IAEA
International Atomic Energy Agency

CHARACTERIZATION OF NORM

Content

- NORM analysis – purposes
- Radionuclides of interest
- Sampling
- Analytical Techniques
- Key messages

NORM Characterization-Purposes

- Understand preoperational baseline radiation levels
- Understand characteristics of materials (ore, wastes, residues etc.)
- For regulatory purposes (to determine of classification – exemption and clearance from regulation)
- For additional information on dose assessments
- Remediation goals for areas contaminated with NORM
- Informed decision making on management of NORM residues and waste

Baseline Background Radiation Surveys

- To characterize the undisturbed natural levels of radionuclides in the environment prior to construction and operation of large scale industrial activities involving NORM
- These levels can be used as reference levels during the remediation and closure of the industrial operation.
- Samples of interest
  - Surface soils (the top 40 cm)
  - Surface and groundwater's (dissolved activity)
  - Fallout dust
- The environmental levels of natural radionuclides are generally very low and the analysis methods require high sensitivity with low levels of detection

Understanding the NORM Material

- Understand radiological properties
  - A total of 36 radionuclides are found in the ^{238}U (14), ^{235}U (11) and ^{232}Th (11) decay chains.
  - In the analysis of a NORM material a decision is required on which radionuclides require to be analyzed and quantified.
  - Mainly focus on long lived radionuclides.

- Understand non radiological aspects (which may impact on the controls)
  - Material may have acid forming minerals
  - Solubility of host materials
  - Does material easily form dust

Focusing on Radiological Aspects Only

- Consider the long lived alpha emitters
  - Uranium series: **^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po**.
  - Thorium series: **^{232}Th, ^{228}Ra and ^{228}Th**.
  - These radionuclides can give rise to internal exposures
- Consider significant gamma emitters (^{208}Tl, ^{228}Ac, ^{226}Ra etc.)
- Consider radon and thoron (and decay products)
- Characterisation may vary depending on the material of interest
  - For unprocessed material, U and Th decay chains can be assumed to be in secular equilibrium. In these cases only the parent radionuclides (ie; U and Th) require to be analyzed.
  - For processed materials, need to understand what radionuclides are present and their concentrations

Regulatory Purposes

- Make a decision on the regulatory regime (i.e.; the graded approach to regulation)

- Make a decision on the regulatory control to be implemented

- Checking the measures that the operator provides for the protection of the workers, members of the public and the environment.

Additional Information for Dose Assessment

- Radiological characterization of workplaces
- For contributing to the routine dose assessment of workers, for example; assessing the inhalation of long lived alpha emitting radionuclides and interpretation of dust sampling results.
- For contribution to specific dose assessment of worker, for example; bioassays

Bioassay Monitoring

The radioactive material in the body may need to be assessed in special circumstances:

- Specialized work situations (e.g. uranium product sections)
- Suspected over-exposure investigations

A variety of methods may be used:

- Urine analysis (e.g. uranium product sections)
- Faecal analysis (e.g. uranium and thorium facilities)
- Lung counting
- Radon or Thoron in breath

Fore Remediation Purposes

- The large scale use of NORM in industrial activities can result in the contamination of the environment (e.g. surface soils) with radionuclides of the uranium and thorium decay chains

- Characterizing any NORM contamination is a necessary step in deciding the optimum future management of that land e.g.
  - predicting future impacts (doses to public and the environment)
  - Selection of remediation measures that will work
  - Worker protection during remediation

- The remediated site may also need to be surveyed and sampled to confirm remediation has been successful

Optimized Management of NORM residues and waste

- The management of such materials should be optimized:
  - ensuring workers and the public are protected
  - minimizing disposals (e.g. recycling or use as construction or building materials)
  - Cost effective
- Good information obtained through appropriate characterization is an essential part of the optimization process

Sampling

The materials requiring sampling and analysis include:

- Large quantities with moderate or low activity concentrations (e.g. ore, tailings, slag, sludges, evaporates) ranging up to a few Bq/g per radionuclide

- Small quantities with the possibility of high activity concentrations (e.g. mineral concentrates, scale, sludge, precipitator dust) ranging up to tens of thousands of Bq/g per radionuclide.

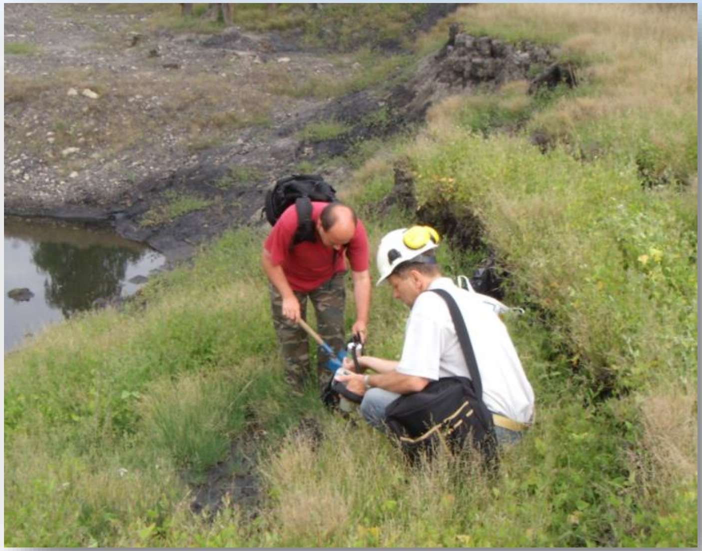
- Therefore the sampling method and analysis sensitivity requirements will vary depending upon the nature of the material and the type of assessment.

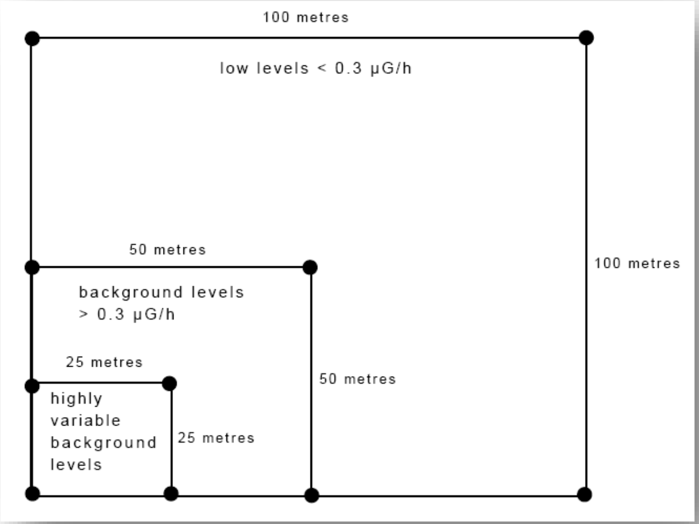
Sampling

- The sampling strategy selected will depend upon the type of material
- The sampling techniques should be based upon a statistically rigorous criteria
- It is important to obtain a representative sample of material for analysis
- Many samples may require to be taken, mixed and homogenized to obtain a representative sample

Elements to consider in Sampling Strategy

- The total number and location of sampling sites (site specific)
- The frequency of sampling
- The method of sampling (grab-continuous)
- Sample preservation techniques
- Identify representative person of
- the public and sensitive areas.





Introduction to Analytical Techniques

- There are various analytical techniques available to quantify the radionuclide content of materials
  - Radiometric techniques (e.g. alpha, beta or gamma spectrometry)
  - Other analytical techniques (e.g. mass spectrometry)
- To be able to select the appropriate techniques, it is important to understand:
  - the capabilities and limitations of the various techniques
    - Selectivity (specific radionuclides, multiple radionuclides or type of radiation)
    - Sensitivity (Limits of detection)
    - Range of concentrations measurable (e.g. from 10 to >10^6 $Bq.kg^{-1}$)
  - technique complexity
  - costs

Analytical Techniques- Gamma Spectrometry

- Gamma spectrometry can detect and measure multiple radionuclides at the same time

- Relatively simple sample preparation

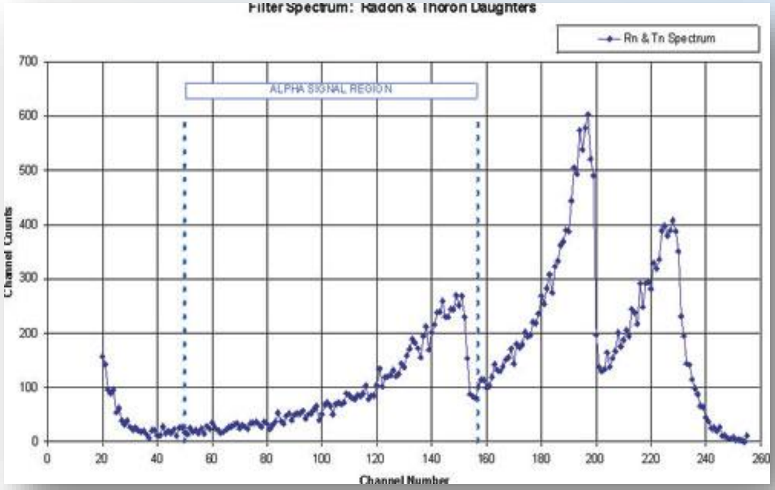
- Relatively short counting times (4-8 hours)

- Different instrument required for low energy gamma emitters (mainly for ^{238}U, ^{235}U, ^{210}Pb)

- Relatively inexpensive

Analytical Techniques- Alpha Spectrometry

- Key method for identifying alpha emitters
- Suitable for measuring very low concentrations
- Complex sample preparation required - radiochemical extraction
- Time consuming
- Expensive



Analytical Techniques- Proportional counting

- Provides information on alpha and beta content
- Cannot identity radionuclides
- Relatively simple sample preparation (thin layer)
- Relatively short count times
- Relatively inexpensive

Analytical Techniques- Liquid Scintillation Counters

- Provides information on alpha and beta content

- Cannot identity radionuclides

- Relatively simple sample preparation but needs to be put in solution

- Relatively short count times

- Relatively inexpensive

Analytical Techniques- INAA

Instrumental neutron activation analysis (INAA):

- A highly sensitive technique
- The sample material is irradiated by neutrons in a nuclear reactor.
- Activation products are formed and are then assessed using gamma spectroscopy.

Other Analytical Techniques-XRF

The XRF (X ray fluorescence spectrometry) method is well suited to the rapid determination of elemental uranium and thorium concentrations in solid samples

- Total U and Th can be detected to very low levels e.g. 1-2 ppm

- The method is useful as a screening technique

- The calibration of the XRF must be specific to the type of material being analyzed e.g. mineral ore, soils, scale, sludge etc.

Other Analytical Techniques-ICP-AES

Inductively coupled plasma atomic emission spectroscopy (ICP-AES):

- Used for the chemical analysis of aqueous solutions of rocks and other materials
- Suitable for the determination of a wide range of major elements and a limited number of trace elements.

Other Analytical Techniques-ICP-MS

Inductively coupled plasma mass spectroscopy (ICP-MS):

- ICP-MS can be used to determine trace elements at environmental levels.
- The technique is well suited to determination of total uranium and thorium.

PPM Conversions

- The above analytical techniques provide the analysis results in ppm total uranium or thorium.

- The following conversions from parts per million to Becquerel's per gram per radionuclide can be used

- 1 ppm uranium = 12.3 mBq ^{238}U per gram of material;

- 1 ppm thorium = 4.1 mBq ^{232}Th per gram of material.

Analytical Technique Selection

- Analytical technique selection will depend on your needs and should be fit for purpose
- For NORM associated with most industrial processes, it is adequate to have a basic analytical infrastructure (eg; XRF, HPGe gamma spectrometry)
- Techniques can be complimentary and used in combination if necessary e.g.
  - Gross alpha-beta counting for routine measurements
  - Radionuclide specific analysis when further detail is required

- The more complex radiochemical techniques more likely to be required for:
  - Background baseline surveys
  - Liquid effluent discharges from NORM facilities
  - Industrial processes where ^{210}Pb and ^{210}Po is of concern

Quality Assurance

- The analysis should be carried out by an ISO accredited laboratory and the methods will be documented.
- The analytical standards and methods must be traceable to national and international standards. Such a laboratory would carry out regular intercomparison exercises.
- If an accredited laboratory is not available the analytical technique must at least be validated against appropriate reference materials (e.g. NORM related materials provided by IAEA or other national/ international bodies)

Key Messages

- Characterisation of NORM is required for a number of important purposes
- There are a number of standard techniques for sampling, measurement and analysis of NORM
- Make sure your selection of techniques are appropriate
- Use of an accredited laboratory for analyses
- Seek competent assistance and advice if necessary