Overview of OBM Cuttings Remediation Methods and Technologies

ASC UPSTREAM 2017

ARTHUR HALE

where energy is opportunity™

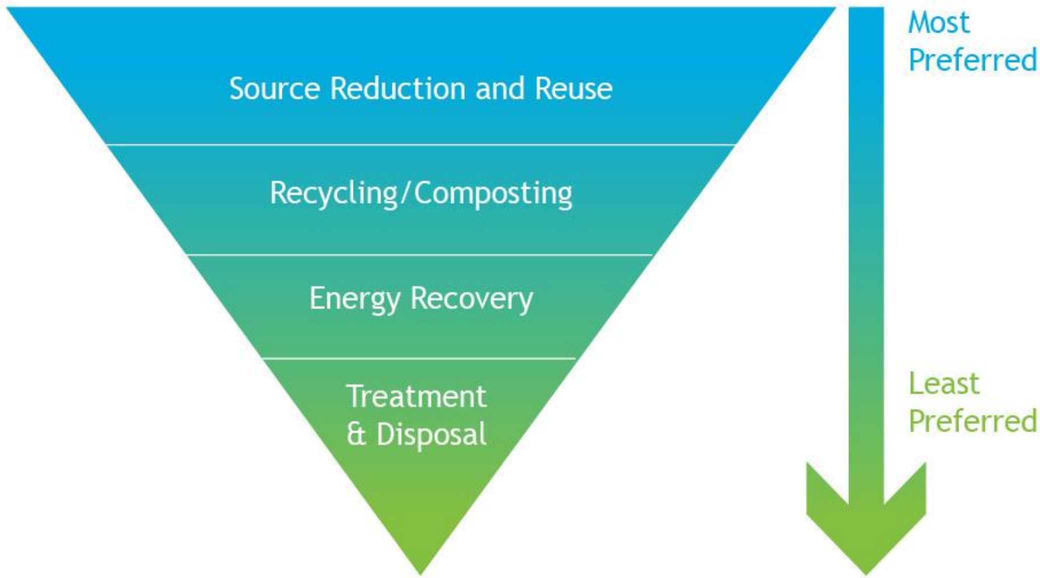
The Issue

According to API, drilling waste is the rock cuttings and fluids that are produced from drilling a new wellbore into the subsurface

Waste Management

Liabilities

- Non-compliance
- Cost-manage and remediate
- Esthetics of Landscape damaged
- Environmental and Health
  - Heavy Metal
  - Salt
  - Hydrocarbon (type and amount)
- Long term



Waste Management Hierarchy

Minimize Amount of Waste

✓ Well Plan

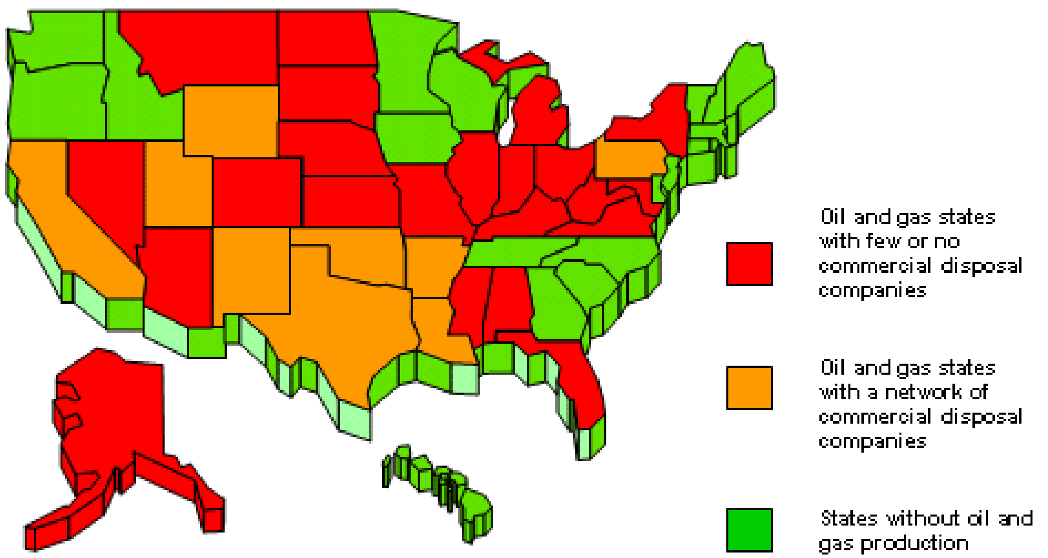
✓ Solids control

✓ Technologies for Managing and Recycling

Economics-Big Business

- On average, 1.2 bbls of drilling waste are produced for every foot drilled
- In 2014, approximately 392,000,000 bbls of drilling waste was generated in the onshore US

- According to Statistics Market Research Reports ,
  - ✓ Global Drilling Waste Management market is estimated at $3.89 billion in 2016
  - ✓ Expected to grow $6.23 billion by 2023
  - ✓ Compound Annual Growth Rate (CAGR) 6.9% from 2016 to 2023.



aramco

Competitive Landscape and Key Vendors

The leading vendors in the market are:

- Baker Hughes
- Halliburton
- National Oilwell Varco
- Schlumberger
- Weatherford

Segmentation by service type:

- Solid control services
- Treatment recycling
- Energy extraction
- Containment and handling

The other prominent vendors in the market are Augean, Cubility, Derrick Corporation, GN Solids Control, KOSUN Group, Newalta, Ridgeline Energy Services, Scott Environmental Services, Scomi Group, Secure Energy Services, SoilTech, Soli-Bond Waste Processing Services, Specialty Drilling Fluids, STEP Oiltools, Binder Scientific and Tervita

Cost Comparison of Drilling Waste Management Techniques

Comparison Factor	Fixation	Thermal Treatment	DCI	Bioremediation/Composting	Landfill	Landspreading / Soil Farming
Environmental Impact	Low	High	Low	Medium	Medium	High
Cost	$9-10/bbl	$40-45/bbl	$10-$15/bbl	$80-90/bbl	$8-30/bbl	$6-15/bbl
Contaminants Handled	Metals, Hydrocarbons	Hydrocarbons	All	Hydrocarbons	All	Hydrocarbons

*DCI Drilling Cuttings Injection

What is being done?

- Minimize Amount of Waste
- Manage the Waste
- Recycle the Waste

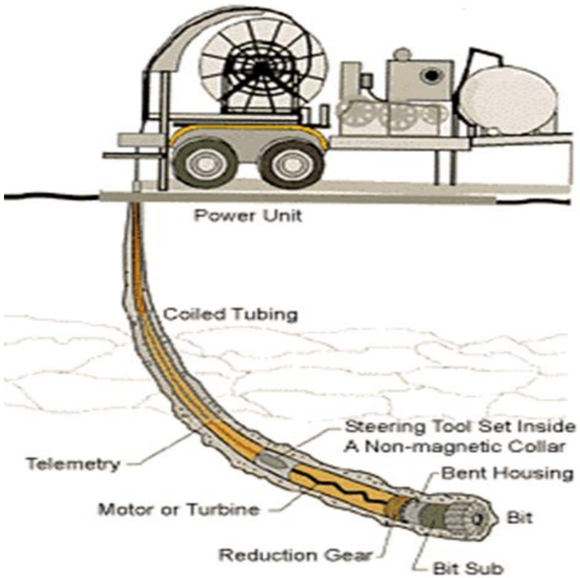
What is being done?

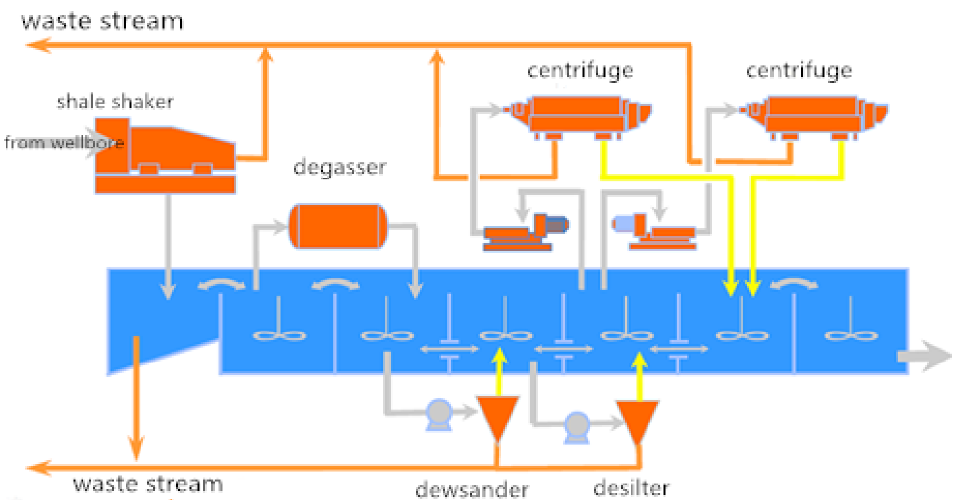
- Minimize Amount of Waste

Waste Management

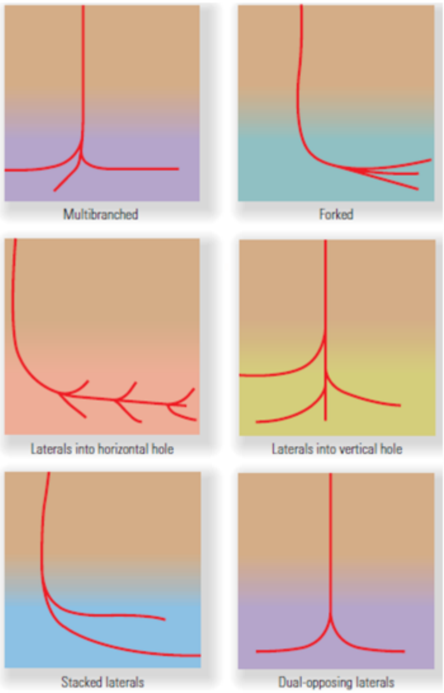
Minimize Amount of Waste

- **Drilling Smaller-Diameter Holes**



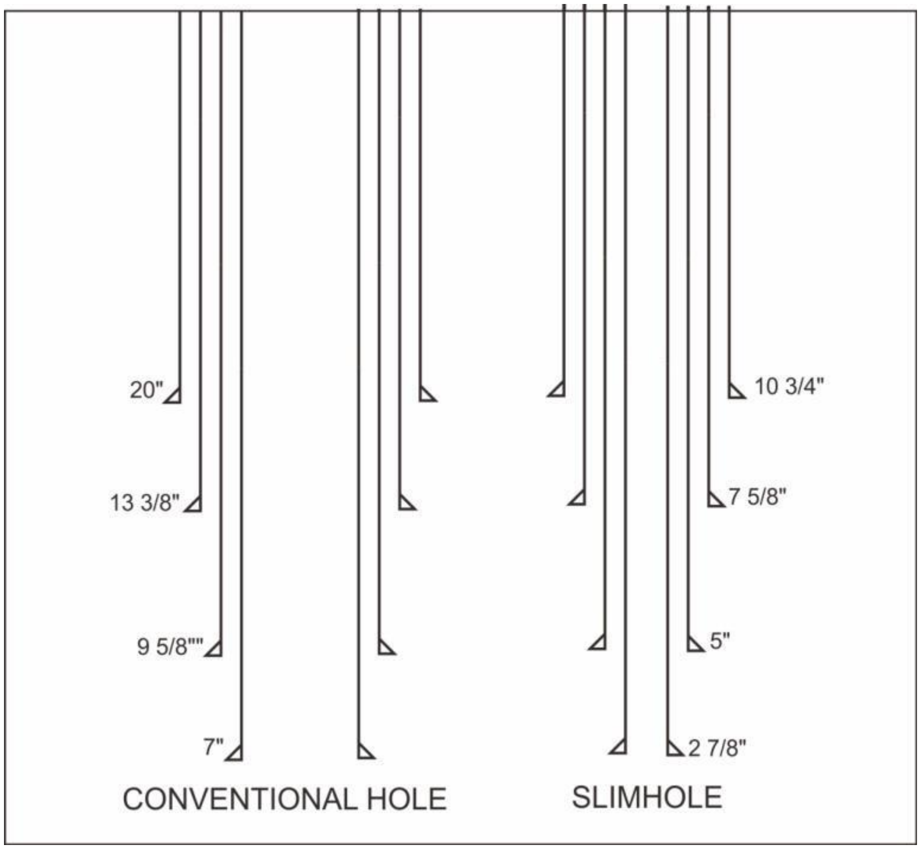


- **Well Plan**



- **Type of Drilling Fluid**
  - Typically WBMs generate more drill cutting
  - Non-aqueous based muds generate less cuttings

Slim Hole



PRO

- **Reduced well costs**-day rate, materials, smaller footprint
- **Reduced personnel-** smaller crew exposure
- **Cuttings and Waste Reduction-** 40-70%

CON

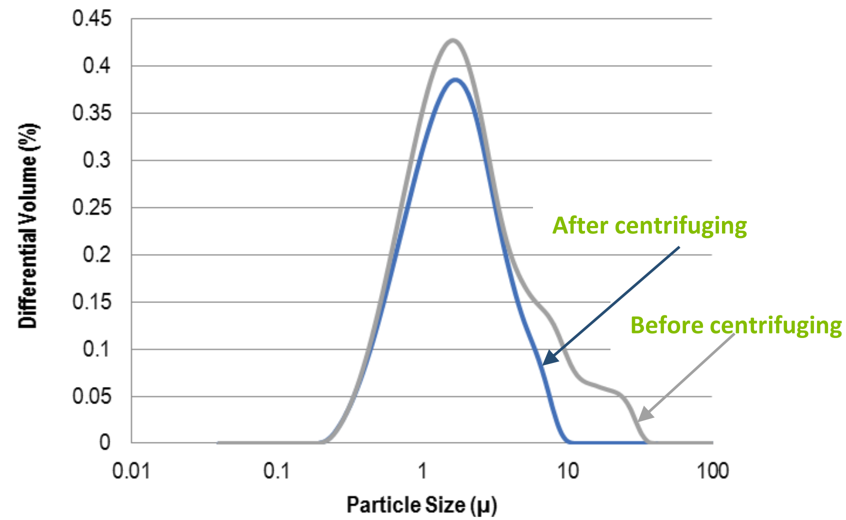
- **Annular pressure loss** is a critical consideration of slimhole drilling.
- **Wellbore instability** can result from pump pressure spikes
- **Limit completion strategies and production**
- **Limit Petrophysical information**

aramco

Solids Control Efficiency

- Current rig technology cannot remove low gravity fines (< 7-10 µm) from NAF

- Low Gravity Solids (LGS) buildup hinders drilling efficiency:
  - pipe sticking,
  - increased torque,
  - decreased ROP,
  - high ECD's
  - high surge and swab pressures



- Typically 1-2 bbls NAF / barrel of rock drilled.

- Onshore tend to reuse fluids for multiple wells.

aramco

Solids Control Efficiency

Factors that impact SRE

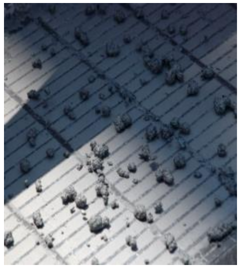
- **Well Design**
- **Amount of solids**
  - Low gravity solids content
  - Mud weight-high gravity solids
  - Amount and specific gravity of each mud additive
- **Rate of penetration, hole size, pump rate**
- **Drilling fluid properties (e.g viscosity)**
- **Solids control equipment** (rig, drying shakers, centrifuges, etc.)
- **Number and configuration pits**
- **Percentage of total dilution**
- **Solids content of reserve pit**

Solids Removal Efficiency	>90%	Excellent
	60-80%	Typical
Oil on Cuttings	Typical >1.5 barrels oil per barrel of cuttings	
	Excellent <1.0 barrels oil per barrel of cuttings	

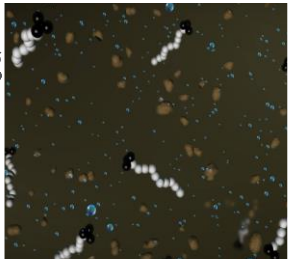
Solids Control Technologies

non traditional

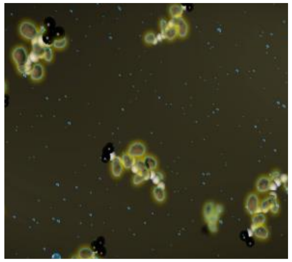
- **M-I SWACO - SCREEN PULSE**
  - Retro-fitted to existing shale shakers
  - Suction applied under the last shaker screen and surface tension on the screen face is broken



- **M-I SWACO - RHE-USE**
  - Process barrels of non-aqueous drilling fluid by water wetting and flocculating solids
  - Followed by high speed centrifuging
  - Oil recovered

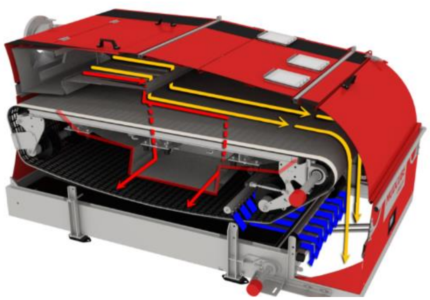


Before Flocculation



After Flocculation

- **Mud Cube**
  - Rotating filter belt carries mud and drilled solids forward while air, at 20,000 liters per minute, is pulled through the belt taking with it the liquid phase.
  - Claim <6.9% by weight oil on cuttings



What is being done

Manage the Waste

Manage the Waste

Techniques to Manage Drilling Waste are driven by the local and state regulatory requirements and restrictions.

- Vary by region and local
- Must be complied with or risk severe penalty and/or potentially license to operate

Manage the Waste

Drilling Waste Management Information System

The information resource for better management of drilling wastes

The Drilling Waste Management Information System is an online resource for technical and regulatory information on practices for managing drilling muds and cuttings, including current practices, state and federal regulations, and guidelines for optimal management practices.

Visitors can use these resources to:

- learn about industry standard practices;
- determine which regulatory requirements must be met;
- select optimal management strategies for their location and circumstances.

Technology Descriptions - Basic information about practices that are currently employed to manage drilling wastes.

Federal and State Regulations- Existing state and federal regulations that form the regulatory context for drilling waste management practices.

Technology Identification- An interactive tool to determine optimal management practices for a given geographical or environmental setting.

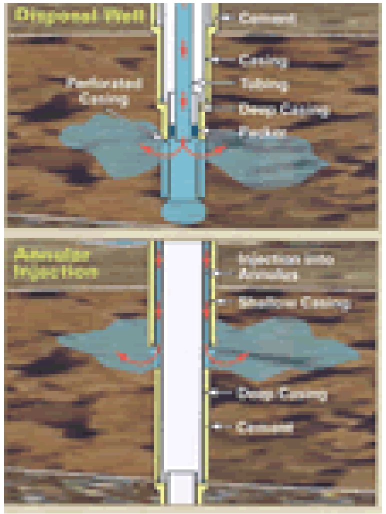
Waste Management

Techniques to Manage Drilling Waste

Landfills

Lined Pit

Cuttings Slurry Injection



Cutting solidification or stabilization

- Minimize leaching of contaminants
- Use for Roads, Construction, etc.

Land Farming

General Use

aramco

Drilling Waste % Drilling Wastes Disposed by Method

Disposal Method		
Evaporate Onsite	**68%**	**Solids with liners**
Buried Onsite		
Hauled Offsite Commercial Landfills	2%	Solids
Injection	13%	Liquid/grounds solids
Discharge to Surface	1%	
Land Spread	7%	Solid/Liquid
Reuse for Other Drilling	7%	Liquids
Other (includes solidification, incineration)	2%	Solids
Total	100%	

Traditional Approaches: Burial

Pros

- Simplicity
- Low cost
- Limited surface area requirements
- Most likely onsite, or nearby in pits

Cons

- Potential for waste to migrate and contaminate groundwater, resulting in liability
- Requires lining that over decades ??

General Use

aramco

Traditional Approaches: Haul to a Commercial Facility

Pros

- When a regulatory agency does not allow onsite disposal
- When onsite techniques are problematic (e.g. in marshy, high water table environments)

Cons

- Transportation to site
- Costly
- Commingling of waste does occur
- Some states have few or no disposal sites (cost-prohibitive)

Landfill

General Use

aramco

Traditional Approaches: Land Farm/Spread/Spray/Composting

Pros

- Simplicity
- Low cost (Land Farming/Spreading/Spray)
- Potential to improve soil conditions
  - Increasing their water-retaining capacity
  - Reducing fertilizer losses.
- Naturally occurring microbes assimilate waste constituents in place

Waste Treatment Compost at Chevron/Texaco Site

aramco

Land Farm/Spread/Spray/Composting

Cons

- Requires transportation
- Salts and metals cannot biodegrade
    - Inorganic compounds and metals must be:
        - Diluted
        - Incorporated into the matrix (exchange reactions)
        - Become less soluble through oxidation, precipitation, and pH effects.
- Potentially large land requirements
- Repeated applications can lead to accumulation of high molecular weight non-degradable hydrocarbons compounds.
- Must be very careful to match soil with waste to ensure no long term modification.
- Composting generally limited to organic constituents
- Composting long term commitment with high cost

Cutting/Liquid Injection.

- The two common forms of slurry injection are *annular injection* and *injection into a disposal well*.
  - Exceed fracture gradient
  - Sub-fracture injection

Cuttings Injection

Pros

- Returns material to subsurface strata below underground source drinking water.
- May be conducted during drilling
- Does not require additional land.

Cons

- Requires transportation
- Potential for groundwater contamination.
- Increased mechanical risk factors (during drilling).
- 50/50 Failure (broach/bridge) potential
- **Geology has to be right**

What is being done

Recycle the Waste

aramco

Definition and Factors of Legitimate Recycling

EPA's definition of legitimate recycling is found in Title 40 of the Code of Federal Regulations (CFR) section 260.43. The four legitimacy factors are as follows:

1.Legitimate recycling must involve a **hazardous secondary material that provides a useful contribution to the recycling process or to a product or intermediate of the recycling process.**

2.The recycling process must produce a **valuable product or intermediate**.

3.The generator and the recycler must manage the hazardous **secondary material as a valuable commodity** when it is under their control.

4. The product of the recycling process must be **comparable to a legitimate product or intermediate.**

aramco

Sham Recycling

•State regulatory requirements for generators may be more stringent than those in the federal program. Be sure to check your state's policies.

•Ineffective or only marginally effective for the claimed use

•Used in excess of the amount necessary

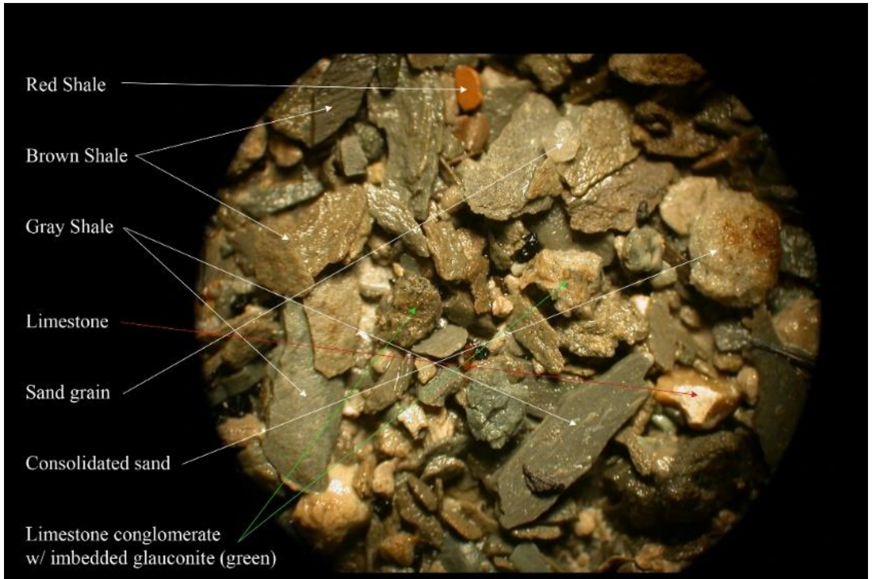
•Handled in a manner inconsistent with its use as a raw material or commercial product substitute

•Recycled product is not comparable to a product made from analogous raw materials

Cutting solidification or stabilization.

- Solidification refers to processes that encapsulate a waste to form a solid material and restrict contaminant migration by decreasing the surface area exposed to leaching and/or by coating the waste with low permeability materials.

- Stabilization refers to processes that involve chemical reactions that reduce the leachability of a waste.



Sample of drill cuttings under a 10x microscope

Cutting solidification or stabilization.

- Portland cement, lime, hot lime, and blast-furnace slag, in addition to novel binders such as microsilica and magnesium oxide cement, with or without the addition of high carbon fly ash
  - Formed of a calcium–silicate–hydrate-based matrix
  - Chloride immobilization is difficult
  - Immobilization of organic contaminants is stable

Pad

Road

Why solidification and stabilization technology?

Pros

•Often meets or exceeds the requirements of state and federal E&P laws

•Minimizing possibility of accidental spills and other liabilities

•Waste is NOT mixed or commingled with other waste

•Reduces costs associated with construction materials

•Drilling is not interrupted - the service is mobile

•Process waste to build engineered pads and/or lease roads

Cons

- Long Term Leaching Potential
- Chloride immobilization difficult
- Small throughput

Energy Recovery

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel.

Waste Management in Unconventional

Techniques to Manage Drilling Waste

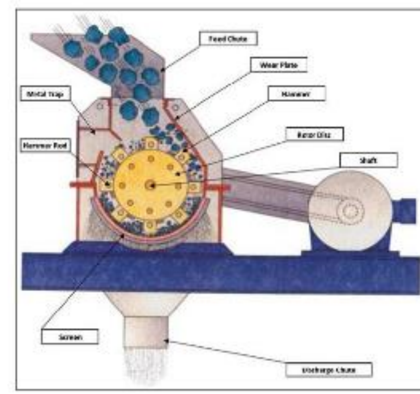
Thermal Treatment Technologies

Incinerations

Thermal Desorption

Rotary Kiln
>1000 C

Indirect Rotary Kiln
~500 C



Hammer mill
250-350 C

General Use

aramco

Summary

aramco

Summary

Discussed

- Minimizing amount of drilling waste (e.g well design, drilling fluid, solids control)
- Manage (treating/disposing) drilling waste (e.g. land spraying/spreading, landfills, etc.)
- Recycling waste options (e.g. thermal desorption, solidification and stabilization)

Drivers for how we deal with drilling waste

- Local/Federal environmental regulations
- Drilling Project Economics
- Social Responsibility