

Contents lists available at ScienceDirect

Process Safety and Environmental Protection

journal homepage: www.elsevier.com/locate/psep

Review

Technologically Enhanced Naturally Occurring Radioactive Materials in oil and gas production: A silent killer



Khalid AL Nabhani, Faisal Khan*, Ming Yang

Safety and Risk Engineering Group (SREG), Faculty of Engineering and Applied Science, Memorial University, St. John's, NL, Canada A1B 3X5

ARTICLE INFO

Article history:

Received 12 July 2015

Received in revised form 17

September 2015

Accepted 22 September 2015

Available online 23 November 2015

Keywords:

TENORM

Radionuclide

Nuclear

Geochemistry

Risk assessment

ABSTRACT

This paper reviews the literature that identifies Naturally Occurring Radioactive Materials (NORM) in oil and gas production. It further explains how processes associated with the recovery of oil and gas enhances NORM'S concentration and also develops Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). It redefines TENORM from technical and scientific perspectives and explains how spectral gamma ray logging technology helps to prove the presence of NORM as an indication of oil and gas presence. This article provides a better understanding of TENORM waste disposal practices that poses serious health and environmental risks. It makes a strong argument for the importance of TENORM risk assessment and management through process safety approaches. Finally, it identifies the knowledge and technical gaps related to TENORM in oil and gas production, which require further studies and research.

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* Corresponding author. Tel.: +1 709 864 8939; fax: +1 709 864 4042.

E-mail address: fikhan@mun.ca (F. Khan).

<http://dx.doi.org/10.1016/j.psep.2015.09.014>

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1. Introduction

Radioactivity accompanying the recovery of petroleum products was first discovered more than a century ago in wastes from crude oil exploitation (Elster and Geitel, 1904). Himstedt and Burton (1904) also reported the presence of higher than background concentrations of Naturally Occurring Radioactive Materials (NORM) in crude petroleum. The presence of NORM was reported in numerous Russian and German research papers between 1920 and 1930s (Al-Farsi, 2008). However, from a radiation protection point of view, an official survey had not been conducted until the early 1970s (AEC, 1972). Subsequent to the discovery of threatening levels of NORM in a North Sea oil platform in 1981, researchers began investigating the presence of NORM in crude petroleum and petroleum industry wastes (Kolb and Wajcik, 1985; Smith, 1987; Wilson and Scott, 1992, 1993; IAEA, 2003a,b). As a result of these studies, exposure to NORM was recognized as a health and safety issue during the extraction and production of oil and gas.

This paper is a prolog for further investigation of some important knowledge gaps related to TENORM that have not yet been addressed in details. This includes but not limited to understanding of the nuclear facts of naturally occurring radioactive material associated with oil and gas production, quantifying the likelihood of TENORM radiation exposure, the possibility of developing (cancerous) chronic diseases, and investigating the risk assessment of current practices. The focus of the present paper is to examine the presence of radioactivity in the oil and gas industry with the intention of highlighting the hazards to human and the environment. It discusses the presence of TENORM in oil and gas formations and provides an overview of the geochemistry, radioactivity, solubility and mobility of such substances. This study also reviews how the technical processes involved in the production of oil and gas can enhance NORM to produce Technically Enhanced Naturally Occurring-Nuclear Radioactive Material (TENORM). Particular focus is placed on the presence of TENORM in produced water and wastes. All of the above-mentioned issues call for the need to develop new approaches for dynamic risk assessment and management of TENORM as part of an integrated process and occupational safety management system.

2. Definitions of NORM/TENORM

NORM is an expression widely used to radioactive materials that are naturally occurring in gases, liquids and solids created by natural processes. In rare instances, NOR (Naturally Occurring Radionuclides) is used as a synonym of NORM (Vandenhove, 2002), although this acronym focuses on the radioactive elements rather than the materials in which the radionuclides are stored (Knaepen et al., 1995). Bradley (2003) introduced the term (NARM) Naturally Accelerator Produced Radioactive Materials. These radioactive materials are artificially produced during the operation of atomic particle accelerators. They occur in the context of medical applications, research fields and industrial processing. Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) is used to describe the natural radioactive materials, in which the concentration of radionuclide is enhanced by man-made procedures. The terms TENR or ENOR are also used to describe Technologically Enhanced Natural Radioactivity and Enhanced Naturally Occurring Radioactivity (Edmonson et al., 1998), respectively. Paschoa and Godoy (2002) replenished usage of the acronym HINAR to describe areas affected by high natural radioactivity. The acronym was used initially in 1975 in the first international conference, held in Brazil, which dealt with both NORM and TENORM (Cullen and Penna Franca, 1977).

National and international organizations have further refined NORM and TENORM definitions. The International Association of Oil and Gas Producers (IAOGP) defined NORM as naturally occurring radionuclides that are present at varying concentrations in the earth's crust and can be concentrated and enhanced by processes associated with the production of oil and gas. This "enhanced" NORM, often known as TENORM, can be created when industrial activities increase the concentrations of radioactive materials or when the material is redistributed as a result of human intervention or some industrial processes (IAOGP, 2008). The U.S. Environmental Protection Agency (EPA) defined "NORM as the materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products that are undisturbed as a result of human activities" (U.S. EPA, 2008). The U.S. EPA defined "TENORM as naturally occurring

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