CHEMICAL ENGINEERING TRANSACTIONS

VOL. 28, 2012

Guest Editor: Carlo Merli

ISBN 978-88-95608-19-8; **ISSN** 1974-9791

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

DOI: 10.3303/CET1228031

Decommissioning and Remediation of NORM/TENORM Contaminated Sites in Oil and Gas

Michele Peroni, Valerio Mulas, Emanuele Betti, Leonardo Patata, Paolo Ambrosini

Saipem S.p.A. - Via Toniolo 1, 61032, Fano (PU) – Italy
paolo.ambrosini@saipem.com

Naturally Occurring Radioactive Materials (NORM) and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) consist of materials enriched with radioactive elements found in the environment, such as uranium, thorium and potassium and any of their decay products, such as radium and radon.
NORM occurs in geological formations and TENORM can be created by industrial activity. Examples of industries that may be of concern include Oil & Gas and phosphate fertilizer production.
In decommissioning and remediation activities regarding sites of potential concern for NORM/TENORM, Saipem adopts site-specific protocols to proper management of on-site and off-site activities. The management cycle is based on NORM/TENORM characterization, radiological risk assessment and contamination control procedures.

1. Introduction

During the production process at Oil & Gas sites, NORM flow with the oil, gas and water mixture and may accumulate for examples at wellheads (in the form of scale), at separation units (in the form of sludges) and at gas plants, steel pipes or storage tanks or tankers (in the form of thin films).
At fertilizer production sites, the primary waste by-products are phosphogypsum (wet-acid process for producing phosphoric acid) and phosphate slag (thermal process).
Other examples of industries and products of concern include sulphuric acid production, coal mine and fly-ash, smelters, refractors, abrasives and ceramics, pigment industry, Thoriated welding, Optical industry and glassware.
The level of NORM/TENORM and the exposure depends not only on activity concentration of the radioactive material involved but also on any chemical or physical processing which may increase the availability of the material. Differences in process methodologies as well as differences in the treatment of liquid wastes and off-gas prior to discharge are key-factors to be defined. Uncontrolled activities associated with NORM/TENORM can contaminate the environment and pose a risk to human health.

2. Overview of NORM waste from the Oil & Gas Industry

2.1 General

NORM residues in the Oil & Gas Industry are typical examples of precipitated materials. These materials are generated by precipitation or sorption of radionuclides from fluids (or gases).

Please cite this article as: Peroni M., Mulas V., Betti E., Patata L. and Ambrosini P., 2012, Decommissioning and remediation of norm/tenorm contaminated sites in oil and gas, Chemical Engineering Transactions, 28, 181-186 DOI: 10.3303/CET1228031

Regarding their genesis, different types of radioactive scale formation have been identified in the oil and gas industry resulting in different types of NORM waste.
Due to differences in how the NORM waste occurs on the oil and gas installations it is beneficial to divide the waste into two categories:

- NORM loose materials
  - Sediments
  - Produced Sand
  - Slop
  - Material from pigging (cleaning of tubulars and other equipment)
- NORM contaminated production equipment
  - Production tubulars
  - Other production equipment.

The oil and gas production NORM waste as it occurs is most often mixed with other components such as heavy oil components (tar, wax), corrosion products and produced sand/clay. Apart from their radioactive properties, the non-radioactive components may require classification as hazardous waste.
The activity concentration of NORM wastes follows typically a log-normal distribution. This must be taken into account when conceiving the measurement program.
The major factors influencing the occurrence of NORM in oil/gas production are:

- Type of production. Oil and gas installations differ largely with respect to types and amounts of NORM.
- NORM pre-history. It is usually well-known from the production phase where NORM is likely to be present on a given installation and what quantities that should be expected.
- The cleanliness state of the installation. The amount of NORM left to be handled during decommissioning will depend on the grade of NORM waste recovery performed in the installation's shut-down phase.
- The presence of oil storage tanks. If (produced) oil storage tanks are present, they may contain considerable amounts of NORM in bottom sediments.
- The presence of pre-processing installations. If NORM is found to be present in the processing modules on the "mother" installation, it is likely that also “satellite” installations and the connecting pipelines and risers are NORM infected.

2.2 Oil production

Oil production NORM is typically found in the process equipment downstream of water separation, in the water separators and the water discharge equipment. Typical equipment types are:

- Production tubulars
- Wellheads and “Christmas trees”
- Risers
- Production manifolds
- Tubes downstream separators
- Separators
- Hydrocyclons
- Vessels and tubes in the produced water discharge system.

In addition NORM may be found in the upstream separator part of the system in places where there either are high turbulences e.g. oil metering systems or slow oil stream velocity (e.g., wide tubes).

2.3 Gas production

In the production of natural gas the absence or near absence of water prevents the formation of sulphate based NORM scale. The gas, however, provides another opportunity for NORM waste formation: radioactive lead (Pb-210) enriched deposits on the inner surfaces of the production equipment. Radioactive lead is formed when radon gas dissolved in the gas stream decays into Pb-210; the first long-lived daughter of Rn-222.

2.4 Liquid discharges

Ra-226 is the dominant radionuclide in the produced waters and consequently plays the major role in all radiological problems.

2.5 Waste management practices

If wastes are not re-injected, they are either stored in drums (sludge, sediments, slop) or stored outdoors on racks and in open containers, possibly covered by a tarpaulin (scrap).

Often, tubings are on both ends to prevent loose scale particles from falling out, and to contain elemental mercury that may be present in the tubulars.

Storage of scrap must ensure that no rust particles are falling directly onto the ground where they would cause soil contamination. If possible, a concrete or plastic liner should be placed under scrap storage areas, which can be easily cleaned after the scrap is removed. After removing the scrap, the ground must be cleaned up to acceptable residual activity concentrations.

The access to the wastes must be prevented by fencing, locking and guarding, the sites and storage containers must be properly marked with radiation warning signs.

Scrap is decontaminated wherever possible, while the resulting cleaning residues are stored in drums before they are either disposed of or treated. The cleaned steel is sent to a scrap dealer or "ordinary" smelter.

Typical scrap decontamination methods include:

- Ultra-high pressure water jetting,
- Mechanical methods (scraping, grinding, sand blasting),
- Chemical methods.

If scrap parts cannot be decontaminated, because they have an irregular geometry, they are either sent to a specialised smelter that can accept radioactive scrap, or disposed of in a landfill.

3. Regulatory EU framework

3.1 96/29/EURATOM

TENORM residues from the production of natural oil/gas are covered by Title VII of the Basic Safety Standards (BSS) Council Directive 96/29/EURATOM.

In the Directive 96/29/EURATOM a special category of exposure situation was introduced for industrial activities involving NORM/TENORM, namely the so-called 'work activities', using regulatory elements of 'practices' and 'interventions'. To distinguish between the 'classical' use of radioactivity and work activities, the following definitions were used:

- Practice: a human activity that can increase the exposure of individuals to radiation from an artificial source or from a natural source where natural radionuclides are processed for their radioactive, fissile or fertile properties, except in the case of an emergency exposure.
- Work activities involve the presence of natural radiation sources and lead to a significant increase in exposure of workers or members of the public, which cannot be disregarded from the radiation protection point of view.

3.2 RP 122-II

The Document "Radiation Protection (RP) 122 - Practical Use of the Concepts of Clearance and Exemption, Part II: Application of the Concepts of Exemption and Clearance to Natural Radiation Sources" 0 uses several generic exposure scenarios (so-called "enveloping scenarios") to derive exemption/clearance levels of the activity concentration for the U-238 and Th-232 decay chains below which regulatory control of residues and materials used in work activities is usually not necessary.

The exemption levels from RP-122-II are reproduced in Table 1 below.

Table 1

Nuclides	All materials	Wet sludges from oil and gas industry
U 238sec incl. U 235 sec	0.5	5
U nat	5	100
Th 230	10	100
Ra 226+	0.5	5

Nuclides	All materials	Wet sludges from oil and gas industry
Pb 210+	5	100
Po 210	5	100
U 235sec*	1	10
U 235+	5	50
Pa 231	5	50
Ac 227+	1	10
Th 232sec	0.5	5
Th 232	5	100
Ra 228+	1	10
Th 228+	0.5	5
K-40	5	100
* Separate values for radionuclides of U 235 series are given here only for information. For NORM these values are never limiting as U 238 and U 235 are always in their fixed natural ratio.		

The exemption limits in the last column of Table above (Wet sludges from oil and gas industry) are much higher because the inhalation pathway can be excluded.

3.3 Transboundary waste shipment

Wastes must, in principle, be disposed of in the country of origin. Exceptions can be made if no suitable disposal routes are available for the given waste in the country of origin. In this case, the EU regulation on the shipment of waste 2006/1013/EC 0 applies.

The EU regulation on the shipment of waste (2006/1013/EC, replacing 93/259/EC) implements some recent developments of the Basle Accord and the OECD decision on the control of shipment and recovery of certain wastes of 2001. Regulations 2006/113/EC has been in force since 12 July 2007 in all member states without the need of transposition into national law.

The Basle Accord, to which around 160 countries have subscribed, defines internationally binding rules regarding the permitting and control of exports and imports of hazardous wastes. Waste shipments require the consent of the country of origin, the country of destination and all transit countries.

“Wastes for recovery“ are to be considered as resource and can be recovered in another member state. For them, too, the regulations of the Basle Accord apply.

3.4 ADR Class 7 regulations

The IAEA regularly publishes regulations regarding the transport of radioactive materials (Transport Safety Regulation TS-R-1 0). The latest edition is from 2011. It is transposed by IAEA member states into national regulations.

3.5 Notification

According to the EU regulation 2006/1013/EC all waste shipments are subject to notification and permitting of the competent authorities in the countries involved. The competent authorities can, in principle, deny permission in part or completely (exceptions are wastes included in the „greenlist“ which does not apply to the oil/gas wastes considered here).

Notification documents must be submitted to the competent authority that checks and verifies the documents and involves other authorities as appropriate. The verification is done using standardized forms, which contain:

- Obligatory information and
- Optional information

to be provided by the waste owner, transporter and consignee (e.g., landfill). The time period allowed for issuing or rejecting a permit is 30 days. The waste shipment and disposal must be completed within one year.
The competent authority of destination for permitting imports (and exports) of wastes subject to notification is the waste authority of the destination of the waste.
If wastes are imported, the first places where the wastes are stored or treated determine which authority is competent for notification.

4. Management protocols

In decommissioning and remediation activities regarding sites of potential concern for NORM/TENORM, site-specific protocols are needed to proper management of on-site and off-site activities. The management cycle is based on NORM/TENORM assessment, radiological risk assessment, monitoring and contamination control procedures.

4.1 NORM/TENORM assessment

The primary objective of radiological characterization survey is to develop an inclusive data set that establishes the types and concentration of NORM/TENORM constituents from such sources in the various environmental pathways.
With the objective to carrying out a comprehensive site assessment, different scenario need to be considered during monitoring planning phase.
A typical scheme of monitoring program is base on the following activities:

1. Facility/site survey
   An inspection survey shall be conducted at each facility/site to determine the presence of NORM/TENORM sources; if NORM/TENORM are likely to be present; an inventory of all sources shall be developed for each facility;
2. NORM/TENORM assessment plan;
3. Background evaluation;
4. Site exposure evaluation (external – internal exposure), to be carried out by:
   a. external gamma measurement (non-intrusive radiological walkover survey), to be done using portable handheld scintillometer, dosimeters;
   b. air and dust monitoring by using samplers at the exposure points (during normal works conditions and specific remediation/decommissiong activities determinations);
   c. representative samples collection and laboratory analysis (activity concentration) from each materials to be remediated/decommissioned.

Figure 1: Site survey

4.2 Risk Assessment
The radiological risk assessment is based on the specific plan to be executed. For that purpose, all relevant exposure pathways are taken into account for any phase of the project, including site preparation, residues removal and clean-up, dismantling phase, wastes handling, temporary storage and final treatment/disposal. Off-site exposure scenarios are base on waste management process (transportation, location and type of final plant). Representative scenarios and site-specific parameter values are used for the calculation of dose and concentration levels.

4.3 Monitoring and control procedures
The comprehensive monitoring and analysis of NORM is difficult and involves a wide range of equipment and techniques. The instruments to be used can depend on both the national legislation of the country in which the measurements are being undertaken and the operational conditions under which they are carried out. These can dictate whether dose rate, alpha/beta contamination or gamma contamination measurements are taken.

Regarding these aspects, different types of procedures need to be developed in order to manage NORM waste.
These procedures must be cover all employees whose work is carried out in the yard, who is involved in the following processes:

- Waste handling
- Work performed under conditions of exposure to NORM waste.

Personal Decontamination
This operating procedure is drawn up to define the operations to be observed at the end of work shift to ensure the decontamination of personnel and the procedures for verification of any washing.

Environmental protection and waste management
This operating procedure is drawn up to define the methods of management, storage and disposal of NORM waste produced.

Pause physiological
This operating procedure is drawn up to define the operations to be observed in order to take advantage of physiological breaks (toilet and fluid intake) within working hours.

Method of measurement of dose and contamination
This operating procedure is drawn up to define how to measure dose and contamination.
This procedure also defines the responsibilities of managing all phases of operations.

Manage and reading dosimeters
This operating procedure is drawn up to define how to manage and read:

- Personal dosimeters on a monthly basis,
- Radon dosimeters at a fixed location, on a quarterly basis.

Acknowledgements

WISUTEC Wismut Umwelttechnik GmbH Jagdschänkenstr. 33 D-09117 Chemnitz, Germany

References

European Commission: Radiation Protection 122, Practical Use of the Concepts of Exemption and Clearance, Part II: Application of the Concepts of Exemption and Clearance to Natural Radiation Sources. Directorate General Environment, 2001.
IAEA: Regulations for the Safe Transport of Radioactive Material 2009 Edition.
Regulation 2006/1013 of the European Parliament and Council on the shipment of waste.
EU Regulation 2006/1013/EC.