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Managing Naturally Occurring Radioactive Materials In The Petroleum Industry In Egypt

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ABSTRACT

Naturally Occurring Radioactive Materials (NORM) have been known to be present in varying concentrations in hydrocarbon reservoirs. These NORM under certain reservoir conditions can reach hazardous contamination levels. The recognition of NORM as a potential source of contamination to oil and gas facilities has become widely spread and gained increased momentum from the industry. Some contamination levels may be sufficiently severe that maintenance and other personnel may be exposed to hazardous concentrations. Health and environmental concerns regarding NORM have become an important safety issue in upstream petroleum industry in Egypt since the early 1990's when NORM have been detected in different gas and oil production facilities. In these facilities, radiation protection measures were taken to realize safe handling and disposal of NORM according to the applicable international standards. This paper describes the extent of the NORM contamination problem in Egypt and presents guidelines for dealing with NORM based on the latest scientific techniques and international experiences.

Key Words : NORM/ Petroleum Industry/ Environmental Problems/ Disposal/ Egypt

INTRODUCTION

Radioactivity associated with nuclear power and nuclear applications has received a lot of recognition and press. A lot more common and a lot less publicized type of radioactive materials is Naturally Occurring Radioactive Materials (NORM). However, NORM is present in our natural environment and is contained in some things you might find hard to believe. No doubt you have eaten foods that contained small amounts of radioactivity from the soil in which they grew. Brazil nuts, mustard, ginger, black pepper, and even salt substitutes are a few of the foods that contain small amounts of NORM. Mineral water, tobacco products, natural gas, and fertilizers also contain NORM.[15]

NORM is no stranger to industry either. The materials removed from water as it is treated before being piped into our homes can be radioactive. Burned coal ashes, which are commonly used as an additive in cement, bricks, road aggregate, and wool insulation are radioactive. Also, the scale that accumulates on the inside surface of oil well pipes and processing equipment may contain NORM. NORM represents a wide range of materials that are radioactive in their natural state. These materials include Carbon-14 and Potassium-40, both of which are present in human body. The radioactive elements of concern in oil and gas production occur naturally throughout the earth's crest; specifically, in the formations from which oil and gas are produced. These elements include Uranium, Thorium and their respective daughter products.

There are two types of NORM contamination which are commonly known in the oil and gas operations; Radium contamination which is common to formation water and Radon contamination which is common to natural gas production. Radium has been known as a trace contaminant of underground water for a long time but was not reported to be a contaminant of scale until the early 1980's. Radon contamination of natural gas has been known for nearly 100 years. However, it was only in 1971 that Radon was found to concentrate in the lighter natural gas liquids during processing and could present a serious health hazard to industry personnel. The Radon contamination problem was discovered when the level of contamination in propylene became sufficiently high to interfere with liquid level sensors detecting slurry levels in a polypropylene plant. (8)

Health and environmental concerns regarding NORM have become an important issue in upstream petroleum industry in Egypt since the early 1990's when NORM have been detected in different oil production facilities. In these facilities, radiation protection measures have been taken to realize safe handling and disposal of NORM according to the applicable international standards.(10)

This paper describes NORM characteristics and its impact in the petroleum industry with a focus on the extent of this problem in Egypt. Also, the environmental and health impacts of NORM are briefly presented. Furthermore, suggested guidelines and recommendations for NORM control are discussed.

NORM IN THE PETROLEUM INDUSTRY

NORM contamination can be expected at nearly every petroleum facility as these facilities host these materials during its passage from the subsurface reservoirs to the surface equipment as shown in figure (1). Some of the NORM contamination can be sufficiently severe that maintenance and other personnel may be exposed to hazardous contamination. NORM was found in oilfield operations originates in subsurface oil and gas formations and is typically transported to the surface in produced water. As produced formation water approaches the surface and its temperature drops, precipitates form in tubing strings and surface equipment. The resulting scales and sludge may contain Radium as well as other Uranium and Thorium daughter products. In addition, Radon is sometimes contained in produced natural gas and can result in the formation of thin radioactive lead films on the inner surfaces of gas processing equipment.

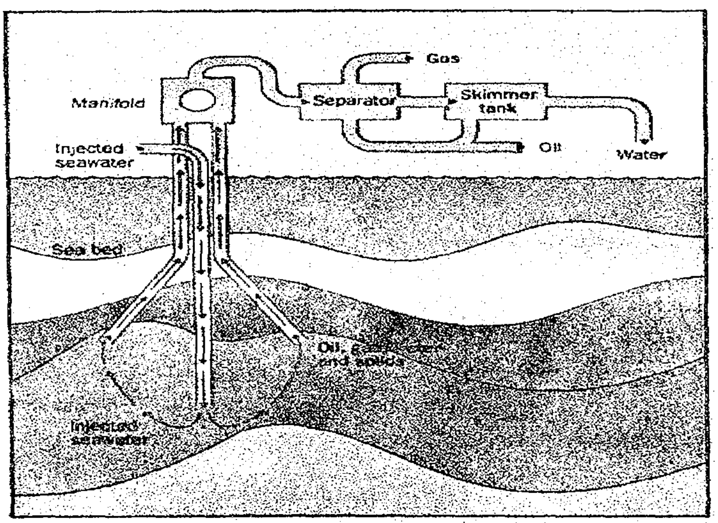


Figure 1: NORM found in subsurface gas and oil formation.

When the radioactive elements are brought to the surface with the produced fluids, a number of changes can take place depending on the characteristics of the specific site. Usually the radioactive elements stay with the water phase of the production fluids and may either incorporate themselves in pipe scale or precipitate into sludge. Consequently, radioactive sludge and scales can build up within process equipment such as pipes, heat treaters, separators, and salt water tanks. The exception to this is Radon that may be dissolved in produced water and released at atmospheric pressure. However, since Radon is a gas, it usually follows the gas production stream. Thus Radon daughters may accumulate in gas processing equipment such as inlet filters and reflux pumps. Radon has a boiling point between that of Ethane and Propane. Consequently, in gas processing facilities, the highest levels are found in pumps, tanks, and product lines associated with Ethane/Propane processing.

CHARACTERISTICS OF NORM WASTE

Petroleum industry wastes are divided into four categories based on the different characteristics that affect radiation exposures from NORM. The categories include sludge from petroleum production equipment; scales from tubing, pipes, and other production equipment; equipment that contain residual NORM scale; and thin deposits of lead-210 on the inside surfaces of gas-plant equipment. The properties that define these categories include radionuclide inventory, mobility, and radiation emissions. Characteristics of each group would be briefly as follows:

Sludge

Sludge accumulated in production equipment typically contain Radium-226 and Radium-228 concentrations ranging from background levels to several hundred picocuries per gram (pCi/g). Since both Radium decay chains exhibit similar radioactivity, they are expressed as total Radium. The ratio of Radium-226 to Radium-228 is assumed to be 3. They typically have a granular consistency dominated by a bulk composition of silicates or carbonates.

Scales

Scales accumulated in tubing, separators, and other equipment contain a broader range of Radium-226 and Radium-228 concentrations, ranging from background levels to several thousands pCi/g. Scales exhibit a lower Radon emanation fraction of about 5%. They occur in very hard, monolithic precipitates in equipment with a bulk dry density between 2 and 3 g/cm^3. Upon removal and disposal, however, they have a nominal bulk dry density of about 1.6 g/cm^3 due to the porosity of about 0.45 between the broken pieces of scale.

Production Equipment

Residual NORM remaining in production equipment after cleaning usually occurs in scales, since these attach tightly to equipment surfaces and are insoluble. Typical scale thickness vary from less than 0.1 inch in production tubing to one inch or more in some water lines. Total Radium concentrations and Radon emanation fractions correspond to those for scales. Densities of disposed equipment vary due to equipment geometry, but porosities typically are large and densities of the NORM waste are small, due to dilution by the equipment mass. The volume of scales remaining in equipment if no mechanical cleaning is done ranges from about 1 percent to 77 percent, with an average of about 6.7 percent of the total equipment volume.

Gas-Plant Equipment

Thin deposits of Lead-210 deposited from Radon daughters on the inside surfaces of gas-plant equipment differ from those of other NORM accumulations in having negligible mass, being invisible, and containing only the last three nuclides of the Uranium decay chain. Activity concentrations are expressed in units of radioactivity per unit area of equipment, since the deposit mass is not measurable or of interest. Occurrences rang from background levels to several hundred thousand disintegration per minute in a 100 square centimeter area (dpm/100 cm^2). Since they occur only in gas-plant equipment, they are usually associated with large equipment masses upon disposal. When removed from equipment surfaces by abrasive cleaning, a metal surface layer approximately 0.004 inches (0.01 cm) thick is assumed to be removed and is part of the NORM waste material for disposal.

HEALTH AND ENVIRONMENTAL PROBLEMS OF NORM

External Radiation Hazards

Gamma radiation exists close to plant and equipment in which NORM scale has accumulated: bends in pipe-work, vessels, filters and other places where the flow is turbulent. Levels increase when plant is opened and exposure to beta particles then may also occur.

Internal Radiation Hazards

Open plant may lead to workers taking radioactive material into their bodies through inhalation, ingestion or cuts in the skin.

Measurements on the outer surfaces of equipment containing NORM usually indicate levels of radiation that are below levels considered to be of concern. When equipment is opened for inspection or repair, personnel can be exposed to radioactivity by inhaling or ingesting NORM. Therefore, in these situations, workers should take precautions to prevent the generation of dust and wear protective clothes. It is also important that NORM waste or equipment containing NORM be managed and disposed by methods that protect the public from unnecessary exposure. Figure (2) illustrates possible external and internal exposures.

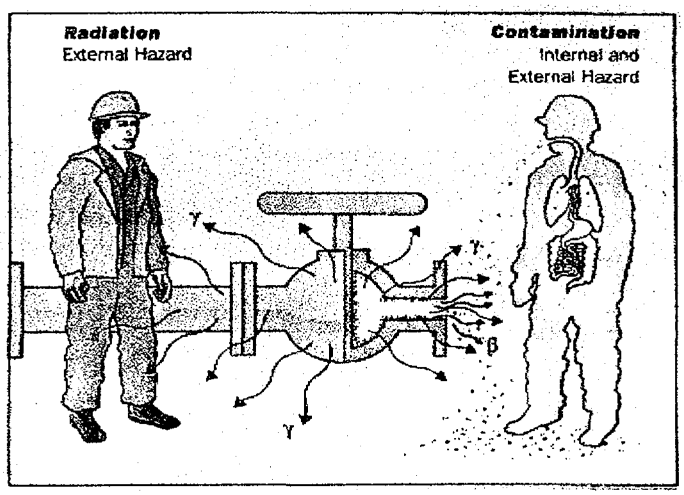


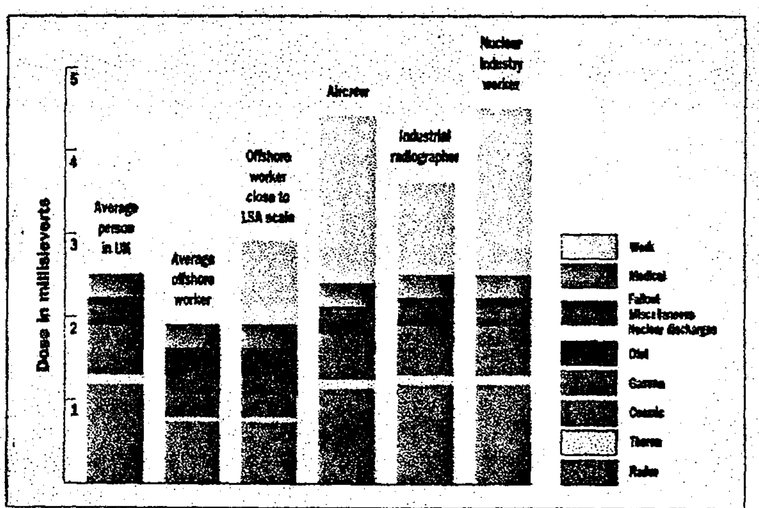
Figure 2: NORM hazard to individuals.

Radioactive materials are unstable and decay over time, emitting ionizing radiation. If body tissue or organs are exposed to excessive radiation, biological damage can occur to the individuals exposed or their descendants, increasing the risk of cancer or birth defects. The degree of harm to people depends on how they are exposed to radioactive materials, whether for example they touch them or eat them as food, on the rate of radioactive decay in the material, and on the type of radiation emitted. In biological tissue, ionization can lead to abnormal chemical reactions and molecular changes which can destroy a cell or change how it functions. In particular, damage to the genetic material in a cell can lead to uncontrolled proliferation of the cell which may result in cancer. In reproductive cells, ionization may give rise to hereditary diseases. Thus, it is important to protect human from unnecessary exposure to excessive levels of radiation. Table (1) shows the expected effects of different dose levels on human bodies.[12]

Table 1: Expected Effects of a Single Whole-Body Dose [12]

Dose Level (Severits)	Effect
0.5	No obvious effects, except possibly minor blood changes such as a reduction in white blood cell count. Full blood recovery in 24 hours.
0.8 - 1.2	Vomiting and nausea for about one day in 5 to 10% of exposed personnel. Fatigue but no serious disability.
1.3 - 1.7	Vomiting and nausea for about one day, followed by other symptoms of radiation sickness in about 25% of personnel. No death anticipated.
1.8 - 2.2	Vomiting and nausea for about one day, followed by other symptoms of radiation sickness in about 50% of personnel. No death anticipated.
2.7 - 3.3	Vomiting and nausea in nearly all personnel of the first day, followed by other symptoms of radiation sickness. About 20% death within 2 to 6 weeks after exposure; survivors convalescent for about 3 months.
4.0 - 5.0	Vomiting and nausea in all personnel of the first day, followed by other symptoms of radiation sickness. About 50% death within one month; survivors convalescent for about 6 months.
5.0 - 7.5	Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100% death; few survivors convalescent for about 6 months.
10.0	Vomiting and nausea in all personnel within 1 to 2 hours. Probably no survivors from radiation sickness.
50.0	Incapacitation immediately. 100% fatalities within one week.

Literature showed that the average annual dose to the work population is 2500 μSv overall, 87% due to natural radiation. In general, an offshore worker will receive a lower overall dose than the average, primarily because offshore Radon concentrations are low. A worker spending a substantial amount of time near scales might receive a somewhat higher dose. Even then his total dose will be less than that received by many other workers. A doubling of the dose from natural radiation would result from: working 200 hours per year in a dose rate of 10 μSv/h, inhaling more than 1/10 of a cup of NORM scale, ingesting more than 1/3 of a cup of NORM scale. Figure (3) shows the average annual radiation doses for different workers.



Average annual radiation doses received by various workers.

Figure 3: Average annual radiation doses received by various workers.

Experimental aspects

Radioactive scales and sludge or contaminated equipment may have to be removed at some time for storage or disposal. Since this could cause environmental problems strict precautions have to be taken to prevent the irradiation and contamination of people, animals, plants and other materials. The problems involved are:

1. Radioactive scales tend to be highly insoluble in acids. They contract with most common non-active shales (e.g. calcium carbonate) which are readily soluble in acids. Difficulties experienced in dissolving scale with inorganic acid should prompt to check for the presence of radioactivity.
2. NORM scale invariably emit alpha and beta particles and gamma rays. Their presence in production systems and equipment can give rise to occupational hygiene problems. A particular concern is with dust particles which can be released in cleaning operations. This dust can be trapped in the tissues of the lung and emit alpha particles which can cause long-term health problems. Where NORM scale is present in production trains or in items such as tubulars or wellheads, concern mainly centers on any effect that gamma radiation could have on those working close by.
3. Radioactive scale on the inside of the tubing strings may interfere with the natural radioactive levels of the surrounding strata, causing anomalies in the readings from gamma ray logs. The observation of such gamma ray anomalies can be an early indicator of the presence of radioactive scales.
4. In most cases, the measured levels of radioactivity are lower than the limits which require radiation protection precautions to be taken. However, as the activity is above background, national authorities tend to be concerned with the environmental effects of the disposal of NORM, and the storage of NORM or contaminated equipment.

RECOMMENDED DOSE AND ACTIVITY LIMITS

The basic recommendations of the International Commission on Radiological Protection (ICPR) are laid down in its publications No. 26 and 30. The "dose equivalent limit" recommended by ICPR is 50 μSv over one year according to the defined working conditions. When radioactive materials are handled, they should be classed as a radioactive substance when the specific activity level (the activity per unit of mass) is greater than 100 Bq/g. This limit only refers to the activity level of the material itself. This must be clearly distinguished from the limit that is used for decontamination purposes: the allowable contamination level for alpha emitters on a surface is usually 2 $Bqcm^{-2}$. Therefore, when either of these limits is exceeded, proper operation, handling and disposal are required. Figure (4) shows the radiation influence of the different radioactive emitters.

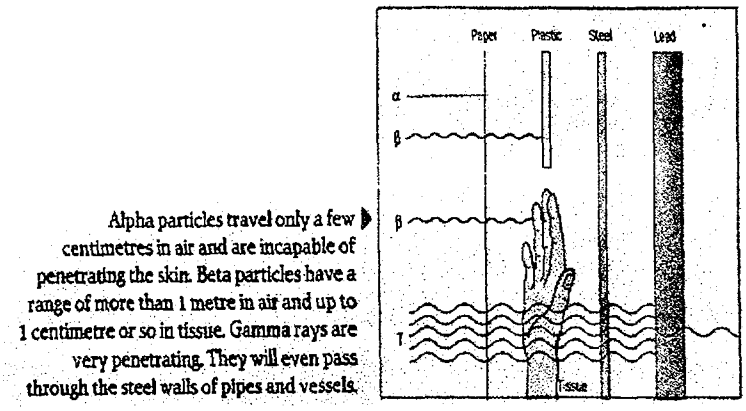


Figure 4: Difference between Alpha particles, Beta particles, and Gamma Rays.

NORM IN EGYPT

NORM has been detected in different oil production facilities in Egypt. In these facilities, radiation protection measures have been taken to realize safe handling and disposal of NORM according to the applicable international standards. Preliminary radiation surveys made on some site equipment of gas fields production facilities at the western desert (high, medium and low pressure separators, test separators, and evaporation bonds). NORM scales and sludge showed levels ranging from few μSv/h to some 35 μSv/h. This resulted from accumulated scales over 8-10 years of continuous operations using evaporation ponds to dispose of the produced formation water. NORM concentrations sometimes are classified into three categories according to the measured gamma radiation levels in these facilities as shown in table (2).

Table 2: NORM Surface Distribution at the Old Evaporation Pond. [11]

Category	Radiation Level (μSv/h)	Effective Area (m^2)	Estimated Volume (m^3)
I	More than 25	80	2
II	25 – 15	324 + 80	60
III	Less than 15	600 +324 +80	150

Other oilfields in the gulf of Suez showed levels as high as 60 μSv/h. An overall strategy for NORM management was applied to determine NORM activity/contamination. Facility wide surveys have identified areas of high exposure and those areas have been marked and posted to inform personnel to be cautious and to limit entry into marked/posted areas to the minimum required. Table (3) shows some field results based on a survey carried out in 1992 on an offshore production platform in the gulf of Suez.

Table 3: Platform NORM Results in Gulf of Suez (November 16, 1992) [6]

Location	NORM Level (μSv/h)
Closed Drain Vessel	
- Boot	5-8
- Bottom of Boot	25
Corrugated Plate Interceptor (CPI) (V150)	
- Bottom of Vessel (4 feet elevation)	60
- Elevation: 6 Feet	10
- Inlet from FWKO (V110)	40-50
- Outlet to Skim Pile	40
- Edge of Yellow Paint Hazard Area	2.5-5
V-170	<2.5
Free Water Knock Out (FWKO) (V110)	
- Bottom Center Line (BCL)	
= At Water Outlet	30
= At Drain Outlet	20
= Near End	10
- 2 feet above BCL at inlet end	6
- 3 feet above BCL at inlet end	2
- Oil and gas outlet	15
Test Separator (V-120)	
- Bottom center line	15
- 5 foot elevation (above deck)	6
- water outlet	6

Inlet Coolers	
- Body of coolers	3
- Outlet line	3
Production Separator (V-190)	
- Bottom center line	20
- 5 feet from deck	5
- Inlet oil line	6
- Outlet oil line	2
- Outlet gas line	<2

NORM REGULATIONS AND NORM DISPOSAL IN EGYPT

To date, national regulations for NORM vary significantly in different countries, ranging from being excluded from regulation to being an integral and indistinguishable part of the regulations. In Egypt, great efforts have been made by the Atomic Energy Authority and the Egyptian Petroleum Sector to address the issue of NORM and manage associated hazards in the oil and gas operations. These efforts were based on the available international safety standards for radiation protection.

At the present time, the Egyptian legislation does not specifically address or regulate NORM handling nor there are designated storage or disposal sites for NORM. Guidelines for disposal of water which contains NORM are not available. Therefore, no materials containing NORM are to be disposed of except to the temporary storage facility or to a government storage facility. Under no circumstances are NORM materials to be disposed of in an uncontrolled, unapproved manner. The Egyptian General Petroleum Corporation (EGPC) is currently preparing a set of instructions to the oil companies for handling potential NORM contaminated equipment through the Atomic Energy Authority.

SUGGESTED GUIDELINES FOR MANAGING NORM

The following are suggestions for use in establishing a programme for the control of NORM contamination:

1) Determine whether there is a NORM contamination problem.

2) Determine areas of potential NORM exposure and contamination.
   a) Make gamma radiation surveys of facilities and equipment.
   b) Make wipe tests on accessible interior surfaces of selected equipment and vessels, especially any in NGL service.
   c) Obtain samples of sludge and scale and analyze for radium and lead-210.
   d) Obtain samples of other waste materials, such as desiccants and filters.
   e) Analyze produced water and waste pond water for radium.

3) Establish programmes to ensure personnel safety, product quality, customer satisfaction, and protection of the environment.

   a) Establish policy on periodic surveys, inspection and maintenance procedures, product controls, and record keeping.
   b) Provide safety-manual material that informs employees and details required procedures, particularly for maintenance personnel.
   c) Recommend a management and audit system.
   d) Develop plans and procedures for the disposal of contaminated waste materials, equipment, and facilities.

GENERAL RECOMMENDATIONS FOR THE CONTROL OF NORM

1) Housekeeping

Attention to housekeeping is important in controlling NORM. Work areas should be regularly cleaned to remove accumulations of NORM containing debris. Wet wiping or use of a vacuum are acceptable methods of cleaning. Dry cleaning methods (sweeping/dry wiping) must not be used as they tend to stir up dust which could contain radioactive particles. All materials collected during cleaning of an area containing NORM should be handled with other NORM residues collected and stored for off-site ultimate disposal. Equipment and tools used in repairing and cleaning NORM contaminated equipment may also be contaminated. These materials must be checked for contamination before leaving controlled areas. Materials found to be contaminated should be kept within the work area until the end of the job, when they can be cleaned or disposed of as waste. Valuable or sensitive items are wrapped in plastic and tape for use in controlled areas. These items are then simply unwrapped before exiting the controlled area and checked for contamination as with other equipment.

2) Marking/Signs/Posting

Areas with a dose rate exceeding 2.5mREM (25mSv) per hour requires the posting of NORM radiation hazard warning signs around the perimeter of that work area. The signs should be posted at a distance from the work area where the dose rate is less than 0.25 mRem per hour. Areas with a dose rate greater than 50 mREM per hour must also be posted with a "High Radiation" sign. Signs must be located at the periphery of the area. A safe work permit must be obtained and a personnel dosimeter badge before entering or working for extended periods in areas posted as having "High Radiation". Workers should not inter into these areas unless the work is required for safety and health reasons or for emergency repairs. NORM coordinators, have a dosimeter instrument for measuring dose rate, should be consulted before any work is undertaken in areas where high dose rates are expected. The NORM coordinators should be consulted before any vessel or piping is opened, and they should be available with instrumentation to measure the level of radiation present while work proceeds.

3) Training

All personnel (onshore, offshore, employees, contractors, and visitors) are to be informed through orientation briefings with the presence of areas of potentially high radiation and advised to limit access to those areas. These briefings should be provided to all visitors to the field. Personnel whose work requires them to be in marked/posted areas will be specifically shown what precautions to take, how to limit work time in areas of high radiation, and shown alternative routes around marked/posted areas. Personnel who will be required to work a significant amount of time will be required to wear a dosimeter badge to record the exposure he receives. All personnel will be advised of the results of the dosimeter upon his request. Several employees should receive training in working around radioactivity in order to provide on-site advice and competence in serving as field NORM coordinators.

4) General Hygiene Precautions

Workers engaged in NORM activities must not eat, smoke, or chew tobacco or gum until they have left the work area and have washed and showered, when they are working in areas having the potential to contain Alpha and/or Beta particles. All personnel wearing respirators or breathing masks must shave every day. A wash station must be provided at all work areas for workers to use in removing any gross contamination they may encounter.

5) Protective Clothing

The wearing of protective clothing and respiratory protection reduces and/or prevents and skin exposures to radioactive material. In conjunction with good personal hygiene, it reduces the proportion of radioactive debris that may be ingested. The normal protective clothing for inspection activities includes reusable washable cloth coveralls or disposable coveralls and gloves. These coveralls may be washed and reused. Ordinary rubber or latex gloves and boots can be used for skin protection; however, the selection of protective clothing materials must also be made based upon the chemicals/products handled. For areas where it is suspected that NORM will be disturbed, coveralls should be supplemented with respiratory protective equipment.

Tape protective clothing at seams such as zippers and at the glove/sleeve interface has to be used to prevent radioactive materials from contaminating personal clothing. For extreme exposure, rain suits can be worn over protective clothing for additional protection. These rain suits should be washed down and handled like other protective clothing. Contaminated clothing and equipment should be assessed and treated similar to the other contaminated equipment.

6) External radiation Exposure Assessment

Personnel who typically work in areas where the external dose rate exceeds 2.5 mREM per hour are required to wear personal dosimeters to measure their radiation exposures. These devices are worn every day throughout the work-shift for a period extending over about 90 days. The devices are then taken to a laboratory for analysis to determine the overall exposure. This information is used to insure that employees are not being exposed to dose rates above the recommended occupational criteria. Additionally, this information should be sent to the medical department for review to determine if specific medical evaluations are required. Currently many petroleum companies uses Thermoluminiscent personal dosimeters which are supplied and analyzed by the Egyptian National Center for Radiation Research and Technology which also provides expert advice, consultation, and training in this area.

7) Dosimeter Badge Control

A standard practice when laboratory or testing data is frequently used, is the use of data or badge controls. With the help of Exxon Biomedical and the Egyptian National Nuclear Research and Technology Center (NRTC), many petroleum companies have placed badges from the NRTC beside badges supplied by an independent laboratory in the United States. Six sets of badges were placed at locations or on personnel expected to experience widely varying levels of NORM exposure. All badges, of different manufactures and supplied from different sources, were exposed together for a period of about 25 days to the same radiation level. These badges were then analyzed by different laboratories. The results of this control exercise demonstrated no reason to be concerned about the accuracy of the dosimeter badge program.

CONCLUSION

1. NORM contamination can be expected at nearly every petroleum facility. However, regular monitoring ensures early detection.
2. The presence of NORM in oil and gas production facilities, gas processing plants, pipelines, and other petroleum equipment and facilities is not, in general, a serious technical problem if properly managed.
3. The concentrations of NORM contamination and the energies of the radiation in Egypt are relatively low and do not usually present series health hazard to the public and personnel in the industry. However, some facilities may be more highly contaminated and may be hazardous to maintenance personnel in particular.
4. Surface equipment and facilities at production sites may be contaminated with NORM, requiring special repair and maintenance procedures and the disposal of NORM scales.

5. A serious problem that must be addressed is the disposal of radioactive materials and equipment since the available options for the disposal of NORM and NORM-contaminated wastes are limited.
6. Although potentially hazardous to personnel and the environment, NORM contamination can be controlled and properly managed.

GLOSSRY

Activity	The quantity of a radionuclide described by the number of nuclear transformations occurring per unit time (see becquerel and curie).
Alpha particle (α)	A charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude to that of a helium nucleus, i.e. two protons and two neutrons.
Becquerel	The SI unit of activity. One Becquerel (symbol Bq) equals one nuclear transformation per second.
Beta particle (β)	Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.
Gamma ray (γ)	Short-wave length electromagnetic radiation of nuclear origin (range of energy from 10 KeV to 9 MeV) emitted from the nucleus.
Radon	In the context of this paper Radon is taken to mean either Radon 222 or Radon 220 – radioactive gases produced by decay of Ra 226 or Ra 224.
Rem	The pre-SI unit of dose equivalent; equal to 0.01 J/kg (see Sievert).
Sievert (symbol Sv)	The unit of (effective) dose equivalent. The sievert has the dimensions of joule per kilogram. The dose equivalent in sieverts is numerically equal to the absorbed dose in grays multiplied by the quality factor (see Gray and Quality factor).

DOSE EQUIVALENT UNITS - SI CONVERSIONS

1μrem	=	0.01μSv	1μSv	=	100 μrem
1mrem	=	0.01mSv=10Mv	1mSv	=	100 mrem
1 rem	=	0.01 Sv=10mSv	1 Sv	=	100 rem
1Krem	=	10 Sv	1KSv	=	0.1Mrem
1Mrem	=	10 KSv	1MSv	=	0.1Grem

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