

MOBILE ONSITE DRILLING WASTE TREATMENT (OWT) FACILITIES – A SOLUTION FOR SAFER, CHEAPER, AND ENVIRONMENTALLY FRIENDLY OPERATIONS

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Abstract. Drilling mud waste, the by-product that generates from Drilling operation, should be treated to comply with GOI (Government of Indonesia) regulations. An oil and gas field in Sumatera Island operated by PT. X produced about 50,000 bbls water base mud per month, but the centralized mud treating facility (CMTF) was designed only to treat 30,000 bbls per month. Besides, transportation using vacuum truck is required to carry the waste from site to CMTF that creates potential of motor vehicle accidents while traveling. Using lean sigma framework with DMAIC methodology, a business case study was developed to find alternatives on how to manage the waste while also improving safety performance. We started with a pilot project, which is done very successfully, and then continuing with a full-scale implementation in the North area. Five (5) mobile (On Site Waste Treatment) OWT units with two (2) different technologies; electro-coagulation and advanced oxidation; are being operated to process drilling waste from the ground pit either while the rig is on location or after it is released. Each mobile OWT has capacity of 24,000 barrels/month. The effluent is regularly checked in the laboratory to ensure the output meets GOI regulations before release to environment. Implementing this Mobile OWT initiative has delivered added value to the Company of about US\$375,000 over a nine (9) month period and improved HES compliance by reducing trips and mileage which in the end will reduce Motor Vehicle Crash (MVC) potential, especially when driving at night in our drilling waste operations. Future improvement could consider how to maintain the discharge solid while processing the mud waste from the same disposal pit; provide solid treating facility and application of closed loop drilling.

Key Words: Drilling, New Technology, Environmental Risk, Waste Treatment

1. Introduction

Managing waste plays important role as drilling activity producing large amount of wastes. Without adequate treatment, waste could be pollutant and contaminant to environment. Therefore, waste –include drilling waste- should be carefully managed with suitable technology in reasonable cost. PT. X, as one of outstanding Oil and Gas Company worldwide, has a commitment to protect people and environment in its guiding principal. PT. X also has vision on corporate social responsibility, stated that “Our goal is to be recognized and admired everywhere for having a record of Environmental Excellence”. Therefore, managing drilling waste effective & efficiently is one of PT. X’s goals.

PT. X commits to comply with Government of Indonesia regulation through CMTF waste management with its drilling waste handling practices as follow:

- Construct earth pit
- Dump drilling waste inside pit (simultaneously while drilling in progress)
- Vacuum Trucks drain liquid phase, haul to CMTF (simultaneously while drilling in progress)
- Treatment in CMTF
- Backfill earth pit
- Result: Comply with GOI regulation (effluent water)

However, there must be many more practices that might be more efficient and more environmentally friendly. A pilot project for onsite waste treatment was developed to evaluate the possibility of using this unit for drilling waste handling. This pilot project had been done very successfully. In the very same year, drilling activity, esp. for infill wells, had been executed aggressively to develop Steam Flood field. Drilling team made significant improvement to reduce cycle time which impacting bigger volume of waste generated per day and less settling time for drilling waste in disposal pit.

On quarter four of the same year, CMTF rejected most of vacuum trucks of drilling waste. CMTF can't handle the higher volume generated and the high solid content (TSS) of less settling time waste. Temporary solutions were: (1) Dilution with surface water & (2) Additional settling tank on CMTF. Dilution was inadequate because of (a) significantly increase cost of vacuum truck & CMTF processing; (b) increase potential for motor vehicle crash due to more vacuum truck trips and (c) reduces the quality of influent water of CMTF due to unknown quality of surface water sources. Additional settling tank didn't solve the problem also because of square tank volume is too small and need more time for drilling waste to settle to desired low solid content. Without a reliable waste treating facility at that time is a serious threat for drilling operation continuity since drilling activity generates lot of waste that need to be treated.

2. Conceptual Framework

The situation of existing centralized mud treatment facility (CMTF) inadequate to process all drilling waste left Drilling operation no choice in handling the waste that continuously being produced since Drilling operation depends on CMTF in handling drilling waste. Therefore, a business case study was developed to find alternatives on how to manage the waste while also improving safety performance. Handling drilling waste on-site becomes an option to be assessed. Independence waste management system, water recycling, cost reduction, motor vehicle safety and waste spill prevention also put into account to consider. The framework used to analyse the problem is lean sigma approach using DMAIC methodology.

3. Methodology

The methodology that used is DMAIC (Define, Measure, Analyse, Improve and Control) approach. In define phase, project team formulize the waste management gap in Drilling team and also limit the project only for specific North Development Field. Then in Measure, team measure the gap that currently exists to be analysed for solution in Analyse phase. The recommendation then taken in improve phase. Improve phase is the longer process in this project. It takes about 1 year to fully implement the solution to solve the issue and later implement and control for the other 1 year. Here is the detail on every phase.

3.1. Define Phase

Drilling Operation of PT. X operates eight (8) rigs in its oil and gas field to drill shallow wells for its Steam Flood Operation and North Field Development projects. Total depth for shallow wells is ranging from 400 to 1000 ft, which are drilled with three (3) until five (5) days cycle time. All of these rigs are using water based mud with mud weight about 8.5 – 13.5 pound per gallon (ppg). Composition of the water based mud mostly are fresh water, barites (weighting agent), betonite (viscosifier), KOH, Lignite, Pac-LV, Pac-R, CMC-HV, CMC-LV, KCl, Na₂CO₃, Frac-seal & Sawdust. Generally, there are 3 kinds of drilling mud used: spud mud, drilling mud & completion fluid. Estimated of usage mud volume for one (1) cycle time is about 800-1500 bbls/well.

Waste generated for each well estimated 2500 bbls/well or about 800 bbls/ day for three (3) days cycle time and 500 bbls/day for five (5) days cycle time. With eight (8) rigs operated, waste generated is about 6000-10000 bbls/day. Mostly drilling waste contains of mud, water (from cleaning or rain), drilled solid (cuttings – clay & sand), cement (return from cementing process), and swamp water. The

waste is accumulated in an earthen disposal pit, which only has volume about 1200 bbls. Therefore, a process to ensure this earthen disposal pit doesn't fill up is needed. The best practice is liquid phase (solid solution in water) of drilling waste is sucked by vacuum truck and transported to centralized waste treatment facility, as shown as Fig. 1.

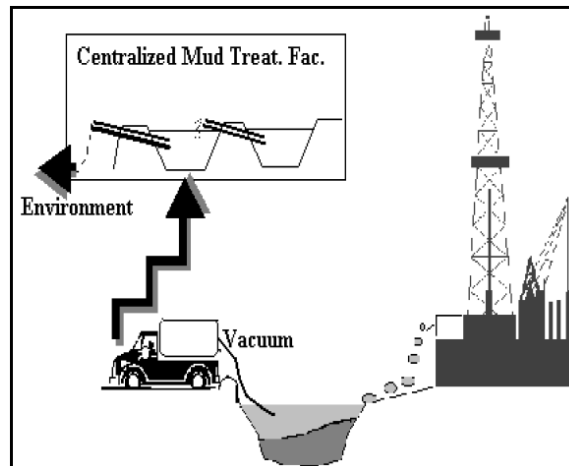


Fig.1: Drilling Waste Handling Practice in PT. X

Centralized Mud-waste Treatment Facility (CMTF) has been operated to ensure drilling waste and other operations' waste are appropriately handled within PT. X & GOI regulatory limit. All wastes produced from operations (Drilling operations is one of the biggest waste producer) are hauled to CMTF for further processes. The effluent water produced from the waste treatment is discharged into the environment after having passed the regulatory limit. CMTF refer to regulation of Government of Indonesia: Kep-03/BAPEDAL/09/1995 for effluent water analysis.

Table 1. CMTF Effluent's Test Result

Laboratory Test	PH	COD (ppm)	Color (ptco)	Turbidity (NTU)	Suspended Solid (mg/l)
Source of Sample					
Before process (Pit A)	7.9	2382	6255	2565	1843
After Chemical Process (sedimentation Tank)	7.5	676	586	196	166
Biology Process (Pit 1)	7.1	258	380	95	89
Out to Jungle	6.9	94	146	17	18
Threshold Limit Value	6 - 9	100			200

Based on above information, the SIPOC diagram then developed as below Figure.

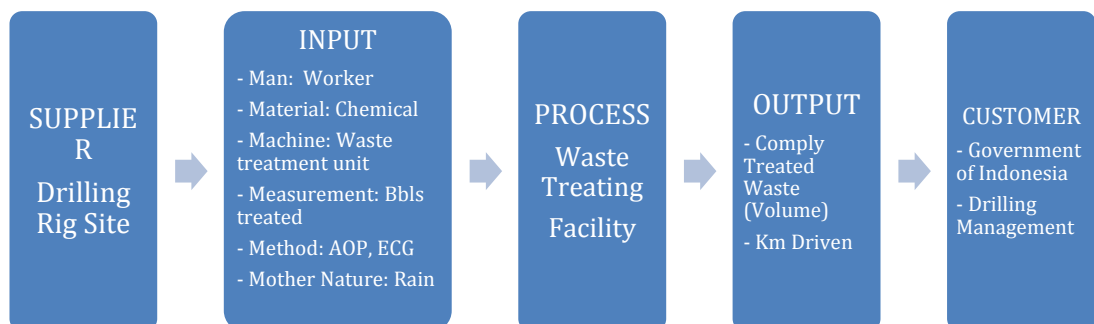


Fig. 2. SIPOC Diagram

3.2. Measure Phase

The data then taken for both km driven and volume of waste treated per day. The data shows that the baseline for km driven is 280,000 km/month and the excess volume that can't be handled by CMTF (need treated by other facility) is about 55,000 bbls/month. The run chart and histogram has been built based on the actual historical data that can't be described or attached in detail here due to company X's information protection issue.

3.3. Analyse Phase

During the Analyse phase, team conducted a session to determine the root cause analysis and fishbone diagram. Based on the root cause analysis, team found that the main root cause is inadequate CMTF facility, either the capacity and or capability. Therefore, team built the possible action item is either to procure another waste treating facility or improve the capacity and capability of current CMTF. But as this CMTF is in a contract and the contractor has minimum capability to improve the capacity and capability of CMTF, then team decided to do the approach on procure another waste treating facility that preferable mobile to reduce the km driven.

The fishbone that built by team mark the machine and material part, esp. the mobile treated unit and the chemical used as experiment. The other items from man, method, measurement and mother nature mostly are marked either as constant or noise.

3.4. Improve Phase

Utilizing mobile waste treatment unit, which capable to process drilling mud waste at 500 bbls per day, started the pilot project of on-site drilling waste treatment. The unit that is called ECOMOBILE produces clean water at the end of the process. The lab analysis figure out that it complies with KepMENLH No.42/MENLH/1996 on 7 parameters (Chemical Oxygen Demand (COD); Oil and fat; Sulfides (H₂S); Ammonia (NH₃N); Phenol total; Temperature and pH).

On-site drilling waste treatment unit started to operate at Steam Flood Field embedded with drilling rig from spud to release. Total 5 jobs were completed in Steam Flood Field. An improvement was done in order to meet with operational needs by pre-treatment process due to high solid content that not anticipated by the contractor at early stages. Series of pre-treatment tanks, solid liquid separators, and additional dosing pump were added in the package of pre-treatment process. Eventually, the jobs were considered successful in term of process and result. It was concluded that the unit is compatible at Steam Flood Field.

The success in Steam Flood Field drew attention among the team; therefore the unit was then sent out to Si (1 well) to treat drilling wastes on-site (by request) consider the distance to nearest CMTF is approximately 55 km. The process was continued to Kr and Gr wells with the same performance as in Steam Flood Field. A request came from the operation need to move the unit to Deep Well, which located over 100 km from the nearest CMTF. Total 3 deep wells were successfully drilled without a single vacuum truck requested to support the operation. The unit was then moved to AAA (3 wells) until end of its period in November 2006. Total 14 jobs were completed throughout the period of pilot contract with total 51,588 bbls of waste.

Based on succeed of this pilot project and better HES performance consideration, on-site mud treating facility became a proven choice, although there is still a lot of room for improvement, esp. on operational and close monitoring concern.



Fig. 3. ECOMOBILE Unit Pilot Project

Drilling team then developed extended pilot project for on-site mud treating facilities. The procurement process for on-site mud treating facility was started with open tender. The intention was independent waste management, especially for North Development projects, which executed by four (4) rigs. Meanwhile, CMTF is used to support waste treatment from Steam Flood-Infill project.

On-site waste treatment technologies may be widely offered by the market since it has been developed and utilized since years ago. Waste Management companies offer many type of waste treatment technology, which need to be appropriately selected to best fit with specific need. One technology may be excellent in certain condition; however, it may not be effective enough for other environment.

Applied on-site waste treatment unit must not affect to existing well pad condition as well as delaying operation, such as pad enlargement, disposal pit deepening, blocking rig movement during MIRU, etc. The unit must be flexible to rig up in any condition of available well pad. This is to anticipate small well pad with surface constraints at the oil and gas field. By strict technical & economical selection process, Notification of Award for the contract was announced. The winner was the previous pilot project company (PT. Y), which provided 3 compact units of on-site mud treating facility with advanced oxidation process (AOP) technology, as contract.

Simultaneously, to fulfil the need of North Development project of five (5) units OWT for independent waste management, contract for 2 other units of on-site mud treating facility was developed. Notification of Award for this contract was belong to PT. Z, which proposed Electro-coagulation technology.

There are 2 technologies that being used for mobile on-site waste treating facilities in drilling which are (1) Advanced Oxidation Process (AOP) – PT. Y.; and (2) Electro-coagulation Contaminant Removal (ECR) – PT. Z. Both of technologies have plus and delta as follow:

Table 2. Comparison between AOP and ECR

AOP	ECR
(+) Only need disposal pit	(-) Need additional pit for settling after ECR (Entering location after rig moving)
(-) Struggling to meet effluent's COD < 100 ppm (part per million)	(+) COD consistently below 100 ppm (part per million)

Advance Oxidation Process (AOP)

Learning from the experience on pilot project which need additional pre-treatment, PT. Y re-designed the mobile onsite drilling mud treating facility after consult with PT. X waste management expert. The flow chart of the redesigned process is shown as Fig. 4.

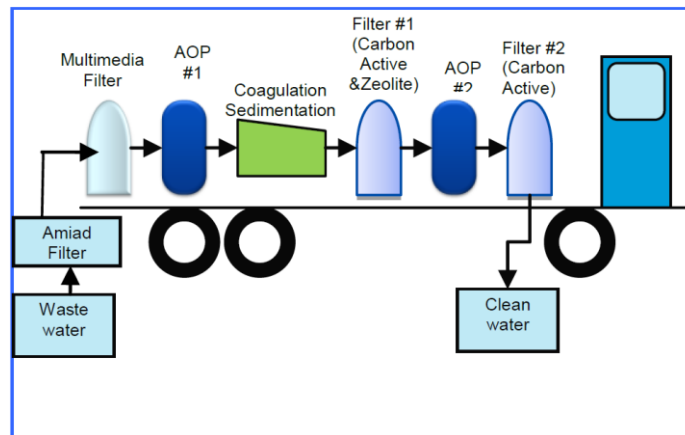


Fig. 4. AOP Flow Process

Equipment function based on its configuration is explained as follow:

- Amiad Filter joined with inlet pump (not at the mobile unit) is used before multimedia filter in order to screen big solid.
- Multimedia filter is one of best solution in order to skim various sizes and types of solids. In our cases multimedia filter is consists of gravel, garnet and sand.
- Advance Oxidation Process #1 work as chemical organic/an-organic cracking, since AOP #1 work to reduce COD and BOD. AOP#1 also work as coagulation aid. Chemical organic /an-organic compounds can be easy to be coagulated, so chemical usage & settling time of solid are reduced.
- Coagulation/ Sedimentation: Chemical coagulant is used to coagulated organic/an-organic and settled at sedimentation tank
- Filter #1 is CA and zeolite filter. This filter works as part of system to reduce micro pollutant, which passed the coagulation/ sedimentation tank.
- Advance Oxidation Process #2 is same as AOP#1, AOP #2 work for reducing organic. However, in our system AOP#2 is work also for reducing ammonia since ammonia cannot reduce by chemical coagulant and filtration
- Filter #2 is carbon active filter, its work as finishing for reducing organic and micro pollutant.

All of the equipment for this flow process are mounted in a compact truck. This unit has capacity to treat drilling waste as much as 800 bbls/ day/ unit. Pressure and temperature for the process is one (1) atmosphere and 20-40 degree Celsius. The unit capable for treating all pH range with maximum Chemical Oxygen Demand (COD) of influent 5000 mg/L. Power consumption is approximately 7.5 kWh with 380 V 3 phase voltage. Top view of this mobile OWT with AOP technology is shown as Fig. 5. Meanwhile the picture of this mounted truck is shown in Fig. 6. Chemical used for this process is coagulant such as aluminium sulphate (Al_2O_3) and PAC (polymer) with comparison between coagulant and water from 1:5 to 1:2, according to jar test result.

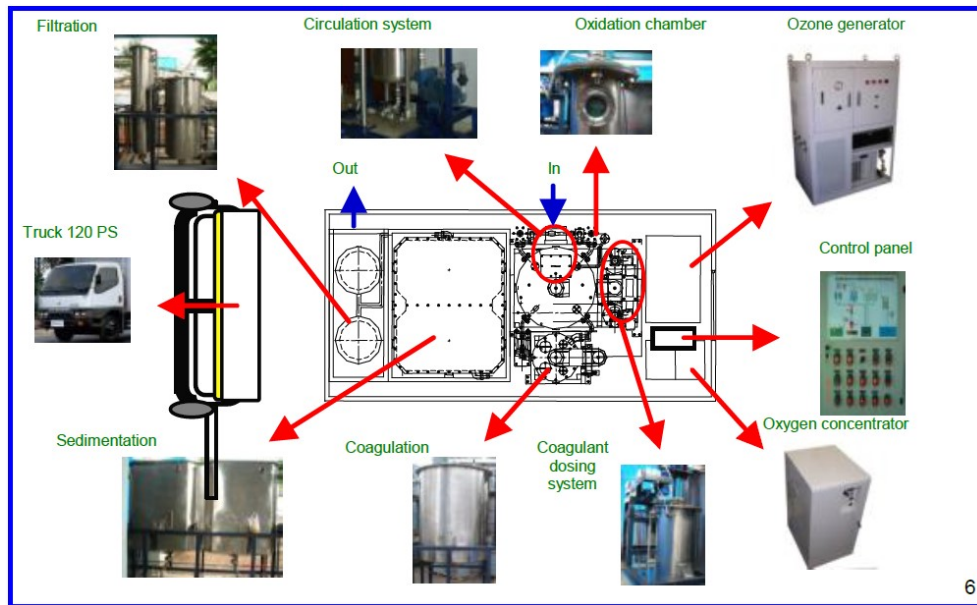


Fig. 5. Top View of Mobile OWT with AOP Technology



Fig. 6. Picture of OWT Mounted Truck (AOP Technology)

Laboratory Testing Method for PT. Y contract (OWT with AOP Technology) refers to GOI regulation: PERMEN LH No.04/2007, includes 8 key parameters, which are: Chemical Oxygen Demand (COD), Oil and fat, Sulphides (H₂S), Ammonia (NH₃N), Phenol total, Temperature, pH, and TDS (Total Dissolved Solid). The laboratory test is done per well and the sample taken must be witnessed by drilling site manager. The contractor should pass all the parameter. Otherwise they get zero compensation. Since contract commencing up until contract expired, the contractor passes all laboratory tests.

Electro-coagulation Contaminant Removal (ECR)

PT. Z offers other technology for mobile onsite drilling waste treatment facility which could produce better quality of effluent to stricter regulation of GOI: Kep-03/BAPEDAL/09/1995 for effluent water analysis. This unit also more economical because charged only by treated fluid/ effluent outcome (flow meter is set at the end of the process) compare with AOP OWT unit, which charged by incoming fluid (flow meter sets at the start of the process). The cost per barrel for this unit is also cheaper (US\$ 1.88/bbls compare with US\$ 2.63/bbls for AOP OWT).

The delta side of this ECR OWT unit is operation consideration: need additional settling pond after ECR process. To cope with this need, which can't provide by current well-pad design, these ECR

OWT units operate after the rig. To avoid disposal pit fully loaded with continuous flow drilling waste, a vacuum truck is needed to transport waste with short distance.

Basic principle of ECR OWT units is: (1) Drilling waste is contained in the disposal pit followed by electro-coagulation treatment; (2) ECR effluent enter sedimentation pond (using water pit in North Development well pad); and (3) Filtrate water from sedimentation process enters sand & carbon filtration unit for further contaminant removal. The ECR process scheme shows in Fig. 7 and the ECR process flow shows in Fig. 8.

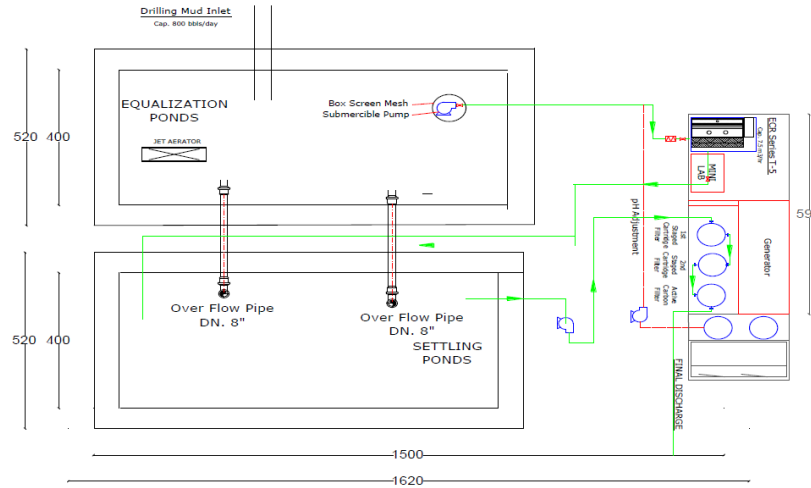


Fig. 7. ECR Process Scheme

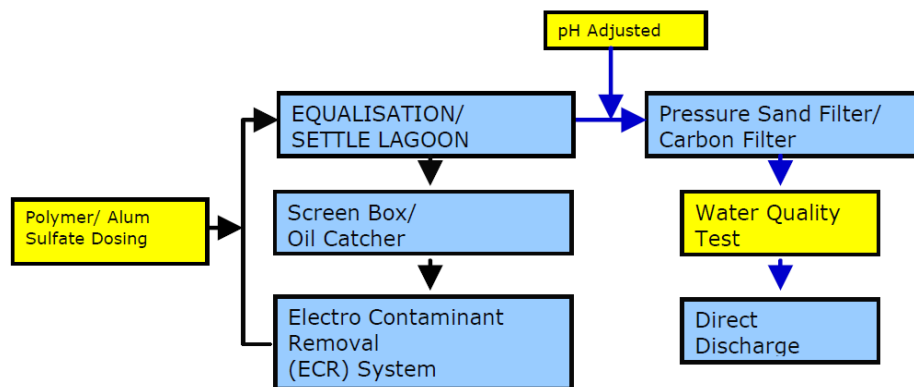


Fig. 8. ECR Flow Process

ECR itself is series of blades which work based strong electrical force. The electro-coagulation process is based on valid scientific principles involving responses of water contaminants to strong electric fields and electrically induced oxidation and reduction reactions. Water contaminants such as ions (heavy metals) and colloids (organic and inorganic) are primarily held in solution by electrical charges. Colloidal systems are destabilized by the addition of ions having an opposite charge to the colloid.

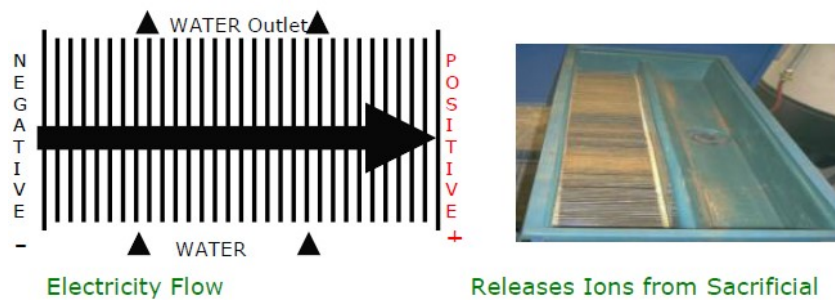


Fig. 9. The ECR Principal

All of the equipment for supporting this flow process is also mounted in a compact truck. This unit has capacity to treat drilling waste as much as 800 bbls/ day/ unit. Operational pressure and temperature for ECR OWT is one (1) atmosphere and 20-40 degree Celsius. Chemical used for this process is polymer, aluminium sulphate and acid for pH adjuster. Power consumption is approximately 15 kWh with 18.8 kVA 3 phase voltage.

Laboratory Testing Method for 17974-OK contract (OWT with ECR Technology) refers to GOI regulation: KEP-03/BAPEDAL/09/1995, which includes 36 key parameters. The parameters are: Chemical Oxygen Demand (COD), Oil and fat, Sulphides (H₂S), Ammonia (NH₃N), Phenol total, Temperature, pH, TSS (Total suspended solid), TDS (Total Dissolved Solid), Dissolved Iron (Fe), Dissolved Manganese (Mn), Barium (Ba), Cupper (Cu), Zink (Zn), Cadmium (Cd), Mercury (Hg), Lead (Pb), Arsenic (As), Selenium (Se), Nickel (Ni), Cobalt (Co), Cyanide (CN), Sulphide (S₂), Fluoride (F), Free Chlorine (Cl₂), Free Ammonium (NH₃-N), Nitrate (NO₃-N), Nitrite (NO₂-N), Biological Oxygen Demand (BOD 5), Methyl blue active compound (MBAS) Chromium 6+ (Cr⁶⁺), Total Chromium, Tin (Sn), Phenol, AOX, PCBS, PCDFS, PCDDS. The laboratory test is done per well and the sample taken must be witnessed by drilling site manager. If contractor fail one of the parameters, they get zero compensation. Since contract commencing, the contractor passes all laboratory test.

Management of OWT units' operation is essential. Although all supporting document (standard operation procedure, job safety analysis, risk assessment & uncertainty management, emergency response plan, MSDS, and etc.) and socialization already in place close monitoring system need to be set to ensure compliance with contract and government regulation. Generally, operation steps for OWT units are: (1) GWP application; (2) Execution in field by close supervision from Drill Site-Manager (DSM); (3) Daily report; (4) Sampling & Laboratory test.

Mobile onsite drilling waste treating facility is considered as an independent facility that need general work permit before entering work location. Therefore, contractors need to apply general work permit for specific wells. Contractors create journey management plan prior to moving and as support document for general work permit. Prior to operation executions, supervisor of OWT units need to report to DSM who is the authorized & responsible person who manages this on-site mud treating facility's performance on location. Unit supervisor & DSM/ tool pusher discuss about location for unit set, quality of work process & procedure, safety, water re-use, other related expectation from DSM/ OWT and operation concerns. Close communication between contractor &

DSM is a must DSM also responsible to signed daily reports which provided by contractor and consists of below information: (1) Daily job activities; (2) Onsite testing result (hourly) for certain parameters (such as Temperature, pH, TDS); and (3) Volume treated per day (24 hours operation). Daily report is sent to office every day for monitoring and invoicing purposes later.

Sample is taken every well to ensure all effluent meet GOI's regulation. For commencement purposes, sample will be taken by PT. X technology support laboratory's personnel. But for every day operation, sample will be taken by contractor representative with witnesses of DSM/ Tool Pusher who

signed in the special sample taken form. This sample then is tested in PT. X Technology support Laboratory in Duri. The result will be used for monitoring and invoicing purposes.

3.5. Control Phase

HES Performance

The spirit of this onsite drilling waste treatment unit is to reduce the possibility of motor vehicle crash that resulting from rapid journey of vacuum truck. The data shown that the vacuum trucks trip (kilometer basis) is reduced from average 28,000 km/month before OWT unit to average 18,000 km/month after OWT unit. This includes vacuum trucks for disposal and vacuum trucks for fresh water. This means that the average vacuum truck journey is reduced by 37% by km as shown in Fig. 10. This is significant safety improvement as lower km correlates with lower motor vehicle crash potential.

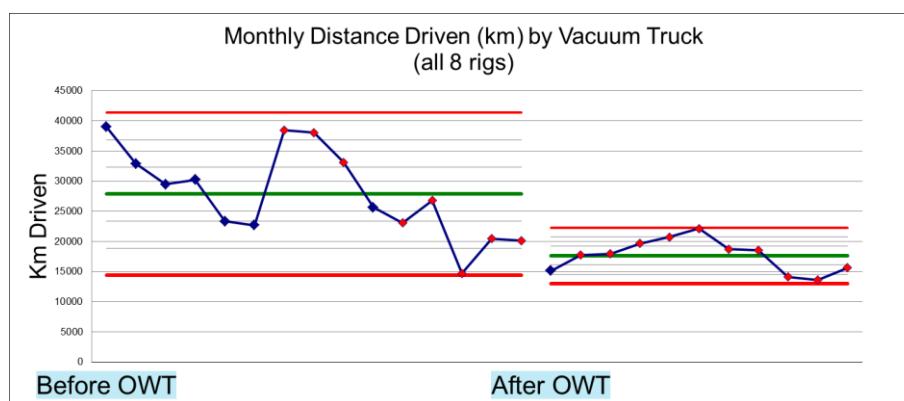


Fig. 10. OWT successfully lower 37% Km driven by vacuum truck

This project is also considered success from HES & Social Issue standpoint since there was no recordable incident (IA/MVC) related to waste treatment activity throughout the project lifetime. In addition, the on-site treatment did not create issue from local community against treated waste discharges. During the operation, there was no additional pad/location, which constructed solely for waste treatment unit. It meant no incremental in well pad size to accommodate the additional unit. The unit is very mobile and can be set at any location condition. Moreover, there was no or minimum operational problem due to equipment failure, such as plugging, down engine, etc.

Cost Saving

Economic of the project should be considered from the total operational cost. The cost is compared with waste handling cost by using vacuum trucks and CMTF. CMTF cost is US\$ 1.8/bbl as well as future vacuum truck rental cost (US\$ 2.5/km or approximately US\$1.4/bbls) were inputted into the calculation reflect the most representative cost. Cost for AOP OWT is US\$ 2.63/bbls and cost for ECR OWT is US\$ 1.88/bbls.

Potential saving from 9 months during OWT project period (9 months for three (3) first units and five (5) months for other two (2) units) is US\$ 376,800. That number came from waste handling for total volume 419,018 bbls and assumption that 25% of recycled water is being re-used. Fig. 11 shows the volume treated per unit OWT per months. Detail cost of project can be seen at the Table 3.

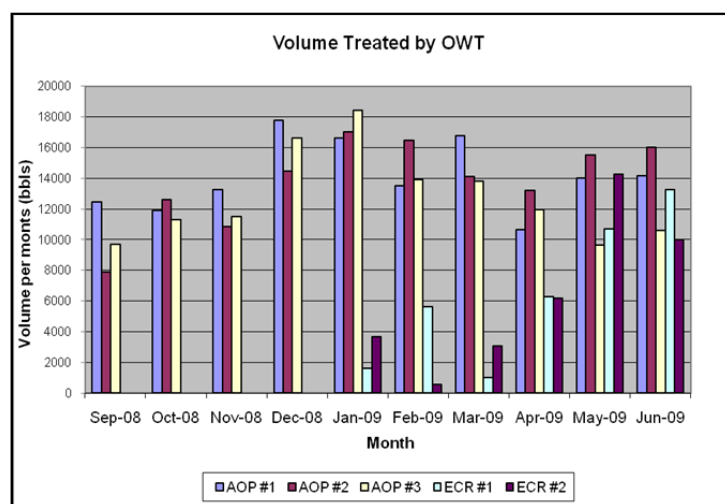


Fig. 11. Waste Volume Treated per unit OWT per months

Table 3. Cost Saving (OWT vs. CMTF)

OWT units	Volume treated (bbls)	Cost OWT	Cost VT	Cost CMTF	Cost CMTF +VT
AOP #1	141,082	\$371,045	\$197,515	\$253,947	\$451,462
AOP #2	138,275	\$363,662	\$193,584	\$248,894	\$442,479
AOP #3	127,490	\$335,298	\$178,486	\$229,482	\$407,967
ECR #1	38,491	\$72,363	\$53,888	\$69,284	\$123,172
ECR #2	37,739	\$70,949	\$52,834	\$67,930	\$120,764
Total	483,076	\$1,213,318	\$676,307	\$869,537	\$1,545,844
Saving from Waste Handling					\$332,526
Water Re-use saving (assume:25% of treated volume)					\$44,281.98
Savings					\$376,807.78

GOI Regulation Compliance

The most important criteria of operate OWT unit is the product itself should comply with GOI regulation. The unit is capable to produce a friendly discharge; it was proven that the products met appropriate GOI regulations as per PERMEN LH No.04/2007 or Kep-03/BAPEDAL/09/1995. It is concluded that the project fulfils the success criteria of product effluent compliance.

In the other hand, there is consideration of permitting from environmental ministry related to the operation of OWT units. PT. X is still in process for applying this permit to government. Current status is all documents already sent and has been reviewed by ministry of environment. Meanwhile, PT. X is waiting for the decision of approval or rejection of the permit.

4. Discussion and Recommendation

On site waste treatment offers benefit not only from safety and economic standpoints, but also it supports what so-called Environmental Liability. The waste should not go anywhere and the responsibility will be charged back to the waste generator should anything impact by the waste. OWT is an effective solution to manage drilling mud waste in Duri Field and has the potential to be implemented on all rigs.

OWT significantly reduces trips and mileage, which in the end will reduce MVC potential, especially when driving at night. The OWT cost per barrel treated (for vacuum truck trip more than 10 km, without including waster reuse cost reduction) is lower than the CMTF. Ultimately, drilling operation will not need any off-site waste treatment and therefore a thread of having fully contained waste treatment facility can be diminished. However, significant improvement against the unit shall be made to eliminate any operational issues.

Mostly, challenges for this onsite waste treatment units are operational issues. One other issue is permitting from GOI ministry of environment. Below are the lists of operational challenge that should be improved.

1. Maintain the discharge solid (sludge that should be thrown back to disposal pit) while processing the mud waste from the same disposal pit (suitable for AOP OWT units)
2. Settling near the rig – location consideration
3. Ensure the laboratory's effluent testing could be done before effluent released to environment
4. People Skills & Knowledge, esp. Technical & Communication Skills

Mobile onsite waste treating facility is focusing on treated fluid phase of drilling waste. There is still solid phase that current practice is being buried directly in earthen disposal pit. To avoid future environmental liability and also commit to protect people and environment, there are some forward visions to be improved in drilling waste management system of Sumatera Drilling operation:

- Solid treating facility in Sumatera operation. Several options need to be access, such as sand management facility (slurry fracture injection), land farming, and etc.
- Closed loop drilling or onsite unit that treated all fluid & solid phase of drilling mud.

5. Acknowledgement

I would like to express my sincere gratitude to Mr. Dermawan Wibisono, as advice given by him has been a great help in forming this paper. My special thanks are also extended to my direct supervisor and all of colleagues and team member in PT. X for the teamwork, support, guidance and advice in several years during this project run.

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