Chapter 8
Environmentally Acceptable Lubricants

8-1. General

Mineral-oil-based lubricating oils, greases, and hydraulic fluids are found in widespread use throughout Corps of Engineers facilities. However, these products are usually toxic and not readily biodegradable. Because of these characteristics, if these materials escape to the environment, the impacts tend to be cumulative and consequently harmful to plant, fish, and wildlife. Due to these potential hazards, the Environmental Protection Agency (EPA) and other government regulators have imposed increasingly stringent regulations on the use, containment, and disposal of these materials. For instance, the EPA requires that no visible oil sheen be evident downstream from facilities located in or close to waterways. Another regulation requires that point discharges into waterways should not exceed 10 parts per million (ppm) of mineral-based oils. Corps facilities such as hydropower plants, flood-control pumping plants, and lock-and-dam sites either are or have the potential to become polluters due to the use of mineral-oil-based materials in these facilities. Grease, hydraulic fluids, and oil leaking from equipment may be carried into the waterway. Because of the difficulty in completely eliminating spills and discharges of these mineral-oil-based materials, and to alleviate concerns about their impact on the environment, a new class of environmentally acceptable (EA) materials is becoming available and starting to find increasing use in sensitive locations. EA lubricants, as contrasted to mineral-oil-based equivalents, are nontoxic and decompose into water and carbon dioxide (CO_2). EA fluids are frequently made from renewable resources, which reduces dependency on mineral oils.

8-2. Definition of Environmentally Acceptable (EA) Lubricants

a. The lubrication industry uses a variety of terms to address "environmental" lubricants. A few of these terms, all preceded by the term "environmentally," are: "acceptable," "aware," "benign," "friendly," "harmless," "safe," "sensitive," and "suitable." Two other commonly used terms are "green fluids" and "food grade" lubricants. The term green fluid is mostly used for lubricants manufactured from vegetable oil. Food grade lubricants are rated by the U.S. Department of Agriculture (USDA) and generally are used in the food industry where incidental food contact may occur. Food grade lubricants may or may not qualify as EA lubricants. Indeed, most food grade lubricants are made of U.S.P. White Mineral Oil which is not toxic but does not meet the biodegradability criteria commonly required of EA lubricants. "Environmentally acceptable" is the most commonly used term and is used by some ASTM committees to address environmental lubricants. This manual uses the term EA.

b. At the present time there are no standards for EA lubricants or hydraulic fluids. Manufacturers and end users agree that for a lubricant to be classified as an EA type it should be biodegradable and nontoxic. This means that if a small quantity of EA fluid is inadvertently spilled into the environment, such as a waterway, it should readily break down and not cause harm to fish, plants, or wildlife.

c. U.S. standards-writing organizations are currently working to develop nationally recognized tests and procedures for demonstrating compliance with various environmental criteria such as biodegradability and toxicity. The ASTM Committee on Petroleum Products and Lubricants has formed a subcommittee, referred to as the Subcommittee on Environmental Standards for Lubricants, which is tasked with developing test methods for determining aerobic aquatic biodegradation and aquatic toxicity of lubricants. The methodology developed by this subcommittee, ASTM D 5864, for determining the aerobic aquatic biodegradation of the lubricants, was accepted for standard use by the ASTM in December 1995. The subcommittee is also developing a test method for determining the aquatic toxicity of lubricants. With approval of these standards, it is expected that these methods will be used by industry for evaluating and specifying EA fluids.

d. However, lacking formally approved U.S. test procedures, suppliers of EA lubricants frequently use established European standards to demonstrate their products' compliance with U.S. criteria. In this manual, references are made to these European standards.

e. The base fluids discussed herein may be used for preparation of hydraulic fluids, lubrication fluids, or greases. Environmental tests referred to in this manual are applicable to all three types of products.

8-3. Biodegradation

a. Definition.

(1) *Biodegradation* is defined as the chemical breakdown or transformation of a substance caused by organisms or their enzymes.

(2) *Primary biodegradation* is defined as a modification of a substance by microorganisms that causes a change in some measurable property of the substance.

(3) *Ultimate biodegradation* is the degradation achieved when a substance is totally utilized by microorganisms resulting in the production of carbon dioxide, methane, water, mineral salts, and new microbial cellular constituents.

b. Tests.

(1) ASTM test method D 5864 determines lubricant biodegradation. This test determines the rate and extent of aerobic aquatic biodegradation of lubricants when exposed to an inoculum under laboratory conditions. The inoculum may be the activated sewage-sludge from a domestic sewage-treatment plant, or it may be derived from soil or natural surface waters, or any combination of the three sources. The degree of biodegradability is measured by calculating the rate of conversion of the lubricant to CO_2. A lubricant, hydraulic fluid, or grease is classified as readily biodegradable when 60 percent or more of the test material carbon is converted to CO_2 in 28 days, as determined using this test method.

(2) The most established test methods used by the lubricant industry for evaluating the biodegradability of their products are Method CEC-L-33-A-94 developed by the Coordinating European Council (CEC); Method OECD 301B, the Modified Sturm Test, developed by the Organization for Economic Cooperation and Development (OECD); and Method EPA 560/6-82-003, number CG-2000, the Shake Flask Test, adapted by the U.S. Environmental Protection Agency (EPA). These tests also determine the rate and extent of aerobic aquatic biodegradation under laboratory conditions. The Modified Sturm Test and Shake Flask Test also calculate the rate of conversion of the lubricant to CO_2 . The CEC test measures the disappearance of the lubricant by analyzing test material at various incubation times through infrared spectroscopy. Laboratory tests have shown that the degradation rates may vary widely among the various test methods indicated above.

8-4. Toxicity

Toxicity of a substance is generally evaluated by conducting an acute toxicity test. While awaiting acceptance of the ASTM test method for determining the aquatic toxicity of lubricants, the most common test methods used by the lubricant industry for evaluating the acute toxicity of their products are EPA 560/6-82-002, Sections EG-9 and ES-6; and OECD 203. These tests determine the concentration of a substance that produces a toxic effect on a specified percentage of test organisms in 96 hours. The acute toxicity test is normally conducted using rainbow trout. Toxicity is expressed as concentration in parts per million (ppm) of the test material that results in a 50 percent mortality rate after 96 hours (LC50). A substance is generally considered acceptable if aquatic toxicity (LC50) exceeds 1000 ppm. That is, a lubricant or a hydraulic fluid is generally considered acceptable if a concentration of greater than 1000 ppm of the material in an aqueous solution is needed to achieve a 50 percent mortality rate in the test organism.

8-5. EA Base Fluids and Additives

Base fluids are mixed with additives to form the final products. These additives are necessary because they provide the resulting end product with physical and chemical characteristics such as oxidation stability, foaming, etc., required for successful application. However, most additives currently used for mineral-based oil are toxic and nonbiodegradable. Therefore, they cannot be used with EA fluids. Furthermore, since the physical and chemical properties of EA fluids are quite different than those of mineral oil, EA fluids will require entirely different additives. Several additive manufacturers are working with the lubricant industry to produce environmentally suitable additives for improving the properties of EA base fluids. Additives that are more than 80 percent biodegradable (CEC-L33-T82) are available. Sulfurized fatty materials (animal fat or vegetable oils) are used to formulate extreme pressure/antiwear additives, and succinic acid derivatives are used to produce ashless (no metal) additives for corrosion protection. Suppliers are using a variety of base fluids to formulate EA hydraulic fluids, lubricating oils, and greases. The base fluid may be the same for all three products. For example a biodegradable and nontoxic ester may be used as the base fluid for production of hydraulic fluid, lubricating oil, and grease. The most popular base fluids are vegetable oils, synthetic esters, and polyglycols.

a. Vegetable oils.

(1) Vegetable oil production reaches the billions of gallons in the United States. However, due to technical complexity and economic reasons, few are usable for formulating EA fluids. The usable vegetable oils offer excellent lubricating properties, and they are nontoxic and highly biodegradable, relatively inexpensive compared to synthetic fluids, and are made from natural renewable resources.

(2) Rapeseed oil (RO), or canola oil, appears to be the base for the most popular of the biodegradable hydraulic fluids. The first RO-based hydraulic fluids were commercially available in 1985. Laboratory tests have identified limits to the use of this oil, but extensive practical experience has yielded relatively few problems. The quality of RO has improved over time, and it has become increasingly popular, but it has problems at both high and low temperatures and tends to age rapidly. Its cost, about double that of mineral oil, still makes it more affordable than many alternative EA fluids.

(3) The benefits of RO include its plentiful supply, excellent lubricity, and high viscosity index and flash point. RO is highly biodegradable. One popular RO achieves its maximum biodegradation after only 9 days. RO possesses good extreme pressure and antiwear properties, and readily passes the Vickers 35VQ25 vane pump wear tests. It offers good corrosion protection for hydraulic systems and does not

attack seal materials, varnish, or paint. Mixing with mineral oil is acceptable and has no influence on oil performance. RO is not water soluble and is lighter than water. Escaped oil can be skimmed off the surface of water. Molecular weight is high, indicating low volatility and low evaporation loss.

(4) Concerns about RO include poor low-temperature fluidity and rapid oxidation at high temperatures. Vegetable oil lubricants, including rapeseed, castor, and sunflower oils, tend to age quickly. At high temperatures, they become dense and change composition; at low temperatures, they thicken and gel. Some RO products are not recommended for use in ambient temperatures above 32°C (90 °F) or below -6°C (21°F), but other products gel only after extended periods below -18°C (0°F) and will perform well up to 82°C (180°F). The major problem with RO is its high content of linoleic and linolenic fatty acids. These acids are characterized by two and three double bonds, respectively. A greater number of these bonds in the product results in a material more sensitive to and prone to rapid oxidation. These problems can be only partially controlled by antioxidants. Refining the base oil to reduce these acids results in increased stability. Testing indicates that vegetable oils with higher oleic content have increased oxidative stability. Genetic engineering has produced rapeseed and sunflower oils with high oleic content for applications requiring better oxidation stability.

(5) Conversion to vegetable-oil-based fluids should present few problems, as all are mixable with mineral oil. However, contamination with mineral oil should be kept to a minimum so that biodegradability will not be affected. Special filter elements are not required. Filters should be checked after 50 hours of operation, as vegetable oils tend to remove mineral-oil deposits from the system and carry these to the filters. Filter-clogging indicators should be carefully monitored, as filter-element service life may be reduced in comparison to mineral-oil operation.

b. Synthetic esters (SE).

(1) Synthetic esters have been in use longer than any other synthetic-based fluid. They were originally used as aircraft jet engine lubricants in the 1950s and still are used as the base fluid for almost all aircraft jet engine lubricants. For EA base lubricants, the most commonly used synthetic esters are polyol esters; the most commonly used polyol esters are trimethylolpropane and pentaerithritol.

(2) Synthetic esters are made from modified animal fat and vegetable oil reacted with alcohol. While there are similarities between RO and SEs, there are important differences. Esters are more thermally stable and have much higher oxidative stability.

(3) SE fluids can be regarded as one of the best biodegradable hydraulic fluids. Synthetic esters with suitable additives can also be nontoxic. They perform well as lubricants. They have excellent lubrication properties: high viscosity index and low friction characteristics. Their liquidity at low and high temperatures is excellent, as is their aging stability. Although they mix well with mineral oils, this characteristic negatively influences their biodegradability. SE fluids offer good corrosion protection and lubricity and usually can be used under the same operating conditions as mineral oils. They are applicable for extreme temperature-range operations and appear to be the best biodegradable fluids for heavy-duty or severe applications. Synthetic esters do have higher first cost and are incompatible with some paints, finishes, and some seal materials. However, it may be possible to extend oil-change intervals and partially offset the higher cost.

(4) Since SE fluids are miscible with mineral oil, conversion may be accomplished by flushing the system to reduce the residual mineral-oil content to a minimum. Special filter elements are not required.

Filters should be checked after 50 hours of operation, as vegetable oil tends to remove mineral-oil deposits from the system and carry them to the filters.

c. Polyglycols (PG).

(1) The use of polyglycols is declining due to their aquatic toxicity when mixed with lubricating additives and their incompatibility with mineral oils and seal materials.

(2) Polyglycol hydraulic fluids have been available for several decades and are widely used, particularly in the food-processing industry. They also have been used since the mid-1980s in construction machinery (primarily excavators) and a variety of stationary installations. They were the first biodegradable oils on the market.

(3) PG fluids have the greatest stability with a range from -45 to 250 °C (-49 to 482 °F). Polyglycols excel where fire hazard is a concern. Oil-change intervals are similar to those for a mineral oil: 2000 hours or once a year.

(4) PG oils are not compatible with mineral oils and may not be compatible with common coatings, linings, seals, and gasket materials. They must be stored in containers free of linings. Some PG oils do not biodegrade well. The rate and degree of biodegradation are controlled by the ratio of propylene to ethylene oxides, with polyethylene glycols being the more biodegradable. The rate and extent of biodegradability diminish with increasing molecular weight.

(5) When a hydraulic system is converted from mineral oil to PG, it is essential that the oil supplier's recommendations are followed. Normally, total system evacuation and one or two flushing procedures are required to avoid any mixing with previously used mineral oil. Mineral oil is less dense than PG fluids, so any residual mineral oil will float to the top and must be skimmed off. According to the manufacturer's recommendations, the final residual quantity of mineral oil may not exceed 1 percent of the total fluid volume. Mineral oil must not be used to replace lost PG fluid, and other contamination of PG with mineral oil must be avoided. Compatibility with varnish, seal, and filter materials also must be considered. Paper filters may need to be replaced with glass-fiber or metal-mesh filters, and these should be checked after the first 50 hours of operation. The filters will retain any residual mineral oil and may become clogged. Because of their excellent wetting properties, PG fluids tend to remove deposits left from operation with mineral oil, and these deposits are carried to the filter. Polyglycols are soluble in water, so water must be excluded from the system.

d. Water.

(1) With the prospect of increasingly stringent environmental restrictions on the use of mineral-oil-based hydraulic fluids, water may become a practical alternative. Pure water has poor lubricity and cannot function as a lubricant in the traditional sense, but water has been used as hydraulic fluid in specialty applications where leakage contamination and fire hazard are major concerns. New designs and use of highly wear-resistant materials have opened up possibilities for new water hydraulic applications. Reasons to use water include the following:

(a) Water costs a fraction of mineral oils and other EA fluids.

(b) Water disposal has little or no impact on the environment.

(c) Water is nonflammable and can be used where high temperatures and oils could create fire hazards.

(d) Water has better thermal conductivity than oil and can transfer heat better allowing smaller heat exchanger to be used.

(e) Water's incompressibility makes it ideal for accurate actuator positioning, whereas oil may be sluggish and imprecise.

(2) Water does have several performance drawbacks, however. Conventional hydraulic oil system components will not work with water, and modifying oil system components for water has had poor results. Component manufacturers are now designing parts specifically for water and are having good results. The following list describes performance drawbacks of water and solutions for overcoming them:

(a) Water has low viscosity, so leakage is a concern. Components with tighter clearances are being manufactured to compensate for this.

(b) Water has low viscosity and low film strength, which means lower lubricity and higher wear. Also, water corrodes metal parts. Stainless steel and high-strength plastic and ceramic bearings and component parts designed for high wear resistance are being developed.

(c) Water has higher vapor pressure than mineral oil which makes it more prone to cause cavitation. Pumps are being manufactured with smoother and larger flow areas and throttling valves are being redesigned with innovative flow geometries to mitigate the cavitation potential.

(d) Water freezes. Nontoxic antifreezes have been developed to lower water's "pour point."

(3) The rate and extent to which water hydraulics are adopted depends on the motivation for further technical development and EA additive development by lubricant producers. The driving factor would be legislation regarding toxic and nonbiodegradable hydraulic fluids.

8-6. Properties of Available EA Products

The ecotoxicological properties, physical properties, and relative costs of the most widely used EA fluids, as compared with conventional mineral-based oils, are shown in Table 8-1. The cost figures do not include the expenses for changing over to the EA oils, which may be substantial. PG may require total evacuation of the system plus one or two flushes. Disposal costs for EA oils may be greater than for mineral oils because recyclers will not accept them. As previously noted, laboratory tests have shown that the degradation rates may vary widely among the various biodegradation test methods. Table 8-1 indicates that the vegetable oil and synthetic-ester-based fluids, if formulated properly, are readily biodegradable. The toxicity tests show that the base stocks of most EA lubricants are nontoxic. The wide range of toxicity in Table 8-1 is caused by additives in the formulated products. The following discussion summarizes important properties of EA fluids.

a. Oxidation stability. One of the most important properties of lubricating oils and hydraulic fluids is their oxidation stability. Oils with low values of oxidation stability will oxidize rapidly in the presence of water at elevated temperatures. When oil oxidizes it will undergo a complex chemical reaction that will produce acid and sludge. Sludge may settle in critical areas of the equipment and interfere with the lubrication and cooling functions of the fluid. The oxidized oil will also corrode the equipment.

Table 8-1
Comparison of Ecotoxicological and Physical Properties of Lubricants

Properties	Conventional Mineral Oil	Polyglycol	Vegetable Oil	Synthetic Ester
% Biodegradability EPA 560/6-82-003	42 - 49	6 - 38	72 - 80	55 - 84
Toxicity[1], LC50, Trout, EPA 560/6-82-002	389 - >5000	80 - >5000	633 - >5000	>5000
Oxidation Stability[1], TOST, hours, ASTM D 943	1000 - 2000	<500	<75	<500
Lubricity[2] ASTM D 2266	Good	Good	Good	Good
Viscosity Index[2] ASTM D 2270	90 - 100	100 - 200	100 - 250	120 - 200
Foaming[2], ASTM D 892	Pass	Pass	Pass	Pass
Pour Point[2] °C (°F) ASTM D 97	-54 to -15 (-65 to 5)	-40 to 20 (-40 to 68)	-20 to 10 (-4 to 50)	-60 to 20 (-76 to 68)
Compatibility with Mineral Oil[2]	-	Not miscible	Good	Good
Relative Cost[2]	1	2 - 4	2 - 3	5 - 20

[1] Cheng et al., 1994
[2] Rhee 1996

Oxidation stability is normally measured by test method ASTM D 943. This test, which is commonly known as Turbine Oil Stability Test (TOST), is used to evaluate the oxidation stability of oils in the presence of oxygen, water, and iron-copper catalyst at an elevated temperature. As Table 8-1 shows the TOST life of mineral oil is more than 1000 hours. Synthetic esters and polyglycols are hydrolytically less stable than mineral oils at elevated temperatures, resulting in lower TOST lives. It has been shown that formulated synthetic esters with proper additives will produce high TOST values. Vegetable oils, on the other hand, have a TOST life of less than 75 hours. To improve the TOST life of vegetable oil products, more research must be done on formulating a proper mixture of base oil with a suitable additive package. Until acceptable commercial formulations are demonstrated, vegetable oils should be confined to applications involving very dry conditions and low temperatures.

b. Lubricity. Lubricity is the degree to which an oil or grease lubricates moving parts and minimizes wear. Lubricity is usually measured by test method ASTM D 2266, commonly known as the Four-Ball Method. Laboratory tests have shown that EA lubricants normally produce good wear properties.

c. Pour point. Pour point defines the temperature at which an oil solidifies. When oil solidifies, its performance is greatly compromised. Pour point is normally evaluated by test method ASTM D 97. The low-temperature fluidity of vegetable-based fluids is poor compared to other fluids listed in Table 8-1. However, the pour point of vegetable-based hydraulic fluids and lubricants may be acceptable for many applications.

d. Viscosity index. Viscosity index (VI) is a measure of the variation in the kinematic viscosity of oils as the temperature changes. The higher the viscosity index, the less the effect of temperature on its kinematic viscosity. VI is measured by test method ASTM D 2270. As Table 8-1 shows, the VI of most EA fluids meets or exceeds the VI of petroleum-based fluids.

e. Foaming. The tendency of oils to foam can be a serious problem in lubricating and hydraulic systems. The lubrication and hydraulic properties of oils are greatly impeded by excessive foaming. Foaming characteristics of oils are usually determined by test method ASTM D 892. Laboratory tests have shown that most formulated EA fluids do not have foaming problems.

f. Paint compatibility. Some common paints used in fluid systems are incompatible with many EA fluids. When it is anticipated that EA fluids may be used in a fluid system, the use of epoxy resin paints should be used to eliminate potential compatibility problems.

g. Elastomeric seal compatibility. Polyurethane seals should not be used with EA fluids. Instead, the use of Viton and Buna N (low to medium nitrile) is recommended. EA fluids are compatible with steel and copper alloys and provide excellent rust protection. The fluid manufacturer must be consulted for specific compatibility data for each material encountered in the application.

h. Degradability. Since EA fluids are biodegradable they will break down in the presence of water and bacteria. Moisture traps in breather intakes and other equipment modifications which will keep moisture out of the system should be considered. EA fluids should be periodically monitored to insure that biodegradation is not occurring.

8-7. Environmentally Acceptable Guidelines

At present there are no industry or guide specifications for EA fluids and greases. However, several manufacturers have developed biodegradable and nontoxic fluids for limited applications. In addition, several hydroelectric facilities operated by the Bureau of Reclamation and the Corps of Engineers are testing these products and are obtaining good results. Until specific standards and specifications are developed, it is recommended that the following guidance be used for qualifying the fluids to be environmentally acceptable:

a. They must be nontoxic. That is, using test method EPA 560/6-82-002, concentrations greater than 1000 ppm of the test material are necessary to kill 50 percent of the test organisms in 96 hours (LC50>1000).

b. They must be readily biodegradable. That is, using the ASTM test method D 5864, 60 percent or more of the test material carbon must be converted to CO_2 in 28 days.

8-8. Changing from Conventional to EA Lubricants

Plant owners and operators considering a change to biodegradable lubricants and hydraulic fluids should, above all, be aware that these products are not identical to conventional mineral oil products. Furthermore, the EA fluids are not necessarily equal to one another. It is important to make a thorough assessment of the requirements of the specific application to determine whether a substitution can be made, and whether any compromises in quality or performance will be compatible with the needs of the user. Switching to EA - products may require special considerations, measures, or adaptations to the system. Depending on the application and the product chosen, these could include the following:

a. Some commercially available synthetic ester and vegetable-oil-based lubricants meet the requirements of nontoxicity and biodegradability. However, the compatibility of these fluids with existing materials encountered in the application, such as paints, filters, and seals, must be considered. The fluid manufacturer must be consulted for specific compatibility data for each material of construction. The manufacturer of the existing equipment must be consulted, especially when the equipment is still under warranty.

b. Extreme care must be taken when selecting an EA oil or grease for an application. Product availability may be impacted due to the dynamic nature of developing standards and environmental requirements. EA lubricating oils should not be used in hydroelectric turbine applications, such as bearing oil, runner hub oil, or governor oil, until extensive tests are performed. It is recommended that the Corps of Engineers Hydroelectric Design Center be consulted prior to the initial purchase of any EA fluids and greases for hydropower applications (see paragraph 8-10).

c. Accelerated fluid degradation at high temperature, change of performance characteristics at low temperature, and possible new filtration requirements should be investigated carefully. The oxidation rate of vegetable-based EA lubricants increases markedly above 82 °C (179.6 °F), and lengthy exposure at the low temperature can cause some products to gel.

d. On a hydraulic power system, when changing over to EA lubricants, the system should be thoroughly drained of the mineral oil and, if possible, flushed. Flushing is mandatory if diesel engine oil was the previous hydraulic fluid. This will avoid compromising the biodegradability and low toxicity of the EA fluids. Disposal of the used fluids should be in accordance with applicable environmental regulations and procedures.

e. More frequent filter changes may be necesary.

f. Moisture scavengers may be necessary on breather intakes to keep water content in the lubricant low.

g. Temperature controls for both upper and lower extremes may need to be added to the system.

h. Redesign of hydraulic systems to include larger reservoirs may be necessary to deal with foaming problems.

i. The use of stainless steel components to protect against corrosion may be necessary.

j. The number of manufacturers who produce EA hydraulic fluids, lubricating oils, and greases continues to expand. Names of the manufacturers include some well known companies that have marketed lubricants for many years as well as a large number of smaller companies that appear to specialize in EA products. Some of these companies also market specialty EA products such as gear oils, wire rope lubricants, air tool lubricants and cutting and tapping fluids. EA turbine oils exist; however, to date, none of the oil suppliers has recommended these products for hydroelectric power plants.

8-9. Survey of Corps Users

a. A survey of all Army Corps of Engineers districts was conducted to determine how extensively alternative lubricants are being used, and with what results. A follow-up with manufacturers of some of the products revealed that many installations that reported using environmentally acceptable products actually were using food-grade lubricants made from synthetic oils or mineral oils. Neither of these base materials is readily biodegradable.

b. The use of environmentally friendly lubricants at Corps of Engineers installations still is far from widespread. Six Corps districts reported using biodegradable oils in one or more applications. The longest use to date has been about 5 years.

c. Several installations reported using rapeseed-based oils as hydraulic fluids. The products are being used in Nashville District in hydraulic power units operating at 53.06 l/min (14 gpm) and 172.4 bar (2500 psi), in lock gate operating machinery in Huntington District and in pressure-activated pitch controls in a pumping plant in Little Rock District. The Wilmington District has converted almost all of the hydraulics in waterfront and floating plant applications to rapeseed oil products, and the Alaska District reports using rapeseed oils in excavators, cranes, and dredges.

d. Nashville District also reported using rapeseed-based lubricants in gate and valve machinery, while Rock Island District uses them to lubricate gate lift chains. Other districts reported having specified EA - oils for specific applications, but have not yet put the new equipment in operation.

e. Operators of installations using the EA products generally are satisfied with their performance and are considering expanding their use. Some operators who installed heaters or coolers to accommodate fluids with limited temperature ranges report increased equipment life because the moderate temperatures reduce stress on the pumps. Although the same environmental regulations apply to reporting and cleanup of all spills, an environmental agency's response to a spill sometimes does take the “environmentally acceptable” nature of the fluid into account. One user observed that a spill in quiet water gelled on the surface “like chicken fat,” making cleanup easy. Finally, most operators report that installation of rapeseed-based oil in a mineral-oil system is as easy as any other complete oil change.

f. Overall, the most positive reports on EA fluids were applications in closed hydraulic systems. In systems open to the environment, degradation and temperature sensitivity cause problems. Exposure to water also can spur biodegradation of the lubricant while in service, a problem of particular significance in hydropower applications. The only two failures of the fluids reported in the Corps of Engineers survey were cases of contamination that caused the fluids to biodegrade while in use.

8-10. USACE Contacts

a. Additional information on hydropower applications can be obtained from the Hydroelectric Design Center, CENPP-HDC, at P.O. Box 2870, Portland, OR 97208.

b. Information on the survey, other EA applications, and associated new lubricants and technologies can be obtained from the U.S. Army Construction Engineering Research Laboratories, CECER-FL-M, P. 0. Box 9005, Champaign, IL 61826-9005.