United Nations Scientific Committee
on the Effects of Atomic Radiation

UNEP

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Radiation exposure due to NORM industries

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based on a presentation by
Malcolm Crick, Secretary of UNSCEAR.

EVALUATING RADIATION SCIENCE FOR INFORMED DECISION-MAKING

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UNSCEAR 60 years

15 countries in 1955

- ARGENTINA
- AUSTRALIA
- BELGIUM
- BRAZIL
- CANADA
- EGYPT
- FRANCE
- INDIA
- JAPAN
- MEXICO
- RUSSIAN FEDERATION
- SLOVAKIA
- SWEDEN
- UNITED KINGDOM
- UNITED STATES OF AMERICA

27 countries in 2016

- ARGENTINA
- AUSTRALIA
- BELARUS
- BELGIUM
- BRAZIL
- CANADA
- CHINA
- EGYPT
- FINLAND
- FRANCE
- GERMANY
- INDIA
- INDONESIA
- JAPAN
- MEXICO
- PAKISTAN
- PERU
- POLAND
- REPUBLIC OF KOREA
- RUSSIAN FEDERATION
- SLOVAKIA
- SPAIN
- SUDAN
- SWEDEN
- UKRAINE
- UNITED KINGDOM
- UNITED STATES OF AMERICA

UNSCEAR 63rd session - 2016

UNSCEAR
Assess and report levels and effects of exposure to ionizing radiation

UNSCEAR 1958

UNEP

UNITED NATIONS

REPORT OF THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

GENERAL ASSEMBLY
OFFICIAL RECORDS : THIRTEENTH SESSION
SUPPLEMENT No. 17 (A/3838)

New York, 1958

Annex B

RADIATION FROM NATURAL SOURCES

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Paragraph

EVALUATING RADIATION SCIENCE FOR INFORMED DECISION-MAKING

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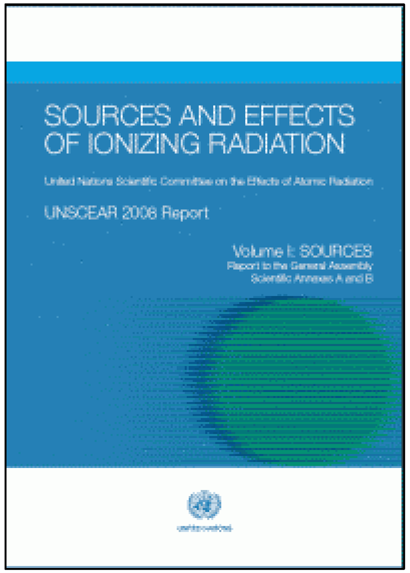
Aim of this presentation:

- Present an overview of exposures arising from different NORM scenarios to help in judging priorities.
  - Occupational exposure
  - Public exposure

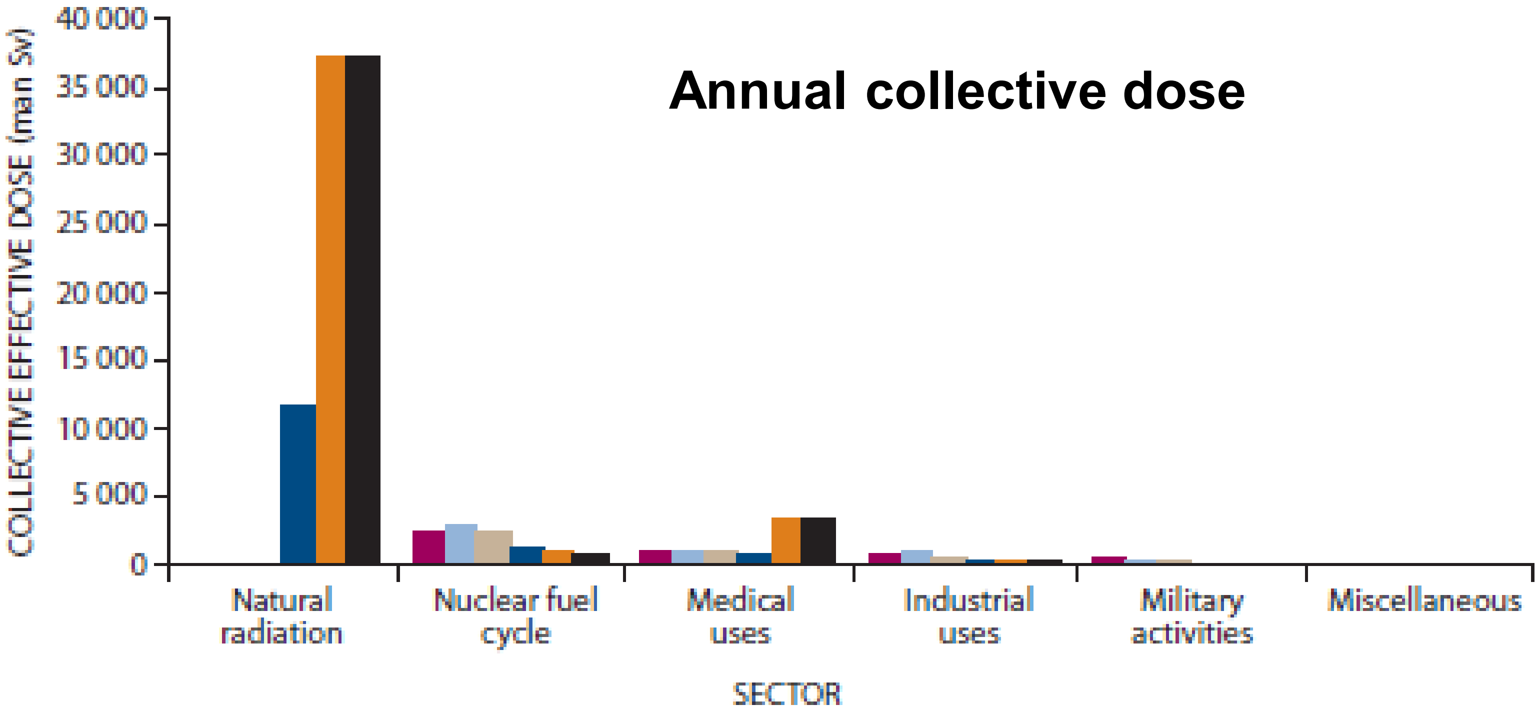
Based on UNSCEAR 2008 report

- Acknowledgements
  - Lead writers: E. Rochedo, D. Melo (Brazil)

- Based on survey data up to around 2002;
- Literature up to 2007;
- Report approved by UNSCEAR 2008;
- Published in 2010 (Annex B for NORM).



Trends in occupational exposure



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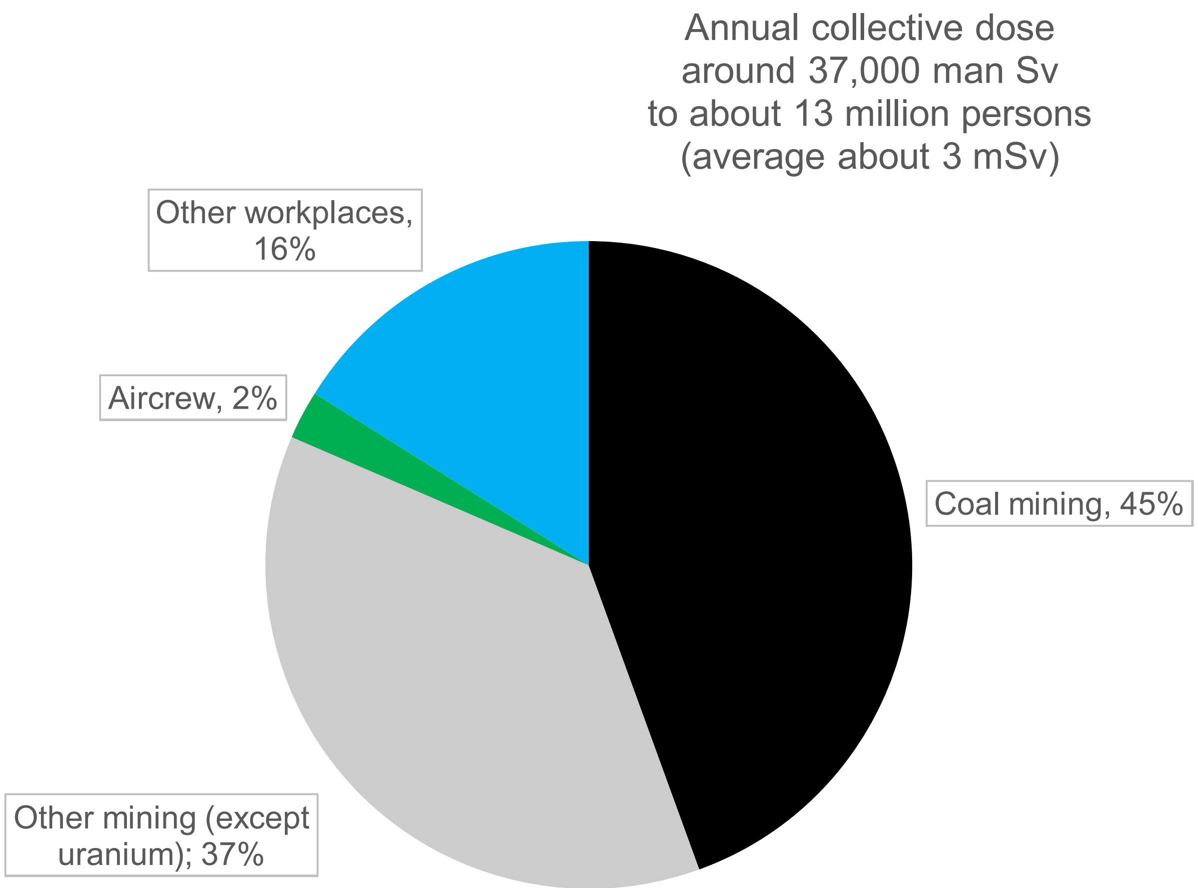
Contributors to occupational exposure



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Exposure characteristics in mining

- Mining ores can contain significant levels of radionuclides from uranium and thorium decay chains.
- Raw materials, by-products, end products may expose workers, who have little appreciation of radiation protection.
- Main sources of exposure in mining are inhalation of radon; inhalation and ingestion of long-lived radionuclides in ore dust; external irradiation.
- Numbers of miners declining.

Underground coal miners

Table 52. Annual doses to underground coal miners in China [C12]

Type of coal mine	*Average annual effective dose (mSv)*	*Collective dose (man Sv)*
Large-sized	0.28	280
Medium-sized	0.55	550
Small-sized	3.3	13 200
Bone-coal	10.9	545
Average	2.4	14 600

Most of exposure from inhalation of radon and progeny

[C12] Chen, L., Z. Pan, S. Liu et al. Preliminary assessment of occupational exposure of underground coal miners in China. Radiat. Prot. 28(3): 129 (2008). (In Chinese.)

Underground gold miners

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Table 53. Occupational exposure in underground gold mines in South Africa [W17]

Year	*Average annual dose (mSv)*	*Number of workers*	*Number of workers receiving doses of >20 mSv*
1997	6.3	258 080	12 904
1998	4.9	232 500	2 325
1999	5.4	175 333	5 260
2000	7	123 333	3 700

W17 Wymer, D. Radiological hazards in the mining industry. Occupational Health: Impact Prevention and Aftermath Strategies Annual Conference. Mine Ventilation Society of South Africa, Pretoria, 28 February to 1 March 2002.

Underground phosphate mine

- Abu-Tartor, largest phosphate mine in Egypt
  - Average annual effective dose
    - Internal exposure 11 mSv
    - External exposure 9 mSv
- Three mines in Eastern Desert of Egypt
  - 100 to 200 mSv per year due to radon
- Other Egyptian mines
  - 70 mSv (12 – 140 mSv) per year due to radon/thoron

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Gas and oil extraction

- ^{226}Ra and ^{228}Ra brought to surface during production
- Radon gas + plate-out from ^{210}Pb
- Radioactive scales and sludges
- Internal hazard for workers + higher gamma exposure rate

- A few to a hundred μSv/h dose rate around equipment
- Annual dose about 1 mSv mainly external, very few data

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Other NORM industries

- Welders using thoriated welding electrodes
- Phosphate fertilizer production
- Zircon milling
- Rare earth processing

- Relatively small numbers of people
- Doses of several millisieverts annually
- Data sparse

Workplaces other than mines

Table 56. Occupational exposure in Germany due to radon inhalation in workplaces other than mines
Data from the UNSCEAR Global Survey of Occupational Radiation Exposures

Workplace	*Period*	*Monitored workers (10^3)*	*Measurably exposed workers (10^3)*	*Annual collective effective dose (man Sv)*	*Average annual effective dose (mSv)*	
					Monitored workers	*Measurably exposed workers*
Spas	1995–1999	0.002	0.002	0.01	4.77	4.77
	2000–2002	0.004	0.002	0.01	4.09	4.47
Waterworks	1995–1999	0.128	0.075	0.24	1.85	3.12
	2000–2002	0.081	0.047	0.11	1.39	2.50
Tourist caves and visitor mines	1995–1999	0.135	0.101	0.31	2.26	3.01
	2000–2002	0.131	0.087	0.23	1.76	2.63

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Factors that affect evaluation

- Reliability of individual monitoring methods and data recording
- Recording of dose values less than MDL
- Assignment of dose values for missing periods
- Evaluation of anomalies, such as unexpectedly high or low values
- Subtraction of background doses
- Protocol as to who should be monitored
- Whether or not internal exposures are included
- UNSCEAR used 9 nSv/Bq h m^{-3} for radon dose conversion

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Conclusions

- There are good epidemiological data on lung cancer and radon exposures in homes and mines.
- Control risk of lung cancer for homes and other buildings on basis of radon concentrations, Bq m^{-3}
- ICRP will publish reference dose coefficients for inhalation and ingestion of radon isotopes and progeny.
- Reference Level of 300 Bq / m^3 equivalent to:
  17 mSv (12 mSv) for Homes
  7 mSv (5 mSv) for Workplaces

Summary for NORM occupational exposure

- Data so sparse that no meaningful trends on global exposures
- Collective dose around 40,000 man Sv annually
  - Perhaps 17,000 man Sv from coal mining
  - 14,000 man Sv from other mining
  - 6,000 man Sv from radon in other workplaces
- Average individual dose about 3 mSv
  - Wide variation depending on local circumstances
  - Some mines give rise to several tens of millisieverts annually, depending on type of mine, geology and working conditions (ventilation)

Nine categories for public exposure

- **uranium mining and milling**
- **metal mining and smelting**
- **phosphate industry**
- coal mines and power generation from coal
- oil and gas drilling
- rare earth and titanium oxide industries
- zirconium and ceramic industries
- applications using natural radionuclides (typically radium and thorium)
- disposal of building material

Uranium mining and milling

- Open pits, underground mines, in situ leaching
- Mill tailings
  - Radon and progeny to atmosphere
  - ^{226}Ra to liquid pathways (^{238}U, ^{230}Th, ^{210}Pb)
- Committee estimated average 25 μSv annually for most countries
- Care about reuse of land for building
- Currently being updated and re-evaluated

Metal mining and smelting

- Sparse data, very site-specific
- Inhalation of dust and radon
- Contamination of groundwater with radium isotopes
- External exposure to slag with high thorium content
- e.g. Assessment for gold mine in South Africa

Pathway	Assessed dose to nearby populations
Ingestion of water	0.04 mSv
Ingestion of fish	0.09 mSv
Ingestion of terrestrial foods	0.002 mSv
Inhalation of radon	0.04 mSv
Inhalation of dust	0.02 mSv

W18 Wymer, D.G. and J.C. Botha. Managing the environmental impacts of low activity wastes from the South African gold mining industry. Session 51-1 in: Eighth International Conference on Environmental Management, Bruges, Belgium, 30 September to 4 October 2001

Phosphate industry

- Processing may generate emissions with ^{238}U and ^{226}Ra
- Local dump sites for phosphogypsum, phosphate fertilizer use, gypsum for building material, radon in building sites
- Slag from producing phosphorous used for constructing roads and houses in USA; led to assessed upper doses of around 1 mSv annually.

Typical public exposures from NORM

Table 13. Doses to members of the public due to the industrial release of NORM in the United Kingdom [W6]

Industry	*Discharge route*	*Pathway*	*Annual dose (μSv)*	
			Critical group	*General public*
Coal-fired power station	Atmospheric releases via stack	All	1.5	0.1
	Building material made from ash	Radon inhalation External	600 900	
Oil and gas extraction	Authorized discharges to sea, and scales	Ingestion of seafood and external exposure due to fishing gear	<30	
Gas-fired power station	Atmospheric releases via stack	All	0.75	0.032
Steel production	Atmospheric releases via stack	All	<100	<2
	Building material made from slag	Radon inhalation External	550 800	
Zircon sands	Atmospheric releases via stack	Inhalation	<1	<1

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Summary for public exposure

- Doses up to few millisieverts annually for few scenarios, e.g. sludges from water treatment as fertilizers, use of waste products for building material
- No consistent approach to make good global assessment of inventories and exposures
- Conventional mining leads to huge volumes of material with enhanced NORM, making challenge for disposal and site restoration
- Diversity of ores with low levels of radionuclides from uranium and thorium chains – concentrated in products, by-products and wastes
- Public exposure normally low, but considerable numbers of people can be exposed

Current UNSCEAR work

- Much work has been done by others over the past decade on characterizing exposures to workers and public from NORM
- UNSCEAR is:
  - conducting new world-wide occupational survey
  - updating assessment of exposures from electricity production
  - planning new public exposure surveys
- Will need to decide on what dose conversion factor for radon it will apply for global assessment.

Many thanks and further information

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