NEW EPA REGULATIONS GOVERNING ENVIRONMENTALLY ACCEPTABLE LUBRICANTS

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ABSTRACT

As environmental enforcement agencies increase pressures and costs for petroleum lubricant spills, many offshore operators are using or considering environmentally safer products. These types of fluids can protect the users against fines, cleanup costs and downtime, but care must be given in selecting the right product for a specific application.

This paper will review the definitions and types of environmentally preferable products and strengths and limitations of each type. It will also review the various definitions of "biodegradable" and the maintenance practices required to prolong the life of the fluid and the equipment.

INTRODUCTION

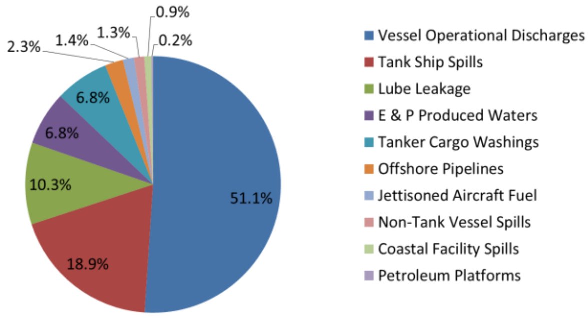
There is growing concern regarding the environmental impact and associated costs of petroleum based fluid discharges. Petroleum is persistent and toxic. It damages living organisms including plants, animals and marine life for many years. In addition, the Coast Guard, EPA and local governments are increasing the range of responsibility of lubricant releases including significant fines and cleanup costs.

The U.S. Environmental Protection Agency (EPA), under the Vessel General Permit (VGP), now requires that all vessels over 79 feet use an "Environmentally Acceptable Lubricant" (EAL) in oil to water interfaces unless technically infeasible. The 2013 VGP revision also requires any above water line hull cleaning or deck wash-downs resulting in discharge to be conducted with "minimally-toxic" and "phosphate free" cleaners and detergents as defined in Appendix A of the permit. The permit further requires cleaners and detergents to be non-caustic and biodegradable. It is expected that most vessels seeking coverage under this permit will be greater than 79 feet in length; however, commercial fishing vessels and other non-recreational vessels less than 79 feet are also eligible for permit coverage under this permit or those vessels may seek coverage under EPA's small Vessel General Permit (sVGP), as available and appropriate.

RELEASE TO THE ENVIRONMENT

A 2010 study estimated the marine inputs of lubricant from 4.6 to 28.6 million liters (1.2 – 7.6 million gallons) of lubricating oil from stern tubes. In addition, 32.3 million liters of oil is introduced to marine waters from other operational discharges and leaks. In total, operational discharges (including stern tube leakage) input 36.9 to 61 million liters (9.7 – 16.0 million gallons) of lubricating oil into marine port waters annually. Leaks of lubricating oil represent 10 percent of the total oil inputs into marine waters, as estimated in the 2003 NRC Oil in the Sea study (see Figure 1). The total annual estimated response and damage costs for these leaks and operational discharges are estimated to be about $322 million worldwide. Total estimated costs for the U.S. are estimated to be $31 million annually (Etkin, 2010).

FIGURE 1: Annual Oil Inputs into the Marine Environment



As demands on lubricant systems increase, the likelihood of accidental release of fluids increases. Increased operating temperatures, pressures and working cycles shorten the life of circuit components. The single best approach to protecting the environment, the equipment and the operation is to prevent leaks and spills through routine maintenance. A good preventative maintenance program will:

- Increase productivity since equipment is utilized more,
- Better utilize in-shop maintenance since there is less emergency work,
- Improve control of spare part inventory and reduce parts usage,
- Reduce equipment down time,
- Reduce safety hazards,
- Increase equipment life,
- Reduce fines and cleanup costs due to environmental release, and
- Reduce down time related to environmental release.

OIL SPILLS

There are increasing regulatory pressures from the EPA, Coast Guard and other environmental organizations. While small releases will not result in a Resource Conservation and Recovery Act (RCRA) clean up, large spills will. All petroleum hydraulic fluid spills are “reportable events”. These events involve a great deal of cleanup cost, administrative procedures and punitive fines that can range from tens of thousands to hundreds of thousands of dollars.

While spilling large quantities of biodegradable hydraulic fluid is still considered under RCRA to be a reportable event, agencies are required to evaluate “biobased oils” differently than petroleum based oils. As awareness of biodegradable fluid increases, state and federal agencies become more lenient regarding fines and cleanup costs. In fact, there are several case studies of equipment releasing several hundred gallons of vegetable based hydraulic fluid into environmentally sensitive areas with no fines and minimal cleanup expense. In most instances, the operator was able to continue working while cleanup efforts were underway. Since the fluids were readily biodegradable and minimally toxic, there was no long-term negative effect to the ecosystem.

There is a common misperception that the Coast Guard approves oils based on the oil not leaving a sheen (see Table 1). The Coast Guard does not approve, recommend or specify fluids. Furthermore, the Coast Guard does not approve or recommend any test procedures, but rather, follows United States statute laws. The oil sheen that is frequently referenced is inferred from the Clean Water Act as defining “any substance that leaves a sheen, emulsification, or discoloration, as a pollutant and can be subject to appropriate fines and regulations governing pollutants”. In fact, the Coast Guard also relies on the guidelines as outlined by equipment manufacturers and highly favors the use of biobased and readily biodegradable fluids.

TABLE 1: Static Sheen Test: Appendix 1 to sub-part A 40 CFR 435

	EnviroLogic® 146	***EnviroLogic® 3046***	***EnviroLogic® 215***	***Mineral Oil Based Hydraulic Fluid***
Silvery or Metallic Sheen	No	No	No	Yes
Increased Reflectivity	No	No	No	Yes
Visual Color	No	No	No	Yes
Appendix 1 to Sub-part A 40CFR435 Result	**PASS**	**PASS**	**PASS**	**FAIL**

ENVIRONMENTALLY ACCEPTABLE LUBRICANTS (EALs)

More and more owners, operators, leaseholders and regulatory agencies are recognizing the benefits of environmentally acceptable lubricant fluids. Using these lubricants can potentially save an operator thousands of dollars in terms of fines, cleanup costs and down time. The EPA defines an EAL as a “Lubricant that is biodegradable, exhibits low toxicity to aquatic organisms and has a low potential for bioaccumulation”. (EPA 800-R-11-002, Publication U.S. Environmental Protection Agency, November 2011.)

As in any emerging industry, companies are offering a variety of products that have a range of environmental benefits and performance attributes. The main four ISO Classification of EAL types are as follows:

1) Vegetable Oil Based (Hydraulic Environmental Triglyceride - HETG)
2) Polyalkylene Glycol Based (Hydraulic Environmental Polyalkylene Glycol – HEPG)
3) Synthetic Ester Based (Hydraulic Environmental Synthetic Ester – HEES)
4) PAO and Related Types (Hydraulic Environmental PAO and others – HEPR)

There are a variety of descriptors used by oil suppliers: environmentally safe, biodegradable, readily biodegradable, food grade. Table 2 below outlines the performance of different classes of lubricants.

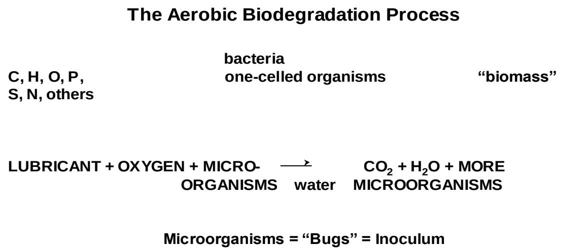
TABLE 2: Fluid Performance Characteristics

	Petroleum Based	*Synthetic Esters*	*Conventional Vegetable Oil*	*PolyAlkylene Glycols*	*EL 100 Series*	*EL 3000 Series*
Readily Biodegradable	No	Yes	Yes	Yes	Yes	Yes
Ecotoxicity	High	Low	Low	Low*	Low	Low
Bioaccumulation Potential	Yes	No	No	No	No	No
Sheen	Yes	No	No	No	No	No
Seal Compatibility	Good	Good	Good	Poor	Good	Good
Wear Performance	Good	Very Good	Very Good	Very Good	Very Good	Very Good
Oxidation Performance	Good	Good	Poor	Very Good	Good	Very Good
Low Temperature Performance	Good	Very Good	Poor	Very Good	Good	Very Good
Viscosity Index	Poor	Very Good	Very Good	Very Good	Very Good	Very Good

BIODEGRADABILITY

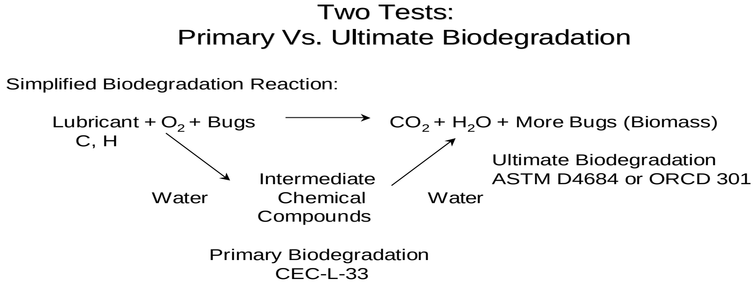
Biodegradation is the measure of chemical breakdown or transformation of a material caused by organisms or their enzymes. Biodegradation usually takes place by an aerobic biodegradation process (see Figure 2).

FIGURE 2: The Aerobic Biodegradation Process



Biodegradation follows two routes called *primary or ultimate* biodegradation. Primary biodegradation is where the breakdown of the chemical results in the loss of one or more active groups in a chemical compound that renders the compound inactive with regard to a particular function. Primary biodegradation may result in the conversion of a toxic compound into a less toxic or non-toxic compound. The second route is Ultimate biodegradation, also referred to as mineralization, whereby a chemical compound is converted to carbon dioxide, water and mineral salts (Betton, 2009).

FIGURE 3. Primary vs. Secondary Biodegradation



In addition to primary and ultimate biodegradation, biodegradation is also defined by two other operational properties: *inherent* biodegradability and *readily* biodegradability. A compound is considered *inherently* biodegradable so long as it shows evidence of biodegradation in any test for biodegradability. Inherently biodegradable oils are products or base oils that show > 20% and < 60% degradation within 28 days. Readily biodegradable is an operational definition indicating some fraction of a compound is ultimately biodegradable within a specific timeframe, as specified by a specific test method. Readily biodegradable is defined as degrading 60% or more within 28 days. This type of degradation is preferable because in most cases, the fluid will degrade long before environmental damage has occurred. Because of this, little is required in terms of long-term bio-remediation. Vegetable-based lubricants, synthetic ester-based and some PAO products exhibit ready biodegradation. There are several petroleum-based lubricants that claim “inherent biodegradability”. These are typically referred to as “Environmentally Safe”. Inherent biodegradation is defined as having the propensity to biodegrade, with no indication of timing or degree. These types of products can persist in the environment for years, continuing to cause substantial damage. They require long-term remediation due to their environmental persistence. Typically, these products are petroleum-based, like conventional lubricants.

Table 3 summarizes the different degradation characteristics of different oils. Mineral oil formulations are typically persistent or inherently biodegradable whereas most of the three classes—Polyalkylene gylcols (PAG), synthetic esters and vegetable oils—are readily biodegradable.

TABLE 3: Biodegradation Characteristics of Typical EALs

Lubricant base oil	Base oil source	Biodegradation
Mineral oil	Petroleum	Persistent / Inherently
Polyalkylene glycols (PAG)	Petroleum - synthesized hydrocarbon	Readily
Synthetic Ester	Synthesized from biological sources	Readily
Vegetable Oils	Naturally occurring vegetable oils	Readily

Source: Mudge, 2010

Biodegradation Test Methods

Primary degradation measures the reduction of Carbon and Hydrogen bonds (C-H) in the initial solution; this is the reduction of the amount of the lubricant. The most widely used test that measures this decrease is the CEC-L-33-A-93.

There are a variety of test methods used to measure readily or inherently biodegradable (see Table 4). This measures the evolution of CO_2 through biodegradation. The most common test for this is the OECD 301 or the ASTM D4684.

TABLE 4: Biodegradation Test Methods

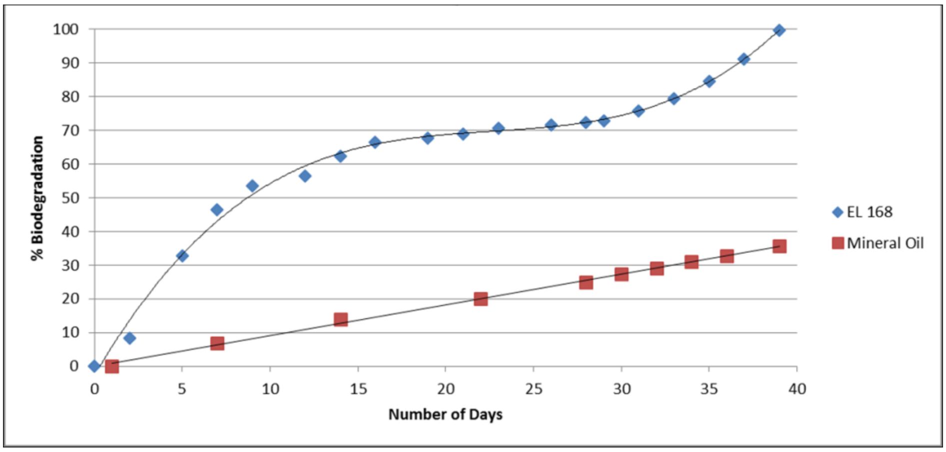
Test Type	Test Name	Measured Parameter*	Pass Level**	Method
Ready Biodegradable (A substance is considered to inherently biodegradable using any of these test if it shows > 20% biodegradability with the test duration)	DDAT	DOC	> 70%	OECD 301A
	Sturm Test	CO_2	> 60%	OECD 301B
	MITI Test	DOC	> 70%	OECD 301C
	Closed Bottle Test	BOD/COD	> 60%	OECD 301D
	MOST	DOC	> 70%	OECD 301E
	Sapromat	BOD/COD	> 60%	OECD 301F
	Sturm Test	CO_2	> 60%	ASTM D-5864
	Bio-kinetic Model	Chromatography	> 60%	ASTM D-7373
	Shake Flask Test	CO_2	> 60%	EPA 560/6-82-003
	BODIS	BOD/COD	> 60%	ISO 10708
Hydrocarbon degrability	CEC Test	Infrared Sprectrum	> 80%	CEC L-33-A-934
Screening Tests (Semi-Official)	CO_2 Headspace Test	CO_2	> 60%	ISO 14593

*DOC - dissolved organic; CO_2 - carbon dioxide; BOD - biochemical oxygen demand; COD - chemical oxygen demand

**Pass levels indicate the percentage of complete mineralization (or ultimate biodegradation) as indicated by the "Measured Parameter" that must occur for a product to be classified.

Illustrated in Figure 4 is the difference in degradation timing of a readily biodegradable product compared to an inherently biodegradable product.

FIGURE 4. Ready Biodegradation



It is easy to see the difference between a readily biodegradable vegetable based product (EnviroLogic® 168) and an inherently biodegradable mineral based product. The EPA and Coast Guard utilize this differentiation when evaluating an oil release.

ECO-TOXICITY

Another measurement to determine environmental effect of a lubricant is “eco-toxicity”. Historically, tests for eco-toxicity have concentrated on the aquatic environment with a number of standard test procedures. Most typically, the tests are for “acute toxicity”. This is a measurement of the concentration required to kill various organisms over a short period of time ranging 24-96 hours. Depending on the tests and its end points, the toxicity of a fluid is described by a loading rate that has a 50% effect (EL50) or causes 50% mortality (LL50) after the stated time. That is, at what concentration of fluid does one half of sample organisms die.

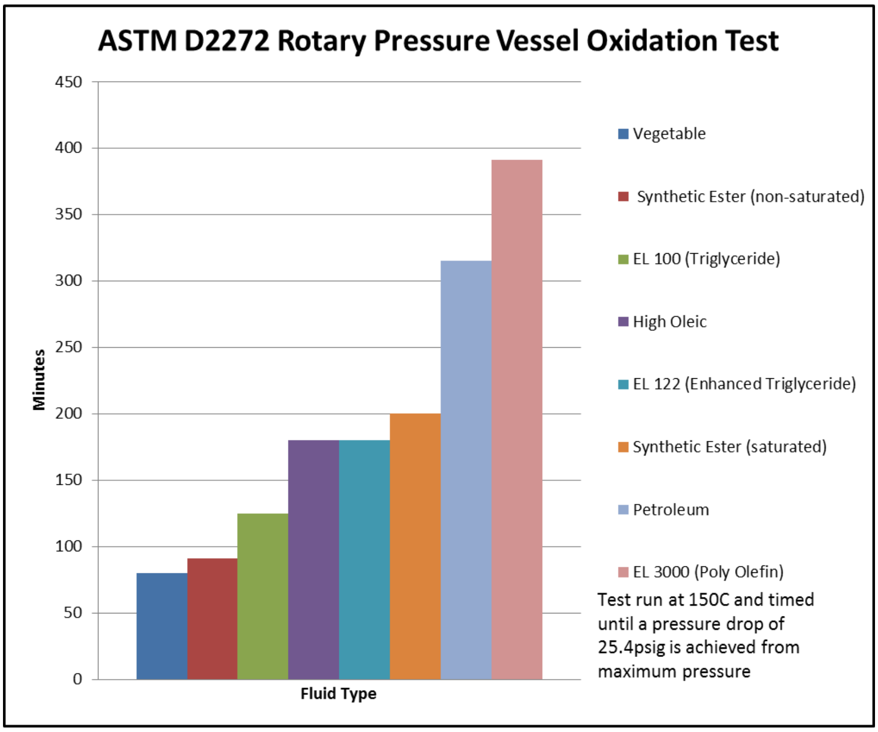
TABLE 5. OECD Aquatic Toxicity Tests

TEST NAME	OECD Test Method
Growth Inhibition Test, Algae	OECD 201
Acute Immobilization Test, *Daphnia* sp	OECD 202
Acute Toxicity Test, Fish	OECD 203
Prolonged Toxicity Test: 14-Day Study, Fish	OECD 204
Respiration Inhibition Test, Bacteria	OECD 209
Early-Life Stage Toxicity Test, Fish	OECD 210
Reproduction Test, *Daphnia magna*	OECD 211
Short-term Toxicity Test on Embryo and Sac-fry Stages	OECD 212

PERFORMANCE OF BIOFLUIDS

There are a wide variety of performance levels among readily biodegradable products. When an environmentally preferable product is required outside common temperature ranges, a readily biodegradable synthetic is usually required. While offering biodegradation, these products can operate in temperatures in excess of 400° F and offer long fluid life. Figure 5 illustrates the comparative oxidative stability of various readily biodegradable hydraulic fluids as compared to petroleum oil.

FIGURE 5. Oxidative Stability



Care must be taken in choosing the appropriate product for the specific application. EAL suppliers can clearly indicate their definition of “environmentally preferable”. The Federal Trade Commission has been very specific in their requirements for environmental claims and state “look for claims that give some substance to the claim, the additional information that explains why the product is environmentally friendly”. Many “would be” EAL suppliers use misleading environmental claims such as “inherently biodegradable” or “food grade”. Suppliers should be able to support performance claims with testing data. These data can include standard industry tests (ASTM), field-testing and equipment manufacturer tests.

PRODUCT DEMONSTRATION

Since there is no standard for environmentally preferable fluids, many different types of products claim to be environmentally safe. For the most part, they fall into four major classes of products:

1. Inherently biodegradable products are those that will break down “some day” and the time to do so is usually measured in years. The environmental safety benefit is that these products are made from either food grade oil or highly refined petroleum based fluids and contain no heavy metals in the additives. While not truly biodegradable, they can have lower levels of toxicity.
2. USDA H1 “food grade” lubricants are approved for use in food processing plants. They are designed for light duty applications where the fluid does not come in contact with food. Food batches must be discarded in the event of contact with the lubricant. Food grade oils are typically impractical for severe marine applications. Finally, they are petroleum-based and therefore environmentally persistent (inherently biodegradable or non-biodegradable) meaning they will be toxic to marine life for long periods of time.
3. Readily biodegradable products, such as vegetable based fluids break down into safe, environmentally compatible components (CO_2 and H_2O) by over 60% in 28 days or less. They are also minimally toxic, so they don’t kill marine life. They typically are designed for low operating temperatures (less that 220°F).
4. Synthetic lubricant products usually offer enhanced performance as compared to vegetable or petroleum products. Some can be readily biodegradable, minimally toxic and can withstand operating temperatures over 400°F.

HISTORY

While readily biodegradable products have a long history of successful performance in a wide range of applications, they are relatively new to the marine industry.

Historically, vegetable based fluids have not exhibited sufficient performance for offshore applications. There were several reasons for this.

1) Fluid formulations
Traditionally, a lubricant is compounded from base oil and a variety of performance chemistries. Early pioneers in the vegetable-based lubricant market used the same chemistry that was used for petroleum lubricants in vegetable based oils. It was a great idea, but it didn’t work. The characteristics of vegetable oils are vastly different than those of petroleum oils. Vegetable oil based lubricants had to be formulated for the individual strengths and limitations of their base oils. Today, there are several vegetable-based products on the market. They offer good performance and value. While all vegetable-based lubricants have temperature limitations, there are some that are better than others. One should check with his/her lubricant supplier to determine maximum and minimum operating temperatures. While most vegetable based

lubricants have a maximum operating temperature of 140°F, there are some that offer protection as high a 220°F. Similarly, most vegetable-based lubricants offer good performance to 30° F, yet there are some that flow below -30°F.

2) Fluid Choice
Even the highest performing biobased fluids have operating limitations in terms of temperature and life expectancy. Using a biobased fluid in an application over 220°F (and as low as 160°F for some fluids) will cause premature and possibly catastrophic equipment failure. There are numerous cases in which using a vegetable based fluid in the wrong application was a major contributor to the failure. Readily biodegradable synthetic fluids should be utilized in extreme, high temperature, environmentally sensitive applications.

3) Fluid Care
Traditional biobased fluids offer unique performance characteristics; however, they require special care to maximize fluid life. While water is the enemy of all lubricants, many biobased fluids are more susceptible to hydrolytic breakdown, the result of which can be acid formation. These acids can attack seals, increase wear and accelerate fluid aging. Proper filtering will prolong the life of these fluids.

DRIVING FORCES

Regulatory Leniency
While significant spills with readily biodegradable fluids are still reportable events, the resultant costs associated with the incident are usually minimized. Good industrial hygiene should be utilized to contain any spill; however, these are usually “non-events”. Since the fluids were readily biodegradable and minimally toxic, there are no long-term negative effects to the ecosystem.

Regulatory agencies including the Coast Guard, EPA and Marpol are increasingly recognizing the environmental benefits of readily biodegradable products. They are aware that in less than 30 days spilled fluid will be reduced to safe, environmentally benign components specifically, carbon dioxide and water. There is no long-term negative impact to the environment and therefore no need for punitive fines. Frequently, an operator can continue working while rectifying the situation.

Another key aspect in assessing a spill related fine is negligence. When an operator is using a readily biodegradable product, regulatory agencies know that they are taking every precaution to avoid spills in the first place and to protect the environment in the event of a spill. Readily biodegradable hydraulic fluids are an inexpensive insurance policy against negative consequences of unauthorized discharges.

Long-term remediation and monitoring is usually very expensive. Since readily biodegradable products will dissipate by 60% or more within a 28-day window, there is no long-term clean up. Moreover, some of these fluids are vegetable-based, minimally toxic and can provide a food source to the ecosystem.

As previously mentioned, the Coast Guard does not approve, recommend or specify any fluids. Furthermore, the Coast Guard does not approve or recommend any test procedures, but rather, follows United States statute laws. The oil sheen that is frequently referenced is inferred from the Clean Water Act as defining “any substance that leaves a sheen, emulsification, or discoloration, as a pollutant and can be subject to appropriate fines and regulations governing pollutants”. The Coast Guard highly favors the use of biobased and readily biodegradable fluids and in the writers’ experience, there has never been a fine levied on a vegetable oil spill.

Legislation
There is mounting pressure from the Federal Government to utilize environmentally preferable products.

The U.S. Environmental Protection Agency (EPA) under the 2013 Vessel General Permit (VGP) now requires that all vessels over 79 feet use an "Environmentally Acceptable Lubricant" (EAL) in oil to water interfaces unless technically infeasible. The VGP revision also requires any above water line hull cleaning or deck wash-downs resulting in discharge to be conducted with "minimally-toxic" and "phosphate free" cleaners and detergents as defined in Appendix A of the permit. The permit further requires cleaners and detergents to be non-caustic and biodegradable. It is expected that most vessels seeking coverage under this permit will be greater than 79 feet in length; however, commercial fishing vessels and other non-recreational vessels less than 79 feet are also eligible for permit coverage under this permit or those vessels may seek coverage under EPA's small Vessel General Permit (sVGP), as available and appropriate.

The Farm Security and Rural Investment Act of 2002, otherwise known as the "Farm Bill", signed into law in May of 2002. It requires all federal agencies to give ***procurement preference*** to biobased products. The language in Title IX, Section 9002 states, "…each Federal agency which procures any items designated in such guidelines shall, in making procurement decisions, give preference to such items composed of the highest percentage of biobased products practicable, consistent with maintaining a satisfactory level of competition, considering such guidelines". The USDA publishes a list of target biobased content by product category at www.biopreferred.gov.

A major piece of legislation is Executive Order 13101 (The Greening of the Government) signed by President Clinton in 1998. E.O. 13101 calls for Federal agencies and federally funded state agencies to purchase environmentally preferable, and specifically, biobased "products and or services that have reduced effect on human health and the environment when compared with competing products or services. The comparison may consider any or all phases of the products life cycle". It charges the head of each executive agency to "develop and implement affirmative procurement programs in accordance with section 6002 of RCRA (42 U.S.C. 6962) and this order and consider use of the procurement tools and methods".

Another Executive Order, E.O. 12852, provides for "sustainable development". In the order, sustainable development is broadly defined as "economic growth that will benefit present and future generations without detrimentally affecting the resources or biological systems of the planet".

While not specifically promoting biobased products, Public Law 104-55 "The Edible Oil Regulatory Reform Act" requires "the head of any Federal Agency to differentiate between fats, oils and greases of animal, marine or vegetable origin, and other oils and greases in issuing certain regulations and for other purposes".

The Clean Water Act of 1972 is the principal federal statute protecting navigable waters and adjoining shorelines from pollution. Since its enactment, the CWA has formed the foundation for regulations detailing specific requirements for pollution prevention and response measures. Section 311 of the CWA addresses pollution from oil and hazardous substance releases, providing EPA and the U.S. Coast Guard with the authority to establish a program for preventing, preparing for, and responding to oil spills that occur in navigable waters of the United States. EPA implements provisions of the Clean Water Act through a variety of regulations, including the National Contingency Plan and the Oil Pollution Prevention regulations.

Under the legal authority of the Clean Water Act, the Discharge of Oil regulation, more commonly known as the "sheen rule" provides the framework for determining whether an oil spill to inland and coastal waters and/or their adjoining shorelines should be reported to the federal government. In particular, the regulation requires the person in charge of a facility or vessel responsible for discharging oil that may be "**harmful to the public health or welfare**" to report the spill to the federal government. The regulation establishes the criteria for determining whether an oil spill may be harmful to public health or welfare, thereby triggering the reporting requirements, as follows:

- Discharges that cause a sheen or discoloration on the surface of a body of water;
- Discharges that violate applicable water quality standards; and
- Discharges that cause a sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines.

Discharges of petroleum lubricants meet these reporting requirements.

CONCLUSIONS

True proof of performance is found in the field. Any fluid supplier should support their customers with routine oil monitoring and interpretation of the results. Since biodegradable products behave differently than conventional petroleum products, one should not count exclusively on the conventional oil analyst's interpretation of test lab results.

It is important to partner with a biofluid supplier, with enough field and technical experience to support an oil-monitoring program and to be willing and able to support product changes.

Many factors should be considered when choosing a readily biodegradable fluid. The key considerations to be evaluated prior to selecting any fluid include:

- Operating temperature
- Operating pressure
- Seals and elastomers
- Water ingress
- Fluid life
- Preventative maintenance cycle
- Spill potential
- Client choice

Readily biodegradable lubricants can save time, money and protect the environment; however, they must be properly maintained. Since the key to long fluid life and top tier performance is keeping the fluid clean and dry, proper filtration is essential.

ABOUT THE AUTHORS

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Mark Miller is the Executive Vice President of Marine Business Development at RSC Bio Solutions since 2013 when the company he cofounded, Terresolve Technologies, was acquired by RSC Bio Solutions. Terresolve engineered, formulated and field demonstrated performance of environmentally acceptable lubricants in marine applications for over 17 years. Prior to cofounding Terresolve, Mr. Miller was Global Major Account Manager for The Lubrizol Corporation providing performance chemistry to major petroleum lubricant companies. Mr. Miller has a B.S. in Chemical Engineering from Tufts University and an M.B.A. from Manhattan College.

For more information about EnviroLogic products, field test results or environmental pedigree, please visit www.rscbio.com or call (800) 661-3558.