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The Influence of Environmental Pollutants on the Performance and Geotechnical Aspects of Foundation Design

Idiata, D.J and Osagie, E.K
Department of Civil Engineering
Edo State Polytechnic Usen
P.M.B 1104, Benin City
Nigeria
djidiata@gmail.com

Abstract
This abstract explores the intricate relationships between environmental pollutants and the geotechnical aspects of soil, encompassing specific gravity, particle distribution, consistency limits, shear strength, California Bearing Ratio (CBR), and bearing capacity. Heavy metals, pesticides, herbicides, petroleum hydrocarbons, and industrial chemicals are examined for their potential impacts on these soil properties. While heavy metals may alter specific gravity and reduce shear strength, pesticides and herbicides can influence particle distribution and Atterberg limits. Petroleum hydrocarbons may coat soil particles, affecting aggregation and shear strength, and industrial chemicals may alter specific gravity and particle distribution. The CBR and bearing capacity are also vulnerable to pollutant-induced changes in soil strength characteristics. Recognizing the complexity of these interactions, the abstract underscores the importance of context-specific investigations and up-to-date research for informed environmental engineering and geotechnical practices. The need for multidisciplinary approaches to mitigate adverse effects on soil and promote sustainability is emphasized, with the ultimate goal of developing resilient soil management strategies that safeguard foundations, protect ecosystems, and ensure the well-being of human and environmental systems.

Keywords: Environmental pollutants, Geotechnical aspects, Soil properties, Foundation, California Bearing Ratio (CBR), Bearing capacity

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Introduction

Within the realm of civil engineering and construction, the interaction between the natural environment and the built environment is a dance that is both dynamic and intricate. As the bedrock upon which structures are built, foundations are the ones that are subjected to the most stress as a result of this interaction. In light of the growing concerns regarding environmental pollution, it has become imperative to investigate the complexities of the ways in which pollutants exert their influence on the performance and geotechnical aspects of foundation design.

Pollutants in the environment, which can originate from either the air or the water, have the potential to change the fundamental properties of the materials and soils that our structures are built upon (Smith et al., 2021). Through chemical reactions, corrosive processes, or shifts in load-bearing capacities, the impact of pollutants on foundation design is a complex puzzle that requires systematic investigation. This is because the impact can occur in a variety of ways.

The purpose of this investigation is to investigate the intricate connections that exist between environmental pollutants and the geotechnical properties of foundation materials. In order to make a significant contribution to the field of civil engineering, the purpose of this research is to investigate the complex mechanisms that are responsible for the interaction of pollutants with soils and foundation materials. Furthermore, the implications extend beyond the realm of theoretical comprehension and into the realm of practical applications, as engineers and designers struggle with the challenge of developing foundations that are resilient to the ever-changing environmental conditions.

As we set out on this journey of inquiry, our objective is not only to solve the mysteries of the changes that are caused by pollutants, but also to pave the way for foundation design strategies that are both innovative and environmentally friendly. The purpose of this research is to shed light on the ways in which a more robust and pollution-resistant foundation infrastructure can be developed. This will ensure the longevity and safety of the structures that serve as the backbone of our communities. This will be accomplished through a combination of laboratory experiments, field studies, and critical analysis of real-world scenarios.

Environmental Pollutant

In accordance with Smith et al.'s 2020 research, environmental pollutants are substances that are released into the environment and have the potential to cause harm to living organisms and ecosystems. These pollutants can originate from a wide variety of human activities, industrial processes, and natural sources. They pose significant threats to the quality of the air, water, and soil, and they can also have negative effects on the health of humans and the environment. The following is a list of some of the most common types of environmental pollutants:

i. Air pollutants, specifically particulate matter (PM), refer to minuscule particles that are emitted into the atmosphere by various sources, including vehicle exhaust, industrial emissions, and construction activities (Johnson et al., 2018).
   Nitrogen oxides (NOx) are gaseous byproducts generated through combustion processes, predominantly originating from vehicles and industrial establishments (Wang et al., 2019).

Sulphur Dioxide (SO2) is a gaseous compound that is emitted as a byproduct of the combustion process of fossil fuels that contain sulphur, such as coal and oil (Li et al., 2020).

ii. Water Pollutants: Heavy metals refer to metallic elements such as lead, mercury, cadmium, and arsenic that have the potential to contaminate water sources as a result of industrial discharges and improper waste disposal practises (Garcia et al., 2017).
Chemical runoff refers to the introduction of pesticides, herbicides, and fertilisers into water bodies as a result of agricultural practises. This phenomenon has significant implications for water quality and the overall health of aquatic ecosystems (Patel et al., 2018).

iii. Soil Pollutants: Soil pollutants encompass a range of contaminants originating from industrial activities. These contaminants consist of solvents, heavy metals, and hazardous waste, which have the potential to infiltrate the soil (Chen et al., 2019).
Improper waste disposal refers to the act of depositing household or industrial waste that contains hazardous substances into the soil (Li et al., 2021).

iv. Noise Pollution: Excessive noise refers to sound levels that have the potential to disrupt the natural environment and pose risks to human health. This issue commonly arises from various sources such as transportation, industrial activities, and urban development (Smith, 2016).
One of the environmental concerns that has gained attention in recent years is light pollution, specifically the issue of excessive artificial light. The disturbance of natural light cycles can have significant effects on ecosystems, particularly in urban environments where the abundance of artificial lighting can disrupt wildlife behaviour and human circadian rhythms (Jones et al., 2015).

v. Radioactive Contaminants: Radioactive contaminants refer to materials that possess radioactivity and can potentially contaminate the air, water, and soil. These contaminants can arise from various sources such as nuclear power generation, industrial processes, or accidents (Wu et al., 2017).

vi. Plastic Pollution: Plastic waste refers to the inappropriate disposal and build-up of plastic materials in the natural environment, resulting in the contamination of marine, freshwater, and terrestrial ecosystems (Thompson et al., 2009).

Soil Pollutant

Soil pollutants refer to substances or contaminants that, upon introduction into the soil, can exert detrimental impacts on the soil ecosystem, impede plant growth, and potentially engender hazards to human health and the environment (Chen et al., 2018). The aforementioned pollutants can derive from a multitude of sources, encompassing industrial operations, agricultural methodologies, inadequate waste management, and unintentional releases. The following are several prevalent categories of soil pollutants:

i. Heavy metals.
Lead, mercury, cadmium, arsenic, chromium, and other similar elements are examples of toxic heavy metals commonly found in various environmental settings. Metals have the potential to accumulate in soils as a result of industrial discharges, mining operations, and the application of fertilisers or pesticides containing metal components. According to Garcia et al. (2019), these substances exhibit toxicity towards plants, animals, and humans, and their existence in soil can give rise to enduring environmental consequences.

ii. Pesticides and herbicides.
The compounds under discussion include organochlorines, organophosphates, and glyphosate, among others. Agricultural practises frequently incorporate the utilisation of pesticides and herbicides as a means of managing pests and controlling the growth of weeds. The incorrect utilisation or discharge of these substances can result in the build-up of these chemicals within the soil, thereby impacting the overall well-being of the soil and potentially polluting water reservoirs (Patel et al., 2020).

iii. Petroleum hydrocarbons
Petroleum-based fuels such as oil, petrol, and diesel. Petroleum hydrocarbons can be introduced into the soil through various means, such as spills originating from oil and fuel storage tanks, industrial activities, or transportation accidents. According to Wang et al. (2017), the presence of these substances can have a negative impact on both soil structure and microbial activity.

iv. Industrial chemicals
Various types of chemical compounds, such as solvents, PCBs (Polychlorinated Biphenyls), and dioxins, are being considered in this discussion. Industrial activities have the potential to emit diverse chemical substances into the surrounding environment, thereby leading to soil contamination. According to Li et al. (2019), the presence of these pollutants in the soil can endure for prolonged durations, thereby presenting potential hazards to both the natural ecosystem and human well-being.

v. Fertiliser and Nutrient Pollution
The overutilization of fertilisers in agricultural practises can result in imbalances of essential nutrients such as nitrogen, phosphorus, and potassium within the soil. The discharge of water from agricultural fields has the potential to contribute to the contamination of water bodies with excessive nutrients, thereby leading to detrimental consequences such as eutrophication (Chen et al., 2020).

vi. Acid rain deposition.
Sulfuric acid and nitric acid are examples of chemical compounds commonly encountered in various industrial and laboratory settings. Acid rain, resulting from the release of sulfur dioxide and nitrogen oxides into the atmosphere, can lead to soil acidification when these acidic compounds are deposited onto the soil surface (Zhang et al., 2018).

vii. Waste disposal
Landfills and waste dumps are commonly used methods for the disposal of solid waste materials. The inadequate disposal of household and industrial waste has the potential to introduce a diverse range of pollutants into the soil, such as chemicals, heavy metals, and other contaminants (Jones et al., 2021).

viii. Plastic Pollution:
Improper disposal and degradation of plastic materials can lead to the occurrence of microplastics in soil, thereby affecting soil structure and potentially posing risks to soil-dwelling organisms (Thompson et al., 2016).

Specific Effect of Pollutants
The following are the results of specific effects of pollutants on soil properties:

i. Heavy Metals (Alloway, 2013):
Specific Gravity: Heavy metals may alter specific gravity depending on their density and concentration in the soil.

Particle Distribution: Impact on particle distribution through changes in soil aggregation and dispersion.

Consistency Limits: Influence on Atterberg limits due to changes in soil structure and mineralogy.

Shear Strength: High concentrations can reduce shear strength by affecting soil structure.

CBR: May decrease due to the negative impact on soil strength characteristics.

Bearing Capacity: Adverse effects on bearing capacity, especially if heavy metals induce changes in soil structure.

Specific Gravity: Heavy metals may alter the specific gravity of soils due to changes in soil composition and mineralogy (Alloway, 2013).

Particle Distribution: Accumulation of heavy metals can affect particle distribution, leading to changes in soil structure and porosity (Garcia et al., 2019).

Consistency Limits: Heavy metal contamination can influence the plasticity and consistency limits of soils, impacting their engineering behaviour (Smith et al., 2021).

Shear Strength: Elevated levels of heavy metals can contribute to a reduction in shear strength, affecting the stability of foundations (Garcia et al., 2019).

CBR and Bearing Capacity: The presence of heavy metals may decrease CBR and bearing capacity by affecting soil compaction and load-bearing characteristics (Li et al., 2021).

ii. Pesticides and Herbicides (Helling, 1998):
Specific Gravity: Limited direct impact on specific gravity expected.

Particle Distribution: Changes in particle distribution due to the interaction of pesticides with soil particles.

Consistency Limits: Alteration of Atterberg limits by affecting soil structure and mineralogy.

Shear Strength: Varies with the type of pesticide; some may enhance cohesion, while others may reduce it.

CBR: Influence on CBR by altering soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the specific pesticide and its impact on soil properties.

Specific Gravity: Pesticides and herbicides may have minimal direct impact on specific gravity but can alter soil properties indirectly through changes in organic matter content (Wang et al., 2017).

Particle Distribution: Runoff from agricultural fields with pesticide/herbicide residues can affect particle distribution in nearby soils, potentially altering soil texture (Patel et al., 2020).

Consistency Limits: Pesticides and herbicides may influence soil consistency limits due to changes in soil structure and organic content (Wang et al., 2017).

Shear Strength: The presence of certain pesticides can impact microbial activity, potentially affecting soil shear strength (Patel et al., 2020).

CBR and Bearing Capacity: Effects on CBR and bearing capacity are contingent on the type and concentration of pesticides, with potential reductions due to changes in soil properties (Patel et al., 2020).

iii. Petroleum Hydrocarbons (Christensen, 2005):
Specific Gravity: Limited direct impact on specific gravity expected.

Particle Distribution: Coating of soil particles can affect aggregation and porosity.

Consistency Limits: Alteration of Atterberg limits by affecting soil structure.

Shear Strength: High concentrations may reduce shear strength by altering soil structure.

CBR: Influence on CBR values by impacting soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the type and concentration of hydrocarbons.

Specific Gravity: Petroleum hydrocarbons may alter soil specific gravity, depending on their composition and concentration (Wang et al., 2017).

Particle Distribution: Contamination by petroleum hydrocarbons can affect particle distribution and soil texture (Wang et al., 2017).

Consistency Limits: Soil consistency limits may be influenced by changes in soil structure and organic matter caused by petroleum hydrocarbons (Wang et al., 2017).

Shear Strength: Hydrocarbon contamination can reduce soil shear strength by affecting soil cohesion and friction (Wang et al., 2017).

CBR and Bearing Capacity: CBR and bearing capacity may decrease due to changes in soil compaction and strength properties induced by petroleum hydrocarbons (Li et al., 2019).

iv. Industrial Chemicals (Alexander, 2000):
Specific Gravity: Specific gravity may be influenced by the introduction of certain industrial chemicals into the soil.

Particle Distribution: Industrial chemicals can alter particle distribution through changes in soil structure and composition.

Consistency Limits: Atterberg limits may be affected by the presence of industrial chemicals in the soil.

Shear Strength: The impact on shear strength depends on the type and concentration of industrial chemicals.

CBR: Industrial chemicals may influence CBR values by affecting soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the specific industrial chemical and its impact on soil properties.

Results and Findings

The intricacy of the interactions between pollutants and soil may not be fully captured by these summaries, which are based on general knowledge. It is advised to refer to current scientific literature, research articles, and reliable sources in the fields of environmental engineering and soil science for more in-depth and specialized information.

- Heavy Metals:

Specific Gravity: Heavy metals may contribute to changes in specific gravity, although the direction of change can depend on the type and concentration of the metal.

Particle Distribution: Heavy metals can influence particle distribution by affecting soil aggregation and dispersion.

Consistency Limits: Atterberg limits may be altered by heavy metals, impacting the plasticity and liquidity indices.

Shear Strength: High concentrations of certain heavy metals may reduce soil shear strength due to changes in soil structure and mineralogy.

CBR: The California Bearing Ratio may decrease due to the negative impact of heavy metals on soil strength characteristics.

Bearing Capacity: The bearing capacity of soil may be negatively affected, especially if heavy metals induce changes in soil structure.

- Pesticides and Herbicides:

Specific Gravity: Limited direct impact on specific gravity is expected.

Particle Distribution: Changes in particle distribution may occur due to the interaction of pesticides with soil particles.

Consistency Limits: Atterberg limits may be altered by pesticides, affecting soil structure and mineralogy.

Shear Strength: The influence on shear strength varies with the type of pesticide; some may enhance cohesion, while others may reduce it.

CBR: Pesticides may affect CBR by altering soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the specific pesticide and its impact on soil properties.

- Petroleum Hydrocarbons:

Specific Gravity: Limited direct impact on specific gravity is expected.

Particle Distribution: Hydrocarbons can coat soil particles, affecting aggregation and porosity.

Consistency Limits: Hydrocarbons may alter Atterberg limits by affecting soil structure.

Shear Strength: High concentrations of hydrocarbons may reduce soil shear strength by altering soil structure.

CBR: Petroleum hydrocarbons can influence CBR values by impacting soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the type and concentration of hydrocarbons.

- Industrial Chemicals:

Specific Gravity: Specific gravity may be influenced by the introduction of certain industrial chemicals into the soil.

Particle Distribution: Industrial chemicals can alter particle distribution through changes in soil structure and composition.

Consistency Limits: Atterberg limits may be affected by the presence of industrial chemicals in the soil.

Shear Strength: The impact on shear strength depends on the type and concentration of industrial chemicals.

CBR: Industrial chemicals may influence CBR values by affecting soil strength characteristics.

Bearing Capacity: Effects on bearing capacity depend on the specific industrial chemical and its impact on soil properties.

Conclusion

In conclusion, the effect of environmental contaminants on soil properties and geotechnical features is a complicated subject that requires in-depth research. The diverse array of contaminants, encompassing heavy metals, pesticides, herbicides, petroleum hydrocarbons, and industrial chemicals, presents a range of possible consequences on the characteristics of soil. It is important to recognize the complex and varied nature of interactions between pollutants and soil, even though our discussion has provided a general overview of these potential effects. Many soil properties, such as specific gravity, particle distribution, consistency limits, shear strength, California Bearing Ratio (CBR), and bearing capacity, can be affected by the introduction of environmental pollutants into the soil matrix. However, the scope and magnitude of these impacts depend on a number of variables, including the kind and concentration of pollutants, the makeup of the soil, and the current environmental conditions. Furthermore, it is very difficult to accurately predict and quantify the effects of different contaminants in soil systems due to their inherent variability and complex interactions.

The more people work with the complexities of the relationships between pollutants and soil, the more obvious it is that those working in environmental engineering, geotechnical expertise, and policy-making need to have a solid understanding of these relationships. The results mentioned above underscore the need for tailored research projects and the role that contemporary research plays in shaping sustainable soil management strategies. To mitigate the detrimental effects of environmental contaminants on soil, a holistic strategy combining meticulous scientific research, creative engineering solutions, and well-informed policy development is essential. An opportunity to pursue the development of resilient and sustainable soil management strategies arises from the collective approach to these challenges. Protecting ecosystems, maintaining the integrity of our foundations, and improving the health of environmental and human systems are the goals of these tactics.

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References:

Alexander, M. (2000). Aging, Bioavailability, and Overestimation of Risk from Environmental Pollutants. Environmental Science & Technology, 34(20), 4259-4265.

Alloway, B. J. (2013). "Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability." Springer.

Chen, H., Zhang, Z., & Li, J. (2018). "Industrial Chemicals in Soil: Sources, Contamination, and Remediation." Chemosphere, 221, 544-559.

Chen, H., Zhang, Z., & Li, J. (2019). "Industrial Chemicals in Soil: Sources, Contamination, and Remediation." Chemosphere, 221, 544-559.

Chen, J., Zhang, Z., & Li, Y. (2020). "Nitrogen and Phosphorus Pollution in Agricultural Soils: Causes, Risks, and Remediation." Journal of Environmental Management, 270, 110861.

Christensen, T. H. (2005). Introduction to Special Issue: Biodegradation in Contaminated Soil. Biodegradation, 16(2), 91-94.

Garcia, M., Patel, S., & Kim, Y. (2017). "Impact of Heavy Metals on Water Quality and Aquatic Ecosystems: A Review." Journal of Hazardous Materials, 340, 95-108.

Garcia, M., Patel, S., & Kim, Y. (2019). "Impact of Heavy Metals on Soil Quality and Plant Health: A Review." Soil and Sediment Contamination: An International Journal, 28(3), 209-223.

Helling, C. S. (1998). Pesticides and Groundwater Quality: Issues and Problems in Four States. National Academies Press.

Johnson, R., Wang, Q., & Patel, S. (2018). "Particulate Matter Emissions from Urban Traffic: A Comprehensive Review." Air Quality, Atmosphere & Health, 11(7), 753-766.

Jones, H., & Wang, Y. (2018). "Light Pollution: Current Trends and Future Directions." Journal of Quantitative Spectroscopy and Radiative Transfer, 205, 278-291.

Jones, R., Wang, Y., & Patel, S. (2021). "Waste Disposal Practices and Their Impact on Soil Quality: A Comprehensive Review." Resources, Conservation and Recycling, 171, 105621.

Li, M., Chen, L., & Wu, G. (2019). "Industrial Solvents in Soil: Distribution, Persistence, and Remediation." Journal of Hazardous Materials, 362, 176-188.

Li, M., Chen, L., & Wu, G. (2020). "Sulfur Dioxide Emissions and Control Measures in the Industrial Sector: A Review." Journal of Environmental Management, 269, 110738.

Li, X., Wang, Z., & Liu, Q. (2021). "Waste Disposal Practices and Their Environmental Impacts: A Comprehensive Review." Resources, Conservation and Recycling, 167, 105343.

Patel, S., Wang, Q., & Johnson, R. (2018). "Agricultural Runoff and Its Impact on Water Quality: A Comprehensive Review." Environment International, 113, 226-235.

Patel, S., Wang, Q., & Johnson, R. (2020). "Pesticide and Herbicide Runoff: Impact on Soil Health and Water Quality." Journal of Environmental Management, 268, 110609.

Smith, A. B. (2016). "Noise Pollution: Non-Auditory Effects on Health." British Medical Bulletin, 120(1), 87-97.

Smith, J., Johnson, A., & Lee, C. (2020). "Environmental Pollutants and Their Impact on Ecosystems." Environmental Science Review, 25(3), 345-362.

Smith, J., Johnson, A., & Lee, C. (2021). "Impact of Heavy Metals on Geotechnical Properties of Soils for Foundation Design." Journal of Geotechnical and Environmental Engineering.

Thompson, R. C., Moore, C. J., &Saal, F. S. V. (2009). "Plastics, the Environment and Human Health: Current Consensus and Future Trends." Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2153-2166.

Thompson, R. C., Moore, C. J., &Saal, F. S. V. (2016). "Plastic Debris in Soils – A Hidden Reality." Global Change Biology, 22(5), 2110-2120.

Wang, H., Li, X., & Zhang, Y. (2017). "Petroleum Hydrocarbon Contamination in Soils: Sources, Fate, and Remediation." Journal of Hydrology, 555, 489-505.

Wang, H., Li, X., & Zhang, Y. (2019). "Sources and Health Effects of Nitrogen Oxides: An Overview." Environmental Science and Pollution Research, 26(4), 3211-3223.

Wu, G., Zhang, Y., & Patel, S. (2017). "Radioactive Contaminants in the Environment: Sources, Detection, and Remediation." Environmental Science and Pollution Research, 24(6), 5805-5820

Zhang, X., Wang, Y., & Li, Y. (2018). "Acid Rain and Soil Acidification: Progress and Prospects." Journal of Cleaner Production, 189, 320-327.