Technical Topic

Lubricant Aquatic Toxicity and Why It Is Important

Introduction

Despite significant advances in connector, hose, and seal technology in recent years, there is no guarantee that lubricating systems won't leak. Leaks can still result from improper assembly, misapplication, and simple wear and tear of the equipment. There now exists greater awareness for the need to reduce leakage in lubricating systems. The US Environmental Protection Agency (EPA) and other worldwide regulatory bodies have sought to reduce spills through stricter regulation, including the possibility for fines, penalties and costly remediation. Increasingly, there is awareness that lubricants coming into contact with soil, water, wetlands, and other sensitive areas can negatively impact the environment. This has both manufacturers and users of lubricating systems switching to more environmentally acceptable alternatives, such as those that are biodegradable and non-toxic. These biodegradable and non-toxic lubricants can offer performance comparable to mineral oil-based fluids in some applications. Customers have found the use of biodegradable and non-toxic lubricants to be suitable for environmentally sensitive applications in construction, mining, forestry, agriculture, hydroelectric dams, and various marine uses including dockside cargo handling, harbor dredging, off-shore drilling, stern tubes, azipods, and deck hydraulic equipment.

This document will examine one of the two main properties of an environmentally aware lubricant, aquatic toxicity. A separate tech topic will address biodegradability. Of course, a suitable environmentally aware lubricant will also provide required performance in the areas of viscosity, oxidation, wear, foaming, demulsibility, and other desired characteristics.

Defining Aquatic Toxicity

Aquatic toxicity is the adverse response(s) of water-based organisms to materials (e.g., chemicals or physical agents) ranging from mortality to physiological responses such as impaired reproduction or growth anomalies. It is related to the broader term ecotoxicity, (i.e., the propensity of a material to produce adverse behavioral, biochemical, or physiological effects in non-human organisms), and acute ecotoxicity (i.e., the propensity of a material to produce adverse behavioral, biochemical, or physiological effects in non-human organisms in a short period of time, usually not constituting a substantial portion of the life span of the organism).

Some of the most commonly used organisms for aquatic toxicity studies include rainbow trout, mysid shrimp, daphnids (water fleas), and green algae.

Examining Aquatic Toxicity

Evaluating a substance's aquatic toxicity can involve examining its effect on growth, reproduction, behavior, or lethality in test organisms. Acute Aquatic Toxicity Tests are conducted to evaluate the short-term effects of lubricant formulations or additives on aquatic organisms. Studies are conducted generally for 48 to 96 hours to assess the impact of the test material on survival or mortality. Representative aquatic species include freshwater and saltwater fish, invertebrates and algae. Initial testing is generally carried out with the more sensitive of the species, i.e., invertebrates such as daphnia, to help provide an indication of the toxicity in other aquatic life. Often, subsequent testing in other aquatic species such as other invertebrates and algae may be dependent upon product registration or regulatory requirements.

The most common end point for expressing aquatic toxicity of water soluble substances in the laboratory is the LC50, which is defined as the lethal concentration (LC) of a substance that produces death in 50% of the exposed organisms during a given period of time. The terminology LL50 (Lethal Load 50) is used instead of the standard lethal concentration (LC50) when the material is not completely soluble in water at the test treat rates, which is typically the case with vegetable oil and ester based fluids. The term LL50 is a statistically or graphically estimated loading rate of test material that is expected to be lethal to 50% of a representative subpopulation of the aquatic organisms under specified conditions for a specific time.

Measuring Aquatic Toxicity

Aquatic toxicity is not a pass/fail test per se. The loading required is set by a combination of at least one or more of the following: the regulatory organization, the end use application, and the test method. The material to be tested in a specific application is loaded and it is determined at what level it starts showing morbidity or otherwise adversely affecting the specimen(s). More often than not the lethal load is determined at 50%, but it could be specified to be other levels. Various levels of toxicity are then defined for applications. Tests are generally carried out with water accommodated fractions (WAF) or water-soluble fractions (WSF) obtained from solutions of the test material in dilution water that are prepared (or loaded) at different concentrations. On addition to water, an equilibrium will be reached between the dissolved and undissolved fractions which will be characteristic of the loading of the substance. The load rate is expressed as the weight of test material added to the volume of aqueous medium used in the preparation of WAF, WSF or mechanical dispersion, and in the interpretation of the results of the toxicity study with a poorly water-soluble lubricant or lubricant component. The WAF (or WSF) is prepared for aquatic testing by removing only the aqueous phase, preventing collection of any residual, undissolved free oil in the aqueous phase.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) includes members from the International Maritime Organization (IMO), Food and Agricultural Organization of the United Nations (FAO), United Nations Educational, Scientific and Cultural Organization – Intergovernment Oceanographic Commission (UNESCO-IOC), World Meteorological Organization (WMO), International Atomic Energy Agency (IAEA), United Nations (UN), and United Nations Environment Programme (UNEP). GESAMP has published a document, The Revised GESAMP Hazard Evaluation Procedure for Chemical Substances Carried by Ships. In these guidelines, as well as in others, in the event that 50% effects are not determined to be likely at the 1000 mg/L loading, then the term "non-toxic" may be applied. The GESAMP document further states that the appropriate test for measuring the acute aquatic toxicity to marine fish is OECD 203 (Fish, Acute Aquatic Toxicity). OECD is the Organization for Economic Cooperation and Development. This is an established and flexible guideline allowing the use of many freshwater and marine species.

Meeting Aquatic Toxicity Criteria

In order to meet ExxonMobil's Environmental Awareness aquatic toxicity criteria, the finished product must have an acute 96-hour LL50 value of greater than 1,000 ppm in rainbow trout, as measured by the OECD 203 test. Since, from extensive testing of base oils used in lubricants, it is known that these materials are all essentially non-toxic, and that problems related to aquatic toxicity are caused by the additives, in addition, the formulation must contain less than 5% additives by weight and contain no heavy metals, no chlorinated organic materials, and no US EPA priority pollutants.

ExxonMobil's environmentally aware lubricants (EAL) typically show results of a LL50 of greater than 5,000 ppm using this OECD test for all US manufactured products. Ecotoxicity data, properly developed, understood, and applied, is useful for evaluating the potential hazard of a material in the environment. For environmental toxicity tests, comparative data should be developed using the same test procedures and the same organisms. Exposures experienced in the laboratory will not be replicated in nature, but do provide a reasonable approximation. The natural environment is a large dynamic ecostructure, while the laboratory environment is static and limited in size. Further, if a contaminant enters a natural aquatic system, the event will most likely be random in concentration and frequency, unlike the laboratory environment, which depends upon constant, measured contamination.

A complete description of aquatic toxicity terms may be found in ASTM D 6046, Standard Classification of Hydraulic Fluids for Environmental Impact.

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