Chapter 15
The Underground Injection of Drilling Waste

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ABSTRACT
The major oilfield processes that can influence the environment are drilling and production. Different materials are used in both processes, and waste is generated. Some of this waste can have significantly harmful effects on the environment; thus, it is necessary to responsibly manage created waste. In virtually all cases, harmful effects can be minimized or eliminated through the implementation of proper waste management. The selection of the method to manage Exploration and Production (E&P) waste depends on laws and regulations, the ecosystem of the location where the operations take place, and the cost-effectiveness of the selected procedures. The most widely used method for the disposal of most petroleum industry waste is underground injection, which enables the permanent disposal of waste slurry by injecting it into a suitable subsurface disposal zone. Performing underground waste injection in a safe, cost-effective manner requires experience, skill, and resources.

INTRODUCTION
As environmental regulations and corporate strategies become stricter and operating companies are held more responsible for proper waste management, a need exists for the safe disposal of oilfield wastes (e.g., drill cuttings, drilling fluids, produced water, tank bottoms, contaminated soil, etc.). One of the techniques that the oil and gas E&P companies have developed to overcome this disposal problem is to inject waste into a subsurface formation where they are likely to remain indefinitely. Waste injection (WI; also known as cuttings re-injection [CRI] or drill cuttings re-injection [DCRI]) is the preferred final disposal method of oilfield wastes for many operators and legislators because it achieves zero discharge in a safe and efficient manner at a lower operating cost than comparable proven technologies. These effects might be particularly true for large-scale projects. Waste injection has proven to be an effective disposal solution for oilfield wastes in both onshore and offshore environments in hundreds of applications throughout the world. Numerous major challenges are faced in the application of drill cuttings and production waste injection.
both on- and offshore. They include regulatory requirements (regulations and permitting), plugging and loss of injectivity, slurry rheology design, the selection of injection and displacement procedures, the containment of injected wastes, well integrity, well interference, interception with other hazards (gas zones, hydrates, and hydrocarbons), not enough processing capacity, equipment breakdown, planned and emergency disconnects, and monitoring (Wright, Davis, Wang & Weijers, 1999; Saasen, Tran, Joranson, Mayer, Gabrielsen & Tronstad, 2001; Guo, Dutel, Wheatley, McLennan & Black, 2000; Abou-Sayed & Guo, 2002). For each challenge, the operator must apply suitable mitigation options. These risks must be identified during project feasibility study, and mitigation options with specific operational procedures should be established. The development and implementation of waste injection in large-scale projects is carefully designed using a risk-based analysis that is composed of fracturing studies of the injection area, technology integration, logistics, equipment specification and process monitoring, all with the aim of performing a seamless and risk-free operation.

BACKGROUND

Drill cuttings injection began in the mid-1980s with small volume annulus injection in the Gulf of Mexico (Malachosky, Shannon, Jackson, 1991). By the early 1990s, its use had broadened in the Gulf of Mexico (Louviere & Reddoch, 1993), the North Sea (Minton, Meader & Willson, 1992; Minton & Secoy, 1992; Willson, Rylance & Last, 1993; Moschovidis, Gardner, Sund & Veatch, 1993; Sirevåg & Bale, 1993; Crawford & Lescarboura, 1993; Schuh, Secoy & Sorrie, 1993; van Gils, Thornton, Kece, Bennet & Yule, 1995), Alaska (Schumacher, Malachosky, Lantero & Hamilton, 1991) and the Mediterranean (Reddoch, Taylor & Smith, 1995) as a cost effective option to comply with environmental waste disposal regulations.

In South Texas (Gardiner, 1994), naturally occurring radioactive material (NORM) was disposed of in subsurface formations. In the mid-1990s, the first large commercial facility with dedicated injection wells began operation (Marinello, Lyon & Ballantine, 1996). This event was followed by large-scale injection operations in Alaska (Schmidt, Friar, Bill & Cooper et al., 1999) and the Gulf of Mexico (Baker, Englehardt & Reid, 1999a, Baker, Englehardt & Reid 1999b; Reed, Mathews, Bruno & Olmstead, 2001).

An example of the continued development of the technology was documented in a 2002 study on commingled drill cuttings and produced water injection (Hagan et al., 2002; Keck, 2002).

In Croatia, INA Oil Company, Plc. has been disposing waste generated during the processes of exploration, drilling, production, refining and hydrocarbon distribution by injection into exploration dry wells and production-depleted wells since the 1990s. At the time, the liquid waste component was injected into an abandoned, specially selected well and approved as a waste injection well, whereas its solid part was neutralized via solidification and disposed at the location of the well, namely in the existing mud pits or specially built waste disposal sites (Gaurina-Medimurec, Kristafor & Matanovic, 1998; Gaurina-Medimurec, 2000). Different types of hazardous waste (liquid and solid wastes) have been disposed of since 2000 applying tubular injection technology and injection pressure below and above pore pressure (Brkic, I. Omrcen & B. Omrcen, 2003). Granules of active coal saturated with mercury-sulfide, without further processing and grinding below 400 microns, was disposed of via injection into formations in which pore pressure was lower than hydrostatic pressure (Leg-1S well and Cre-1 well). Residual ash, in 5% bentonite suspension and active coal were injected into the dolomitic breccia of great secondary porosity (loss zone, open hole) at the intervals of 3,530 to 3,540 m and 3,680 to 3,730 m (Leg-1S well; Brkic et al., 2003). Dispersed sulfur slurry and residual ash in 5% bentonite