White Paper

Environmentally Friendly Lubricants:
Biodegradable or Nontoxic

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Over the past decade and possibly longer, biodegradation has been the predominant yardstick to measure how lubricants rate for being environmentally friendly. It was thought that the more completely a lubricant decomposes to harmless hydrogen-carbon-oxygen compounds, the better the lubricant will be for the environment. While a high degree of biodegradation can be a lubricant benefit, biodegradation alone does not provide a complete picture of how a lubricant affects the environment. Consideration should also be given to the different ways a lubricant affects the environment.

For example, consider a lubricant that will be 100 percent degraded in 28 days. Is it still environmentally friendly if it is toxic and destroys or alters a significant portion of plant or animal life during the degradation process?

First, how is a lubricant defined as being environmentally friendly? What method quantifies its success? How do those who are developing environmentally friendly lubricants know if they are truly improving or merely maintaining the status quo?

Toxicity

A measurement to consider beyond biodegradation is toxicity. Determining the toxicity of a lubricant is crucial to establishing its status as environmentally friendly. However, it has been difficult to find a test method that is simple, cost-effective and quick in evaluating lubricant toxicity. Numerous toxicity test methods have been available for years, and some of these traditional screening protocols have been used to evaluate lubricants. Some of the tests have adapted well to evaluating lubricants, others have required great modification and others do not work at all. All traditional toxicity tests seem to suffer when testing lubricants because the methods tend to be suited for aqueous samples, not lubricants that are nonaqueous.

Many toxicity tests attempt to determine the lethal dose (LD_{50}) of an animal species being tested. The LD_{50} determines the amount of exposure the studied species can tolerate with a resulting 50 percent mortality rate. The species of animal studied is virtually limitless and can range from water fleas to sea creatures to mammals.

Traditional toxicity tests require a well-equipped laboratory (usually dedicated solely to toxicity testing) and a well-trained laboratory support staff knowledgeable in the intricacies of the specific testing. Additionally, an inventory of the test species must be maintained. This is relatively easy for smaller and lower life forms of test species, but as testing evolves to larger mammals, the maintenance of the test animals becomes more difficult and costly. The traditional toxicity testing can take weeks to months to acquire data, cost thousands of dollars and still not produce high-quality data with good reproducibility.

For more than two decades, an alternative toxicity screening method has been available that when compared to traditional toxicity testing protocols offers the following benefits:

1. **Compact** – Eight to 10 feet of bench-top space and some room in the lab freezer for reagents, rather than entire laboratories and animal containment facilities
2. **Fast** – Results returned in minutes rather than days or months
3. **Economical** – A few hundred dollars compared to multiple thousands to run a test

4. **Easy to perform** – A person skilled with reasonable laboratory techniques who can operate a disposable micropipette and make serial dilutions will be an expert within days.
5. **Reliable** – Excellent repeatability and reproducibility, easy quality control checks

The alternative toxicity screening method is known as the Microtox® Rapid Toxicity Testing System. Developed in the late 1970s and commercialized by the Microbics Corporation, the ownership of the technology has gone through acquisitions and mergers since its development. Currently, it is owned by Modern Water (www.modernwater.com) in Guildford, United Kingdom.

The Microtox test uses bioluminescent bacteria as its test species. The simplicity of the test is that a measurable activity of the living luminescent bacteria is the production of light. If the bacteria's metabolism slows or the bacteria die, the quantity of light lessens or ceases. The Microtox test measures a 50 percent effective concentration (EC_{50}) rather than the traditional LD_{50}. The EC_{50} is the concentration of a sample at which a 50 percent reduction in bioluminescence occurs and it is analogous to the 50 percent inhibition concentration (IC_{50}) used in other toxicity tests.

The Microtox testing system provides the user with the tools necessary to quickly prepare the bacteria, quantify its light production, serial dilute the product to be tested, incubate, re-measure the light production, collect and analyze the data, and produce an EC_{50} value.

While the Microtox system is easy to use and cost-effective, it also has some obstacles to overcome when evaluating lubricants. Like other toxicity protocols used for evaluating lubricants, there is the aqueous/nonaqueous dilemma. The luminescent bacteria used in the Microtox protocol needs a pH-controlled saline solution (the laboratory equivalent of seawater) to be activated from a freeze-dried long-term storage state. Adding the lubricant directly to the bacteria in the saline solution does not produce useable data.

Spilled Lubricant

To work around the dilemma, a laboratory scale model of what would occur in the real world if there were an oil spill or accidental release of a lubricant into a body of water is produced. In reality, spilled lubricant will float to the water's surface and form a two-phase solution of water with an oil slick on top. Wind, sunlight, wave action and currents will stir and mix the two phases until the lubricant biodegrades, is physically removed from the water or the spilled lubricant becomes so dissipated it is no longer detectable.

Regardless of how the spilled lubricant is removed from the water, while it is present, there is potential for the water to extract toxic material from the oil into the water phase. This extraction process can be duplicated in the laboratory. Using a known quantity of the pH-controlled saline solution to act as the water phase, a known quantity of the lubricant to be tested is added to the saline solution. This two-phase solution is placed in a laboratory shaker and agitated to duplicate water currents and wave action. Upon completion of agitation, the two-phase solution is separated and the water phase is tested in the Microtox protocol. No formal procedure exists for the extraction process; however, ASTM D6081 "Practice for Aquatic Toxicity Testing of Lubricants: Sample Preparation and Results Interpretation" is an excellent reference and a good guideline to follow. Trial and error will dictate how long and how hard the solution is shaken, with the goal being a uniform and consistent extraction, making for more reproducible final data.

Limitations

Like all toxicity tests, there are limitations to the bacteria used in the Microtox test. In technical literature, it has been reported that the bacteria are less sensitive to some common contaminants (some metals and ammonia compounds) than other traditionally accepted toxicity protocols. Conversely, the bacteria are more sensitive to sulfur and sulfur compounds. Simply put, the Microtox method results do not correspond one-to-one with the results produced by the other traditional toxicity methods, however a high degree of correlation exists. This does not make the Microtox results right or wrong; it merely requires more consideration and evaluation of the results.

A distinct advantage of the utilization of bacteria as a test organism over other species is the population of bacteria utilized in a test verses other conventional species. In the Microtox protocol, up to one million bacteria are utilized per test vial, while other protocol use significantly less.

The Microtox method results are not influenced by the responses of a small number of test organisms. An additional advantage is that bacteria are about as far down the food chain as anything can get. If a test substance can be toxic to a very low form of life, how far up the food chain does it remain toxic? Also, how does the test substance ultimately affect the food chain?

The Microtox protocol has been slowly but steadily gaining acceptance as a screening tool for toxicity evaluation. Worldwide, there has been a faster and more general acceptance than in the United States. Methods and procedures that are well documented in more than 350 peer-reviewed papers have led to “standards status” in France, Germany, Netherlands, Spain, Sweden, United Kingdom and other countries. Additionally in Canada, the Energy and Utilities Board has established a method to estimate toxicity of oil well drilling sump fluids using a procedure based on the Microtox protocol.

In the United States, there is an ASTM method, ASTM D5660 “Standard Test Method of Assessing the Microbial Detoxification of Chemically Contaminated Water and Soil Using a Toxicity Test with a Luminescent Marine Bacterium.” The standard was developed in the mid-1990s, reviewed, and was published in 1996. More recently, the U.S. Environmental Protection Agency (EPA) has published a proposal to add Microtox Toxicity Test Technology to the approved methods for Whole Effluent Toxicity (WET) testing. The proposal was published in the April 6, 2004 *Federal Register* and comments on the proposal are currently being reviewed by the EPA. If the EPA proposal becomes an accepted standard, testing for National Pollutant Discharge Elimination System (NPDES) permits would be able to use the Microtox protocol.

No one screening test will provide the definitive evaluation of toxicity. There are simply too many variables affecting toxicity that are not capable of being compiled and measured by a single method of screening. However, a simple, low-cost, fast and reliable test such as the Microtox Rapid Toxicity Testing System can be an effective tool to point to where other toxicity screening protocols may be necessary. The Microtox protocol – at a minimum – will give an indication of toxicity and environmental friendliness.

About Lubrication Engineers

A leader in lubricants since 1951, Lubrication Engineers, Inc., manufactures and markets premium lubricants formulated from highly refined base oils. Enhanced with proprietary additives, LE oils and greases provide unmatched performance in nearly any application operating in normal-to-severe conditions. All Lubrication Engineers® lubricants are manufactured in an ISO 9001:2000 certified quality system at LE’s state-of-the-art plant in Wichita, Kan., and are available worldwide. With its comprehensive offering of lubricants and related reliability products, LE provides its customers with increased profitability through longer equipment life, extended service intervals, reduction in energy use, fewer repairs and less need for inventory.