CONCENTRATION LEVELS OF LUBRICATING OILS ON CONCRETE FLOORS IN AN INDUSTRIAL LEARNING ENVIRONMENT AND SUBSEQUENT SOIL CONTAMINATION

Vitor Lorival Kudlanvec Junior
Department of Civil Construction,
Federal University of Parana (UFPR), Curitiba, Brazil
vitorlorival86@ufpr.br

ABSTRACT

The aim of this study was to investigate the behaviour of hydrocarbon pollutants on industrial floors lacking waterproofing protection and to understand the implications of these pollutants on soil contamination. Industrial floors are frequently exposed to various contaminants, such as oils and greases from diverse sources. In this investigation, a metalworking laboratory that had been operational for 42 years underwent the application of polyurethane-based paint on its concrete floor, resulting in the appearance of oil bubbles on the painted surface. Consequently, the primary objective of this research was to assess the degree of hydrocarbon contamination on the floor to comprehend the encountered issue. The conducted test, following the SM 5520E standard for hydrocarbon detection, revealed that in areas prone to pathological manifestations, the concentration of hydrocarbons increased by 74%, 45%, and 14% with each layer of protected concrete, compared to the equivalent layer in the control region. Furthermore, there was a notable concentration of hydrocarbons in the soil beneath the floor, registering a 51% increase compared to the control region and a substantial 91% increase compared to the adjacent concrete region.

KEYWORDS: *soil contamination; hydrocarbons; concrete penetration*

I. INTRODUCTION

Industrial floors are frequently exposed to various forms of contamination, notably oils and greases, posing a potential threat to both the floor and its underlying foundation [1]. This not only jeopardizes the structural integrity but also elevates the risk of accidents such as slips and falls.

Several factors contribute to oil and grease contamination on industrial floors, including inadvertent spills resulting from equipment malfunctions like broken hoses or pipe leaks, natural wear and tear on machinery, insufficient maintenance practices, and external sources such as forklifts transporting these substances on their tires and wheels, leaving residues along their movement paths [1].

The infiltration of oily substances into concrete has been a long-standing issue. A study by Gast et al. [2] revealed that solutions of linseed oil boiled in mineral spirits could permeate the porous structure of concrete at a rate of up to 7 millimetres in 105 days, contingent upon the viscosity conditions of the oil (see figure 1). Notably, there is a dearth of recent studies addressing this specific aspect. Conversely, extensive research has been conducted on the penetration of other chemical contaminants like chlorides, sulphates, and carbon dioxide, which pose threats to concrete and reinforcement through corrosion and material expansion mechanisms [3][4][5][6].

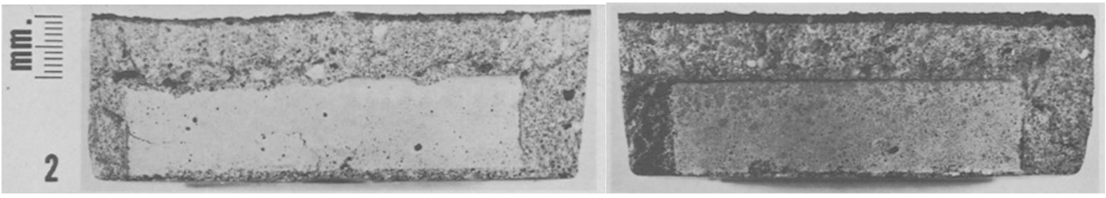

Figure 1: Effect of exposing concrete specimens to an oily solution for 7 days (left), and 35 days (right) [2].

As per [7], organic compounds such as polycyclic aromatic hydrocarbons (PAHs) and those belonging to the benzene, toluene, ethylbenzene, and xylene (BTEX) group are produced by various sources, notably the oil industry. Hydrocarbons of the lubricating oil type, whether used or contaminated, fall under the category of hazardous waste, necessitating adherence to regulations governing their collection, treatment, and final disposal [8].

Numerous studies [9][10][11][12][13] underscore the high toxicity of used lubricating oils, containing chemical additives that take around 300 years to decompose and lack biodegradable characteristics. These oils have the potential to induce biological alterations in the soil. The abundance of carbon sources can stimulate the growth of heterotrophic microorganisms, leading to the conversion of available soil nitrogen into microbial biomass nitrogen [14][15]. Additionally, the material exhibits genotoxic characteristics and is carcinogenic to both humans and animals, adversely affecting the normal functioning of the liver and kidneys [15]. Improperly disposing of just one litre of lubricating oil per day on the ground or in water courses is equivalent to the domestic sewage of 40 thousand inhabitants [16].

In consideration of these environmental apprehensions, this article endeavors to elucidate a case study conducted within a metal-mechanical laboratory. The investigation identified a discernible accumulation of oil on a concrete floor after the application of waterproofing paint. The primary aim of this study was to scrutinize the behavioral dynamics of soil-contaminating material beneath the floor, particularly in terms of its infiltration through the microstructure of the concrete. The overarching objective was to mitigate or eradicate this source of pollution, aligning the facility with established principles of judicious environmental practices. Within the purview of solid waste management, emphasis is duly placed on the prioritization of non-generation, reduction, reuse, recycling, treatment of solid waste, and the environmentally conscientious final disposal of waste [17].

This article will expound upon the identified issue, explicate the methodology deployed for quantifying oil concentration within distinct strata of concrete, and subsequently proffer a presentation of the discerned outcomes. Furthermore, the article will engage in a scholarly discussion pertaining to the contamination profile discerned at the study site, thereby furnishing a comprehensive understanding of the prevailing state of the soil environment.

II. METHODS

2.1. Case presentation

The focal point of this study revolves around a metal mechanics laboratory situated in a vocational education school in Curitiba, Brazil. During a building renovation that included the application of paint to the concrete floor, an intriguing observation was made. At the conclusion of the procedure, bubbles emerged in various areas of the environment, as depicted in figure 2. Upon pressing these bubbles, a substantial amount of lubricant utilized in turning and milling equipment was released into the surroundings. The occurrence of bubbles in the paint is attributed to the osmotic pressure of the liquid within the floor. Following the application of polyurethane-based resin paint, a physical barrier hindered the unrestricted passage of the liquid into the atmosphere, leading to the observed phenomenon.

Figure 2 - Occurrence of lubricating oil bubble under paint on concrete floor

The environment where these pathological manifestations manifest themselves has been operational for a span of 42 years, accommodating equipment such as lathes, bench drills, and others with analogous functions. These apparatuses employ lubricating oil to diminish the coefficient of friction between their mobile elements, thereby mitigating wear and kinetic effort amidst their moving surfaces. Figure 3 illustrates one of the pieces of equipment utilized in the laboratory, showcasing the occurrence of lubricating oil on its surface.

Figure 3 - Lubricating oil in a lathe equipment.

2.2. Test Methods

The assessment gauging the extent of floor contamination by oils and greases adhered to the specifications outlined in the SM 5520 E standard [18]. This standard is specifically designed for the identification of biological lipids and mineral hydrocarbons. Furthermore, in conjunction with this examination, a moisture test was conducted on the samples, following the protocols outlined in the Methods Manual of the Ministry of Agriculture, Livestock, and Supply [19].

The conducted tests involved the mechanical extraction of concrete samples obtained from the existing floor. This extraction process took place in two distinct areas: the region characterized by the highest prevalence of oil bubbles (termed the critical region) and a control region devoid of any such manifestations. Each collected unit was meticulously demarcated, with corresponding identification of the removal depth. In the context of this examination, concrete removal depths spanned from 0 to 5 centimetres, 5 to 10 centimetres, and 10 to 15 centimetres. Additionally, part of the graded crushed stone base supporting the concrete floor was extracted. Given the permeable nature of this base, any hydrocarbons present in this layer are considered as contributors to soil contamination beneath the floor. The collection procedure is elucidated in Figure 4, providing a visual representation of the steps involved in gathering the material slated for testing.

Figure 4 - On-site sample extraction procedure

The testing methodology designated as "5520 E" represents a modification of the Soxhlet method, deemed suitable when confronted with the presence of sludge or a substantial quantity of solid materials in suspension [20]. This method revolves around the extraction of oils through solvents, where soluble constituents of an inert material are transferred into a solvent in contact with the matrix. Executed as a gravimetric process, the test sequence adheres to the outlined procedure below:

- Weigh approximately 2 to 5 grams of the ground sample within a pre-prepared Soxhlet cartridge equipped with filter paper and cotton.
- Completely cover the sample by filling the cartridge with cotton.
- Subject the cartridge to a 2-hour drying period in an oven set at 105°C.
- Utilize a flat-bottomed flask with a ground mouth, pre-dried at 105°C, to weigh the prepared sample.
- Insert the cartridge into the Soxhlet extractor.
- Connect the flask to the Soxhlet extractor and introduce 250mL of petroleum ether.
- Establish a connection to the condenser.
- Activate the hotplate and maintain heating for an extended duration.
- Uncouple the assembly.
- Place the flask in the oven at 105°C for 1 hour.
- After cooling in a desiccator, weigh the flask to complete the test procedure.

Therefore, the fraction of hydrocarbons in the sample can be defined as in equation (1).

$$H = \frac{(BW_1 - BW_2)}{SW} \tag{1}$$

Where BW_1 is the weight of the balloon with the hydrocarbons, BW_2 is the weight of the original balloon and SW is the weight of the sample. The result is usually given in milligrams of hydrocarbons per kilogram of sample (mg/kg).

III. RESULTS AND DISCUSSIONS

The results of test that indicates the level of contamination of the floor by oils and greases allowed us to obtain results that are presented in table 1.

Table 1 - Presence of hydrocarbons in concrete floors and soil profile.

Depth	Material	Critical Region		Control Region	
		Total Hydrocarbons (mg/kg)	**Humidity at 105 °C**	**Total Hydrocarbons (mg/kg)**	**Humidity at 105 °C**
5 centimeters	Concrete	22.43	5.05	12.85	7.14
10 centimeters	Concrete	19.08	7.25	13.16	8.44
15 centimeters	Concrete	14.45	15.8	12.62	8.41
20 centimeters	Soil	27.62	25.2	18.34	17.54

By analyzing the results, it becomes evident that there is a decline in hydrocarbon concentration as the depth of the floor increases within the critical region where pathological manifestations occur, reaching ground level. Notably, in areas most impacted by these manifestations, hydrocarbon concentration is 74% higher than in the control region within the initial 5-centimeter layer, 45% higher in the second layer, and 14% higher in the third. This pattern indicates a diminishing percolation capacity of the contaminant with increasing depth, attributed to the loss of load through the concrete's pore structure. Even in the control region, which lacks visible bubble manifestations in the new paint, a substantial concentration of hydrocarbons is observed.

Furthermore, a notable concentration of hydrocarbons is identified in the soil beneath the floor, with a concentration 51% higher than the soil in the control region and 91% higher than the concrete region in contact with this soil. This underscores the contaminant's ability to accumulate significantly in the soil below the floor, despite the "funneling" effect that leads to concentration throughout the floor's thickness.

Concerning humidity results, no deviance from the expected pattern was observed in this structural type. The terrain's characteristics contribute to higher soil humidity, with water percolating through capillary pressure, maintaining a consistent presence of moisture throughout the floor's thickness and gradually decreasing with height.

IV. CONCLUSIONS

Soil contamination by hydrocarbons poses a significant environmental challenge demanding immediate and comprehensive intervention. Hydrocarbons, originating from petroleum and various sources, are hazardous substances capable of persisting in the soil over extended periods. This persistence has detrimental effects on ecosystems and poses potential risks to human health, particularly when located in proximity to water sources and urban supply dams.

In scenarios such as the one presented, where oil leaks are potential sources, even on concrete floors, there exists the risk of oil penetrating the structure through the porous network of the concrete, leading to soil contamination. Therefore, implementing measures to safeguard the floor and prevent direct contact between the material and concrete is imperative. A crucial aspect involves controlling machine lubricants on industrial floors made of reinforced concrete, and the application of paint during building renovation can serve as an effective protective layer.

In addition to these mitigation strategies, decisions made during the floor structure's design phase can proactively prevent percolation. This includes specifying concrete with enhanced mechanical resistance and a reduced water/cement ratio, resulting in lower porosity. Additionally, incorporating a plastic canvas between the floor base ballast and concrete acts as a physical barrier, hindering the passage of contaminants and bolstering the overall protection of the environment.

ACKNOWLEDGEMENTS

The authors thank the Engineering and Building Management of the Federation of Industries of the State of Paraná – Fiep, and the National Industrial Learning Service of Paraná – Senai/PR, for their support in conducting this study.

REFERENCES

[1]. Kujlu R., Moslemzadeh M., Rahimi S., Aghayani E., Ghanbari F., Mahdavianpour M., (2020) “Selecting the best stabilization/solidification method for the treatment of oil-contaminated soils using simple and applied best-worst multicriteria decision-making method”. *Environ. Pollut*. Vol. 263, pp. 114447. https://doi.org/10.1016/j.envpol.2020.114447.

[2]. Gast, L. E., Kubie, W. L., Cowan, J. C., (1971). “Linseed oil on concrete: Penetration of linseed oil compositions into sheet-and liquid membrane-cured concretes”. *Journal of the American Oil Chemists' Society*. Vol. 48 n. 12. https://doi.org/10.1007/BF02609288.

[3]. Roy, G.D. (2001). “Improving concrete durability with cementitious materials”. *Concrete International*, Vol. 23 n. 9, pp. 47-51.

[4]. Liu, G.J., Zhang, Y.S., Ni, Z.W. Huang, R. (2016). “Corrosion behavior of steel submitted to chloride and sulphate ions in simulated concrete pore solution”. *Construct. Build. Mater*, Vol. 115, pp. 1-5. https://doi.org/10.1016/j.conbuildmat.2016.03.213

[5]. Yang, Y., Patel, R.A., Churakov, S.V., Prasianakis, N.I., Kosakowski, G., Wang, M., (2019). “Multiscale modeling of ion diffusion in cement paste: electrical double layer effects”. *Cem. Concr. Compos*, Vol. 96, pp. 55-65. https://doi.org/10.1016/j.cemconcomp.2018.11.008

[6]. Wu, Z., Zhang, J., Xu, W. Ding, Y. Ren, Q., Sun, Q., Zhu, Y., 2023. “Development of cementitious capillary crystalline waterproofing agents and durability study of concrete in the presence of chloride

with sulfate in aqueous environment". *J. Build. Eng*, Vol. 79, pp. 107798. https://doi.org/10.1016/j.jobe.2023.107798.

[7]. Euzébio, C. S., Rangel, G. S., Marques, R. C., 2019. "Oil spill and its impacts on the environment and human health". *Revista Brasileira De Ciências Ambientais* Vol. 52. ISSN 2176-9478. http://dx.doi.org/10.5327/Z2176-947820190472.

[8]. Associação Brasileira de Normas Técnicas – ABNT, (2004). "NBR 10004, Solid Waste: Classification". Rio de Janeiro: ABNT.

[9]. Willing, A. (2001). "Lubricants based on renewable resources – an environmentally compatible alternative to mineral oil products". *Cremosphere*. Vol. 43 n. 1. https://doi.org/10.1016/S0045-6535(00)00328-3.

[10]. Silveira, E. L. C., Caland, L. B., Moura, C. V. R., (2006). "Determination of contaminants in lubricating oils used in sewage contaminated by these lubricants". *Química Nova*, Vol. 29 n. 6. ISSN 1678-7064. https://doi.org/10.1590/S0100-40422006000600009.

[11]. Gusmão, J. S., Fraga, M. S., Dias, J. S., (2013). "Reverse logistics applied to used or contaminated lubricating oils produced at gas stations in the city of Boa Vista-RR". *Caderno de Ciências Humanas e Sociais Aplicada*.

[12]. Meng, Y. Liu, X. Lu, S. Zhang, T. Jin, B., Wang, Q., Tang, Z., Liu, Y., Guo, X., Zhou, J. Xi, B., (2019). "A review on occurrence and risk of polycyclic aromatic hydrocarbons (PAHs) in lakes of China". *Sci. Total Environ*. Vol. 651 n. 2, pp. 2497–2506. https://doi.org/10.1016/j.scitotenv.2018.10.162.

[13]. Davoodi, S.M., Miri, S., Taheran, M., Brar, S.K., Galvez-Cloutier, R., Martel, R., (2020). "Bioremediation of Unconventional Oil Contaminated Ecosystems under Natural and Assisted Conditions: A Review" *Environmental Science & Technology*. v. 54, n. 4. ISSN 2054-2067. https://doi.org/10.1021/acs.est.9b00906.

[14]. John, R. C., Ntino, E. S., Itah, A. Y., (2016). "Impact of crude oil on soil nitrogen dynamics and uptake by legumes grown in wetland ultisol of the Niger Delta, Nigeria". *Journal of Environmental Protection*, Vol. 7 n. 4, pp. 64646. ISSN 2152-2219. http://dx.doi.org/10.4236/jep.2016.74046.

[15]. Wang, S., Xu, Y., Lin, Z., Zhang, J., Norbu, N., Liu, W. (2017) "The harm of petroleum-polluted soil and its remediation research". *AIP Conference Proceedings*. Vol. 1864 n. 1. ISSN 1551-7616. https://doi.org/10.1063/1.4993039.

[16]. APROMAC. Associação de Proteção ao Meio Ambiente de Cianorte, (2005). "Management Report at the National Environmental Council - CONAMA: Justification for the option for re-refining". Cianorte: APROMAC.

[17]. Federative Republic of Brazil, 2010. "Law 12,305 of August 2, 2010. Establishes the National Solid Waste Policy; amends Law 9,605 of February 12, 1998, and takes other measures". Brasília, DF: Official Gazette of the Union.

[18]. Standard Methods Committee of the American Public Health Association, American Water Works Association, Water Environment Federation, (2022). *Standard Methods for the Examination of Water and Wastewater: 5520 Oil and Grease*. 24. ed. Washington DC: APHA Press, 1516 p. ISBN 0875532993.

[19]. MAPA, Brazilian Ministry of Agriculture, Livestock and Supply, (2022). *Official Methods for Analysis of Products of Animal Origin*.

[20]. Carvalho, R. G., Kruk, N. S., Kawachi, E. Y., Queiroz, P. I. B., (2019). "A test method for determining oil concentration in samples of water contaminated with oils and greases". *Engenharia Sanitaria e Ambiental*, Vol. 24 n. 3. ISSN 1809-4457. https://doi.org/10.1590/S1413-41522019127950.

AUTHOR

Vitor Lorival Kudlanvec Junior

Assistant Professor at DCC-UFPR. Holds Master's degree from PPGEC-UFPR. Graduated in Civil Engineering from UFPR. Has experience in Civil Engineering, with an emphasis on Structures, working mainly on the following topics: structural projects in reinforced concrete and metallic structures, structural repair, structural repair mortar.