Radiation exposure from radionuclides of natural origin in agricultural uses of coal ash

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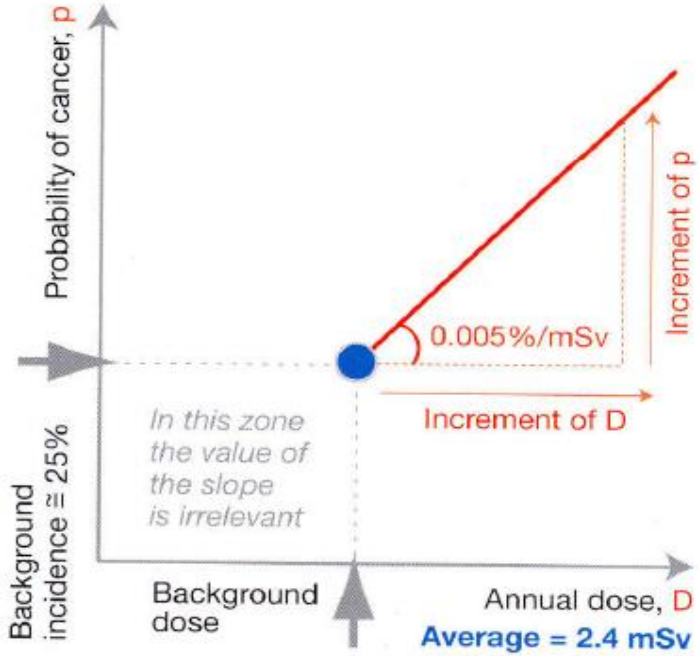
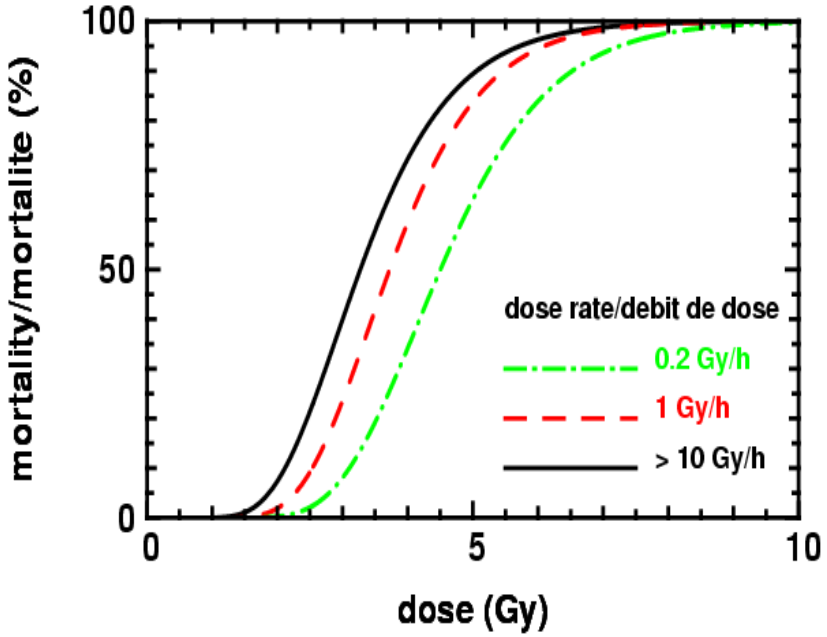
Introduction

- Coal Ash (CA) contain trace amounts of ^{226}Ra, ^{232}Th and their decay products and ^{40}K, at higher activity concentration than common soil or growing media.
- Average activity concentrations can be of the order of 150, 150 and 250 Bq/kg, respectively.
- Radionuclides in the decay chains and ^{40}K emit α, β and γ radiation, thus causing radiation exposure to humans.
- The consequences of the use of CA as growing media (bottom ash - BA) or sludge stabilizer)fly ash – FA) were assessed
- The occupational exposure of workers and the potential public exposure were calculated

Deterministic and Stochastic effect



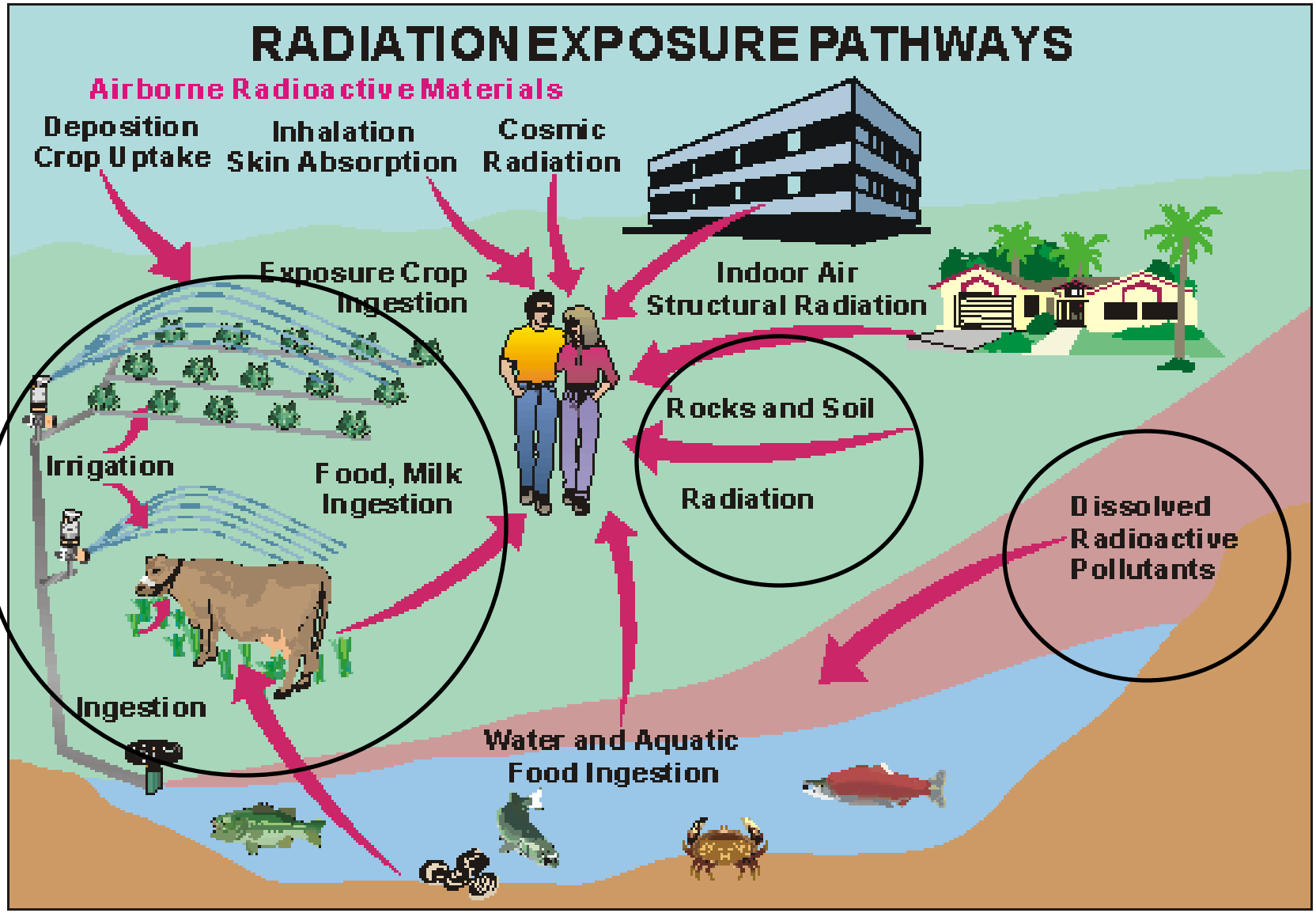


- Increase risk of cancer
  - No threshold
  - Linear response
  - Latency

- Acute Radiation Syndrome
  - ~ 1Sv threshold
  - Higher the dose, higher the damage
  - Few days-weeks

Exposure pathways

- External exposure
  - Exposure to gamma radiation
  - Source: growing media or sludge
  - Workers < 1 or 20 mSv/y
- Internal exposure
  - Exposure to alpha and beta radiation from radionuclides in ingested food
  - Exposure to Rn (workers)
  - General public < 0.3 mSv/y


RADIATION EXPOSURE PATHWAYS
Airborne Radioactive Materials
Deposition
Crop Uptake
Inhalation
Skin Absorption
Cosmic
Radiation
Exposure Crop
Ingestion
Indoor Air
Structural Radiation
Irrigation
Food, Milk
Ingestion
Rocks and Soil
Radiation
Dissolved
Radioactive
Pollutants
Ingestion
Water and Aquatic
Food Ingestion

שקף 6 מתוך

External exposure to workers

- Assumptions
  - The radionuclides are in secular equilibrium in the chain
  - Sludge containing 2 ton/d of FA
  - CA and FA homogeneously distributed in soil/sludge
  - 2000 hrs/y
  - Rn exposure neglected
- Data
  - Conversion factors (Bq/kg => Sv/h)*
  - Maximum (FA) activity concentration : 200, 250 and 450 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K.
- Annual dose limit for workers 1 mSv

* Eckerman K.F. and Ryman J.C. External exposure to radionuclides in air, water and soil, Federal Guidance Report No. 12. EPA-402-R-93-081. USEPA, 1993.

Internal exposure and environmental impact

- Assumptions
  - Consumption of 1 kg/d of food produced using CA (sludge or growing media).
  - The radionuclides are in secular equilibrium in the chain
  - Exposure from ^{40}K not considered
- Data
  - Generic transfer factors from soil to crops for Ra ~ 10^{-6}.
  - Activity concentration in crops grown using CA or FA.
  - Activity concentration in milk
  - Determination of the leaching of radionuclides into soil solution (Std. EPA method)
- Annual general public dose limit < 0.3 mSv

Results

- External exposure to growing media with BA
  - Gardens: 200 m^3/d (20 cm)
  - Agriculture: 100 m^3/d (60% BA, 40% organic material)

- External exposure from sludge stabilizer (40% FA)

	No ash	Ash	Excess dose	Limit*
Agriculture workers	24 μSv	64 μSv	40 μSv	1000 μSv
Sludge workers		2.2 μSv	NR	trivial

* IAEA BSS 115 (1996)

Results

- Measurements of crops using BA as growing media [Bq/kg]

Crop	No BA		BA		Regulatory limit*
	^{226}Ra	^{232}Th	^{226}Ra	^{232}Th	
Asphodel	< 0.23	<0.10	< 0.24	<0.13	10
Pepper	< 0.22	<0.10	< 0.22	<0.16	10
Lettuce	< 0.22	<0.13	< 0.21	<0.13	10
Cucumbers	< 0.17	<0.17	< 0.10	<0.09	10
Strawberry	< 0.12	<0.13	< 0.17	<0.15	10
Tomatoes	< 0.40	<0.50	<0.40	<0.30	10
Basil	< 0.23	<0.11	< 0.21	<0.21	10
Milk	< 0.06	<0.05	< 0.06	<0.03	1**

* RL from Israel Ministry of Health

* *GL from codex alimentarius for alpha emitters after a nuclear accident

Results

- Measurements of crops using FA as sludge stabilizer [Bq/kg]

Crop	No FA		FA		Regulatory limit*
	^{226}Ra	^{232}Th	^{226}Ra	^{232}Th	
Wheat	0.51	<0.37	0.57	<0.34	10
Wheat –sand	<0.65	<0.43	<0.8	<0.49	10
Wheat - loess	<1.91	<0.92	<0.97	<0.62	10
Wheat - clay	<1.01	<0.73	<1.09	<0.63	10

* RL from Israel Ministry of Health

Results

- Leaching experiments
- Measurements of leachate [Bq/l]

Ash type	Leachate				
	^{226}Ra	^{228}Ra	^{224}Ra	^{238}U	^{232}Th
LL	<0.05	<0.09	0.06	<0.08	<0.001
BBP	<0.05	<0.08	0.11	<0.0012	0.0022
Blank	<0.05	<0.08	<0.09	<0.0012	<0.001
Drinking water limit	0.5	0.2	2.1	3.0	0.6

- $U < 5x10^{-6}$
- $Th < 1x10^{-5}$,
- $Ra < 1x10^{-3}$

Conclusions

- Radiation risk assessment of the use of coal ash (bottom and fly ash) in agriculture as growing media, gardening and sludge stabilizer was performed
- No traces of radionuclides were found above detection levels in the crops or milk
- The leaching of radionuclides from sludge to soil solution was lower than 10^{-3} (Ra) to 10^{-6} (Th, U)
- The activity concentration in the soil solution was below drinking water regulations
- The highest potential exposure to workers and general public are far below the annual dose limits

Acknowledgment

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Thank you

Questions?

Natural decay series

URANIUM 238 (U238) RADIOACTIVE DECAY

type of radiation	nuclide	half-life
	uranium—238	4.5×10^{9} years
α	thorium—234	24.5 days
β	protactinium—234	1.14 minutes
β	uranium—234	2.33×10^{5} years
α	thorium—230	8.3×10^{4} years
α	radium—226	1590 years
α	radon—222	3.825 days
α	polonium—218	3.05 minutes
α	lead—214	26.8 minutes
β	bismuth—214	19.7 minutes
β	polonium—214	1.5×10^{-4} seconds
α	lead—210	22 years
β	bismuth—210	5 days
β	polonium—210	140 days
α	lead—206	stable