

NORM waste management in the oil and gas industry: the Syrian experience

M. S. Al-Masri , H. Suman
Atomic Energy Commission of Syria (AECS)
Damascus, P. O. Box 6091, SYRIA

Abstract

This paper describes the Syrian experience with respect to Naturally Occurring Radioactive Materials (NORM) waste produced by the Syrian oil industry. Three main categories of NORM waste were identified. First, hard scales from decontamination of contaminated equipment and tubular that are considered to contain the highest levels of radium isotopes (^{226}Ra , ^{228}Ra , ^{224}Ra); this type of waste being currently stored in standard barrels in a controlled area. Second, sludge wastes containing low levels of radium isotopes were found with large amounts in each Syrian oilfield; plastic lined disposal pits were constructed in each area for temporary storage. However, disposal criteria for the above two categories of NORM waste are still under discussions. Third, contaminated soil with NORM as a result of uncontrolled disposal of production water was also considered as NORM waste. The Syrian criteria for disposal and clean up of this type of waste has been defined and the approved option by the Regulatory Office for disposal being the disposal mounds.

Introduction

Naturally Occurring Radioactive Materials (NORM) resulting from the ^{232}Th and ^{238}U -series can be concentrated and accumulated in tubing and surface equipment in the form of scale and sludge as a consequence of physical and chemical processes associated with the oil and gas industry^{1,2,3,4}. Radioactive wastes containing NORM are production water, which contains mainly radium isotopes, solid residues and production equipment. Solid residues consist of sludge and scales from tubing pipes and other production equipment. These radioactive wastes require treatment or disposal by appropriate

-
- Email: msmasri@aec.org.sy

methods. Uncontrolled disposal of this type of waste could lead to environmental pollution and thus eventually to radiation exposure of members of the public. However, the largest generated volume of these wastes is produced water. Production water is usually separated from oil and disposed of by some means such as down an injection well or disposal well. Some companies may discharge this water into the environment for evaporation. Unlined lagoons or pits are usually built to collect this water and become highly contaminated with NORM.

The presence of NORM in Syrian oilfields has been recognized since 1987 and the present paper describes the actions taken to manage NORM wastes in cooperation between the Atomic Energy Commission of Syria and the operating companies. In addition, the related regulatory controls associated with the disposal of such wastes are presented.

NORM Measurement Methods

1. Determination of Ra isotopes in solid samples

All soil and scale samples were dried in the oven for 48 hours at 105 °C. The samples were then grinded and about 40g of each sample was filled in a special counting container and stored for two weeks for counting. ^{226}Ra activities in the collected samples were then determined by measuring its gamma emitting daughters, ^{212}Pb , ^{212}Bi , ^{214}Pb , ^{214}Bi , ^{228}Ac by gamma spectrometry using high resolution (1.85 keV at 1.33 MeV), high relative efficiency (26% and 80%) low background HpGe detectors.

Sludge samples were stirred manually by a glass rod and filled in 0.5 liter plastic for counting.

2. Determination of ^{226}Ra in production water samples

Water samples were found to contain oil therefore, filtration through filter papers was required. Radioactivity analysis for determination of ^{226}Ra in the production water was carried out by gamma spectrometry analysis. This was performed using two methods. First, the filtered sample (0.5 l) is stored in a plastic counting container, closed and counted after 2 weeks; this method being used when ^{226}Ra concentration is expected to be high (higher than 3 Bq/l). The second method is to concentrate Ra from the sample

(5-10 l) by precipitation with barium sulfate. The precipitate is then dissolved in 0.5 l of 0.5 mol/l EDTA and the sample is placed in plastic container for counting. Each sample was counted for 24 hours using Ge (Li) Detector (Relative Efficiency 10%) and HpGe detector (Relative Efficiency 26.5%).

3. Determination of ^{210}Po and ^{210}Pb

0.2 gram of each solid sample was spiked with a known amount of ^{208}Po (0.2 Bq) as a yield tracer. Each sample was then digested using a combination of mineral acids (nitric and hydrochloric acid) for at least 24h. When the solution was clear, the sample was then gently evaporated to near dryness. The residue was then dissolved in 100 ml of 0.5 mol/l hydrochloric acid. The solution was then heated to 80°C and ^{210}Po was spontaneously plated onto a rotating silver disc after reduction of iron with ascorbic acid. Alpha counting of ^{208}Po (5.15 MeV) and ^{210}Po (5.3 MeV) was done using an alpha spectrometer (Oasis, Oxford). The plating and counting were then repeated after 6 months of storage of the solution to measure the ingrowth of new ^{210}Po from ^{210}Pb and to calculate the ^{210}Pb concentration in the original sample. The lower limit of detection of the method used was 0.4 Bq/ kg dry wt.

NORM Waste Categories

1. Category I: Scale containing NORM waste

Hard scales from decontamination of contaminated equipment and tubular using high-pressure water systems or mechanical cleaning are considered to contain the highest levels of radium isotopes (^{226}Ra , ^{228}Ra , ^{224}Ra). Scales are currently stored in standard storage barrels in a controlled area; the number of barrels is increasing with time (around 93 barrels up till now). Table 1 shows some of scale samples analysis results; high levels of radium isotopes can be observed. The options for disposal of this type of waste are still under investigation; one of the most widely used is the re-injection into abundant wells. However, there are several internationally studied methods, some of which are land spreading, disposal mounds and others^{1,5,6,7}. On the other hand, big natural gas power stations have been built and operated for the last ten years. Maintenance operations of the gas stations produce tens of tons of scales containing radon daughters, ^{210}Pb and ^{210}Po with relatively high concentrations; only radon gas is

usually present in natural gas. Some results of scales recovered from three big power stations are presented in Table 2. The common practice used to dispose of these materials is the disposal mounds where unlined pits being built near each power station.

2. Category II: Sludge containing NORM waste

Sludge, oily sediment that is produced during cleaning operations of oil separators, storage tanks and other surface equipment, is considered as NORM waste. These wastes contain less activity than the hard scale; Table 3 shows some results of sludge samples analysis. Some oil companies have disposed of these waste into unlined pits; resulting in large areas being contaminated. Other companies implementing NORM management systems are currently using plastic lined disposal pits that are constructed in each area for temporary storage. However, regulatory approvals were given to oil companies to dispose of these wastes by mixing them with the NORM contaminated soil into a regulated disposal pits. Other permanent disposal methods are still under discussion.

3. Category III: NORM contaminated soil

The third main NORM waste produced by the Syrian oil and gas industry is contaminated soil. Over 150,000 m³ of contaminated soil have been recognized. Radium-226 activity has reached a value as high as 100 Bq/g at the hot spots. Table 4 shows some average values at different sites. Contamination was found to be concentrated at the surface layer to a depth of 50 cm in most areas; few exemptions were observed where the contamination was found below 50 cm.

Remediation work has been initiated where urgent regulatory controls were needed and implemented. The Syrian criteria for disposal and clean up of contaminated soil has been defined as follows⁷:

1. Soil containing not more than 0.15 Bq/g of ²²⁶Ra does not need any treatment.
2. Soil having specific activity of ²²⁶Ra higher than 5.2 Bq/g need to be managed as radioactive waste.
3. Contaminated areas containing ²²⁶Ra with concentration between 0.15 Bq/g and 5.2 Bq/g need a special treatment on site to reduce the exposure to a value below 100 µSv/a.

The above-mentioned criteria are based on the following considerations:

It is widely recommended to adopt the dose that would be received by members of the public due to exposure to contaminated areas with NORM, or the risk associated with it, as a measure to be used for setting up a criterion. This quantity reflects the effect of the NORM contaminated soil on human beings through all possible pathways; occupancy and habits of the local public should be considered. Moreover, the dose depends inevitably on scenarios, with some degree of non-reliability, for the evolution of the population and environment in the specific region, e.g. to assess the effect of chronic exposure. However, it is difficult to use this quantity as an operational quantity. Thus it is better to adopt, as an operational quantity, the contamination concentration at the site; mass or surface concentration of some representative radionuclide activity, e.g. ^{226}Ra , or the total activity concentration of the site can be used.

A quantified risk assessment study was conducted^{8,9}. This study gave a relation between the average ^{226}Ra activity concentration in the contaminated sites and the doses that would be received by members of the public, Figure 1 and Table 4. However, it was found that the external exposure is the most dominant pathway; it is larger by at least one order of magnitude than the exposure from all other pathways. It was found that a linear relationship is dominant as long as the activity concentration is below 15 Bq/g and the activity concentration of 0.15 Bq/g of ^{226}Ra , would give a dose of approximately 1 mSv/a to an individual who is a permanent resident onsite while a value of 5.2 Bq/g would give 20 mSv/a assuming 100% occupancy; the current occupancy in all of the contaminated sites is far below 10%.

It was proposed to construct disposal mounds for disposal of contaminated soil having activity higher than 5.2 Bq/g under strict regulatory control. This option of disposal is internationally accepted and used for disposal of uranium mining and milling waste^{10,11}. AECS approved this methodology and imposed protective measures against human and animal intrusion and natural erosion. Many radiological controls were adopted to minimize all risks associated with the civil engineering works. An environmental monitoring program was also requested for the disposal pits and the surrounding areas. The program includes periodic checks for the integrity of the pits, radon emanation monitoring and ground water monitoring. All contaminated soil having concentrations higher than 5.2 Bq/g of ^{226}Ra has been moved to disposal mounds where strict

procedures and continuous supervision from AECS to ensure protection and safety for the workers, public and the environment, have been applied.

4. Other NORM waste in Syrian oil fields

Other two important wastes were also observed in the Syrian oil fields, viz. contaminated equipment and production water. Contaminated equipment is stored in NORM yards until they decontaminated and cleaned; controlled areas were defined in each oil field and inspected periodically by the Regulatory Office.

Production water is usually separated from oil and disposed of by some means such as down an injection well or disposal well. Some of the results of radioactivity analysis are presented in Table 5; ^{226}Ra concentration may reach a value of 100 Bq/l. These levels can be considered high in comparison with other reported values in the world; the highest reported value in the world was found to be 120 Bq/l¹. All operating companies in Syria are currently disposing production water into disposal wells, which is an internationally accepted method.

Conclusion

Three main NORM waste categories in the Syrian oil fields have been defined. Contaminated soil with NORM is highly managed where criteria for clean up and disposal has been set; most of the contaminated soil is being transferred to disposal mounds. Hard and soft NORM scale and sludge wastes are either stored in standard barrels or lined pits; there are no criteria for clearance or disposal of such waste and more efforts are required to set up such criteria.

Acknowledgement

The authors would like to thank Prof I. Othman (G.D. of AECS) for his support and encouragement. Also, many thanks to all technical staff of safety and protection department and the regulatory office for their contributions in this work.

References

1. R.D. BARIED, G.B. MERRILL, R.B. KLEIN, V.C. ROGERS, K.K. NILSON, Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment (American Petroleum Institute, 1996), 1-1-5-18.
2. R. S. OBRIEN, M. M. COOPER. Appl. Radiat. Isot 227 (1998) 31.
3. G. JONKERS, F.A. HARTOG, W.A.J. KNAEPEN, P.F.J. LANCEE, Characterization of NORM in the oil and gas production (E&P) industry. Proc of Int. Symposium On Radiological Problems with Natural Radioactivity in the Non-Nuclear Industry. Amsterdam, September 8-10, 1997, pp. 23-47.
4. W.A. WOJCIK, Science of the Total Environment 45 (1985) 77.
5. G.H. OTTO, "A National Survey on Naturally Occurring Radioactive Materials (NORM) in Petroleum Producing and Gas Processing Facilities", Dallas, TX, 17, (1989).
6. H. NICHOLAS. *Oil & Gas Journal* 68 (1991).
7. ATOMIC ENERGY COMMISSION OF SYRIA, Administrative Council Decision, Damascus, 4419811, (1998).
8. ATOMIC ENERGY AUTHORITY TECHNOLOGY, "Quantified Risk Assessment for NORM Contaminated Land at AFPC, Syria", AEAT, 1997.
9. INTERNATIONAL ATOMIC ENERGY AGENCY,, "Clearance Levels for Radio Nuclides in Solid Materials, Application of Exemption Principles", IAEA-TECDOC-855, (1996).
10. NRPB, "Radiological Protection Objectives for Land Contaminated with Radio Nuclides, A Consultative Document", NRPB-M728, (1996).
11. INTERNATIONAL ATOMIC ENERGY AGENCY, "Decommissioning of Facilities for Mining and Milling of Radioactive Ores and Close-Out of Residues", International Atomic Energy Agency, Technical Reports Series No. 362, Vienna, (1992).

Table (1) NORM concentrations in some hard scales

Sample	NORM Concentrations (Bq/g)		
	²²⁴ Ra	²²⁶ Ra	²²⁸ Ra
Scale1	27±2	147±6	55±3
Scale2	105±6	1020±45	179±11
Scale 3	115±6	1050±48	181±79
Scale 4	33±2	153±8	43±3

Table (2) NORM concentrations in scales produced from natural gas power stations

Station	NORM Concentrations (Bq/g)	
	²¹⁰ Po	²¹⁰ Pb
T-1	2371±85	160±10.4
N-1	224±14	174±9
N-2	320±15	< 12

Table (3) NORM concentrations in some sludge samples

Sample type	NORM Concentrations (Bq/kg)		
	²²⁴ Ra	²²⁶ Ra	²²⁸ Ra
ST-1	396±24	750±38	510±15
ST-2	562±34	1000±50	660±20
ST-3	385±15	470±18	359±18

Table (4) Average contamination levels and the doses received by individuals in different areas assuming 100% occupancy.

Location	Th	OM1	OM2	OM2	EIW	Mal
Average ²²⁶ Ra (Bq/g)	77	5.2	12.1	4.2	4.0	2.4
Equivalent Dose	59	20	46	16	16	9.2

Table (5) Some results for production water

Sample Description	²²⁶Ra Activity (Bq/L)
DS104-JAFRA G/S	56.2±2.7
JAFRA-TA 610	50.8±4.0
ATALLA-V 114	60.3±3.1

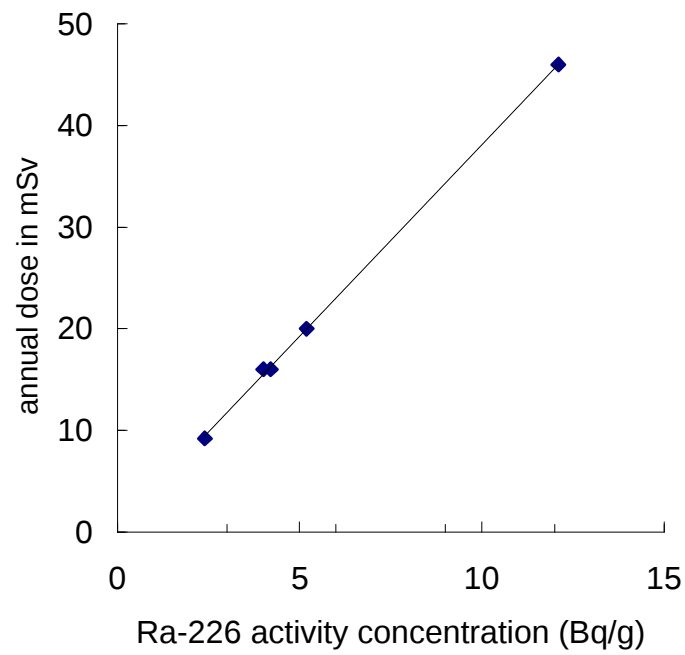


Figure 1.The relation between the dose received by individuals and the activity concentration of ^{226}Ra . The line shown is a linear regression given by the equation " $y = 3.773 x + 0.386$ ".