

**Materials Characterization Paper**  
*In Support of the*  
**Advanced Notice of Proposed Rulemaking –**  
**Identification of Nonhazardous Materials That Are Solid Waste**

**Used Oil**

*December 16, 2008*

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**1. *Definition of Used Oil***

EPA defines used oil as any oil that has been refined from crude oil, or any synthetic oil, that has been used and as a result of such use is contaminated by physical or chemical impurities.<sup>1</sup>

EPA's criteria for used oil:

- **Origin:** Used oil must have been refined from crude oil or made from synthetic materials (i.e., derived from coal, shale, or polymers). Examples of crude-oil derived oils and synthetic oils are motor oil, mineral oil, laminating surface agents, and metal working oils. Thus, animal and vegetable oils are not included. Bottom clean-out from virgin fuel oil storage tanks or virgin oil recovered from a spill, as well as products solely used as cleaning agents or for their solvent properties, and certain petroleum-derived products such as antifreeze and kerosene are also not included.
- **Use:** The oil must have been used as a lubricant, coolant, heat (non-contact) transfer fluid, hydraulic fluid, heat transfer fluid or for a similar use. Lubricants include, but are not limited to, used motor oil, metal working lubricants, and emulsions. An example of a hydraulic fluid is transmission fluid. Heat transfer fluids can be materials such as coolants, heating media, refrigeration oils, and electrical insulation oils. Authorized states or regions determine what is considered a "similar use" on a site-specific basis according to whether the material is used and managed in a manner consistent with Part 279 (e.g., used as a buoyant).
- **Contaminants:** The used oil must be contaminated by physical (e.g., high water content, metal shavings, or dirt) or chemical (e.g., lead, halogens, solvents or other hazardous constituents) impurities as a result of use.

**2. *Annual Quantities of Used Oil Generated and Used***

**(1) Sectors that Generate Used Oil:**

- According to EPA, generators of used oil include "businesses that handle used oil through commercial or industrial operations or from the maintenance of vehicles and equipment." Examples include.<sup>2</sup>

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<sup>1</sup> See 40 CRF 279.1 for the specific definition.

- Automotive repair shops
  - Vehicle service stations
  - Fleets
  - Grocery stores
  - Metal working industries
  - Energy industry
  - Boat marinas (EPA 2008b)
- Exhibit 1 lists the NAICS codes of the major sectors that generate used oil.

***Exhibit 1: NAICS Codes for Used Oil Generators***

NAICS	NAICS Title
111 <sup>1</sup>	Crop production
221 <sup>2</sup>	Electric services
221 <sup>2</sup>	Electric and other services combined
324 <sup>2</sup>	Petroleum and coal products
332, 333 <sup>2</sup>	Special industry machinery
333 <sup>1</sup>	Metal working industries
333, 336 <sup>2</sup>	Construction machinery and equipment
421 <sup>2</sup>	Scrap and waste materials
445 <sup>1</sup>	Grocery stores
484, 488, 492, 493, 562 <sup>2</sup>	Motor freight transportation and warehousing
713 <sup>1</sup>	Boat marinas
811 <sup>1</sup>	Automotive repair shops
811 <sup>1</sup>	Fleets
811 <sup>1</sup>	Vehicle service stations
814 <sup>1</sup>	Private households
562 <sup>1</sup>	Waste Management and Remediation Services
<b>Sources:</b>	
1. Description of sectors from EPA 2008b; NAICS identified from U.S. Census Bureau 2007.	
2. EPA 2005b.	

**(2) Quantities of Used Oil Generated:**

Exhibit 2 summarizes the annual generation and management of used oil. As indicated in the exhibit, an estimated 70 percent of used oil is either used as a fuel (i.e., burned for energy recovery) or re-refined into lubricating oil. However, depending upon the year, estimates indicate that as much as 90 percent of all collected used oil is burned for energy recovery, leaving 10 percent or less to be re-refined into lubricating oil (Svizzero 2008).

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<sup>2</sup> EPA's regulatory definition of used oil generators does not include 1) farmers who produce less than an average of 25 gallons of used oil per month and 2) individuals who generate used oil through the maintenance of their personal vehicles and equipment. Although EPA's regulatory definition does not include these groups, the data included in this document reflect used oil generated by all entities that generate this material.

**(3) Trends in Generation:**

The data sources consulted for this document do not include information on the trend in the generation of used oil. A 2006 report from the Department of Energy indicates, however, that the volume of oil changed by consumers themselves (e.g., households and owners/operators of commercial vehicles) declined from 60 percent of total oil changes in 1997 to 45 percent in 2005 (DOE 2006, p. 5-2). This shift in practice may have helped increase the recycling rate for used oil. During the 1997-2005 period, the recycling rate for used oil generated by service stations increased from 66 percent in 1997 to almost 100 percent (DOE 2006, p. 5-2).

**Exhibit 2: Overview of Annual Generation and Use**

<b>Commodity</b>	<b>Annual Quantity Generated</b>	<b>Annual Quantity Used as Fuel</b>	<b>Annual Quantity Disposed of in Landfills or Improper Locations</b>	<b>Annual Quantity Re-refined</b>	<b>Total Quantity Stockpiled</b>
Used Oil	1.35 billion gallons	784.4 million gallons	200 million gallons	160.7 million gallons	unknown
<b>Sources:</b> Unless otherwise noted, data are from the Utah Department of Environmental Quality 2008a and 2008b and United States Department of Energy 2006, p.1-4. These sources include annual generation and management estimates, but do not specify the year.					

**3. Uses of Used Oil****(1) Combustion Uses:**

- Use as feedstock at petroleum refinery
- Use as an alternative fuel (EPA 2008b)

For the purposes of regulating used oil burned for energy recovery, EPA makes a distinction between on-spec used oil and off-spec used oil based upon a finding that only certain contaminants in used oil pose a significant threat to human health or the environment. As a result, EPA has established maximum concentration limits for these constituents of concern, as summarized in Exhibit 3.<sup>3</sup> If the used oil is shown not to exceed any allowable level, it is on-spec and can be burned in any combustion device. Otherwise, it is considered off-specification.

National information on the distribution between on-spec and off-spec used oil was not readily available, but we were able to identify this information for used oil generated in Florida. In 2005, an estimated 110,308,107 gallons of used oil and oily

<sup>3</sup> The limits are set such that the emissions resulting from the burning of used oil containing these contaminants, at or below established “on-spec” limits, will pose no more threat to human health or the environment than the emissions resulting from the burning of virgin oil or diesel (68 FR 44662, July 30, 2003).

waste were managed in Florida. Of this, 56,569,512 gallons (51.3 percent) were recycled as follows:

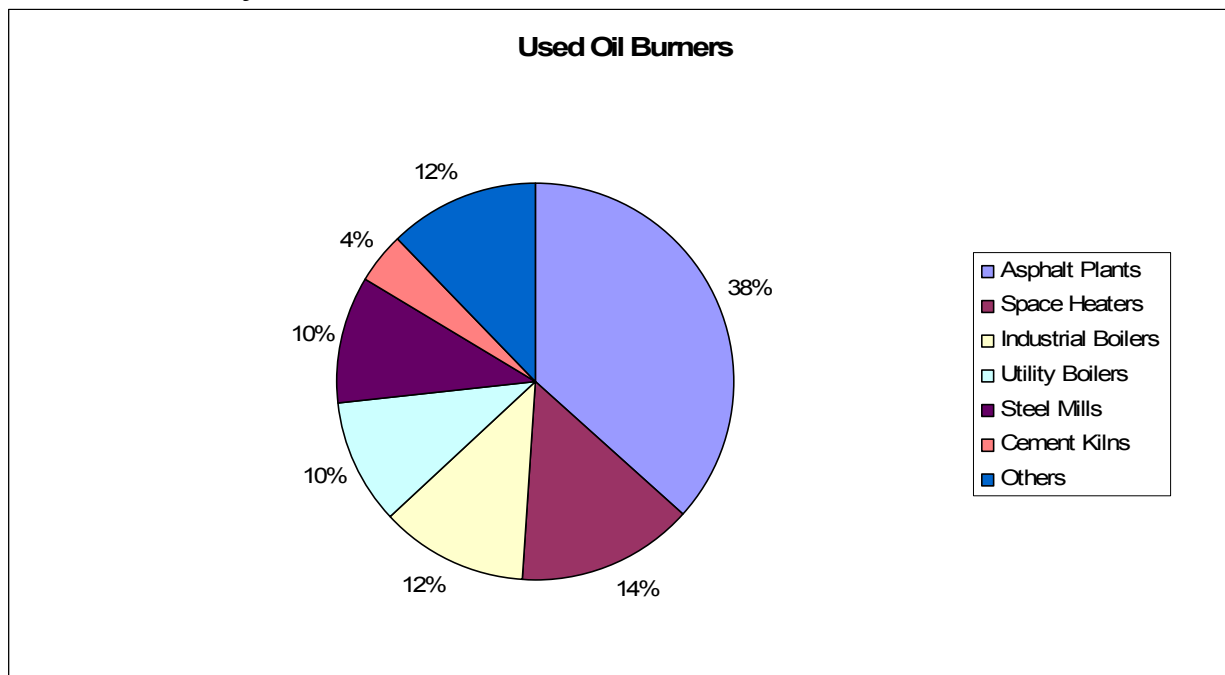
41,386,124 gallons (73.2 percent) were marketed as an on-spec used oil fuel  
 1,775,815 gallons (3.1 percent) were burned as an off-spec used oil fuel  
 13,407,573 gallons (23.7 percent) were marketed for other industrial uses (e.g. phosphate beneficiation) (FL DEP 2006)

Based on the above, we would assume that approximately 73 percent of the used oil generated and used each year is on-spec.

**Exhibit 3: Criteria for On-Specification Used Oil**

Property	Allowable Level
Arsenic	5 ppm maximum
Cadmium	2 ppm maximum
Chromium	10 ppm maximum
Lead	100 ppm maximum
Total Halogens	4,000 ppm maximum <sup>1</sup>
Flashpoint	100° F minimum
<p><b>Source:</b> EPA 2001</p> <p><b>Notes:</b> 1. Used oil containing more than 1,000 ppm total halogens is presumed to be a hazardous waste under the rebuttable presumption provided under §279.10(b)(1). Such used oil is subject to subpart H of part 266 rather than part 279 when burned for energy recovery unless the presumption of mixing can be successfully rebutted.</p>	

As shown in Exhibit 4, asphalt plants are the largest users of used oil as fuel, followed by space heaters and industrial boilers. It is likely that asphalt plants use on-spec used oil adhering to the criteria noted in Exhibit 3 above.

**Exhibit 4: Users of Used Oil**

(DOE 2006, p. 5-2)

- (2) **Non-Combustion Used Oil Uses:** Used oil may be re-used if it is processed or regenerated (EPA 2008b).
- (3) **Quantities of Used Oil Landfilled:** Approximately 200 millions gallons of used oil are landfilled or improperly disposed annually (Utah Department of Environmental Quality 2008a).<sup>4</sup>
- (4) **Quantities of Used Oil Stockpiled/stored:** Readily available data sources on used oil do not suggest that this material is stockpiled or stored (for long periods of time) in large quantities. This is because its value as a fuel or product leads to its prompt use.

#### 4. **Management and Combustion Processes for Used Oil**

##### (1) **Types of Units Combusting Used Oil:**

Facilities burn both on-specification and off-specification used oil. However, off-spec used oil may only be burned in specified combustion devices (EPA 2008):

- Industrial furnaces as defined in 40 Code of Federal Regulation (CFR) §260.10 and §279.61(a). Industrial boilers as defined in 40 CFR §260.20 that are located

<sup>4</sup> The data source for this estimate does not specify the year represented by this estimate.

at facilities that are engaged in a manufacturing process where substances are transformed into new products.

- Utility boilers as defined in 40 CFR §260.20 that are used to produce electric power, steam, heated or cooled air, or other gases or fluids for sale.
- Used oil-fired space heaters provided that the burner meets the provisions of 40 CFR §279.23.
- Hazardous waste incinerators subject to regulation under 40 CFR parts 264 and 265, subpart O.

**(2) Supply/Processing Chain for Used Oil:**

The Standards for the Management of Used Oil in the Code of Federal Regulations define processing as “chemical or physical operations designed to produce from used oil, or to make used oil more amenable for production of, fuel oils, lubricants, or other used oil-derived product. Processing includes, but is not limited to: blending used oil with virgin petroleum products, blending used oils to meet the fuel specification, filtration, simple distillation, chemical or physical separation and re-refining” (40 CFR 279.50(a)).

**(3) Processing Used Oil for Fuel Applications:**

Used oil is generated from many different sources and then consolidated at key collection points (e.g., commercial and industrial operations, automotive repair shops, branch collection networks, and fleets) through well-established channels before being shipped to processing facilities and end users. Based on communications with used oil recyclers and marketers, the steps to process used oil for use as a fuel are as follows:

- Test the oil to determine whether it’s on-spec or off-spec. The recyclers and marketers who we contacted indicated that nearly all used oil is on-spec;
- Using solvents, remove as much water (and sometimes antifreeze) from the oil as possible;
- Filter out metal scraps and other larger particles using screens. The filtering can be done when the oil is collected, or in the burner when the oil is added (Saunders 2008 and Blackburn 2008).

The filtering and water extraction processes described above are standard practice in the industry. That is, most used oil goes through these processing steps prior to being used as a fuel (Saunders 2008 and Blackburn 2008).

In addition to the processing steps outlined above, processors often store used oil in tanks, allowing oil to separate from other liquids and settle to the bottom of the tank. This allows processors to provide their customers with relatively high-quality used oils (Saunders 2008 and Blackburn 2008).

Estimated counts of the entities involved in the various stages of used oil processing and use include the following:

- 379 used oil transporters and transfer facilities
- 150 used oil processors and re-refiners
- 750 burners of off-specification used oil

- 340 used oil fuel marketers (Office of Management and Budget 2005, p. 52)

**(4) State Status of Used Oil use as Fuel:**

Based on a review of information from the 2006 Beneficial Use Survey conducted by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), none of the 34 states responding to the survey reported that they had given used oil a beneficial use designation as a fuel (ASTSWMO 2007, p.B-38-39). States typically regulate used oil practices under federal used oil management standards (EPA 2008c).<sup>5</sup> This may include establishing programs to encourage appropriate use of used oil. For example, DOE indicates that 24 states have enacted purchasing program preferences to stimulate the demand for used oil (DOE 6-3 to 6-4).

**5. Used Oil Composition and Impacts**

**(1) Composition of Used Oil**

- 140,000 Btu per gallon<sup>6</sup> (EPA 2008b)
- A 2003 study by Dominguez-Rosado and Pichtel indicates that used motor oil has the following metals concentrations:
  - Zinc: 838 mg/kg
  - Lead: 110 mg/kg
  - Cadmium: 9.4 mg/kg
  - Barium: 4,100 mg/kg
  - Chromium: Not detected (Dominguez-Rosada and Pichtel 2003)
- Used oil often contains approximately 2 to 5 percent additives (DOE 2006, p. 9-14). Exhibit 5 summarizes the most common of these additives. In addition to these additives, used oil may include a number of physical and chemical contaminants, including metals, dirt, and solvents (EPA, 2008a).

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<sup>5</sup> As of September 30 2008, 31 states have received federal authorization for the Recycled Used Oil Management Standards and an additional 10 states have adopted the Standards.

<sup>6</sup> The heat input of used oil on a Btu per pound basis depends on the density of the used oil. Assuming a density of 7.88 pounds per gallon (consistent with the density of No. 6 fuel oil), the 140,000 Btu per gallon estimates translates to 17,766 Btu per pound.

**Exhibit 5: Common Additives Found in Used Oil**

<b>Purpose of Additive</b>	<b>Additives</b>
Anticorrosion	Zinc dithiophosphates, metal phenolates, fatty acids and amines
Antifoamant	Silicone polymers, organic copolymers
Antiodorant	Perfumes, essential oils
Antioxidant	Zinc dithiophosphates, hindered phenols. Aromatic amines, sulphurized phenols
Antiwear Additive	Chlorinated waxes, alkyl phosphites and phosphates, lead naphthenate, metal triborates, metal and ashless dithiophosphates
Color Stabilizer	Aromatic amine compounds
Corrosion Inhibitor	Metal dithiophosphates, metal dithiocarbamates, metal sulfonates, thiadiazoles, and sulfurized terpenes
Detergent	Alkyl sulfonates, phosphonates, alkyl phenates, alkyl phenolates, alkyl carboxylates, and alkyl substituted salicylates
Dispersant	Alkylsuccinimides, alkylsuccinic esters
Emulsifier	Fatty acids, fatty amides, and fatty alcohols
Extreme Pressure Additives	Alkyl sulfides, polysulfides, sulfurized fatty oils, alkyl phosphites and phosphates, metal and ashless dithiophosphates and carboxylates, metal dithiocarbamates, and metal triborates
Friction Modifier	Organic fatty acids. Lard oil. Phosphorous based compounds
Metal Deactivator	Metal Deactivator Organic complexes containing nitrogen and sulfur amines, sulphides and phosphates
Pour point depressant	Alkylated naphthalene and phenolic polymers, polymethacrylates
Rust Inhibitor	Metal alkylsulfonates, alkylamines, alkyl amine phosphates, alkenylsuccinic acids, fatty acids, alkylphenol ethoxylates, and acid phosphate esters
Seal Swell Agent Organic	Organic phosphates aromatic hydrocarbons
Tackiness Agent	Polyacrylates and polybutenes
Viscosity	Polymers of olefins, methacrylates, di-enes or alkylated styrenes
<b>Sources:</b> DOE 2006, Table 9 and EPA 2005a, Appendix C-2.	

**(2) Impact Information**

- Cost Impacts:** The cost impact associated with consuming used oil as a fuel depends on both the value of the fuel that it displaces and the cost of processing used oil. The Department of Energy reports that the market value of used oil is approximately 65 to 75 percent of the price of No. 6 fuel oil (DOE 2006, p. 4-4), but it is unclear whether this estimate applies to processed or unprocessed used oil. At October 2008 fuel prices, the 65 to 75 percent estimate suggests that the value of used oil is approximately \$1.14 to \$1.31 per gallon.<sup>7</sup> In addition, in terms of the economic benefit realized by facilities that sell their used oil, a used oil recycler in Idaho indicates that the price paid by oil recyclers for unprocessed used oil varies depending on the quantity and frequency of sale (Blackburn 2008). At current oil prices, used oil recyclers pay between \$0.60 and \$1.07 per gallon for used oil (Blackburn 2008).
- Emissions Impacts of Used Oil as a Fuel:** To characterize the potential environmental impacts and benefits associated with the use of used oil as an alternative fuel, we identified comparative emissions information for used oil and

<sup>7</sup> This is based on a price of \$1.75 per gallon for No. 6 fuel oil (DOE 2008).



for the fuels it typically replaces: distillate fuel oil and residual fuel oil. More specifically, we obtained information on the emissions associated with the combustion of each of these fuels *and* the emissions associated with cradle-to-gate processing of the virgin fuel oil, impacts that would be avoided by burning used oil as an alternative. Exhibit 6 below summarizes this information. Note that this analysis does not include the emissions associated with the preparation of used oil for combustion, and may therefore overstate the relative air emissions reductions associated with using this alternative fuel. However, the majority of the upstream impacts of used oil are the result of the generation of the primary product associated with the oil; the processing required to prepare used oil for combustion is limited. Additionally, since not all contaminants in used oil cause health or environmental risk, maximum concentration limits can be set such that used oil burned with concentrations at or below the limits will not create risk. These concentration limits define the difference between on-spec and off-spec used oil.

Exhibit 6 shows that the principal benefits of combustion of used oil are associated with upstream production offsets and include substantial reductions of NO<sub>x</sub> and CO emissions. In terms of combustion-specific emissions, use of used oil results in notably lower NO<sub>x</sub> emissions, in particular when compared to residual fuel oil. On the other hand, particulate matter and lead emissions may be substantially higher than virgin fuel oil, depending on the concentrations of those compounds in the used oil.

Note that other uses for used oil may be environmentally preferable to combustion (e.g., recovery and reuse as a lubricant) but this analysis examines only combustion uses.

**Exhibit 6: Emission Factors for Used Oil and Alternatives**

Pollutant	Used Oil	Distillate Fuel Oil		Residual Fuel Oil	
	Combustion	Combustion	Combustion plus Upstream	Combustion	Combustion plus Upstream
----- Lb./MMBtu -----					
<i>Criteria Pollutants</i>					
PM2.5	-	-	-	-	-
PM10	0.162 – 0.190	0.011	0.011	0.093	0.093
PM, unspecified	0.203 – 0.238	-	0.012	-	0.012
NOx	0.131	0.173	0.234	0.367	0.428
VOCs	-	0.001	0.363	0.002	0.367
SOx	0.051 – 1.014	0.209	0.394	1.593	1.781
CO	0.034	0.036	0.082	0.033	0.079
Pb	$1.79 \times 10^{-3}$ – $2.16 \times 10^{-3}$	$4.60 \times 10^{-6}$	$5.61 \times 10^{-6}$	$5.80 \times 10^{-5}$	$5.90 \times 10^{-5}$
Hg	-	$1.58 \times 10^{-6}$	$1.77 \times 10^{-6}$	$8.67 \times 10^{-6}$	$8.85 \times 10^{-6}$
<p><b>Sources:</b> Distillate fuel oil and residual fuel oil emissions from Franklin Associates 1998. Used oil emissions from EPA 1995, Vermont Agency of Natural Resources 1996, and Colorado Department of Public Health and Environment.</p> <p><b>Notes:</b> “-” signifies data not available; may equal zero. Heating value of used oil assumed to be 145 MMBtu/1000 gal.</p> <p>The emission information presented in this table is derived from Life Cycle Inventory (LCI) data, as compiled by Franklin Associates. LCI data identifies and quantifies resource inputs, energy requirements, and releases to the air, water, and land for each step in the manufacture of a product or process, from the extraction of the raw materials to ultimate disposal. The LCI can be used to identify those system components or life cycle steps that are the main contributors to environmental burdens such as energy use, solid waste, and atmospheric and waterborne emissions. Uncertainty in an LCI is due to the cumulative effects of input uncertainties and data variability.</p> <p>There are several life cycle inventory databases available in the U.S. and Europe. For this paper, we applied the most readily available LCI database that was most consistent with the materials and uses examined. These LCI data rely on system boundaries as defined by Franklin Associates, as described in the documentation for this database, available at: <a href="http://www.pre.nl/download/manuals/DatabaseManualFranklinUS98.pdf">http://www.pre.nl/download/manuals/DatabaseManualFranklinUS98.pdf</a>.</p>					

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