*Full Length Research Paper*

# Petroleum cuts as solvent extractor for oil recovery from petroleum sludge

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**Petroleum cuts were used as solvents to recover oil from dry and semi dry petroleum sludge. The effects of various parameters, namely shaking time, temperature and the solvent volume upon oil recovery were investigated. Within the range of the studied operating conditions herein, the maximum oil recovery obtained varied from 80 - 97% depending upon the amount of oil within the sludge and the solvent efficiency used for extraction. A detailed study of the kinetics of solvent extraction based on oil recovery was carried out. This technology reuses of separated components and minimizing greatly the waste disposal problems created by land ban. The overall cost as well as time involved for recovery and the disposal of hydrocarbon residue has been decreased. Capillary gas chromatography was used to estimate the economic value and reuse of recovered oil.**

**Key words:** Petroleum cuts, solvent extraction, petroleum sludge, shaking time, oil recovery and capillary gas chromatography.

## INTRODUCTION

The heavy ends that separate from the crude oil are deposited on the bottoms of storage vessels are known as sludge or "tank bottoms". Sludge is a combination of hydrocarbons, sediment, paraffin and water. Sludge can accelerate corrosion, reduce storage capacity and disrupt operations. Paraffin-based crude oil sludge forms when the molecular orbital of individual straight-chain hydrocarbons are blended by proximity, producing an induced dipole force that resists separation. These dipole forces are called London Dispersion Forces, or Van der Waal bonds, and are responsible for like molecular aggregation Greg et al., 2004.

A huge amount of oily sludge is generated from petroleum refineries during their storage operations and through on-going operations. This sludge contains a reasonable amount of oil (hydrocarbons). Most of the storage tanks and other vessels in a refinery contain bottom sediments which accumulate over time. These sediments contain solids settled along with the hydrocarbons and water. The industrial sludge could contain not only organic and inorganic matter, but also bacteria and viruses, oil and grease, nutrients such as nitrogen and phosphorus, heavy metals and organochlorine compounds Priestly, 1991; Lin and Hsiu, 1997.

Sludge usually accumulates in refineries because of pump failures, desalter failure, oil draining from tanks and operation units, periodic cleaning of storage tanks and pipeline ruptures (Kuriakose and Manjooran, 2001).

Saikia et al. (2003) discussed that during cleaning operations, all these wastes are removed and dumped in a nearby pit. The typical composition of sludge is 10 -12% solids, 30 - 50% water and 30 - 50% by weight oil Saikia et al., 2003. Because of its hazardous nature, storage and management oily sludge is a crucial issue in almost all refineries. Apart from this, during storage and from the pit also poses a problem as it leads to contamination of

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**Table 1.** Characterization of the studied sludge sample.

| Test Sample | Physical properties | Water content, wt%, ASTM D95 | Volatile matter @ 105°C for 24 h, wt% | Solid content @550 °C, wt% | Nonvolatile Hydrocarbons, wt% | Carbon residue, wt%, ASTM D189 | Ash, wt%, ASTM D482 |
|---|---|---|---|---|---|---|---|
| TK-C2 | Dried solid, oil content melted @ 65°C | Nil | 0.73 | 16.73 | 82.54 | 29.60 | 15.63 |
| TK-C15 | Semi dry solid, oil content  melted @ 50°C | Nil | 6.69 | 2.88 | 90.43 | 13.03 | 2.63 |

ground water. In incineration processes oil sludge or oil waste is incinerated to give ash, flue gases, and energy,the energy is usually used for the production of steam for steam turbines, or heating, and it is used as a heating source for the waste oil-reclaiming unit Silva et al., 1998. Several process technology options for treating petroleum sludge have emerged during the past several years in response to the enhancement of environmental regulation governing these wastes. Current technologies for treating refinery wastes are very expensive and are mostly inadequate to meet current and future regulations Conaway, 1999. Most of these technologies do not satisfy a new sustainable development approach and the elimination of the greenhouse effect leading to climate change. There is a demand for a universally applicable technology for the treatment of petroleum sludge. The technology should be capable of recovering petroleum in a form that can be redirected to a refinery for further processing to produce higher quality petroleum products (Maria and Shiva, 2005). Over the next few decades, oil will remain the single largest source of primary energy (Einar, 2002).

Solvent extraction can be both an effective and cost efficient process for separating hazardous contaminants from non-hazardous materials and concentrating the hazardous materials for further treatment. Because the contaminants are separated, the treatment selected can be targeted to the contaminant. As a result of solvent extraction, some contaminants may be recycled or reused in manufacturing, thus, minimizing disposal requirements (Environmental Protection Agency, United States, 1996).

## MATERIALS AND METHODS

### Chemical materials

i) n-Heptane (pure) 99% from sds.
ii) Ethylene dichloride 99% from Egyptian petrochemical company.
iii) Toluene 99% from Elameria Petroleum Company.
iv) Methylene dichloride and diethyl ether each 99% from ADWIC.
v) Naphtha cut (straight run naphtha), (Table 1).
vi) Kerosene cut (straight run naphtha), (Table 1).

### Sampling techniques

Representative samples from two different crude oil tanks (TK-C2 & TK-C15) are collected during manual clean. Solid sample from TK-C2 and semi dried sample from TK-C15.

### *Solvent extractions of samples*

The solvents chosen in our study are methylene dichloride, diethyl ether, ethylene dichloride, toluene, n-heptane, naphtha cut and kerosene cut. Kinetic study was performed to estimate the ideal conditions of extraction.

### *Characterization of samples*

Oily sludge is a mixture of different kinds of hydrocarbons (light and heavy fractions), water, soil, and suspended materials (Silva et al., 1998). The following fractions of sludge were assessed (Table 1).

i) Water content: - was measured according to ASTM - D95 American Standard for Testing and Materials, 2001 for standard method.
ii) Volatile hydrocarbon content: to determine the amount of light hydrocarbons inside the oily sludge, a sample of known mass was put in an oven (with ventilation) at 105°C for 24 h. The reduction in mass indicated the moisture and light hydrocarbon content in the sludge. As water content was measured previously, the light hydrocarbon content (in wt. %) was calculated as follows:

Light hydrocarbon = ([(reduced mass in g)/ (mass of tested sample in g)] x 100%) – (water content in wt. %)

iii) Solid content: Dried samples (105°C) were placed in a furnace at 550 °C for 120 min. The residue showed the solid content of the sludge as weight percent:

Solid = [(residue remaining after burning in g)/ (mass of tested sample in g)] x 100%

iv) Nonvolatile hydrocarbon content - after measuring the water content, light hydrocarbon content, and solids content, the nonvolatile hydrocarbon content can be calculated in weight percent as follows:

Nonvolatile hydrocarbon = 100% - (light hydrocarbon in wt. % + solid in wt. % + water content in wt. %).

**Table 2.** Characterization of petroleum cuts as solvent extraction.

| Test / Sample | Specific gravity @15 °C/15 °C, ASTM D4052 | Flash point, °F, ASTM D93 | Distillation, ASTM D86 | | Color Lovibond, IP 17 | Sulfur content, wt%, ASTM D1266 |
|---|---|---|---|---|---|---|
| | | | Initial, °C | Final, °C | | |
| Naphtha Cut | 0.711 | - | 38 | 168 | 0.5 | 0.08 |
| Kerosene Cut | 0.789 | 97 | 137 | 227 | 1 | 0.25 |

**Table 3.** Hydrocarbons recovery from solid sludge TK-C2 at various volumes of the studied solvents.

| Solvent type / Sludge-solventration | N-Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 1- 4 | 45.50 | 50.20 | 50.30 | 51.45 | 49.60 | 65.56 | 63.16 |
| 1 - 7 | 60.70 | 68.14 | 65.54 | 67.10 | 65.45 | 80.54 | 83.99 |
| 1 - 8 | 66.89 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |
| 1 - 9 | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | -- | -- |
| 1 -10 | 72.48 | -- | -- | -- | -- | - | - |

### Preparation of samples

Solid samples (TK-C2) are grinded, and then sieved with ASTM sieve 60/80 and then collected from receiver. Weighting 5 g of sample in each bottle with cap and adding threefold of solvent, at 70°C and shaking for 30 min., allowing to settling and decant of liquid into vials and kept in the refrigerator to be injected later in gas chromatography.

### Gas chromatography

Recovered hydrocarbon samples were analyzed using Hewlett Packard gas chromatograph of model 5890 series Π equipped with flame ionization detector (FID), using HP-1 fused silica capillary column packed with 100% dimethyl polysiloxane as stationary phase, 100 m in length, 0.53 mm int. diameter, and thickness film 0.5 μm. Nitrogen (Oxygen-free) was used as mobile phase, all gas flow rates were set to manufacturer specifications, performing conditioning and standardization of the system. The flow rate was measured from the end of the column with a soap bubble flow rate. Methane as an unretained marker was used to correct the dead volume in the column. Injections were made in split mode with a split ratio of 1:15. Glass linear is packed with deactivated glass wool which changed after six injections .The column oven was programmed from 50°C (hold 1 min) to 350°C at a rate 5°C / min with 190 min hold at 350°C. The injector temperature is set at 300°C and the detector temperature is 320°C. The data was estimated by integration of the area under the resolved chromatographic profile, using total Chrom, Ver. 6.2.1 software, via interface NCI 900, manual injection of 1 μL of samples after washing syringe with sample's solvent and injected 1 μL of solvent.

### RESULTS

### Characterization of sludge samples and petroleum cuts

The characterization of the two studied sludge samples from two different crude oil tanks TK-C2 and TK-C15 are given in Table 1. The physicochemical properties of these two cuts are measured according to the standard methods ASTM and given in Table 2.

### Factors affecting the recovery of hydrocarbons

#### Solvent - sludge ratio

Different types and volumes of the studied solvents in the extraction process from solid sludge and semisolid sludge were selected and given in Tables 3 and 4. The addition occurs as batches of each 5 min with the minimum ratio 1:2 (sludge *(gram)*: solvent (ml)).

#### Temperature

The temperature was studied at the ideal sludge-solvent ratio and at shaking time 45 min. This study carried out for both solid sludge TK-C2 and semi solid sludge TK-C15 at three different temperatures, room temperature 35, 70 and 80°C the effect of temperature on the oil recovery from solid sludge was given in Table 5 and from semi solid sludge was given at Table 6.

#### Shaking time

The effect of shaking time (period of shaking) was studied at ideal sludge-solvent ratio and at temperature 70°C that obtained from the pervious study. The effect of shaking time on the oil recovery from solid sludge was given in Table 7 and from semi solid sludge was given in Table 8.

**Table 4.** Hydrocarbons recovery from semi solid sludge TK-C15 at various volumes of the studied solvents.

| Solvent type / Sludge-solvent ratio | N-Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 1 - 2 | 55.59 | 67.85 | 69.20 | 69.68 | 59.99 | 78.03 | 80.97 |
| 1 - 3 | 65.92 | 83.00 | 80.70 | 87.60 | 73.77 | 90.80 | 92.00 |
| 1 - 4 | 77.60 | 91.00 | 89.60 | 95.92 | 83.00 | 97.09 | 97.20 |
| 1 - 5 | 85.20 | 95.68 | 95.32 | 95.92 | 91.00 | 97.09 | 97.20 |
| 1 - 6 | 90.75 | 95.68 | 95.32 | -- | 95.06 | -- | -- |
| 1 - 7 | 94.26 | -- | -- | -- | 95.06 | -- | -- |
| 1 - 8 | 94.26 | -- | -- | -- | -- | -- | -- |

**Table 5.** Hydrocarbons recovery from solid sludge TK-C2 at various temperatures.

| Solvent type / Temperature (°C) | N-Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 35.00 | 48.70 | 44.14 | 40.16 | 45.97 | 49.54 | 47.73 | 48.21 |
| 70.00 | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |
| 80.00 | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |

**Table 6.** Hydrocarbons recovery from semi solid sludge TK-C15 at various temperatures.

| Solvent type / Temperature (°C) | N-Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 35.00 | 65.92 | 67.85 | 69.20 | 69.68 | 59.99 | 78.03 | 80.97 |
| 70.00 | 94.26 | 95.68 | 95.32 | 95.92 | 95.06 | 97.06 | 97.20 |
| 80.00 | 94.26 | 95.68 | 95.32 | 95.92 | 95.06 | 97.06 | 97.20 |

**Table 7.** Hydrocarbons recovery from solid sludge TK-C2 at various times.

| Solvent type / min. | N- Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 45.00 | 47.50 | 49.20 | 48.30 | 49.45 | 47.60 | 62.56 | 60.16 |
| 60.00 | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |
| 75.00 | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |

The recovery percentages of the paraffin and UCM using different solvents from solid sludge and semisolid sludge were given in Tables 9, 10 and Figures 1, 2, respectively. The used solvents for extraction were n-heptane, toluene, methylene dichloride ethylene dichloride and diethyl ether. In addition to the petroleum cuts naphtha and kerosene. The isoprenoids pristane and phytane and the ratios $nC_{17}$/pristane and $nC_{18}$/phytane from both solid and semisolid sludges were given in Tables 11 - 12 and shown in Figures 3 - 4, respectively.

The specific gravity of the recovered hydrocarbons from solid and semi solid sludge using petroleum cuts was given in Table 13,

## DISCUSSION

### Characterization of sludge samples and petroleum cuts

Table 1, showed that the sludge TK-C2 is dried solid and

**Table 8.** Hydrocarbons recovery from semi solid sludge TK-C15 at various times.

| Solvent type min. | N- Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| 15.00 | 65.92 | 67.85 | 69.20 | 69.68 | 59.99 | 78.03 | 80.97 |
| 30.00 | 81.00 | 88.00 | 86.96 | 85.00 | 78.77 | 89.00 | 90.00 |
| 45.00 | 94.26 | 95.68 | 95.32 | 95.92 | 95.06 | 97.09 | 97.20 |
| 60.00 | 94.26 | 95.68 | 95.32 | 95.92 | 95.06 | 97.09 | 97.20 |

**Table 9.** Recovery % of paraffins and UCM with different solvents from solid sludge.

| Solvent type / Carbon group type | N- Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| paraffin | 22.58 | 32.92 | 33.81 | 16.30 | 25.33 | 31.75 | 69.47 |
| UCM | 49.90 | 43.02 | 38.49 | 53.75 | 44.86 | 48.79 | 14.52 |
| Total Recovery | 72.48 | 75.94 | 72.30 | 70.05 | 70.19 | 80.54 | 83.99 |

**Table 10.** Recovery % of paraffins and UCM from semi solid sludge.

| Solvent type / Carbon group type | N- Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| paraffins | 30.301 | 36.656 | 23.894 | 41.789 | 20.823 | 44.284 | 89.40 |
| UCM | 63.959 | 59.024 | 71.426 | 54.131 | 74.237 | 52.806 | 7.80 |
| Total Recovery | 94.26 | 95.68 | 95.32 | 95.92 | 95.06 | 97.09 | 97.20 |

the second sludge TK-C15 is semi dry solid. From their physical properties which measured at the same conditions, it has been found that, the two sludge samples under study have no water content. The solid content and carbon residue are higher in the dry solid sludge TK-C2 than in the semi dry solid sludge TK-C15.

In this study, the solvents used for extracting hydrocarbons are methylene dichloride, diethyl ether, ethylene dichloride, toluene and n-heptane. Beside these solvents we have used naphtha cut and kerosene cut as solvent for hydrocarbons recovery from the studied of solid and semi solid sludge samples. From Table 2 their properties, the naphtha fraction started from pentane at boiling point 38°C until reached decane at boiling point 168°C and the kerosene fraction started from decane at boiling point 137°C until reached pentadecane at boiling point 227°C.

The sulfur content in kerosene fraction exhibits higher value than naphtha fraction, due to the high molecular weight and high specific gravity of kerosene fraction as shown in Table 2.

**Factors affecting the recovery of hydrocarbons**

*Solvent - sludge ratio*

In order to study the preferred and ideal solvent sludge ratio, we would measure the recovery of hydrocarbons from sludge using various volumes of the studied solvents (different sludge-solvent ratio) as given in Table 3. Various volumes of the studied solvents were used at constant temperature of 70°C and constant shaking time of 45 min until the recovery was fixed.

It has been found that toluene is the best single solvent used for extracting hydrocarbons from sludge giving recovery of 75.94% using a volume of 8 ml but it is difficult  to remove it from the recovered oil. But the petroleum fractions naphtha and kerosene cuts are preferred for the process of hydrocarbon recovery reaching 83.99% using volume 7 ml only from these cuts.

*Temperature*
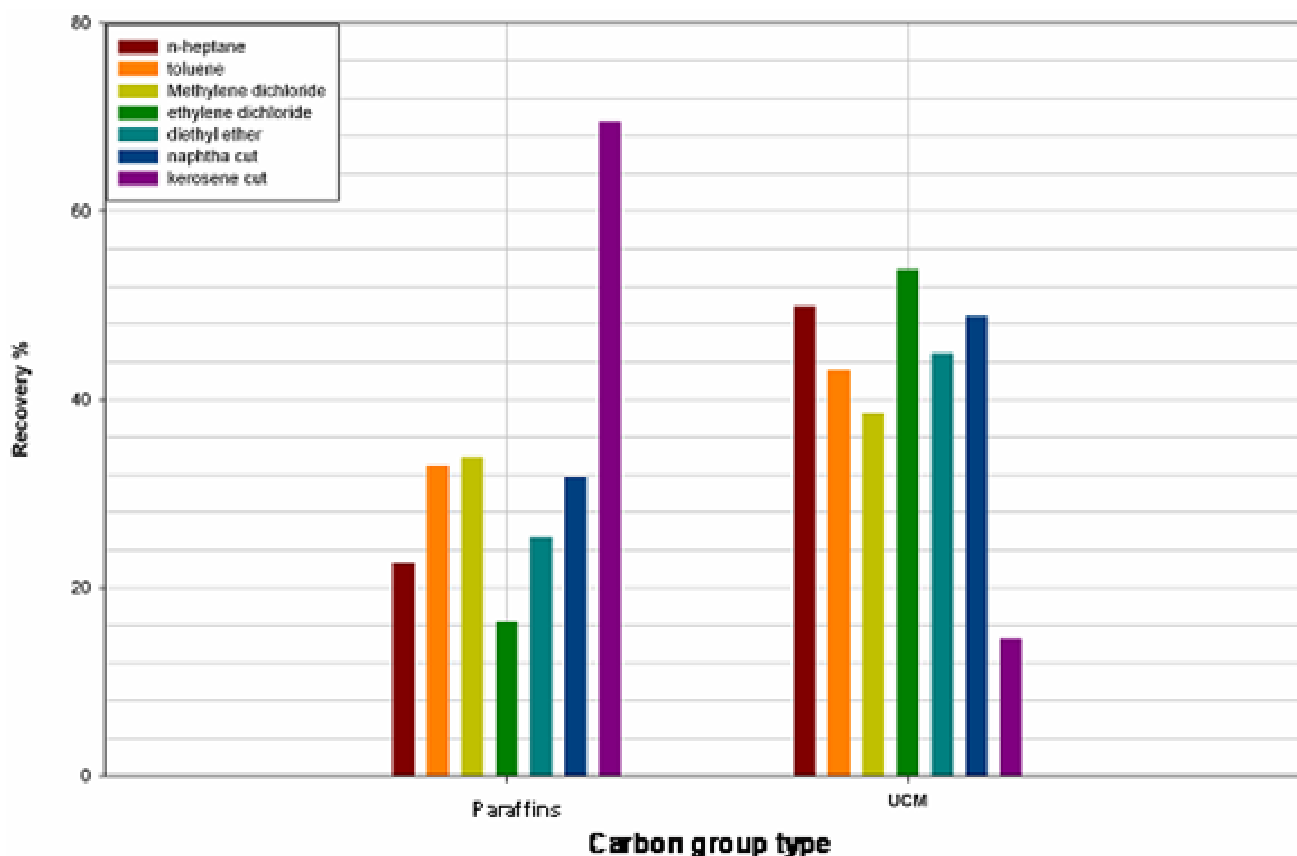
Generally, the oil recovery  increases as a function of

**Figure 1.** Distribution of paraffins and UCM with different solvents from solid sludge**.**

**Table 11.** Recovery % of pristane, phytane, nC17/pristane and nC18/phytane with different solvents from solid sludge.

| Solvent type / Carbon group type | N- Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| Pristane | 0.25 | 0.24 | 0.24 | 0.16 | 0.25 | 0.27 | 0.71 |
| Phytane | 0.35 | 0.31 | 0.32 | 0.22 | 0.32 | 0.38 | 0.87 |
| Pristane/Phytane | 0.71 | 0.77 | 0.76 | 0.74 | 0.76 | 0.71 | 0.82 |
| nC17/Pristane | 2.01 | 1.90 | 1.97 | 2.01 | 1.92 | 1.99 | 1.86 |
| n C18/Phytane | 1.51 | 1.41 | 1.51 | 1.51 | 1.47 | 1.50 | 1.52 |

**Table 12.** Recovery % of Pristane, Phytane, nC17/Pristane and nC18/Phytane from semi solid sludge.

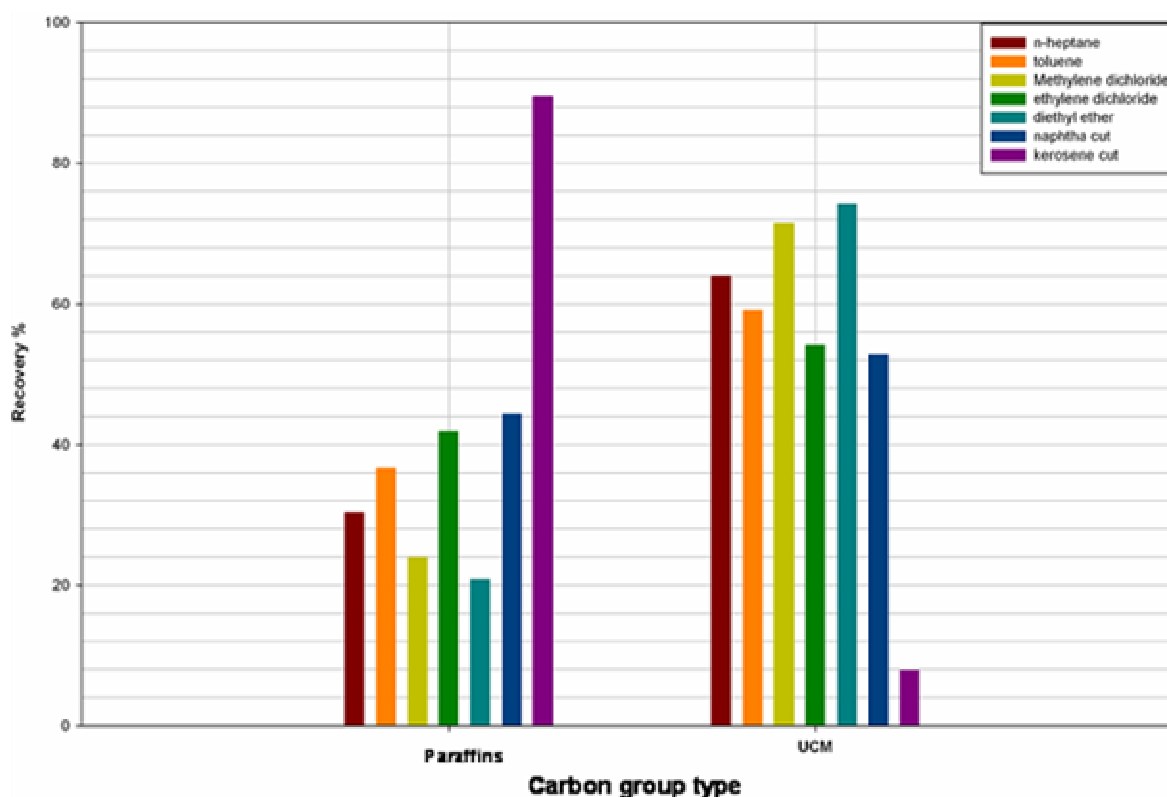| Solvent type / Carbon group type | N-Heptane | Toluene | Methylene dichloride | Ethylene dichloride | Diethyl ether | Naphtha cut | Kerosene cut |
|---|---|---|---|---|---|---|---|
| Pristane | 0.39 | 0.51 | 0.34 | 0.59 | 0.21 | 0.63 | 2.53 |
| Phytane | 0.57 | 0.66 | 0.52 | 0.72 | 0.34 | 0.87 | 3.03 |
| Pristane/Phytane | 0.69 | 0.77 | 0.66 | 0.81 | 0.61 | 0.73 | 0.83 |
| nC17/Pristane | 2.39 | 2.02 | 2.51 | 1.93 | 4.89 | 2.44 | 1.93 |
| n C18/Phytane | 1.47 | 1.41 | 1.51 | 1.42 | 2.68 | 1.68 | 1.50 |

**Figure 2.** Distribution of paraffins and UCM with different solvents from semi solid sludge.

**Table 13.** Specific gravity of recovered hydrocarbons**.**

| Sample Test | TK_C 2 : Naphtha 1 : 8 (g) :(ml) | TK_C 2 : Kerosene 1 : 8 (g) :(ml) | TK_C 15 : Naphtha 1 : 8 (g) :(ml) | TK_C 15 : Kerosene 1 : 8 (g) :(ml) |
|---|---|---|---|---|
| Specific gravity @15 °C/15 °C ASTM D5002[20] | 0.7901 | 0.8179 | 0.7893 | 0.8002 |

temperature till reached to the maximum value then, there is no increase in recovery with any increase of temperature. The temperature 70°C is preferred for all individual solvents and petroleum cuts using solid and semi solid sludge giving the maximum oil recovery for each solvent.

The petroleum cuts naphtha and kerosene are the more efficient solvents for the two studied sludge samples giving maximum oil recovery. Using petroleum cuts the oil recovery reached more than 80% from solid sludge and more than 97% from semi solid sludge.

**Shaking time**

The shaking time was affected by the physical properties of sludge samples, generally, the oil recovery increases as the shaking time increase. For solid sludge sample, the recovered oil was completed at shaking time 75 min. and for semi solid sludge sample; the recovered oil was completed at shaking time 45 min. Using the petroleum fractions naphtha and kerosene cuts at the optimum conditions of extraction, sludge-solvent 1 - 7 ratio, temperature 70°C and shaking time 75 min for solid sludge sample and 45 min for semi solid sludge, we can obtain maximum oil recovery. Tables 9, 10 and Figures 1, 2 indicate the recovery percentages of the paraffin and UCM using different solvents from solid sludge and semisolid sludge. It has been found that the total recovery from semi solid sludge was higher than that from solid sludge using the same solvents and the same conditions. This may be due to the nature of the sludge.

Naphtha and kerosene cuts exhibit highest hydrocarbon recovery from solid and semi solid sludge than the other
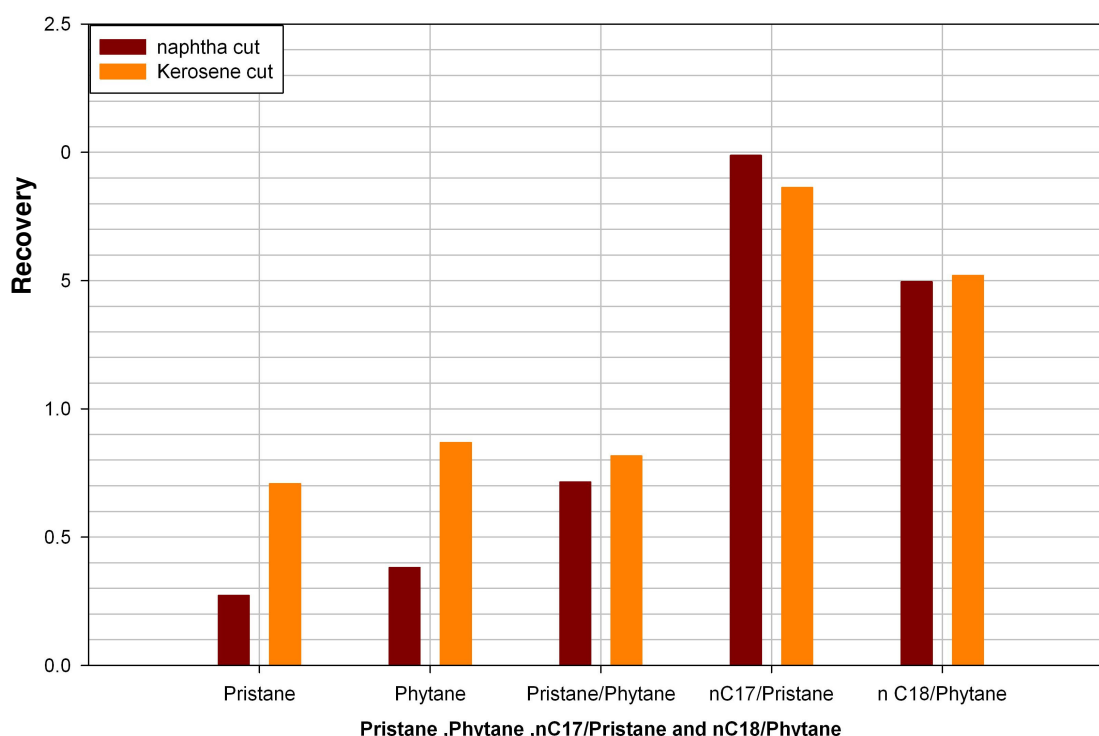
**Figure 3.** Isoprenoid ratios from solid sludge using naphtha and kerosene cuts.

used solvents, reflecting their powerful extraction. The pristane and phytane are important isoprenoids used as fingerprinting the original crude oil. There presence and their ratios (pristane / phytane) are used as biomarkers and give information about the extracted crude oil from sludge.

Also, the ratios $nC_{17}$/pristane and $nC_{18}$/phytane from both solid and semi solid sludge in Tables 11 and 12 and Figures 3 and 4 reflect the recovery of the normal paraffin's and their corresponding isoprenoids.

## The resulting benefits

### Value-added products

A substantial amount of money each year can be saved by applying this method by two ways: eliminated hydrocarbons from sediment being disposal and the recycled of the used solvent by refinery beside the amount of product that produced from recovered hydrocarbons (Table 13).

### Greenhouse gases (GHGs) mitigation

Gradual release of volatile hydrocarbons, which are

trapped in the colloidal particles, causes a significant increase in the amount of greenhouse gases worldwide. Light hydrocarbons are important contributors to the GHG effect; for example, methane has a heat-trapping effect 21 times higher than that of carbon dioxide. Therefore, the capture of these gases could have a huge impact on global warming. In addition, the reuse of sludge results in preserving natural resources and would substantially decrease the emission of GHG. This estimation is based on simple life cycle analysis of a fuel product. If a refinery is assumed to produce 30 000 tons of oily sludge each year (Environmental Protection Agency, United States, 1996). The recovery of only 30% of these sludge components per refinery will lead to the generation of 10 000 tons of fuel products per year per refinery. Bearing in mind that there are significant numbers of refineries across the world, the reduction of GHG will be considerable (Silva, 1998).

## Conclusion

i) The petroleum fractions naphtha and kerosene are the efficient solvents increasing the total recovery of hydrocarbon residue from oily sludge. This method is a stable, simpler, higher performing and significantly more economical process than the other solvent extraction
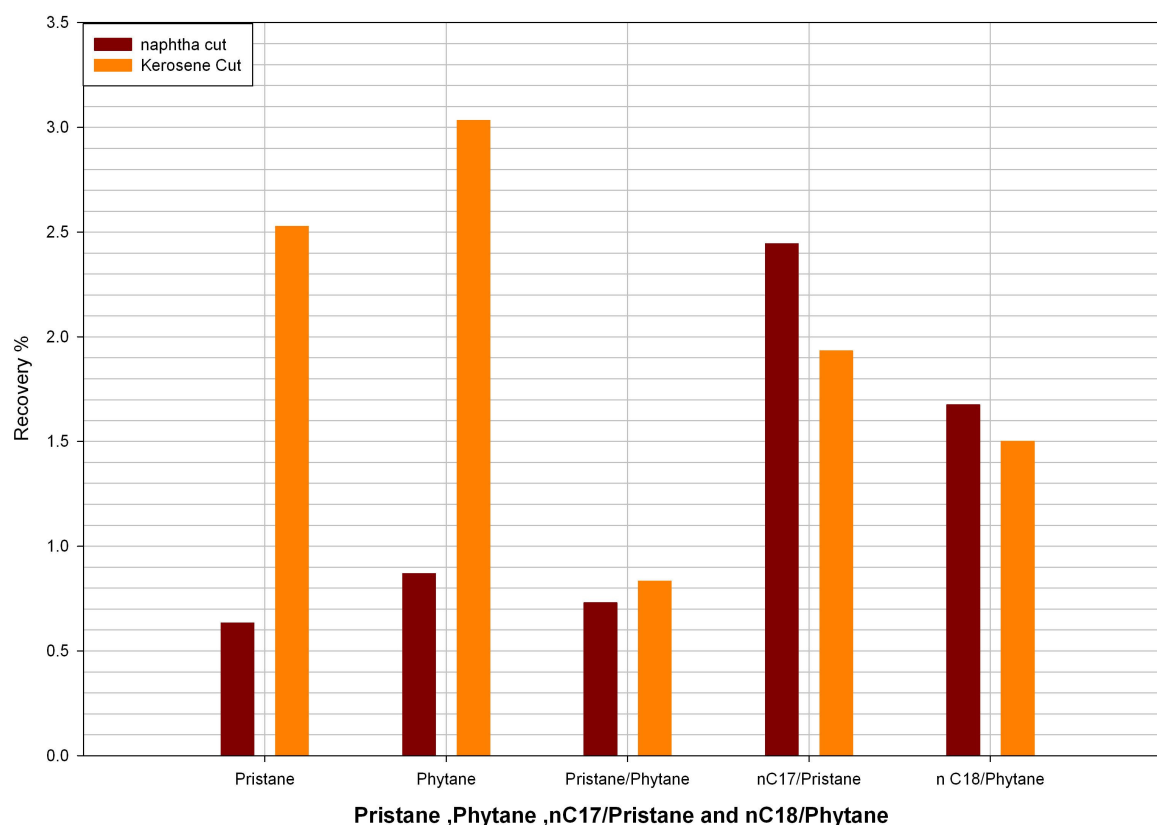
**Figure 4.** Isoprenoid ratios from semi solid sludge using naphtha and kerosene cuts.

technologies.

ii) Recycling of maximum hydrocarbon residue from a waste-stream product to a usable refinery product was achieved using the optimum conditions: sludge-naphtha or kerosene ratio 1 - 7, temperature 70°C and shaking time 75 min for solid sludge sample and 45 min for semi solid sludge.

iii) The selected petroleum fractions as solvent extraction change the management of petroleum wastes and reuse of separated components and solve the waste disposal problems created by land ban. Also, they decrease the overall cost and time involved for recovery and disposal of hydrocarbon residue.

**REFERENCE**

Greg MH, Robert AH, Zdenek D. (2004). Paraffinic sludge reduction in crude oil storage tanks through the use of shearing and resuspension, Acta Montanistica Slovaca  Ročník 9, číslo, 3: 184-188.

Priestly AT (1991). "Report on Sewage Sludge Treatment and Disposal-Environmental Programs and Research Needs from an Australian Perspective". CSIRO, Division of chemicals and Polymers. p. 1 – 44.

Lin CY, Hsiu WW (1997). "Effects of Sulphide, Sulphite and Sulphate on Acidogenesis in Upflow Anaerobic Sludge Blanket Process". J. Environ. Sci. Health A, 32: 1171 – 1184.

Kuriakose AP, Manjooran KB (2001). Bituminous paints from refinery sludge. Surface Coatings Technol., 145: 132–138.

Saikia MSB, Bora MM, Dutta NN (2003). Oil recovery from refinery sludge a case study, CHEMCON-2003, Abstract number-CHM 027.

Silva LJ, Sealock LJ, Elliot DC, Baker EG (1998). "Petroleum Sludge Treatment". Wiley Encyclopedia Series in Environmental Science, Environ. Anal. Remediation. 6: 3686-3695.

Conaway LM (1999). Method for processing oil refining waste. United States Patent, 5: 928 522.

Maria E, shiva H (2005). Can. J. Civ. Eng. 32: 164-169 (2005), NRC Canada, Published on the NRC Research Press Web site at http://cjce.nrc.ca, on 23 March.

Einar S (2002). The world summit on sustainable development the petroleum industry, perspective and response. In Proceedings of the 17th World Petroleum Congress, Rio de Janeiro, Brazil, 1–5 September 2002. Vol. 1. World Petroleum Congress, London, U.K.

Environmental Protection Agency, United States (1996), Solid Waste and Emergency Response(5102G),EPA 542-F-96-003.

American Standard for Testing and Materials (ASTM-D95-05) (2001). Standard Test Method forWater In Petroleum Products and Bituminous Material by Distillation.

American Standard for Testing and Materials (ASTM–D189-05) (2001), Standard Test Method for Conradson Carbon Residue of Petroleum Products.

American Standard for Testing and Materials (ASTM–D482-03) (2001). Standard Test Method for Ash from Petroleum Products.

American Standard for Testing and Materials (ASTM–D4052-96) (2001), Standard Test Method for Density and Relative Density by Digital Densitymeter.

American Standard for Testing and Materials (ASTM-D93-02a) (2001). Standard Test Method for Flash Point By Pensky Martens Closed Cup Tester.

American standard for testing and materials (ASTM – D86-05) (2001), Standard Test Method for distillation ofpetroleum products at Atmospheric Pressure.

The Institute of Petroleum, London, (IP17/52) (1994). Determination of Colour by the Lovibond Tintometer.

American standard for testing and materials (ASTM – D1266-98) (2001). Standard Test Method for Sulfur in Petroleum Products (Lamb method).

American standard for Testing and Materials (ASTM – D5002-99), (2001) Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer.