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A Review of Optimisation of Transportation of Drill Cuttings Waste

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Abstract: Transportation and monitoring of oil and gas operations require advanced logistics supply chain management. This paper adopts the desktop study research method, using credible pieces of literature such as textbooks and online journals and articles, to identify preferable waste management options for transportation drill cuttings wastes and improving the oil and gas business. Findings reveal that haulage of drill cuttings is regulated differently depending on the environmental compliance requirements locally and internationally. Though challenging, the shipment of drill cuttings from cradle to grave can be improved, based on the localised monitoring mechanisms and possibly, the adaptation of spatial technologies which inversely progress logistic outcomes.

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Environmental problems in Nigeria are now becoming more daring than ever before. Various policies and institutions have often been put in place to tackle such problems. However, one notable missing link in the current efforts geared towards ameliorating the environmental problems besetting the nation is the failure of policymakers and implementers to integrate established local knowledge and practices of environmental resources/risk management. A call is thus made for the integration of knowledge in the formulation and implementation of environmental protection policies (Nna, 2015). Geographic Information System (GIS) technology has been applied to large scale transportation planning and engineering applications. More often, however, GIS is applied in a prescriptive way to small-scale problems, for example, to plot optimal routes for buses, delivery trucks, or emergency vehicles. While routing is a specific category of spatial interaction which considers a given set of origins and destinations for which specific (often optimal) routes are found, a transportation model can provide a framework for the assessment of relationships and feedback effects between transportation and the spatial structure (Jean-Paul, 2020).

The Science of Drill Cuttings Transport: Drill Cuttings transport phenomena refer to the resultant forces acting on the particles, which are drag force due to the settling of particles and lift force where the drilling fluid can lift cutting particles. Factors affecting particle transport include flow speed, the shape of particles, flow regime (degree of turbulence), and annular space (Khalil and Adnan, 2020). The development of relevant and accurate cuttings transport models requires that experimental, modelling, and simulation studies target the respective flow scenarios obtainable in practical drilling

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operations (Epelle and Gerogiorgis, 2019). The efficiency of cuttings transport is a very important factor for a good drilling operation program. The transportation of these cuttings through the annulus is a complex problem that is affected by many parameters. For effective cuttings transport prediction, it will require that all these parameters be considered simultaneously. Predictions of pressure losses and cuttings transportation through the annulus are very complex during drilling operations due to the combination of interacting drilling parameters (Menegbo et al., 2019). The process of cutting transportation and proper hole cleaning is substantial in any drilling program. The success of any drilling operation is the result of an efficient and properly cleaned hole. Hole cleaning is the capability of the drilling fluid to transport the cutting produced during drilling operations up to the surface and suspend the cuttings (Bourgoyne and Millhein, 1991).

The Need for A Waste Management Program: A concern of any waste management program is the movement of drilling wastes from point-to-point on-location or transfer offsite. Logistics, environmental laws, and budget will influence what is practical and effective. Proper storage and transportation of drilling waste is one component of a successful waste management project. Several technologies exist to perform the task. No one is superior in every circumstance to another (Richard and Love, 2019). Flatbed trucks are normally used during the exploration phase of oil drilling operations, especially the moving of rig components, accessories and camp facilities; as well as hauling materials, tools, supplies, and equipment needed by the rig and camp operations, from supply warehouses to the rig site. Further, routine shipment of materials needed for the drilling and completion well, and goods, drinking water and other items necessary for the sustenance of the rig crew are necessities. An irregular truck service or breakdown of the trucks along the way may result in shortages, an increase in the overall cost of the rig-up process and disruption of the drilling work programme (Mortagy and Eleithy, 1980).

Transportation in the Oil and Gas Industry: Transportation and distributions network holds an important role to maintain business stability in the oil and gas industry (Amelia et al., 2021). Optimisation and analytics technologies are currently playing a vital role in enabling the oil and gas industry to achieve its goals (Furman et al., 2017). Oil and gas companies need visibility into their supplier, project, customer, and business processes to ensure complete tracking and monitoring of the movement of goods (Robinson, 2017). The oil and gas industry can be complicated when it comes to logistics due to shipping items like bulky equipment, hazardous supplies, and strict delivery deadlines (PLS, 2022). Due to globalization, the role of world trade and transportation has increased. Oil is the number one energy source for many industries (Mast, 2005). Along with the increase of globalisation, the world trend for oil consumption shows a constantly increasing tendency (Hilmola, 2011; Nation Master, 2009; Tierney, 2004). Christopher (2011) postulates that a company with better logistics and supply chain management can improve and sustain its competitive advantage over rival companies (Szuco and Hassen, 2012).

Crude oil logistics activities, which are mostly carried out using ships, are one of the contributors to greenhouse gas (GHG) emissions. GHG emissions from logistics activities are predicted to increase significantly by 2050, so they need to be controlled with the right logistics planning strategy (Atmayudha et al., 2021). Advancement in science and technology is currently driving intelligent and automatic control technologies in various engineering fields (Yang et al., 2021; Jia, 2020; Tan et al., 2016; Shang et al., 2015; Wang et al., 2012), to enable real-time data acquisition and monitoring of transportation linkages (Wang et al., 2020; Sousa et al., 2015). At present, the optimisation theory and method have been widely used in the optimisation scheduling and optimal operation scheme of complex production systems (AIP, 2018).

Generation of Drill Cuttings Waste: Untreated cuttings are sometimes slurried, by the addition of water, to improve pumping performance and slurried cuttings may be shipped to shore in bulk. Treated drill cuttings are more easily transported as a dry powder although cuttings generated onshore are generally ‘damped’ with water at a rate of between 5 and 10% by volume to reduce dust nuisance (Paul et al., 2003). Internationally, the total amount of cuttings, which has been discharged to the United Kingdom Continental Shelf (UKCS) up to 2000, is estimated to be approximately 2,000,000 tonnes. This figure represents those cuttings, which were discharged from multiple well sites only, and approximately a further 5,000 to 6,000 single wells have also been drilled during that period (OSPAR Commissioning, 2019). The international standards require that the waste produced from crude oil and natural gas exploration and production should be regulated by national and international laws. In Nigeria, the most relevant law relating to the dumping of crude oil-related materials in the environment is the Oil in Navigable Waters Act (Cap 337 L.F.N.1990). However, the Act has no provisions for drill waste management. According to Tchobanoglus et al., (1993), waste management is a consciously planned activity, directed towards the control of generation, storage, collection, transfer, transport, processing, and disposal of all types of waste (Tchobanoglus et al., 1993). Therefore, the phrase, waste management is used to describe the gathering, transportation, dumping or recycling, detoxication and monitoring of wastes. The essence of managing waste is to circumvent the adversative effects on the environment, and human health and to preserve human and material resources (WMR, 2009). Every activity designed and executed to control waste is classed as waste management such actions include collecting, transporting, segregating, and treatment and recycling (Kato et al., 2019).

Transportation of Drill Cuttings Waste: Pneumatic conveyance of drill cuttings is broadly split into two types: (i) dilute/lean phase conveyance; and (ii) dense phase conveyance (Morris et al., 2006). In dilute or lean phase conveying, particles are fully suspended in the conveying air and transported at low pressure and high velocity. Examples of dilute phase conveyance include blowing of cement and barite (dilute phase pressure conveying) and dilute phase vacuum conveyance. Vacuum collection systems can collect, store, and move drilled cuttings within an enclosed environment, minimising spills and contamination. Vendors state that vacuum collection systems are effective in minimising safety and environmental risks associated with cuttings collection and containment, as well as being relatively simple to mobilise and demobilise. They can transfer cuttings vertically as well as horizontally, which offers flexibility in space requirements (MI-SWACO, 2014). The use of skip and ship has the advantage of being relatively simple but poses environmental and safety risks, particularly relating to increased crane operations. As noted by (Morris et al., 2006), a typical offshore well can generate more than 1,000 tonnes of cuttings and require several hundred cuttings boxes. These boxes must be lifted onto a boat, transported to the rig, lifted onto the rig, and then lifted to the filling station on the rig. Once filled with cuttings, the box is lifted from the filling station, transferred down onto the boat, and finally lifted off the boat when it returns to the shore base (Gilbert et al., 2010). This means six or more crane lifts are required for each cuttings box filled, and at 200 boxes per well, this amounts to 1,200 individual crane lifts. This represents a significant safety risk to workers at the rig site, on boats, and at the shore base. Larger boxes may be used but this can be constrained by the available handling equipment (Morris et al., 2006). In a subsea completion, the well is drilled from a floating platform and the blowout preventer and production equipment are installed on the sea floor with tie-ins for produced oil and gas to a pipeline or surface storage vessel. Production may be transported to shore through pipelines or via oil tankers. The drilling fluid exiting the drill bit suspends the cuttings and carries them up the annulus to the surface where they are separated from the drilling fluid by the solids control equipment on the drill rig. The cuttings may be further processed before disposal or put into storage containers for subsequent treatment and disposal onsite or for transport to shore. Processed drill cuttings may be discharged to the ocean, re-injected into a suitable disposal formation, or transported to shore for treatment, disposal and/or beneficial reuse. The choice of drilling waste management options depends on the type of drilling fluids used, local regulations, drilling facility space/weight limitations, environmental considerations, and cost-benefit analysis (IOGP, 2016).

Transportation Network: The petroleum industry is material flow intensive, thus, effective management and optimisation of the chain are critical (Saad et al., 2018). A waste manifest is issued by the oil and gas company to provide details of the type of waste that is being transported, treated, stored, or disposed of in a legal, safe, and environmentally friendly manner (EGASPIN, 2018). Traditional transport modelling methods have to date had limited application in the modelling of the transportation network, due to their focus on large-scale transport analysis zones rather than small, link-level features which affect travel decisions (Cervero, 2006). The transport of drill waste to shore has been practised successfully in numerous operations worldwide. The process of transport to shore, known as skip and ship, is very simple. Cuttings are collected from the cuttings ditch and transferred, usually by screw auger, to a suitable location for loading. As well as collecting cuttings the system should handle liquid overspill from the shakers and waste from centrifuges. The drilling waste is loaded, normally into specially designed skips of around 8 tons capacity, via a steerable chute. For onshore operations, the skips can be placed directly below the shale shakers. Empty and full skips are stored on the rig and depending on the drilling program filled skips may be offloaded either onto a dedicated collection vessel or to a standard platform supply vessel (PSV). Once back loaded the drilling waste is disposed of onshore. Landfilling or incineration of untreated cuttings is an acceptable solution depending on the local legislation. Another option is to fix the oil to the cuttings using fly ash, leaving a relatively stable, but still potentially hazardous, product. It is also possible to employ a technique to clean the cuttings and recover the base oil, leaving a benign solid waste and reusable oil (Drilling for Gas, 2009).

Drill Cuttings Transportation Companies in Nigeria: Onshore landfill disposal of waste through burial onshore is generally referred to as landfilling, which is widely used throughout the world for the final disposal of a wide range of wastes. The main principle of landfills (as opposed to land application of waste) is to ensure that wastes are contained (by the geology of the site and/or engineering measures) such that the waste itself and the products of waste decomposition do not harm the surrounding environment. A facility of this type is commonly referred to as an 'engineered landfill' or 'sanitary landfill', to distinguish them from sites where waste is dumped with no measures to protect the environment. Different countries have different specific requirements for landfill site selection, construction, and management. The European Union (EU) Directive on the Landfilling of Waste defines a landfill as "a waste disposal site for the deposit of the waste onto or into the land (i.e., underground), including internal waste disposal sites (i.e., the landfill where a producer of waste is carrying out its waste disposal at the place of production), and a permanent site (i.e., more than one year) which is used for the temporary storage of waste". The EU definition of a landfill, however, excludes "the use of inert waste which is suitable, in redevelopment/restoration and filling-in work, or for construction purposes, in landfills and the deposit of unpolluted soil or non-hazardous inert waste resulting from prospecting and extraction, treatment, and storage of mineral resources as well as from the operation of quarries" (EU, 1999).

Landfills for Drill Cuttings Waste: In the United States, non-hazardous waste landfills are regulated by the individual states, but in compliance with Title 40 of the Code of Federal Regulations (CFR) 258: Criteria for Municipal Solid Waste Landfills (commonly referred to as 'Subtitle D'). While many E&P wastes are exempt from regulation as hazardous waste under the Resource Conservation and Recovery Act (RCRA) Subtitle C, these wastes are generally subject to non-hazardous waste regulation under RCRA Subtitle D and applicable state regulations (USEPA, 2014). The International Finance Corporation (IFC) publishes a series of Environmental, Health and Safety (EHS) Guidelines, which describe the standards expected of projects receiving IFC funding. IFC define 'sanitary landfill' as a carefully engineered, structurally stable formation of segregated waste cells separated by soil cover material, with base and side slopes designed to minimise infiltration and facilitate collection of leachates' (IFC, 2007). For general landfills (i.e., non-hazardous), IFC refers to applicable national requirements and internationally recognised standards (including US EPA and EU Landfill Directive). For hazardous waste landfills, IFC recommends: a bottom lining system, preferably with two or more low permeability liners; a leachate collection system above the upper liner to limit leachate depth to 0.3 m, and in the case of double-lined systems, install leak detection between the two liners (IFC, 2007). Some jurisdictions have permitted drilling waste to be disposed of in situ at the rig site, by burial of the drilling pit which contains the cuttings. The extent to which this approach is permitted and the necessary conditions (e.g., use of impermeable liners) will vary between jurisdictions. For example, in the United States, individual States publish guidelines on acceptable drilling pit management methods (RCT, 2015; COGCC, 2014).

Scenarios of Shipment of Drill Cuttings Waste: Waste shipped to shore to the drilling waste treatment facility could be challenging for fulfilling the requirements for safety, logistics and environment due to remote and sensitive areas and harsh climate conditions in the Barents Sea. Moreover, the transport of waste to shore for treatment has also a negative effect on the environment by increasing air pollution, energy consumption and increasing marine traffic. In the Northern parts of Norway, waste treatment facilities are poorly developed (EIA et al., 2006). Hammerfest is the northernmost location with an established drilling waste treatment facility, for the disposal of water-based drill cuttings. However final treatment is still handled further south due to capacity and technical limitations. Moreover, the only place that has completed treatment for other drilling waste than water-based drill cuttings and the facility for final treatment of both slop and oil-based cuttings in northern Norway is Sandnesjøen which is located south of the Barents Sea. A typical offshore well can generate more than 1000 tons of cuttings and require several hundred skips. All these skips must be lifted onto a boat, transported to the rig, lifted onto the rig, and lifted to the filling station on the rig. Once filled with cuttings, the skip is lifted away from the filling station, lifted down onto the boat, and finally lifted off the boat when it returns to the shore base. This means six or more crane lifts are required for each skip filled, and at 200 skips per well this amounts to 1200 individual crane lifts (Svensen and Taugbol, 2011; Morris et al., 2006). There are many health, safety and environmental issues connected to it and the number of crane lifts makes these high-risk methods due to polar low and high wind in the area. The environmental effect causes a lack of concentration and is the reason for human errors. Falling objects can be dangerous during operations; trapped fingers or bodies are also in danger. Nine out of ten fatal an accident on the Norwegian shelf is caused by human error during crane lifting activities. In addition, these skips can take up considerable deck space on a rig, many of which were never designed for these types of operations. In periods with high activity, one major problem is availability and turn-around of skips; this is because of the problems onshore. During the winters of 2009 and 2010, the Norwegian continental shelf went through a long lead time because cutting was frozen in skips waiting onshore to get emptied (Ayele et al., 2013).

The options for handling 1.3 million cubic metres of drill cuttings around the environs of the North Sea oil platforms were discussed at an oil industry stakeholders' meeting (UKOOA, 1999a). Greenpeace preferred the option of shipment to shore policy though there was an option of dropping the drill cuttings on the sea floor (UKOOA, 2000, 1999b). Further research conducted by Artz (2001) asserts that this is a very complex issue, as moving the piles would disturb the seabed and release pollution into the area. Drilling the piles to allow aerobic bacteria to reach deep into the piles will also cause the release of pollutants, as well as reduce the available oxygen to the indigenous benthic communities, which could threaten their ecosystem. Biological modification of the piles may increase the biological effects (Best et al., 1985) by making the contaminant more accessible to marine flora and fauna. Currently, the piles are not showing much evidence of remediation - even after 20 years (Artz, 2001). Their release magnifies the toxicity of the drill cuttings and creates a corrosive, reducing environment. Drill cuttings produced now are mostly shipped to shore where there are several options available for their disposal or treatment (Turner, 2002).

Challenges in Transportation of Drill Cuttings: Waste management is unique, based on the requirement and conditions of the drilling site. However, the selection of the options must be taking into consideration all aspects. Zero discharge is the ultimate target of waste management. The selection of waste management method must consider the economics, environmental and operational aspects of waste management. Proper waste treatment must be done before any direct discharge to the sea. Sea discharge may prove to be the most economical option, considering the immediate cost of disposal, but the decision must also consider environmental impact, local regulations, and operational aspects such as additional equipment for treatment. Onshore discharge, on the other hand, will give zero discharge at the drilling site but will incur additional costs and liability at the onshore discharge site. Onshore discharge can incur additional logistic and labour costs, which must be included in the economic evaluation of discharge options. Exposure to human and weather constraints are some other issues, which need to be evaluated apart from direct economic and environmental impact. At drilling sites such as the North Sea, where weather is unpredictable, transporting drilling waste to an onshore site can be a challenging task. Drill cuttings re-injection is preferred in some areas such as the North Sea, North Slope in Alaska, the Gulf of Mexico, Canada, Venezuela, and Indonesia (Guo and Abou-Sayed, 2003). During the 1354 early years, around 30,000 barrels of slurry can be injected into one well. With the current development, several millions of slurries can be re-injected into one well (Guo and Geehan, 2007).

Conclusion: This paper reviewed the optimisation techniques in transportation to appraise the shipment of drill cuttings from the point of drilling to the treatment facility and the disposal site. It was found that the adaptation of spatial technologies to the haulage of cuttings will improve the net energy for road transportation, especially in monitoring millage, waste and cargo manifests, fuel consumption and movement of cuttings in skips. Thus, spatial technologies can improve the system of transportation of cuttings, waiting time, and track disruption during inter-state travels.

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