Establishment of Reference Levels for regulatory control of workplaces where materials are processed which contain enhanced levels of naturally-occurring radionuclides

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Outline of talk

- EC report Radiation Protection RP107
  - JS Penfold, SF Mobbs, JP Degrange, T Schneider

- Background to report
- Review of industries
- Methodology for calculating doses
- Derivation of reference levels and screening levels
- Use of reference levels and screening levels

Background to RP107

- Title VII of BSS allows competent authorities to choose which NORM industries to regulate
- Harmonisation of approach in EU preferred
- Establish reference levels for regulatory control
- Aid to classification of workplaces

Review of industries

- Identify industries processing NORM
- Identify materials and quantities: mineral ores, by-products, residues, and products
- Identify processes and working procedures
- Identify range of activity concentrations in the material at all stages
- Determine radionuclide chains and whether they are in secular equilibrium

Industries identified in RP107

- Phosphate industry
  - mining and milling, phosphate ore processing: wet process, thermal process, fertilisers
- Processing of metal ores
  - Tin, Niobium, Aluminium, Copper, Iron and steel, Zinc, Molybdenum, Vanadium, Hafnium, Zirconium
- Zircon sands and refractory materials
- Rare earth extraction
- Manufacture and use of thorium compounds
- Titanium dioxide pigment industry
- Oil and gas extraction industry

Methodology for dose calculation

- Normal exposure scenarios: conservative end of normal range
- Unlikely exposure scenarios: maximising assumptions

- Pathways are inhalation of dust, inadvertent ingestion of dust, external irradiation, skin contamination, inhalation of radon
- Use scenarios and pathways to calculate doses to workforce
- Radionuclide chain decay is an added complication

Radionuclide chains

- About 40 radionuclides in the three natural decay chains
- Some are short lived and hence always in secular equilibrium with their parent
- Divide into chain segments: each segment is in secular equilibrium with 'head of segment'

- U-238 chain: U+238, U-234, Th-230, Ra+226, Pb+210, Po-210
- Th-232 chain: Th-232, Ra+228, Th+228
- U-235 chain: U+235, Pa-231, Ac+227

Natural decay chains

- Assume secular equilibrium through chain for most calculations
- Exceptions are:
  - Fume precipitate: Pb+210 and Po-210 only
  - Barium sulphate precipitate: Ra+226 only
  - Thoriated tungsten electrodes: Th isotopes and short lived progeny
  - Phosphogypsum: enhanced Ra isotopes
  - Fertilisers: variable, also high K-40

Exposure situations giving highest doses

- Inhalation of dust: dusty conditions with little respiratory protection
- Ingestion of dirt/dust: dirty and dusty areas with little protective clothing
- External irradiation: close to large amounts with little shielding
- Skin contamination: same situations as ingestion
- Inhalation of radon: in room with large amounts and little ventilation

Exposure Scenarios

- stockpile in warehouse
- removal of residues
- work near furnace
- work near pipes and vats
- fabrication of products
- glass coating
- work in store
- welding
- grinding electrodes
- handling

Dose calculation

- Two sets of calculations: ‘Normal’ and ‘Unlikely’
- Doses from different concentrations of feedstock: minimum, indicative, and maximum
- Results given in Table 3 of RP 107
- Gives doses, dominant pathway, percentage contribution

- Normal assumptions and indicative concentrations: estimated doses range from 0.1mSv/y to few hundred mSv/y
- Unlikely assumptions and max concentrations: estimated doses all above 1mSv/y

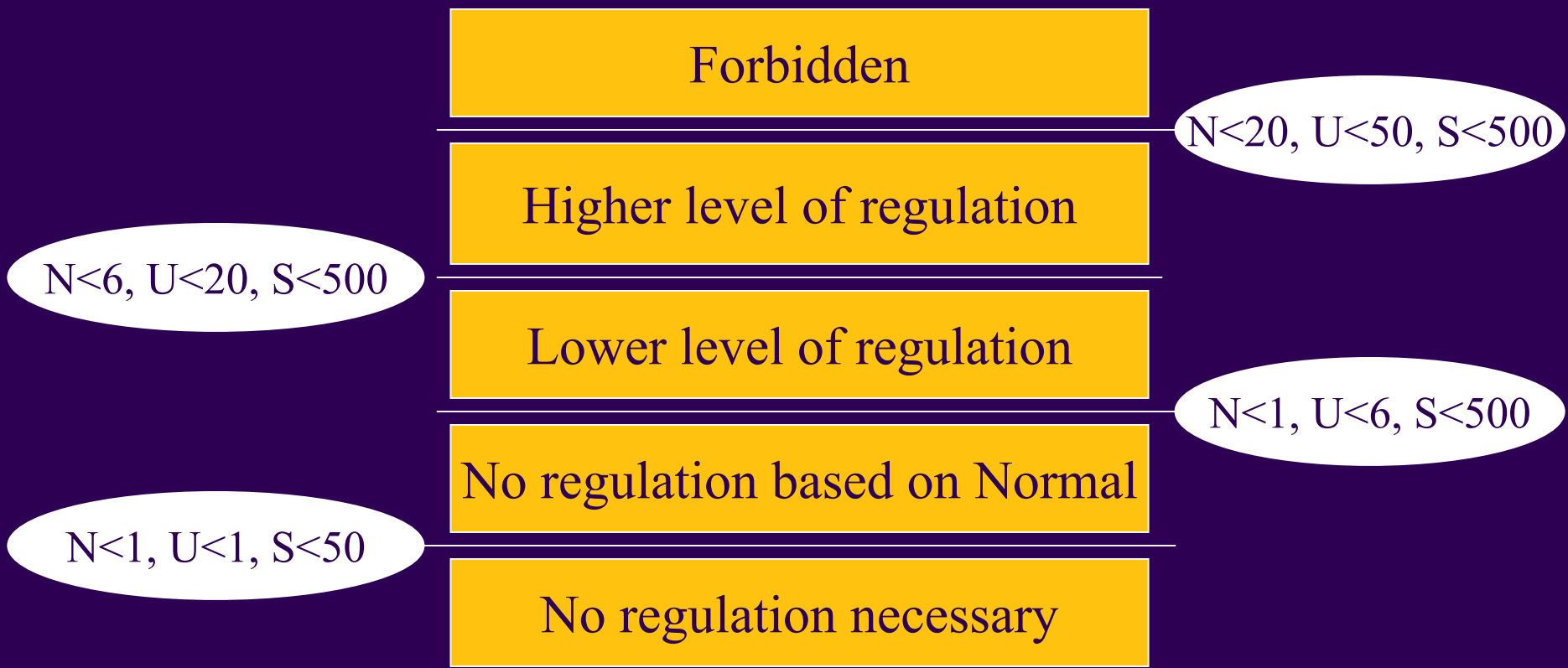
Derivation of reference levels

- Select dose criteria and develop classification system
- Compare estimated doses from materials with dose criteria
  - consider ‘normal’ and ‘unlikely’ situations
- Derive reference levels (Bq/g) for particular materials (ie maximum concentration that gives doses that meet the criteria)
- Reference level (Bq/g) = Dose criteria/Dose per unit activity

Dose criteria for reference levels

- Four effective dose criteria considered:
  - 1mSv/y dose limit for public
  - 6mSv/y dose limit for work in supervised area
  - 20mSv/y dose limit for worker, averaged over 5 years
  - 50mSv/y dose limit for worker in any one year
- Skin dose criteria 50mSv/y or 500mSv/y
- Criteria used in combinations to form basis of classification scheme

Classification scheme
Dose criteria in mSv/y



Reference levels

- Concentrations (Bq/g) in source material corresponding to boundaries between the classes ie maximum concentration that fits each of the first 4 classes

- **Reference levels** ie radionuclide concentration that corresponds to the dose criteria. This ignores other radionuclides. Need to apply summation rule to account for other radionuclides. Results in RP 107 Tables 7a,b,c,d

- Summation rule: sum of (activity concentration of radionuclide/reference level of radionuclide) for all radionuclides <1

Screening levels

- **Screening levels** (Bq/g) take account of other nuclides **so they are easier to use**

- selected one radionuclide to be representative of material
- screening level is concentration of that radionuclide that corresponds to the dose criteria, taking account of the likely concentrations of other radionuclides and chains in the material.
- RP 107 Table 6.

Screening levels (Bq/g)

Material	Nuclide	No reg	No reg Normal	Lower level	Higher level
Phosphate ore	U+238	0.08	0.2	1	3
Pyrochlore feedstock	Th-232	0.1	0.2	1	4
Tin smelting slag	U+238	0.2	0.8	5	10
Zircon sands	Th-232	0.02	0.05	0.3	1
Monazite sand	Th-232	0.5	2	10	30
W-Th welding rods (use)	Th-232	20	100	500	1000
Ilmenite feedstock	U+238	0.09	0.2	1	4
Radium scales	Ra+226	9	40	200	400
Radium sludge	Ra+226	3	10	50	100
Pb/Po precipitate	Pb+210	50	300	1000	2000
Fertiliser (P)	U+238	0.2	0.6	4	10

Reference levels (Bq/g)
No regulation necessary based on Normal assumptions

Material	Th-232	U+238	Ra+226	Pb+210	U+235
Phosphate ore	10	80	0.5	300	50
Pyrochlore feedstock	10	80	0.1	300	70
Tin smelting slag	10	80	3	300	40
Zircon sands	7	40	1	200	40
Monazite sand	10	80	0.8	300	70
W-Th welding rods (use)	300				
Ilmenite feedstock	10	80	0.6	300	50
Radium scales			60		
Radium sludge			20		
Pb/Po precipitate				1000	
Fertiliser	10	80	1	300	40

Use of screening and reference levels

- Compare concentration in source material with screening levels to obtain preliminary estimate of classification
- Take measurements
- Review assumptions in RP107 to see if relevant.
- Use reference levels to obtain better estimate of classification and determine important pathways
  - Can calculate values for different radionuclide composition, see Appendix G

Conclusions

- Classification system proposed for non-nuclear industry processing naturally occurring radionuclides
  - 5 Classes with 4 boundaries
- Screening levels and reference levels derived for these 4 boundaries
- Different levels for different materials
- Use screening levels and reference levels to identify degree of regulation required
- Results in RP 107 can be used to aid optimisation of doses to workforce: concentrations, protection, contact time