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NORM Management in the Oil and Gas Industry: From Production to Decommissioning

Preza P.H*.; Fortins G.; Jabarra, G.

Rio de Janeiro/RJ, Brazil.

Correspondence: *preza.pedro@outlook.com

Abstract: The accumulation of Naturally Occurring Radioactive Material (NORM) during oil and gas production is a well-known phenomenon in mature markets with established legislation and disposal methods. In Brazil, MTE Regulatory Standard No. 37, issued in 2018, established the first labor regulation addressing NORM as an occupational hazard. Since then, oil companies have focused on managing waste disposal, with particular emphasis on NORM management. As Brazil anticipates an increase in decommissioning and dismantling activities, advancing methods, regulatory limits, and solutions for NORM management is critical. This article presents the specific regulations and the practical experience for radiological protection of workers and proper radioactive waste management within oil and gas installations. Through technical visits, dose rate monitoring, and legislative analysis, the study contextualizes the operational environment of exploration and production units, detailing health risks, waste characteristics, and storage requirements. The article also underscores the sector's complexity, emphasizing the variability in NORM accumulation across different installations and the necessity for targeted protective measures due to the potential exposure of employees during cleaning and inspection activities.

Keywords: NORM, Oil and Gas, Radioactive Waste, Radiological Protection, Cleaning process, NORM packaging, NORM Storage, Decommissioning, Platform, Petroleum.

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Gestão de NORM na Indústria de Óleo e Gás: Da Produção ao Descomissionamento

Resumo: O acúmulo de Material Radioativo de Ocorrência Natural (sigla NORM para *Naturally Occurring Radioactive Material*) durante a produção de petróleo e gás é um fenômeno bem conhecido em mercados maduros, com legislação estabelecida e métodos específicos de descarte. No Brasil, a MTE Norma Regulamentadora Nº 37, emitida em 2018, marcou a primeira regulamentação trabalhista que aborda o NORM como um risco ocupacional. Desde então, as empresas da indústria de óleo e gás têm focado na gestão do descarte de resíduos, com ênfase particular na gestão de NORM. Com o aumento previsto das atividades de descomissionamento e desmantelamento no Brasil, é fundamental avançar nos métodos, limites normativos e soluções para a gestão de NORM. Este artigo apresenta as regulamentações específicas atrelada às experiências práticas para a proteção radiológica dos trabalhadores e o gerenciamento adequado dos resíduos radioativos em instalações de petróleo e gás. Através de visitas técnicas, monitoramento de taxas de dose e análise legislativa, o estudo contextualiza o ambiente operacional das unidades de exploração e produção, detalhando os riscos à saúde, as características dos resíduos e os requisitos de armazenamento. O artigo destaca a complexidade do setor, enfatizando a variabilidade na acumulação de NORM entre diferentes instalações e a necessidade de medidas protetivas específicas devido à potencial exposição dos funcionários durante as atividades de limpeza e inspeção.

Palavras-chave: NORM, Óleo e Gás, Rejeito Radioativo, Proteção Radiológica, Limpeza, Acondicionamento, Armazenamento, Descomissionamento, Plataforma, Petróleo.

1. INTRODUCTION

The exploration and production of oil and gas is an extremely complex scenario, encompassing various types of units and facilities designed to meet the demands of the offshore sector, each with its specific role in the process. These installations are responsible for multiple operations, including drilling and well intervention, installation and removal of subsea pipelines and equipment, production, processing, and storage of products, as well as the cleaning and storage of parts, pipelines, and equipment that may be potentially contaminated [6].

According to the International Atomic Energy Agency (IAEA), NORM (Naturally Occurring Radioactive Material) refers to radioactive materials found in subsurface rock formations that sometimes accompany economically valuable materials [7]. During the exploration of these materials, they may be brought to the surface, could spread into the environment. Due to the potential presence of NORM in oil and gas reservoirs, facilities involved in these activities in Brazil are subject to regulations set by the National Commission of Nuclear Energy (CNEN).

The decommissioning of oil and gas facilities, as defined by (National Petroleum Agency - *Agência Nacional de Petróleo*) ANP Resolution No. 817/2020 [8], involves a set of activities related to the permanent cessation of facility operations, permanent abandonment, well plugging, structure removal, proper disposal of materials, waste, and environmental recovery of the area. These activities encompass both general factors to be considered and specific factors related to the installation and its location. The market estimates an average lifespan of 15 to 25 years for offshore installations [9]. As of January 2021, 33% of the offshore production units in operation in Brazil had been in service for over 25 years, according to ANP [9].

Decommissioning processes face challenges related to the presence of NORM, necessitating proper management throughout the decommissioning and dismantling of installations. CNEN, as the regulatory body for radioactive materials in Brazil, issued Resolution 288 in 2021 [5], regulating cleaning and packaging activities for waste containing natural radionuclides. This regulation allows companies to obtain approvals to perform NORM-related cleaning activities.

During decommissioning processes, all underwater equipment, connected to the oil and gas platform (whether fixed or mobile), undergoes disassembly, transportation, cleaning, and recycling [9]. However, this comprehensive scope encounters regulatory challenges, emphasizing the need for more robust regulations that are aligned with the industry's operational demands. Such adaptation is essential to ensure that the regulatory approach effectively addresses the complexities involved in decommissioning and dismantling processes.

2. OBJECTIVE

The objective of this article is to analyze the management of Naturally Occurring Radioactive Material (NORM) in the oil and gas industry in Brazil, addressing both operational and decommissioning phases. The study aims to identify and discuss the current regulations in Brazil, the challenges faced by installations, and best practices for radiological protection and radioactive waste management. Additionally, it seeks to propose guidelines for the development of robust policies that integrate regulatory, operational, and safety aspects, ensuring the protection of worker health and environmental preservation during the decommissioning process of offshore units.

3. MATERIALS AND METHODS

This study employs a comprehensive approach to analyze the management of Naturally Occurring Radioactive Material (NORM) in both the operational and decommissioning phases of the oil and gas industry. The methodologies used encompass a combination of technical visits, continuous monitoring, regulatory analysis, and laboratory assessments.

Approximately 42 technical visits were conducted at 26 oil and gas industry facilities to gather operational details and identify potential sources of NORM exposure. Radiation levels were monitored at these facilities to assess the environmental and occupational risks associated with NORM. Additionally, continuous monitoring of ambient dose equivalent was performed in decommissioning projects to evaluate radiation exposure over time.

A detailed examination of the legislative framework was undertaken, focusing on regulations set by the National Commission of Nuclear Energy (CNEN) and the International Atomic Energy Agency (IAEA). Key CNEN norms and resolutions relevant to the industry include:

- CNEN-NN-3.01 – Basic Radiological Protection Guidelines [1]
- CNEN-NN-3.02 – Radioprotection Services [2]
- CNEN-NN-5.01 – Regulations for Safe Transport of Radioactive Materials [3]
- CNEN-NN-8.01 – Management of Low and Intermediate Level Radioactive Waste [4]
- CNEN Resolution No. 288, published on December 22, 2021 [5]

Resolution No. 288 is particularly notable as it addresses cleaning and packaging activities involving radioactive waste with naturally occurring radionuclides in oil and gas exploration and production installations.

Approximately 64 operational procedures of oil and gas units were analyzed to describe their impact on NORM management. This included identifying health risks to workers, the nature of waste generated, and the packaging requirements for radioactive waste. For decommissioning processes, specific procedures for managing radioactive waste were outlined, focusing on the challenges faced and the strategies adopted for safe disposal.

The study integrates findings from technical visits, monitoring data, legislative analysis, and laboratory results to provide a holistic view of NORM management throughout the oil and gas lifecycle. This approach aims to address the complexities of NORM in both production and decommissioning phases, offering insights into best practices and regulatory requirements.

4. RESULTS AND DISCUSSIONS

The management of Naturally Occurring Radioactive Material (NORM) in the oil and gas industry reveals several critical aspects and challenges across different stages of operations and decommissioning.

4.1. NORM ACCUMULATION AND MANAGEMENT CHALLENGES

Over the past five years, decommissioning and dismantling activities have highlighted significant issues in NORM management. NORM accumulates in two primary types: as oily sludge, which leads to material buildup, and as scale, which needs inventory management of contaminated parts.

For instance, during the decommissioning of an FPSO (Floating Production Storage and Offloading) in 2020, approximately 2,500 drums were generated from the cleaning of cargo tanks and separator vessels, with around 500 drums classified as containing NORM (sluge or/and scale). In 2023, another FPSO decommissioning project generated about 1,500

NORM (sluge or/and scale) drums. The absence of a final disposal site for radioactive waste in Brazil poses a significant challenge, as offshore companies cannot unload drums containing radioactive waste, even when properly packaged. These drums await approval from CNEN for exportation, leading to logistical challenges and potential operational disruptions.

Scales present another challenge, especially during the dismantling phase. To access it its necessary to cut sheets, parts, and pieces for cleaning activities and monitoring process that is required to ensure that surface contamination levels fall below regulatory limits. To survey radiation levels of cleaned flexible pipes is one activity that shows a very big challenge. The existing space between its internal layer and the multiple layers can be more than 20 centimeter thickness. This highlights the need for robust radiation protection protocols and proper waste management practices during the dismantling process.

4.2. REGULATORY FRAMEWORK AND APPLICABILITY

The analysis of the legislative framework, including CNEN Resolution No. 288, provides critical insights into the management of radioactive waste in the oil and gas industry. Resolution No. 288 is particularly relevant for exploration and production installations where cleaning and packaging activities involve radioactive waste containing NORM.

Various units and installations are subject to these regulations, including production units (FPSOs, FSOs, fixed platforms), drilling units (drillships and semi-submersibles), subsea pipeline and equipment removal units (PLSVs, CSVs, AHTSs), and logistic bases involved in cleaning and disposal. Each unit type presents unique challenges for NORM identification and management. For example, some units do not directly handle NORM, others have routine activities involving people entering tanks and equipment contaminated by NORM.

4.3. MONITORING AND NORM GENERATION

Reliable radiation monitoring is essential for identifying NORM and assessing potential generation volumes. Sensitive equipment, such as scintillometers, is recommended

for accurate measurements. Monitoring locations include oil loading and storage tanks, pipelines, and processing equipment in production units, as well as drilling activities and equipment in drilling units.

The potential for NORM generation varies across different types of units. Production units and logistic bases, which perform cleaning activities, have a higher potential for generating substantial volumes of NORM compared to drilling and subsea installation/removal units, which handle potentially contaminated parts but do not perform cleaning activities.

4.4. SAFETY MEASURES AND PACKING

Proper package of radioactive material is crucial for human safety and environmental protection. Radioactive waste from cleaning activities should be packaged in packages certified as Industrial Package (IP) as requested by IAEA and CNEN. If it's used metal packages as drums, to mitigate leakage risks, these drums should be stored within overpacks, providing an additional layer of protection. The use of "Industrial Package Type I" containers, compliant with CNEN and IAEA standards, ensures the safety and integrity of waste during handling and transportation.

The study underscores the importance of effective radiation protection and waste management practices throughout the oil and gas lifecycle. Addressing the complexities of NORM in both production and decommissioning phases requires adherence to regulatory guidelines, proper containment strategies, and ongoing monitoring to safeguard workers and the environment.

CONCLUSIONS

The management of Naturally Occurring Radioactive Material (NORM) within the oil and gas industry, spanning both operational and decommissioning phases, presents a complex array of challenges and considerations.

Historically, NORM from the oil and gas sector has been characterized by low activity concentration of radionuclides and consequently low equivalent dose rates. However, due to its large volume of generation and the direct contact that workers may have during cleaning and inspection activities, there is a heightened need for stringent radiological protection measures and waste management protocols. Neglecting these measures can lead to significant health risks for workers, environmental contamination, and potential damage to company reputations.

The study reinforces the necessity for oil and gas facilities in Brazil to align with CNEN regulations concerning Radiological Protection and Radioactive Waste Management. This includes production units (FPSOs, FSOs, fixed platforms), drilling units (drillships and semi-submersibles), subsea pipeline and equipment removal units (PLSVs, CSVs, AHTSs), and logistic bases handling decommissioned pipelines and equipment. Although individual exposure to NORM is generally low compared to other radioactive materials, the risk of contamination remains substantial due to its unshielded nature.

An effective Radiological Protection Plan should comprehensively address all radiological protection measures and operational procedures for handling radioactive waste. Similarly, a thorough Radioactive Waste Management Plan must cover all stages of waste handling—from identification and packaging to storage and final disposal.

The decommissioning and dismantling of oil platforms in Brazil reveal critical issues, particularly the lack of a final disposal site for radioactive waste. The generation of significant volumes of NORM packages and challenges related to scales highlight the need for more robust regulatory strategies. The study underscores the importance of developing and

implementing effective policies and strategies to manage NORM, ensuring both environmental preservation and worker safety.

The findings stress the need for an integrated approach that includes regulatory, operational, and safety aspects. Collaboration among regulators, offshore companies, and occupational health professionals is essential to address the challenges associated with NORM management and ensure safe, sustainable decommissioning practices.

In summary, the complexity of managing NORM in the oil and gas industry necessitates comprehensive planning and adherence to regulatory standards to protect human health and the environment. Addressing these challenges through improved practices and robust policies is critical for the safe and effective management of radioactive materials in Brazil's oil and gas sector.

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