DRILLING WASTE TREATMENT

Introduction

Exploration for oil and gas results in the creation of drilling wastes that consist of a mix of drill cuttings and non-recoverable drilling muds. These wastes are often contaminated with a mixture of hydrocarbons, metals and metalloids (Table 1).

Contamination types, levels and their behavior within drilling wastes is determined by the local geological conditions and drilling mud design; notably lubrication fluids, weighting agents and anti-foaming agents. Such additives can contain potentially toxic elements such as aluminum and barium. Besides being contaminated, drilling wastes often have a high pH due to the addition of lime, caustic soda, soda ash and/or sodium bicarbonates. Furthermore, drilling wastes can have a high Chemical Oxidation Demand (COD), extremely low redox potentials, high exchangeable sodium and elevated electrical conductivity. Such conditions can also inhibit the natural biological degradation of hydrocarbons present in the drilling wastes.

These properties can make the materials toxic to plants and soil micro-organisms and invertebrates. Without appropriate treatment drilling wastes can represent a significant risk to human, ecological, crop and surface- and ground-water receptors.

The bioavailability, leachability and behavior of contaminants in drilling wastes, and the subsequent risk they present to receptors, is controlled by their properties and the environmental conditions they are exposed to. The level of risk which drilling wastes presents to receptors can therefore change from their 'fresh' state as their condition, or local environmental conditions, change over time. Simply ascertaining the risk of exposure to contaminant levels in 'fresh' drill arisings does not fully consider the risk of future contaminant release, exposure, or potential impacts to receptors.

Landspread, burial of drilling waste and disposal onto the sea floor at best isolate the problem with the aim of preventing toxicity to human receptors but leave latent environmental liabilities intact. This incurs cooperative risks that require the creation of environmental bonds tying up capital.

The C-Cure Approach

C-Cure have developed an innovative and sustainable approach for drilling waste assessment, treatment and management. This involves:

1) Evaluation of the condition (pH, redox, EC), and levels, availability, impacts and risks of contaminants within fresh or legacy drilling wastes
2) Assessment of local land-use, climatic and environmental conditions
3) Assessment of how local environmental conditions are likely to alter the properties of the drilling wastes, and the subsequent behavior, risks and liabilities of contaminants to receptors
4) Appraisal of immediate and future risks of contaminant exposure to receptors
5) Determination if treatment of the drilling waste material is required to mitigate immediate and future risks
6) Provision of a bespoke treatment solution to treat immediate contaminant levels whilst providing a 'life jacket' treatment to prevent the future release and exposure of contaminants due to potential future changes in environmental conditions.

This approach is set against local land-use, environmental conditions and surpasses all known best practice regulatory requirements.

Treatment is designed to remove any immediate and latent environmental liability associated with the drilling waste through the sustainable stabilisation of hydrocarbons, metals and metalloids into non-bioavailable and non-leachable forms.

Our approach provides a unique and comprehensive treatment solution that effectively breaks existing and prevents future pollutant-receptor linkages. Our solutions take account of local conditions, contaminant toxicity and environmental risk factors such as existing and potential future pH, redox potential and land use, thus ensuring long term environmental stability. The aim is to ascertain risk, minimize environmental impacts and liabilities, and reduce treatment costs.

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The C-Cure Treatment

C-Cure has developed an innovative treatment solution based on application of a range of charcoal based products which can be combined to provide significant benefits compared to traditional treatment options for drill arisings. The C-Cure technology provides:

1. **Fast adsorption of leachable organic contaminants to meet Environmental Quality Standards (EQS).**

2. **Fast adsorption of leachable metals and metalloids to meet EQS.** C-Cure has developed charcoals capable of adsorbing up to 35% of their weight in metal and 1.5% metalloid contaminants.

3. **Retention of adsorbed contaminants across a broad range of redox and pH conditions.** Our products retain metals and metalloids in un-leachable forms at pH as low as 3, across a broad range of oxidised and reduced conditions. Organic contaminants are held by our product in a non-leachable and ecologically safe form. When conditions for bioremediation are ripe the bio-accessible fraction of the organic contaminants will degrade whilst residual persistent organics are safely retained within the charcoal.

4. **A balanced C:N:P:K ratio, moisture and aeration to facilitate natural attenuation.** C-Cure products can be combined with mineral fertilisers to provide an optimal C:N:P:K ratio, whilst also containing essential micro-nutrients such as iron. The porous structure of our products also provides aeration, which can be further enhanced with co-amendment with a proprietary oxygen release compound.

5. **A fast and effective method of determining treatment success.** C-Cure products are fast acting, can be tested and optimised very simply through standard TCLP type testing, and give *'almost immediate'* detoxification to meet EQS criteria.

6. **Produce a final material which would ideally be suitable for land-spread**, or at a minimum for encapsulation with no long term risk to the environment. Through the processes outlined above, C-Cure products provide an immediate detoxification whilst offering long-term stability.

Our products and services therefore offer a sustainable, cost effective and rapid solution for the treatment of a variety of drilling wastes that will satisfy recognised international regulations.

Table 1. Concentrations of several metals in water based drill cuttings from an offshore platform in southern California. (Source: Neff, 2005).

Metal	Heavy metal concentration (mg kg^{-1} dry weight)	
	Drilling Mud	Cuttings
Barium	53,900	15,084
Silver	0.37	0.50
Arsenic	10	10
Cadmium	1.17	2.89
Chromium	91	104
Copper	24	70
Mercury	0.09	0.07
Nickel	39	47
Lead	23	356
Vanadium	76	100
Zinc	167	664

C-Cure technology compared with other methods

Methods for dealing with drilling wastes vary, and include disposal to sea, thermal treatment, biological treatment, burial in pits or disposal to landfill. Both biological and thermal treatment options aim to deal with the hydrocarbons that are present in the waste, but fail to deal with inorganic contaminants such as heavy metals (Table 2). Furthermore, heavy metals inhibit the microbial degradation of hydrocarbons, making biological treatment ineffective.

Table 2. Advantages and disadvantages of some treatment options for drilling waste

Factor	Treatment		
	Land Farming	Bio-remediation	Thermal treatment
Hydro-carbons	Incomplete degradation	Incomplete degradation	Complete removal
Heavy metals	Not treated	Not treated	Not treated
Transport costs	Medium to high	Medium to high	High
Space required	Large	Large	Low to medium
Timeframe required	Months	Months	Days
Energy Requirements	High	Medium	Very high
Capital Expenditure	Medium	Low	High

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In comparison the C-Cure solution offers:

- **A process that deals with both heavy metals and hydrocarbons**
- **A process that is fast acting**
- **A process that requires minimum space**
- **A process that is easy to implement**
- **A process that can be implemented 'on site'**
- **A low energy solution**
- **A solution that does not require expensive treatment infra-structure**

CASE STUDY

Use of the C-Cure Approach on six drilling wastes from production sites in Asia

Six drilling wastes were assessed using the C-Cure Approach. Assessments were made of contaminant levels in the arisings and of local environmental condition and land-use. The results of the assessment demonstrated that two of the materials met Environmental Quality Standards without further treatment. These materials were deemed to be of sufficient quality to be suitable as soil forming materials to create natural habitat on an area of the drill site. The remaining four materials required treatment to address immediate risks of elevated levels of leachable and bioavailable hydrocarbon and metal contaminants.

Treatment of legacy drill arisings from production sites in Asia

The aim of this assessment was to determine the effect of the C-Cure treatment on both hydrocarbons (methanol extractable total petroleum hydrocarbons) and leachable heavy metals.

An experiment was set up where the drilling waste was amended with increasing amounts of C-Cure product (0, 0.5, 1, 1.5 and 2%) (wt/wt) to determine the optimal amendment rate for achieving hydrocarbon binding (sequestration) within the drilling waste.

The results show that the C-Cure product was highly effective at binding leachable hydrocarbons (Figure 1) with > 95% reduction in TPH being achieved with a C-Cure amendment rate of 2% (wt/wt).

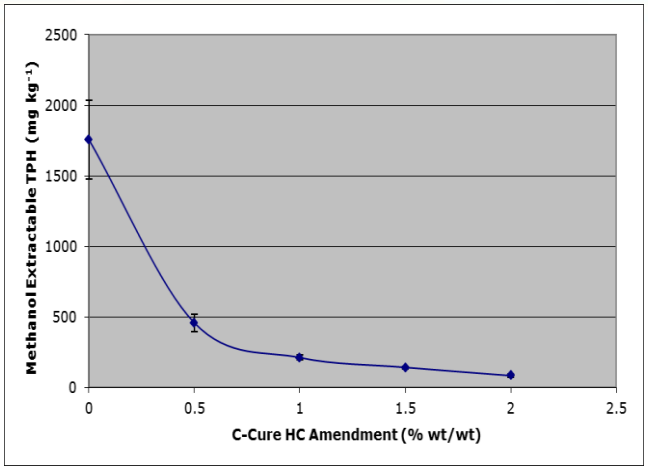

Figure 1. Concentrations (mg/kg) of methanol extractable hydrocarbons (TPH) in drill cuttings stored in a lined pit. Drill cuttings were treated with different amounts of C-Cure product to reduce leachable hydrocarbons. Data are presented as averages ± standard error of the mean.

The drilling wastes also contained a cocktail of leachable metals (including barium, aluminum, copper and lead), had a pH of >10, and were in a reduced state having a redox potential of -110mV. The wastes were amended with 2% (wt/wt) C-Cure product. Materials were incubated for three days and remained water logged for the duration of the experiment. After incubation, leachable metals were extracted from the drilling waste and concentrations were measured using ICP-OES. Comparison was made to the un-amended (Control) samples to determine the efficacy of the C-Cure amendment.

Table 3: Leachable metals present in non-treated drilling wastes and drilling waste that was amended with C-Cure product (2% by weight).

Treatment	Leachable metals (mg kg^{-1} dry weight)			
	Al	Ba	Pb	Cu
Non-treated	261.4	13.2	2.0	1.4
C-Cure treated	60.2	2.1	0.8	0.2
Reduction	77%	84%	60%	86%

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An assessment was then made in how local environmental conditions might change in the future, which would influence the risk of contaminant release and risk to receptors. Amendment with the C-Cure product was made to optimise immobilization of heavy metals, including aluminum and barium using a combination of environmental management and C-Cure amendment. A comparison was made between treated and untreated material. After incubation, leachable metals were extracted from the drilling waste and concentrations were measured using ICP-OES (Table 4).

Table 4: Leachable metals present in non-treated drilling waste and drilling waste treated with an amendment of 2% C-Cure product in combination with environmental management.

Treatment	**Leachable metals ($\mu g\ kg^{-1}$ dry weight)**		
	Al	**Ba**	**B**
No treatment	2804	10145	405
C-Cure treatment	194	164	149
Reduction	**93%**	**98%**	**63%**

Conclusions

- The Cure Approach identified that two of the six materials did not require remedial treatment, and could be used as a soil forming material for habitat establishment. This provided considerable financial savings.
- The C-Cure treatment provided significant reduction in leachability and bioavailability of hydrocarbons and heavy metals in the drilling wastes requiring treatment, to levels well within regulatory Environmental Quality Standards.
- Treatment was optimised to also provide an effective 'lifejacket' against potential changes in environmental conditions.
- The treated material was of a sufficient standard to enable re-use on site as a soil forming material for the reintroduction of an area of natural habitat on the drill site.
- Use of the C-Cure treatment was deemed to provide the most cost-effective and sustainable treatment method.

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