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Novel Dewatering System Successfully Used in Remote Area of Kenya

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Abstract

Use of a novel high-volume dewatering system at a remote location in Kenya led to measurable reduction in dewatering process time as well as a reduced waste volume for disposal.

Introduced in remote and environmentally sensitive areas of the Amazon jungle in Ecuador, this technology was utilized on over 65 wells drilled in the Ecuadorian Amazon jungle between 2012 and 2015. The higher process-capacity, water conservation and waste minimization benefits of this technology increased in importance as environmental restrictions required more efficient treatment and recovery technologies.

Conventional dewatering systems require significant time to process larger volumes of drilling fluids. Due to the volumes needed to be treated and the time restriction between rig moves from one location to another in Kenya, a more efficient dewatering system with a higher volume throughput capacity was needed. This novel dewatering system deployed in Kenya consists of two modules: First stage is the dewatering module where the solids flocculate and agglomerate. Second stage is in the separation module where the solids separate and are removed for disposal while the clean fluid is recycled back to the dewatering module for reuse.

The system operates in real-time, at higher throughput rates, which significantly reduces waste fluid, and clean up time at well end. A step change increase in barrels per hour fluid treated was noted when compared to traditional dewatering, with magnitudes of greater than 5 times achieved in the field in Kenya.

Introduction

The novel dewatering system is a high volume enhanced gravity dewatering system, which uses conventional dewatering chemistry for coagulation and flocculation, but no need for the application of a centrifuge for second stage mechanical clarification. The action of gravity in the separation module is amplified using a series of deflector plates that are specifically positioned and designed to encourage the solids to separate towards the bottom of the separation tank.

Additionally, there is an oversized slow rotating agitator installed which assists the settled solids to the direction of the discharge port for disposal.

The unit design is an improvement on an original technology that is used in North America to process water and brine based drilling fluids providing significant drilling ROP and waste management benefits over traditional solids control and dewatering systems. The high-volume dewatering system is designed with an increased throughput capacity to process larger volumes of fluids with higher levels of drill solids content.

A prototype high-volume dewatering system was developed and tested in 2011. Once final modifications and fine tuning were completed a full-scale field unit was developed and introduced into the Ecuador drilling market, and to date 200 wells have been successfully drilled in Ecuador using the high-volume dewatering system.

High-Volume Dewatering System Compared to Standard Dewatering

There are a number of significant advantages between the High-Volume Dewatering System and a standard dewatering set up. The key differentiators are:

A decanting centrifuge is not required to mechanically separate the solids from the fluid phase. The High-Volume Dewatering System uses an enhanced gravity process to achieve separation and clear fluid returns. With a typical dewatering set up, the flow restriction is with the centrifuge as they are limited to 50-70 gpm (depending on the size & type), with the High-Volume Dewatering System there is no such flow restriction, enabling a seamless process of up to 1200 gpm depending on the right conditions and the type of fluid being processed.

The High-Volume Dewatering System can process fluid with a higher amount of both solids volume and particle size compared to a standard dewatering system where solids plugging the smaller pipe work and the centrifuge feed tube is a repeat issue. This increases the range of fluid able to be processed, leaving minimal dead volume when emptying rig tanks or waste pits. The High-Volume Dewatering System is not hindered by gearbox torque limitations as per centrifuge-based systems and maintenance requirements are much less.

The System's Dewatering Module has four tank compartments of which two are utilized for flocculent and/or coagulant, these tanks are each 40 bbl enabling larger batches to be processed, additionally these tanks can also be used in series, ensuring there is a continued supply of dewatering fluid for processing and no need to shut down the operation to replenish.

The High-Volume Dewatering System's waste fluid tank at the front end of the process is 80 bbl capacity, this enables a rig tank to be discharged of spent drilling fluid immediately, freeing that tank for other uses. With standard dewatering units, there is no upstream storage for the feed waste fluid, restricting the rig tank from other use until it is empty.

Kenya Operations Overview

Initially the operation in Kenya was for 4 appraisal wells, however this was soon increased to up to 12 wells.

All wells were drilled using a buried waste pit system where all associated liquid drilling wastes were discharged for processing and disposal.

A standard dewatering system complete with decanter centrifuge was supplied for the initial wells as per contract. However the speed of drilling, number of wells and the efficient rig moving operations identified the need for a dewatering system that would ensure that all water based waste was processed within the shortest possible amount of time, this included all Water Based Drilling Fluid, Cement Spacer, Cement Pre and Post Flow, Cement Wash Up and Rig Pit Cleaning Fluid. Volumes per well were expected to exceed 5000 bbls, with up to 2000 bbls being spent WBM.

A conventional dewatering system with a Decanter Centrifuge would not have the capacity to meet the Operator expectations of a dry location prior to the rig moving to the next drilling location. This was illustrated during the first two wells as processing with the conventional dewatering package proved challenging due to the high volume of WBM to be treated in a short timeframe, resulting in waste pits not being emptied prior to the rig moving.

The service company offered the operator the High-Volume Dewatering System as an alternative to ensure the rig and services could move to a new location without delay and with the waste pits empty.

The High-Volume Dewatering System was introduced to the operation on the third well and continued to be utilized throughout the remainder of the project.

The High-Volume Dewatering System proved to significantly increase the volume of waste processed per well without compromising on the quality of water returned from the system. Field feedback identified some bottlenecks to optimized performance and were summarized for future projects:

1. Unable to take suction direct from the rig mud tanks. Drilling Fluid was very susceptible to clear and rapid dewatering
2. Suction directly from the waste pit where various solids and fluids were disposed without having detailed knowledge of the fluid composition.
3. Restricted amount of dewatering products available to assist in difficult separation batches

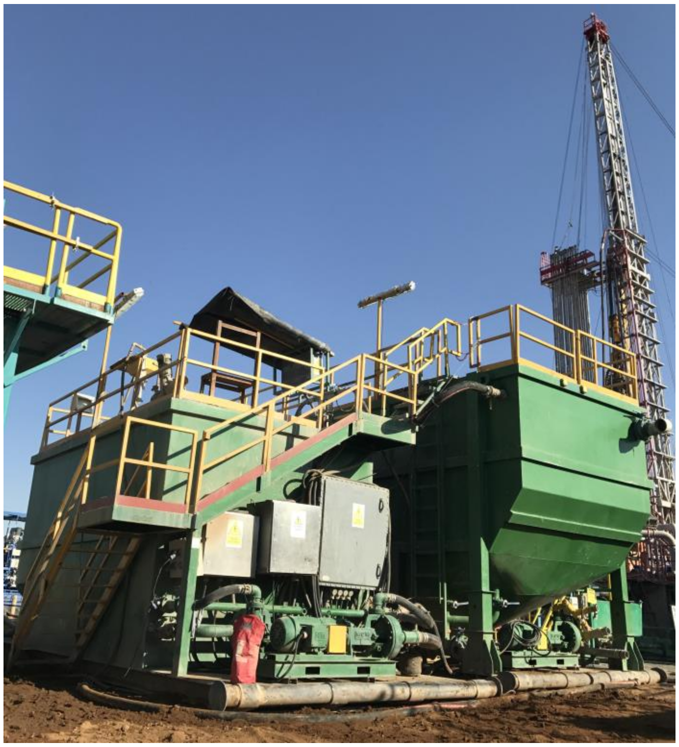

Fig. 01 – High-Volume Dewatering System.

The wells in Kenya were drilled and completed within 20-30 days with rig moves between locations taking as little time as 2.8 days from rig down to rig up for all services.

The service company's Kenya team were instrumental in ensuring there were no delays in moving the rig services to the next location with all waste fluid processed and leaving the waste pits empty of fluid and only leaving solids that are not able to be dewatered which significantly reduced the amount of waste to be hauled away for disposal and remedial work required once the rig had left.

All rig ups were completed without delaying drilling operations. There were no NPT or breakdowns associated with the High-Volume Dewatering System during the 7 wells it was utilized.


Fig. 02 – Remaining Waste Pit volume at Standard Dewatering System Rig Down (Well #2).


Fig. 03 – Remaining Waste Pit volume at High-Volume Dewatering System Rig Down. (Well #5)

Typical Wellbore Geometry and Drilling Fluid

Various casing and well depth configurations were drilled using an MMO and Potassium Sulfate/Polymer for the WBM sections from various depths. 20" Conductor was driven, 13 3/8" casing set followed by 9 5/8" casing and finally 7" casing set at TD.

Table 1 – Drilling Fluid Properties for MMO Fluid System

Density	9.0 – 9.5 ppg
Plastic Viscosity	ALAP
Yield Point	25 – 50 lb/100 ft^2 (ambient temp)
6 RPM	12 – 30 (ambient temp)
API Fluid Loss	< 10.0 ml/30 min
Total Hardness	< 200 ppm
pH	10.5 – 11.5
MBT	< 20 ppb
Drill Solids	< 6%

Table 2 – Typical Drilling Fluid Properties for Potassium Sulfate/Polymer system

Density	9.0 – 10.0 ppg
Plastic Viscosity	ALAP
Yield Point	20 – 25 lb/100 ft^2 (ambient temp)
6 RPM	10 – 15 (ambient temp)
API Fluid Loss	< 8.0 ml/30 min
Total Hardness	< 200 ppm
pH	9.0 – 9.5
K_2SO_4	35 ppb (K_+ >45k mg/l)
MBT	< 12 ppb
Drill Solids	< 6%

All lower sections of each well were drilled with SBM. Saraline 185v was the recommended base oil to use in these formulations due to its good track record of onshore use, aerobic biodegradation and field performance.

Table 3 – Typical Drilling Fluid Properties for Saraline SBM System.

Density (ppg)	10.6 – 11.5
Plastic Viscosity (cP)	ALAP
Yield Point (lb/100ft^2)	15 – 20 @ 120°F
6 rpm	8 - 12
Electrical Stability (Volt)	> 400
HP-HT Fluid Loss (ml/30min)	< 4 ml @ 250°F/500psi
O/W ratio	70/30 – 75/25
Brine activity Aw	0.82 - 0.84
Drilled Solids (%)	< 6

The first well was drilled with MMO fluid System, however the client decided to utilize a Potassium Sulfate/Polymer based system for the Water Based Sections of the remaining wells, the system properties were modified and adjusted to keep optimum condition during the different wells by adding more inhibitors such as PHPA and Amine compounds to present more inhibition and minimize the experienced bit balling issue, this was decided on a well by well and real time basis as drilling conditions and parameters changed.

The WBM Sections saw Sandstone, Claystone, Siltstone, Volcanic and some limestone formations.

Solids Control & Drilling Waste Management Equipment Overview

The rig based solids control system consisted of:

2 x single deck, 3 panel shakers and 1 x single deck mud cleaner housing 2 x 12" desander cones.

The service company supplied a full suite of solids control and Drilling Waste Management equipment for the duration of the project for the WBM, SBM sections and completions/workovers which included:

- Vertical Cuttings Dryer.
- 16" Decanter Centrifuges.
- Standard and High-Volume Dewatering systems.
- Full Auger system.
- Associated Tanks and various PD and clean up Pumps.
- Vacuum units and pressure washers.
- Dual Pod Filtration Equipment.

Waste Management

During the project, the client constructed the waste pits on each pad with the same sloped sided square design and a capacity of nearly 6000 bbl rather than the more efficient horseshoe design that would enable fluid run off and increased segregation. The pit design proved to be one of the biggest challenges for the dewatering operation as all pit cleaning and cement clean up solids and fluids were disposed into the one pit as well as the spent drilling and completion fluids. The two major challenges were not having a detailed composition of the fluid that was disposed, thereby pilot testing repeatedly, but also keeping suction with the heavy and high volume of solids in the pit. However, the Service Company's Kenya team devised various solutions to ensure the efficient removal of the waste fluid was achieved.

Any processed water from dewatering that was not utilized for reuse in making flocculent fluid was transferred to a dedicated buried, lined pit where it was treated with biocides and lime to reduce amount of degradation. When required it was recycled and used for base fluid to replenish WBM drilling fluid, additionally between sections and at the end of each well was used for pit cleaning and wash down operations.

All water based solids were buried on site and any non-aqueous solids including the solids remaining in the waste pit were removed to a storage facility for further processing at a later date. At the end of each well, the recovered water was stored in the recovered water pit and allowed to evaporate over time.

Fig 4 – Recovered Water from Dewatering. Pit capacity: 5,911 BBL. Note: The lack of water clarity is due to the addition of lime and biocide to reduce stagnation & degradation.

Water Usage

While using the standard dewatering unit during the first two wells, fresh water was required to be hauled to the rig site to build new drilling fluids, this was due to not being able to process fast enough to supply the rig with enough reusable water in time.

After the High-Volume Dewatering System was in use no water was required to be hauled to site as there was continually enough reusable water recovered from the High-Volume Dewatering System after what was required to build new flocculation solution.

Dewatering Principles

Dewatering is the process of removing the majority of colloidal size solids from used water base drilling muds by adding chemicals to coagulate and flocculate the solids contained in the mud.

This blended chemically enhanced fluid is then pumped to a solids, liquid separation unit for solids removal.

Without chemical enhancement known as the dewatering process, the mechanical liquid solids separation capability of a centrifuge is limited to around 2-3 microns. Dewatering overcomes this limitation by "flocculation" of the feed mud by pretreating chemically to increase the "effective particle size" of the suspended solids.

As a result, dewatering reduces of the liquid waste volume generated, allows normally contaminated and disposed waste to be recycled and provides release in an environmentally safe and cost-effective manner.

Difference between Coagulation and Flocculation

The terms coagulation and flocculation are often used interchangeably especially when referring to the physical state of the drilling fluid. In terms of dewatering, however, these two terms have distinctly different meanings.

- Coagulation is the reduction of the electrostatic charges of a particle, which allows these particles to then move closer together.
- Flocculation in contrast to this pertains to the physical bridge that is formed between two or more particles, which agglomerates these particles into a porous, three-dimensional structure referred to as a “floc”.

Coagulation is generally the first stage in the dewatering process. This involves the addition of chemicals to water causing colloidal particles within the water to stick or bond together when contact is made. Mixing is utilized during coagulation to provide a rapid and uniform dispersion of the chemicals and also increase the opportunity for particle to particle contact. Normally, the entire process occurs in less than one second.

Flocculation generally follows coagulation and can be described as a chemical and physical bridging or agglomeration of the coagulated particles. The flocculation process involves gently mixing the particles until distinct, suspended flocs are formed.

Separation of the liquid and solids of a mud system occurs easily as the centrifuge removes the larger flocked solids as a moist sludge. The Dewatered sludge is discharged into a cuttings tank and the cleaned effluent is returned to storage or the active mud system. If necessary a portion of the centrifuge effluent can be recycled for the dilution volume required by the dewatering system or returned to the active mud system or to the drill water tanks for use as dilution.

Not all drilling fluid suspensions, which contain a high proportion of colloidal organic substances, can be directly flocculated. Most often, they require a coagulant applied first to destabilize the particles then followed by a flocculent to aggregate the particles Coagulation is most often accomplished with alum (aluminum sulfate), ferric chloride, ferric sulfate, lime or a liquid polymer coagulant, organic and /or inorganic.

Flocculation is used to describe the action of polymeric materials that form bridges between individual particles. Bridging occurs when segments of a polymer chain absorb on different particles and help these particles aggregate. The flocculation process is often enhanced by the addition of flocculation aids, such as polyelectrolytes. Polyelectrolytes may be natural organic commands but are most often synthetic polymers.

The type of charge on the polymer chain (anionic, cationic, or non-ionic) classifies the synthetic polyelectrolytes. The addition of polyelectrolytes to water containing coagulated particles generally result in an increase in floc size. There are currently over 1,000 commercial polyelectrolytes available.

The most commonly used flocculent are polyacrylamides, which is a non-ionic polymer. Polyacrylamide polymers can be given an anionic (negative) by co-polymerizing acrylamide with acrylic acid. Cationic Polyacrylamide polymers are prepared by co-polymerizing acrylamide with a cationic monomer.

For each suspension, a certain degree of anionic, cationic or non-ionic character is beneficial. Usually, the intrinsic flocculating power increases with the molecular weight.

The High-Volume Dewatering System Process

The High-Volume Dewatering System is a two-stage process, once a series of jar tests are complete to ascertain the correct chemistry required to efficiently break and separate the solids from the liquid:

1. Chemical Addition:
   - Stage one is to mix the correct concentrations of flocculent and/or coagulant with water to create a homogenous solution. The chemical type and concentrations are dependent on the completed jar tests and is continually tuned as the waste fluid properties change.
   - Fill the Waste Fluid compartment with the raw drilling fluid/waste that is to be processed.
   - Together with the flocculent solution, recirculate the raw fluid via the Static Mixing Manifold where both fluids are mixed in a turbulent flow to start the chemical reaction.
   - Adjust the flow rate of the flocculent solution until optimum separation is achieved, which is done by taking samples from the inline sample point.
   - Once this is achieved, the combined fluid is diverted to the Separation Module.
2. Separation Process:
   - The second stage is in the Separation Module where the fluid transitions to a laminar flow where separation begins.
   - As the tank fills, the fluid is directed to the lower deflector plates where remaining solids are encouraged to fall and the fluid is pushed over the top.
   - As the tank becomes full, the upper and larger deflector plates create the same separation process on the clearer fluid. The further the fluid flows through the process the clearer it becomes with the assistance of the multi-level defector plates.
   - As the solids fall the large bladed and slow rotation agitator pushes the solids to the suction point at the bottom of the tank.
   - The clear fluid is diverted to the water compartment in the Chemical Addition Module where it is tested for specific properties and either reused to make up more flocculent solution or pumped out for storage and/or reuse.
   - Once solids have built up in the tank (usually at least half full) the discharge valve is opened and the solids are transferred out using a high torque, high volume Positive Displacement pump for disposal.

Sample testing is continued every 30-45 minutes throughout the dewatering operation to ensure any chemistry adjustments are efficiently ascertained and completed.

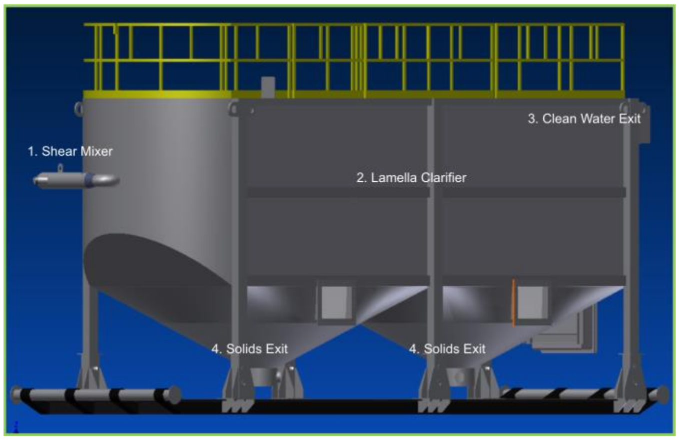

Fig. 5 - High-Volume Dewatering System Separation Module Process Flow

- Waste fluid and dewatering chemical enters via an inline shear mixer (1)
- Fluid passes through the lamellar clarifier section where liquid/solid separation takes place (2)
- Clear fluid exits the clarifier (3)
- Solids Fall, compact and exit the clarifier (4)

Results

The introduction of the High-Volume Dewatering System proved to be invaluable by enabling the Operator in Kenya to reduce their overall liquid waste and reuse the recovered water from the dewatering process to make new drilling fluid and for use in pit cleaning.

With process improvements, the High-Volume Dewatering System unit continued to show value for the Operator. Over the duration of 9 wells', 7 utilizing the High-Volume Dewatering System, the volume of waste fluid has increased well by well resulting in over 33,515 bbl of waste fluid processed using the High-Volume Dewatering System.

This significantly reduced the amount of time required for dewatering from 17 days for 2468 bbl using conventional dewatering methods to 6 days for 6130 bbl using the High-Volume Dewatering System package.

Conclusions

1. The High-Volume Dewatering System proved to be an excellent system upgrade to the standard dewatering system where a high volume of fluid must be processed in a short period.
2. Utilizing the High-Volume Dewatering System saved on average 11 days of dewatering time while also increasing the amount processed by a further 2650 bbl per well.
3. All WBM and waste pits emptied and dewatered prior to rigging down.
4. No water based waste liquid was hauled off site due to the waste pit being full during operations reducing mileage required on public roads.
5. 100% of the recoverable water based liquid waste was processed on each well site prior to rigging down resulting in reduced cost of hauling and disposal of un-stabilized and slops.
6. The whole system operates in real-time which significantly reduces waste fluid clean up time at the end of the well.

Table. 04 – Total Volume Processed per Well
(MSM= High-Volume Dewatering System)

Well	Dewatering Method	Volume Dewatered (BBL)
Well #1	Standard	2468
Well #2	Standard	3500
Well #3	High-Volume Dewatering System	5005
Well #4	High-Volume Dewatering System	2260
Well #5	High-Volume Dewatering System	3600
Well #6	High-Volume Dewatering System + Centrifuge	5020
Well #7	High-Volume Dewatering System	5540
Well #8	High-Volume Dewatering System	5960
Well #9	High-Volume Dewatering System	6130
	Total Volume Processed (BBL)	39483

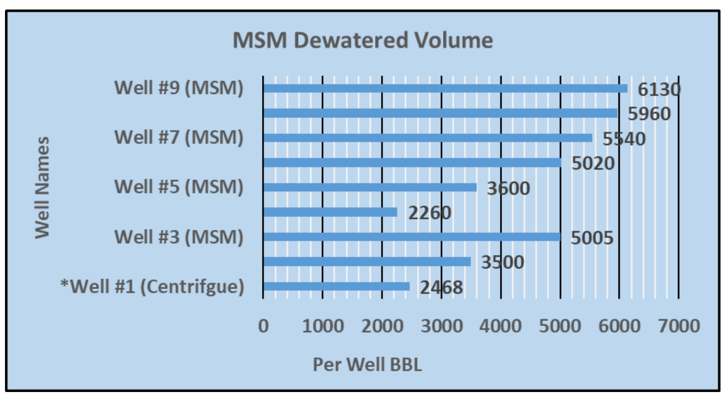

Fig. 6 – Comparison between wells & Dewatering Methods (MSM= High-Volume Dewatering System).

Once the learning curve was complete and efficiencies were optimized from bringing a new technology in to a new location, the operator in Kenya was overall very pleased with the High-

Volume Dewatering System performance, and advised they would continue to use this technology in future projects.

Acknowledgments
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References
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Nomenclature
bbl(s)/BBL = barrel(s)
gpm = Gallons per Minute
MMO = Mixed Metal Oxide
WBM = Water Based Mud
SBM = Synthetic Based Mud
OBM = Oil Based Mud
PD = Positive Displacement
NPT = Non Productive Time