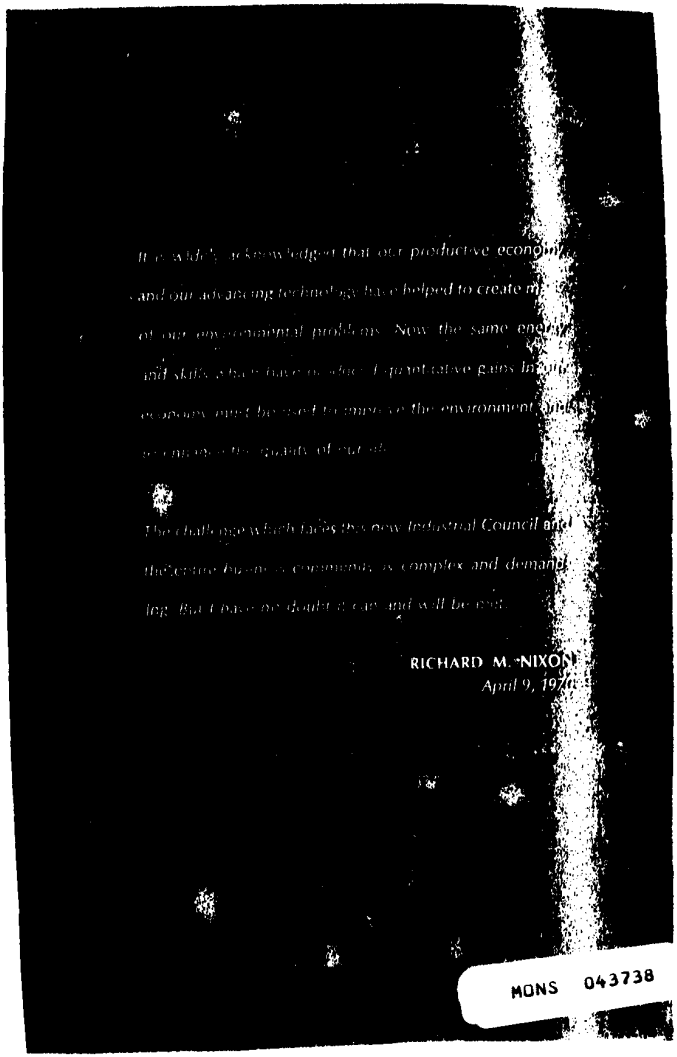
THE USE AND DISPOSAL OF ELECTRICAL INSULATING LIQUIDS

SUB-COUNCIL REPORT
June 1971

NATIONAL INDUSTRIAL POLLUTION CONTROL COUNCIL



MONS 043737


It is widely acknowledged that our productive economy
and our advancing technology have helped to create many
of our environmental problems. Now the same energy
and skills that have given us these quantitative gains in our
economy must be used to improve the environment and
to improve the quality of our life.
The challenge which faces the new Industrial Council and
the entire business community is complex and demanding.
But I have no doubt it can and will be met.
RICHARD M. NIXON
April 9, 1970
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National Industrial Pollution Control Council
Washington, D.C. 20230

June 21, 1971

Honorable Maurice H. Stans
Secretary of Commerce
Washington, D. C. 20230

Dear Mr. Secretary:

I have the honor to transmit to you for the President and the Chairman of the Council on Environmental Quality a Progress Report of actions underway by industry with regard to specific pollution problems.

This Report has been prepared by a Sub-Council of the National Industrial Pollution Control Council as an information paper. It describes the actions and presents the views of those industries most directly involved with the particular pollution problems addressed.

Such Progress Reports will be prepared by our Sub-Councils on major pollution problems confronting industry and will be updated from time to time.

Sincerely,

Bert S. Cross
Chairman

Enclosure

MONS 043741

National Industrial Pollution Control Council
Washington, D.C. 20230

June 14, 1971

Dear Chairman Cross:

As Chairman of the Electric and Nuclear Sub-Council of the National Industrial Pollution Control Council, I have the honor of submitting to you this report on our industry's efforts to evaluate the pollution problem caused by the discarding of old household appliances.

Sincerely,

D. C. Burnham

Enclosure

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SUMMARY

Electrical insulating liquids (EIL), their application and disposal are studied against a background of similar information relating to petroleum products in total.

Naphthenic mineral oils are found to comprise over 80 percent by volume of the total usage of EIL. Polybutenes are second, at almost 10 percent. Thus, 90 percent of EIL are petroleum-based. Being relatively non-toxic and biodegradable, they represent no environmental threat when subjected to conventional secondary waste treatment. Furthermore, assistance in reclaiming or proper disposal of used mineral oils can usually be obtained from the suppliers of these products.

The third largest-volume EIL group is the askarels, or polychlorobiphenyls. This group has some toxic properties and contains members which have recently become suspect ecologically. Accordingly, the report contains recommendations regarding the control and disposition of askarels.

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INTRODUCTION

This study of the use and disposal of electrical insulating liquids has been undertaken in support of the objectives of the Electric and Nuclear Sub-Council of the National Industrial Pollution Control Council. Its purpose is to examine electrical insulating liquids (EIL) for their possible toxicological or ecological impact and, as appropriate, to provide information which may lead to advice concerning government programs which would facilitate private sector efforts directed at environmental improvement, or voluntary actions by industry. Specific areas of interest include pollution which may occur from the plants where EIL are used in manufacture of electrical apparatus, and that which may occur during use or disposal.

A variety of insulating liquids is used in electrical apparatus such as transformers, circuit breakers, capacitors, and high-voltage cable in order to optimize, for each application, a range of design parameters typified by dielectric strength, losses, dissipation factor, arc and flame suppression, heat transfer coefficient, and product life expectancy. Requirements and conditions to be met will, in a given instance, quickly narrow the practical options available to the designer down to a very few or even to a single fluid. For this reason it should be borne in mind that, even though a particular electrical insulating liquid may be characterized as containing the potential of contributing to the pollution of the environment, the socially-desirable and economically correct action may lie in the adoption of precautions and control measures rather than in the substitution of a material which would not perform the required function as well.

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CLASSIFICATION OF ELECTRICAL INSULATING LIQUIDS (EIL)

While there are a great many types of electrical insulating liquids used for special purposes, such as scientific apparatus, there are only a few used in such quantity as to be of economic importance to the electrical industry and relevant to the subject of national pollution control. The specifications and general characteristics of the principal electrical insulating liquids (hereinafter referred to as EIL) are shown in Table No. 1.

TABLE NO. 1: EIL CLASSIFICATION

Application	Specification	Type of Material
Combustible	ASTM D1040-69	Naphthenic mineral oil
Transformers, Oil Circuit Breakers	FED VV-I-530a (Note 1.3)	
Capacitors, Cable	ASTM D2297-68	Naphthenic mineral oil
Capacitors, Cable	ASTM D2296-68	Polybutene oil
Cable, Low Pressure	ASTM D1818-63	Naphthenic mineral oil
Cable, High Pressure	ASTM D1819-66	Naphthenic mineral oil
Noncombustible		
Capacitors	ASTM D2233-68 (Note 2)	Polychlorinated biphenyl
Transformers, Capacitors	ASTM D2283-70a (Note 1.1, 1.2, 2.0) FED VV-I-1219 (Note 1.1, 1.2, 2.0)	Polychlorinated biphenyl mixtures with diluents

NOTE: 1.0 Certain grades contain small quantities of additives which serve as antioxidants and/or scavengers for hydrogen chloride. Commonly used materials and typical concentrations are:

1.1 dicyclo-diepoxy carboxylate	0.14%
1.2 phenoxypropene oxide	0.22%
1.3 2,6 ditertiary butyl p-cresol	0.15%

2.0 Certain grades contain trichlorobenzene and/or tetrachlorobenzene as diluents.

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QUANTITIES AND USAGE OF EIL

Six of the nine specifications listed in Table No. 1 are petroleum oils. Table No. 2 provides a breakdown of the principal uses of naphthenic mineral oils as insulating liquids. The information on transformer and cable usage is derived from the market estimates of several oil producers (10).* Switchgear (circuit breaker) and capacitor data are estimated from knowledge of one manufacturer's usage and assumed market position (10).

The second column of data in Table No. 2, field use, may be taken as a measure of the generation of waste oil during the use of the apparatus. The gallonage shown represents direct shipment of oil to users of electrical apparatus, as distinguished from manufacturers. Make-up oil is seen to be about 17 percent of the total usage of naphthenic EIL. The waste percentage varies with the class of apparatus, being zero in the case of capacitors and highest in the case of cable.

TABLE NO. 2: USE OF NAPHTHENIC OIL AS AN INSULATING LIQUID IN U.S., 1968

Millions of Gallons

Apparatus	Original Equipment Use	Field Use (Make-up)	Total	Percent of Total
Transformers	39.13	7.57	46.70	92.0
Switchgear	2.07	.40	2.47	4.9
Cable	1.05	52	1.57	3.1
Capacitors	.02	0	.02	...
Total	42.27	8.49	50.76**	100

** 1.21 million 42-gal. barrels.

Table No. 3 is similarly derived and presents an analysis of the total quantity of EIL according to the apparatus in which it is used. The grand total of EIL used in the year 1968 is estimated to be 62 million gallons (or 1.5 million 42-gal. barrels). The subtotal consisting of the first two entries, naphthenic oil and polybutene liquid, is 57.26 million gallons (1.4 million barrels); thus 91 percent of the

* Numbers in parentheses are references to the Bibliography at the end of the report.

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total annual usage of EIL is petroleum based. The remainder is mostly askarels (polychlorinated biphenyls, abbreviated PCB).

The chlorinated benzenes shown are not used alone, but as diluents for the askarels, in some applications. The category, Other, includes relatively small quantities of such materials as dibutyl sebacate and silicone oil, used in specialized apparatus of low production quantities.

TABLE NO. 3: QUANTITIES AND USES OF PRINCIPAL INSULATING LIQUIDS IN THE U.S., 1968

Millions of Gallons

Liquid	Transformers	Switchgear	Capacitors	Cable	Other	Total	Liquid, % of Total
Naphthenic Mineral Oil	46.70	2.47	.02	1.57	.30	51.06	82.4
Polybutene Liquid				6.20		6.20	10.0
Askarels (PCB)	1.35		2.46			3.81	6.1
Chlorinated Benzenes	.79		.01			.80	1.3
Castor Oil			.10			.10	.2
Other			.01		.02	.03	....
Total	48.84	2.47	2.60	7.77	.32	62.00*	100.0
Use, Percent of Total	78.8	4.0	4.2	12.5	.5	100.0	

* 1.48 million 42-gal. barrels.

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TOXICOLOGY

MINERAL OILS

Naphthenic oils and polybutenes are essentially non-toxic. The only reported danger is from inhalation of vapor or mists, in which the maximum allowable concentration is 5 parts per million.

TOXICITY AND SAFE HANDLING OF ASKARELS (13)

Inhalation

At ordinary temperatures the askarels have not presented industrial toxicological problems. The hazard of potential toxic exposure varies with their volatility: the lower-chlorinated, more-volatile ones present more of a potential problem from the standpoint of both inhalation and skin contact. When askarels are used at elevated temperatures, engineering controls must be applied, either by the use of closed systems or by effective local-exhaust ventilation together with general workroom exhaust.

Vapor at room temperature should not be breathed in a confined space, and no vapor of any askarel evolved at elevated temperatures should be allowed to be dispersed into the general workroom.

Inhalation tests on animals indicate that the maximum safe concentration of vapor is in the range of from 0.5 to 1.0 milligram of the lower-chlorinated askarels per cubic meter of air. The threshold limit values (maximum allowable concentration for an 8-hour working day) set by the American Conference of Government Hygienists are 1.0 milligram of the lower chlorinated askarels per cubic meter of air and 0.5 milligram of the more highly chlorinated compounds per cubic meter of air.

Skin Contact

Schwartz patch tests on 200 volunteers showed that 54 percent chlorinated askarel was neither a primary skin irritant or a sensitizer.

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Prolonged or repeated skin contact with askarels must be avoided by the use of gloves and protective garments, because of the possible occurrence of a condition called chloracne. Although reports of this condition caused by askarels are rare, it can be produced by excessive skin contact. If any askarel is spilled on the skin, the skin should be washed in the usual manner with a soap solution.

A burn caused by contact with a hot askarel should be treated like any ordinary burn. Material adhering to the burned area need not be removed immediately, unless treatment of the burn demands it, in which case either soap and water or repeated washings with a vegetable oil are recommended.

ECOLOGY

Mineral Oils

Mr. Claude E. ZoBell has written, "Mineral oils are susceptible to microbial oxidation, and certain fractions undergo autoxidation. This seems to be Nature's way of remedying oil pollution in soil as well as in sea water. . . . In controlled laboratory experiments, we find that oil-oxidizing bacteria convert an average of 30-40 percent of the carbon content of hydrocarbons into bacterial cell substance or protoplasm." (14)

Mineral oils and polybutenes are not known to have a long-time effect upon the ecology. In the short term, the effect of large scale spills has received considerable notice in the public press. Small amounts, in isolation, have no detrimental effects. The materials are biodegradable and exist naturally in the environment. Thus, consideration of possible adverse ecological effects arising from the use of mineral oil in electrical apparatus becomes primarily a matter of scale, rather than properties of the oil. Also there are several well known methods of reclaiming and/or otherwise disposing of these oils satisfactorily. Assistance in this regard can usually be obtained from the supplier of the mineral insulating oil.

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Askarels

The askarels, particularly those with more than 50 percent chlorination, have recently been identified as a possible ecological threat to marine and bird life. The attention of the industry was called to this subject in a number of published articles and specifically in a widely-distributed letter from the Monsanto Company (sole U.S. producer) under the date of February 18, 1970. (11) Certain askarels introduced into eco-systems are believed to act in a manner somewhat analagous to the persistent pesticides, being concentrated in successive links of the food chain.

For the short term, effects of askarels may be kept from the environment by limiting applications to closed systems (of which transformers and capacitors are examples) and by the exercise of suitable precautions in the disposition of waste.

For the longer term, the producer is working to develop modified chlorinated biphenyls which will be biodegradable. This means that even if minute quantities are released to the environment by accidental spills the consequences will be minimal, and it will be possible to remove the modified materials from waste water streams in conventional secondary treatment facilities. (12)

MINERAL INSULATING OIL IN PERSPECTIVE

As indicated above, mineral oil is characterized as harmless to the environment if the amount released is not excessively concentrated in time or space. The data in the Appendix were assembled to place this matter in perspective. For example, it is found that the total use of mineral oil in electrical apparatus is about 0.03 percent of all oils (Table A-1); that total field make-up is approximately 0.005 percent of all oils. Perhaps a more realistic comparison is the one drawn in the Appendix, i.e., that total usage as insulating oil is equal to a small fraction--10 percent--of the amount of used lubricating oil now being applied directly to land and stream. These comparisons do not lessen the need for prudent disposal of mineral insulating oil

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in accordance with accepted industry practice, but they do suggest a low action priority in the context of a national assessment of pollution problems in the electrical industry.

It is concluded that any recommendation at this time for industry action on mineral oils would serve only to dilute the force of recommendations to be made in an area where greater leverage exists: the containment of askarels.

RECOMMENDATIONS

In view of the suspected ecological hazard presented by state-of-the-art formulations of polychlorinated biphenyls, it is recommended that the electrical industry employ the following guidelines in the manufacture and servicing of electrical apparatus:

1. Provision is to be made for qualified destruction of PCB waste materials, such that there will be no release of materials to the atmosphere or to ground or surface water significant from the standpoint of toxicity or adverse ecological impact. Initially, the only process which appears to meet these requirements is incineration under carefully controlled conditions. With proper adjustment of temperature, residence time in the incinerator, and other parameters, products of combustion will be limited to HCl, CO_2, and H_2O (in the form of steam). The hydrochloric acid may be absorbed in a scrubber and the resultant solution neutralized with lime to form calcium chloride solution, $CaCl_2$. In the process described, the only effluents to the environment will be a plume of steam, carbon dioxide, and brine, the discharge of which must be held to regulatory limits.
2. All liquid waste is to be held in impervious containers pending disposal.
3. Solid wastes contaminated by PCB's are to be held in impervious containers pending disposal or purging. Purging may be accomplished by cleaning with proper fluids. The resulting contaminated liquids may be incinerated as above.

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As the result of programs undertaken since the industry was first alerted to indications of ecological harm from PCB's, the industry has progressed a long way toward the implementation of these recommendations. At least two enterprises are accepting liquid wastes for incineration; facilities are being prepared for the processing of contaminated solids; evaluations of improved formulations are in progress; and a committee of the American National Standards Institute has been authorized to consider what standards may be appropriate.

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APPENDIX

TOTAL FLOW OF PETROLEUM PRODUCTS

Because a high percentage of the total volume of electrical insulating liquids is petroleum based, the use and disposition of EIL can best be understood against a background of the quantities of petroleum products used throughout the economy, and how they are disposed of.

Table No. A–1 displays the quantities and uses of petroleum products in the U.S. for 1968 (the most recent year for which relatively complete data could be searched out). This Table is useful in providing a perspective for the viewing of the consumption of electrical insulating oils. Item 3.12, Electrical Insulating Oil, is the total of naphthenic and polybutene EIL, and corresponds to only 0.04 percent of "all oils."

Disposal of Oils Similar to Electrical Insulating Oils

Lubricating oil (Item 3.7 of Table A–1) was chosen for a comparative study because of its similarity to electrical insulating grades of petroleum oil. Although no national study has been made, data are available (3) from which a reasonable estimate can be formed of what happens to lubricants throughout their life history, on a nation-wide scale.

Lubricants may be classified conveniently in two groups: automotive and industrial. Table No. A–2 is an estimate of the usage, waste generation, and disposition of automotive lubricants throughout the country, and Table No. A–3 presents similar data for industrial lubricating oils. A large portion of the waste generated is collected by scavenging firms, and the fate of this portion is indicated in Table No. A–4. Table No. A–5 summarizes the results of the investigation of lubricating oil waste practices. It will be noted that a little over half of all lubricating oil ends as waste, and of this half, more than half is dumped on the ground in one way or another—as locally disposed waste, as road oil, in town dumps, etc.

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The concern of the petroleum industry for this situation, and the vigorous steps being taken to evaluate its effect and to devise ameliorative procedures, where indicated, is the subject of another study. See *Final Report of the Task Force on Used Oil Disposal*, American Petroleum Institute (9).

For the purpose of the present study, it may be pertinent to note that the total usage of petroleum-derived insulating oils (1.4 million barrels) is equal to one-tenth of that portion of waste lubricating oil being dumped on the ground or sewered, according to available estimates of current practices.

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TABLE NO. A-1

QUANTITIES AND USES OF PETROLEUM PRODUCTS IN THE U.S., 1968

Use Category — Millions of 42-gallon Barrels

	Kero-sene	Distil-late	Resid-ual	Gaso-line	Jet Fuel	Other	Total	Per-cent
1.0 *Heating and Energy Conversion*								
1.1 Electric Utilities		3.0	185.0				188.0	
1.2 Heating	76.2	512.0	173.0				761.2	
1.3 Industrial		45.8	135.7				181.5	
1.4 Oil Companies		9.4	39.3				48.7	
1.5 Off H'w'y Diesel		49.5					49.5	
1.6 Mili. (excl. Jet)		12.6	35.0				47.6	
1.7 Fuel for all other	26.7	12.6	8.3				47.6	
Total	102.9	644.9	576.3	0	0	0	1324.1	27.0
2.0 *Transportation*								
2.1 Railroads		84.1	4.3				88.4	
2.2 Highway Diesels		127.3					127.3	
2.3 Motor Vehicles				1925.4			1925.4	
2.4 Piston Aircraft				30.6			30.6	
2.5 Jet Aircraft					349.4		349.4	
2.6 Ships bunk'd in U.S.		18.2	87.6				105.8	
Total	0	229.6	91.9	1956.0	349.4	0	2626.9	53.6
3.0 *Material Conversion and Other*								
3.1 Liquified Gases						330.6	330.6	
3.2 Still Gas						149.8	149.8	
3.3 Asphalt						141.2	141.2	
3.4 Petrochem. Feedstocks						92.9	92.9	
3.5 Coke						76.3	76.3	
3.6 Ethane, Ethylene						55.2	55.2	
3.7 Lubricants						48.5	48.5	
3.8 Spec'l Naphthas						27.0	27.0	
3.9 Not Elsewhere listed						16.4	16.4	
3.10 Road Oil						7.1	7.1	
3.11 Wax						4.4	4.4	
3.12 Elec. Ins. Oil						1.4	1.4	
Total	0	0	0	0	0	950.8	950.8	19.4
4.0 *Grand Total*	102.9	874.5	668.2	1956.0	349.4	950.8	4901.8	100.0

The basic reference for the fuel oils is (4.2) (see BIBLIOGRAPHY); for gasoline and jet fuel (a blend of gasoline, kerosene, and distillate), (6); "Other," (6), (4.4) and (10). Some figures from other sources have been adjusted to yield totals in "final summary," reference (4.4).

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TABLE NO. A-2

LUBRICATING OIL—AUTOMOTIVE
ESTIMATE OF USAGE, WASTE GENERATION, AND DISPOSITION IN THE USA

(Following the pattern observed in the Commonwealth of Massachusetts)

1968

User	(1) User Distribution, %	(2) Calc. U.S. Usage at % in (1), Million Gallons	(3) % Ending as Waste	(4) Waste, Million Gallons	(5) % of (4) Collected	(6) Waste collected, Mil. Gal.	(7) Waste uncollected, Mil. Gal.	(8) Dumped on Ground Mil. Gal.	(9) Sewered, Mil. Gal.
Service Stations Performing Oil Changes	54.9	658	63	415	87.7	364	51	45	6
Other Svc. Sta.	1.6	19	0	0	0	0	0	0	0
Car Dealers, Garages	16.1	194	90	175	88.0	154	21	20	1
Fleet Operators	18.8	226	63	142	60.0	86	56	52	4
Do-it-yourself Oil Changers	5.4	65	63	40	0	0	40	37	3
Agriculture & Marine Users	3.2	38	50	19	0	0	19	18	1
Total	100.0	1200	—	791	—	604	187	172	15

The total U.S. usage, 1200 million gallons (28.6 million barrels) is derived from a 1967 survey by the Bureau of the Census—see Sources of Information, reference (7). The total was adjusted to 1968 usage by means of information in reference (4.4). Percentage distributions and disposal patterns are drawn from a survey made by the Arthur D. Little Company in the Commonwealth of Massachusetts, reference (5). Applying the Massachusetts pattern to the USA as a whole involves errors of unknown magnitude; a staff estimate by the FWQA yields a figure of 350 for the first entry in column (4) above (reference 2), an estimate 15.7 percent below that derived here. The American Petroleum Institute (reference 9) terms the ADL study "indicative of present disposal practices."

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TABLE NO. A–3

LUBRICATING OIL—INDUSTRIAL
ESTIMATE OF USAGE, WASTE GENERATION, AND DISPOSITION IN THE USA

(Following the pattern observed in the Commonwealth of Massachusetts)

1968

(Millions of Gallons)

Use Category	(1) Distri-bution %	(2) Calc. U.S. Usage	(3) % Waste	(4) Vol. of Waste	(5) % Collect.	(6) Vol. Coll.	(7) Vol. Un-coll'ct'd	(8) % Burned	(9) Vol. Burned	(10) % Sewered	(11) Volume Sewered
Lubricating Oil	51.0	426	35	149							
Hydraulic Fluid	27.4	229	20	46							
Straight Cutting Oil	10.5	88	30	26							
Soluble Cutting Oil	11.1	93	30	28						100	28
Total	100.0	836*		249	76	189	60	1.2	3		28

Data in columns (1), (3), (5), etc. are from the A.D. Little report, Bibliography Reference (3).

* Bureau of Mines total lubricants, less automotive use from Table No. A-2.

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TABLE NO. A–4

FATE OF COLLECTED WASTE OIL

Estimate of U.S. Disposal Practices Based on Massachusetts Pattern

1968 — Millions of Gallons

Final Disposition	Automotive Percent [1]	Automotive Volume	Industrial Percent [2]	Industrial Volume	Total Volume Collected Waste Lube Oil
Reprocessed to Fuel Oil or Re-refined	69.1	417	—	—	417
Used as Road Oil	21.7	131	52.6	100	231
Used on Farms	4.6	28	—	—	28
Disposed of Locally (Town Dumps or Local Roads)	—	—	47.4	89	89
Unknown	4.6	28	—	—	28
Total Collected	100	604 [3]	100	189 [4]	793

[1] *Study of Waste Oil Disposal Practices in Massachusetts*, Ref. (1).
[2] Table No. A-2.
[3] Table No. A-3.

TABLE NO. A–5

FATE OF WASTE LUBRICATING OIL U.S., 1968

Summary of Estimates in Collected and Uncollected Categories

Ultimate Fate	Volume, Millions of Gallons	Volume, Millions of 42-gal. Barrels	Distribution, Percent of Total Lubricating Oil Used
Dumped or Applied on Ground	549	13.1	27
Poured into Sewers	43	1.0	2
Reprocessed, Re-refined, and/or Burned	420	10.0	21
Unknown	28	0.7	1
Total Ending as Waste	1040	24.8	51
Total Used, as Memo Item	2036	48.5	100

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