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Land Application of Drilling Fluids: Landowner Considerations

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BACKGROUND

Petroleum and natural gas are major sources of revenue in Texas. However, disturbance caused by construction of drilling locations, oilfield roads, and installation of pipelines can result in reduced crop production, increased susceptibility of the damaged sites to erosion, and increases in noxious and poisonous plant densities. In addition, on-site disposal of drilling fluids used in the drilling process can create problems if not managed properly. Drilling fluids have been and currently are land applied in many parts of Texas. In some areas, the use of clayey drilling fluids on sandy soils has improved water holding capacity and plant growth. However, in many areas of the state, improper rates of application of high salt drilling fluids have resulted in the death of plants and severely damaged soils that have failed to recover even after many decades (Photo 1).

Photo 1. Denuded oil well reserve pit in west Texas with high soil salt concentrations.

The Environmental Protection Agency (EPA) classifies oil and gas drilling fluids as "special wastes" which are exempted from amendments to the Resource Conservation and Recovery Act (RCRA) issued by Congress in 1980. As a result, regulations regarding the handling and disposal of oil-field generated wastes vary from state to state. The Railroad Commission of Texas (RRC) is authorized to regulate disposal of drilling fluids under Title 16 (Economic Regulation), Part 1 (Railroad Commission of Texas), Chapter 3 (Oil and Gas Division) of the Texas Administrative Code. Under Statewide Rule 8, adopted by the Railroad Commission, authorized disposal procedures include landfarming and burial of certain drilling wastes, including drilling fluids.

Drilling fluids, also called drilling muds, typically consist of about a 5% slurry of bentonite clay in a base fluid of water, diesel, or mineral oil, an organic material such as lignite or lignosulfonate to stabilize the slurry, and a density increasing material, usually barite ($BaSO_4$), to help float out rock particles. However, the quantity and chemical composition of a particular drilling fluid will vary with conditions in the hole, such as depth and type of formation. These fluids remove cuttings from the hole, cool the drill bit, and seal off porous geologic strata. The fluid is periodically pumped into a reserve pit (constructed earthen pit) circulated to allow cuttings to settle, and then reused (Photo 2). When drilling is completed, much or all of the fluid is disposed of in the pit, allowed to dry, and then mixed with soil from the pit berms or simply covered. In other situations, drilling fluids may be disposed of by removal and transport to an approved landfill, or by land application.

Photo 2. Oil well reserve pit containing drilling fluids.

Landfarming or land application is a process whereby drilling fluids are spread on the land surface. The rate of application depends on the characteristics of the soil and the chemical composition of the drilling fluid. Land application is often preferred to reduce the costs of disposal, and may be conducted either on-site (where the drilling occurred) or at an off-site location. This process also is used to treat and/or dilute potentially harmful constituents in the drilling fluid, when present. These constituents may include petroleum hydrocarbons, salts and/or heavy metals.

Petroleum hydrocarbons including oil and grease can be toxic to plants in modest concentrations either due to direct contact or through adverse effects on soil properties. When oil is spilled on growing plants, low molecular weight compounds, for example fuel oil, act as a solvent on the lipid membranes of tender plant parts. Total soil hydrocarbon concentrations greater than 1% have been found to be toxic to most plant species and this level is normally considered the threshold between non-contamination and contamination. Soil oxygen levels are reduced because diffusion of oxygen through the oil and/or grease layer is poor and because microbes use the available oxygen as they breakdown the oil. As a result, the soil can become anaerobic (low oxygen), which is limiting to plant growth. In addition, plant available nutrients (particularly nitrogen and phosphorus) are rapidly used by these microbes in the process of degrading the oil and can become deficient for plant growth. Finally, and commonly the most damaging to plant growth, soil particles coated with oil can become hydrophobic which reduces water infiltration, drainage and storage in the soil, and its availability to plants.

Salts in drilling fluids can affect both plants and the soil. The salts present in drilling fluids can come from 1) the materials used to formulate the drilling fluids, and/or 2) poor quality groundwater or salt containing geologic formations that are contacted during drilling. High levels of soluble salts decrease water availability to plants, basically creating a drought-like stress which can cause plants to wilt and potentially die. A soil is typically considered salt-affected or “saline” when the electrical conductivity of the saturated paste extract exceeds 4 millimhos per centimeter (mmhos/cm). However, sensitive plants may be affected by even lower soil salt levels. In loamy to clayey soils and under drying conditions, salts will often wick to the soil surface and accumulate, sometimes producing a white appearance (Photo 3). Several of the salt elements like sodium and chloride can be toxic to plants in high concentrations.

Photo 3. Salt accumulation on the surface of the soil at a reserve pit.

Another element, boron, can be toxic to some plants even at relatively low concentrations (< l part per million, ppm) in the soil. Sodium also can have an adverse effect on the soil by degrading soil structure. Soils affected by sodium often will be powdery and structureless on the surface when dry, or can become hard and very compacted. This reduces air and water movement into the soil and will limit plant growth. A sodium adsorption ratio (SAR) of 10 or more indicates the potential for adverse effects of sodium on soil physical properties.

Heavy metals are elements that may or may not be plant nutrients, but can be harmful to plant and/or animal health in low to high concentrations depending on the element. Some heavy metals will cause plant death at high concentrations. Others can accumulate in plant tissue (without harm to the plant) to levels which are harmful or toxic to animals and/or humans. The heavy metals most commonly found in drilling fluids include arsenic, barium, chromium, copper, lead, nickel and zinc. The amounts present will depend on the formulation of the drilling fluid and the geologic formations encountered during the drilling process.

LAND APPLICATION

The decision to land apply drilling fluids should be based on the chemical composition of the drilling fluid, and the amount and characteristics of the land area available. The first step is to obtain a chemical analysis of the drilling fluid and a representative (composite) sample of the native soil from the proposed land application area. No single measurement, such as a simple chloride analysis, is sufficient to properly evaluate and manage drilling fluid disposal. A thorough analysis should include the following measurements for both the drilling fluid and native soil unless otherwise specified:

1. Total salts – measured as the electrical conductivity (EC) of the saturated paste extract and reported in parts per million (ppm) or millimhos per cm (mmhos/cm).
2. Extractable individual ions – calcium, magnesium, sodium, boron, chloride, and sulfate-sulfur measured in the saturated paste extract and reported in milligrams per kilogram (mg/kg) or ppm.
3. Sodium Adsorption Ratio (SAR) – calculated from the saturated paste analyses for calcium, magnesium, and sodium.
4. Total heavy metals – arsenic, barium, chromium, copper, lead, nickel, and zinc reported in mg/kg.
5. Total petroleum hydrocarbons (TPH) – drilling fluid only, reported in mg/kg.
6. Routine + micronutrient soil nutrient test – pH, and extractable nitrate-nitrogen, phosphorus, potassium, calcium, magnesium, sodium, sulfur, copper, iron, manganese, and zinc.
7. Soil texture – native soil only.
8. Cation exchange capacity – native soil only.

Photo 4. Revegetated reserve pit.

A qualified professional can utilize the results of these tests to determine if land application is appropriate for a particular situation. If so, they can provide the proper rate of application (barrels per acre, tons per acre, or inches of depth) of drilling fluid so that the process does not cause long-term adverse effects on soil properties. These results also can be used to determine if additional soil amendments may be needed to promote treatment of the waste. For example, gypsum (calcium sulfate) may be recommended to offset high levels of sodium in the drilling fluid and prevent problems with soil structure. In other cases, nutrients are applied to support the growth of soil microbes capable of decomposing hydrocarbons, and to enhance plant growth for site recovery.

Land application should be conducted carefully to ensure that the rate of application is correct. Excessive rates can seriously damage the soil, and create long-term problems which are very difficult and expensive to correct. Once the drilling fluid has been applied it is typically disked or otherwise thoroughly mixed and incorporated into the upper 4 to 6 inches of soil. This assists with the decomposition of any organic materials and initially dilutes salts and other elements that may be present in high concentrations. The area may then be prepared and planted with a desirable plant species or species mixture (Photo 4).

Land owners are advised to develop a formal contractual agreement with the company or individual responsible for disposal of the drilling fluid. The agreement should stipulate testing requirements for drilling fluids and native soils, the land application procedures and limits, and any expectations for replanting and/or recovery of the impacted land. This may include periodic monitoring and further soil testing on the site. In some cases, it is desirable to require annual or semi-annual testing to ensure that constituent levels are within acceptable concentrations. In addition, specific requirements for vegetation recovery may be established, such as percent ground cover and/or survival for a specified period of time into the future (e.g. 1 to 3 years). The landowner should consider requiring the land application company to post a bond to insure longer-term compliance with specific land management requirements. The costs of sample collections, analyses, soil amendments such as gypsum and fertilizer, and selected seeds or vegetation, etc. can be included in the contractual agreement as the responsibility of the company or individual responsible for the disposal of the drilling fluids.

Careful development of a management plan for land application of drilling fluids is important to ensure that the land resource is utilized in an environmentally sound fashion and is protected for the future. By accomplishing this, the surrounding land and water resources also will be protected from potential off-site impacts. For questions and assistance related to drilling fluid disposal or a land application program, contact your local district office of the Railroad Commission of Texas (http://www.rrc.state.tx.us/). Web resources include a map of RRC district locations (http://www.rrc.state.tx.us/forms/maps/ogdivisionmap.php) and contact information for district offices (http://www.rrc.state.tx.us/contact/index.php). For more information on testing contact the Texas AgriLife Extension Service Soil, Water and Forage Testing Laboratory (979-845-4816), or your local county Extension office.

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