NORM in Oil and Gas Industry – Challenges and IAEA guidance

P.P. Haridasan

Radiation Safety and Monitoring Section

Division of Radiation, Transport and Waste Safety

IAEA

International Atomic Energy Agency

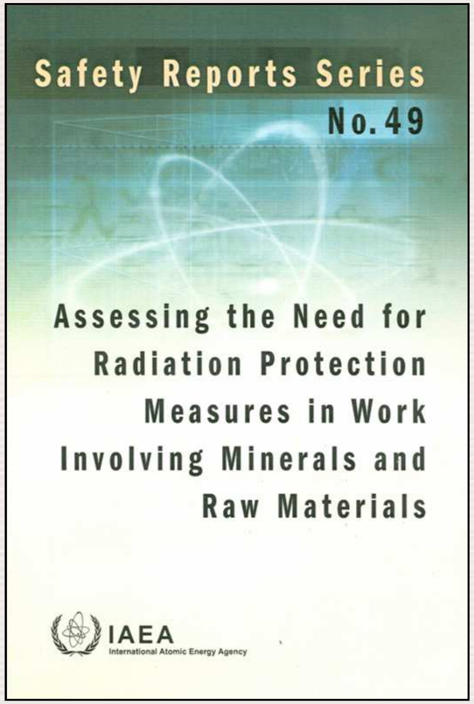
Contents

- The industry
- Radiation protection issues
- Basic safety standards
- Sealed and unsealed sources
- NORM in oil and gas industry
- Protection of workers and public
- Management of waste
- Other issues and challenges
- IAEA SAFETY REPORT SERIES NO.34
- IAEA TRAINING COURSE SERIES NO.40

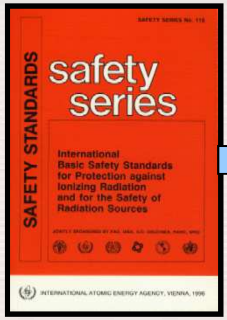
NORM Industry

Industry sectors most likely to require some form of regulatory consideration

1. Uranium mining and processing
2. Rare earths extraction
3. Thorium extraction & use
4. Niobium extraction
5. Non-U mining – incl. radon
6. Oil and gas industry
7. Production and use of TiO_2
8. Phosphate Industry
9. Zircon & zirconia
10. Metals production (Sn, Cu, Al, Fe, Zn, Pb)
11. Burning of coal etc.
12. Water treatment – incl. radon



The new BSS



IAEA Safety Standards

for protecting people and the environment

Radiation Protection and
Safety of Radiation Sources:
International Basic
Safety Standards

INTERIM EDITION

General Safety Requirements Part 3
No. GSR Part 3 (Interim)

IAEA
International Atomic Energy Agency

IAEA

The BSS - New structure

The structure of the revised BSS follows from the recommendations of ICRP 103

- three exposure situations:
  - Planned
  - Emergency
  - Existing
- three categories of exposure
  - Occupational
  - Public
  - Medical
- 52 Overarching requirements

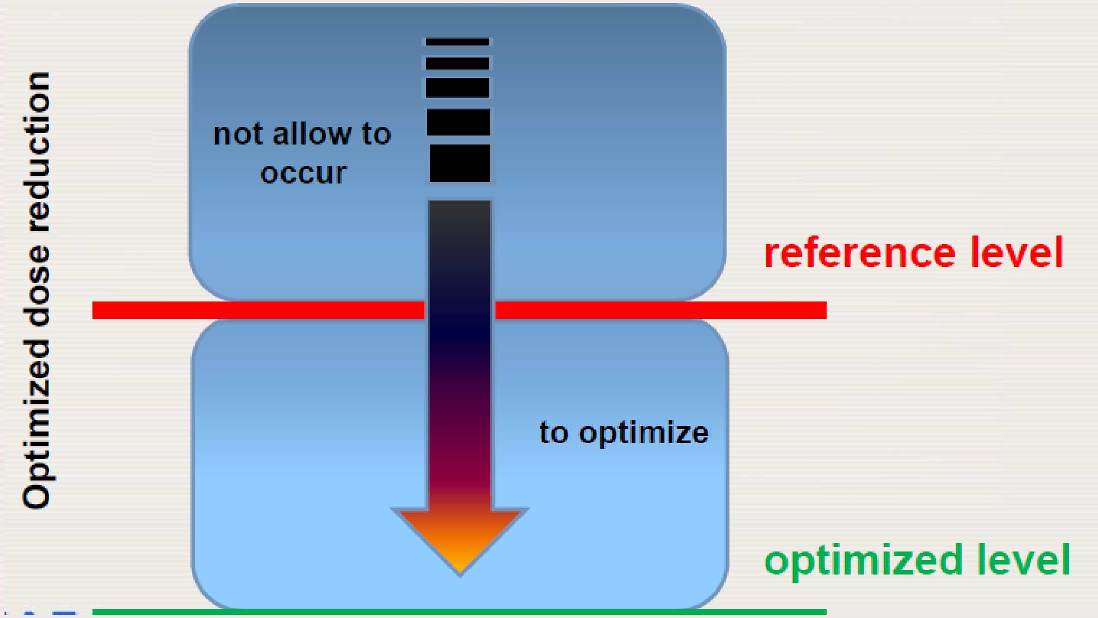
IAEA

Existing exposure situations – reference levels

Reference levels are not the same as action levels

- Action levels are levels at or below which remedial action (and thus the need for optimization) is not normally necessary

- Reference levels are levels above which it is inappropriate to plan to allow exposures to occur, and below which optimization of protection should be implemented
  - Retaining the same numerical value implies a significant increase in the stringency of control



Oil & Gas Industry…..

- A Global industry operating in many countries
- Operating in difficult and diverse work environments
  - climatic and adverse surroundings
  - isolated locations and remote technical support
- Organizationally and technically complex
- Relies heavily on specialised service and supply companies

IAEA

Different types of rigs

- floater rigs operate in shallow water
- deep water
- production platforms and installations

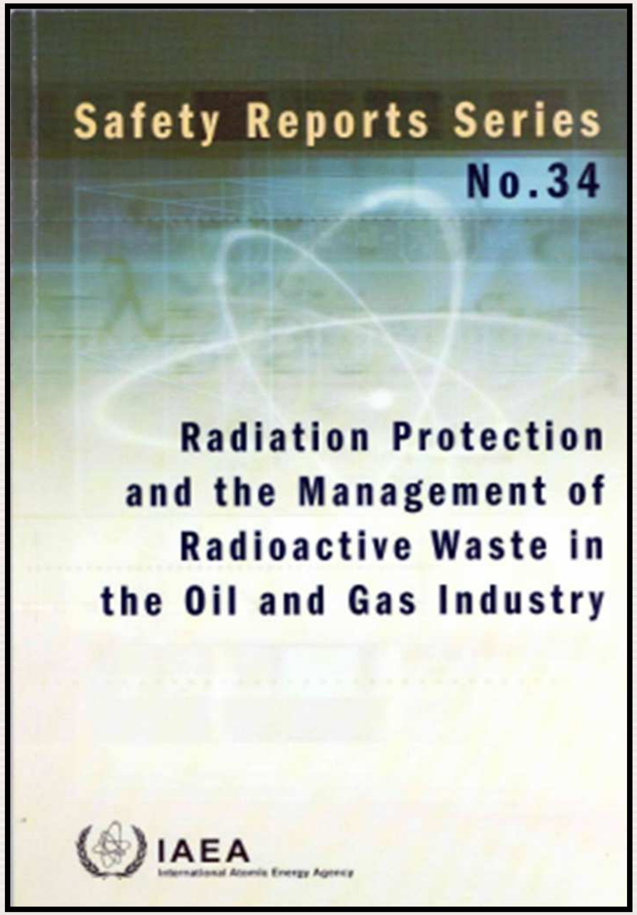
Industry specific conditions

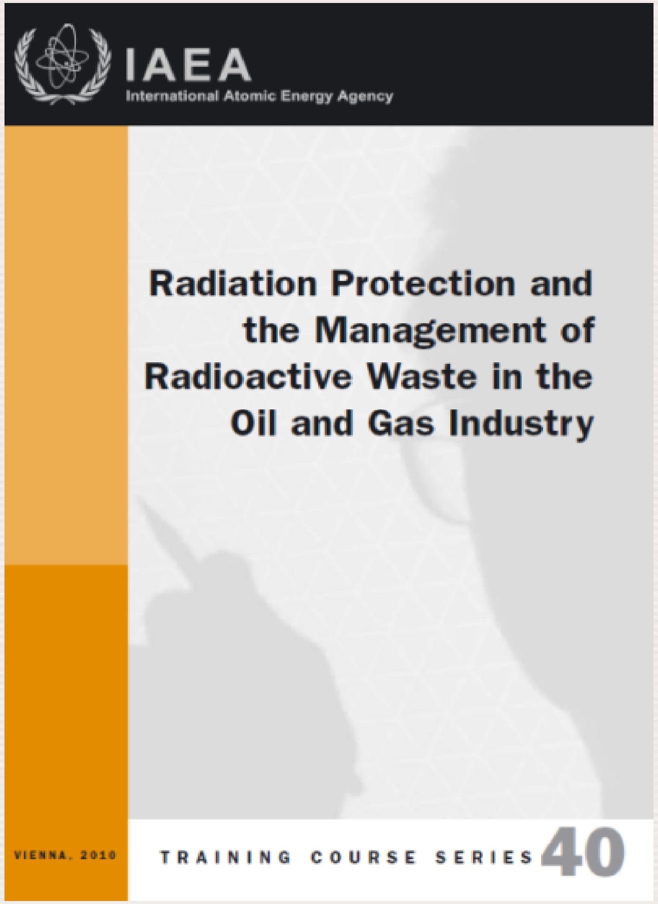
- Onshore & Offshore

Employers : Independents; Majors; Operators; Service and supply companies

- Extensive use of radiation generators and sealed and unsealed radioactive sources
  - radiation sources and generators subjected to extremes of temperature, pressure, etc
  - potentially explosive and flammable situations
  - high mobility of sources shipped-in with other equipment
- Significant quantities of NORM originating from the reservoir rock

IAEA Guidance for Oil and Gas Industry





IAEA Safety Report 34

- THE OIL AND GAS INDUSTRY
- SEALED RADIATION SOURCES AND RADIATION GENERATORS IN THE OIL AND GAS INDUSTRY
- UNSEALED RADIOACTIVE SUBSTANCES
- NORM IN THE OIL AND GAS INDUSTRY
- DECOMMISSIONING OF OIL AND GAS PRODUCTION FACILITIES
- ORGANIZATIONAL RESPONSIBILITIES AND TRAINING IN THE OIL AND GAS INDUSTRY
- APPENDIX
  - RADIATION MONITORING IN THE WORKPLACE .
  - METHODS FOR THE DECONTAMINATION OF PLANT AND EQUIPMENT
  - TRAINING COURSES FOR PERSONS WORKING WITH IONIZING RADIATION IN THE OIL AND GAS INDUSTRY
  - METHODS OF RADIOACTIVE WASTE CHARACTERIZATION

Chapter 5

- Origin and radiological characteristics of NORM
- Main forms of appearance of NORM
- Radionuclide concentrations in NORM
- Radiation protection aspects of NORM
  - Extenal exposure
  - Internal exposure
  - Decontamination of plant and equipment
  - Practical radiation protection measures
- Waste management considerations with respect to NORM
  - Wastes from the decontamination of plant and equipment
  - Waste management strategy and programmes
  - Characteristics of NORM wastes & Disposal methods

sealed sources and generators might be used:

- Construction and maintenance
- Exploration
- Production
- Downstream transport and processing
- Marketing transport and distribution

- *several challenges on sources – beyond the workshop topics*

Occurrence of NORM in the oil and gas industry

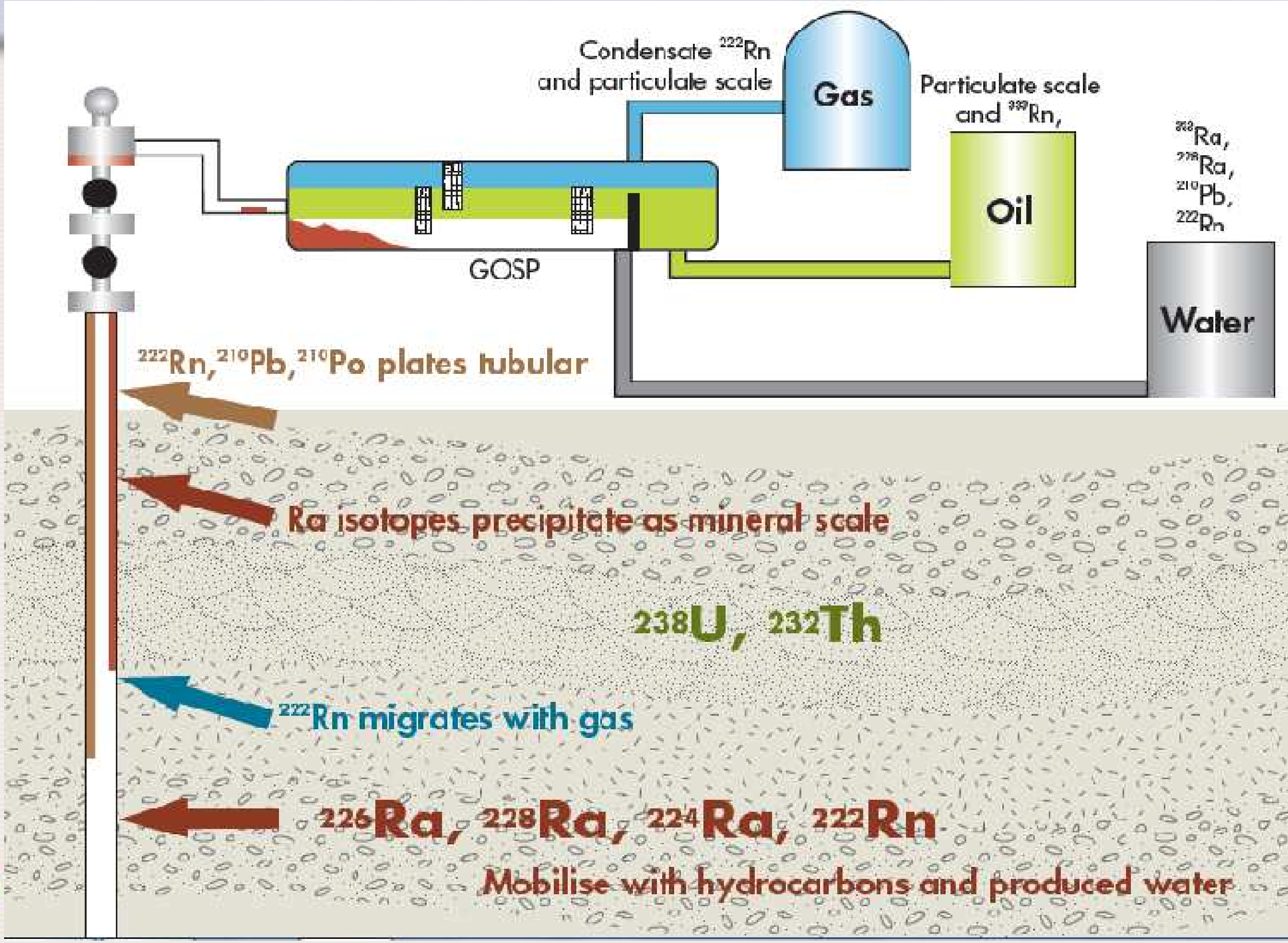
ORIGIN

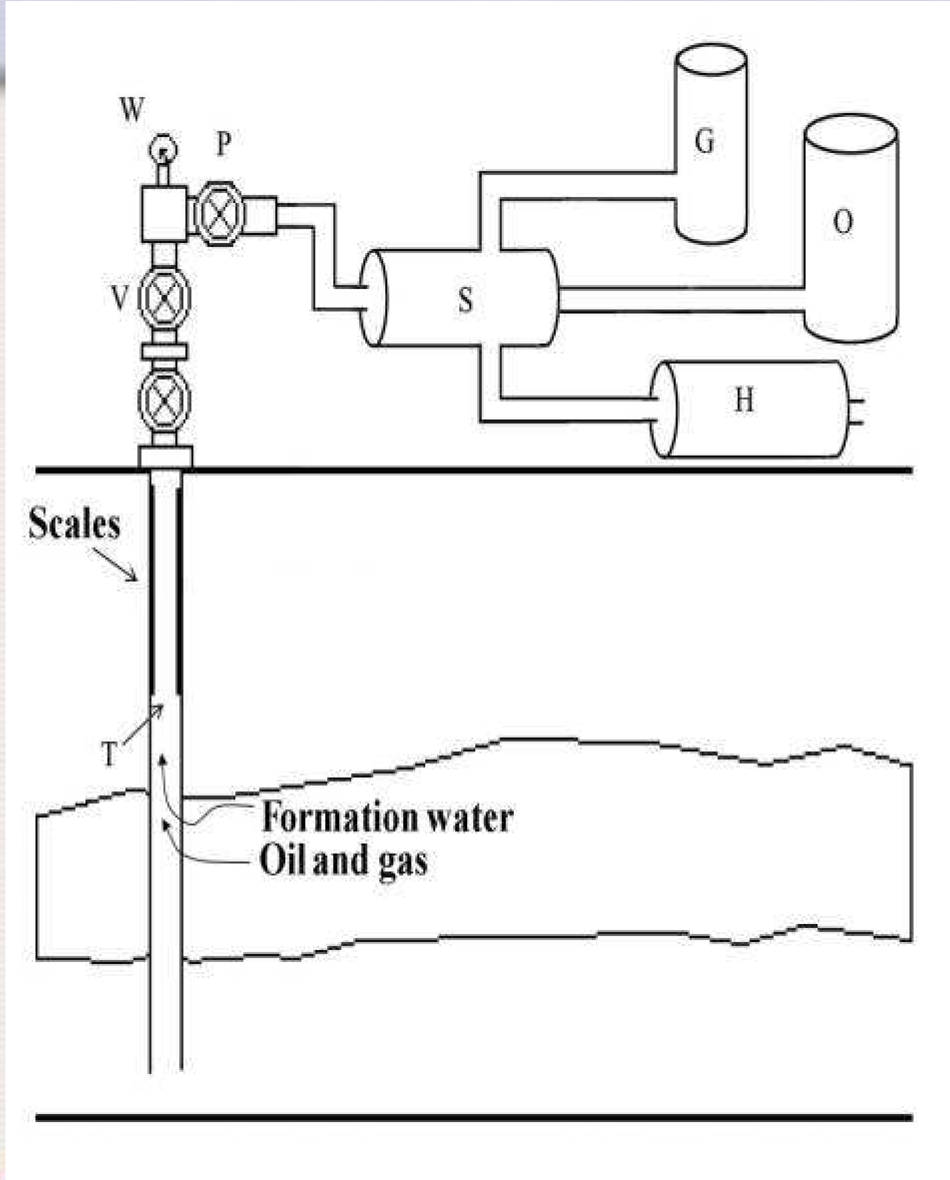
Mobilization and deposition

- Dissolved matter in formation water
- Transport with produced water
- Deposition on insides of pipes, valves, vessels

IAEA

The Origin and potential sites of NORM scales





- T = tubulars
- V = valve
- W= well head
- P = pump
- S = separator
- H = water treatment
- G = gas treatment
- O = oil storage

Why scales occur

- Reservoir water is rich in calcium, barium and strontium ions. Injection water is rich in sulphate ions. When they mix, precipitation of calcium, barium and strontium sulphate occurs.
- Pressure and temperature drops also promote precipitation.
- This causes a layer of scale to form inside production tubing and process vessels.

Where it appears ?

•**Scale appears within the well fluid handling system -**

- **Tubing string (especially tailpipe)**
- **Liner, below the packer**
- **Subsurface Safety Valves**
- **Wellheads**
- **Manifolds**
- **Separators**
- **Oil coolers**
- **Produced water pipework**
- **Service water system, Pig wax, Storage cells ….etc.**

…and how ?

- Incompatible waters mix as they pass through perforations - this starts scale depositing in the tailpipe and tubing, then throughout the plant.
- Deposition is heaviest in areas of turbulence - bends, valves, restrictions.
- Also where temperature or pressure changes occur - chokes, separators, coolers.
- Separator deposits - clays may absorb radionuclides directly from water.
- Service water systems probably due to concentrating natural radioactivity from seawater.

IAEA

Looks like…

- Pure barium sulphate scale is hard dense white solid. (this could be the case in tubulars).
- usually light or dark brown.
- Can be stratified, like rings in a tree trunk.
- Sometimes deep in the surface matrix, so not visible.
- Separator sludges are granular suspensions.
- Pig waxes are black tarry materials, often with chunks of rust and scale mixed in..

IAEA

Radionuclides in Scales/Sluges

Radium containing deposits formed from

- dissolution of alkaline earth elements in formation water
  - calcium, strontium, barium
  - radium-226, radium-228
- mixing with injected water, temperature and pressure drop
- deposition as carbonate and sulphate scales

Deposits containing Pb-210

- Lead from reservoir
  - dissolution of lead in formation water
  - mixing with injected water, temperature and pressure drop
  - deposition as Pb, PbS

- Pb-210 deposits from Rn-222
  - Gas treatment and transport equipment

- Pb-210 deposits from Ra-226
  - Decay of Ra-226 in carbonate and sulphate deposits

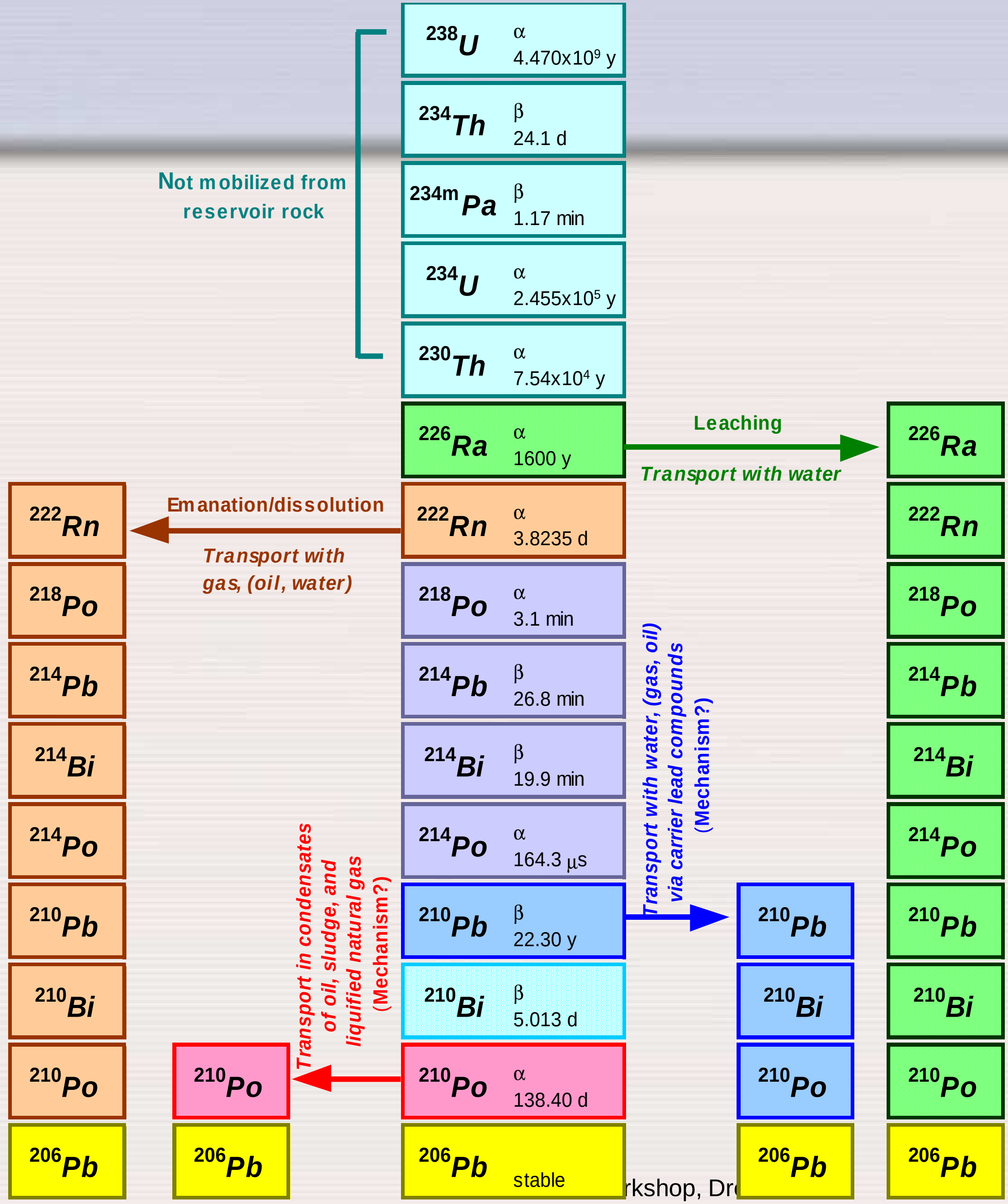
Scales. Sludge, deposits, films

Radium scales	Radium sludge	Lead deposits	Lead films
^{226}Ra, ^{228}Ra, ^{224}Ra & progeny	^{226}Ra, ^{228}Ra, ^{224}Ra & progeny	^{210}Pb & progeny	^{210}Pb & progeny
Hard deposits containing sulphates and carbonates of Ca, Sr, Ba • wet parts of production installations • well completions	Sand, clay, paraffins, heavy metals • separators • skimmer tanks	Stable lead deposits • wet parts of production installations • well completions	Very thin films • oil & gas treatment and transport

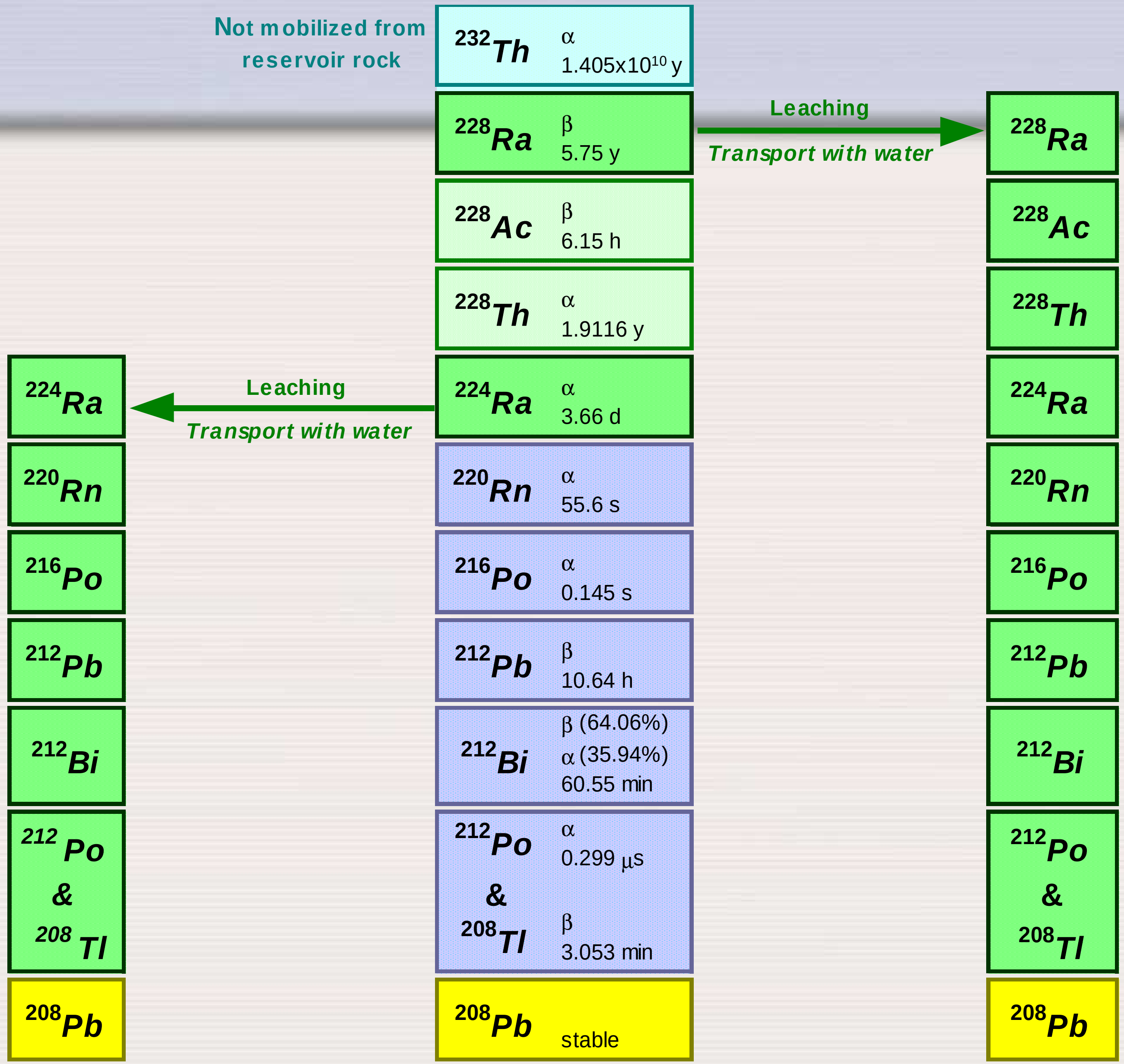
•More …

•More …

Polonium films	Condensate	Natural gas	Produced water
^{210}Po & progeny	^{210}Po	^{222}Rn, ^{210}Pb, ^{210}Po	^{226}Ra, ^{228}Ra, ^{224}Ra, ^{210}Po
Very thin films • condensate treatment facilities	Unsupported • gas production	Noble gas, plated on surfaces • consumers domain • gas treatment and transport	More / less saline, large volumes in oil production • each production facility



^{238}U α 4.470x10^{9} y
^{234}Th β 24.1 d
^{234m}Pa β 1.17 min
^{234}U α 2.455x10^{5} y
^{230}Th α 7.54x10^{4} y
Not mobilized from reservoir rock
^{226}Ra α 1600 y
Leaching
Transport with water
^{222}Rn α 3.8235 d
Emanation/dissolution
Transport with gas, (oil, water)
^{218}Po α 3.1 min
^{214}Pb β 26.8 min
^{214}Bi β 19.9 min
^{214}Po α 164.3 μs
^{210}Pb β 22.30 y
^{210}Bi β 5.013 d
^{210}Po α 138.40 d
^{206}Pb stable
Transport with water, (gas, oil) via carrier lead compounds (Mechanism?)
Transport in condensates of oil, sludge, and liquified natural gas (Mechanism?)
^{226}Ra
^{222}Rn
^{218}Po
^{214}Pb
^{214}Bi
^{214}Po
^{210}Pb
^{210}Bi
^{210}Po
^{206}Pb


Not mobilized from reservoir rock
232Th α 1.405x10^10 y
228Ra β 5.75 y
228Ac β 6.15 h
228Th α 1.9116 y
224Ra α 3.66 d
220Rn α 55.6 s
216Po α 0.145 s
212Pb β 10.64 h
212Bi β (64.06%) α (35.94%) 60.55 min
212Po α 0.299 μs
&
208Tl β 3.053 min
208Pb stable
Leaching
Transport with water
228Ra
228Ac
228Th
224Ra
220Rn
216Po
212Pb
212Bi
212Po & 208Tl
208Pb
Leaching
Transport with water
224Ra
220Rn
216Po
212Pb
212Bi
212Po & 208Tl
208Pb

IAEA

Radionuclide Concentrations

- Ra-226, Ra-228 and Ra-224 in scales and sludge range from less than 0.1 Bq/g up to 15 000 Bq/g
- Ra isotopes lower in sludge than in scales
- Pb-210, which usually has a relatively low concentration in hard scales but which may reach a concentration of more than 1000 Bq/g in lead deposits and sludge.
- Th isotopes not mobilized from reservoir rock but possibility of Th-228 ingrowth from Ra-228

IAEA

Analytical Aspects

Sludges and scales

- Sample preparation – dry and homogenize
  - can be problematic with glycol and oil residues present
- For ^{226}Ra 186 keV can be used in gamma spectrometry
  - check for absence of U on 63.5 keV of ^{234}Th
- If U is present use ^{214}Pb or ^{214}Bi for ^{226}Ra
  - ensure secular equilibrium in gas-tight geometry

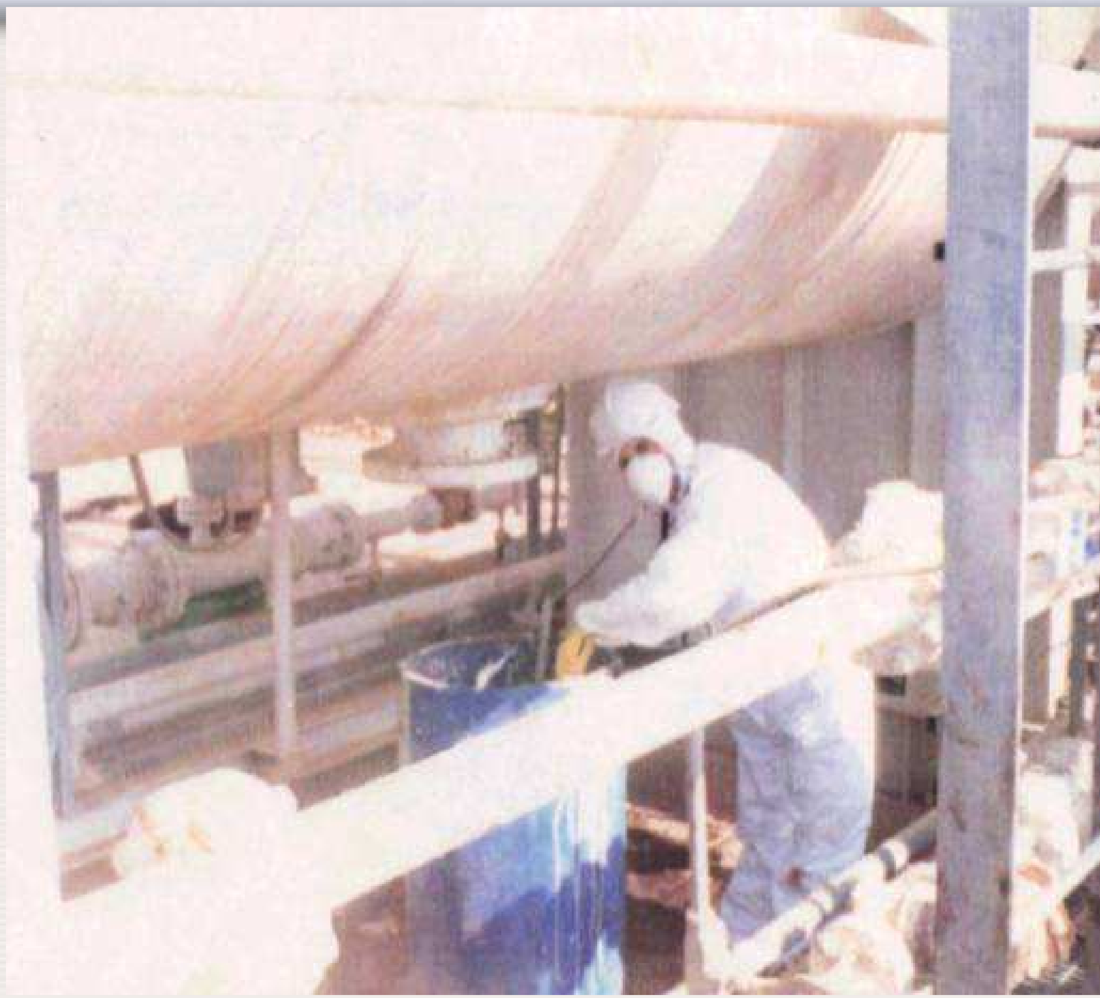
ANALYTICAL ASPECTS

Produced water, without pre-concentration

- At levels > 10 Bq/L
  - Direct gamma measurement
- At levels < 10 Bq/L
  - Precipitation of ^{226}Ra, ^{210}Pb, ^{228}Ra, ^{228}Th
  - Separation of activity as solids

Decontamination methods

- Manual removal and vacuuming
  - simple equipment
  - removal of loose material
  - transfer of slurries and sludges



Decontamination methods

- Mechanical removal
  - drilling and reaming
  - airborne risks from dry gritting, milling, grinding and polishing
  - removes hard scale
  - better used wet
  - scales recovered
  - specialized

Decontamination methods

- Chemical descaling
  - *in situ* and at decontamination facilities
  - uses acids and complexing agents
  - acts on surfaces otherwise inaccessible
  - *in situ* to remove scales that interfere with safety and/or production rate
  - produces chemical and radioactive liquid waste

IAEA

Decontamination methods

- High pressure water jetting (HPWJ)
  - 10–250 MPa water with fine sand for extra abrasion
  - retain mists, water and radioactive contamination
  - specialized use of pumps and safety precautions
  - facilities onshore but also used offshore

Decontamination methods - Melting

- few facilities authorized to accept contaminated scrap
- risk of contaminating vehicles, storage areas, cranes and scrap cutting system
- NORM taken into slag or released in the off-gas dust and fumes
- recovery of contaminated slag, off-gas filters, etc

WASTE MANAGEMENT

Wastes arising

- produced water
- sludges and scales
- surface contaminated items
- solid waste from decontamination
- liquid and chemical waste from decontamination
- solids from decommissioning processes
  - slag, flue dust, airborne contamination, off-gas filters

General considerations

- Volumes
  - produced water: 1.5 to 30 m^3/d (gas), 2400 to 40 000 m^3/d (oil)
  - sludges and scales: <1 to >10 t per year
- Wide variation in activity concentrations
  - Produced water: typically a few Bq/L, maximum a few hundred Bq/L for ^{226}Ra, ^{228}Ra, ^{224}Ra, ^{210}Pb
  - Sludges/scales: <1 to >1000 Bq/g for ^{226}Ra, ^{228}Ra, ^{224}Ra + progeny
- Non-radioactive constituents
  - toxic hydrocarbons
  - heavy metals, e.g. Hg, Pb, Zn
- Regulatory approaches
  - still being developed in most (all?) countries

General considerations (cont'd)

- Choosing the right disposal option
  - Essential part of radwaste management programme
  - Start at an early stage of the project
  - Must comply with national and international legal requirements
  - Optimize occupational and public doses – minimize risk to humans and environment but be cost-effective
  - Risk assessment essential for all disposal options requiring regulatory authorization

General considerations (cont'd)

- What are the basic disposal options?
  - Dilute and disperse – authorized liquid, liquid/solid, and gaseous discharges
  - Concentrate and contain at an authorized facility
  - Process the waste, e.g. by incineration or other methods
  - Reinject into reservoir
  - Clearance from regulatory control – must meet regulatory criteria based on total annual activity or activity concentration

Produced water disposal options

- Large volumes preclude storage or treatment
- Disposal by reinjection into the reservoir
  - Used onshore and offshore
  - May have production implications (breakthrough)
  - No radiological implications apparent
- Disposal by discharge to the sea and estuaries
  - Risks depend on local conditions and potential exposure pathways – may need to be assessed
  - Regulator may set discharge levels (total annual activity, activity concentration) below which authorization not required
  - May be subject to maritime conventions (London, OSPAR)
- Disposal by discharge to seeping ponds

Disposal of produced water by discharge to seeping ponds

(seepage pits, artificial lagoons)

- Impact depends on
  - activity concentrations and volume of produced water
  - proportion of activity contained in deposited salts
  - dilution into local surface and ground waters
- A form of waste treatment – “concentrate and contain”

IAEA

Disposal of produced water by discharge to seeping ponds

- Particular issues:
  - Selection of suitable sites
  - Access controls
  - Impact on surface & ground water
  - Cleanup and remediation costs
  - Satisfactory final disposal of residues

IAEA

Disposal options for sludges and scales

Widely used options

- Discharge from offshore facilities into the sea
- Injection into hydraulically fractured formations
- Disposal into abandoned wells
- Land farming and land spreading

- *limited use*
  - Surface disposal (shallow land burial)
  - Melting as furnace scrap for recycling

- *Studies only*
  - Deep underground disposal

Disposals of sludge and scales to sea

Possibly subject to:

- National policy restrictions
- Restrictions on
  - residual hydrocarbons
  - particle size
  - annual activities
- Assessments of
  - exposure pathways
  - environmental impact
- Controls on exposure of rig workers, divers, fishermen etc.

IAEA

Disposal of sludge and scales by land farming / land-spreading

- With or without dilution
- Acceptability issues relating to sludges containing heavy metals and toxic hydrocarbons
  - worker and public doses
  - regulatory aspects
- Need to consider risk of groundwater contamination

Surface disposals of sludges and scales (shallow land burial)

- Poor option for sludges if non-radioactive contaminants present
- Considerable remediation problems arising from earthen pit disposal of scales
- Stability, economic, technical and practical factors
  - Site selection – take maximum advantage of natural site characteristics
  - Climate, meteorology, hydrology, flooding
  - Geography, geology, geochemistry, geomorphology
  - Seismicity, mineralogy, demography, land use
  - Anticipated duration of facility – temporary or final
    - for temporary – consider amenability to decommissioning and subsequent final disposal
  - Consider impacts on groundwater

Disposal of contaminated metal scrap by melting and recycling

- Eliminates need to decontaminate hardware
- Low residual activity in steel billet
- Wastes
  - Most radionuclides dispersed in the slag
  - Volatile radionuclides (^{210}Pb, ^{210}Po) dispersed in off-gas (dust, fumes)

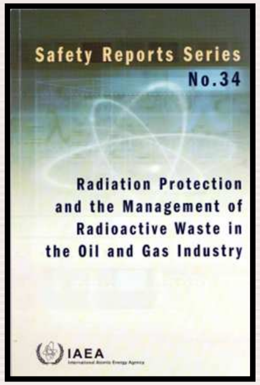
- Mix with uncontaminated scrap
  - Allows clearance of steel billets
  - Facilitates authorized disposal of slag, flue dust and filters
- Occupational exposure
  - Mainly dust inhalation from handling, transporting, storing, segmenting, cutting, shearing of scrap

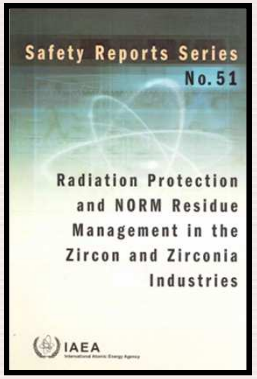
- Metal dealers monitor for orphaned sources and may reject all radioactivity because of legal liability concerns

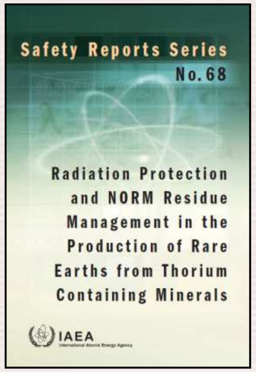
Disposal of sludges and scales by deep underground disposal ??

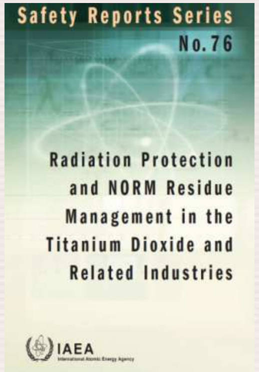
- Studies done for high & intermediate level radioactive waste from nuclear fuel cycle
- May utilize salt caverns, disused metal mines
  - dependent on proximity of non-operational mines to oil and gas production regions (transport costs)
- Costs to set up, operate and maintain the repository may be high relative to alternative options
- Waste treatment, handling and packaging need to be considered

IAEA Industry Specific Safety Reports

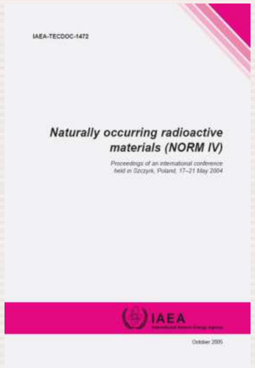








•Phosphate Industry



NORM 7 Symposium - 2013

Beijing, China

April 22-26, 2013

More information : **www.norm7.org**

Deadline for abstract submission : 15 December 2012

IAEA

Many thanks for your attention

E-mail: P.P.Haridasan@iaea.org

IAEA