Review of Naturally Occurring Radioactive Materials and Applied Radiation-based Technologies Management in the Oil and Gas Industry

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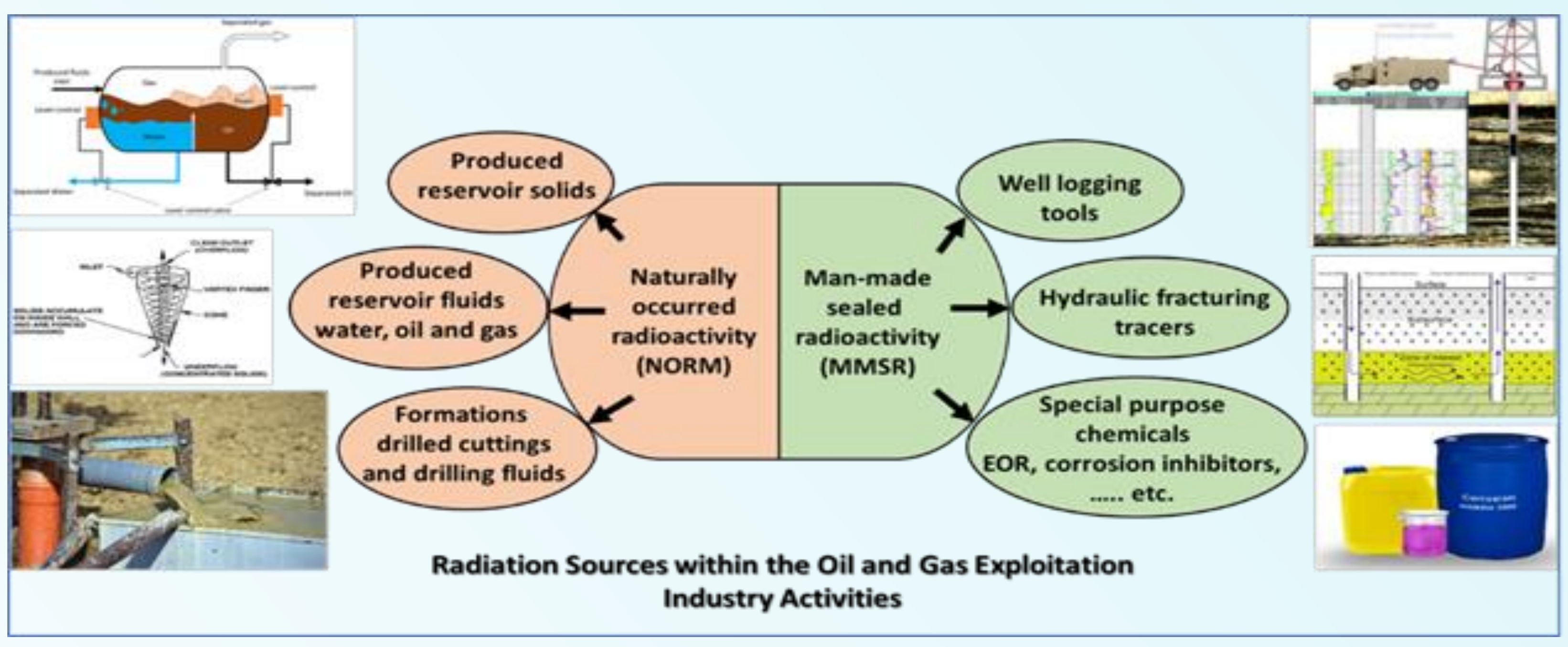
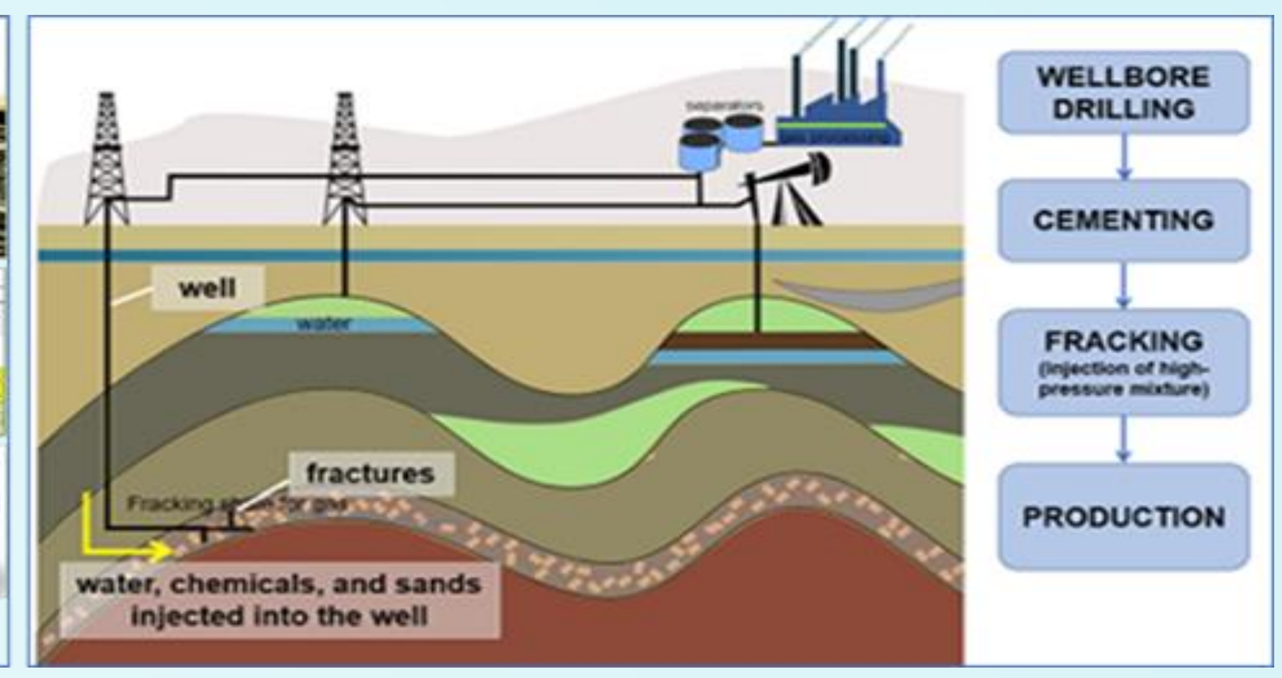
Abstract

For nearly a century, radiation-based technologies have been positively contributing to industry, medicine, agriculture, and research. For example, the oil and gas industry utilize many radiation sources in various applied radiation-based technologies. These technologies, in addition to the naturally occurring radioactive materials (NORM) in the earth's crust, represent the main source of radioactivity that may exist in the drilling, production, and formation evaluation phases. The effects could be contaminated wastes and produced fluids on the surface or contamination of the tested subsurface formations and fluids. All equipment, tools, and machinery have hazards associated with their use, and radiation-based technologies are no different. However, radiation-based technologies are valuable tools and widely used by the oil and gas industry in areas such as oil and gas exploration, production, industrial inspection, refineries, laboratory analysis, and security inspection. The objectives of this study are to review and outline several activities in the oil and gas industry where radioactive materials are implemented. This work would provide a clear picture for beginner petroleum engineers and other workers in the oil and gas industry of the implementation, utilization, and protection procedures when dealing with radioactive-based materials, equipment, and waste.

Introduction



Radiation Sources within the Oil and Gas Exploitation Industry Activities



Methodology

In modern society, petroleum and its derivative products are the second most widely used materials after water [12]. Oil and gas waste management involves the systematic handling, treatment, and disposal of waste materials generated during the exploration, extraction, refining, and distribution processes within the oil and gas industry. The goal of effective waste management is to minimize environmental and health impacts, promote sustainability, and ensure compliance with relevant regulations. The oil and gas industry utilize many radiation sources in various radiation-based technologies, which provide significant benefits to the daily operations of the industry. To maximize the benefits and minimize the hazards associated with the use of radiation-based technologies, national radiation protection standards are implemented. The use of radiation sources is controlled by both international and national rules and regulations [7, 13]. The key steps involved in oil and gas waste management are waste identification, segregation and storage, waste minimization, treatment and recycling, disposal, and monitoring and reporting. International Organization for Standardization (ISO) standards play a significant role in providing guidelines and frameworks for effective waste management practices. The main ISO standards related to oil and gas waste management are ISO 14001, ISO 9001, and ISO 50001 [7], API (American Petroleum Institute) Recommended Practices, SPE (Society of Petroleum Engineers) technical papers, SPWLA (Society of Petrophysicists and Well Log Analysts) standards. Additionally, all staff at the rig site must have attended safety training courses and participate in daily rig site meetings.

Discussion

Well Drilling Process

Since oil and gas are trapped in the earth underground, it is essential to drill wells to produce these fluids. Drilling a well resulting in tons of drilled rock cutting and waste fluids that may contain naturally occurred hazard and/or radioactive materials. The vast majority (>95% of 120 million tons) of the annual oil & gas waste comprises 'produced' water and drill cuttings from offshore production and exploration wells. Some of the drill cuttings, drilling fluid, and 'produced' water are treated offshore and disposed of in the ocean. The historical environmental effects of this have been atrocious, but recent regulations have significantly improved this [1].

Well Logging Process

Well logging is the practice of measuring the properties of underground rock formations through a drilled well. A well log is the trace or record of the data from a down-hole sensor tool plotted against depth using a combination of both radiation-based and non-radiation-based tools [2]. Measurement of formation density is made using a sealed high-energy gamma-ray source (cesium-137). This bombards the formation with high-energy gamma rays. The attenuation of these gamma rays gives an accurate measure of formation density and porosity; this has been a standard oilfield tool since 1965. The use of radioactive sources in borehole logging is governed by regulations under the appropriate radiation control legislation in all territories. Standards for radiation safety in well logging [3, 4, 5] provide recommendations on the use of radioactive sources and radiation generators in well logging, including in the manufacture, calibration, and maintenance of well logging tools. It provides recommendations on radiation protection and safety for the storage, use, and transport of such radiation sources. Accidents may happen due to lack of regulatory control, equipment failure, poor training, or not following safety procedures. It is rare to have recorded accidents related to radiation-based well logs; however, incidents such as loss of control of a well logging source being transferred from a transport container or source damage during tripping out of the hole may happen [6].

Reservoir Treatment Wastes

In oil and gas industries, chemical wastes are either unwanted or expired remains. These wastes can be generated throughout different phases, including the exploration, drilling, extraction, refining, and distribution processes within the industry. Oil and gas wastes can exist in different types, such as liquid waste, semiliquid rubbish, solid rubbish, chemical waste, spent catalysts, emissions, etc. Waste types and quantities may vary depending on operations, production stage, and location of oil and gas facilities [7]. The rest of the waste (~120,000 tons/year), like spent chemicals, oils, scrap metals from decommissioning, tank sludge, and radioactive scale, is sent onshore via pipelines, barges, or tankers for special treatment and reuse, recycling, or disposal [8].

Radioactive Tracers for Hydraulic Fractures Direction and Permeability Detection

During hydraulic fracturing, specially engineered fluids containing chemical additives and proppant (e.g., sand) are pumped under high pressure into a well to create and hold open fractures within the geologic formation. Hydraulic fracturing is often performed in stages, and following each stage, some fluids return to the surface as fracturing fluid returns ('flowback'). It is important to note that the use of horizontal drilling in conjunction with hydraulic fracturing can often result in large volumes of flowback, a key attribute distinguishing wastes generated during hydraulic fracturing in unconventional reservoirs from wastes generated during other types of exploration and production activities. For example, larger volumes of flowback require larger on-site storage capacity, either using land-based units (pits) or tanks [9]. The exact location of the permeable zones lying within the productive horizon has been a major problem faced by the petroleum engineer for decades, and it has been a problem that has seldom been solved with certainty. Reservoir engineers usually have to incorporate a question mark in their estimates of future reservoir performance because of blanks in the core data. Although the use of radioactivity or electrical logs for the estimation of porosity has been of great assistance in furnishing a record for the reservoir engineer, this application of logging data has not completely solved the problem. In short, the industry needs an in-situ well surveying method that can locate and estimate the permeability of the zones existing within a given pay section. A fluid carrying a soluble, chemically inert, gamma-ray-emitting isotope is pumped down the borehole and out into the permeable zones of the formation. The greater gamma activity of the permeable zones thus permits them to be differentiated from the impermeable zones, which contain no active tracer [10].

Produced Reservoir Fluids and Solids

Produced oil, gas, and water have none to very low radioactivity. However, formation solids might contain low to moderate radioactivity in some areas around the world. The same naturally occurring materials detected in the petroleum industry are found in the earth's crust, in the ocean, in groundwater, in building materials, in the air we breathe (highest inside houses and in caves), in food, and of course within our body. Humans have always lived with these radioactive substances and adapted to an environment with constant exposure to radioactive rays. [11].

Conclusion

1. The utilization of radioactive tracers and well logs are necessary and utilized on a routine basis in the oil and gas industry.
2. Radioactive materials and chemicals have been used for a long time under controlled conditions with minimal recorded accidents.
3. Standards for the utilization of radioactive materials and chemicals in the oil and gas industry are well established.
4. Standards for radioactive and chemical waste management are well established.

Operation Phase	Incident Reasons	Potential Radiation Hazards	Frequency
Radiation hazards in oil and gas well drilling and reservoir fluid production	• Unsecure transportation of radioactive materials • Human errors in following safety standards • Loss of radiation sources	• Potential for personnel exposure • Environmental pollution • Geologic formation contamination • Contamination of the produced hydrocarbon	No records
Radiation hazards in well logging and chemical tracers' applications	• Unsecure transportation of radioactive sources • Human errors in following standards • Partially recovered radiation sources (damaged) • Unrecovered (stuck) radiation sources • Loss of radiation sources • Loss of control of well logging source	• Potential for personnel exposure • Environmental contamination • Geologic formation contamination • Contamination of the produced hydrocarbon	Very rare
Example Key Service Providers: 1. Schlumberger, 2. Halliburton, 3. Baker Hughes, 4. Weatherford, and others			