



Hong Kong Institute of Occupational and Environmental Hygiene
香港職業及環境衛生學會 A member of IOHA and HKFMS




香港輻射防護學會
Hong Kong Radiation Protection Society

Protection strategies for Radon

in The IAEA Safety Standards Series No. GSR Part 3 (Interim Ed., 2011) Radiation Protection and Safety of Radioactive Sources: International Basic Safety Standards.
Presented by ST Yip
on 7 August 2014


Contents

- Naturally Occurring Radioactive Materials and Radon and Thoron in our workplace and environment.
- New Radiation Protection Safety Standards and 'As Low As Reasonable Achievable'
- What 'll happen next?



Introduction

- Indoor Radon concentration
 - One of the IAQ parameters
 - For dwellings
 - For offices and public areas
- Radon in workplace?? (industries & constructions)
- Latest developments
 - ICRP recommendations 2007
 - IAEA BSS 2011
 - EU Directive 2013/59/Euratom

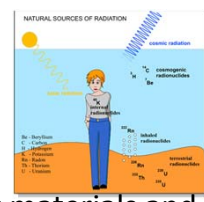


Radon

- An element of atomic number 86
- a colourless and odourless **radioactive gas**.
- It occurs **naturally** as a decay product of radium. Present in most soil and rocks, **granite** in particular, it decays further into a series of short-lived radioisotopes that take the form of **very tiny particles**.
- Epidemiological studies show that exposure to radon or its decay products may increase the incidence of **lung cancer**.
- Quoted from 'Control of Radon Concentration in New Buildings' EPD ProPECC PN 1/99.

Natural Radiation sources in our environment

- cosmic ray,
- radon,
- food and drink,
- gamma ray from building materials and soil/rock,
- On average, a person in Hong Kong receives a radiation dose of about 2.5 mSv/a from all natural sources of radiation



source of information: www.weather.gov.hk/blog/en/archives/00000099.htm

Radon and our radiation dose

Sources of Radiation

Category	Percentage
Natural Radiation	80%
Man-made Radiation	20%
Food/drinks	9%
Radon gas from ground	42%
Cosmic rays	13%
Buildings/soil	16%
Medicine	Almost 20%
Others	Below 1%

Reference: Sources and Effects of Ionizing Radiation, UNSCEAR 2008 Report

Adopted from www.dbcp.gov.hk/eng/safety/knowledge_clip_image003.jpg

Dose due to Radon: Worldwide average 2.4 mSv;
25% <1 mSv; 65% in 1-3 mSv; 10% >3mSv

Radon and Radon Progeny

- Radon emits alpha
- Decay to radioactive particles
- Target organ: Lungs
- Causing Lung Cancer

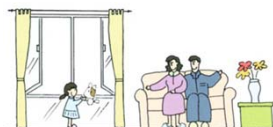
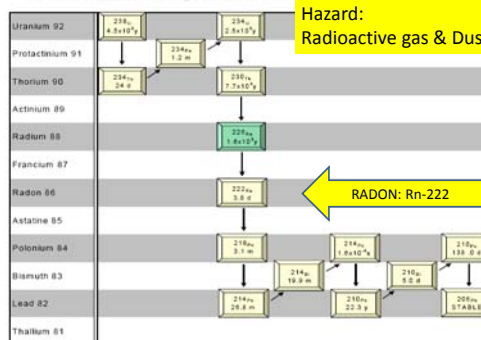


FIGURE 2a: Radioactive Decay of Uranium-238

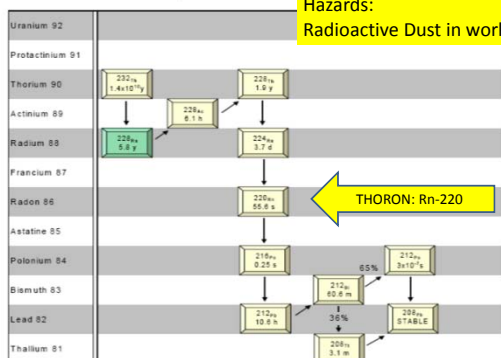
Half Life =3.8 days;
Hazard:
Radioactive gas & Dust



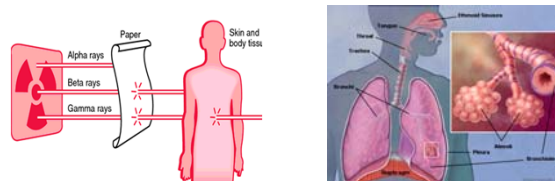
Source: Technical Report on Management of Naturally Occurring Radioactive material in waste 2005, Draft report

FIGURE 2b: Radioactive Decay of Thorium-232

Half Life =55.6s;
Hazards:
Radioactive Dust in workplace



Radon emits alpha rays:



Radon gives

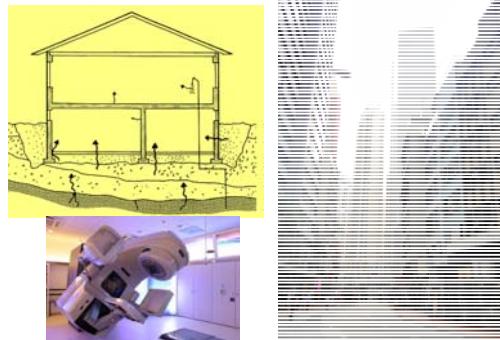
- only internal hazards specially to the lung,
- no external hazard
- (but not the other nuclides in the series)

Construction, Tunnel and Quarry



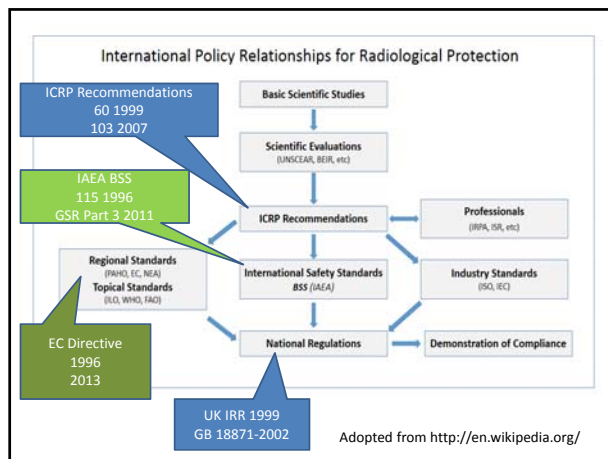
Natural Occurring Radioactive Materials containing U, Th and K-40

Houses, Buildings, Basements



Radiation Protection for radon and NORM

International Recommendations and Basic Standards



International Commission on Radiation Protection Recommendations

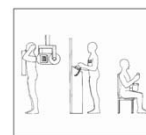
- Three Principles of Protection
 - Justification
 - Optimization of protection (ALARA)
 - Application of Dose Limits



Natural Occurring Radioactive Materials?
How low is low enough?

New structure in ICRP 103

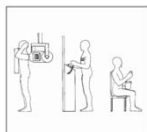
- Three Exposure situations
 - Planned
 - Existing
 - Emergency
- Three categories of exposures
 - Medical
 - Occupational
 - Public



ICRP's system of protection

Type of Situation	Occupational Exposure	Public Exposure
Planned Exposure	Dose Limit Dose Constraint	Dose Limit Dose Constraint
Emergency Exposure		
Existing exposure		

Controlled by regulation



ICRP's system of protection

Type of Situation	Occupational Exposure	Public Exposure
Planned Exposure	Dose Limit Dose Constraint	Dose Limit Dose Constraint
Emergency Exposure	Reference Level	Reference Level

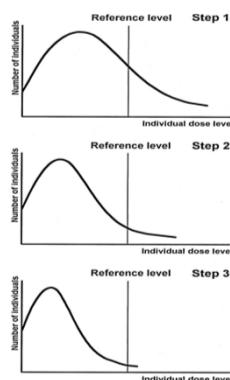


ICRP's system of protection

Type of Situation	Occupational Exposure	Public Exposure
Planned Exposure	Dose Limit Dose Constraint	Dose Limit Dose Constraint
Emergency Exposure	Reference Level	Reference Level
Existing exposure	N.A.	Reference Level



Reference level in existing exposure situation



- The use of a reference level in an existing exposure situation and the evolution of the distribution of individual doses with time as a result of the optimization process.
- [Fig 4. Cap 6 ICRP 103]

IAEA BSS on radon

Special criteria for radon in workplaces

- Exposure to radon is not normally regulated as a practice, as it is subject to the requirements for existing exposure situations:
 - A reference level is set, above which it is not appropriate to plan to allow exposures to occur — maximum 1000 Bq/m³
- *However, ...*

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IAEA BSS on radon

Special criteria for radon in workplaces

Occupational exposure to radon is subject to regulation according to the applicable requirements for planned exposure situations if:

- Exposure to other U, Th series radionuclides is already controlled as a planned exposure situation, *or*
- After remedial action, the radon concentration remains above the reference level,
- e.g. underground mining of non-radioactive ores

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Graded approach to regulation

- One of the key principles:
 - application of the requirements for planned exposure situations “shall be commensurate with characteristics of the practice or source and with the magnitude and likelihood of exposures.”
- for NORM industries
 - the exposures are generally (but not always) moderate with little or no likelihood of extreme radiological consequences from accidents.

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Graded approach to regulation

- Exemption: Not to regulate
 - If dose from gamma and dust is less than about 1 mSv/a, after taking existing occ. hygiene controls into account
- Notification (similar to exemption but regulator remains informed)
 - If dose from gamma and dust << dose limit,
- Notification + registration
 - Minimal additional controls for gamma and dust needed
- Notification + licensing
 - Specific measures to control actions of workers



Existing exposure situations – reference levels

- General reference levels (applicable to both natural and artificial sources):
 - Normally in the range 1–20 mSv/a
 - Commodities: ≤ 1 mSv/a
- Radon:
 - in terms of radon activity concentration in air
 - ≤ 300 Bq/m³ in homes
 - ≤ 1000 Bq/m³ in workplaces
 - These values are roughly equivalent to 10 mSv/a

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IAEA BSS Requirement 50: Public exposure due to radon indoors

- The government shall **provide information** on levels of radon indoors and the associated health risks and, if appropriate, shall establish and implement **an action plan** for controlling public exposure due to radon indoors.
- Reference level for ²²²Rn for *dwelling and other buildings with high occupancy factors for members of the public* will not exceed an annual average activity concentration due to ²²²Rn of 300 Bq/m³ (corresponding to 10 mSv)

IAEA BSS Requirement 52: Exposure due to radon in Workplaces

- The regulatory body shall establish a strategy for protection against exposure due to ²²²Rn in workplaces, including the establishment of an appropriate reference level for ²²²Rn.
- The reference level for ²²²Rn shall be set at a value that does not exceed an annual average activity concentration of ²²²Rn of 1000 Bq/m³.

³⁶ On the assumption of an equilibrium factor for ²²²Rn of 0.4 and an annual occupancy rate of 2000 hours, the value of activity concentration due to ²²²Rn of 1000 Bq/m³ corresponds to an annual effective dose of the order of 10 mSv.

IAEA BSS on NORM



- Exposure to natural sources – normally considered as an existing exposure situation
- However, certain exceptions : If the activity concentration of any of the radionuclides in the U and Th decay chain is above 1 Bq/g, apply requirements for planned exposure situations.

IAEA: Reference levels for radionuclides in commodities

Commodities (para 5.22):

- construction material
- food (FAO/WHO Codex)
- drinking water (WHO)



Of reference level 1 mSv

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Reference level for building materials

- Annual effective dose to the representative person generally that does not exceed a value of about 1 mSv.

Draft Safety Guide DS421 (currently with CSS for approval) proposes the use of an activity concentration index as a screening tool for identifying building materials that may need to be subject to restrictions

$$I = \frac{C_{Ra}}{300 \text{ Bq/kg}} + \frac{C_{Th}}{200 \text{ Bq/kg}} + \frac{C_K}{3000 \text{ Bq/kg}}$$

C_{Ra} is activity concentration of ²²⁶Ra, C_{Th} : ²³²Th, C_K : ⁴⁰K

$I < 1$ for bulk materials or $I < 6$ for superficial materials (e.g. tiles), then annual effective dose less than reference level of 1 mSv

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COUNCIL DIRECTIVE 2013/59/EURATOM

- to establish *reference levels* for **indoor radon** concentrations and for *indoor gamma radiation* emitted from **building materials**,
- and to introduce requirements on the recycling of residues from industries processing naturally-occurring radioactive materials into **building materials**.

Occupational Exposure

- occupational exposure to radon in workplaces requiring notification in accordance with Article 54(3), ...



Reference Level for Radon

The reference level for the annual average activity concentration in air **shall not be higher** than 300 Bq m^{-3} , unless it is warranted by national prevailing circumstances.

Apply to both dwellings and workplaces



Annex VI List of industrial sectors most likely to require some form of regulatory

- Production of thorium compounds and manufacture of thorium-containing products
- Cement production, maintenance of clinker ovens
- Coal-fired power plants, maintenance of boilers
- ...
- (listed here are those, I believe, can be found in Hong Kong)



Annex XVIII National Action Plan

- Strategy for conducting *surveys* of indoor radon concentrations
- indicators of situations with potentially high exposure to radon
- Identification of types of workplaces and buildings with public access, such as *underground workplaces*, and those in certain areas, where measurements are required, on the basis of a risk assessment, considering for instance occupancy hours.



national action plan ...

- establishment of reference levels for dwellings and workplaces.
- Assign responsibilities (governmental and non-governmental), coordinate mechanisms and available resources for implementation of the action plan.
- Strategy for reducing radon exposure in dwellings and giving priority to high risk ones



national action plan ...

- Strategies for facilitating post construction remedial action.
- Strategy, including methods and tools, for preventing radon ingress in new buildings, including *identification of building materials with significant radon exhalation*.
- Schedules for reviews of the action plan.



national action plan ...

- Strategy for communication to increase public awareness and inform local decision makers, employers and employees of the risks of radon, including in relation to smoking.
- Guidance on methods and tools for measurements and remedial measures. Criteria for the accreditation of measurement and remediation services shall also be considered.



national action plan ...

- Where appropriate, provision of financial support for radon surveys and for remedial measures, in particular for private dwellings with very high radon concentrations.
- Long-term goals in terms of reducing lung cancer risk attributable to radon exposure (smokers)
- Where appropriate, consideration of other related issues and corresponding programmes such as programmes on energy saving and indoor air quality.



How about Hong Kong

Current situations and challenges



Radon is a public health issue

- To reduce no of cases of Lung Cancer
- Hong Kong started with 'No Smoking'
- Then Low Radon??



How about Hong Kong

- Legislation/Regulation
 - Radiation Ordinance
 - Occupational Safety & Health Ordinance
- Notification to ??
- Control of Building Materials by??

How about Hong Kong

- Promotion of Public Awareness??
 - EPD: *IAQ Certification Scheme*
 - Building Department: *Comprehensive Environmental Performance Assessment Scheme for Buildings*
 - CEDD: Caisson and Tunnel Construction Manual

Workplaces

- Tunnels and underground facilities/spaces
- Construction of tunnels and underground spaces.
- Hand-dug caissons (CEDD, OSHC)

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RADON HAZARD FROM CAISSON AND TUNNEL CONSTRUCTION IN HONG KONG

W. K. LAM, T. W. TSIN and T. P. NG
Occupational Health Division, Labour Department, Hong Kong
(Received 22 September 1987 and in final form 1 December 1987)

Water Work, Sewage and Drainage systems

- Very long tunnels; low occupancy
- Radon flows into plant rooms of regular occupancy

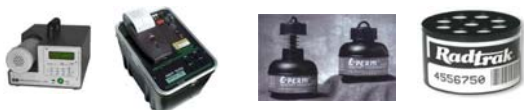
Tai Po to Butterfly Valley Fresh Water Tunnel

(Tai Po Treatment Works Raw and Treated Water Aqueducts)

- 14 km raw water tunnel, treated water tunnel and short tunnels, 2 shafts, 1.2 km raw water tunnel, 1.2 km treated water tunnel
- ...granite, seven major faults and over 20 minor faults, low to moderate inflows in granite, extremely high inflows in volcanics up to 14,940 l/min, water temperature 34-36 °C, **high radon levels**
- Source: CEDD Catalogue of HK tunnels (Up to Sept 2013)

Radon measurement

- Accreditation/competency
- Instrument
- calibration
- Technique for high humidity conditions in workplaces



More information in the internet

- IAEA Safety Standards Series No. GSR Part 3 (Interim Ed., 2011)
- CE COUNCIL DIRECTIVE 2013/59/EURATOM
- WHO Radon Handbook
- Reference: Presentations of PP. Haridasan, IAEA in AOCRP4 May 2014