Health, Safety and Environmental

Introduction

Awareness... has made environmental concerns a key factor...

Awareness of the environment among the public, regulatory agencies, customers and service companies has made environmental concerns a key factor in drilling operations. Environmental issues are broad-based and complex, influencing all aspects of drilling fluid system design and use. Health, Safety and Environmental (HS&E) regulations overlap to some degree, but they consider the issues from different perspectives. Health and safety issues deal primarily with worker protection, while environmental issues deal with any impact to the environment and/or the health of the community exposed to the effects of drilling operations.

Preventing pollution and minimizing environmental impact in a cost-effective way are the foremost tasks confronting the industry today. M-I and Swaco are committed to developing products and waste management technology that enhance drilling and production while protecting the environment and the well-being of the people who use our products.

Minimizing Pollution

Identifying the source

The first step in minimizing pollution is to identify pollution sources associated with drilling fluids at the wellsite. Discharges into the air and water are usually grouped into three categories:

- **Point source.** A source of pollution that is discharged into the environment through a distinct point. An example of a point source of air pollution might be an exhaust pipe from a diesel engine in stationary service. An example of a point source for water might be cuttings discharged through a pipe into the ocean. Usually, these types of discharges can have some type of control device placed at the point of discharge to treat or collect the waste.
- **Non-point source** (fugitive emissions). A source of pollution not discharged into the environment through a distinct point. An example of a non-point source for air might be vapors generated at the shale shakers and over the surface mud system. An example of a non-point source for water might be rainwater that runs off a property in sheet flow (not through a ditch or channel). Usually, these types of discharges cannot have a control device placed at the point of discharge to treat or collect the waste.
- **Mobile sources.** A point source of pollution that is not stationary. An example for air might be a tailpipe on a car or truck. An example for water might be a bilge pump on a boat. Usually, these types of discharges can have some type of control device placed at the point of discharge to treat or collect the waste.

Discharges of solid waste are made into or upon the land and are not classified as any of the above three sources. Dry solids, sludges, liquids and contained gasses — either buried or spread on the ground — are considered solid wastes. An example of solid waste might be empty mud sacks that are buried.

Identify the pollutant

The second step in minimizing pollution is identifying materials that may have a negative impact on the environment.

Organic wastes can... cause toxic effects...

...heavy metals refers to a group of toxic metals...

The level of impact a discharge makes on the environment is a function of what types of materials are contained in the waste and the environment into which they are discharged. For example, high levels of sodium chloride in drilling fluids will have little impact if discharged into the ocean which has naturally high levels of salt. Discharge of the same drilling fluid into a freshwater stream or farm land would have a much greater impact because the animal and plant life are not acclimated to saltwater environments.

Listed below are eight basic items that have the potential to cause environmental damage, depending on the discharge environment.

Heavy metals from products and underground formations tend to react with drilled solids and clays and are only slightly mobile in the environment. The term heavy metals refers to a group of toxic metals that are considered potentially hazardous. They include mercury, cadmium, chromium, lead, soluble barium and others. These metals will not biodegrade and can be problematic for many years. For example, heavy metals can bioaccumulate and be passed up the food chain, causing health problems such as birth defects.

Salt compounds can inhibit plant growth by disrupting the ability of plants to uptake water. Increased salt concentration in freshwater can be toxic to fish and other aquatic organisms and to plants. Salt compounds usually are water-soluble, which increases their mobility, expanding the area of possible environmental impact.

Organic wastes often are extremely harmful to the environment. These types of wastes can be as simple as human/animal waste, which increases oxygen demand in streams and rivers and carries diseases, or as complex as industrial wastes, such as petroleum hydrocarbons or specialty products manufactured from organic chemicals. Organic wastes can bioaccumulate, causing toxic effects upon the food chain. These substances are highly mobile and can travel through the air and water, thus increasing their impact area.

Acids or bases can alter the pH and kill animals and plants; pH shock from drilling wastes not properly disposed of, whether liquid or solids, will disrupt the ecosystem immediately.

Total Suspended Solids (TSS) can damage nearby surface bodies of water not only aesthetically but also through reduction of both the amount and the quality of available light necessary for plant growth. This additional loading also exerts a mechanical toxicity, i.e. stress and/or coating of respiratory organs. The increased suspended solids contain organic components which, as they degrade, reduce the oxygen in surrounding waters.

Toxicity is used to determine the combined effects of pollution on test organisms. Instead of, or in addition to, analyzing individual types of pollution such as heavy metals and salts, many regulations require toxicity monitoring.

Radioactivity is a more recent concern in the oilfield environment. Naturally Occurring Radioactive Material (NORM) is the source of the radioactivity causing a concern. NORM is usually associated with production operations and has not been a significant factor in drilling operations.

Measuring Pollution

Sampling techniques are different for air, water and solid waste.

Sample collection. Most errors in analyzing waste occur because the waste was not sampled properly. The goal is to provide a sample that will represent the pollution accurately. If the wrong procedure is used, then the hazards of the waste may be either overstated or understated. Sampling usually occurs at point source discharges. Sampling techniques are different for air, water and solid waste.

Air sampling usually is conducted at the smoke stack that discharges the air. The samples are taken by traversing the stack with a sample collection device tube that is connected to a sample bottle. Samples also can be taken of ambient air using high-volume collection devices that trap air contaminants with filters.

In addition to requiring direct monitoring of air pollution, many regulations allow the use of estimates based on engineering calculations. The estimates can be used to lower the cost of determining air pollution.

Water sampling. Water samples are taken at the point of discharge into a receiving body of water using either grab samples or composite samples. Grab samples are taken over a short period of time. Composite samples are a series of small samples taken during specific intervals and then mixed to form a single sample.

Solid waste sampling is taken before a material is removed from the property for disposal. Composite samples are used to sample the waste.

The basic rules for sampling are very important and should be followed every time a sample is collected. This procedure is designed to help produce consistent results as well as reliable documentation for the regulatory agencies (see Figure 1).

1. Follow a detailed written procedure; if none exists, use common sense and record the procedure used.
2. Collect a single sample for homogeneous substances or a composite sample for non-uniform substances.
3. Use a clean container.
4. Clearly label the container with: Company name, location, date and time, source of sample, name of collector, and test to be performed.
5. Properly seal container, protect or refrigerate, if required.
6. Expedite shipment to testing location, following appropriate regulations, and keep a record of sample collection.

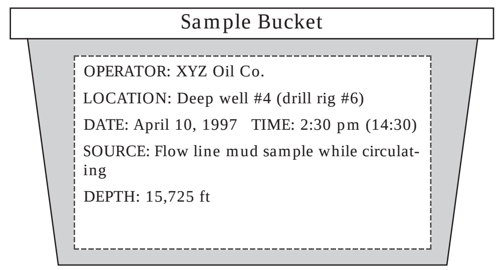


Figure 1: Summary of sample collection guidelines.

1. Always try to find a detailed written protocol for the type of sample you are taking.
2. If no written protocol is available, common sense will determine the best sampling method.
3. If no written protocol is available, write down exactly how the sample was taken and send the description with the sample.
4. Grab samples are good for waste streams that are homogeneous in nature. Composite sampling is good for wastes that are not homogeneous.
5. Use a clean container to collect the sample. Label the sample with the following information:
   - Exact sample location.
   - Date and time of sample.
   - Name of person who took the sample.
   - Which tests need to be conducted.
6. Send the sample in as quickly as possible for analysis. Keep the sample cool (not frozen) if it contains organic materials.

7. Soil samples that are sent internationally must be treated with special care to avoid transference of unwanted parasites.

Sample testing

Testing samples...is an important part of determining potential environmental impacts.

Testing samples of drilling muds, cuttings and associated waste is an important part of determining potential environmental impacts. Knowledge of test methods and procedures is critical in using test results to comply with the discharge permit and protect the environment. These tests require equipment and procedures which are not available at the rig site. Regulations vary, depending on the location. In the U.S.A. and most other countries, testing must be performed by approved laboratories. Two types of testing used for environmental analysis are bioassay testing and analytical testing.

Bioassay testing. Bioassay tests are conducted on animals to determine waste or product toxicity. A dose response relationship is determined for each test material. As the concentration of test material is increased in the animals' environment, a greater percentage of the animals respond to the toxicity by dying. Results from bioassay tests are reported by identifying specific points in the dose response relationship. Most discharge permits that use bioassay testing set limits based on the LC_{50} or LD_{50} test result. The higher the LC_{50}, the lower the toxicity (see Figures 2, 3 and 4).

- **LC_{50}** (Lethal Concentration 50%) — The concentration of a substance in air or water that will kill 50% of a test animal population.
- **LD_{50}** (Lethal Dose 50%) — The dose of a toxicant, expressed as a proportion of body weight, that will kill 50% of a test animal population.

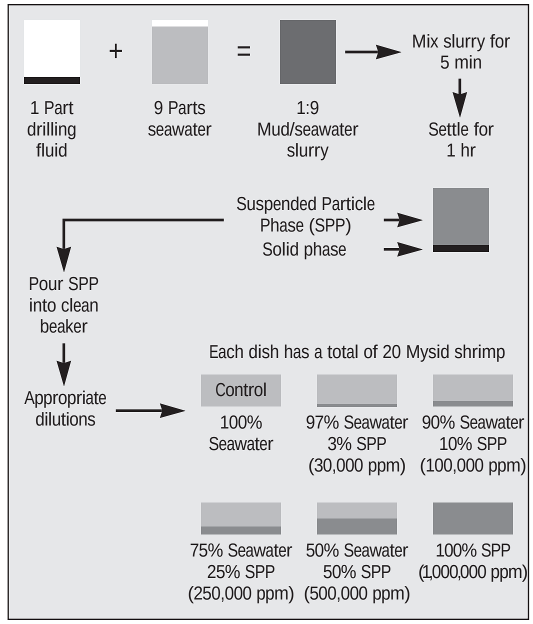


Figure 2: 96-hour Mysid bioassay LC_{50} test.

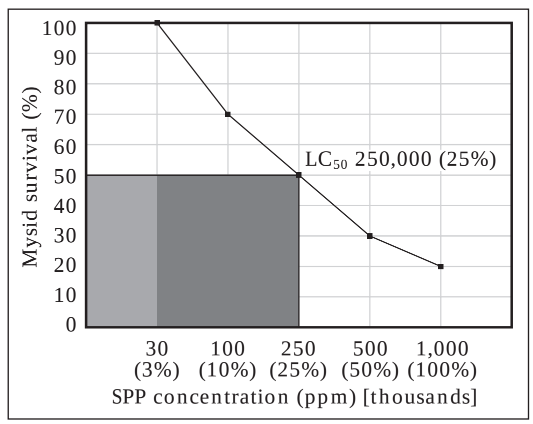


Figure 3: Example of passing LC_{50}.

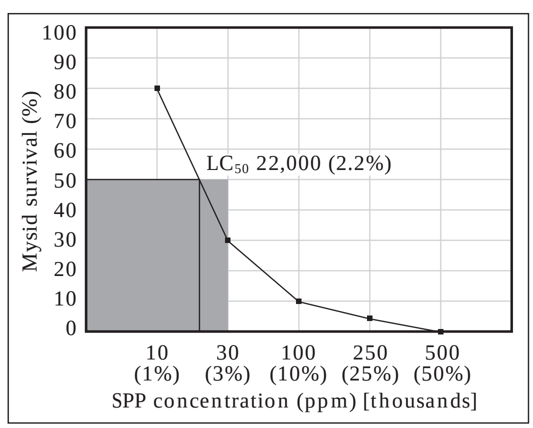


Figure 4: Example of failing LC_{50}.

...it is extremely important to be specific when...using analytical chemistry.

Analytical testing. Many types of analytical testing instruments and procedures exist for determining concentrations of contaminants. Therefore, it is extremely important to be specific when requesting and evaluating environmental data generated using analytical chemistry.

Chemical analyses of oilfield wastes typically can be broken down into two broad categories: Total testing and leachate testing.

- **Total testing** involves the complete digestion of a quantity of waste in order to determine the total amount of a contaminant in the sample. The results from these tests are reported as weight/weight ratios. For example, total barium would be reported in mg/kg.
- **Leachate testing** measures the quantity of a contaminant which can be leached from a quantity of waste using an extraction fluid. Results from these tests are reported in weight of contaminant per unit volume of leachate. An example of this type of data would be Louisiana 29B leachate testing for oil and grease, which would be reported in mg/l.

The types of testing required for the characterization of oilfield wastes are dictated by the responsible regulatory body. It is imperative to know which types of testing are required because these will control which mud products and remediation options are available. If total testing is required, the disposal option selected will involve prevention, dilution or destruction of the potential contaminant.

Many procedures require a sample to be in a solution...

Sample preparation. Many procedures require a sample to be in a solution before it can be tested. The sample preparation may dilute and/or concentrate the contaminant prior to analysis.

Examples of sample preparation. Acid leaching solid waste samples for total metal analysis involves using a strong acid to dissolve the total concentration of metals into solution. The reported concentration is not necessarily available to the environment.

Toxic Characteristic Leachate Procedure (TCLP). A weak acid is used to leach metals out of a solid waste. This represents what may be available in the environment.

Sample testing. Typically, analytical testing of samples is used to identify the potential environmental impact of a waste material. Testing of waste usually focuses on identifying concentrations of materials of concern, such as heavy metals or organics. However, sometimes the analysis indicates a characteristic of the waste such as its potential to biodegrade quickly. A review of some of the types of testing available helps to identify which test is appropriate.

Common tests for organic pollution in solid waste

Frequently, the tests listed below are conducted to screen for the presence of organic compounds. If these tests indicate high concentrations of organic materials in the waste, additional tests are then conducted to determine the composition and properties of the organic material.

Oil and Grease (O&G) test. The measurement of organic compound that can be extracted with a strong solvent. Naturally occurring fatty compounds from animal and vegetable matter can be identified as oil and grease.

Total Petroleum Hydrocarbon (TPH) test. Identifies the portion of the oil and grease concentration that can be attributed to non-polar compounds. The TPH test uses a strong solvent to extract organic substances and then remove the polar compounds that frequently represent naturally occurring oil and grease.

Inorganic materials can have a negative impact on the environment.

Flash point test. Identifies, in general terms, the volatility of the material tested and the potential it has to cause a fire or explosion.

Common tests for inorganic pollution of solid waste

Inorganic materials can have a negative impact on the environment. Screening tests listed below are used to identify potential problems:

pH test. Determines the inverse log of OH ion concentration.

Electrical conductivity test. An indirect measurement of the ionic concentration in the soil, which usually is a function of the concentration of salt in the soil.

Common tests for organic pollution of water

Biological Oxygen Demand (BOD) test. Measures the oxygen consumption of the waste water during a set period of time.

Chemical Oxygen Demand (COD) test. Measures the quantity of oxygen required to oxidize organic material in the water chemically.

Common tests for inorganic pollution of water

Total Suspended Solids (TSS) test. A measurement of the solids that can be filtered out of waste water.

Total Dissolved Solids (TDS) test. A measurement of the solids that are in a filtered sample when it is dried.

Common tests for organic air pollution

The common test for organic pollution in air is the **Volatile Organic Compounds (VOC) test**.

Common tests for inorganic particulate pollution of air

- NO_x - Nitrous oxides.
- SO_x - Sulfur oxides.
- CO - Carbon monoxide.

Specific tests for contaminants in solid waste, water and air

Testing for specific contaminants is conducted when screening tests or knowledge about the waste indicates additional testing is needed. This type of testing is expensive and time-consuming and should be used only when other testing, knowledge of the waste or permit requirements indicate it is necessary. Listed below are the specific materials that are most frequently requested:

- Extraction examples of heavy metals — Barium, cadmium, chromium, lead, mercury, silver and the non-metal elements arsenic and selenium.
- Examples of organic materials — Benzene, toluene and xylene pentrachlorphenol.
- Examples of salts — Sodium chloride and potassium chloride.

Interpreting and understanding the results

Once test results are received, the next step is to compare the results against some standard to determine if the discharge is acceptable.

In cases where the discharges are covered by a permit or a regulation, the standard can be found in the regulation.

In cases where there is no regulation or permit, the result can be compared to background (ambient) conditions. In order to compare the sample to background levels, two samples must be taken — a sample of the discharge and a sample representative of the background conditions.

The critical rule in analysis of results is to compare "apples to apples" and not "apples to oranges." Comparisons should be made for the same type of sample, the same digestion procedure and the same analytical procedure.

In addition to raw test data, other environmental factors, such as availability of the contamination to the environment, must be evaluated.

Listed below are several common units used for reporting results of analytical testing:

- ppm — parts per million (equivalent to mg/kg).
- ppb — parts per billion (not to be confused with "pounds per barrel" abbreviation).
- mg/l — milligrams per liter.
- % — by weight.
- % — by volume.
- mg/m^3 — milligrams per cubic meter.

Managing Pollution

Within the trend toward lowering of environmental impact, there is a widely recognized hierarchy of preferred management techniques. The techniques are listed below (and are described in ways that are relevant to drilling fluids).

Hierarchy of management techniques:

1. Pollution prevention/source reduction.
2. Recycling/reuse.
3. Volume minimization.
4. Treatment for disposal.

Pollution prevention/source reduction

The most desirable way of controlling pollution is to minimize or eliminate it at the source. Pollution prevention can be achieved by reducing either the volume of waste or its hazardous characteristics. The most common ways to do this are substituting products or changing operating practices.

...recycling is for situations where source reduction is not possible.

- Substituting a product with lower concentrations of heavy metals is an example of product substitution that will minimize heavy metal contamination.
- Using a mud that inhibits swelling shales is an example of product substitution that minimizes the volume of waste.
- Making sure that products are protected from rain so that they will not be damaged is an example of changing operating practices to minimize pollution.

Upgrading solids-control equipment to improve removal efficiency is one of the most effective operating practice changes that can be made to reduce the drilling waste volumes generated. For example, if an acceptable drill-solids concentration is 5%, then every barrel of drilled solids not removed by mechanical equipment requires 19 barrels of dilution to maintain this 5% concentration. Since surface pit and hole volumes are finite, inefficient solids-control equipment results in excessive jetting of mud to reserve pits or overboard discharge.

Recycling or reuse of materials to minimize waste

The recycling option is for situations where source reduction is not possible. Reusing a liquid mud is an example of product reuse. Be aware that some recycling efforts are not legitimate and can do more harm than good. An example of "sham recycling" is spraying used oil (a toxic substance) as a weed killer. To avoid such problems, follow these basic rules:

- Use a product for its intended purpose only and at its recommended concentration.
- Avoid sham recycling.

Minimizing the quantity of disposable waste

The third waste disposal option is to minimize the quantity of disposable waste. This can be done either by changing operating practices or treating the waste. Segregating contaminated waste from uncontaminated waste is an example of a change in operating practice. Using a closed-loop, solids-control system with chemically enhanced centrifuging is a method of treatment to reduce waste volume.

Treatment

Treatment of contaminated materials is the least desirable method of pollution control. Listed below are some of the basic waste treatment control methods:

Air pollution

Particulates:
- Cyclone separators.
- Bag houses.
- Wet scrubber.

Organic materials:
- Wet scrubber.
- Process flare.

Water pollution and solid waste

Organic materials:
- Biological destruction.
- Thermal recovery.
- Thermal destruction.
- Solidification/fixation.
- Solvent extraction.
- Ultra filtration.
- Gravity separation.
- Annular injection.

Salt

- Reverse osmosis/ultrafiltration.
- Solidification/fixation.
- Annular injection.

Heavy metals

- Acid leaching.
- Solidification/fixation.
- Micro-bubble flotation.
- Annular injection.

Waste Management Options for Drilling Fluids and Cuttings

Offshore operators have three basic choices with regard to waste disposal...

Offshore options

Offshore operators have three basic choices with regard to waste disposal — discharge, haul to shore, or grind and inject. If the operator discharges the waste, then much of the previous discussion about pollution will play a role in mud system design.

Advances in minimizing the potential environmental impact of drilling fluid discharges often results in the workers having fewer exposures to potentially harmful materials.

If the operator decides to inject the waste, this must be taken into account in the very early stages of well planning in terms of tubular design and casing points. Annular injection involves grinding all solid and liquid waste into a slurry. This slurry is then pumped down the annulus, between two casing strings, into a subsurface fracture. In addition, the operator must have a contingency disposal option in the event that all the fluid cannot be injected.

If waste mud and cuttings are to be hauled to shore, the primary concerns will be the volume, storage and transportation, and the liabilities associated with different methods of handling and land disposal.

Onshore options

The primary considerations involved in disposal of muds and associated wastes used onshore are heavy metals, salt and hydrocarbon content. Most U.S. states regulate the permitting, processing and disposal of reserve pit contents with regard to these three parameters. When trying to determine the best method for disposal of such mud constituents, the operator must consider the economics, the disposal operation, the environmental impact of the final product and any residue.

Several disposal methods are approved for reserve pit cleanup.

Several disposal methods are approved for reserve pit cleanup. As long as the environmental impact is controlled, the operator has the option to choose the most cost-effective method for handling the waste. In the future, however, some common disposal methods found today probably will be restricted, and the economics therefore may not play as strong a role as they do now.

The total cost of the disposal method selected includes the operating cost, transportation, energy use, maintenance, labor and disposal of any residue formed. Also, the operator must consider potential future liability.

When dealing with the operational issues, important factors include safety, reliability and processing rate.

Finally, the operator must consider the environmental impact. If governmental regulations are satisfied for the waste generated, then the operator must test the residue formed during the process and determine the proper method for its disposal. Questions to be answered include: Does the unit create any air, water or solid waste emissions? Is the process an integral part of the operation or a separate unit? If the unit is separate, then the processed waste may be covered under separate regulations and may not be exempted for the oil and gas industry.

Discharging… into a reserve pit is the most common waste management technique used…

Discharging mud and cuttings into a reserve pit is the most common waste management technique used in the U.S. today. It is followed by dewatering of the pit and backfilling the solids. When used in conjunction with advanced drilling fluid products, this method can be the best technology for minimizing waste at the source.

However, because contaminants such as heavy metals, salts and hydrocarbons can be incorporated into the drilling fluid from underground formations, the discharge pit technique has limitations. In many areas, chemical analysis of reserve pit contents is required to confirm safe levels of potentially harmful substances such as salt or oil.

Landfarming or landspreading is a popular disposal method in many areas of the world, especially for low-solids, nondispersed mud systems that have low oil and salt content. Landfarming is a disposal method where both dilution and destruction of potentially harmful substances are employed. Native soil is mixed with mud and cuttings (dilution) and natural processes such as biodegradation reduce organics to simpler compounds (destruction). Leachability of contaminants can be addressed through dilution and/or stabilization.

The landfarming method is encouraged in some countries to help condition the soil. Several U.S. states have allowed the landfarming of oil mud cuttings. With the advent of less toxic, synthetic-base muds, this waste management technique may continue to expand. As with reserve pit closure technology, chemical analysis is often required to confirm that potentially harmful substances are at safe levels.

Annular injection has applications in certain discharge environments. While offsite disposal and reserve pits can be eliminated with the use of injection technology, concerns about groundwater contamination have restricted or even prohibited the use of this technology in some areas. Again, preplanning is critical to the success of annular injection.

Stabilization can be used as an additional onsite measure to minimize potential environmental impacts. By incorporating potentially harmful substances like heavy metals into a chemically stable matrix, the rate of toxicant leaching into the environment is reduced to safe levels. Improving the quality of materials used to stabilize the waste can enhance the effectiveness of this technology significantly.

This technology is most effective in stabilizing heavy metals, and can be applied to fluids containing modest levels of hydrocarbons and/or salt. However, high levels of salt and oil contamination can weaken the matrix of the stabilized waste and result in unacceptable levels of toxicant-leaching into the environment.

Stabilization should not be confused with solidification...

Stabilization should not be confused with solidification, a method in which dry materials are mixed with the waste stream to change its physical state without addressing the leaching of potential contaminants.

New techniques. Several new methods of disposal are being reviewed. Incineration and bacterial degradation, for example, are used with oil-base mud systems.

Incineration destroys organic material at high temperatures. However, this produces air pollution, high temperatures and pressures, and possible mechanical failures of the incinerator. High energy consumption also is a major concern.

Bacterial degradation has been used for many years. Recently, producers have begun using freeze-dried bacteria and nutrient packages to speed up the degradation of oil in pits. This method works well but is time-consuming.

Distillation and critical fluids extraction are both concerned with the recycling of oil. Oil is stripped from cuttings using solvents or heat and then returned to the active mud system. When excessive heat is used, chemical cracking can occur. If performed properly, distillation allows recovery of the oil, reducing mud system costs.

Removal of the oil from the cuttings allows a wider range of cuttings disposal options, reduces the size of the reserve pit needed (or eliminates it altogether), and reduces future liability. With distillation, however, great caution must be used, since chemical cracking can change the flash and aniline points of the returned oil.

Tighter controls and regulations can be expected in the future, and the cost of drilling fluids will increase to meet worldwide environmental and health restrictions.

Because of the increased use of less toxic mud systems, cleanup costs will be reduced. Options for disposal will increase and thus reduce closing costs. The balance between the up-front cost of the mud and the final closure cost will be a driving force in product development.

Lastly, the trend will be toward closed-loop systems and recycling of systems, which will diminish the need for reserve pits and reduce the volume of waste for disposal.

ASSOCIATED WASTES

Frequently overlooked and particularly troublesome are some of the wastes associated with drilling fluid systems. Specifically, these are residues associated with equipment/processing and wash water. This is an area in which minimizing the volume of waste generated can mitigate high disposal costs and potentially high future liability.

Wash water should be reused where possible. Any residues from mud-cleaning equipment that can be placed in the reserve pit lawfully should be placed there immediately instead of returning them to the warehouse for clean-out.

Many drums and pails can be triple-rinsed, with the wash water going into the mud system. Such cleaned, empty containers are then either returnable or potentially disposable as nonhazardous.

Bulk packaging is gaining popularity because it minimizes pollution by reducing the number of containers. It also conserves raw materials and can reduce the exposure of personnel to the product.

Environmental, Health and Safety Regulations

Environmental regulations have an impact on drilling fluid products...

North Sea countries also require routine toxicity testing...

Environmental regulations

Environmental regulations have an impact on drilling fluid products and fluid systems, either directly through restrictions or indirectly through controls such as economics. Products are tested during both development and manufacturing stages before being released to the marketplace.

Drilling fluid systems are complex and are regulated as a whole rather than by their parts. Chemical constituents are tested individually to determine environmental and health impacts. Regulations dealing with products and fluid systems are divided into offshore and onshore schemes.

(NOTE: Environmental regulations vary by country and by locale. No attempt is made here to detail these regulations, which can change rapidly. The discussion is intended only to acquaint the reader with the nature of regulations.)

Offshore regulations

Offshore regulations deal primarily with the discharge of drilling fluid and associated cuttings (and other discharges) after use. In the U.S., discharge regulations are issued by the Environmental Protection Agency (EPA). The regulations are called the National Pollutant Discharge Elimination System (NPDES).

The Effluent Limitation Guidelines, known as New Source Performance Standards (NSPS), serve as a basis for regional permits. These regulations have evolved over the years to cover many discharge issues. The primary controls for the offshore subcategory are toxicity testing, heavy metals and free oil content of the waste discharge, as well as toxic chemical prohibitions.

Toxicity testing of drilling fluids has become an important component of offshore discharge permits. The primary test now used in the U.S. is the 96-hour LC_{50} test using the Mysid shrimp, *Mysidopsis bahia* (see Figures 2, 3 and 4). The toxicity limit for offshore discharges in the U.S. was established as a technology standard based on the analysis of eight generic muds used at the time the effluent limitations were written.

Most water-base drilling fluids are only slightly toxic. However, some specialty additives used in water-base mud systems will cause the mud to fail the toxicity limit of 30,000 ppm.

Product restrictions have not been a major issue under the NPDES permit system. The NSPS requires a limit on some heavy metals in barite, a major component of drilling fluids. The primary reason for these restrictions is the potential bioavailability of heavy metals to marine animals.

North Sea countries have developed a mutually acceptable set of tests. In fact, filling toxicity requests from other countries is becoming standard business practice. These requests often are satisfied with data obtained in routine tests.

North Sea countries also require routine toxicity testing of both mud products and systems. Product evaluation includes not only toxicity testing but chemical evaluation, as well. Required tests include a biodegradability examination, which can indicate the rate of degradation through biological destruction. Another test, the n-octanol water partition coefficient test, indicates the solubility of the product in water and, thus, possible bioaccumulation. Product bans on certain metals and toxic organics are in place.

These developments in regulations will have an impact on future offshore mud systems. Newer systems will contain lower concentrations of heavy metals and less oil. They will be less toxic.

This will, in turn, change the technology used to drill wells offshore. These issues will become more prominent as drilling moves into deeper water and the option to haul cuttings and mud ashore becomes less economical.

Injection of waste mud and cuttings into underground formations is an alternative technology that competes with discharge into the marine environment.

Onshore regulations

In North America, the issue of drilling fluid waste revolves around what to do with the reserve pit. In 1980, the U.S. placed regulation of solid and hazardous waste with the EPA. Under this regulation, drilling wastes (drilling fluids and cuttings) were exempted from consideration as hazardous wastes.

...drilling wastes are regulated either by state or federal agencies...

In the U.S., drilling wastes are regulated either by state or federal agencies, depending on jurisdiction. Issues center on the permitting of reserve pits, waste disposal options, monitoring, and eliminating some disposal methods or restricting them to certain types of mud systems. Pre-drilling plans requested by some states include environmental issues. Other states require detailed maps of locations for future reference and monitoring programs.

The three primary environmental concerns associated with reserve pit contents are heavy metals, salt and oil. In addition to soil contamination, there is the possibility of contamination of surface water systems (creeks, streams, lakes and rivers) and subsurface ground water systems (aquifers).

Several states, led by Louisiana and Texas, have published parameter limitations dealing with the salt, trace metal and oil content of reserve pits. In these states, disposal and/or treatment options are limited by the results of pit content analysis. Therefore, more emphasis should be placed on preplanning of the mud system and solids control, with an eye to the environmental repercussions, such as disposal costs, at the end of the well.

Storm water runoff is a problem at warehouses, mud plants, grinding plants, etc. Pollutants that can be carried in the runoff include residues from product mixing and storage areas, automotive oil residues from parking lots, etc. Steps must be taken to ensure this pollution is minimized or treated prior to runoff.

Site clean-up and remediation of the pits and waste at drilling locations already are under tight control. They will become tighter. Land owners are no longer content to take the operator at his word. They require proof that the waste disposal method used will not affect their use of the land. The disposal of trash, empty drums and unused chemicals is controlled more closely today than in the past. In the future, chemical analysis and toxicity testing possibly will be required prior to pit closure.

In Canada, landfarming methods are favored for onshore disposal of drilling muds and cuttings. As was discussed earlier in this chapter, landfarming is the disposal of sludge onto leased or owned land and the tilling of the material into the soil. Canadian regulations control the amount of land used per volume of disposed-of waste material. Volumes are controlled based on the salt content, oil content and heavy metal loading. Evaluations are based on both toxicity testing and chemical analysis.

In Europe, most waste is transported offsite for disposal...

In Europe, most waste is transported offsite for disposal at secure treatment and landfill sites. Landfarming and onsite disposal are not common practices in most areas of Europe. In certain areas of Southeast Asia, however, the solidification of mud pits, including oil-base muds, is a popular disposal method.

Health and safety are important considerations during product development.

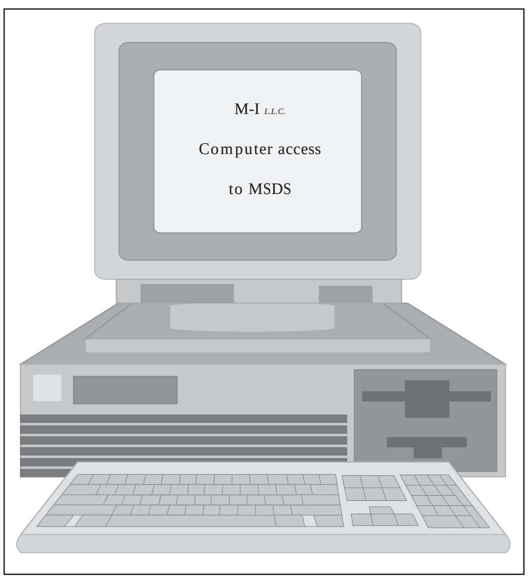
HEALTH AND SAFETY

Health and safety are important considerations during product development. Component choices based on concerns such as flash point and toxicity, among others, have helped M-I to design safer and more environmentally friendly products.

Reporting of health and safety information is regulated by government agencies. The U.S. Occupational Safety and Health Administration (OSHA) Hazard Communication Act is designed to protect workers. The Community Right-to-Know law, commonly referred to as SARA Title III, is designed to protect the community and the environment in which drilling occurs.

The Workers' Right-to-Know law (Hazard Communication Act) has three main components: The Material Safety Data Sheet (MSDS), labeling requirements and training.

- Material Safety Data Sheets contain health and safety data and safe-handling procedures. MSDS sheets must be readily available at a work site any time hazardous products are present, whether workers are present or not. MSDS for all M-I products are available on computer disks.



- OSHA requires that the name and address of the manufacturer appear on the container. OSHA also requires that hazard warning labels be visible on all packages (drums, pails, sacks, etc.) that contain hazardous chemicals. These labels must present an immediate visual warning of the potential hazards posed by the product. OSHA further requires that health effects of overexposure and other more detailed health and safety information be readily available from the manufacturer or a responsible third party. A name and address must be provided for contact in case of an emergency.
- Training workers to understand the contents of MSDS sheets is mandatory to prepare them to read and understand hazard warning labels. Training also must include sections devoted to health studies, routes of exposure and the appropriate Personal Protective Equipment (PPE). All sections of the current MSDS format must be discussed in detail, providing thorough coverage of topics such as spill response, fire response, routes of exposure, packaging and labeling.

Both the Canadian federal government and European governments have or soon will have similar workers' right-to-know programs. The U.K. has C.O.S.H.H. (Control Of Substances Hazardous to Health) to ensure worker health standards. Canada has the W.H.M.I.S. (Workplace Hazardous Materials Information System) for the same reason. In Europe, the Safe Handling Of Chemicals (SHOC) document is the equivalent of the MSDS but also contains information on environmental impact. The SHOC document has been approved for use in all North Sea drilling operations and is becoming the standard form for many international operators.

International standards of transport and labeling provided by the

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International Air Transport Association (IATA) and the International Maritime Organization (IMO) set restrictions on product shipments. Because each country may add to those restrictions (such as has been done in the U.S. through the Department of Transportation), it is important to have correct, current regulations for the country involved. Usually, this information can be found on both the MSDS and SHOC information sheets.

One method for labeling products and chemicals is the Hazardous Materials Identification System (HMIS®) used on the U.S. MSDS. As the sample label in Figure 5 shows, the system indicates the potential risk presented by a substance, using four categories — H (health hazard), F (flammability), R (reactivity) and Personal Protection. Each category's area on the label is color-coded for quick identification — H = blue, F = red, R = yellow and Personal Protection = white. Within each color-coded category is an area that qualifies the level of risk presented by, or precaution to be taken for, that category. This HMIS label is often found on laboratory reagents and chemical samples. Please study Figure 5 to familiarize yourself with the levels of qualification for each category.

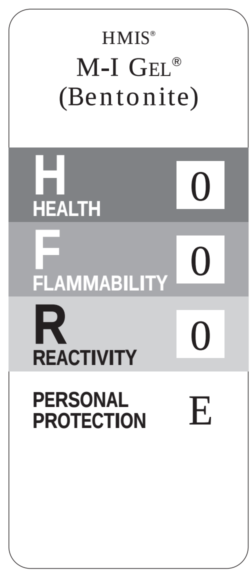
HMIS Hazard Interpretation

Hazard Index
4 Severe hazard.
3 Serious hazard.
2 Moderate hazard.
1 Slight hazard.
0 Minimal hazard.

Degree of Health Hazard
Type of possible injury
4 Life-threatening, major or permanent damage may result from single or repeated exposures.
3 Major injury likely unless prompt action is taken and medical treatment is given.
2 Temporary or minor injury may occur.
1 Irritation or minor reversible injury possible.
0 No significant risk to health.

Degree of Flammability
Susceptibility of materials to burning
4 Very flammable gases, very volatile flammable liquids, and materials that in the form of dusts or mists readily form explosive mixtures when dispersed in air.
3 Liquids ignitable under almost all normal temperature conditions, solids that burn rapidly and any materials that ignite spontaneously at normal temperatures in air.
2 Liquids which must be moderately heated before ignition will occur and solids that readily give off flammable vapors.
1 Materials that must be preheated before ignition can occur.
0 Materials that will not burn.

Degree of Reactivity
Susceptibility to release of energy
4 Materials which in themselves are readily capable of detonation or of explosive decomposition or explosive reaction at normal temperatures and pressures.
3 Materials which in themselves are capable of detonation or of explosive decomposition or of explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation.
2 Materials which in themselves are normally unstable and readily undergo violent chemical change but do not detonate.
1 Materials which in themselves are normally stable but which may become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently.
0 Materials which are normally stable even under fire exposure conditions and which are not reactive with water.



Personal Protection Index
A Safety glasses.
B Safety glasses, gloves.
C Safety glasses, gloves, synthetic apron.
D Face shield, gloves, synthetic apron.
E Safety glasses, gloves, dust respirator.
F Safety glasses, gloves, synthetic apron, dust respirator.
G Safety glasses, gloves, vapor respirator.
H Splash goggles, gloves, synthetic apron, vapor respirator.
I Safey glasses, gloves, combination dust and vapor respirator.
J Splash goggles, gloves, synthetic apron, combination dust and vapor respirator.
K Airline hood or mask, gloves, full protective suit, boots.
X Situations requiring specialized handling.

Figure 5: HMIS label and index description.

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Individual safety measures

Slips, trips and falls are the most common causes of drilling fluid-related injuries. This is particularly so when working with oil-base drilling fluids. Slippery conditions are prevalent in rig areas where oil, water or gel are spilled, splashed, etc. Gel (bentonite) is extremely slippery when wet. The rig floor, shaker area and pit areas are prime locations for accidents.

Climbing/descending stairs or ladders is extremely hazardous in such areas. One hand should be free to use handrails. Areas that constitute obvious slip hazards should be cleaned up. All slip-trip-fall hazards should be reported immediately to the appropriate supervisor at the well site. Overall good housekeeping helps eliminate slips, trips and falls.

Another potential health and safety concern is exposure of humans to products used in drilling fluids. Usually, employee exposure to such products is highest during mixing. The OSHA Permissible Exposure Level (PEL) must be considered carefully before such products are mixed. If it is likely that PELs will be exceeded, ventilation increases or other environmental modifications should be combined with use of Personal Protective Equipment (PPE) to ensure appropriate employee protection.

Employees will receive safety training in all areas relevant to their job descriptions. However, mud engineers must contend with two potentially significant exposures:

- Dust, dry materials and/or packaged liquids during mud mixing.
- Contact with liquid mud after mixing.

PPE specified on the MSDS sheet will protect employees adequately during mixing. After mixing, different concerns emerge, primarily liquid-on-skin contact and vapor-to-lung exposure. In general, the stricter PPE requirements for mixing are no longer in force when mud is "in the pits." Employees tend to relax after mixing is complete. However, this is not a wise course of action. Post-mixing exposures can be every bit as serious. Mud engineers must be aware of such hazards and protect themselves accordingly. This includes quick removal and proper handling and cleaning of contaminated clothing and PPE. Many injuries have occurred because employees wore clothing splashed with mud or mud additives for long periods in the mistaken belief there was no danger.

It is important to understand the potential hazards of muds present in the workplace and take the appropriate cautionary measures. One of the most significant measures is washing and then changing clothes after significant exposures to muds which do pose hazards. While most of the guidelines are specific to oil-base muds, they are relevant to synthetic and water-base muds as well. Current updates of all these safety procedures are available from the EHS department in Houston.

Safety training requirements

Mud engineers receive safety training in many different areas. Some training is mandatory. Other training is location, situation, work or operator specific. M-I offers some 35 different in-house safety training courses. The following is a summary of mud engineer training requirements and some other optional courses (In parentheses is the number of years the employee may work before retraining in the subject must be completed):

Training mandatory upon hire

Basic safety awareness.
Alcohol and controlled substance standard orientation.
Hazard communication (1).
Defensive driving (DDC) (3).
Exposure control plan (bloodborne pathogens plan).
M-I PPE program.

American Red Cross CPR (1).
American Red Cross First Aid (3).
Hydrogen sulfide (1).
Respiratory protection (1).
Eye/face protection (1).
Slips, trips and falls (1).

AS-NEEDED TRAINING

DOT HAZMAT training (3).
Forklift safety (1).
Fire safety (1).
Water survival (offshore survival) (1).
HAZWOPR (1).
Lockout/tagout (1).
Confined space (1).
Environmental awareness (2).
Oil spill response (2).
Chemical hygiene plan (2).
Laboratory safety.
Electrical safety (1).

Summary

Awareness about Health, Safety and Environmental (HS&E) issues is crucial. Training and compliance are mandated by governmental agencies, by operators, and by the public. HS&E planning is an integral part of the drilling plan for every well.

Regulations can and have served as a stimulus for new technology.

Regulations can and have served as a stimulus for new technology. Unfortunately, such regulations also can act as a deterrent when they appear to inhibit testing and implementation of new technologies. Thus, the manner in which regulations are drawn and the adaptability of regulators themselves in interpreting regulations are important to the development of better solutions.

M-I and Swaco are responding to HS&E challenges with better technologies. Drilling and environmental preservation are not viewed as conflicting activities. Human ingenuity has been challenged to meet both, and the challenge has been accepted. Real progress has been made, and continuous improvements are being pursued.