Acta Sci. Pol.
Architectura 23 (2024), 319–328
aspa.sggw.edu.pl ISSN 1644-0633 (suspended) eISSN 2544-1760 DOI: 10.22630/ASPA.2024.23.24

ORIGINAL PAPER

Received: 16.08.2024
Accepted: 20.09.2024

LABORATORY STUDIES ON THE EFFECTS OF OIL POLLUTION ON SOIL PROPERTIES

Anna Podlasek✉, Anna Gmur

Institute of Civil Engineering, Warsaw University of Life Sciences – SGGW, Warsaw, Poland

ABSTRACT

Soil pollution is one of the world's most debated and widespread environmental issues. In particular, oil spills pose a significant global threat, with an environmental impact only slightly below that of radioactive contamination. This study conducted laboratory tests on the granulometric composition and consistency limits of soil samples artificially contaminated with engine oils. Three different types of engine oils were added to the soils in proportions of: 2.5%, 5% and 10% by dry weight of the soil sample, respectively. The trends in changes of the parameters determined due to pollution were evaluated. The study included a comparative analysis of the results of studies on the parameters of polluted soils carried out in Polish and foreign scientific centres. For silty sand (siSa), the content of the clay fraction decreased from an initial 7% to a range of 1–3%. For clayey sand (clSa), the content of the clay fraction decreased from 13% to a range of 1–7%. The plastic limit (*PL*) was 13.24% for siSa and 16.42% for clSa. The tested soils contaminated with engine oil were classified as non-plastic. The liquid limit (*LL*) for siSa and clSa was around 21%. The *LL* of siSa decreased from 21% to 15% due to contact with all types of engine oils. For clSa, the *LL* decreased to a range of 10–14%, depending on the type of engine oil. The results of this study highlight the engineering importance of understanding soil behaviour under oil contamination, which is crucial for assessing the stability and safety of structures in contaminated areas and for designing effective remediation strategies.

Keywords: oil spill, contamination, granulometric composition, consistency limit

INTRODUCTION

Oil compounds are among the most common soil contaminants due to extensive pipeline leaks, inadequate oil waste management and accidents at various stages of fuel transfer (Karthick, Roy & Chattopadhyay, 2019; Haghsheno & Arabani, 2022). Moreover, the activities of repair workshops, production facilities, military bases, landfills, power stations and the entire municipal infrastructure contribute to pollution from petroleum-based contaminants (Korzeniowska-Rejmer & Izdebska-Mucha, 2006).

The intensity and toxicity of oil spills were found to pose a global threat, with oil spills ranking second only to radioactive contamination in terms of environmental hazard (Tumanyan, Tyutyuma, Bondarenko & Shcherbakova, 2017). The extent of pollutants' migration in the soil–water system depends mainly on the properties of the soil and the type of pollutant (Biswas et al., 2018; Nartowska, 2023). If a pollutant penetrates vertically into the soil, some portion of it will be adsorbed by soil particles already in the vadose

Anna Podlasek https://orcid.org/0000-0003-0326-5672
✉anna_podlasek@sggw.edu.pl

BY-NC

zone. If the contaminant is light (e.g., petrol), it can move more freely between the soil particles and migrate further. Heavier substances, such as lubricants and diesel fuels of all types, have a limited ability to migrate (Yang et al., 2024).

Changes in soil parameters due to contamination have been documented in many studies (Izdebska--Mucha & Korzeniowska-Rejmer, 2009; Kicińska, Pomykała & Izquierdo-Diaz, 2022). One of these changes is in the granulometric composition. Polluted soil samples differ significantly in their content of individual fractions compared to model soil samples (Izdebska-Mucha & Korzeniowska-Rejmer, 2009; Czado, Korzeniowska-Rejmer & Pietras, 2010; Osinubi, Eberemu, Bello & Adzegah, 2012). Decreases or increases in the content of individual fractions in the soils, sometimes by as much as several tens of percent, primarily indicated a change in soil type. The main reason for this is that the admixtures of various chemical compounds (sulphur, heavy metals) found in contaminants, such as petroleum substances, which are destructive. They break down part of the bonds present in the particles of the soil skeleton. Soils with a high clay fraction are particularly susceptible to such destruction. Consequently, cohesive soils are the least resistant to chemical aggression, and it is mainly in these soils that the greatest changes in physical, chemical or mechanical properties can be observed (Rajabi & Sharifipour, 2019). Elsaigh and Oluremi (2022) discovered that the geotechnical characteristics of highly cohesive soil are significantly influenced by hydrocarbon contaminants, regardless of their source, in comparison to granular soils. They also found that despite the soil's nature and mineral content, soils contaminated with hydrocarbons exhibit a greater potential for collapse. This was also confirmed by studies on artificially contaminated soils and contaminated samples taken directly from the site.

Among the soil characteristics altered by oil contamination are (Korzeniowska-Rejmer, Motak & Rawicki, 1995; Izdebska-Mucha, 2005; Rakowska et al., 2012; Azam, Xiao, Mia, Rahman & Zaman, 2022):

1. Granulometric composition. Due to oil contamination, there are significant changes in the granulometric composition. The content of the sand and clay fractions decreases, while the content of the silt fraction increases.
2. Specific density and bulk density. When the soil is saturated with hydrocarbons, the values of specific density and bulk density decrease. Changes in these values, as well as changes in the granulometric composition, also affect the porosity of the soil. This can lead to soil settlements and numerous voids, especially if the soil has been in contact with the contamination for a long time.
3. Consistency limits. A decrease in plasticity is observed in cohesive soils. As a result of rolling tests, soils are usually classified as non-plastic.
4. Mechanical parameters. Based on many years of research on contaminated soils, changes in the mechanical parameters of the soils have been observed. These are mainly a decrease in soil cohesion (c), angle of internal friction (°) and primary modulus of compressibility (M_0). All of these values decrease with increasing contaminant concentration. The shear strength (τ) of the soil also decreases.

In areas where industrial activities are common, or where spills have occurred, understanding how contamination affects soil behaviour is important for ensuring the safety and durability of engineering structures. Czado et al. (2010) showed that even a relatively small amount of oil contamination in sandy soils can lead to a significant reduction in the resistance of the subsoil beneath the foundation. They demonstrated that for 2% oil contamination, the reduction in foundation resistance is more than 15%, and for 10% contamination, the resistance value can be reduced by more than 50%. Analysis of these results clearly indicates that when designing foundations for facilities such as petrol stations or liquid fuel tanks, where the potential risk of soil contamination with oil substances is relatively high, additional increased partial safety factors are necessary.

The research findings show that the changes in the engineering properties of soils significantly increase settlement and negatively influence the subsoil's bearing capacity parameters. This demonstrates the need for an assessment of soil parameters prior to construction. It also indicates that soil properties should be reassessed, even in built-up areas, if they are contaminated, to evaluate the degree of soil degradation (Surygala, Śliwka, Kołwzan & Greinert, 2000; Iwanicka, Janiszewska & Koda, 2020). Investigating the engineering behaviour and properties of contaminated soil is essential for identifying the most effective remediation methods or other practical uses for contaminated soil (Haghsheno & Arabani, 2022).

Most of the literature on changes in soil parameters due to contamination is primarily documented for cohesive soils such as clays. However, there is a notable need to fill the knowledge gaps for other soil types to better understand their response to contamination. In addition, most of the literature focuses on the effects of diesel, motor oil or crude oil, while this research examines the impact of engine oil. This study contributes to the knowledge base of how different types of engine oil contamination affect various soil types, providing valuable insights for the development of effective remediation strategies.

In view of the above, the aim of this study was to investigate the changes in the basic properties (granulometric composition, consistency limits) of two types of soils contaminated with different engine oils in proportions of 2.5%, 5% and 10% of the dry weight of the soil. The hypothesis of this study was that the addition of engine oils would reduce the clay content and plasticity of the soil, thereby affecting its suitability for engineering applications.

MATERIAL AND METHODS

Tested soils

Two natural soil samples were used in the study. The first was silty sand (siSa). The second soil was clayey sand (clSa). The samples were collected in the Warsaw area. The tested soils were classified according to their granulometric composition based on the PN-EN ISO 14688-1 standard (Polski Komitet Normalizacyjny [PKN], 2018).

Oil used

During laboratory tests, the model soil samples were contaminated by three types of engine oil: Oil 1 (ρ = 0.855 g·cm^{-3}), Oil 2 (ρ = 0.850 g·cm^{-3}), Oil 3 (ρ = 0.843 g·cm^{-3}). Oils were added to the soil samples in proportions of 2.5%, 5.0%, and 10.0% by dry weight of the soil sample, respectively. The soil–engine oil mixtures were stored in closed containers for one month.

Soil analysis

The particle size distribution of the soils was analysed according to the PN-EN ISO 14688-1 standard (PKN, 2018). A combined approach of sieve analysis for the coarser fractions (≥ 0.2 mm) and hydrometer (areometric) analysis for the finer fractions (< 0.2 mm) was used. The liquid limit (*LL*) and plastic limit (*PL*) of the soils were determined according to the EN ISO 17892-12 standard (International Organization for Standardization [ISO], 2018). The *LL* was determined using the Casagrande apparatus, while the *PL* was measured using the standard rolling method. The analyses of *LL* and *PL* were carried out in duplicate for natural soil samples and samples contaminated with three different engine oils.

RESULTS AND DISCUSSION

Effect of oil contamination on soil particle size distribution

As a result of the study, changes were observed in the percentages of the different fractions, depending on both the type of engine oil and its concentration. In particular, a significant decrease in the content of the clay fraction was observed. For silty sand (siSa), the content of the clay fraction decreased from an initial 7% to values in a range of 1–3% (Table 1). For clayey sand (clSa), the content of the clay fraction decreased from 13%, to values in a range of 1–7% (Table 2).

Table 1. Fractional percentages according to the degree of oil contamination for siSa

Fraction	Before contamination [%]	After contamination with oil								
		Oil 1			Oil 2			Oil 3		
		2.5%	5.0%	10.0%	2.5%	5.0%	10.0%	2.5%	5.0%	10.0%
Clay fraction	7	3	1	1	1	2	1	1	2	1
Silt fraction	31	38	33	27	28	31	24	31	28	29
Sand fraction	62	59	66	72	71	67	75	68	70	70

Source: own work.

Table 2. Fractional percentages according to the degree of oil contamination for clSa

Fraction	Before contamination [%]	After contamination with oil								
		Oil 1			Oil 2			Oil 3		
		2.5%	5.0%	10.0%	2.5%	5.0%	10.0%	2.5%	5.0%	10.0%
Clay fraction	13	7	4	1	5	3	2	6	4	3
Silt fraction	25	18	16	11	15	14	10	23	19	16
Sand and gravel fraction	62	75	80	88	80	83	88	71	77	81

Source: own work.

It was observed that the higher the concentration of oil contaminants in the soil, the lower the content of the clay fraction. A study by Korzeniowska-Rejmer and Izdebska-Mucha (2006) also showed a clearly noticeable decrease in the clay fraction for soil contaminated with diesel (10%). The content of the clay fraction decreased, according to the cited study, from 15% to 12%. This relationship is due to the fact that the clay fraction is the least resistant to chemical aggression. Similar studies have been carried out in many foreign research centres. Al-Obaidy and Shaia (2019) showed negative changes regarding grain size and plasticity index. In addition, changes were noted regarding other mechanical properties, such as a reduction in the value of the angle of internal friction and a reduction in the value of shear stress. Izdebska-Mucha and Korzeniowska-Rejmer (2009) showed that cohesive soils (clays) contaminated with petrol and diesel oil take on the properties of fine-grained non-cohesive soils, which – in particular – excludes their use as insulating materials in landfill liners. According to Korzeniowska-Rejmer and Izdebska-Mucha (2006), the sand fraction in silts reduced from 27% to 10% due to 25% oil contamination. This was also confirmed by Bian, Liu, Cai, Chu and Tian (2016), who demonstrated the reduction (from 13.8% to 7.7–8.3%) of the sand fraction in silty clay contaminated with 10% kerosene or diesel. The observed reduction in the sand fraction due to the breakdown of larger soil aggregates may be the result of long-term physical and chemical aggression.

The effects of the addition of engine oils to soils on its particle size distribution changes are presented in Figures 1 and 2. These changes in granulometric composition may also reduce the values of the geotechnical parameters responsible for the strength and deformability of the soil, thereby altering its properties as a building subsoil (Korzeniowska-Rejmer & Izdebska-Mucha, 2006).

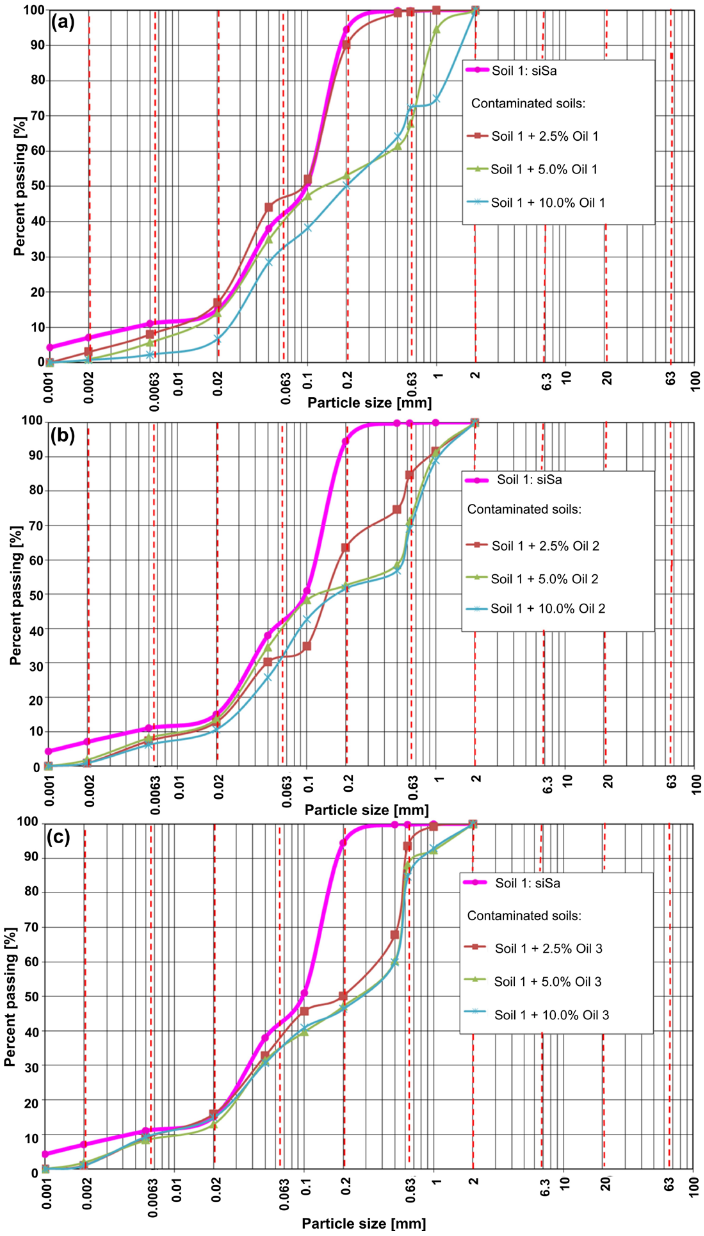

Fig. 1. Particle size distribution of siSa and soil–engine oil mixtures: (a) Oil 1, (b) Oil 2, (c) Oil 3

Source: own work.

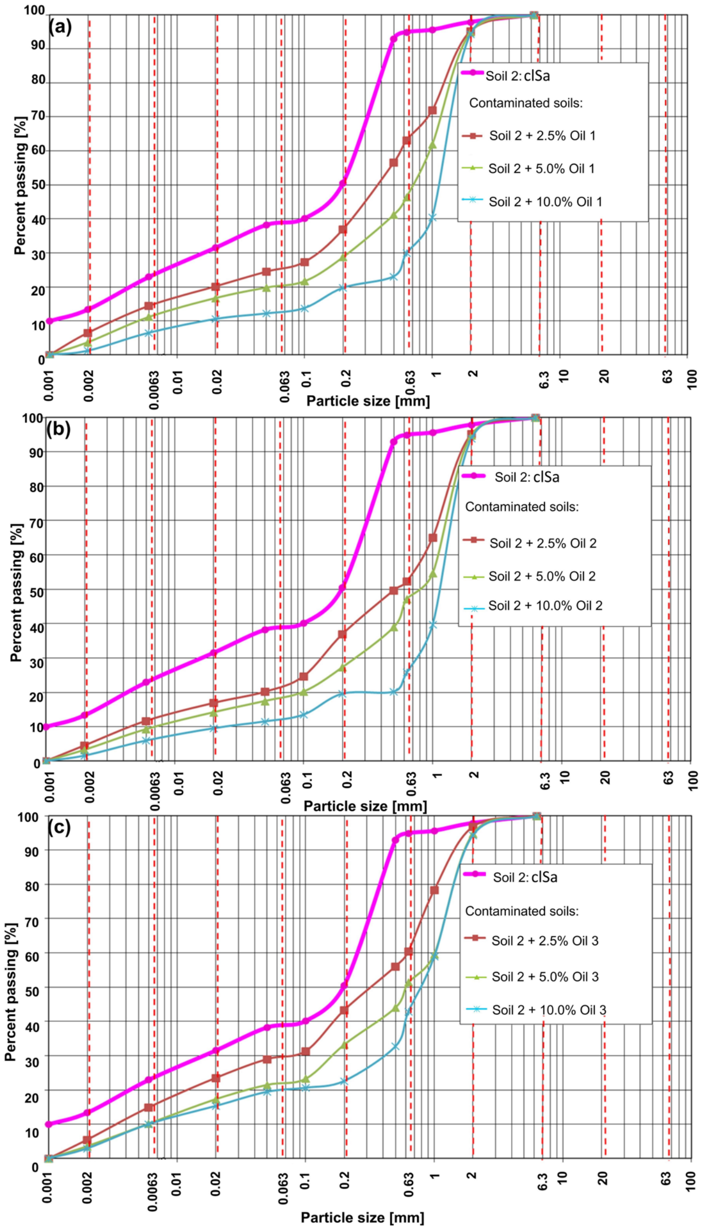

Fig. 2. Particle size distribution of clSa and soil–engine oil mixtures: (a) Oil 1, (b) Oil 2, (c) Oil 3

Source: own work.

Effect of oil contamination on plastic limit (*PL*)

In this study, the plastic limit was 13.24% for silty sand (siSa) and 16.42% for clayey sand (clSa). Soils contaminated with engine oil were classified as non-plastic. Similar studies were carried out by Korzeniowska--Rejmer and Izdebska-Mucha (2006), who showed that soils contaminated with oils could also be characterised as non-plastic. Similar conclusions were reached in a study by Izdebska-Mucha (2005), who showed that all clay samples tested after saturation with petrol were classified as non-plastic. Swaroop and Rani (2015) showed a reduction in the *PL* from 35% for uncontaminated clay to about 22.5% for 5% oil-polluted clay and to about 13% for 10% oil-polluted clay. Tong, Chen, Zheng and Li (2012) revealed that both the *LL* and *PL* of clay loam changed to a less favourable state due to oil pollution. The results of their analysis lead to the same conclusions as those observed in the tests carried out in this study. Another example confirming that phenomenon is the work of Nazir (2011) and Akpokodje, Juwah and Uguru (2022), who clearly stated a decrease in *PL* and *LL* for oil-contaminated soils (over-consolidated clays). In a study by Jia et al. (2009), a completely different behaviour of coastal sediments under the influence of oil pollution was observed. The authors showed that the *LL*, *PL*, and plasticity index (*PI*) all increased with higher oil contamination levels. They concluded that the increase in Atterberg limits is due to the viscous nature of the pore fluid. In saturated fine-grained soils, the pore fluid occupies the voids within the soil structure and forms a thin layer between mineral contacts. This layer acts as a lubricant, allowing the soil particles to pack closer together. Lubrication at particle contact points is due to the viscosity of the pore fluid. As the viscosity of the pore fluid increases, it alters the interactions between minerals and pore fluid at the contact, making it harder to change the uniform state of the soil, which is reflected in the increased Atterberg limits. Also, according to Hewayde, Abbas and Kubba (2019), the increase in the percentage of engine oil in the soil resulted in an increase in the *PL* (from 15% to 21%) for organic silts and organic silty clays of low plasticity (symbol OL according to the Unified Soil Classification System; Casagrande, 1948).

Effect of oil contamination on liquid limit (*LL*)

The study showed that contamination with engine oil significantly affected the *LL* (Fig. 3). For the two uncontaminated soil samples (siSa and clSa) the *LL* was around 21%. For the samples contaminated with engine oil at a mass fraction of 10%, it decreased to values in a range of 14.5% to 15.4% for siSa and 9.6% to 16.2% for clSa.

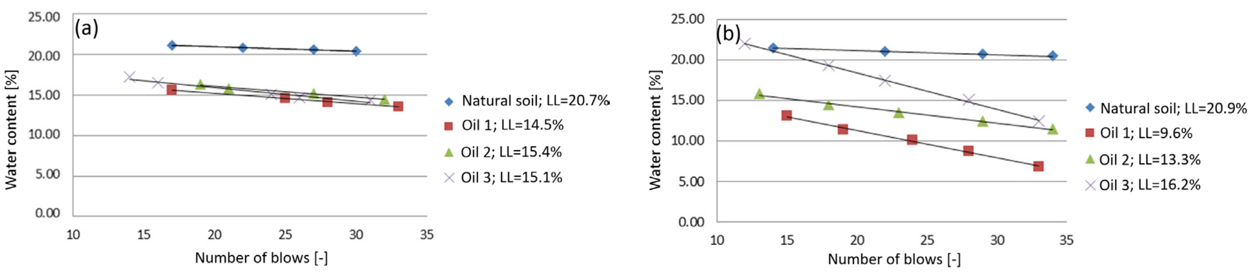

Fig. 3. Results of the Casagrande tests for natural soil samples: siSa (a) and clSa (b) and contaminated with the addition of three engine oils at a level of 10%

Source: own work.

The *LL* of the siSa decreased from 21% to around 15% regardless of the type of engine oil. For the clSa, the largest decrease in *LL* was observed due to contamination with Oil 1 (9.6%) and the smallest with Oil 3 (16.2%). Contact of the soil with Oil 2 decreased the *LL* to a level of 13.3%.

In comparison, Izdebska-Mucha (2005) tested several materials contaminated with petrol and diesel oil. In both cases, a significant decrease in the *LL* was observed compared to uncontaminated soils. For Neogene clays of the Poznań series, a decrease from 64% to 34–36% was observed. The *LL* of illitic clays was reduced from 46% to 24% (petrol pollution) and 26% (diesel oil pollution). For bentonite, a reduction in the *LL* was observed from 257% to 34% for petrol pollution and to 37% for diesel oil pollution. For kaolinite, the *LL* was reduced from 51% to 45% and 37% for petrol and diesel oil pollution, respectively. The smallest changes were observed for glacial till (*LL* reduction from 24% to 23% for diesel oil pollution; no reduction for petrol pollution).

Phougat (2017) observed similar relationships in a study on oil-contaminated clays. A significant decrease in Atterberg limits was observed for all contaminated samples. Both the *LL* and *PL* decreased, and the soils were characterised as non-plastic. A correlation of the intensity of changes with the duration of chemical aggression was also noted. The longer the samples were exposed to oil, the more their properties changed.

Hewayde et al. (2019) demonstrated that the increase in engine oil contaminant percentage resulted in a decrease in the *LL* of cohesive soils (*LL* = 44% for uncontaminated soil, *LL* = 43% for 5% engine oil content, *LL* = 41% for 10% engine oil content, *LL* = 39% for 15% engine oil content).

In a study by Akinwumi, Diwa and Obianigwe (2014), the addition of crude oil to the soil resulted in an increase in the *LL*, *PL* and *PI* of the contaminated sandy clay. This was attributed to the increase in the thickness of the diffuse double layer. The addition of crude oil to the soil decreased its permeability. This was attributed to the incorporation of crude oil into the pore spaces of the soil. This is partly in agreement with the study of Tong et al. (2012), who showed that the Atterberg limits of diesel-contaminated clay loam decrease with increasing oil content while the *PI* changes slightly. They found that the 'pseudo-viscosity' caused by crude oil leads to a decrease in *PL* and an increase in *LL*.

CONCLUSIONS

The influence of engine oil on soil properties is considerable, particularly on the content of individual soil fractions. This study has shown that engine oil-contaminated soils behave similarly to non-cohesive soils. In particular, the presence of petroleum substances significantly reduces the liquid limit and causes engine oil-contaminated soils to be classified as non-plastic.

Based on these findings, it is advisable to consider the significant changes in soil properties when designing engineering structures in areas contaminated by engine oils. The observed reduction in clay content and plasticity in contaminated soils could affect their bearing capacity and overall stability. Consequently, modified engineering approaches and remediation strategies may be necessary to effectively address these altered soil properties.

While this study provides valuable insights into the effects of engine oil contamination on silty sands and clayey sands, further research is needed. Future studies should investigate the behaviour of oil contaminants across a wider range of soil types. In addition, it is essential to examine the long-term effects of oil contamination, including its evolution over time and the potential for progressive degradation or chemical transformation of the contaminants. Further research should also explore the combined effects of multiple contaminants and their interactions with different soil types in order to develop more effective remediation techniques and engineering solutions for industrially degraded sites.

Authors' contributions

Conceptualisation: A.P. and A.G.; methodology: A.P.; validation: A.P.; formal analysis: A.P. and A.G.; investigation: A.P. and A.G.; resources: A.P.; data curation: A.P. and A.G.; writing – original draft preparation: A.P. and A.G.; writing – review and editing: A.P.; visualisation: A.P. and A.G.; supervision: A.P.

All authors have read and agreed to the published version of the manuscript.

REFERENCES

Akinwumi, I. I., Diwa, D. & Obianigwe, N. (2014). Effects of crude oil contamination on the index properties, strength and permeability of lateritic clay. *International Journal of Applied Sciences and Engineering Research*, *3* (4), 816–824.

Akpokodje, O. I., Juwah, H. O. & Uguru, H. (2022). Impacts of petroleum spills on geotechnical properties of soils: A review. *Journal of Engineering Innovations and Applications*, *1* (1), 1–6.

Al-Obaidy, N. K. & Shaia, H. (2019). Evaluation the geotechnical properties of oil-polluted soil from two selected areas in Thi-Qar Governorate-Iraq. *University of Thi-Qar Journal*, *14* (1), 17–30.

Azam, M. S., Xiao, Z., Mia, M. R., Rahman, M. M. & Zaman, T. (2022). Effects of Oil Contamination on the Geotechnical Properties of Clayey Soil. *Journal of ICT, Design, Engineering and Technological Science*, *6* (2), 8–14. https://doi.org/10.33150/JITDETS-6.2.2

Bian, H., Liu, S., Cai, G., Chu, Y. & Tian, L. (2016). Effects of LNAPLs contamination on the basic properties of silty clay. In *Geo-Chicago 2016* (pp. 345–354). Chicago: American Society of Civil Engineers.

Biswas, B., Qi, F., Biswas, J. K., Wijayawardena, A., Khan, M. A. I. & Naidu, R. (2018). The fate of chemical pollutants with soil properties and processes in the climate change paradigm – A review. *Soil Systems*, 2 (3), 51.

Casagrande, A. (1948). Classification and identification of soils. *Transactions of the American Society of Civil Engineers*, *113* (1), 901–930.

Czado, B., Korzeniowska-Rejmer, E. & Pietras, J. (2010). Analiza zmian nośności podłoża budowlanego w wyniku jego zanieczyszczenia substancjami ropopochodnymi na przykładzie gruntów piaszczystych. *Górnictwo i Inżynieria*, *2*, 165–170.

Elsaigh, W. A. H. & Oluremi, J. R. (2022). Assessment of geotechnical properties of oil contaminated subgrade soil. *Soil and Sediment Contamination: An International Journal*, *31* (5), 586–610.

Haghsheno, H. & Arabani, M. (2022). Geotechnical properties of oil-polluted soil: a review. *Environmental Science and Pollution Research*, *29* (22), 32670–32701.

Hewayde, E., Abbas, M. & Kubba, Z. (2019). Influence of engine oil on geotechnical properties of cohesive soil. *International Journal of Engineering Research and Technology*, *12* (1), 33–41.

International Organization for Standardization [ISO], (2018). *Geotechnical investigation and testing – Laboratory testing of soil. Part 12: Determination of liquid and plastic limits* (EN ISO 17892-12).

Iwanicka, E., Janiszewska, S. & Koda, E. (2020). Remediacja i stabilizacja zanieczyszczonego podłoża pod istniejącymi budynkami-analiza przypadku. *Acta Scientiarum Polonorum. Architectura*, *19* (1), 63–71.

Izdebska-Mucha, D. (2005). Wpływ zanieczyszczeń ropopochodnych na wybrane geologiczno-inżynierskie właściwości gruntów spoistych. *Przegląd Geologiczny*, *53* (9), 766–769.

Izdebska-Mucha, D. & Korzeniowska-Rejmer, E. (2009). Wpływ zanieczyszczeń ropopochodnych na właściwości fizyczne gruntów stosowanych do budowy mineralnych barier uszczelniających składowiska odpadów. *Czasopismo Techniczne Politechniki Warszawskiej*, *11*, 39–54.

Jia, Y. G., Wu, Q., Meng, X. M., Yang, X. J., Yang, Z. N. & Zhang, G. C. (2010). Case study on influences of oil contamination on geotechnical properties of coastal sediments in the Yellow River Delta. In *Advances in Environmental Geotechnics: Proceedings of the International Symposium on Geoenvironmental Engineering in Hangzhou*, China, September 8–10, 2009 (pp. 767–771). Berlin–Heidelberg: Springer.

Karthick, A., Roy, B. & Chattopadhyay, P. (2019). A review on the application of chemical surfactant and surfactant foam for remediation of petroleum oil contaminated soil. *Journal of Environmental Management*, *243*, 187–205.

Kicińska, A., Pomykała, R. & Izquierdo-Diaz, M. (2022). Changes in soil pH and mobility of heavy metals in contaminated soils. *European Journal of Soil Science*, *73* (1), e13203. https://doi.org/10.1111/ejss.13203

Korzeniowska-Rejmer, E. & Izdebska-Mucha, D. (2006). Ocena wpływu zanieczyszczeń ropopochodnych na uziarnienie i plastyczność gruntów spoistych. *Inżyniera i Ochrona* Środowiska, *9* (1), 89–103.

Korzeniowska-Rejmer, E., Motak, E. & Rawicki, Z. (1995). Wpływ zanieczyszczeń olejowych na stan techniczny podłoża gruntowego i budynku magazynowania paliw. *Przegląd Budowlany*, *10*, 13–15.

Nartowska, E. (2023). The risk of contamination of the first aquifer in the central part of the Świętokrzyskie Voivodship (MHP-814 Piekoszów). *Acta Scientiarum Polonorum. Architectura*, *22*, 58–67.

Nazir, A. K. (2011). Effect of motor oil contamination on geotechnical properties of over consolidated clay. *Alexandria Engineering Journal*, *50* (4), 331–335.

Osinubi, K. J., Eberemu, A. O., Bello, A. O. & Adzegah, A. (2012). Effect of fines content on the engineering properties of reconstituted lateritic soils in waste containment application. *Nigerian Journal of Technology*, *31* (3), 277–287.

Phougat, N. (2017). Geotechnical properties of contaminated soil. *International Journal of Current Engineering Sciences*, *6* (7), 141–148.

Polski Komitet Normalizacyjny [PKN], (2018). *Geotechnical investigation and testing – Identification and classification of soil. Part 1: Identification and description* (PN-EN ISO 14688-1).

Rajabi, H. & Sharifipour, M. (2019). Geotechnical properties of hydrocarbon-contaminated soils: a comprehensive review. *Bulletin of Engineering Geology and the Environment*, *78*, 3685–3717.

Rakowska, J., Radwan, K., Ślosorz, Z., Pietraszek, E., Łudzik, M. & Suchorab, P. (2012). *Usuwanie substancji ropopochodnych z dróg i gruntów*. Józefów: Wydawnictwo Centrum Naukowo-Badawczego Ochrony Przeciwpożarowej im. Józefa Tuliszkowskiego Państwowego Instytutu Badawczego.

Surygała, J., Śliwka, E., Kołwzan, B. & Greinert, H. (2000). *Zanieczyszczenia naftowe w gruncie*. Wrocław: Oficyna Wydawnicza Politechniki Wrocławskiej.

Swaroop, S. S. & Rani, V. (2015). Effect of Oil Contamination on Geotechnical Properties of Clayey Soil. *International Journal of Engineering Research and Technology*, *3* (29), 1–4.

Tong, L., Chen, W. S., Zheng, X. L. & Li, M. (2012). Effect of oil contamination on Atterberg limits of soil. *Advanced Materials Research*, *374*, 336–338.

Tumanyan, A. F., Tyutyuma, N. V., Bondarenko, A. N. & Shcherbakova, N. A. (2017). Influence of oil pollution on various types of soil. *Chemistry and Technology of Fuels and Oils*, *53*, 369–376.

Yang, M., Wang, B., Xia, Y., Qiu, Y., Li, C. & Cao, Z. (2024). Changing Soil Water Content: Main Trigger of the Multi--Phase Mobilization and Transformation of Petroleum Pollution Components – Insights from the Batch Experiments. *Water*, *16* (13), 1775.

BADANIA LABORATORYJNE WPŁYWU ZANIECZYSZCZEŃ OLEJOWYCH NA WŁAŚCIWOŚCI GRUNTÓW

STRESZCZENIE

Zanieczyszczenie gruntu jest jednym z najbardziej dyskutowanych i powszechnych zagadnień środowiskowych na świecie. W szczególności wycieki oleju stanowią znaczące globalne zagrożenie, a ich wpływ na środowisko jest jedynie nieco mniejszy niż w przypadku skażenia radioaktywnego. W niniejszej pracy przeprowadzono badania laboratoryjne składu granulometrycznego i granic konsystencji próbek gruntów sztucznie zanieczyszczonych olejami silnikowymi. Do gruntów dodano trzy różne rodzaje olejów silnikowych w proporcjach: 2,5%, 5%, 10% w stosunku do suchej masy próbek gruntów. Oceniono tendencje zmian właściwości gruntów pod wpływem zanieczyszczeń. W pracy dokonano analizy porównawczej wyników badań parametrów gruntów zanieczyszczonych prowadzonych w polskich i zagranicznych ośrodkach naukowych. W przypadku piasku z pyłem (siSa) zawartość frakcji ilastej (Cl) zmniejszyła się z początkowych 7% do zakresu 1–3%, w przypadku piasku z iłem (clSa) zawartość frakcji Cl zmniejszyła się z 13% do zakresu 1–7%. Granica plastyczności (w_p) wynosiła 13,24% w przypadku siSa i 16,42% w przypadku clSa. Badane grunty zanieczyszczone olejem silnikowym zostały sklasyfikowane jako nieplastyczne. Granicę płynności (w_L) na poziomie 21% oznaczono w przypadkach siSa i clSa. Granica płynności siSa zmniejszyła się z 21% do około 15% na skutek kontaktu ze wszystkimi rodzajami olejów silnikowych. W przypadku clSa granica płynności zmniejszyła się do zakresu 10–14% w zależności od rodzaju oleju silnikowego. Wyniki tej pracy podkreślają inżynierskie znaczenie zrozumienia zachowania się gruntu pod wpływem zanieczyszczenia olejowego, co ma kluczowe znaczenie przy ocenie stabilności i bezpieczeństwa konstrukcji na zanieczyszczonych obszarach oraz dla projektowania skutecznych strategii remediacji.

Słowa kluczowe: wyciek oleju, zanieczyszczenie, skład granulometryczny, granica konsystencji