Feasibility Study of Cuttings-Injection Operation: A Case Study of the Niger Delta Basin


Abstract

Problems encountered during initial trials of cuttings injection (CI) in Nigeria resulted in the technology being perceived by regulators as an infeasible disposal option in the Niger Delta basin and it was considered to be removed from the approved list of disposal options. This study was conducted to review the disposal technology, assess the deficiencies in the initial trials with respect to the Niger Delta geology, and proffer a framework for an environmentally-feasible application of the technology. The results of the study revealed that the geology of the Niger Delta is favorable for CI operation because of favorable lithology and a lack of strong seismic events. However, due to variations in the depth of the base of fresh water a suitable injection domain cannot be mapped across the Niger Delta basin. Therefore, each project needs to be evaluated on a case-by-case basis using site-specific information.

The lessons learned from the previous practices were identified and an integrated project approach was recommended to achieve an environmentally appropriate use of CI in the Niger Delta basin.

Introduction

The introduction of a new and more restrictive environmental regulation by the Department of Petroleum Resources (DPR) in Nigeria in 2002 significantly reduced the options for in-situ management of oil field waste, including drill cuttings. This created a new challenge in looking for alternative, economical management options that met the new regulatory requirements. One technically acceptable and cost-effective option is cuttings injection. Unfortunately, some of the earlier trials of this technology in the country left several questions unanswered. These included concern about the long-term effects of injection; possible contamination of the freshwater sands; potential effects on the hydrocarbon producing intervals; cuttings breaching back to the surface; and possible tectonic effects.

As a result, the DPR needed more information on the feasibility of cutting injection as a management option in the Niger Delta basin due to the particular nature of its geology. The DPR considered removing this disposal option from the approved list, unless they could be convinced otherwise. A joint committee was established consisting of representatives of the DPR and some members of the Oil Producer Trade Section (OPTS) to demonstrate the viability of CI as an option for waste management given the right technologies, well engineering practices, and adequate geological and environmental considerations.

History of Injection Projects in the Niger Delta

Cuttings (waste) injection in Nigeria is in the development stage. To date, only two operators have practiced this technology in the Niger Delta. The first operator used this technology to dispose of the waste fluids generated during its 1995-1996 land drilling campaign. The waste fluids generated from each well were injected into the casing annulus (surface/intermediate x production casing), and the annulus was sealed off with cement. In one of the wells, a total of 1,655 barrels was injected with a maximum injection pressure of 1,000 psi. 167 sacks of 15.8 ppg cement was bullhead into the annulus to cap off the same.

The second operator carried out its first trial in 1995. An existing well was worked over and recompleted as a through tubing injector well. The receiving stratum was a sand formation at 4,300-4,600 ft subsea. The cuttings and waste fluid to be injected came from a new well that was drilled simultaneously with the injection process. A total of 2,500 bbls of drilled cuttings were generated from the different hole sections of the new well. A total of 12,065 bbls of waste made up of 7,500 bbls cuttings slurry, 3,565 bbls waste fluid, and 1,000 bbls flush water, was injected downhole of the injector well. This was done in 33 batches. This trial encountered a number of operational challenges, including overloading of the slurrification tanks, breakdown of the equipment, and...
blockage of the cuttings injection treatment and injection lines. Due to inadequate slurry rheology causing screenout of perforations, coil tubing was deployed twice to clean out the injector well.

The second operator has since conducted other cuttings injection projects since 2001. One of these operations was canceled prior to kickoff due to the perception of the community that the wastes were toxic. The communities were also reluctant to accept wastes brought in from other communities to be injected in theirs. On other projects, there were also allegations that the wastes being injected breached to the surface.

**General Overview of Technology**

Drill Cuttings (waste) injection involves a slurrification of wastes and injection into subsurface formation(s) with sufficient geological properties to accommodate and permanently isolate the waste at a safe depth from potable water sources and recoverable hydrocarbon. It offers the following advantages over other disposal methods: the achievement of zero waste discharge (drilling waste returned to its native environment); reduction of future liability when the injection loop is closed, and handling of the wastes onsite at drilling operation. CI has also been demonstrated to be an environmentally-appropriate method for managing natural occurring radioactive materials (NORM). Cuttings injection has been successfully applied in various geographical settings worldwide.

**Modeling.** Modeling is an essential part of the cuttings injection planning, design, and engineering. It provides a tool for simulating the essential dynamic occurrence taking place downhole and in the subsurface during a cuttings injection operation. It is used to determine the optimum parameters required to ensure the fractures developed are contained within the targeted injection zone. Also, the lateral and vertical extent of the fractures can be estimated and modeled to ensure they do not cut across overlying sealing beds, intersect with other well bores, natural fractures, faults, drinking water aquifers; or cause migration of waste fluids into underground potable water sources.

Modeling is an important process in the CI operation and it is often done by using hydraulic fracturing simulators. A fully three-dimensional hydraulic fracturing simulator is preferable to predict the fracture geometry with confidence. The capabilities of the three-dimensional simulation include:

- Modeling of both single and multiple fracturing compatibilities.
- Risk management based on a probabilistic model.
- Use of fewer assumptions resulting in accurate results.
- Interface with three-dimensional and multiple fracture visualization software.

**Geology of the Niger Delta**

The Niger Delta is a prodgradation deltaic system with very high sedimentation and subsidence rates. The system has been active since the Cretaceous and is still active today. The major structural style of the delta is growth faults. Each major growth fault creates accommodation space and allows for large amounts of sediments to be deposited. These depocenters get progressively younger in the offshore direction.

The interbedded sandstones and shales of the transitional marine to marine Agbada Formation are deposited over the massive marine Akata Formation shales. The massive continental sands of the Benin Formation overlie the Agbada. Figure 1 is a schematic illustration of the lithology of the Niger Delta. The Formations vary in age in different parts of the delta. Most of the oil and gas production occurs in the Agbada formation.

**The Base of Freshwater.** A study of wire line logs across the Niger Delta revealed that the freshwater base varies from less than 1,000 ft to over 8,000 ft. The resistivity of freshwater is very high and gradually decreases as the water becomes more saline and is less than 2 ohm in saline sands. Over 300 wells were analyzed and the 2 ohm cutoff values were contoured to illustrate the regional base of freshwater in the Niger Delta (Figure 2). Sections A-A’ and B-B’ in Figure 2 are shown in Figures 3 and 4. The solid pink lines, in Figures 3 and 4, mark the base of freshwater and can be seen cutting across the formations. The dashed red lines, in Figure 3, mark lines of equal age and show the thick younger section in the offshore side of the section. (Note that the base freshwater does not follow age or formations.) In some cases, the base of freshwater was seen to occur within the massive Benin sands and in other areas, it occurs in the inter-bedded Agbada formation. Also, hydrocarbon zones were observed within the freshwater column. Although there are some areas with good injection formation candidates, there are others where the disposal domains are not suitable for economic and safe CI operations. The discontinuous nature of the sands and the variability in the depth of the base of freshwater make it impossible to map a regional horizon for CI operations through out the Niger Delta.

**Lessons Learned from Previous Injection Projects in the Niger Delta**

Generally, the lessons learned from the previous injection projects in the Niger Delta are no different from those encountered in other parts of the world at the developmental stage of CI operation. The lessons learned in the Niger Delta experience can be classified into five categories: Regulatory, Operations, Environment, Stakeholder Engagement, and Expertise.

**Regulatory.** Though the existing regulations are comparable to other regulations worldwide (e.g., Gulf of Mexico), there are differences. A quality assurance and control flow process (Figure 5) was recommended. In addition, there is the need for adequate communication between operators and the regulatory
agencies. This is crucial to gaining their understanding and approval. Involving them at the beginning indicates to them that the operator wants to comply with pertinent regulations. It also provides the operator an opportunity to hear concerns of regulatory personnel so special needs can be addressed and appropriate changes made to the work plan.

**Operations.** One of the significant operational problems is the plugging of the tubing, annulus, or perforations due to solids settling from the slurry during periods between successive slurry injection phases, or during pump failure, when the slurry is static. This can be prevented by establishing proper slurry rheology specifications and fully displacing the wellbore with fresh water after each injection phase. Also, to further insure the successful completion of the injection campaign, an injectivity test should be performed to establish target injection rates. Another significant problem is excessive erosion of casing, tubing, and other system components caused by pumping solids-laden slurry at high pressure. For annular injection, the wellhead might need to be modified to include protection sleeves (extra long casing slips with wear skirts) at the annular wing valve injection ports, usage of two ports, a low injection rate, a corrosion-resistant alloy (e.g., tungsten carbide) tubing hanger, and hardfacing of the casing hanger. For through-tubing injectors, the tubing material might be constructed of L-80 carbon steel with high wall thickness. It is important to note that the problems discussed in this section are operational in nature and do not affect environmental protection.

**Environment.** There is a need to precede cuttings injection projects by a fracture modeling study using numerical predictive models of various degrees of sophistication. These indicate the likely propagation behavior of the fracture relative to the injected volume. These simulations provide guidance on the necessary well spacing from the injection point, the number of injection wells required for a particular field development, the pressure regime for the tubing design, and the specification for the surface equipment.

**Stakeholder Engagement.** Facility siting involves a triangle of engineering, geological issues and aspects of stakeholder engagement. Some recommended strategies for addressing these include:

- A working cooperation and partnering arrangement between operators and regulators at all levels of government to plan and implement the consultation and communication processes with host communities throughout the project.
- Providing pre-siting information and education for host communities, regulators and other stakeholders. This should include a discussion of potential environmental and safety impacts and the actions that will be taken to mitigate them.

**Expertise.** The expertise of the operators of cutting injection process is one of critical component in the chain that is often not given much attention as the geological and the geomechanical study. This has often resulted in costly failures that could have been avoided. Experience shows that the success of any cuttings injection operation depends on the expertise of the personnel and service providers involved right from conceptualization to operation. It is also advantageous to use one service provider to provide a complete solution or package for the entire project. Then, the vital assumptions made in the engineering design are easily understood and the necessary adjustment made during the operational phase.

**Conclusions**

1. The study revealed that the geology of the Niger Delta basin is generally favorable for cuttings injection because of the presence of favorable lithology (available disposal zones with good sealing shales) and lack of strong seismic events. However, variations in shale continuity, sand development, and the variability of the depth of the base of freshwater make it necessary to evaluate each project independently using all the available data for the area and optimized engineering technologies. Not all areas will be suitable for CI projects.

2. The ultimate selection of suitable injection sites/horizons involved a careful and extensive analysis of the critical geologic factors in conjunction with the results of formation fracture simulation and modeling.

3. A multi-disciplinary and integrated approach, which includes the geology, environmental, drilling engineering, and social effects was proffered as the best practice approach to ensuring an environmentally-friendly cuttings injection project.

4. The study showed that cuttings injection is feasible in the Niger Delta basin and each project needs to be conducted on a case by case basis. This was accepted by the regulators, and hence remains as a disposal option in the Niger Delta.

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**References**


The Benin Formation is a continental facies consisting of over 90% sand with localized sands and shales.

The Agbada Formation is an inter-bedded sequence of sandstones and shales consisting of transitional marine to marine facies.

The Akata Formation consists of massive marine shales with occasional sandy stringers near the top.

Figure 1: Schematic Illustration of the Litho-Stratigraphic Column of the Niger Delta

Figure 2: Regional Map of Freshwater Base in the Niger Delta
**Figure 3: Cross Section A-A’ of the Regional Map of the Freshwater Base**

- Note that the Benin and Agabada Formations vary in age and depth.
- The horizons in red are biostratigraphically controlled age correlative horizons.
- The Base of Fresh water is not a geologic surface.
- Potential injection formations cannot be correlated.
- Some areas may not have horizons suitable for safe CRI operations.

**Figure 4: Cross Section B-B’ of the Regional Map of the Freshwater Base**

- In some areas the sand/shale ratio is very high and therefore unsuitable for CRI.
- The Base of Fresh Water can be very deep making CRI non-economic.
- Potential injection formations cannot be regionally correlated.
- Some areas may not have strata suitable for safe CRI operations.
Quality Control and Quality Assurance Program

Data Requirement and Procedure

Data Analysis and Geological Review

Subsurface Analysis

CRI Equipment Specification

Well Specification and Design

Potential Risk and Mitigation Option

Preliminary Injection Testing

Pilot or Pre-Injection Testing & Fine-Tuning

Final CRI Operation Procedure

Data Acquisition

Monitoring/Diagnostic Analysis Tool box

Assurance and Reporting

Figure 5: Quality Control and Assurance Flow Process