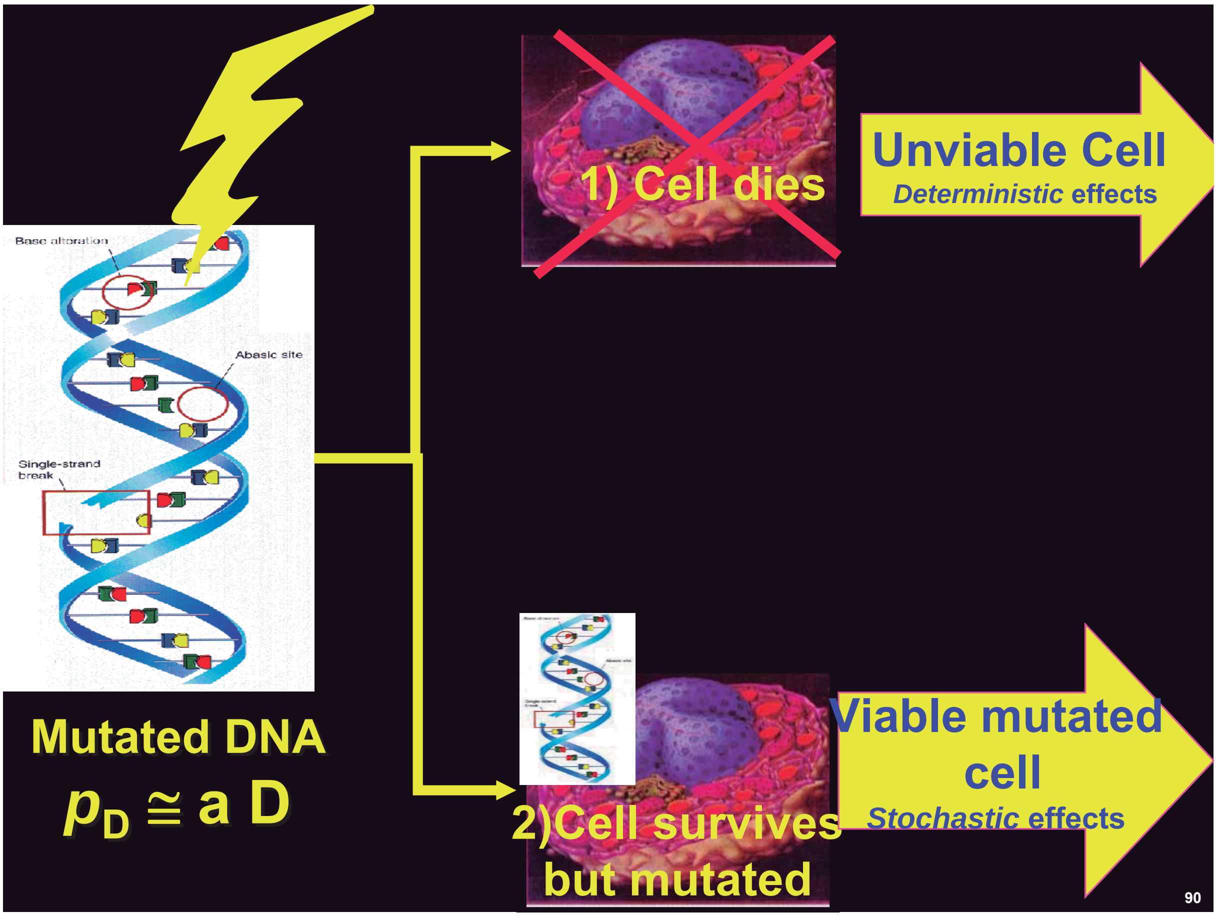



Base alteration
Abasic site
Single-strand
break

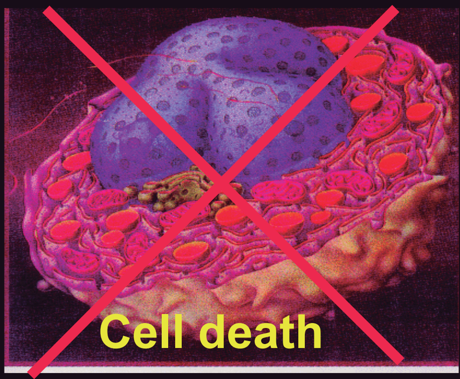

Simple double-
strand break
Complex
lesion


radiation
hits a cell
nucleus!
No change
DNA mutation
Base alteration
Abasic site
Single-strand
break
88


Base alteration
Abasic site
Single-strand break
DNA mutation
$p_D \cong a\,D$
1) Mutation repaired
No effects
2) Mutation not repaired properly
Cell remains mutated
89


Base alteration
Abasic site
Single-strand break
Mutated DNA
$p_D \cong a\,D$
1) Cell dies
Unviable Cell
Deterministic effects
2)Cell survives but mutated
Viable mutated cell
Stochastic effects
90

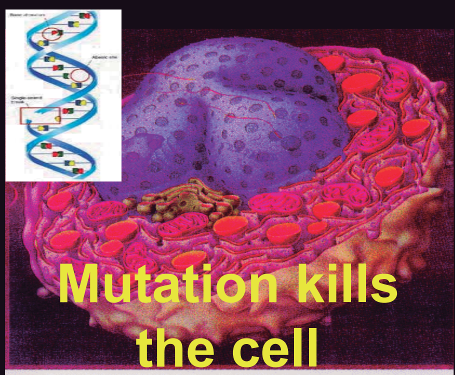
First possible outcome cell death



Unviable Cell

91

Massive cell killing may generate prompt ‘*deterministic*’ health effects



Deterministic effects

92

Early health effects

Potential *deterministic* effects

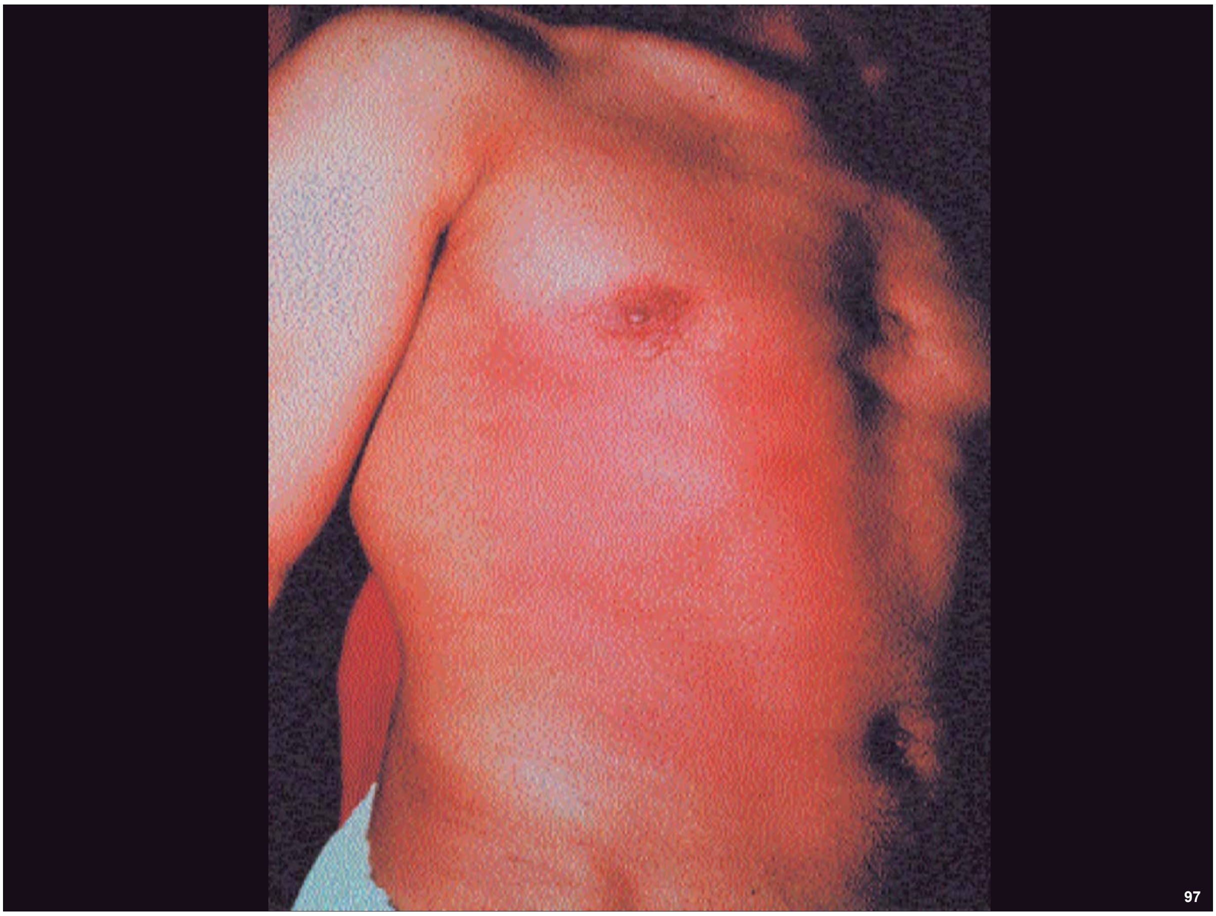
- Tissue reactions
- Burns
- Organ failure
- Death

94

The occurrence of deterministic effects in exposed individuals is diagnosed by

radio-pathologists.

95

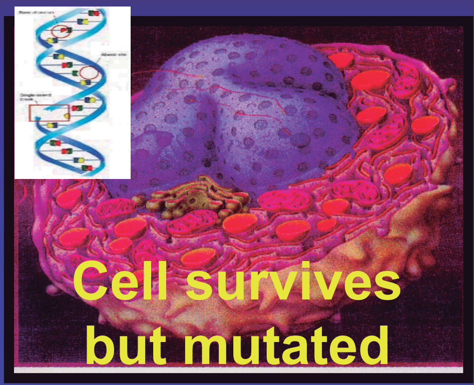


97

98

99

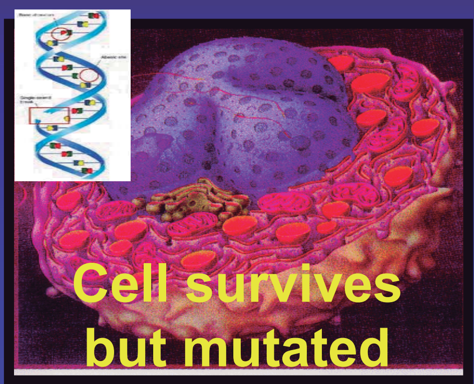
Second possible outcome of DNA mutation:
A viable but mutated cell



Altered process

101

The altered process may generate late ‘*stochastic*’ health effects



Stochastic effects

102

Delayed health effects

potential *stochastic* effects

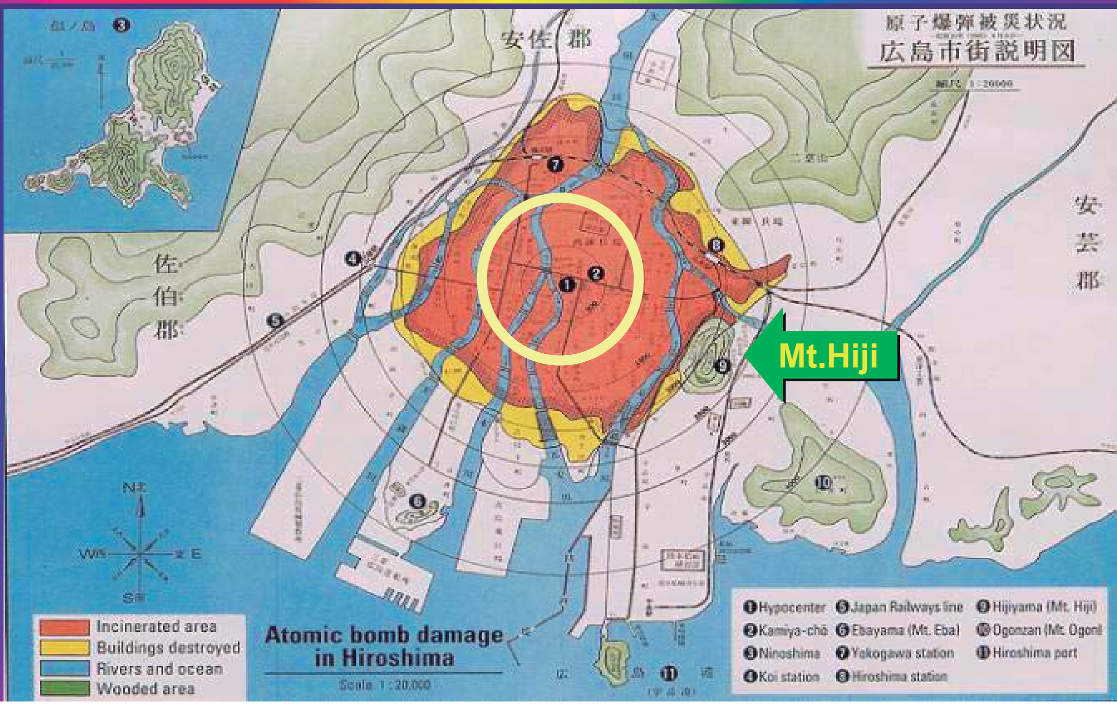
- Cancer
- Hereditable
- Antenatal

104

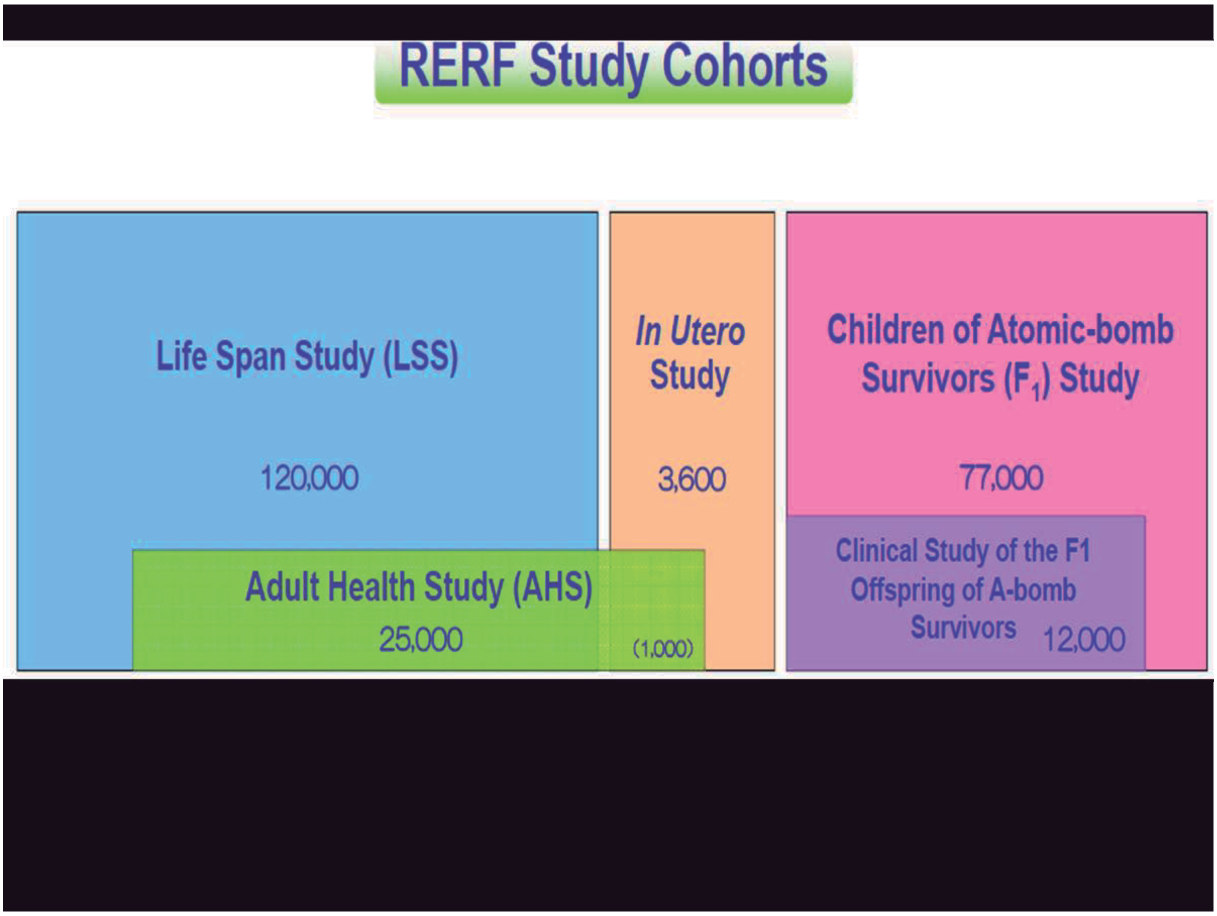
The prevalence of stochastic effects in an exposed population is estimated by radio-epidemiologists.

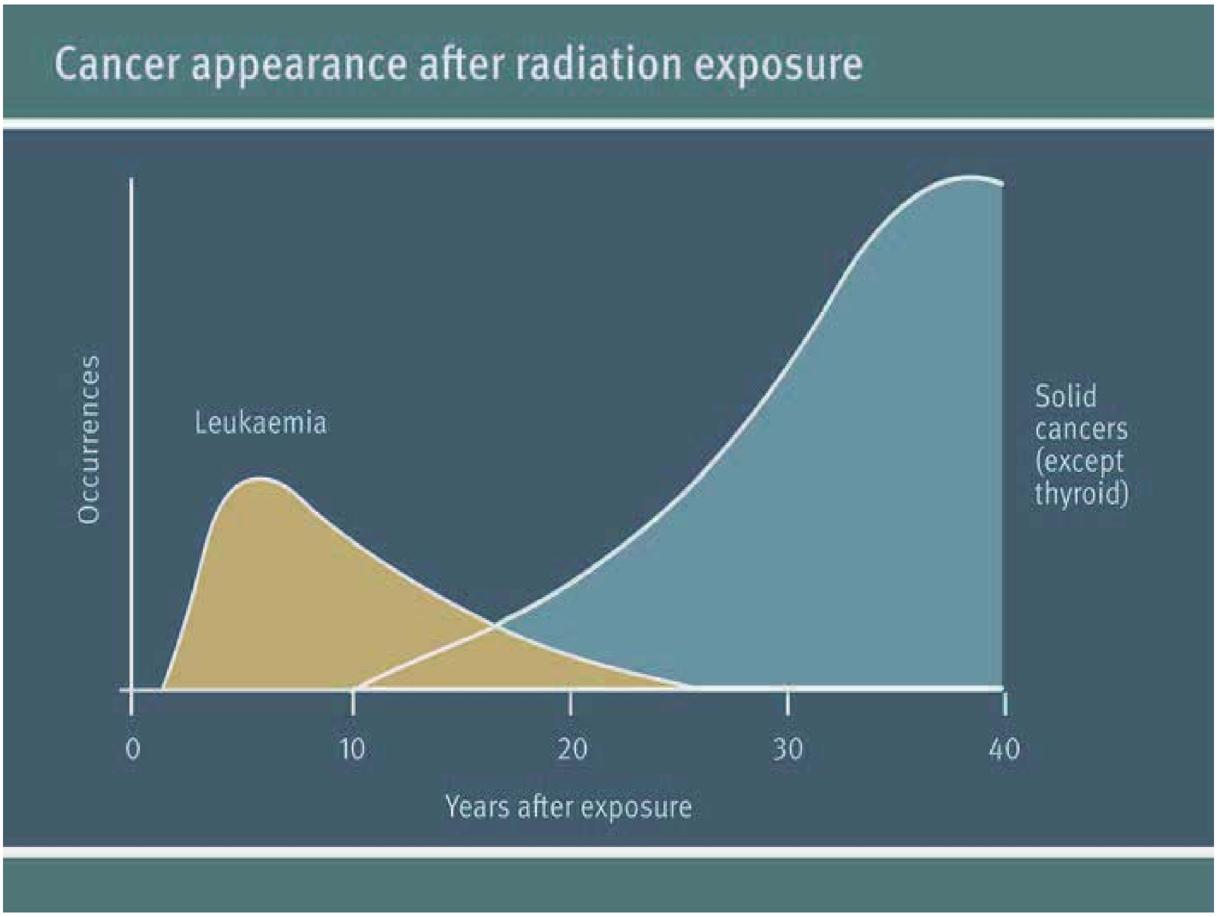
105

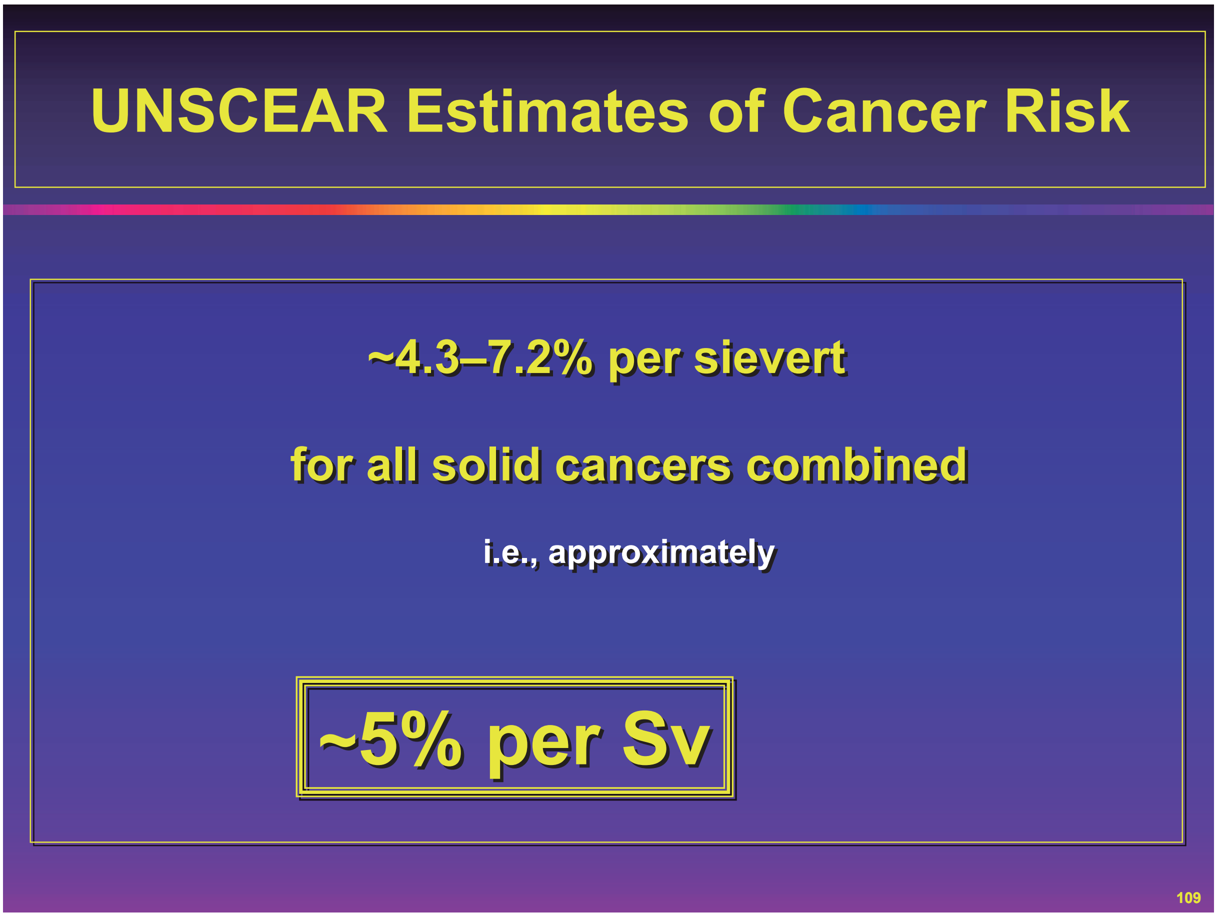
Cohort of Hiroshima & Nagasaki
(LIFE SPAN STUDY, LSS)

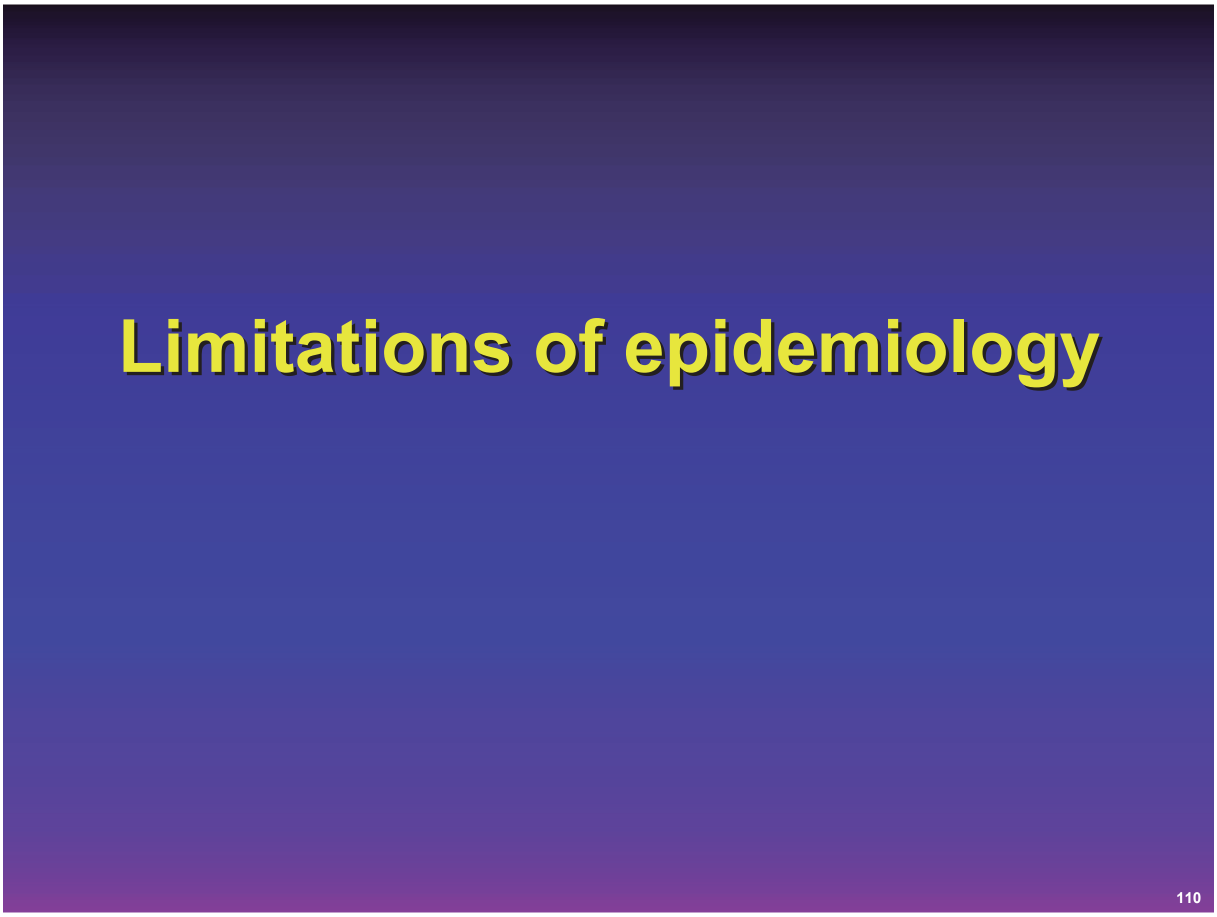


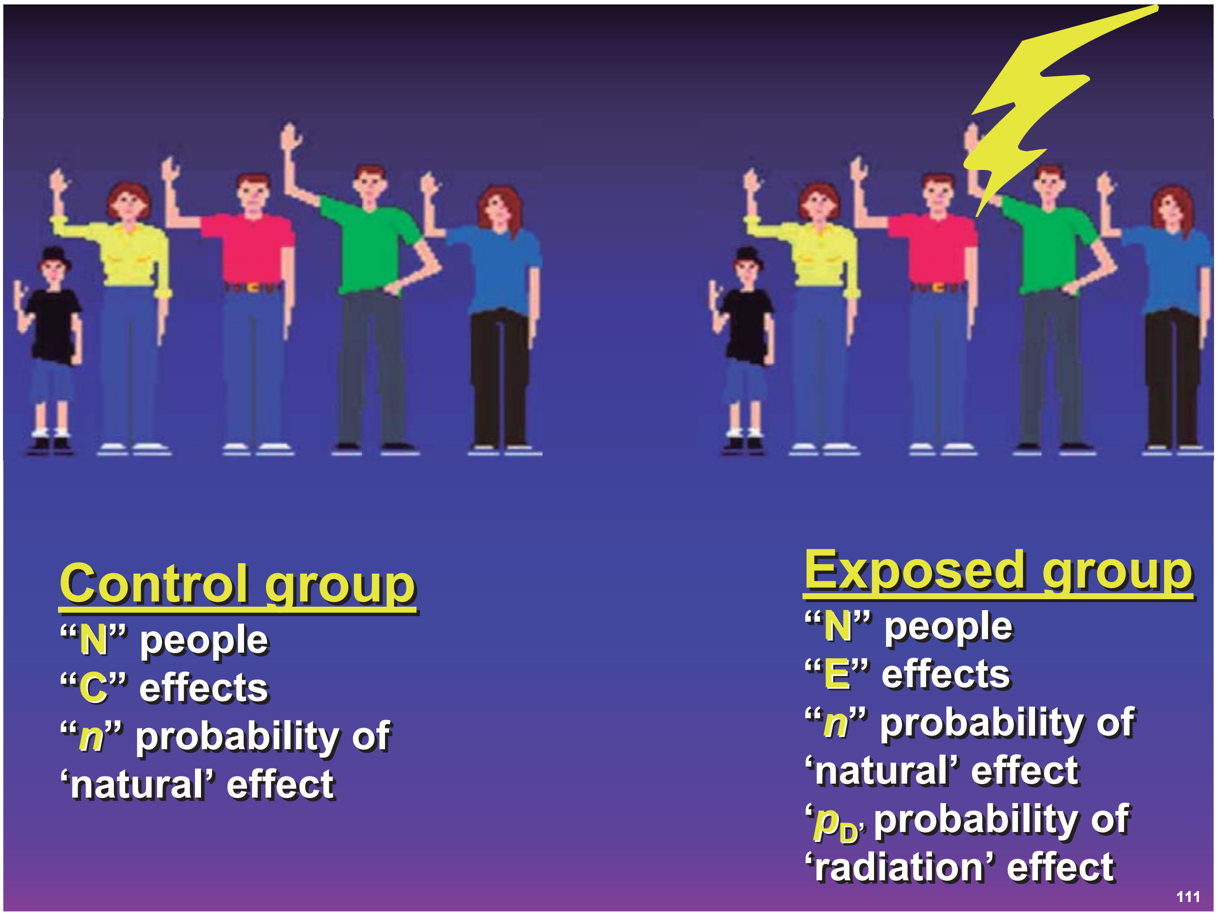
106

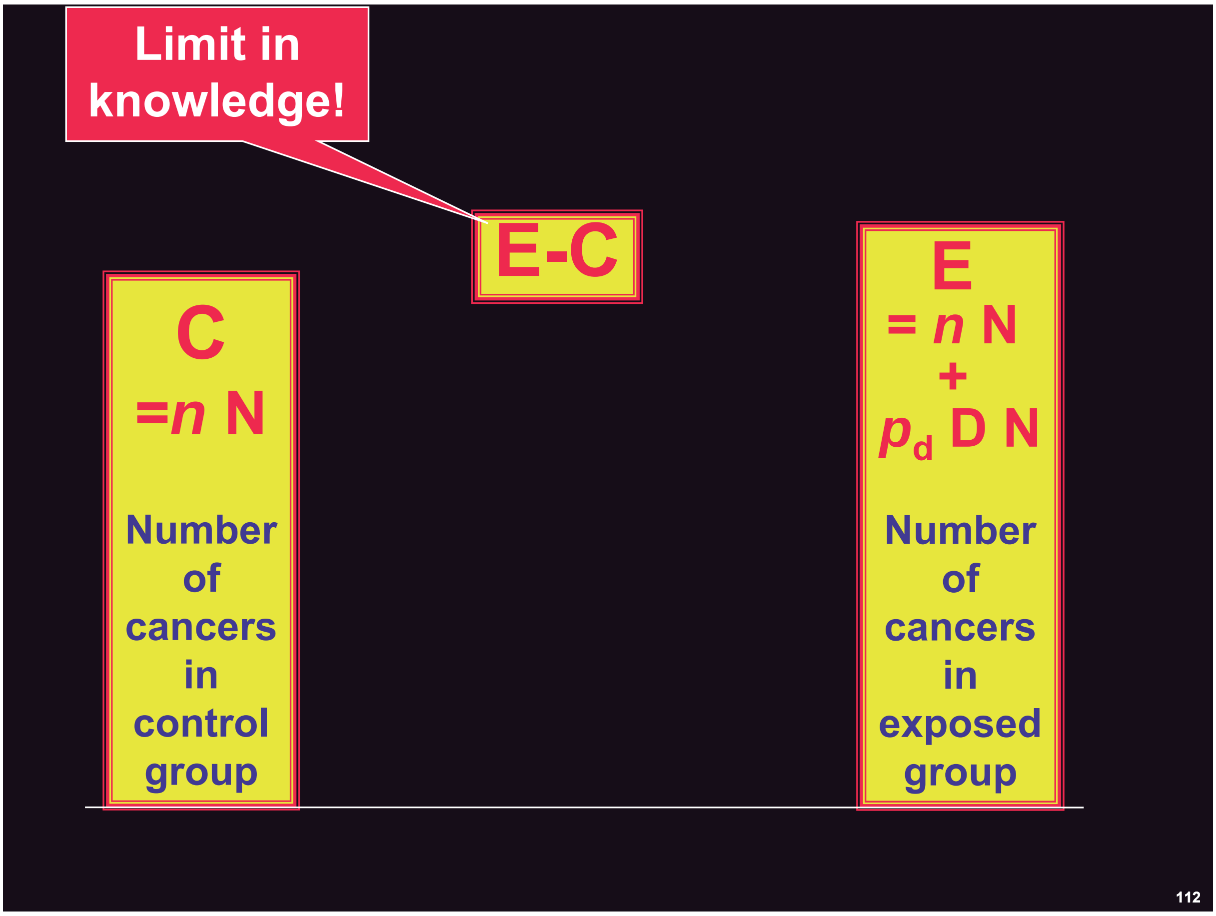

RERF Study Cohorts
Life Span Study (LSS)
120,000
In Utero Study
3,600
Children of Atomic-bomb Survivors (F1) Study
77,000
Adult Health Study (AHS)
25,000
(1,000)
Clinical Study of the F1 Offspring of A-bomb Survivors
12,000


Cancer appearance after radiation exposure
Occurrences
Leukaemia
Solid cancers (except thyroid)
0
10
20
30
40
Years after exposure


UNSCEAR Estimates of Cancer Risk
~4.3–7.2% per sievert
for all solid cancers combined
i.e., approximately
~5% per Sv
109


Limitations of epidemiology
110


Control group
"N" people
"C" effects
"n" probability of
'natural' effect
Exposed group
"N" people
"E" effects
"n" probability of
'natural' effect
'p_D' probability of
'radiation' effect
111

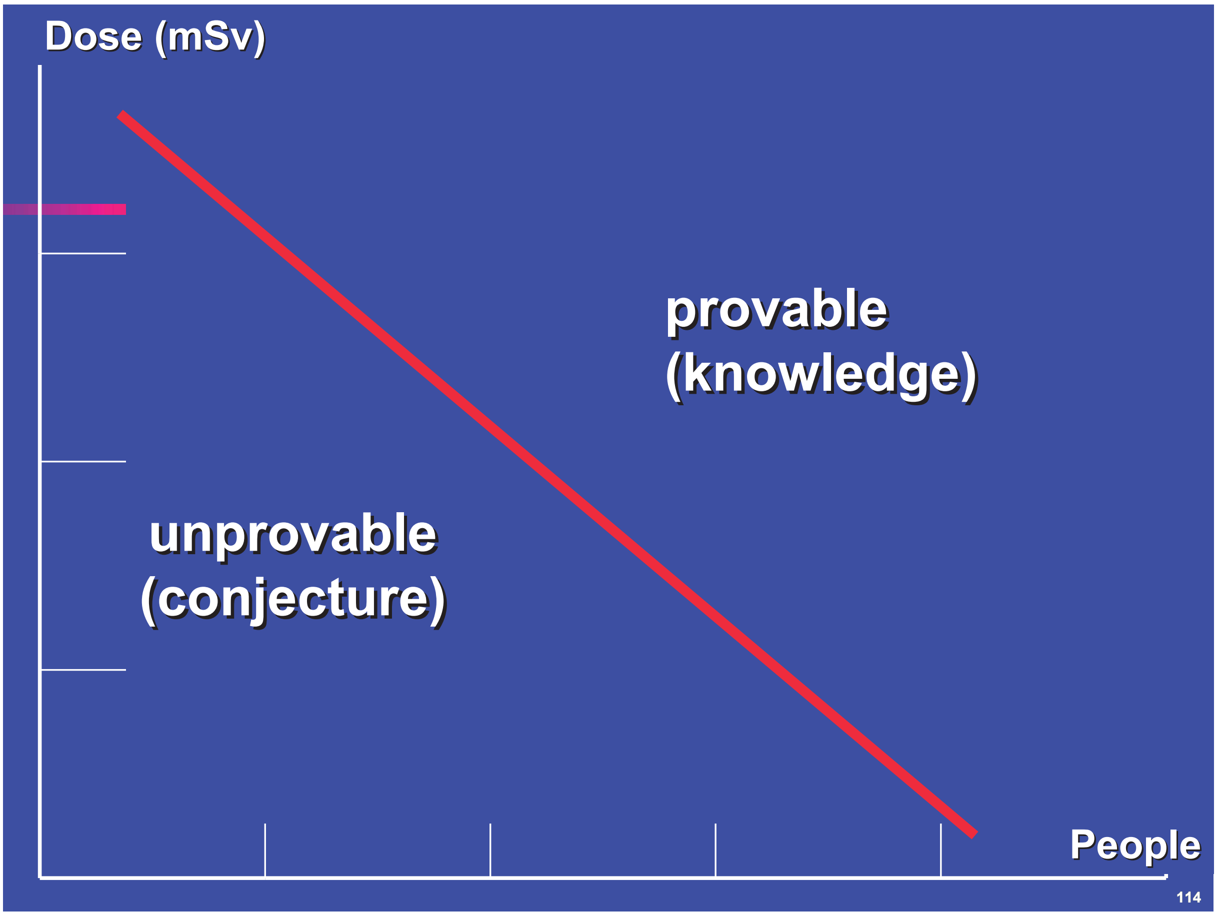

Limit in knowledge!
E-C
C
$=n$ N
Number of cancers in control group
E
$= n$ N
+
p_d D N
Number of cancers in exposed group
112

Statistical limits

$$N > constant / D^2$$

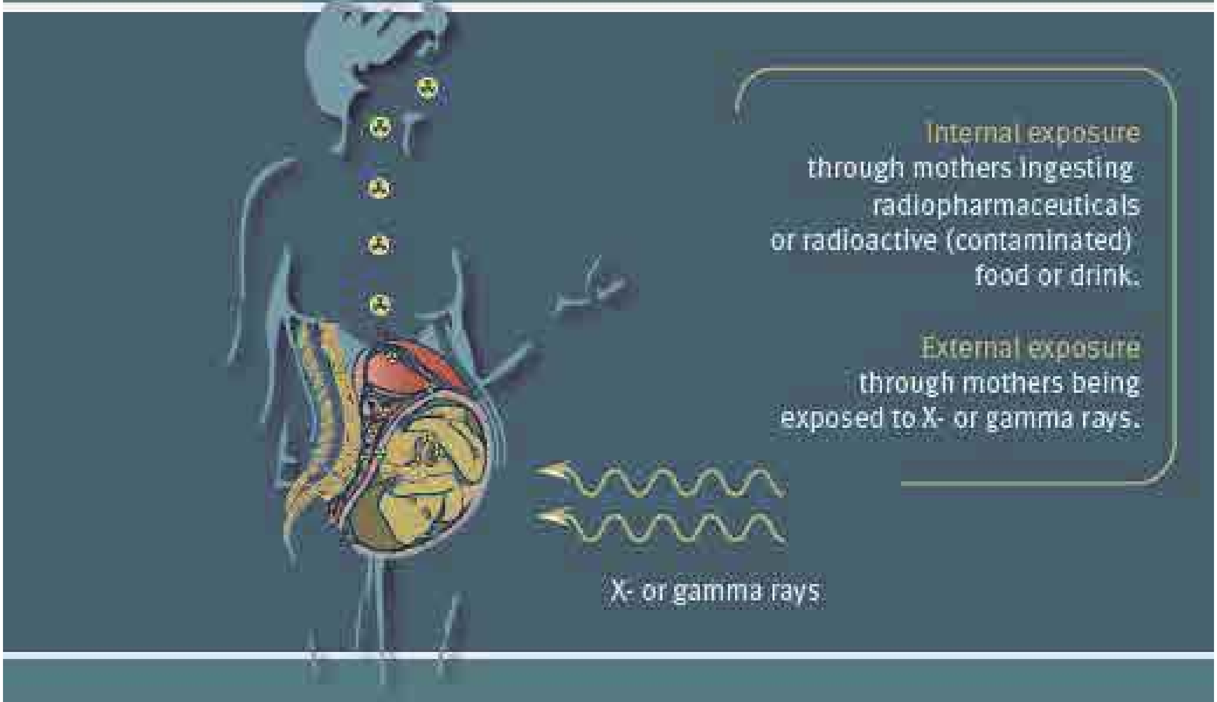
which is the equation giving the number of people, N, needed for proving excess cancers at dose D.

113



Effects on offspring

Radiation exposure pathways for embryos



Antenatal Effects

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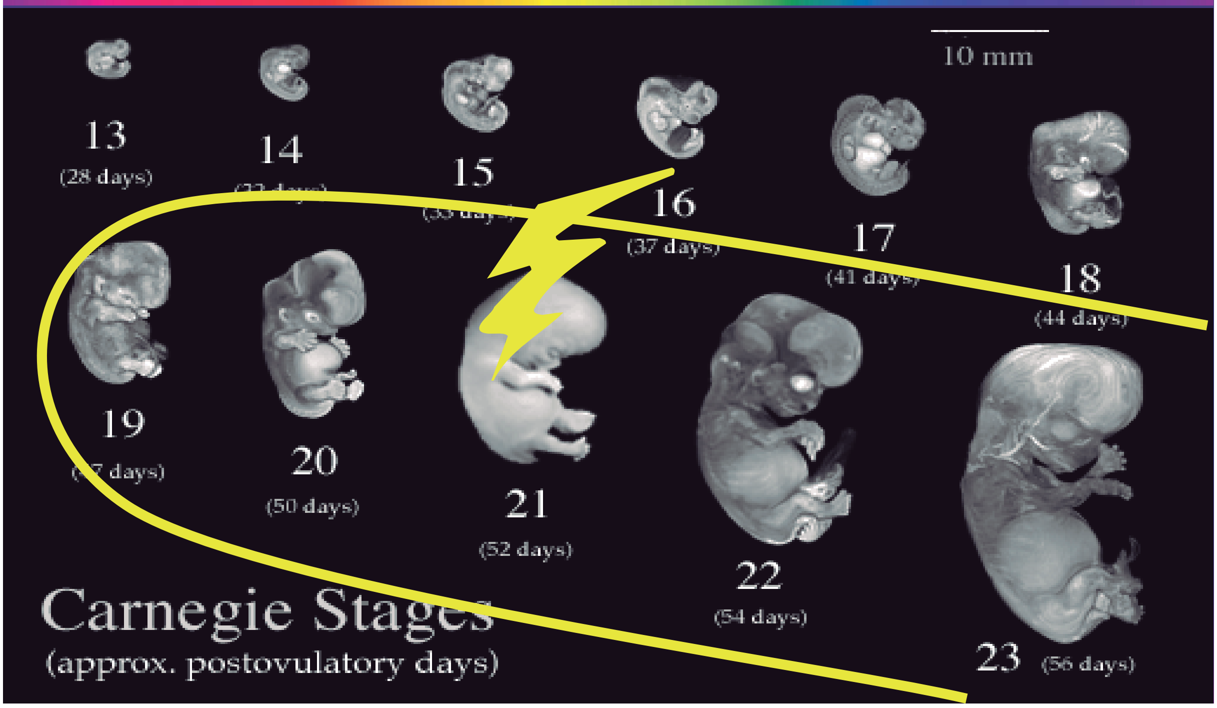
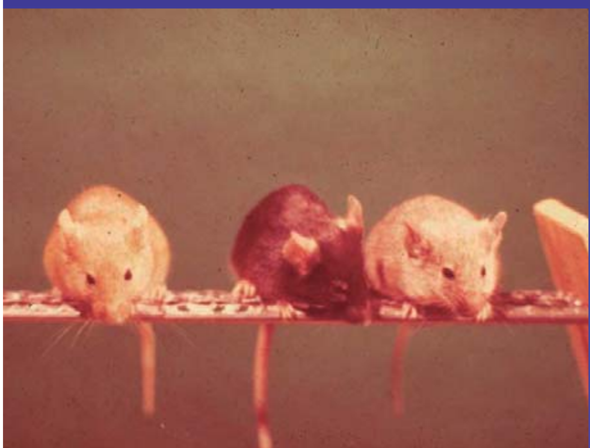
Antenatal Effects



Hereditable Effects

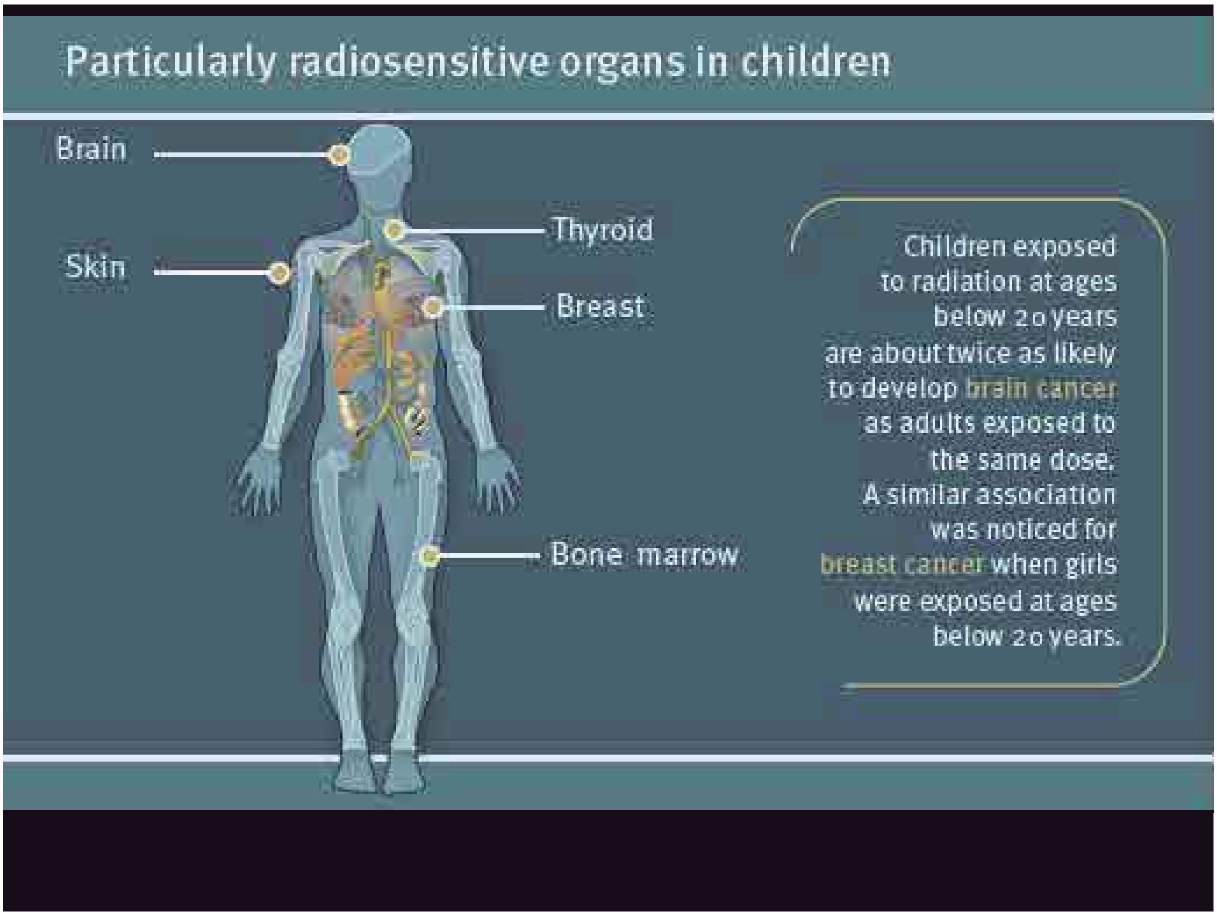
119

No hereditary effects have been observed in humans exposed to radiation: suspicions are based on animal studies



120

Effects in children



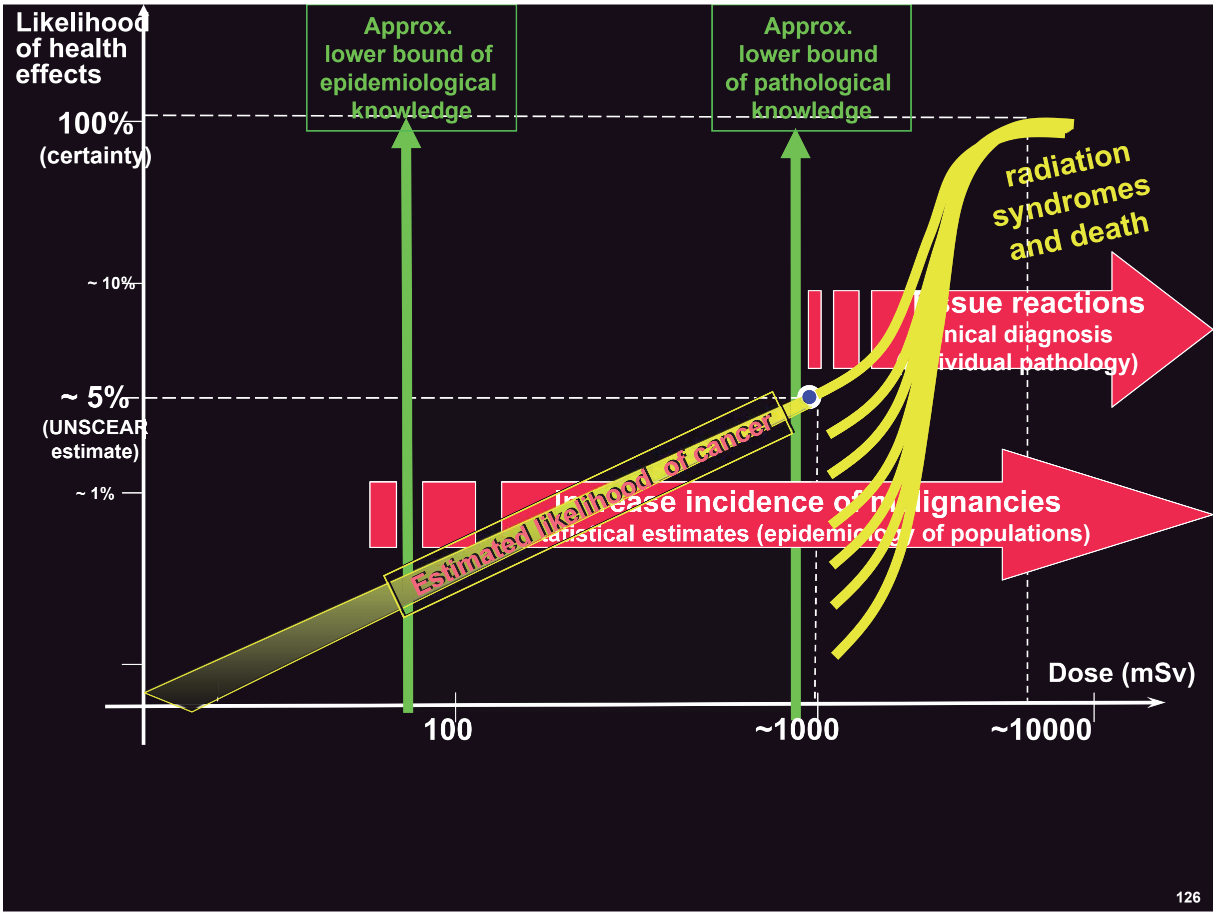
Take away points

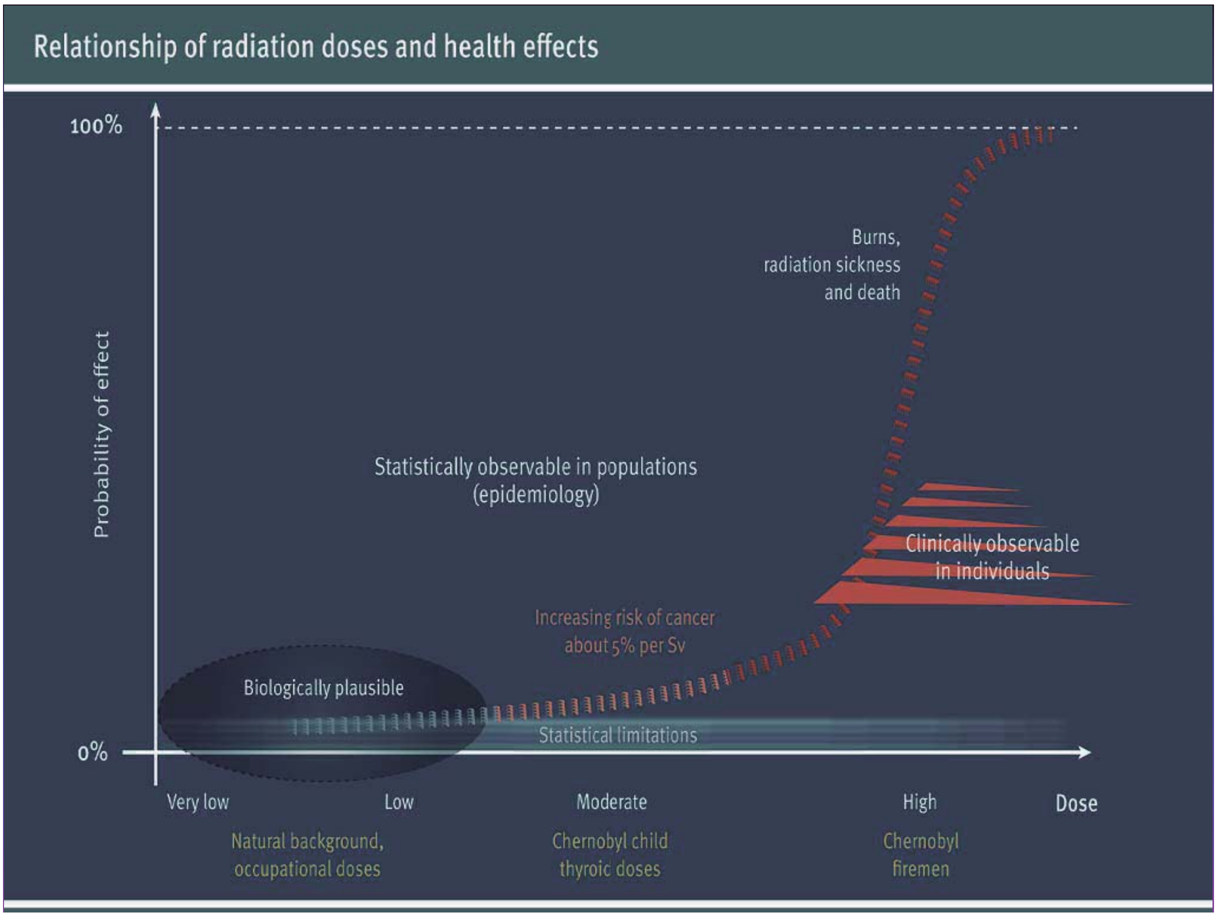
123

1. Radiation exposure at high acute levels, e.g. above several thousand of millisieverts is very dangerous.
2. Radiation exposure at low chronic levels, e.g. towards tens of millisieverts per year, presents an extremely low risk.
3. Radiation exposure at very low chronic levels, e.g. < 1 millisievert per year, is not an individual health issue.

124

Relationship of radiation doses and effects





This dose-response relationship provides the scientific basis of the interational radiation safety regime

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SCIENCE

Epistemology of radiation

Method, validity and scope of the scientific knowledge about radiation

↓

PROTECTION MODEL

Radiation Protection Paradigm

Conceptual ideal for keeping people protected

↓

INTERNATIONAL INTERGOVERNMENTAL NORMS

Global Radiation Safety Regime

Establishing globalsafety standards and providing for their global application

UNSCEAR

ICRP

Euratom FAO IAEA ILO IMO OECD/NEA PAHO UNEP WHO

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Fourth Part

What is the legal challenge?

Attributing health effects *vs* Inferring risks

&

Imputing (i.e. legally charging) radiation harm

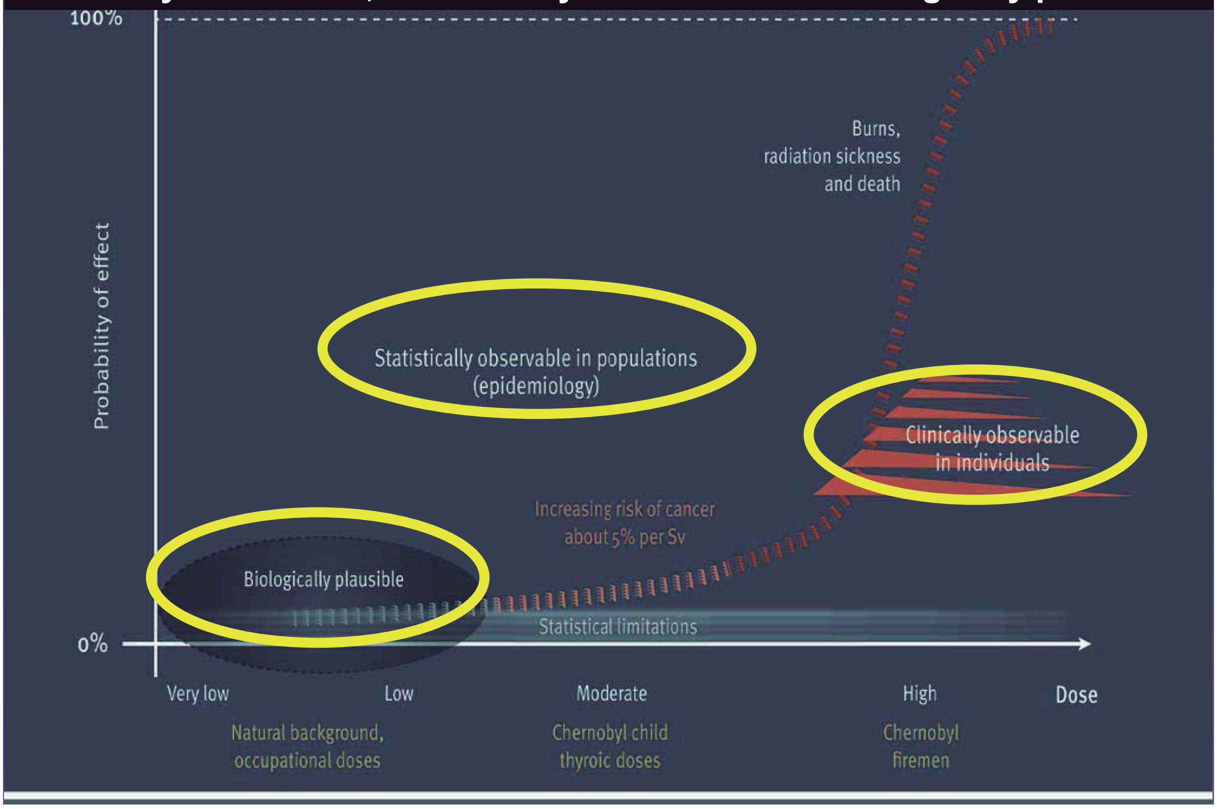
130

How radiation effects are distinguished?

131

A clear distinction between effects:

clinically observable, statistically observable and biologically plausible



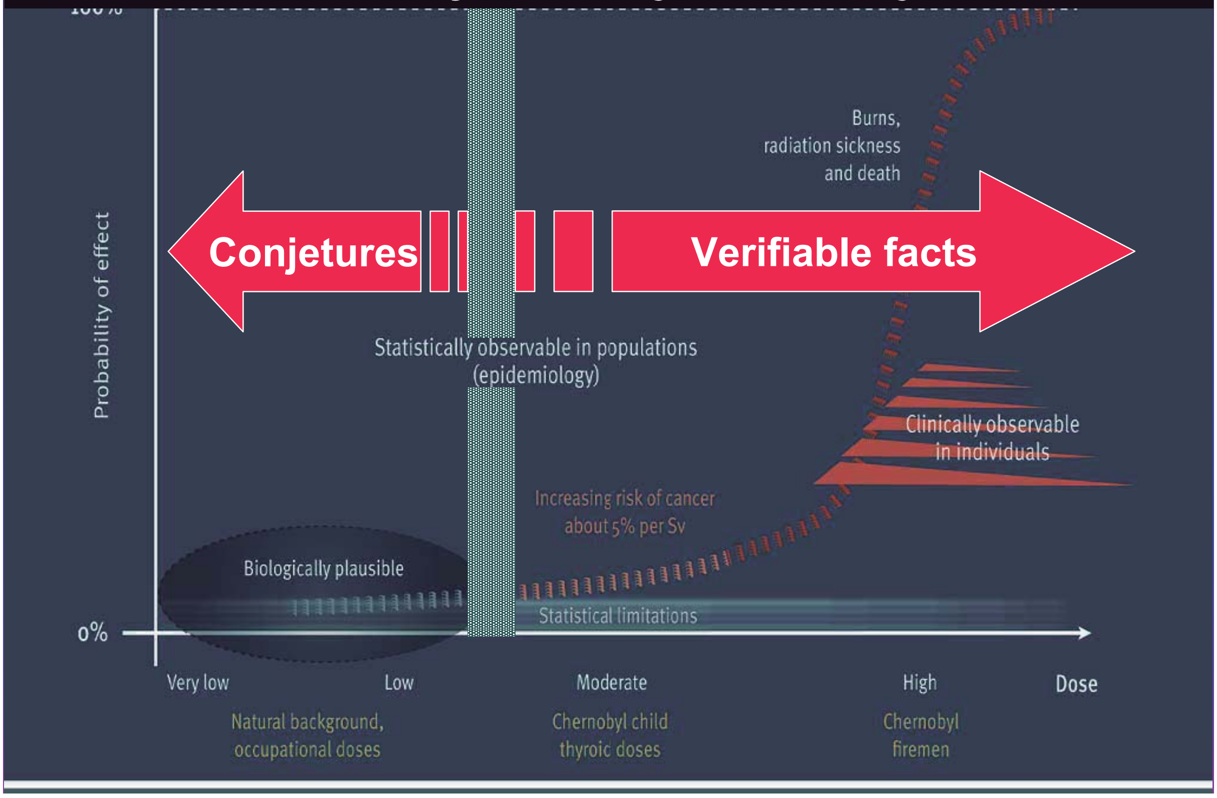
objective verifiable facts

vis-à-vis

subjective conjectures

133

At high doses the effects are verifiable facts, but at low doses they are subjective conjectures



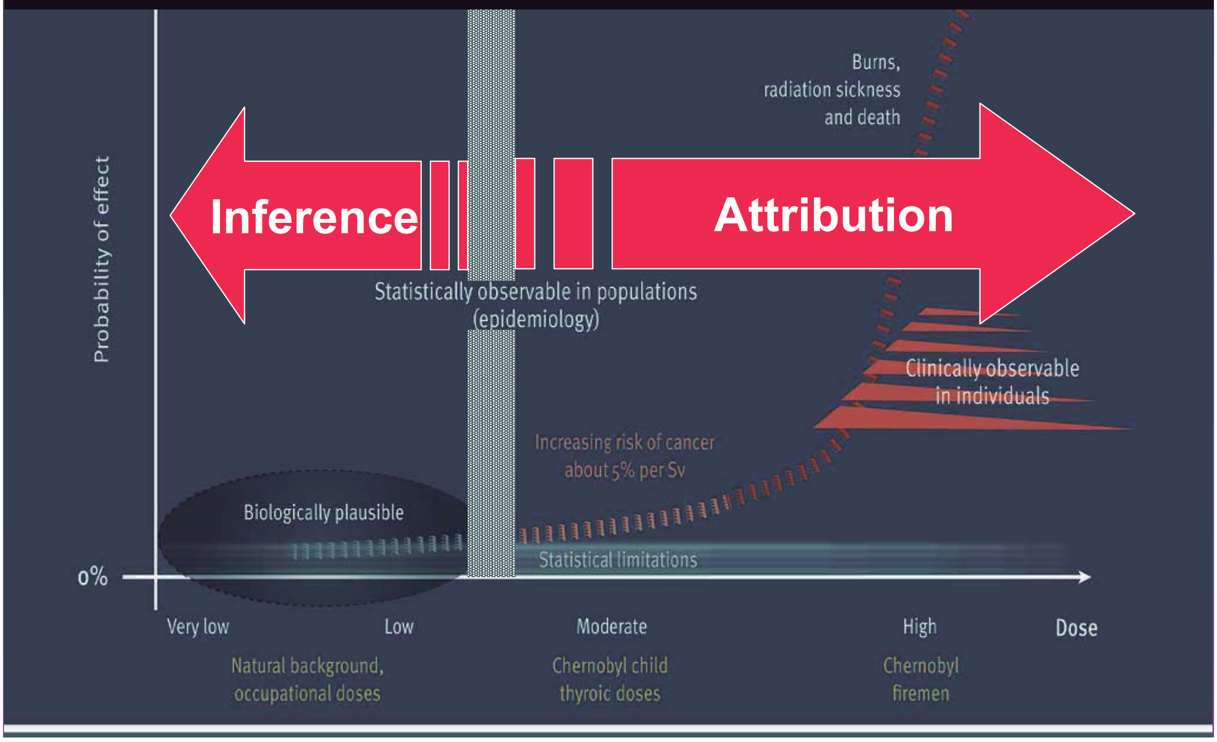
Attribution

vis-à-vis

inference

135

At high doses the effects are *attributable* to the exposure, but at low doses there is just a subjective *inference* of radiation risk



The fundamental issue:

Mathematically:

5%/Sievert = 0.005%/milliSievert

….but….

Epistemiologically:

5%/Sievert ≠ 0.005%/milliSievert

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Individual diagnosis

vis-à-vis

collective estimate

vis-à-vis

subjective extrapolation

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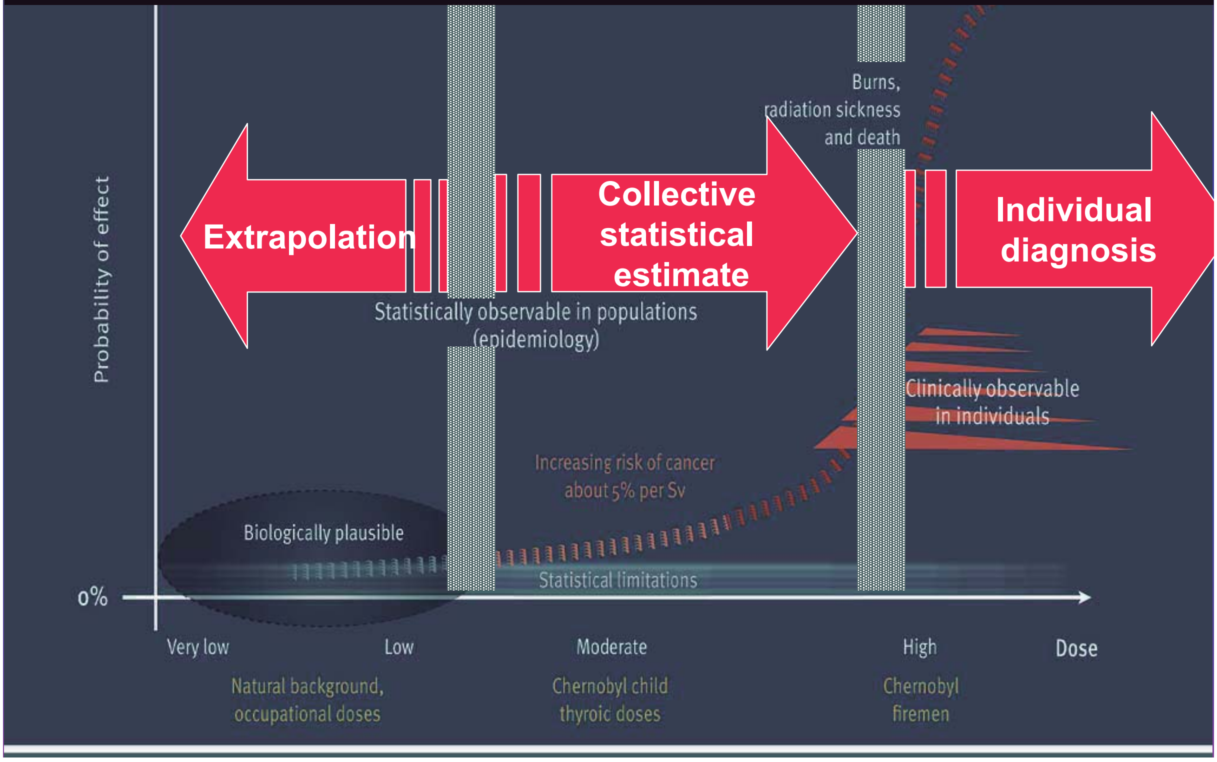
At very high doses the effects are diagnosable in the exposed individual, at moderate doses they can be collectible estimated, at low doses they are just extrapolable



Expert witness

Who are the experts who may attest?:

- Pathologists
- Epidemiologists
- Radioprotectionists

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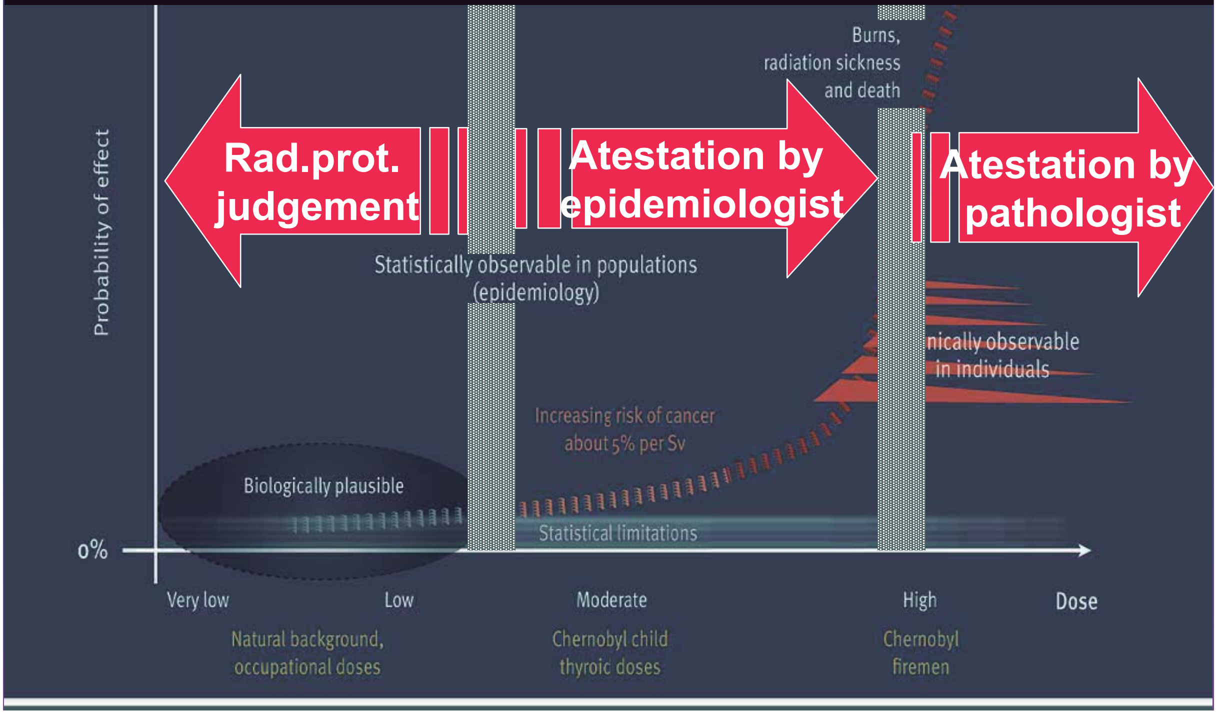
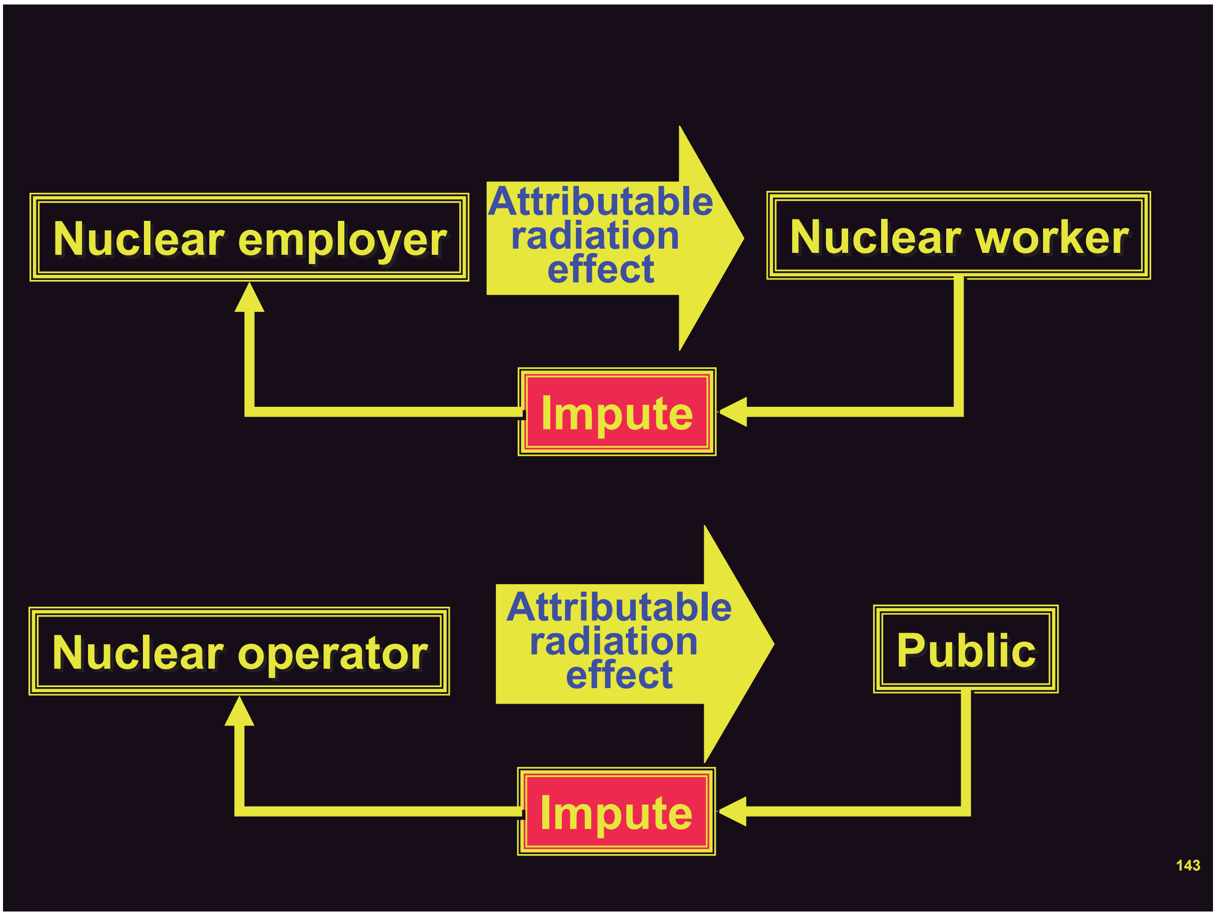
At high doses individual effects can be attested by pathologists, at moderate doses collective effects can be attested by epidemiologists, at low doses risks can not be attested but they can be conjectured by rad.prot.’ judgment



Imputation

Actions based on law for assigning radiation harm to those responsible of radiation exposure situations.

Precursor of the derivative concepts of *charging,suing, indicting, prosecuting* and *judging*



Harm on an individual exposed to high radiation doses

- Individual harm attested by an expert pathologist
- Classic case of imputation……
- ………nothing special!

Harm on a cohort of people exposed to moderate and high doses

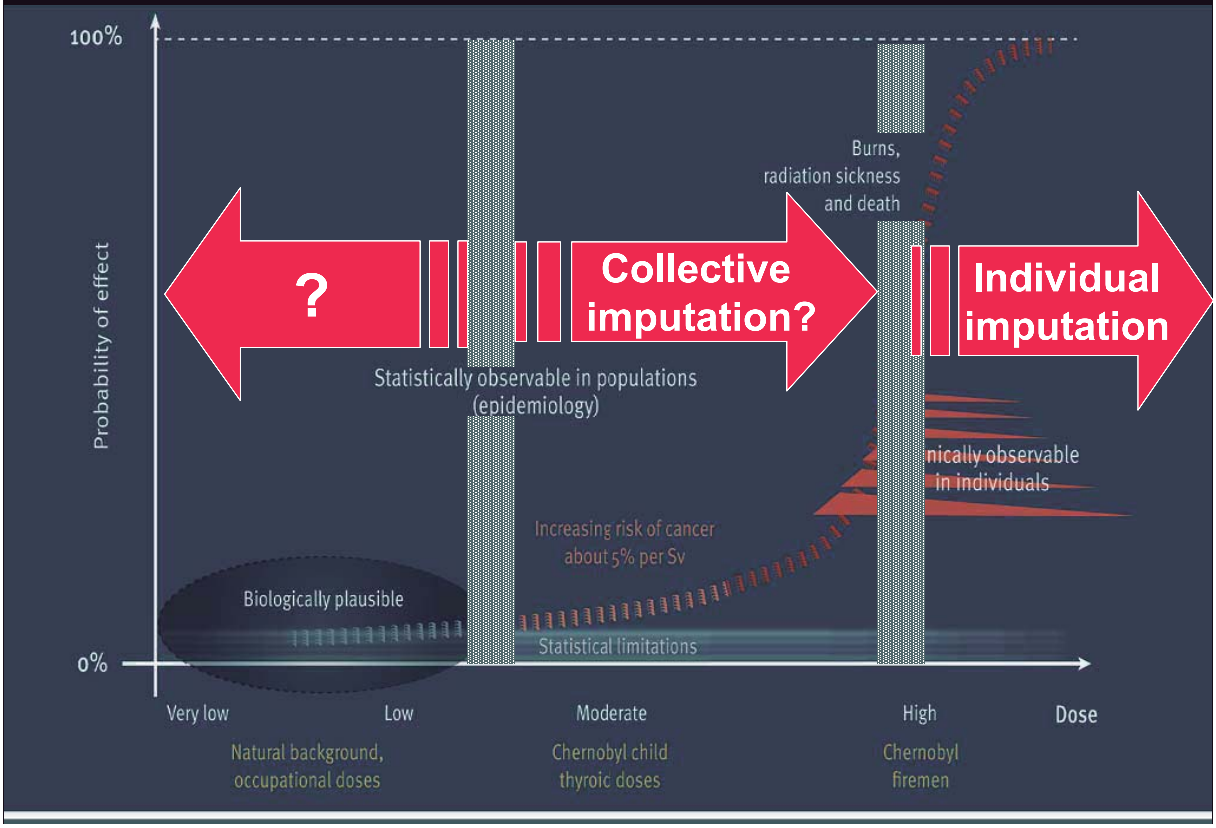
- Harm identified as an **increase in the prevalence of disease** (e.g., cancer) in the cohort, as attested by an **expert epidemiologist.**
- Possible imputation through a *class action*

This is a type of lawsuit where one of the parties is a group of people who are represented collectively by a member of that group. It is relatively common in U.S. Other countries are introducing similar actions (e.g. consumer organizations to bring claims on behalf of consumers)

Harm following low dose exposures: association with radiation can not be attested but conjectural risks could be inferred

?

Imputing



Solving world-wide

the legal conundrum of

imputation of harm following

low-dose radiation exposure situations

is a challenge for you as a new

generation of lawyers!

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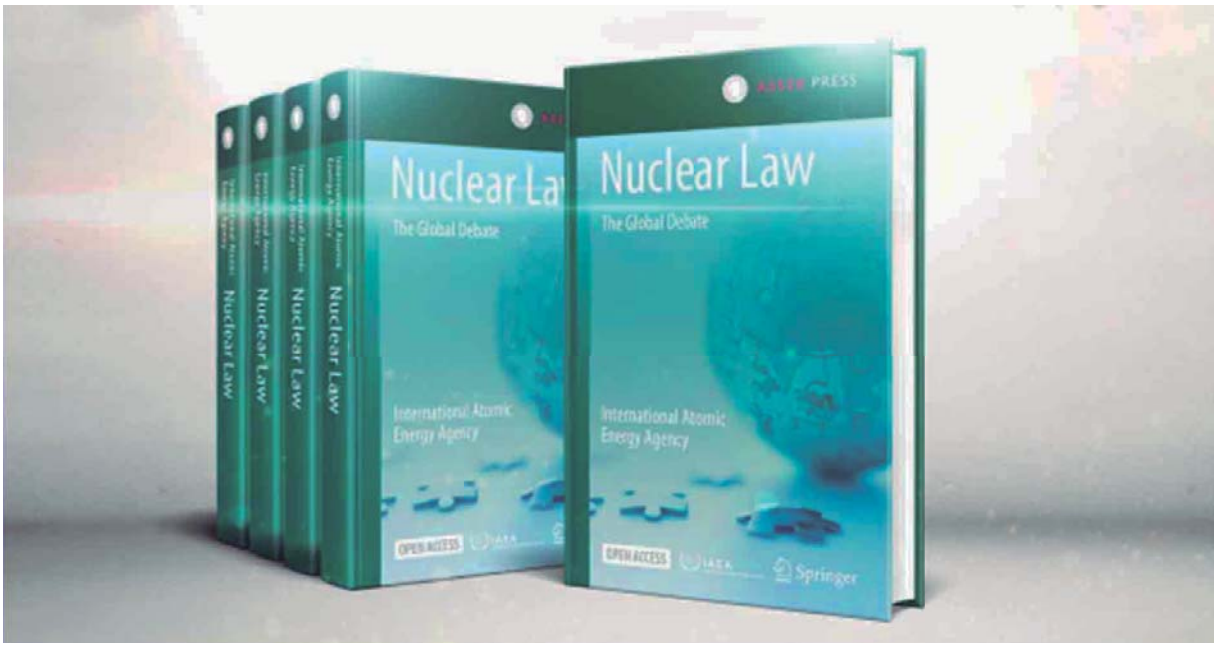

Chapter 7
Legal Imputation of Radiation Harm to Radiation Exposure Situations

Abel Julio González

Epilogue

Potential challenges

150

First challenge:

Solving issues on exposure to natural radiation sources

151

- Is under the 'nuclear law' a worker employed in a working place located in a high background area.
- Is exposure of aircrew under 'nuclear law'?

Nuclear law definition:

Occupational exposure means exposure of workers incurred in the course of their work.

ICRP definition:

…..with the exception of: excluded exposures and exposures from exempt activities or sources; any medical exposure; and the 'normal local' natural background radiation.

- How to solve the cunundrum of regulating consumer goods containg natural radioactive substances?

E.g., should mineral water be under nuclear law?

Second challenge:

Would tritium become a legal issue?

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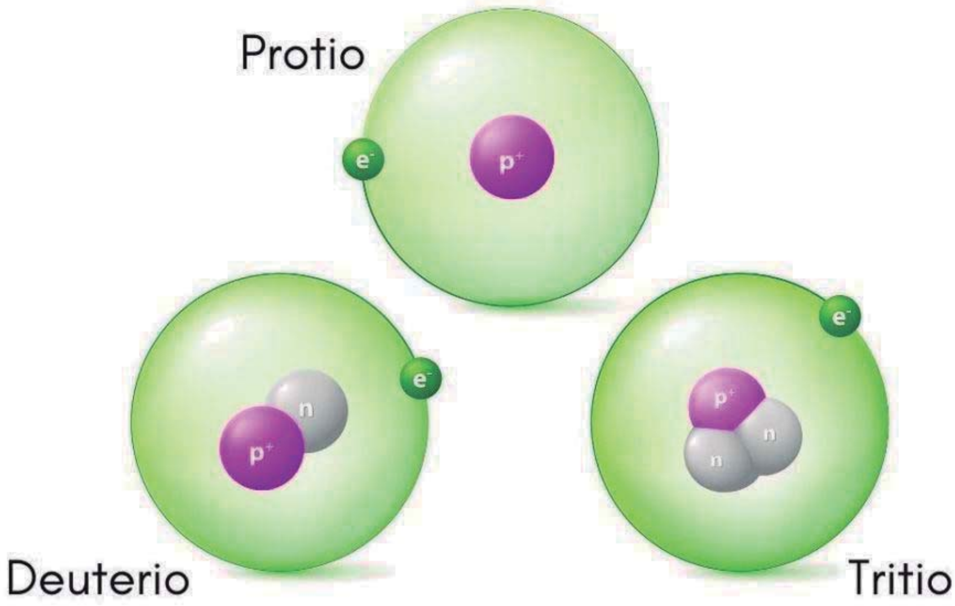
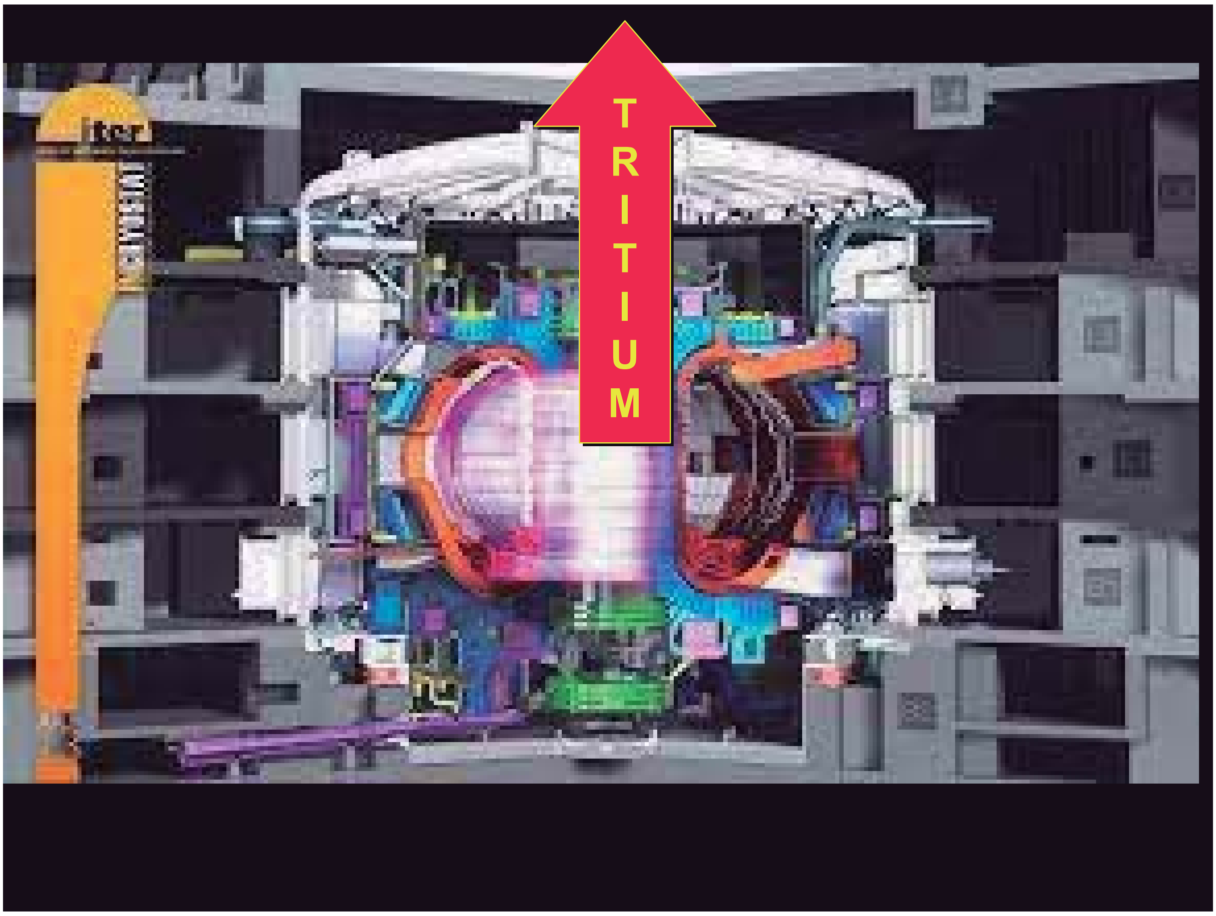
HIDROGEN ISOTOPES

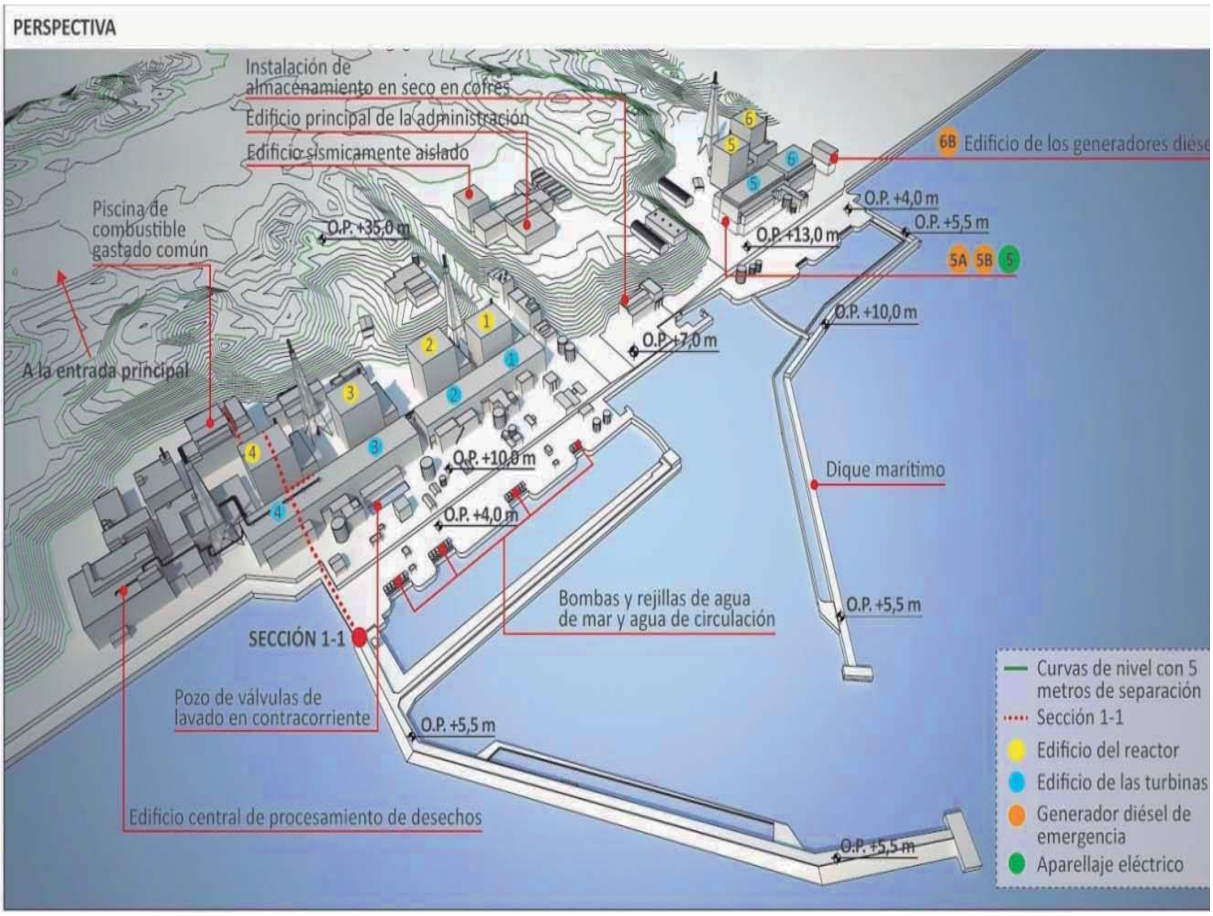


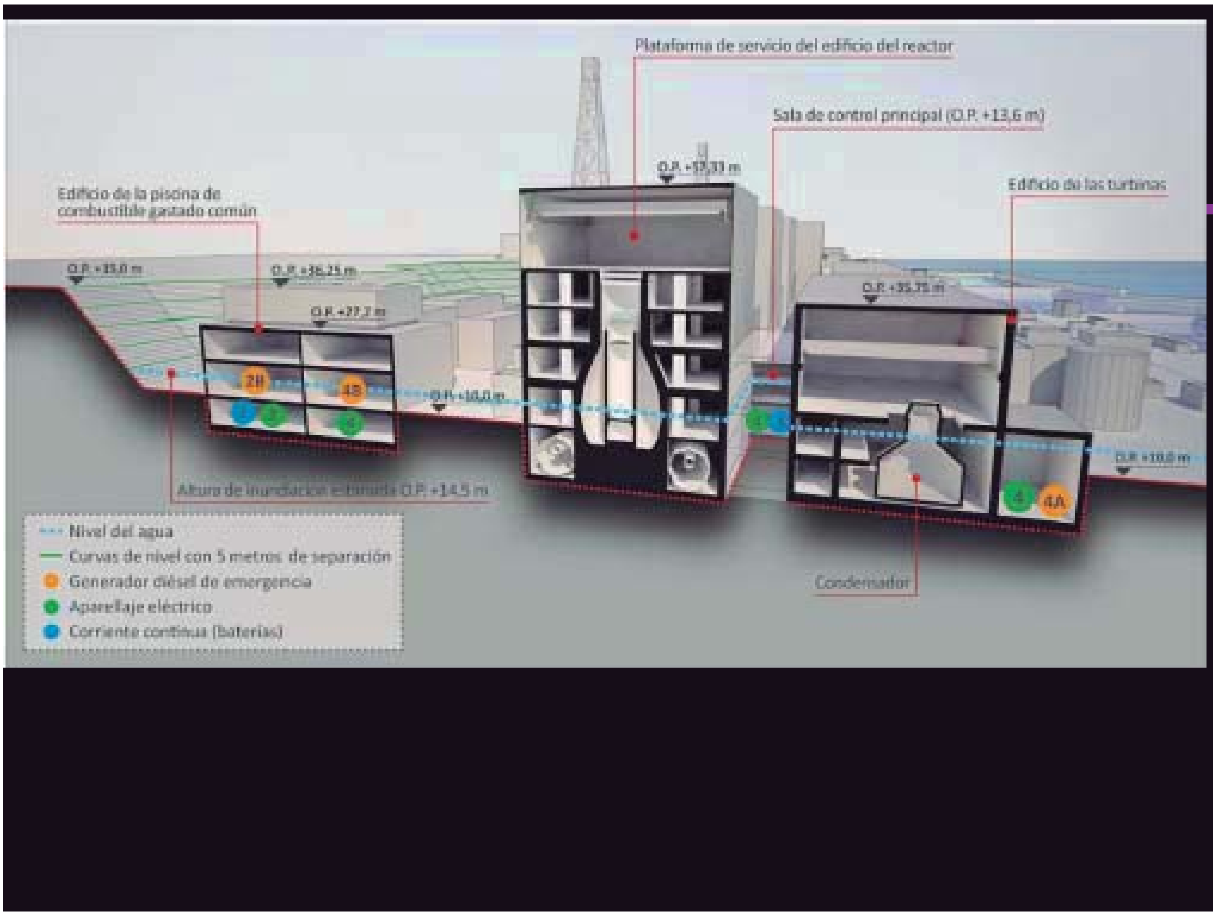
Nuclear Fusion: the European ITER project

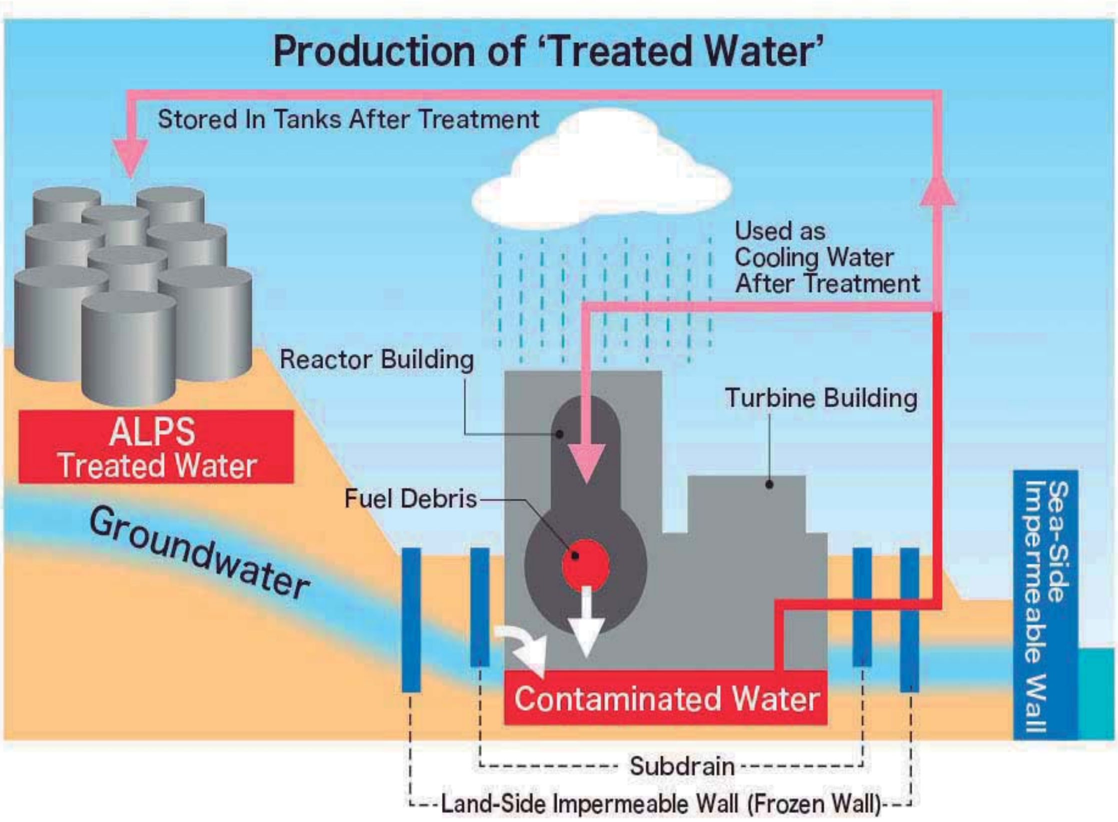


A trigger


Fukushima Dai-ichi NPP
Discharges into the sea of large amounts of water containing tritium
Source: www.tepco.co.jp


PERSPECTIVA
Instalación de almacenamiento en seco en cofres
Edificio principal de la administración
Edificio sísmicamente aislado
Piscina de combustible gastado común
A la entrada principal
O.P. +35,0 m
6B Edificio de los generadores
O.P. +4,0 m
O.P. +5,5 m
O.P. +13,0 m
5A 5B 5
O.P. +10,0 m
O.P. +7,0 m
O.P. +10,0 m
O.P. +4,0 m
Dique marítimo
Bombas y rejillas de agua de mar y agua de circulación
O.P. +5,5 m
SECCIÓN 1-1
Pozo de válvulas de lavado en contracorriente
O.P. +5,5 m
Edificio central de procesamiento de desechos
O.P. +5,5 m
Curvas de nivel con 5 metros de separación
Sección 1-1
Edificio del reactor
Edificio de las turbinas
Generador diésel de emergencia
Aparellaje eléctrico


Plataforma de servicio del edificio del reactor
Sala de control principal (O.P. +13,6 m)
Edificio de la piscina de combustible gastado común
Edificio de las turbinas
Condensador
Nivel del agua
Curvas de nivel con 5 metros de separación
Generador diésel de emergencia
Aparellaje eléctrico
Corriente continua (baterías)


Production of 'Treated Water'
Stored In Tanks After Treatment
Used as Cooling Water After Treatment
Reactor Building
Turbine Building
ALPS Treated Water
Groundwater
Fuel Debris
Contaminated Water
Sea-Side Impermeable Wall
Subdrain
Land-Side Impermeable Wall (Frozen Wall)

Negative reaction

Public & Governments

Evolución del paradigma de protección contra los efectos de la radiación ionizante y la seguridad de fuentes de radiación

González, A.J.

La Carrera de Especialización en Protección Radiológica y Seguridad de las Fuentes de Radiación forma parte de la propuesta académica del Centro de Capacitación Regional, que tiene sede en Buenos Aires, Argentina. La ARN es responsable de su gestión y dicta, junto a la Facultad de Ingeniería de la Universidad de Buenos Aires, esta carrera y la de Seguridad Nuclear. Ambas carreras están acreditadas por la Comisión Nacional de Evaluación y Acreditación Universitaria (CONEAU), organismo argentino que garantiza la calidad de la educación universitaria.

El Acuerdo a Largo Plazo firmado en 2008 entre la República Argentina y el Organismo Internacional de Energía Atómica (OIEA), declaró a Argentina como sede y a la ARN como responsable de la gestión del Centro de Capacitación Regional.

Clase dictada en el Seminario de Clausura de la Carrera de Especialización en Protección Radiológica y Seguridad de las Fuentes de Radiación, dictado en conjunto por la ARN y la Universidad de Buenos Aires. Argentina, 26 de agosto de 2022.

Carrera de Especialización en Protección Radiológica y Seguridad de Fuentes de Radiación

Universidad de Buenos Aires - Autoridad Regulatoria Nuclear - Organismo Internacional de Energía Atómica

SEMINARIO DE CLAUSURA

Virtual (Plataforma LANENT) 26 de agostp de 2021 entre las 14:30 y las 16:30

Evolución del paradigma de protección contra los efectos de la radiación ionizante y la seguridad de fuentes de radiación

Abel J. González

Autoridad Regulatoria Nuclear

Academias: de Ciencias de Bs.As, del Mar, y del Ambiente

Representante ante el United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

Miembro de la Commission of Safety Standards del OIEA

Ex-Vice-Presidente de la International Commission on Radiological Protection (ICRP)

Autoridad Regulatoria Nuclear;✉Av. Del Libertador 8250;(1429)Buenos Aires,Argentina☎+54 1163231306;

Introducción

El paradigma de protección contra los efectos de la radiación ionizante y la seguridad de fuentes de radiación

El paradigma ha sido

- establecido bajo la égida del *Organismo Internacional de Energía Atómica* (OIEA), y es
- copatrocinado por todas las organizaciones relevantes del sistema de las Naciones Unidas,
- sobre las bases científicas provistas por el *Comité Científico de las Naciones Unidas sobre los Efectos de la Radiación Atómica* (UNSCEAR) y
- siguiendo recomendaciones de la *Comisión Internacional de Protección Radiológica* (ICRP),

¡El paradigma es excepcional en su amplitud y reconocimiento universal e intergubernamental!

Está:

- fundado en doctrinas éticas universales
- basado en sólidas bases científicas, y

es:

- excepcionalmente completo, y
- reconocido internacionalmente.

Por lo tanto,

- Los invito a que ayuden a ¡PRESERVARLO!
- ¡Evitando su distorsión o abandono!

No obstante,
¡el paradigma debe actualizarse!

Deberá mantenerse al corriente con (por ejemolo):

- **Los últimos consensos científicos sobre la epistemología de los efectos de la radiación.**
- **Las nuevas demandas sociales contemporáneas sobre protección y seguridad.**

Dicha actualización también permitirá la incorporación de muchas lecciones sobre la aplicación del paradigma aprendidas e informadas en los últimos años

(por ejemplo, ¡de Fukushima!).

Lecciones de Fukushima

(¡2013!)

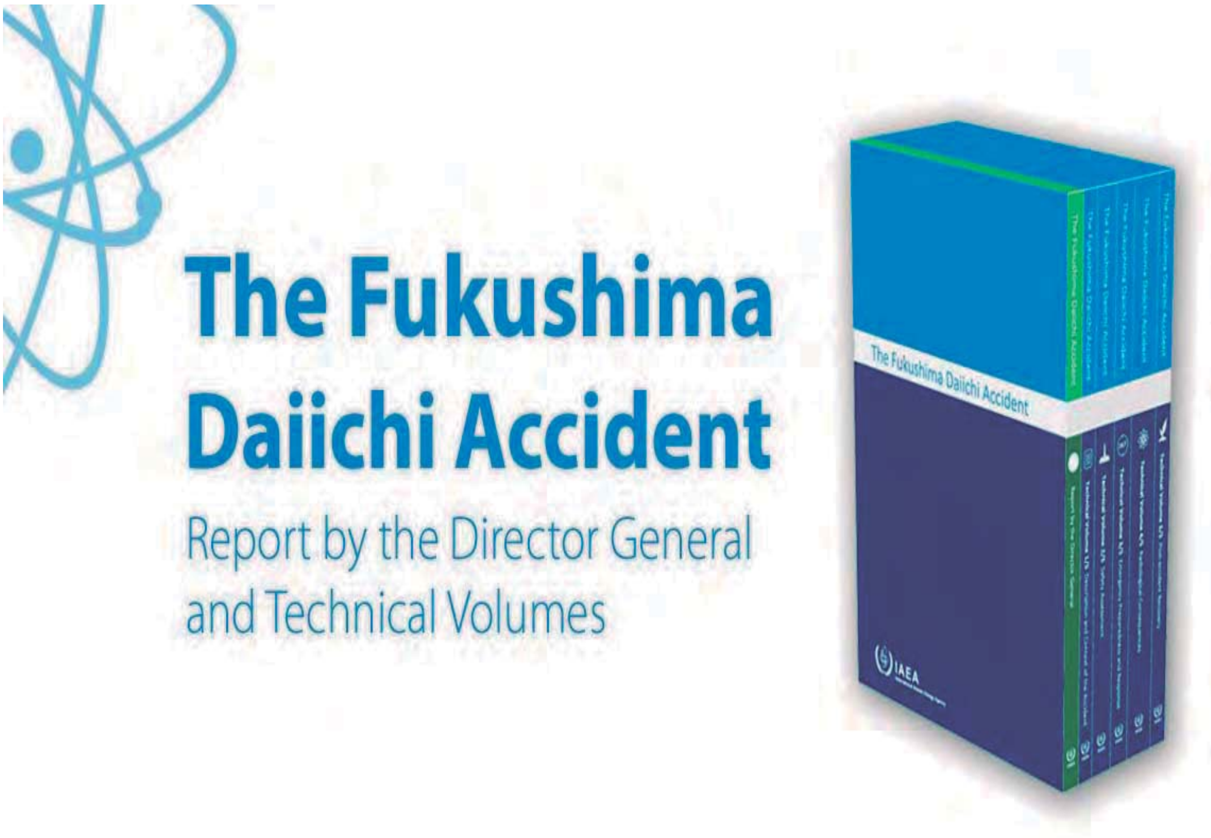
IOP PUBLISHING — JOURNAL OF RADIOLOGICAL PROTECTION

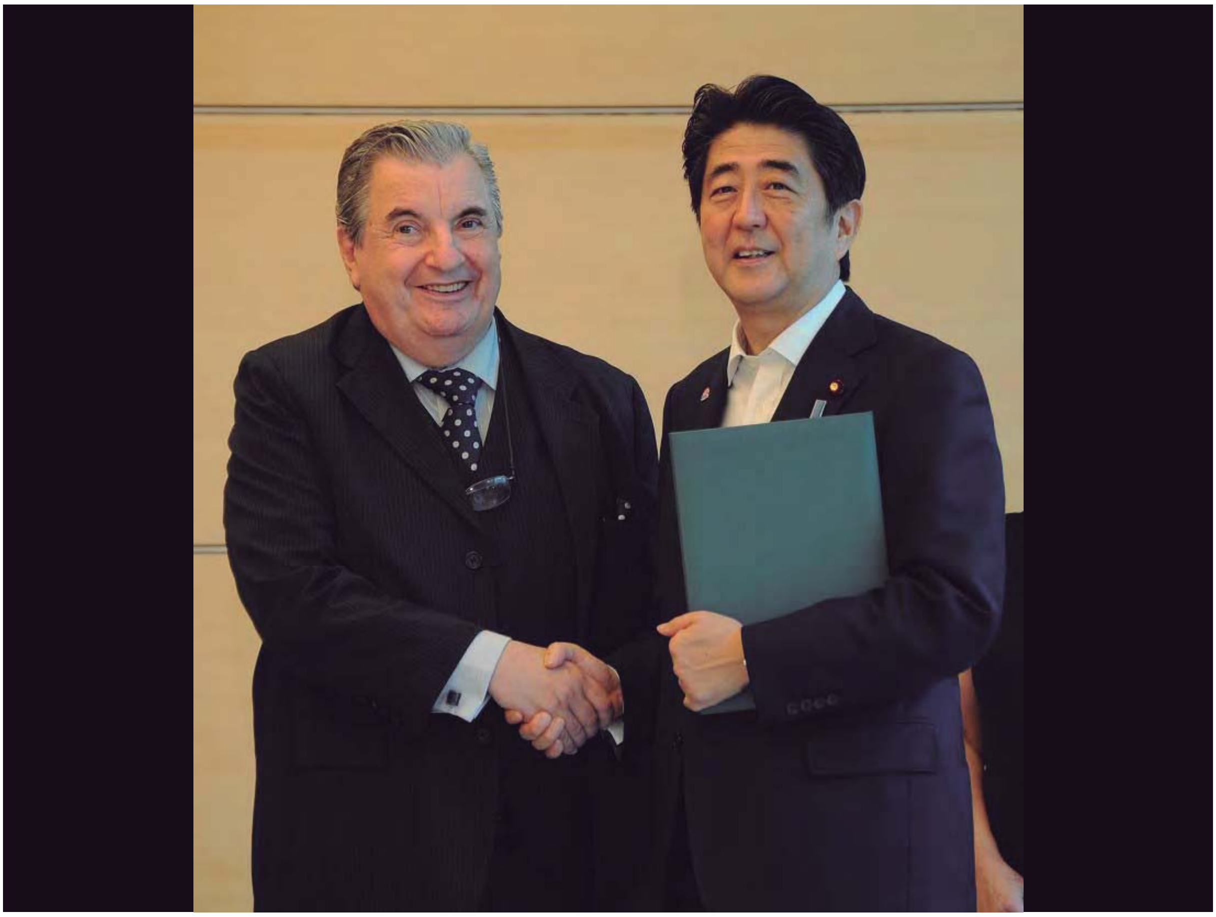
J. Radiol. Prot. 33 (2013) 497–571 — doi:10.1088/0952-4746/33/3/497

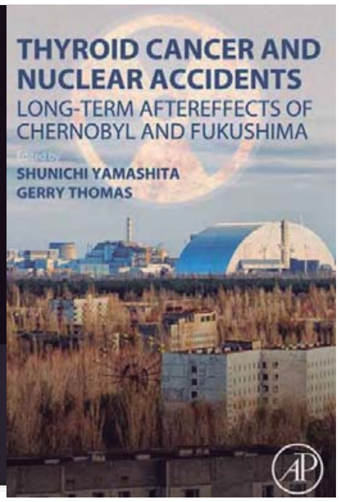
MEMORANDUM

Radiological protection issues arising during and after the Fukushima nuclear reactor accident

Abel J González[1], Makoto Akashi[2], John D Boice Jr[3], Masamichi Chino[4], Toshimitsu Homma[4], Nobuhito Ishigure[5], Michiaki Kai[6], Shizuyo Kusumi[7], Jai-Ki Lee[8], Hans-Georg Menzel[9], Ohtsura Niwa[10], Kazuo Sakai[2], Wolfgang Weiss[11], Shunichi Yamashita[10,12] and Yoshiharu Yonekura[2,13]


The Fukushima
Daiichi Accident
Report by the Director General
and Technical Volumes
The Fukushima Daiichi Accident
IAEA





CHAPTER 4

Reassessing the Capability to Attribute Pediatric Thyroid Cancer to Radiation Exposure: The FHMS Experience

Abel J. González
Argentine Nuclear Regulatory Authority, Buenos Aires, Argentina

Dentro de estas limitaciones, les voy a sugerir 10 posibles temas para pensar en la actualización del paradigma

(No están en ningún orden preestablecido)

Tema 1:

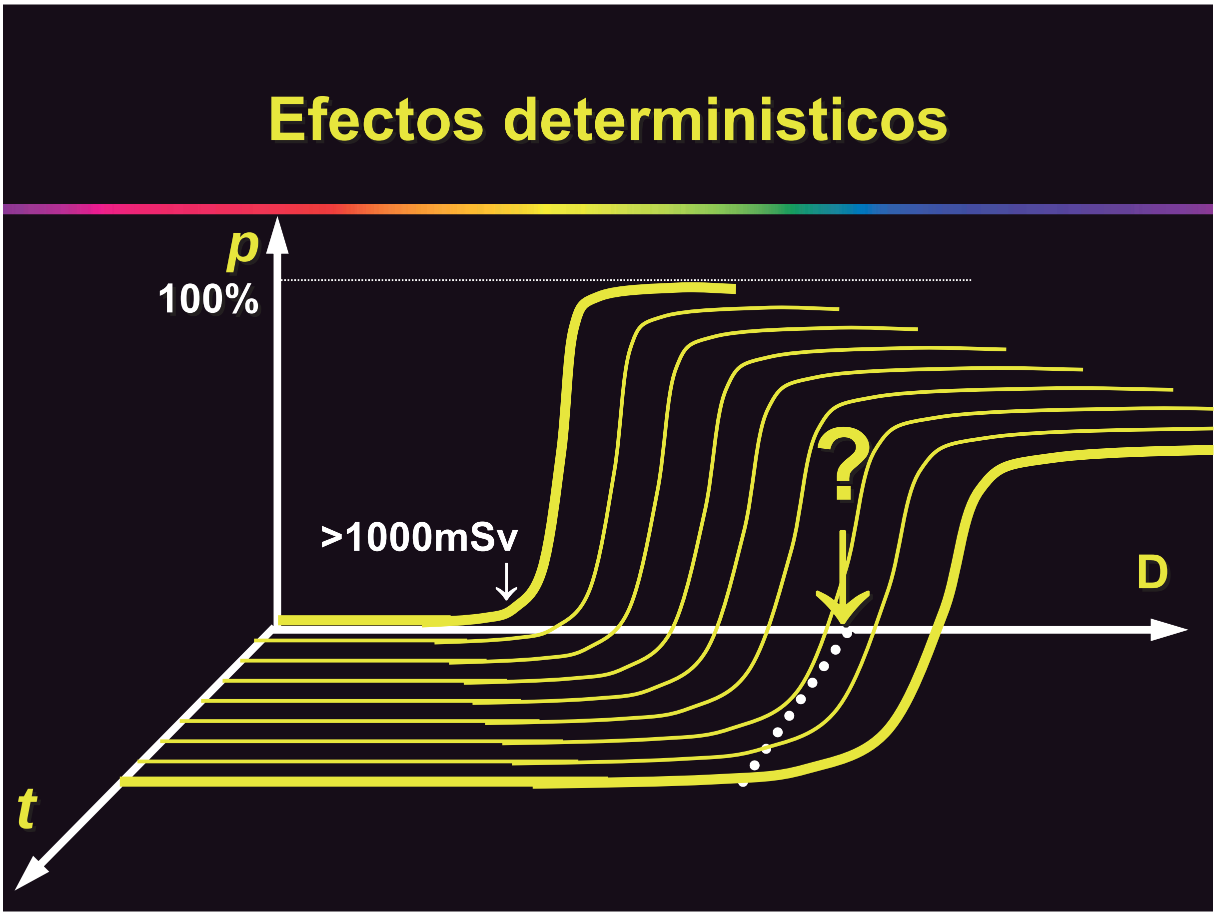
Novedades epistemológicas

Hechos *vis-à-vis* conjeturas en las ciencias de los efectos de la exposición a la radiación ionizante.

Primera conjetura:

Efectos deterministicos

Comportamiento con dosis prolongadas



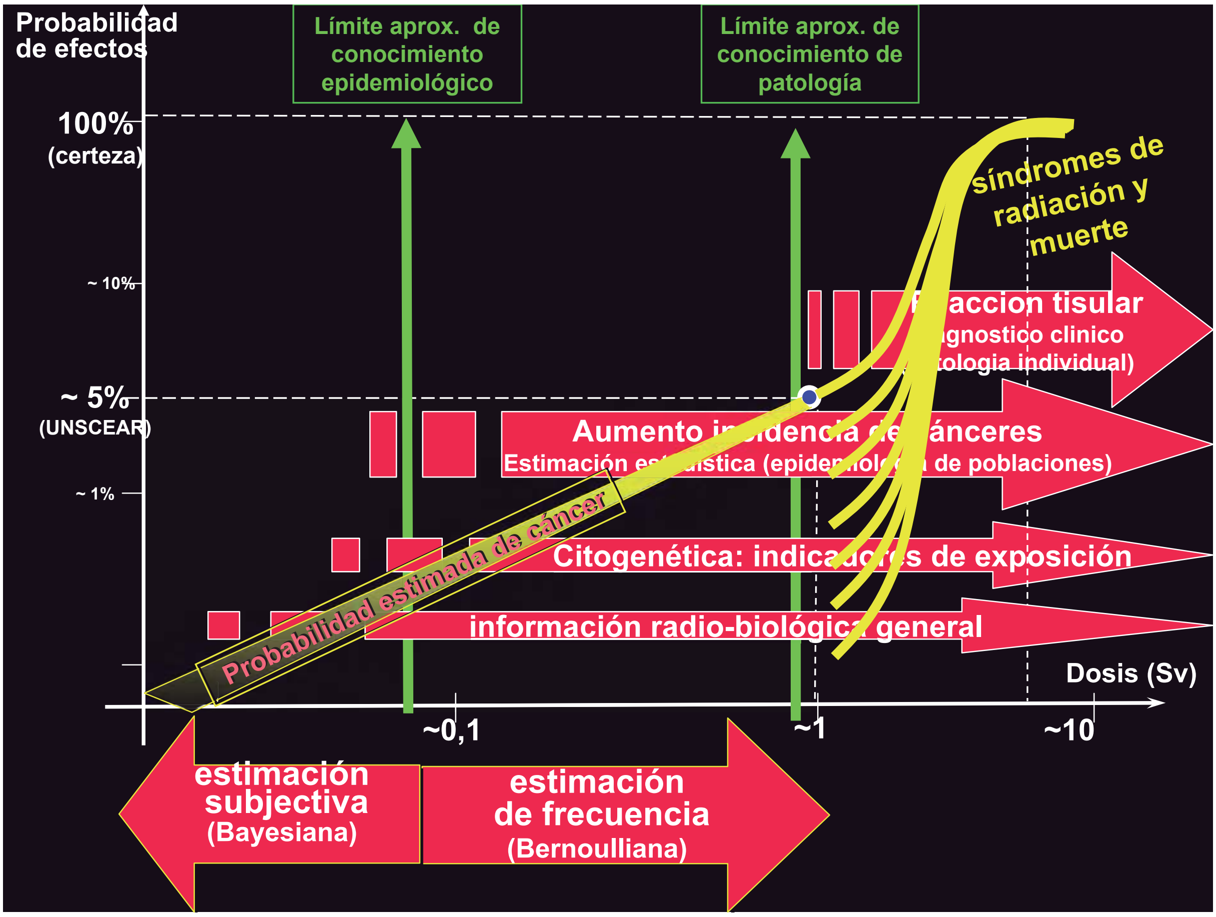
Segunda conjetura:

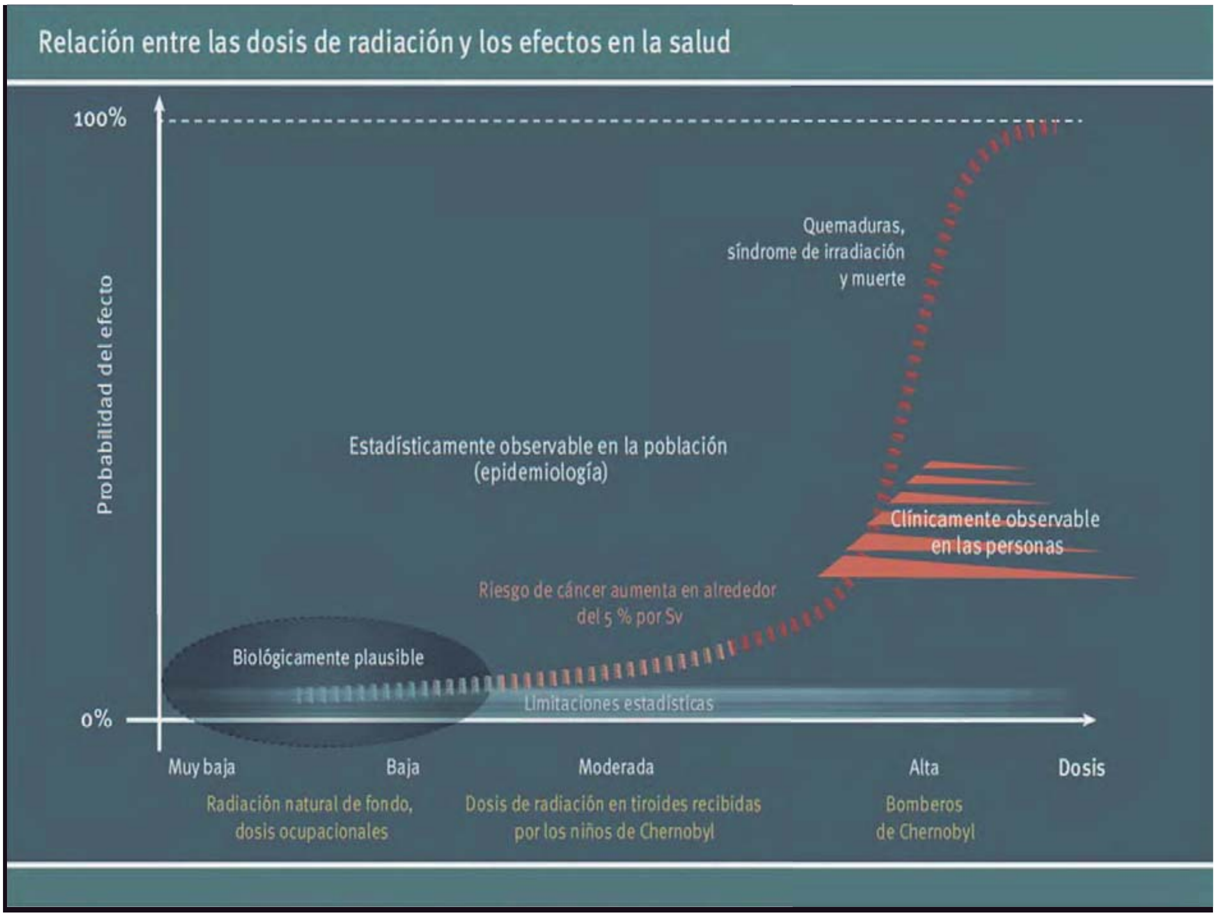
La relación dosis respuesta para

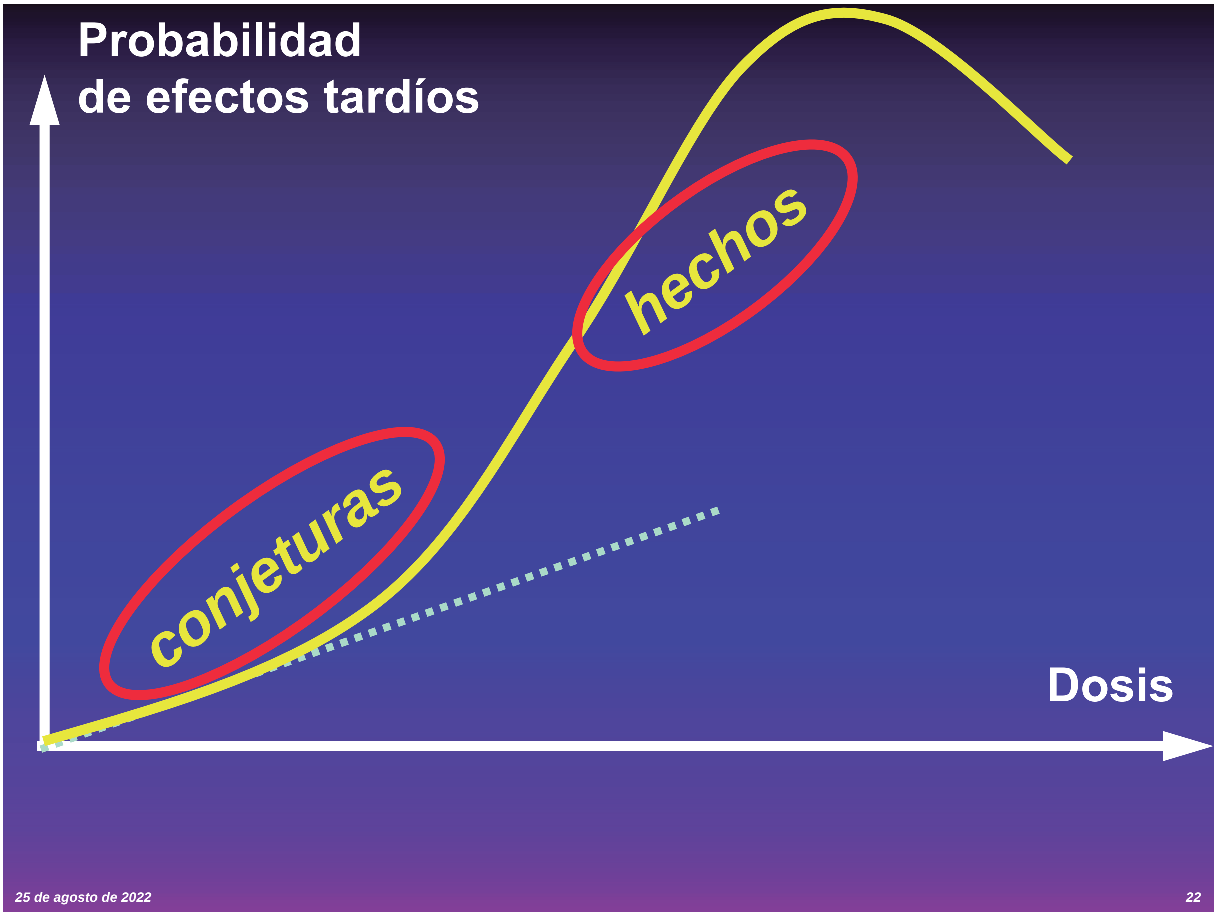
efectos estocásticos

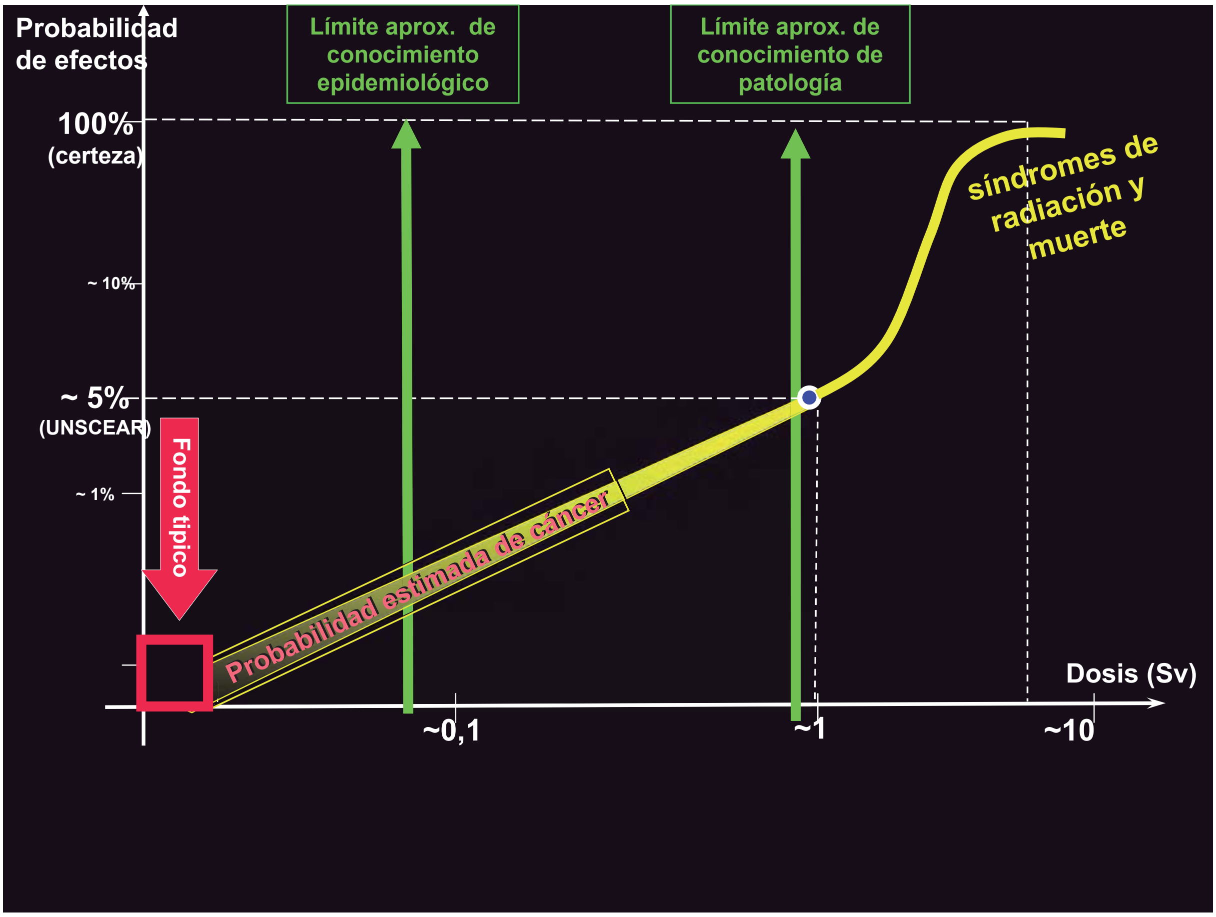
Relación dosis-respuesta

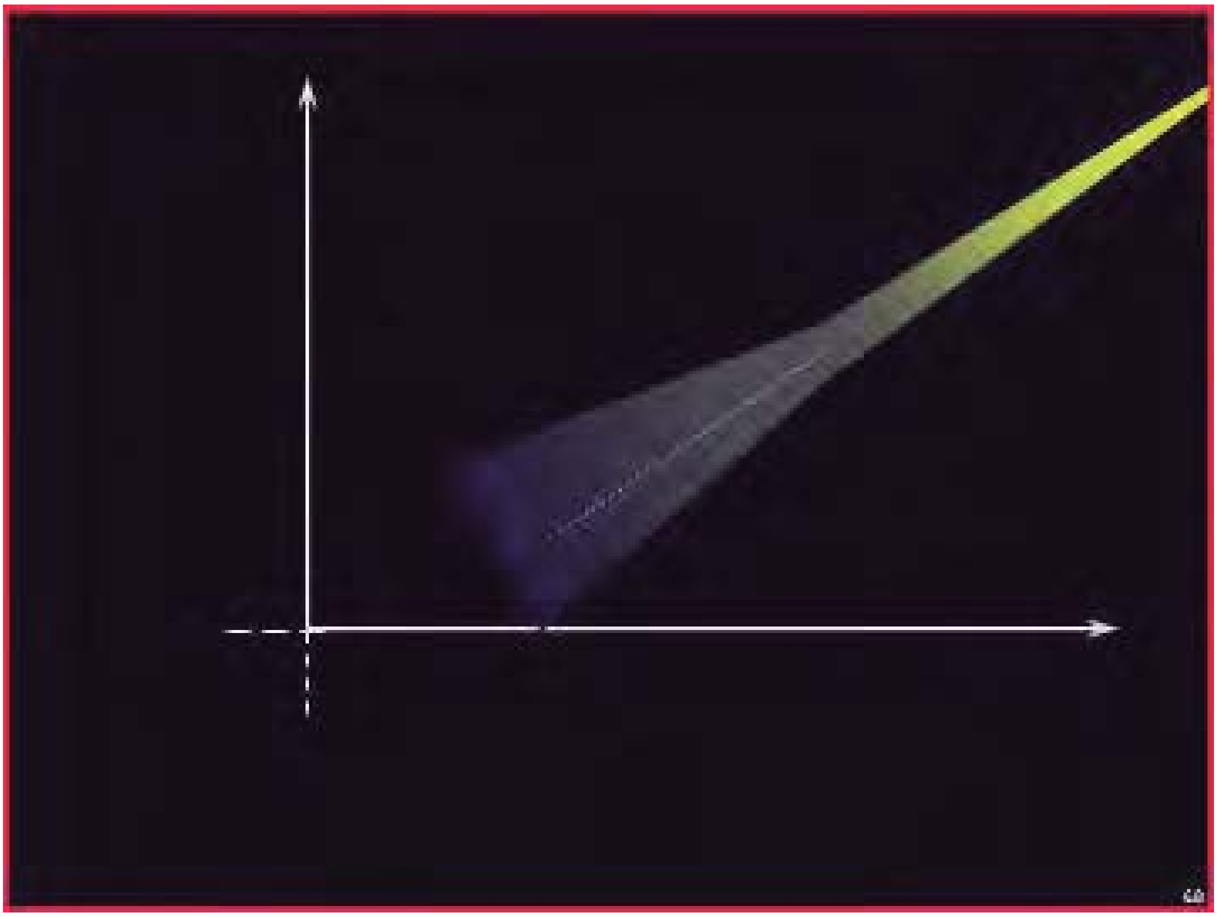
19

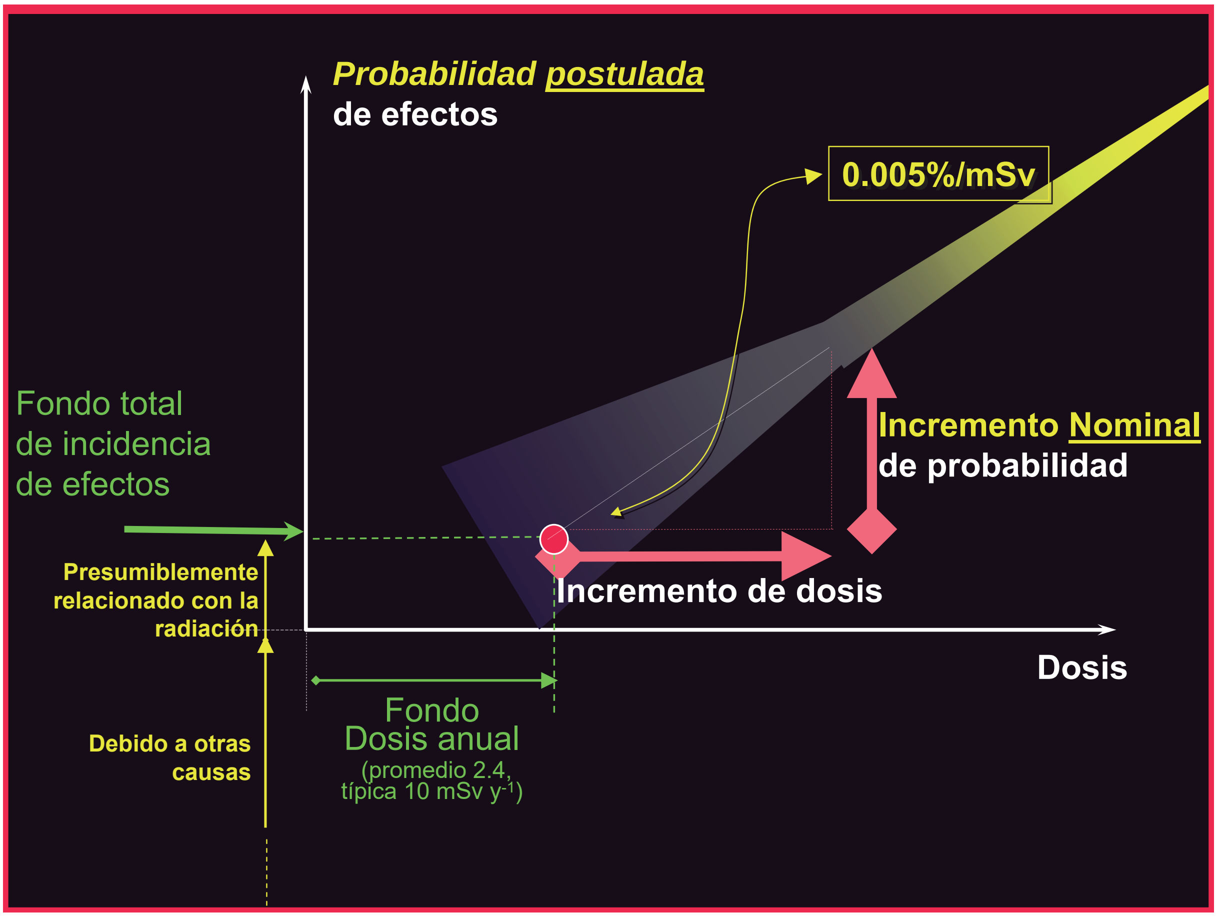



Relación entre las dosis de radiación y los efectos en la salud
100%
0%
Probabilidad del efecto
Quemaduras,
síndrome de irradiación
y muerte
Estadísticamente observable en la población
(epidemiología)
Clínicamente observable
en las personas
Riesgo de cáncer aumenta en alrededor
del 5 % por Sv
Biológicamente plausible
Limitaciones estadísticas
Muy baja
Baja
Moderada
Alta
Dosis
Radiación natural de fondo,
dosis ocupacionales
Dosis de radiación en tiroides recibidas
por los niños de Chernobyl
Bomberos
de Chernobyl


Probabilidad
de efectos tardíos
hechos
conjeturas
Dosis
25 de agosto de 2022
22


Probabilidad
de efectos
Límite aprox. de
conocimiento
epidemiológico
Límite aprox. de
conocimiento de
patología
100%
(certeza)
~ 10%
~ 5%
(UNSCEAR)
~ 1%
Fondo típico
síndromes de
radiación y
muerte
Probabilidad estimada de cáncer
Dosis (Sv)
~0,1
~1
~10





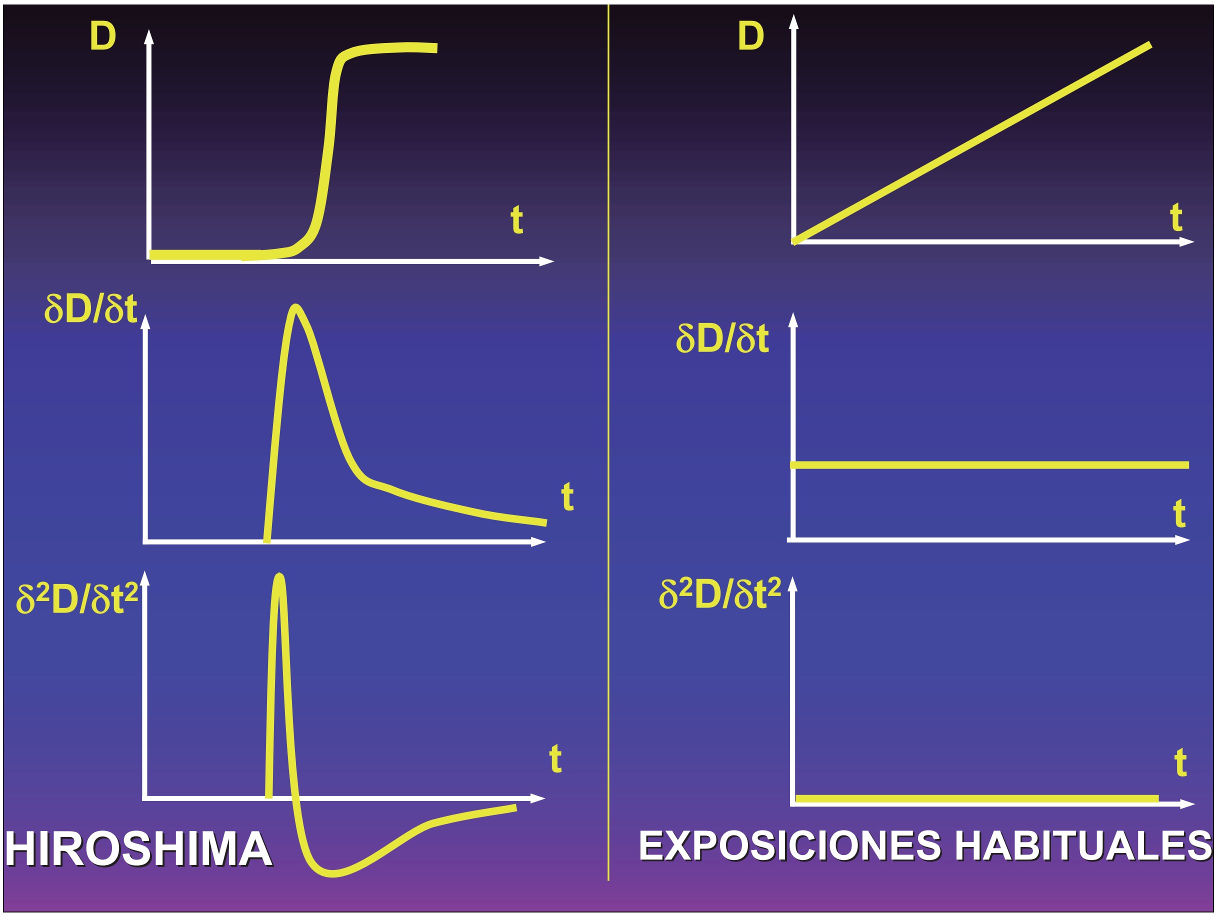
Tercera conjetura:

Influencia de la tasa de dosis (primera derivada de la dosis) y del cambio en la tasa de dosis (segunda derivada de la dosis)

26

Si la dinamica de la respuesta celular a la radiation variara con los cambios temporales de la dosis

... debería la $\delta D/\delta t$ ó la $\delta D^2/\delta t^2$ influenciar el riesgo, $\Delta p/\Delta D$?



RADIATION RESEARCH 173, 283–289 (2010)
0033-7587/10 $15.00
© 2010 by Radiation Research Society.
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DOI: 10.1667/RR2012.1

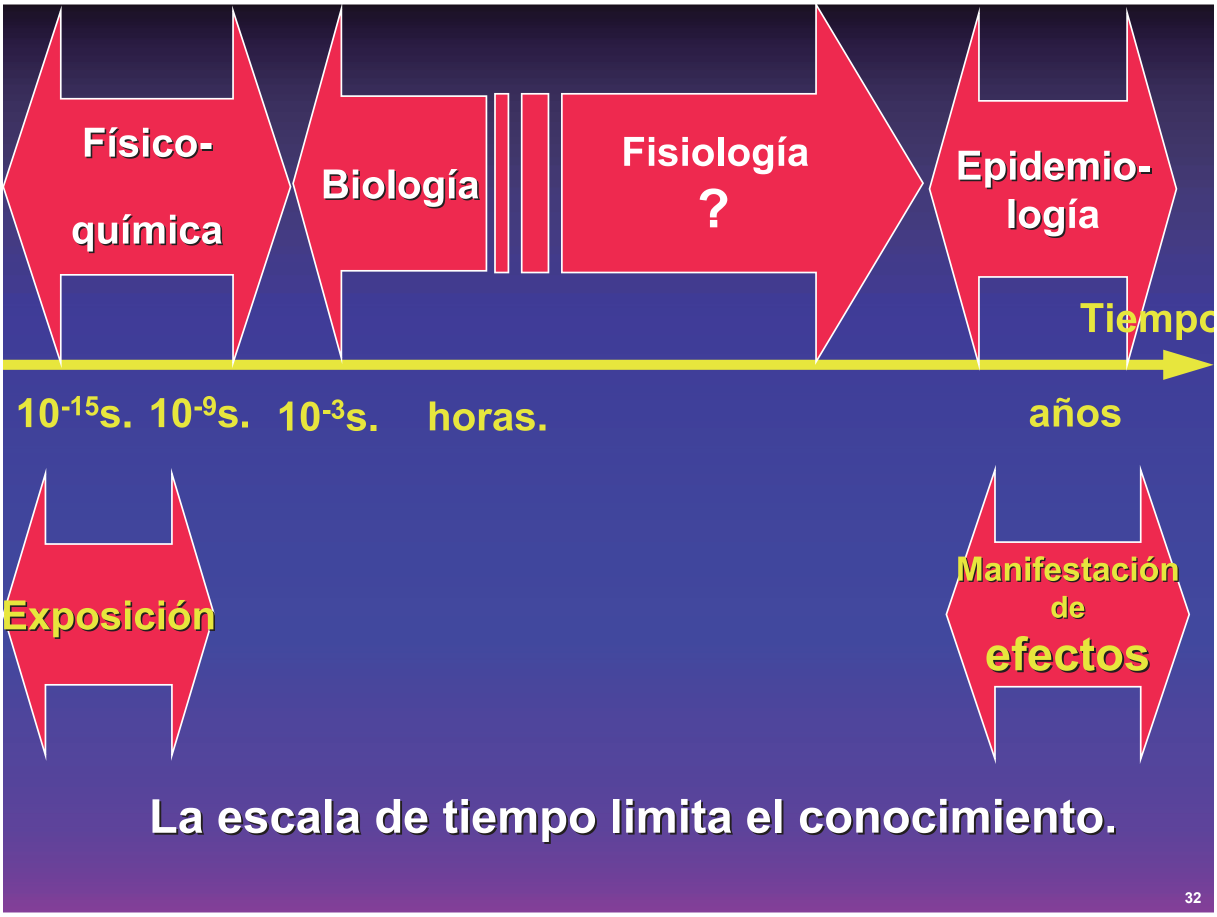
Cytogenetic Damage in Cells Exposed to Ionizing Radiation under Conditions of a Changing Dose Rate

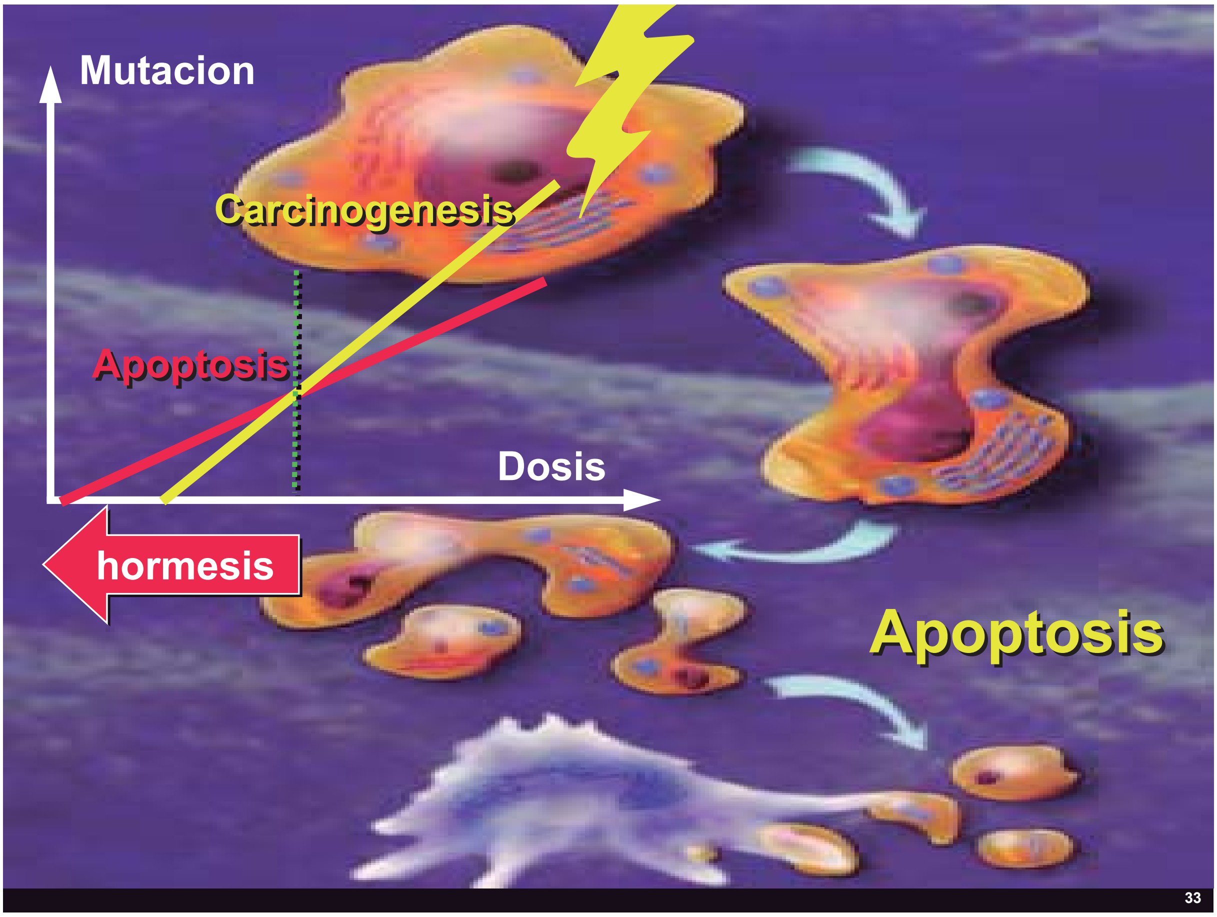
Karl Brehwens,[a] Elina Staaf,[a] Siamak Haghdoost,[a] Abel J. González[b] and Andrzej Wojcik[a,c,1]

[a] *Centre for Radiation Protection Research, GMT Department, Stockholm University, 106 91 Stockholm, Sweden;* [b] *Argentine Nuclear Regulatory Authority, Buenos Aires, Argentina; and* [c] *Department of Radiobiology and Immunology, Institute of Biology, Jan Kochanowski University, 25-406 Kielce, Poland*

Cuarta conjetura:
posible influencia en el riesgo de daños fuera del blanco y otros fenómenos

31




Mutacion
Carcinogenesis
Apoptosis
Dosis
hormesis
Apoptosis
33

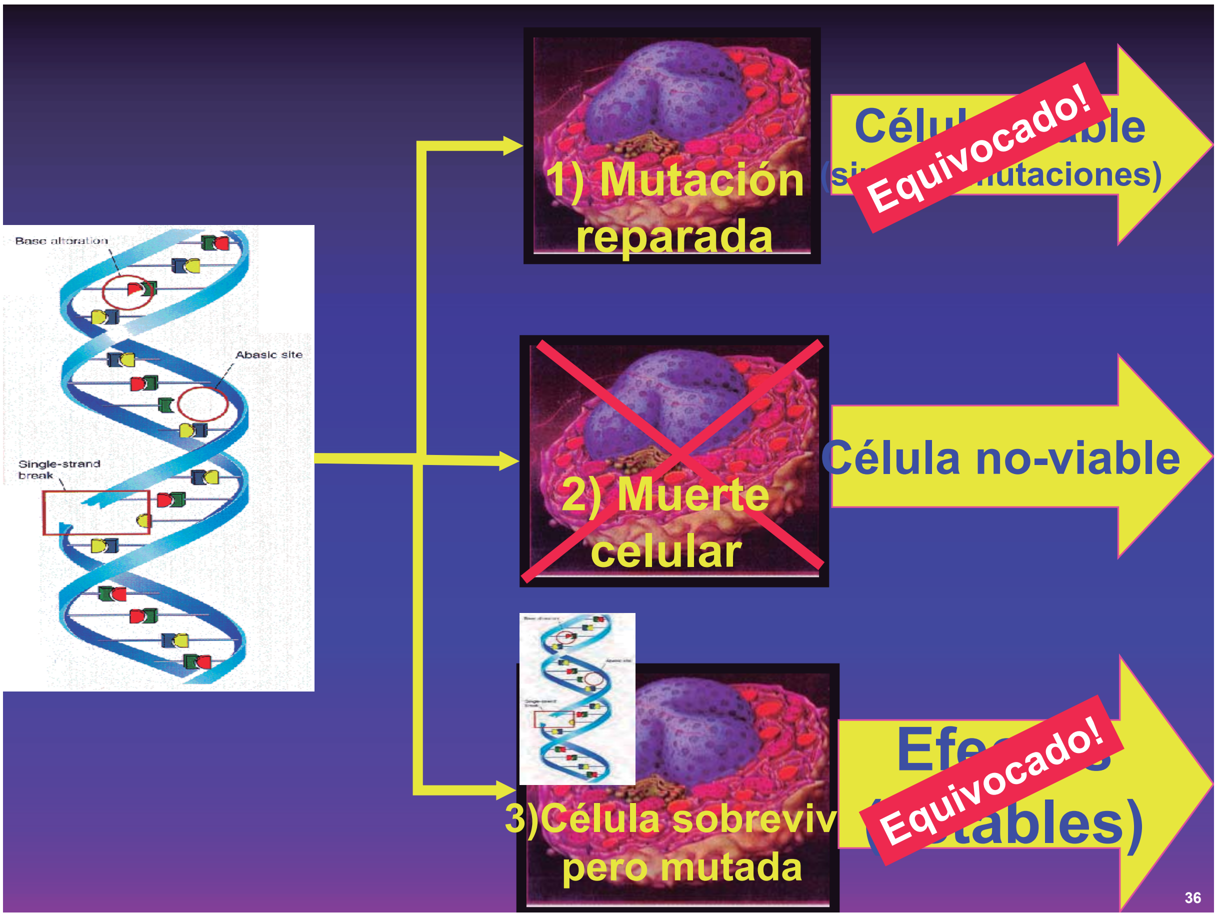

RESPUESTA ADAPTIVA
Mutación
Mutación
Mutación
34

Inestabilidad Genómica …

… o … adquisición incremental de

alteraciones en el genoma.

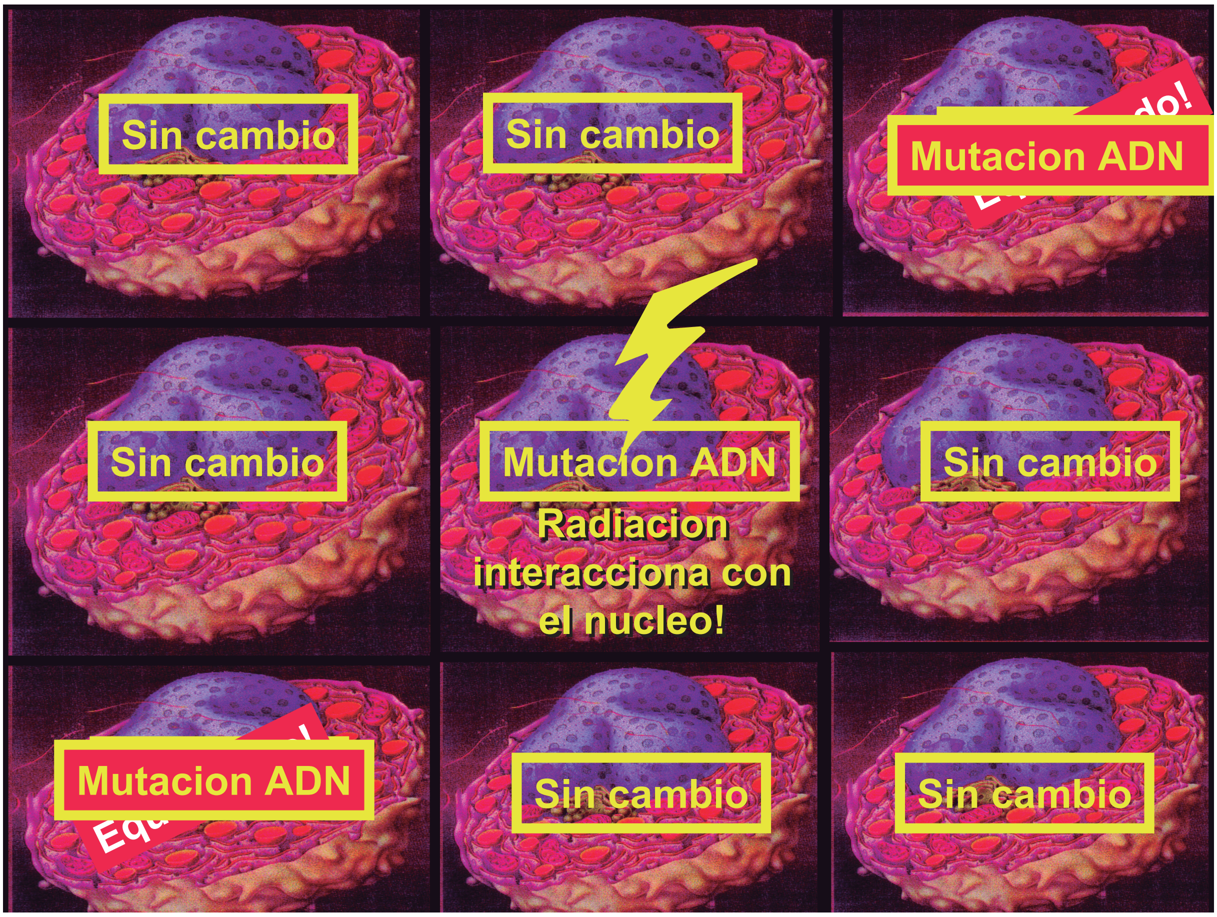
35



Efecto 'vecindad' (bystander)

- Habilidad de células afectadas por la radiación para transmitir manifestaciones de daño a otras células que no habían sido afectadas por la radiación.

37



Efectos Abscopales

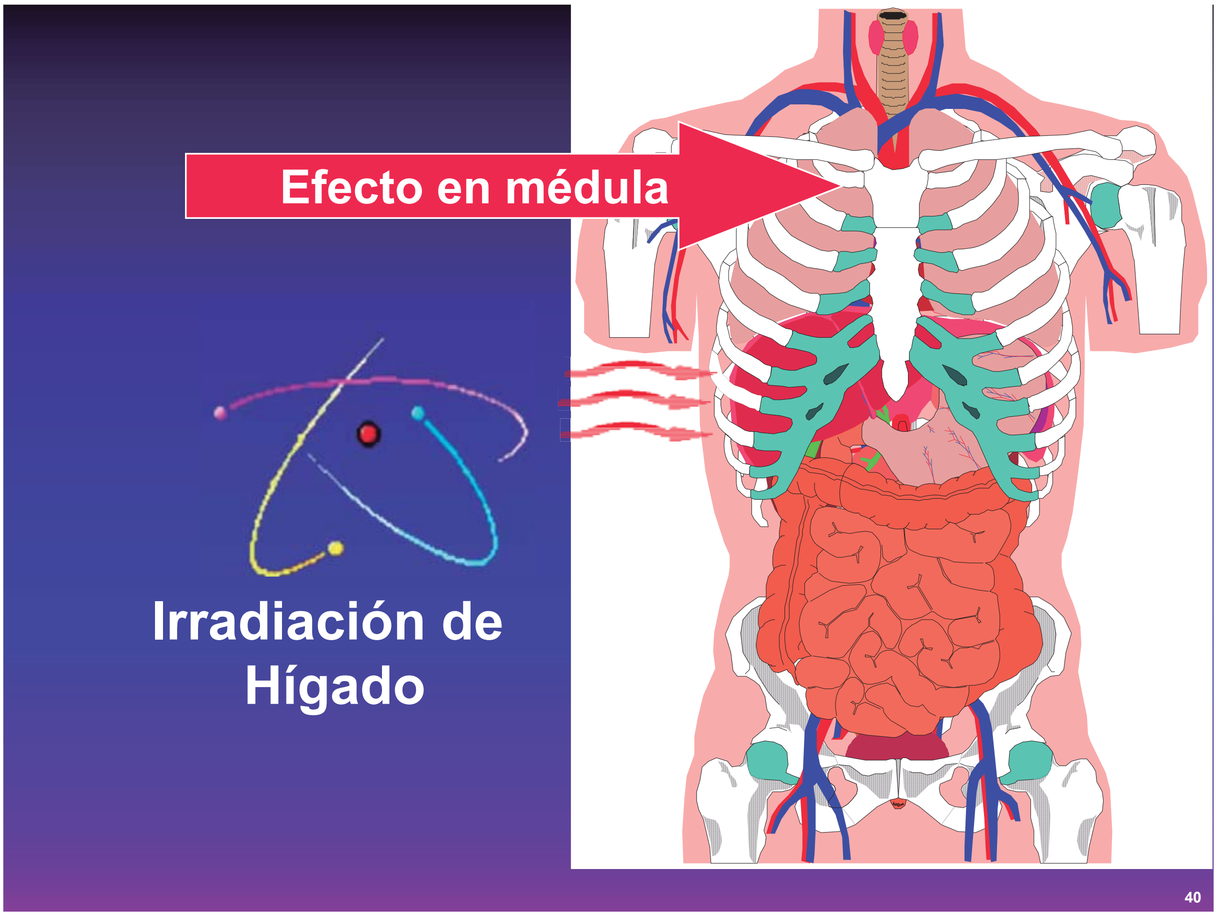
Respuesta a la radiación

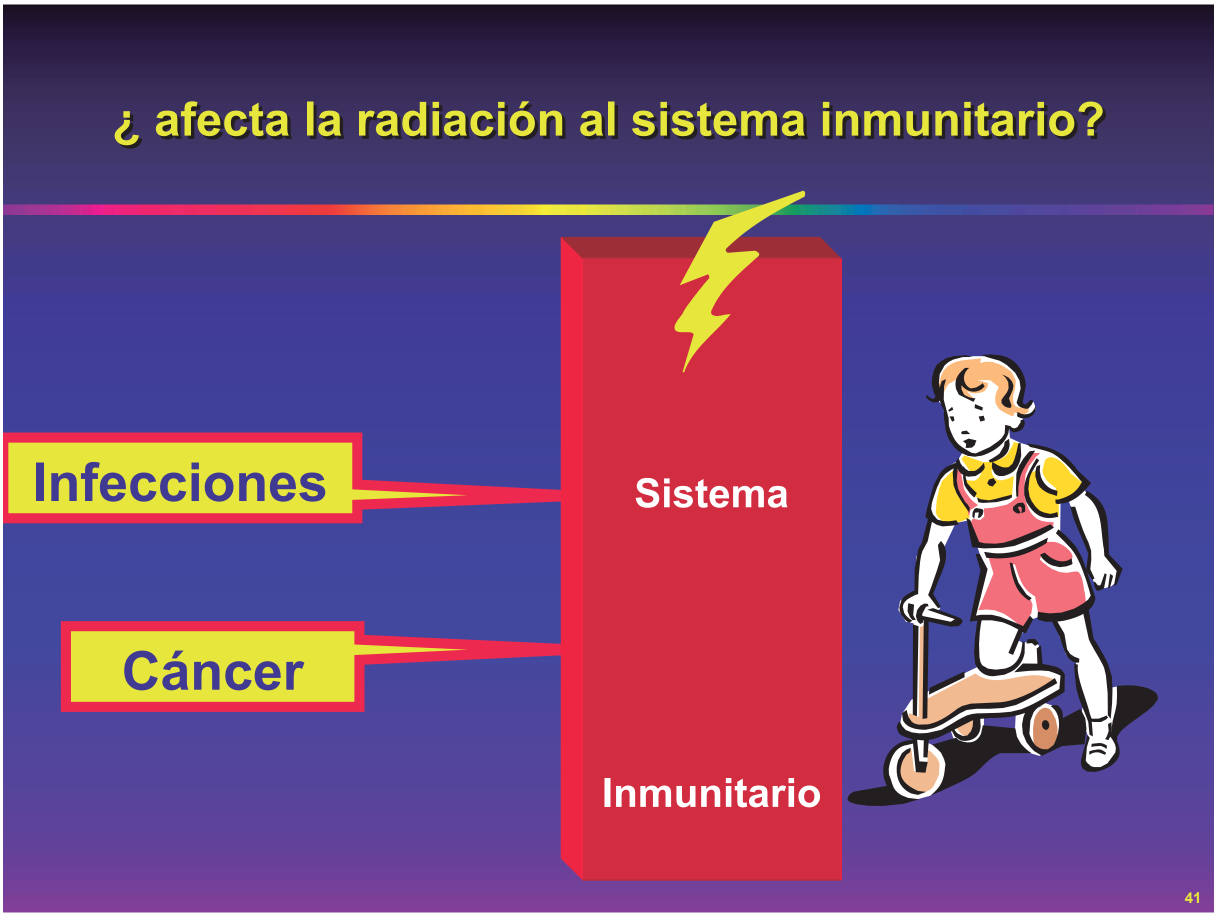
de tejidos alejados

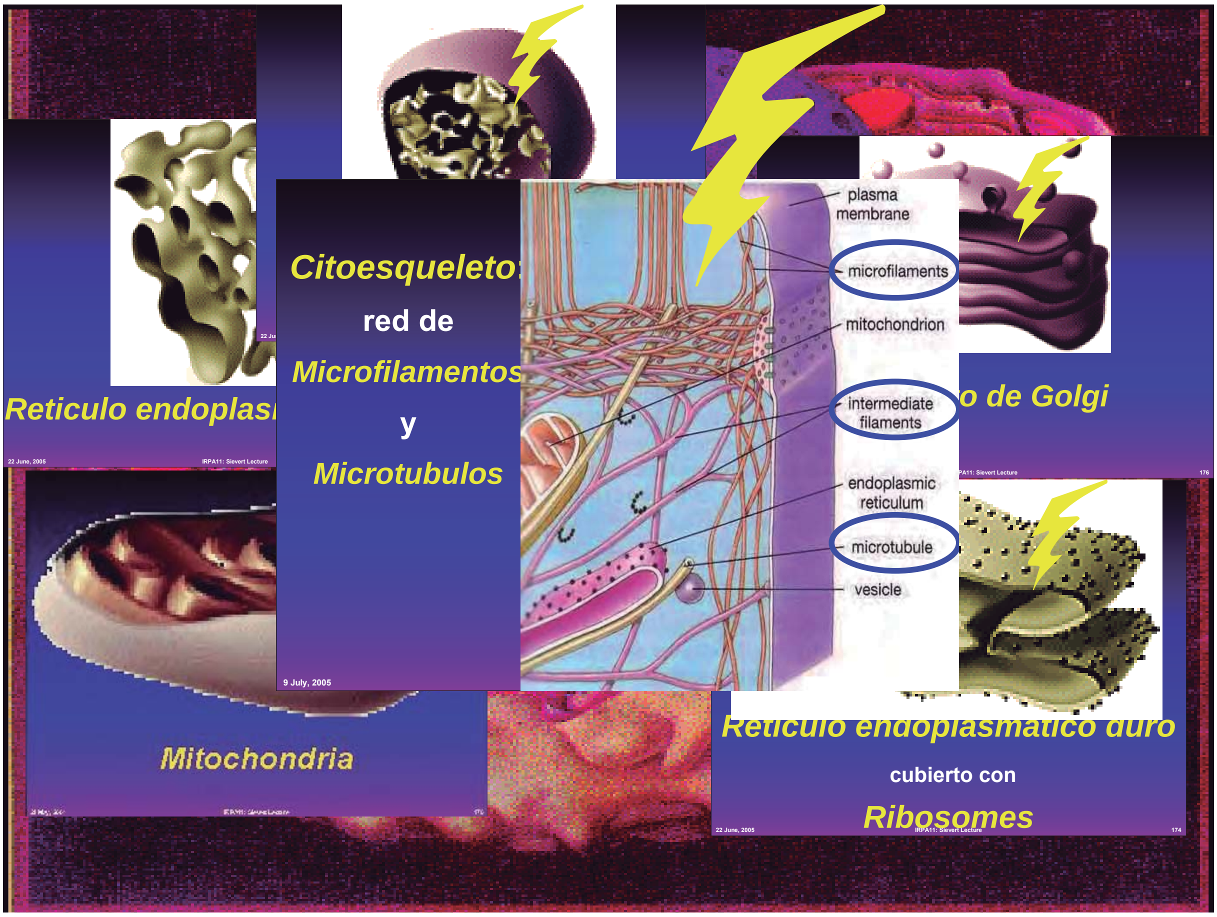
del área de exposición.

Human & Experimental Toxicology, Volume 23, Issue 2, 1 February 2004, Arnold

39




¿ afecta la radiación al sistema inmunitario?
Infecciones
Cáncer
Sistema
Inmunitario
41


Reticulo endoplas
Citoesqueleto:
red de
Microfilamentos
y
Microtubulos
9 July, 2005
plasma membrane
microfilaments
mitochondrion
intermediate filaments
endoplasmic reticulum
microtubule
vesicle
o de Golgi
Mitochondria
Reticulo endoplasmatico duro
cubierto con
Ribosomes
22 June, 2005
174

Quinta conjetura:

Extrapolaciones

epidemiologicas

43

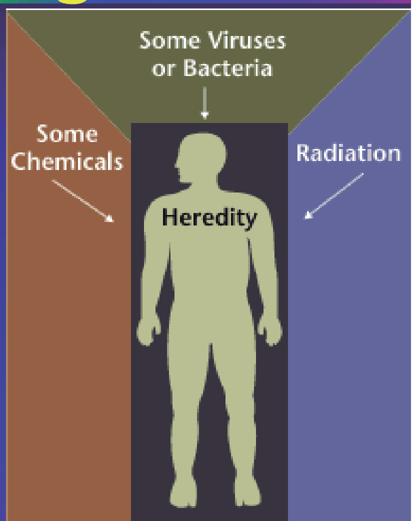
Límites de detectabilidad en radio-epidemiología

Debido a que la radiación

es un carcinógeno débil,

y a que la incidencia de

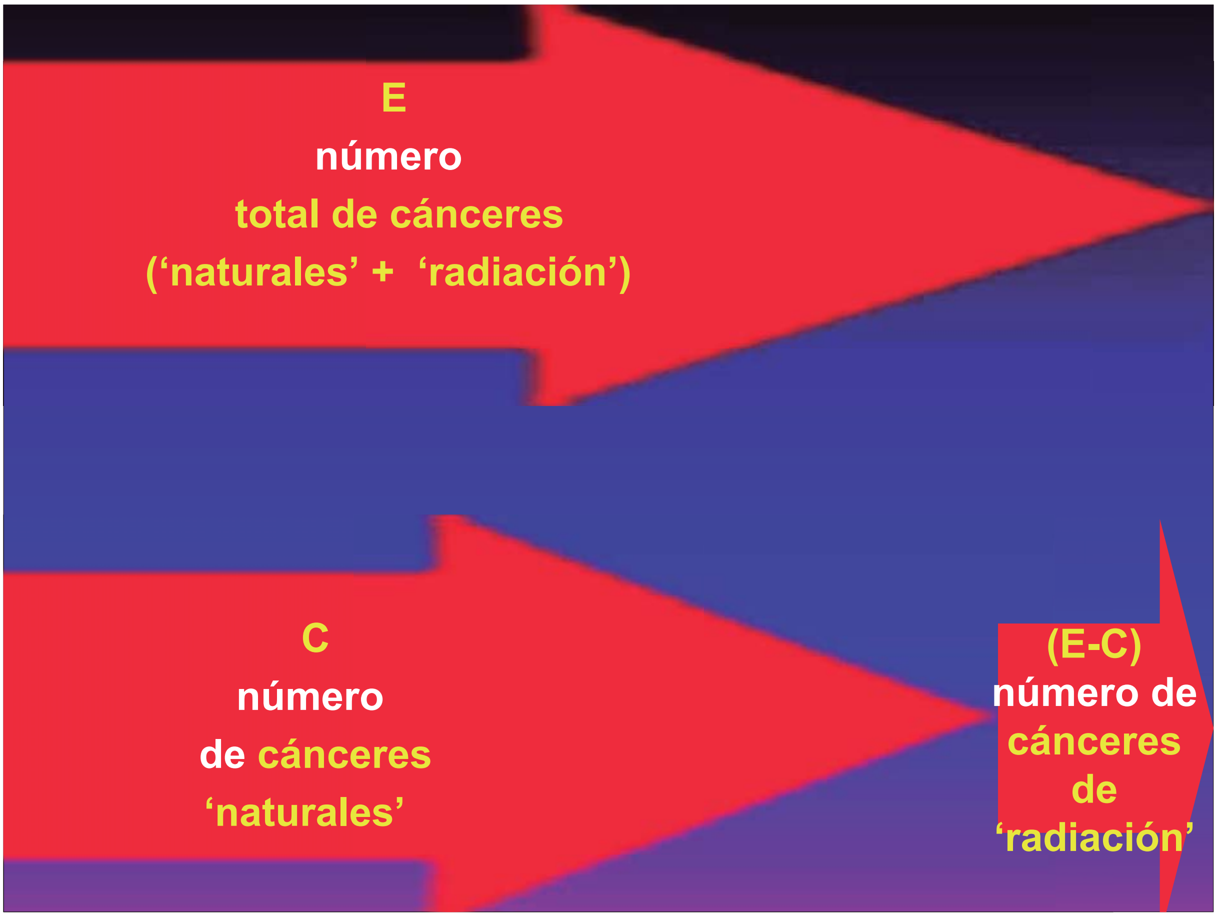
cáncer en general es



muy alta es prácticamente imposible

detectar efectos de a dosis bajas.


Grupo de control
"N" personas
"C" cánceres
"n" probabilidad de un cancer 'natural'
Grupo expuesto
"N" personas
"E" cánceres
"n" probabilidad de un cancer 'natural'
'p_D' probabilidad de un cancer de 'radiación'


E
número
total de cánceres
('naturales' + 'radiación')
C
número
de cánceres
'naturales'
(E-C)
número de
cánceres
de
'radiación'

Significado epidemiológico

- El número esperado de cánceres en el grupo de control será:

$$C = n\,N$$

- El número esperado de cánceres en el grupo expuesto será:

$$E = n\,N + p_d\,D\,N$$

- El número esperado de cánceres en exceso será

$$E - C$$

- La desviación estándard es

$$\sigma = \sqrt{2\,n\,N + p_d\,D\,N}$$

- Si el exceso de cánceres debe detectarse con una confianza estadística del 95%

$$E - C > 2\,\sigma$$

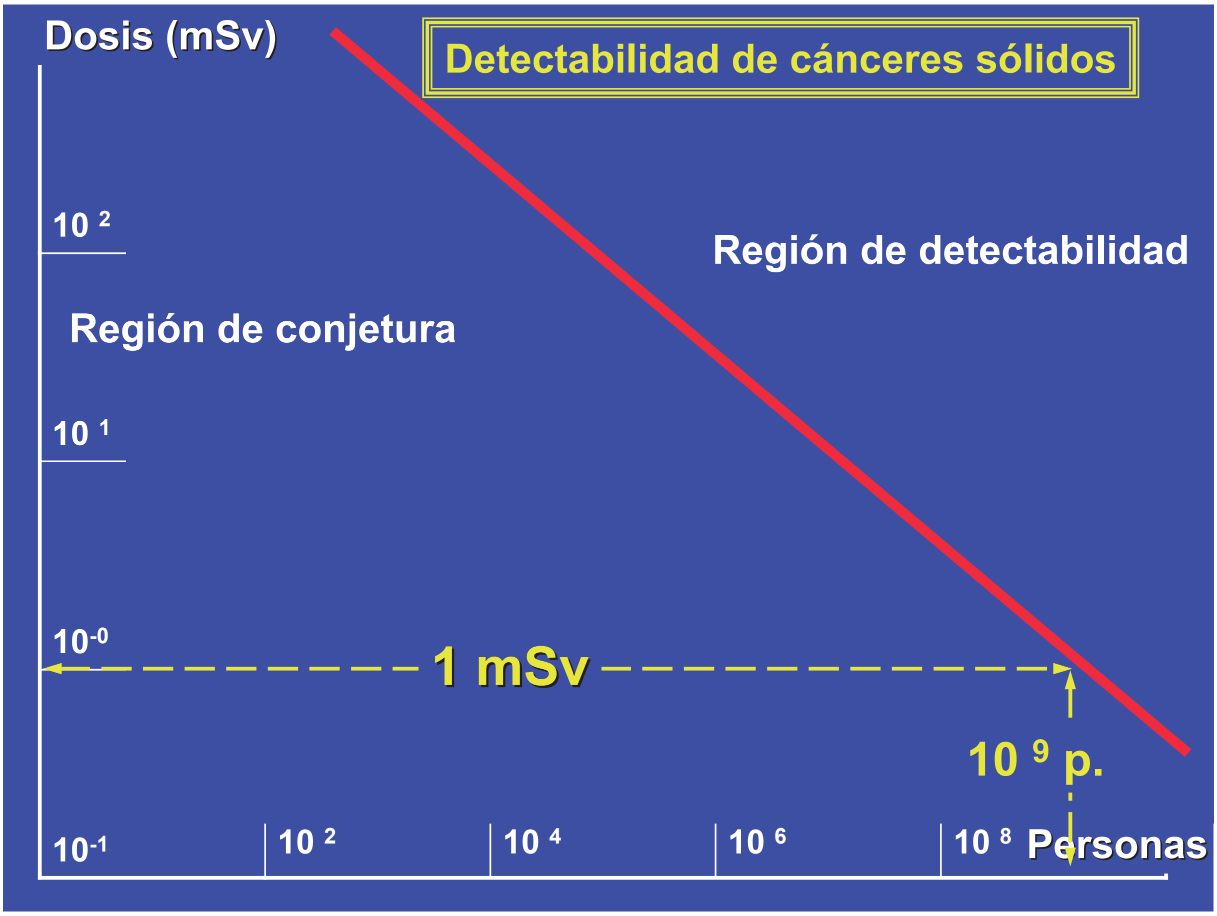
Operando algebraicamente y como n >> p_d D,

$$N > constante / D^2$$

que es la ecuación que da el número de personas, N, necesarias para detectar un exceso de cánceres en la dosis D.

(Constante = 8 n / p_d^2)

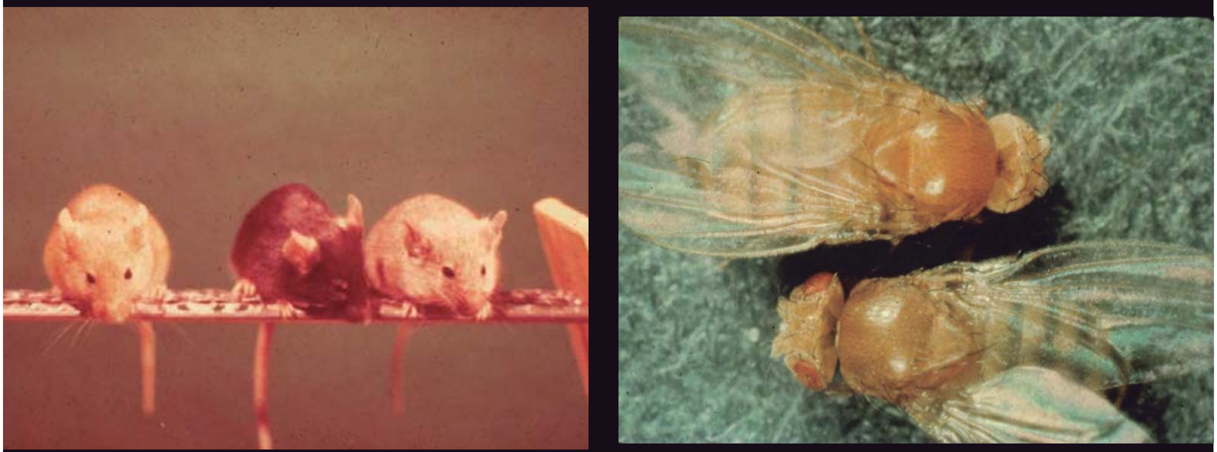
Dosis, D (mSv)	~ Number of people, N
1	>1.000.000.000
10	>10.000.000
100	>100.000
1000	>1.000

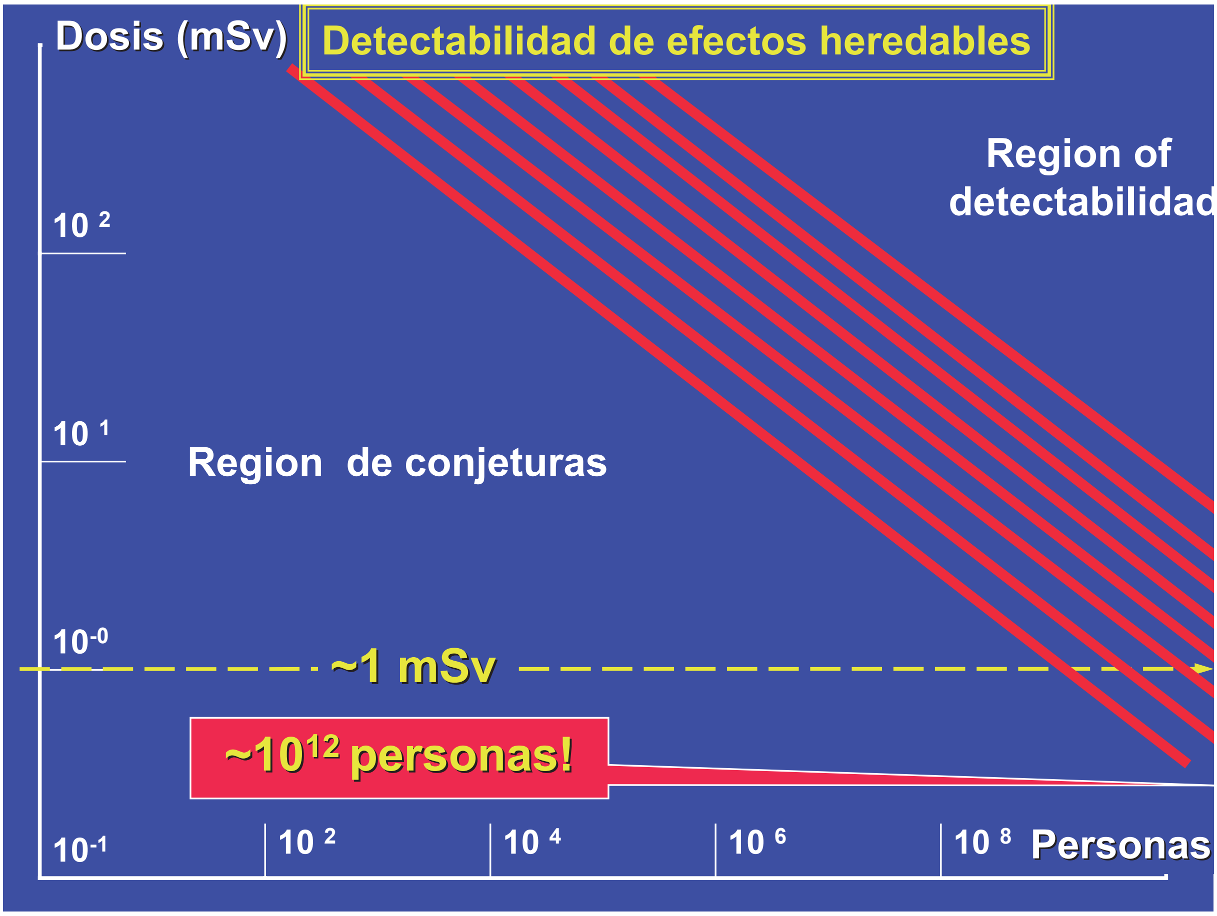


Epidemiología

de los efectos hereditables

Las estimaciones de riesgos hereditarios se basan en estudios animales y no se han manifestado en el especie humana

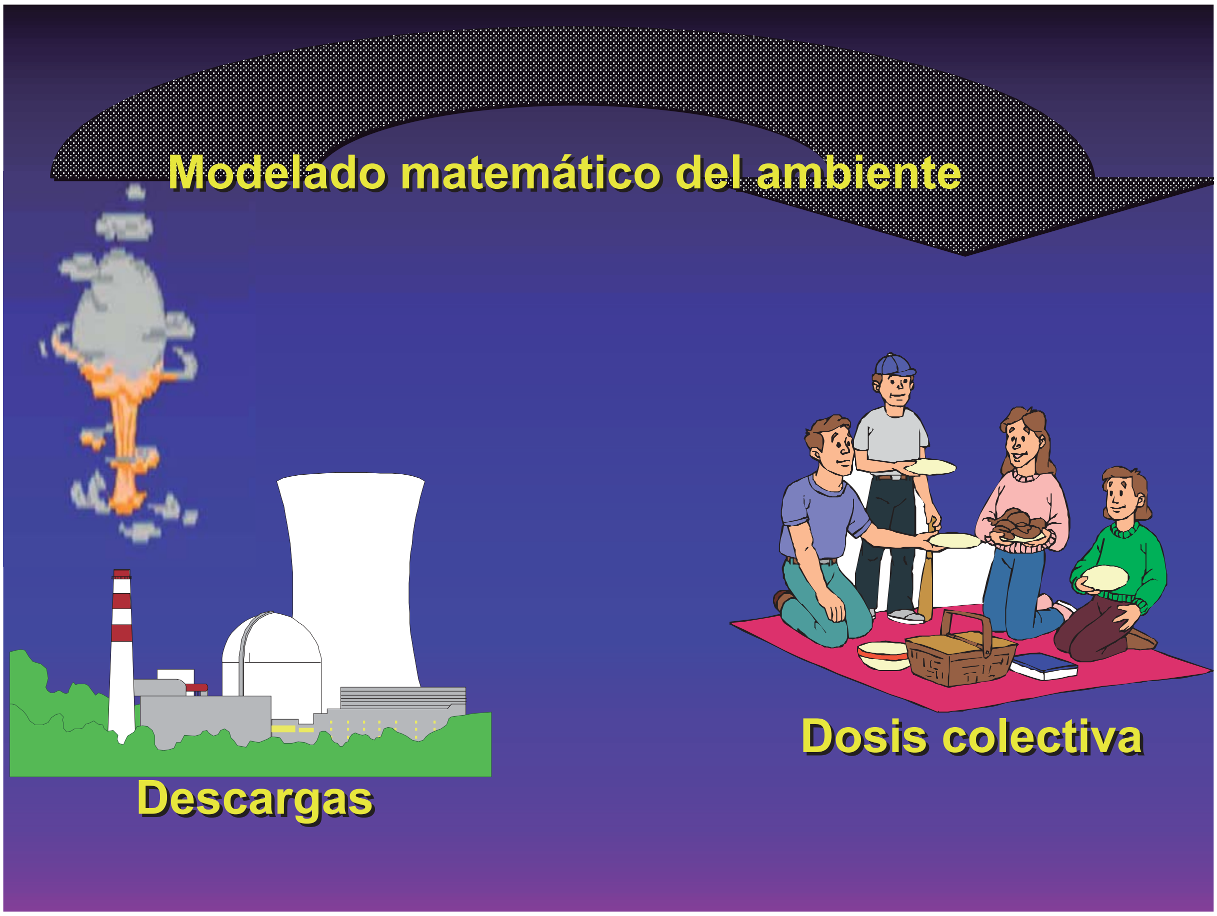


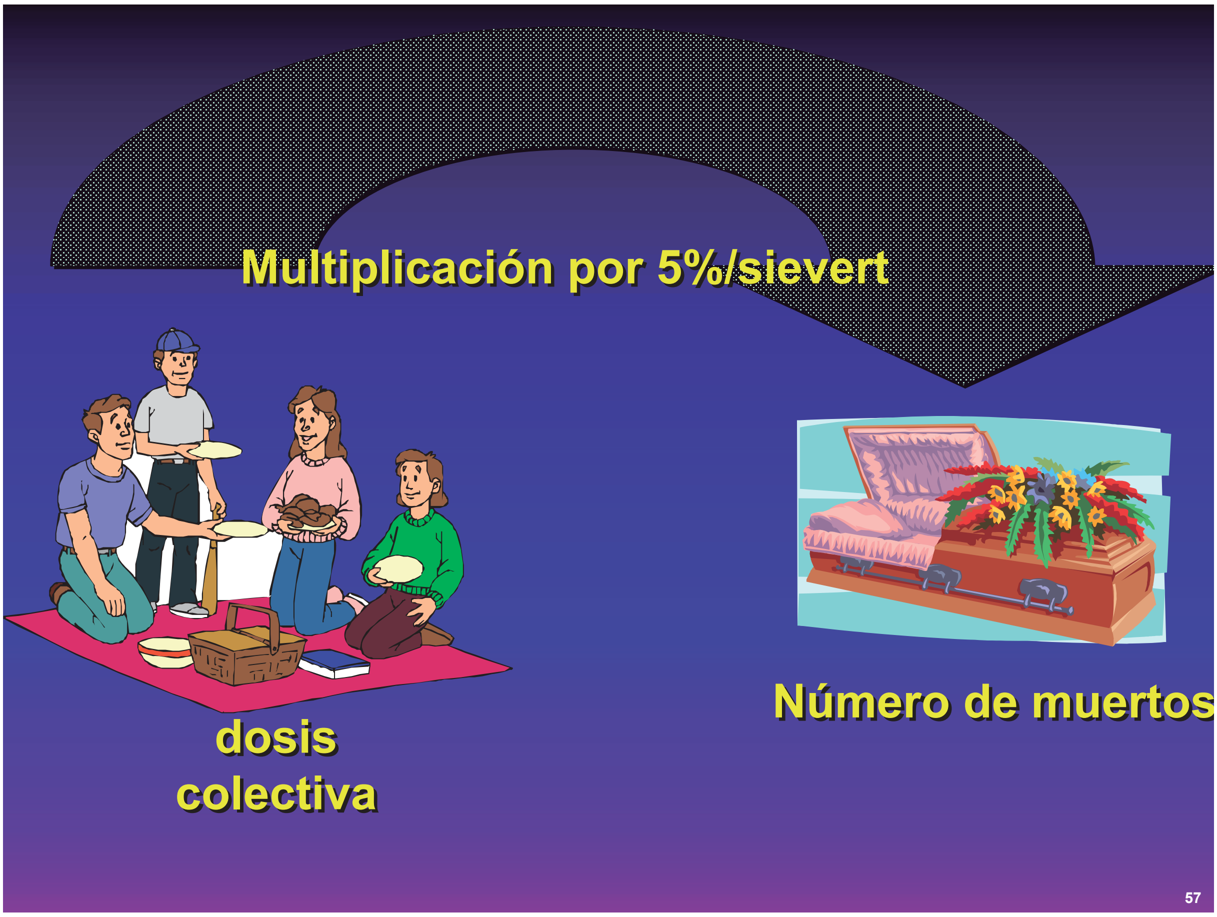


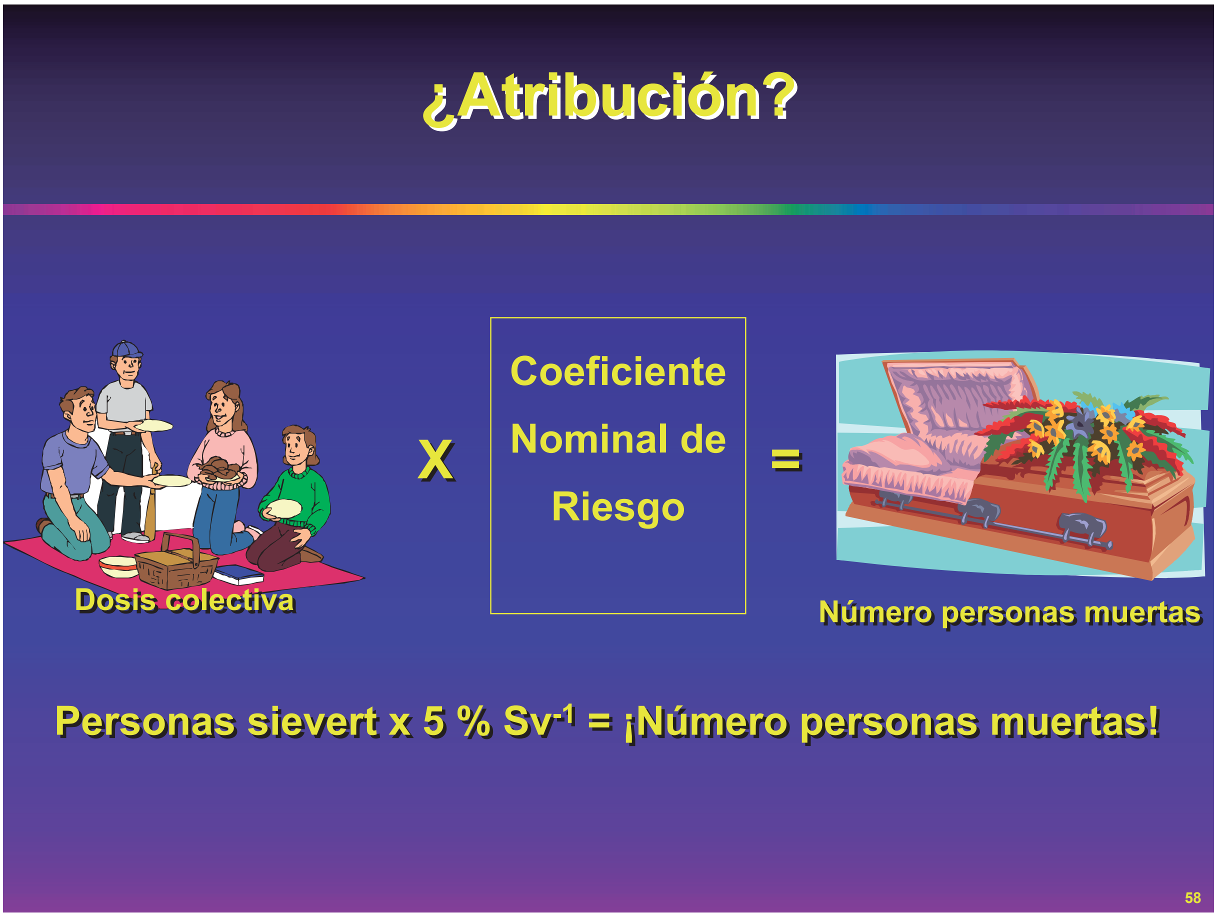
Conundrum:

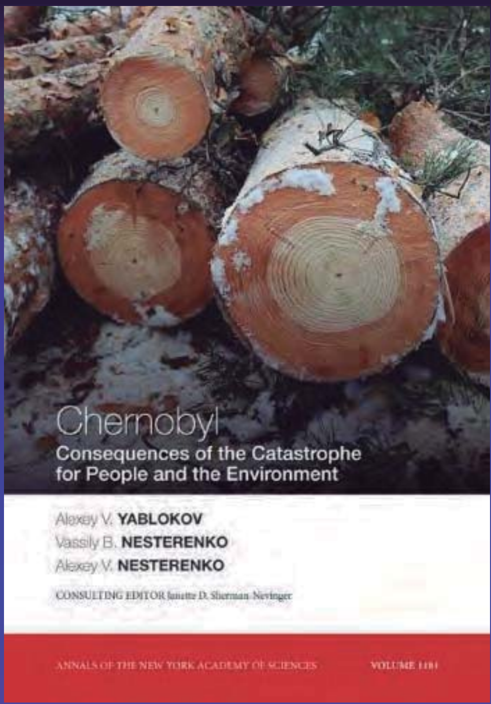
La atribución de daño a bajas dosis

55




Multiplicación por 5%/sievert
dosis
colectiva
Número de muertos
57


¿Atribución?
X
Coeficiente
Nominal de
Riesgo
=
Dosis colectiva
Número personas muertas
Personas sievert x 5 % Sv-1 = ¡Número personas muertas!
58



Chernobyl:
Consequences of the Catastrophe for People and the Environment
Annals of the New York Academy of Sciences

Alexey V. Yablokov (Editor),
Vassily B. Nesterenko (Editor),
Alexey V. Nesterenko (Editor),
Janette D. Sherman-Nevinger (Editor)

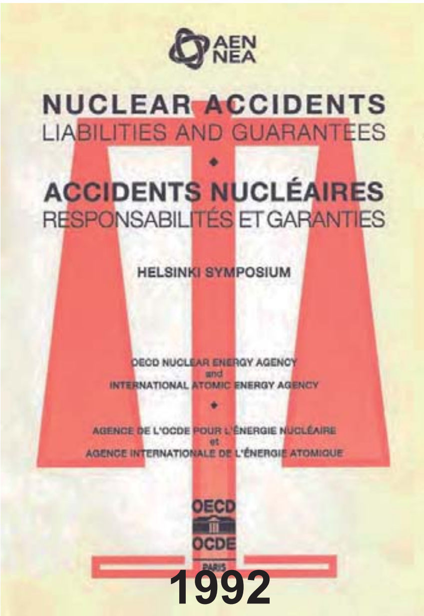
It concludes that based on records now available,
some 985,000 people died of cancer caused by the Chernobyl accident!

59

Estas imputaciones han causado daños muy serios, no conjeturales sino reales: serios efectos psicológicos y psiquiátricos en Chernobyl y en Fukushima

El objetivo de nuestros trabajos sobre este tema fue insistir en que una solución científica para este conundrum se necesitaba con urgencia.

61



Session I - Séance I

The lessons of the Chernobyl accident

Les leçons de l'accident de Tchernobyl

Chair-Présidence: Y. Sahrakorpi (Finland)

The radiological health consequences of Chernobyl: the dilemma of causation, by A. Gonzalez (IAEA) 25

Chernobyl vis-à-vis the nuclear future: An international perspective

Abel Julio González

Health Physics, November 2007. Volume 93, Number 5. pp 571-592

172 *Int. J. Low Radiation, Vol. 8, No. 3, 2011*

Epistemology on the attribution of radiation risks and effects to low radiation dose exposure situations

Abel Julio González

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CLARIFYING THE PARADIGM ON RADIATION EFFECTS & SAFETY MANAGEMENT: UNSCEAR REPORT ON ATTRIBUTION OF EFFECTS AND INFERENCE OF RISKS

ABEL J. GONZÁLEZ
Representative at the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
Member of the Commission of Safety Standards (CSS) of the International Atomic Energy Agency (IAEA)
ex-Vice-Chairman of the International Commisssion on Radiological Protection (ICRP)
Autoridad Regulatoria Nuclear de Argentina (ARN)
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Received July 03, 2014

NUCLEAR ENGINEERING AND TECHNOLOGY, VOL.46 NO.4 AUGUST 2014 467

[redacted]

Radiation Protection in Australasia Vol. 31, No. 2 Refereed Article

CLARIFYING THE PARADIGM FOR PROTECTION AGAINST LOW RADIATION DOSES: RETROSPECTIVE ATTRIBUTION OF EFFECTS *VIS-Á-VIS* PROSPECTIVE INFERENCE OF RISK

Abel J. González

[redacted]

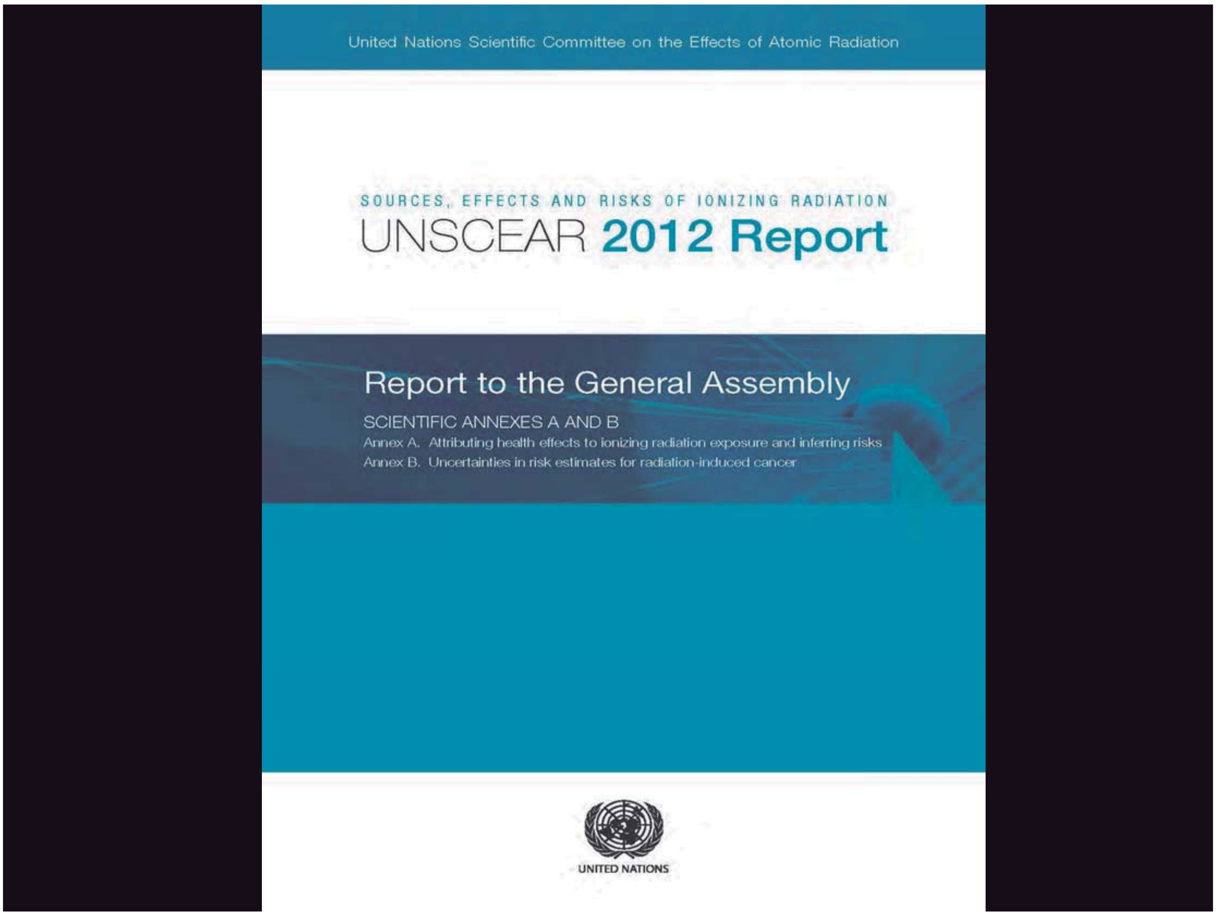
Tesis

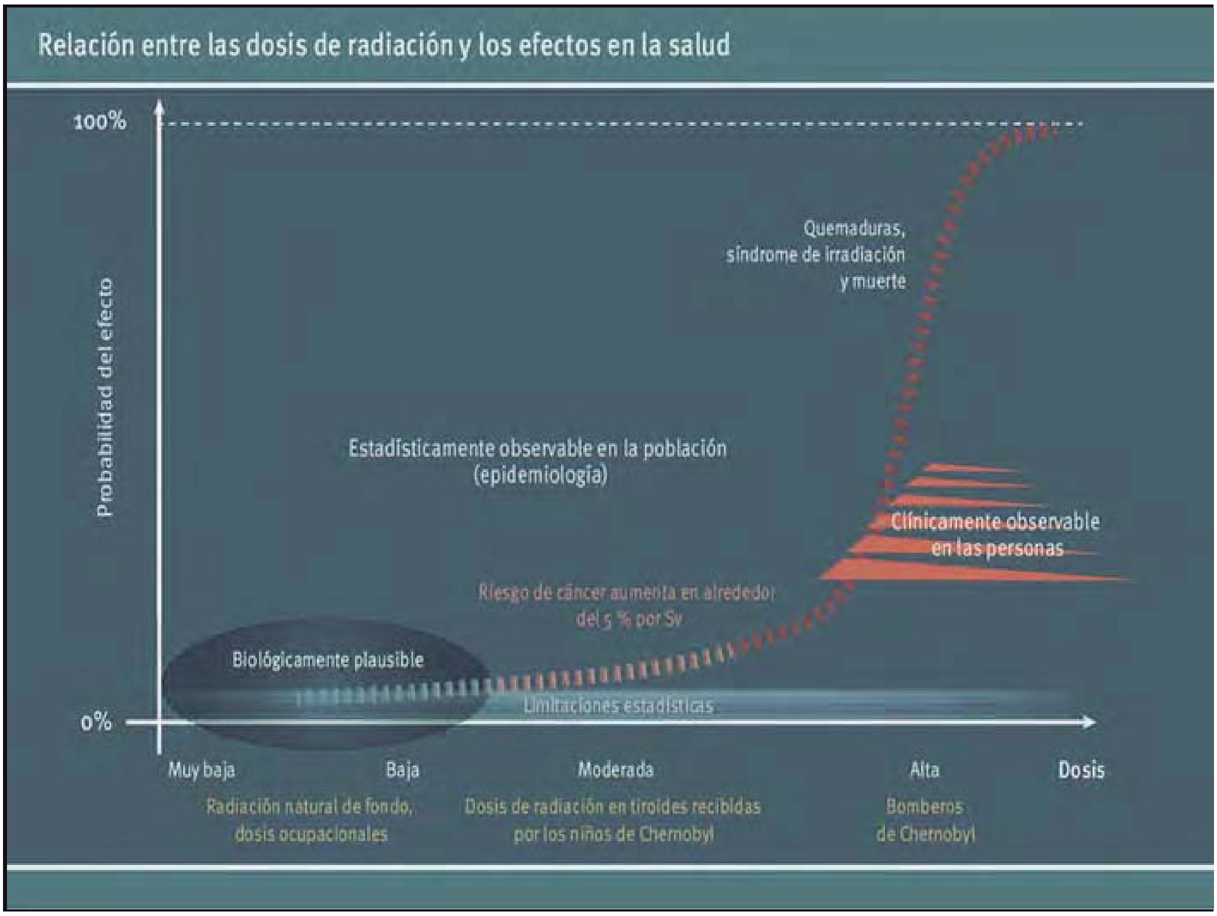
A bajas dosis de radiación:

1. Efectos reales no son atribuibles objetivamente

2. Riesgos plausibles pueden ser inferibles subjetivamente

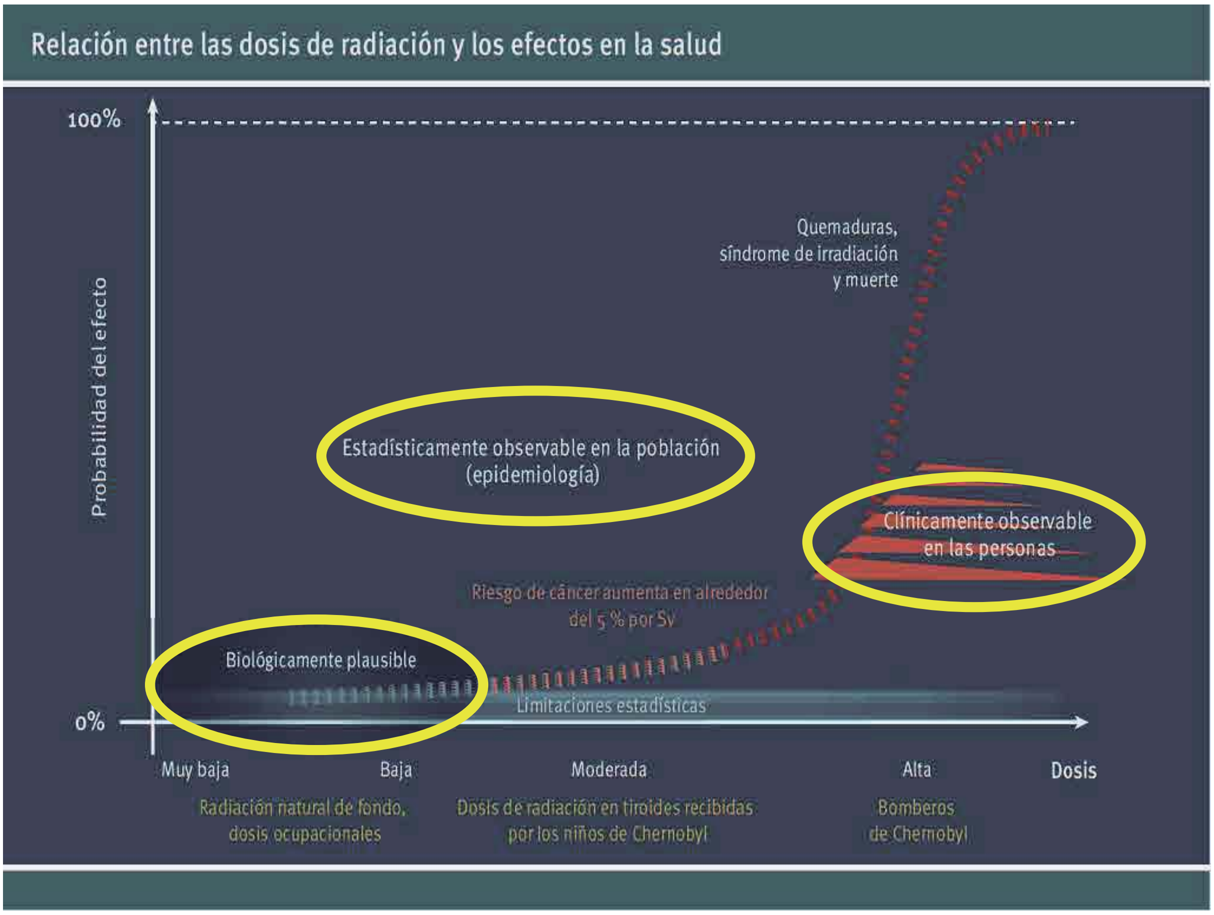
67





Observación de efectos

70

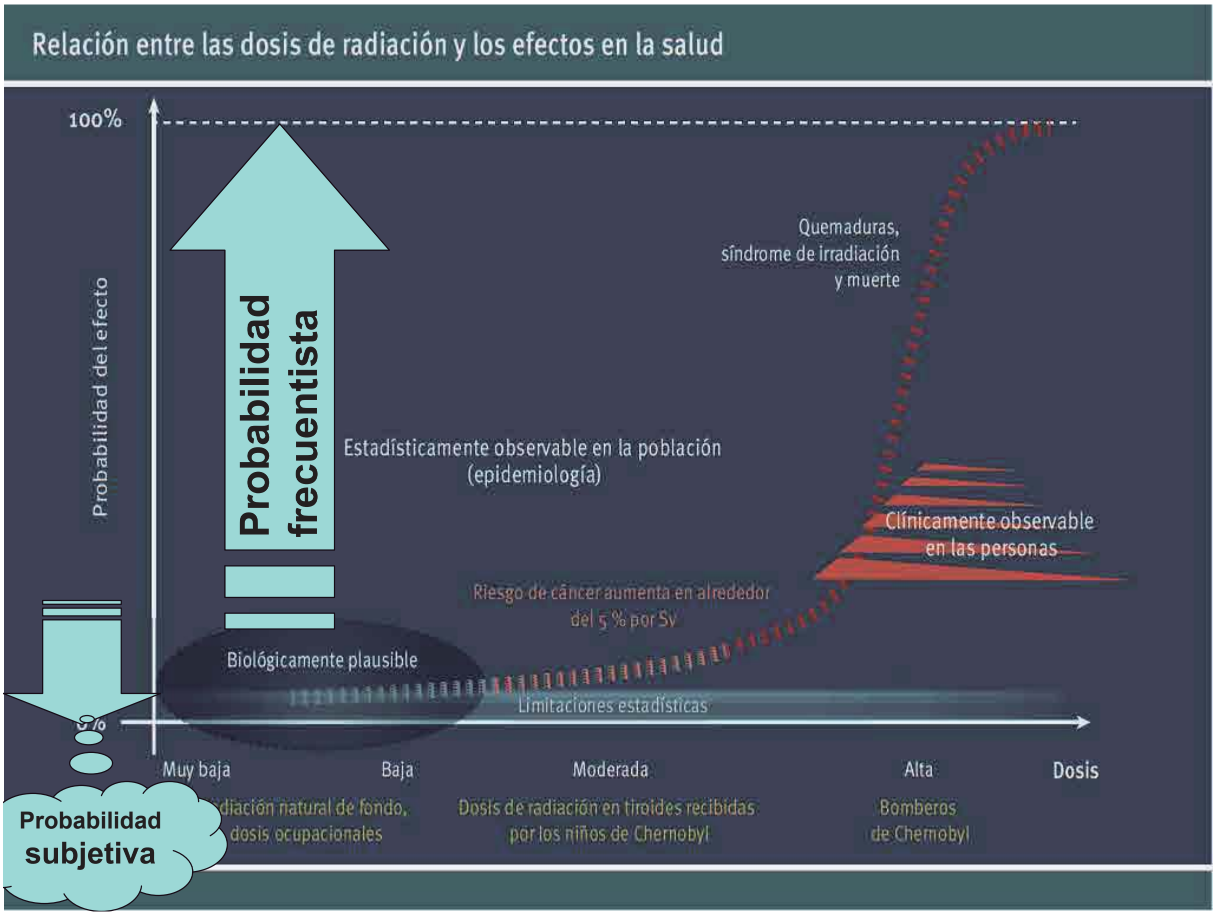


Probabilidades frecuentistas

versus

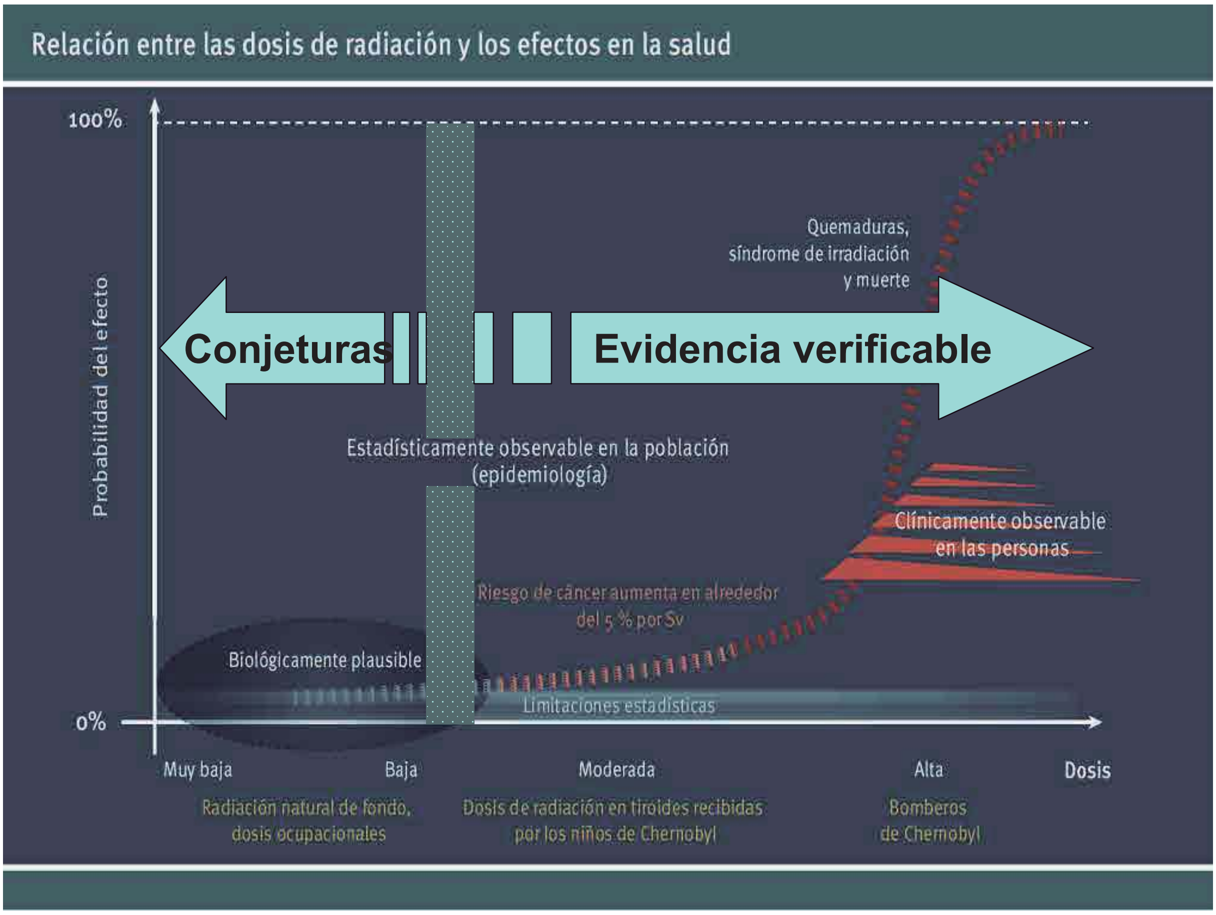
Probabilidades subjetivas

72



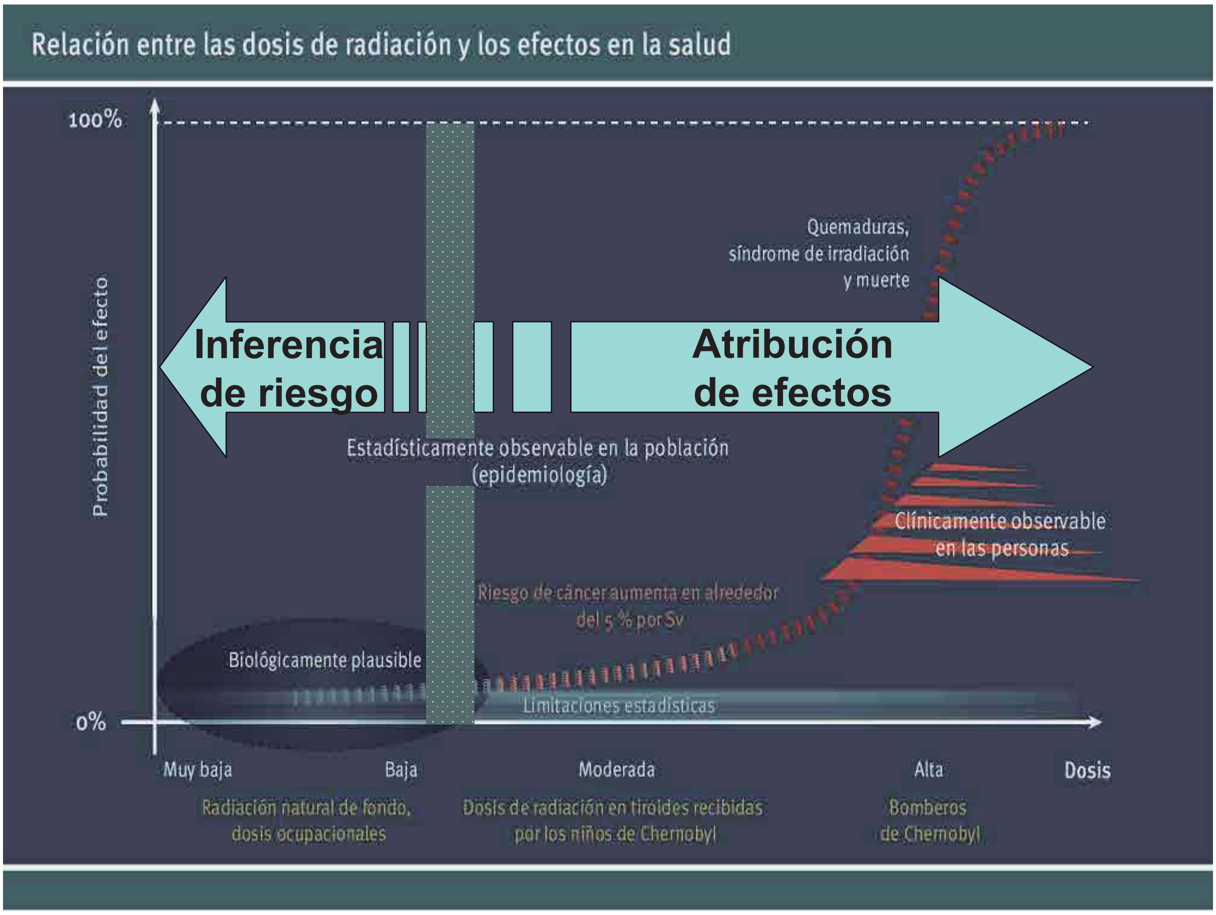
Hechos *versus* Conjeturas

74



Atribución *versus* Inferencia

76



Diagnóstico individual

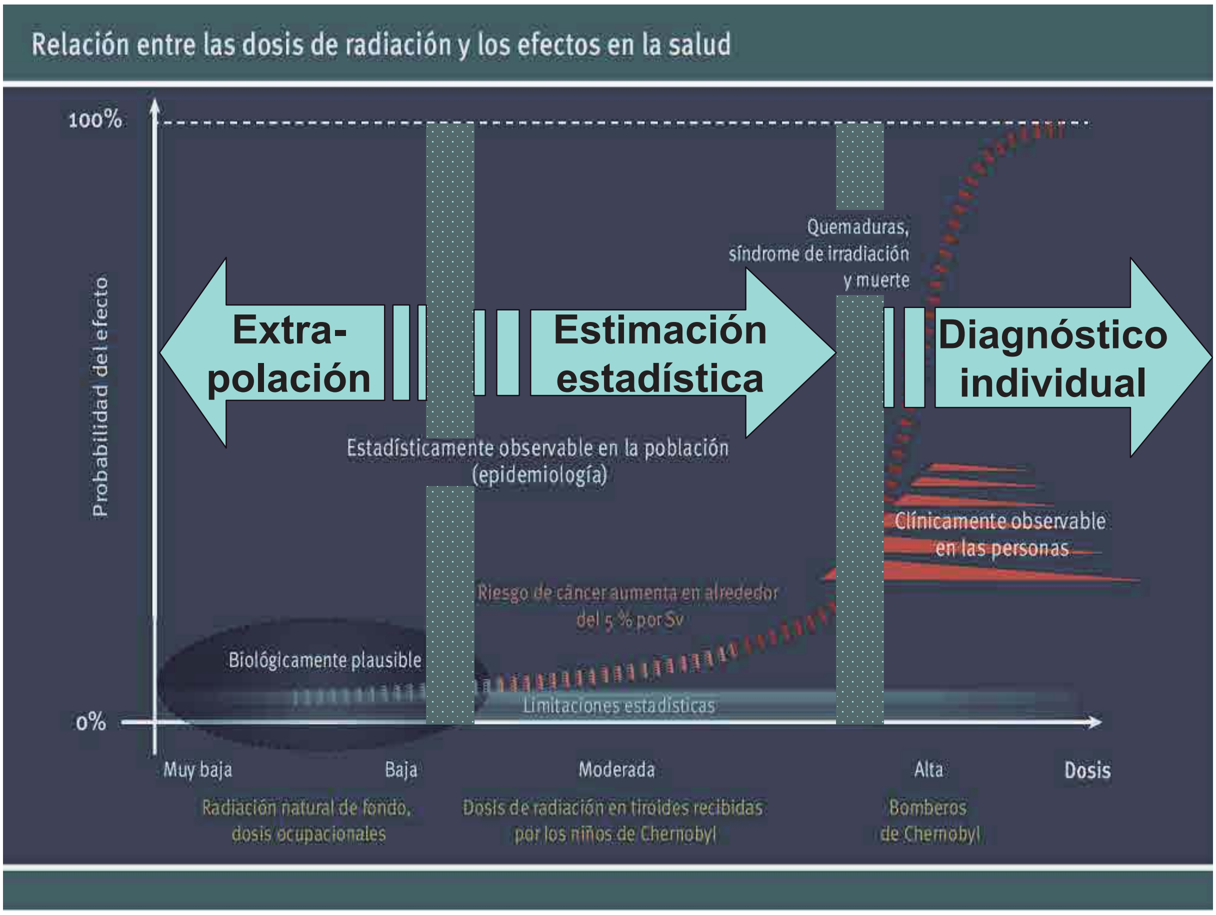
versus

Estimación estadística

versus

Extrapolación subjetiva

78



Atribución individual

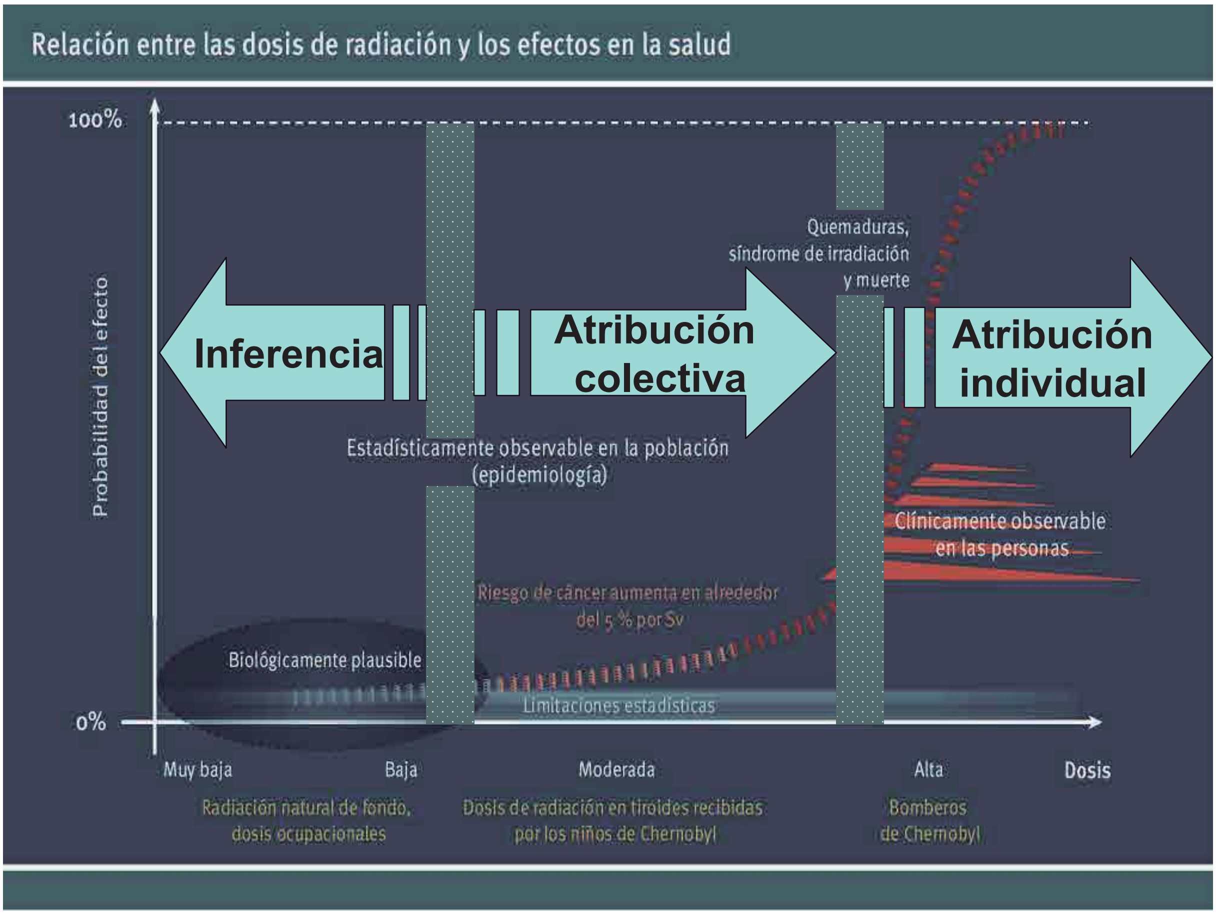
versus

Atribución colectiva

versus

Inferencia

80



Atestación patológica

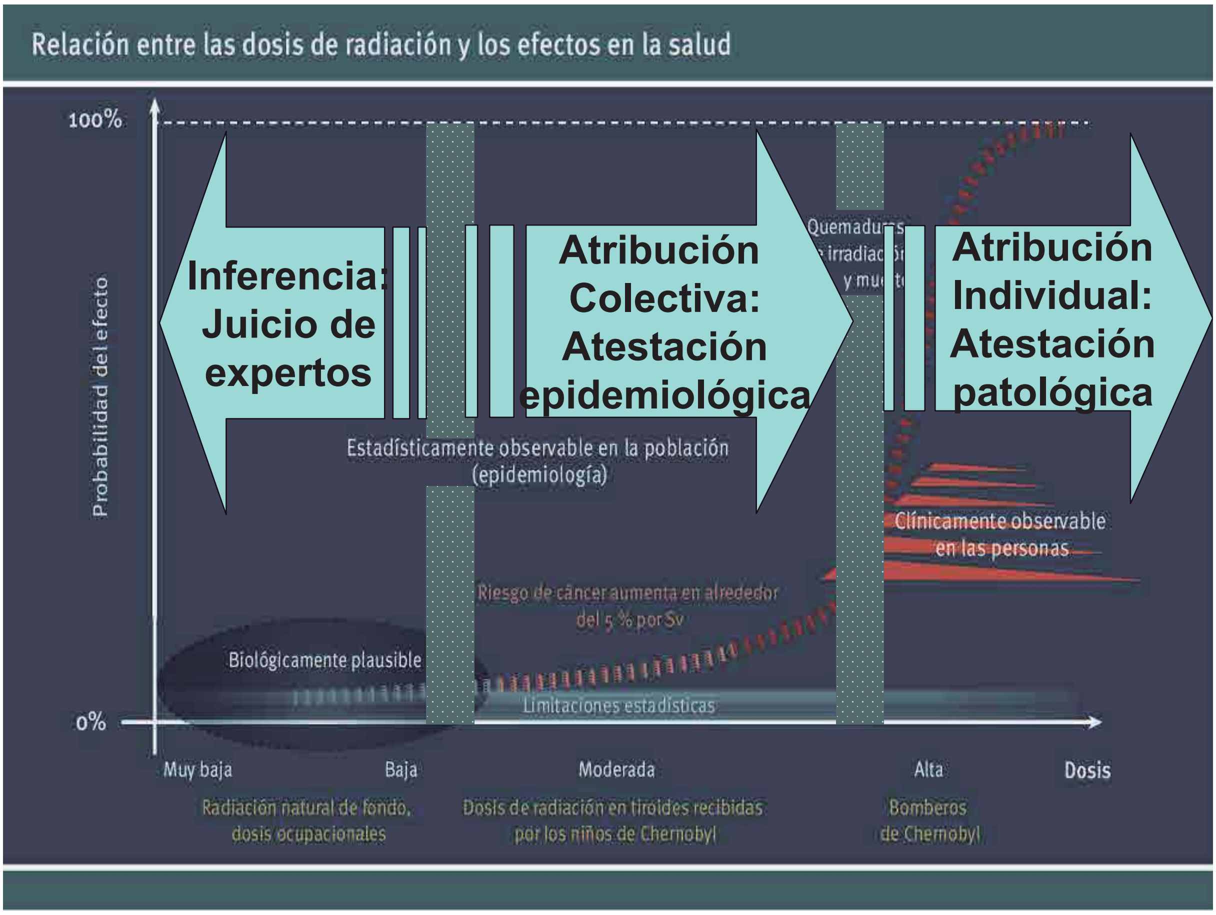
versus

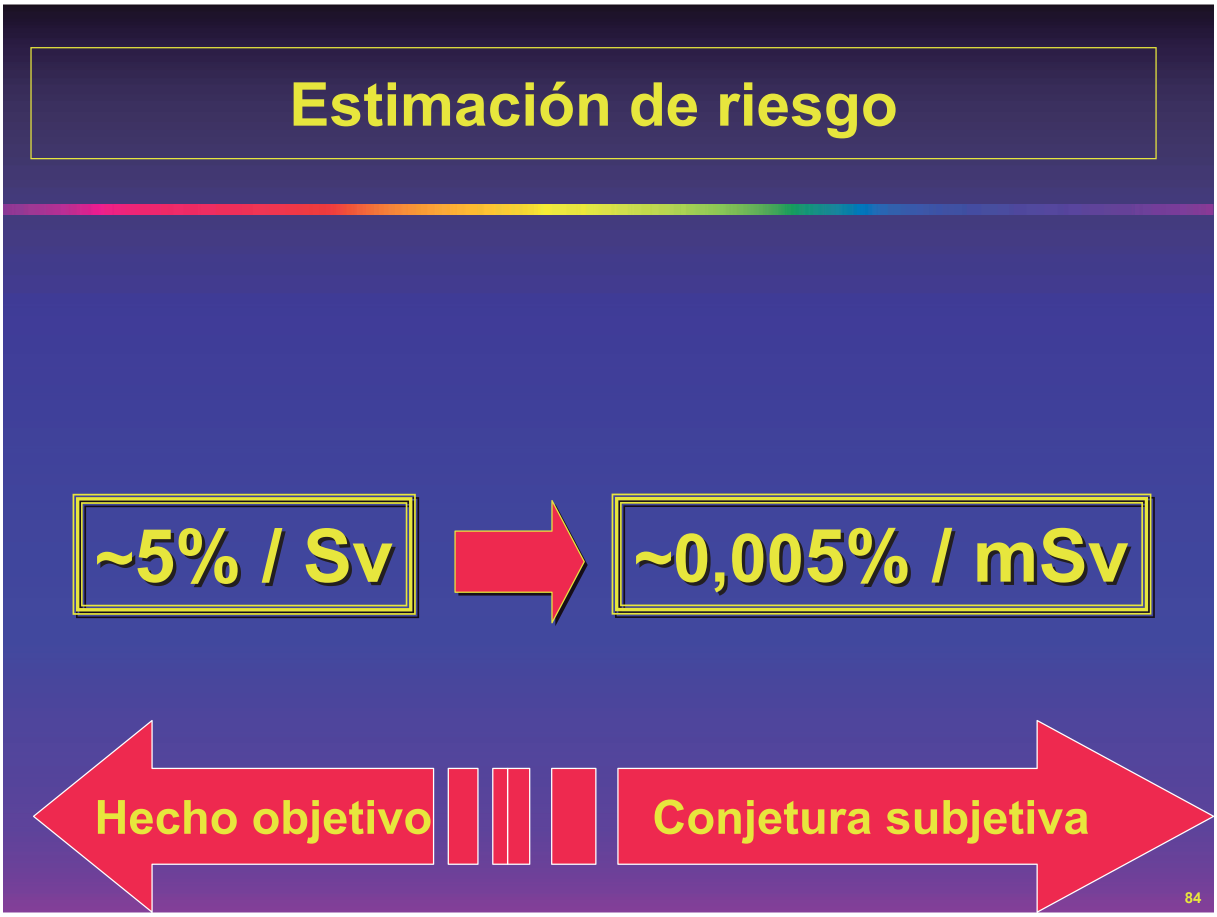
Atestación epidemiológica

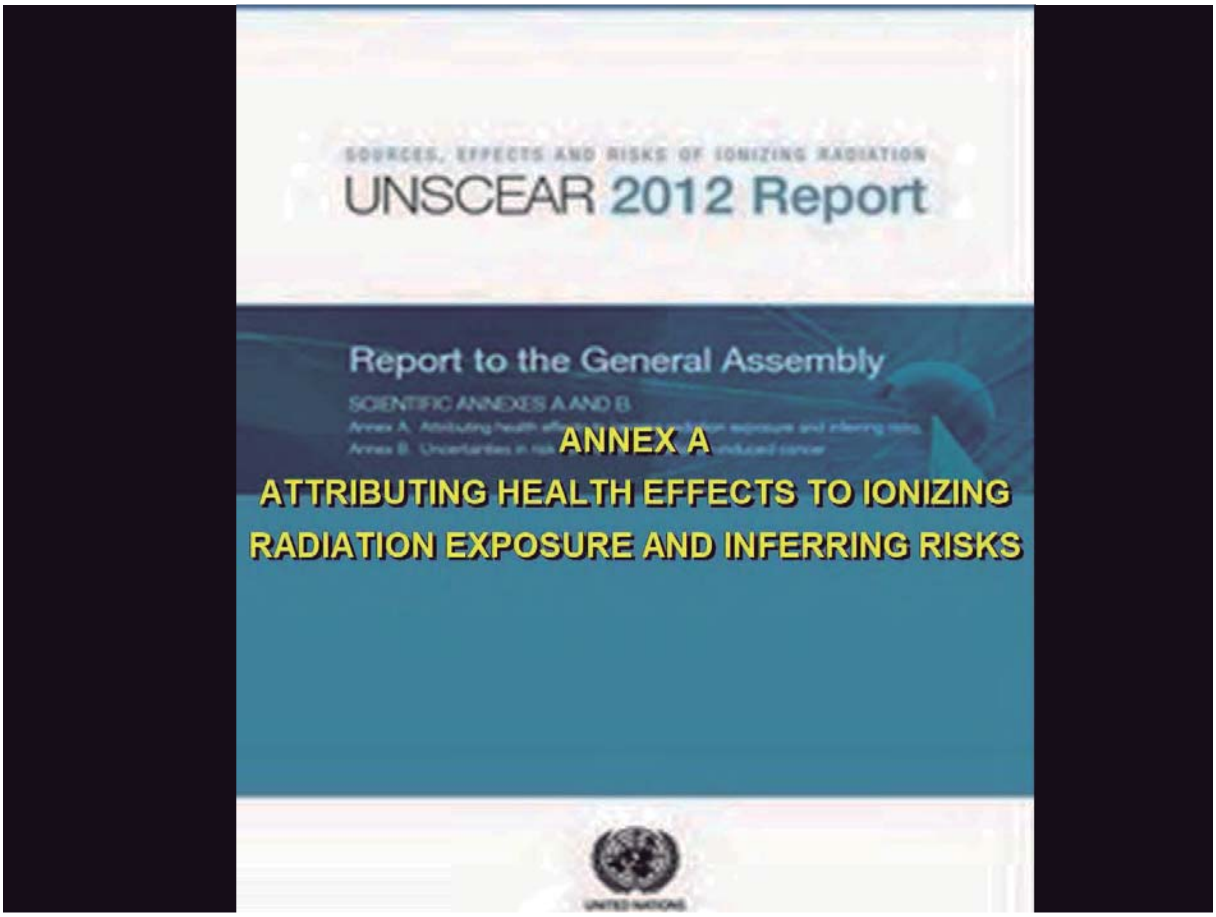
versus

Juicio subjetivo de expertos

82

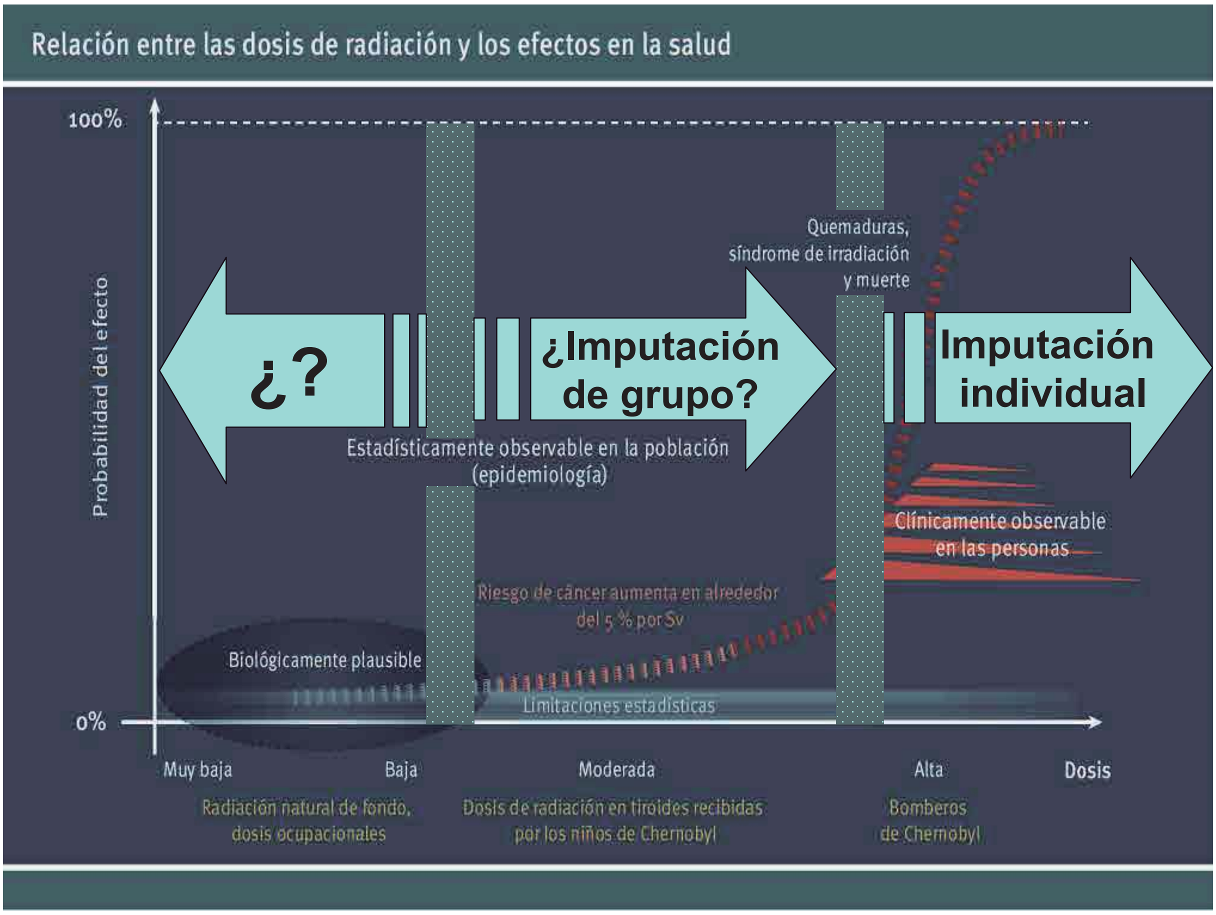

Relación entre las dosis de radiación y los efectos en la salud
100%
0%
Probabilidad del efecto
Inferencia: Juicio de expertos
Atribución Colectiva: Atestación epidemiológica
Atribución Individual: Atestación patológica
Estadísticamente observable en la población (epidemiología)
Clínicamente observable en las personas
Riesgo de cáncer aumenta en alrededor del 5 % por Sv
Biológicamente plausible
Limitaciones estadísticas
Muy baja
Baja
Moderada
Alta
Dosis
Radiación natural de fondo, dosis ocupacionales
Dosis de radiación en tiroides recibidas por los niños de Chernobyl
Bomberos de Chernobyl


Estimación de riesgo
~5% / Sv
~0,005% / mSv
Hecho objetivo
Conjetura subjetiva
84



Imputabilidad

86



Libro del OIEA con motivo de la Primera Conferencia Internacional sobre Derecho Nuclear (ICNL) 2022.

Chapter 7
Legal Imputation of Radiation Harm to Radiation Exposure Situations

Abel Julio González

Tema 2:

Confusión sobre ‘*LNT*’

‘LNT’ para epidemiólogos

- **Una conjetura epidemiológica:**

  la incidencia de efectos por unidad de dosis en dosis altas (con evidencia epidemiológica) permanece igual en dosis bajas (sin evidencia epidemiológica).

‘LNT’ para biólogos

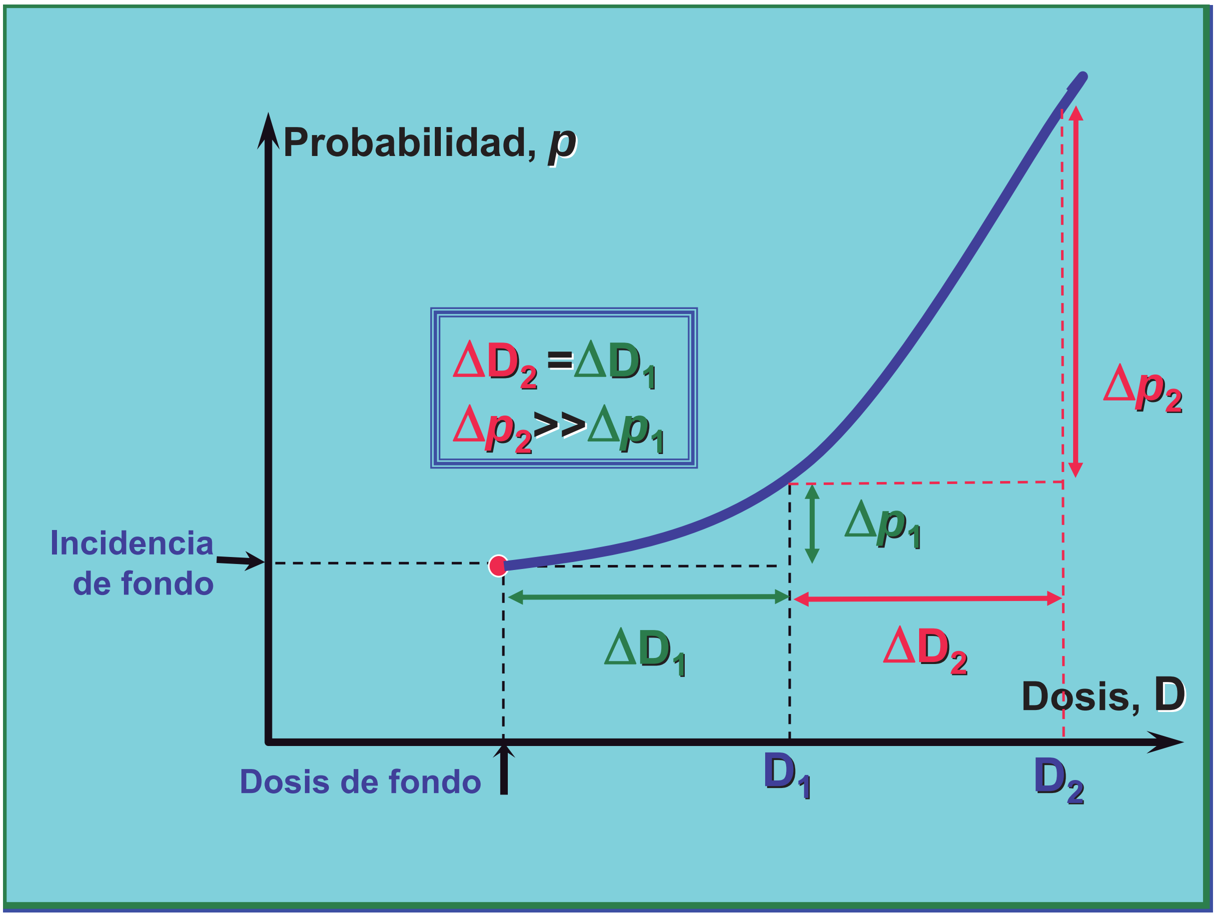
- **Una teoría biológica:**

  A dosis bajas de radiación, un incremento en la dosis producirá un incremento directamente proporcional en la probabilidad de contraer cáncer o efectos hereditarios atribuibles a la radiación.

‘LNT’ para radioproteccionistas

- **Un modelo de protección radiológica:**

Un enfoque práctico para la gestión de la protección radiológica que considera la protección por dosis adicionales independientemente del nivel de dosis acumulada.


Probabilidad, p
ΔD2 =ΔD1
Δp2>>Δp1
Δp2
Δp1
Incidencia
de fondo
ΔD1
ΔD2
Dosis, D
Dosis de fondo
D1
D2


'LNT'
¡LNT TIENE QUE SER ACLARADO!

Tema 3:

Magnitudes y unidades

Una lección derivada del accidente de Fukushima

- Las magnitudes y unidades utilizadas en el paradigma causaron una gran confusión y problemas de comunicación……

……incluyendo:

Las diferencias entre las magnitudes no se comprenden bien, incluso por audiencias de alto nivel educativo;

Por ejemplo, diferencias entre:

dosis absorbida,

dosis equivalente

equivalente de dosis

dosis efectiva

La distinción entre las magnitudes

físicas

de protección y

operativas

es aún más difícil de entender.

El uso de la misma unidad para diferentes magnitudes, sin especificar la magnitud, aumentó la confusión y los malentendidos.

Por ejemplo, el uso de la unidad sievert para

- dosis equivalente (incurrida por un órgano),
- dosis efectiva (contraída por el cuerpo), y
- equivalente de dosis (campo de radiación).

¡No está claro por qué se necesitan tantas magnitudes diferentes para proteger a las personas contra la radiación!

Conclusiones de Fukushima

- La comunidad de protección radiológica tiene el deber ético de aprender de las lecciones de Fukushima y resolver los desafíos identificados.
- Antes de que ocurra otro accidente mayor:

¡Deben resolverse las confusiones sobre el sistema internacional de magnitudes y unidades!

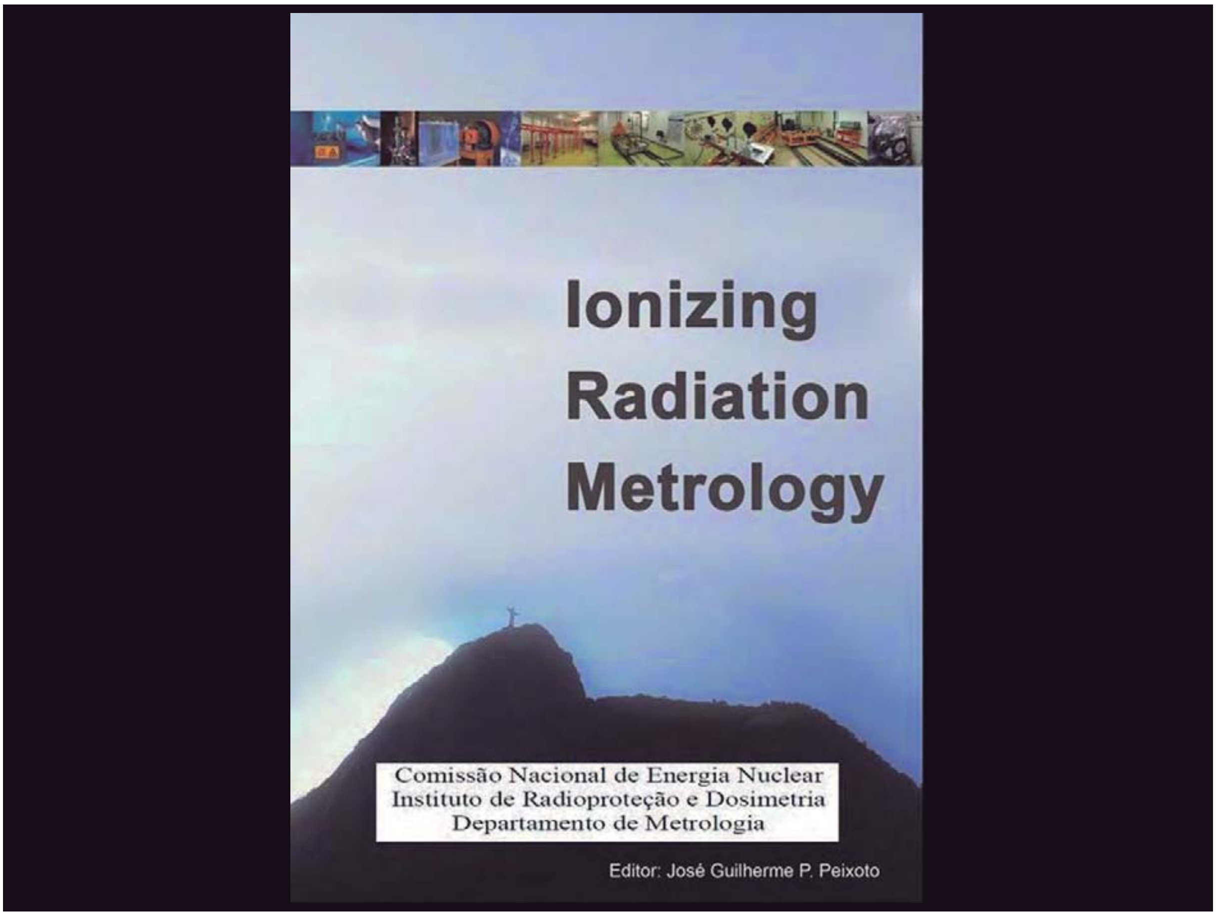
Critica

(año 2014)

CBMRI

Primeiro Congresso Brasileiro de Metrologia da Radiação Ionizante

Rio de Janeiro, Brazil, 23-25 November 2014.



Chapter V
Radiation Protection Quantities and Units: Desirable Improvements

Abel Julio González
Carlos Eduardo Veloso de Almeida
Francisco Spano

Nuevas recomendaciones de ICRU + ICRP

- Las nuevas recomendaciones de ICRU + ICRP se deben incorporar al paradigma.

... pero ...

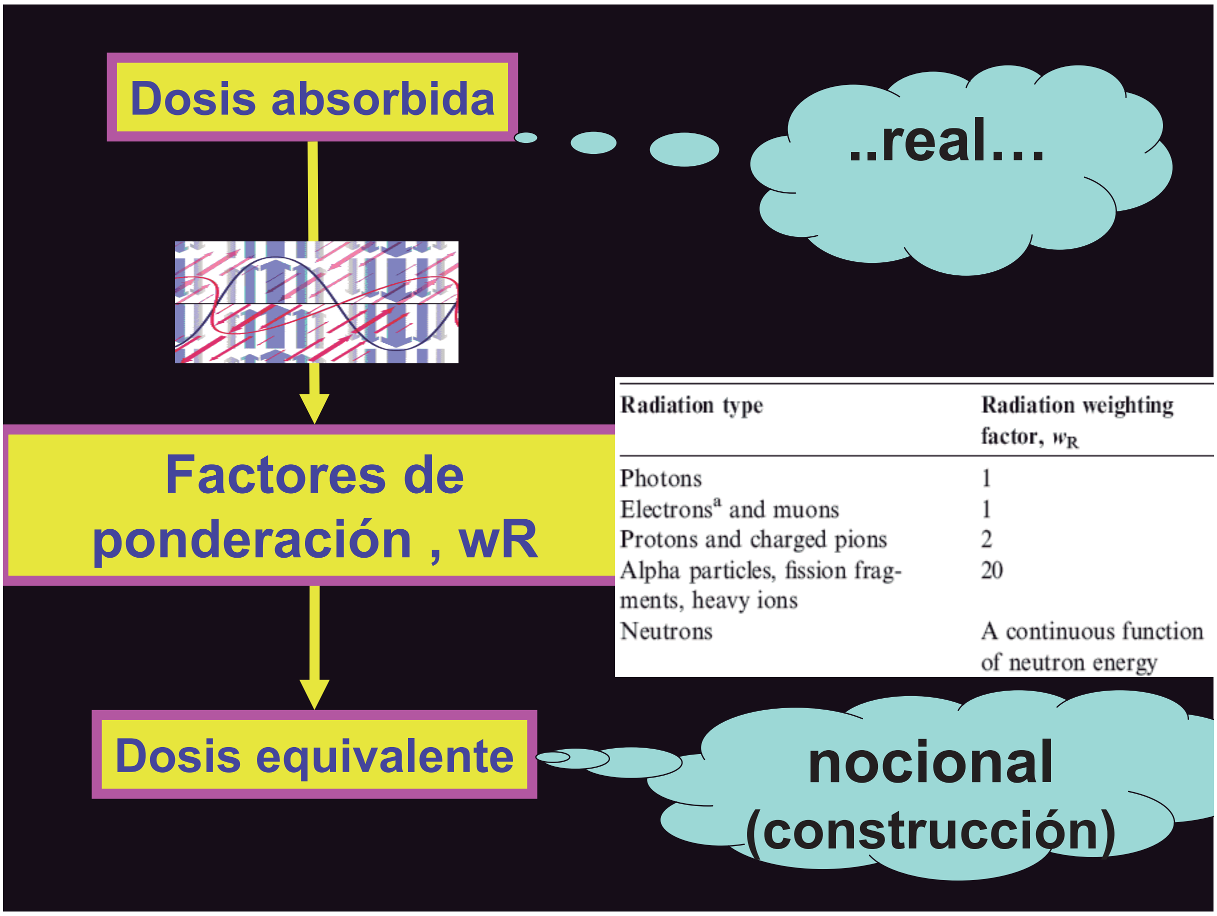
¡pueden ser necesarios otros cambios!

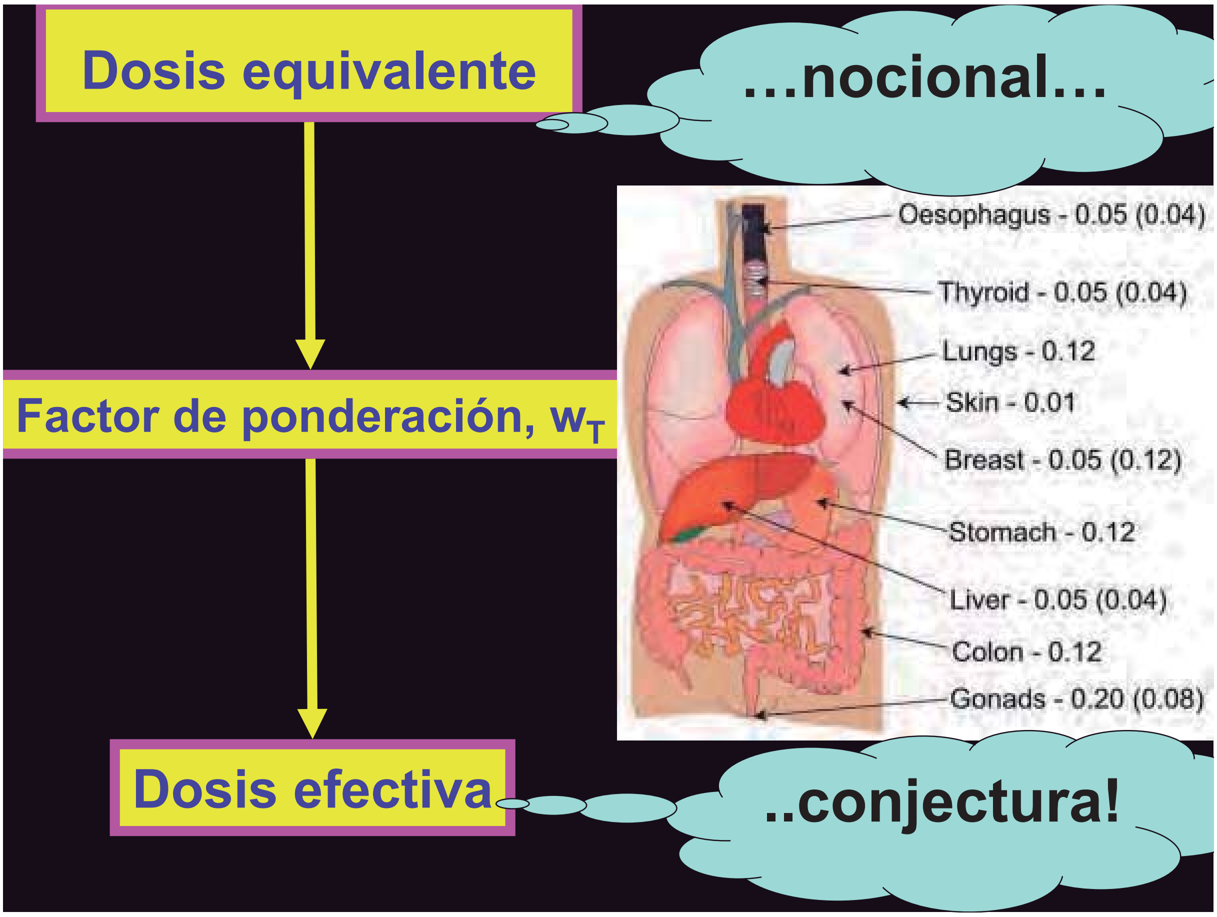
- Incluyendo una mejor distinción entre
  - magnitudes intensivas (por ejemplo, dosis) y
  - magnitudes extensivas (por ejemplo, dosis colectiva)

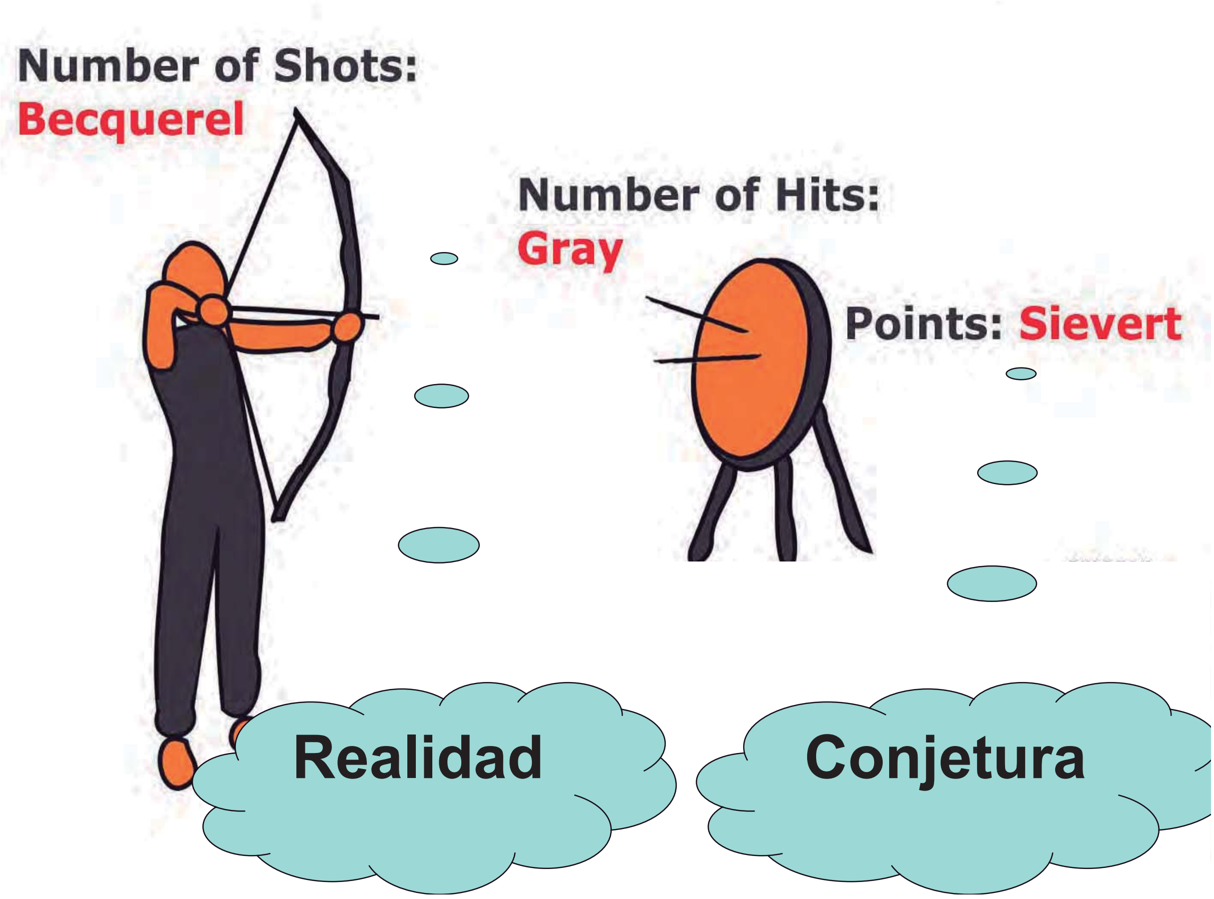
El problema epistemológico fundamental :

¿Debe utilizarse la misma magnitud y unidad (sin ninguna condición) para:

- calcular efectos atribuibles, e
- inferir riesgos conjeturales?


Dosis absorbida
..real…
Factores de ponderación , wR
Radiation type | Radiation weighting factor, w_R
Photons | 1
Electrons[a] and muons | 1
Protons and charged pions | 2
Alpha particles, fission fragments, heavy ions | 20
Neutrons | A continuous function of neutron energy
Dosis equivalente
nocional (construcción)


Dosis equivalente
…nocional…
Factor de ponderación, w_T
Oesophagus - 0.05 (0.04)
Thyroid - 0.05 (0.04)
Lungs - 0.12
Skin - 0.01
Breast - 0.05 (0.12)
Stomach - 0.12
Liver - 0.05 (0.04)
Colon - 0.12
Gonads - 0.20 (0.08)
Dosis efectiva
..conjectura!


Number of Shots:
Becquerel
Number of Hits:
Gray
Points: Sievert
Realidad
Conjetura


Dudas epistemiológicas

La gran duda epistemológica:

¿Deberían utilizarse las mismas magnitudes y unidades para cuantificar:

- efectos fácticos atribuibles en individuos,
- efectos fácticos atribuibles en cohortes
- riesgos conjeturales inferidos?

¿Es correcto utilizar las mismas magnitudes y unidades para estas tres situaciones legales tan distintas?

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¿Debería utilizarse la misma familia de "magnitudes y unidades" (sin ninguna condición) como:

- magnitudes intensivas, y
- magnitudes extensivas?

(Esto no sucede en otras áreas de la física)

Magnitudes intensivas

- Una magnitud intensiva es una magnitud física cuyo valor no depende de la cantidad de sustancia para la que se mide.

(Por ejemplo, la magnitud *temperatura*)

¡La *dosis individual* es una magnitud intensiva!

Magnitudes extensivas

- Una *magnitud extensiva* es una magnitud física cuyo valor es proporcional al tamaño del sistema que describe.

  (Por ejemp., la *energía* es una *magnitud extensiva*)

  ¡La *dosis colectiva* es una *magnitud extensiva* !

¿Es epistemológicamente correcto utilizar la magnitud *dosis* tanto para *dosis individuales* como para *dosis colectivas*?

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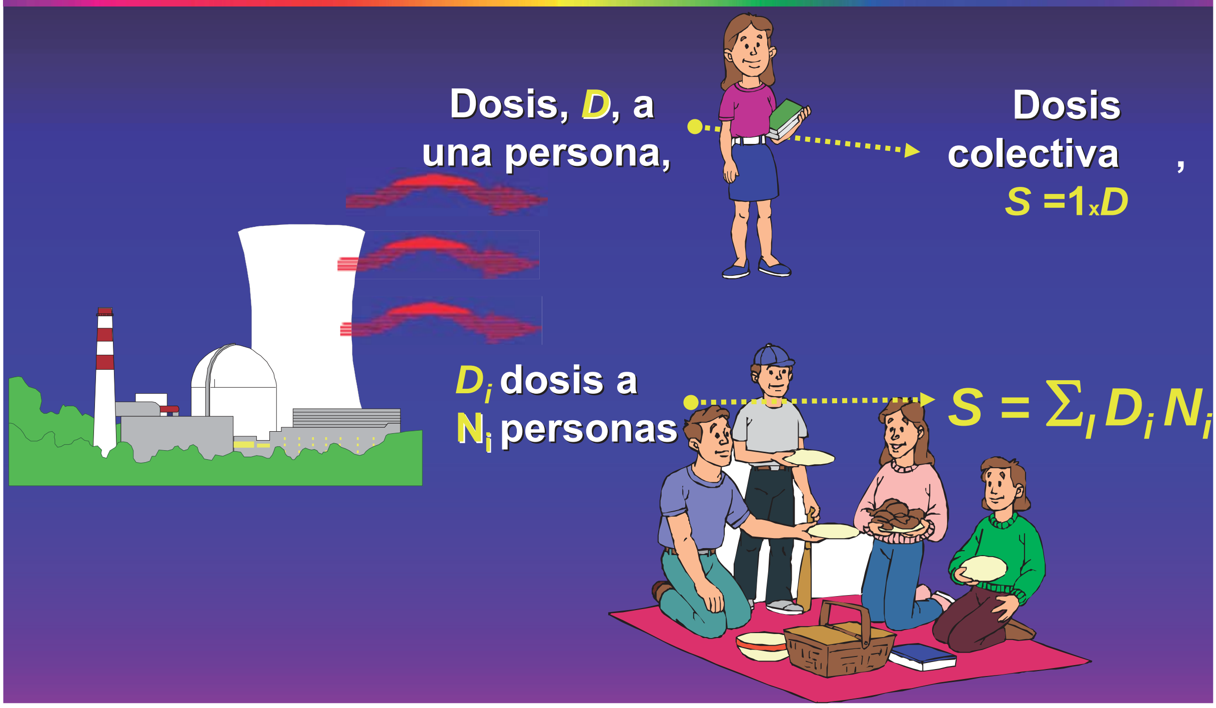
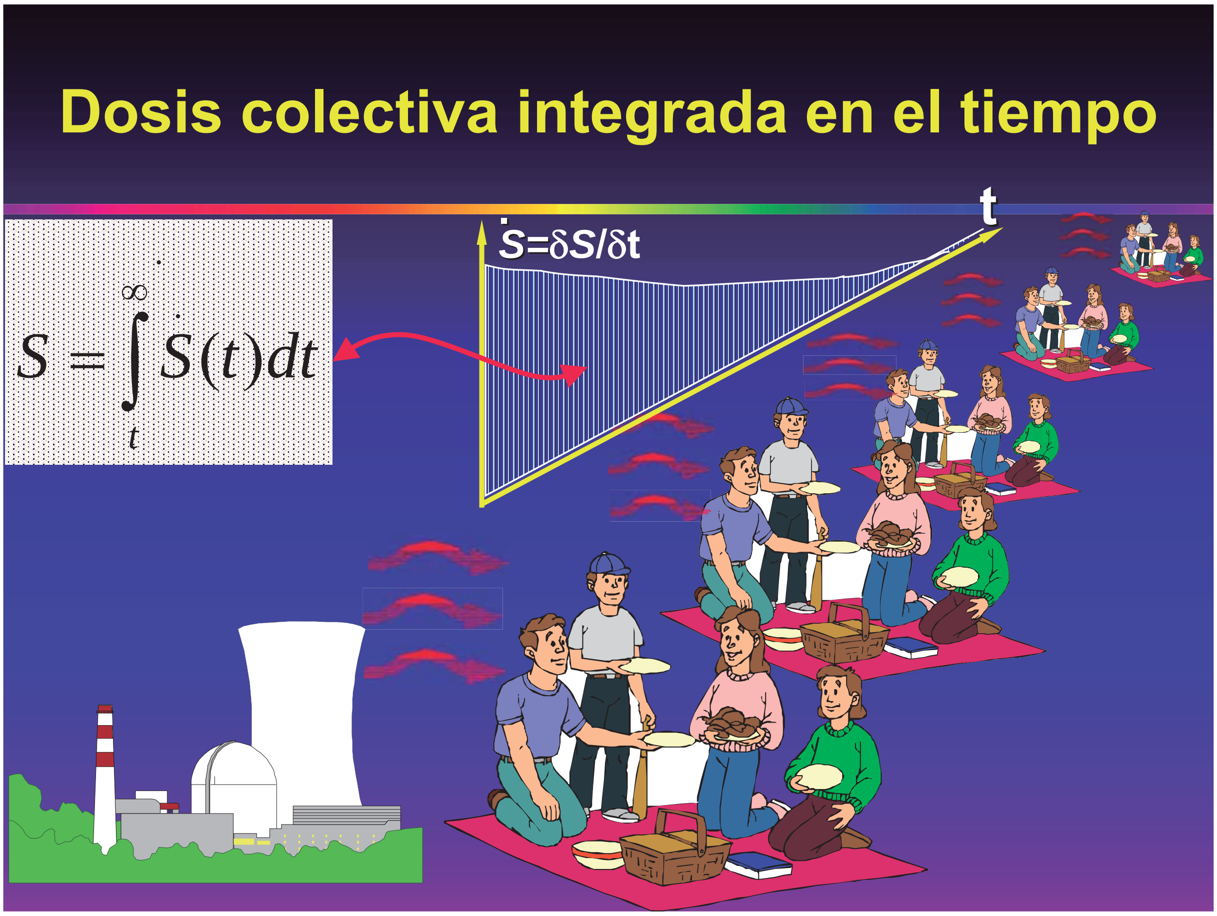
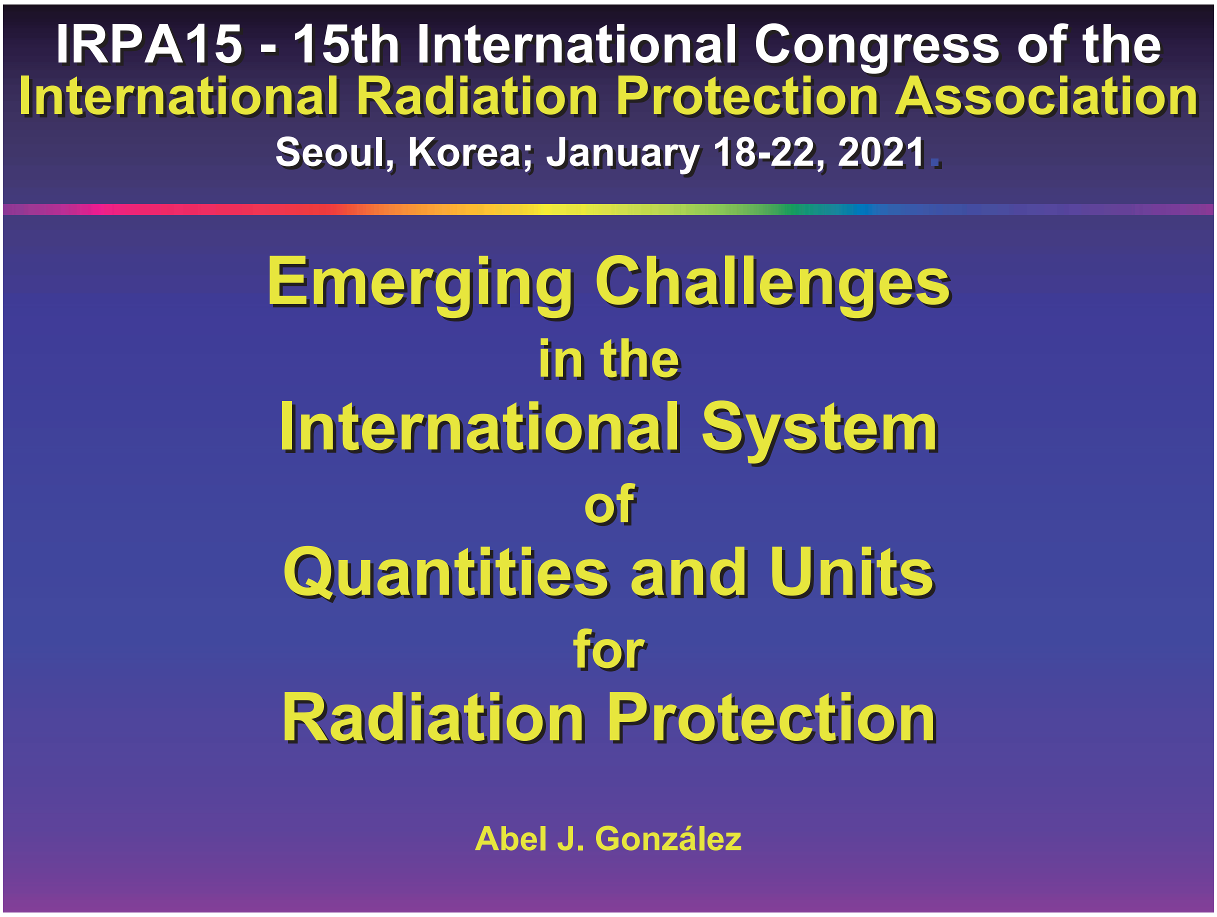
Un tema controversial

El uso de la magnitud dosis colectiva

La dosis colectiva, *S*




Dosis colectiva integrada en el tiempo
$S = \int_t^\infty \dot{S}(t)dt$
$\dot{S}=\delta S/\delta t$
t


IRPA15 - 15th International Congress of the
International Radiation Protection Association
Seoul, Korea; January 18-22, 2021
Emerging Challenges
in the
International System
of
Quantities and Units
for
Radiation Protection
Abel J. González

Tema 4:

Alcance del paradigma

Alcance (scope)

Hay que definir el alcance del paradigma:

- Describiendo exposiciones no susceptibles de protección, que deben *excluirse* del paradigma.
- Analizando exposiciones con protección optimizada, que deben ser *exentas* del paradigma.

Radiación Natural

- La exposición a la radiación natural básicamente no se consideró al construir el paradigma.
- Este lapsus original debe corregirse.
- Las NORMs necesitan una consideración especial.

‘Contaminación’

El miedo a la "contaminación" ha causado daños psicológicos y estragos económicos

- Contaminación de la superficie
- Contaminación residual
- Contaminación de bienes de consumo

¿Qué nivel de “contaminación” puede ser excluido del paradigma?

¡Ha llegado el momento de que el paradigma aborde este problema con claridad!

IRPA15 - 15th International Congress of the International Radiation Protection Association
Seoul, Korea; January 18-22, 2021.

Radioactivity in Goods Supplied for Public Consumption or Use: Towards an Internationally Harmonized Regulatory Framework

Abel J. González

Tema 5:

Las situaciones de exposición

Tipos de situaciones de exposición

- Situaciones de exposición planificada
- Situaciones de exposición de emergencia
- Situaciones de exposición existente

Situaciones de exposición planificada

Situaciones de exposición planificada

- Son aquéllas que involucran la introducción y la operación planificada de fuentes de exposición a la radiación.

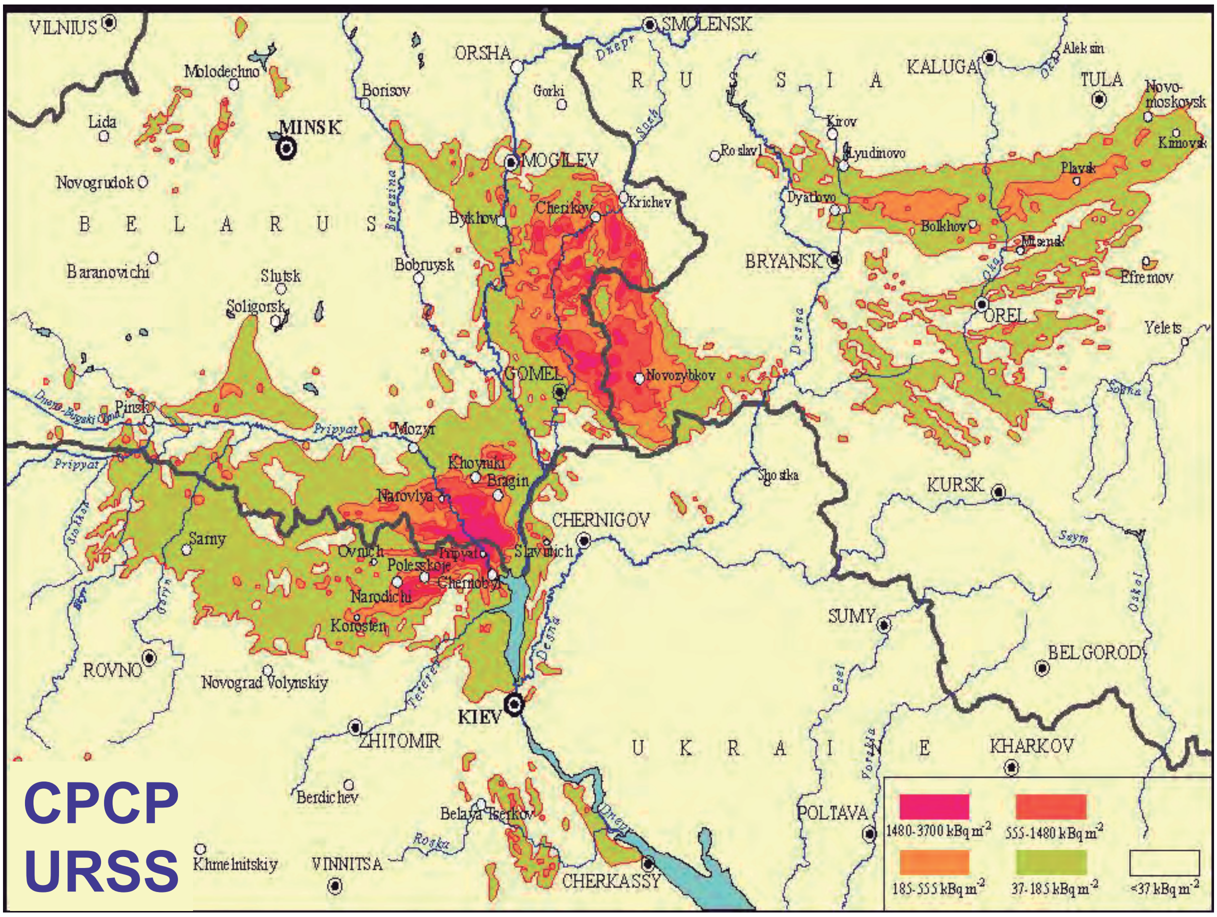
(Clasificadas previamente como *prácticas*.)

Situaciones de exposición de emergencia

Situaciones de exposición de emergencia

- **Son situaciones inesperadas de exposición que demandan una atención urgente,**

  (como las que pueden ocurrir durante la operación de una situación planificada o como consecuencia de un acto malévolo).



Situaciones de exposición existente

Situaciones de exposición existente

- Son definidas como estados de exposición que ya existen cuando tiene que ser tomada una decisión sobre su control.

‘Existing’ ó ‘Extant’

- En castellano ‘ser’ y ‘estar’ son diferentes

La situación de exposición que ES

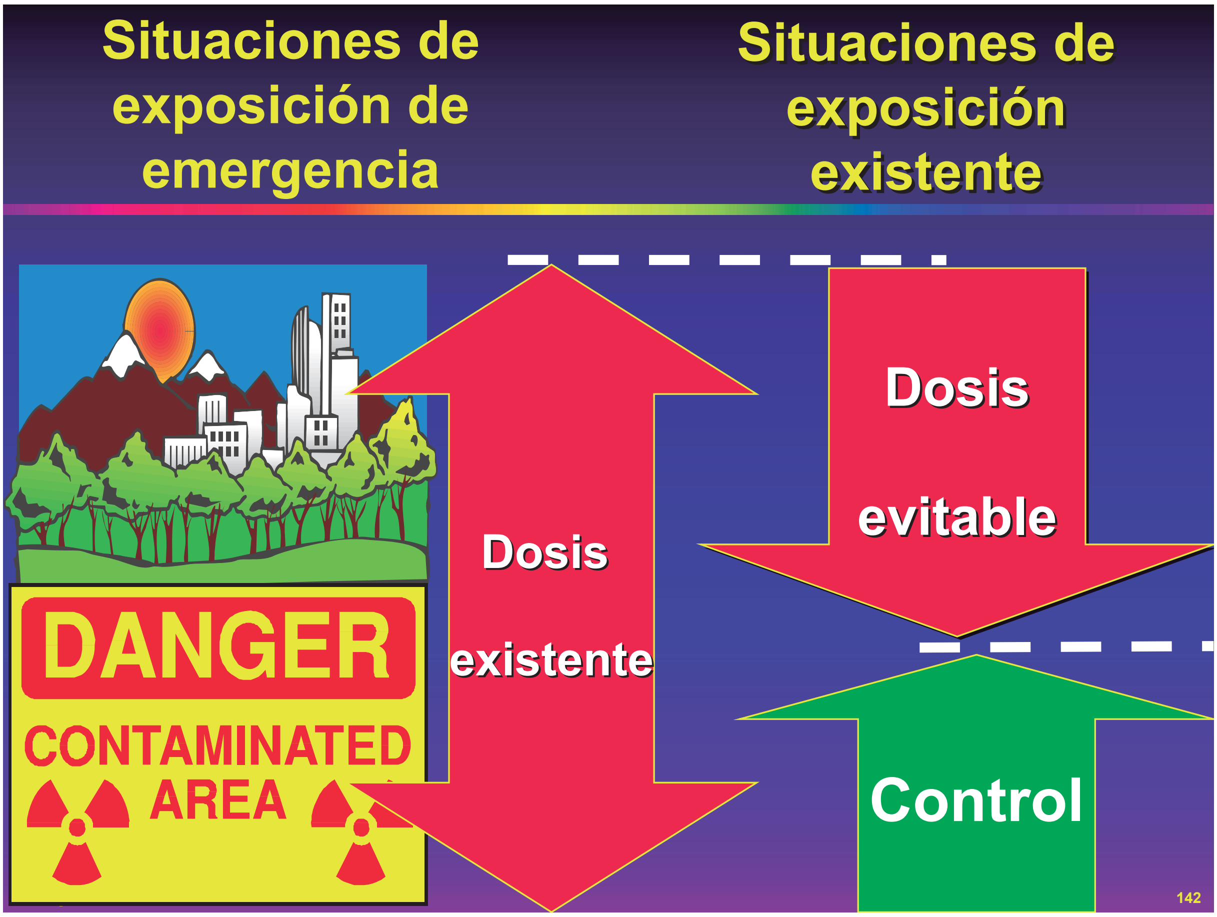
(y existe de siempre, por ejemplo rayos cósmicos)

es distinta a

la situación de exposición que ESTÁ

(no siempre, p ej. exposición residual de Fukushima)


Del aire que respiramos.
Unos 30.000 átomos se desintegran cada hora en los pulmones.
Del espacio.
Unos 100.000 neutrones y 400.000 partículas de los rayos cósmicos cada hora nos llegan al cuerpo
De los alimentos
Unos 15.000.000 átomos de potasio-40. Unos 7.000 átomos de uranio se desintegran cada hora en nuestro cuerpo.
Del suelo y los edificios.
Unos 200.000.000 de fotones gamma llegan al cuerpo cada hora.


Situaciones de exposición de emergencia
Situaciones de exposición existente
DANGER
CONTAMINATED AREA
Dosis existente
Dosis evitable
Control
142

Tema 6:

Los principios fundamentales

Principios Fundamentales

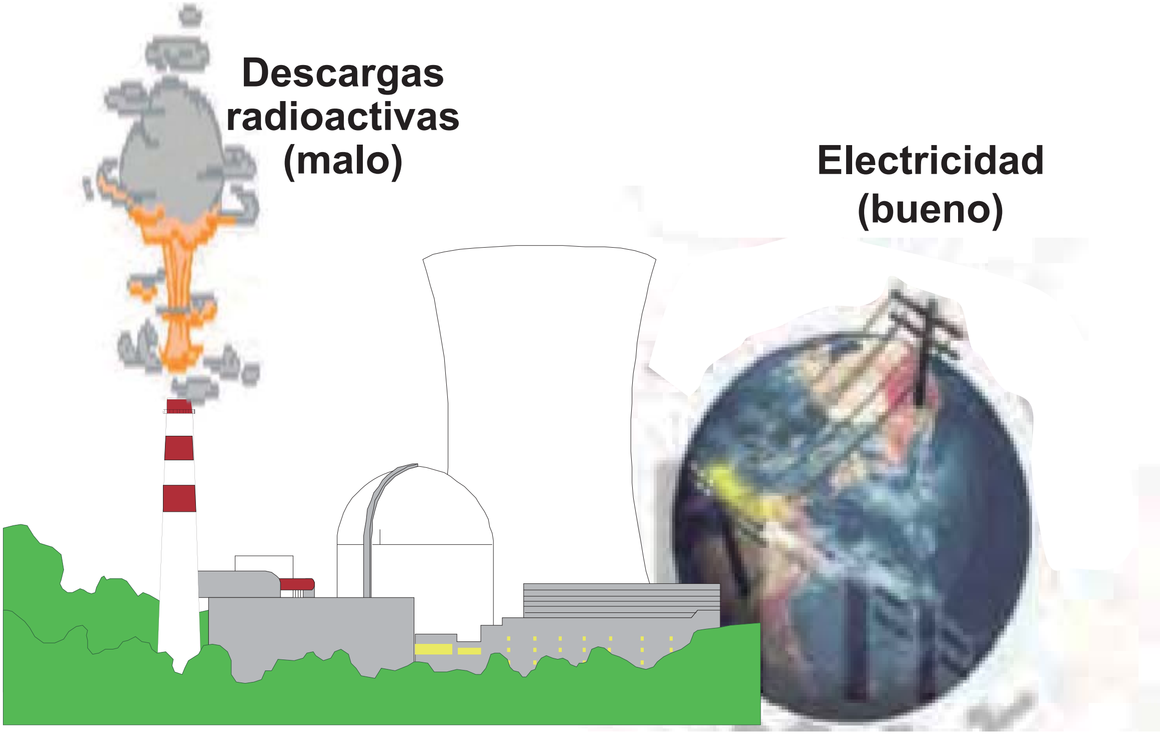
- Principio de justificación
- Principio de optimización de la protección
- Principio de limitación de dosis individuales

- Principio de la prudencia hacia de las generaciones futuras y el medio ambiente

Principio de justificación

- **Cualquier decisión que altere la situación de exposición a la radiación debería ocasionar más beneficio que daño.**

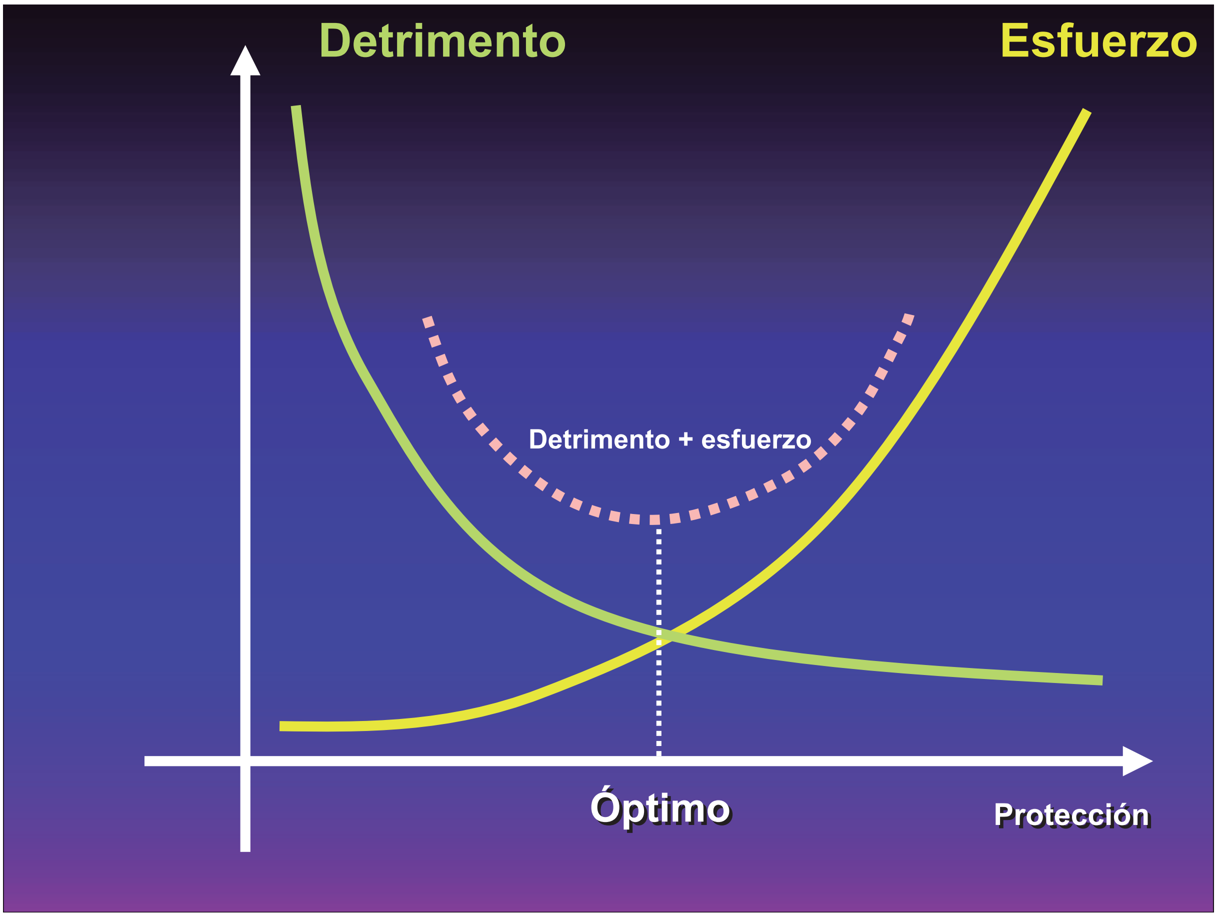
Beneficio > Detrimento



Bueno > Malo

Principio de optimización

- El nivel de protección contra la radiación debe ser el mejor para las circunstancias prevalecientes, maximizando el margen de beneficio a daño.



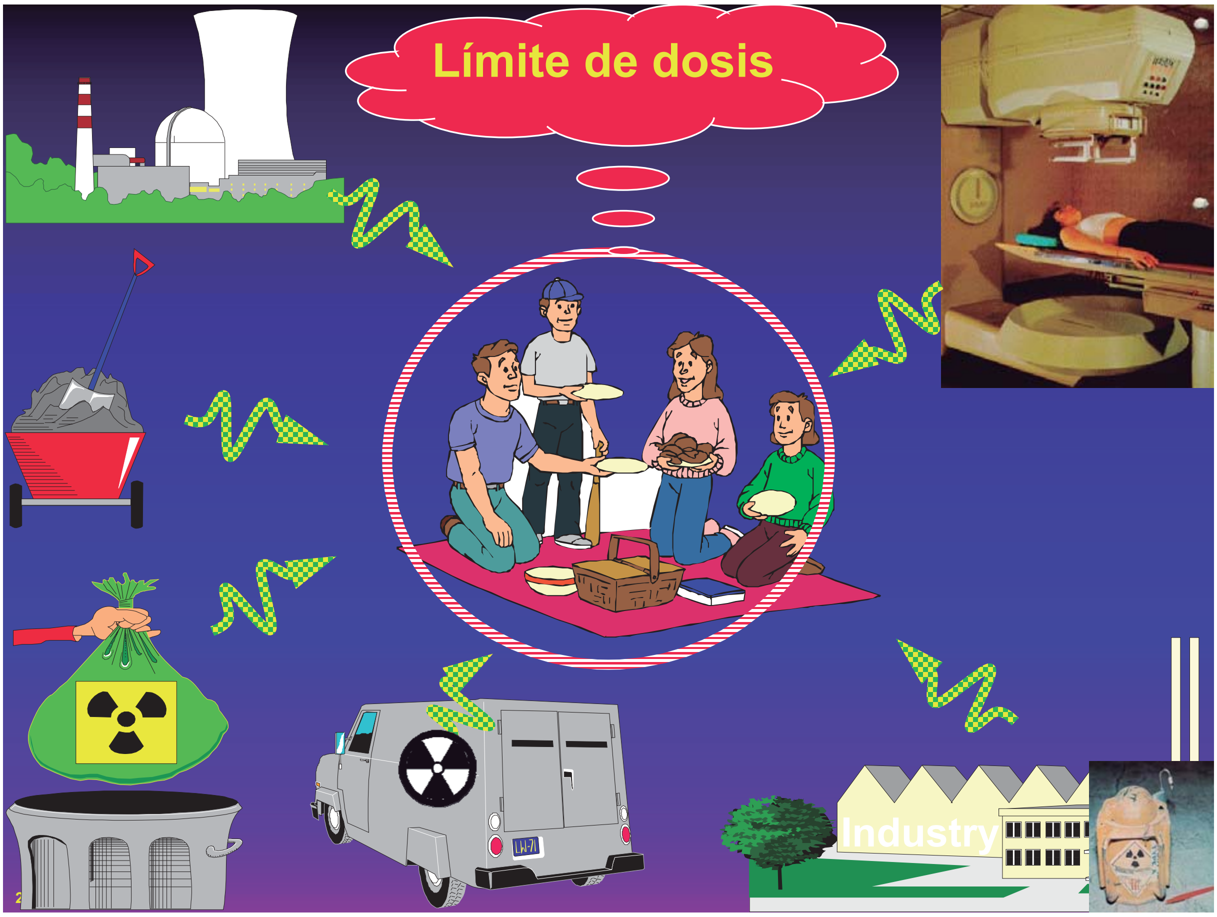
Principio de limitación de dosis

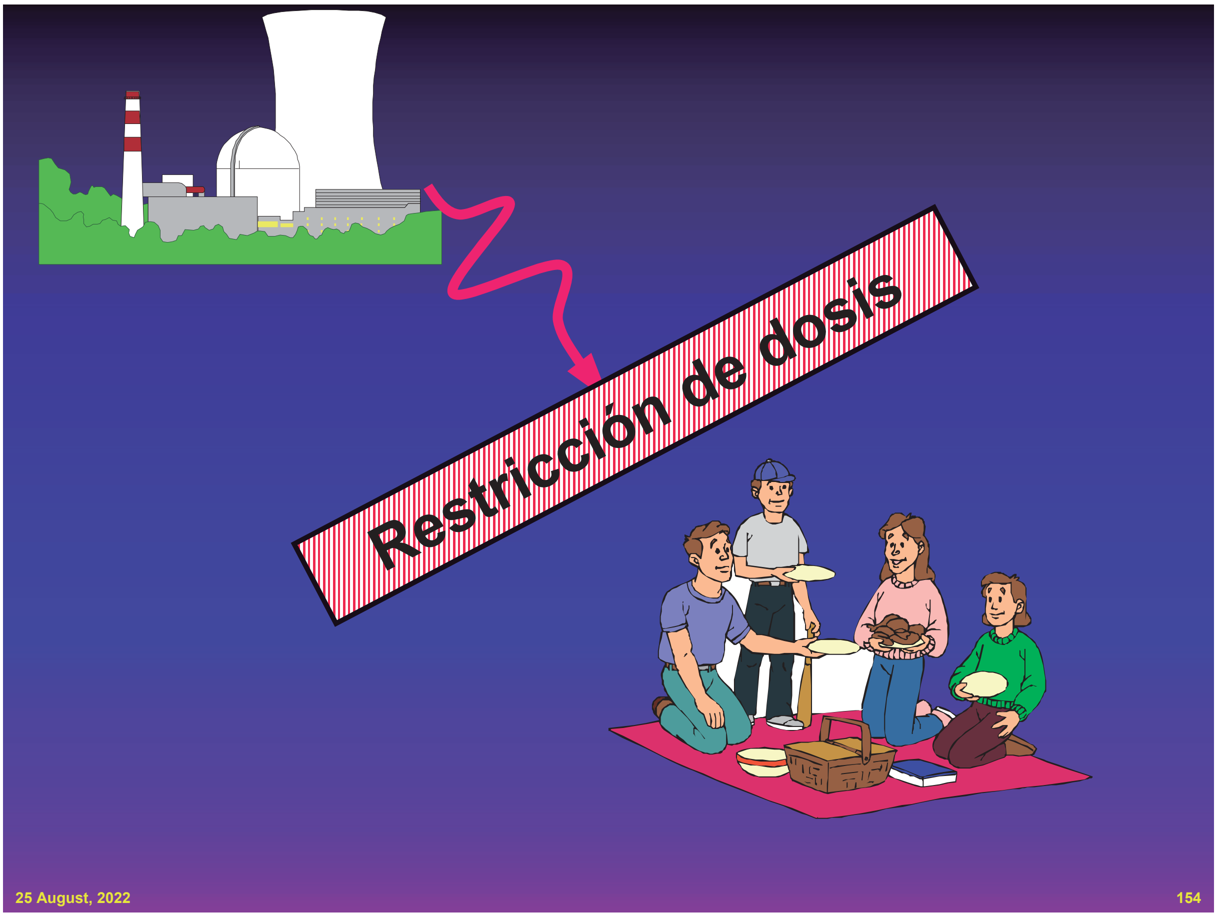
- La dosis total incurrida por cualquier individuo, debida a fuentes controladas en situaciones de exposición planificada (excepto la exposición médica como paciente), no debe exceder límites apropiados y predeterminados.

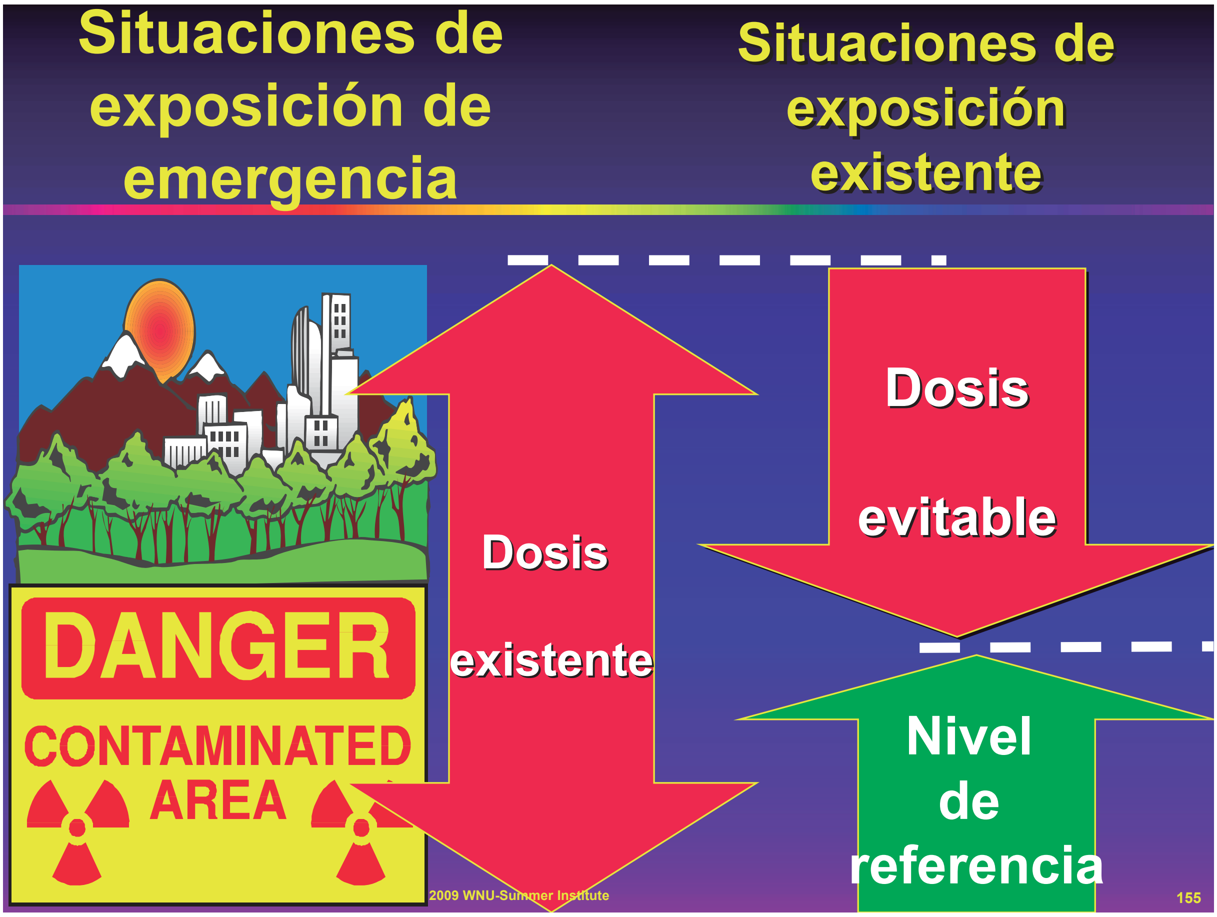
Fuentes controladas en situaciones de exposición planificada

Límite de dosis

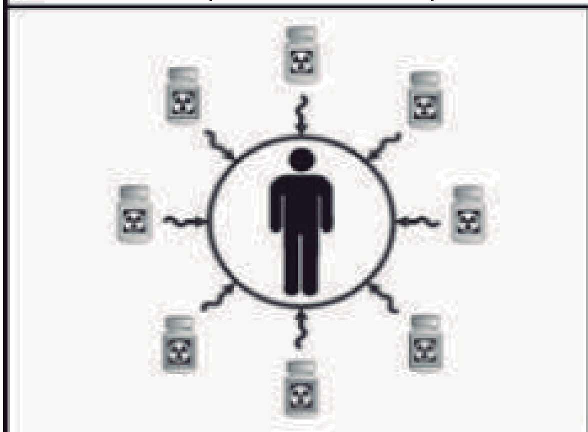
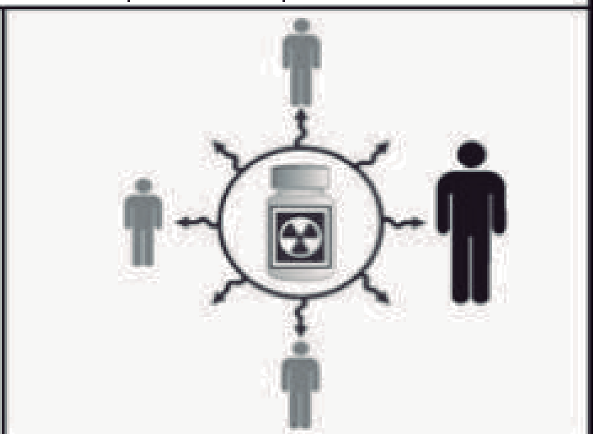
- El valor de la dosis efectiva o la dosis equivalente recibida por individuos que no debe ser excedido a causa de todas las exposiciones planificadas.


Límite de dosis
Industry


Restricción de dosis
25 August, 2022
154



Límites de dosis vis-à-vis restricciones de dosis y niveles de referencia

Limites de dosis	Restricciones y niveles de referencia
Proteger al trabajador de la exposición ocupacional y a la Persona representativa de la exposición al público	
	
De todas las fuentes reguladas en situaciones de exposición planificada	De una fuente en todas las situaciones de exposición

Sugerencia
Revisar el concepto de limite de dosis

La gran confusion sobre los ‘límites’ de dosis

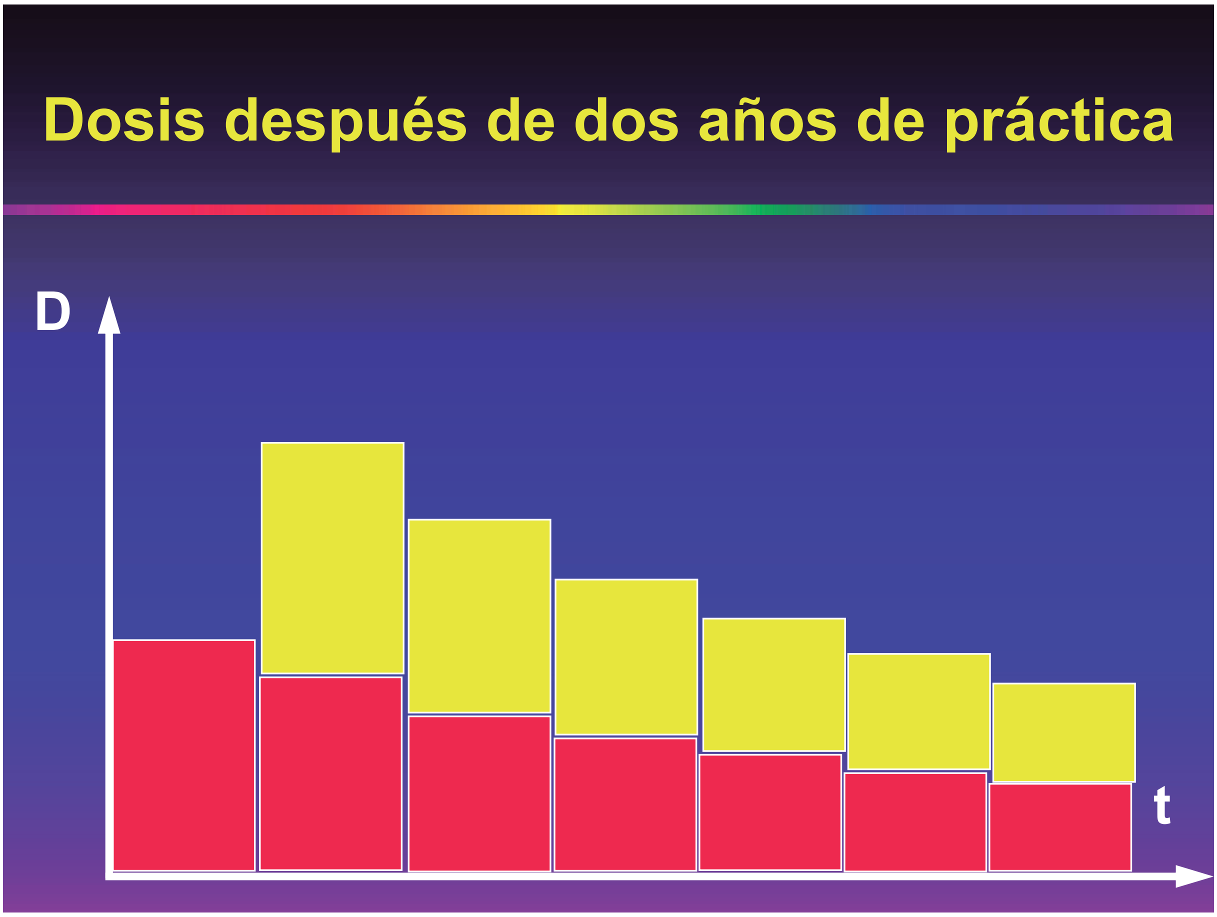
- Los "límites" de dosis no ajustan a la comprensión del concepto de "límite“
  - No son un punto terminal, más allá del cual no debe pasar una dosis personal.
- Es necesaria una revisión profunda de este concepto, y de la lógica detrás del 1mSv/año.

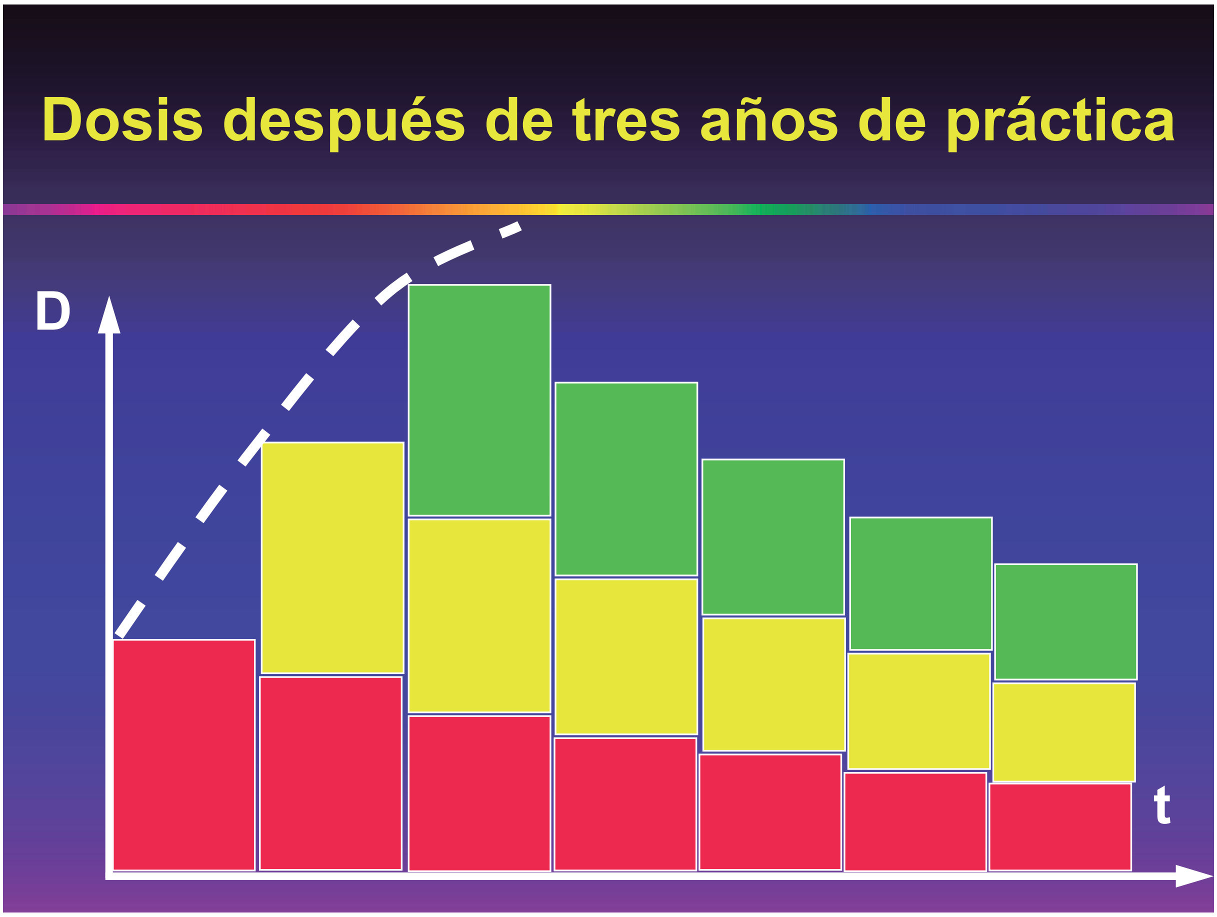
Principio de prudencia hacia las generaciones futuras y el medio ambiente

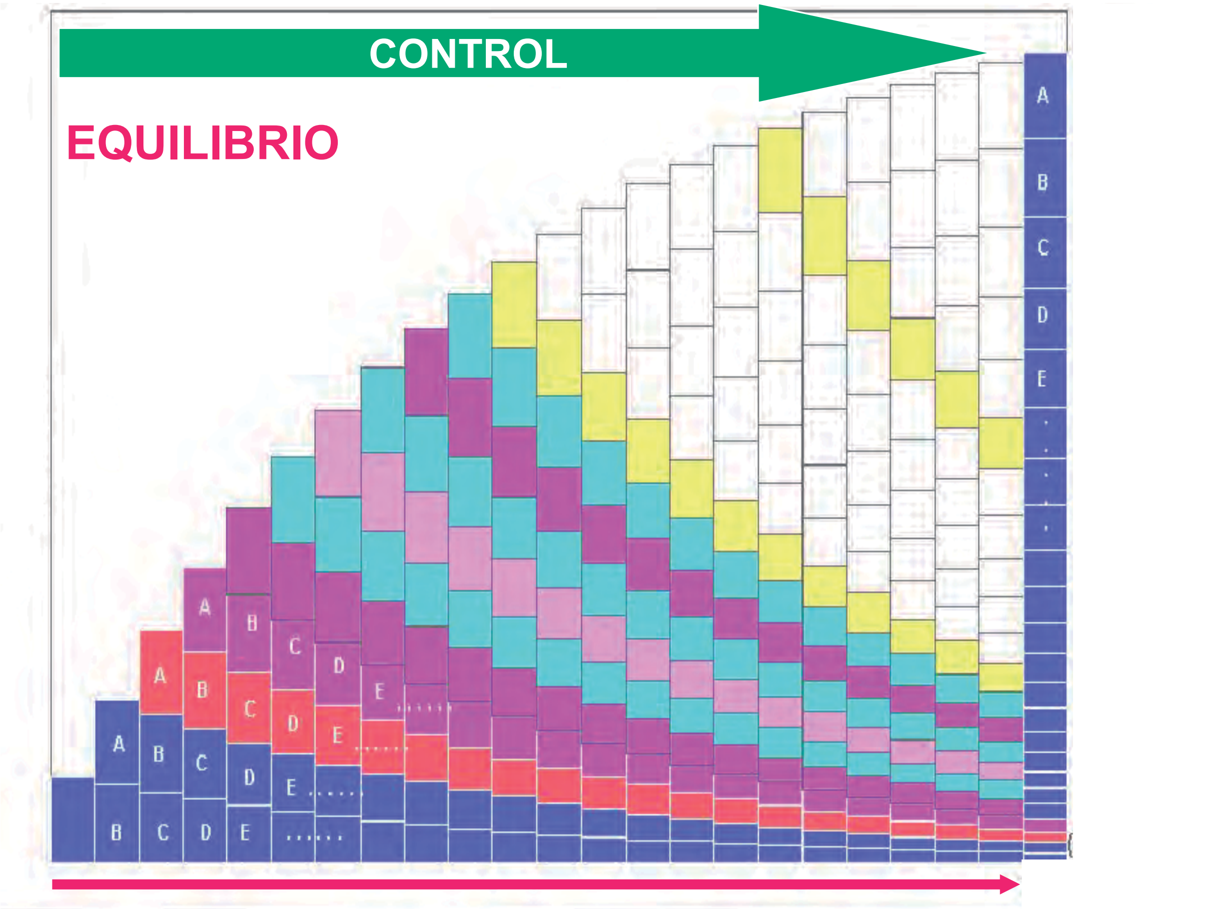
- Las personas y el medio ambiente, no solo del presente sino también del futuro, deben protegerse contra riesgos plausibles.

Protección de las generaciones futuras

Dosis después de un año de práctica


Dosis después de dos años de práctica
D
t


Dosis después de tres años de práctica
D
t



Protección
del
medio ambiente

Pricipios de protección del medio ambiente

- mantener la diversidad biológica,
- asegurar la conservación de las especies, y
- proteger la salud y estado de los hábitats naturales y de las comunidades y ecosistemas.

Se debe especificar sobre qué fundamentos éticos se basan los principios del paradigma

Ética

Conjunto de *principios morales* que gobiernan o influencian nuestra conducta

Etica

- Debe describirse la ética sobre la cual se basan los principios.

(La Publicación 138 de la ICRP trata sobre valores más que sobre ética)

- Se sugiere la siguiente descripción:

Doctrines sobre ética

- **Ética teolológica**
  (ética de las consecuencias)
- **Ética utilitaria**
  (ética de la efectividad)
- **Ética deontológica**
  (ética del deber)
- **Ética areática**
  (ética de la virtud)

Ética teolológica
(ética de las consecuencias)

Epigrama:

"El fin justifica los medios"

'Vale más hacer y arrepentirse, que no hacer y arrepentirse.'
Maquiavelo

Ética utilitaria
(ética de la efectividad)

Epigrama:

"Consigue el mayor beneficio para la mayor cantidad de personas"

Ética deontológica
(ética del deber)

Epigrama:

"No hagas a los otros lo que no te gustaría que te hicieran a ti "

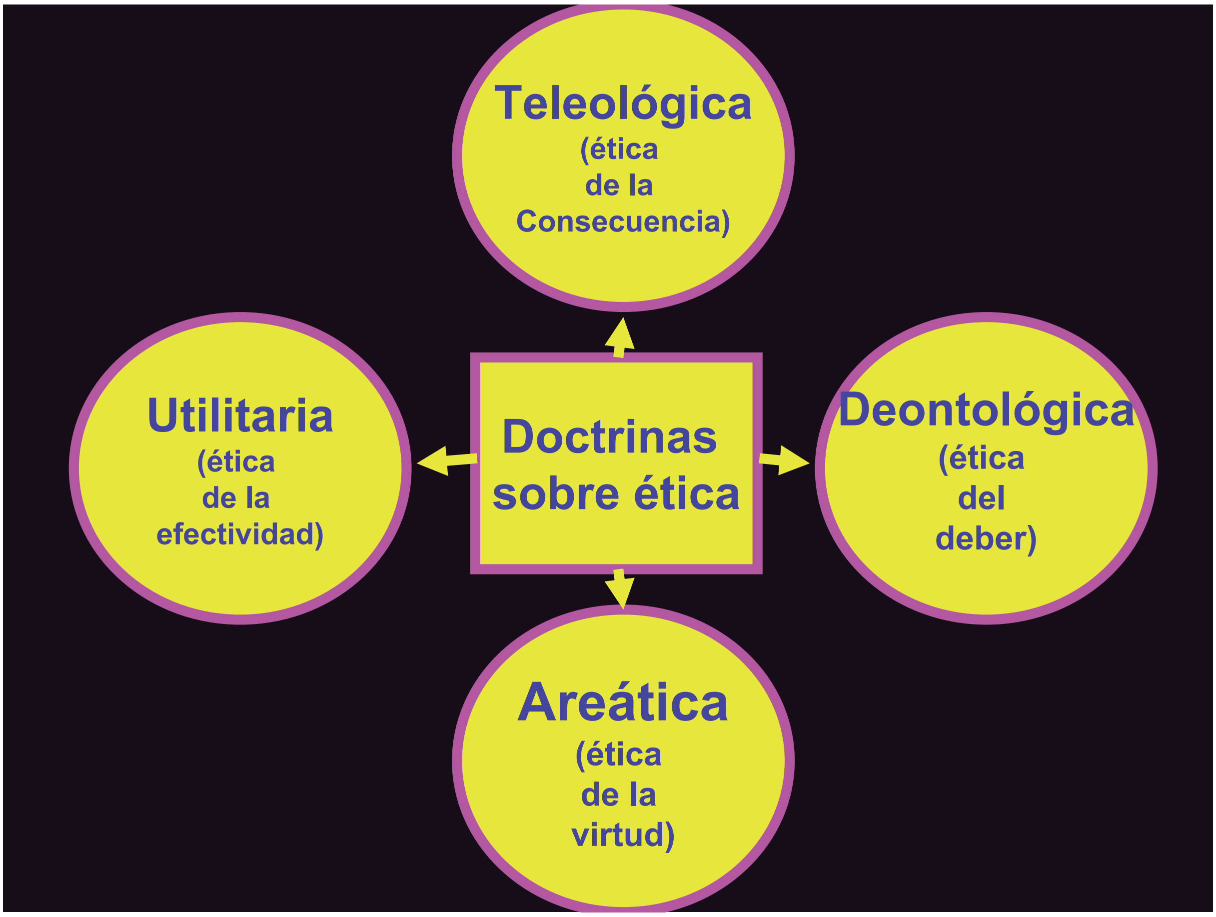
Confucio

Ética areática
(ética de la virtud)

Epigrama:

"La virtud está en hacer beneficios que sin duda no van a ser correspondidos."

Seneca



Teleología & Justificación

- Los fines o las consecuencias de una acción que involucre la exposición a la radiación son los que deben determinar su moralidad, es decir se debe determinar si tal acción es beneficiosa o perjudicial
- Cualquier decisión que altere una situación de exposición a la radiación debe hacer más bien que mal

Utilidad & Optimización

- La moralidad de una acción de protección deben ser juzgada en relación a su contribución a la utilidad general; es decir, a que produzca el mayor bienestar a la sociedad.
- El nivel de protección contra la radiación debe ser el mejor para las circunstancias prevalecientes, maximizando el margen de beneficio a daño

Deontología & Límites Individuales

- La moralidad de la protección debe ser juzgada por la bondad o rectitud de las acciones de protección sobre los individuos, y no sólo por sus consecuencias generales o utilidad social.
- La desigualdades individuales que podrían causar las acciones justificadas y la opción de protección optimizada debe ser prevenidas mediante la restricción de las dosis individuales (con límites de dosis, restricciones y niveles de referencia)

Areatismo & Futuro

- La moral de las acciones de protección debe ser su juzgada por su (arête) virtuosismo y no sólo por sus consecuencias, utilidad u obligaciones individuales
- Se debe proteger, no solo a la generación presente sino también a las futuras y a su medio ambiente, contra daños radiológicos que sean científicamente plausibles aunque no fueran certeros.


Justificación
↔
Teleología
Optimización
↔
Utilidad
Ética
de la
Protección
Limitación
↔
Deontología
Futuro
↔
Areática


Justificación
↔
Teleología
Optimización
↔
Utilidad
Ética
de la
Protección
Limitación
↔
Deontología
Futuro
↔
Areática

Tema 7

Las categorías de exposición

Categorías de exposición

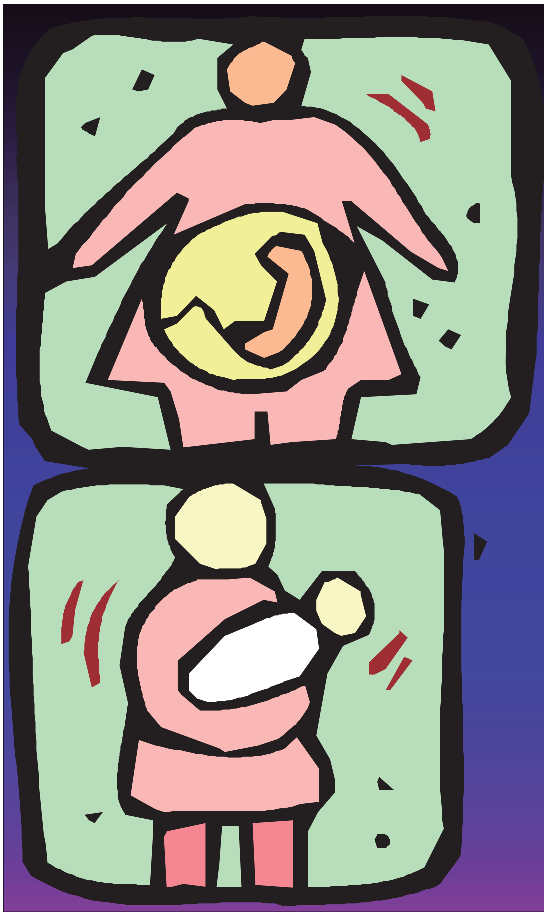
- exposición ocupacional
- exposición del público, y
- exposiciones médicas

(de pacientes y cuidadores-confortadores y voluntarios)

Occupational exposure

Debería revisarse, con la OIT, para considerar, entre otros, los siguientes casos de exposición ocupacional:

- Radiación natural
- Trabajadores de otras diciplinas
- Trabajadores voluntarios
- Respondedores



El trabajador femenino: protección especial para los bebes *in utero* y los lactantes

Exposición del público

- **Exposición incurrida por los miembros del público procedente de fuentes de radiación, en adición a la debida a la radiación natural local normal y a cualquier exposición ocupacional o médica.**

Recomendaciones para la protección del público

Protección para

actividades planificadas

(Prácticas)

Requerimiento:

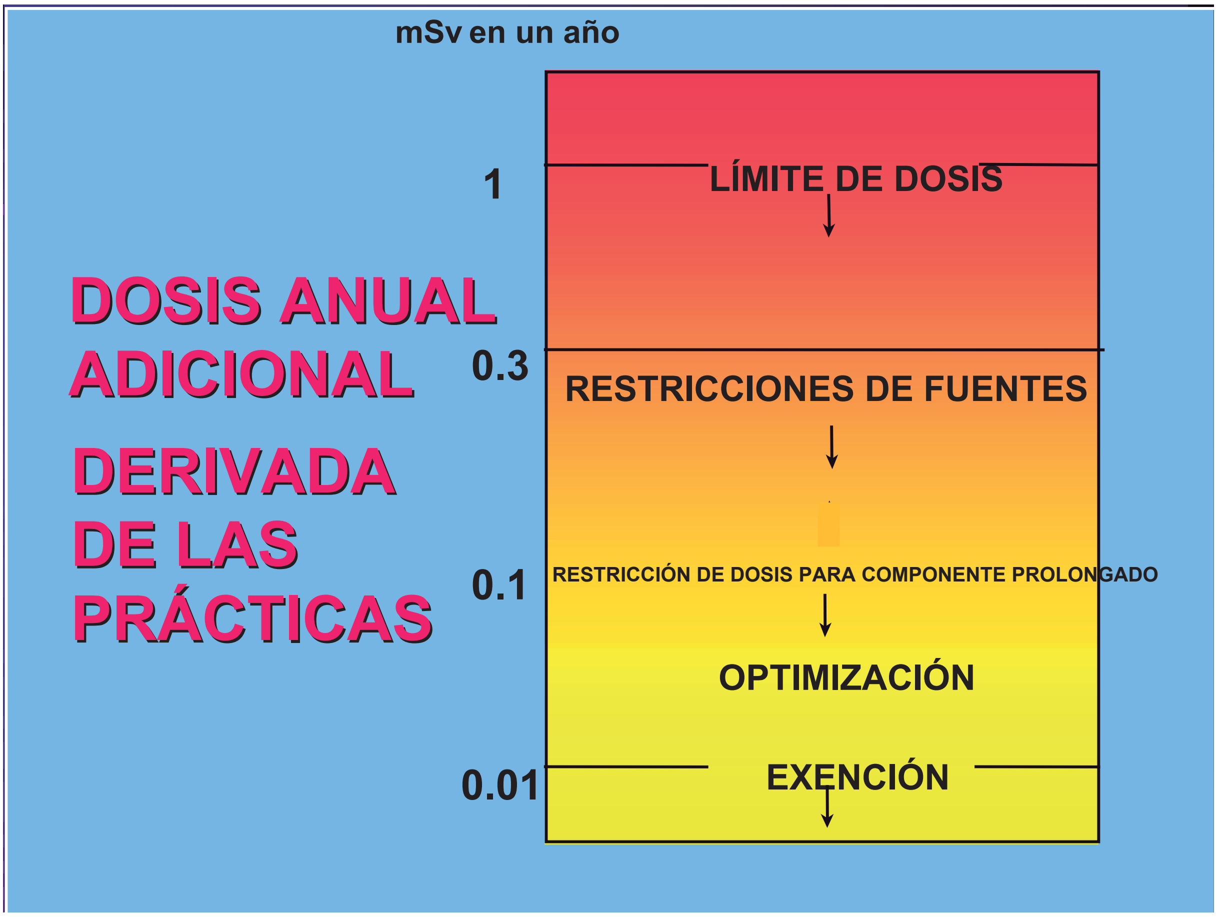
Limitar las dosis adicionadas

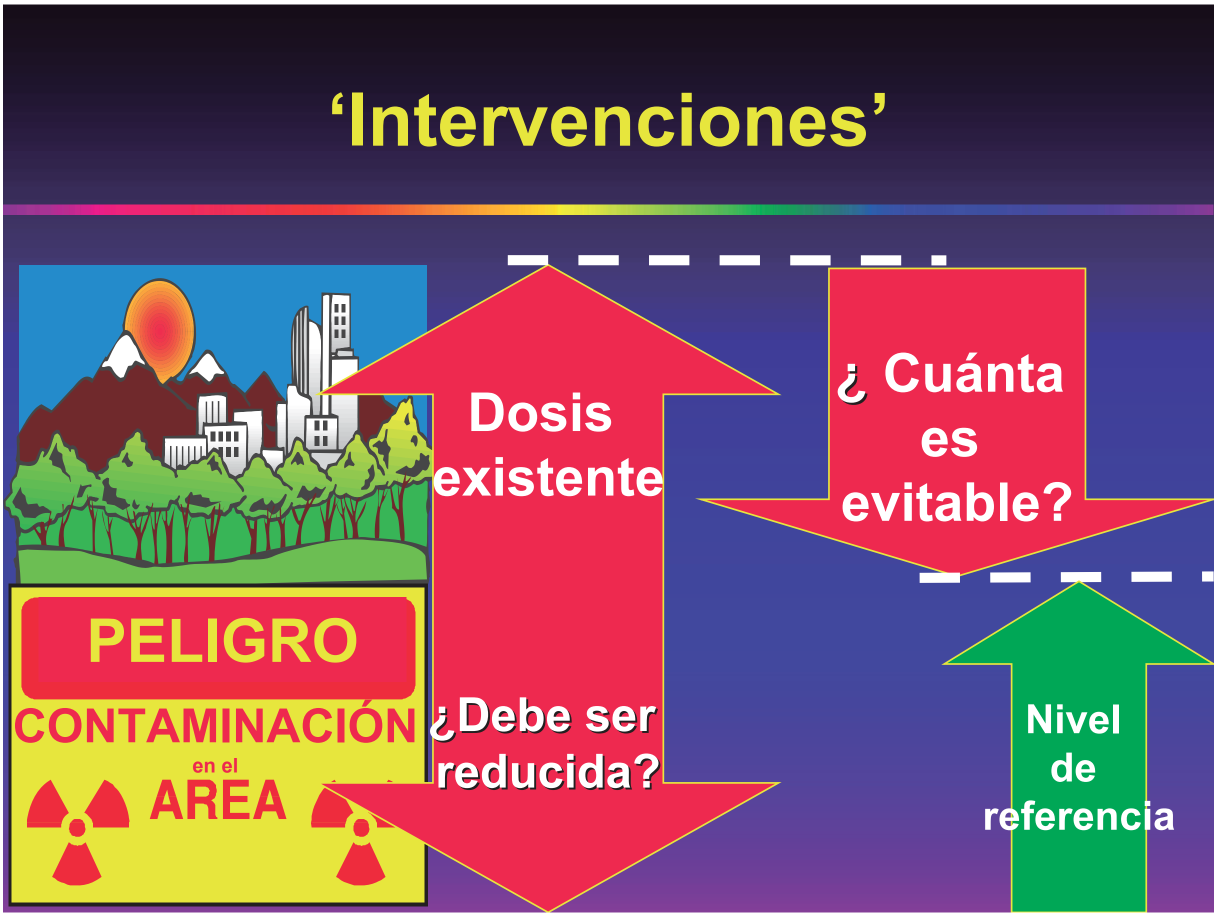
Protección para **situaciones existentes y emergencias**

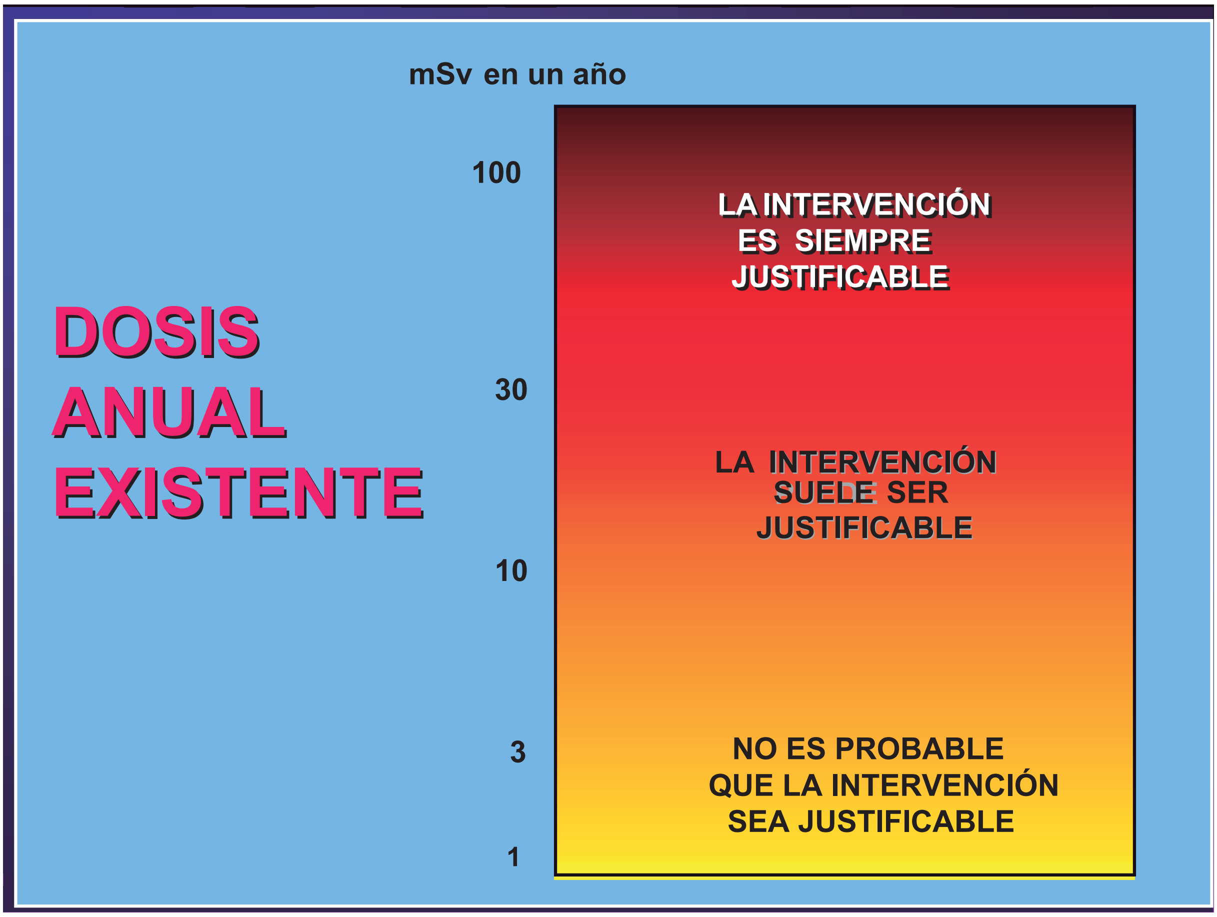
(Intervenciones)

Requerimiento:

Reducir las dosis existentes evitables




'Intervenciones'
Dosis existente
¿Debe ser reducida?
¿ Cuánta es evitable?
Nivel de referencia
PELIGRO
CONTAMINACIÓN
en el
AREA


mSv en un año
100
30
10
3
1
DOSIS ANUAL EXISTENTE
LA INTERVENCIÓN ES SIEMPRE JUSTIFICABLE
LA INTERVENCIÓN SUELE SER JUSTIFICABLE
NO ES PROBABLE QUE LA INTERVENCIÓN SEA JUSTIFICABLE

Resumen de las recomendaciones de la ICRP: Sistema unificado con restricciones de dosis individuales (en mSv / año)

100 — SIN BENEFICIO INDIVIDUAL O A LA SOCIEDAD
- Trabajadores en emergencias
- Evacuación/relocación en emergencias
- Alto nivel de exposiciones existentes
- Información, entrenamiento, monitoreo

20 — BENEFICIO DIRECTO O INDIRECTO AL INDIVIDUO
- Exposición Ocupacional
- Emergencias: cubierta, profilaxis con iodo
- Exposiciones existentes (radón)
- Confortadores de pacientes
- Información, entrenamiento, evaluación

1 — BENEFICIO DIRECTO A LA SOCIEDAD O AL INDIVIDUO
- Situaciones normales
- No información o entrenamiento
- No evaluación de dosis individual

0.01 — Valor mínimo de cualquier restricción

La Exposición Médica

- Pacientes
- Medicos y enfermeras (ocupacional)
- Confortadores
- Voluntarios en la Investigación Biomédica

Exposición ‘médica’

Las exposiciones médicas deben disecarse:

- Separando y dividiendo las exposiciones de los pacientes en:
  - Exposiciones de diagnóstico del paciente, y
  - Exposiciones de tratamiento del paciente

(incluido el problema de la exposición adventicia y la protección contra neoplasias malignas secundarias).

- Separando en categorías independientes:
  - Exposición de confortadores y
  - Exposición de voluntarios en investigación médica

IRPA15 - 15th International Congress of the

International Radiation Protection Association

Seoul, Korea; January 18-22, 2021

Considerations on Potential Regulatory Actions for

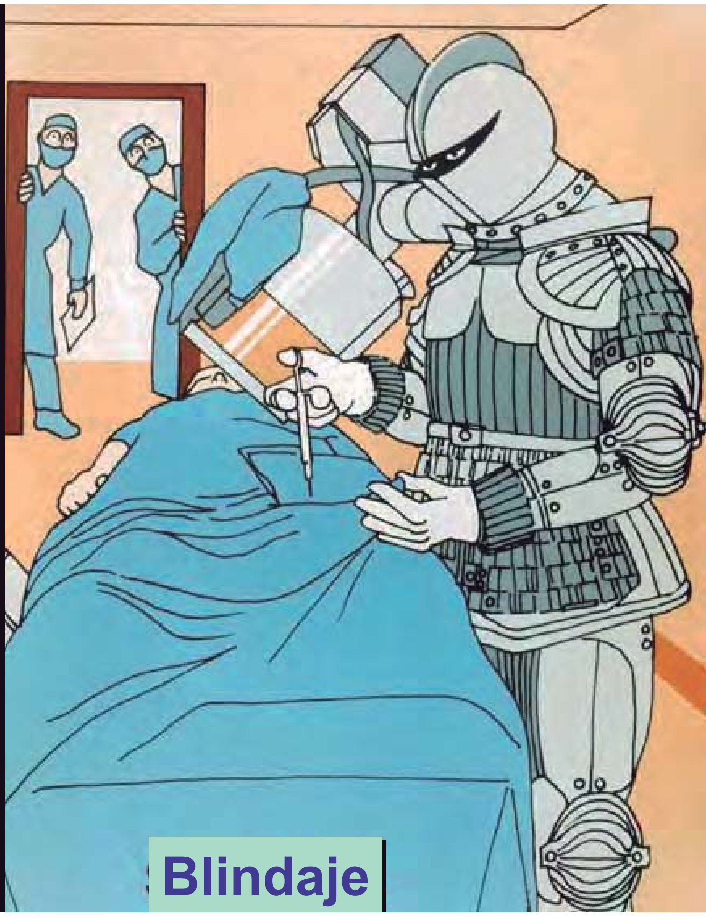
Radiation Protection in Radiotherapy:

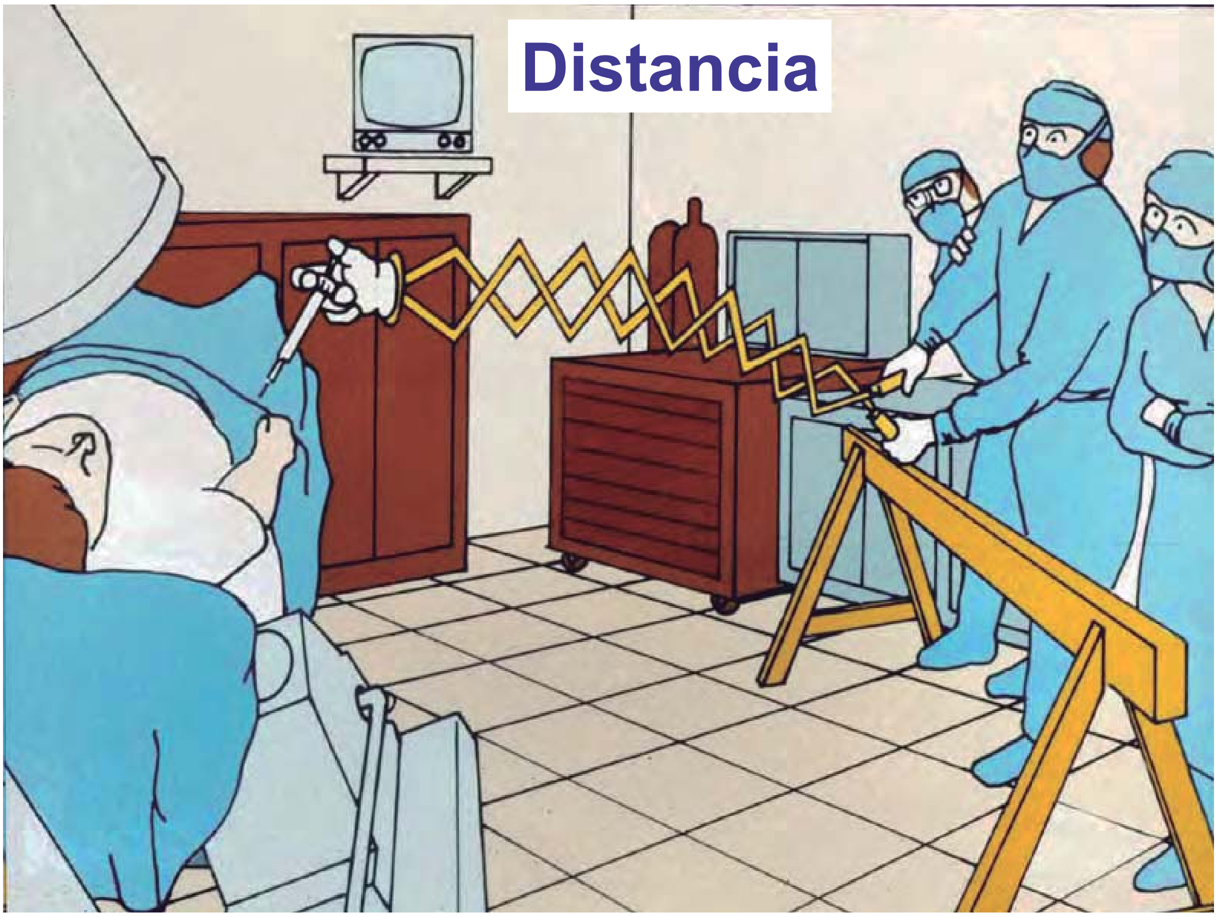
Monitoring Unwanted Radiation Exposure in Radiotherapy

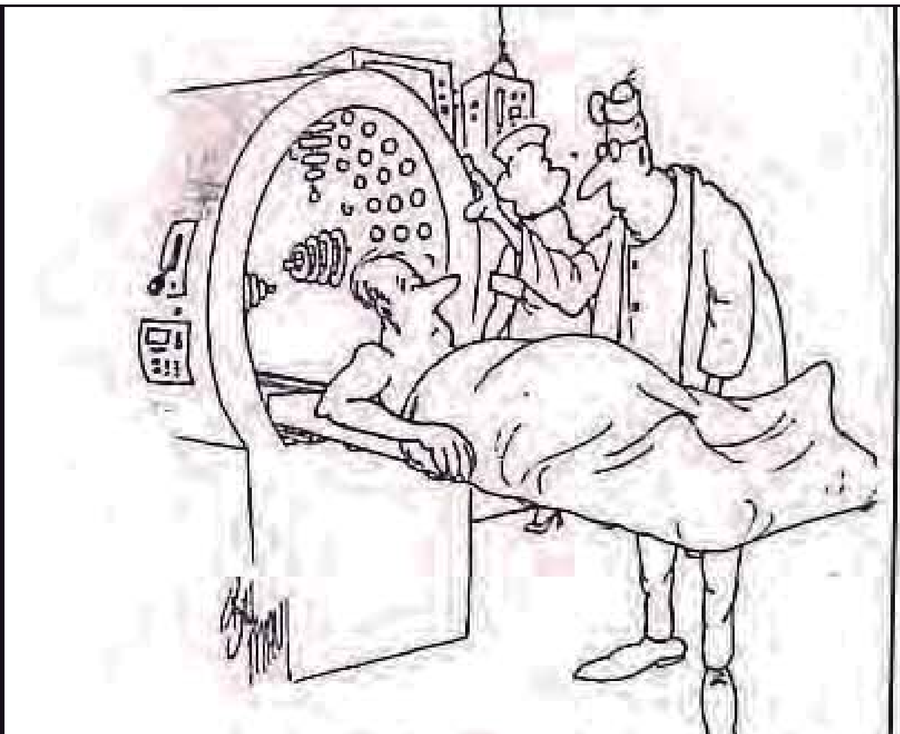
Abel J. González

¿Exposición médica?....o….*ad-hoc* paradigma

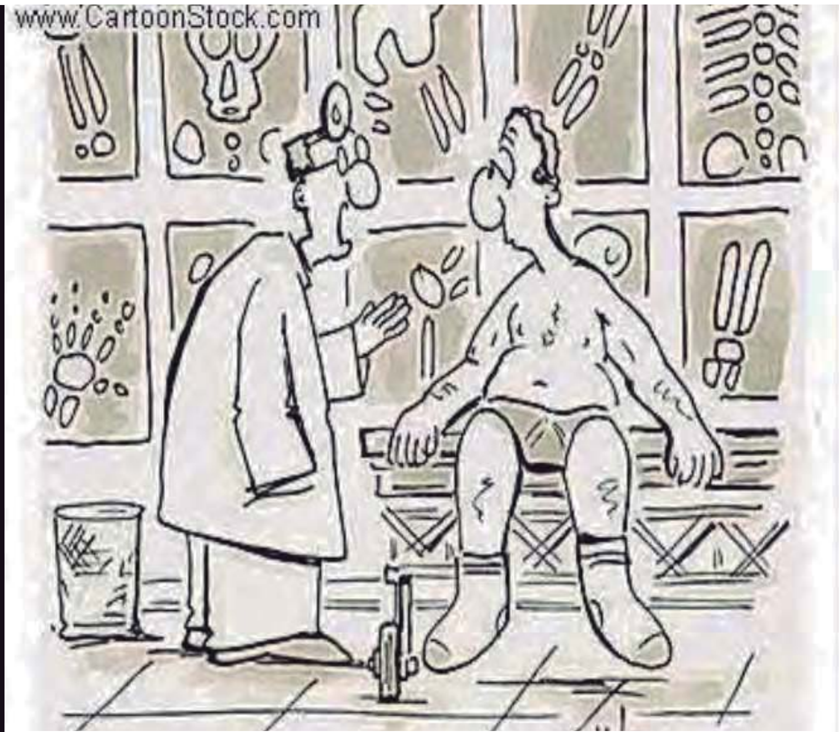
…pero no olvidemos que la protección en medicina siempre tendrá dificultades insalvables…



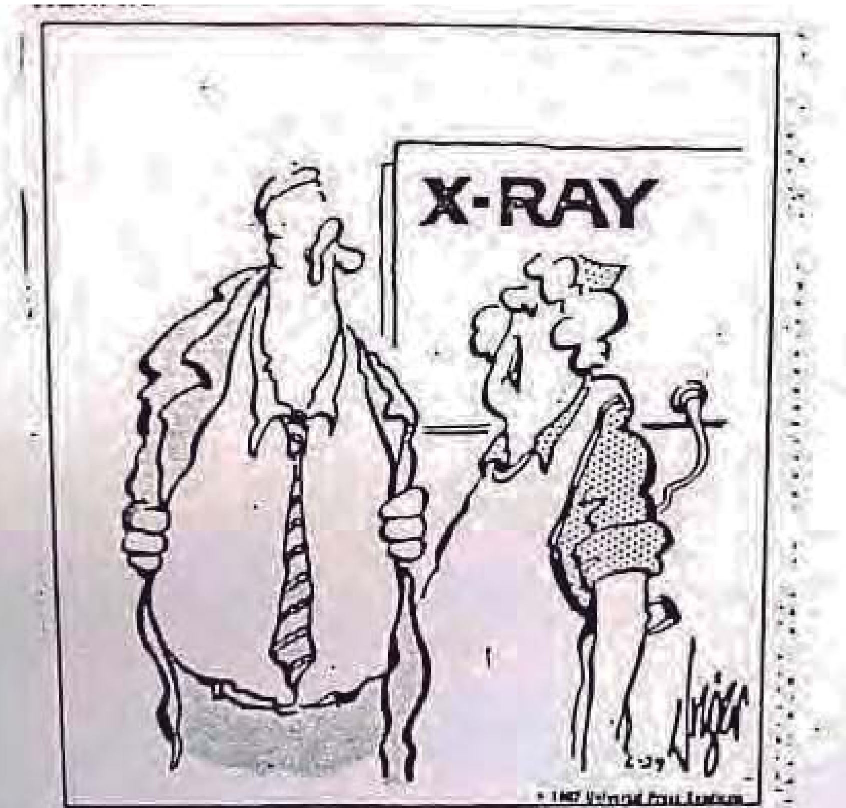




Este equipo es experimental.
Lo único seguro es que el diagnóstico le va a costar 10.000 pesos.

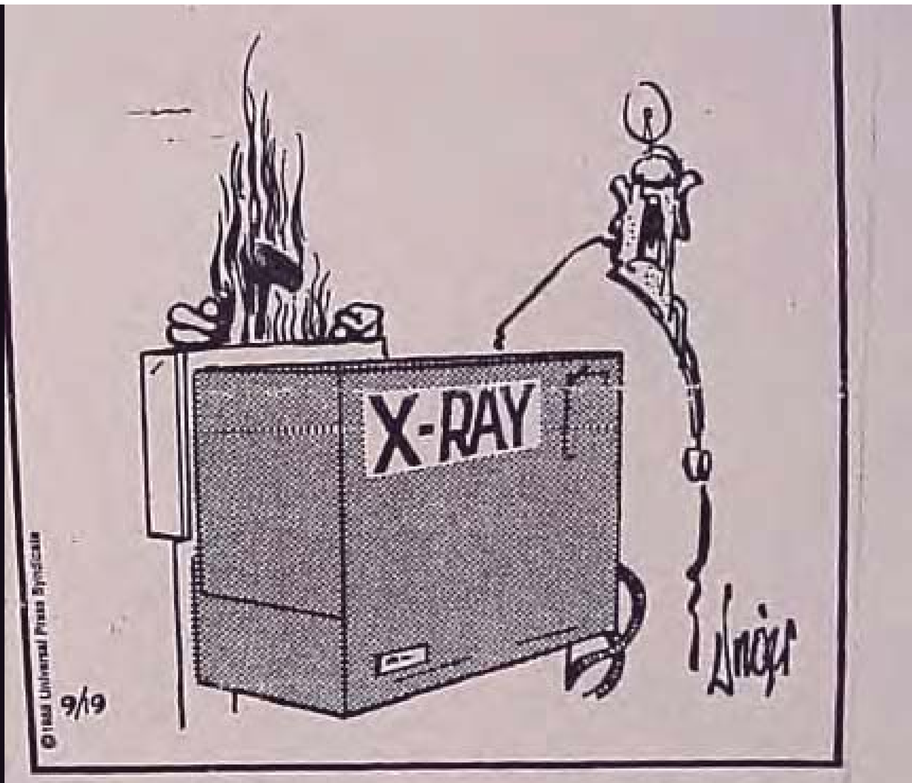


De acuerdo a sus radiografías yo diría que Usted ha sido expuesto a mucha radiación



No se desvista que aumento los kV!

Tendré que radiografiarle el brazo nuevamente. Esta radiografía parece sobre-expuesta



Creía que habías arreglado al equipo!

Tema 8

Ell régimen intergubernamental

Epistemología

Método, validez y alcance del conocimiento científico sobre la radiación y sus efectos

↓

Paradigma

Modelo conceptual para proteger contra la radiación

↓

Régimen Global

Establecimiento de estándares internacional y provisiones para su aplicación global

UNSCEAR

ICRP

25

RÉGIMEN INTERNACIONAL DE SEGURIDAD

- ✓ CONVENCIONES VINCULANTES
- ✓ ESTÁNDARES INTERNACIONALES
- ✓ PROVISIONES PARA SU APLICACIÓN

211

CONVENCIONES VINCULANTES

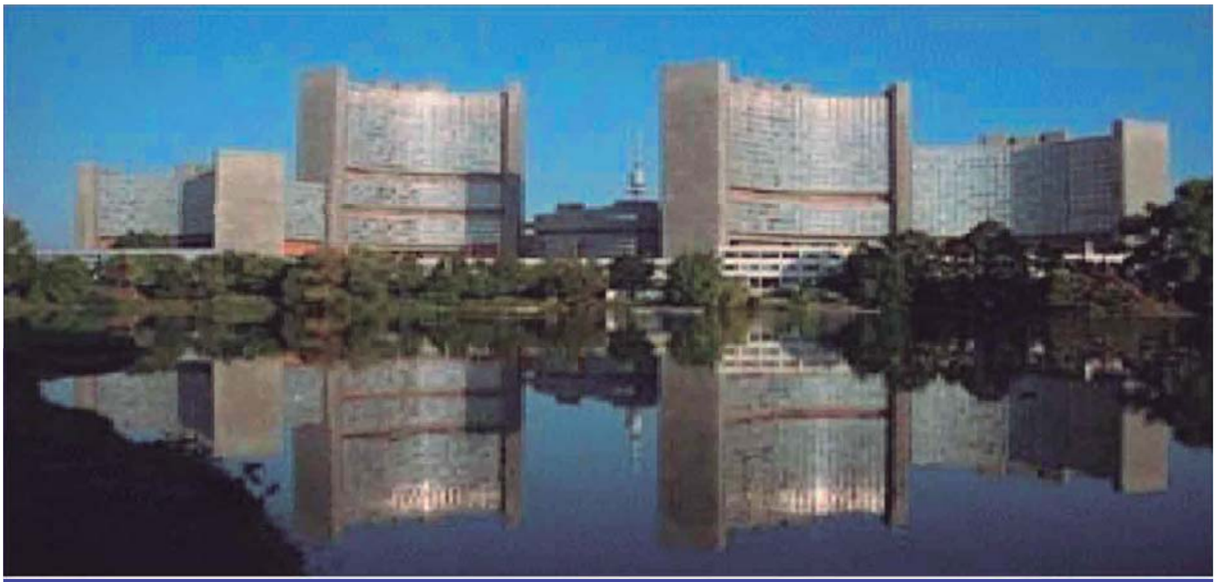
- ✓ NOTIFICACIÓN PRONTA
- ✓ ASISTENCIA
- ✓ SEGURIDAD NUCLEAR
- ✓ SEGURIDAD DEL COMBUSTIBLE GASTADO

Y DE LOS RESIDUOS RADIOACTIVOS

212

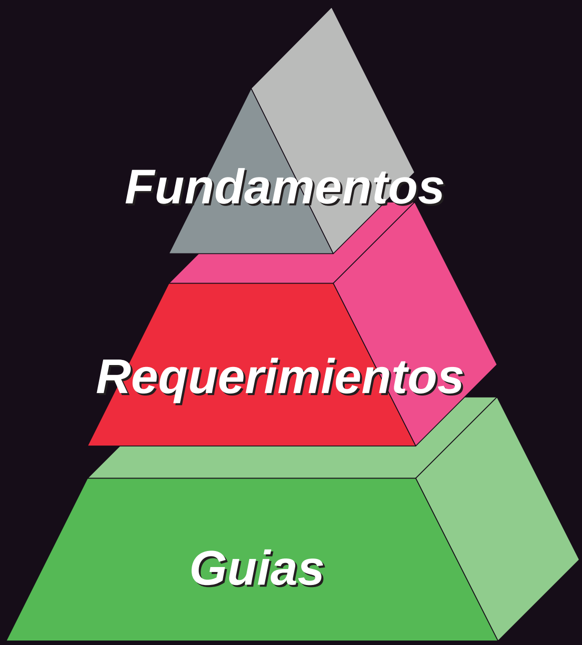
La Normativa Internacional e Intergubernamental

El OIEA es responsable de la normativa



El OIEA es el único órgano del sistema de las Naciones Unidas con responsabilidades estatutarias específicas en seguridad.

Jerarquía de las Normas



25 August, 2022

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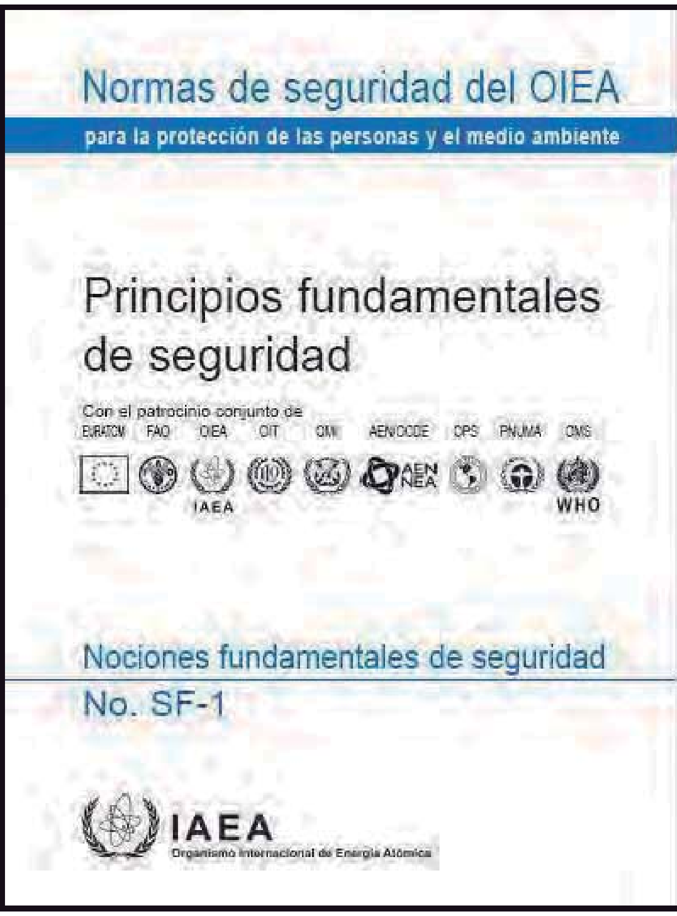

Normas de seguridad del OIEA

para la protección de las personas y el medio ambiente

Principios fundamentales de seguridad

Con el patrocinio conjunto de

EURATOM FAO OIEA OIT OMI AEN/OCDE OPS PNUMA OMS

IAEA AEN NEA WHO

Nociones fundamentales de seguridad

No. SF-1

IAEA

Organismo Internacional de Energía Atómica

Provisiones para la aplicación de la normativa internacional

Tema 9:

El licenciamiento 'social'

Licenciamiento social

- Las nuevas demandas de *concesión de licencia social* para actividades humanas que impliquen exposición a la radiación deberían asimilarse específicamente en el paradigma.
- El concepto de *tolerabilidad* es crucial

Las licencia social debería ser ahora parte del paradigma

Tema 10
La comunicación

Una deficiencia importante del sistema actual:

¡El paradigma actual no es útil para la información pública!

¿Sería deseable llenar este vacío?

El problema de la comunicación


Dosis absorbida & riesgo
No!.. Dosis equivalente & riesgo
No!.. Dosis efectiva & riesgo
Que es ‘dosis’; que es ‘riesgo’?


¡Dosis > radiación > riesgo!


¿Dosis? ¿Radiación?¿Riesgo?


¡Dosis! ¡Radiación! ¡Riesgo!

Argentinian Regulatory Criterion Proposal for Mission Time in Events Trees for L1 PSA for New Nuclear Power Reactors

Carlin Llorente, F.J. and Torano, P.N.

Presentado en: International Conference on Topical Issues in Nuclear Installation Safety: Strengthening Safety of Evolutionary and Innovative Reactor Designs del Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 18 al 21 de octubre de 2022

ARGENTINIAN REGULATORY CRITERION PROPOSAL FOR MISSION TIME IN EVENTS TREES FOR L1 PSA FOR NEW NUCLEAR POWER REACTORS

F. J. CARLIN LLORENTE[1], P. N. TORANO[1]

[1]Nuclear Regulatory Authority (ARN) of Argentine, Buenos Aires, Argentina

Abstract

In the framework of the licensing of the Argentine CAREM 25 prototype nuclear reactor, the Argentine Nuclear Regulatory Authority (ARN) agreed with the Responsible Entity a work plan to carry out the evaluation of the Level 1 Probabilistic Safety Assessment (L1 PSA), which is considered as Mandatory Documentation related to the Commissioning License Milestone. As a starting point of the work plan, from the regulatory point of view, the need arose to focus on the analysis of the Mission Time used for modelling the initiating events postulated in the L1 PSA, because this time varies when applied to the analysis of active and passive systems. The particularity of this type of nuclear reactor is that the mission time for passive systems (it´s called: the grace period for the CAREM 25 reactor) is longer than for active systems. Therefore, the paper presents a regulatory criterion proposal for the Mission Time of the sequences of the event trees of the L1 PSA for new nuclear power plants. The work consisted of the analysis of different IAEA accepted definitions for the term Mission Time, the review of the bibliography from several sources and the state of the art in the matter. Later, an analysis of the information collected was carried out by the experts, taking into account the design of the CAREM 25 prototype reactor.

1. INTRODUCTION

In the framework of the licensing of the Argentine CAREM 25 prototype nuclear reactor, the Argentine Nuclear Regulatory Authority (ARN) agreed with the Responsible Entity (the licensee) a work plan to carry out the evaluation of the Level 1 Probabilistic Safety Assessment (L1 PSA), which is considered as Mandatory Documentation related to the Commissioning License Milestone. As a starting point of the work plan, from the regulatory point of view, the need arose to focus on the analysis of the Mission Time (MT) used for modelling the initiating events postulated in the L1 PSA, because this time varies when applied to the analysis of active and passive systems. The particularity of this type of nuclear reactor is that the mission time for passive systems (it´s called: the grace period for the CAREM 25 reactor) is longer than for active systems.

Therefore, the paper presents the Argentine regulatory criterion proposal for the Mission Time of the sequences of the event trees of the L1 PSA for new nuclear power plants.

2. METHODOLOGY

The work consisted of reviewing the bibliography from several sources and the state of the art in the matter. Later, an analysis of the information collected was carried out by the experts, taking into account the design of the CAREM 25 prototype reactor.

The steps selected to carry out the work of the Mission Time determination were the following:

2.1 – Mission Time Definition Analysis
2.2 – Proposal of the Responsible Entity for the Mission Times
2.3 – Analysis of the State of the Art

Each point is developed below.

2.1. Mission Time Definition Analysis

As a starting point, it was considered appropriate to look for the definition of the Mission Time that is presented in the IAEA documents.

- **IAEA Safety Guide "050-P-4"- 1992**

This document mentions "…Analysis Time: Different periods of time (Mission Time) after the initiating event (such as a day, a week or a month) can be considered, as necessary depending on the impact on the important accidental sequences or their predicted frequencies. This can influence capacity and reliability considerations for systems and components…" [1].

- **IAEA Safety Guide "SSG-3" - 2010**

This document mentions "…Mission Time: it is the time that the system will need to operate for the reactor to reach a safe and stable shutdown state and that will allow the implementation of long-term measures to maintain that state…" [2].

2.2. Proposal of the Responsible Entity for the Mission Times

As a second point, the proposal of the Nuclear Safety Division of the Responsible Entity (the licensee) was analyzed. It proposed using two Mission Times for the L1 PSA of the CAREM-25 Reactor, making a differentiation between active and passive systems. For active systems, the Responsible Entity proposed using 24 hours and 36 hours for passive systems (CAREM 25 reactor grace period).

2.3. Analysis of the State of the Art

As a last point, a search of the state of the art in what corresponds to the Mission Time (MT) was made. The focus was on seeing if specific times were defined or definitions presented. The following criteria were used to perform the search.

(a) IAEA Guides,
(b) Publications about SMR and Advanced Reactors and
(c) U.S. Nuclear Regulatory Commission (NRC) documents

The following table presents a summary of the publications found.

Table 1 – Summary of the publications

	References	Is the Mission Time specified in the reference?	Comment
IAEA	Safe Guide: 050-P-4 “PROCEDURES FOR CONDUCTING PSA OF NPP (LEVEL 1)” [1]	It does not specify.	The reference says “Different time periods (mission time) following the initiating events can be considered (such as one day, one week, one month), as necessitated by the impact on important accident sequences and their predicted frequencies”.
IAEA	Safe Guide: SSG-3_ “Development and Application of Level 1 PSA for NPP” [2]	This has been taken to be 24 or 48 h for most initiating events. For new designs that provide the features to delay core damage, consideration of a longer mission time may be necessary.	The reference says “The success criteria should specify the mission times for the safety systems, that is, the time that the safety systems will need to operate so that the reactor reaches a safe, stable shutdown state and that will allow for long term measures to be put in place to maintain this state”.
IAEA	TECDOC-1135 “Regulatory review of PSA Level 1” [3]	It does not specify. The time must be based on the “best estimate” analysis of the transients.	The reference says “If success criteria are used from deterministic design basis analyses, those that are conservative should be clearly stated and justified. They must be carefully reviewed to verify that such a degree of conservatism does not mask relevant sequences”
INL	SMR Probabilistic Risk Assessment (PRA) Detailed Technical Framework Specification [4]	Current static event tree/fault tree approaches use a predetermined “mission time” (usually 24 hours) that dictates the cut-off for core damage or not. This limitation would be removed since the simulation is able to determine when (via physics) a safe condition has been reached and the simulation is stopped.	The reference says “This timing can have huge impacts when dealing with station blackout scenarios as demonstrated in the Fukushima accidents, which all occurred over extended (greater than 24 hours) periods of time”
INL	Advanced SMR PRA Technical Exchange Meeting [5]	It does not specify.	The reference presents a graph that serves to understand how scenarios that considering a "mission time" do not lead to core damage, but if the time is increased, it is very likely that the core damage will be reached, see Fig. 1 in ANNEX.

Table 1 – Summary of the publications (cont.)

References		Is the Mission Time specified in the reference?	Comment
INL	Safe and Stable State in Standardized Plant Analysis Risk Model Event Trees [6]	Using this PRA Standard [7] requirement as the basis, the following guidelines are recommended to define mission time for modelling safe stable states in SPAR models. - Perform T-H analysis using 24 h as MT. - Then, review the T-H results should not just focus on checking the plant parameters against the acceptance criteria (e.g., is the peak core temperature greater than 982°C?), but also checking the trends of the plant parameters (e.g., the peak core temperature is less than 982°C at the end of the T-H case run, but is it still increasing? The parameter acceptance criteria checks determine whether a safe state or core damage state is reached within the defined sequence mission time, while the parameter trending checks determine whether a safe state is also stable. - If stable plant conditions are not achieved within the predefined sequence mission time, then extend the sequence mission time and re-evaluate the sequence. Although extending sequence mission times and re-evaluating the sequence could be a repetitious process until stable plant conditions are achieved, the analyst can simply choose 72-hour as the new sequence mission time and re-evaluate the sequence. A choice of 72 hours here represents a balance between the diminishing returns in terms of analytical rigor and the increasing likelihood that non-modeled mitigative/recovery actions will have terminated the accident. (note: In the reference, there are 7 steps but here only present 2).	The reference makes a distinction between: - **SSC Mission Time**: the time period that a system or component is required to operate in order to successfully perform its function. - **Accident Sequence Mission Time** (or sequence mission time): This is used as an input in T-H analyses for the specified accident sequences.
Workshop on PSA for New and Advanced Reactors	Level-1 PSA to support the design of the KALIMER-600 Sodium Cooled Fast Reactor [8]	It is assumed that the mission time is 1 week.	The reference says "Is the time that the Passive Decay Heat Removal Circuit should operate after an accident".

Table 1 – Summary of the publications (cont.)

References		Is the Mission Time specified in the reference?	Comment
Workshop on PSA for New and Advanced Reactors	Development of PSA Audit Guideline and Regulatory PSA Model for SMART [8]	Extended mission time for the Passive Residual Heat Removal System.	The reference says "The Passive Residual Heat Removal System in the SMART design needs to be successfully operated for 36 hours before the reactor coolant system reaches the temperature where the shutdown cooling system can be started for further removal of decay heat. Therefore, reviewers should check the impact of the assumptions".
Workshop on PSA for New and Advanced Reactors	Use of PSA in the Development of SMRs [8]	It does not specify.	The reference says "The passive safety systems for the SMR allow for no operator intervention required for 7 days".
Workshop on PSA for New and Advanced Reactors	Achievement of the level 1 PSA in support to the CEA 2400 MWth Gas Cooled Fast Reactor [8]	From 24 to 168 h.	The reference says "DHR is split over two periods, from IE to 24 h, and from 24 to 168 h, during which front line systems or missions may be different. This choice is related to some systems 24 h range, such as batteries and ternary water pools". See Fig. 2 in ANNEX.
Workshop on PSA for New and Advanced Reactors	Problems Facing the Use of Passive Safety Systems [8]	---	The reference says "Merging probabilistic models with T-H models, i.e. dynamic reliability, is required to accomplish the evaluation process of T-H passive systems in a consistent manner: this is particularly relevant with regard to the introduction of a passive system in an accident sequence, since the required mission time could be longer than 24 h as usual level 1 PSA mission time".
Workshop on PSA for New and Advanced Reactors	Lessons learnt from PSAS for new and advanced reactors in Russia [8]	Mission Time > 24 h, at least 3 days (72 h).	The reference says "The calculations for accident sequences should be extended beyond the time point when the reactor has been tripped and other safety systems actuated, until a long term stable state has been reached".

Table 1 – Summary of the publications (cont.)

References		Is the Mission Time specified in the reference?	Comment
NuScale	Probabilistic Risk Assessment and Severe Accident Evaluation – Chapter 19 PART 2 - TIER 2 rev.2 [9]	Use of a 72 hour mission time for a passive design. Standard industry PRA practice uses a 24 hour mission time. Time -dependent component failures generally modelled using a 72 hour mission time.	The reference says "Use of a 72-hour mission time is consistent with the guidance for passive reactor designs". The reference says "The 72-hour mission time is conservatively longer than the 24-hour mission time in ASME/ANS RA-Sa-2009 to account for the slower plant response of the NuScale design".
NRC	Risk Assessment of Operational Events – Handbook Vol.1 Internal Events rev. 2.01 [10]	Mission Time > 24 h.	The reference says "Mission Time > 24 h for sequences in which stable plant conditions would not be achieved by 24 hours using the modeled plant equipment and human actions".

After analyzing the references presented in Table 1, we get the following outcomes:

- For SMR type reactors, the traditional approach of considering a MT of 24 hours for the systems is not sufficient due to the presence of passive systems that remain operational by design for more than that time and other characteristics such as big inventory of water.

- In the Fukushima accident it became clear that station blackout scenarios occurred over long periods of time (more than 24 hours).

- A default fixed value of MT cannot be established for SMR reactors since it varies with the particular characteristics of each design.

Therefore, a conclusion from the regulator's point of view, which is applicable to new power reactors, whether they are of traditional design (e.g. PWR) or SMR type (e.g. CAREM 25), is that for each accident sequence MT must be justified on the basis of the trend of the relevant parameters and the dynamics of the accident sequences. Therefore, the analyzed time must be extended until a stable situation or a trend towards a stable situation is reached.

3. CONCLUSION

The task of evaluating the MT of CAREM 25 served as a trigger to identify the need to establish criteria for determining the MT of new nuclear power plants. The challenge was to define whether such criteria would be applicable to both traditional design (e.g. PWR) and SMR type (e.g. CAREM 25).

The conclusions that were addressed after analyzing the state of the art are the following:

- For SMR type reactors, the traditional approach of considering a MT of 24 hours for systems is not sufficient due to the presence of passive systems that remain operational by design for more than that time and other characteristics such as big inventory of water.

- In the Fukushima accident it became clear that station blackout scenarios occurred over long periods of time (more than 24 hours).

- A default fixed value of MT cannot be established for SMR reactors since it varies with the particular characteristics of each design.

Based on the conclusions mentioned, the paper presents the Argentine regulatory criterion proposal for the Mission Time of the sequences of the event trees of the L1 PSA for new nuclear power plants (traditional or SMR)

The following proposal is formulated for the definition of the Mission Time of the sequences of the event trees of the L1 PSA:

- The review of the thermal-hydraulic results of the accident sequences should not be limited to verifying compliance with the acceptance criteria by the plant parameters within a predefined mission time.

- The Mission Time for each accident sequence must be justified based on the trend of the relevant parameters and the dynamics of the accident sequences. Therefore, the analysed time must be prolonged until a stable situation or a trend towards a stable situation is reached.

4. REFERENCES

[1] IAEA, Procedures for conducting probabilistic safety assessments of nuclear power plants (level 1), Safe Guide: 050-P-4, VIENNA (1992).

[2] IAEA, Development and Application of Level 1 PSA for NPP, Safe Guide: SSG-3, VIENNA (2010).

[3] IAEA, Regulatory review of probabilistic safety assessment (PSA) Level 1, TECDOC-1135, VIENNA (2000).

[4] Idaho National Laboratory (INL), Small Modular Reactor (SMR) Probabilistic Risk Assessment (PRA) Detailed Technical Framework Specification, NL/EXT-13-28974, USA (2013).

[5] Idaho National Laboratory (INL), Advanced SMR PRA Technical Exchange Meeting, INL/EXT-13-30170, USA (2013).

[6] Idaho National Laboratory (INL), Safe and Stable State in Standardized Plant Analysis Risk Model Event Trees, INL/LTD-16-38575, USA (2016).

[7] ASME/ANS, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," ASME/ANS RA-Sb-2013, Addenda to ASME/ANS RA-S-2008, USA (2013).

[8] NUCLEAR ENERGY AGENCY (NEA), Workshop on PSA for New and Advanced Reactors, NEA/CSNI/R (2012), FRANCE-Paris (2011).

[9] NuScale, Final Safety Analysis Report, Chapter Nineteen Probabilistic Risk Assessment and Severe Accident Evaluation, PART 2 - TIER 2 rev.2, USA (2018).

[10] Nuclear Regulatory Commission (NRC), Risk Assessment of Operational Events – Handbook Vol.1 Internal Events, Rev. 2.01, USA (2017).

5. ANNEX

Below, are the figures that were obtained from the publications found on Mission Time.

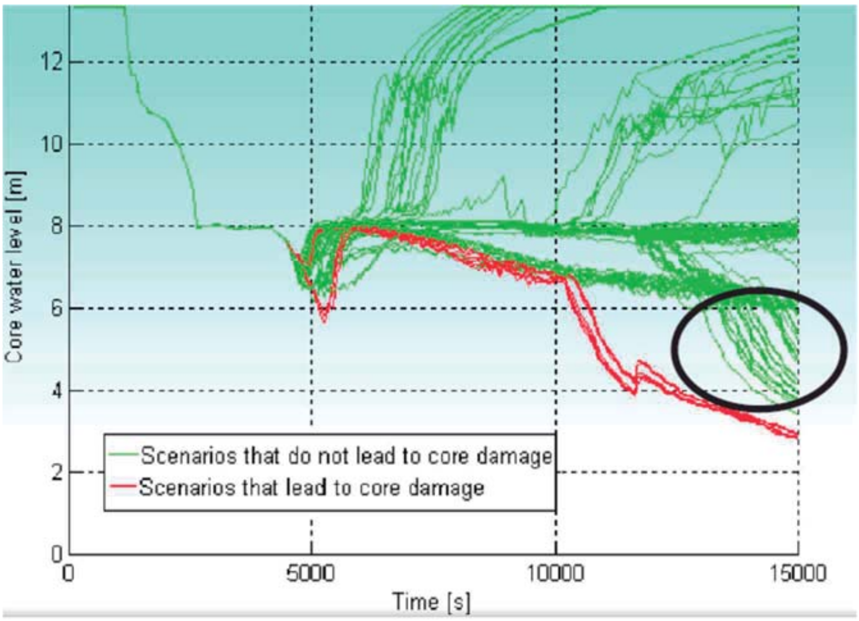


FIG. 1: The graph serves to understand how scenarios that considering a "mission time" do not lead to damage to the core, but if this time is increased, most likely it will lead to damage to the core, [5].

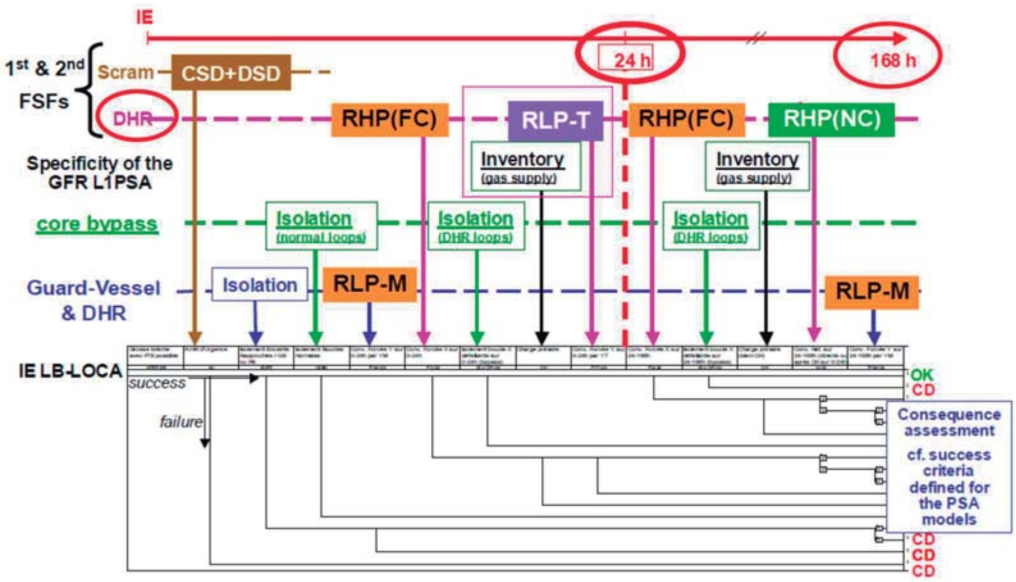


FIG. 2: The graph shows that in the event tree model for a Large LOCA the Residual Heat Removal System (DHR) has two Mission Times, 24 h and 168 h (7 days) [8].

Monitoreo en instalaciones del Ciclo del Combustible Nuclear en Argentina

López Canton, F.; Martiri, L.; Michelli, M.V. y Saavedra, A.

Presentado en: XII Congreso Regional de Seguridad Radiológica y Nuclear y en el X Congreso Regional de la Asociación Internacional de Protección Radiológica (IRPA).
Santiago de Chile, Chile, 23 al 27 de octubre de 2022

XII CONGRESO REGIONAL DE SEGURIDAD RADIÓLOGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

Monitoreo en instalaciones del Ciclo del Combustible Nuclear en Argentina

Facundo López Canton
Lucas Martiri
María Verónica Michelli
Analía Saavedra

Autoridad Regulatoria Nuclear, Argentina

Área Temática: Protección Radiológica

100

XII CONGRESO REGIONAL DE SEGURIDAD RADIÓLOGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

Monitoreo en instalaciones del Ciclo del Combustible Nuclear en Argentina

CCN en Argentina

Instalación nuclear: instalación donde se procesa, manipula, almacena o utiliza material radiactivo fisionable.

Clase I	14
Clase II	21
Clase III	3

- Conversión a UO_2 para reactores de potencia.
- Fabricación de elementos combustibles para reactores de potencia.
- Fabricación de elementos combustibles para reactores de investigación y blancos de irradiación para producción de ^{99}Mo.
- Producción de U_3O_8 para reactores de investigación.
- Recuperación de uranio de scraps y residuos.
- Almacenamiento interino de elementos combustibles gastados de reactores de investigación.
- Depósitos de material nuclear.
- Desarrollo de elementos combustibles MOX.
- Mock-up de enriquecimiento de uranio.

Compuestos de uranio

Tipo F	Tipo F/M	Tipo M	Tipo M/S	Tipo S
UF_6	$UO_2(NO_3)_2$	UF_4	U_3O_8	
Uranil-TBP	$U_2O_7(NH_4)_2$	U metálico vaporizado	UO_2	
UO_2F_2	$UO_4.nH_2O$			
$UO_2(CO_3)_3(NH_4)_4$	UO_3			

Límite Anual de Incorporación

$$ALI\,(Bq) = \frac{0{,}02\ Sv}{e(50)\ \left(\frac{Sv}{Bq}\right)}$$

Concentración Derivada en Aire

$$DACi\left(\frac{Bq}{m^3}\right) = \frac{0{,}02\ Sv}{e(50)\left(\frac{Sv}{Bq}\right)\ x\ Vr\ (m^3)}$$

Composición isotópica	Isótopo	% m/m
U natural	^{238}U	99,28
	^{235}U	0,72
	^{234}U	0,0055
U enriquecido al 3,6%	^{238}U	96,37
	^{235}U	3,6
	^{234}U	0,033
U enriquecido al 20% nominal	^{238}U	86,12
	^{235}U	19,64
	^{234}U	0,2088

Composición isotópica	Tipo	DAC (Bq/m^3)
U natural	F	14,36
	M	5,20
	S	1,46
U enriquecido al 3,6%	F	14,35
	M	5,18
	S	1,46
U enriquecido al 20% nominal	F	13,47
	M	4,80
	S	1,36

100

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

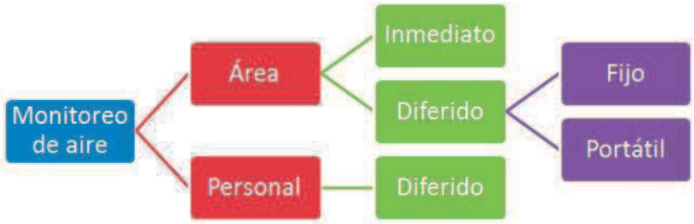
Monitoreo en instalaciones del Ciclo del Combustible Nuclear en Argentina

Monitoreos de aire

Objetivo: determinar la concentración de un radionucleído en el aire para conocer la calidad del aire respirable en un área de trabajo.

$$Cm,i\left(\frac{Bq}{m^3}\right)=\frac{Ai\,(Bq)}{Vm\,(m^3)}$$

$$\frac{Cm,i\left(\frac{Bq}{m^3}\right)}{DACi\left(\frac{Bq}{m^3}\right)}=N$$



Inmediato (online)

Diferido fijo

Diferido portátil

Personal

Control regulatorio

Licenciamiento

Envío a ARN de documentación técnica:
- Descripción de los sistemas de ventilación y los sistemas de monitoreo
- Plan de Monitoreo Radiológico.

- Evaluación y aprobación por ARN.
- Revisión periódica (con cada renovación de Licencia de Operación cada 5 años)

Inspecciones

- Se verifica el funcionamiento correcto de los sistemas y equipos de monitoreo de aire.
- Se verifican los registros de los resultados de los monitoreos que realizan los operadores.
- En algunas inspecciones, la ARN realiza monitoreo de aire con equipamientos propios (muestreos personales y muestreos con bomba portátil) para realizar mediciones y verificaciones independientes.

Puntos a destacar

- +30 instalaciones del CCN en Argentina controladas por la ARN.
- Importancia de controlar/minimizar la incorporación de uranio. Vía más relevante la inhalación.
- Diferentes tipos de monitoreo de aire.
- Control regulatorio mediante licenciamiento, evaluaciones de seguridad e inspecciones.

100

Development and application of indicators for the assessment of radiation safety systems in radiopharmaceuticals production facilities with cyclotron

Maggiolo, A.; Espósito, M. and Rabi, G.

Presentado en: International Conference on Accelerators for Research and Sustainable Development: From Good Practices Towards Socioeconomic Impact de la International Atomic Energy Agency (IAEA).
Viena, Austria, 23 al 27 de mayo de 2022

IAEA-CN301-055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Autoridad Regulatoria Nuclear
PRESIDENCIA DE LA NACIÓN

Development and application of indicators for the assessment of radiation safety systems in radiopharmaceuticals production facilities with cyclotron

Autoridad Regulatoria Nuclear – Buenos Aires - ARGENTINA

INTRODUCTION

The 'Class I Particle Accelerators Control Sector' of the Nuclear Regulatory Authority (ARN) developed a tool that helped perform **safety assessments**, particularly for the evaluation of **safety systems implementation** and the **application of radiation safety standards** at radiopharmaceutical production facilities with cyclotrons.

This tool consisted on **indicators** that were developed following the guidelines in 'Criterios para el licenciamiento y requisitos de inspección en instalaciones con ciclotrones para producción de radioisótopos utilizados en aplicaciones e investigaciones médicas' (2013) from FORO.

For the preparation of the tool, the requirements were divided in three categories: **plans, safety systems** (which includes **interlocks**, **manual systems** and **alarms**), and **records**.

In the paper, the conditions at cyclotron facilities that are in **operation stage** in Argentina are analysed. There are currently five facilities in operation stage, two of which have self-shielded cyclotrons, and the main radiopharmaceutical produced in the country is FDG.

METHODS

Itwas necessary to perform a safety assessment in order to determine the level of adequacy for each category, by **reviewing the documentation and procedures of the facilities under regulatory control.**

For each requirement, it could be determined whether a requirement was **fully, partially** or **not fulfilled** and it was assigned a value of 2, 1 or 0 respectively, in order to quantify the compliance.

Fulfilled	2	✓
Partially	1	!
Not fulfilled	0	✗

The results were collected using a spreadsheet, as the example shown in the next *figure*:

List of requirements | % of adequacy

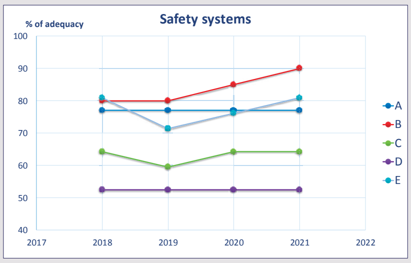
Plans	FACILITY A (77,8) Fulfilled?	Observations
Site and location	✓	
Facility layout, rooms function and distribution	!	
Location of cyclotron, hot cells and transfer lines	✓	
Communication between rooms	!	
Flow of personnel and materials	✓	
Room classification	✓	
Identification and location of safety equipment and detectors	✓	
Air flow and differential pressure in hot cells and rooms	✓	
Constructive plans	✗	

RESULTS

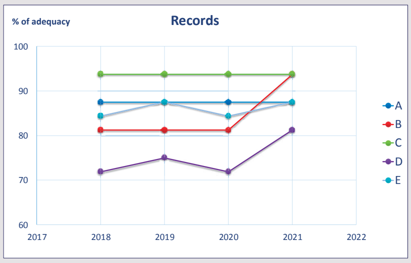
The following charts show the results obtained for each category, representing the **evolution of the percentage of adequacy** to the standards from **2018 to 2021**, for the **facilities that are currently operating**. For the purpose of the paper, the facilities are named *A, B, C, D* and *E*.

Percentage of adequacy of plans for facilities A to E, from 2018 to 2021.

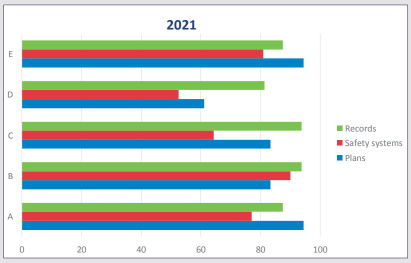
One major improvement was the addition of a last person button at *Facility B*. *Facility D* is the one with the least fulfilment with nearly 50% of adequacy because it does not have modern equipment in the radiopharmacy laboratory. However, the facility is in process of updating the laboratory and relevant improvements are expected in the upcoming year.



Percentage of adequacy of safety systems for facilities A to E, from 2018 to 2021.



Percentage of adequacy of records for facilities A to E, from 2018 to 2021.



Results of the las assessment (2021) for facilities A to E, for the three categories.

CONCLUSIONS

- It was observed a **tendency towards improvement** in all the facilities.
- The tool is a **systematic** and **simple** way to measure the results of the safety assessments and to follow the evolution of different safety aspects.
- It is **helpful for the regulatory body** to ensure that safety conditions are being improved over time and to detect safety aspects which need improvement. The process of developing this tool was really **fruitful for inspectors**; the information has to be complemented with regulatory inspections in order to verify that safety systems function correctly.
- It could be **extended to other stages** (construction, commissioning, decommissioning) and to **other types of facilities**, considering the particularities of each case.
- The **enforcement of new standards** in facilities that are already constructed and have been operating for several years is not an easy task for the regulatory body. However, it is one of the **main goals of the regulator to ensure that the safety conditions always tend to be better** and stay aligned as much as possible with the state of the art for this type of facilities.

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Enfoque graduado en el control regulatorio de las instalaciones del Ciclo de Combustible Nuclear en Argentina

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Presentado en: XII Congreso Regional de Seguridad Radiológica y Nuclear y en el X Congreso Regional de la Asociación Internacional de Protección Radiológica (IRPA).
Santiago de Chile, Chile, 23 al 27 de octubre de 2022

Reunión Anual de la Asociación Argentina de Tecnología Nuclear – AATN.
Buenos Aires, Argentina, 19 al 22 de diciembre de 2022

ENFOQUE GRADUADO EN EL CONTROL REGULATORIO DE LAS INSTALACIONES DEL CICLO DE COMBUSTIBLE NUCLEAR EN ARGENTINA

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Autoridad Regulatoria Nuclear
Argentina

RESUMEN

El Ciclo de Combustible Nuclear (CCN) en Argentina abarca más de 50 instalaciones, distribuidas en todo el país y con importantes diferencias respecto a sus características particulares. El control regulatorio de estas instalaciones presenta grandes desafíos y para lograr que sea eficaz y eficiente es necesario aplicar un **enfoque graduado**.

La Autoridad Regulatoria Nuclear (ARN) introdujo de manera explícita el concepto de enfoque graduado en la última versión de la norma AR 10.1.1: “Norma Básica de Seguridad Radiológica”, rev.4 (2019) [1], así como en la norma AR 10.6.1: “Sistema de gestión para la seguridad en las instalaciones y prácticas” [2] ambas de aplicación a la totalidad de las instalaciones bajo control regulatorio. Históricamente el concepto de enfoque graduado fue aplicado sin ser definido, como por ejemplo en la clasificación de las instalaciones en clase I, clase II y clase III. En las instalaciones del CCN, la ARN utiliza el enfoque graduado durante el licenciamiento de las instalaciones, en la evaluación de la documentación, en el licenciamiento del personal y durante la elaboración y ejecución del plan de inspecciones. Se toman en consideración: la escala de operaciones, ubicación geográfica, cantidad de material, forma física, nivel de enriquecimiento de uranio, composición química, complejidad técnica de los sistemas, posibles consecuencias radiológicas de un evento[1], experiencia operativa y disponibilidad de recursos, entre otros factores.

En este trabajo se presentan ejemplos específicos de aplicación del enfoque graduado en el control de las instalaciones del CCN bajo distintos indicadores. El enfoque graduado es un concepto fundamental para optimizar los recursos sin comprometer la seguridad por lo que resulta necesario seguir trabajando hacia su aplicación sistemática y documentada.

1. Introducción

La Autoridad Regulatoria Nuclear de Argentina (ARN), tiene como objetivo desarrollar y aplicar un régimen regulatorio para todas las actividades nucleares que se realizan en la República Argentina, y debe llevar a cabo tareas de verificación en más de 1280 instalaciones bajo control regulatorio, distribuidas en todo el país (*Fig. 1*).

[1] Evento: suceso incidental (incluidos sucesos iniciadores, precursores de accidentes y cuasi accidentes), suceso accidental o malicioso. [2]

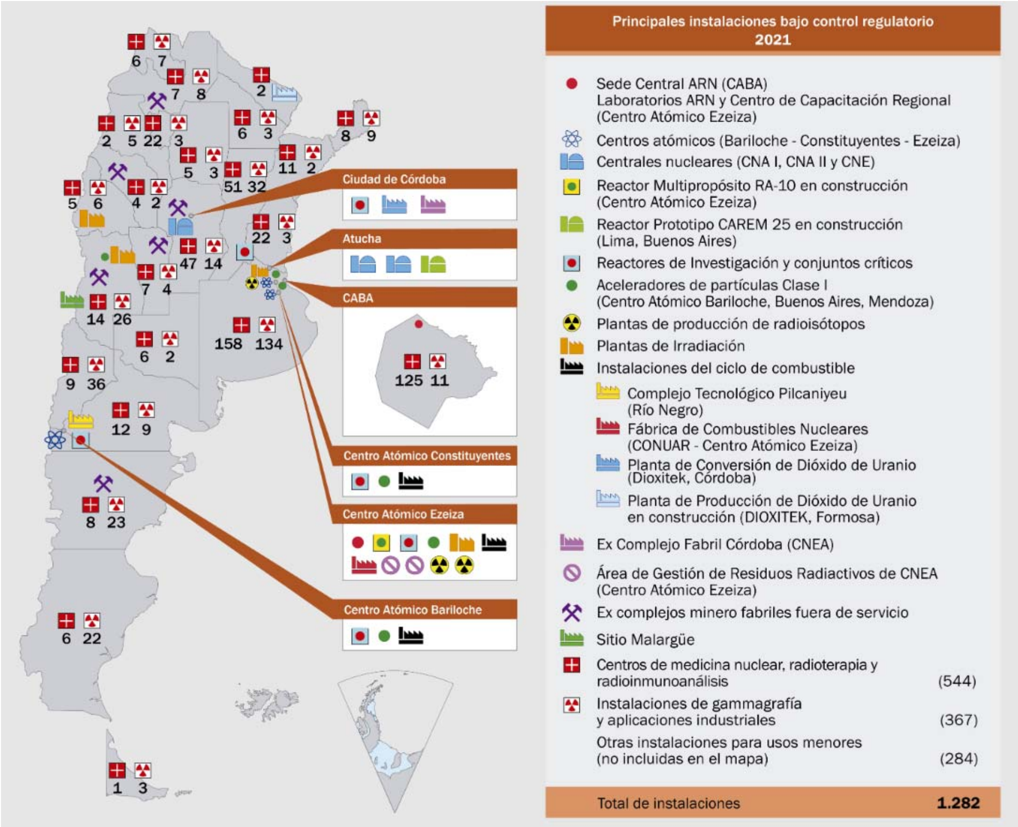

Fig.1: Principales instalaciones bajo control regulatorio en Argentina y el número de instalaciones en cada provincia.

El gran número de actividades bajo control regulatorio en una superficie que supera los 1,2 millones de km^2, la diversidad de riesgos, características y complejidad tecnológica, y la variabilidad en los materiales radiactivos y nucleares que se manipulan, hacen necesaria la implementación de un **Enfoque Graduado** (EG) en el sistema regulatorio argentino.

El EG en el licenciamiento, la fiscalización y control desde el punto de vista de seguridad radiológica y nuclear, salvaguardias y protección y seguridad física se aplica para destinar recursos regulatorios en una graduación apropiada según el riesgo, la complejidad tecnológica y la potencialidad de cada actividad a ser autorizada y controlada por la ARN.

El EG no es un concepto nuevo, habiendo sido usado extensamente desde los inicios de la actividad nuclear en Argentina, incluso sin definirlo, ya que nace del sentido común: “graduar” el rigor del accionar regulatorio en función de los riesgos de la actividad a llevar a cabo. Sin embargo, en los últimos tiempos hubo un impulso importante desde organismos internacionales y autoridades locales para definirlo, desarrollar criterios con la menor ambigüedad posible y estructurar su aplicación de forma documentada, lo cual representa un gran desafío.

Es importante destacar que el enfoque graduado no es una forma de evitar requerimientos, sino lograr el cumplimiento de los mismos de manera proporcional, teniendo en cuenta los riesgos y haciendo un uso adecuado de los recursos. Por ejemplo, un informe de seguridad es requerido para todas las instalaciones, sin importar el riesgo de las mismas. Sin embargo el detalle del análisis, el nivel de la información suministrada y la frecuencia de la revisión puede ser significativamente menor para instalaciones con menor riesgo, en comparación con el requerido para instalaciones de mayor riesgo.

Un esquema regulatorio pensado con un enfoque graduado contribuye a la optimización de recursos tanto del órgano regulador como del regulado, y otorga flexibilidad para adaptarse a condiciones cambiantes. Situaciones externas como fueron las limitaciones en viajes y en trabajo presencial durante la pandemia del Covid-19, o crisis económicas y limitaciones de recursos, hacen que sea necesario realizar esta optimización sin comprometer la seguridad y lograr altos estándares de seguridad.

2. El Ciclo de Combustible Nuclear en Argentina

El Ciclo de Combustible Nuclear (CCN) en Argentina, sin incluir los reactores nucleares, comprende múltiples actividades tales como la minería de uranio, que en la actualidad comprende etapas de parada prolongada, cierre y remediación de los sitios, plantas de concentración de uranio, purificación y conversión de uranio, desarrollos en enriquecimiento de uranio, fabricación de combustible nuclear, recuperación de uranio enriquecido, almacenamiento interino de elementos combustibles irradiados y la gestión de los residuos radiactivos. Si bien en Argentina no hay reprocesamiento directo de los combustibles y placas irradiadas, existe un laboratorio radioquímico que recupera uranio irradiado de los filtros de la planta de producción de molibdeno por fisión. Adicionalmente, hay instalaciones de investigación y desarrollo, mediciones y análisis que dan soporte para distintas etapas del CCN. La Figura 2 muestra la distribución de las instalaciones del CCN en la Argentina, incluyendo a las centrales nucleares.

Fig. 2: Instalaciones del Ciclo de Combustible Nuclear bajo control regulatorio en Argentina, incluyendo reactores.

El número actual de instalaciones del CCN supera las 50, clasificándose en clase I, clase II y clase III, y dividiéndose en dos líneas principales: una línea es la de uranio natural (0,711 % en ^{235}U) o ligeramente enriquecido (0,85% en ^{235}U), dedicada al abastecimiento de los reactores nucleares de potencia, y la otra línea es la de uranio de bajo enriquecimiento (menos del 20% en ^{235}U), destinada a la producción de elementos combustibles para los reactores de investigación y de blancos para la producción de ^{99}Mo. Adicionalmente, se encuentra en las primeras etapas la fabricación de los elementos combustibles para el reactor CAREM-25, el cual es un prototipo para el primer reactor modular argentino, con un enriquecimiento de hasta el 3,1%.

Teniendo en cuenta la gran variedad de instalaciones y procesos que se incluyen en el CCN en Argentina, con la consecuente diversidad de riesgos, resulta particularmente importante el uso del EG en la aplicación de los requerimientos regulatorios a los diferentes tipos de instalaciones.

3. El Enfoque Graduado en el marco regulatorio argentino

La Ley Nº 24.804, "Ley Nacional de la Actividad Nuclear" [3], sancionada en 1997, le asigna a la ARN la responsabilidad de "*controlar que las personas y el ambiente tengan una protección adecuada contra los efectos perjudiciales para la salud que puedan derivarse de la exposición a las radiaciones ionizantes*". Para este fin, la ARN estableció un marco regulatorio compuesto de 64 Normas y 10 Guías Regulatorias, el cual es actualizado periódicamente.

La ARN ha aplicado el Enfoque Graduado desde sus inicios en la clasificación de instalaciones, en las exigencias para el personal de cada tipo de instalaciones, en los requerimientos de documentación a presentar para demostrar cada evaluación de seguridad y en las inspecciones, así como en el alcance de algunas de sus normas.

En la última versión de la norma AR 10.1.1: "Norma Básica de Seguridad Radiológica", rev.4 (2019) [1], el concepto de Enfoque Graduado fue definido según:

Enfoque graduado: *"proceso o método en el que el rigor de las acciones de control y las condiciones a ser aplicadas se corresponden con el nivel de riesgos asociados, esto es con la probabilidad de ocurrencia y las posibles consecuencias de la pérdida de control".*

A su vez, se indica que la clasificación de las instalaciones en clase I, clase II y clase III debe seguir los principios de enfoque graduado:

Instalación clase I o instalación clase II o instalación clase III: *"instalación o práctica clasificada, siguiendo un enfoque graduado, en función del riesgo radiológico asociado a las fuentes de radiación en la instalación o práctica, el impacto radiológico ambiental o las consecuencias radiológicas de las exposiciones potenciales o las dosis ocupacionales involucradas y, de corresponder la complejidad tecnológica".*

De manera análoga, la norma AR 10.6.1: "Sistema de gestión para la seguridad en las instalaciones y prácticas", Rev. 0 (2020) [2], utiliza la misma definición de enfoque graduado y establece que "*El sistema de gestión debe ser desarrollado y aplicado adoptando un enfoque graduado y los criterios utilizados se deben documentar*".

La introducción del concepto en ambas normas está armonizada con lineamientos internacionales en donde el uso documentado del enfoque graduado es fomentado y es un primer paso para avanzar en una mayor formalización de su uso práctico y estructurado.

4. Aplicación del Enfoque Graduado

4.1 Desarrollo de un método de graduación

El enfoque graduado es aplicable a la mayoría de los sistemas donde se requiera un grado de control, sin embargo los criterios deben desarrollarse caso por caso teniendo en cuenta la ponderación de factores específicos. Esta ponderación puede cambiar según sea la etapa en la que se encuentra la instalación y las condiciones externas imperantes (como restricciones impuestas ante una emergencia sanitaria y limitaciones de recursos), por lo que el análisis debe tener la flexibilidad suficiente para ser reevaluado.

Establecer un método sistemático para graduar es fundamental, con el fin de asegurar consistencia y minimizar subjetividades. Luego de identificar la organización, sistema, o componente al cual se le va a aplicar la graduación, se debe realizar un análisis del mismo: determinar el funcionamiento en detalle del sistema y los factores involucrados con impacto en la seguridad, incluyendo las implicancias una pérdida de control. Para facilitar el proceso, se debe generar una división por niveles según la significancia: entre más alto sea el impacto del nivel, mayores serán las medidas de control.

Como regla general, para realizar una graduación, una organización debe:

- **Determinar el criterio para graduar**

Se deben identificar las áreas con un mayor impacto en la seguridad y establecer un criterio respecto a la importancia relativa de cada factor.

- **Determinar el número óptimo de "niveles de graduación"**

Se deben establecer los niveles. En general 3-4 niveles se consideran adecuados [4]. La práctica común es que el grado "1" o "A" sea el de mayor riesgo o implicancia, siguiendo en orden decreciente.

- **Determinar lo que implica cada nivel.**

Determinar la relación entre determinado nivel, y los requerimientos que se van a solicitar para su control.

En la *Fig. 3* se presenta un esquema del proceso para graduar un sistema

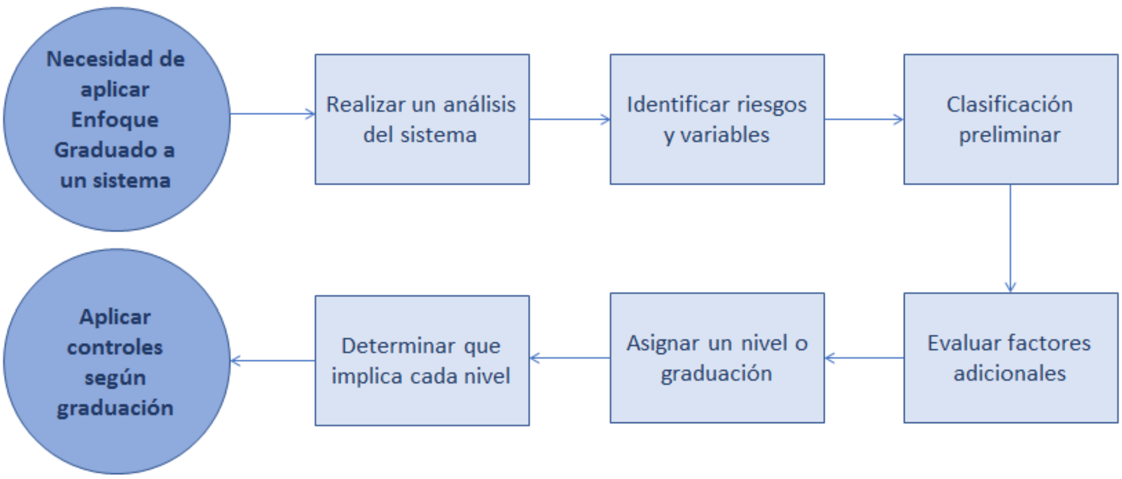

Fig. 3: Proceso para graduar un sistema

Los esquemas de graduación tienen que estar fundamentados en un análisis detallado de los sistemas, y deben ser realizados por personal con un nivel de experiencia y competencias adecuadas.

4.2 Enfoque graduado en licenciamiento de instalaciones y su personal

La norma AR 10.1.1: “Norma Básica de Seguridad Radiológica”, rev.4 (2019) [1], clasifica las instalaciones en clase I, clase II y clase III, y establece que dicha clasificación debe hacerse con un **enfoque graduado**.

Para instalaciones del CCN (sin incluir los reactores nucleares), los factores de mayor relevancia para considerar una graduación en el enfoque regulatorio son:

- Nivel de enriquecimiento de ^{235}U
- Cantidad y forma física del material presente
- Características del emplazamiento
- Escala de las operaciones
- Consecuencias de la liberación del material radiactivo al ambiente
- Interfaz con riesgos convencionales
- Complejidad de los sistemas

Como criterio principal se establece que un accidente de criticidad es el evento más grave desde el punto de vista radiológico en este tipo de instalaciones, por lo que instalaciones que procesen, manipulen o almacenen uranio con un enriquecimiento mayor al 1% en ^{235}U son clasificadas como clase I. Esto permite un mayor control durante el diseño y la construcción de la instalación, así como un mayor seguimiento en la capacitación y entrenamiento del personal. Por otro lado, la clasificación en clase II o clase III se determina por un equipo técnico de la ARN caso por caso luego de la presentación del informe de seguridad, teniendo en cuenta las variables enunciadas para el enfoque graduado.

A fines de su licenciamiento, una instalación clase I requiere un licenciamiento por etapas, que pueden ser: Licencia de Construcción, Licencia de Puesta en Marcha, Licencia de Operación y Licencia de Retiro de Servicio. A su vez, este tipo de instalaciones requieren contar con un organigrama de personal aprobado por la ARN donde cada puesto debe estar cubierto por una o más personas según corresponda. El personal designado en el organigrama debe aprobar un examen para obtener una **Licencia Individual**, que abarca contenidos generales de seguridad radiológica y nuclear y, después de un período de entrenamiento en el trabajo, debe aprobar otra instancia de examen para la obtención de una **Autorización Específica**, la cual está enfocada en la seguridad del puesto a desempeñar.

El marco para el licenciamiento de personal de instalaciones clase I se describe en la Norma AR 0.11.1 “Licenciamiento de personal de instalaciones Clase I”, Rev. 3 [5], y los lineamientos y contenidos de los exámenes se describen en la Guía AR 10: “Programas de formación especializada y capacitación específica para el licenciamiento de personal de instalaciones radiactivas Clase I”. Rev. 0 [6]

Aplicando un enfoque graduado, los contenidos de los exámenes de Licencia Individual se dividen en “Nivel 1”, destinado a personal que se propone para ocupar puestos de jefatura, y “Nivel 2” para el resto de los puestos.

Por otro lado, una Instalación clase II requiere Licencia de Operación y una Instalación clase III requiere Registro. Para estas instalaciones el personal debe tramitar un Permiso Individual que puede incluir un examen o no, según considere la ARN aplicando un enfoque graduado. Los lineamientos para el licenciamiento del personal en instalaciones clase II y clase III del CCN están dados en la Norma AR 0.11.4: “Licenciamiento de personal de instalaciones Clase II y Clase III del Ciclo de Combustible Nuclear”, Rev. 0 [7]

La Figura 4 resume el licenciamiento de personal para instalaciones clase I, clase II y clase III.

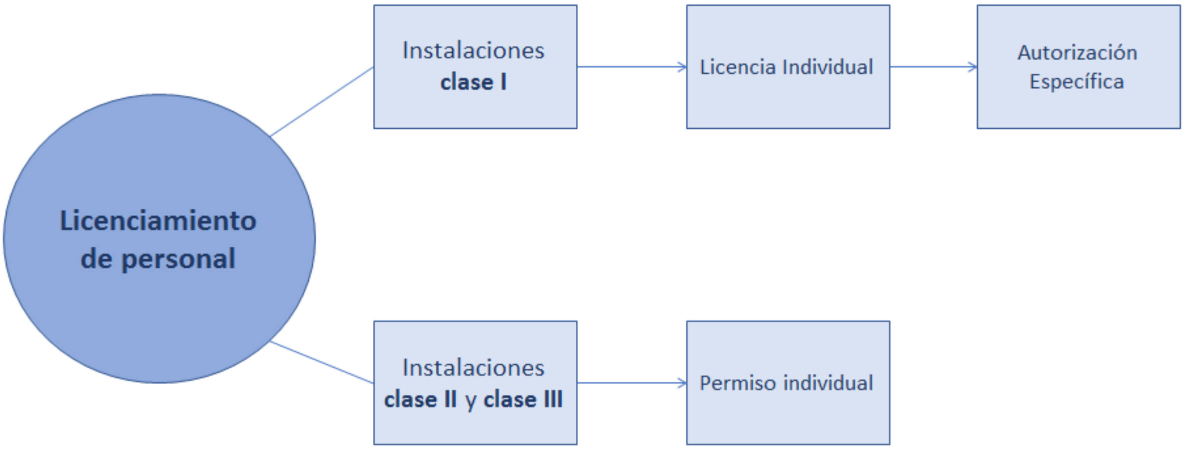

Fig. 4: Esquema para el licenciamiento de personal

Para solicitar el inicio del licenciamiento de una instalación, la Entidad Responsable[2] debe realizar y enviar una evaluación, demostrando que la instalación o practica es segura desde el punto de vista de la seguridad radiológica y nuclear. El enfoque graduado también se aplica en la extensión y el contenido de la documentación mandatoria que la Entidad Responsable debe presentar como parte de dicha evaluación. También se aplica el enfoque graduado en el alcance y la profundidad de la verificación que realiza la ARN sobre la documentación mandatoria antes de otorgar una licencia.

4.3 Enfoque graduado en el diseño e implementación del plan anual de inspecciones

Las inspecciones regulatorias son una de las principales actividades del organismo regulador, ya que permiten un seguimiento presencial de las condiciones de seguridad. Entre las principales actividades a realizar se encuentran:

- Verificación de registros (dosis del personal, monitoreos)
- Relevamiento del estado de la instalación
- Verificación de sistemas de seguridad
- Mediciones independientes de tasa de dosis
- Mediciones independientes de contaminación
- Verificación de sistemas de ventilación
- Verificación del personal (plantel mínimo, personal con Autorizaciones Especificas)

Al definir el plan anual de inspecciones regulatorias se deben tomar en cuenta todos los factores mencionados en la sección 4.2 de una manera holística, sin embargo la ponderación de los mismos puede variar respecto a la considerada durante el licenciamiento. Adicionalmente, se agregan factores operacionales que son de vital

[2] Entidad Responsable: persona humana o jurídica a la que la Autoridad Regulatoria le ha otorgado una o varias licencias, registros o autorizaciones de práctica no rutinarias.

importancia, como la experiencia regulatoria reciente, cultura de seguridad de la instalación, historial de eventos, cambios en el personal o modificaciones de los sistemas con implicancia en la seguridad, junto con el contexto nacional e internacional.

A continuación, se presenta un método para estructurar la elaboración del plan de inspecciones. Al tratarse de más de 50 instalaciones, es conveniente elegir un número acotado de factores para el análisis, lo cual se logra agrupando los mismos. Siguiendo este razonamiento, se eligen 4 factores principales, los cuales se van a dividir en 3 niveles: A, B o C. A los fines de la cuantificación, a cada nivel se le asigna un número, y la sumatoria se traduce en el número de inspecciones planeadas para el año siguiente en cada instalación. Este criterio es importante que quede documentado como parte del sistema de gestión que tenga implementado la organización.

Factores para aplicar la graduación en el desarrollo de un plan de inspecciones

- Historial regulatorio

Dentro del historial regulatorio reciente se encuentran: eventos, requerimientos pendientes, autorizaciones de práctica, modificaciones en la instalación, cultura de seguridad, cambios en el personal, si están próximos a una renovación de licencia, entre otros factores.

- Clase de instalación (clase I, clase II, clase III)

Este factor queda definido por el licenciamiento de la instalación, según fue explicitado en la sección 4.2. En este factor, se están considerando distintos aspectos de seguridad y riesgos propios de la instalación, independientemente del estado de situación actual de la misma.

- Desempeño operativo

En este factor se debe considerar la carga de trabajo de la instalación, si está operando, en parada prolongada o en mantenimiento, así como la correspondiente disponibilidad de recursos.

- Complejidad técnica y escala de operaciones

En este factor se agrupan la complejidad técnica de los sistemas, los riesgos convencionales que pueden existir, y la escala de las operaciones, incluyendo la cantidad de material y los recursos humanos disponibles.

En la Tabla 1, se presenta a modo de ejemplo la aplicación en 15 instalaciones del CCN (sin incluir reactores nucleares) de la metodología que considera el enfoque graduado para cuantificar el número de inspecciones anuales para cada instalación.

Determinación del número de inspecciones

Luego de la clasificación, a efectos de cuantificar la evaluación realizada se asigna el valor de A=1, B=0.5, C=0, y sumando los valores de los 4 factores se obtiene un valor de referencia para asignar el número de inspecciones a realizar por año. En el caso de valores fraccionarios, se puede redondear al entero superior, o al entero inferior, teniendo en cuenta criterios adicionales, como por ejemplo la situación sanitaria del país, disponibilidad de recursos, disponibilidad de inspectores, etc.

Si la cuantificación da igual a 0, que sería una instalación clase III, con categoría C en *Historial regulatorio*, C en *Desempeño operativo* y C en *Complejidad técnica*, significaría que el número de inspecciones es el mínimo: 1 cada 2 años, y la asignación o no de una inspección en el año siguiente depende de cuándo fue realizada la última inspección.

Tabla 1: Enfoque graduado para determinar número de inspecciones anuales

Instalación	Clasificación	Historial regulatorio	Desempeño operativo	Complejidad técnica/Escala	Número de inspecciones por año
Gestionadora de residuos radiactivos	A	A	A	A	**4**
Planta de fabricación de elementos combustibles para reactores de investigación (U enriquecido)	A	A	A	A	**4**
Fábrica de elaboración de elementos combustibles para reactores de potencia	A	A	A	A	**4**
Planta de fabricación de polvos de uranio	A	B	A	A	**3,5**
Planta de Producción de UO_2 (uranio natural)	B	A	A	A	**3.5**
Laboratorio de recuperación de uranio enriquecido	A	B	C	A	**2,5**
Planta de enriquecimiento de uranio, escala mock-up	B	B	C	A	**2**
Planta de almacenamiento en pileta de combustibles irradiados	A	B	C	B	**2**
Depósito de Uranio Enriquecido	A	C	C	B	**1,5**
Taller de fabricación de bultos de uranio empobrecido	B	B	C	C	**1**
Laboratorio de investigación y desarrollo, enriquecimiento por láser	B	C	C	C	**0,5**
Instalación minero fabril en proceso de	B	C	C	C	**0.5**

remediación y clausura					
Complejo minero en estado de remediación y parada prolongada	B	C	C	C	**0,5**
Depósito de almacenamiento interino de residuos radiactivos	B	C	C	C	**0,5**
Laboratorio para pruebas de hidrología de uranio	C	C	C	C	**0**

5. Conclusiones

El Enfoque Graduado es un concepto fundamental en el control regulatorio, ya que permite llevar a cabo el licenciamiento, la fiscalización y el control de las instalaciones de manera eficaz y con un uso eficiente de los recursos, siendo de particular importancia al trabajar en instalaciones con un amplio rango de riesgos, como es el caso del Ciclo del Combustible Nuclear en Argentina. La Autoridad Regulatoria Nuclear utiliza el enfoque graduado para la clasificación de instalaciones, para el licenciamiento de las instalaciones y del personal y para el desarrollo e implementación del plan de inspecciones.

La aplicación del enfoque graduado tiene que hacerse de manera integral, teniendo en cuenta un conjunto de factores que deben analizarse caso por caso, y de manera estructurada para reducir ambigüedad y asegurar consistencia. Graduar no significa no cumplir con los requerimientos regulatorios, sino determinar la forma más adecuada de cumplir con los mismos.

Su aplicación en el control de las instalaciones del Ciclo de Combustible Nuclear en Argentina ha dado resultados satisfactorios, permitiendo mantener el control regulatorio de manera eficaz y formalizando los criterios para determinar la frecuencia, el alcance y la magnitud del control regulatorio.

Se debe seguir trabajando en la elaboración de procedimientos y guías para estructurar de forma documentada su utilización, facilitar la selección de criterios y mejorar su implementación.

6. Referencias

[1] Norma AR 10.1.1, Rev. 4: “Norma Básica de Seguridad Radiológica”.

[2] Norma AR 10.6.1: “Sistema de gestión para la seguridad en las instalaciones y prácticas”.

[3] Ley N° 24.804: “Ley Nacional de la Actividad Nuclear”.

[4] IAEA-TECDOC-1740 “Use of a Graded Approach in the Application of the Management System Requirements for Facilities and Activities”.

[5] Norma AR 0.11.1, Rev.3: “Licenciamiento de personal de instalaciones Clase I”.

[6] Guía AR 10: “Programas de formación especializada y capacitación específica para el licenciamiento de personal de instalaciones radiactivas Clase I”.

[7] Norma AR 0.11.4: “Licenciamiento de personal de instalaciones Clase II y Clase III del Ciclo de Combustible Nuclear”, Rev. 0.

7. Agradecimientos

Especiales agradecimientos a la Autoridad Regulatoria Nuclear (ARN) y a la Sociedad Argentina de Radioprotección (SAR) por el apoyo y la confianza dados para presentar este trabajo, y que el mismo sea considerado para el premio “Jóvenes Profesionales en Protección Radiológica en América Latina y el Caribe”, Edición 2022.

Desarrollo preliminar de un modelo termohidráulico de una facilidad experimental tipo PWR por medio del código TRACE5

Messiga, J.P.; Troparevsky, M.I. y Corzo, S.F.

Presentado en: Reunión Anual de la Asociación Argentina de Tecnología Nuclear (AATN).
Buenos Aires, Argentina, 19 al 22 de diciembre de 2022

DESARROLLO PRELIMINAR DE UN MODELO TERMOHIDRÁULICO DE UNA FACILIDAD EXPERIMENTAL TIPO PWR POR MEDIO DEL CÓDIGO TRACE5

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Argentina

RESUMEN

Las facilidades experimentales se han diseñado y construido a lo largo de los años para proporcionar información sobre los distintos fenómenos que pueden ocurrir en los reactores nucleares. El modelo ROCOM (Rossendorf Coolant Mixing Model) fue una instalación de prueba que emulaba un reactor PWR KONVOI. El mismo permitía el análisis de fenómenos de importancia crítica para la integridad estructural y funcional del reactor, como el mezclado de corrientes a distintas temperaturas y PTS (Pressurized Thermal Shock). La bibliografía sobre esta facilidad es amplia y permite el modelado del mismo por medio de códigos termohidráulicos. En el presente trabajo se realizó un cálculo utilizando TRACE5 patch 5 (código desarrollado por US-NRC) con la finalidad de evaluar uno de los transitorios documentados en esta facilidad. En el mismo se simula la prueba 1.1 del proyecto OECD PKL2 y se compara con resultados experimentales. Dicha prueba consiste en el mezclado de agua fría (loop 1) y agua caliente (Loops 2 a 4). Entre los aspectos más relevantes del estudio, se puede mencionar la utilización del componente “vessel” en el modelado del reactor, el cual permite discretizar el mismo de forma tridimensional. Además, tiene la capacidad de incorporar porosidad, cambios de área en celda y pérdidas de carga, entre otros aspectos. Los resultados mostraron buen acuerdo respecto a los datos experimentales, demostrando la capacidad de este componente frente a eventos en la vasija de un reactor.

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PRESIDENCIA DE LA NACIÓN

Desarrollo preliminar de un modelo termohidraulico de una facilidad experimental tipo PWR por medio del código TRACE5

Mag. Ing. Juan Pedro Messiga

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Desarrollo preliminar de un modelo termohidraulico de una facilidad experimental tipo PWR por medio del código TRACE5

El código TRACE: Generalidades

Utilidad

- Modelar y simular estados estacionarios, transitorios operacionales y secuencias accidentales en reactores nucleares.

Características

- Incluye componentes 1D y 3D
- Calcula las ecuaciones de conservación de masa, energía y cantidad de movimiento junto con las ecuaciones de cierre
- Considera dos fases, con no condensables disueltos
- Permite tratar procesos termodinámicos que no están en equilibrio térmico

Métodos

- Utiliza el método de volúmenes finitos
- La discretización del tiempo se realiza utilizando métodos semi-implícitos

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El componente VESSEL

- Los elementos hidraúlicos 1D suelen requerir un esfuerzo extra para modelar los fenómenos tridimensionales
- TRACE incorpora un componente 3D llamado VESSEL
- Representa estructuras volumétricas en coordenadas cilíndricas o cartesianas
- Se puede utilizar para modelar vasijas de presión o piletas
- El carácter 3D y las opciones de usuario de este componente le dan a TRACE una mayor versatilidad que otros códigos
- Hasta el día de hoy sigue siendo estudiado y analizado

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La facilidad experimental ROCOM

- Construido con el propósito de investigar el mezclado que se produce en reactores PWR KONVOI
- Escala de 1:5 respecto al original
- Incluye el reactor y cuatro loops (bombas, generadores de vapor y cañerías)
- Bombas de caudal ajustable que le permite gran variedad de caudales
- Permite simular la inyección de agua del ECCS
- Cables de medición de temperatura (conductividad térmica)

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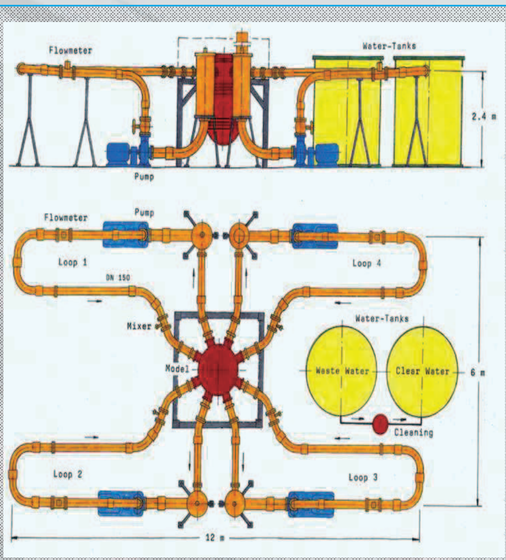

Lay-out de la facilidad ROCOM

Recipiente de presión del reactor

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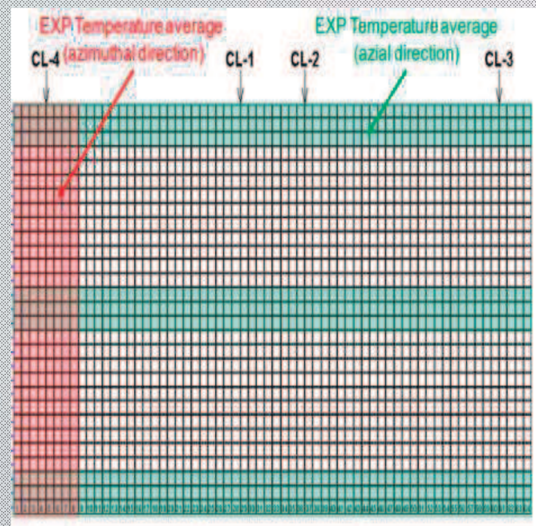
Core Support Plate



Ubicación de mediciones en downcomer

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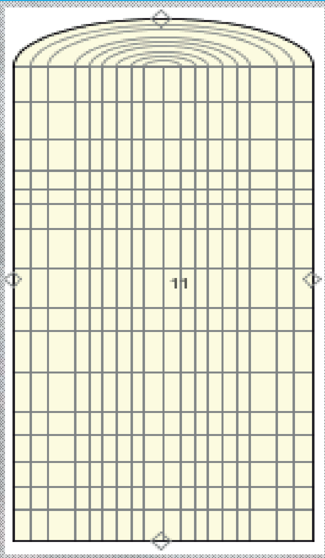
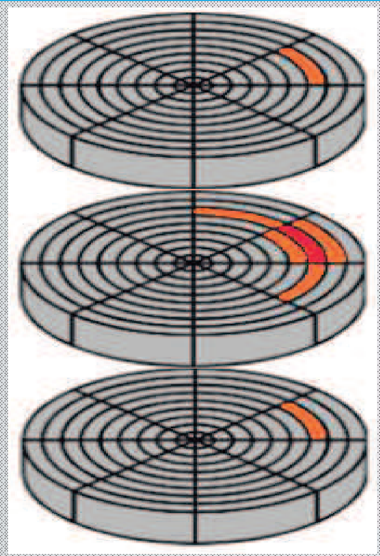


Componente hidráulico VESSEL



Celdas de un VESSEL

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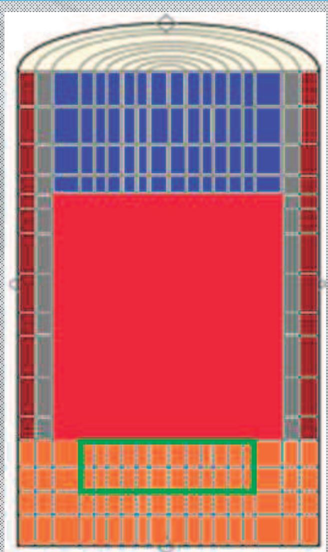

Componentes del reactor

- Downcomer
- Zona de tubos
- Upper plenum
- Lower plenum
- Cilindro perforado
- Pared

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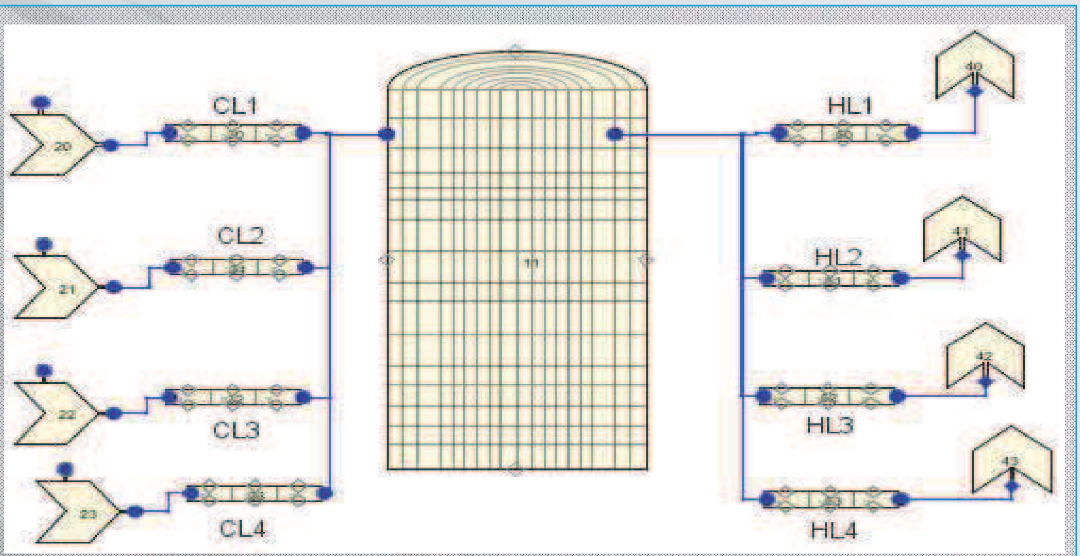

Esquema de la planta

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Temperatura promedio en el Downcomer

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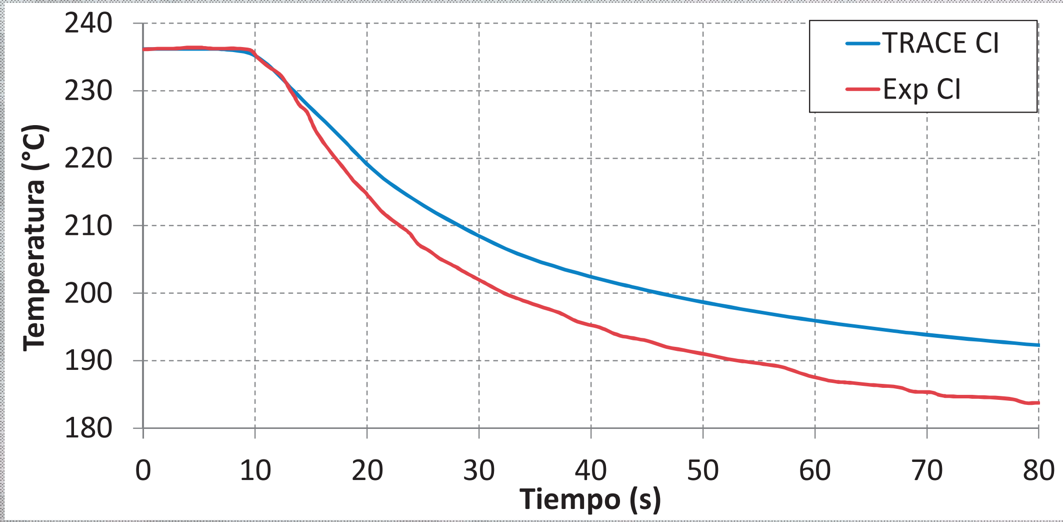

Temperatura promedio en Core Support Plate

Desarrollo preliminar de un modelo termohidraulico de una facilidad experimental tipo PWR por medio del código TRACE5

Conclusiones

- Se pudo realizar un modelo independiente de la facilidad experimental ROCOM utilizando el componente VESSEL.
- La evolución de la temperatura se condice con la de los datos experimentales.
- Los resultados en el downcomer presentan pocas diferencias respecto a los datos experimentales. En cambio, en la core support plate se observa una diferencia que llega a ser de casi 9 °C (al final de la simulación).
- Las diferencias entre los resultados y los datos experimentales (poco significativas en el downcomer y de 9 °C en la core support plate) se adjudican a que el programa TRACE no tiene modelo de mezclado turbulento. Este fenómeno parece ser mucho más importante en el lower plenum y la core support plate que en el downcomer.

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Desarrollo preliminar de un modelo termohidraulico de una facilidad experimental tipo PWR por medio del código TRACE5

Tareas futuras

- Buscar nuevas pruebas para realizar simulaciones análogas a la presentada en este trabajo, y comparar los resultados
- Realizar un modelo del reactor utilizando un código de sistemas similar a TRACE con componentes 1D y posteriormente comparar resultados, analizando las ventajas de utilizar un componente VESSEL.
- Modelar esta misma prueba utilizando un código CFD.

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Gracias por su tiempo

Autoridad Regulatoria Nuclear

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Determinación del polimorfismo genético inducido por radiaciones ionizantes en la Plaga Tuta Absoluta

Yusef, M.V.; López, S.N.; Michelin, S.C. y Solís, A.

Presentado en: Reunión Anual de la Asociación Argentina de Tecnología Nuclear (AATN).
Buenos Aires, Argentina, 19-22 diciembre de 2022

DETERMINACIÓN DEL POLIMORFISMO GENÉTICO INDUCIDO POR RADIACIONES IONIZANTES EN LA PLAGA TUTA ABSOLUTA.

Yusef,M.V 1 *, López,S.N. 2, Michelin, S. C. 3, Solís, A. 1

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2 Insectario de Investigaciones para Lucha Biológica (I.I.L.B.) Instituto de Microbiología y Zoología Agrícola (IMYZA), Instituto Nacional de Tecnología Agropecuaria (INTA) Castelar. lopez.silvia@inta.gob.ar
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INTRODUCCIÓN

Tuta absoluta es una plaga distribuida en todo el mundo que afecta principalmente a los cultivos de tomate produciendo pérdidas de hasta el 100%.

El control de plagas se realiza por métodos químicos, biológicos y mediante la Técnica del Insecto Estéril (TIE). En este último caso, la esterilización de los insectos que serán liberados a campo se realiza por radiaciones ionizantes.

Para evaluar el éxito de la TIE es necesario conocer el comportamiento de los machos irradiados y poder compararlo con el de la población silvestre. Para ello, es fundamental disponer de una técnica que permita diferenciarlos cuando son capturados en trampas de feromonas.

El objetivo de este trabajo fue implementar la técnica Random Amplification of Polymorphic DNA polymerase chain reaction (RAPD-PCR) para diferenciar insectos normales de aquellos irradiados y su Filial 1 (F1)

MATERIALES Y MÉTODOS

- Las polillas se criaron sobre plantas de tomates en condiciones controladas de laboratorio a 24+1°C y 75+5% H.R. y fotoperiodo L:O 16:8. Se enfriaron a 3 °C y se irradiaron (60 Co) con dosis de 150 Gy y tasa de dosis de 34 Gy/min.
- Extracción de ADN de cada polilla - Amplificación RAPD-PCR
- Amplificación : 41 ciclos - (1 min a 94 °C, 1 min a 34 °C, 1 min a 72°C y 10 min a 72°C
- Primers - Secuencia 5´- 3´

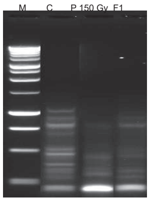
OP-H9: TGTAGCTGGG - OP-A17: GATTGTTTGT - OP-A8: GTGACGTAGG

OP-D12: CACCGTATCC - OP-D13: GGGGTGACGA

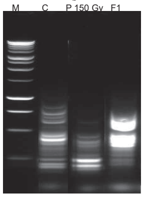
- Análisis de los fragmentos amplificados en geles de agarosa 1,5%.
- Índice de similitud (IS) de Nei - Li en ADN de polillas adultas de *T. absoluta*

RESULTADOS

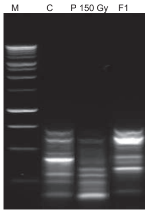
Las figuras 1- a, b, c, d y e, ejemplifican la cantidad y tamaño de los fragmentos amplificados con cada uno de los primers para los insectos control, irradiado y F1 y sus respectivas matrices donde se indica el peso molecular de cada banda y representado por 1 y 0 la presencia o ausencia de las mismas en las tres muestras. En el cuadro 1 muestra el IS entre el control, polillas irradiadas y sus descendientes F1.



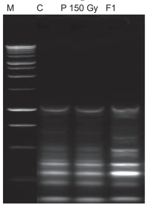
	N° bandas	Pares de bases (Pb)	Control	P 150 Gy	F1
PRIMER OP-H9	1	310	1	0	0
	2	275	1	0	1
	3	230	1	1	1
	4	198	1	0	0
	5	147	1	0	0
	6	142	0	0	1
	7	134	1	0	0
	8	126	0	1	1
	9	108	1	0	0
	10	105	1	0	0
	11	99	0	1	0
	12	93	1	0	1
	13	88	0	1	0
	14	83	1	0	1
	15	76	1	1	1
TOTAL	15		11	5	7



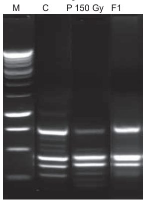
	N° bandas	Pares de bases (Pb)	Control	P 150 Gy	F1
PRIMER OP-A170	1	384	1	0	0
	2	311	1	0	0
	3	284	1	0	0
	4	260	1	0	0
	5	238	1	1	1
	6	217	0	0	1
	7	204	0	0	1
	8	181	1	1	1
	9	161	1	0	0
	10	156	1	1	1
	11	147	0	1	1
	12	138	1	0	1
	13	123	1	1	1
	14	112	1	1	1
	15	103	0	0	1
	16	99	0	1	0
	17	97	1	0	0
	18	94	0	1	0
TOTAL	18		12	8	10



	N° bandas	Pares de bases (Pb)	Control	P 150 Gy	F1
PRIMER OP-A8	1	228	1	0	1
	2	196	1	1	1
	3	159	1	0	0
	4	150	0	0	1
	5	137	1	0	0
	6	133	0	0	1
	7	118	0	1	1
	8	108	1	1	0
	9	105	0	0	1
	10	93	1	1	0
	11	82	0	1	0
	12	73	1	1	0
TOTAL	12		7	6	6



	N° bandas	Pares de bases (Pb)	Control	P 150 Gy	F1
PRIMER OP-D13	1	354	1	1	1
	2	233	1	1	0
	3	206	0	0	1
	4	172	1	1	1
	5	153	1	1	1
	6	136	1	1	0
	7	128	1	1	1
	8	107	1	1	1
	9	89	1	1	1
	10	66	1	1	1
TOTAL	10		9	9	8



	N° bandas	Pares de bases (Pb)	Control	P 150 Gy	F1
PRIMER OP-D12	1	417	1	0	0
	2	309	1	1	1
	3	258	1	0	0
	4	229	1	0	0
	5	209	1	1	0
	6	175	1	1	1
	7	155	1	1	1
	8	129	1	1	0
	9	122	0	1	0
	10	108	0	1	0
TOTAL	10		8	7	3

Fig. 1: Patrón representativo RAPD-PCR en geles de agarosa al 1,4 % resultante de la amplificación del ADN genómico de machos adultos de *T. absoluta* y sus respectivas matrices - a: Primer OP-H9; b: Primer OP-A17; c: Primer OP-A8; d: Primer OP-D13; e: Primer OP-D12
M: patrón, C: control, P 150 Gy: padre irradiado con 150 Gy; F1: hijo de P 150 Gy

	CONTROL	P 150 Gy	F1
OP-H9			
CONTROL	1	0,25	0,39
P 150 Gy		1	0,5
F1			1
OP-A17			
CONTROL	1	0,5	0,54
P 150 Gy		1	0,45
F1			1
OP-A8			
CONTROL	1	0,61	0,15
P 150 Gy		1	0,33
F1			1
OP-D12			
CONTROL	1	0,67	0,54
P 150 Gy		1	0,6
F1			1
OP-D13			
CONTROL	1	1	0,82
P 150 Gy		1	0,82
F1			1

Cuadro 1: Detección de polimorfismos en el ADN utilizando el Índice de Similitud de Nei –Li para los 5 primers en polillas de *T. absoluta* - control, padre irradiado con 150 Gy e hijo F1

CONCLUSIONES

Se observó que los ADN de las polillas irradiadas y su F1 presentan menor número de fragmentos amplificados respecto al control La variación en el numero y tamaño de bandas entre los controles, insectos irradiados y de la F1 puede ser debida fundamentalmente a mutaciones o rearreglos cromosómicos inducidos por las radiaciones ionizantes que impiden o facilitan el reconocimiento de secuencias complementarias a los primers utilizados.

Se concluye que la utilización de los primers OP-H9 y OP-A8 indican el menor IS o sea que permiten detectar el mayor grado de polimorfismo entre insectos controles, irradiados y sus descendientes (F1), lo cual implica que esta técnica puede ser empleada para el objetivo propuesto.

Regulatory Control at the Construction Stage of a Radiopharmaceuticals Production Facility with Cyclotron in the Context of COVID-19 Pandemic

Rabi, G.; Maggiolo, A. y Espósito, M.

Presentado en: International Conference on Accelerators for Research and Sustainable Development: From Good Practices Towards Socioeconomic Impact del Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 23 al 27 de mayo de 2022

REGULATORY CONTROL AT THE CONSTRUCTION STAGE OF A RADIOPHARMACEUTICALS PRODUCTION FACILITY WITH CYCLOTRON IN THE CONTEXT OF COVID-19 PANDEMIC

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M.R. ESPÓSITO
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Abstract

Inspections and regulatory processes at the construction stage of a radiopharmaceuticals production facility with cyclotron have certain particularities that distinguish them from the processes related to other stages of the life of a facility. Particularly, the construction of a concrete shielding of great thickness, such as a non-self-shielded cyclotron vault, requires a set of specific controls by the regulatory body for the purpose of avoiding construction failures that could ultimately affect the safety conditions during the operational phase.

Due to the pandemic COVID-19 restrictions, the Nuclear Regulatory Authority, through the 'Class I Particle Accelerators Control Department', implemented alternative forms to develop the regulatory tasks associated to a facility denominated 'Cyclotron- Radiopharmacy Laboratory' from Oulton Institute located in Córdoba City, Province of Córdoba, Argentina, during the construction stage that had satisfactory results.

1. INTRODUCTION

The regulatory framework established by the Nuclear Regulatory Authority of Argentina (ARN) determines four stages for the authorization process of a radiopharmaceutical production facility with cyclotron; since it is classified as a Class I facility: construction, commissioning, operation and decommissioning [1]. This scheme of authorization stages is in line with the IAEA recommendations as the state of art for this type of facilities. In such way, in Argentina, the development of the construction stage of a cyclotron - radiopharmacy facility requires an authorization from the regulatory body [2].

This construction stage includes not only the development of civil works, but also the assembly of equipment and components of the facility. The documentation submitted by the applicant to get this authorization has to cover the following topics: facility layout, flow of materials and personnel, shielding design, ventilation system design, radiological impact on workers and the public, etc.[3]

The 'Class I Particle Accelerators Control Sector' of ARN did a detailed analysis of these documents in order to verify that all the radiation safety aspects were properly considered. In March 2020, the ARN granted the authorization of construction to begin the civil work of the facility 'Cyclotron - Radiopharmacy Laboratory' from Oulton Institute located in Córdoba City, Province of Córdoba, Argentina.

Regulatory inspections are a valuable instrument for verifying compliance with the conditions under which the authorization of construction is granted. Furthermore, since March 2020, the Government of Argentina has stablished restrictions to the circulation due to the sanitary emergency that was declared in view of the new coronavirus COVID-19, which affected the development of on-site regulatory tasks.

2. CRITERIA

There are a series of considerations that have to be taken into account in order to verify the conditions stipulated during the design phase, concerning radiation protection of workers, the public and the environment are being followed.

During the construction stage, a large proportion of the regulatory controls are intended to check that some criteria related to the cyclotron vault are followed, such as:

1. A cyclotron vault must be a monolithic structure; this is achieved by a one single cast of concrete or, in case it were no technically possible, by another technical solution that guarantee the shielding capacity of the vault.
2. Formwork and shoring systems must not reduce the shielding capacity; these elements remain inside the structure after the concrete curing decreasing the shielding capacity, so they should be replaced by heavy extern shoring systems.
3. Assembly of ducts ins and outs to the vault must avoid the leakage of neutrons; 90-degree bends over the three cardinal axes are necessary to be placed.
4. Future decommissioning tasks must be foreseen; the adoption of concrete blocks that work as a 'sacrificial' layer that facilitate the future dismantling works of the vault.

The compliance of these criteria has been a challenge for the licensee. Some of these criteria could be applied and others presented some difficulties (that are described below) that made necessary to apply innovative technical solutions.

1. A cyclotron vault must be a monolithic structure,

It was informed to ARN that there was no available concrete supply in Córdoba city to complete one single cast at once. Thus, it was necessary to plan several concrete casts to erect the vault in layers of concrete. A construction through layers of concrete can produce deficiencies in the contact surfaces that could affect the shielding capacity of the vault and the consequent risk of radiation leakages. After a discussion with the facility manager, it was agreed to insert a double wooden frame inside the steel armor, along the perimeter of the vault. A short time after the pour of concrete of the layer is finished, the wooden frame would be retired to produce 'steps' that avoid interface plans between the layers of concrete.

The construction project of the vault that was presented by the facility to ARN is illustrated in the next figure.

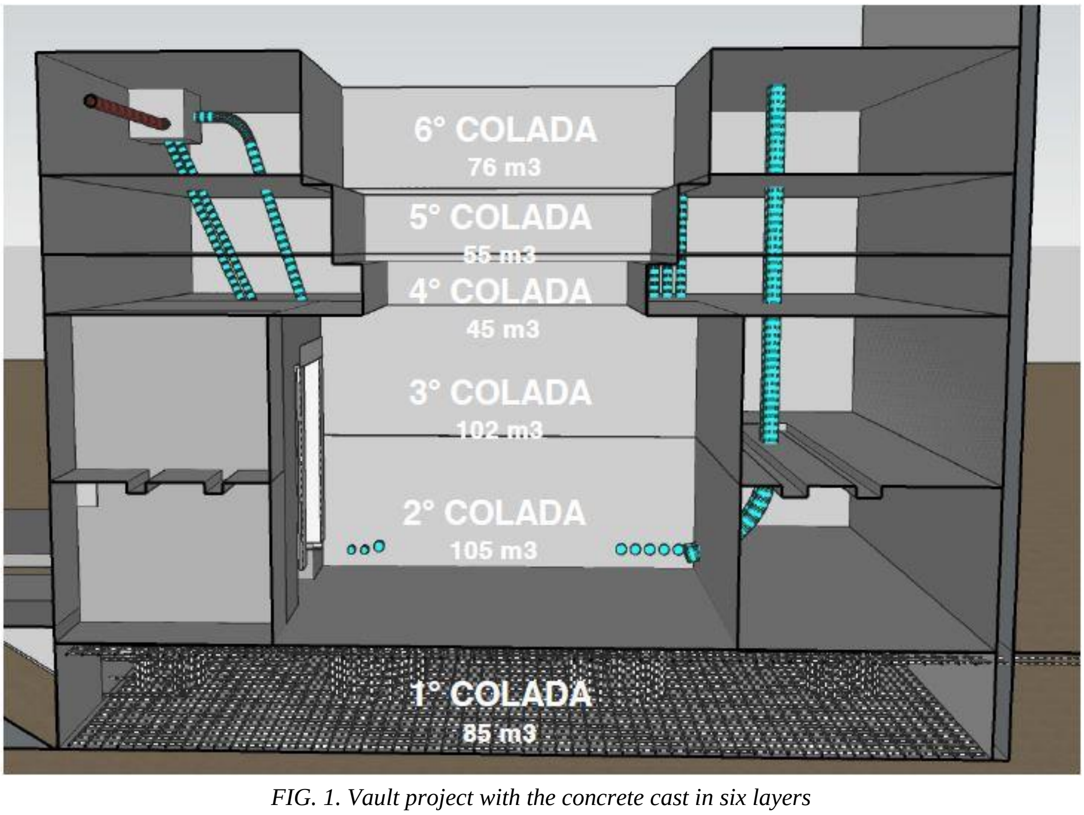

FIG. 1. Vault project with the concrete cast in six layers

The ARN analyzed that plan and suggested to modify the height of the layers n°2 and 3, because the interface surface between those layers matched the proton acceleration plan of the cyclotron and its targets. (*See FIG. 2*)

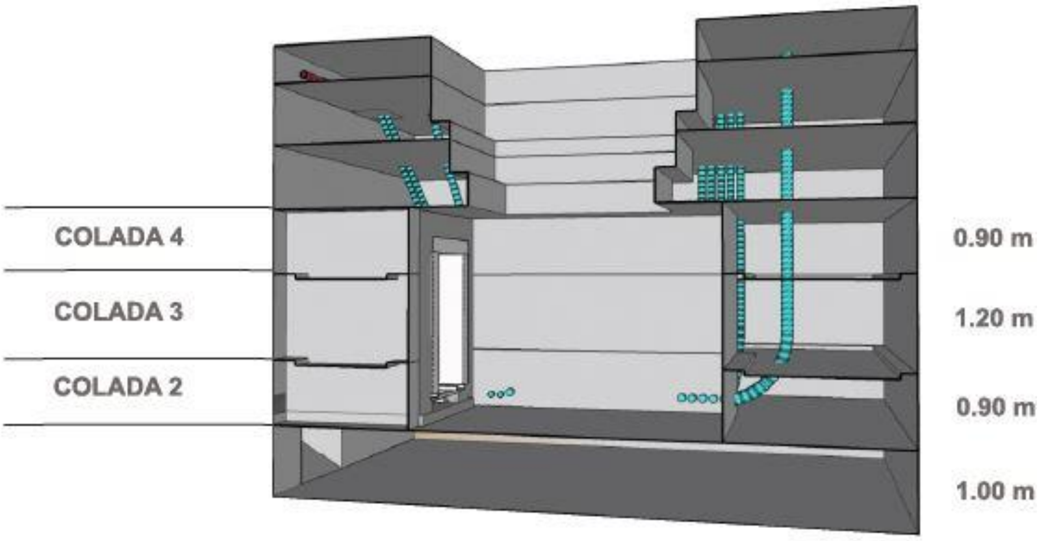

FIG. 2. Vault with the layers' height modified

In addition to this, it was requested to vibrate the concrete with appropriate equipment during the pouring, to prevent the generation of air bags inside the vault shielding.

2. Formwork and shoring systems must not reduce the shielding capacity,

It is common in civil constructions the use of metallic tensors to grew the resistance of the concrete containment during the pouring and simplify the formwork assembly. These tensors remain in the shielding structure and might produce possible radiation leakages due to metal corrosion. For this reason, it is requested to replace the use of tensors for extern shoring systems that have to be able to resist the concrete pressure.

Extern shoring systems were foresaw in this project and this criteria could be successfully complied through the adoption of different kinds of shoring systems. (*See FIG. 3*)

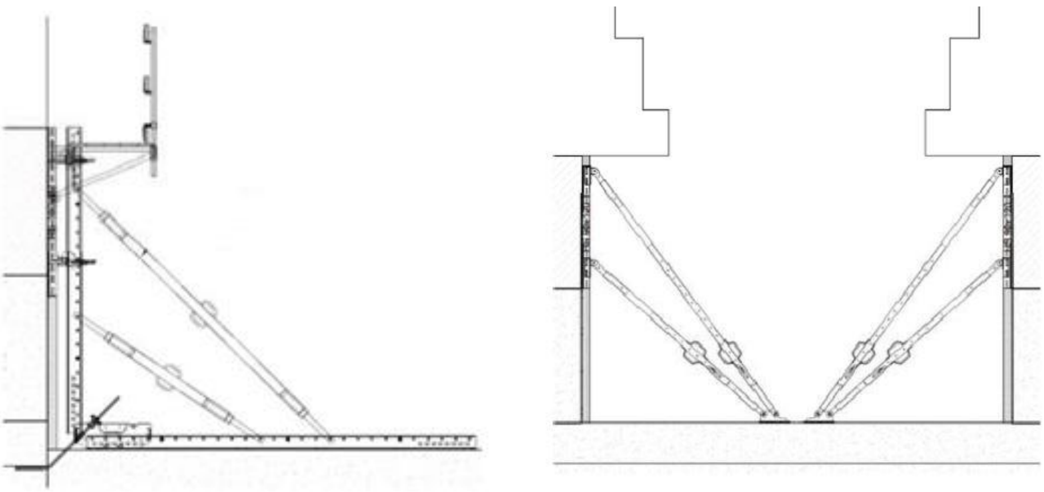

FIG. 3. Shoring systems

3. Assembly of ducts ins and outs to the vault must prevent the leakage of neutrons,

The route of ins and outs ducts to the vault that were presented in the ventilation system project, satisfies the requirements by adopting three 90-degree turns over the cardinal axes preventing neutron leakages. This can be observed in the next figure.

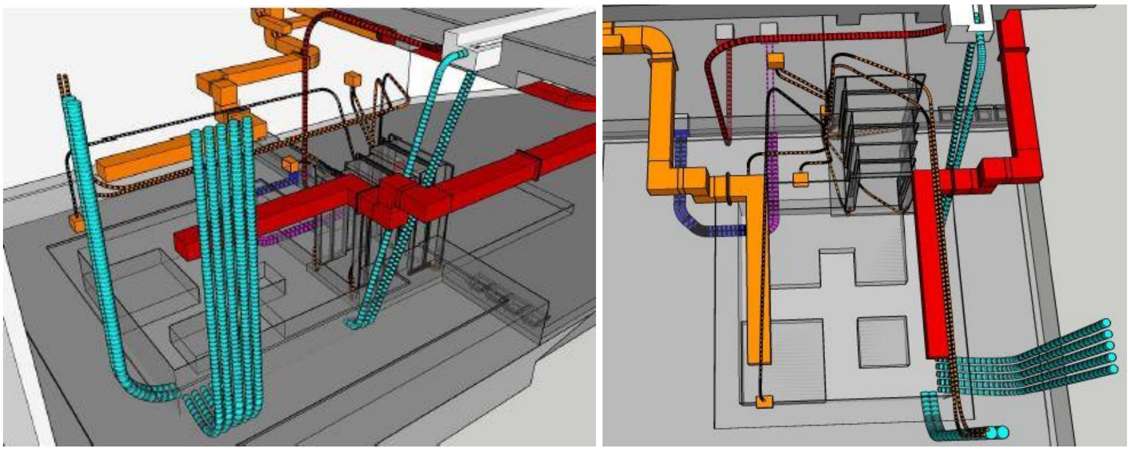

FIG. 4. Project of ins and outs ducts of ventilation system

4. Future decommissioning tasks must be foreseen.

ARN requested the facility to include a sacrificial layer in the vault project. The facility presented a project of concrete blocks with a particular design (*See FIG. 5*). This design of blocks to assemble allows the interior walls of the vault to be covered easily.

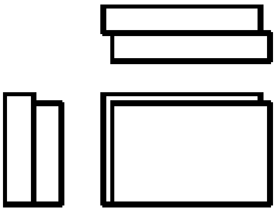

FIG. 5. Concrete blocks project for 'sacrificial' layer

Considering the expected use of local shieldings for FDG production targets, the resulting concrete blocks thickness is 10 cm.

3. INSPECTIONS AND REGULATORY CONTROL

The development of inspections during the construction stage and especially prior to the pouring of the concrete, allows the regulatory body to verify whether the criteria described in the previous section have been considered.

The restrictions established due to the COVID-19 pandemic made it difficult to travel to Córdoba city to carry out on-site inspections. Thus it was required to implement alternative solutions in order to continue with the regulatory control adequately. ARN adapted its regulatory processes incorporating the remote work, and to this extent, the 'Class I Particle Accelerators Sector' followed the execution of the civil works remotely by reviewing photographic reports that the facility sent to the ARN continually.

In this context, photographic records of the civil works were critical and it was extremely important that workers in charge of taking these photos understood what needed to be depicted in them. For this purpose, a remote meeting between inspectors of ARN and the civil work staff was made. Inspectors of ARN clarified relevant concepts as well as answered questions and the staff could take great pictures of the civil work progress.

The following pictures show the fulfillment of the criteria, according to the approved project.

— A cyclotron vault must be a monolithic structure,

FIG. 6. Wooden frame inside the armor previous the concrete cast

FIG. 7. Double wooden frame inside the armor

FIG. 8. The 'step' generated by the wooden frame

FIG. 9. *A civil worker vibrating the concrete during the cast*

— Formwork and shoring systems must not reduce the shielding capacity,

FIG. 10. Shoring system to extern vault wall

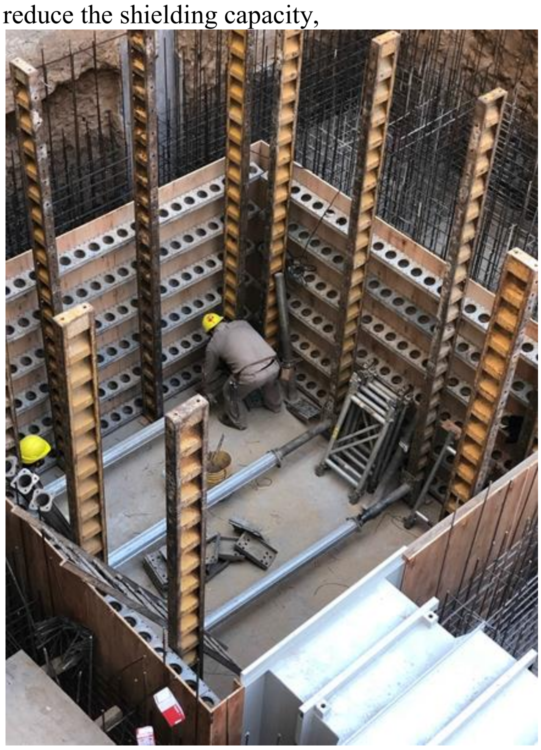

FIG. 11. Shoring system to intern vault wall

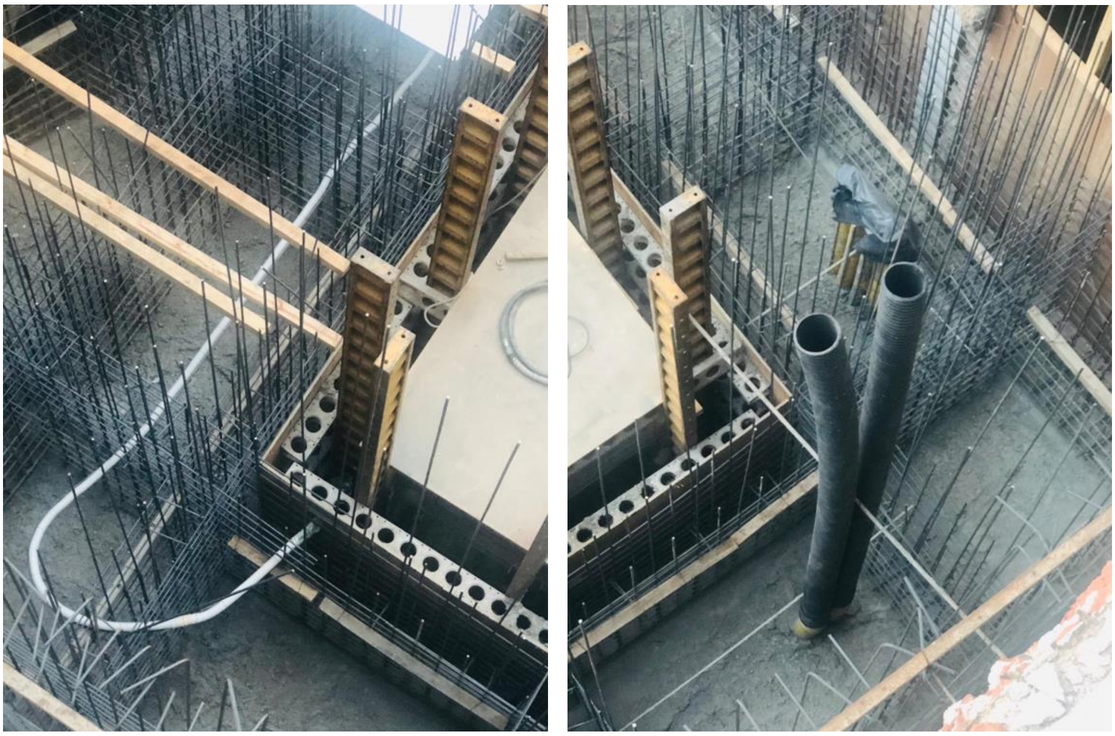

FIG. 12. Absence of intern metallic tensors

— Assembly of ducts ins and outs to the vault must prevent the leakage of neutrons,

FIG. 13. Ins and outs ventilation ducts from the vault

The proper assembly of ventilation ducts was verified by these pictures. In addition to this, the electrical cabling, water, gas and product supply tubing to and from the cyclotron were also properly placed on trenches in the vault floor, connecting to the underside of the cyclotron.

FIG. 14. General services piping

- Future decommissioning tasks must be foreseen.

FIG. 15. Concrete blocks for ′sacrificial′ layer

The inner walls of the cyclotron vault were covered with concrete blocks as it was approved in the design phase. These concrete blocks were built on the construction site.

4. CONCLUSIONS

The objectives of the regulatory control during the vault construction were successfully fulfilled. The current criteria in the matter were properly considered and adapted according to the needs and the technical limitations, as it could be observed.

The Covid-19 restrictions forced inspections processes to be adapted and the results obtained by the ‘Class I Particle Accelerators Sector’ of ARN in the control of construction stage tasks have been very positive until now. The implementation of a remote meeting to exchange knowledge with not only the operators but also the civil work team has been a great decision in order to assure that the verification could be done properly, taking into account that some relevant aspects can be verified only during the concrete cast but not later.

The early participation of the regulatory bodies in the evaluation of the design projects and the fluid communication with the operators could demonstrate that streamlines the progress of the civil work.

Fortunately, a few months after the concrete cast, the restrictions were released and the inspectors of ARN could verify on site that the construction progress is in accordance with the approved project. However, it is valuable to consider that despite the fact that remote controls had satisfactory results, they do not replace on-site verifications; because the remote control success relies strongly on an effective communication between the licensee and the regulatory body, which could not always be the case.

Currently, the construction authorization is still valid and this stage continues by the assembly of the radiopharmacy systems and the radiological protection equipment. The cyclotron is already placed and also the hot cells of the radiopharmacy lab. At April of 2022, the external contractors are finishing their construction jobs and the commissioning authorization has been already requested to ARN.

ACKNOWLEDGEMENTS

A special recognition should be given to Oulton Institute authorities and to ‘Cyclotron - Radiopharmacy Laboratory’ staff who gave permission to show pictures of the work performed in the civil work of the facility.

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Regulatory Framework Adopted by the Nuclear Regulatory Authority of Argentina for the Licensing of the Argentine Center of Proton Therapy and Progress Achieved

Rabi, G. and Martiri, L.

Presentado en: International Conference on Accelerators for Research and Sustainable Development:
From Good Practices Towards Socioeconomic Impact del
Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 23 al 27 de mayo de 2022

REGULATORY FRAMEWORK ADOPTED BY THE NUCLEAR REGULATORY AUTHORITY OF ARGENTINA FOR THE LICENSING OF THE ARGENTINE CENTER OF PROTON THERAPY AND PROGRESS ACHIEVED

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Abstract

The Argentine public health system is currently carrying out the project of the Argentine Proton Therapy Center (CeArP), being the first in the region to incorporate high-energy proton beams for cancer treatment. This center is designed to have two treatment rooms and a Research and Development laboratory, provided with a 230MeV proton beam generated by a cyclotron. This project represents a challenge for the regulatory body, the Nuclear Regulatory Authority of Argentina (ARN), as it does not have a specific regulatory framework or staff with prior experience in this technology. The paper summarizes the activities conducted by the ARN during the CeArP licensing process, describes the regulatory approach adopted and the implemented steps to strengthen its capacities. Finally, the milestones achieved so far, the lessons learned and future plans are presented in the paper, as well as the challenges caused by COVID-19 pandemic that led to adapting de regulatory process with remote collaborative work to analyze the documentation.

1. INTRODUCTION

In 2016, the National Commission of Atomic Energy (CNEA) notified to the Nuclear Regulatory Authority of Argentina (ARN) the plan to carry out the project of the Argentine Proton Therapy Center (CeArP). The original project included a treatment room and a Research and Development laboratory, provided with a 230MeV proton beam generated by a cyclotron. Despite pauses in the project that delayed construction, progress continued and modifications were implemented, adding one more treatment room to the original design. The placement has been defined in Buenos Aires City, in a strategic zone, next to the Oncology Institute "Dr. Angel H. Roffo" and the "Nuclear Medicine Center Foundation (FCDN)".

This center would be the first in Latin-America with this type of technology, representing a challenge not only for the entity in charge to operate the facility, but also on the regulatory side. During this time ARN had to work improving their technical capabilities to deal with this new technology properly. Furthermore, the regulatory framework of ARN had to be adapted to carry out the regulatory processes in a proper way.

Finally, in February 2021, the Responsible Entity presented the documentation formalizing the beginning of the licensing process of the facility.

2. REGULATORY APPROACH

The ARN is facing this regulatory endeavour working on different strategies. Since the beginning of the project, the development of technical capabilities of the personnel has been a priority. Furthermore, adapting the regulatory framework and different organizational aspects in order to facilitate the licensing processes to a new technology has been a great challenge.

2.1. Training

Since ARN was notified of the Argentine Proton Therapy Center (CeArP) project in 2016, efforts are being made by the regulatory body to further develop the technical capabilities of its human resources, through the participation of members of the evaluation group in technical meetings, workshops, specializations studies, collaboration projects with other regulatory bodies and internal training sessions related to proton therapy, among others.

2.1.1. Participation in technical meetings, workshops

ARN has encouraged the participation of the personnel in technical meetings and workshops; events as a technical meeting in the University of Philadelphia that took place in 2016 with the vendor of the center, or the 1st Argentine Workshop of Proton Therapy in 2019.

2.1.2. Specialization Studies

Most of the members of the evaluation group have completed the IAEA funded Specialization Course in Radiological Protection and Safety of Radiation Sources. Moreover, one member chose the licensing of a proton therapy center as the final project for the Specialization.
Additionally, another member embarked on master's studies through a Fulbright scholarship in the United States, at the University of Florida, which houses an active proton therapy center. He was able to take different courses on various topics relevant to the licensing of the center and participate in the Penn Radiation Oncology, “Fifth Annual course in Proton Therapy”, in November 2018.

2.1.3. Internal training sessions

A comprehensive reading of IAEA-TECDOC 1891 was performed; the document was distributed among the personnel for its reading and study after its publication in January 2020. A session was organized to discuss the most relevant topics of the document.

2.1.4. Collaboration projects with other regulatory bodies

There is a collaboration project signed in 2021 between ARN and CNEN (the regulatory body of Brazil), where it was included the cooperation in ‘Proton therapy and authorization processes in high energy cyclotrons’. Thus, exchange activities were programmed including remote virtual meetings and technical visits in Argentinian and Brazilian facilities. The authorization processes for facilities’ personnel were also included in the agenda, which is in progress.

2.2. Regulatory framework

The Nuclear Regulatory Authority of Argentina (ARN) is the responsible of establish, develop and implement a regulatory regime for all nuclear activities carried out in Argentina. The national law Act 24.804, which came into force on April 25, 1997, gives to the ARN the power of dictate the country standards. The regulatory framework of the nuclear activity is sustained by 64 regulatory standards and 10 regulatory guides. It classifies the facilities as Class I, Class II and Class III considering the following criteria [1]:

- radiological risk associated to the radiation sources in the facility or practice,
- environmental radiological impact,
- radiological consequences of potential exposures,
- the ocupational doses and,
- technological complexity.

From the argentine regulatory framework, does not emerge a direct classification for a proton therapy facility. This classification is not trivial, since all the medical applications with accelerators are classified as Class II facilities and cyclotrons are generally considered Class I. But in this case, the facility was considered as one single element.

ARN has strengthened its regulatory framework for authorization and processes oversight, to ensure that national and international standards are met. For this purpose, ARN has defined some general guidelines related with the authorization processes of the facility and the regulatory task assignments.

2.2.1. *Authorization process*

The Argentine Proton Therapy Center (CeArP) was categorized as a Class I facility **¡Error! No se encuentra el origen de la referencia.**. This classification was defined using a graded approach, considering not only the radiological risk of its operation, but also the consequences of an incidental/accidental event and its technological complexity [3]. The authorization process is being implemented in four stages, with construction, commissioning, operation and decommissioning authorizations, as established by the ARN standards for Class I facilities and the recommendation of IAEA **¡Error! No se encuentra el origen de la referencia.**.

2.2.2. *ARN Strategic plan*

The authorization process of the Proton Therapy Center has been included as a priority in the ARN strategic plan for 2021-2025. In this manner, ARN reaffirms its commitment to radiation safety with the corresponding allocation of resources [5].

2.2.3. *Creation of the Project*

To carry out these regulatory endeavours, a multidisciplinary working group was formed by the ARN, with strategic personnel with background in regulatory affairs in an attempt to leverage prior experience. The creation of the 'Licensing Project of the Argentine Center of Proton Therapy' gives a formal structure, but taking into account that their members belong to different working areas of the ARN with their own responsibilities.

The 'Project' has its following objectives:

- Manage the licensing of the facility, until the eventual granting of the Operating License,
- Plan regulatory activities related to licensing,
- Generate the necessary communications with the Responsible Entity,
- Manage documentation related to licensing,
- Coordinate the necessary evaluations and give intervention to suitable personnel of the "Class I Particle Accelerators" sector and the "Radiotherapy and Brachytherapy" department, in addition to submitting requests for external evaluations to management when necessary,
- Prepare the relevant reports

The 'Project' depends on the 'Radiation Safety, Safeguards and Security' Department of ARN and it is essentially formed by two sectors: "Class I Particle Accelerators Control" and "Radiotherapy and Brachytherapy¨. Two members of other ARN sectors with experience in safety assessments have been summoned to the working group, and to this day, it is composed of six members.

3. RESULTS

After several years of work, results are starting to be seen in each of the lines of action in which the ARN has advanced.

3.1. Training

The training activities carried out to date have given satisfactory results, being able to strengthen the capacities of the staff introducing themselves in the particularities of the proton therapy. In addition, the trainings have allowed the personnel of the two main sectors participant to be able to get involved in the regulatory aspects that derive from the other and thus increase the technical capacities of the group.

There are some other activities planned to be carried out soon, as the technical visits of experts and the development of knowledge exchange activities with other regulatory bodies with experience on authorization and inspection process of this technology.

3.2. Authorization processes

3.2.1. Facility

In February 2021, the Responsible Entity submitted to the ARN the Preliminary Safety Report required for granting the construction authorization, which has been evaluated by the working group of the 'Licensing Project of the Argentine Center of Proton Therapy'. Due to the COVID-19 restrictions, the regulatory processes needed to be adapted; in this way, the safety assessment of this documentation was realized remotely.

Virtual technical meetings were realized for this purpose, where technical discussion enriched the group work. Other ARN sectors have contributed in the evaluation working in specific topics. Technical reports with the safety assessment conclusions were made and circulated among the group.

At the moment, the experience of virtual work in safety assessment has been very positive for this working group. The work has been smooth and efficient and it is expected to continue in this way with the evaluation of the remainder documentation that it is expected to come.

3.2.2. Staff

Facility personnel will be authorized through a mixed licensing scheme, combining the staff licensing process applicable to Class I facilities with the one for obtaining individual permits that applies to Class II facilities [6] [7]. This licensing scheme has been developed by applying a graded approach to existing ARN standards for staff licensing during the evaluation of the proposed organizational structure of the Proton Therapy Center. Emphasis will be placed on ensuring adequate education and training for all positions in the organization chart, as well as the application of an Integrated Safety Management System that includes a program for the promotion of a strong safety culture, according to ARN standards, in particular **AR 10.6.1** "Management System for Safety" and GSR Part 3 [8].

4. CONCLUSION

The efforts made by the ARN since the notification of the construction plan to assume the licensing of a new technology, such as proton therapy, are showing promising results.

On one hand, special efforts have been made to support and promote staff training. The ARN understood from the beginning that the training process must be continuous and once started, the skills of the personnel must be maintained and improved. From 2016 to date, several training activities have been completed with satisfactory results. It is planned to continue in this direction in the years to come.

On the other hand, it has been necessary to strengthen the regulatory framework in order to carry out the licensing process in accordance with national and international standards. For this reason, work is being done on the application of a graded approach both to the licensing of the facility itself and in the personnel licensing process, with visible progress.

To meet the aforementioned objectives, the development of an ‘ad hoc’ working group, with complementary backgrounds, can be considered an adequate decision. Proof of this is the work carried out, within the context of the restrictions due to the pandemic, delivering concrete results such the complete evaluation of the first version of the Preliminary Safety Report.

Finally, the ARN's commitment to safety and good practices has been demonstrated, which are not only expressed in documents such as the strategic plan, but also in regulatory actions and we hope to continue on this path.

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Foreseeing Regulatory Strategies to Strengthen Occupational Radiation Protection

Rojo, A.M.

Presentado en: International Conference on Occupational Radiation Protection – Strengthening Radiation Protection of Workers – Twenty Years of Progress and the Way Forward del Organismo Internacional de Energía Atómica (OIEA).
Ginebra, Suiza, 5 al 9 de septiembre de 2022

FORESEEING REGULATORY STRATEGIES TO STRENGTHEN OCCUPATIONAL RADIATION PROTECTION

Rojo, A.M.

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ABSTRACT

Esta presentación se realizó en respuesta a la invitación del OIEA a integrar la mesa redonda "Desafíos regionales en la implementación de la protección radiológica ocupacional" (*Regional challenges in implementing occupational radiation protection*).

En esta ponencia titulada "Previsión de estrategias normativas para fortalecer la protección radiológica ocupacional" se expuso, en una primera parte, la experiencia de más de 70 años de Argentina en tópicos relacionados con el "llamando a la acción" del OIEA en la Conferencia previa del 2014, relacionados con la formación de recursos humanos regionales, la participación en foros para el fortalecimiento de la protección radiológica y el desempeño en la misión I.R.R.S.

En una segunda parte, se detalló la tarea del CONSEJO ASESOR EN APLICACIONES DE RADIOISÓTOPOS Y RADIACIONES IONIZANTES (C.A.A.R.) como parte estratégica del proceso de ARN para el licenciamiento de personal en instalaciones médicas, industriales e investigación con la función de verificar que sean observados los requisitos regulatorios establecidos en la normativa de aplicación.

Se destacó la relevancia de contar con una opinión experta e independiente aportada en las recomendaciones al Directorio por los vocales de este Consejo Asesor, en cuanto a la aprobación o rechazo de solicitudes de permisos individuales, la actualización o propuestas de nuevos requerimientos, y la revisión de los programas de educación y entrenamiento de los regulados.

Se concluye que los Consejos Asesores contribuyen efectivamente en las estrategias para el fortalecimiento del proceso de licenciamiento aportando transparencia y expertice para la actualización de la Normativa, principalmente, en el caso de nuevas tecnologías, prácticas médicas y nuevos radiofármacos.

"Foreseeing regulatory strategies to strengthen occupational radiation protection"

Ana María Rojo

Nuclear Regulatory Authority
ARGENTINA

Regional challenges in implementing occupational radiation protection

Round table: Friday, 9 september 2022, 10.30-11:30 A.M.

www.argentina.gob.ar/**arn**

Background

Call-for-Action: 2nd O.R.P. 2014 (Argentine follow up)

IRRS – ARGENTINA – 22nd August to 2nd September 2022

www.argentina.gob.ar/**arn**

Background

Call-for-Action: 2nd O.R.P. 2014

(Argentine follow up)

5.- Increase training and education in occupational radiation protection

Training and education includes periodic refresher training

(Argentine trains and requires training by licensing process)

Application of the requirements for education; training; qualification and competence in protection and safety

Education and Training Appraisal (EduTA) mission to Argentina

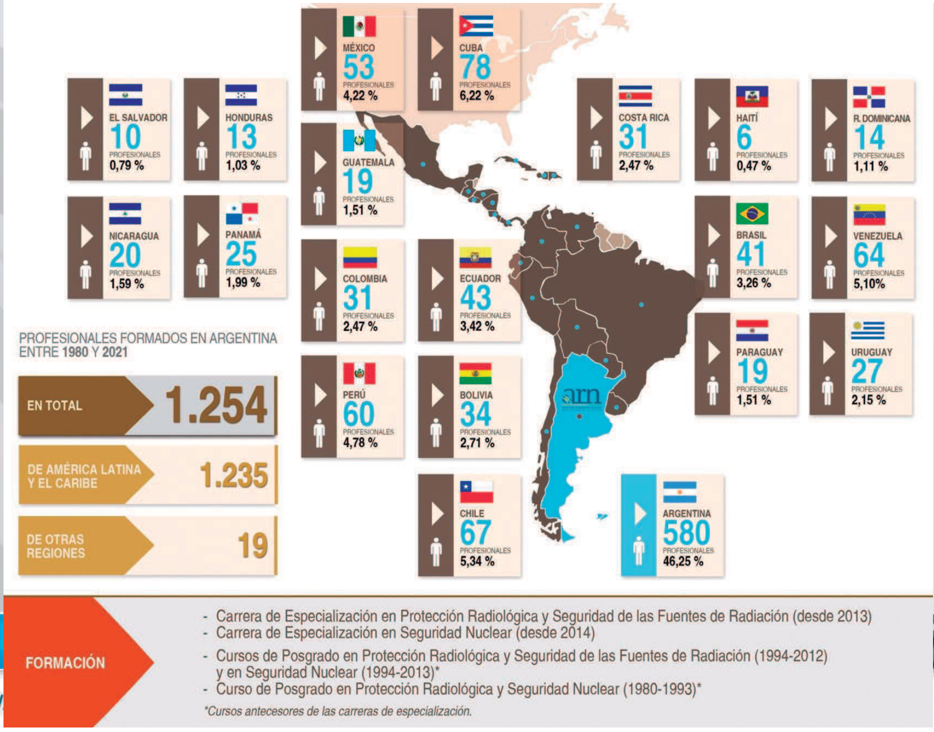
6-10 November 2017

https://www.argentina.gob.ar/noticias/argentina-recibe-una-mision-internacional-para-evaluar-la-ensenanza-en-proteccion

Background

Call-for-Action: 2nd O.R.P. 2014

Professionals Trained in Argentina



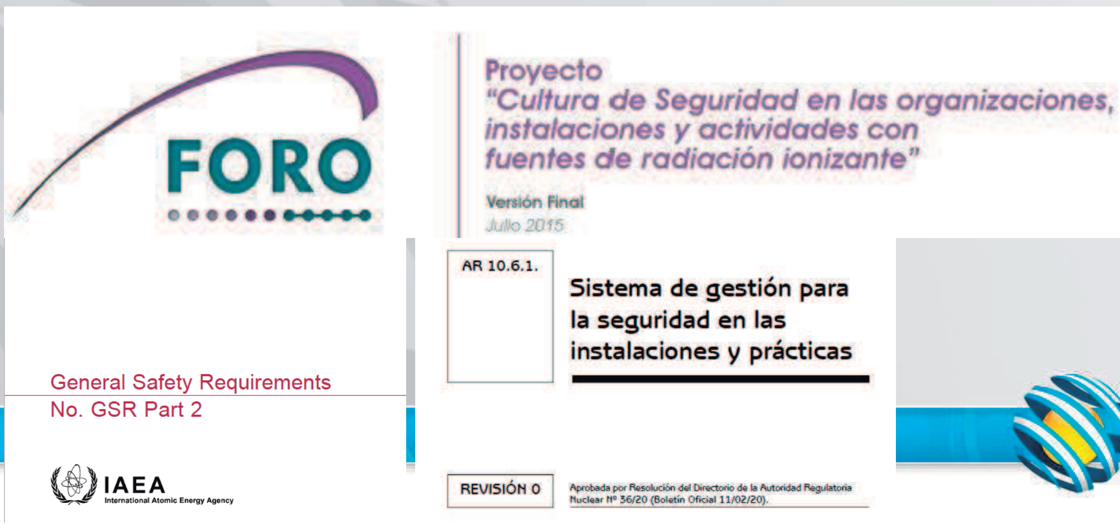
Background

Call-for-Action: 2nd O.R.P. 2014

(Argentine follow up)

- **6. Improve safety culture among workers exposed to ionizing radiation**

  *Promote safety culture by regulatory authorities through outreach and education (**Argentine participates actively)***



Regulatory strategies: Identify challenges for an effective enforcement

Focusing Priorities

INDEPENDENCE
Transparency & Openness

Which?

Communication

Promotion of an active participation

Finding improvements

Credibility

ORP

Confidence of interested parties

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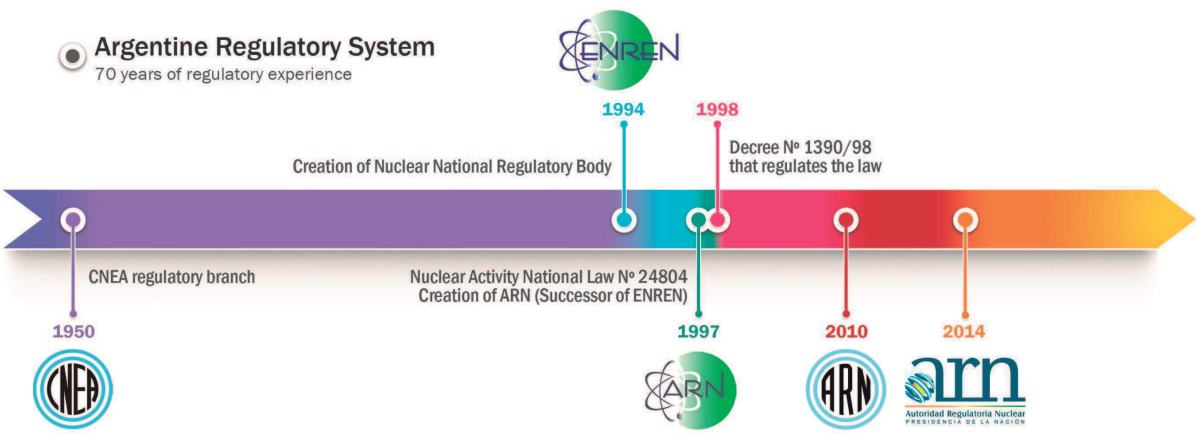
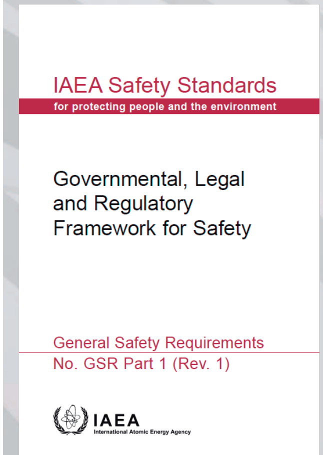
Milestones of Nuclear Regulatoty Authority
Advisory Councils



C.A.A.R.
ADVISORY COUNCIL ON MEDICAL, INDUSTRIAL AND RESEARCH USES OF RADIOISOTOPES AND IONIZING RADIATION USES

Gobernmental, legal and regulatory framework for safety GSR PART 1 REV-1


IAEA Safety Standards
for protecting people and the environment

Governmental, Legal and Regulatory Framework for Safety

General Safety Requirements
No. GSR Part 1 (Rev. 1)

IAEA
International Atomic Energy Agency

4.18 The regulatory body may decide to give formal status to the processes by which it is provided with expert opinion and advice. If the establishment of **advisory bodies**, whether on a temporary or a permanent basis, is considered necessary, it is essential that such bodies provide ***independent advice***, whether technical or non-technical in nature.

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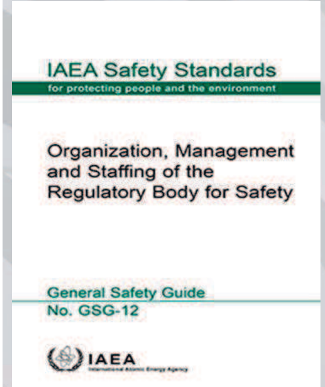
Organization, Management and Staffing of the Regulatory Body for Safety GSG 12

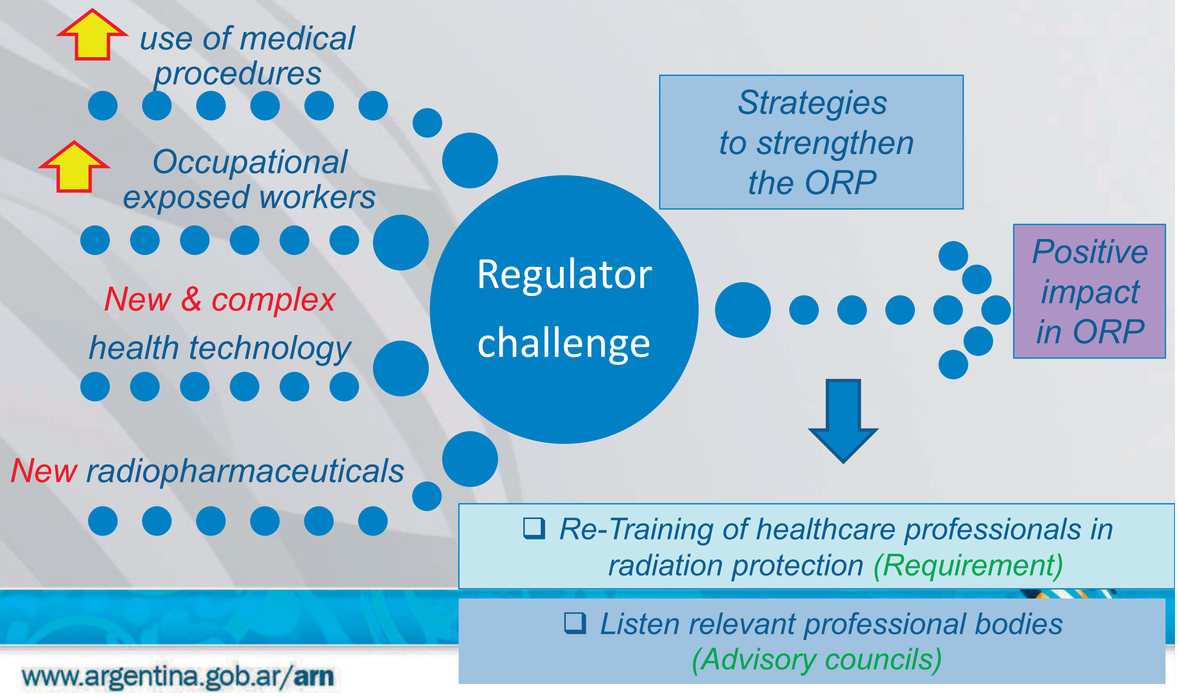


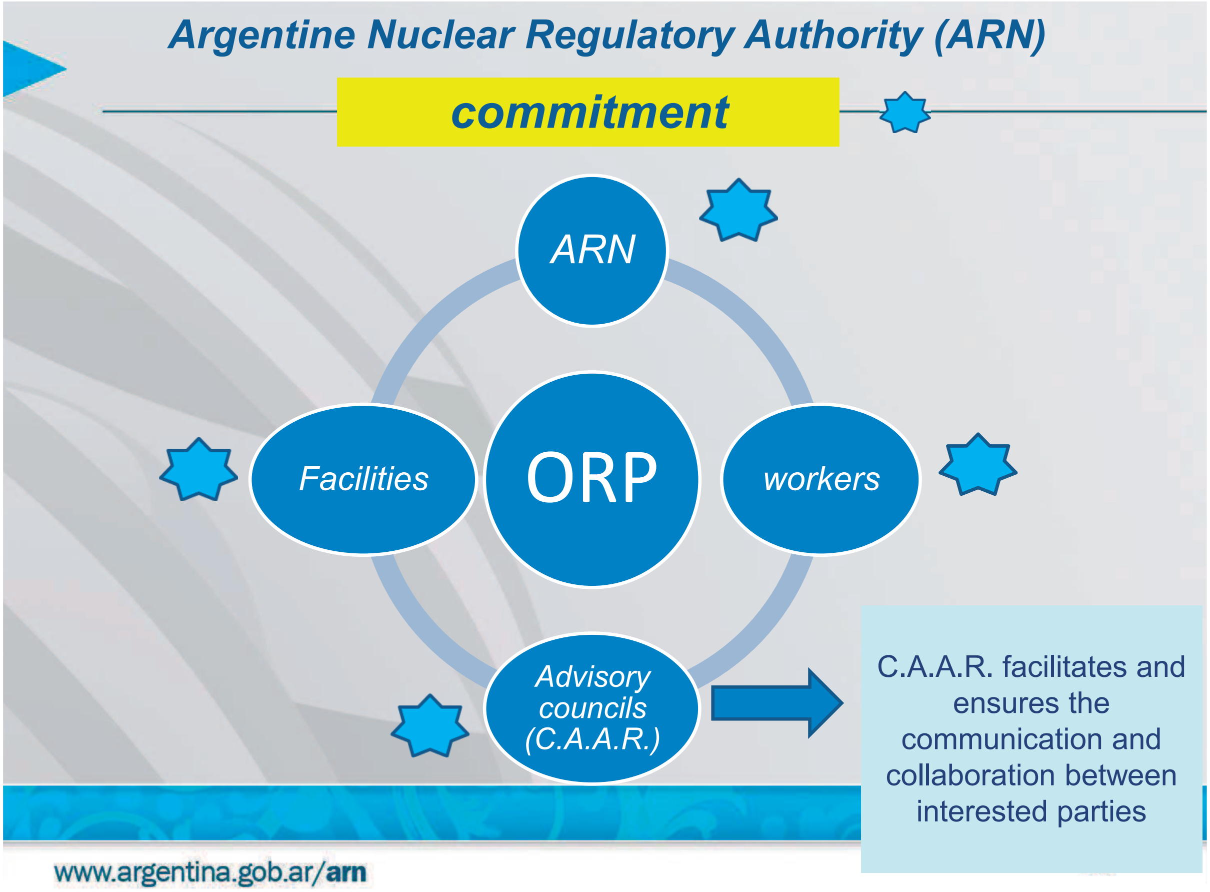
*4.38. The regulatory body may choose to give a **formal structure** to the processes by which expert opinion and advice are sought and provided. An effective advisory committee can provide a valuable service to the regulatory body by helping to ensure that policies and regulations are clear, practical and complete, and provide a good balance between the interests of authorized parties and the needs of the regulatory body and other interested parties.*

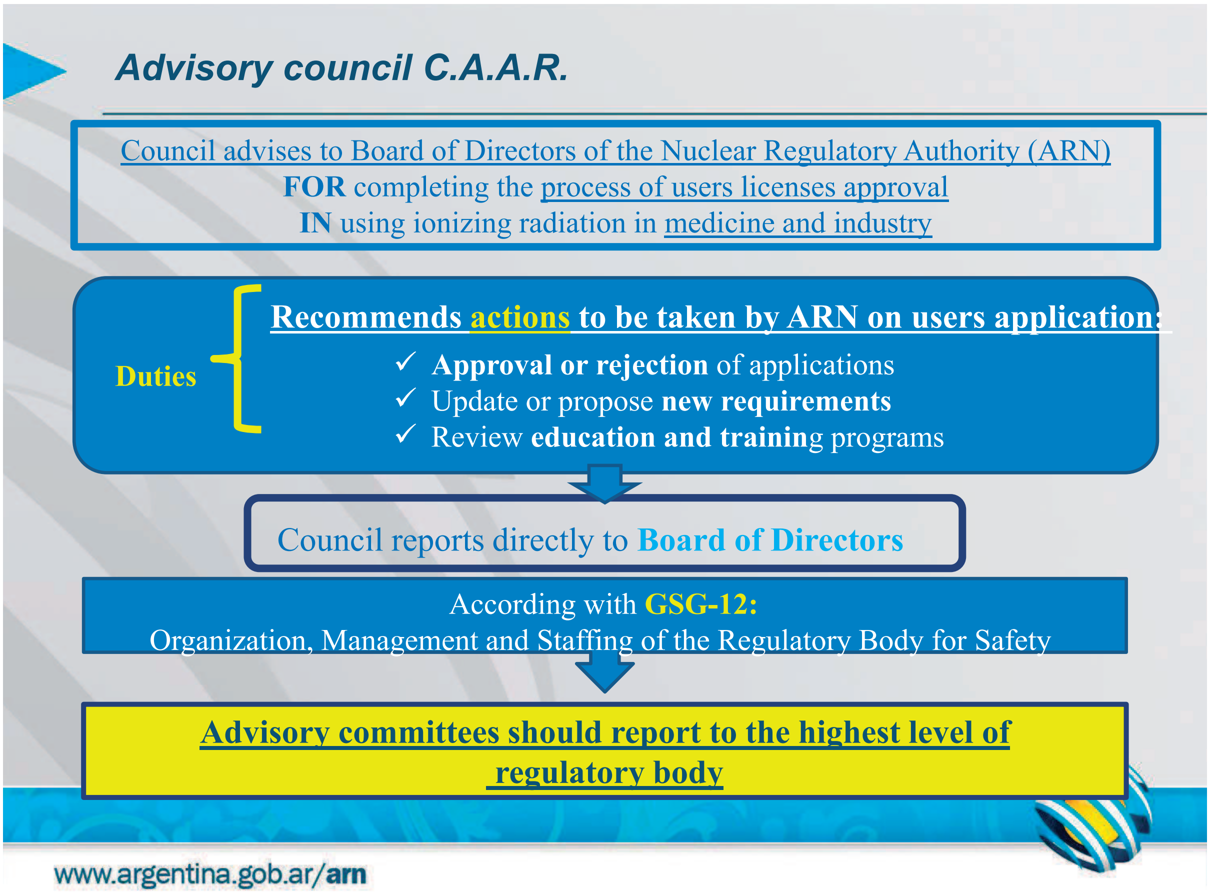
*4.39. Advisory committees should **report to the highest level of authority** within the regulatory body.*

Regulatory strategies: Identify challenges for an effective enforcement

MEDICINE




Argentine Nuclear Regulatory Authority (ARN)
commitment
ARN
Facilities
ORP
workers
Advisory councils (C.A.A.R.)
C.A.A.R. facilitates and ensures the communication and collaboration between interested parties
www.argentina.gob.ar/arn

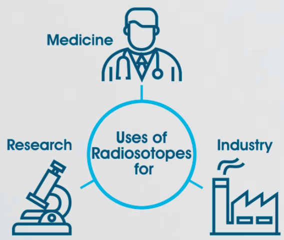

Advisory council C.A.A.R.
Council advises to Board of Directors of the Nuclear Regulatory Authority (ARN)
FOR completing the process of users licenses approval
IN using ionizing radiation in medicine and industry
Duties
Recommends actions to be taken by ARN on users application:
✓ Approval or rejection of applications
✓ Update or propose new requirements
✓ Review education and training programs
Council reports directly to Board of Directors
According with GSG-12:
Organization, Management and Staffing of the Regulatory Body for Safety
Advisory committees should report to the highest level of regulatory body
www.argentina.gob.ar/arn

C.A.A.R. Council

Advisory Council of the Nuclear Regulatory Authority Argentine

IS *a collegiate body, for advising Board of Directors*

FOR *granting application of R.P. Standars*



ARN *counts on*

- ✔*Stakeholder expertise*
- ✔*Stakeholder commitment*

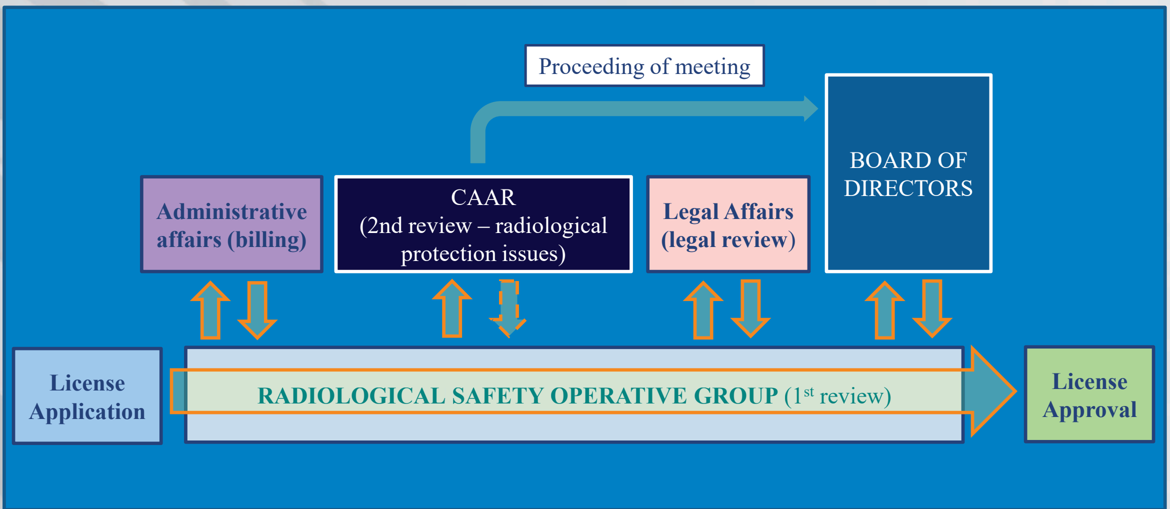
CAAR strengthens the process of licensing in Argentina

- ✓ *for affording greater confidence and quality to the process*
- ✓ *for providing greater transparency*

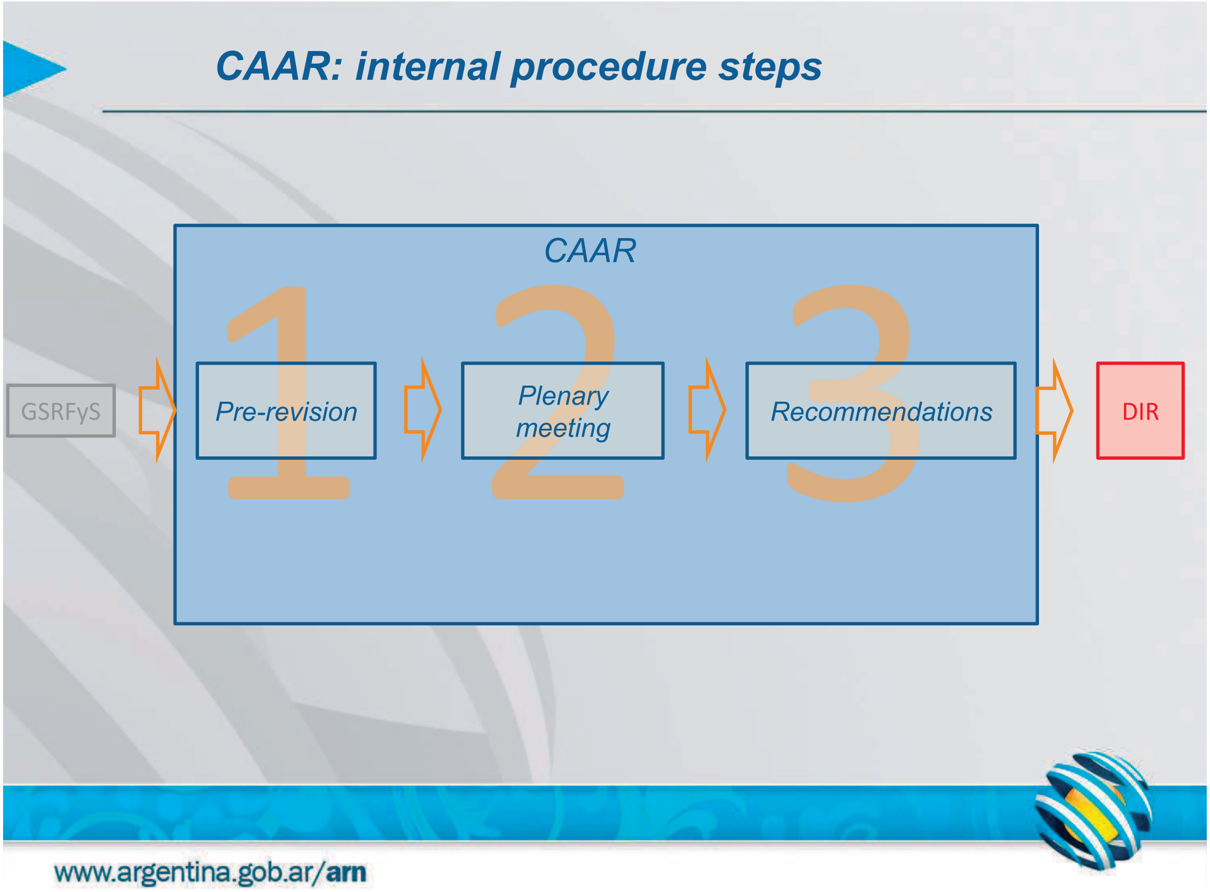
Advisory council demonstrates contribute effectively with regulatory strategies to strengthen occupational radiation protection

Licensing Process

CAAR conducts a second revision checking the compliance with the requirements applicable to the personnel licensing



www.argentina.gob.ar/arn


CAAR: internal procedure steps
CAAR
GSRFyS
1
Pre-revision
2
Plenary meeting
3
Recommendations
DIR
www.argentina.gob.ar/arn


CAAR Members
Stakeholders, recognized expertise in:
Nuclear Medicine
Radiopharmaceutical Production
Radiation Oncology
Industrial Uses
Medical Physics
Nuclear Regulatory Authority staff, acting as:
President
Vice President
Secretary
www.argentina.gob.ar/arn

CAAR: EXTERNAL MEMBERS

Nuclear Medicine Physicians:

- ✓ **María José Bastianello;** *Clinician Research and Medical Education Center, Norberto Quirno*
- ✓ **Ana Cristina Zarlenga;** *CNEA, National Atomic Energy Commission, Oncology Institute, Roffo,Bs As University*
- ✓ **Dra. Mariela Silvina Agolti;** *Clínica Modelo, Paraná Entre Rios*

Radiopharmaceutical produciion and research:

- ✓ **Guillermo Casale**; *Bacon Laboratories SAIC*
- ✓ **Silvia Inés Gómez de Castiglia** *Tecnonuclear Laboratories SA*

Radiotherapy:

- ✓ **Pablo Menéndez**; *Oncology Institute, Angel Roffo, Buenos Aires University*
- ✓ **Carlos Pizzo**; *RT Cumbres GG, Rosario, Santa Fe and ITR San Nicolás, Buenos Aires*
- ✓ **Pablo Andrés Castro Peña;** *Radiotherapy-Oncology Instituto Zunino –Marie CurieFundation , Córdoba*

Medical Physicist

- ✓ **Mauro Namías**; *Nuclear Diagnostic Center Foundation*
- ✓ **Ricardo Ruggeri**; *Health Leben, Rio Negro y Neuquen Medical Foundation*
- ✓ **Leopoldo Mazzucco**, *Private Radiotherapy Center, Río IV, Córdoba*

Industrial applications:

- ✓ **Emilio Nicolás Olivar Godaz**; *CNEA National Atomic Energy Commission*
- ✓ **Marcelo Kisielewicz** *Schlumberger Argentina S.A*
- ✓ **Benjamín Tenconi** *Hidrovía S.A.*

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Thank you!!

Ana Maria ROJO

CAAR
Argentine Advisory Council on Medical, Industrial and Research Uses of Radioisotopes and Ionizing Radiation Uses

ARN
Nuclear Regulatory Authority

Email: arojo@arn.gob.ar

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Enhancing Gender Equality in Nuclear Security Regulation

Roston, V.

Presentado en: *Seminario Online* “La educación como clave para abordar la brecha de igualdad de género en la seguridad física nuclear global” de la Women in Nuclear Security Initiative (WINSI).
8 de julio de 2022

Autoridad Regulatoria Nuclear
PRESIDENCIA DE LA NACIÓN

Enhancing gender equality in nuclear security regulation

Ms. Victoria Roston

www.argentina.gob.ar/arn

Nuclear Regulatory Authority (ARN)

Overview

Autoridad Regulatoria Nuclear
PRESIDENCIA DE LA NACIÓN

- Radiological Safety
- Nuclear Safety
- Safeguards & Nonproliferation
- **Physical Protection (Security)**

- Regulation
- Verification
- Enforcement

Women 44%

Regulatory profile: 54%

Nuclear security profile: 10%

ARN STAFF 371

www.argentina.gob.ar/arn

Nuclear Regulatory Authority
Representation in Nuclear Security

- Point of Contact for the:
  - CPPNM and its Amendment
  - Code of conduct for the safety and security of radioactive sources
  - IAEA Incident and Trafficking Database (ITDB)
- Alternate Member of the IAEA Nuclear Security Guidance Committee (NSGC)
- Co-chair of the Global Initiative to Combat Nuclear Terrorism (GICNT) Response and Mitigation Working Group
- CAOC for IAEA Unified System for Information Exchange in Incidents and Emergencies (USIE)
- WINS Academy Ambassador

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Nuclear Regulatory Authority
Gender Policies

arn
Autoridad Regulatoria Nuclear
PRESIDENCIA DE LA NACIÓN

⟷

Ministerio de las Mujeres, Géneros y Diversidad
Argentina

Framework Cooperation Agreement that will enable the ARN:

- Develop an institutional framework on gender, equity and diversity policies
- Develop tools to deal with and prevent situations of gender violence
- Design and implement a comprehensive training plan on gender perspective, diversity and gender-based violence and harassment

Strong **commitment** to **gender equality**

www.argentina.gob.ar/**arn**

Nuclear Regulatory Authority
Gender Initiatives

Autoridad Regulatoria Nuclear
PRESIDENCIA DE LA NACIÓN

IAEA | WiN Argentina | NEA Nuclear Energy Agency | WINS | International Gender Champions | IRPA

Task Group on Improving Gender Balance

Impact Group

Task Group

www.argentina.gob.ar/arn

Nuclear Security Training Program
Development

www.argentina.gob.ar/arn

Nuclear Security Training Program
Execution

- **General training**
  - Induction course
  - Refresher courses

- **Regional Training Center for Latin America and the Caribbean for the education and training in Nuclear, Radiological, Transportation and Waste Safety**
  - Specialization Degree on Radiation Protection and Safety of Radioactive Sources
  - Specialization Degree on Nuclear Safety
  - Basic Course on Radiation Protection

Centro de Capacitación Regional
PARA AMÉRICA LATINA Y EL CARIBE

Nuclear Security Training Program (cont'd)
Execution

- **Security specific training**
  - On the job training
  - Field training for inspectors
  - Internal theme-based seminars
  - Participation in regional and international training courses

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Conclusions

- Supporting rising **female leaders**
- **Initiatives** that highlight the experiences and achievements of **women in nuclear security**
- Promoting and sustaining a **gender-balanced culture**
- Dialogues and action plans among relevant actors
- Promotion of **formal training spaces and inclusion** of nuclear security

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Thank you!

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Non-Proliferation Policies and Institutional Affairs Department
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The Argentine Support Programme
Past, present and future

Serrano Bentancour, A.; Acosta, G.M.; Díaz, G. and Villamayor, R.

Presentado en: 14th Symposium on International Safeguards: Reflecting on
the Past and Anticipating the Future del Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 31 de octubre al 4 de noviembre de 2022

THE ARGENTINE SUPPORT PROGRAMME
Past, present and future

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Abstract

Argentina joined the Member State Support Programme in 1994, as a means to contribute to the International Atomic Energy Agency's safeguards development and implementation needs. Over these years, the Argentine Support Programme (ARG-SP), while relatively modest in size, has supported several and relevant tasks that were effective in solving technical safeguards issues. The national coordination of the ARG-SP, responsible for overall programme management, oversight and direction, is under the Nuclear Regulatory Authority (ARN) –organization dedicated to the regulation and control of the nuclear activity in the areas of radiological and nuclear safety, physical protection and nuclear security, and safeguards and nonproliferation–. Through in-kind contributions and with the support of key local partners, the ARG-SP is currently focused on the development of innovative methods and techniques, DA and NDA measurement of nuclear material, sealing, containment verification, capacity-building, and other activities under the areas of management, strategic planning and partnership. This paper provides an overview of the ARG-SP since its creation, reviews the most relevant technical tasks carried out in the past four years, and shares the challenges and steps to follow.

1. INTRODUCTION

The Member State Support Programme to the International Atomic Energy Agency's Safeguards (MSSPs) arose from two main reasons: "(1) A decision by the Board that any development needs would best be met through Member State facilities rather than have the Agency develop its own in-house capability; and (2) the recognition by the Agency that certain safeguards deficiencies and needs could only be met by the development of new equipment and techniques" [1]. Since late 70s, Member States have been contributing to the International Atomic Energy Agency's (IAEA) safeguards mission through their MSSPs.

The MSSPs pursue tasks across the full range of the Department of Safeguards' multi-disciplinary technical work, including the development of instruments and techniques, facility and nuclear material access for training, expert consulting, among others [2].

Argentina joined the MSSP in 1994, with a relatively modest and in-kind contribution under the coordination of the National Board of Nuclear Regulation (ENREN), which in 1997 became the Nuclear Regulatory Authority (ARN). Since then, the Argentine Support Programme (ARG-SP) to IAEA safeguards has been managed by the ARN.

The ARN is the national agency in charge of regulating nuclear activities in Argentina, with competence on radiological and nuclear safety, physical protection, safeguards and nuclear non-proliferation matters. It is an autarchic entity within the jurisdiction of the Presidency of the Nation, with authority, competence and adequate financial and human resources to fulfil its assigned responsibilities; and it is independent of any organization dedicated to the use or the promotion of nuclear energy in any of its forms [3].

Safeguards-related activities are performed by two areas within the ARN: the Non-Proliferation Policies Division and the Control of Safeguards and Physical Protection Division. Since 2016, with the aim to better integrate an appropriate mix of skills and combine different kinds of expertise, the Coordination of the ARG-SP has been managed by these divisions.

The ARG-SP Coordination reviews individual task requested from the IAEA, decides which will be accepted, identifies the experts/facilities that will participate and monitors the progress and results of each task. To perform those duties, the Coordination interfaces with partners it deems appropriate to be involved in the different activities, by coordinating meetings to agree on the main milestones and deliverables of each task; providing support when necessary and following up on the progress of the projects. The main Argentine partners are the National Atomic Energy Commision (CNEA) and Nucleoeléctrica Argentina (NA-SA). Both of them give support through technicians and specialists in the nuclear fuel cycle and provide installations for visits and testing of materials, equipment and technology.

CNEA is the public organization devoted to research and development (R&D) in the peaceful uses of nuclear energy, fosters technologically innovative activities in the nuclear area and develops and transfers new technologies in associated fields [4]. CNEA has three Atomic Centres and a Technological Complex, owns and operates research reactors and is responsible for the CAREM SMR project, among other relevant activities. For its part, NA-SA is the state-owned company in charge of the operation of the three nuclear power plants in Argentina (Atucha I, Atucha II and Embalse) and the management of projects that ensure the normal operation of its facilities [5].

Likewise, the programme has the invaluable participation of the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), which has been crucial to achieving success in some of the most important tasks carried out by the programme. The ABACC is a bilateral safeguards agency aimed at the management and implementation of the Common System of Accounting and Control of Nuclear Materials (SCCC), established by the Agreement between the Republic of Argentina and the Federative Republic of Brazil for the Exclusively Peaceful Use of Nuclear Energy.

Additionally, the Embassy and Permanent Mission of the Republic of Argentina to International Organizations in Vienna, which is part of all official communications with the IAEA Secretariat, also contributes to the ARG-SP by attending MSSP meetings based in Vienna and providing support to the coordination of the programme.

2. OVERVIEW OF THE ARG-SP

For over 25 years, the Argentine programme has made tangible contributions to the IAEA's safeguards mission supporting relevant tasks, most of them focused on safeguards approaches, NDA techniques and containment and monitoring systems [6]. Argentine participation in the MSSP has always been guided by the conviction that safeguards must remain objective and technically based and that States capabilities should contribute to improve both, their effectiveness and efficiency.

With that aim, the first tasks accepted by the ARG-SP were directly linked to measurement methods and containment/monitoring systems, which would lay the basis of most of future contributions. Subsequently, the programme began to participate in tasks related to systems studies and information processing. Thematic distribution of the tasks carried out by the ARG-SP can be seen in FIG. 1.

Through the years the focus of the programme has been mainly on projects from the Division of Technical and Scientific Services (SGTS), the Division of Concepts and Planning (SGCP) and the Office of Safeguards Analytical Services (SGAS).

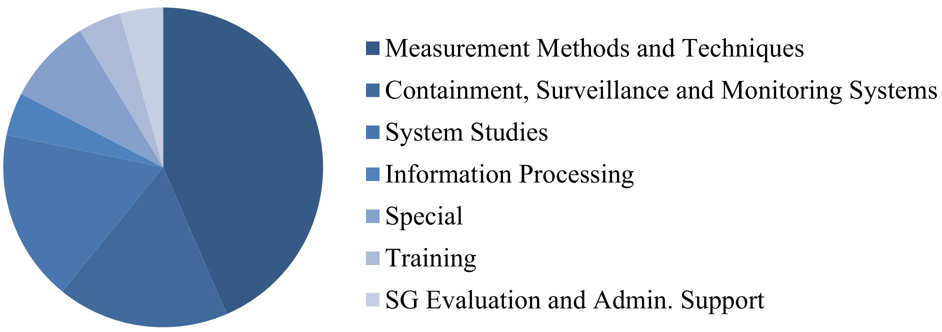

FIG. 1. Thematic distribution of ARG-SP tasks

Following the guidelines of the Coordination of the Programme, the ARN includes in its annual oversight report -intended to monitor, supervise and control the administration and management of the public resources- the participation in the meetings of the Argentine Support Programme to IAEA Safeguards. Moreover, activities within the ARG-SP are contemplated in ARN's Institutional Strategic Plan 2021-2025, under the strategic line "Consolidate safeguards and non-proliferation policies and compliance with international commitments"[1].

Although Argentina has a modest budget dedicated to the ARG-SP, the programme has made important in-kind contributions by providing access to different type of facilities for testing and expansion of safeguards equipment and techniques and support from specialized human resources to continuously improve verification activities. Since its creation in 1994, 25 tasks were accepted and 11 remain active (TABLE 1).

The next sections describe the two tasks that synthesize the spirit of the ARG-SP, due to the importance of the contribution that is sought to be generated through its participation in the MSSP and to the successful coordination between different stakeholders. The last section includes a summary of other ongoing tasks.

TABLE 1

Task ID	Title	Status	Acceptance date
ARG A 857	Gamma/Neutron Signature C/S Device for SF Canisters	Completed	28/08/1992
ARG A 884	Verifications of "As Built" SF- Dry Storage Canisters	Completed	28/08/1992
ARG A 893	Feasibility Study on the Application of Bundle Counters/Core Discharge Monitors at Atucha 2 and Atucha 1 Reactors (OLRs).	Completed	07/04/1993
JNT A 1019 ARG	Implementation of Verification Methods for the Uranium Content in Diffusion Enrichment Plants (USA, ARG)	Completed	18/01/1995
ARG E 923	Remote Monitoring of Safeguards Equipment	Completed	18/01/1995
ARG A 1154	Qualification of Environmental Network Laboratories	Terminated	03/08/1998
ARG D 1228	Provision of Open Source Information	Terminated	16/03/1999
ARG E 1155	Unattended Monitoring System for Spent Fuel Transfers in a CANDU-600 Reactor	Completed	14/04/1999
ARG C 1165	Integrated Safeguards (Preparation for a Consultants' Meeting)	Completed	14/04/1999
ARG E 1156	Remote Data Transmission for Unattended Monitoring System in a CANDU-600 Reactor	Completed	14/04/1999
ARG C 1166	Application of the State-level Integration Concept on Fuel Cycles Under Safeguards	Completed	14/04/1999
ARG A 1645	Impact of Retrieval of Spent Fuel on Radiation Traces Taken on Dry Spent Fuel Storages	Completed	08/06/2006
ARG A 1637	Support for Instrumentation Technology Foresight	Active	15/09/2006
ARG A 1769	UF6 Sampling Method using Alumina	Active	21/08/2008
ARG C 1770	Guidance for Designers and Operators on Design Features and Measures to Facilitate the Implementation of Safeguards at Future Nuclear Fuel Cycle Facilities	Completed	21/08/2008
ARG A 1906	NWAL Qualification for Heavy Water Laboratory	Active	08/07/2011
ARG C 2310	Support for the 2018 Safeguards Symposium	Completed	01/06/2017
ARG D 2283	Creation of e-learning modules, supporting the preparation of State declared information	Active	24/08/2017
ARG A 2318	2D Laser Sealing System Test at RAD1	Active	19/09/2017
ARG A 2452	Field Testing of the ABACC-Cristallini Method	Active	22/04/2019
ARG F 2550	International Target Values (ITV) 2020	Active	14/09/2020
ARG A 2571	Field-testing of an Unmanned Surface Vehicle and neXt generation Cerenkov Viewing Device	Active	04/12/2020
ARG B 2627	IAEA Safeguards Traineeship Programme Support	Active	29/11/2021
ARG X 2628	COMPASS: Comprehensive Capacity Building Initiative for SSACs and SRAs	Active	29/11/2021
ARG X 2629	Support for the 2022 Safeguards Symposium	Active	29/11/2021

[1] https://www.argentina.gob.ar/sites/default/files/2018/10/plan_estrategico_institucional_2021-2025_vc-corta.pdf

2.1. “UF6 Sampling Method using Alumina” and “Field Testing of the ABACC-Cristallini Method”

ABACC, with the support of Argentine and Brazilian researchers and laboratories, has developed a UF6 sampling method for enrichment determination, named “ABACC-Cristallini Method”, based on a conceptual development of the Argentine chemist Osvaldo Cristallini. “The ABACC-Cristallini UF6 sampling method consists of retaining the UF6 by adsorption in alumina (Al2O3) pellets and subsequent hydrolysis of the UF6 into uranyl fluoride (UO2F2) collected in a P-10 tube” [7].

The IAEA was interested in implementing this method and proposed the MSSP task “UF6 Sampling Method using Alumina”. The ARG-SP accepted the task in 2008 and designated an officer from the CNEA as point of contact. The ARG-SP together with the Brazilian-SP asked ABACC to coordinate the validation process of the method within this task and appointed ABACC officers as point of contact. The activities carried out within “the framework of the Brazilian and Argentinean Safeguards Support Programs with the coordination of ABACC represents a significant step towards the ultimate goal of using ABACC-Cristallini UF6 method in place of some or most of the traditional UF6 sampling for safeguards. The intercomparison results obtained from different laboratories will be the basis of the validation process to confirm that the new method can be used for routine safeguards application at the enrichment plants” [8].

It is worth mentioning that, in parallel, ABACC continued to cooperate with other partners to validate and implement the method. As a result, in 2019, the ABACC-Cristallini UF6 sampling method was approved by the American Society for Testing and Materials (ASTM) and published as ASTM C1880-19: “Standard Practice for Sampling Gaseous Uranium Hexafluoride Using Alumina Pellets”.

In 2017, and following the success of the “UF6 Sampling Method using Alumina” task, the IAEA submitted a proposal to some MSSP to begin field testing in order to validate the ABACC-Cristallini method at the commercial facility level. Again, the ARG-SP and the Brazilian-SP asked ABACC to play a leading role within the new proposal (“Field Testing of the ABACC-Cristallini Method”). The ARG-SP accepted the task in order to contribute by providing expertise and technical advice on the method itself. “Following support program regular meetings, and exchanges with State Authorities including on-site visits, the task was finally accepted by different countries and test campaigns were launched in 2019” [9].

“The IAEA is currently validating the sampling technique at commercial uranium enrichment plants. Samples are delivered and analysed at NML to confirm the method performance. Practicalities of implementing this sampling method, such as conformance with facility safety procedures, working instructions, training, etc., are taking place at each facility so that the method can become a routine sampling method for UF6” [10].

The validation of the ABACC-Cristallini Method and its field testing at the commercial facility level are key activities for the ARG-SP, as a tangible contribution to the efficient application of safeguards. Among other advantages, the ABACC-Cristallini method allows handling non-reactive, non-volatile, solid UO2F2 sample instead of highly reactive and volatile UF6, where the sample amount is minimum and can be transported with lower radioactivity level, reducing radiological risks [11].

2.2. “2D Laser Sealing System Test at RAD1”

The task “2D Laser Sealing System Test at RAD1” was intended to analyse a new containment solution that does not require physical attachment of seals and has the potential benefit of improving the effectiveness and efficiency of spent fuel verification. In particular, the task emerged as a solution to face the challenges to maintain the Continuity of Knowledge (CoK) in a new Dry Storage located in the Atucha I NPP, by monitoring the movement of canisters into each silo in the form of a Laser Curtain for Containment (LCCT) [12].

“The LCCT creates a containment curtail which detects intrusion into predefined regions-of-interests (ROIs). Although its data is completely independent of optical surveillance – a requirement for dual C/S – the LCCT’s two-dimensional spatial data complements video data camera well, providing inspectors with high confidence that CoK has been maintained” [13]. The LCCT was developed by the IAEA with the technical assistance of the European Commission’s Joint Research Centre (JRC) and received the support of ABACC and Argentina through the ARG-SP for field tests.

The ARG-SP formally accepted the task in 2017 through which it made available two Argentine facilities to carry out the necessary tests and provided support for the technical activities. For that aim, it involved the ABACC and two facility operators: NA-SA and the CNEA. The outcome of the task was expected to be relevant, not only because it would provide an alternative that would reduce the inspection effort and resource requirements, as well as radiation exposure, but also because the 2DLC had the potential to benefit other storage facilities outside of Argentina facing similar challenges in maintaining CoK.

In 2018, the preliminary testing in the pond area was conducted in order to get ready for a pre-installation test in the silos. "Although the proposed goals of the test were achieved, it showed that additional tests should be conducted to address important issues observed at that time before considering its use as a component of the C/S system. During 2019, the IAEA setup a LCCT test bed at its own premises in Vienna to perform further tests. The results were shared with ABACC. After a comprehensive review and analysis of the data, both agencies decided to conduct a near full-scale joint test to confirm the adequacy of the LCCT system for use at Atucha-1 dry storage facility. This ABACC/IAEA functionality joint test was conducted in November 2019 in an Argentine facility which features were ideal to simulate the Atucha I NPP storage, with the cooperation of ARN under the MSSP" [14].

The LCCT was successfully installed in December 2021, completing the original task. At the end of August 2022, the LCCT technology became operational as part of the UMS system implemented at Atucha 1 NPP. The field test demonstrated that the system is reliable and continues to function regardless of optical surveillance and any lighting issues that arise, while saving safeguards inspector effort. The main conclusion of the task is that LCCT fulfills its function as a new containment solution and can potentially be used as a tracking technology. As of today, the LCCT constitutes one of the components of the dual Containment and Surveillance system in the new Dry Storage of Atucha 1 NPP, together with the surveillance cameras.

2.3. Other ongoing tasks

As mentioned above, the ARG-SP usually makes in-kind contributions by providing access to different type of facilities and support from its specialized human capital.

This includes, for example, the support to the field-testing of technology, as it is the case of the task "Field-testing of an Unmanned Surface Vehicle and neXt generation Cerenkov Viewing Device". Under this task, a Robotized Cerenkov Viewing Device (RCVD) was successfully tested at Atucha 1 NPP spent fuel ponds, in February 2022, obtaining valuable experience and useful information for the designers. The advantages of the RCVD for spent fuel verification campaigns are "better consistency in the measurements, an improved safety and a higher efficiency" [15]. In particular, the field test at Atucha 1 NPP made it possible to confirm that the RCVD meets the requirements for a safe deployment inside a spent fuel pond. Also the safety features of the control command software were validated and the images of the spent fuel assemblies in visual and near-ultraviolet ranges were validated. The results of the test are expected to help the IAEA ensure that the final design will be acceptable to facilities and useful to IAEA Safeguards inspectors [16].

Also, in the past years the ARG-SP was able to resume the task "NWAL Qualification for Heavy Water Laboratory", after renewing the commitment of NA-SA new authorities, which operates the laboratory that will go through the qualification process to support the IAEA's Network of Analytical Laboratories (NWAL). The Argentine laboratory is expected to add supplementary capacity for the analysis of heavy water samples, considering that there is only one laboratory currently qualified under the NWAL: the Magyar Tudományos Akadémia (MTA) in Hungary [17].

In terms of specialized human resource, it is worth mentioning the participation of seven experts from different Argentine institutions in the Consultants Group Meeting on "International Target Values 2020" and their contribution to the elaboration of its final document. The objective of the ITV-2020 project is to" issue the next set of updated and expanded ITV […] The proactive and early engagement of international stakeholders and the lessons learned from virtual meetings led the authors to consider a more continuous approach to ITV that would be more dynamic and collaborative, more resilient to resource disruptions, and more adaptive to changes in international communication culture and platforms" [18].

A few years ago the ARG-SP decided to be more active in training projects by making available its human capabilities and its facilities for this purpose, knowing that is an area of continuous need for IAEA Safeguards that rely on the availability of specialist facilities, expertise and materials to ensure that inspector capabilities are kept up-to-date [19]. The ARN "has always had a wide commitment to training and considers that these activities are a key towards competence building in the various angles of safeguards implementation" [20], therefore, the coordination of the ARG-SP expects to reinforce this commitment through the ARG-SP

Specifically, the ARG-SP has been working in the task "Creation of e-learning modules, supporting the preparation of State declared information" for providing the translation of the e-learning modules into Spanish, with the aim of reaching a broader audience. To that end it devoted a team that combines the professional and technical expertise of a public translator, working in the Non-Proliferation Policies and Institutional Affairs Department of the ARN, and four ARN non-proliferation and safeguard's experts. At the beginning of the 2022, the ARG-SP sent its contributions to the IAEA and expects to take further steps.

The ARG-SP also seeks to contribute to safeguards training efforts through the "Comprehensive Capacity-Building Initiative for SSACs and State Authorities (COMPASS)" and the "IAEA Safeguards Traineeship Program Support". The ARG-SP is aware of the importance of the COMPASS initiative, which "provides tailored safeguards assistance to States to help them strengthen and sustain the effectiveness of their State system of accounting for and control of nuclear material (SSAC) and their state or regional authorities (SRAs) responsible for safeguards implementation" [21]. Within this framework, the ARG-SP has offered safeguards experts to provide technical training on the IdentiFINDER equipment and specialists to support the Development of a National Training Program on Safeguards of a Latin American country, with the option of planning practical exercises in Argentina, including the search for and identification of radioactive sources and materials. Regarding the "IAEA Safeguards Traineeship Program" the ARG-SP looks forward to contribute to its objective of increasing the number of qualified candidates eligible to work at the IAEA or within their State or Regional regulatory authority responsible for safeguards [22], by sharing, for example, the Argentine experience in nuclear regulation with a focus on research reactors.

3. SHAPING THE FUTURE ARG-SP

Nuclear safeguards have been shifting to meet the changing nuclear proliferation concerns. IAEA experts pointed out that as the challenges and opportunities for the Agency's verification have evolved, so too has the nature of needed support [23]. In recent years, the great and rapid technological advances have demanded a timely and innovative response from the IAEA to be able to fulfil its safeguards mission. To this end, the support of the MSSP has been crucial.

The ARG-SP is committed to enhancing its contribution to IAEA safeguards through the MSSP and is setting its goals towards its 30th anniversary, in 2024.

One of these goals is to improve the structure and formal organization of the ARG-SP with the aim of facilitating practical cooperation and interaction between the Coordination and stakeholders and clarifying procedures and responsibilities of organizations involved in the programme implementation. This includes the outlining of the guiding principles and objectives of the ARG-SP and the approval of an internal procedure for the management of all communications through the national Electronic Document Management (GDE) system.

The second goal is to increase the visibility of the ARG-SP in order to strengthen its outreach efforts. This objective responds to the decision of generating new partnerships with national universities and technology companies to provide support in areas so far unexplored by the programme. Inspired by the experiences of other MSSPs, an official brochure on the ARG-SP will be designed for this purpose. In recent years, the programme has been reinforcing its outreach activities and has already carried out various actions, in close collaboration with the Communication and Design area of the ARN, some of which were related to the support provided by the programme to the organization of the safeguards symposiums.

The third goal of the ARG-SP is to increase efforts in a key assistance area: education and training, where activities have been growing in number, diversity and importance over the past decade within the Department of Safeguards [24]. As above mentioned, the ARN has always had a wide commitment to training and attaches great importance to reinforce capacity-building efforts [25]. One of the lessons learned from the pandemic is the importance of the availability of virtual learning resources, which also have the advantage of supporting safeguards national authorities' training with reduced costs and greater accessibility. With the aim of avoiding duplication of efforts and aware that training and capacity building are directly linked to the development of core and functional competencies of IAEA staff and enhancement of effectiveness of State System of Accounting for and Control of Nuclear Material (SSAC's) [26], the ARG-SP will give priority to the tasks suggested by the IAEA in this area.

Based on the fulfilment of these objectives, it is expected not only to reinvigorate the ARG-SP, but also to renew its commitment to the IAEA safeguards by looking ahead.

ACKNOWLEDGEMENTS

The authors would like to express their deepest appreciation to the colleagues from the Non-Proliferation Policies Division and the Control of Safeguards and Physical Protection Division of the ARN and to the Points of Contact of each task of the ARG-SP for the information provided to complete this paper.

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Argentine Experience in the Licensing of CAREM 25 Prototype Reactor

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Presentado en: International Conference on Topical Issues in Nuclear Installation Safety: Strengthening Safety of Evolutionary and Innovative Reactor Designs del Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 18 al 21 de octubre de 2022

ARGENTINE EXPERIENCE IN THE LICENSING OF CAREM 25 PROTOTYPE REACTOR.

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Abstract

The CAREM 25 is the first nuclear power reactor entirely designed and built-in Argentina. It is a prototype of a light water low power reactor with some features that simplify its design and contributes to a higher safety level. The construction of this prototype by National Atomic Energy Commission (CNEA), must demonstrate feasibility and safety on a smaller scale than that planned for commercial modules. The Nuclear Regulatory Authority (ARN) of Argentina carried out the CAREM 25 licensing process, which is based on the Argentinian nuclear legal framework and its performance regulatory approach. This framework defined the milestones for the beginning of construction and, in order to issue the construction authorization, the ARN established additional mandatory documentation requirements (License Conditions) regarding the traditional nuclear power plant licensing process to reinforce authorization. ARN construction authorization is granted against a safety demonstration based on comprehensive deterministic and probabilistic safety analysis. One of the most challenging aspects of the licensing process of the CAREM 25 prototype reactor was assessing the safety demonstration of a new reactor design, unique in Argentina. Regarding to this, the regulatory approach of CAREM 25 licensing was developed under the concept of an "integral" evaluation of mandatory documentation. The paper presents the experience of the ARN compiled during the years that have elapsed since the beginning of the project.

1. INTRODUCTION

The Atomic Energy National Commission started the project of the **C**entral **AR**gentina de **E**lementos **M**odulares (CAREM) in the early 80’s and it was officially presented by National Atomic Energy Commission (CNEA) in 1984 at a conference of the IAEA in Lima, Peru.

During the course of the 90's, the project advanced with the hiring of INVAP S.E. (Argentinean nuclear vendor of R&D complex technological systems) for the development of of the conceptual engineering and experimental facilities, under the supervision of the CNEA specialists. Basic engineering was developed jointly by CNEA and INVAP during 1998-2000, and then the project was halted due to economic issues. The project was re-launched in 2006 entirely by the management of CNEA, in the framework of the re-start of the Argentine nuclear plan that includes the finishing for Atucha II Nuclear Power Plant (CNA-II NPP), refurbishment of Embalse NPP (CNE) and the construction of RA-10 Research Reactor. Basic engineering was completed and engineering for construction began.

In 2007 CNEA sent the request for issuing the Construction License for CAREM 25. The Nuclear Regulatory Authority (ARN) of Argentina carried out the CAREM 25 prototype reactor licensing process, which is based on the Argentinian nuclear legal framework and its performance regulatory approach. This framework defined the milestones for beginning the construction and, in order to issue the construction authorization, the ARN established additional mandatory documentation requirements (License Conditions) regarding the traditional nuclear power plant licensing process to reinforce authorization. ARN construction authorization is granted against a safety demonstration based on comprehensive deterministic and probabilistic safety analysis.

2. ARGENTINE LEGAL AND NORMATIVE FRAMEWORK

2.1. Legal framework

In the framework of the Argentine Constitution (Fig.1), the national nuclear policy was initially established by Decree No. 10.936 [1] enacted in 1950, which created the National Atomic Energy Commission (CNEA) with the objective of developing and handling nuclear technology. The control of the safety aspects of all nuclear activities performed in the country until the year 1994 was performed by the CNEA through its regulatory division, according to Law No. 14.467 [2] and Decree No. 842/58 [3].

In 1994, the National Government assigned the exclusive performance of these duties to an independent state agency with federal competence. This was implemented in the frame of Decree No. 1.540/94 [4] that reorganized the activities of the nuclear sector, and divided them into three entities; Nuclear National Regulatory Body (ENREN), Nucleoeléctrica Argentina Sociedad Anónima (NA-SA), and the National Atomic Energy Commission (CNEA), respectively responsible for the regulation, for the operation of nuclear power plants, and for research and development of the aspects related to the peaceful and safe use of nuclear energy. Before that division, all these activities were developed by CNEA. The above mentioned decree was then formally substituted by the Federal Law No. 24.804 [5] known as the "National Law of Nuclear Activity" sanctioned by the Argentine National Congress in 1997 and later complemented by the Decree No. 1.390/1998 [6]. The Nuclear Regulatory Authority (ARN) was created, as the successor of the ENREN. Within this context, Law No. 24.804 is the current legal framework for the peaceful use of nuclear energy in Argentina. Article 1 of the mentioned Law establishes that concerning nuclear matters the National Government, through the National Atomic Energy Commission (CNEA) and the Nuclear Regulatory Authority (ARN), shall define the state policy.

The nuclear policy shall meet all the obligations assumed by the Argentine Republic as a party to the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Tlatelolco Treaty) [7], the Treaty on Non-Proliferation of Nuclear Weapons (NPT) [8], Agreement (between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials and the International Atomic Energy Agency for the Application of Safeguards [9], in addition to the commitments assumed by Argentina as a member of the Nuclear Suppliers Group and the National Regime for the Control of Sensitive Exports (Decree No. 603/92) [10] and the Convention on Nuclear Safety (Law No. 24.776/97) [11].

In 2006, from Decree 1107/06 [12] of the Executive Power, the construction and commissioning project of the CAREM 25 Reactor Prototype was declared of national interest.

In 2009, Law No. 26.566 [13] was passed, declaring "of national interest" and "entrusting the CNEA with the design, execution, and commissioning of the CAREM 25 Reactor Prototype". This law established important benefits from the state that facilitate the development of the project. For example an exemption from all national taxes, authorization for the creation of an escrow to integrate the different sources of resources, facilities for the expropriation of real estate necessary for the works, a special customs control regime for the entry into the country of elements related to the project, mechanisms to facilitate and encourage the hiring of national companies participating in the project, among other measures.

2.2. Normative framework

The first Regulatory Standards related to the granting of licenses for NPP were established more than thirty years ago by the regulatory branch of the CNEA.

One of the functions granted by the Nuclear Activity Law No. 24,804/97 [5] to the Regulatory Body is the power to "issue and establish the standards, which regulate and control nuclear activities, of compulsory application, within the whole national territory". As a result, a normative system was established comprising subjects such as radiological and nuclear safety, safeguards of nuclear materials, and security. The system is known as "AR Standards" [14].

Actually, ARN is in an ongoing process of harmonization between the Argentine Regulatory Standards and the new versions of IAEA Safety Standards. Nevertheless, Argentine Regulatory Standards are already consistent with IAEA's corresponding standards in general terms, considering that ARN has adopted a performance or goal-oriented approach.

In addition, Argentine experts participates in the IAEA standards committee´s activities, technical working groups and cooperation projects, in order to strengthen the nuclear safety in achieving the objectives of the IAEA Action Plan and Nuclear Safety Convention.

Regarding the licensing of CAREM 25 prototype reactor, there was no need to change the normative framework. AR Series 3 Standards for the Design of Nuclear Power Reactors were used by the designer as design criteria and in some cases where there was a lack of national requirements or guidelines, international standards were used as a way to expand the scope of AR Standards or to clarify its practical application.

In 2015 ARN agreed with the Vienna Declaration on Nuclear Safety and adopted it to prevent accidents with radiological consequences and to mitigate such consequences should they occur. In this sense, ARN decided to carry out a normative framework integral review that includes addressing the Vienna Declaration in national standards. About the design features of CAREM 25, it has an improved implementation of the Defense in Depth (DiD) concept and, therefore, it can be considered as an example of how the basic objective of the Vienna Declaration could be implemented in future projects.

2.3. Regulatory approach

The Argentine Regulatory Standards are based on a set of fundamental concepts, which are part of the Performance Approach philosophy (goal-oriented approach), sustained by the regulatory system, concerning radiological and nuclear safety, safeguards, and security.

ARN understands that a performance-based regulatory approach does not imply limiting the requirements to qualitative issues. Moreover, it is perfectly compatible with specific deterministic requirements and even numerical criteria, as well as:

— Defense in Depth concept
— The single failure criterion
— Conservative approach for the demonstration of Safety Cases

As mentioned earlier, Regulatory Standards are not prescriptive but in compliance with safety objectives. Compliance with these objectives must be demonstrated by the Responsible Entity (RE) by detailed analysis written in mandatory documents that can be objectively assessed by ARN. The role of the regulator is to be sceptical and critical, which implies an interaction between professionals of ARN and the RE, in order to ensure a common understanding of the overall safety approach. This includes the statement of safety goals, the engineering solutions adopted, the analytical tools for evaluating and improving safety, and the methodology for deriving safety requirements.

ARN regulatory approach is consistent with the IAEA approach to the establishment of safety (engineering) requirements, derived from the Safety Classification of Structures, Systems, and Components (SSCs), which in turn is based on the Safety Analysis, demonstrating the functional safety of a design.

Regarding the adoption of a performance-based regulatory approach, some advantages, learned by the verified application experience are the following:

— The nature of the interaction between ARN and the RE contributes to early detection of possible non-compliances or deficient compliance with regulatory requirements (in early design stages), avoiding the increase in time and efforts in fulfilling such requirements in later phases of a project (fabrication or construction).
— The design solutions to comply with regulatory requirements come, in general, from the supplier (Nuclear Vendor) through the RE, that know in detail the installation and the system involved in.
— The establishment of safety objectives keeping openness to different design solutions helps to manage projects from different vendors, i.e. Nuclear reactors (including Small Modular Reactors) with different safety approaches while keeping coherence on the need for objective demonstration of the compliance with regulatory requirements.

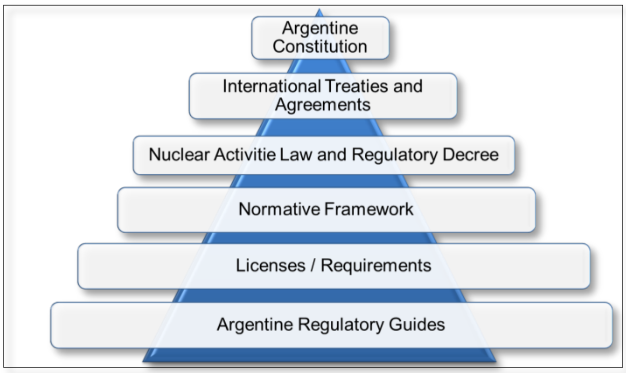

FIG. 1: Argentina Legal and regulatory framework abstract.

3. LICENSING PROCESS

3.1. Licensing Process of Nuclear Facilities

The licensing process for nuclear facilities is defined in the AR 0.0.1 standard "Licensing of Class I Facilities" [15] (Fig. 2), which considers the granting by the Regulatory Authority of construction, commissioning, operation, and decommissioning licenses, as a condition at the beginning of the RE activities related to each stage. The conditions that the Responsible Entity must comply with at each stage of the process are based on each of the Licenses. The validity of Licenses is defined in all cases and is also subordinated to the fulfilment of the conditions stipulated in its articles of terms and conditions. Likewise, failure to comply with any of the rules, conditions, or regulatory requirements is sufficient reason for the ARN to apply its power to suspend or cancel said validity, in accordance with the current sanctions regime.

The Pre-licensing stage is stablished as a regulatory practice and is defined by the Memorandum of Understanding (MOU). MOU is an agreement between Regulator and RE, since an early stage of the project, of the regulatory requirements and expectations in terms of licensing process and safety level that must be fulfilled by the design of the proposed plant and demonstrated through the Safety Analysis to be further submitted to ARN.

The Construction License covers the construction phase and preliminary tests and is issued when regulatory standards and requirements of the siting, basic engineering, and expected safety operation conditions have been met all relevant regulatory standards, prior to starting this stage. During this stage, a continuous interaction between RE and the ARN is initiated. It is a dynamic process, as complex as the demands involved.

The Commissioning License is regulated by the requirements established in the Regulatory Standards AR 3.7.1. [16] and AR 3.8.1. [17] and set conditions for the approach to criticality, operation with increasing power up to its nominal value, as well as verifications and tests of the SSCs to determine whether they comply with the original design basis.

The Operating License is issued when the ARN verifies that the conditions of the commissioning license, the regulatory standards and the specific requirements applicable to a given facility are met. It is the conclusion obtained by the Regulatory Authority after the result of the analysis of the mandatory documentation and detailed studies presented by the RE, as well as the inspections carried out during the construction and commissioning stages together with the recommendations of the Ad Hoc Commissioning Committee.

The Decommissioning License is granted when the process of the definitive closure of a nuclear facility is carried out, in order to enable the unrestricted use of the site of its location.

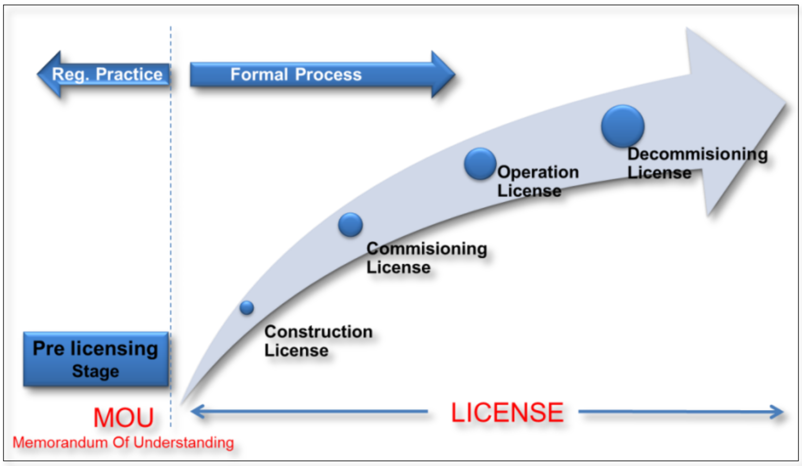

FIG. 2: Argentina Licensing Process for Nuclear Facilities.

3.2. CAREM 25 licensing scheme

Bearing in mind that the CAREM 25 reactor was considered a prototype, the ARN defined a licensing scheme applicable to construction, preliminary tests and commissioning. In the first stage, this framework established the milestones for the beginning of construction and, in order to issue the construction authorization[1]. In particular, the ARN has set additional mandatory documentation requirements regarding the traditional nuclear power plant licensing process. This license scheme was approved by the ARN in 2010 and was communicated to the Responsible Entity (CNEA).

The beginning of CAREM 25 prototype reactor construction stage was authorized by ARN with the issue of Authorization to Use the Site and Construction (AUSC) [18]. The mandatory documentation required for obtaining such authorization consisted in the submissions of the following subjects:

- Design Information (PSAR format)
- Environmental Radiological Impact.
- Waste Management.
- Radiological Emergency.
- Quality management.
- Project Schedule.

Additionally, this authorization had "license conditions", a Regulatory Requirement[2] (RQ-CAREM-003) [19] that reinforced the authorization, since compliance with this Regulatory Requirement (RR) conditioned the start of construction of the nuclear module of the reactor. The content of the RR was based on findings obtained as a result of the PSAR evaluation, related to engineering whose resolution has an impact on civil works, whether due to structural functions, confinement or shielding.

In December 2014, the ARN lifted the condition on the AUSC nuclear module after the assessment of the necessary information presented by Responsible Entity as corrective actions for the evaluation findings.

3.2.1. Relevant aspects of design information (PSAR) assessment

The regulatory approach of CAREM 25 licensing was developed under the concept of an "integral" evaluation of mandatory documentation, essentially the PSAR. The Construction Authorization of CAREM 25 prototype reactor was granted by ARN against an assessment of safety demonstration based on comprehensive deterministic and probabilistic safety analysis.

From above, establishing the engineering requirements on Structure, Systems and Components SSCs (namely, the Safety Classification) was verified and assessed by ARN. The most relevant PSAR chapters under analysis were (Fig.3), Safety Analysis (Deterministic and Probabilistic - Chap.15), Safety Classification of SSC (Chapter 3) and description chapters like Engineering features (Chapter 6). They have an integrating function of the content of the report: by the development of a comprehensive methodology for Safety Classification of SSC, Engineering Requirements are derived, and the compliance of these must be demonstrated in the chapters with description of design- engineering of SSCs.

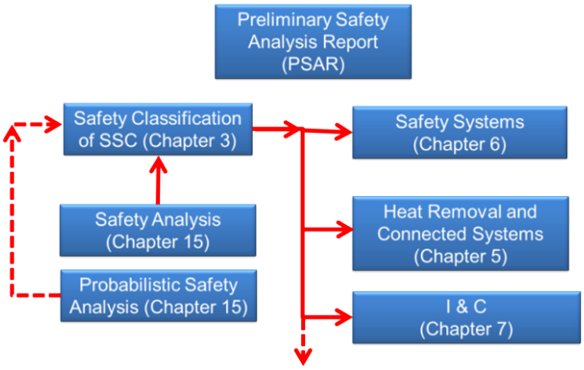

FIG. 3: Relevant PSAR chapters under analysis.

[1] The paper use "authorization" and "license" as synonyms.
[2] A Regulatory Requirement it's a regulatory document by which the Responsible Entity for a NPP is urged to carry out the required actions within a given period.

3.2.2. Some licensing challenges faced by ARN:

— Methodology for the Safety Classification of SSC consolidates. ARN reviewed the SSC safety classification methodology in depth. Special attention was paid to the SSCs with the passive operation and to the rules defined to assign the safety class of SSCs from the safety category and engineering rationale.
  Safety demonstration by computer modelling and simulation for SSC within consolidated experience. Termohidraulics and neutronics codes Verification & Validation (V&V). ARN doesn´t have specific standards for the system codes used for safety analysis/demonstration (TH, neutronics, fuel behavior, etc.). Most commonly used codes have been already validated and verified within respective correlations range (RELAP5, TRACE5, CATHENA, CATHARE, MARS, ATHLET, and others). However, due to the special design features of CAREM 25 reactor, ARN required a comprehensive analysis of each condition and physical phenomena that could occur during PIEs transients/accidents and checking codes capability for capturing and representing them. This procedure holds mainly for thermal-hydraulics and neutronics codes (cell and core level). Some specific codes have been developed for engineering/design, e.g. steady-state conditions, DNB, and instabilities maps. ARN provided guidance on how to develop models/codes, its documentation, and the quality assurance process required (based on CNSC RG G-149).
— Safety demonstration by tests on facilities with adequate similarity.
  - High Pressure Natural Circulation Rig (CAPCN) was designed to reproduce intensive parameters and most of the dynamic phenomena of the CAREM 25 reactor coolant system.
  - The RA-8 critical assembly was built to test the CAREM 25 prototype core Critical Heat Flux measurement in a model of the fuel elements.
  - High pressure test loop for characterization of the hydraulic Control Rod Drives.

  The licensing and assessment of these test facilities were considered a challenge to ARN due to the special design features of CAREM 25 reactor.
— Construction inspections. In order to meet established regulatory requirements, ARN only conducts inspections and audits on the Responsible Entity, not to vendors. The Responsible Entity is in charge of assuring that the supplier quality program is implemented, and the defined design criteria are accomplished. ARN reviews the mandatory documentation presented, in order to define and plan the inspection tasks. For example, ARN leads an inspection program at the site of the reactor CAREM 25 related with construction of civil structures, supported by TSOs.

3.3. Revision of CAREM 25 licensing scheme

In 2019, the ARN decided to update the licensing model for facing the following stage in the lifecycle; Commissioning. This decision was driven by the evolution of the CAREM 25 project and the experience gained in other licensing projects (Atucha II NPP, Embalse NPP Long-Term Operation). The selected model is in compliance, as far as practicable, with the existing licensing process for Argentinean NPPs in terms of mandatory documents (table of contents and scope) and general approach. This was formally communicated to CNEA in October 2019 [20].

In terms of regulatory process, the next licensing milestone will be the issuance of a Commissioning License by which ARN will authorize the performance of tests in accordance to a programme that has to be timely submitted for the regulatory review and approval. The Commissioning License would be valid until the tests of the demonstrative aspects of safety declared in the Safety Analysis Report (SAR) have been completed, whether they are functional tests or verifications of systems, the effectiveness of operating procedures, response to accidents, etc., and for a limited time period.

4. CONCLUSION

Acceptance criteria set by ARN for CAREM 25 prototype reactor licensing, included compliance with the design criteria, regulatory standards and current regulatory requirements. In all cases, the acceptance criteria are fulfilled with large margins.

In relation to this, the ARN was able to verify the correct implementation of requirements associated with:

- The Defense in Depth Principle, internalized in the design.
- Accountable safety margins regarding design limits in all design base scenarios.
- The Safety Classification of SSC has a systematic methodology and allows establishing engineering requirements that ensure an adequate functional capacity, robustness and reliability of the relevant SSCs.
- The safety requirements coming from the post Fukushima accident lessons were included in the design (before the occurrence of the accident).

The ARN could also verify additional features of CAREM design, associated to:

- Elimination by design of initiating events.
- Handling a wide range of multiple failure scenarios without exceeding Safety Limits.
- Extension of the grace period (operator actions not required to avoid core damage) up to 36 h.

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Respuesta radiológica e información pública.
Dos desafíos, el mismo reto

Truppa, W.A.; Vazquez, M.; Cateriano, M.; Rodríguez, M.;
Segato, A.; Pailos, E.; Esperanza, V.; Barone, M.; Brulc, B.; Perl, M.;
Porchia, B.; Arias, M.; Duarte, M.L. y Navarro, N.

Presentado en: XII Congreso Regional de Seguridad Radiológica y Nuclear y en el X Congreso Regional
de la Asociación Internacional de Protección Radiológica (IRPA).
Santiago de Chile, Chile, 23 al 27 de octubre de 2022

RESPUESTA RADIOLÓGICA E INFORMACIÓN PÚBLICA. DOS DESAFÍOS, EL MISMO RETO

Truppa, W.A.; Vazquez, M.; Cateriano, M.; Rodriguez, M.; Segato, A.; Pailos, E.; Esperanza, V.; Barone, M.; Brulc, B.; Perl, M.; Porchia, B.; Arias, M.; Duarte, M.L. y Navarro, N.

Autoridad Regulatoria Nuclear
Argentina

Proyecto Regional de Cooperación Técnica RLA9090
Fortalecimiento de la Infraestructura de reglamentación para mejorar la seguridad radiológica en América Latina y el Caribe

INTRODUCCIÓN

Es claro el rol de los sistemas de respuesta ante un evento con consecuencias para el público, donde se busca tomar el control de la situación tan pronto como sea posible.

Esto va de la mano con la robustez del plan de respuesta y la capacitación y experiencia del personal involucrado. Del mismo modo la información al público de las posibles consecuencias, es otro aspecto relacionado con la respuesta.

MATERIALES AND MÉTODOS

La Autoridad Regulatoria Nuclear (ARN) a través de su Sistema de Respuesta en Emergencias Radiológicas (SIER) evalúa y elabora los informes correspondientes relacionados con el tipo de emergencia que corresponda.

A su vez prepara el material para la información pública detallando el contenido de la información necesaria para alertar a la población sobre las medidas de protección.

Esto forma parte de la estrategia y las políticas de transparencia de gestión de la ARN y es un mecanismo que se considera necesario para construir confianza con los usuarios autorizados, organismos de respuesta y el público.

Los eventos radiológicos, así como otro tipo de situaciones se publican normalmente en la página web de ARN, donde además del evento ocurrido, se informan las recomendaciones de protección según sea el caso, como así también las novedades relacionadas con la respuesta. De esta manera, se toma como ejemplo, un caso ocurrido, donde un equipo para control de contrabando que contenía material radiactivo que había sido sustraído de su titular autorizado, pudo ser recuperado gracias a la información disponible en la página web de ARN.

RESULTADOS

La comunicación pública es parte de la gestión de la respuesta. Esta situación obliga a mantener un contacto muy estrecho con el público y otros organismos que pueden colaborar en la recuperación del control.

CONCLUSIONES

La descripción del equipo o fuente radiactiva fuera de control, las medidas básicas de protección contra la radiación, informar sobre el riesgo radiológico y los mecanismos de comunicación en caso de hallarlo, forman parte de la estrategia de la ARN para reducir el riesgo para los miembros del público a la vez que muestra el compromiso con la protección de los individuos y el ambiente.

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

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Respuesta radiológica e información pública. Dos desafíos, el mismo reto.

Walter Adrián Truppa, Marina Vazquez, Miguel Cateriano, Mónica Rodriguez, Allan Segato, Edgardo Pailos, Viviana Esperanza, Mariana Barone, Brian Brulc, Martin Perl, Blas Porchia, Martín Arias, Laura Duarte, Noelia Navarro

AUTORIDAD REGULATORIA NUCLEAR ARGENTINA

Emergencias Radiológicas y Nucleares

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
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El sistema regulador Argentino en números

123

Recursos

372
Trabajadores

$ 1.998 millones
Presupuesto total de la ARN

Acciones

18.107
Días-persona en inspecciones y evaluaciones regulatorias

884
Tomas de muestras ambientales para monitoreo radiológico

2.840
Documentos regulatorios emitidos

1.867
Ensayos de muestras realizadas en laboratorios propios

1.334
Autorizaciones de importación y exportación

20
Egresados del Curso Básico de Protección Radiológica

Alcance regulatorio

1.282
Instalaciones bajo control regulatorio en todo el país

64
Normas Regulatorias

10
Guías Regulatorias

14
Instalaciones bajo monitoreo radiológico ambiental

3.949
Trabajadores bajo vigilancia radiológica ocupacional

Información Pública

125
Novedades y publicaciones de interés regulatorio en la página web ***argentina.gob.ar/arn***

15
Pedidos de información, respondidos en los términos de la Ley Nº 27275 Derecho de Acceso a la Información Pública

53.405
Personas que vieron contenidos en ***Facebook***, ***Youtube*** y ***LinkedIn***

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El marco regulatorio

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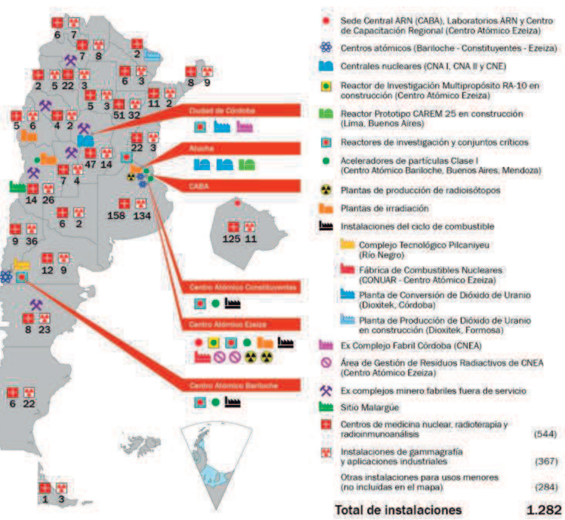

A fines de agosto y principios de setiembre, Argentina recibió una misión IRRS del OIEA, donde un numeroso grupo de expertos internacionales interactuaron en 10 áreas regulatorias. Entre ellas, el área relacionada con emergencias radiológicas y nucleares.

Concluyó la revisión internacional para la seguridad nuclear y radiológica

La misión internacional del OIEA evaluó la infraestructura regulatoria existente en Argentina

Compartir en redes sociales

Publicado el viernes 02 de septiembre de 2022

La República Argentina recibió la misión IRRS del Organismo Internacional de Energía Atómica (OIEA) que se desarrolló durante dos semanas, del 22 de agosto al 2 de septiembre de 2022, para **revisar toda la infraestructura regulatoria para la seguridad nuclear y radiológica de la Autoridad Regulatoria Nuclear (ARN)**, respecto al grado de implementación de las normas de seguridad del OIEA. La misión se realizó a pedido del gobierno de la República Argentina y fue recibida por la ARN.

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Mecanismos de respuesta

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- Es claro el rol de los sistemas de respuesta ante un evento radiológico, donde se busca tomar el control de la situación tan pronto como sea posible.
- Esto va de la mano con la robustez del plan de respuesta y la capacitación y experiencia del personal involucrado. Del mismo modo la información al público de las posibles consecuencias es otro aspecto relacionado profundamente con la respuesta.

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Sistema de respuesta ante situaciones de emergencia

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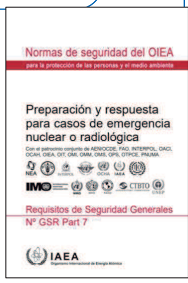
SIER

- Atiende emergencias radiológicas en instalaciones y la vía pública.
-Operativo 24hs x 365 días.
-Convocado por usuarios, público o fuerzas de seguridad o primeros respondedores.

SIEN

- Atiende emergencias nucleares y cumple con los tratados de Pronta Notificación y Asistencia.
- Operativo 24hs x 365 días.
- Convocado por el operador de la CN o el OIEA en caso de asistencia internacional.



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Preparación para la respuesta

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- Simulacro Central Nuclear Embalse 2022

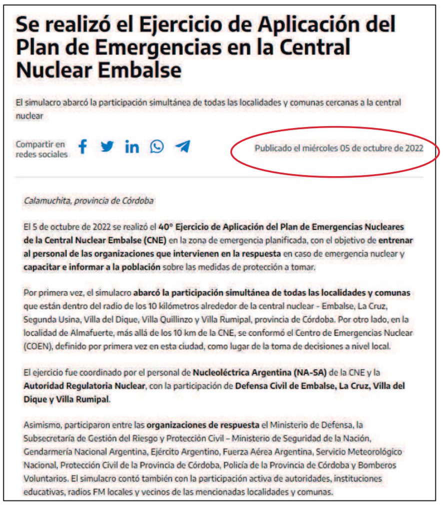
Ejercicio de Aplicación del Plan de Emergencias

Las centrales nucleares operan de manera segura y deben tener, como cualquier otra instalación, un **plan de emergencia** ante la posibilidad de un accidente, para reducir las posibles consecuencias para la salud y el ambiente.

Los planes de emergencia de las centrales nucleares son aprobados por la ARN y describen las tareas a realizarse en las etapas de preparación y respuesta. Los planes de emergencia se practican mediante **ejercicios de aplicación o simulacros** que se realizan todos los años, con la participación de NA-SA, la ARN, las organizaciones de respuesta y la población vecina a las centrales nucleares. Estos ejercicios son también supervisados por la ARN.

Los ejercicios permiten la **coordinación y el entrenamiento de las organizaciones de respuesta,** que practican las tareas que tienen asignadas en una emergencia. Como parte de la preparación para estos ejercicios, se realizan también **actividades de difusión y capacitación** para que la población de las localidades vecinas a las centrales conozca las medidas de protección y cómo llevarlas a cabo.

Escuela primaria "Primera Junta" – Villa Rumipal | Escuela primaria "Almirante Brown" – Villa Del Dique



Se realizó el Ejercicio de Aplicación del Plan de Emergencias en la Central Nuclear Embalse

El simulacro abarcó la participación simultánea de todas las localidades y comunas cercanas a la central nuclear

Compartir en redes sociales

Publicado el miércoles 05 de octubre de 2022

Calamuchita, provincia de Córdoba

El 5 de octubre de 2022 se realizó el **40° Ejercicio de Aplicación del Plan de Emergencias Nucleares de la Central Nuclear Embalse (CNE)** en la zona de emergencia planificada, con el objetivo de **entrenar al personal de las organizaciones que intervienen en la respuesta** en caso de emergencia nuclear y **capacitar e informar a la población** sobre las medidas de protección a tomar.

Por primera vez, el simulacro **abarcó la participación simultánea de todas las localidades y comunas** que están dentro del radio de los 10 kilómetros alrededor de la central nuclear - Embalse, La Cruz, Segunda Usina, Villa del Dique, Villa Quillinzo y Villa Rumipal, provincia de Córdoba. Por otro lado, en la localidad de Almafuerte, más allá de los 10 km de la CNE, se conformó el Centro de Emergencias Nuclear (COEN), definido por primera vez en esta ciudad, como lugar de la toma de decisiones a nivel local.

El ejercicio fue coordinado por el personal de **Nucleoléctrica Argentina (NA-SA)** de la CNE y la **Autoridad Regulatoria Nuclear**, con la participación de **Defensa Civil de Embalse, La Cruz, Villa del Dique y Villa Rumipal**.

Asimismo, participaron entre las **organizaciones de respuesta** el Ministerio de Defensa, la Subsecretaría de Gestión del Riesgo y Protección Civil – Ministerio de Seguridad de la Nación, Gendarmería Nacional Argentina, Ejército Argentino, Fuerza Aérea Argentina, Servicio Meteorológico Nacional, Protección Civil de la Provincia de Córdoba, Policía de la Provincia de Córdoba y Bomberos Voluntarios. El simulacro contó también con la participación activa de autoridades, instituciones educativas, radios FM locales y vecinos de las mencionadas localidades y comunas.

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Preparación para la respuesta

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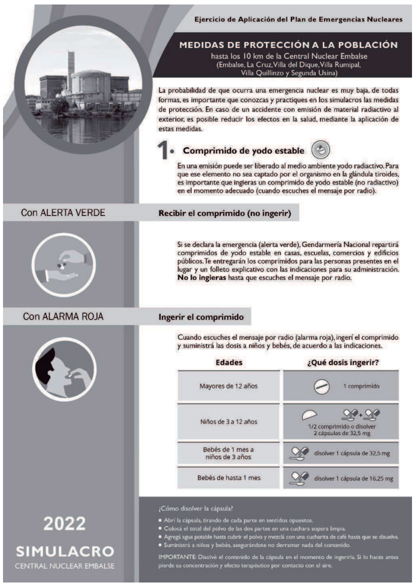

Ejercicio de Aplicación del Plan de Emergencias Nucleares

MEDIDAS DE PROTECCIÓN A LA POBLACIÓN
hasta los 10 km de la Central Nuclear Embalse
(Embalse, La Cruz, Villa del Dique, Villa Rumipal, Villa Quillinzo y Segunda Usina)

La probabilidad de que ocurra una emergencia nuclear es muy baja, de todas formas, es importante que conozcas y practiques en los simulacros las medidas de protección. En caso de un accidente con emisión de material radiactivo al exterior, es posible reducir los efectos en la salud, mediante la aplicación de estas medidas.

1. Comprimido de yodo estable

En una emisión puede ser liberado al medio ambiente yodo radiactivo. Para que ese elemento no sea captado por el organismo en la glándula tiroides, es importante que ingieras un comprimido de yodo estable (no radiactivo) en el momento adecuado (cuando escuches el mensaje por radio).

Con ALERTA VERDE — **Recibir el comprimido (no ingerir)**

Si se declara la emergencia (alerta verde), Gendarmería Nacional repartirá comprimidos de yodo estable en casas, escuelas, comercios y edificios públicos. Te entregarán los comprimidos para las personas presentes en el lugar y un folleto explicativo con las indicaciones para su administración. **No lo ingieras** hasta que escuches el mensaje por radio.

Con ALARMA ROJA — **Ingerir el comprimido**

Cuando escuches el mensaje por radio (alarma roja), ingerí el comprimido y suministrá las dosis a niños y bebés, de acuerdo a las indicaciones.

Edades	¿Qué dosis ingerir?
Mayores de 12 años	1 comprimido
Niños de 3 a 12 años	1/2 comprimido o disolver 2 cápsulas de 32,5 mg
Bebés de 1 mes a niños de 3 años	disolver 1 cápsula de 32,5 mg
Bebés de hasta 1 mes	disolver 1 cápsula de 16,25 mg

¿Cómo disolver la cápsula?
- Abrí la cápsula, tirando de cada parte en sentidos opuestos.
- Colocá el total del polvo de las dos partes en una cuchara sopera limpia.
- Agregá agua potable hasta cubrir el polvo y mezclá con una cucharita de café hasta que se disuelva.
- Suministrá a niños y bebés, asegurándote no derramar nada del contenido.

IMPORTANTE: Disolvé el contenido de la cápsula en el momento de ingerirla. Si lo hacés antes pierde su concentración y efecto terapéutico por contacto con el aire.

2022
SIMULACRO
CENTRAL NUCLEAR EMBALSE

CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
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Objetivos de la respuesta

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- **Recuperar el control** de la situación y mitigar las consecuencias
- **Salvar vidas**
- **Evitar** los **efectos deterministas graves** (o reducirlos al mínimo)
- Prestar **primeros auxilios**
  - Proporcionar tratamiento médico indispensable
  - Manejar el tratamiento de lesiones por radiación
- Reducir el riesgo de **efectos estocásticos**

Objetivos de la respuesta

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- La Autoridad Regulatoria Nuclear (ARN) a través de la Subgerencia Intervención en Emergencias Radiológicas y Nucleares evalúa y elabora los informes correspondientes relacionados con el tipo de emergencia que corresponda.
- **Capacita a los respondedores y fomenta la interacción entre grupos de respuesta.**
- A su vez prepara el material para la información pública detallando el contenido de la información necesaria, para alertar a la población sobre las medidas de protección en caso de hallarlo.
- Esto forma parte de la estrategia y políticas de transparencia de gestión de la ARN y es un mecanismo que se considera necesario para construir confianza con los usuarios autorizados, organismos de respuesta y el público.


Objetivos de la respuesta

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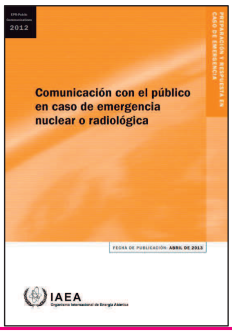
Información pública. Descripción del evento o suceso

- Establecer la causa (extravío, robo, etc.)
- Describir el radionucleído y tipo de radiación relacionada con la emergencia
- Cuando ocurrió el evento
- Informar el riesgo radiológico
- Mencionar los mecanismos para reducir la radiación alrededor del escenario establecido y las medidas para la protección
- Teléfonos o mecanismos de contacto en caso de hallarlo



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Objetivos de la respuesta

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- Los eventos radiológicos, así como otro tipo de situaciones se publican en la página web de ARN, donde además del evento ocurrido, se indican los datos de contacto y los teléfonos del SIER en caso de informar cualquier tipo de novedad sobre el evento radiológico en cuestión o también, si surgieran consultas del público al respecto, a través de la Subgerencia de Comunicación, que trabaja estrechamente con nuestro sector.

Inicio / Autoridad Regulatoria Nuclear / Informes sobre sucesos notificados

Información para la comunidad
- Acerca de ARN
- Elaboración participativa de normas
- Informes sobre sucesos notificados
- Vigilancia radiológica ambiental
- Laboratorios
- Sitios web de interés

Informes sobre sucesos notificados

Compartir en redes sociales

La ARN gestiona un **sistema permanente de intervención en emergencias radiológicas y nucleares**, que responde ante situaciones que pudieran, de manera real o potencial, exponer al público a material radiactivo o radiación.

En estas intervenciones, la ARN asume un rol de autoridad por sobre los responsables de las instalaciones o materiales y otros actores involucrados en la emergencia.

- Parada programada de la Central Nuclear Embalse (03/10/2022)
- Accidente laboral en la Central Nuclear Atucha I (09/09/2022)
- Parada programada de la Central Nuclear Atucha I (05/09/2022)
- Participación de ARN en inspección en depósito de materiales en CABA (09/06/2022)
- Parada no programada de la Central Nuclear Atucha I (19/05/2022)
- Parada programada de la Central Nuclear Atucha II (09/03/2022)
- Información sobre casos positivos de COVID-19 en las centrales nucleares

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Ejemplo de recuperación inmediata del dispositivo robado

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- Informar sobre un evento, es un mecanismo de transparencia.
- La **confianza y la disponibilidad de la información** son elementos clave para la comunicación del riesgo.

Robo de equipo medidor con fuente radiactiva en Valle Viejo, Catamarca

Compartir en redes sociales

El lunes 3 de febrero de 2020, la Autoridad Regulatoria Nuclear recibió el llamado de un organismo público informando del robo de un equipo portátil medidor de humedad con fuente radiactiva, como el de la foto, en la localidad de Valle Viejo, provincia de Catamarca.

El equipo **contiene una fuente radiactiva que puede provocar daños a la salud** si es manipulado por personas inexpertas o su fuente radiactiva es extraída del equipo o dañada.

El **equipo portátil** es de **color celeste, robusto de unos 10 kilos y mide 80 cm de largo por 30 cm de ancho.** Está identificado con el símbolo radiactivo, con la marca Troxler, modelo 4302. Se utiliza para medir la humedad de suelos en obras viales.

En caso de encontrarlo, **no lo toque y mantenga una distancia de al menos 5 metros.**

Llame a:

- la **delegación de Policía o Bomberos más cercano** al lugar del hallazgo
- los números de emergencia de la Provincia
  - **103 Defensa Civil**
  - **100 Bomberos**
  - **101 / 911 Policía de Catamarca**
- o a la **Autoridad Regulatoria Nuclear** a estos teléfonos, las 24 horas del día.
  011-15-4471-8686
  011-15-4470-3839
  011-15-4421-4581

Hallaron el equipo con fuente radiactiva robado en Valle Viejo, Catamarca

Compartir en redes sociales

La Autoridad Regulatoria Nuclear **confirma que el miércoles 5 de febrero de 2020 se recuperó el equipo** medidor de humedad con fuente radiactiva que había sido robado el pasado 3 de febrero, en la localidad de Valle Viejo, provincia de Catamarca, por el cual se había emitido un alerta nacional.

El equipo y la fuente radiactiva alojada en su interior **se encontraron en perfectas condiciones de seguridad**. El blindaje del equipo no presentó signos de haber sido vulnerado, por lo cual **el material radiactivo no estuvo en contacto con las personas ni el medio ambiente**.

El equipo se trasladó al predio del INTA en Valle Viejo para su guarda segura.

Ejemplo de recuperación diferida del dispositivo robado

- En este caso, se toma un caso ocurrido, donde un equipo que contenía material radiactivo fue sustraído de su titular autorizado, y gracias a la información disponible en la página web de ARN, pudo ser recuperado tiempo después.

Robo de equipo medidor de densidad en Campana

Compartir en redes sociales

El lunes 16 de enero de 2017 la Autoridad Regulatoria Nuclear recibió el llamado de un organismo público informando del robo de un equipo medidor de densidad marca Polimaster, que se encontraba dentro de un vehículo estacionado en la localidad de Campana, Provincia de Buenos Aires.

El equipo es utilizado para la detección de contrabando y se compone de una fuente radiactiva de muy bajo riesgo radiológico.

La Autoridad Regulatoria Nuclear tomó intervención realizando las acciones y dando aviso inmediato a la Sección Seguridad Radiológica de la Superintendencia de Bomberos de la Policía Federal Argentina y a la Gendarmería Nacional Argentina.

El equipo medidor de densidad es de marca Polimaster, modelo PM 1401T, con número de serie de fuente 70027 (ver foto abajo).

Se solicita que en caso de encontrar abandonado en la vía pública un equipo similar, se avise de inmediato a los teléfonos señalados abajo, con el fin de proceder a su recuperación y disposición segura.

Sistema de Intervención en Emergencias Radiológicas:
(011) 15 4421-4581 / 15 5600-5118

Robo de equipo medidor de densidad en Campana

Compartir en redes sociales

(Actualizado al 5 de agosto de 2021)

El lunes 16 de enero de 2017, la Autoridad Regulatoria Nuclear (ARN) recibió el llamado de un organismo público informando del robo de un equipo medidor de densidad marca Polimaster, que se encontraba dentro de un vehículo estacionado en la localidad de Campana, provincia de Buenos Aires.

El equipo, modelo PM 1401T, con número de serie de la fuente radiactiva 70027 (ver foto abajo), es utilizado para la detección de contrabando y emplea como material radiactivo Ba-133 con un riesgo radiológico asociado muy bajo.

La ARN tomó intervención realizando las acciones necesarias, dando aviso inmediato a la Sección Seguridad Radiológica de la Superintendencia de Bomberos de la Policía Federal Argentina y a la Gendarmería Nacional Argentina.

El 5 de agosto 2021, se recibió un llamado de un particular que manifestó el hallazgo de un equipo que coincidía con la descripción de dicho dispositivo. Gracias a esta información, el equipo pudo ser recuperado. El robo había sido efectuado a un vehículo oficial de la Administración Federal de Ingresos Públicos (AFIP), de donde se sustrajo el equipo Polimaster.

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Resultados

- Toda situación de emergencia, requiere una rápida evaluación del tipo de evento y la aplicación de medidas adecuadas para el tipo de emergencia que se trate.

- La comunicación pública es parte de la gestión de la respuesta. Esta situación obliga a mantener un contacto muy estrecho con el público y otros organismos, que pueden colaborar en la recuperación del control.

Participación de ARN en inspección en depósito de materiales en CABA

Compartir en redes sociales

El 19 de mayo de 2022, la Autoridad Regulatoria Nuclear (ARN) recibió una notificación de la Unidad Fiscal Especial en Materia Ambiental (UFEMA) de la Ciudad Autónoma de Buenos Aires (CABA), en la que se solicitó al Sistema de Intervención en Emergencias Radiológicas (SIER) de la ARN que se hiciera presente el 20 de mayo de 2022 para colaborar durante una inspección integral a un depósito de materiales, ubicado en CABA.

Durante la inspección, la ARN pudo constatar el hallazgo de algunas piezas dentro de una caja de madera, que correspondían al cabezal de un equipo acelerador lineal, que se utiliza para tratamiento médico.

El 31 de mayo de 2022, la entidad responsable de los repuestos encontrados en el depósito, destinado a la reparación y mantenimiento de partes de equipos de aceleradores lineales, solicitó a esta ARN la correspondiente autorización para el traslado y la disposición definitiva de tres piezas de uranio depletado como residuo radiactivo, ante el Programa Nacional de Gestión de Residuos Radiactivos que gestiona la Comisión Nacional de Energía Atómica (CNEA).

El 8 de junio de 2022, con la autorización emitida por la ARN, la CNEA realizó el retiro de este material y su traslado seguro al Centro Atómico Ezeiza, donde realizará su disposición final.

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Conclusiones

- Los mecanismos de respuesta deben ser activados de forma inmediata ante una emergencia radiológica.
- La participación interdisciplinaria entre organismos de respuesta debe ser coordinada.
- La capacitación es otro aspecto relevante de la respuesta.
- La descripción de un evento radiológico, las medidas básicas de protección contra la radiación, el riesgo involucrado y los mecanismos de comunicación en caso de hallarlo, forman parte de la estrategia de la ARN para reducir el riesgo para los miembros del público y para los organismos de respuesta.
- La información pública es parte del compromiso de la ARN con la seguridad.

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SIER
Sistema de Intervención en Emergencias Radiológicas

SIEN
Sistema de Intervención en Emergencias Nucleares

Gracias por su tiempo

Autoridad Regulatoria Nuclear

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Integración de la respuesta radiológica en el desarrollo de los planes de emergencia

Truppa, W.A.; Vazquez, M.; Cateriano, M.; Rodríguez, M.;
Segato, A.; Pailos, E.; Esperanza, V.; Barone, M.;
Brulc, B.; Perl, M.; Porchia, B. y Arias, M.

Presentado en: XII Congreso Regional de Seguridad Radiológica y Nuclear y en el X Congreso Regional de la Asociación Internacional de Protección Radiológica (IRPA).
Santiago de Chile, Chile, 23 al 27 de octubre de 2022

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

Integración de la respuesta radiológica en el desarrollo de los planes de emergencia

Walter Adrián Truppa, Marina Vazquez, Miguel Cateriano, Mónica Rodriguez, Allan Segato, Edgardo Pailos, Viviana Esperanza, Mariana Barone, Brian Brulc, Martin Perl, Blas Porchia, Martín Arias

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Argentina

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XI CONGRESO REGIONAL DE SEGURIDAD RADIÓLOGICA Y NUCLEAR
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Integración de la respuesta radiológica en el desarrollo de los planes de emergencia

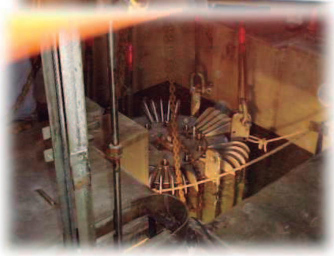
Introducción

Uno de los problemas específicos que se puede presentar en la ejecución de un plan de emergencia, es que el mismo no contemple los distintos escenarios posibles y sus consecuencias. A la vez que requiere una definición clara de roles y responsabilidades durante la respuesta. En ese sentido debe tenerse en cuenta el documento **GSR parte 7 - Requisito 4. Evaluación de los peligros: "**El gobierno se asegurará de que se lleve a cabo una evaluación de los peligros que siente las bases de un enfoque graduado de la preparación y respuesta para casos de emergencia nuclear o radiológica".

Materiales y Métodos

La Subgerencia Intervención en Emergencias Radiológicas y Nucleares (SIERYN) de la **Autoridad Regulatoria Nuclear (ARN),** ha desarrollado un Instructivo para la preparación de planes de emergencia. Dicho Instructivo posee las recomendaciones, contenidos mínimos y recursos necesarios, acorde a la categoría que tiene la instalación, en función de los posibles escenarios y sus riesgos radiológicos o nucleares. Entre los aspectos relevantes este instructivo se incluyen:

- Categorías de Preparación para Emergencia
- Clasificación de las emergencias
- Estructura del Plan de Emergencia
- Contenido de un Plan de Emergencia o Procedimiento
- Roles y responsabilidades
- Marco legal
- Evaluación del riesgo y planificación de la respuesta
- Acordonamiento y clasificación de las áreas afectadas
- Concepto y gestión de operación
- Protección de los trabajadores en emergencias
- Monitoreo radiológico y descontaminación superficial
- Aspectos médicos de la respuesta
- Entrenamiento, ejercicios y simulacros
- Soporte logístico
- Mecanismos de coordinación y comunicación



Las recomendaciones de este instructivo servirán para facilitar la preparación del plan de respuesta de las instalaciones bajo control regulatorio, en caso de una emergencia radiológica o nuclear, acorde a los lineamientos de las normas aplicables.

Resultados

En ese sentido, se ha aplicado un enfoque graduado para que cada plan de emergencia sea diseñado y evaluado a la medida de la instalación. Durante la planificación y aplicación de las medidas de protección y otras medidas de respuesta en una emergencia, deberían tenerse en cuenta: desarrollo de efectos deterministas graves, aumento de los efectos estocásticos, efectos desfavorables para el ambiente y la propiedad, otros efectos como por ejemplo psicológicos, desórdenes sociales, problemas económicos, etc.

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Integración de la respuesta radiológica en el desarrollo de los planes de emergencia

A continuación se presenta una tabla con la descripción de las categorías comprendidas en este instructivo. Acorde a cada categoría, el contenido del plan o procedimiento de emergencia debe contener el desarrollo de posibles escenarios.

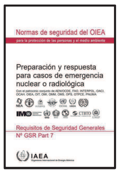
	Emergencia general	Emergencia en la instalación	Anomalía o desviación
Categoría I	X	X	X
Categoría II		X	X
Categoría III		X	X
Categoría Otras instalaciones		X	X

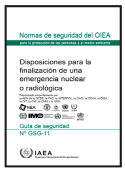
Como objetivo final de este instructivo , se recomienda una revisión de cada ítem que integra el plan o procedimiento de emergencia, de manera de verificar que la documentación necesaria para la revisión, contiene todos los aspectos necesarios.

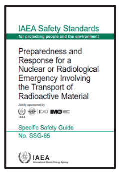
VERIFIQUE SI CUMPLE CON LOS REQUISITOS	SI	NO	N/A
Describió brevemente la instalación			
Ubicó la instalación en el mapa			
Describió los roles y las responsabilidades del personal que estará afectado a la respuesta			
Definió un organigrama para emergencias			
Definió los niveles de intervención			
Desarrolló los posibles escenarios de amenaza de la instalación, y como se resolvería cada uno de ellos			
Detalló el equipamiento que posee para un caso de emergencia			
Ubicó el equipamiento que definió anteriormente en un plano			
Detalló los dispositivos de medición para el monitoreo y su ubicación en el plano de la instalación			
Detalló las capacitaciones del personal que intervendrá en una emergencia			
Detalló la protección de los trabajadores de emergencias: recursos para la radioprotección, dosimetría, provisión de comprimidos de iodo, etc			
Realizó convenios con las organizaciones de apoyo externo a la instalación			
Programó un Plan de capacitación para las organizaciones de respuesta externas que intervienen en la emergencia			
Detalló las comunicaciones durante la emergencia			
Si la instalación se encuentra en un predio compartido con otras instalaciones, describió la coordinación e integración con los planes de emergencia de estas otras instalaciones			
Describió cómo se instruye a las visitas, proveedores y/o personal eventual, que pudiera estar ocasionalmente en la instalación durante una emergencia			

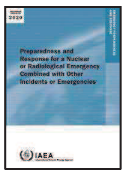
Conclusiones

- Los planes de emergencia **son un requisito mandatorio**, de manera de que cada instalación, acorde a los riesgos que plantea su operación, defina los posibles escenarios y los recursos necesarios para coordinar las acciones de respuesta.
- Los planes de emergencia deben ser **ensayados y definidos** de forma tal, que el tiempo necesario para la toma de decisiones sea el menor posible, aumentando la eficacia de la respuesta.
- Las **recomendaciones del OIEA** aportan información concreta sobre la importancia de la interacción entre las distintas fases que se deben evaluar para la preparación de un plan de respuesta.









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Marco Normativo Regulatorio.
Bases y Evolución

Valentino, L.

Presentado en: Reunión Anual de la Asociación Argentina de Tecnología Nuclear (AATN).
Buenos, Aires, Argentina, 19 al 22 de diciembre de 2022

MARCO NORMATIVO REGULATORIO.
BASES Y EVOLUCIÓN

Valentino, L.

Autoridad Regulatoria Nuclear
Argentina

La Ley Nacional de la Actividad Nuclear, Nº 24804 le confiere a la Autoridad Regulatoria Nuclear (ARN), entre otras funciones, la de establecer y actualizar normas y guías regulatorias. El cuadro normativo de la ARN se establece a partir de la propia experiencia regulatoria, los estándares internacionales del Organismo Internacional de Energía Atómica (OIEA), los criterios de seguridad instituidos en las convenciones internacionales, y los criterios científicos recomendados por la Comisión Internacional de Protección Radiológica (ICRP), el Comité Científico de las Naciones Unidas para el estudio de los Efectos de las Radiaciones Atómicas (UNSCEAR) y todo otro organismo internacional reconocido sobre la temática a desarrollar.

La ARN es el organismo del Estado argentino dedicado a la regulación y fiscalización de la actividad nuclear, en las áreas de seguridad radiológica y nuclear, protección y seguridad física, y salvaguardias y no proliferación.

Las normas regulatorias son de cumplimiento obligatorio para las instalaciones y prácticas reguladas por la ARN en el país, y establecen los requisitos para todas las etapas de vida de las instalaciones o prácticas, y para el accionar del personal involucrado. Asimismo, estos documentos, de alta jerarquía, son la base para el diseño y la planificación de las inspecciones llevadas a cabo por la ARN.

Las guías regulatorias, se vinculan a normas regulatorias y son de carácter orientativo y de referencia, y contienen recomendaciones para el cumplimiento de requisitos contenidos en las normas.

Se presentará el cuerpo normativo vigente, enfatizando sobre nuevos enfoques de verificación y control basados en los alcances de una nueva norma regulatoria de seguridad, la ARN 10.6.1, Rev. 0, “Sistema de gestión para la seguridad en instalaciones y prácticas”, emitida por la ARN y en vigor desde el 1º de abril de 2021.

Mediante la presentación se remarcará la importancia fundamental que imparten las Normas y Guías regulatorias como aliados para alcanzar los niveles de seguridad requeridos, considerando que el diseño y elaboración de estos documentos se enfocan a minimizar los riesgos radiológicos asociados al uso de materiales radiactivos y nucleares.

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Marco Normativo Regulatorio
Bases y Evolución

Subgerencia Normativa Regulatoria

Lucía Valentino

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Antecedentes para el desarrollo del Marco Normativo Nacional

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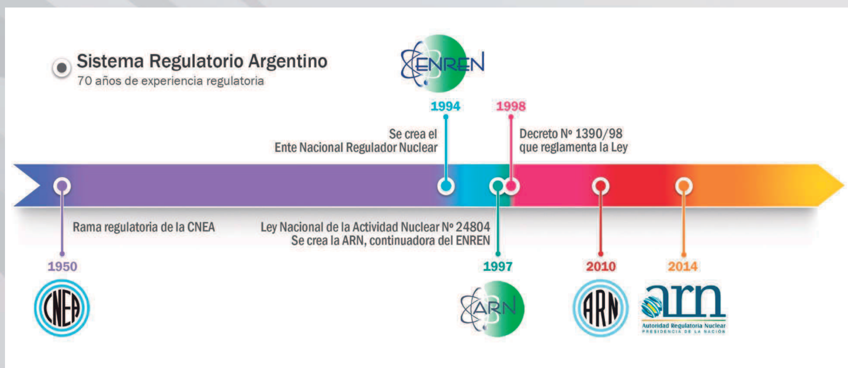
Antecedentes del Marco Normativo actual

- Desde sus inicios, la actividad nuclear en la Argentina contó con un marco regulatorio.
- La facultad para dictar las normas recayó a través de los años en la **Comisión Nacional de Energía Atómica (CNEA)**, el **Ente Nacional Regulador Nuclear (ENREN)**, y la **Autoridad Regulatoria Nuclear (ARN)**



El ENREN refrendó la normativa vigente al momento de su creación

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Hitos en el proceso de elaboración del Marco Normativo nacional

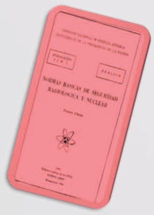
1958 — Por el Decreto 824 se aprueba el **Reglamento para Uso de Radioisótopos y Radiaciones Ionizantes**

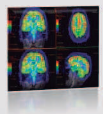
1961 — Se adopta el **Reglamento para el transporte seguro de materiales radiactivos del OIEA**

1966 — Se publica la primera edición de las **Normas Básicas de Seguridad Radiológica y Nuclear**

1976 — Se emiten las “**Normas para el uso de radioisótopos en medicina**” y “**Normas para proceder a la autorización de responsables como asesores físicos en servicios de radioterapia**”

1979 — El Consejo Asesor para el Licenciamiento de Instalaciones Nucleares **“CALIN”** comienza a emitir Normas aplicables a instalaciones nucleares





Hitos internacionales en el proceso de elaboración del Marco Normativo nacional

1987 — Entró en vigencia la **Convención sobre la Protección Física de los Materiales Nucleares**

1994 — Entró en vigencia la **Convención sobre Seguridad Nuclear**

2001 — Entró en vigencia la **Convención Conjunta sobre Seguridad en la Gestión del Combustible Gastado y sobre Seguridad en la Gestión de Desechos Radiactivos**

2016 — Entró en vigencia la enmienda a la **Convención sobre la Protección Física de los Materiales Nucleares**

Armonización del Marco Normativo nacional con documentos internacionales

- Normas y Guías de seguridad del OIEA

- Las recomendaciones del ICRP

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Otras series de documentos del OIEA

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Consideraciones generales

- El OIEA está autorizado por su Estatuto a establecer **normas de seguridad** para **proteger la salud** y reducir al mínimo los efectos nocivos de las radiaciones ionizantes para la vida y la propiedad
- El OIEA debe utilizar sus normas en sus propias operaciones,
- Un Estado **puede adoptar** las normas del OIEA,
- Las normas de seguridad del OIEA son **revisadas periódicamente**,
- La **asistencia del OIEA** para la aplicación de sus normas, se ha convertido en elemento clave de un régimen de seguridad mundial

….Sin embargo, las normas de seguridad sólo pueden ser eficaces si se aplican correctamente en la práctica.

Prólogo Director General del OIEA (SF-1)

Normas de Seguridad del OIEA

Enuncian los **principios**, **requisitos** y **recomendaciones** para garantizar la seguridad y constituyen una referencia mundial para la protección de las personas y del medio ambiente

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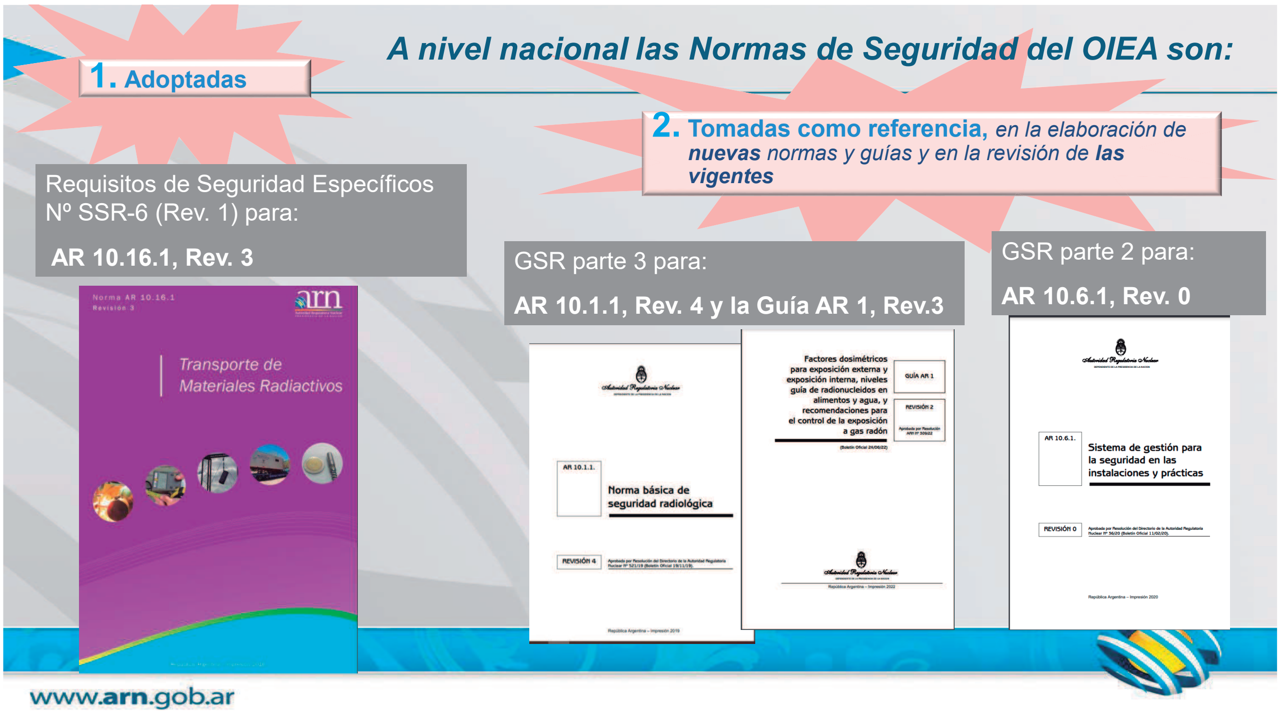
A nivel nacional las Normas de Seguridad del OIEA son:
1. Adoptadas
2. Tomadas como referencia, en la elaboración de nuevas normas y guías y en la revisión de las vigentes
Requisitos de Seguridad Específicos Nº SSR-6 (Rev. 1) para:
AR 10.16.1, Rev. 3
GSR parte 3 para:
AR 10.1.1, Rev. 4 y la Guía AR 1, Rev.3
GSR parte 2 para:
AR 10.6.1, Rev. 0
Transporte de Materiales Radiactivos
Norma básica de seguridad radiológica
Sistema de gestión para la seguridad en las instalaciones y prácticas
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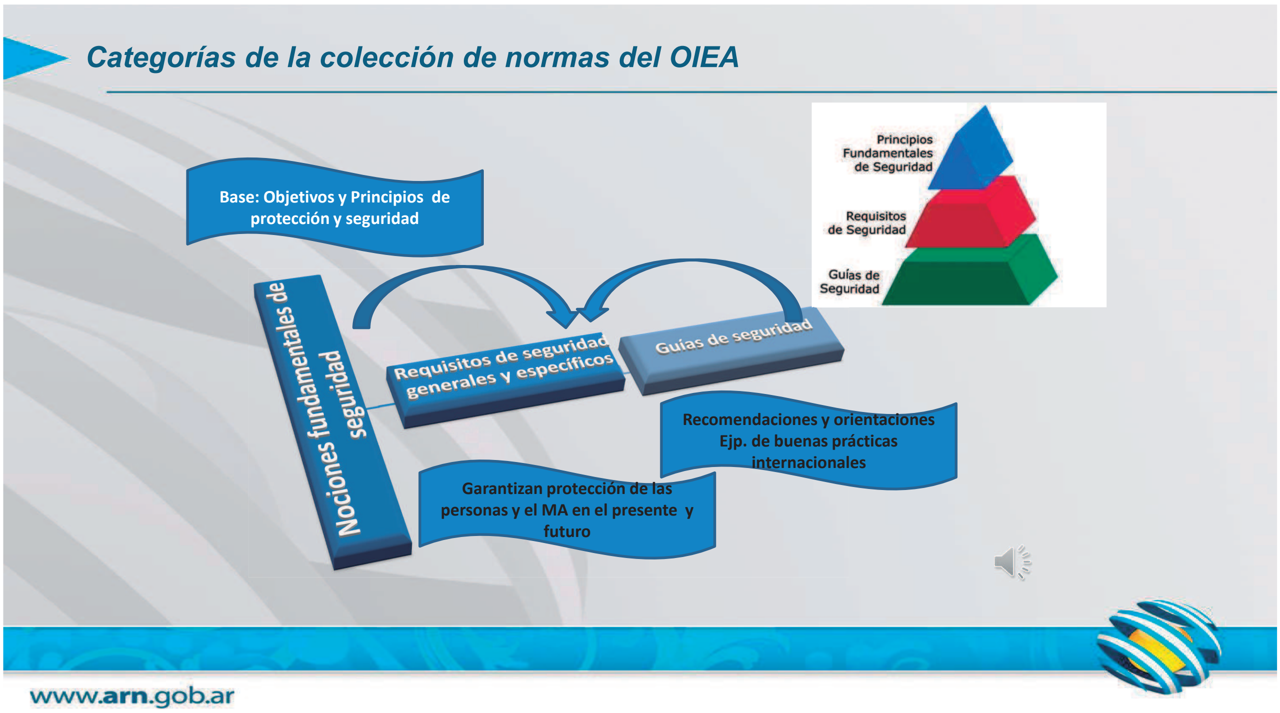

Categorías de la colección de normas del OIEA
Base: Objetivos y Principios de protección y seguridad
Nociones fundamentales de seguridad
Requisitos de seguridad generales y específicos
Guías de seguridad
Recomendaciones y orientaciones Ejp. de buenas prácticas internacionales
Garantizan protección de las personas y el MA en el presente y futuro
Principios Fundamentales de Seguridad
Requisitos de Seguridad
Guías de Seguridad
www.arn.gob.ar

Inclusión de los Principios Fundamentales de Seguridad

En Argentina, se han reflejado en distintos documentos:

- Constitución Nacional,

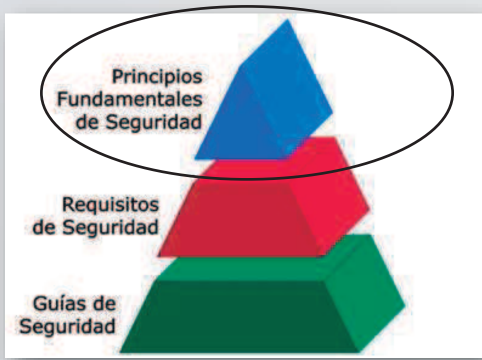
- en Leyes y Decretos, y

- en las Normas "Básicas" AR

Principios Fundamentales de Seguridad - Safety Fundamentals:

Presentan los *objetivos y principios fundamentales* de protección y seguridad, y

constituyen la *base de los requisitos de seguridad*

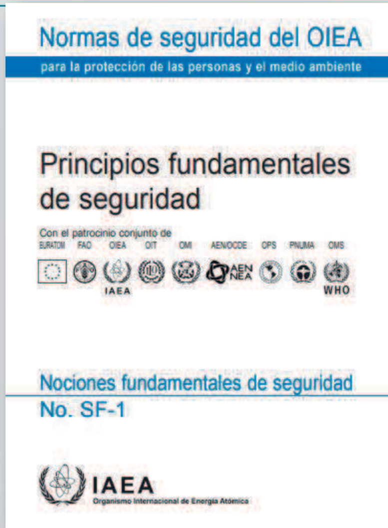


Normas de Seguridad del OIEA

SF-1 "Principios fundamentales de seguridad" incluye:

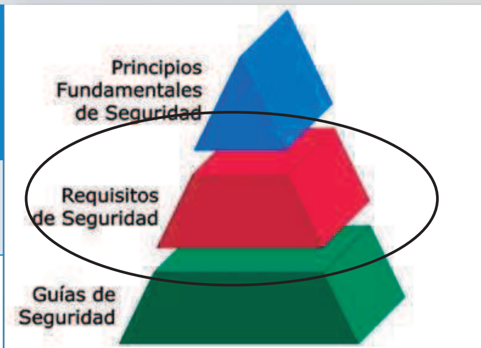
- **Objetivo fundamental de la seguridad:** ***Proteger a las personas y el medio ambiente contra los efectos nocivos de las radiaciones ionizantes.***

- **Diez Principios de Seguridad**



Requisitos de Seguridad - Safety Requirements:

Conjunto integrado y coherente de requisitos de seguridad que se han de **cumplir para garantizar la protección** de las **personas** y el **medio ambiente**, tanto en el **presente** como en el **futuro**
Se rigen por los objetivos y principios de las Principios Fundamentales de Seguridad
De no cumplirse, deben adoptarse **medidas** para alcanzar o **restablecer el grado de seguridad requerido**
Se emplean **formas verbales imperativas**
Cuando no se dirigen a una parte en particular, significa que **incumbe cumplirlos a las partes que corresponda**



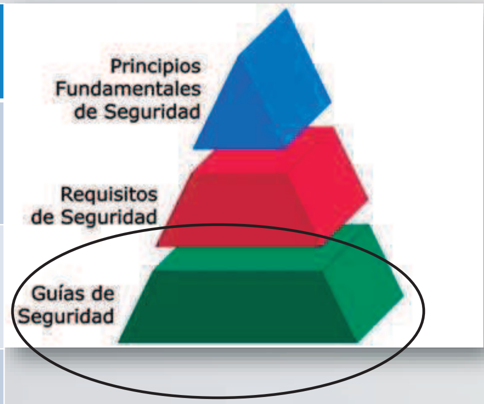
Guías de seguridad - Safety Guides

Recomendaciones y orientación para cumplir los requisitos de seguridad

Indican un **consenso internacional**, por lo que es apropiado adoptar las medidas recomendadas u otras medidas equivalentes

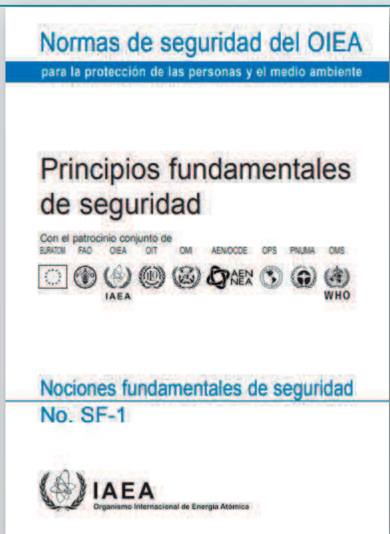
Contienen **ejemplos de buenas prácticas internacionales** que existen para **ayudar a los usuarios** que tratan de alcanzar altos grados de seguridad

En la formulación se emplean **formas verbales condicionales**



Principios Fundamentales de seguridad en SF-1

Diez Principios de Seguridad, que constituyen la **base para elaborar los requisitos** y aplicar las medidas de seguridad con el fin de alcanzar el objetivo fundamental de la seguridad.



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Principios Fundamentales de Seguridad del OIEA

Principio 1: RESPONSABILIDAD DE LA SEGURIDAD	**La responsabilidad primordial de la seguridad debe recaer en la persona u organización a cargo de las instalaciones y actividades que generen riesgos asociados a las radiaciones**
Principio 2: FUNCIÓN DEL GOBIERNO	**Debe establecerse y mantenerse un marco de seguridad jurídico y gubernamental eficaz, que incluya un órgano regulador independiente**
Principio 3: LIDERAZGO Y GESTIÓN EN PRO DE LA SEGURIDAD	**Deben establecerse y mantenerse un liderazgo y una gestión que promuevan eficazmente la seguridad en las organizaciones que se ocupan de los riesgos asociados a las radiaciones y en las instituciones y actividades que los generan**

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Principios Fundamentales de Seguridad del OIEA

Principio 4: JUSTIFICACIÓN DE LAS INSTALACIONES Y ACTIVIDADES	**Las instalaciones y actividades que generen riesgos asociados a las radiaciones deben reportar un beneficio general**
Principio 5: OPTIMIZACIÓN DE LA PROTECCIÓN	**La protección debe optimizarse para proporcionar el nivel de seguridad más alto que sea razonablemente posible de alcanzar**
Principio 6: LIMITACIÓN DE LOS RIESGOS PARA LAS PERSONAS	**Las medidas de control de los riesgos asociados a las radiaciones deben garantizar que ninguna persona se vea expuesta a un riesgo de daños inaceptable**
Principio 7: PROTECCIÓN DE LAS GENERACIONES PRESENTES Y FUTURAS	**Deben protegerse contra los riesgos asociados a las radiaciones las personas y el ambiente del presente y del futuro.**

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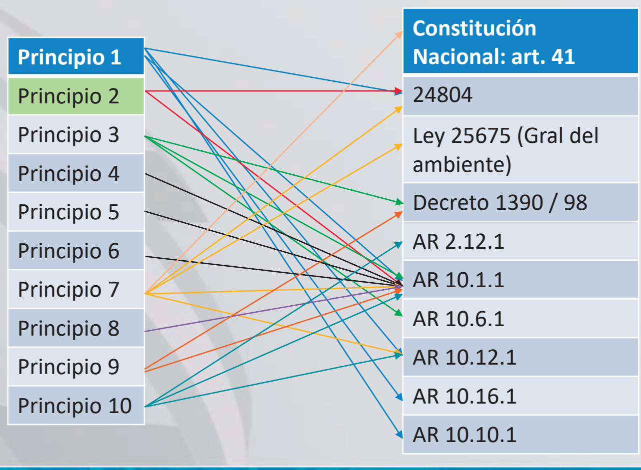
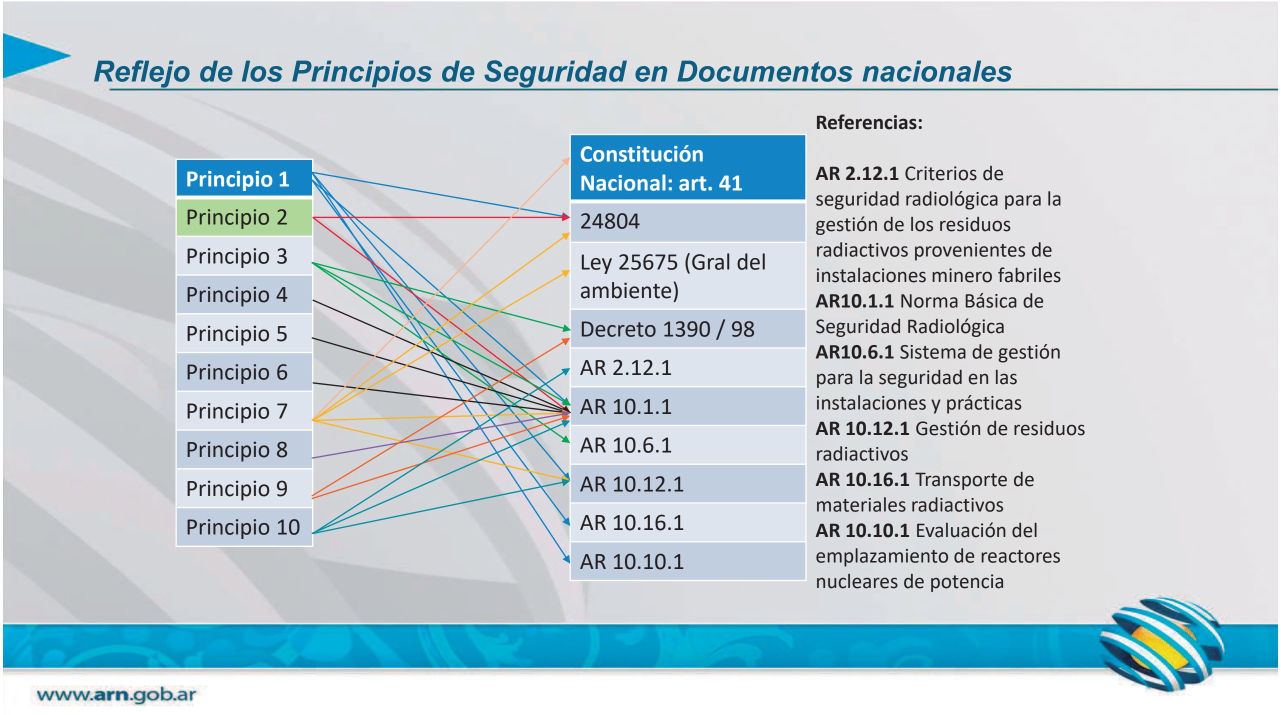
Principios Fundamentales de Seguridad del OIEA

Principio 8: PREVENCIÓN DE ACCIDENTES	**Deben desplegarse todos los esfuerzos posibles para prevenir los accidentes nucleares o radiológicos y para mitigar sus consecuencias**
Principio 9: PREPARACIÓN Y RESPUESTA EN CASOS DE EMERGENCIA	**Deben adoptarse disposiciones de preparación y respuesta para casos de incidentes nucleares o radiológicos**
Principio 10: MEDIDAS PROTECTORAS PARA REDUCIR LOS RIESGOS ASOCIADOS A LAS RADIACIONES EXISTENTES O NO REGLAMENTADOS	**Las medidas protectoras para reducir los riesgos asociados a las radiaciones existentes o no reglamentadas deben justificarse y optimizarse**

Reflejo de los Principios de Seguridad en Documentos nacionales



www.arn.gob.ar



Situación Actual y Desafíos

www.arn.gob.ar

Fundamentos para la elaboración del Marco Normativo Regulatorio

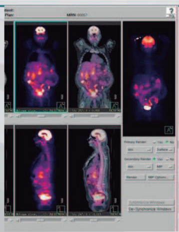
Artículo 16 de la Ley Nacional de la Actividad Nuclear Nº 24.804 - publicada en el Boletín Oficial el 25 de abril de 1997

La Autoridad Regulatoria Nuclear (ARN) está facultada para:

Dictar las **normas regulatorias** referidas a **seguridad radiológica y nuclear**, **protección física** y **fiscalización del uso de materiales nucleares**, **licenciamiento** y **fiscalización de instalaciones nucleares**, **salvaguardias internacionales** y **transporte de materiales nucleares** en su aspecto de seguridad radiológica y nuclear y protección física

www.arn.gob.ar

Marco Normativo Regulatorio aplicable a:



- Seguridad Radiológica
- Seguridad Nuclear
- Protección y Seguridad Física
- Salvaguardias y No Proliferación
- Transporte de Material Radiactivo

www.arn.gob.ar

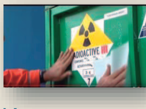
Marco Normativo Regulatorio

Verificación de las cuatro ramas regulatorias

Establece requisitos para:

- Usar del material nuclear y las fuentes de radiación

- Licenciar instalaciones y prácticas
- Licenciar al personal



- Verificar el transporte de materiales nucleares y fuentes de radiación

- Fiscalizar y Controlar instalaciones y prácticas

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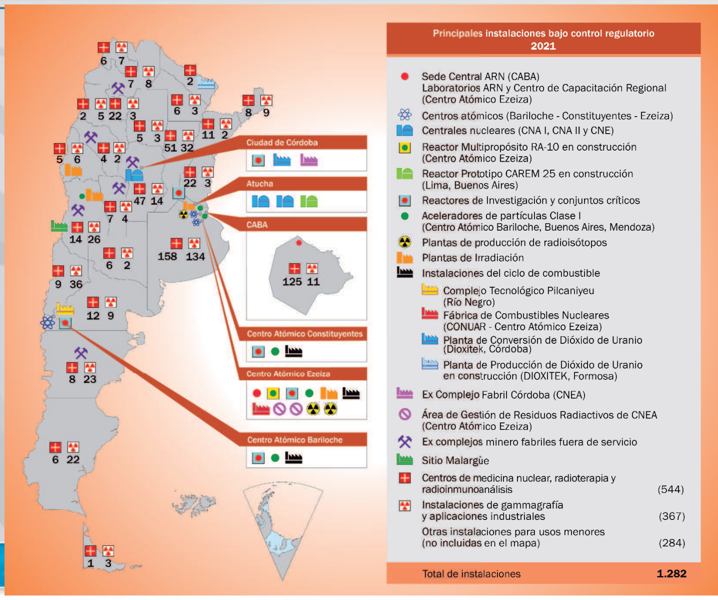
Distribución de las Instalaciones en Argentina



www.arn.gob.ar

Subgerencia de Normativa Regulatoria

Funciones

- Elaborar las normas regulatorias nacionales atendiendo necesidades de áreas técnicas
- Armonizar el conjunto de normas regulatorias internamente y con las normas de seguridad del OIEA y otra documentación internacional
- Actualizar, modificar y completar el cuerpo normativo
- Opinar sobre documentación técnica en proceso de elaboración por el OIEA.

Noma y Guía Regulatoria - Diferencia

La ARN, en el ámbito de su competencia, elabora:

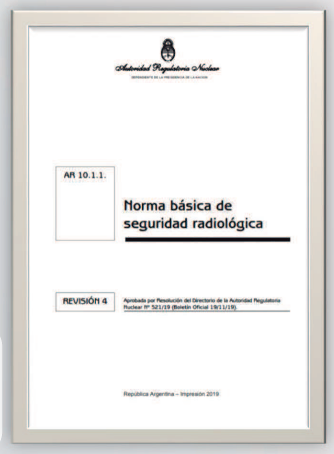
Norma Regulatoria: documento aprobado de cumplimiento obligatorio respaldada por la Ley N° 24.804, a la que debe ajustarse toda persona humana o jurídica para desarrollar una actividad nuclear en la República Argentina

Guía Regulatoria: documento aprobado complementario a la norma emitida por la ARN destinado a las personas humanas o jurídicas que desarrollan una actividad nuclear, para orientarlas, mediante recomendaciones técnicas, en el cumplimiento de las Normas o requerimientos emitidos por la ARN, referidos a prácticas específicas o para realizar evaluaciones de seguridad

El marco normativo actual de la ARN cuenta con
64 Normas** y **10 Guías Regulatorias

Características de las Normas Regulatorias

- Documentos de "desempeño". Cumplimiento de objetivos de seguridad y por lo tanto no son prescriptivas
- Incorporan la experiencia regulatoria, operativa y científico-técnica
- Son compatibles con los estándares del OIEA y con las recomendaciones del ICRP y las convenciones adoptadas por el país



www.arn.gob.ar

Características de las Guías Regulatorias

- Ofrecen soporte a los regulados
- Generalmente son desarrolladas ante solicitud de las partes interesadas
- Pueden desarrollarse en cualquier momento durante la vigencia de la Norma Regulatoria que complementa

www.arn.gob.ar

Marco Normativo Vigente

64 Normas AR, agrupadas en :

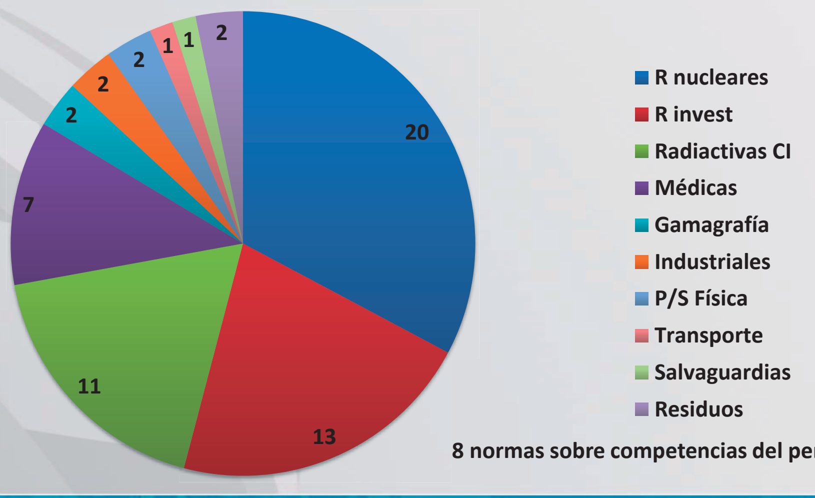
Básicas:

- ✓ Seguridad Radiológica
- ✓ Sistema de Gestión para la seguridad en instalaciones y practicas
- ✓ Evaluación del emplazamiento de reactores de potencia
- ✓ Gestión de los residuos radiactivos
- ✓ Protección física de materiales e instalaciones nucleares
- ✓ Seguridad física de fuentes selladas
- ✓ Garantías de no desviación de materiales nucleares y de materiales, instalaciones y equipos de interés nuclear
- ✓ Transporte de Material Radiactivo

Específicas:

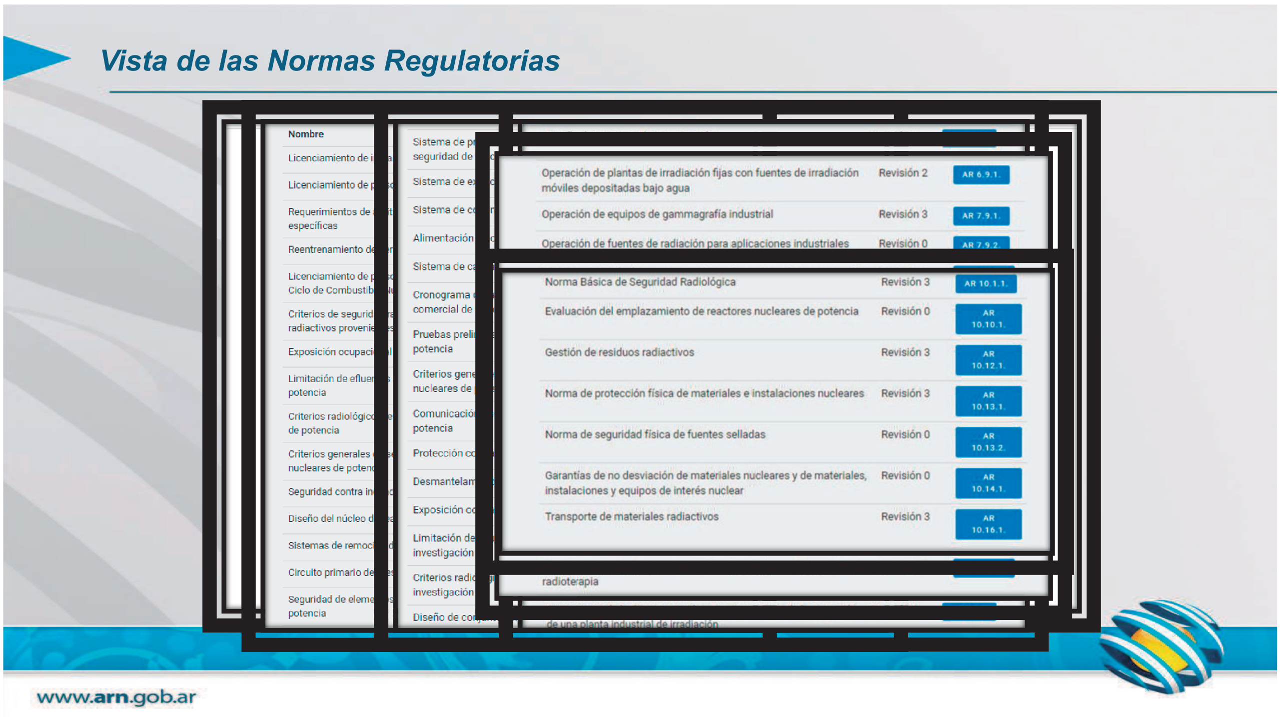
- ✓ Licenciamiento
- ✓ Centrales nucleares
- ✓ Reactores de investigación
- ✓ Aceleradores (Clase I) e instalaciones radiactivas
- ✓ Aplicaciones industriales
- ✓ Aplicaciones médicas
- ✓ Minería y concentración de uranio

Distribución de NR

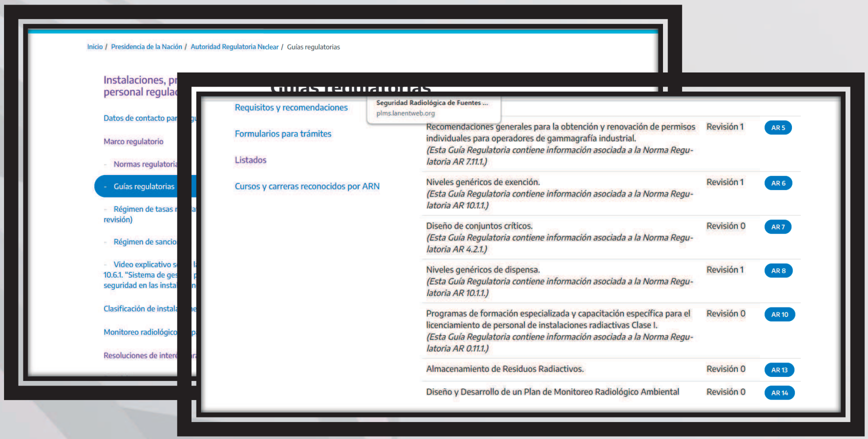


8 normas sobre competencias del personal


Marco Normativo actual
AR0.0.X
0.11.X
2.12.X
3.1.x
3.2.X
3.3.X
3.4.X
3.5.X
3.6.X
3.7.X
3.8.X
3.9.X
3.10.X
3.17.X
4.1.X
4.2.X
4.5.X
6.7.X
10: Norma Básica
13: Referida al área regulatoria de Protección y Seguridad Física
X: cantidad de normas emitidas
10.10.X
10.12.X
10.13.X
10.14.X
10.16.X
www.arn.gob.ar


Vista de las Normas Regulatorias
Operación de plantas de irradiación fijas con fuentes de irradiación móviles depositadas bajo agua
Revisión 2
AR 6.9.1.
Operación de equipos de gammagrafía industrial
Revisión 3
AR 7.9.1.
Operación de fuentes de radiación para aplicaciones industriales
Revisión 0
Norma Básica de Seguridad Radiológica
Revisión 3
AR 10.1.1.
Evaluación del emplazamiento de reactores nucleares de potencia
Revisión 0
AR 10.10.1.
Gestión de residuos radiactivos
Revisión 3
AR 10.12.1.
Norma de protección física de materiales e instalaciones nucleares
Revisión 3
AR 10.13.1.
Norma de seguridad física de fuentes selladas
Revisión 0
AR 10.13.2.
Garantías de no desviación de materiales nucleares y de materiales, instalaciones y equipos de interés nuclear
Revisión 0
AR 10.14.1.
Transporte de materiales radiactivos
Revisión 3
AR 10.16.1.
www.arn.gob.ar

Vista del Conjunto de Guías Regulatorias



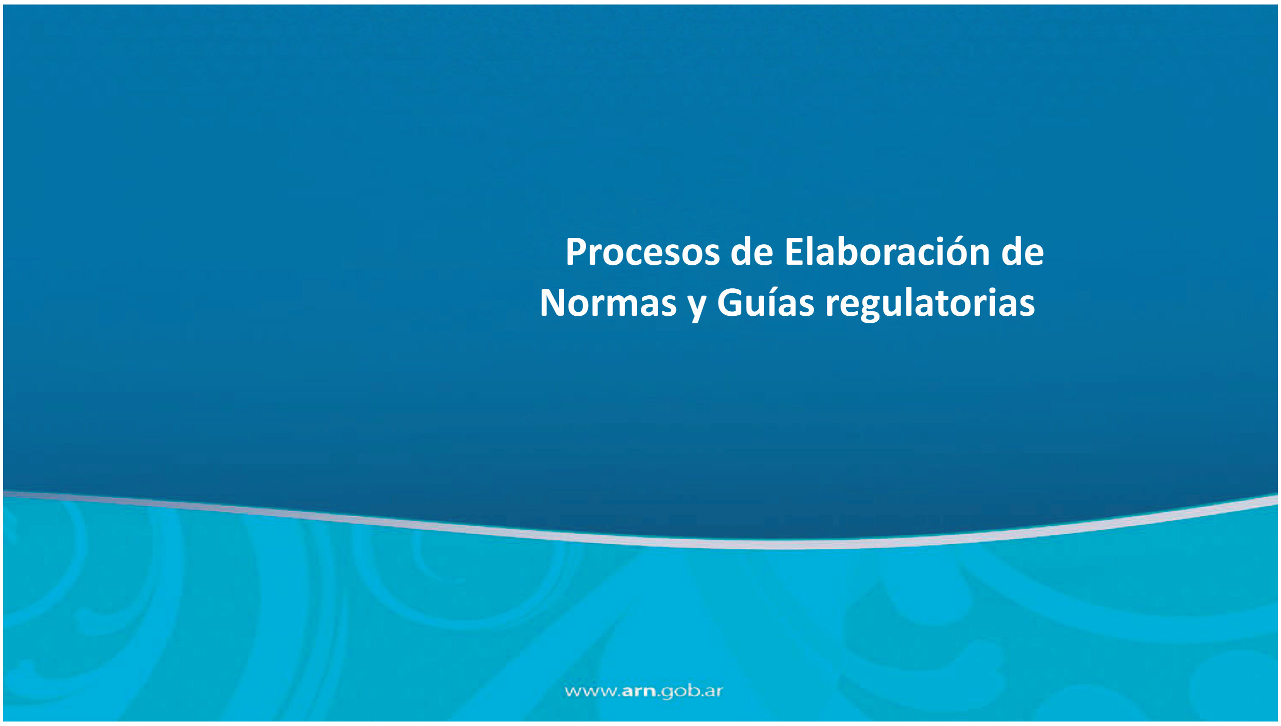
Revisión Integral del Marco Normativo de la ARN - Desafío

Desarrollo en la ARN

SNR analizó el marco regulatorio vigente	Análisis del marco normativo para cada sector
Elaboración de un diagnóstico	
Propuesta de un plan de trabajo	

Nueva		Revisión	
Norma	Guía	Norma	Guía
33	34	24	2

*Se concluyó en la necesidad de **elaborar nuevas** normas y guías; y en **revisar y actualizar o modificar** normas y guías vigentes*


Procesos de Elaboración de
Normas y Guías regulatorias
www.arn.gob.ar


Proceso de elaboración y revisión de normas y guías regulatorias
NORMATIVA REGULATORIA
P-NORM-01
Rev. 7
30-11-17
Elaboración y revisión de normas y guías regulatorias
ELABORACIÓN Y REVISIÓN DE NORMAS Y GUÍAS REGULATORIAS
CODIGO P-NORM-01 | REVISION 07 | VIGENCIA 30/11/2017
Elaboró
Revisó
Aprobó
Nombre
Lucía Valentino
Patricia Vidal
Beatriz Gregori
Proceso - Sector
Subgerencia Normativa Regulatoria
Subgerencia Normativa Regulatoria
Subgerencia Normativa Regulatoria
Cuadro de últimas revisiones
Revisión
Descripción del cambio
Fecha
00
Edición original
23/01/2004
01
Se clarificaron las responsabilidades de las actividades y sectores intervinientes en el proceso de preparación de nuevas
06/07/2005
www.arn.gob.ar

Proceso de elaboración de normas y guías Regulatorias

- ✓ Identificar necesidad de revisión o elaboración de una norma o guía
- ✓ Elaborar y aprobar la Iniciativa Regulatoria (IR)
- ✓ Aplicar del Procedimiento de Consulta Previa (de corresponder)
- ✓ Elaborar el proyecto de norma o guía
- ✓ Efectuar un proceso iterativo de revisión hasta obtener proyecto final
- ✓ Aplicar el Procedimiento de Elaboración Participativa de Normas

(no aplicable a Guías Regulatorias)

- ✓ Aprobar la Norma o Guía
- ✓ Publicar e iniciar difusión

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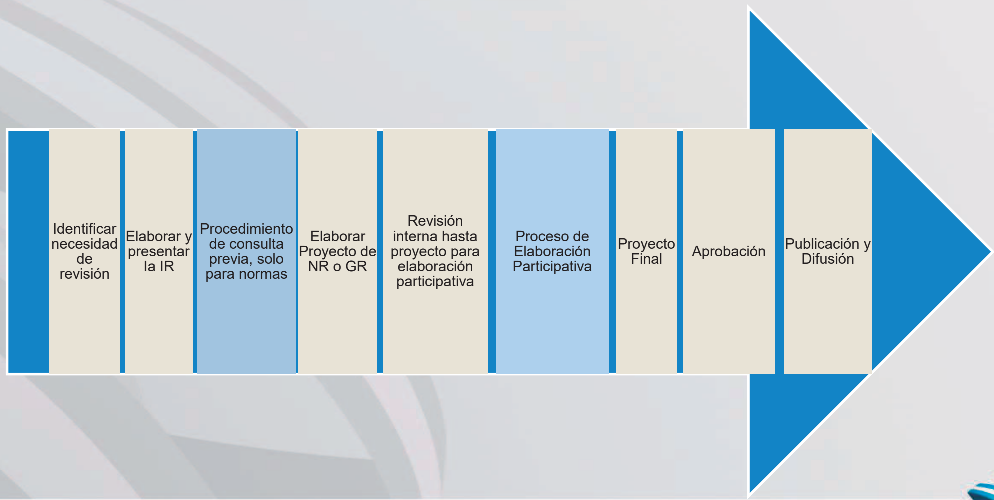
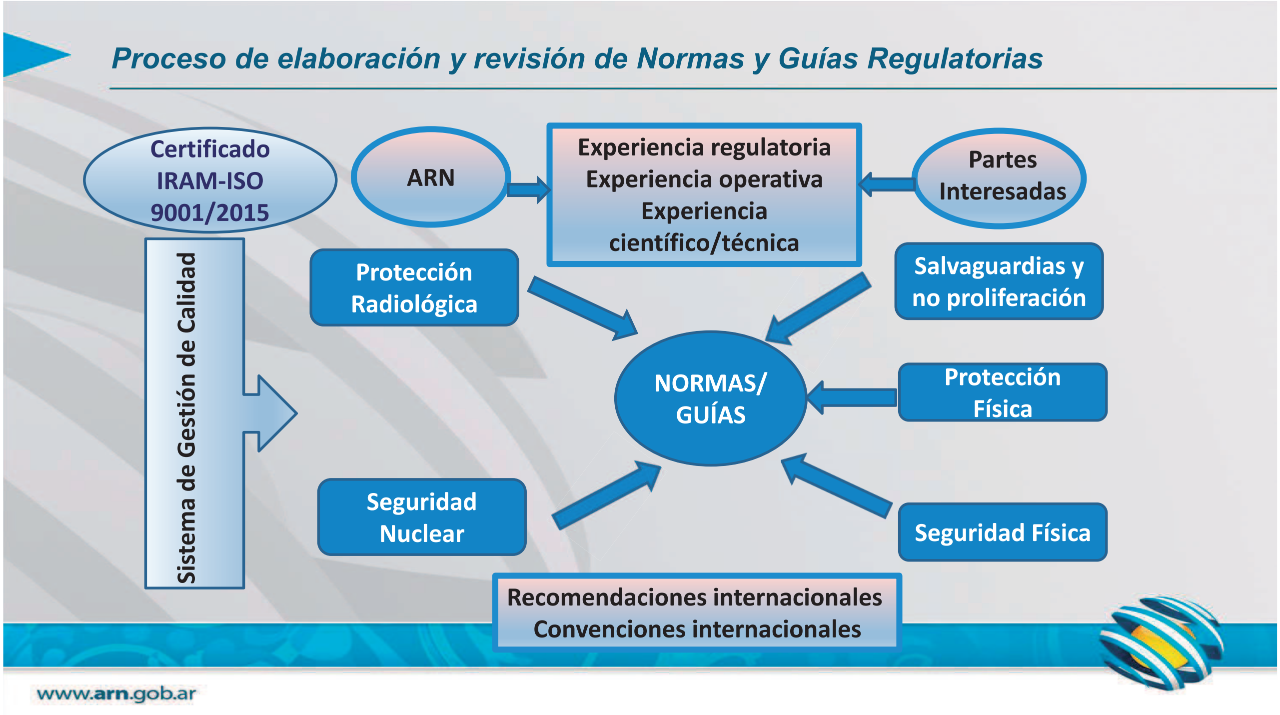
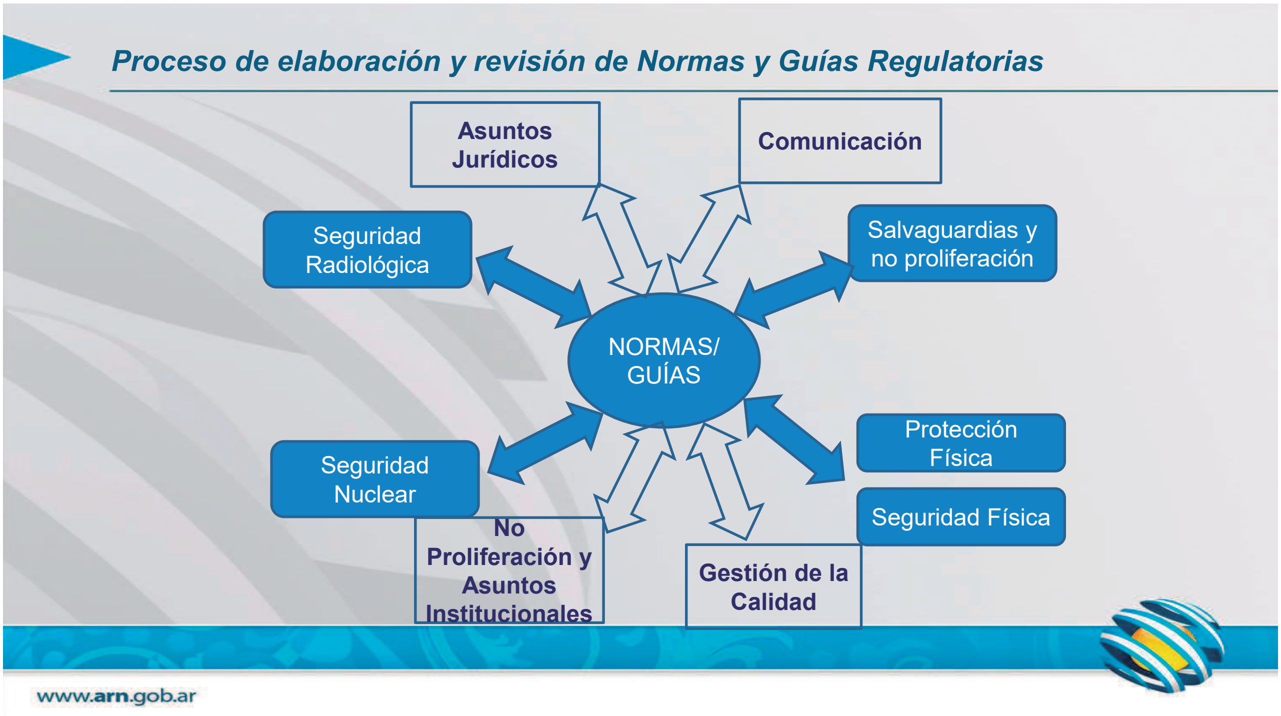
Proceso de elaboración de Normas y Guías Regulatorias



www.arn.gob.ar


Proceso de elaboración y revisión de Normas y Guías Regulatorias
Certificado IRAM-ISO 9001/2015
ARN
Experiencia regulatoria
Experiencia operativa
Experiencia científico/técnica
Partes Interesadas
Sistema de Gestión de Calidad
Protección Radiológica
Salvaguardias y no proliferación
NORMAS/ GUÍAS
Protección Física
Seguridad Nuclear
Seguridad Física
Recomendaciones internacionales
Convenciones internacionales
www.arn.gob.ar


Proceso de elaboración y revisión de Normas y Guías Regulatorias
Asuntos Jurídicos
Comunicación
Seguridad Radiológica
Salvaguardias y no proliferación
NORMAS/ GUÍAS
Protección Física
Seguridad Nuclear
Seguridad Física
No Proliferación y Asuntos Institucionales
Gestión de la Calidad
www.arn.gob.ar

1. Proceso de consulta previa

Debe aplicarse en el caso que se deba *"modificar o dictar una nueva norma que alcanza a instalaciones nucleares relevantes ya licenciadas"*

- Ley 24.804, Art. 16, Inc. ll: "*Determinar un procedimiento de consultas con los titulares de licencias para **instalaciones nucleares relevantes** toda vez que se propongan **nuevas normas regulatorias o se modifiquen las existentes**. El procedimiento deberá prever que las modificaciones de normas existentes o el dictado de nuevas normas se fundamenten en un criterio de evaluación basado en la **relación beneficio/costo** de la aplicación de la nueva regulación"*

- *Decreto 1390/98 establece el Procedimiento de Consulta Previa "..antes de modificar o dictar una nueva norma aplicable a instalaciones nucleares relevantes **ya licenciadas**..*
  - Constitución Comité ad hoc
  - Participación de los licenciatarios en el proceso de elaboración

2. Proceso de elaboración participativa de normas

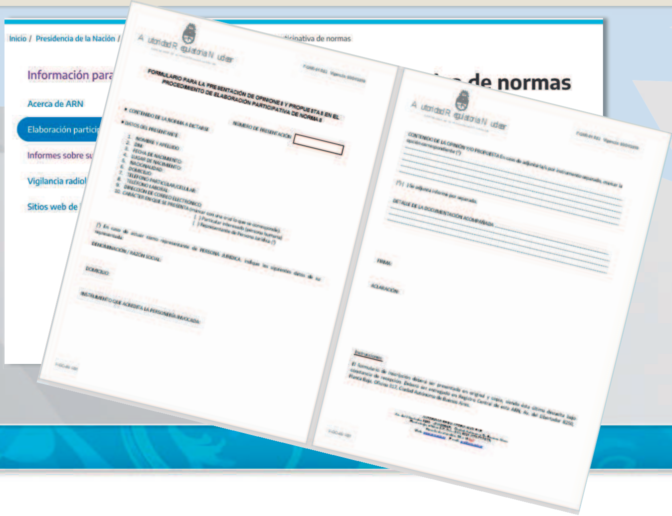
Por el **Decreto 1172/2003 de Acceso a la Información Pública** se aprobó el **Reglamento para la Elaboración Participativa de Normas**

El procedimiento para la Elaboración Participativa de Normas:

- constituye un mecanismo por el cual se habilita un espacio institucional para la **expresión de opiniones y propuestas** respecto de proyectos de normas antes de emitidas por la ARN.
- permite y promueve una efectiva **participación ciudadana** en el proceso de elaboración de las normas.
- garantiza el respeto de los **principios de igualdad, publicidad, informalidad y gratuidad**.

2. Proceso de elaboración participativa de normas

Se inicia mediante una **Resolución del Directorio de la ARN** una vez que el proyecto de Norma ha sido **consensuado internamente**



2. Proceso de elaboración participativa de normas

Publicación

*La ARN publica durante **2 días** en el **Boletín Oficial**, y **15 días** en su **página web**, el contenido del acto de apertura del procedimiento de Elaboración Participativa de Normas, invitando a la ciudadanía a expresar sus opiniones y propuestas.*

En los casos en que, **a juicio de la ARN resulte procedente**, puede ampliarse la publicación a diarios de circulación nacional, medios locales y especializados en la temática de la norma

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2. Proceso de elaboración participativa de normas

Vista del expediente y registro de opiniones y propuestas

- Expediente a disposición de los interesados para consulta, en el lugar que defina la ARN. Las copias del mismo son a costa del solicitante.
- La ARN habilita un **Registro** para la incorporación de opiniones y propuestas que deben realizarse **por escrito** y presentarse a través del **formulario**.
- La presentación es **libre y gratuita**.
- El **plazo** para la presentación de opiniones y propuestas es de **15 días** desde la publicación del acto de apertura del procedimiento de Elaboración Participativa de Normas.
- La ARN brinda una casilla de correo electrónico y una dirección postal a efectos de recibir **comentarios informales**, los cuales no se incorporan al expediente.

2. Proceso de elaboración participativa de normas

Consideración de las presentaciones

Concluido el plazo para recibir opiniones y propuestas, la ARN deja constancia en el expediente sobre la cantidad de opiniones y propuestas recibidas, y de cuáles considera pertinentes incorporar al proyecto de norma.

La ARN únicamente debe expedirse sobre aquellas presentaciones incorporadas al expediente.

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2. Proceso de elaboración participativa de normas

Difusión

Las normas y guías una vez aprobadas por el Directorio de la ARN:

- se publican en el **Boletín Oficial** por el plazo de 1 día,
- se incorporan a la **página web de la ARN** y,
- de ser necesario, se comunica a los regulados por **otros medios**

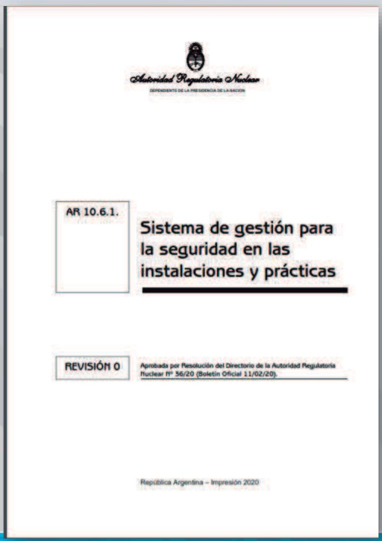
www.arn.gob.ar

Norma AR 10.6.1, Rev. 0

Sistema de gestión para la seguridad en instalaciones y prácticas

www.argentina.gob.ar/arn

¿Porqué una norma sobre Sistema de gestión para la seguridad?


Autoridad Regulatoria Nuclear

AR 10.6.1.

Sistema de gestión para la seguridad en las instalaciones y prácticas

REVISIÓN 0

Aprobada por Resolución del Directorio de la Autoridad Regulatoria Nuclear Nº 56/20 (Boletín Oficial 11/02/20).

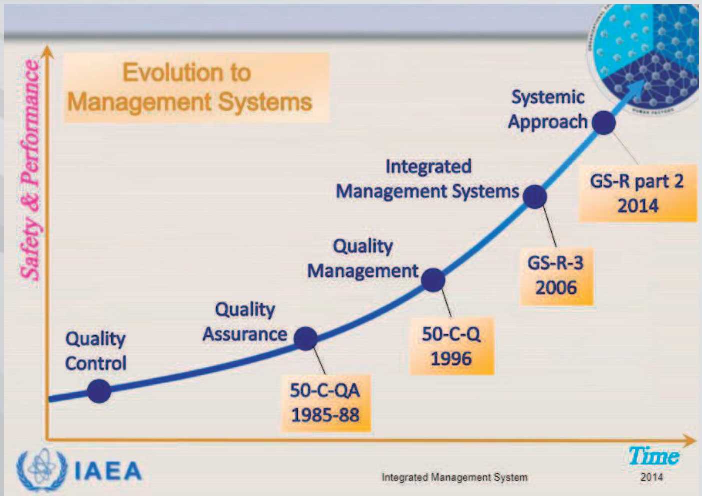
República Argentina – Impresión 2020

Nos alinea con la Normativa internacional, acordada por la Argentina en su carácter de Estado Miembro del OIEA: GSR- Parte 2 y GSR Parte 3

El gran desafío:
Integrar en un sistema, sin comprometer a la seguridad, los elementos de:

- seguridad radiológica y nuclear,
- seguridad y protección física,
- salvaguardias,
- calidad,
- higiene y seguridad convencional,
- ambientales,
- económicos,
- sociales,
- organizacionales y
- factores humanos

Evolución de las normas del OIEA



Consignas sobre el diseño del primer borrador de la AR 10.6.1

Armonizar y superar:

- AR 3.6.1 Rev. 2 (no esta en vigor)

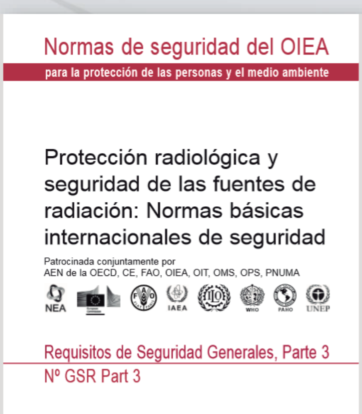
Surge:

- Proyecto de norma AR 10.7.1 “Glosario de normas regulatorias”

Tomar como referencia, cuando corresponda:

- ISO 9000:2015 e ISO 9001:2015,
- GSR parte 3 y GSR parte 2
- Glosario de seguridad tecnológica del OIEA

GSR Parte 3

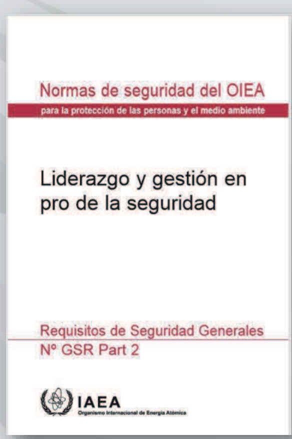

Normas de seguridad del OIEA
para la protección de las personas y el medio ambiente
Protección radiológica y seguridad de las fuentes de radiación: Normas básicas internacionales de seguridad
Patrocinada conjuntamente por
AEN de la OECD, CE, FAO, OIEA, OIT, OMS, OPS, PNUMA
Requisitos de Seguridad Generales, Parte 3
Nº GSR Part 3

REQUISITOS GENERALES RELATIVOS A LA PROTECCIÓN Y LA SEGURIDAD

REQUISITOS DE GESTIÓN: 5

Las partes principales asegurarán que la protección y la seguridad estén efectivamente integradas en el **sistema general de gestión** de las organizaciones de las que sean responsables

GSR Parte 2



Los **sistemas de gestión** diseñados para cumplir los requisitos seguridad integrarán elementos relacionados con la seguridad tecnológica, la salud, el medio ambiente, la seguridad física, la calidad, los factores humanos y organizativos, la sociedad y la economía.

El **sistema de gestión** respalda la consecución del objetivo fundamental de la seguridad de proteger a las personas y el medio ambiente contra los efectos nocivos de las radiaciones ionizantes y tiene en cuenta las interrelaciones entre la seguridad tecnológica y la seguridad física.

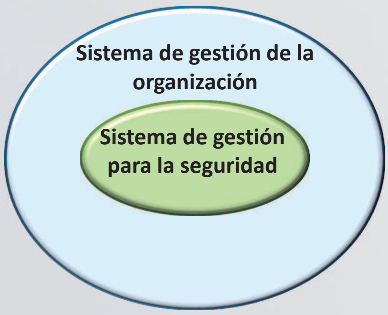
Esta norma de seguridad concentra la experiencia de los Estados Miembros en lo referente al **desarrollo, la aplicación, el mantenimiento y la mejora de los sistemas de gestión**

www.argentina.gob.ar/**arn**

Para implementar un sistema de gestión para la seguridad se necesita:

compromiso con la protección y la seguridad de las Direcciones de las Entidades Responsables

Se debe demostrar el cumplimiento efectivo de los requisitos sobre **la protección y la seguridad** en el **sistema de gestión para la seguridad** inmerso en el **sistema de gestión de la organización**



Se debe asegurar que los elementos de **protección y seguridad** del **sistema de gestión para la seguridad** son proporcionales a la complejidad de la actividad y a sus riesgos radiológicos

www.argentina.gob.ar/**arn**

59

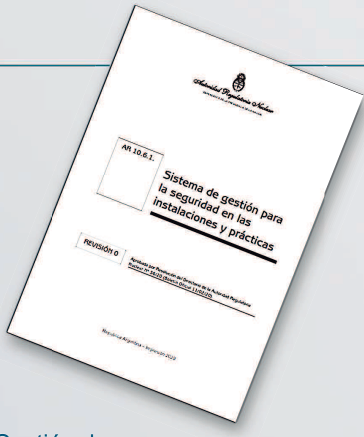
Marco normativo regulatorio vigente

https://www.argentina.gob.ar/arn/instalaciones-practicas-y-personal-regulado/marco-regulatorio

Operación de instalaciones de telecobaltoterapia	Revisión 3	AR 8.2.3.
Uso de fuentes radiactivas no selladas en instalaciones de medicina nuclear	Revisión 1	AR 8.2.4.
Permisos individuales para el empleo de material radiactivo o radiaciones ionizantes en seres humanos	Revisión 2	AR 8.11.1.
Requisitos mínimos de formación clínica activa para la obtención de permisos individuales con fines médicos	Revisión 0	AR 8.11.2.
Garantías de no desviación de materiales nucleares y de materiales, instalaciones y equipos de interés nuclear	Revisión 0	AR 10.14.1.
Transporte de materiales radiactivos	Revisión 3	AR 10.16.1.

La ARN aprobó el 7 de febrero de 2020 la **Norma AR 10.6.1 "Sistema de gestión para la seguridad en las instalaciones y prácticas"**, mediante la Resolución N°36/2020 de su Directorio, publicada en Boletín Oficial el 11 de febrero de 2020.
La norma entrará en vigencia el 1° de enero de 2021 y podés consultarla aquí.

Contenido de la Norma 10.6.1



A. OBJETIVO

B. ALCANCE

C. EXPLICACIÓN DE TÉRMINOS

D. REQUISITOS

D.1 Responsabilidad por el sistema de gestión

D.2 Generalidades del sistema de gestión

D.3 Integración del sistema de gestión

D.4 Documentación del sistema de gestión

D.5 Provisión de los recursos

D.6 Gestión de procesos

D.7 Gestión de cadena de suministro

D.8 Fomento de la Cultura de Seguridad

D.9 Evaluación y mejora del sistema de gestión

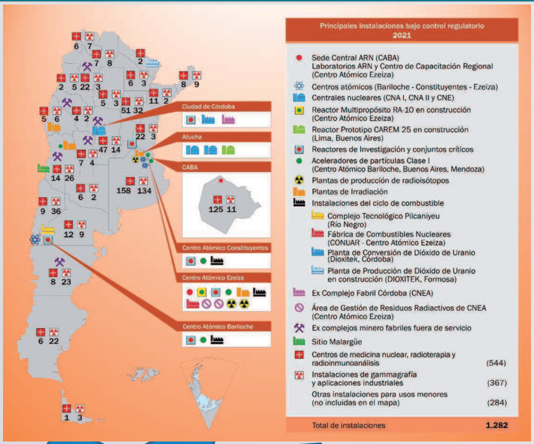
Norma AR 10.6.1, Rev.0

OBJETIVO

Establecer los requisitos para el desarrollo y la implementación de un sistema de gestión que contribuya a asegurar la seguridad radiológica y nuclear, la seguridad y la protección física y las salvaguardias y la no proliferación

ALCANCE

Aplicable a todas las instalaciones y prácticas que regula la Autoridad Regulatoria, de acuerdo a las atribuciones que le confiere la legislación vigente



1.282 instalaciones reguladas por la ARN

Nuevos Términos incluidos en la norma AR 10.6.1, Rev.0

- Cadena de suministro
- Calibración
- Competencia
- Cultura organizacional
- Cultura de seguridad
- Eficacia
- Enfoque graduado
- Gestión del conocimiento
- Indicador
- Manual de gestión
- Liderazgo
- Sistema de gestión
- Trazabilidad
- Verificación

Proceso de elaboración de la AR 10.6.1, Rev.0 - timeframe

2015
Primer borrador

2019
Se publicó en la web proyecto de norma AR10.6.1 para la elaboración participativa de norma.

Se analizaron todas las propuestas recibidas en SNR

Febrero 2020
Se publicó en el BO y web de ARN la

AR 10.6.1, Resolución 36/2020 del Directorio de ARN

Enero de 2021
Entra en vigencia AR 10.6.1

Se deroga la AR 3.6.1

Consideraciones

- Contar con un Cuerpo Normativo Regulatorio es una ***responsabilidad nacional***
- Son numerosos los Estados Miembros que han decidido ***adoptar las normas de seguridad de OIEA*** e incorporarlas en sus marcos regulatorios
- Las normas del OIEA son un medio coherente y fiable de asegurar el eficaz ***cumplimiento de las obligaciones*** contraídas en virtud de las ***convenciones***
- Los objetivos de las Normas Regulatorias se alcanzan con la ***apropiada toma de decisiones*** por parte de la Entidad Responsable;
- La Entidad Responsable debe ***demostrar a la Autoridad Regulatoria*** que los medios técnicos que propone permiten cumplir los requisitos establecidos en las normas

Consideraciones

- ✓ La Elaboración de una norma regulatoria es un ***proceso extenso***
- ✓ El proceso de elaboración y revisión de Normas y Guías Regulatorias **incluye a los regulados y a todas las partes interesadas**
- ✓ La norma sobre sistema de gestión para la seguridad marca una evolución al enfocarse en ***la seguridad desde los sistemas de gestión*** de las Entidades Responsables

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Gracias por su atención!

Autoridad Regulatoria Nuclear

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Capacitación virtual: Conceptos básicos en intervención en emergencias radiológicas y nucleares. Adaptándonos a nuevos escenarios y necesidades

Vázquez, M.; Di Giorgio, M.; Discacciatti, A.; Puerta Yepes, N.; Rearte, J.; Gossio, S.; Truppa, W.A.; Rodríguez, M.; Martinez, X.; Zyngiel, A.; Cascon, A.; González Redondo, H.; Poccioni, C.; Pérez de Antueno, M.; Ovejero, M.; Cuiulli, J.M.; Núñez, C.; Ruiz, E. y Portas, M.

Presentado en: XII Congreso Regional de Seguridad Radiológica y Nuclear y en el X Congreso Regional de la Asociación Internacional de Protección Radiológica (IRPA).
Santiago de Chile, Chile, 23 al 27 de octubre de 2022

CAPACITACIÓN VIRTUAL: CONCEPTOS BÁSICOS EN INTERVENCIÓN EN EMERGENCIAS RADIOLÓGICAS Y NUCLEARES. ADAPTÁNDONOS A NUEVOS ESCENARIOS Y NECESIDADES

Vázquez, M.[1]; Di Giorgio, M.[1]; Discacciatti, M.[1]; Puerta Yepes, N.[1]; Rearte, J.[1]; Gossio, S.[1]; Truppa, W.[1]; Rodríguez, M.[1]; Martinez, X.[1]; Zyngiel, A.[2]; Cascon, A.[2]; González Redondo, H.[2]; Poccioni; C.[2]; Pérez de Antueno, M.[2]; Ovejero, M.[3]; Cuiulli, J.M.[3]; Núñez, C.[4]; Ezequiel Ruiz, E.[4] y Portas, M.[5]

[1] Autoridad Regulatoria Nuclear
[2] Instituto de Medicina y Radiomedicina Gente Sana
[3] Coordinación de Salud y Bienestar de las Fuerzas Armadas
[4] División Riesgo Radiológico y Nuclear de la Policía Federal Argentina
[5] Hospital de Quemados de la Ciudad de Buenos Aires

Argentina

PROYECTO REGIONAL DE COOPERACION TECNICA RLA 9091

INTRODUCCIÓN

Durante la pandemia de COVID 19, que motivó el aislamiento de las personas y la suspensión de las actividades de capacitación presencial, las metodologías virtuales permitieron continuar con las actividades de formación continua. Asimismo, para los profesionales que debido al ritmo de sus actividades rutinarias o su ubicación geográfica no pueden acceder a nuevos conocimientos, estas herramientas han cobrado relevancia.

MATERIALES Y MÉTODOS

La Autoridad Regulatoria Nuclear (ARN) y el Instituto de Medicina y Radiomedicina Gente Sana (IMRM) desarrollaron un video curso dirigido principalmente a profesionales de la salud y primeros respondedores en emergencias radiológicas y nucleares. Esta actividad de capacitación es compaginada y coordinada por la Unidad de Capacitación y Entrenamiento de la ARN. Los capítulos del curso son autoadministrables y con instancias de autoevaluación para verificar los conocimientos adquiridos. Finalmente, los alumnos son evaluados en forma virtual sincrónica, planteando casos que permitan demostrar la comprensión en forma integral.

El temario comprende:

- Las radiaciones ionizantes, tanto del punto de vista físico como biológico.
- Los servicios de radiopatología que acompañan la respuesta a la emergencia como dosimetría física, interna y biológica entre otros.
- Las enfermedades asociadas a la exposición a radiaciones ionizantes.
- El accionar de los primeros respondedores y otras organizaciones en la escena.
- Aspectos legales vinculados al daño por radiación.

RESULTADOS

La convocatoria para la primera edición ha sido muy importante, y condujo al requerimiento de dos instancias para el 2022 y para el 2023, para abarcar la demanda de inscriptos, lo que demuestra la importancia de estas estrategias para la difusión del conocimiento.

CONCLUSIONES

El impacto de esta modalidad de capacitaciones en la comunidad de profesionales no específicamente relacionados en sus actividades diarias con las radiaciones ionizantes, redundará en una mayor y mejor capacidad de respuesta a las emergencias radiológicas y nucleares.

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XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

CAPACITACIÓN VIRTUAL: CONCEPTOS BÁSICOS EN INTERVENCIÓN EN EMERGENCIAS RADIOLÓGICAS Y NUCLEARES. ADAPTÁNDONOS A NUEVOS ESCENARIOS Y NECESIDADES

Marina Vázquez, Marina Di Giorgio, Adrián Discacciatti, Nancy Puerta Yepes, Julieta Rearte, Sebastián Gossio, Walter Truppa, Mónica Rodríguez, Ximena Martinez1,
Alejandra Zyngiel, Adriana Cascon, Horacio González Redondo, Carlos Poccioni; Mariana Pérez de Antueno2
Marcela Ovejero, Juan Manuel Cuiulli3
Christian Núñez, Ezequiel Ruiz 4
Mercedes Portas 5

1Autoridad Regulatoria Nuclear
2Instituto de Medicina y Radiomedicina Gente Sana
3 Coordinación de Salud y Bienestar de las Fuerzas Armadas
4Division Riesgo Radiológico y Nuclear de la Policía Federal Argentina
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XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA
Santiago de Chile, desde el 23 al 27 de octubre de 2022

Introducción

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Durante la pandemia de COVID 19, que motivó el aislamiento de las personas y la suspensión de las actividades de capacitación presencial, las metodologías virtuales permitieron continuar con las actividades de formación continua.

En situaciones de normalidad los profesionales respondedores en emergencias debido al ritmo de sus actividades rutinarias o su ubicación geográfica no pueden acceder a nuevos conocimientos. Por ello las capacitaciones a distancia y asincrónicas han cobrado relevancia ya que permite adaptarlo a sus necesidades.

Las capacitaciones en idioma español en esta modalidad y temática son muy escasas.

Materiales y Métodos I

46

-La Autoridad Regulatoria Nuclear (ARN) y el Instituto de Medicina y Radiomedicina "Gente Sana" (IMRM) desarrollaron un video curso no arancelado dirigido principalmente a profesionales de la salud y primeros respondedores en emergencias radiológicas y nucleares.

-El video curso consta de capítulos los cuales son autoadministrables y con instancias de autoevaluación para verificar los conocimientos adquiridos.

- Finalmente los alumnos son evaluados en forma virtual sincrónica, planteando casos que permitan demostrar la comprensión de la temática en forma integral.

- Contenidos generales:

  Las radiaciones ionizantes, tanto del punto de vista físico como biológico.

  Los servicios de radiopatología que acompañan la respuesta a la emergencia como dosimetría física, interna y biológica entre otros.

  Las enfermedades asociadas a la exposición a radiaciones ionizantes.

  El accionar de los primeros respondedores y otras organizaciones en la escena.

  Aspectos legales vinculados al daño por radiación.

  Seminarios sincrónicos relacionados con eventos de magnitud como Fukushima, Chernobyl etc.

Vazquez M. et al. CAPACITACIÓN VIRTUAL: CONCEPTOS BÁSICOS EN INTERVENCIÓN EN EMERGENCIAS RADIOLÓGICAS Y NUCLEARES. ADAPTÁNDONOS A NUEVOS ESCENARIOS Y NECESIDADES 2022

Materiales y Métodos II

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1) Cuerpo docente multidisciplinario:

Físicos con expertise en dosimetría externa e interna

Médicos especialistas en radiomedicina y protección radiológica, emergencias, psiquiatría, radioterapia, medicina laboral, cirugía plástica y reconstructiva

Biólogos especialistas en biodosimetria y radiopatología

Licenciados en emergencias y ecología

Fuerzas Armadas con orientación QBRN y del Ministerio de Defensa

Bomberos pertenecientes a Brigadas de Riesgos Especiales

Especialistas en Derecho

2) Plataforma virtual LANENT (Red Latinoamericana para la Educación y la Capacitación en Tecnología Nuclear) administrada para este video-curso por una especialista en contenidos E-Learning

Esta actividad de capacitación es compaginada y coordinada por la Unidad de Capacitación y Entrenamiento de la ARN

Vazquez M. et al. CAPACITACIÓN VIRTUAL: CONCEPTOS BÁSICOS EN INTERVENCIÓN EN EMERGENCIAS RADIOLÓGICAS Y NUCLEARES. ADAPTÁNDONOS A NUEVOS ESCENARIOS Y NECESIDADES 2022

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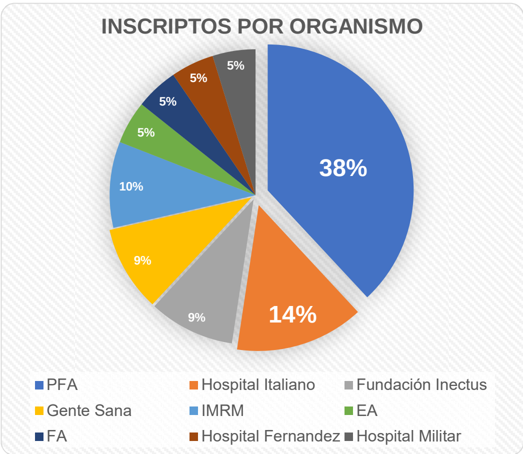
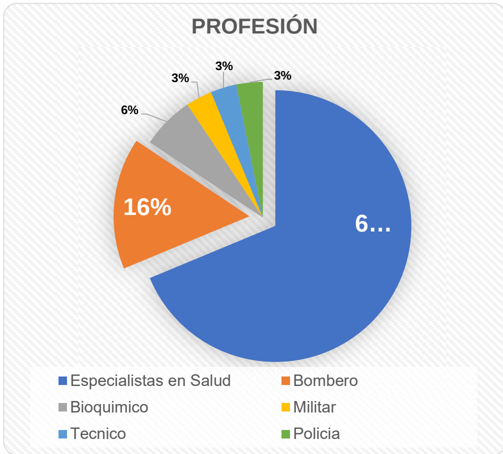
Resultados I

En el año 2022 se realizaron dos ediciones del Video Curso.
1° edición (Solo Argentina)





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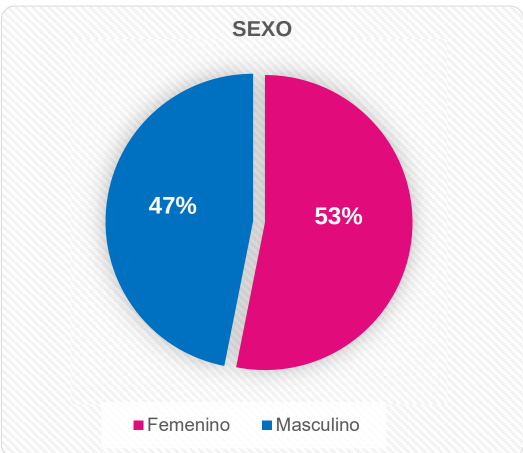

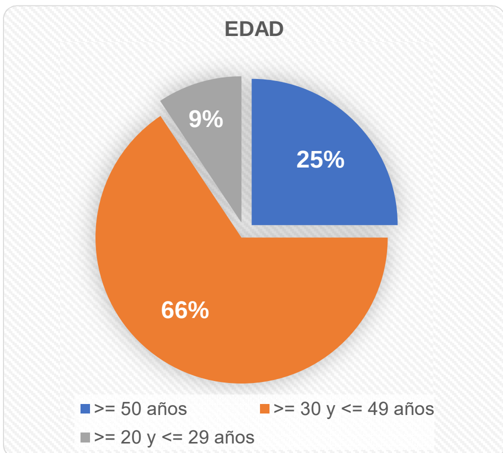

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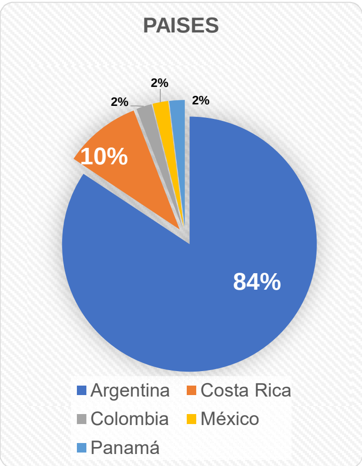
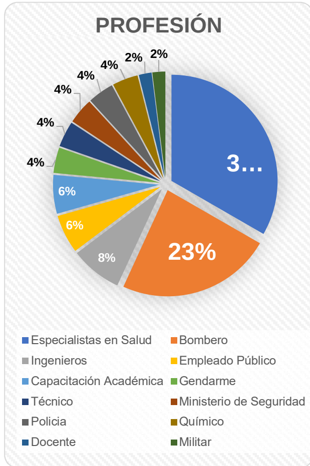
Resultados II

En el año 2022 se realizaron dos ediciones del Video Curso.
2° edición





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Resultados II

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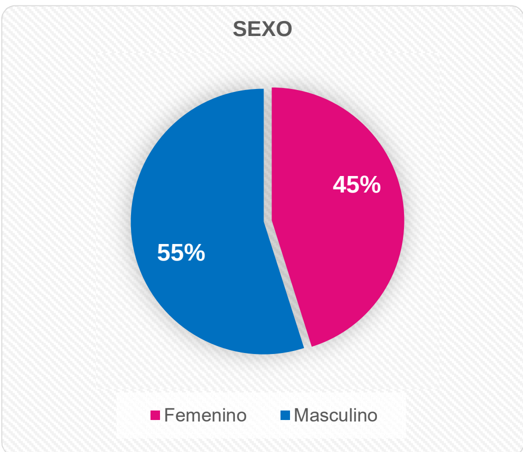

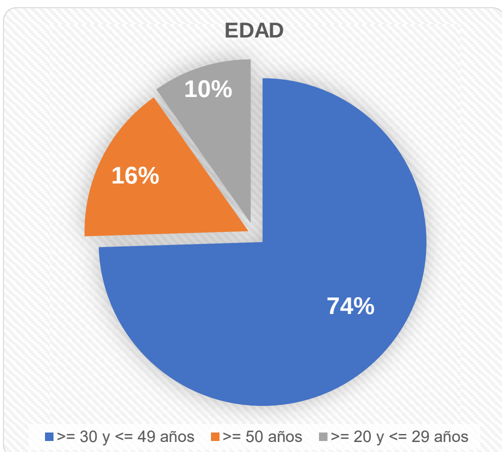

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA

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Intro Video Curso

Módulo 1

1. Introducción
2. Interacción de la radiación con la materia y efectos biológicos de las radiaciones.
3. Midiendo la radiación
4. Efectos en la salud de las radiaciones ionizantes.
5. Respuesta Médica en emergencias radiológicas y nucleares.
6. Radiación y embarazo.
7. Carcinogénesis radioinducida.
8. Aspectos emocionales en accidentes radiológicos y nucleares.
9. Triage médico y radiológico.

Módulo 2

1. Magnitudes de uso en protección radiológica.
2. Quemaduras radiológicas
3. Contaminación interna (exposición interna) con radio nucleídos.
4. Dosimetría externa y reconstrucción dosimétrica en emergencias médicas.
5. Recomendaciones para primera respuesta a emergencias con material radiactivo.
6. La biodosimetría como técnica esencial para guiar el tratamiento médico en la respuesta multiparamétrica a emergencias nucleares y radiológicas.
7. Presentación de Ca Ing. QBN y Apy. Emerg. 601. Ejército Argentino + Sanidad Militar.
8. La Importancia de los Planes de Emergencia.
9. Preparación ante Emergencias Nucleares. Planes de Emergencia.
10. Manejo Seguro de Cadáveres Portadores de Radiaciones Ionizantes.
11. Radio-Litigación.

XII CONGRESO REGIONAL DE SEGURIDAD RADIOLÓGICA Y NUCLEAR
CONGRESO REGIONAL IRPA

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Conclusiones I

-La adecuada respuesta en emergencias radiológicas y nucleares requiere la capacitación de los diferentes actores (primeros respondedores, personal que brinda atención a la salud, fuerzas de seguridad y protección civil).

-El impacto de esta modalidad de capacitaciones en la comunidad de profesionales no específicamente relacionados en sus actividades diarias con las radiaciones ionizantes, redundará en una mayor y mejor capacidad de respuesta a las emergencias radiológicas y nucleares.

-La efectividad de la intervención para enfrentar y mitigar las consecuencias de los accidentes radiológicos requiere de la **optimización de los recursos humanos** y materiales, situación para la que resulta esencial una adecuada **capacitación**.

Conclusiones II

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El E-Learning a través de este video-curso:

-facilita que los participantes aprendan en forma activa y a su ritmo

-el acceso de los docentes a las autoevaluaciones y foro de preguntas posibilita un seguimiento de los mismos

-traspasa barreras geográficas y minimiza costos

-los encuentros sincrónicos además de la evacuación de dudas permiten la interacción entre las distintas disciplinas de los participantes "conocimiento previo de sus actividades y funciones"

Esta previsto continuar con el video-curso " Conceptos básicos en Emergencias Radiológicas y Nucleares" y crear una versión con conceptos "avanzados" para distintos profesionales para el año 2023

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Para mayor información e inscripción:

https://www.argentina.gob.ar/arn/capacitacion-y-formacion-regulatoria/centro-de-capacitacion-regional

Mail: uce@arn.gob.ar

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2022

Safeguards Implementation in Argentina during COVID-19 Pandemic

Villamayor, R.; Díaz, G.; García Fraga, V. and Giordano, L.

Presentado en: 14th Symposium on International Safeguards: Reflecting on
the Past and Anticipating the Future del Organismo Internacional de Energía Atómica (OIEA).
Viena, Austria, 31 de octubre al 4 de noviembre de 2022

SAFEGUARDS IMPLEMENTATION IN ARGENTINA DURING COVID-19 PANDEMIC

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Buenos Aires, Argentina.

Abstract

The Nuclear Regulatory Authority (ARN) of Argentina through the Control of Safeguards and Physical Protection Division (SCSyPF) is responsible for the application of safeguards within the country. Its responsibilities include conducting national safeguards inspections, coordinating international safeguards inspections with the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and the International Atomic Energy Agency (IAEA), participating in the import and export control of nuclear materials and nuclear commodities, and administrating the State System of Accounting for and Control of Nuclear Material (SSAC), among others.

Since the beginning of the COVID-19 pandemic, the National Government implemented a decree with a set of sanitary measures known as Preventive and Mandatory Social Isolation (ASPO by the acronym in Spanish). The ASPO represented a challenge to the implementation of safeguards in Argentina. The SCSyPF tackled this challenge adopting the necessary measures to continue fulfilling its duties within the new framework established by this unexpected situation. It is important to stress that the safeguards inspections continued being carried out even under a very strict lock down. During the pandemic, restrictions were imposed not only by the national and local authorities but also by the different facility operators. In that situation, the coordination with different State organizations involved was essential.

This paper summarizes the measures adopted by the SCSyPF to guarantee the implementation of national and international safeguards during the pandemic.

1. SAFEGUARDS IMPLEMENTATION IN ARGENTINA

The Agreement between the Republic of Argentina and the Federative Republic of Brazil for the Exclusively Peaceful Use of Nuclear Energy [1] has been in force since December 1991. In order to verify the commitment of the States Parties under the Bilateral Agreement, ABACC was created. ABACC's objective is to administer and implement the Common System of Accounting and Control of Nuclear Materials (SCCC), also established by the Agreement. The SCCC is a full scope safeguards system that is being applied in both countries with the purpose of verifying that all nuclear materials in all nuclear activities are not diverted to the manufacture of nuclear weapons or other nuclear explosive devices. A Quadripartite Safeguards Agreement among Argentina, Brazil, ABACC and IAEA [2] was signed in December 1991. This agreement is a full scope safeguards agreement, similar to INFCIRC/153 model agreement, which entered into force in March 1994 after its ratification by the Congresses of both countries. Thus, all the Argentinian facilities are under safeguards control by ABACC and IAEA.

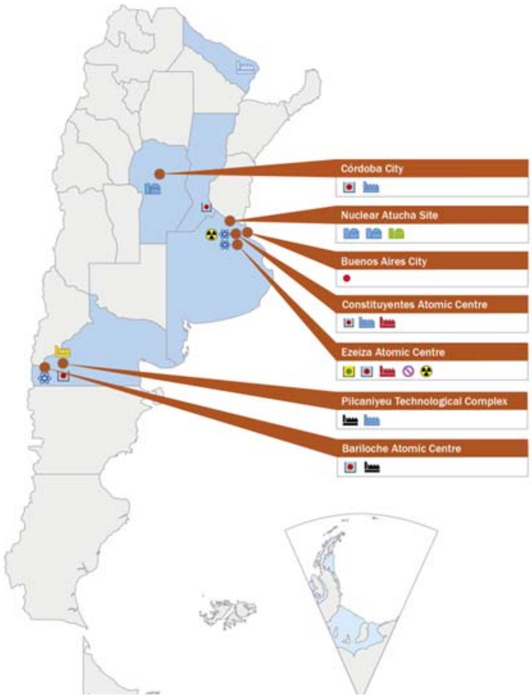

FIG 1 *Distribution of facilities under safeguards in Argentina*

The Nuclear Regulatory Authority (ARN) of Argentina - which through National Nuclear Activity Act (Law No. 24.804) - is the State agency in charge of regulating and supervising activities at the national level in matters of radiological and nuclear safety, safeguards and non-proliferation, and physical protection and security matters. The ARN's SCSyPF is responsible for the application of safeguards within the country. Its responsibilities include conducting national safeguards inspections, coordinating and participating in international safeguards inspections with ABACC and IAEA, participating in the import and export control of nuclear materials and nuclear commodities, and administrating the State System of Accounting for and Control of Nuclear Material (SSAC). In order to fulfil its responsibilities, every year the SCSyPF perform about 70 domestic safeguards inspections and participate in about 60 international safeguards inspections at 50 nuclear facilities and locations outside facilities (LOFs) (FIG.1) within the country. These inspections imply a total inspections effort of 700 person-day.

2. IMPACT OF THE PANDEMIC IN SAFEGUARDS IMPLEMENTATION

On March 11, 2020, the World Health Organization (WHO) declared the outbreak of the new coronavirus SARS-CoV-2 causing the disease COVID-19 as a pandemic. On March 20, 2020, the Argentine Government, with the aim of protecting public health, established the measure of "Social Isolation, Preventive and Mandatory" known as ASPO [3]. In principle, the measure would be in force until March 31 inclusive.

Many of the measures implemented by the Argentine Government to provide an immediate response to the spread of the virus had a direct consequence in the implementation of safeguards at the national level:

- Flight restrictions: the severe restrictions imposed on commercial flights on the vast majority of routes caused the cancellation of practically all flights causing difficulties to reach nuclear facilities and LOFs.
- Cross-border travel: the introduction of strict immigration measures and the closure of borders restricted the entry only to Argentine citizens and residents.
- Land travel restrictions: the introduction of restrictions, particularly with regard to the movement of people and the availability of other services such as hotel accommodation and businesses linked to tourism within the national territory. This made it even more difficult for inspectors and technicians to circulate. Each province had its own restrictions; most of them did not allow the transit from one province to another.
- Access restrictions to offices and laboratories of ARN.
- Restrictions on access to facilities and LOFs within the country: the closure of nuclear facilities or sites, or the introduction of strict access restrictions to these places had a direct impact on the planning of the implementation of safeguards.
- Health and safety requirements: the Government established the obligation of a negative COVID test and two weeks quarantine period after entering the country. Additional requirements were applied to enter different provinces and to access nuclear facilities.
- Facility Operation: The COVID-19 pandemic had an impact on the normal operation of Argentinians nuclear facilities. Small facilities devoted to Research and Development (R&D)

activities and LOFs that were not directly connected with energy production or medical supplies were not working on a regular basis. Nuclear fuel cycle activities were considered "essential activities" by the National Government, so they had not been interrupted, redirecting all resources, including human resources, in a way to assure the normal the operation of these facilities. The construction of new facilities in Argentina was interrupted during several months in 2020.

3. ACTIONS TAKEN TO REDUCE THE IMPACT OF THE PANDEMIC IN THE NORMAL ACTIVITIES

3.1 National Safeguards staff

- During the pandemic, the safeguards staff was considered essential personnel. This allowed them to perform national and international safeguards inspections. ARN inspectors were allowed to circulate, to travel from one province to another and to access to ARN's Headquarters and to the different Atomic Centers despite the lockdown.
- Home office activities were recommended as much as possible to reduce the presence at the office. R&D activities were on hold.
- "Risk population" was released of the obligation of going to work.
- Domestic safeguards field activities: Re-scheduling of inspections and activities (only if the impact of "not carrying out" the activity is low). Focusing the inspection effort on achieving the safeguards objectives, the SCSyPF adapted its inspection schedule, changing the date of inspections and other activities.
- The planning of in-field verification activities included the creation of the so-called "Inspection team bubbles", whose main objective was to minimize the impact of potential exposure due to close contact or virus infection. Each team was made up of inspectors who tried to optimize the time assigned to each task to be carried out in the shared work spaces, taking care in addition to following all health protocols.
- COVID-19 Testing: The SCSyPF coordinated the performance of rapid tests or PCR for its inspectors before initiating verification activities in selected facilities or group of facilities. This task required the joint collaboration and support of the different departments of the ARN.
- Encouraging a responsible behavior by training: the SCSyPF worked in the promotion of a general protocol of prevention and safety measures, where the ARN met all the requirements established by the country's Ministry of Health

3.2 Infrastructure and other tools

- Virtual platforms to replace, in some extent, face-to-face activities: during the period of restrictions, virtual meetings and interviews were held with the aim of continuing with some routine activities that the SCSyPF develops together with the operators and other ARN departments. Also, eventually some inspections activities were carried out in such way. (I.e. accounting data examination).
- The ARN ensured tha SCSyPF staff were equipped with all extra Personal Protection Equipment.

3.3 International Safeguards Inspectors (ABACC and IAEA)

- COVID-19 health and safety measures that were implemented in the country directly affected all international safeguards field activities. Whenever necessary, the SCSyPF coordinated Re-scheduling of inspections and activities. At all times, the ARN acted as an interlocutor between the operators, IAEA and ABACC, and the other government stakeholders that were involved.
- During the establishment of 14 days quarantine at inspector arrival: the SCSyPF and ARN authorities have played a very important role in ensuring compliance with all State requirements. Specific examples include the support for agencies to find accommodation in times of lockdown or the provision of necessary assistance to obtain special circulation permits when necessary. In the second quarter of 2020, this requirement was replaced by increasing the frequency of COVID testing.

- COVID 19 tests before starting activities in selected facilities or group of facilities.
- Encouraging a responsible behavior.

3.4 Communication channels

- Creation of communication channels with State, Province and Local governments.
- Creation of communication channels with other governmental stakeholders not usually involved in safeguards activities planning, e.g. security forces, National Civilian Aviation Administration (ANCAC), Ministry of Health, amongst other.

3.5 Key Challenges Faced Implementing Safeguards during Pandemic

- Traveling restrictions in the country
- Charter flights
- Land travels
- Circulation Permits

3.6 Inspector's security concern (COVID free zones)

- Police escort
- COVID testing

4. COORDINATION CHALLENGE

During the procedures of entering and leaving the country, the ARN has played a fundamental role in the coordination of logistical matters. In this way, communication channels were established with the Ministry of Foreign Affairs, International Trade and Worship, the ANCAC, Customs, and the Ministry of Health of each province. Some logistical issues associated made Agencies to consider an alternative procedure to short notice random inspection (SNRI) scheme in Argentina. The entrance of foreigners, including inspectors, had to be informed in advance, in order to get clearance from the Ministry of Interior and the Ministry of Health. These entrance procedures made it difficult to maintain the unpredictability of the SNRI scheme. In addition, Country entrance procedures required performing quarantine and carrying out COVID tests. In this sense, an Ad-hoc procedure had been agreed and had been successfully implemented since July 2020. It is important to mention that the flexibility of Operators, the National Authority and both safeguards Agencies was essential to achieve the procedure goals.

Additionally, the work inside facilities was organized in several independent teams in order to overcome any situation that could be generated due to staff COVID-19 infections. Some operators and facility personnel were included in that group. This condition could interfere in the normal development of the inspections, even though we have already considered this possibility during inspections coordination.

5. LESSONS LEARNED IN IMPLEMENTING SAFEGUARDS DURING PANDEMIC

The restrictions imposed on international flights and the measures imposed related to health and safety, as well as access to true and updated information, subject to frequent changes, represented a great challenge when planning safeguards verification activities. The SCSyPF was able to overcome this challenge and played a fundamental role as coordinator between all the interested parties.

Additionally, the SCSyPF managed to advance in the expansion of the use of Information Technologies through the integration of virtual communications platforms in inspection activities, complying at all times with the necessary cybersecurity considerations.

The establishment of a contingency plan which highlights the creation of the so-called "inspection bubbles" allowed to optimize continue with all the verification activities and optimize the time assigned to one of them.

The need to define and establish secure and reliable communication channels allowed the development of partnerships with "non-nuclear related" stakeholders such as Federal security forces, Local Governments, Ministries, among others.

ACKNOWLEDGEMENTS

We would like to express our deepest appreciation to our colleagues from the Control of Safeguards and Physical Protection Division of the ARN and Leonardo Pardo (former ARN) for their valuable contributions to this paper.

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PARTE II

Resúmenes de publicaciones en revistas científicas y técnicas

SPECTRAL LINE SHIFT OF BALMER AND PASCHEN IONS BY SELF-CONSISTENT METHODS *

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Abstract

The aim of this work is to investigate the Stark shifts of some hydrogenic atoms and ions in hot dense plasmas. For this, Debye-Hückel (DH) and Ion-Sphere (IS) potential are used to estimate H_α(HI) and P_α(HeII) line shift. These calculations have been implemented through self-consistent methods by using atomic structure code AUTOSTRUCTURE. These results have been compared with 50 experimental data for H_α and more than 40 measurements for P_α obtained by different authors. The main conclusion is that a self-consistent calculation with the Ion-Sphereperturbing potential fairly well describes the shifts of hydrogenic ions in plasmas for electron density in the range ($10^{17} - 3 \times 10^{19}$) cm^{-3}.

* Publicado en: Spectrochimica Acta Part B; v.192, 2022.
https://doi.org/10.1016/j.sab.2022.106425

LEGAL IMPUTATION OF RADIATION HARM TO RADIATION EXPOSURE SITUATIONS *

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El Organismo Internacional de Energía Atómica (OIEA) publicó el libro *Derecho Nuclear: El Debate Mundial* en 2022. La publicación incluye una compilación de ensayos escritos por líderes mundiales y artículos de destacados académicos, políticos y científicos en la materia, sobre este campo legal altamente especializado.

El capítulo 7 ha sido una contribución del Ing. Abel J. González, en el que analiza cómo podría establecerse la responsabilidad ante un tribunal de justicia en casos de exposición a la radiación.

El libro *Derecho Nuclear: El Debate Mundial* fue presentado en la Primera Conferencia Internacional sobre Derecho Nuclear del OIEA, que se realizó del 25 al 29 de abril de 2022 en Viena, Austria.

Abstract

The doctrine for legal imputation (including the derivative concepts of legal charging, suing, indicting, prosecuting and judging) of detrimental health effects to those responsible for radiation exposure situations has been a matter of debate for many years and its resolution is still unclear. While the attribution of harm in the situations involving high radiation dose is basically straightforward, the challenge arises at medium doses and becomes a real conundrum for the very common situations of exposure to low radiation doses. The ambiguous situation could be construed to be a Damocles sword for the renaissance of endeavours involving occupational and public radiation exposure. This chapter describes the epistemological situation on the attribution of radiation health effects and the inference of radiation risks, relying on estimates from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported to the UN General Assembly. It discusses the implications of UNSCEAR's refined paradigm for assigning legal liability. The chapter concludes with a recommendation to develop an international legal doctrine on the ability to impute detrimental radiation health effects.

* Publicado en: International Atomic Energy Agency. "Nuclear Law. The Global Debate". Chapter 7, p. 141-159 IAEA, Vienna, Austria, 2022. 333 p. ISBN 978-94-6265-495-2. https://doi.org/10.1007/978-94-6265-495-2

IMPUTACIÓN LEGAL DE DAÑO POR RADIACIÓN A SITUACIONES DE EXPOSICIÓN A LA RADIACIÓN *

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RESUMEN: El artículo aborda cuestiones no resueltas en derecho nuclear asociadas a la imputación de daño por radiación a situaciones de exposición a la radiación. Discute los desafíos para establecer vínculos causales entre la exposición a la radiación y los efectos en la salud utilizando evidencia fáctica objetiva y resume el consenso internacional sobre la diferenciación de la atribución de efectos ciertos y la inferencia de riesgos conjeturales. Se requiere testimonios de experto profesionales enfocados, a saber: radiopatólogos para atribuir efectos en los tejidos de individuos expuestos; radioepidemiólogos para atribuir aumentos en la incidencia de efectos estocásticos en cohortes expuestas; y, radioprotecciónistas para inferir riesgos con fines de protección radiológica. Se concluye que el consenso científico sobre los efectos en la salud atribuibles a la exposición a la radiación debe servir como base para el desarrollo de instrumentos legales que proporcionen un tratamiento uniforme de las acciones de imputación, en particular para situaciones de exposición a dosis bajas. Dadas las diferencias culturales, reglamentarias y legislativas entre los países, la comunidad jurídica internacional debería fomentar la adopción de un entendimiento jurídico común sobre causa y efecto en relación con la radiación, lo que permitiría mejorar la seguridad jurídica de los emprendimientos con radiación y nucleares. Establecer tal consenso universal para guiar la aplicación de la ley en cualquier situación de exposición a la radiación reduciría la incertidumbre y beneficiaría el desarrollo y la armonización de diferentes leyes nacionales.

ABSTRACT: *The article addresses unresolved issues in nuclear law associated with the imputation of radiation damage to radiation exposure situations. It discusses the challenges for establishing causal links between radiation exposure and health effects using objective factual evidence and summarizes the international consensus on differentiating attribution of factual effects and inference of conjectural risks. It calls for focussed professional expert witnessing, namely: radio-pathologists for attributing tissue effects in exposed individuals; radio-epidemiologists for attributing increases in incidence to stochastic effects in exposed cohorts; and, radio-protectionists for infering risks for radiological protection purposes. It concludes that the scientific consensus on the health effects attributable to radiation exposure should serve as the basis for the development of legal instruments providing uniform treatment of the legal actions of imputation, in particular for low-dose exposures situations. Given the cultural, regulatory and legislative differences among countries, a common legal understanding of cause and effect in relation to radiation should be fostered and adopted by the international legal community to improve legal security for radiation and nuclear endeavours. Establishing such universal consensus to guide law enforcement in any radiation exposure situation would reduce uncertainty and benefit the development and harmonization of different national laws.*

* Publicado en: Radioprotección; no. 104, 2022

ETHICAL, LEGAL, SOCIAL AND EPISTEMOLOGICAL CONSIDERATIONS OF RADIATION EXPOSURE *

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Abstract

This chapter will explore the ethical, social, epistemological, and legal considerations relevant to Radiobiology. The chapter will cover the basic principles relevant to each aspect along with more in-depth analyses where relevant. Each section will be followed by exercises to help the reader to better understand and assimilate the content of the sections.

* Capítulo 12 del libro "Radiobiología"
https://link.springer.com/chapter/10.1007/978-3-031-18810-7_12

MONTE CARLO CALCULATION OF ORGAN AND EFFECTIVE DOSES DUE TO PHOTON AND NEUTRON POINT SOURCES AND TYPICAL X-RAY EXAMINATIONS: RESULTS OF AN INTERNATIONAL INTERCOMPARISON EXERCISE *

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Abstract

This paper summarizes the results of an intercomparison on the use of the ICRP Reference Computational Phantoms with radiation transport codes, which was organized by EURADOS working group 6. Three exercises are described: exposure to an anterior-posterior (AP) photon point source, exposure to an AP neutron point source, and exposure to two typical medical X-ray examinations. The three exercises received 17, 8 and 8 solutions, respectively. Participants originated from fifteen different countries, and used a wide range of Monte Carlo codes. Due to difficulties in defining the precise source location unambiguously in the exercise description, agreement to within ~10% of the reference solution was considered satisfactory for a given participant's results. Although some participants provided initial solutions in good agreement with the reference solutions, differences of several tens of percent, or even several orders of magnitude, were exhibited for many of the others. Following feedback and suggestions from the organizers, revised solutions were submitted by some of the participants for the photon exercises; in general, agreement was improved. The overall observations from these three intercomparison exercises are summarized and discussed.

* Publicado en: Radiation Measurements; v. 150, 2022.
https://doi.org/10.1016/j.radmeas.2021.106695

RADIACIONES IONIZANTES Y NO IONIZANTES *

Vazquez, M.[1]; Puerta Yepes, N.[1]; Taja, M.E. [1]; Cortez, A.E.; et ál.

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El libro *“Toxicología Clínica: Fundamentos para la prevención, diagnóstico y tratamiento de las intoxicaciones”* está dirigido a estudiantes de medicina e interesados en la asistencia de pacientes con cuadros sospechosos de intoxicaciones en los servicios de emergencias.

Las especialistas de la ARN – Marina Vázquez, Nancy Puertas y María Emilia Taja – contribuyeron en la redacción del apartado sobre radiaciones ionizantes, que integra el capítulo titulado *“Radiaciones ionizantes y no ionizantes”.* Este apartado aborda generalidades de las mismas, principios básicos de radiobiología, síndromes relacionados con la exposición interna y externa, estudios complementarios y dosimétricos que se aplican, y principios de tratamientos.

Deseamos destacar la contribución de María Emilia Taja (1971-2015), médica especializada en radioprotección con experiencia en radiopatología y medicina laboral, quien se desempeñó en la ARN. María Emilia se destacó por su capacidad para trabajar en equipo y compartir lo aprendido con sus colegas; y sus cualidades personales de amabilidad, dedicación, compromiso y compañerismo, proactiva en su tarea de radioproteccionista y en la asistencia médica.

La presentación del libro se realizó el 19 de abril de 2022 en el Salón del Consejo Directivo de la Facultad de Medicina de la Universidad de Buenos Aires.

* Damin, C.F. “Toxicología Clínica. Fundamentos para la prevención, diagnóstico y tratamiento de las intoxicaciones”. Capítulo 22. Médica Panamericana, Buenos Aires, 2022. ISBN 9789500696920. 687 p.
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RADIACIONES IONIZANTES Y NO IONIZANTES

Vazquez, M.; Puerta Yepes, N.; Taja, M.E.; Cortez, A.E.; et ál.

RESUMEN

El significativo incremento de actividades que utilizan material radiactivo en diferentes ramos de la producción, industria, medicina, investigación y servicios conlleva un riesgo potencial de incidentes con exposición a radiaciones ionizantes, que requieren la pronta adopción de medidas para evitar o reducir las consecuencias adversas. Su impacto en la salud dependerá de diferentes factores tales como las características intrínsecas de la fuente de radiación, el tipo de radiación, el número de víctimas involucradas, la eficiencia y eficacia de la respuesta brindada en el control del incidente y en la asistencia médica. Existen varios tipos de radiación ionizante: partículas (radiación alfa o beta) y ondas del espectro electromagnético de alta frecuencia y baja longitud de onda (rayos γ y rayos X). Las radiaciones ionizantes pueden dañar directamente el DNA o cualquier otra molécula, o bien hacerlo a través de los llamados radicales libres originados en la radiólisis de sistemas acuosos. Todas las moléculas que constituyen la materia viva son susceptibles de sufrir daño radiológico radioinducido. Las células son más radiosensibles cuanto mayor sea su actividad mitótica y menos diferenciadas en estructura y función, con excepción de los linfocitos y ovocitos que son muy radiosensibles aun cuando no se dividen y son altamente diferenciados. Los efectos biológicos de las radiaciones ionizantes pueden ser estocásticos o probabilísticos (todo o nada, por ejemplo los cánceres sólidos o la leucemia) o deterministas o tisulares (en los que la gravedad del efecto depende de la dosis y del número de células letalmente dañadas, por ejemplo el síndrome agudo de radiación [SAR] y el síndrome cutáneo radioinducido–[SCR]). La exposición de una persona a la radiación puede deberse a irradiación externa, contaminación externa o contaminación interna dependiendo de cómo está ubicada la fuente de radiaciones con respecto a la persona y si existe una vía de ingreso (inhalación de material radiactivo presente en el aire, ingestión de alimentos o agua contaminados, o contaminación de una herida abierta). El SAR evoluciona clínicamente en 4 fases sucesivas (hematopoyética, gastrointestinal, neurovascular y de muerte o recuperación). La aparición de fiebre y/o dolor abdominal y/o diarrea es clara indicación de traslado e internación hospitalaria porque supone dosis por encima de 3-4 Gy. La evolución de los parámetros hematológicos es fundamental para el seguimiento. La dosimetría citogenética es el procedimiento de referencia (*gold standard*). Si se sospecha que el paciente está contaminado internamente, se tomará un hisopado nasal y una muestra de orina o heces, que servirán para la identificación y la determinación semicuantitava de la incorporación del radionúclido. También pueden realizarse mediciones de la carga corporal y su distribución. El muestreo debe comenzar lo antes posible y dependerá del agente contaminante, de su naturaleza físico-química y de la vía de entrada en el organismo. El tratamiento consistirá esencialmente en el manejo de la hipoplasia o aplasia medular, la prevención y tratamiento de las infecciones y hemorragias, así como el mantenimiento del equilibrio electrolítico y nutricional. El manejo de pacientes contaminados externamente requiere idealmente la asistencia de especialistas en radioprotección y un ambiente adecuado, para evitar la diseminación de la contaminación (protección de las instalaciones y del personal). Normalmente, el retiro de la vestimenta del individuo contaminado es suficiente para remover 90% o más de la contaminación externa, seguido de la descontaminación con lavados con agua tibia y jabón neutro. Dependiendo de la vía de ingreso, puede utilizarse el lavado gástrico o el lavado pulmonar. También está disponible la quelación de algunos metales pesados radiactivos, la dilución isotópica, el bloqueo metabólico, la administración de agentes movilizadores, de diuréticos. Como estas medidas no están exentas de riesgos, se valorará el beneficio de administrarlas en cada caso. En toda emergencia radiológica, los cuidados primordiales son aquellos que están dirigidos a salvaguardar la vida del paciente. La atención de las lesiones convencionales severas o urgentes tienen prioridad absoluta por sobre las consideraciones radiológicas, mientras que la exposición externa y/o la contaminación radiactiva constituyen problemas secundarios. No se justifica negar asistencia a un accidentado con riesgo de muerte o pérdida de un miembro por temor a la contaminación radiactiva. La protección eficaz contra la exposición externa requiere: a) aumentar la distancia a la fuente; b) reducir el tiempo que se pasa cerca de la fuente de radiación y c) blindar la fuente. La protección contra contaminantes biológicos será suficiente para la protección contra la contaminación radiactiva.

Las radiaciones no ionizantes (RNI) están en el extremo del espectro electromagnético correspondiente a longitudes de onda relativamente largas y frecuencias bajas que no son capaces de romper enlaces químicos. La vida actual se desarrolla en un ambiente en el que coexiste una compleja y cada vez mayor diversidad de campos electromagnéticos (CEM); la electricidad, las microondas y los campos de radiofrecuencia (radio, TV, sistemas de telecomunicación, wifi, telefonía celular) son algunos ejemplos, que también alcanzan el espectro óptico (infrarrojo, visible, ultravioleta). Mientras que los efectos biológicos

y sobre la salud humana a corto plazo debidos a la exposición a campos eléctricos y magnéticos de frecuencia industrial son bien conocidos y permiten establecer valores umbrales claros, persisten las incertidumbres sobre la existencia de efectos a largo plazo, especialmente cáncer. La información científica actualmente disponible no indica que los campos magnéticos y/o eléctricos afecten el sistema neuroendocrino, ni existe evidencia sustancial de asociación entre la exposición a CEM-FEB y enfermedades tales como el mal de Parkinson, el mal de Alzheimer, la esclerosis lateral amiotrófica, la esclerosis múltiple y las cardiovasculares; tampoco resulta concluyente la evidencia de cualquier asociación entre la exposición a CEM-FEB y efectos sobre el desarrollo, la reproducción, efectos neuroconductuales en la actividad eléctrica del cerebro, la cognición, el sueño y el humor. El efecto más fuertemente establecido de los campos magnéticos por debajo del límite para la excitación muscular o nerviosa directa es la inducción de la percepción de una tenue luz parpadeante en la periferia del campo visual (llamados fosfenos magnéticos), que se cree son la consecuencia de la interacción del campo eléctrico inducido y las células eléctricamente excitables en la retina. La OMS clasificó a los campos magnéticos de frecuencia extremadamente baja y los campos electromagnéticos de radiofrecuencia como "posiblemente cancerígenos para los seres humanos" (grupo 2B) a partir de la evaluación de estudios publicados que arrojaron evidencia limitada en relación con la leucemia infantil para los primeros y de gliomas para los segundos. Evidencia limitada significa que los estudios que establecen una relación causal entre la exposición al agente y el cáncer humano no ofrecen elementos suficientes para descartar que los resultados sean la consecuencia de deficiencias metodológicas en el diseño o el análisis estadístico –probabilidad, error y variables de confusión–). La evolución de las tasas de incidencia de tumores cerebrales en los países desarrollados no respalda la relación entre el uso del teléfono móvil y la percepción de un mayor riesgo de padecer estos tumores. La denominada hipersensibilidad electromagnética no es una enfermedad reconocida en la Clasificación Internacional de Enfermedades (CIE-OMS), por lo que no existe un protocolo validado y aceptado por la comunidad científica para su diagnóstico y tratamiento. Las nuevas evidencias publicadas no confirman los efectos adversos para la salud derivados de la exposición a las RF emitidas por las antenas de telefonía móvil, transmisión de radio y televisión y sistemas inalámbricos (wifi) utilizados en el trabajo, la escuela o el hogar. Los valores límites establecidos están basados en los efectos inmediatos sobre la salud provenientes de exposiciones de corto plazo, pero no sucede lo mismo con los efectos a largo plazo, que es el centro de las investigaciones actuales, ya que dentro de esta categoría se halla la posible asociación de los CEM con el cáncer.

LISTADO DE AUTORES