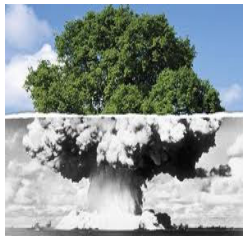
Elio GIROLETTI
dipartimento Fisica
Università degli Studi di Pavia

progetto: EARTH AMBASSADOR

radioattività: NOI E L'AMBIENTE



Crema, 29 novembre 2019

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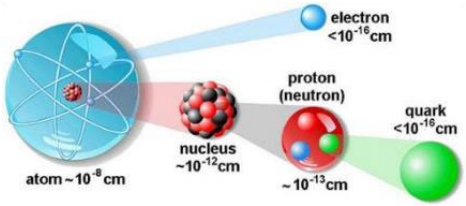
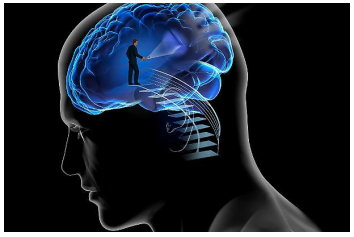
- Radioattività e radiazioni ionizzanti
- Possibili effetti sull'uomo
- Radiazioni naturali nell'ambiente
- Radiazioni «artificiali» e ambiente
- Conclusioni

Crema, 29 novembre 2019

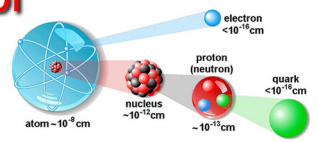
CERVELLO VUOTO? ....SI!!!





7×10^{27} atoms in the average body (70 kg adult human male)

Atomi & isotopi



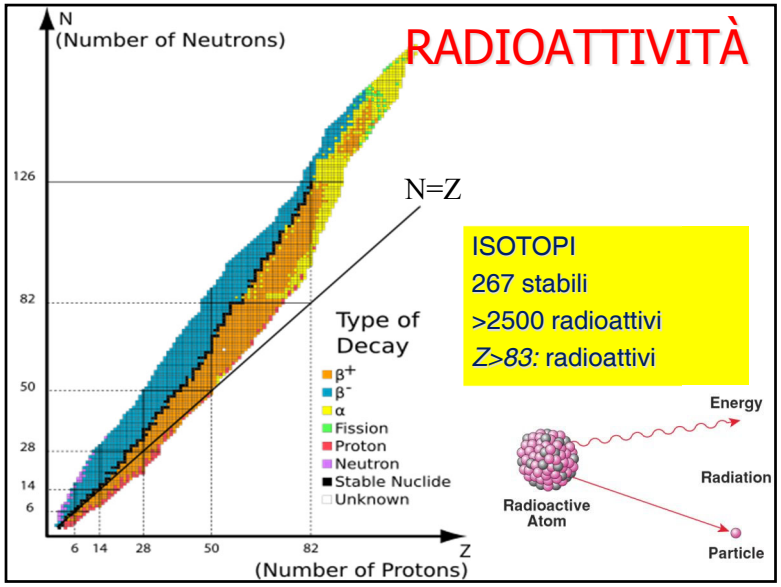
$${}^{A}_{Z}X$$

- X = simbolo chimico
- A = n. nucleoni
- Z = n. protoni = n.elettroni
- A-Z = n. neutroni

isotopo di un elemento ha lo stesso numero atomico (Z) ma diverso numero di neutroni e di massa (A)

^{219}Rn, ^{220}Rn, ^{222}Rn

RADIOATTIVITÀ



ISOTOPI
267 stabili
>2500 radioattivi
Z>83: radioattivi

RADIAZIONI *IONIZZANTI*

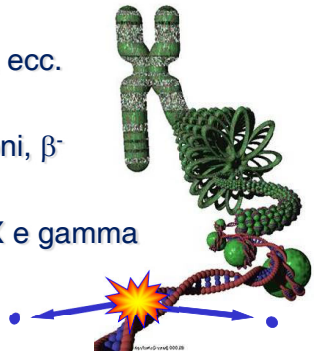
radiazione: trasporto di energia nello spazio

direttamente ionizzanti

- part. cariche: protoni, ioni, ecc.
- alfa: 2n+2p, α
- beta: positroni, β^+ - elettroni, β^-

indirettamente ionizzanti

- elettromagnetiche: raggi X e gamma
- neutroni



radiazioni NON ionizzanti

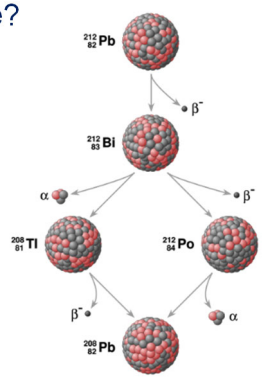
radiazioni emesse da:

- telefoni cellulari
- antenne (radiotelevisive e cellulari)
- linee alta tensione
- risonanza magnetica
- forno a microonde
- ecografia (ultrasuoni)

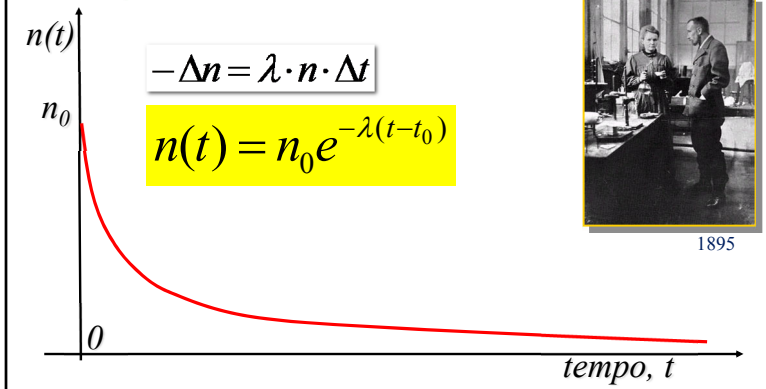
non hanno energia sufficiente per ionizzare

decadimento radioattivo

- ✓ quanto tempo per decadere?
- ✓ decadono tutti insieme?
- ✓ hanno una vita massima?



decadimento radioattivo



$$-\Delta n = \lambda \cdot n \cdot \Delta t$$

$$n(t) = n_0 e^{-\lambda(t-t_0)}$$

1895

n(t) = n.ro nuclidi rimanenti, n_0 = n.ro nuclidi iniziali
λ è costante ed è caratteristica di ogni radionuclide

HALF LIFE (T. DIMEZZAMENTO)

Radionuclide	Half Life (approx.)
^{85}Kr	10.7 y
^{32}P	14.3 day
^{14}C	5,730 y
^{192}Ir	73.8 day
^{60}Co	5.2 y
^{222}Rn	3.82 day
^{137}Cs	30 y
^{241}Am	462 y
^{226}Ra	1,620 y
^{238}U	4.51 x 10^9 y

$$T_{1/2} = \frac{\ln(2)}{\lambda} = \frac{0.693}{\lambda}$$

RADIOATTIVITA' IN CORPO

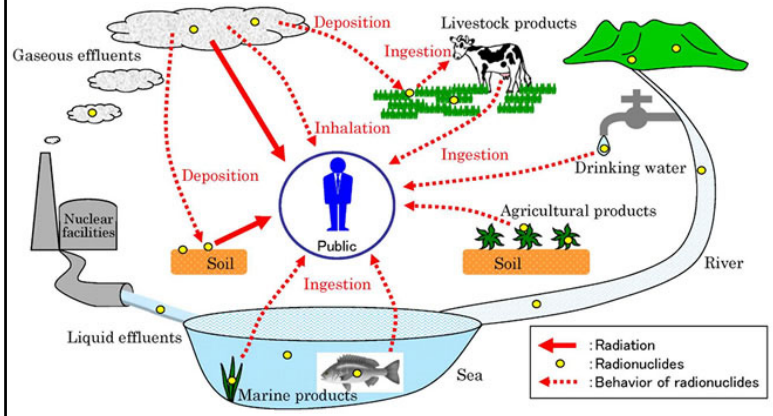
K-40

Natural radionuclides	activity [Bq]
K-40 (T½ =1.27E9 y)	4,500
C-14 (T½ =5,400 y)	3,800
Rb-87 (T½ =48.8E9 y)	650
Pb-210, Bi-210, Po-210	60
Rn-220 daughters	30
H-3 (T½ =13.7)	25
Be-7 (T½ =53.2 d)	25
Others	7
TOTAL	~9-10 kBq

1 Bq = 1 disintegrazione nucleare /sec

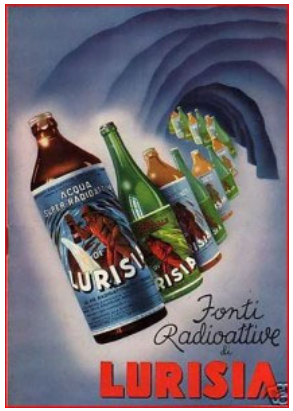
A. Romer, marzo 2004

RADIOECOLOGIA

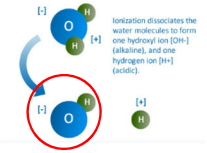


deposizione inquinanti

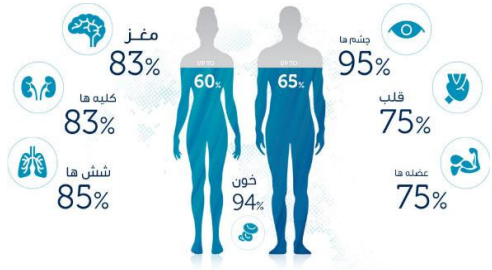
storia... radioattivo fa bene ….?



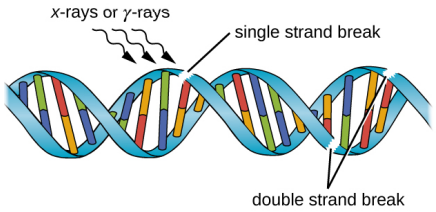
CERVELLO ACQUOSO? ...SI!!!

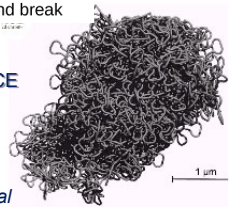


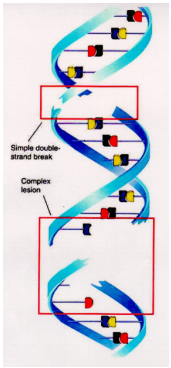
~87% of the atoms in the body are H or O



EFFETTI delle RADIAZIONI IONIZZANTI



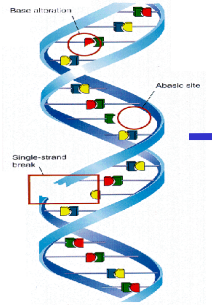




IONIZATION MAKES THE DIFFERENCE
It is important
HOW the energy is absorbed,
not only how much!
i.e.: 4 Gy is a letal dose, but for a 70 kg body, the deposited energy is only 67 cal (280J), as much as a warm coffe…!

video: DNA irradiation

EFFETTI DELLE RI



1) mutazione riparata → sopravvive

2) Cellula muore → non sopravvive (eff. deterministici)

3) Cellula sopravvive ma mutata → eff. stocastici (tumore dopo anni)

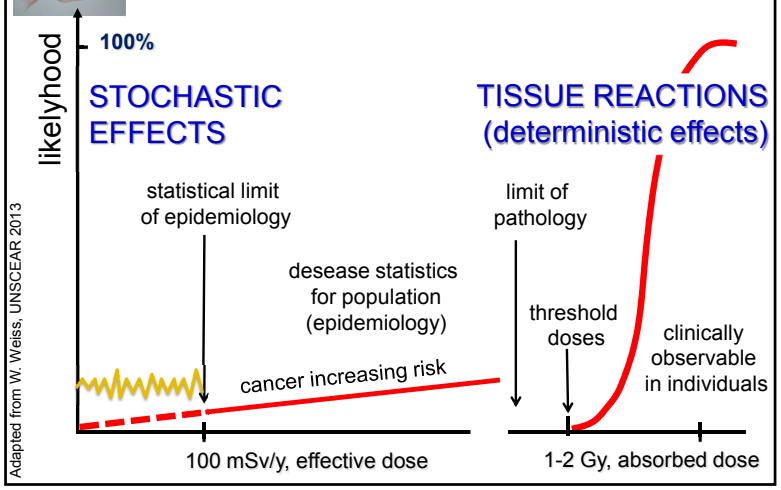
A. Gonzales,
Sievert lecture, Madrid 2004

POSSIBILI EFFETTI

reazioni tessutali (deterministici)
frequenza e gravità variano con la dose; esiste una soglia di dose; comprendono: radiodermite, cataratta, sterilità temporanea o permanente, sindrome acuta da raggi, decesso e… radioterapia!

stocastici (probabilistici)
probabilità e non gravità è proporzionale alla dose; si ipotizza assenza di soglia; distribuiti casualmente tra esposti; insorgono naturalmente tra la popolazione (>20%); dopo anni; comprendono: leucemie, tumori solidi e malattie ereditarie nella progenie

POSSIBILI EFFETTI



Reazioni tessutali (alte dosi)

Atrophic indurated plaque

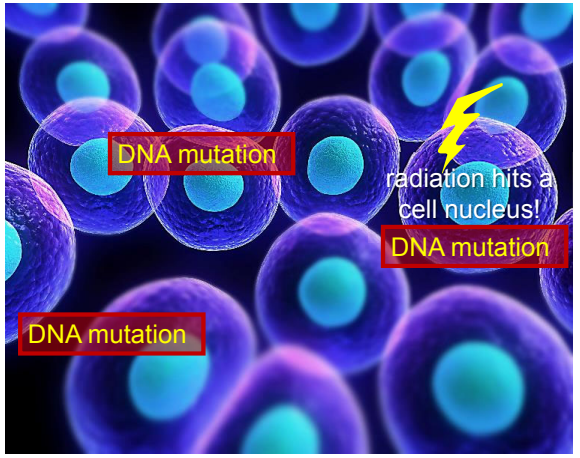
Hyper & hypo pigmentation, with telangiectasia

Chronic radiodermatitis in 17 year old female patient after x2 radiofrequency ablation procedures

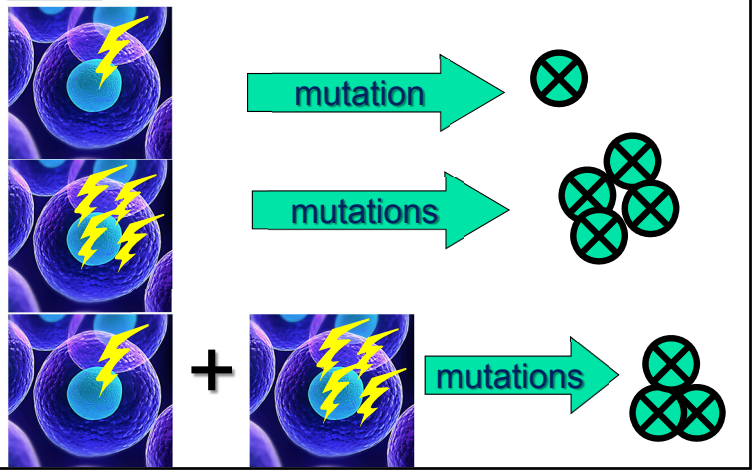
ICRP

BYSTANDER EFFECT

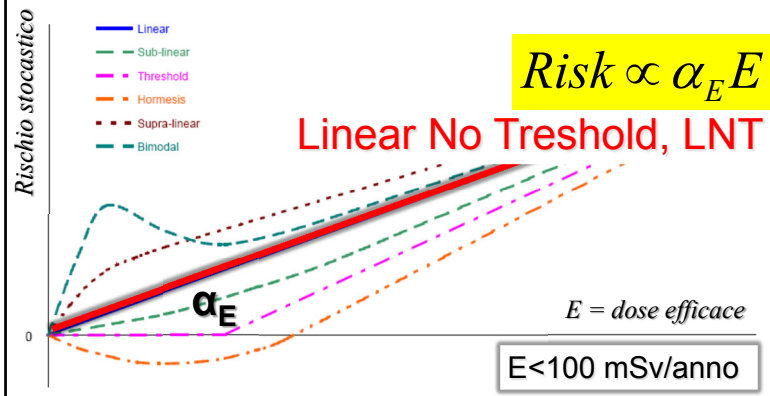
(mostly alpha particles)



ADAPTATIVE RESPONSE
(mostly X and gamma rays)



POSSIBLI CURVE RISPOSTA DOSE – EFFETTI STOCASTICI



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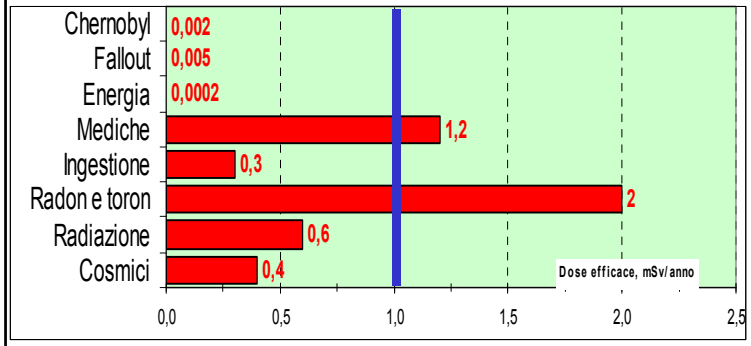
Crema, 29 novembre 2019

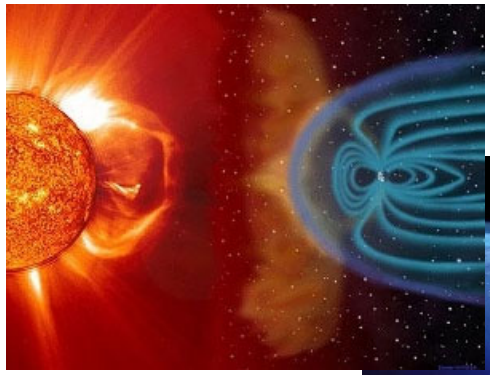
DOSI MEDIE alla POPOLAZIONE ITALIANA

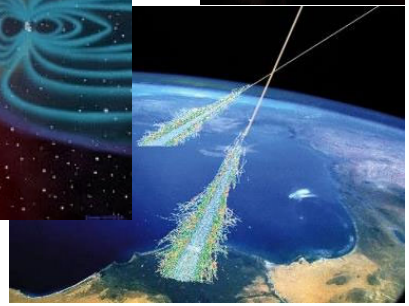


totale ≈4,5 mSv/a

APAT, Annuario 2006

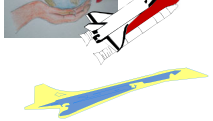
RAGGI COSMICI

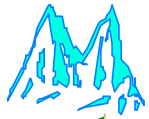




Solar wind

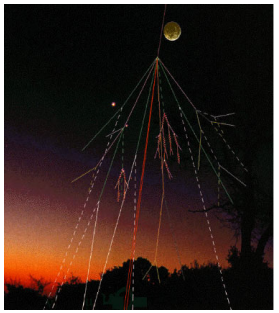
RAGGI COSMICI – dose





360 km 0,04 mSv/h
100 km
eventi solari possono causare dosi >1000 mSv; dipende dagli schermi
15 km 0,01
10 km 0,005 **20 ore volo: ~0,1 mSv!**
equipaggio aereo: >2 mSv/a
6,7 km 0,001 - Himalaya
3,7 km - Lhasa; Kami (Bolivia)
2,25 km ~0,0001 - Città del Messico
mare 0,00003

radionuclidi COSMOGENICI



RADIONUCLIDI NATURALI
DI ORIGINE COSMOGENICA

Radionuclide	Tempo dimezzamento	Principali radiazioni emesse
H-3	12,3 anni	β
Be-7	53,6 g	β
C-14	5730 anni	β
Na-22	2,61 anni	β

radionuclidi naturali NON COSMOGENICI

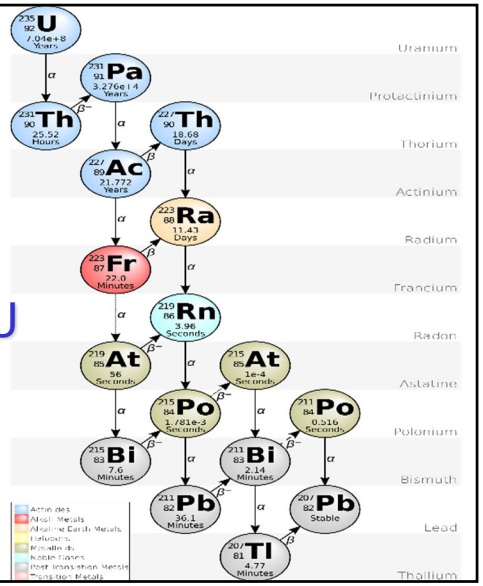
radionuclide	Tempo dimezzamento	Principali radiazioni emesse
K-40	1,3E9 anni	β,γ
Rb-87	5E10 anni	β
La-138	1,1E11 anni	β,γ
Sm-147	1,3E11 anni	α,
Lu-176	3E10 anni	β,γ
Re-187	5E10 anni	β

ed inoltre...
le famiglie radioattive naturali del torio e dell' uranio

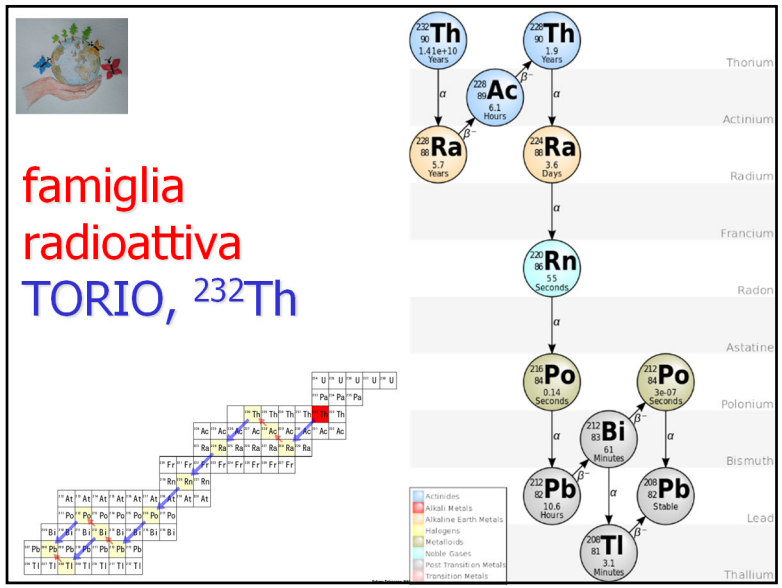
famiglie radioattive naturali

- famiglia torio, Th-232 (4n)
- famiglia uranio, U-238 (4n+2)
- famiglia attinio, U-235 (4n+3)
- hanno in comune:
  - capostipite: elemento a vita molto lunga
  - ultimo: isotopo del piombo
  - elemento gassoso: isotopo del radon:
    - torio: Rn-220, toron
    - uranio: Rn-222, radon
    - attinio, Rn-219, attinon

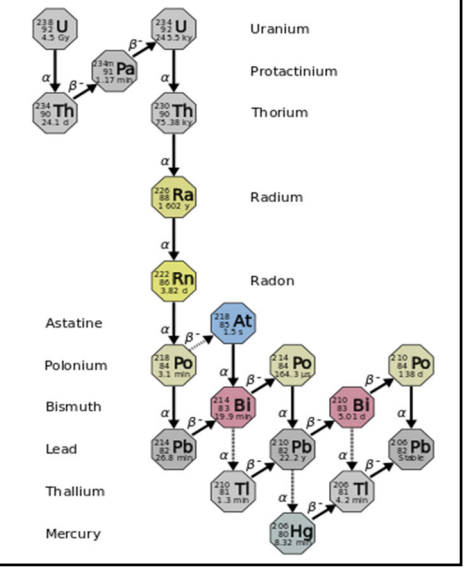
famiglia radioattiva ATTINIO, ^{235}U



famiglia radioattiva TORIO, ^{232}Th



famiglia radioattiva URANIO, ^{238}U



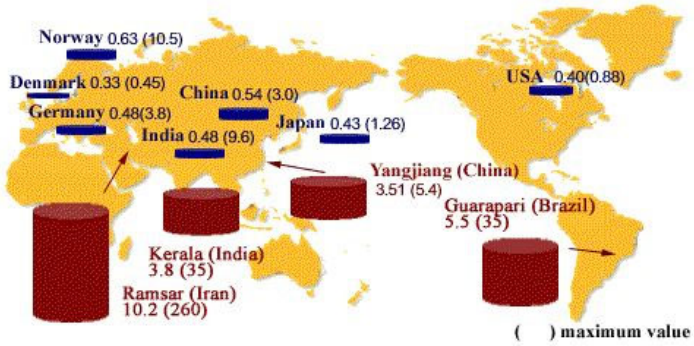
Radioactive beaches in Brasil…

SPIAGGE RADIOATTIVE

High radiation levels at Guarapari's beaches (Espirito Santo), a popular seasonal tourist attraction, where readings of up to 175 mSv/year have been measured. The source is sand eroded from monazite, an ore of the naturally radioactive element thorium commonly found in mountains

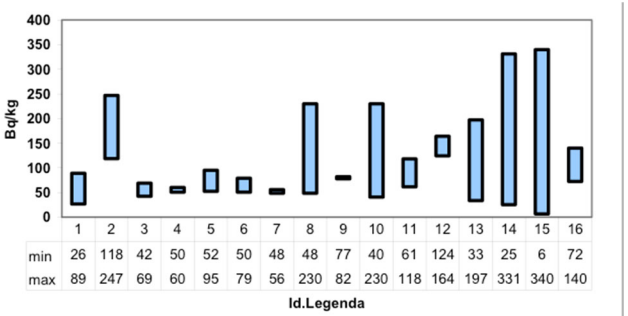
Radioactivity around the world

dose in mSv/y, average (maximum value)



The Very High Background Radiation Area in Ramsar, Iran: Public Health Risk or Signal for a Regulatory Paradigm Shift? P. A. Karam and S. M. Javad Mortazavi

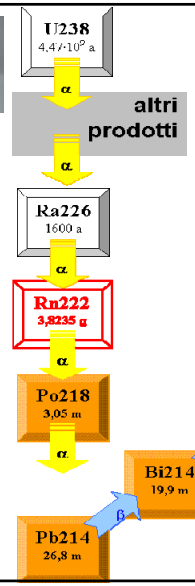
^{226}Ra nelle PIASTRELLE



S. VERITA', TESI DOTTORATO, 2009

1. Pakou et al., 1994; 2. Bruzzi et al., 1991; 3. Bruzzi et al., 1991; 4. Amrani & Tahat, 2001; 5. Papastefanou et al.,1984; 6. Bruzzi et al., 2000; 7. Righi & Bruzzi, 2006; 8. Righi & Bruzzi, 2006; 9. Higgy et al., 2000; 10. Khalifa, 2005; 11. El Afifi et al., 2006; 12. Ahmad & Hussein, 1998; 13. Righi et al.2007; 14.Gres porcellanato (misure dottorato) 15. Piastrelle smaltate (misure dottorato); 16. Gres (CINA)

radon, ^{222}Rn: figli

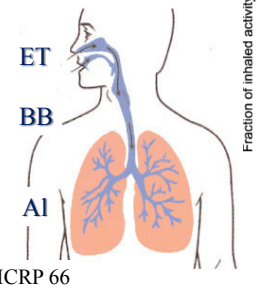


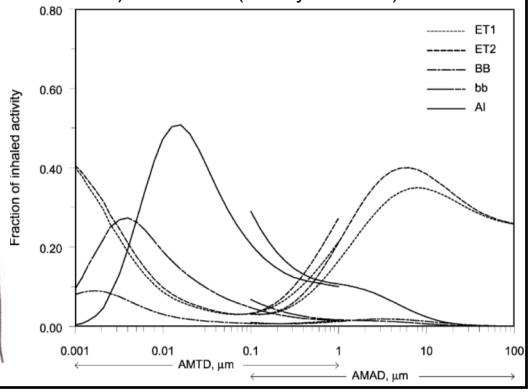
dose non deriva dal ^{222}Rn ma *dai prodotti di decadimento, metalli pesanti radioattivi:*

- polonio, Po218 e Po214,
- piombo, Pb214,
- bismuto, Bi214.

Particle size (AMAD or AMTD) inside the respiratory tract

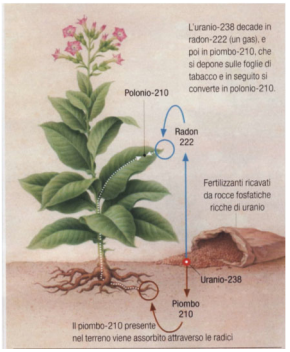
Deposition in each respiratory tract region for a reference worker, as a function of aerosol median size. In the transition size-range (0.1–1 mm) values are given for both AMAD (mainly sedimentation) and AMTD (mainly diffusion)

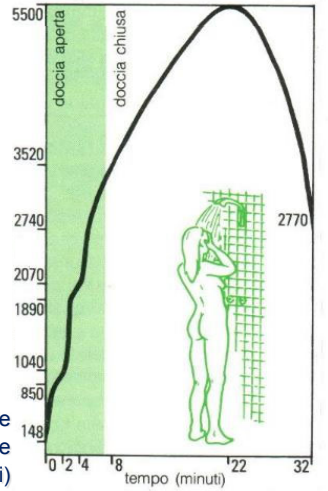




ICRP 66

fumo e doccia al RADON





Il rischio può essere significativo se l'acqua proviene da pozzi locali (no acquedotti)

Radioattività naturale e H_2O

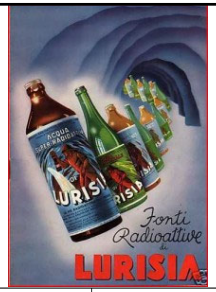
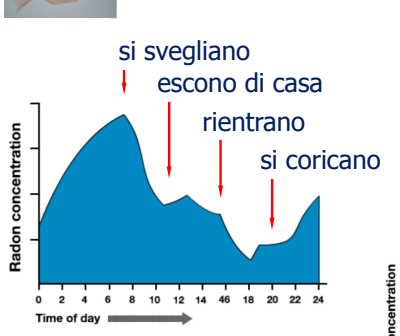


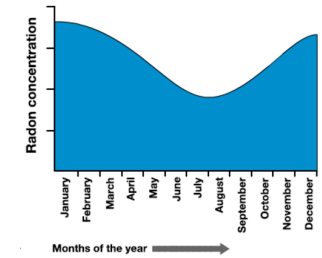
Tabella 9: Dose totale indicativa annuale

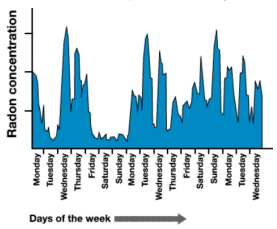
Popolazione	Identificativo	mSv/anno U-238	mSv/anno U-234	mSv/anno totali
Lattanti	Garbarino bouvette	0.015	0.017	0.032
	Garbarino sorgente	0.120	0.194	**0.314**
Bambini	Garbarino bouvette	0.005	0.006	0.011
	Garbarino sorgente	0.040	0.066	**0.106**
Adulti	Garbarino bouvette	0.006	0.006	0.012
	Garbarino sorgente	0.045	0.073	**0.118**

Losana et al., Il caso lurisia

RADON VARIAZIONI

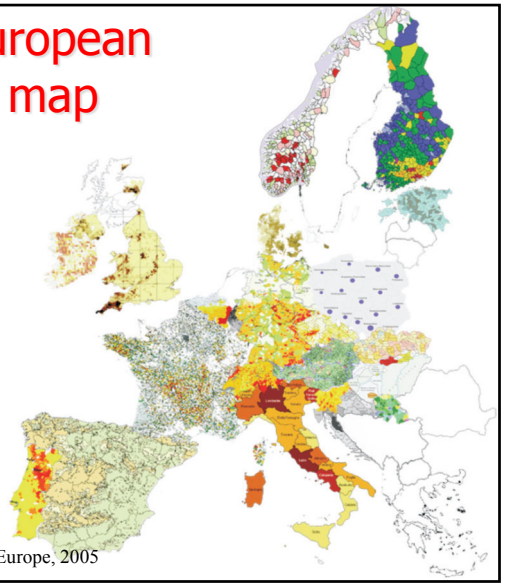






UKradon.org, 2017

the European radon map



EUR 21892 EN –
An overview of radon surveys in Europe, 2005

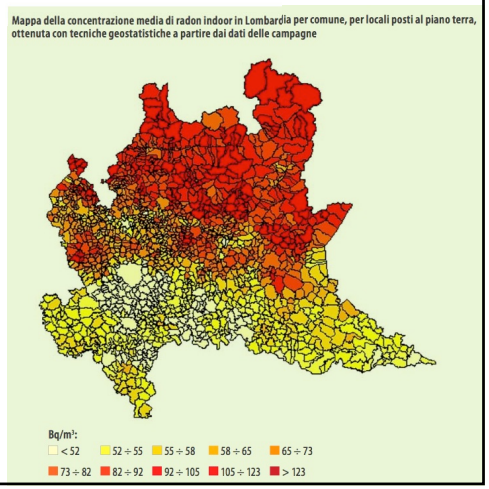
^{222}Rn in Italy

Radon indoor (houses):
- average: 70,1 Bq/mc
- 4,1% >200 Bq/mc
- 0,9% >400 Bq/mc

ISS, 2013

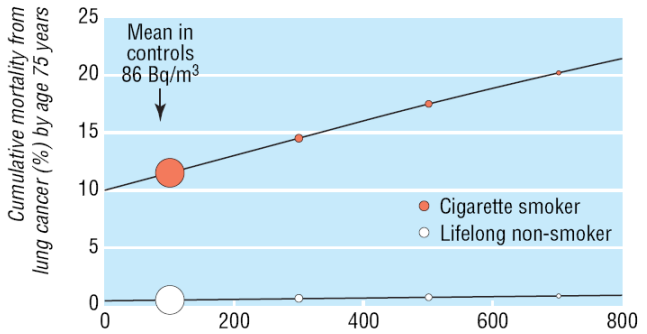
^{222}Rn in Lombardia

Radon indoor
houses and schools:
- average: 124 Bq/mc
- measures: 3600
- year: 2003/04



Mappa: proiezioni geostatistiche
ARPA, 2013

radon: absolute risk



Darby, S et al., BMJ 2005; 330:223

Cumulative absolute risk of death from lung cancer by age 75 y versus usual Rn concentration at home for cigarette smokers and lifelong non-smokers. Areas of circles proportional to numbers of controls with usual radon levels in ranges

BMJ

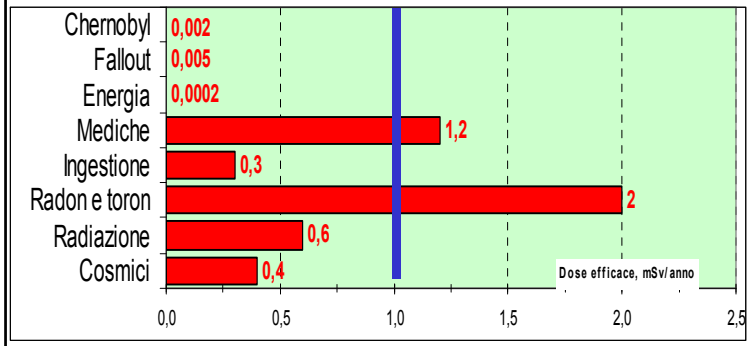
radon: effetti benefici?

Atyrau, Kazakhstan, 2004

Radhausberg Mountain

foto Scannicchio, Grecia

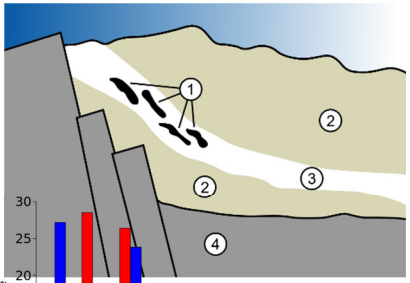
DOSI MEDIE alla POPOLAZIONE ITALIANA



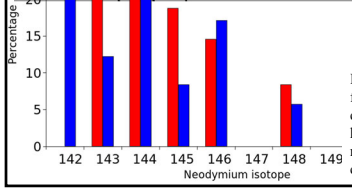
totale ≈4,5 mSv/a

APAT, Annuario 2006

NATURAL NUCLEAR REACTOR

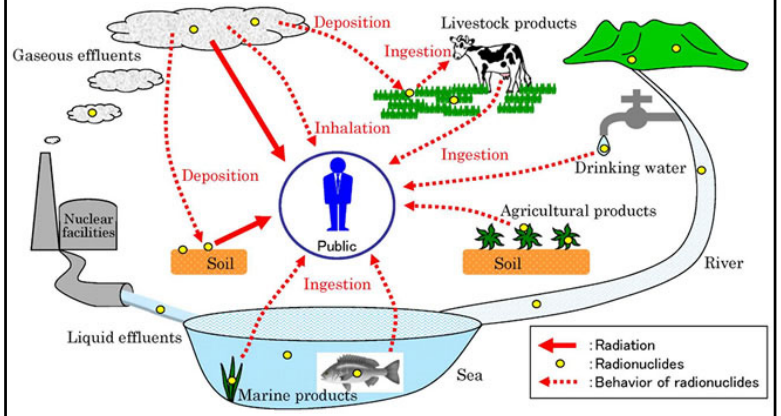


Geological situation in Gabon leading to natural nuclear fission reactors: 1. Nuclear reactor zones; 2. Sandstone; 3. Uranium ore layer; 4. Granite (OKLO reactor)



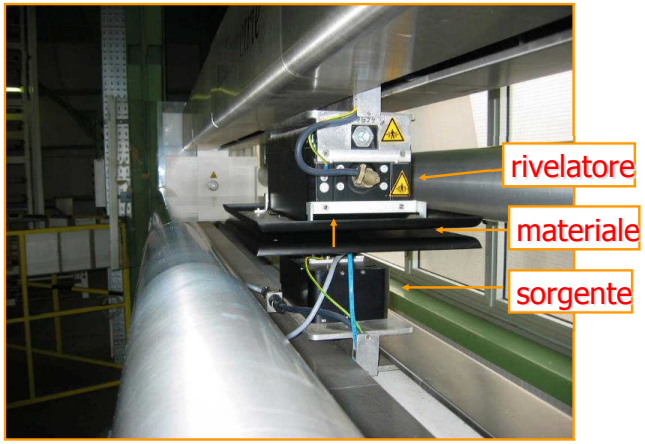
Isotope signatures of natural neodymium and fission product Nd from 235U which had been subjected to thermal neutrons. Oklo contained less than 6% of the 142Nd while natural Nd contains 27%; however Oklo contained more of the 143Nd isotope. Subtracting the natural isotopic Nd abundance from the Oklo-Nd, the isotopic composition matched that produced by the fissioning of 235U.

RADIOECOLOGIA

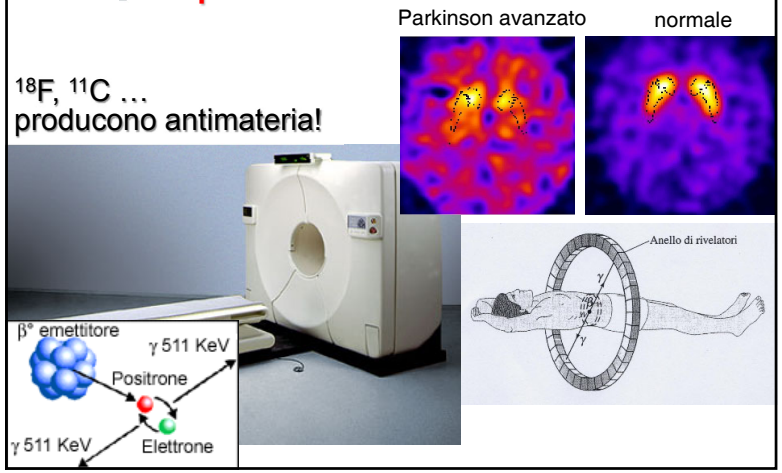


deposizione inquinanti

MISURA DI SPESSORE in trasmissione (Kr-85)



ANTIMATERIA in ospedale! PET

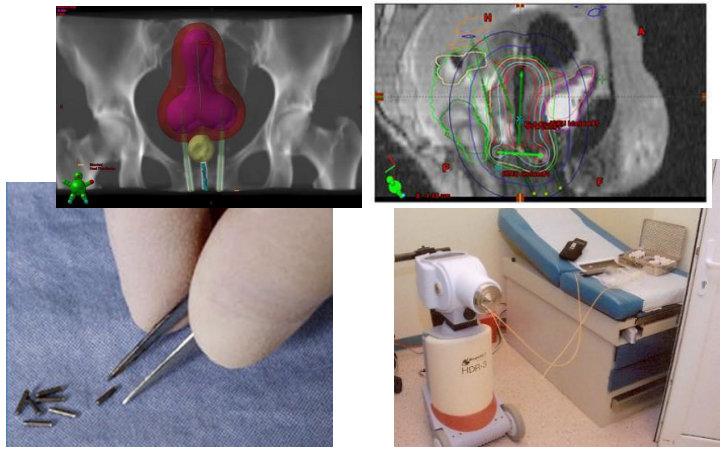


medicina nucleare vasche raccolta

Ogni scarico registrato e documentato

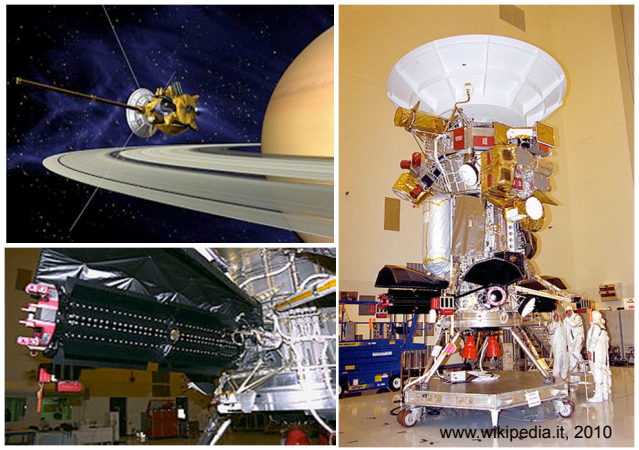
Maugeri, Medicina nucleare, 2014

Brachiterapia

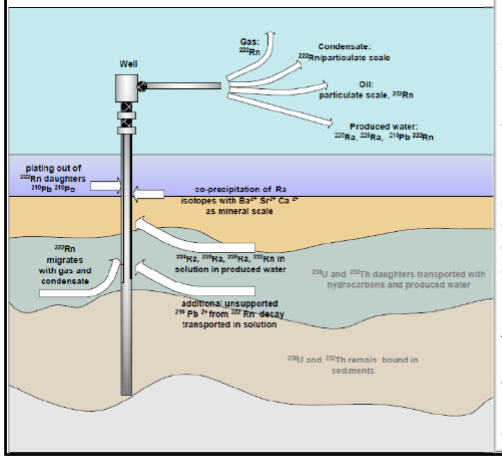


PROPULSORI SPAZIALI NUCLEARI

generatore termoelettrico radioisotopi - Cassini



NORM in Oil & Gas (E&P NORM)



long-lived U and Th isotopes are not mobilized from the rock formations. However Ra-226, Ra-224, Ra-228 and Pb-210 are mobilized, and appear mainly in the water co-produced during extraction. These isotopes and their radioactive progeny can then precipitate out of solution, along with sulphate and carbonate deposits as scale or sludge in pipes and equipment. Rn-222 is the immediate decay product of Ra-226 and preferentially follows gas lines. It decays (through several rapid steps) to Pb-210 which can therefore build up as a thin film in gas extraction equipment.

NORM: concentrazione di radionuclidi negli impianti di produzione di olio e gas

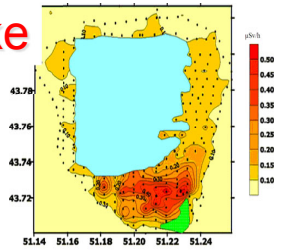
nuclide	scale concentration, Bq/g “dutch offshore” data
^{228}Th	40 – 200
^{228}Ra (*)	0 – 400
^{226}Ra (*)	0 – 900
^{210}Pb	6 - 2.500

(*) soprattutto $Ba(^{226}Ra)SO_4$ - $Ca(^{226}Ra)CO_3$ - $Ca(^{226}Ra)SO_4$

Radiation Protection, UE, 115 rep., 2003

NORM in oil companies

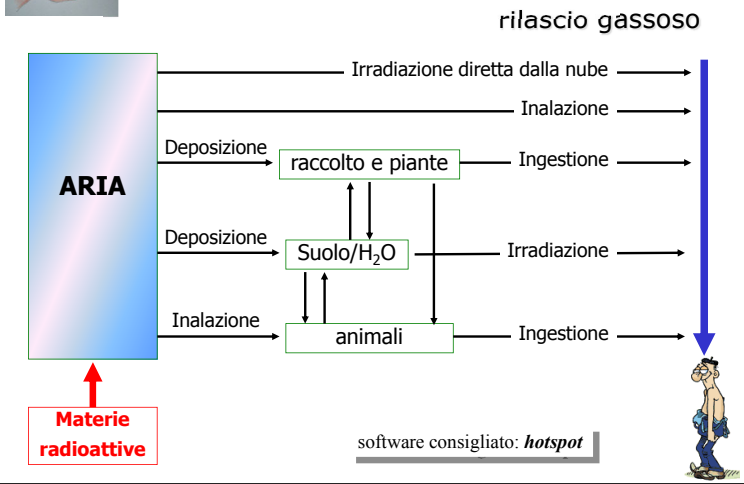
Koshkar-Ata lake



Map outline of a gamma-field (h=5 cm) in vicinity of the tailing pool Koshkar-Ata
(Kuterbekov K.A. et al, 2005)

- Before 77 km^2 area, now: 38.6 km^2 H_2O and 38.4 uncovered;

RADIOECOLOGIA

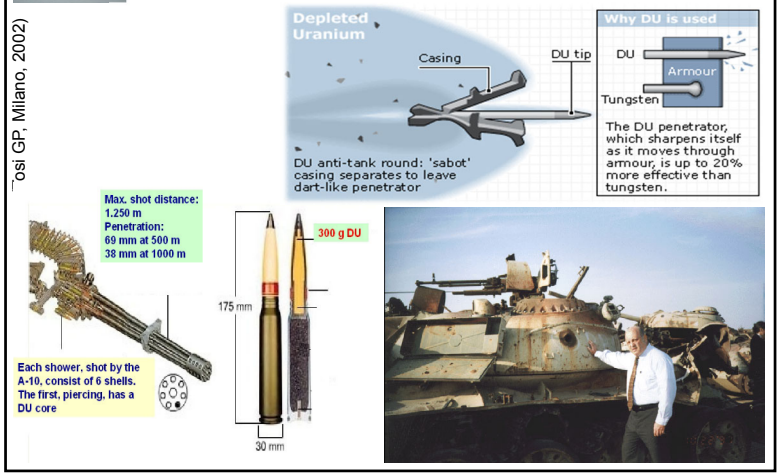


C-14 IN FONDO AGLI OCEANI

Esemplare di *Hirondellea gigas*, crostaceo, vive nelle profondità oceaniche

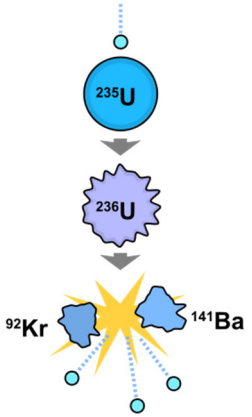
Il ritrovamento in ambienti remoti come la Fossa delle Marianne del carbonio radioattivo usato nei test con gli ordigni nucleari dimostra la portata dell'impatto delle attività umane sul pianeta. «Di solito pensiamo che le fosse oceaniche siano abbastanza remote e profonde da essere incontaminate. Ma in realtà, non è così. Nelle fosse oceaniche può finire di tutto». Jiasong Fang, geo-microbiologo alla Hawaii Pacific University. Scientific American, 2019

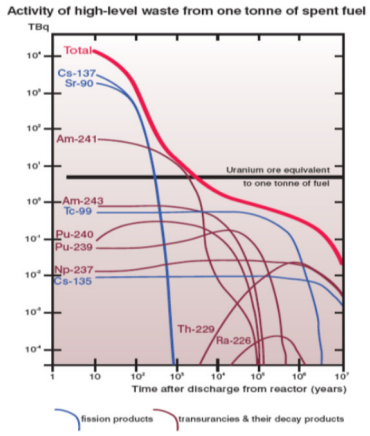
URANIO DEPLETO uso militare



osi GP, Milano, 2002)

reazioni nucleari e prodotti di fissione

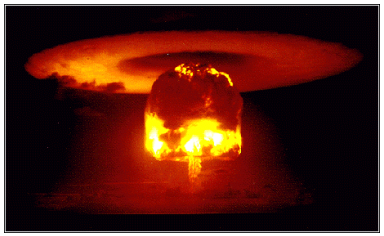


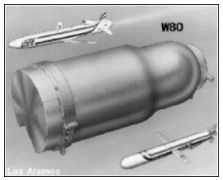


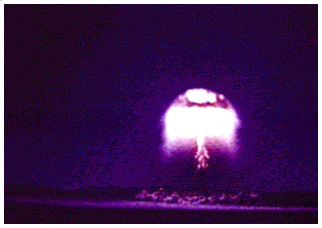
NORM – uranium mining

deposits

ENERGIA NUCLEARE AD USO MILITARE



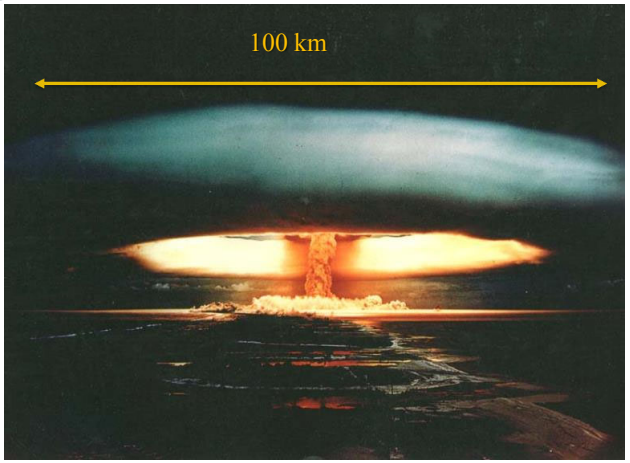




1975/96 - atollo di Mururoa

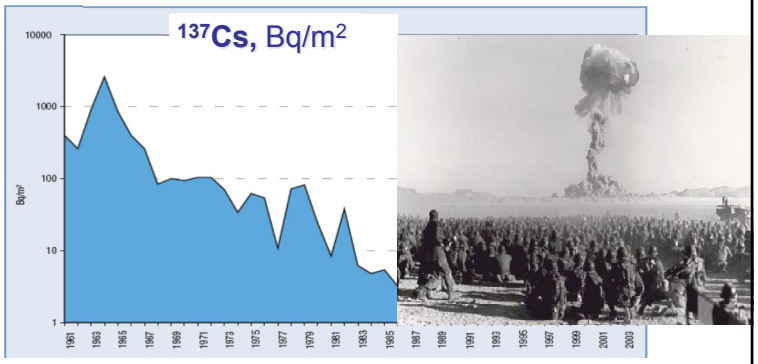
test nucleari francesi

La più potente



radioprotezione, …storia

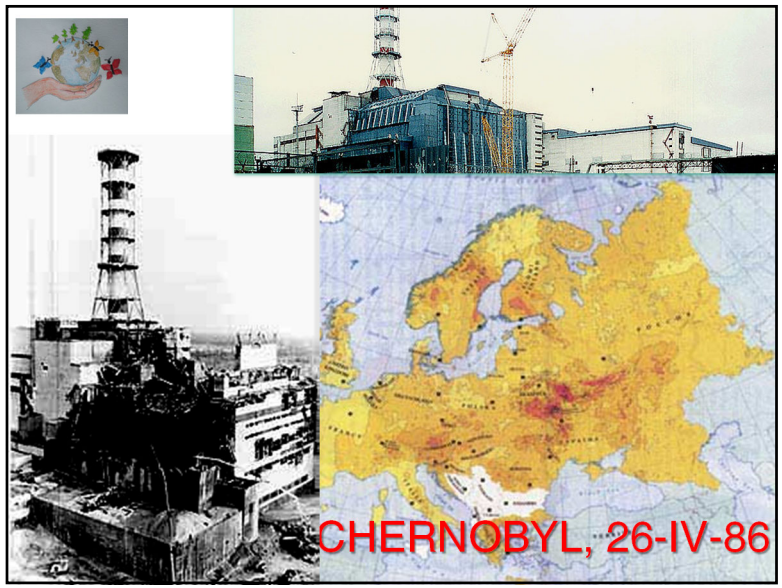
fall-out esplosioni nucleari in atmosfera



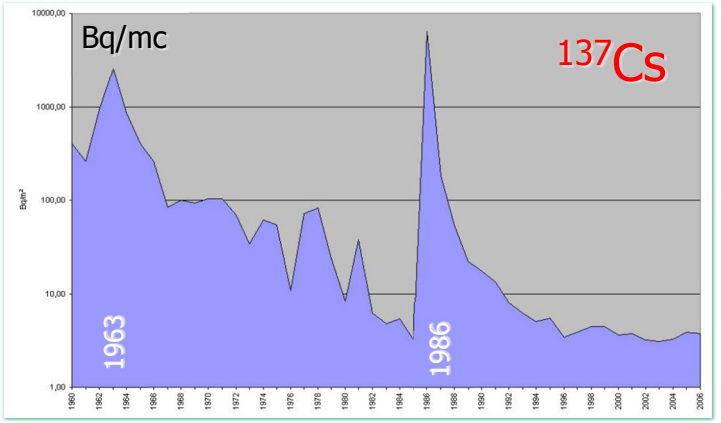
- *1955:* 200 casi di leucemia in superstiti di bombe atomiche

Figura 15.7: Andamento annuale della deposizione totale di Cs-137 in Italia

ANPA, Stato dell' ambiente, 2004

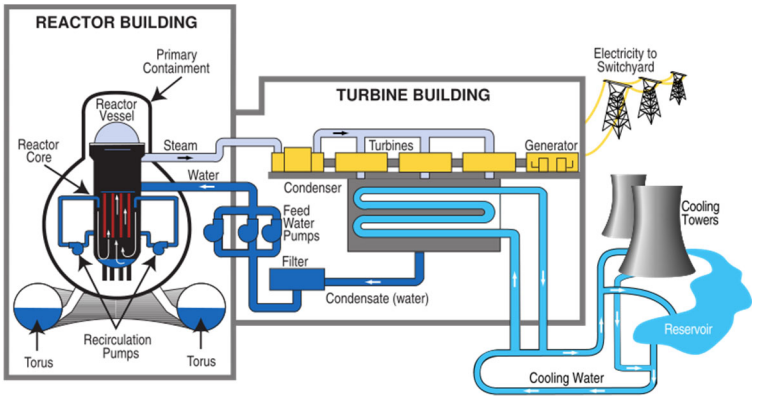


FALLOUT + Chernobyl

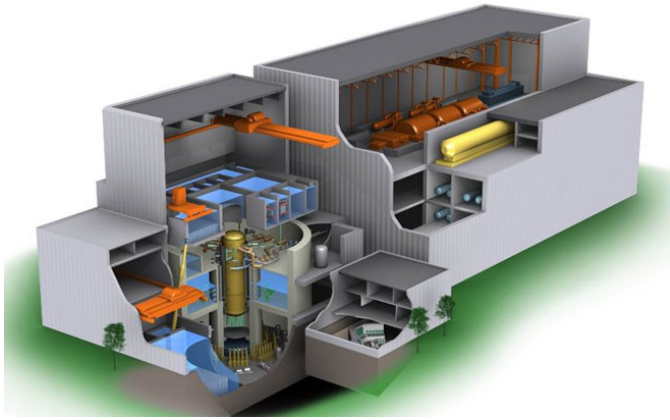


ANPA, Annuario 2007

boiling water reactor Fukushima, 2011

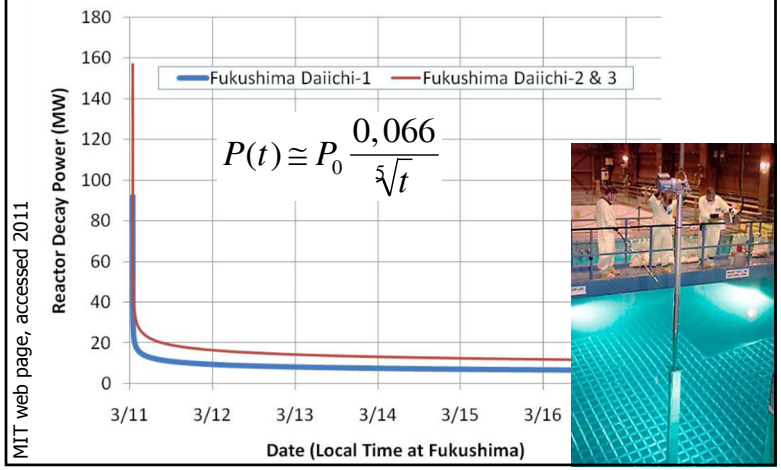


boiling water reactor Fukushima, 2011



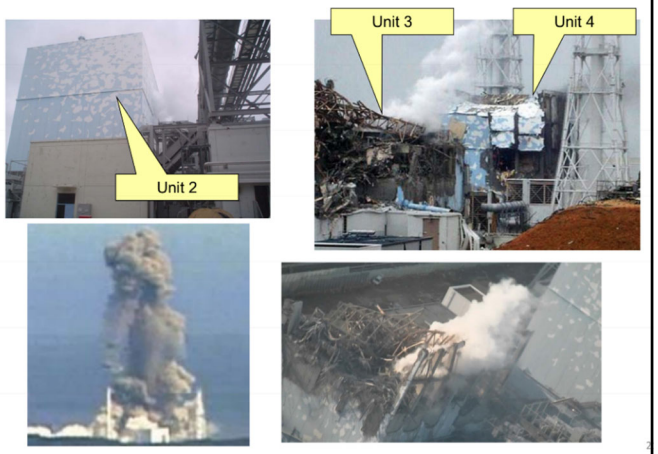
GE-Hitachi web page, 2011

raffreddare, raffreddare e raffreddare …



MIT web page, accessed 2011

esplosioni a Fukushima



NISA update report, 4-IV-2011

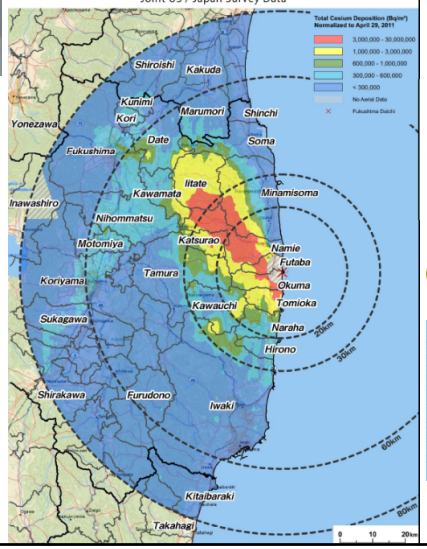
Fukushima come Chernobyl? impossibile perché ...

Chernobyl

Fukushima, unit 4

Aerial Measuring Results

Joint US / Japan Survey Data



Soil deposition
Cs-137
Bq/mq

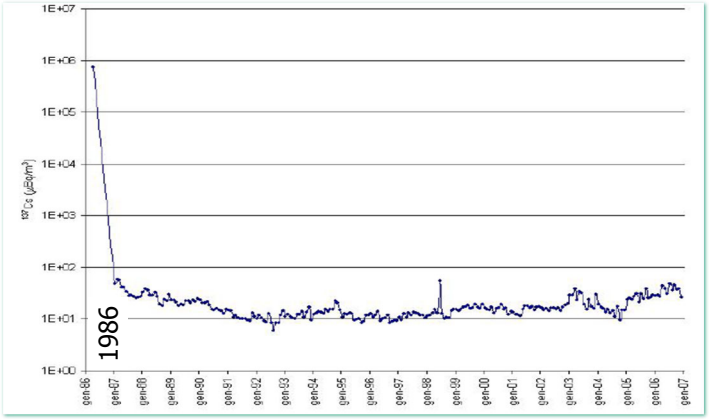
U.S. DEPARTMENT OF ENERGY

Total Cesium Deposition (Bq/m²)
Normalized to April 29, 2011

- 3,000,000 - 30,000,000
- 1,000,000 - 3,000,000
- 600,000 - 1,000,000
- 300,000 - 600,000
- < 300,000
- No Aerial Data
- Fukushima Daichi

74

FALLOUT: contaminazione



ANPA, Annuario 2007

CARBONE ….RADIOATTIVO?

ceneri volatili prodotte dalle centrali a carbone disperdono nell'ambiente una dose di radiazioni 100 volte superiore a quella di una centrale nucleare della stessa potenza. USA, Germania, UK, Cina, ecc.: molta della loro energia proviene dal carbone (Cina: una nuova centrale ogni 10 giorni): questo è un dato preoccupante, poiché le centrali a carbone producono inoltre più CO2 e gas serra di una centrale nucleare.

Elio GIROLETTI
dipartimento Fisica
Università degli Studi di Pavia

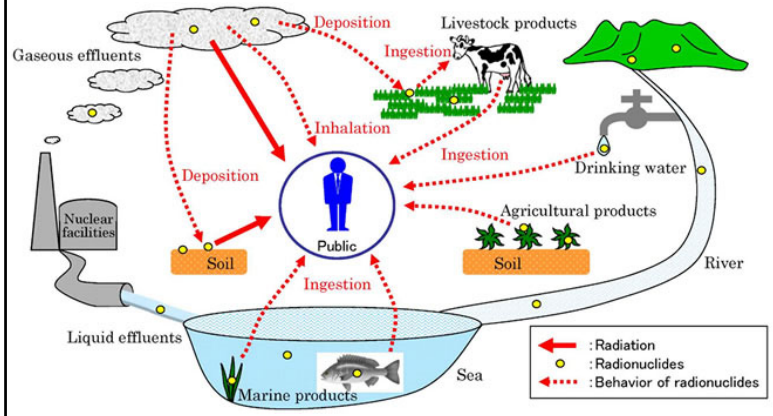
progetto: EARTH AMBASSADOR

radioattività: NOI E L'AMBIENTE

Radioattività e radiazioni
Possibili effetti sull'uomo
Radiazioni naturali nell'ambiente
Radiazioni artificiali e ambiente
Conclusioni

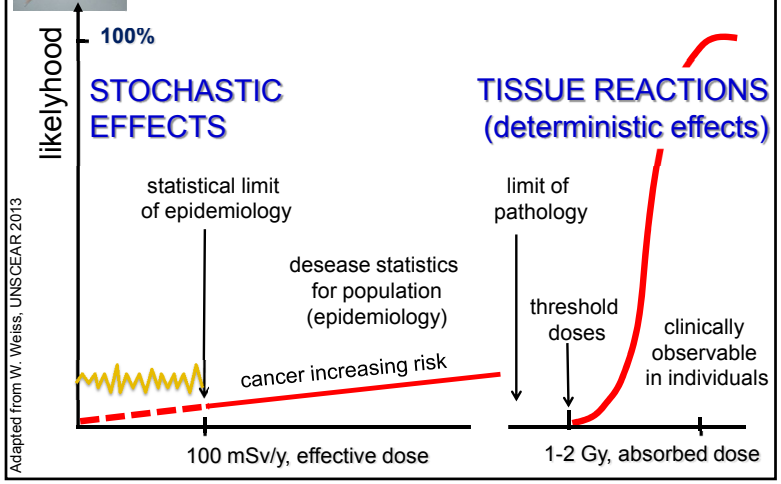
Crema, 29 novembre 2019

RADIOECOLOGIA

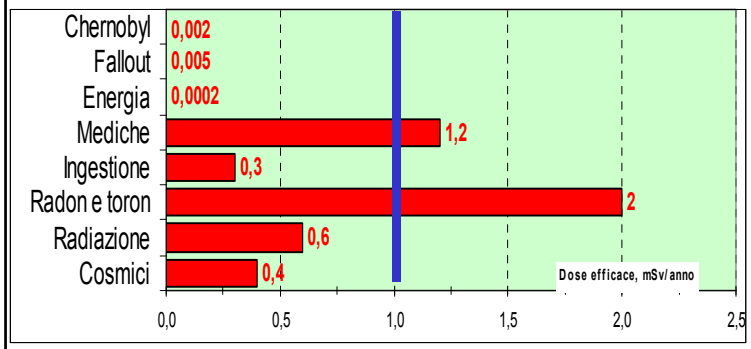


deposizione inquinanti

POSSIBILI EFFETTI



DOSI MEDIE alla POPOLAZIONE ITALIANA



totale ≈4,5 mSv/a

APAT, Annuario 2006

DOSI in radiodiagnostica

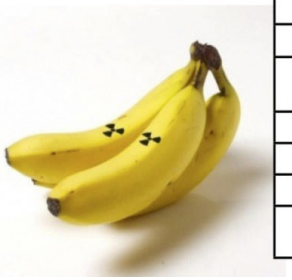
tipo di esame (preocedura) anno 2006	Dose efficace mSv	Dose proced/ DoseRxTorace PA, n.rel.
Ortopantomografia	0,01	0,5
Singola radiografia al torace, PA	0,02	1
Densitometria ossea	0,03	1,5
Cranio	0,05	3
Procedura radiografica torace	0,14	7
Mammografia	0,32	16
Addome	0,75	38
Rachide lombare	0,94	47
Pelvi e anca	1,04	52
Rachide in toto	1,52	76
TC rachide	1,58	79
Tratto gastrointestinale superiore	2	100
TC testa	2,25	113
Urografia	2,9	145
Tratto gastrointestinale Inferiore	4,09	205
Radiologia interventistica	7,59	380
Radiologia interventistica	8,2	410
TC altre	8,33	417
TC Torace	8,9	443
Radiol. interventistica cardiologica	11,37	569
TC Pelvi	14,1	705
TC addome	16	802

dosi tratte da Padovani et al., pubblicaz. interna ,(2008)

BANANA equivalent dose, BED

Bananas are a natural source of radioactive isotopes.

Eating one banana = 1 BED = 0.1 μSv = 0.01 mrem



Number of bananas	Equivalent exposure
100,000,000	Fatal dose (death within 2 weeks)
20,000,000	Typical targeted dose used in radiotherapy (one session)
70,000	Chest CT scan
20,000	Mammogram (single exposure)
200 - 1000	Chest X-ray
700	Living in a stone, brick or concrete building for one year
400	Flight from London to New York
100	Average daily background dose
50	Dental X-ray
1 - 100	Yearly dose from living near a nuclear power station

quale priorità?

sorgente	decessi stimati/anno
radon (+)	1500 – 5000
esami medici inutili (*)	500 - 800
antenne - elettrodotti	<5

(+) fonte: Min.Salute 2002; (*) ipotizzando una possibile riduzione della dose media annua pari a 0,26 mSv attraverso i programmi di qualità radiologica (20% delle dosi impartite in radiodiagnostica -1,3 UNSCEAR 2000-)

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Thanks ...FOR YOUR INTEREST!

elio.giroletti@gmail.com