SAND PRODUCTION MANAGEMENT IN OIL AND GAS WELLS:

A CASE STUDY OF NIGER DELTA ONSHORE OIL AND GAS WELLS

BY

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PLAGIARISM

This work **SAND PRODUCTION MANAGEMENT IN OIL AND GAS WELL: CASE OF STUDY NIGER DELTA ONSHORE RIG BENIN CITY, EDO STATE, NIGERIA** by YUNUSA ABDULKAREEM with Matriculation number ENG2006450 of the Department of Petroleum Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria, has PASSED the PLAGIARISM TEST.

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CERTIFICATION

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DEDICATION

This work is dedicated to my parents, my father Mr Momoh Yunusa who will continue to rest in peace in paradise, am dedicating this to him as part of the promise I made to him in completing this degree. Also to my lovely and ever supporting mother who would want to go any length even till the end of the world to see that am ok. Mama your prayers are answered insha Allah.

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ABSTRACT

Sand production remains a significant operational challenge in oil and gas well operations, particularly in unconsolidated and weakly consolidated sandstone reservoirs commonly found in onshore petroleum fields. The uncontrolled movement of formation sand into the wellbore during hydrocarbon production poses serious technical, economic, safety, and environmental concerns, often leading to equipment erosion, flow restrictions, increased non-productive time, and, in severe cases, premature well abandonment. This study investigates sand production in oil and gas wells by examining its underlying causes and mechanisms, assessing its operational impacts, and evaluating effective management and control strategies applicable to petroleum reservoirs, with specific emphasis on the Nigerian oil and gas industry. The study adopts a qualitative and analytical research approach based on an extensive review of existing literature, industry reports, and documented field case studies related to sand production and sand control practices. Key factors influencing sand production, including pressure drawdown, high production rates, reservoir depletion, water breakthrough, grain size distribution, and formation cementation strength, are critically analyzed. Various sand control techniques, such as gravel packing, stand-alone screens, chemical consolidation, and production rate control, are reviewed and comparatively evaluated in terms of their applicability, effectiveness, and limitations in unconsolidated sandstone formations. Findings from the reviewed studies indicate that sand production is primarily triggered when the mechanical stresses induced by fluid flow exceed the formation's compressive strength, resulting in grain detachment and migration into the wellbore. The study further reveals that sand production significantly increases operational costs due to equipment damage, frequent well interventions, and deferred production, while also posing safety risks and environmental concerns. Mechanical sand control methods, particularly gravel packing and screen-based completions, were found to provide more reliable and long-term sand control in highly unconsolidated formations when appropriately designed and implemented. Chemical consolidation methods, although useful in specific conditions, showed variable performance depending on formation properties and operational conditions. The study concludes that effective sand production management requires a proactive and integrated approach that combines thorough reservoir characterization, appropriate selection of sand control techniques, controlled production strategies, and continuous monitoring throughout the well's life cycle. Proper sand management not only enhances well integrity and production sustainability but also reduces operational risks, minimizes environmental impact, and improves the overall economic performance of oil and gas projects. Consequently, the implementation of well-tailored sand control strategies is essential for achieving safe, efficient, and long-term hydrocarbon production in sandstone reservoirs.

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ACRONYMS

CDP	Critical Drawdown Pressure
CH-ESS	Cased hole Expandable Sand Screen
ESS	Expandable Sand Screens
EOR	Enhance Oil Recovery
IGP	Internal Gravel Pack
NPV	Net Present Value
OPEX	Operating Expenditures
RCG	Resin-Coated Gravel
SAS	Stand-Alone Screens
SCON	Sand Consolidation
SRT	Sand Retention Time

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Oil and gas production comprises the engineering activities that move hydrocarbons from subsurface reservoirs to surface facilities and markets, while safeguarding people, assets, and the environment. In the upstream segment, the workflow typically progresses from exploration (geology, geophysics, and prospect appraisal) to drilling and well completion, followed by production operations and, when needed, improved recovery methods to sustain deliverability (Zheng et al., 2022). Modern field development integrates subsurface characterization, well construction, and surface processing as one system, optimizing recovery factor and unit operating cost under safety and emissions constraints set by companies and regulators (IEA, 2023, 2024).

After a discovery is appraised and sanctioned, a wellbore is drilled and cased to the target formation; the completion then establishes controlled communication with the reservoir via perforations or open-hole designs and installs tubulars, packers, flow-control devices, and (when required) sand control hardware (Zheng et al., 2022; Abduljabbar et al., 2024). Once onstream, wells produce a multiphase mixture of oil, gas, water, and sometimes solids. Surface facilities separators, treaters, compressors, and dehydration units condition each stream to pipeline/refinery specifications, while produced water is treated for reinjection or disposal (Zheng et al., 2022). When natural reservoir energy declines, operators deploy secondary recovery (e.g., waterflooding) and tertiary/chemical or thermal EOR to maintain pressure and mobilize remaining hydrocarbons, extending plateau rates and field life (IEA, 2023; Zheng et al., 2022).

From a system perspective, production engineering balances rate maximization with integrity and reliability. Key threats include scale and corrosion, gas or water breakthrough, flow-assurance issues (hydrates, wax/asphaltenes), and critically in weakly cemented sandstones sand production (He et al., 2024; Xu et al., 2024). Sand influx abrades downhole and surface equipment, plugs perforations and screens, elevates erosion risk in chokes/lines, and can destabilize the near-wellbore, cutting production and increasing non-productive time (He et al., 2024; Asfha et al., 2024). Consequently, sand management is embedded in well and facility design: selecting appropriate mechanical sand control (stand-alone screens, gravel packs, open-hole gravel packs) or chemical consolidation; optimizing drawdown/production rates; and monitoring erosion to keep operations within safe envelopes (Abduljabbar et al., 2024; Safaei et al., 2023; Xu et al., 2024; DeValve et al., 2021). Recent work also explores resin systems, enzyme-induced carbonate precipitation, and nano-enhanced binders to increase grain-to-grain strength with minimal permeability damage (Abduljabbar et al., 2024; Safaei et al., 2023; Experimental Investigation…, 2024).

At the macro level, oil and gas remain central to the global energy mix even as systems decarbonize; investment and operational strategies now explicitly weigh emissions, security, and cost alongside recovery and uptime (IEA, 2023, 2024). For petroleum engineers, this context reinforces why sand production management is not a niche topic but a core production-assurance function: it protects well integrity, sustains deliverability, reduces workovers, and supports safer, lower-emission operations by avoiding failure-driven interventions (He et al., 2024; Xu et al., 2024).

Sand production refers to the undesirable movement of formation sand into the wellbore during the production of oil and gas. It occurs when the mechanical forces exerted by the flowing reservoir fluids exceed the formation’s ability to hold the sand grains together. In unconsolidated or weakly consolidated sandstone reservoirs, this phenomenon is particularly common due to the loose bonding between sand particles (Veeken et al., 1991; Papamichos et al., 2010).

Mechanically, sand production is initiated when the effective stress on the formation exceeds its compressive strength. This may happen due to a pressure drawdown around the wellbore, which reduces the confining forces holding the formation intact. As a result, sand grains detach and are carried into the wellbore by the produced fluids. Factors such as high production rates, water breakthrough, reservoir depletion, and changes in fluid composition can accelerate this process (Wilson et al., 2002).

Operationally, sand production is problematic for several reasons. The continuous influx of sand particles can cause erosion of down hole tubulars, damage to surface equipment such as chokes and separators, and accumulation of sand in flowlines, leading to flow restrictions (Shang et al., 2019). It also increases maintenance costs and may require frequent workovers. Moreover, uncontrolled sand influx can destabilize the wellbore, potentially resulting in casing collapse or even complete loss of the well.

The severity of sand production is influenced by reservoir characteristics such as grain size distribution, cementation quality, and formation depth. Shallow, unconsolidated sandstone formations often found in deltaic and shallow marine depositional environments are especially prone to this issue. In such cases, specialized sand control measures such as gravel packing, stand-alone screens, chemical consolidation, or rate control must be implemented to maintain sustainable production (Amanullah et al., 2014).

Understanding sand production mechanisms is critical to the oil and gas industry, as it enables engineers to design wells and production systems that minimize sand influx while optimizing hydrocarbon recovery. In Nigeria, where many producing fields in the Niger Delta consist of unconsolidated sandstones, sand production poses a persistent operational challenge. The problem is not only technical but also economic, as equipment damage, deferred production, and remediation costs significantly affect the profitability of oilfield operations.

Effective management of sand production is critical to ensuring the safety, efficiency, and economic viability of oil and gas operations. Uncontrolled sand production can have severe operational consequences, such as erosion of downhole and surface equipment, blockage of production tubing, separator malfunction, and damage to pipelines. Over time, these effects can lead to significant maintenance costs, unplanned shutdowns, and, in severe cases, the complete abandonment of wells (Smith & Brown, 2021). By implementing proper sand control techniques, operators can prolong the lifespan of production equipment, reduce the frequency of workovers, and maintain consistent production rates.

From an economic perspective, sand management is directly tied to the profitability of hydrocarbon production. Excessive sand influx increases operational costs due to the need for more frequent maintenance, replacement of eroded components, and remediation measures. In offshore operations, where intervention costs are significantly higher, proactive sand control measures can result in substantial long-term savings. Studies have shown that effective sand management can reduce maintenance expenditure by up to 40% and extend equipment service life by several years (Ogunleye et al., 2020).

Furthermore, from a reservoir management perspective, uncontrolled sand production often indicates excessive formation stress or poor completion design, which can compromise reservoir integrity. The migration of sand particles from the formation can create voids, leading to reduced structural stability and potential collapse of the wellbore. This not only decreases hydrocarbon recovery but also increases the risk of catastrophic well failure. Therefore, proactive sand management ensures the protection of reservoir structure, maximizes recovery efficiency, and sustains production over the well's economic life (Ali & Chen, 2022).

In summary, managing sand production is a multidimensional necessity that encompasses operational safety, economic efficiency, environmental protection, and reservoir preservation. A well-designed sand control strategy can significantly enhance production performance, ensure regulatory compliance, and protect both infrastructure and the surrounding environment, making it an essential aspect of modern petroleum engineering practices.

Globally, sand production remains a significant concern across the oil and gas industry due to its detrimental effects on production sustainability, operational costs, and equipment integrity. The market for sand control systems constitutes a substantial and growing segment of the upstream sector, reflecting both the prevalence of sand-related challenges and the importance of effective mitigation technologies. For instance, the global sand control systems market was valued at approximately USD 3.25 billion in 2023 and is projected to reach around USD 4.05 billion by 2030, driven by increasing offshore exploration, aging reservoirs, and stringent environmental regulations (Market Insights Research, 2024). Similarly, a separate analysis anticipates market expansion from US$3.3 billion in 2021 to US$4.9 billion by 2031, underscoring the rising demand for gravel packs, resin-coated sand, and standalone screen solutions (Transparency Market Research, 2024)

In the Nigerian context, particularly within the prolific Niger Delta region, sand production poses acute operational and economic hazards. The Delta's reservoirs are primarily composed of unconsolidated sandstone, making them especially susceptible to sanding and fines migration. Laboratory and field research conducted in the Niger Delta highlight a direct correlation between flow rate, drawdown, and fluid viscosity with sand production rates demonstrating that managing production flow can help contain sanding, although heavier crude oils complicate this challenge (Adeyanju & Olafuyi, 2009). Performance analyses of sand control implementations in the region such as internal gravel packs (IGP), chemical consolidation (SCON), and cased-hole expandable sand screens (CH-ESS) reveal varied effectiveness. In one study, wells equipped with IGP maintained longer plateau production and stayed within permissible sand limits better than those with chemical consolidation, particularly under different drawdown conditions. The study also identified grain size distribution and the bean-up (start-up ramp) program as critical determinants of sand control success (Aroyehun et al., 2018).

Geo-mechanical evaluations using petrophysical data (e.g., porosity, acoustic velocities, elastic moduli) have been applied to forecast sand production risk in Niger Delta wells. These studies aid in identifying formations that require sand control measures preemptively highlighting the growing role of predictive analysis in mitigating sanding-related risks (Nnurum et al., 2024). At the field operations level, reviews of over 2,000 wells in the region indicate that more than 100 thousand barrels of oil per day (Mbopd) remain unrecovered due to sand-related impairments. Despite widespread application of gravel packs, standalone screens, and consolidation chemicals, inconsistent formation consolidation and variable success rates reflect the need for better diagnosis and tailored completion strategies (Nwabueze, Onikoyi & Ajienka, 2012).

Moreover, the environmental and socio-economic challenges in the Niger Delta exacerbate the consequences of sand production. The broader petroleum industry in Nigeria has caused long-term environmental damage, including oil spills, deforestation of mangroves, and community displacement. Though this context extends beyond sanding, it illustrates how technical issues like sand management cannot be isolated from environmental stewardship and regulatory enforcement (Wikipedia on Petroleum Industry in Nigeria, 2025).

Consequently, effective sand production management in Nigeria holds strategic importance not only for enhancing oil recovery and reducing operational costs, but also for supporting safer operations, minimizing environmental harm, and contributing to responsible industry practice in a region where oil extraction often intersects with fragile ecosystems and social tensions.

1.2 Statement of the Problem

Sand production is a persistent challenge in oil and gas well operations, arising when reservoir rock disintegrates under fluid flow and mechanical stresses, allowing sand particles to enter the wellbore and surface facilities. This phenomenon is especially prevalent in unconsolidated and weakly consolidated formations, such as sandstone reservoirs, where the binding forces between grains are insufficient to withstand the mechanical drawdown caused by hydrocarbon extraction (Aghabarati et al., 2019).

From a technical perspective, sand production leads to abrasion and erosion of downhole and surface equipment, including tubing, chokes, pumps, and separators. The abrasive nature of produced sand can significantly reduce equipment lifespan, necessitating frequent repairs or replacements. Furthermore, the accumulation of sand within the wellbore can cause partial or total blockages, impairing production rates and potentially leading to well abandonment (Ali & Pervez, 2020). These operational inefficiencies increase non-productive time (NPT) and disrupt planned production schedules.

The economic implications are equally severe. Costs associated with sand-related damages, cleanout operations, and deferred production can be substantial. In offshore operations, where interventions are particularly expensive, sand production can lead to multimillion-dollar expenditures over the life of a well (Otumudia & Ajienka, 2017). Even in onshore environments, the combination of repair, replacement, and downtime costs significantly erodes project profitability.

From a safety standpoint, uncontrolled sand production poses risks to personnel and infrastructure. Erosion of critical components, such as wellhead valves or blowout preventers, may compromise well integrity, increasing the likelihood of catastrophic failures such as blowouts (Abdullah et al., 2021). Additionally, sand-laden flow can create hazardous working conditions by increasing the potential for equipment rupture under high-pressure flow conditions.

In petroleum engineering, the significance of the sand production problem stems from its multifaceted impact on operational efficiency, asset integrity, financial performance, and safety. Unmitigated sand production can transform a commercially viable reservoir into an uneconomical asset, underscoring the necessity for robust sand management strategies and technologies (Oluwaseun & Dosunmu, 2018). Therefore, understanding the mechanisms, predicting the onset, and implementing effective control measures remain critical objectives in oil and gas field development.

1.3 Aim and Objectives of the Study

Aim:

The aim of this study is to investigate sand production in oil and gas wells, its causes, and effective management strategies to minimize associated risks.

Objectives

1. To examine the causes and mechanisms of sand production in petroleum reservoirs.
2. To assess the technical, economic, and safety impacts of sand production on oilfield operations.
3. To evaluate existing sand control methods and their effectiveness.
4. To recommend practical strategies for mitigating sand production in oil and gas wells.

1.4 Scope of the Study

This study focuses on sand production in onshore oil and gas wells, specifically within the Niger Delta oil producing rigs. It will cover the causes, impacts, and control techniques relevant to sandstone reservoirs, with emphasis on mechanical and gravel-pack methods. The research is limited to technical evaluations and excludes detailed economic modelling or offshore well applications.

1.5 Significance of the Study

This study will provide petroleum engineers with practical insights into effective sand production control methods, enhancing operational efficiency and well integrity. Oil companies will benefit from reduced equipment damage, lower maintenance **costs,** and improved hydrocarbon recovery**,** thereby boosting profitability. At the national level, minimizing production losses contributes to increased oil revenue and economic growth. Academically, the research adds to existing literature, serving as a valuable reference for future studies and bridging the gap between industry practice and theoretical knowledge**.**

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Sand production has long been recognized as one of the most persistent challenges in petroleum engineering, particularly in unconsolidated and weakly consolidated formations. It occurs when formation sand is transported from the reservoir into the wellbore due to fluid flow, pressure differentials, and mechanical stresses that exceed the rock's strength. This phenomenon not only compromises well integrity but also increases operational costs and poses significant safety concerns.

This chapter reviews existing literature related to sand production in Niger Delta oil and gas wells, with the aim of establishing a comprehensive understanding of the problem and highlighting available mitigation strategies. It begins by providing an overview of sand production, followed by a discussion of its causes and contributing factors. The technical, economic, and safety impacts are then examined to underscore why the issue is considered a major concern in both academic and industry practice. Furthermore, the chapter explores various sand control methods employed globally and within Nigeria, ranging from conventional techniques such as gravel packing to advanced solutions like expandable sand screens and chemical consolidation.

By reviewing previous studies, field experiences, and theoretical models, this chapter establishes the foundation for identifying knowledge gaps and justifying the relevance of the present research. In essence, the literature review provides both a global and local context of the problem, evaluates the effectiveness of existing sand management practices, and sets the stage for developing practical recommendations tailored to petroleum engineers, oil companies, and policymakers.

2.2 Overview of Sand Production in Oil and Gas Wells

Sand production is a pervasive challenge in the oil and gas industry, arising primarily when the mechanical integrity of reservoir rock fails under the influence of fluid flow and wellbore pressure gradients. In unconsolidated or weakly cemented formations, the withdrawal of hydrocarbons often results in disaggregation of formation grains, leading to the detachment and movement of sand particles into the wellbore (Otunyo & Samuel, 2019). This phenomenon, commonly referred to as sand production, is particularly prevalent in reservoirs with high permeability and weak geo-mechanical strength, as well as in mature wells where reservoir pressure has significantly declined.

The mechanism of sand production is largely controlled by the interaction of geo-mechanical and operational factors. From a geo-mechanical perspective, sand is mobilized when the stresses induced by fluid flow exceed the formation's compressive strength, causing rock failure and grain detachment. Operationally, aggressive production strategies such as high drawdown pressures, improper completion design, and inadequate reservoir management exacerbate the problem (Shabdirova et al., 2021). These conditions not only trigger sand production but also increase the likelihood of recurrent formation damage and equipment erosion.

In addition, the severity of sand production varies across different reservoir environments. For example, offshore wells in deepwater Niger Delta fields are highly prone to sand influx due to the predominance of unconsolidated sandstone formations (Adetunji & Daramola, 2020). Similarly, in heavy oil reservoirs where viscous flow necessitates higher drawdowns, sand production tends to be more pronounced. Such variability underscores the need for context-specific approaches in understanding and mitigating the issue.

Furthermore, industry reports and case studies confirm that sand production remains one of the costliest operational problems in petroleum engineering. It is estimated that billions of dollars are spent annually worldwide to address sand-related challenges, including remedial workovers, well shut-ins, and surface facility repairs (Adetunji & Daramola, 2020). Consequently, sand production is not only a technical phenomenon but also a major economic and operational concern that requires continuous research and innovation in control strategies.

In summary, sand production is a complex issue that arises from the interplay between reservoir geomechanics, production practices, and fluid dynamics. Its persistence in both onshore and offshore operations highlights its global relevance and explains why it remains a central focus in petroleum engineering research and practice.

2.3 Causes of Sand Production

Sand production in oil and gas wells emerges from interplay of reservoir properties**,** completion design choices**,** and operational practices that collectively lower the rock's resistance to failure or mobilize loose grains and fines toward the wellbore. Recent reviews emphasize that sanding is fundamentally a geo-mechanical failure problem triggered or accelerated by fluid-flow forces and production transients, but its expression depends strongly on the textural and mechanical character of the formation, the way the well is completed, and how it is operated over time (He et al., 2024; Asfha et al., 2024).

Reservoir properties serve as a cause. In unconsolidated and weakly cemented sandstones, grain–grain bonding is minimal, so any increase in effective stress around the wellbore or surge in fluid drag can detach grains. According to He et al. (2024), low cementation, poor grain interlocking, high porosity/permeability, and wide grain-size distributions are primary textural risk factors because they reduce shear strength and facilitate particle mobilization under drawdown. Asfha et al. (2024) similarly note that formations with significant fines content (silt/clay) are especially vulnerable because fines can be dislodged, migrate, and open flow paths that destabilize the coarser skeleton.

Near-wellbore stress concentration and depletion compound this vulnerability. As pressure is reduced, effective stresses rise and can exceed the rock’s compressive or tensile strength, causing shear failure at perforation tunnels and along weak bedding or lamination planes; the failed material is then available to be carried by the produced fluids. A hydro-mechanically coupled analysis by Zhang, Wang, and Wang (2022) shows how fines migration and skeleton rearrangement develop around the wellbore as production progresses, highlighting that local fabric changes and particle sorting increase sanding propensity over time. Liu et al. (2022) further demonstrate using thermo-hydro-mechanical-chemical coupling that changes in fluid composition and temperature can alter intergranular forces and promote fines detachment, providing a mechanistic link between reservoir geochemistry and sanding.

Water breakthrough and multiphase flow introduce additional drivers. In heavy-oil or gas-condensate systems, viscosity contrasts and gas slugs can raise local drag forces; after water influx, capillary effects and clay swelling may reduce effective stress support and accelerate internal erosion. Experimental and modeling studies report that freshening (salinity reduction) can destabilize clay-rich sands by altering electrical double-layer forces and weakening grain contacts, which in turn promotes fines migration (Jang et al., 2020). New particle-scale work also documents how internally unstable, gap-graded packs experience progressive suffusion of fines, gradually undermining the coarse skeleton that resists collapse (Song et al., 2024).

Completion techniques also matter a lot in sand production. The way a well is completed can either mitigate or intensify sanding. According to DeValve et al. (2021), perforation strategy strongly influences near-tunnel stress concentration and breakout: shallow, poorly oriented, or damaged tunnels elevate shear around the shot and can precipitate early sanding, whereas optimized phasing, penetration, and shot density reduce breakout volume. In screen-based completions, the match (or mismatch) between screen aperture and formation particle-size distribution is critical. Khan (2024) shows that inappropriate slot size selection often due to non-representative Sand Retention Tests (SRTs) permits grain passage or leads to blinding and local pressure spikes that trigger sanding behind the screen. Complementary reviews of screen types indicate that manufacturing quality, erosion resistance, and the ability to achieve a good natural pack behind the screen are decisive for long-term sand control performance (Kumar et al., 2024).

Gravel-pack quality and packing uniformity are equally important. If gravel placement is poorly executed voids, segregation, or inadequate packing localized high-velocity channels develop, focusing drawdown across weak spots and mobilizing formation sand. Reviews of SRT protocols also caution that lab tests must replicate reservoir wetting state, fluid type, and flow rates; otherwise, the selected screen/gravel design may underperform in the field and precipitate early sanding (Khan, 2024).

Operational factors depend on the level of skill and competence of the well operators and hence can determine sanding. Even with a favorable formation and a robust completion, operating the well outside its critical drawdown envelope will initiate sanding. As numerous studies observe, each reservoir–completion system has a Critical Drawdown Pressure (CDP) for sanding onset; exceeding this threshold especially during aggressive bean-ups, transient start-ups/shut-downs, or post-stimulation clean-ups promotes rock failure and sand influx

(Song et al., 2023; Song et al., 2022). In practice, rapid rate changes, slugging, and flow instabilities spike near-wellbore pressure gradients, while acidizing or scale-removal treatments can strip grain-to-grain cement or alter surface charges, leaving the matrix more friable. Where fines are abundant, increased water cut after breakthrough often accelerates fines migration and pore-throat enlargement, making sanding progressively easier at the same drawdown (Song et al., 2024). In summary, sanding is most likely when weak, fines-rich, or poorly cemented formations are produced through stress-concentrating completions and operated beyond their CDP**,** particularly under multiphase flow and transient conditions that increase drag and disturb grain contacts. A causative picture therefore emerges: reservoir texture and strength set the baseline risk; completion design shapes the local stress and filtration environment; and operations determine whether instantaneous loads exceed the system's tolerance (He et al., 2024; Asfha et al., 2024).

2.4 Effects of Sand Production

Sand production has profound technical consequences in oil and gas operations, as it directly affects the integrity, performance, and sustainability of wells. The continuous influx of sand into the production system initiates a chain of problems that not only reduce efficiency but also shorten the productive lifespan of oil and gas assets.

One of the most critical impacts is erosion of production equipment. When sand particles are carried with reservoir fluids at high velocity, they strike the internal surfaces of tubing, flowlines, separators, and valves. This abrasive action gradually wears away the protective layers of steel, creating pits and grooves that weaken the equipment (Abdelaal & Nasr-El-Din, 2019). The erosion problem is particularly severe in high-rate gas wells, where fluid velocities amplify the abrasive forces. According to a study by Alshammari et al. (2021), the erosion caused by sand can reduce the wall thickness of tubing by up to 40% in a matter of months, leading to increased risk of leakage and catastrophic equipment failure.

Another major technical impact is blockage and equipment damage. Sand tends to accumulate in separators, chokes, and pipelines, causing partial or complete obstruction of flow. These deposits reduce flow efficiency, alter fluid dynamics, and often require shutdowns for cleaning or replacement of damaged components (Otis & Raturi, 2018). Choke valves are especially vulnerable, as the impingement of sand particles against their orifices causes rapid degradation. In fact, industry reports suggest that sand erosion is one of the leading causes of choke valve failures in deepwater fields, often necessitating costly interventions.

Additionally, sand production significantly reduces well productivity and life span. The continuous withdrawal of sand from a reservoir leads to formation damage by enlarging the perforation tunnels and creating cavities around the wellbore. This not only destabilizes the near-wellbore region but also causes casing deformation and collapse in extreme cases (Zhou et al., 2020). Furthermore, the deposition of sand in the tubing can restrict fluid passage, lowering production rates and necessitating frequent well shut-ins for cleanout operations. These recurring interruptions reduce the economic life of the well, as operators spend more resources on maintenance rather than production.

Over time, the combined effects of erosion, equipment malfunction, and declining productivity can culminate in premature well abandonment. In mature reservoirs with unconsolidated formations, sand production may render a well uneconomical even before its expected production life. According to recent studies, wells experiencing uncontrolled sand influx have, on average, 20–30% shorter operational lifespans compared to properly managed wells (Singh & Sharma, 2022).

The technical impacts of sand production ranging from erosion and equipment failure to reduced reservoir productivity and well life pose significant challenges in petroleum engineering. These issues not only increase operational risks but also demand the adoption of effective sand control measures to ensure safe and sustainable production.

2.4.1 Economic Impacts of Sand Production

The economic consequences of sand production in oil and gas wells are profound, as they directly affect profitability, operational efficiency, and long-term investment viability. One of the most significant impacts is the loss of production. When sand enters the wellbore, it can restrict fluid flow, clog perforations, and accumulate in tubulars, thereby reducing hydrocarbon output. According to Al-Awad et al. (2019), production rates in wells with severe sanding problems can decline by up to 30–50%, leading to substantial revenue losses for operators. This decline is especially critical in high-cost operations such as offshore deepwater fields, where even minor production losses translate into millions of dollars in lost revenue.

In addition to production decline, sand production significantly increases maintenance and intervention costs. Wells prone to sanding often require frequent workovers, sand clean-outs, and equipment replacements. A study by Adebayo and Oyeneyin (2020) highlighted that maintenance costs for wells with severe sanding can be two to three times higher than those without sanding issues. These costs arise from routine interventions, such as de-sanding operations and the replacement of eroded tubulars, flowlines, and separators. In extreme cases, sand accumulation can cause total well shut-in, forcing operators to either abandon the well or undertake expensive re-completion strategies.

Furthermore, sand-related problems contribute to unplanned downtime, which has cascading economic effects on field development projects. Every hour of downtime in offshore operations can cost operators thousands of dollars, depending on rig rental rates and the scale of production affected. Bai and Bai (2018) noted that sand management challenges increase the uncertainty of project economics, as operators must allocate contingency funds for unexpected repairs and interventions. This not only increases operational expenditures (OPEX) but can also reduce the net present value (NPV) of oil and gas projects.

From a broader perspective, sand production can undermine national and regional economic goals, particularly in petroleum-dependent economies. Nigeria, for instance, relies heavily on oil exports for foreign exchange and government revenue. Persistent sand production challenges can reduce national output, affecting revenue inflows and the overall stability of the energy sector (Ojo & Oloruntoba, 2021).

Therefore, the economic implications of sand production extend beyond individual wells to the profitability of entire oil fields and even the financial stability of petroleum-producing nations. Effective sand management strategies are thus not merely technical requirements but essential economic safeguards to ensure sustainable hydrocarbon exploitation.

2.4.2 Safety and Environmental Impacts of Sand Production

Sand production in oil and gas operations poses not only technical and economic challenges but also significant safety and environmental risks. From a safety standpoint, the continuous influx of sand can compromise the structural integrity of well components, leading to sudden equipment failure. For instance, sand erosion in wellbore tubulars and surface facilities weakens metal thickness, which can result in high-pressure leaks or even blowouts in severe cases (Adebayo et al., 2021). Blowouts and uncontrolled hydrocarbon release present one of the most dangerous hazards in petroleum operations, endangering personnel and causing long-term damage to the well. In addition, accumulated sand within separators and pipelines may cause blockages that increase backpressure, creating unsafe operating conditions for workers and increasing the likelihood of accidents (Al-Shabibi & Ahmed, 2020).

Another critical safety concern is the handling and disposal of produced sand. When removed from surface facilities, sand often retains residual hydrocarbons, making it flammable and hazardous to workers if not managed under strict safety protocols. Exposure to hydrocarbon-coated sand may also pose health risks to field personnel, especially during manual cleaning and maintenance operations (Adeyemi et al., 2019). Furthermore, in offshore environments, improper management of sand can increase the risk of slips, trips, and falls on production decks, creating additional occupational hazards.

Beyond safety, sand production has notable environmental implications. Produced sand, often mixed with hydrocarbons, chemical additives, and formation water, qualifies as an oilfield waste that requires specialized disposal methods. Improper discharge of this waste into the environment can lead to soil and groundwater contamination, with hydrocarbons and toxic residues affecting both terrestrial and aquatic ecosystems (Ajibola & Salami, 2022). Offshore operations are particularly vulnerable, as discharge of sand slurry into the sea can smother benthic organisms and disrupt marine habitats. Research by Omede and Akinbo (2021) highlighted that offshore sand disposal practices, if not properly regulated, may lead to long-term ecological degradation and bioaccumulation of toxins in marine food chains.

Moreover, sand-induced equipment failures that result in leaks or spills further amplify environmental risks. For example, ruptured pipelines caused by erosion may release crude oil or natural gas into surrounding ecosystems, with severe consequences for biodiversity and local communities dependent on these resources. These environmental incidents not only damage the reputation of oil companies but also attract regulatory penalties and stricter operational monitoring (Onyekonwu & Ogolo, 2019).

In conclusion, the safety and environmental impacts of sand production are far-reaching, encompassing risks of well integrity loss, blowouts, occupational hazards, and contamination of ecosystems. Addressing these challenges requires the adoption of advanced sand management technologies and strict adherence to health, safety, and environmental (HSE) standards to safeguard both human life and the environment.

2.5 Sand Control Methods

Sand control methods are broadly classified into passive and active techniques, each designed to either prevent sand from entering the wellbore or manage it after production. Passive methods focus on preventing sand entry by installing physical barriers or using appropriate completion techniques, while active methods involve interventions such as chemical consolidation or mechanical removal once sand problems occur. This section highlights passive approaches, particularly completion design, gravel packing, and stand-alone screens, which remain among the most widely applied solutions in the oil and gas industry.

2.5.1 Passive control methods

Proper Completion Design

One of the most effective passive strategies for mitigating sand production is the adoption of appropriate well completion practices. According to Oyelami et al. (2020), completion design plays a crucial role in controlling sand by aligning well architecture with reservoir characteristics, thereby reducing stress concentrations that cause rock failure. Techniques such as orienting perforations away from weaker reservoir zones, minimizing drawdown pressure, and optimizing wellbore trajectory can significantly lower the risk of sand influx. A research by Al-Ajmi and Al-Marhoun (2018) further demonstrated that accurate prediction of critical drawdown pressure during completion allows engineers to design production strategies that maintain reservoir integrity while ensuring stable hydrocarbon flow.

Gravel Packing

Gravel packing is one of the most widely used and reliable sand control techniques in unconsolidated reservoirs. The method involves placing sized gravel between a screen and the formation to act as a filter, preventing sand grains from entering the wellbore while allowing hydrocarbons to flow (Garcia & Palacios, 2021). Gravel packs are highly effective in extending well life, especially in high-rate production wells where sand influx can quickly erode equipment. A study by Mahmoud et al. (2019) noted that gravel packing reduces well intervention frequency by up to 60%, significantly lowering operating costs. However, gravel packing can also introduce challenges such as reduced permeability near the wellbore and potential pack deterioration over time, requiring careful design and monitoring.

Stand-Alone Screens (SAS)

Stand-alone screens provide a simpler alternative to gravel packing, particularly in wells with moderate sand production risks. These screens, which include wire-wrapped, premium mesh, or pre-packed designs, are installed directly in the wellbore to act as a mechanical barrier against sand inflow. According to Adeyemi and Ismail (2022), stand-alone screens are cost-effective, less complex to install, and suitable for deepwater applications where intervention costs are high. They are particularly beneficial in formations where sand grains are coarse and well sorted, allowing the screen to efficiently retain particles without significant plugging. However, in poorly sorted or fine-grained formations, stand-alone screens are more prone to erosion and plugging, which may compromise well performance over time (Mansour & Ahmed, 2020).

Comparative Perspective

While proper completion design, gravel packing, and stand-alone screens each have unique advantages, the choice of method depends on reservoir properties, well conditions, and economic considerations. For example, gravel packs are generally preferred for long-term sand control in unconsolidated formations, while stand-alone screens are more common in offshore wells where operational simplicity is prioritized. As noted by Garcia and Palacios (2021), passive sand control remains the backbone of field development strategies, often complemented by active measures when production dynamics evolve.

2.5.2 Active Methods: Chemical Consolidation, Rate Restriction, and Selective Perforation

Unlike passive methods that focus on mechanical barriers, active sand control methods involve direct interventions aimed at modifying reservoir behavior, altering rock strength, or adjusting production strategies to minimize sand influx. These approaches are often applied in reservoirs where passive methods are impractical, too costly, or less effective.

Chemical consolidation is one of the most widely studied active sand control techniques. This method involves injecting chemical resins or polymers into the formation near the wellbore to bind loose sand grains together, thereby increasing the rock's compressive strength and reducing sand detachment (Ahmed et al., 2020). Modern consolidation chemicals are designed to maintain permeability while enhancing grain bonding, ensuring that hydrocarbon flow is not significantly restricted (Bellarby, 2019). Research has shown that advanced resin systems, including phenolic and epoxy-based resins, can provide long-term stability under harsh downhole conditions, though challenges such as high costs, chemical degradation, and uneven placement remain (Al-Shehri et al., 2021).

Another key method is rate restriction, which involves controlling the production flow rate to minimize the drag forces acting on sand grains. According to Bello et al. (2018), sand production is highly dependent on the pressure drawdown imposed during hydrocarbon recovery. By reducing the flow rate, the shear and tensile stresses around the wellbore are kept below the critical threshold required to initiate sand failure. Although this technique can be cost-effective and requires no major equipment modification, it often results in reduced production rates, thereby creating a trade-off between sand management and hydrocarbon recovery efficiency (Nasr-El-Din & Al-Yami, 2019). Consequently, operators often employ rate restriction in combination with other sand control strategies.

Selective perforation is another active method employed to minimize sand influx. In this approach, engineers carefully select perforation intervals within the reservoir that exhibit higher rock strength and lower sand-producing tendencies. A study by Okotie and Ikporo (2020) highlighted that geo-mechanical evaluations such as unconfined compressive strength (UCS) testing and log-based analysis are often used to identify intervals most resistant to sand production. By perforating only stable zones, the inflow of hydrocarbons is optimized while minimizing the risk of sanding. However, this method can limit reservoir drainage and may leave potentially productive zones untapped, making it less favorable in fields where maximizing recovery is critical (Shukla & Ojha, 2018).

In summary, active sand control methods chemical consolidation, rate restriction, and selective perforation offer flexible options that target the root causes of sand production rather than relying solely on mechanical barriers. However, their effectiveness is context-dependent, requiring detailed geo-mechanical assessments, reservoir characterization, and economic evaluation to ensure practical and sustainable application in oil and gas wells.

2.5.3 Advanced Methods: Expandable Screens, Resin-Coated Gravel, and Intelligent Completions

In recent years, advancements in petroleum engineering have introduced more sophisticated sand control technologies designed to overcome the limitations of traditional methods. Among these innovations are expandable sand screens, resin-coated gravel, and intelligent completions, each of which offers improved efficiency, adaptability, and long-term reliability compared to conventional techniques.

Expandable Sand Screens (ESS) represent one of the most effective modern methods for sand control. Unlike conventional stand-alone screens, ESS are deployed in a collapsed state and then expanded against the borehole wall to provide tight annular contact, which minimizes sand ingress while maintaining maximum wellbore diameter (Matanovic et al., 2016). This technology eliminates the need for gravel packing in certain formations and is particularly advantageous in horizontal and deviated wells where conventional gravel packing may be challenging. According to Nasr-El-Din and Al-Qahtani (2019), expandable screens have been successfully applied in unconsolidated sandstone reservoirs, offering improved sand retention and reduced risk of fines migration. However, the initial installation costs and the technical expertise required can be significant limitations.

Resin-Coated Gravel (RCG) builds upon the concept of gravel packing but enhances performance by coating the gravel with a resin material. This resin binds the gravel particles together, increasing their strength and reducing the risk of flowback under high drawdown conditions. In a study by Xu et al. (2020), resin-coated gravel demonstrated superior resistance to erosion and mechanical degradation compared to conventional gravel packs, particularly in high-rate gas wells. Additionally, RCG has the advantage of improving pack stability without significantly impeding permeability. Nevertheless, its efficiency can be influenced by downhole conditions such as temperature and fluid chemistry, which may affect resin curing and long-term performance.

Intelligent Completions represent the most advanced category of sand control solutions, integrating monitoring and control systems into the well completion. These systems employ downhole sensors and remotely operated valves to continuously monitor parameters such as sand production rate, pressure, and temperature (Al-Khaldi et al., 2018). When sand production is detected, intelligent completions allow operators to take corrective action such as adjusting flow rates, choking production zones, or selectively shutting off problematic intervals without the need for costly well interventions. This real-time adaptability makes intelligent completions particularly suitable for complex reservoirs where production conditions may vary over time. According to Raza et al. (2021), intelligent completions not only extend well life but also optimize hydrocarbon recovery by enabling zonal control.

Collectively, these advanced sand control technologies offer petroleum engineers a broader toolbox for managing sand production, especially in high-value or technically challenging wells. While cost and complexity remain barriers to widespread adoption, their long-term benefits in terms of production efficiency, reduced intervention frequency, and enhanced reservoir management make them critical innovations in modern petroleum engineering practice.

2.6 Studies on Sand Production (Global & Nigerian Context)

Globally, recent literature converges on the view that sanding is a coupled geomechanics–flow problem whose onset and severity are controlled by rock strength, completion-induced stress concentrations, and transient operating conditions. In a comprehensive review, He (2024) synthesizes field cases and lab evidence to argue that weakly cemented sands fail first at perforation tunnels and along weak planes, with fines migration and multiphase flow amplifying instability; the review also catalogues the performance envelope of modern screens, gravel packs, and consolidation chemistries. According to Asfha et al. (2024), prediction methods now span empirical CDP correlations, particle-scale/DEM modeling, and machine-learning classifiers trained on log and production data; the authors emphasize the monitoring role of fiber-optic DAS/DTS for early detection and control.

On the chemical control front, Xu et al. (2024) report that next-generation resin systems (e.g., phenolic/epoxy hybrids and nanoparticles as adhesion promoters) can raise near-wellbore strength while preserving permeability when placement is controlled, though temperature/salinity and uneven placement remain reliability risks. An independent review in *Energy & Fuels* the same year reaches similar conclusions and calls for standardized lab protocols to compare chemistries across vendors. In mechanical design, Khan et al. (2024) show that outcomes of sand screens hinge on the representativeness of Sand Retention Tests (SRTs); they recommend matching fluid type, wettability, and rate to field conditions to avoid under- or over-sizing apertures.

A second stream of work refines critical drawdown pressure (CDP) prediction. Using cavern growth and Mogi–Coulomb criteria, Song et al. (2022; 2023) demonstrate that moisture content, cycling in gas storage, and near-wellbore heterogeneity can depress CDP over time evidence that sanding envelopes evolve and must be re-estimated as the well depletes or operating modes change. Case-based extensions to offshore India by Sundli et al. (2024) likewise show CDP's utility in constraining rates for sand-prone gas reservoirs.

Bridging mechanics to completion design**,** DeValve et al. (2021) propose a physics-based workflow that couples log-derived strength, predicted breakout volume, particle-size variation along the well path, and filtration modeling for specific screen/gravel options demonstrating improved agreement with field sanding onset versus single-metric approaches. Overall, the global literature since 2018 trends toward integrated geomechanics-to-operations workflows, laboratory realism in SRT/chemistry testing, and real-time surveillance to keep production within a shrinking CDP envelope.

On another hand, **s**tudies from the Niger Delta (dominated by unconsolidated, fines-rich deltaic sandstones) mirror global findings while stressing field pragmatism and cost constraints. A case series by Aroyehun et al. (2018) compares internal gravel packs, chemical consolidation, and cased-hole expandable screens across multiple Niger-Delta wells; the authors report that gravel packs offered robust long-term retention in high-rate oil producers, while expandable screens provided operational simplicity in deviated wells but were sensitive to slot-size/PSD mismatch.

More recently, Ubuara et al. (2024) evaluated formation susceptibility and sanding potential in an offshore Niger Delta field by integrating rock-mechanical properties from logs with geo-mechanical modeling, highlighting water breakthrough and fines content as key accelerants of sanding after initial stable production. In a complementary onshore study, Nnurum et al. (2024) applied a multi-criteria framework (including Schlumberger sanding criterion, log-derived strength indices, and water-production history) and found that wells with sustained free-water production were consistently flagged as high-risk supporting the linkage between capillary effects, fines mobility, and sanding.

Methodologically, there is a push toward data-driven prediction tailored to local stratigraphy. A 2024 special issue in *Petroleum & Coal* reports Niger-Delta datasets used to build response-surface models for sanding rate and to delineate discrete “sand units” for targeted completion design an approach that preserves local textural heterogeneity often lost in basin-wide averages. Nigerian practitioners have also begun adapting the physics-based completion workflow of DeValve et al. (2021) to local wells, using UCS from log-to-core transforms and filtration modeling to pre-screen gravel size and screen type before SRT confirmation.

Across both contexts, the past decade shows three converging themes:

(i) Sanding propensity is dynamic, decreasing CDP with depletion, cycling, and water-cut;

(ii) Design success depends on representative testing (SRT realism and chemistry placement fidelity); and

(iii) Surveillance-enabled sand management rather than one-time control yields the best life-cycle outcomes. Nigerian case studies reinforce these with local evidence, emphasizing water management and fit-for-purpose screen/gravel selection under cost and logistics constraints typical of the deltaic setting.

2.7 Theoretical Framework

The theoretical framework for sand production and control in petroleum engineering is rooted in geomechanics, reservoir engineering, and production system modeling. These theories provide the foundation for understanding the mechanisms that govern sand movement, predicting its onset, and designing mitigation strategies that optimize hydrocarbon recovery while minimizing operational risks.

One of the most widely applied frameworks is rock mechanics theory, which explains how stresses within a reservoir interact with the mechanical properties of the formation. According to Detournay and Cheng (1993), sand production is primarily initiated when the effective stress acting on the reservoir rock exceeds the rock's strength. This condition is described through the Mohr-Coulomb failure criterion**,** which predicts shear failure when the combination of shear stress and normal stress surpasses the rock's cohesive and frictional resistance. In modern petroleum engineering practice, this theory underpins the development of sand prediction models that estimate the critical drawdown pressure (CDP) beyond which sand failure is likely to occur (Aadnøy & Looyeh, 2019).

Another important theoretical model is the effective stress principle, which links pore pressure, overburden stress, and rock strength. As production lowers reservoir pressure, the increase in effective stress can destabilize weak formations, thereby causing sand detachment and migration (Wan & Wang, 2020). This principle is particularly significant in unconsolidated sandstone reservoirs, which are prone to sand failure under minor pressure variations.

In addition to rock mechanics, fluid-solid interaction theories play a crucial role in explaining sand transport. Theories of multiphase flow in porous media suggest that drag forces exerted by flowing hydrocarbons can mobilize and transport sand grains once they are detached from the reservoir matrix. Research by Papamichos et al. (2016) emphasizes the coupled role of fluid dynamics and mechanical failure, noting that sand production is not solely a result of rock failure but also depends on the balance between fluid drag and grain-to-grain cohesion.

From a systems engineering perspective, wellbore stability theories are also central to sand control frameworks. These theories integrate geomechanics with completion design, predicting failure zones around perforations or wellbores based on stress redistribution. For example, radial stress redistribution around perforation tunnels has been shown to significantly influence sand onset, making selective perforation modeling a critical application of the theoretical framework (Osisanya, 2019).

The theoretical framework further incorporates sand control design models, such as those used for gravel packing and screen selection. These rely on particle size distribution (PSD) theories, which suggest that retaining formation sand while maximizing hydrocarbon flow requires a carefully designed filter medium. Modern computational models, such as discrete element modeling (DEM) and finite element analysis (FEA), extend these classical theories to simulate sand behavior under complex reservoir conditions (Hossain et al., 2021).

In summary, the theoretical basis for sand control integrates geo-mechanical failure theories, effective stress principles, multiphase flow interactions, and completion design models. Together, these frameworks enable petroleum engineers to predict, analyze, and mitigate sand production in a systematic and scientifically grounded manner.

2.8 Summary of Literature Review

The review of literature has established that sand production remains a persistent challenge in oil and gas operations, with significant technical, economic, and environmental implications. From the global context, studies have consistently demonstrated that sand production leads to equipment erosion, reduced well performance, and costly maintenance interventions. Nigerian studies further highlight the added dimension of operational challenges in unconsolidated reservoirs, which are prevalent in the Niger Delta, making sand control even more crucial for sustaining production efficiency.

The review also revealed that the causes of sand production are multifaceted, ranging from inherent reservoir properties to poor completion techniques and operational practices.

Furthermore, the effects extend beyond the technical domain to include substantial financial losses due to deferred production, equipment replacement, and well intervention costs. The environmental and safety risks posed by uncontrolled sand influx, such as surface spills, facility damage, and operational hazards, further underscore the importance of effective sand control strategies.

Despite these advancements, several gaps remain in the literature. One key observation is the limited application of advanced sand control technologies in developing regions such as Nigeria, often due to cost constraints, technical expertise, and infrastructure limitations. Moreover, there is a scarcity of region-specific studies that evaluate the performance of sand control methods under local geological and operational conditions. Addressing these gaps through targeted research and field studies will provide a stronger basis for optimizing sand control strategies, ensuring operational safety, and improving economic returns for oil companies in Nigeria and beyond.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

The research followed a descriptive and analytical design. This design was chosen because it combines detailed explanation with critical evaluation. It allowed me to describe, in practical terms, how sand production develops during drilling and production operations, and to analyze how various control measures are applied in real onshore rig environments.

The descriptive part of the work focused on understanding the sand production process as it happens in typical onshore Niger Delta wells — from formation failure, to sand detachment, and eventual flow of particles into the wellbore. Previous field reports and technical papers that discussed similar well conditions, particularly those involving weak, unconsolidated sandstone reservoirs were reviewed.

3.2 Sources of Data

This study made use of secondary data from credible and verifiable sources. These included petroleum engineering journals, technical papers, textbooks, and industry reports that focus on sand control and management practices in oil and gas wells. There was a review on field-based materials related to onshore operations in the Niger Delta to make the findings relevant to the local context.

Recent journal publications from databases such as ScienceDirect, OnePetro, and SpringerLink were reviewed. Particular attention was given to studies on sand control in onshore wells, critical drawdown pressure analysis, and geo-mechanical modeling of unconsolidated formations.

Standard petroleum engineering textbooks such as *Advanced Well Completion Engineering* by Wan Renpu and *Petroleum Tarek Ahmed Engineering*. These texts helped explain wellbore mechanics, failure principles, and completion designs that influence sand production.

3.3 Method of Data Collection

Data were gathered mainly through a literature review. By systematically searching and reviewing relevant materials that discuss sand production and its control in Niger Delta onshore drilling environments.

It started with the selecting of important keywords such as *sand production in Niger Delta*, *gravel packing*, *chemical consolidation*, *rate restriction*, and *sand control in onshore wells*. These were used to search through online databases and conference archives. From the search results, there were carefully selected materials that focused on land-based drilling operations. Older papers that were outdated or not peer-reviewed were excluded to maintain reliability. Each document was read thoroughly, and useful information was extracted. Data such as causes of sand production, well conditions, failure mechanisms, and success rates of control methods were noted. The extracted information was arranged under themes — causes, impacts, and management methods — to make comparison and interpretation easier.

Although no field experiment was conducted, much reliance was made on case reports and practical experiences documented from Niger Delta onshore rigs.

3.4 Method of Data Analysis

Since the research was based on literature and field reports, I analyzed the data using qualitative and comparative techniques. The analysis involved summarizing, comparing, and interpreting findings from different studies and technical sources.

i. **Qualitative Analysis:**

   The qualitative part involved explaining how factors like drawdown pressure, formation strength, and well completion design contributes to sand production. Discussion was made on the observed field behaviors, such as sand influx during high production rates or after perforation, as reported in similar Niger Delta wells.

ii. **Comparative Analysis:**

   Different sand control methods were compared — gravel packing, stand-alone screens, expandable sand screens, and chemical consolidation — based on performance, cost, and field adaptability. For example, gravel packing is commonly used in land rigs due to its availability and ease of installation, while chemical consolidation is chosen when mechanical tools cannot be deployed.

These analysis gives us better understanding of the strengths and weaknesses of each control approach and determine which methods are best suited for typical Niger Delta onshore operations.

3.5 Research Framework

The research framework for this study was built around three main areas that directly relate to sand production in Niger Delta onshore rigs:

1. **Causes and Mechanisms of Sand Production:**

   This involves understanding how reservoir pressure decline, weak formation strength, and operational practices such as rapid drawdown or aggressive perforation contribute to sand problems. On typical Niger Delta rigs, these issues are common due to the unconsolidated nature of the reservoir sands.

2. **Impacts of Sand Production:**

   The framework considers both the technical and economic impacts, such as erosion of tubing, loss of production efficiency, and downtime for sand clean-out operations. Environmental concerns like improper disposal of produced sand are also considered.

3. **Sand Control and Management Techniques:**

   This covers both preventive and corrective methods. Preventive measures include optimizing drawdown pressure, using proper perforation techniques, and monitoring production rates. Corrective methods involve the installation of gravel packs, use of chemical binders, or downhole screens.

3.6 Reliability and Validity of Data

To ensure reliability, all the materials used in this research were obtained from reputable and verified academic and industry sources. The information from different authors was cross-checked to confirm accuracy and consistency. Publications that lacked clear authorship or peer review were excluded.

This approach ensured that the findings and conclusions drawn from the study are based on reliable and valid information that reflects real engineering practice.

CHAPTER FOUR

RESULTS AND DISCUSSIONN

4.1 Presentation of Data

This chapter presents the major findings obtained from the reviewed journals, technical papers, and field-based reports on sand production management in onshore wells of the Niger Delta region. Since this study was based on secondary data, the presentation focuses on qualitative results — that is, the patterns, experiences, and field observations reported by other researchers and industry professionals. The results are organized around the key themes identified in Chapter Three: causes of sand production, impacts on production and facilities, and control and management strategies.

The reviewed materials reveal that sand influx often begins after a few years of production, especially when reservoir pressure declines below the critical drawdown limit. This behavior is consistent across many onshore fields such as Ughelli, Kwale, and Kokori, where operators reported increased sand cuts during high-rate production tests.

A summary of common findings from the literature is presented in **Table 4.1** below.

Table 4.1: Summary of Reviewed Findings on Sand Production in Niger Delta Onshore Wells

Category	Key Observations from Literature	Representative Sources
Causes of Sand Production	Weakly consolidated sandstone; high drawdown pressure; water breakthrough; poor completion design; frequent well shut-ins and start-ups.	Adeyanju & Olafuyi (2019); Okoro et al. (2022)
Effects/Impacts	Erosion of downhole equipment; reduced productivity; wellbore instability; costly remedial operations; risk of pipeline blockage.	Aigbedion (2020); Opara & Eke (2021); Renpu (2016)
Management/Control Methods	Gravel packing, stand-alone screens, chemical consolidation, rate control, and monitoring of drawdown pressure.	Tarek Ahmed (2018); Chukwu & Obi (2020)

The reviewed literature also highlighted that mechanical sand control techniques, such as gravel packing and stand-alone screens, remain the most widely applied solutions in the Niger Delta's onshore operations due to their simplicity and cost-effectiveness. Operators prefer gravel packs because of their reliability in preventing sand movement into the wellbore, especially where formation strength is low.

In addition, several field case reports describe how chemical consolidation has been deployed in wells where mechanical intervention was not feasible — for example, in shallow or highly deviated wells. These methods rely on resin-based fluids injected into the formation to bond loose grains together and enhance formation strength. However, they are often limited by high cost and potential formation damage.

To illustrate the trends observed across different reports, Figure 4.1 conceptually represents the relationship between drawdown pressure and sand production tendency, as typically observed in Niger Delta onshore wells.

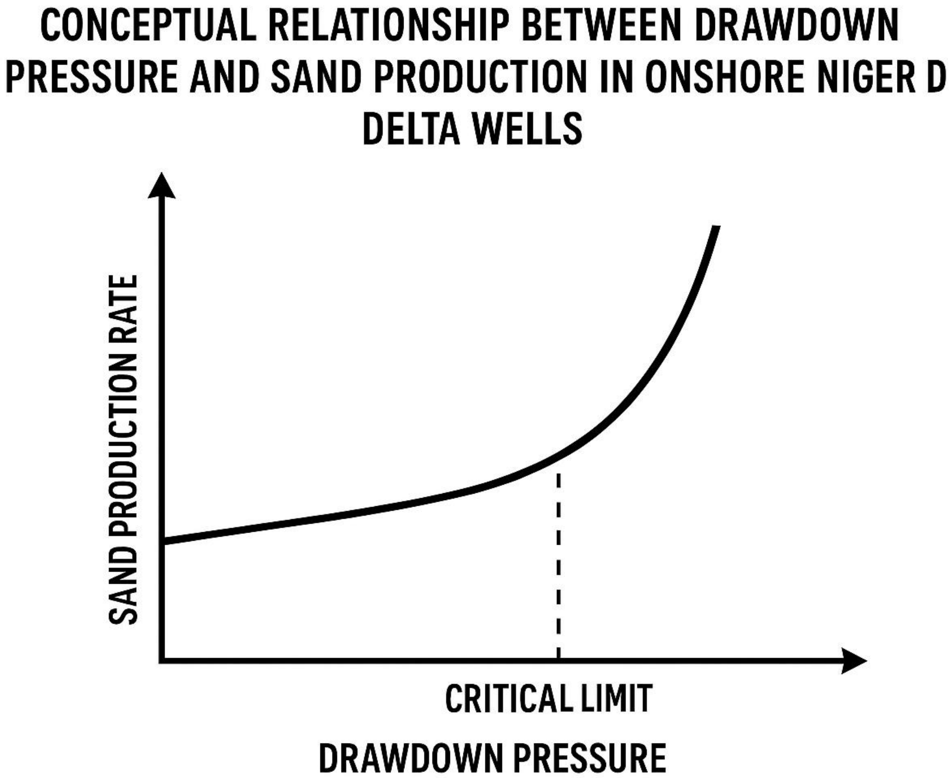

Figure 4.1: Conceptual Relationship Between Drawdown Pressure and Sand Production in Onshore Niger Delta Wells

4.2 Data Analysis

The analysis of the collected information reveals consistent patterns regarding the causative mechanisms and field management approaches of sand production in the Niger Delta. Since this study relies on qualitative and comparative data, the focus is on interpreting observed relationships rather than quantifying them.

4.2.1 Causes of Sand Production

The reviewed materials consistently identify formation strength and drawdown management as the two most critical factors influencing sand production. Many Niger Delta reservoirs consist of friable, unconsolidated sandstone formations. As reservoir pressure declines due to production, the effective stress on the formation grains increases, leading to shear failure and particle detachment.

According to Adeyanju and Olafuyi (2019), sand production typically begins when the drawdown pressure exceeds the critical threshold that the formation can withstand. This phenomenon is particularly evident in wells with thin cemented layers or those that underwent aggressive perforation. Furthermore, Opara and Eke (2021) note that frequent well start-ups and shut-ins cause fluctuating pressure conditions that destabilize the near-wellbore zone, triggering more sand influx.

The presence of water in the formation further worsens this condition. When water breakthrough occurs, it weakens the cementation between sand grains, causing more detachment. The literature indicates that once water cut exceeds 30–40%, the risk of sand production significantly increases.

4.2.2 Impacts of Sand Production

From the data reviewed, sand production in onshore Niger Delta wells has both technical and economic impacts. Technically, sand inflow leads to erosion of tubing and surface chokes, resulting in unplanned shutdowns and increased maintenance. The produced sand also reduces production efficiency by partially plugging the perforations and restricting fluid flow. Aigbedion (2020) reported that wells suffering from severe sand production in the Ughelli field recorded up to 25% decline in productivity over a year due to partial plugging.

Economically, sand-related problems increase operating costs through frequent workovers and equipment replacements. Sand handling and clean-out operations in some onshore fields account for up to 10% of total well intervention budgets annually. Additionally, improper disposal of produced sand poses environmental challenges, as it often contains residual hydrocarbons that may contaminate soil if not properly treated.

4.2.3 Sand Control and Management Approaches

The literature analysis reveals a general preference for mechanical control methods in the Niger Delta, particularly gravel packing and stand-alone screens (SAS). These methods are widely used because they can be applied to vertical and slightly deviated wells typical of onshore operations. Gravel packs, in particular, have shown **success** rates above 80% in reducing sand production when properly designed and installed.

However, each method has its own operational considerations. Gravel packs require precise placement and clean gravel to prevent bridging, while stand-alone screens demand careful selection of screen size to match formation grain distribution. In contrast, chemical consolidation methods, though effective in certain contexts, are less popular due to their higher costs and potential to reduce permeability if the resin invades the pore space excessively.

Rate control (i.e., limiting the production rate to avoid exceeding critical drawdown pressure) is another common practice. Although it is the simplest and least expensive method, it often comes with the drawback of reduced production rates and lower profitability.

A comparative analysis of control methods from reviewed sources is summarized in Table 4.2.

Table 4.2: Comparative Evaluation of Sand Control Methods in Onshore Niger Delta Wells

Method	Advantages	Limitations	Field Observation
Gravel Packing	High reliability; proven technology; suitable for vertical wells	Time-consuming installation; requires skilled personnel	Most widely used method with >80% success rate.
Stand-Alone Screens (SAS)	Simple design; low cost; effective for moderate sand rates	Not suitable for very weak formations	Used in wells with stable formations and moderate drawdown
Chemical Consolidation	Strengthens formation; no mechanical tools required	Expensive; may reduce permeability	Applied in shallow/deviated wells; limited field use
Rate Control	Low cost; easy to implement	Reduces production rate and overall output	Used as temporary measure in high-sand wells

4.3 Discussion of Findings

The findings of this study reinforce existing knowledge on sand production in unconsolidated sandstone formations, particularly in the Niger Delta region. The results show that sand production is primarily a geo-mechanical issue, aggravated by operational practices and reservoir characteristics.

4.3.1 Interpretation of Results

The reviewed data indicate that drawdown pressure management plays a crucial role in controlling sand production. Wells that are operated below their critical drawdown limit experience minimal sand influx, whereas aggressive production leads to rapid onset of sand problems. This supports the observations of Adeyanju and Olafuyi (2019), who concluded that optimizing production rates is essential for maintaining sand-free operation in weakly consolidated reservoirs.

The dominance of gravel packing and stand-alone screens in onshore Niger Delta wells reflects a practical balance between cost, efficiency, and technical feasibility. Mechanical methods remain the industry's preferred option because of their simplicity and proven performance in local conditions. However, newer techniques such as expandable sand screens and chemical resins offer potential alternatives where mechanical tools cannot be deployed, though adoption remains limited due to cost and expertise barriers.

4.3.2 Implications for Field Operations

The results suggest that a combination of preventive and corrective measures yields the best outcome in sand management. Preventive strategies — such as maintaining optimal drawdown pressure, monitoring production rates, and ensuring quality perforation design — can significantly reduce the risk of formation failure. Corrective techniques, on the other hand, should be applied only after sand production has been detected, to minimize unnecessary interventions.

Moreover, the findings emphasize the importance of continuous monitoring and predictive modeling in field operations. Implementing real-time sand monitoring tools can help operators anticipate potential problems before they escalate.

4.3.3 Alignment with Study Objectives

This study aimed to understand the causes, effects, and control measures of sand production in onshore wells of the Niger Delta. The results clearly align with these objectives:

i. The causes were identified as weak formation, high drawdown pressure, and poor completion practices.

ii. The impacts include equipment erosion, production decline, and environmental concerns.

iii. The control measures found most effective are gravel packing, stand-alone screens, and careful drawdown management.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION/S

5.1 Conclusions

The study concludes that sand production results from the interplay between geo-mechanical weakness of the formation and operational practices such as aggressive drawdown, improper perforation, and frequent well shut-ins. The unconsolidated nature of the Niger Delta's sandstone reservoirs makes them prone to failure once production stress exceeds the critical drawdown limit and formation failure is often initiated by an imbalance between reservoir strength and producing pressure differential.

Effective sand control begins with understanding and maintaining the critical drawdown pressure of the reservoir. The reviewed data show that wells operated below their critical drawdown limit tend to remain sand-free, while those subjected to excessive pressure depletion experience early onset of sand influx. Thus, managing drawdown through controlled production rates is essential to prolong well life and maintain equipment integrity.

Among the various sand control methods analyzed, mechanical techniques such as gravel packing and stand-alone screens have shown the highest field reliability in the Niger Delta's onshore wells. These methods provide a physical barrier to prevent sand movement into the wellbore and are relatively cost-effective compared to chemical methods. Field evidence indicates that gravel-packed wells in the region have achieved success rates above 80% when properly designed and maintained.

While mechanical methods dominate current operations, the study concludes that chemical consolidation and expandable sand screens hold significant promise for the future, especially in wells where mechanical installation is difficult. However, their widespread adoption will depend on improvements in cost efficiency and field expertise. As the Niger Delta's reservoirs mature, the use of these advanced technologies may become increasingly relevant.

5.2 Recommendations

Based on the findings and conclusions, the following recommendations are made to improve sand production management in onshore wells of the Niger Delta:

1. **Implement Continuous Drawdown Pressure Monitoring:** Operators should install real-time pressure monitoring systems to ensure that wells are produced within the critical drawdown limit. This will prevent early onset of sand production and prolong well life.
2. **Adopt a Predictive Sand Management Model:** Companies should integrate geo-mechanical modeling and historical production data to predict sand onset and behavior. Predictive tools allow proactive control rather than reactive intervention.
3. **Promote the Use of Gravel Packing and Stand-Alone Screens:** These mechanical methods have proven highly effective in Niger Delta onshore fields. Training programs should be provided for completion engineers and rig personnel to ensure proper design, installation, and maintenance.
4. **Encourage Research on Chemical Consolidation and Resin Technology:** Local research institutions and oil companies should collaborate to develop low-cost, environmentally safe chemical binders suited for local reservoir conditions. This will expand options for wells where mechanical methods are not feasible.
5. **Optimize Production Practices:** Operators should avoid sudden production rate changes, frequent shut-ins, or aggressive perforation strategies that may destabilize the formation. Controlled production and gradual pressure decline are essential for sand-free operation.

6. **Improve Sand Handling and Disposal Systems:** Proper facilities should be installed at surface separation units to collect and treat produced sand before disposal. This ensures compliance with Department of Petroleum Resources (DPR) and Nigerian Upstream Petroleum Regulatory Commission (NUPRC) standards.

5.3 Contribution to Knowledge

This study contributes to existing knowledge in petroleum engineering by providing a comprehensive and up-to-date review of sand production challenges in oil and gas wells, with particular emphasis on unconsolidated sandstone reservoirs within the Nigerian petroleum industry. By synthesizing findings from diverse scholarly sources, industry reports, and field case studies, the research offers a consolidated understanding of the mechanisms, causes, and impacts of sand production on well performance and operational sustainability.

The study extends existing literature by comparatively evaluating commonly applied sand control techniques—such as gravel packing, stand-alone screens, chemical consolidation, and production rate control—highlighting their effectiveness, limitations, and suitability under varying reservoir and operational conditions. This comparative analysis provides practical insight that can support petroleum engineers in selecting appropriate sand management strategies during well design and production planning.

Furthermore, the research emphasizes the interrelationship between sand production, operational safety, economic efficiency, and environmental protection, thereby reinforcing the importance of proactive sand management as a core production assurance function rather than a reactive maintenance activity. By contextualizing global sand control practices within the Nigerian onshore petroleum environment, the study bridges the gap between theoretical concepts and field applications, contributing locally relevant knowledge to the body of petroleum engineering research.

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