Toxicological Synopsis for Mineral-based Transformer Oils (CAS#64742-53-6)

(November, 2004)

Technical Evaluation

Mineral oils, specifically those defined as "hydrotreated light naphthenic petroleum distillates" and assigned Chemical Abstract Service Number (CAS#) 64742-53-6 (also known as transformer oil or mineral oil dielectric fluid (MODEF)) commonly are used as lubricants and heat transfer agents in transformer applications. A mineral oil of this CAS # complies with ASTM specifications for mineral insulating oil used in electrical apparatus (ASTM, 2001). As a result of widespread transformer applications, there are potential environmental issues related to the release of these transformer oils to soils following damage to, or a malfunction of, in-service equipment. This synopsis reviews relevant toxicological information for this class of mineral oils, as distinguished by CAS # 64742-53-6 including a Texaco Material Safety Data Sheet (MSDS; Texaco, 1999) on transformer oils, prepared by Equilon Enterprises and dated 01/04/99, as well as additional references from the toxicological literature. The Texaco MSDS, which was essentially unchanged from the 1993 version (Texaco, 1993), concluded that the transformer oil was "practically non-toxic" for oral and dermal exposures, was "slightly irritating" following dermal application, and exhibited "no appreciable effect" following application to the eyes. Similar MSDS documents from other petroleum manufacturers draw essentially equivalent conclusions regarding this product (e.g., Chevron MSDS for Texaco Transformer Oils, no date).

When evaluating the toxicological profile of mineral transformer oils, it is useful to consider why this product should be viewed differently from other petroleum distillates, and why it should be considered in a separate category. As a practical

matter, the literature is clouded by use of the term "mineral oil" in a way that includes products ranging from used vehicle lubricating oils to industrial cutting oils (NTP, 2002). In contrast, the transformer oil used by most electric utility companies is required to conform to carefully articulated ASTM specifications that are in place to ensure the oil's stability to oxidation, good electrical insulating properties, and ability to maintain low-temperature fluidity (ASTM, 2001).

The refining process for transformer oils typically includes hydrogenation of the distillate under pressure and in the presence of a catalyst, followed by steam stripping, and may include final treatment with Fuller's earth. Recent alternative treatment methods use a combination process with an initial solvent extraction to remove aromatics, resins and sulfur compounds, that is then followed by hydrogenation. This specifically removes undesirable constituents including nitrogen and oxygen compounds, most sulfur compounds, tars and unsaturated hydrocarbons, as well as solid hydrocarbons, particularly amorphous and crystalline waxes. The product resulting from these specifications is a highly refined mineral oil with properties and toxicity potential that distinguish it from other petroleum distillates. The high level of refining may account for the U.S. Food and Drug Administration (FDA) approval of mineral oil for certain common medicinal purposes, such as laxatives and as a delivery vehicle for application of drugs to nasal mucous membranes (HSDB, 2004), and for "contact uses" as food additives (Klaassen, 2001). As a point of interest, it has been estimated that an average person in a developed country ingests approximately 50 grams per year of mineral oil from food products (Heimbach et al., 2002).

Three studies published prior to 1993 that were not referenced in the Texaco MSDS contain important relevant information. Evans et al. (1989) tested mineral oil used in a large manufacturing facility. Samples taken at yearly intervals over five years

were independently tested for skin irritation in New Zealand rabbits, sensitizing potential in guinea pigs, and carcinogenic potential in the mouse. No evidence of skin irritancy, sensitizing potential or carcinogenicity was observed in any of the samples.

Leighton (1990) tested the effects of ingestion of up to 16 ml/kg per day of several types of petroleum oils, including mineral oil, on laboratory mice. Liver enlargement was pronounced in the test animals, along with atrophy of thymus and spleen, following ingestion of all petroleum oils except mineral oil. No adverse effects were reported for mineral oil except for a small reduction in thymus weight. The authors concluded that the thymus reduction was a non-specific response to stress imposed by the forced ingestion of the treatment oils. Neither of these references would result in a conclusion different from that presented in the Texaco MSDS documents.

A topical 90-day study conducted by the National Toxicology Program (NTP, 1992), exposed male and female F344/N rats and C3H mice to "Mineral Oil, USP." The NTP concluded that the only treatment-related dermal effect was cutaneous irritation in the mouse. An increase in liver and kidney weights was observed in the male and female F344/N rats and liver weights were increased in both sexes of C3H mice treated topically with mineral oil. These effects were not reported consistently in other published studies.

Several relevant studies have been published subsequent to the development of the original toxicological information section of the 1993 MSDS on Texaco transformer oils. Using C3H mice in a 2-year study, Freeman et al. (1993) investigated the influence of chronic skin irritation on the tumorigenic potential of several middle distillate petroleum products with and without use of a highly refined mineral oil as a diluent and control. A few of the animals (e.g., 2 to 22%) that were treated with mineral oil

evidenced some skin irritation (e.g., rated "minimal to moderate"); however, none of the mineral oil treated mice developed tumors or any other reported effects in what was essentially a lifetime duration study.

Nash et al. (1996), published a toxicological review regarding topical exposure to white mineral oils, that were described by those authors as "highly refined", being produced by processes similar to those defined earlier as hydrotreatment and hydrogenation in the formation of transformer oils. Those processes are designed to remove the PAH components that have been implicated in toxic effects of other types of mineral oils. Those authors concluded that "there is no evidence of any hazard identified for topical exposure to white mineral oils at any dose in multiple species." They pointed out that oral studies of white mineral oils in rats have suggested toxicity (Firriolo et al., 1995), including microgranulomata in the liver and histiocytosis in the mesenteric lymph nodes. No tumors were noted in the latter study. It should be noted that the material tested in that latter study was a paraffinic, hydrotreated mineral oil, not a naphthenic, hydrotreated mineral oil. Two other oral studies in F344 rats cited by Nash et al. (1996), that implicate mineral oils in toxic responses, have shown a much less significant effect for the white mineral oil (transformer-oil-like) product as opposed to a different mineral oil product (Baldwin et al., 1992; BIBRA, 1992). Of equal importance is the fact that, in contrast to the F344 rats, adverse effects were not observed in dogs or in two other strains of rats (Nash et al., 1996). The strain-specific nature of the effect lessens its importance.

Smith et al. (1995) studied the effects of four different highly refined mineral oils on Long-Evans rats and beagle dogs. The oils were administered at levels ranging from 300 to 1500 parts per million (ppm) in the diet for 90 days. No adverse treatment-related effects were reported from any of the mineral oils tested on mortality rate,

physical appearance, behavior, organ weights or histopathology of tissues in the rats. In dogs, other than a slight laxative effect, no adverse effects were observed in the analyses of body weights, hematology, clinical chemistry, red/white blood cell counts and histopathology of the tissues. The authors concluded that "repeated exposure to relatively high levels of white mineral oil in the diets does not produce significant subchronic toxicity" in dogs or rats.

Chronic dermal studies in mice, performed by Broddle et al. (1996) with various petroleum streams, included hydrotreated light naphthenic petroleum distillate (CAS No. 64742-53-6). These authors reported that this hydrotreated light naphthenic distillate caused low levels of alopecia (hair loss), erythema (inflammatory reddening of the skin) and scabbing after approximately one year of repetitive exposure, and was a "dermal carcinogen of low potency." The number of mice with tumors (e.g., incidence was 15% with a mean latency of 94 weeks) was relatively low, but statistically significant when compared to the sham-treated controls. The authors attributed the carcinogenic potential to the presence of polynuclear aromatic hydrocarbons (PNAs) in the product. Hydrotreatment is intended to reduce or eliminate unsaturation and aromaticity of PNAs and to cleave heterocyclic compounds with consequent reduction or elimination of carcinogenicity. However, the authors state that the degree of hydrotreatment of the stream used in this study was undetermined. Therefore, it is possible that the carcinogenicity was a result of inadequate hydrotreatment of the stream which would otherwise have eliminated the PNAs.

More recently, NTP listed mineral oils (untreated and mildly treated) in the category of "known human carcinogens" in the 10th Report on Carcinogens (NTP, 2002). The determination was based on the occurrence of squamous cell carcinoma of the skin and scrotum, sinonasal cancers, and possibly lung cancer among workers in a

variety of occupations. Experimental studies with these mineral oils in animals have shown variable results (NTP, 2002). While this NTP classification shouldn't be ignored, there are two reasons why it doesn't apply strictly to the case of transformer oils in soil. First, the NTP classification [and the IARC (1984) and IARC (1987) which it cites in support] addresses primarily occupational circumstances where inhalation, ingestion and dermal exposure to mineral oil mists and concentrated liquids were the medium of direct exposure. That circumstance is quite different from the conditions encountered with soils that may be impacted by what typically are small volume releases from transformer equipment. Second, the term "mineral oils" in that document is used to describe a much broader category of oils, many of which are much less refined than the highly refined naphthenic transformer oils.

Although most mineral oils are generally considered nontoxic, it should be noted that some authors have demonstrated immune system effects from mineral oil components (e.g., pristane; Shaheen et al., 1999). Such demonstrations of immunotoxicity from hydrotreated, light naphthenic mineral transformer oils are lacking. The specific mineral oil identified as Bayol F (also known as Incomplete Freund's Adjuvant), and certain mineral oil components (e.g., squalene and η-hexadecane), have been reported to induce lupus-related autoantibodies in nonautoimmune mice (Kuroda et al., 2004). All hydrocarbons tested in that study, including medicinal mineral oils, induced hypergammaglobulinemia, as well as autoantibodies. The data of these authors suggest that the induction of autoantibodies correlated with the amount of C15 - C25 hydrocarbons present in an oil. The significance of these findings for pathogenesis of human disease is unclear, and the authors correctly note that hydrocarbon exposure via the intraperitoneal route may be

different from other routes of exposure, and thus may pose less risk (Kuroda et al., 2004).

Another condition that reportedly was associated with mineral oil exposure is exogenous lipoid pneumonia. This pneumonia is an uncommon condition resulting from aspirating or inhaling fatlike material, such as mineral oil found in laxatives and various aerosolized industrial materials. Acute toxicity of this type can occur, but the disease is usually slow to develop (Spickard and Hirschmann, 1994). While there may be some occupational application for that information, the significance to environmental exposures (e.g., soil) is negligible.

Peristianis (1989) reported on an unconventional assay for possible carcinogenic activity of mineral oils, termed the short-term "sebaceous gland suppression" (SGS) test. The cutaneous carcinogenic activity of mineral oils reportedly could be estimated effectively by the SGS test. However, the test has not been routinely reported in the literature as a validated methodology in the 15 years since this paper was published. Thus, its applicability and predictive relevance are not clear.

Summary and Conclusions

As judged from the body of available toxicological data from standard tests, the hydrotreated, light naphthenic mineral oils, such as those typically used in utility transformer applications, exhibit a negligible degree of toxic potential. The only reproducible effect appears to be slight irritation following repetitive dermal application. The existing classification of "mineral oils" as carcinogens by NTP and IARC appears to be based upon inhalation, ingestion and dermal exposure under occupational scenarios to mists and liquids of a wide variety of refined and unrefined oil products, and is not directly applicable to the subset of mineral oils represented by

the electric utility transformer oils. U.S. EPA does not presently classify "mineral oils" as carcinogens.

References Cited

ASTM. 2001. D3487-00. Standard Specification for Mineral Insulating Oil Used in Electric Apparatus. Approved November 10, 2000. Published January 2001.

Baldwin, M.K. et al. 1992. Feeding studies in rats with mineral hydrocarbon food grade white oils. Toxicol. Pathol. 20:426-435; as cited in Nash et al., 1996.

BIBRA. 1992. A 90-day feeding study in the rat with six different white mineral oils (N15(H), N70(H), N70(H), P15(H), N10(A), and P100(H), three different mineral waxes (a low melting point wax, a high melting point wax and a high sulfur wax) and coconut oil. Project no. 3.1010, BIBRA Toxicology International. Carshalton, Surrey; as cited in Nash et al., 1996.

Broddle, W.D. et al. 1996. Chronic dermal studies of petroleum streams in mice. Fund. Appl. Toxicol. 30:47-54.

Chevron. No date given. Material Safety Data Sheet. TEXACO Transformer Oils.

Evans, M.J. et al. 1989. The chemical, physical and biological properties of a neat cutting oil during prolonged use in a large manufacturing facility. Ann. Occup. Hyg. 33(4):537-553.

Firriolo, J.M. et al. 1995. Comparative 90-day feeding study with low viscosity white mineral oil in Fischer-344 and Sprague-Dawley derived CRL:CD rats. Toxicol. Pathol. 23:26-33; as cited in Nash et al., 1996.

Freeman, J.J. et al. 1993. Evaluation of the contribution of chronic skin irritation and selected compositional parameters to the tumorigenicity of petroleum middle distillates in mouse skin. Toxicol. 81:103-112.

Heimbach, J.T. et al. 2002. Dietary exposures to mineral hydrocarbons from food-use applications in the United States. Food Chem. Toxicol. 40:555-571; as cited in Kuroda et al., 2004.

HSDB (Hazardous Substance Database). 2004. On-line chemical database.

IARC (International Agency for Research on Cancer). 1984. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Polynuclear Aromatic Compounds. Part 2. Carbon Blacks, Mineral Oils, and Some Nitroarenes. Vol. 33. 245 pp. Lyon, France.

IARC (International Agency for Research on Cancer). 1987. IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Overall Evaluations of Carcinogenicity. Supplement 7. 440 pp. Lyon, France.

Klaassen, C.D. 2001. Casarett and Doull's Toxicology. The Basic Science of Poisons, Sixth Edition. McGraw-Hill. New York, NY.

Kuroda, Y. et al. 2004. Distinctive patterns of autoimmune response induced by different types of mineral oil. Toxicol. Sci. 78:222-228.

Leighton, F.A. 1990. The systemic toxicity of Prudhoe Bay Crude and other petroleum oils to CD-1 mice. Arch. Environ. Contam. Toxicol. 19:257-262.

Nash, J.F. et al. 1996. A toxicological review of topical exposure to white mineral oils. Food Chem. Toxicol. 34(2):213-225.

NTP (National Toxicology Program). 1992. NTP Technical Report on Toxicity Studies of Black Newsprint Inks Administered Topically to F344/N Rats and C3H Mice. NIH Publication 92-3340; as cited in Nash et al., 1996.

NTP (National Toxicology Program). 2002. 10th Report on Carcinogens. U.S. Department of Health and Human Services. Public Health Service. National Toxicology Program. December, 2002.

Peristianis, G.C. 1989. Sebaceous gland suppression as a short-term test of the cutaneous carcinogenic activity of mineral oils. J. Appl. Toxicol. 9(4):245-254.

Shaheen, V.M. et al. 1999. Immunopathogenesis of environmentally induced lupus in mice. Environ. Health Perspect. 107(Suppl. 5):723-727.

Smith, J.H. et al. 1995. Subchronic feeding study of four white mineral oils in dogs and rats. Drug Chem. Toxicol. 18:83-103.

Spickard III, A. and J.V. Hirschmann. 1994. Exogenous lipoid pneumonia. Arch. Intern. Med. 154:686-692.

Texaco. 1993. Material Safety Data Sheet. Equilon MSDS: 01515ET. Transformer Oil Inhibited.

Texaco, 1999. Material Safety Data Sheet. Equilon MSDS: 01515ET. Transformer Oil Inhibited. Updated 01/04/99.