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UNDERSTANDING THE BASICS OF NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM) IN THE OIL AND GAS INDUSTRY

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INTRODUCTION

The Interstate Oil and Gas Compact Commission (IOGCC) has prepared this pamphlet to provide the public with a basic understanding of NORM in the context of oil and gas operations. An understanding of NORM is necessary to insure that workers, the general public and the environment are protected.

WHAT IS NORM?

NORM is the acronym for naturally occurring radioactive material. This label distinguishes these natural substances from those that might be made through human activity, such as in laboratories, research equipment or nuclear generators. NORM constituents are considered of slight concern, unless there is exposure of a high enough concentration of the radioactive materials at a given location.

NORM is widespread in the environment. Being a natural form, NORM exists in phosphates mined for fertilizer, coal used to fire electric generation plants, in ground water used for municipal and private water supplies and in conjunction with some natural gas. NORM waste is considered Technology Enhanced Natural Radioactive materials (TENR); that is, these materials have been concentrated through technological processes to the degree that localized radiation has increased to levels of some concern. As TENR, NORM is found in building materials (gypsum board) fertilizer and scale formed on the inside of oil well production tubing. In most cases, radiation of these levels should not be of any serious concern.

In the oil field, the term NORM refers to very dispersed and low concentration radioactive materials associated with production operations. Naturally occurring radioactive materials have been found associated with oil and gas operations at a limited number of locations. In the extremely small concentrations usually encountered, the radioactive activity is of only slight concern.

WHAT IS RADIATION?

Radiation is released through the decay of unstable, and therefore radioactive, materials over time. Radiation can be cosmic rays from the sun or X-rays from the machine in your dentist's office. In NORM, there are three basic types of radiation: alpha particles, beta particles and gamma rays. They are all released due to the instability of a radioactive atomic nucleus. The level of natural -- or background -- radiation varies across the country.

An atomic nucleus consists of particles called nucleons which consist of protons (positively charged) and neutrons (no charge). The nucleus is surrounded by a cloud of orbiting electrons (negatively charged). Neutrons can also be thought of as bundled protons and electrons, equivalent to a neutral charge.

Alpha particles do not travel more than 4 to 5 inches from the source. They are large enough that they cannot pass through a typical sheet of paper. As a particle, it can also be washed off the skin, although limited absorption is possible through the pores of the skin. Alpha particles are of greatest concern when a source material emitting the particles can be inhaled or ingested and become imbedded in the lungs or digestive tracts.

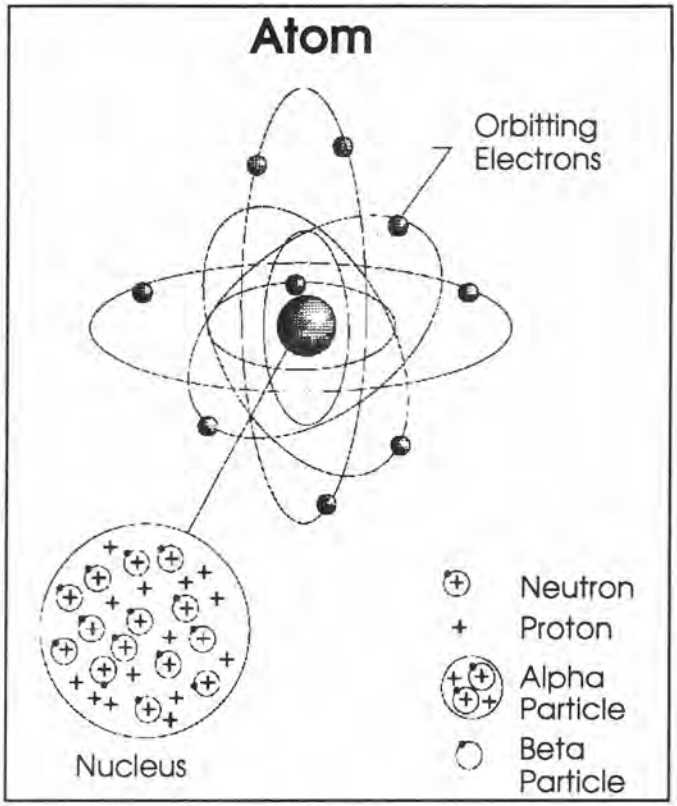

Figure 1
Generic Atom with Selected Sub-particles

Beta particles can travel only a little over three feet. They can, however, penetrate a sheet of paper. Beta emissions are generally stopped by the equivalent of a 1/2-inch sheet of aluminum or a thick book.

Gamma radiation will penetrate multiple sheets of paper, a thick book or the entire body. Gamma radiation is capable of traveling long distances, and is the only type of radiation to be of concern more than a few feet away from a source.Lead shielding is required to stop gamma radiation at the source. However, gamma radiation diminishes the further it travels from the source.

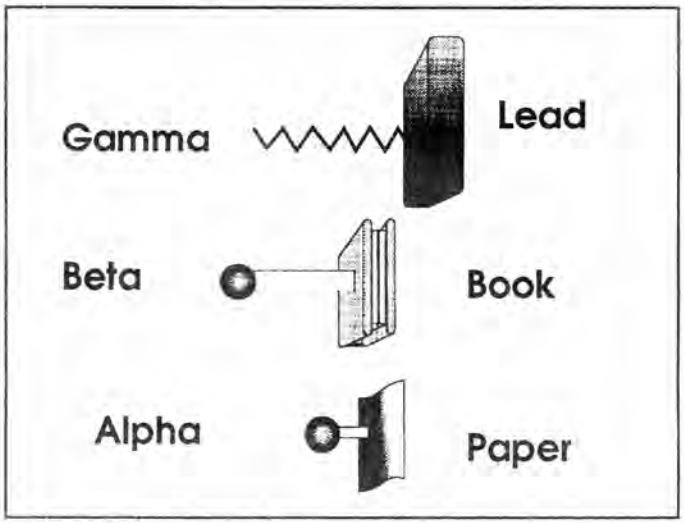

Figure 2
Penetration characteristics of alpha, beta and gamma radiation

Therefore, distance from a radioactive source is critical to protection. The level of radioactivity at one foot away will be four times less at two feet away and 16 times less at four feet away.

A radioactive element will decay, releasing one or more types of radiation, until it reaches a stable state, at which time it ceases to be radioactive. Radioactive elements may have many decay steps to go through before they stabilize, and the steps may take a long time to occur. Uranium ^{238} (U^{238}) has a half-life of 4.5 billion years, which means that after that one-half of the original mass of uranium will have decayed to the next step in its decay series. The extremely long half-lives of some radionuclides is the reason for concern with some radioactive contaminants. U^{238} decays through each step by emission of alpha or beta particles. Within the U^{238} series exist the two isotopes of greatest concern for the oil and gas industry, radium^{226} (Ra^{226}) and radon^{222} (Rn^{222}) with half-lives of roughly 1,602 years and 4 days, respectively.

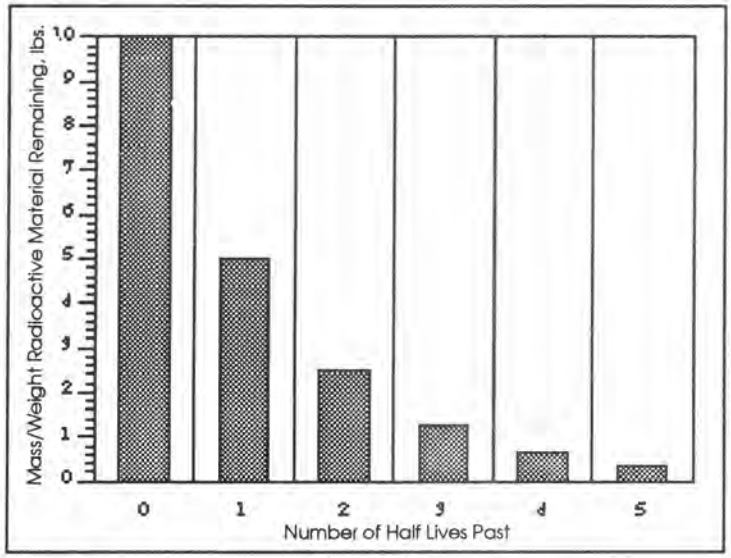

Figure 3
The Half-Life Concept of Remaining Radioactive Material with the Passage of Time

NORM IN THE OIL FIELD

NORM was recognized to exist in oil and gas operations in the 1980s. The first observation of note was in the North Sea oil and gas operations where NORM was found in scale and sludge in surface facilities.

In 1986, NORM was identified in tubing removed from a well in Mississippi as part of regular servicing. After that discovery, the industry and the American Petroleum Institute (API) began surveys of oil and gas facilities to determine the locations and amount of NORM that might be encountered. These surveys found that NORM is present in small quantities at widely scattered locations at very low levels of radioactivity. Guidelines for evaluation were proposed in API Bulletin E2, in April 1992. The map shown on the next page was generated from the API survey and shows that NORM appears to be limited to certain areas of the country. Even within these areas, NORM was found

only at a limited number of locations. Radiation levels encountered were notably higher in certain regions, including the Gulf Coast (from Brownsville, Texas to the Florida Panhandle), northeast Texas, southeast Illinois, southern Kansas, southern Alaska, eastern Oklahoma and northeastern Montana.

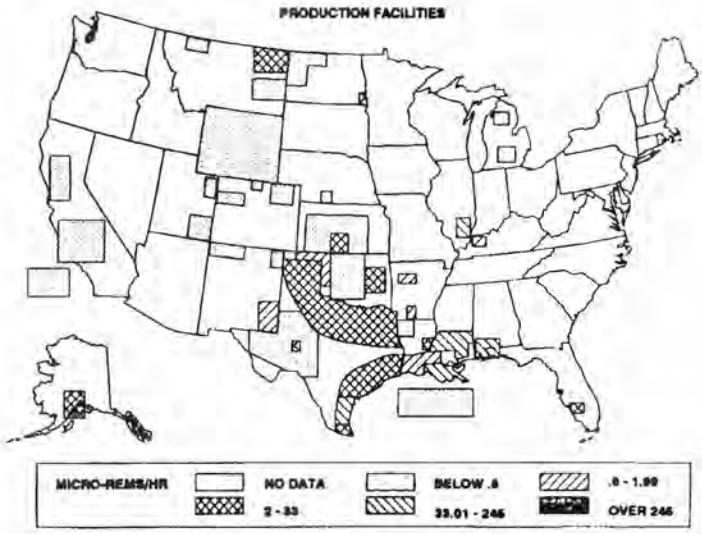

Figure 4
1989 API National Survey on NORM in Production Facilities
(Median Reading Values Minus Background)

The two types of radioactive material of concern in oil and gas operations are radium and radon. Radium may be found in waters that are produced in conjunction with oil and gas. When the water production in a well increases, there is greater likelihood that radium will become a problem *if it exists at that site*. Radium may be found with scale and sludge in production tubulars (pipes and tubing) and treatment vessels. As scale develops, radium may be concentrated to the point that radioactivity becomes a problem. If scaling can be reduced or eliminated in those situations where radium occurs, it may not present a problem because concentration will not occur.

Scale forms in tubulars, valves and vessels -- anywhere that conditions change the chemical and physical characteristics of the flowing stream. Such changes include pressure and temperature drops through tubing, connectors or valves, vessels and filter systems. In general, a pressure drop will also cause a reduction in temperature, which causes dissolved solids to fall out of the water, forming scale and sludge. Very little, if any, of the radium is found in the oil; it is almost exclusively in the water.

Radon is found dissolved in water or as a component of natural gas. It eventually ends up predominantly in the gas stream due to pressure drops associated with surface treatment and separation. Radon decays into products that will leave extremely thin films of radioactive material in tubing, compressors, filters and valves. Again, this concentration of NORM may become a problem over time.

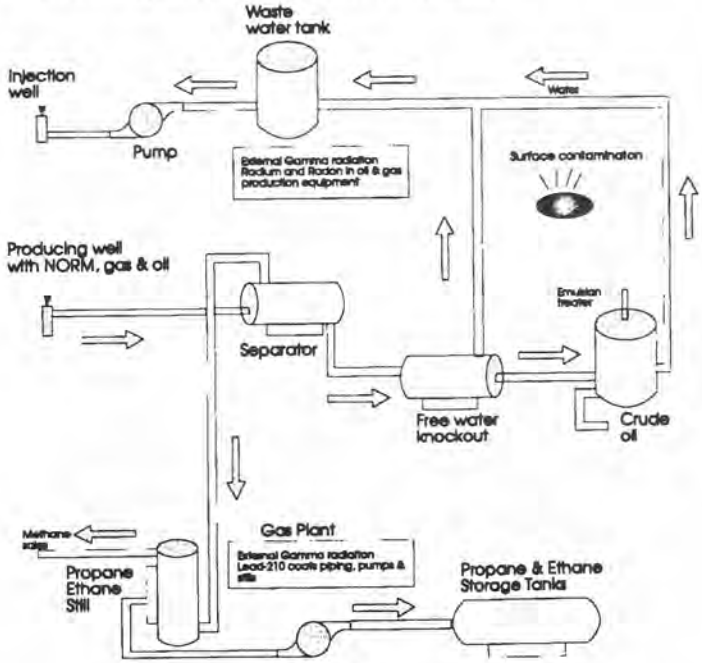

Figure 5
Potential Locations of NORM in Production Facilities

NORM REGULATIONS

Currently, regulations pertaining to NORM have come primarily from state agencies. The states in which NORM has been found to be a significant public concern have filled the gap in federal regulations which were put forth in the past primarily to deal with nuclear power generation and the atomic energy industry.

NORM is covered to some degree under federal acts governing occupational safety and health standards (administered by Occupational Safety and Health Administration) and primary drinking water standards (administered by the Environmental Protection Agency) under the *Safe Drinking Water Act (SDWA).*

The primary issues involved with NORM regulation are how to determine the levels at which NORM poses a health risk, how to measure NORM and how to dispose of NORM wastes. Various threshold levels and methods and units of measurement are being proposed or implemented in regulations and enforcement.

Because different areas of the country have varying background radiation levels, a total radiation reading translates to different levels of increased radioactive contamination in the equipment or soils being measured. This matter must be considered in these regulations.

RELATIVE HEALTH RISKS

The health risk associated with exposure to radiation depends on many factors, including the level and type of radioactivity, the dose based on distance from the source and shielding and the effect of radiation on different parts of the human body.

These factors are taken into account when determining effect and relative risk of exposure to radiation as measured in *roentgen equivalents in man*, or rem. (The roentgen a measure for radioactive energy.) Rem is the unit of measurement for both occupational and non-occupational exposure to radiation.

Whole body limits for occupational exposure is 5 rem per year and non-occupational exposure is .1 rem per year.

Estimated Average Radiation Exposures for U.S. Citizens (Annual Dose Rates)

Background (terrestrial) radiation		.2 rem
Sleeping with spouse (from K^{40} and K^{14})		.001 rem
Los Angeles to New York plane trip		.009 rem
Medical X-ray		.04 rem
Cosmic ray dose rates in the U.S. at lea level		.035 rem
at 5,000 feet		.44 - .06 rem
at 10,000 feet		.085 rem
Gamma rays at sea level inside a brick or concrete building		.091 - .216 rem
Gamma rays from NORM, non-industrial (primary and daughter products)	coastal	.018 - .038 rem
	plateau	.078 - .143 rem
Smoking 1.5 packs of cigarettes per day		8.0 rem
Estimated average total exposure in the U.S.		.360 rem

As can be seen from the table above, there are many sources of radiation that the public is exposed to during the course of a typical day or year.

If a large group of people is exposed to a significant level of radiation, more will develop cancer than a similar, but unexposed group of people. However, what constitutes a *significant* level that will induce cancer has yet to be determined. Oilfield NORM has not been linked to any specific case of cancer.

The cancers developed by the people in the above group will not be unique in type, but will vary from person to person. It is not known why specific doses may affect the health of different people to varying degrees nor why they may affect completely different parts of the body in different individuals.

Although we would like to know more specifically how low-level radiation affects us, too many other factors affect health in the general public to permit analysis of specific health risks for types or dosages of low-level exposure.

RELEVANT EXPOSURE PATHWAYS AND PROTECTION

Various pathways exist for workers and the public to be exposed to NORM. The significance of the exposure pathway is even greater as regulators consider the actual and relative risk of exposure and impact on health. Potential pathways may include inhalation of dust, ingestion of food and/or direct irradiation of a person. There may be single exposure routes or multiple combinations of exposure. In the environment, NORM may be suspended in the air or blown by the wind.

External exposure to NORM is often for a very short period of time and of minor concern. More often, internal exposure through inhalation of radium dust or radon gas is of greater concern. Ingestion of contaminated food is of intermediate concern as the contaminants may not leave the body and might become concentrated metabolically, as radium is concentrated in bone tissue.

Identifying these primary exposure pathways allows one to determine situations that might enhance exposure, whether it be travel through an area of suspended radium dust or working in an enclosed room with suspended dust or radon gas. Such was the situation with workers during the 1920s who painted radium paint on watch dials.

These workers were exposed to extremely high levels of NORM over an extended period of time due to high concentrations of radon gas in enclosed rooms and radium ingested through the licking of brush tips to insure fine lines on the watch face.

In general, the radioactivity associated with NORM in the oil and gas industry is from scale and sludge confined within the tubing and other equipment. Opening these items removes the metal barrier between the radioactive source and the worker and could result in higher levels of exposure. In addition, removal of the scales and sludges can release airborne radioactive dust that can be inhaled and become imbedded in the lungs. This has been assumed to be the primary concern for health and safety.

During removal of this concentrated NORM, workers must be protected from contacting the radioactive material to ensure that they will not receive dangerous doses of radioactivity.

Protection from NORM can then be seen to be behaviorally related, too. If practices that would increase contact and potential exposure can be eliminated, the bulk of the work to reduce the hazard is done. The remaining required practices can be addressed through protective clothing and accessories. Filtered breathing apparatus can minimize exposure to radioactive dust particles and reduce radon inhalation. Adequate ventilation can remove high radon levels from the working area. Proper clothing, often disposable or reusable after cleaning, can be used to minimize contact and block particle emissions from impacting the human body, thereby significantly reducing such hazards.

For further information on NORM and who you might contact in your area, please call the IOGCC headquarters office at (405) 525-3556, or write:

Interstate Oil and Gas Compact Commission
900 N.E. 23
P.O. Box 53127
Oklahoma City, OK 73152-3127

The Interstate Oil and Gas Compact Commission is composed of 29 states responsible for virtually all the nation's domestic petroleum production. The organization is an authority on oil and gas issues.

The IOGCC's mission is to promote conservation and efficient recovery of domestic petroleum resources while protecting health, safety and the environment.

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