EMRAS

Working Group on modelling of naturally occurring radioactive materials (NORM) releases and of remediation benefits for sites contaminated by extractive industries

Minutes of the 1st Working Group Meeting

IAEA Headquarters, Vienna, 1st-5th September 2003

This working group started its discussions without any previous experience or preparation, as the Agency has not had any involvement with NORM other than on the regulatory side (Meeting in Vienna, September, 2002).

Potential issues, which were seen as important for consideration by the working group, were summarised as a result of the preliminary discussions as

- What information is available now?
- Why are we doing this?
- How is NORM different from problems involving anthropogenic radionuclides in the environment?
- How is NORM similar to problems involving anthropogenic radionuclides in the environment?
- Should models be industry specific?
- What models are already available?
- What problem are we solving?
- Micro-scale or macro-scale?
- Remediation issues

It was agreed to approach the problem in terms of the major topics and/or issues listed below:

- STAKEHOLDERS
- SCOPE
- How is the NORM problem different from other problems?
- How is the NORM problem similar to other problems?
- THE OVERALL MODELLING PROBLEM
- REMEDIATION ISSUES
- ACTION PLAN

A summary of the Working Group's discussions on each of these topics is presented below.

1. STAKEHOLDERS

The consensus of the group was that there are four groups of stakeholders with different (and some common) requirements in terms of outcomes. These are tabulated below.

Stakeholders	Expected outcomes
Industry	A list of models that can be used for assessment of the impact of manufacturing or disposing of materials containing NORM that result from the operations of the particular industry, together with an evaluation of the suitability and reliability of the models Data sets that can be used to check and/or verify an available model, together with an evaluation of the reliability of the data and the uncertainties in the data
Public	Proof of safety Trust in the procedures (models, data acquisition, assessment procedures)
Governments/Regulators	Proof of compliance Trust in the procedures
Modellers	A clear statement of the problem Validated and appropriate data sets for model development, testing and verification

2. SCOPE

The basic questions concerning the Scope of the working group were presented as:

- In what situations is NORM important?
- Radionuclides – which radionuclides are to be considered
- Pathways – which pathways are important for transfer of NORM, both in release to the environment and transfer through the environment?
- Processes – which transfer processes are important?
- Local factors – how should site-specific factors/issues be addressed?

A discussion of the scope of this program led to the following conclusions:

1. Radon in homes is not within the scope of this program. This includes radon released from building materials and soil gas.
2. Radon release from stacks, waste rock piles, ore stock piles, into the environment is within the scope of this program.
3. Issues arising from the nuclear fuel cycle (U-238 in spent fuel rods) are outside the scope of this program.
4. The construction industry is outside the scope of this program.
5. Situations where NORM is important include
    - Tailings (wet and dry)

- Shallow ground burial of wastes
- Smelter stacks and coal-fired power station stacks (volatilisation of Po)
- Waste rock piles
- Retention ponds
- Scales and sludges
- Residues and legacy wastes
- Building materials
- Land fill

There is a wide range of industries that generate NORM products or wastes. The types of industries (industrial operations) to be considered are summarised in the table below.

Industry	Environment	Products and Waste
Mining and milling	Everywhere	Wide range of products and wastes – liquids and solids
Oil & gas production	Marine & on-shore	Scales, sludges
Mineral processing	Everywhere	wide range of products and wastes – liquids and solids
Power generation (fossil fuels)	Everywhere	Solids and gases
Phosphate industry	Everywhere	Liquids and solids

3. How is the NORM problem different from other problems?

The group discussed the differences between problems involved in modelling NORM and the problems associated with other radionuclides. The major differences are summarised below:

- NORM is everywhere!
  - NORM occurs everywhere in the environment as a result of a wide range of human activities. This means that the effects of NORM on humans and the environment are not limited to a small number of sites. This in turn implies that there may be a very wide range of possible site characteristics to be considered, particularly with respect to historical operations.
- Long decay chains

  NORM contains radionuclides that can be single nuclides such as ^{40}K, or radionuclides such as ^{226}Ra which are members of long decay chains. There are several problems associated with these decay chains that are unique to NORM studies:
  - The decay chain radionuclides have a very wide range of physical properties. For example, the 238U chain contains 14 members with radioactive half-lives ranging from billions of years to hundreds of microseconds. Most of these radionuclides occur as solids, but radon is a gas.

- Within the radionuclides in each decay chain there is a very wide range of chemical properties. One of the most important is solubility, as this affects the mobility of the radionuclides in the environment.
- Differences in physical and chemical properties of the radionuclides in the decay chains means that NORM (samples) can contain highly variable mixtures of radionuclides.

- There is a wide range of NORM-generating processes – this problem will be discussed in more detail later.
- There is a wide range of environmental transport processes for NORM – this may make it difficult to assign values to the parameters used in models.
- The background levels of the different radionuclides in NORM are highly variable. This means that
  - It may be difficult to separate operational effects from background, particularly in situations where the industry producing NORM has been in operation for a long time, and no baseline studies were carried out before operation commenced. This may cause difficulties with model verification
- Perception – NORM has not been widely perceived as a potential issue, but
  - In some situations doses to workers or members of the public are higher than in the nuclear power industry
- There is a lack of international standards on manufacture, use, transport and disposal of materials containing NORM

4. How is the NORM problem similar to other problems?

What is similar about NORM and other radionuclides in terms of environmental modelling?

The group then turned to a discussion of the **similarities** between NORM and other radionuclides in the environment. It was agreed that

1. In many cases the processes by which NORM is released into the environment are similar to the processes by which anthropogenic radionuclides are released.
2. The modelling concepts are the same.
3. The transfer processes are the same (bulk transfer, diffusion,)
4. The chemical processes are the same (speciation, ion exchange,)

5. OVERALL MODELLING PROBLEM

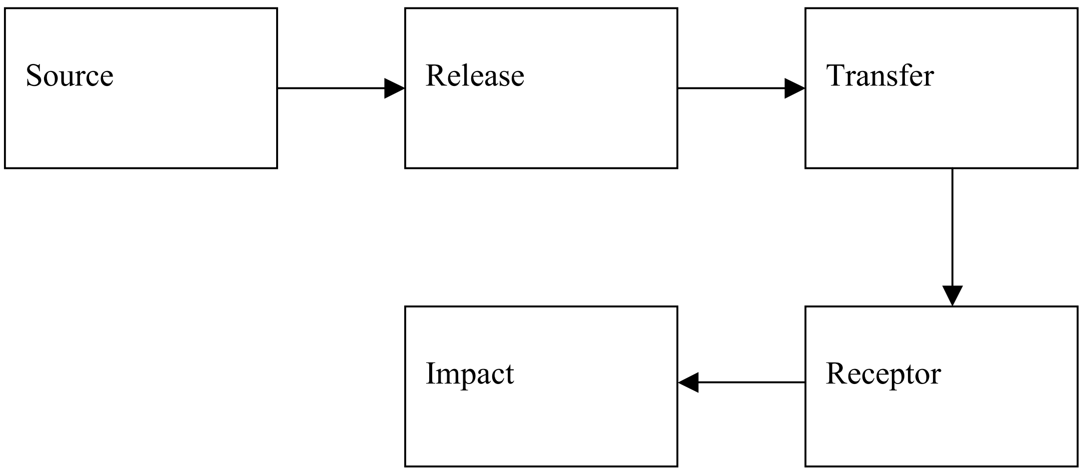
The overall modelling program has several components. Models are required for assessment purposes. These models have to be tested against real data from operations where NORM-containing materials are produced or handled. The data sets and scenarios used for developing and testing models must be carefully checked and validated. These issues were discussed at length and the working group established an approach, which is detailed in the following sections.

5.1 General Approach

As a first step in seeing how the general modelling problem might be approached the group broke the overall problem into three parts as shown in the sketch below:

It was agreed that all stages of the problem require both modelling and measurements (data) for assessment purposes. In particular it was noted that for legacy wastes and residues, modelling of the source could be extremely important.

As the working group's discussions proceeded it became apparent that this three stage approach was not adequate. In particular it was noted that there is a distinct difference in modelling terms between specification of the source configuration (geometry, radionuclide concentrations, etc) and the mechanisms by which these materials are released into the environment. It was also agreed that in modelling terms, there is a difference between receptor, which can be regarded as the distribution of radionuclide concentrations in space and time (measurable by monitoring programs) and impact on humans and/or the environment. Therefore the basic outline of the process was amended to that shown below:



It was noted that this is also the process that would be followed for an assessment problem involving a single radionuclide. It was also noted that, in principal, each radionuclide in a decay chain could be modelled with existing models, with the link between the different radionuclides being provided by a model or module designed to simulate the radioactive decay processes.

The main reasons for separating receptor and impact are

- It may not be necessary to calculate doses in some situations

- There are already models available for estimating doses, if the environmental concentrations of the radionuclides are given

Some other potential issues were also noted at this time

1. Uncertainties in available data plus variations in the background levels may mean that complex or sophisticated models are not needed in many situations.
2. The uncertainties in the transfer calculations may be large enough to make dose estimates (with the extra uncertainties introduced in the process of calculating the doses) meaningless.
3. Dose cannot be measured.

5.2 Modelling requirements

Most existing models for assessing the effects of materials containing radionuclides on the environment and on human health have been developed to aid in the assessment of problems associated with the nuclear power industry. These models may be applicable to NORM, but it is not obvious that this will be so in all cases.

The working group discussed the problem of providing models for testing the impact of NORM-containing materials. It was agreed that

- These models must be tested against appropriate data sets.
- Models that are submitted for testing in this program must have a description provided by the model developer(s). This must include
  - A concise description of the modelling approach used
  - A clear statement of the assumptions used in the model
  - A description of the approach to modelling processes (e.g. transfer coefficients, diffusion coefficients, transfer times, etc.)
  - A description of the transfer pathways included in the model
  - An indication of the limitations of the model
  - An indication of model applicability – where the model should and should not be used

  This information should be provided by the model developer(s) and should be modified, refined, etc. as part of the testing/verification process.
- Peer review is an essential part of the modelling development/testing/verification process
- As pointed out by one of the other working groups, ANALOGY is a very useful tool for driving expert judgement(s)
- It will be very important to maintain good communication with the aquatic/watershed working group and the TRS-364 revision working group
- Obvious gaps in the existing models need to be identified
- The physical scale of the problem can determine the type of model used
- Horizontal distances tend to be much larger than vertical distances, for most environmental problems
- There is a very wide range of time scales involved in modelling NORM, not just in terms of environmental processes, but due to the physical properties of the radionuclides

There are two types of models that can be used for this work:

- Scenario-based models – these models tend to include all stages of the general problem
- Process-based models – these models tend to concentrate on the individual stages of the general problem

Models of source terms and configurations - these need to be able to accurately reflect the configuration of the source

Release models

These include

- Acid rock drainage models
- Leaching models
- Dust suspension/resuspension models
- Stack discharge models
- Radon exhalation models

Transfer models

These include

- Air dispersion models
- River and estuary models
- Marine dispersion models
- Surface run-off models
- Groundwater models
- Models of biological systems (animals, organisms)

Impact models

Types of impact models/processes/pathways include models for

- Inhalation
- Ingestion
- External exposure
- Injection/absorption of radionuclides

It was also noted that there is a need to provide general advice, particularly to industry, on how to approach environmental modelling problems. The discussion produced a consensus, which can be summarised as

Use a step approach

- Start with simple (screening) models to check plausibility
- If necessary go to more sophisticated models

It was also noted that it is important for the group to be able to provide guidance and advice on the applicability of available data sets for model verification studies

Another issue is that it is important to check whether currently available data sets can to be tested with existing models (assuming both models and data are available).

The group also noted that the approach to modelling NORM in the environment could be to look at the transfer processes, or at the individual pathways from source to receptor.

Data requirements

Data are needed (essential) for use in developing, testing, and verifying models.

One anticipated outcome of this program is the development of benchmark scenarios, with appropriate data for use in testing models.

Since NORM is a worldwide problem, it is also desirable to develop standard scenarios for use in problems where similar environmental conditions apply.

Five generic pathways were identified:

- Airborne
- Surface water (fresh)
- Ground water
- Marine
- Direct (external exposure to gamma radiation)

It was noted that while these generic pathways are relevant to each stage of the overall problem they are given different names in each stage (for example, at the source stage the groundwater pathway is usually described as leaching or acid rock drainage)

It was noted that problems can be treated in two possible ways

- Which pathways are relevant
- Which quantities (radon, dust, air concentration, deposited material) are important

It was agreed very early in the discussions of the group that a review of the existing knowledge base is essential, to determine what models and data are available, and to identify deficiencies and gaps in the existing knowledge

One way of approaching environmental problems is the **scenario-based approach**. For this it is essential to know what codes and data are available.

Availability of data

Some possible scenarios/operations for which data may be available at an early stage of the program are listed below, with a brief indication of the operation, the source(s) of NORM and the associated problems.

Syria

1. Oil fields – production water lagoons – groundwater contamination
2. Phosphogypsum loading dock operations – airborne dust and discharge to marine environment
3. Phosphoric acid plant – airborne dust, surface water contamination, groundwater contamination

Germany

1. Wismut – uranium mine residues and tailings – solid and liquid wastes – groundwater contamination, radon release

2. Th gas mantle manufacturing residues
3. Mansfield – Cu shales – solid and liquid wastes

Belgium

1. Waste repository- uranium-mill tailings and residues- solid waste & some liquid discharge – surface water and groundwater contamination

Ukraine

1. Uranium mining and milling residues - tailings dams, waste rock dumps – ground water contamination
2. Ash around coal-fired power plants
3. Thorium sands

France

1. A number of small sites

Australia

1. Underground copper mine, with U, Au and Ag byproducts – solid and liquid wastes – airborne dust and radon release, groundwater contamination
2. Open-cut uranium mine – mill, tailing dams, ore and waste rock piles – airborne dust and radon release, groundwater contamination, surface water contamination

South Africa

1. Uranium mining – solid and liquid wastes – groundwater
2. Phosphate manufacture – solid and liquid wastes – airborne, groundwater

Canada

1. Uranium mining and milling – solid and liquid wastes – airborne dust and radon release, groundwater contamination

Brazil

1. Niobium mining

The group agreed that it would be necessary to look for other data sets to ensure that a wide range of industrial operations, waste types and climatic conditions are covered. This can be done in several ways

- A literature search
- Personal contacts

There is also a need to highlight gaps in the currently available data, and to check on the access of data

It was also noted that it is important for the group to be able to provide guidance and advice on the applicability of available data sets for model verification studies

6. REMEDIATION

An important application of the models developed for NORM is use in remediation issues. The group noted that modelling would be useful both for predicting the effects of proposed remediation strategies and assessing the effects of strategies after implementation. The group also noted that

- Many remediation strategies involve modification of the source and/or the release processes
- Removal of material may produce a net benefit at one location, but a net detriment at another location

The group agreed that modification of the source would not require the development of different models for remediation assessment, as the modifications would generally involve a change in the configuration of the source or a change (reduction) in radionuclide concentration(s). The group also noted that modifying the release processes would not require the development of different models, except in extremely unusual situations, because, in modelling terms, changing the release processes would generally involve altering the rates at which NORM was released to the environment. An example of this would be injecting material into the soil at a contaminated site to reduce the rate at which water percolated through the contaminated soil; in modelling terms the model used for assessment of the site in its original state could be used with modifications to the rate(s) at which radionuclides are leached into the environment. In general the group agreed that the differences between "normal" assessment problems and remediation assessment problems are not such as to require different *models.*

7. ACTION PLAN

The outline plan produced by the working group for the overall program is summarised as follows:

1. Start of program (planning)
2. Define general scenarios for model testing and verification
3. Call for data sets
4. Refine scenarios
5. Send out scenarios and data to modellers
6. Start intercomparisons between models and between models and real data
7. Compare results
8. Collect more data if necessary, revises and refine models and scenarios
9. Publish

This leads naturally to three practical issues

- How to establish contact with interested outside parties
- Setting up a realistic timetable for the work program
- Assigning tasks to members of the working group

8. SUMMARY AND CONCLUSIONS

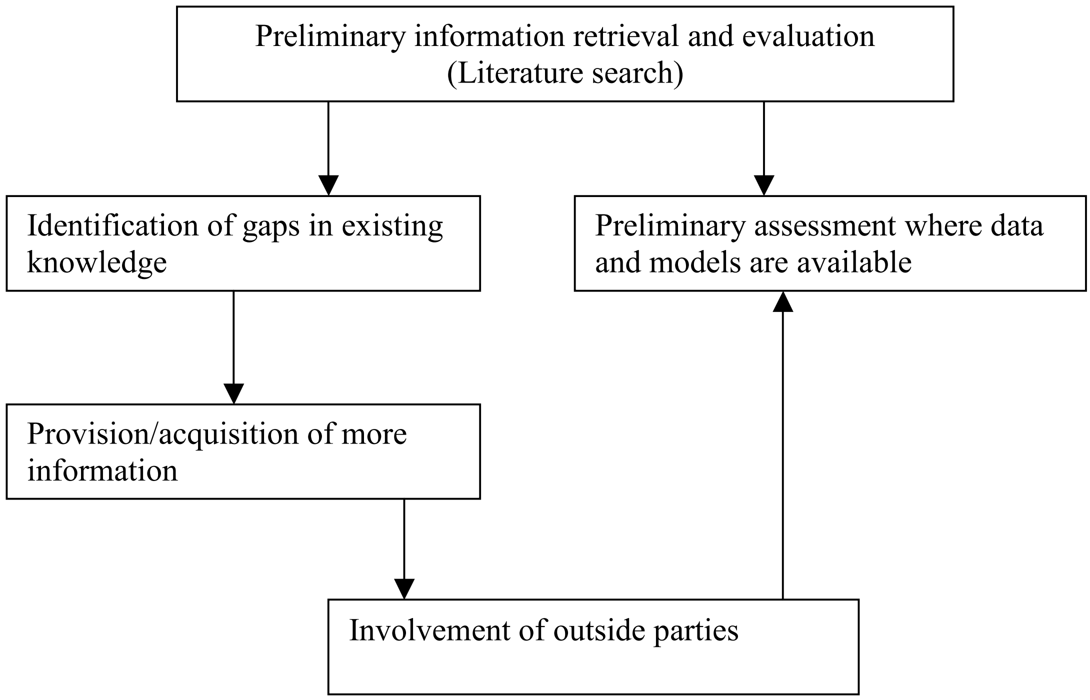
Two important consequences of the similarities and differences between NORM and non-NORM problems are that

1. Model developers will have to demonstrate that models that work for non-NORM radionuclides can be applied to NORM. This cannot be assumed.
2. The working group will have to be careful to develop scenarios, for evaluating and testing models, which are appropriate to NORM issues.

The working group agreed that

- It will be essential to validate data sets before using them for testing and verifying models
- The suitability of proposed models should be assessed against agreed criteria, using the information provided by the model developer(s)
- The model verification process must include the provision of values of parameters and radionuclides at intermediate steps, and a demonstration that these values are "correct". This will help to demonstrate that each model is internally consistent and aid in the checking process.
- An annex to the group's preliminary report could include some examples of the suggested procedure
- It is not essential to include dose calculation in the modelling
- It is essential to maintain the link between measurements and modelling, to ensure that
  - the people doing measurements are aware of the limitations of the modelling
  - the model developers are aware of the meaning and limitations of the data
- It is essential to have a clear idea of what data are required for assessment purposes

The group discussed a work plan for the first stage of the program. This is summarised in the sketch below:



The group agreed that there is a great deal of information available regarding NORM, but not in a form that makes it immediately useful for this program. Therefore the first step is to collect information and evaluate the available information in terms of the requirements of the program. There are three types of information required, NORM industries, available data and existing models.

Task #1: NORM industries

It was decided to compile a list of industries in which materials containing NORM are produced. It is implicit throughout this program that the materials of interest are those in which the natural balance of radionuclides has been disturbed in some significant way.

These industries should be classified in terms of

1. The process(es) by which the NORM is produced
2. The types of NORM (solid, liquid gas; bulk, scales, slurries…)
3. Source configurations (stacks, tailings/retention ponds, spoil heaps, product stockpiles, waste rock piles…)
4. Mechanisms and pathways by which NORM is released into the environment

Personnel: all members of the group

Task #2: Available data

The aim of this process is to search for and collect available data that may be used for assessing and verifying models for use in this program. The data should be classified in terms of the following:

1. Type of data (concentrations of radionuclides in soil, water or air; meteorological data; other; spatially averaged data; time averaged data;..)
2. Uncertainties in the data
3. Have the data been validated?

Personnel: Klaus Gehrcke, Anne-Christine Servant, Constantin Rudya, Mohammad Said Al-Masri, Frank Harris, Rick O'Brien

Task #3: Existing models

This task involves searching for existing models, listing them and classifying them in terms of the following:

1. The scale of the problem addressed by the model (local, regional; microscale, mesoscale…)
2. The type of model (K-model (diffusion), , compartment)
3. The types of processes include in the model (K_d model (partitioning between phases), speciation, convection, diffusion…)
4. The types of pathways include in the model (direct exposure, airborne, surface water, ground water, marine)

Personnel: Olaf Nitzsche, Theo Zeevaert, Rick O'Brien

It was also agreed by the group and strongly emphasised that communication between the people working on tasks #2 and #3 is essential

Time scales: Tasks 1-3 should be achievable within 3 months

The process of assessing available models should be started as soon as suitable data sets and models are identified, without waiting for the entire information –gathering process to be completed.