USED OIL RECYCLING AND TREATMENT IN THE UNITED ARAB EMIRATES ECONOMICAL AND ENVIRONMENTAL ASSESSMENTS

Ahmad Hamad[1], Essam Al Zubaidy[2], Ahmed Aidan[3], Talha Hadaki[4], and Nasri El-Kareh[4]

1: Assistant Professor, Chemical Engineering Department, KFUPM, Correspondence Author
2: Lab Instructor, Chemical Engineering Department
3: Lab Engineer, Chemical Engineering Department
4: Senior Student, Chemical Engineering Department, American University of Sharjah
Sharjah, P.O.Box 26666, UAE

E-mail: ahamad@aus.ac.ae

ABSTRACT

In this work, we are investigating used oil recycling opportunities in United Arab Emirates. The economical assessment shows that it is worthy to recycle used oil. In the Emirate of Sharjah alone, recycling used oil could save $168,000 per year in fuel, or 250,000 gallons of base oil. The environmental assessment shows that more than 50% of used oil generated in the Emirate of Sharjah is not recorded. This is a serious problem that threatens our natural resources such as water and soil. Laboratory analysis of some properties of different classes of engine oils shows that recycling used oil could be pursued effectively.

Keywords: *Used oil, environment, recycling, natural resources*

الملخص

تم دراسة امكانية اعادة استخدام زيوت التزييت في دولة الامارات العربية المتحدة - الشارقة . حيث بينت دراسة الجدوى الاقتصادية بانه يمكن توفير ١٦٨٠٠٠ $ في السنة كوقود او ٢٥٠٠٠٠ جالون كزيت تزييت معاد تكريره . اما الدراسات البيئية فقد بينت بان اكثر من ٥٠% من الزيت المستعمل المنتج في امارة الشارقة لم يتم تسجيله و هذا ما قد يؤدي الى مشاكل بيئية خطيرة على الماء كمصدر طبيعي و كذلك التربة. ان الدراسات المختبرية بينت امكانية اعادة خواص زيوت التزييت بما يلائم استخدامه في مختلف المكائن.

INTRODUCTION

The damage of used oil comes from mismanagement. Millions of liters of used oil are thrown in trash, often ending up in landfills, from which oil can contaminate ground and surface water and reduce soil productivity. In addition, consumers pour used oil down sewers and drains, disrupting treatment plants and contaminating waterways. It is estimated that 50-100 ppm of used oil can foul sewage treatment processes (Holmes et al., 1993). Water resources in the Gulf are scarce, and their protection is required.

Besides its great impact on the environment, if used oil is properly recycled and reused, it could have significant savings on fresh crude oil. It is estimated that people who change their own motor oil in the US throw away 120 million gallons per year of recoverable oil. If this oil is recycled, it could save 1.3 million barrels of crude oil per day (Holmes et al., 1993). The same scenario is applicable to UAE and other Gulf States. One gallon of used oil contains about (140,000) Btu of energy if used as fuel. In addition, used oil could be re-refined back into usable base stock oil. Only one gallon of used oil could be utilized to yield the same 2.5 quarters (62.5% recovery) of lubricating oil provided by 42 gallons of crude oil (Holmes et al., 1993).

The objectives of this work are to investigate economical and environmental impacts on recycling used oil within the UAE and to promote public, governmental and industrial awareness about used oil recycling. Theoretical and experimental analyses are conducted to support this work and obtain reliable data. The chemical complexity and challenge of processing used oil into value added products encouraged us to get a research fund from Schlumberger oil field services.

CONTAMINANTS IN USED OIL

Used oil material contains small quantities of substances that could contaminate air, soil and ground water. Used oil could contain trace metals, chlorinated solvents, and miscellaneous organic compounds. The presence of metals could be attributed to oil additives or as a result of engine or bearing wear. A typical formulation of gasoline engine oil is shown in the following table (Kreith, 1994).

Table 1: Typical Formulation of Gasoline Engine Oil

Ingredient	Percent by Volume
Base Oil (solvent 150 neutral)	86
Detergent Inhibitor (ZPDD-zinc dialkyl dithiophosphate	1
Detergent (barium and calcium sulfonates)	4
Multifunctional additives (polymethyl-methacrylates)	4
Viscosity Improver (poly isobutylene)	5

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Additives are added to inhibit metal corrosion and oxidation of oil. They also act as detergents, dispersants, and antiwear compounds. On the other hand, oil additives contain hazardous material such as magnesium, lead, zinc, and organics, and they increase the concentrations of chlorine, sulfur, and nitrogen in lube oil. They also can form corrosive acids if they get oxidized during combustion. A test on used oil samples taken directly from used oil generators in the US (Kreith, 1994) indicated that almost 100% of the samples were above detection limits in barium, cadmium, chromium, lead, and zinc and about 8% of the samples were above detection limits in arsenic. In addition, 100% of the samples were above chlorine detection limits. If leaded gasoline is used, then lead becomes a major contaminant in used oil. Chlorinated solvents are found in used oil as a result of illegal or careless mixing of oil additives. Other aromatic organics such as benzene, toluene, and benzo(a)pyrene also exist in appreciated limits in used oil.

REGULATIONS OF USED-OIL RECYCLING

The Used Oil Recycling Act defines used oil as any oil which has been refined from crude oil, used, and as a result of such use, contaminated by physical or chemical impurities (Kreith, 1994). Used oil is not listed as a hazardous waste under US EPA unless it exceeds the limits in toxic and hazardous components such as chlorinated solvents. The following table gives specification limits for used oil fuel (Kreith, 1994).

Table 2: Specification Limits for Used Oil Fuels

Contaminant and Property	Limit
Arsenic	$\leq$ 5 ppm
Cadmium	$\leq$ 2 ppm
Lead	$\leq$ 100 ppm
Chromium	$\leq$ 10 ppm
Total Halogens	$\leq$ 4000 ppm
Flash Point	$\geq$ 100 ^{o}F

To recycle used oil to be used as base oil depends on the specifications of the base oil. In later sections of this paper, comparisons among used oil, recycled oil, and fresh oil will be made to illustrate the difference in specifications among the three types of oil.

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SURVEY DATA OF USED OIL GENERATED IN UAE

Gathering data about used oil generated in the Emirates of Sharjah and United Arab Emirates is a critical step in this research effort. Used oil in UAE is generated from different sources such as factories, workshops, oil change shops, and others. The used oil is kept in drums and collected by trucks and tankers to be shipped to scrub companies. The scrub companies store these used oil drums in their yards to be sold to national and international used oil processing and recycling companies. We had several options to estimate motor used oil generation in Sharjah and UAE. We tried to obtain data from scrub companies; however, this data was not sufficient since it does not reflect total used oil generation.

Data obtained from Sharjah Municipality indicated that the quantity of used oil generated in the Emirates of Sharjah in the year 1999 is about 180,000 gallons. However, this data does not seem to reflect the actual picture of used oil generation in Sharjah, UAE. The following statistics supports this claim. The automotive industry in UAE recommends changing engine oil every 3,000 km driven due to the hot weather. This translates into approximately 4 or 5 quarts (1-1.25 gallons) of used oil generated per 95 gallons of fuel (Kreith, 1994). Hence, the data from Sharjah Municipality implies that automobiles consume around 17 million gallons of fuel per year. If each automobile is driven for 24,000 km per year, it is then expected to generate a minimum of 8 gallons of used oil per year. This implies that there are 22,500 automobiles in Sharjah. This is little compared to the 43,300 automobiles registered in Sharjah in year 1999. The discrepancy in the Municipality numbers could be attributed to several reasons. A lot of people do engine oil change themselves. Most of the times, those people trash used oil. Another reason could be attributed to in-efficient data reporting by used oil generators and collectors.

Based on the numbers mentioned, the 43,300 automobiles are expected to generate more than 400,000 gallons per year of used oil. These numbers reflect the seriousness of used oil generation and recycling in Sharjah and UAE, and actually the whole region. Trashed used oil would damage natural resources and would waste a useful energy resource.

To encourage used oil collection, processing and recycling, several methods could be followed:

- Educate public about the energy and environmental benefits of recycling used oil. Protecting our scarce natural resources should be highlighted.
- Promote nationwide awareness of the negative effects of improper disposal of used oil
- Create several used oil collection centers in every city and require of lube oil traders to maintain used oil collection facilities.
- Impose fines on improper disposal of used oil

RECYCLING TECHNOLOGIES AND PROCESSES USED IN UAE

There are several processes that are used in UAE to process used oil to fuel or base oil. One of these processes is discussed in this section. This process is a batch acid-clay process developed by a Solar lubricant company in Ajman, United Arab Emirates. In the next section component analysis is conducted on the final product of this process and compared to used oil and a high quality fresh based oil available in the market. The brief process description of the acid – clay treatment of waste oil is as follows:

1) Used oil is fed to storage tanks and then enters a dehydration vessel to remove moisture. The temperature in the dehydration vessel reaches 180 ^{o}C in order that the moisture is completely removed from the oil.

2) The hot oil then enters a cooling tank to reduce the temperature using cooling water. The oil is cooled down to prevent any corrosion of surfaces of subsequent the equipment.

3) The process stream is pumped to settler tanks and then to a mixing tank where the stream is mixed with sulphuric acid of concentration 98% and some diesel. The purpose of adding diesel is to make the mixing process easier while the acid's purpose is to remove the impurities and metal traces.

4) The mixture is then pumped to settling tanks where the acid layer is drained from the bottom and mixed with CaO or lime to neutralize the acidic layer formed in the acid treatment tank. It should be noted that even though the acidic layer is neutralized, it still remains a hazard problem to the environment because the CaO added is not enough to make it completely basic or suitable to the ground.

5) The remaining layer of diesel and oil coming out from the acid settler tank then enters a mixing tank where the clay is added and then is mixed thoroughly,

6) it is then pumped to a vacuum distillation network at a temperature of 280-290 deg C where the diesel vaporizes and is recycled back to the previous tank where it is fed with the acid. After the distillation process,

7) the oil stream is to cooled down once again to about 120 deg C in a cooling tank using cooling water.

8) Clay is then separated of the oil using a plate and frame filter press. At that time, the oil would still contain some clay so it is finally

9) fed to a micromesh filter press in order to keep the oil free as much as possible from the clay to reach the finished product of 99% base oil.

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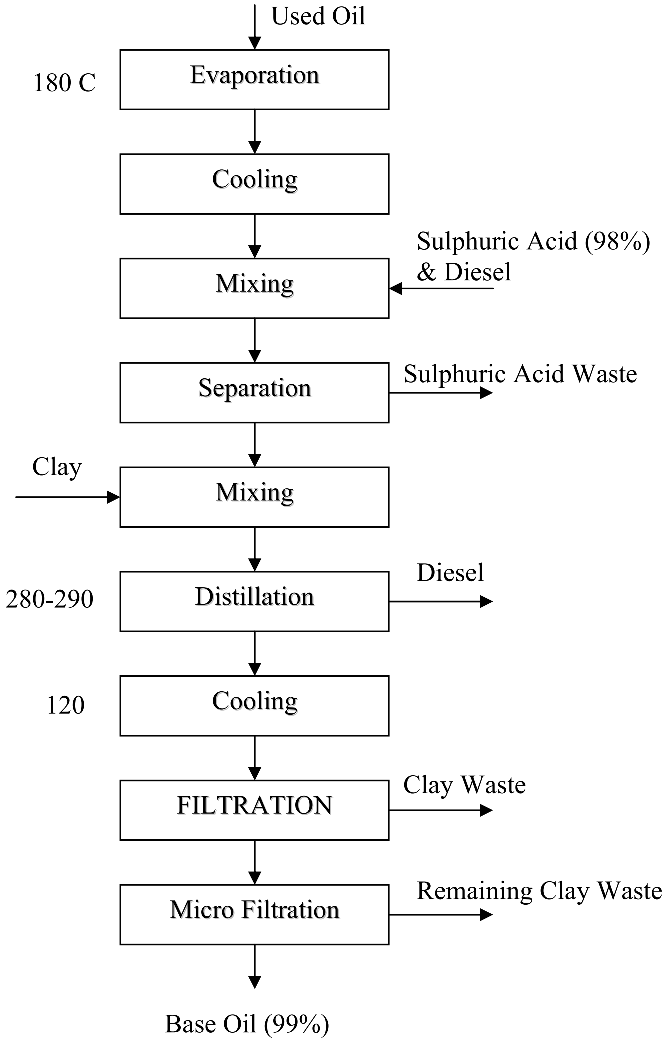

Figure 1: A Process for Used Oil Re-Refining to Base Oil Used in UAE

ECONOMICAL ASSESSMENT

In this section, economical assessment is presented to illustrate the benefits of used oil recycling in the Emirates of Sharjah. Based on the numbers mentioned above, a minimum of 400,000 gallon of used oil is expected to be generated annually. We will do two different economical assessments, one for used oil being used as fuel and the second for recycling used oil as base lubricant oil. For using used oil as a fuel, it is estimated that each gallon of used oil contains 140,000 Btu (Holmes et al., 1993). This means that a minimum of 56,000 million

Btu (MMBtu) per year could be generated. If we assume \$3/MMBtu, the worth of this energy would be \$168,000 per year. For a small emirate like Sharjah, this number could be very much appreciated. If we assume 62.5% recovery of used oil as base lubricant oil, 250,000 gallons of base lubricant oil would be recovered every year. If the price of one gallon of this oil is \$4, \$1,000,000 could be generated annually as revenue. In addition, re-refining used oil requires only one third of energy required to produce lubricant oil from crude oil (Holmes et al., 1993). Furthermore, recycling 400,000 gallons of used oil could save 16.8 million gallons of crude oil (Holmes et al., 1993).

ENVIRONMENTAL IMPACTS OF RECYCLING USED OIL

The proper recycling used oil would protect our environment and our natural resources. Instead of dumping the used oil to our landfills, sewage, or water, it could be collected, treated, and reused. Used oil is a viable source of energy and recovering it means creating another source of energy in UAE and it means safer environment. On the other hand, improper recycling of used oil can severely harm our environment and natural resources. As illustrated earlier, used oil contains hazardous components. If used oil is used as fuel without any pretreatment, it will release upon burning toxic components to our environment and pollute the air we breathe and the water we drink. Unfortunately, this oil is mostly used as fuel in cargo ships or burned on-sites. Such activities need to be monitored and regulated in more depth especially in the Arabian Gulf area. In addition, some processes that are used to re-refine used oil end up generating their waste. This waste is either dumped in landfills or sent to another treatment facility. More research is needed to reduce such waste and enhance recovery efforts of used oil.

PROPERTIES OF USED OIL BEFORE AND AFTER RECYCLING

For this work, several samples were taken from the above process for property analysis. Several properties for three oil classes were determined. Classes of oil include used oil, treated used oil, treated used oil with additives, and fresh oil. Properties estimated include: carbon residue, water content, metal content, ash content, water and sediment, distillation characteristics, flash point, viscosity, and viscosity index. Majority of these tests were conducted in the Chemical Engineering laboratory and others were conducted in collaboration with Intertek Testing Services (ITS) laboratory in Sharjah, United Arab Emirates. The results of these tests are presented below in Table (3). The metal content test analysis was conducted at ITS for a large number of metals, see Table (4) below.

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ANALYSIS OF EXPERIMENTAL RESULTS

The data in Table 3 show that used oil has the lowest flash point among all classes of oil though it is the most viscous. This is due to the contaminants present in the used oil. Some of these contaminants include light hydrocarbon components and water in appreciable amounts, which in turn contribute to the low flash point. The metals, ash, and other heavy contaminants contribute toward the high viscosity of used oil. The distillation analysis shows that about 20% of the used oil evaporated at 189^{o}C and 90% evaporated at 330^o C. Whereas, for fresh

Table 3: Properties of Different Classes of Oil

Physical Property	ASTM method	Used oil Collected	Recycle oil (Acid/clay treatment)	Recycle oil with additives SAE 40	Fresh new base oil SAE 40, SF /CC
Specific gravity,	D 1298	0.880	0.864	0.8387	0.8824
Flash point ,CCPM, ^{o}C	D 93	148	188	195.5	206
Water and sediment, vol%	D 4007	7	0.5	Nil	Nil
Water content , vol%	D 95	5	Nil	Nil	Nil
Viscosity, @ 37.8 ^{o}C, cst	D 445	195.25	135	137.25	185
Carbon residue, wt%	D 189	1.43	0.43	0.45	0.89
Ash content, wt%	D 6245	1.7	0.375	0.325	0.308
Sulphated ash, wt%	D 874	1.8	0.672	0.712	0.854
Distillation characteristics, ^{o}C	IP 123				
IBP		85	94	101	104
10%		175	214	206	184
20%		189	252	251	204
30%		222	266	257	228
40%		242	270	261	237
50%		265	271	269	252
60%		276	297	286	270
70%		314	310	294	278
80%		319	312	302	280
90%		330	313	307	302
Normal heptane insoluble, wt%	D 3279	3.370	0.337	0.339	0.088

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Table 4: Metal Content in ppm for Different Classes of Oil

Metals contaminants	Origin	Metal concentration, ppm			
		Used oil ICP method	Recycle oil ICP method	Recycle oil with additives SAE 40 AAS method	Fresh oil with additives SAE 40, SF/CC ICP method
Iron (Fe)	Engine wear	76	12	< 1	<1
Aluminum (Al)	Bearing wear	8	1	< 1	<1
Chromium (Cr)	Engine wear, anti friction bearings	2	< 1	< 1	<1
Copper (Cu)	Bearing wear	13	42	< 1	<1
Lead (Pb)	Leaded gasoline / bearing wear, oil additives	946	14	<1	39
Tin (Sn)	Bearing, piston and brushings wear	1	3	Not detected	3
Silver (Ag)	Wrist-pin bushing, anti friction bearings, silver solder	< 1	< 1	< 1	< 1
Nickel (Ni)	Engine wear, anti friction bearings	1	20	<1	3
Vanadium (V)	Oil contamination	< 1	< 1	< 1	<1
Titanium (Ti)	Oil contamination	1	< 1	Not detected	<1
Cadmium (Cd)	Oil contamination	< 1	3	Not detected	<1
Manganese (Mn)	Water contamination	2	< 1	Not detected	<1
Molybdenum (Mo)	Friction modifier additives	6	14	Not detected	<1
Silicone (Si)	Anti foam and anti freeze additives, ingested dirt and sand, gasket sealant	22	3	<1	5
Boron (B)	Ingested dirt and sand, gasket sealant	20	5	Not detected	46
Sodium (Na)	Water contamination	58	10	< 1	<1
Barium (Ba)	Water contamination	3	2	Not detected	<1
Calcium (Ca)	Detergent additives	1357	642	672	35
Magnesium (Mg)	Detergent additives, oil alkaline reserve	150	83	7	1335
Phosphorus (P)	Anti oxidant, anti wear additives	621	579	Not detected	742
Zinc (Zn)	Anti oxidant, anti wear additives, galvanized parts in circulating oil systems	701	444	18	903

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oil, 20% evaporated at 204 °C and 90% evaporated at 302 °C. It is very surprising that the recycled oil and the recycled oil with additives have the lowest viscosity, much lower than fresh base oil. This could be attributed to the additives added to the recycled oil. In addition, the recycling process described above was very efficient in removing heavy components including heavy metals. The carbon residue and sulphated ash analyses show that the fresh oil has higher values than recycled oil with and without additives. Most likely, this is due to the type of additives added to the fresh oil. The major metal contaminants found in used oil are calcium and lead. Calcium is present in used oil due to additives but the majority could be attributed to water. Lead is attributed to the lead gasoline that is still used in the UAE. However, the clay process is very effective in removing the lead and to a lesser extent in removing the calcium. The high discrepancy of metal content between recycled (treated) oil and the recycled oil with additives could be a result of mixing recycled oil with large quantities of fresh oil. Zinc, phosphorous and magnesium present in high quantities in fresh oil. The origin of each metal found in used oil is included in Table 4.

CONCLUSIONS

There are good economical and environmental incentives to recycle used oil in UAE and other countries in the region. More attention and education toward oil recycling are needed. Treated, used oil can become a viable fuel resource and could substitute large quantities of crude oil used to produce fresh base oil. More research and tests need to be conducted to compare different types of used oil, recycled oil, and fresh oil. New cost effective and environmentally benign processes need to be investigated to re-refine used oil.

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