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UNIDO REPORT

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CLEAN TECHNOLOGY FOR RECYCLING WASTE OIL

ANALYSIS OF SAMPLES OF WASTE OILS AND RECYCLED OIL

Veritas Petroleum Services

27 March 1992

CONTENTS

INTRODUCTION

In 1991, The United Nations Industrial Development Organisation (UNIDO) initiated a study to examine the scale of pollution and health problems arising from the disposal of waste lubricants. This study also included an appraisal of the financial benefits which might arise from the use of modern technology in the recycling of waste lubricants.

The study involved visits to 12 countries by experts appointed by UNIDO. Reports of these visits have been published separately.

During the course of these visits, the experts collected samples of waste lubricants and recycled lubricants (where available). The samples were sent to Veritas Petroleum Services, Høvik, Norway, for analysis under Contract No. 91/039. The results obtained are included in this report.

The contract with Veritas Petroleum Services excluded any tests for PCB and PAH content of the samples. These items were included in a separate contract with Instytut Technologii Nafty, Warszawa.

SUMMARY AND CONCLUSIONS

Samples were received from:

The Republic of Korea
Singapore (not included in the main project)
Indonesia
Kenya
Ecuador
Chile
Brazil
Senegal

It was not possible to obtain samples from Malaysia, and it is believed that samples were despatched from Pakistan, Zimbabwe and Egypt, but these were not received by the VPS laboratory in Norway.

It is understood that samples will be sent from Mexico in mid 1992. The samples will be analysed and the results will be published as an addendum to this report.

Budgetary constraints prohibited a fully comprehensive analysis of the samples, but a test regime was agreed with the following objectives.

The test regime for waste oil samples was designed to indicate the degree of contamination with other waste materials, the health hazards associated with a particular sample, and the potential as a feedstock for a recycling process.

Testing of the rerefined oils was designed to provide a measure of its suitability as a base oil feedstock for a lubricants blending plant.

Commercially available field test kits used for assessing the PCB content of used oils often rely upon the measurement of the total chlorine content as the PCB indicator. PCB compounds and chlorinated solvents will be included in the measurement of organically bound chlorine, suggesting that the field test kits measuring total chlorine can only provide a crude indication of the possible presence of PCBs.

In this study, measurements have been made of the total chlorine content (inorganic plus organic), and separately of the organic chlorine content.

The results of the PCB and PAH tests to be carried out in Warsaw will form a necessary part of any meaningful assessment of the health hazards and possible commercial value represented by the sample.

In some cases, both waste oil and recycled oils have been provided from the same source. However, these are not believed to be "before and after" processing samples of the same batch and, therefore, the results should not be used as an indicator of the performance of a particular recycling plant.

The test results on the sample of rerefined oil from Singapore show high values for Zinc and Phosphorus content. This suggests that an anti-wear additive package may have been added to the recycled base oil. It would, therefore, be misleading to view the results on this sample as indicative of the performance of the Meinken process - a better indicator is provided by the results of the tests on the recycled base oil supplied from Kenya, where a modern Meinken plant is in operation.

It would be appropriate, when the results from Warsaw are also available, to ask the individual experts to comment on both sets of data, since only they are aware of the history of the samples.

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : S. KOREA

Sample identification : (A) Waste oil from Dae Ho Petroleum Co.

(B) Waste oil from Samsung Refining Co.

(Samples provided by M.O.E.)

U.N.I.D.O. Reference	(a)	(b)			
V.P.S. Sample Number	7910265	7910266			
Colour, visual	Black	Dark Brown			
Density @ 15°C, ASTM D4052, Kg/m3	890	890			
Water % v/v, ASTM D95	0.1	0.8			
Flash point °C, ASTM D93	150	161			
TAN, mg NaOH/g, ASTM D664	4.45	0.94			
Pentane insol, % m/m, ASTM D893(b)	0.07	0.57			
Chlorine, mg/kg (neutron activation)	1900	390			
Org. bound chlorine mg/kg (extraction & neutron activation)	1900	390			
Sulphur, % m/m ASTM D4239	0.25	0.41			

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : SINGAPORE

Sample identification : (A) Waste oil collected from Pioneer Refining Company

U.N.I.D.O. Reference	(a)				
V.P.S. Sample Number	7910231				
Colour, visual	Black				
Density @ 15°C, ASTM D4052, Kg/m3	n.a.				
Water % v/v, ASTM D95	approx. 20				
Flash point °C, ASTM D93	n.a.				
TAN, mg NaOH/g, ASTM D664	4.50				
Pentane insol, % m/m, ASTM D893(b)	1.32				
Chlorine, mg/kg (neutron activation)	n.a.*				
Org. bound chlorine mg/kg (extraction & neutron activation)	n.a.				
Sulphur, % m/m ASTM D4239	0.79				

* Chlorine (halogen) by "Dorhmann" method 1670 mg/L

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : INDONESIA

Sample identification :

(A) Waste oil from used lubricating oil collection station.

(B) Used lubricating oil from car service station.

(C) Used lubricating oil from car service station.

(D) Used lubricating oil from car service station.

(E) Waste industrial lubricant.

U.N.I.D.O. Reference	(A)	(B)	(C)	(D)	(E)
V.P.S. Sample Number	7910488	7910489	7910490	7910491	7910492
Colour, visual	Black	Brown	Black	Black	Black
Density @ 15°C, ASTM D4052, Kg/m3	903	904	890	895	907
Water % v/v, ASTM D95	0.1	<0.1	1.3	1.1	<0.1
Flash point °C, ASTM D93	174	143	190	199	211
TAN, mg NaOH/g, ASTM D664	2.28	3.92	3.03	4.41	3.45
Pentane insol, % m/m, ASTM D893(b)	0.14	0.18	0.13	0.05	0.96
Chlorine, mg/kg (neutron activation)	100	160	120	38	85
Org. bound chlorine mg/kg (extraction & neutron activation)	92	120	110	36	76
Sulphur, % m/m ASTM D4239	1.42	1.03	0.67	0.50	1.06

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : KENYA

Sample identification : (C) Waste oil feedstock to Optimum Lubricants recycling plant.

U.N.I.D.O. Reference	(C)				
V.P.S. Sample Number	7910672				
Colour, visual	Black				
Density @ 15°C, ASTM D4052, Kg/m3	870				
Water % v/v, ASTM D95	0.5				
Flash point °C, ASTM D93	66				
TAN, mg NaOH/g, ASTM D664	3.6				
Pentane insol, % m/m, ASTM D893(b)	0.41				
Chlorine, mg/kg (neutron activation)	36				
Org. bound chlorine mg/kg (extraction & neutron activation)	76				
Sulphur, % m/m ASTM D4239	0.35				

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin: ECUADOR

Sample identification:

(B) Riobamba - Motor Car Oil (Gasoline)

(C) Quito - Motor Car Oil (Gasoline)

(D) Quito - Diesel Motor Oil

(E) Guayaquil - Diesel Motor Boat Oil

(F) Guayaquil - Motor Car Oil (Gasoline)

U.N.I.D.O. Reference	(B)	(C)	(D)	(E)	(F)
V.P.S. Sample Number	7910585	7910586	7910587	7910588	7910589
Colour, visual	Black	Dark Brown	Black	Black	Black
Density @ 15°C, ASTM D4052, Kg/m3	911	899	905	887	898
Water % v/v, ASTM D95	0.2	<0.1	<0.1	0.2	0.3
Flash point °C, ASTM D93	83	103	230	132	96
TAN, mg NaOH/g, ASTM D664	7.1	4.5	8.0	5.9	7.8
Pentane insol, % m/m, ASTM D893(b)	2.25(1)	0.78	1.78(2)	0.09	1.52
Chlorine, mg/kg (neutron activation)	82*	85*	360	260	80*
Org. bound chlorine mg/kg (extraction & neutron activation)	56*	45*	140	240	46*
Sulphur, % m/m ASTM D4239	0.80	0.22	0.72	0.60	

(1) Toluene insolubles, % m/m, 1.8

(2) " " " " 1.60

*Inorganic and organically bound bromine compounds also detected at similar levels.

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : CHILE

Sample identification :

(A) Composite of used gasoline engine oils from a number of oil change centres in Santiago.

(D) Composite of used diesel engine oils from a number of oil change centres in Santiago.

(E) Composite of used oils taken from collecting tanks at Derivadas de Petroleos S.A., DEPSA, Chile.

U.N.I.D.O. Reference	(A)	(D)	(E)		
V.P.S. Sample Number	7910766	7910769	7940770		
Colour, visual	Brown	Black	Black		
Density @ 15°C, ASTM D4052, Kg/m3	902	911	907		
Water % v/v, ASTM D95	0.2	0.1	5.6		
Flash point °C, ASTM D93	94	195	88		
TAN, mg NaOH/g, ASTM D664	3.6	12.6	7.9		
Pentane insol, % m/m, ASTM D893(b)	0.53	2.02	1.37		
Chlorine, mg/kg (neutron activation)	900	240	1100		
Org. bound chlorine mg/kg (extraction & neutron activation)	320	220	650		
Sulphur, % m/m ASTM D4239	0.97	1.0	0.95		

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : BRAZIL

Sample identification : (C) Average waste oil, Refinery 1, SAO PAULO

(D) Average waste oil, Refinery 2, RIO DE JANEIRO

U.N.I.D.O. Reference	(C)	(D)			
V.P.S. Sample Number	7920003	7920004			
Colour, visual	Brown	Black			
Density @ 15°C, ASTM D4052, Kg/m3	911	904			
Water % v/v, ASTM D95	6.5	0.1			
Flash point °C, ASTM D93	161	117			
TAN, mg NaOH/g, ASTM D664	4.0	8.8			
Pentane insol, % m/m, ASTM D893(b)	1.42	0.66			
Chlorine, mg/kg (neutron activation)	440	340			
Org. bound chlorine mg/kg (extraction & neutron activation)	280	220			
Sulphur, % m/m ASTM D4239	0.94	0.99			

U.N.I.D.O. WASTE OIL SAMPLES

Country of origin : SENEGAL

Sample identification : A) Huile Usèe SRH Dakar No. 1

B) Huile Usèe SRH Dakar No. 2

U.N.I.D.O. Reference	A	B			
V.P.S. Sample Number	7920025	7920026			
Colour. visual	Black	Black			
Density @ 15°C, ASTM D4052, Kg/m3	907	907			
Water % v/v, ASTM D95	3.0	3.0			
Flash point °C, ASTM D93	179	177			
TAN, mg NaOH/g, ASTM D664	5.4	6.3			
Pentane insol, % m/m, ASTM D893(b)	1.25	1.25			
Chlorine, mg/kg (neutron activation)	460	410			
Org. bound chlorine mg/kg (extraction & neutron activation)	240	260			
Sulphur, % m/m ASTM D4239	0.92	0.87			

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : S. KOREA

Sample identification : (A) Re refined oil from SAMSUNG REFINING CO.

(B) Re refined oil from DONSUNG REFINING CO.
(Sample provided by M.O.E.)

U.N.I.D.O. Reference	(a)	(b)
V.P.S. Sample number	7910267	7910268
Colour ASTM D1500	7.0	L 4.5
Density @ 15°C, Kg/m3, ASTM D4052	885	847
Viscosity, cSt. @ 40°C, ASTM D445	77	39
Viscosity, cSt. @ 100°C, ASTM D445	9.4	6.1
Micro carbon residue, % m/m, ASTM D4530	0.1	0.1
Pour point, °C, ASTM D97	-12	-12
Ash, % m/m, ASTM D482 (t=540°C)	0.01	<0.01
Sulphur, % m/m, ASTM D4239	0.28	0.25
Chlorine, mg/kg, (neutron activation)	n.a.*	190
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	n.a.	190
Vanadium, mg/kg, Ashing I.C.P.	<1	<1
Sodium, mg/kg, Ashing I.C.P.	<1	1
Aluminium, mg/kg, Ashing I.C.P.	<1	7
Silicon, mg/kg, Ashing I.C.P.	<1	5
Iron, mg/kg, Ashing I.C.P.	1	1
Nickel, mg/kg, Ashing I.C.P.	<1	<1
Manganese, mg/kg, Ashing I.C.P.	<1	<1
Calcium, mg/kg, Ashing I.C.P.	<1	<1
Lead, mg/kg, Dilution I.C.P.	<1	<1
Chrome, mg/kg, Dilution I.C.P.	<1	<1
Cadmium, mg/kg, Dilution I.C.P.	<1	<1
Arsenic, mg/kg, Dilution I.C.P.	<5	<5
Zinc, mg/kg, Dilution I.C.P.	2	<1
Phosphorous, mg/kg, Dilution I.C.P.	16	18

* Chlorine (halogen) by "Dorhmann method" - 40 mg/L

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : SINGAPORE

Sample identification : (A) Re refined oil collected from Pioneer Refining Co.

U.N.I.D.O. Reference	(a)	
V.P.S. Sample number	7910232	
Colour ASTM D1500	L 5.5	
Density @ 15°C, Kg/m3, ASTM D4052	889	
Viscosity, cSt. @ 40°C, ASTM D445	50	
Viscosity, cSt. @ 100°C, ASTM D445	7.4	
Micro carbon residue, % m/m, ASTM D4530	1.6	
Pour point, °C, ASTM D97	0	
Ash, % m/m, ASTM D482 (t=540°C)	I.18	
Sulphur, % m/m, ASTM D4239	1.15	
Chlorine, mg/kg, (neutron activation)	120	
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	120	
Vanadium, mg/kg, Ashing I.C.P.	< 1	
Sodium, mg/kg, Ashing I.C.P.	1	
Aluminium, mg/kg, Ashing I.C.P.	< 1	
Silicon, mg/kg, Ashing I.C.P.	< 1	
Iron, mg/kg, Ashing I.C.P.	4	
Nickel, mg/kg, Ashing I.C.P.	< 1	
Manganese, mg/kg, Ashing I.C.P.	< 1	
Calcium, mg/kg, Ashing I.C.P.	1	
Lead, mg/kg, Dilution I.C.P.	8	
Chrome, mg/kg, Dilution I.C.P.	< 1	
Cadmium, mg/kg, Dilution I.C.P.	< 1	
Arsenic, mg/kg, Dilution I.C.P.	< 5	
Zinc, mg/kg, Dilution I.C.P.	4300	
Phosphorous, mg/kg, Dilution I.C.P.	3200	

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : INDONESIA

Sample identification : (F) Re refined oil provided to Unido expert - origin believed to be a plant in the U.S.A.

U.N.I.D.O. Reference	(F)	
V.P.S. Sample number	7910493	
Colour ASTM D1500	0.5	
Density @ 15°C, Kg/m3, ASTM D4052	871	
Viscosity, cSt. @ 40°C, ASTM D445	29.3	
Viscosity, cSt. @ 100°C, ASTM D445	5.06	
Micro carbon residue, % m/m, ASTM D4530	<0.1	
Pour point, °C, ASTM D97	-9	
Ash, % m/m, ASTM D482 (t=540°C)	<0.01	
Sulphur, % m/m, ASTM D4239	0.02	
Chlorine, mg/kg, (neutron activation)	0.4	
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	0.2	
Vanadium, mg/kg, Ashing I.C.P.	3	
Sodium, mg/kg, Ashing I.C.P.	1	
Aluminium, mg/kg, Ashing I.C.P.	1	
Silicon, mg/kg, Ashing I.C.P.	<1	
Iron, mg/kg, Ashing I.C.P.	<1	
Nickel, mg/kg, Ashing I.C.P.	1	
Manganese, mg/kg, Ashing I.C.P.	<1	
Calcium, mg/kg, Ashing I.C.P.	1	
Lead, mg/kg, Dilution I.C.P.	<1	
Chrome, mg/kg, Dilution I.C.P.	<1	
Cadmium, mg/kg, Dilution I.C.P.	<1	
Arsenic, mg/kg, Dilution I.C.P.	<1	
Zinc, mg/kg, Dilution I.C.P.	<1	
Phosphorous, mg/kg, Dilution I.C.P.	<1	

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : KENYA

Sample identification : (A) Optimum Lubricants Recycling Plant - Finished Spindle Oil

(D) Optimum Lubricants Recycling Plant - Finished Base Oil

U.N.I.D.O. Reference	(A)	(D)
V.P.S. Sample number	7910671	7910673
Colour ASTM D1500	2.5	L 4.0
Density @ 15°C, Kg/m3, ASTM D4052	875	890
Viscosity, cSt. @ 40°C, ASTM D445	32.8	128.5
Viscosity, cSt. @ 100°C, ASTM D445	5.6	13.4
Micro carbon residue, % m/m, ASTM D4530	<0.1	0.1
Pour point, °C, ASTM D97	+ 3	-6
Ash, % m/m, ASTM D482 (t=540°C)	<0.01	0.01
Sulphur, % m/m, ASTM D4239	0.33	0.35
Chlorine, mg/kg, (neutron activation)	13	3
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	13	3
Vanadium, mg/kg, Ashing I.C.P.	< 1	3
Sodium, mg/kg, Ashing I.C.P.	< 1	2
Aluminium, mg/kg, Ashing I.C.P.	< 1	13
Silicon, mg/kg, Ashing I.C.P.	1	< 1
Iron, mg/kg, Ashing I.C.P.	1	13
Nickel, mg/kg, Ashing I.C.P.	< 1	2
Manganese, mg/kg, Ashing I.C.P.	< 1	3
Calcium, mg/kg, Ashing I.C.P.	< 1	2
Lead, mg/kg, Dilution I.C.P.	< 1	< 1
Chrome, mg/kg, Dilution I.C.P.	< 1	< 1
Cadmium, mg/kg, Dilution I.C.P.	< 1	< 1
Arsenic, mg/kg, Dilution I.C.P.	< 1	< 1
Zinc, mg/kg, Dilution I.C.P.	< 1	3
Phosphorous, mg/kg, Dilution I.C.P.	< 1	< 1

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : CHILE

Sample identification : (F) Composite of re refined oils taken from storage tanks at Derivadas de Petroleos S.A., Depsa, Chile.

U.N.I.D.O. Reference	(F)	
V.P.S. Sample number	7910771	
Colour ASTM D1500	3.5	
Density @ 15°C, Kg/m3, ASTM D4052	882	
Viscosity, cSt. @ 40°C, ASTM D445	61	
Viscosity, cSt. @ 100°C, ASTM D445	8.1	
Micro carbon residue, % m/m, ASTM D4530	0.2	
Pour point, °C, ASTM D97	-9	
Ash, % m/m, ASTM D482 (t=540°C)	0.05	
Sulphur, % m/m, ASTM D4239	0.49	
Chlorine, mg/kg, (neutron activation)	48	
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	49	
Vanadium, mg/kg, Ashing I.C.P.	1	
Sodium, mg/kg, Ashing I.C.P.	90	
Aluminium, mg/kg, Ashing I.C.P.	2	
Silicon, mg/kg, Ashing I.C.P.	9	
Iron, mg/kg, Ashing I.C.P.	9	
Nickel, mg/kg, Ashing I.C.P.	< 1	
Manganese, mg/kg, Ashing I.C.P.	9	
Calcium, mg/kg, Ashing I.C.P.	13	
Lead, mg/kg, Dilution I.C.P.	10	
Chrome, mg/kg, Dilution I.C.P.	< 1	
Cadmium, mg/kg, Dilution I.C.P.	< 1	
Arsenic, mg/kg, Dilution I.C.P.	< 1	
Zinc, mg/kg, Dilution I.C.P.	1	
Phosphorous, mg/kg, Dilution I.C.P.	10	

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : BRAZIL

Sample identification : (E) Regenerated oil, Refinery 1, Sao Paulo

(F) Regenerated oil, refinery 2, Rio de Ja Neiro

U.N.I.D.O. Reference	(E)	(F)
V.P.S. Sample number	7920005	7920006
Colour ASTM D1500	2.5	L 3.5
Density @ 15°C, Kg/m3, ASTM D4052	887	888
Viscosity, cSt. @ 40°C, ASTM D445	67	77
Viscosity, cSt. @ 100°C, ASTM D445	8.7	9.8
Micro carbon residue, % m/m, ASTM D4530	0.2	0.2
Pour point, °C, ASTM D97	0	0
Ash, % m/m, ASTM D482 (t=540°C)	0.01	<0.01
Sulphur, % m/m, ASTM D4239	0.48	0.49
Chlorine, mg/kg, (neutron activation)	23	63
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	22	69
Vanadium, mg/kg, Ashing I.C.P.	< 1	< 1
Sodium, mg/kg, Ashing I.C.P.	6	< 1
Aluminium, mg/kg, Ashing I.C.P.	1	< 1
Silicon, mg/kg, Ashing I.C.P.	1	< 1
Iron, mg/kg, Ashing I.C.P.	1	< 1
Nickel, mg/kg, Ashing I.C.P.	< 1	< 1
Manganese, mg/kg, Ashing I.C.P.	< 1	< 1
Calcium, mg/kg, Ashing I.C.P.	2	< 1
Lead, mg/kg, Dilution I.C.P.	< 1	< 1
Chrome, mg/kg, Dilution I.C.P.	< 1	< 1
Cadmium, mg/kg, Dilution I.C.P.	< 1	< 1
Arsenic, mg/kg, Dilution I.C.P.	< 1	< 1
Zinc, mg/kg, Dilution I.C.P.	< 1	< 1
Phosphorous, mg/kg, Dilution I.C.P.	1	< 1

U.N.I.D.O. RE REFINED OIL SAMPLES

Country of origin : SENEGAL

Sample identification : C) Huile Regenerèe à L'Acide, SRH Dakar No. 1

D) Huile Regenerèe à L'Acide, SRH Dakar No. 2

U.N.I.D.O. Reference	C	D
V.P.S. Sample number	7920027	7920028
Colour ASTM D1500	4.0	4.0
Density @ 15°C, Kg/m3, ASTM D4052	891	891
Viscosity, cSt. @ 40°C, ASTM D445	111	111
Viscosity, cSt. @ 100°C, ASTM D445	12.3	12.3
Micro carbon residue, % m/m, ASTM D4530	0.3	0.3
Pour point, °C, ASTM D97	-3	-3
Ash, % m/m, ASTM D482 (t=540°C)	0.01	0.01
Sulphur, % m/m, ASTM D4239	0.71	0.74
Chlorine, mg/kg, (neutron activation)	24	23
Org. bound chlorine, mg/kg, (extraction plus neutron activation)	23	24
Vanadium, mg/kg, Ashing I.C.P.	< 1	< 1
Sodium, mg/kg, Ashing I.C.P.	< 1	< 1
Aluminium, mg/kg, Ashing I.C.P.	< 1	< 1
Silicon, mg/kg, Ashing I.C.P.	< 1	< 1
Iron, mg/kg, Ashing I.C.P.	< 1	< 1
Nickel, mg/kg, Ashing I.C.P.	< 1	< 1
Manganese, mg/kg, Ashing I.C.P.	< 1	< 1
Calcium, mg/kg, Ashing I.C.P.	< 1	< 1
Lead, mg/kg, Dilution I.C.P.	< 1	< 1
Chrome, mg/kg, Dilution I.C.P.	< 1	< 1
Cadmium, mg/kg, Dilution I.C.P.	< 1	< 1
Arsenic, mg/kg, Dilution I.C.P.	< 1	< 1
Zinc, mg/kg, Dilution I.C.P.	< 1	< 1
Phosphorous, mg kg, Dilution I.C.P.	< 1	< 1