

Organic Solvents Optimization in Base Oil Recovery from Lubricating Oil Contaminated Soil

Motshumi Diphare, Antonette Malepe and Edison Muzenda

Abstract—This is short communication on organic solvents optimization in the recovery of base oils from lubricating oil contaminated soils. The performances of five extracting solvents namely; n-hexane, toluene, heptane, butane, benzene, and carbon disulphide were evaluated. A thermal treatment in an aqueous caustic solution and solvent extraction was employed to recover the base oil. The procedure involved adding contaminated soil into a NaOH solution at 80°C while being agitated. Then a solvent was introduced to extract the oil. Hexane and carbon di-sulphide recovered the most (85%) and lowest (45%) oil respectively. The solvent extraction performance increased with increase in solvent carbon chain length. 1:4 was found to be the optimum solvent to soil ratio.

Keywords—Base oil, contaminated soil, extraction, optimization, performance.

I. INTRODUCTION

OIL is an important resource which after use, should be recycled or regenerated. During production, transportation and consumption oil can enter the environment through accidental spillages, leaks from pipes and pumps, and sometimes by intentional discharge human beings. The main environmental concern with oil is that, if not handled carefully, it may pose significant hazards to human health and the ecology.

Polycyclic aromatic hydrocarbons (PAHs) are some of the most widespread organic pollutants in oil contaminated soil [1]. They are mainly formed from anthropogenic processes, as by-products of incomplete combustion of carbon-containing fuels such as petroleum related products. Oil as well as other commercial hydrocarbon mixtures containing alkanes, alkenes, aromatics and polar compounds could be considered extensively biodegradable in soils [2]. Variations in the extent of biodegradation were reported in literature [3], [4]

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depending on soil and hydrocarbon source type, concentration of total hydrocarbons, and oxygen and nutrients availability.

Various technological approaches such as chemical, physical, biological and thermal have been proposed for treating oil contaminated land. Clean-up technologies such as incineration, bioremediation and landfilling are expensive. These technologies focus on destroying the contaminants and are time consuming [5] while others such as soil washing separate the contaminants from soil without chemically modifying them [6].

Among the various remediation technologies, soil washing such as solvent extraction has been reported as being very attractive due to its high efficiency [7]. Previous studies [8]-[10] have shown recoveries between 75% and 99% using solvent extraction. Typically, either an individual solvent or a mixture of solvents can be used to wash out oils from contaminated soils [11].

The two steps involved in the extraction of the oil from a solid matrix are desorption from the solid matrix followed by elution from the solid into the extracting fluid, implying that the oil is transferred from the solid phase to the liquid phase [7]. Then the solvent is separated from the contaminants with the residual oil requiring further treatment to remove the solvent remains through drying.

Reference [12] studied the removal of heavy crude oil from contaminated soils using hexane-acetone mixture as the extracting solvent at various extraction conditions. 96% of oil was recovered at a soil-solvent mixing ratio of 10:1.

Reference [8] tested water-solvents mixtures at laboratory scale using a rotating shaker to remove 19 PAHs from highly contaminated soil. 95% removal of PAHs were achieved using ethanol at extraction times of more than 60 minutes. This study was aimed at testing various solvents to achieve better recoveries at minimum extraction time. The influence of soil to solvent mixing ratios on recovery was also investigated.

II. MATERIALS AND METHODS

A. Materials

75g of NaOH solution with a concentration of 20% w/w was prepared and heated to 80°C. Then 100g of oil contaminated soil was added while agitating at 300 rpm. After 10 min of agitation the mixture was left to cool to less than 40°C, reducing the evaporation of the extraction solvent. After

the addition of solvent, the mixture is then cooled to 30°C and then filtered using a pressure filter to separate solids from the liquid. The filtrate was then distilled to separate water, solvent and oil. Fig. 1 shows a process flow diagram for solvent extraction.

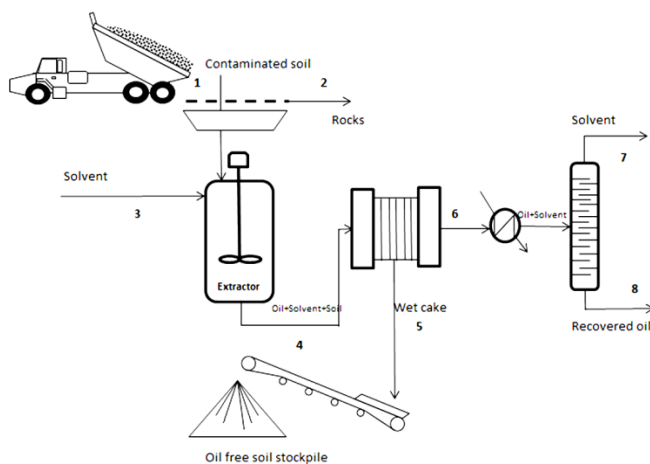


Fig. 1 Process flow diagram for solvent extraction

III. RESULTS AND DISCUSSIONS

The solvent extraction process involves the use of a solvent to selectively extract lubricating oil from an oil contaminated soil mixture. Lubricating oil consists of base oil and additives which help to impart certain characters of the oil such as viscosity and these should be rejected by the solvent. A solvent should also dissolve the base oil and precipitate other substances to form sludge. In this study, a base solvent was added to enhance the separation of base oil from additives.

The choice of extraction solvent is dependent on several factors such as soil oil concentration and soil type. Reference [13] reported that for lowly polluted soil, the lubricating oil is mainly found on the surface and a more polar solvent such as acetone is preferred to break up the soil aggregates and to allow maximum contact between particles. However, for highly polluted soil, a relatively nonpolar solvent such as toluene or cyclohexane would be a better solvent. Other non-polar solvents including 1- pentanol, n-hexane, toluene, dichloromethane and benzene are usually employed in the extraction of lubricating oil due to their lipophilic characteristics [14]. The polarity of solvent with respect to that of the lubricating oil contaminants also influences solubility [15]. A solvent has good dissolving efficiency when its polarity is similar to that of oil pollutants. A good solvent should dissolve base oil and precipitate other substances to form sludge. The efficiency of the extraction solvents can also be related to the various interactions between the solvent and oil molecules, due to the size of the main carbon chain and the solvent molecules configuration [16].

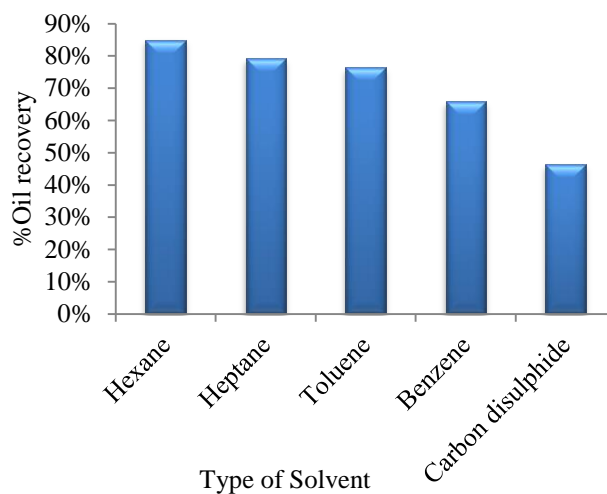


Fig. 2 The influence of various solvent

Fig. 2 shows the influence of solvent on oil recovery. The highest recovery was obtained using hexane (85%) while carbon di-sulphide gave a recovery of 45%. The variation is due to solubility of the base oil in these solvents.

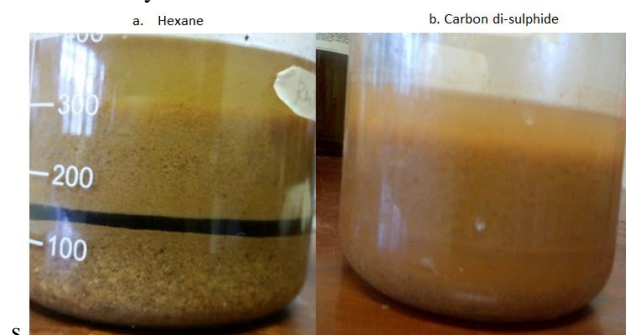


Fig. 3 Hexane and Carbon di-sulphide after extraction

The increase in recovery with increase in solvent carbon chain length as carbon atoms lose hydrogen ions and act as a carrier medium for the oil molecules. However, this contradicts the findings in this work for Hexane and Heptane. Hexane recovered more oil compared to heptane due to its favourable interaction and affinity for oil than heptane. The performance of the extraction solvents can also be attributed to the interaction between the solvent and oil molecules arising from the size of the main carbon chain and the solvent molecules configuration [17]. Previous studies [17], [18] have shown hexane to be an excellent oil extraction solvent from waste lubricants.

The increase of solvent to soil ratio enhances the interaction between the oil contaminants and extraction solvent as well as the concentration gradients between liquid–solid phases. It also increases the medium mutual solubility of oil in the solvent resulting in reduction of oil losses in the sludge phase and promoting sludge removal [17].

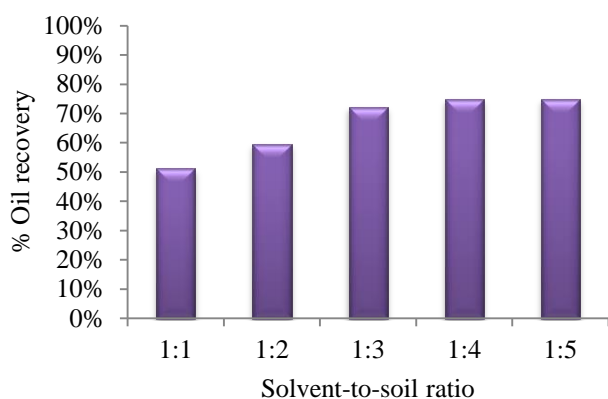


Fig. 4 The influence of solvent to soil ratio

Oil recovery increased with increase in solvent to soil ratio until the optimum ratio of 1:4, Fig. 4. This represents the optimum solvent: oil ratio whereby minimum oil losses in sludge phase were achieved at the specified extraction temperature. At lower solvent to soil ratio, solvent becomes saturated with base oil resulting in reduced oil recovery while at higher solvent/ soil ratio maximum oil could be extracted and oil free sludge is obtained. The increase in liquid-solid ratio facilitated the diffusion of the desorbed contaminants into the aqueous phase, enhancing oil removal. However excessive solvents would increase the cost of subsequent solvent recycling. Distillation can be used to regenerate the spent solvent. Solvents were lost during distillation (10%), evaporation (20%) and also during filtration.

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REFERENCES

- [1] C. L. Yap, S. Gan, H. K. Ng, "Application of vegetable oils in the treatment of polycyclic aromatic hydrocarbons-contaminated soils," *Journal of Hazardous Materials*, vol. 177, pp. 28-41, 2010.
- [2] M. Nocentini, D. Pinelli, F. Fava, "Bioremediation of a soil contaminated by hydrocarbon mixtures: the residual concentration problem," *Chemosphere*, vol. 41, pp. 1115-1123, 2000.
- [3] I.D. Bossert, G.C. Compeau, "Cleanup of petroleum hydrocarbon contamination in soil. In: Young, Y.L., Cerniglia, C.E. (Eds.), *Microbial transformation and biodegradation of toxic organic chemicals*," Wiley-Liss, New York, USA, pp. 77-125, 1995.
- [4] M.H. Huesmann, "Incomplete hydrocarbon biodegradation in contaminated soils: Limitations in bioavailability or inherent recalcitrance?" *Bioremediation Journal*, vol. 1 (1), pp. 27-39, 1997.
- [5] N. Vasudevan, P. Rajaram, "Bioremediation of oil sludge contaminated soil," *Environmental International*, vol. 26, pp. 409-411, 2001.
- [6] K. Urum, S. Grigson, T. Pekdemir, S. McMenemy, "A comparison of the efficiency of different surfactants for removal of crude oil from contaminated soils," *Chemosphere*, vol. 62, pp. 1403-1410, 2006.
- [7] G. Z. Wu, F. Coulon, Y. W. Yang, H. Li, H. Sui, "Combining Solvent Extraction and Bioremediation for Removing Weathered Petroleum from Contaminated Soil," *Pedosphere*, vol. 23(4), pp. 455-463, 2013.

- [8] A. P. Khodadoust, R. Bagchi, M. T. Suidan, R. C. Brenner, N. G. Sellers, "Removal of PAHs from highly contaminated soils found at prior manufactured gas operations," *J. Hazard. Mater.*, vol. 80, pp. 159-174, 2000.
- [9] N. Saifuddin, K. H. Chua, "Extraction of tetrachloroethylene from weathered soils: a comparison between Soxhlet extraction and microwave-assisted extraction," *Malay. J. Chem.*, vol. 5, pp. 030-033, 2003.
- [10] A. Silva, C. Delerue-Matos, A. Fi'uzza, "Use of solvent extraction to remediate soils contaminated with hydrocarbons," *J. Hazard. Mater.*, vol. 124, pp. 224-229, 2005.
- [11] S. Gan, E.V. Lau, H.K. Ng, "Remediation of soils contaminated with polycyclic aromatic hydrocarbons (PAHs)," *J. Hazard. Mater.*, 2009
- [12] L. Xingang, D. Yongliang, W. Guozhong, L. Zhongyuan, L. Hong, S. Hong, "Solvent extraction for heavy crude oil removal from contaminated soils," *Chemosphere*, vol. 88, pp. 245-249, 2012.
- [13] J. D. Berset, M. Ejem, R. Holzer, and P. Lischer, "Comparison of different drying, extraction and detection techniques for the determination of priority polycyclic aromatic hydrocarbons in background contaminated soil samples," *Analytica Chimica Acta*, vol. 383, no. 3, pp. 263-275, 1999.
- [14] L. Wang, M. Zhang, X. Wang, W. Liu, "The preparation of CeF3 nanocluster capped with oleic acid by extraction method and application to lithium grease," *Material Research Bulletin*, vol. 43, pp. 2220-2222, 2008.
- [15] M. T. Pena, M. C. Casais, M. C. Mejuto, and R. Cela, "Optimization of the matrix solid-phase dispersion sample preparation procedure for analysis of polycyclic aromatic hydrocarbons in soils: comparison with microwave-assisted extraction," *Journal of Chromatography*, vol. 1165, no. 1-2, pp. 32-38, 2007.
- [16] A. Kamal, F. Khan, "Effect of extraction and adsorption on re-refining of used lubricating oil," *Oil Gas Sci. Technol.* vol. 64 (2), pp. 191-197, 2009.
- [17] N.O. Elbashir, S.M. Al-Zahrani, M.I. Abdul Mutalib, A.E. Abasaheed, "Chemical Engineering and Processing: Process Intensification," vol. 41 pp. 765, 2002.
- [18] R. M. Rafie, A.R. I. Inaam, H.T. Alladdin, M. Gordon, "Waste lubricating oil treatment by extraction and adsorption," *Chemical Engineering Journal*, vol. 220, pp 343-351, 2013.