Physicochemical Effects of Paint Waste on Soil Microbial Community

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ABSTRACT

Improper disposal of paint waste poses a growing environmental concern due to its complex composition of heavy metals, organic solvents, and synthetic polymers. This study investigates the physicochemical impact of paint waste on soil microbial communities, aiming to understand how such pollutants alter soil properties and biological activity. Soil samples were collected from the paint factory dumpsite which represent 0m, 100m and 200m away then control was at 500m away. Physicochemical parameters—including pH, electrical conductivity (EC), organic carbon, total nitrogen, available phosphorus—were measured alongside isolating microbes from the soil. Results revealed that paint waste significantly disrupted soil pH, EC was very high at the dumpsite and also reduced as we went further away from the site. Microbes isolated includes Bacillus sp, Pseudomonas sp, Micrococcus sp, Staphylococcus sp, Aeromonas sp, Flavobacterium sp, Aspergillus sp, Penicillium sp, Mucor sp, and Fusarium sp. These changes corresponded with reduced microbial diversity and activity. Our findings highlight the detrimental impact of paint waste on soil microbial ecosystems, emphasizing the need for stricter waste management practices and further research into bioremediation strategies. The study underscores the intricate link between chemical pollution and microbial ecological balance in terrestrial environments.

Keywords: Paint waste, physicochemical impact, Environment and Soil.

INTRODUCTION

The indisputable effect of the increasing human population is the increased growth of industries to satisfy their varied needs. Waste management is becoming a critical issue as a result of this increase in industrial activity, as it is necessary to reduce environmental contamination and its related effects. The paint industry is one of the most notable worldwide causes of pollution, mainly because of its effluent releases, gas emissions, and disposal of organic and inorganic chemical waste that contribute to environmental contamination (Aniyikaiye et al., 2019).

Paint is a complicated mixture of pigments, solvents, and additives that is used to apply colour to a variety of surfaces. According to Phulpoto et al., (2016), pigments are added to binders and additives, which help the paint stick to surfaces, to give it colour and stop corrosion. In order to help the paint, spread evenly, solvents are used. Although paints are divided into several categories, two main groups can be distinguished by the kind of thinning agent that is applied. According to Odokuma et al., (2013), paintings thinned with organic solvents or mineral turpentine are called oil-based or solvent-based paints, whereas paints thinned with water are called emulsion paints or water-based vinyl or acrylic paints.

The demand for high quality paints among the general population has led to an increase in paint manufacture worldwide in recent times. While the paint industry has undeniably revolutionized the global economy, certain drawbacks have been attributed to the effluent produced during its manufacturing processes Orjiakor et al., (2019).

In Nigeria and other developing countries, industrial wastewater is a major source of soil pollution. Large volumes of both hazardous and non-hazardous waste are naturally released into the soil and water environment

during the paint production process, according to Olaoye and Oladeji (2015). This can cause ecological imbalances, bioaccumulations in aquatic organisms, and health issues. Paint production also uses a lot of water. Various techniques have been employed to address the pollutants found in industrial effluents. These methods encompass chemical precipitations, conventional coagulation, reverse osmosis, ion-exchange, solvent extraction, membrane filtration, chemical precipitation, electrodialysis, lime coagulation, and oxidation and reduction processes. However, the substantial capital investment required and the reported adverse environmental consequences associated with these physicochemical techniques have prompted the quest for more viable alternatives. In chemistry, a metal with a density greater than 5.0 g/cm3 is referred to as a heavy metal, which includes 45 elements like Fe, Mn, Pb, Cu, Zn, Cd, and Hg. Despite the relatively high levels of Fe and Mn in the soil, their effects on pollution are typically not taken into account. Based on their biochemical properties, soil heavy metals can be separated into two groups: those that are toxic to humans, animals, and crops (like Pb, Cd, and Hg), and those that are beneficial to biological systems (like Cu, Zn, Mn, and others) when present in moderation (Diana et al., 2025).

Also, human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications. Reported sources of heavy metals in the environment include geogenic, industrial, agricultural, pharmaceutical, domestic effluents, and atmospheric sources. Environmental pollution is very prominent in point source areas such as mining, foundries and smelters, and other metal-based industrial operations (He et al., 2005). Comparing the relevance of industrial effluents, Chidozie and Nwakanma (2017), found that pollutants emitted by the paint sector are by far the most significant, particularly in terms of heavy metal compositions. The dangers of heavy metals to human health and the environment cannot be over emphasized. Some of the biggest health risks connected with heavy metal exposure include genetic mutation, deformity, cancer, and renal damage (Oladele et al., 2018).

Soil is used to denote the outer loose materials of the earth surface; it is formed as a result of rock weathering. Soil is rich in organic matter and so it provides an excellent media for the growth of many organisms including bacteria, fungi, actinomycetes, algae, and protozoa. In ecology, soil is an active habitat especially for biological interaction except for occasional insects or earthworms (Sundararaj, 2004).

Microorganisms perform essential functions for soil ecosystems, including the cycling of minerals and the breakdown of organic compounds. The fertility and structure of the soil are preserved in large part by these actions. A rich and diverse population of microorganisms is supported by the topsoil, which has higher nutrient levels than the subsurface (Jolly et al., 2008).

Soil is an interesting medium for growing microorganisms due to its diverse nutrient content, which is required for their metabolic processes. Although these nutrients are not always readily available, soil is a rich source of microorganisms. 1g of agricultural soil, for example, can contain thousands of diverse kinds of microorganisms in the form of colony-forming units (CFUs) (McKinney, 2004).

MATERIALS AND METHOD

Study Site Selection

The study sites for assessing paint waste contamination and isolation of microbial isolates were carried out at two paint producing industries both located at Umuahia North Local Government Area. Umuahia coordinates lie between latitude 5° 31´ 29.63´´N and longitude 7° 29´ 40.60´´E. These sites are selected based on historical records, environmental reports and field surveys to ensure their relevance to the study. In contrast, a control sites away from the contaminated site was chosen to serve as a baseline for comparison. The control site has no documented history of contamination and was selected based on their distance from potential pollution sources.

Sample Collection

A systematic soil sampling strategy was used for accurately assessing paint waste contamination. Stratified random sampling was employed to capture the vertical distribution of contaminants at varying depths: 0–10 cm, 10–30 cm, and 30–50 cm. This approach is to ensure that contamination levels are evaluated across different soil

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layers, providing insights into pollutant migration and accumulation (Ahmed et al., 2018). By analyzing multiple depths, it will provide avenues in understanding whether contaminants are confined to the surface or have leached into deeper layers, influencing remediation strategies.

Composite soil samples were collected by combining subsamples (10 Kg of soil samples from each depth) from multiple points within each site. This method minimizes spatial variability and provides a more accurate depiction of contamination levels across the study area. A total of five composites samples for this study was collected. The samples were stored at 4℃ for physicochemical analyses, ensuring minimal changes in chemical composition. These standardized procedures were employed to ensure reliable data collection, aiding in comprehensive contamination assessments and effective pollution mitigation strategies.

Isolation of microbes from the soil

The soil microorganisms were isolated using the serial dilution technique on nutrient agar medium. One gram of soil from the sample was suspended in 10 ml of distilled water, mixed thoroughly for 15 minutes, and vortexed. Each suspension was serially diluted from 10^{-1} to 10^{-6}. The organisms were isolated from the diluted sample using the spread plate technique, where 0.1 ml was pipetted out onto plates with nutrient agar, spread with a glass L-shaped rod, and incubated for 24 hours at 37℃ for bacteria and 120 hours at 36℃ for fungi. The most pronounced colonies were isolated and kept at 4℃ for additional research (Kannan et al., 2018).

Determination of Physico-chemical Properties of Soil

In this study, soil chemical properties were analyzed using standard procedures.

Total nitrogen

This was determined using the Kjeldahl digestion method as adopted by Bremner (2017).

Total Nitrogen (TN) (%) in the soil sample was calculated using the Equation below

$$\text{Total Nitrogen (\%)} = \frac{(V_s - V_b) \text{ x N x } 1.4007}{W} \qquad \text{Eqn 1}$$

Where:

V_s = Volume (mL) of HCl used for titration of the sample

V_b = Volume (mL) of HCl used for titration of the blank

N = Normality of HCl (0.01N)

1.4007 = Conversion factor (based on atomic weight of nitrogen and Hcl molarity)

W = Weight of soil sample (in grams)

Available Phosphorus

The soil sample were quantified using Olsen's method and adopted by Murphy & Riley (2016). The available phosphorus concentration in the soil sample was calculated using the Equation 2.

$$\text{Available Phosphurus } (\frac{mg}{kg}) = \frac{C \text{ x } V}{W} \qquad \text{Eqn 2}$$

Where:

C= Phosphurus concentration from the calibration curve (mg/L)

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V = Volume of extratant used (mL) (typically 50 mL)

W = Weight of the soil sample (g) (typically 2.5g)

Exchangeable Cations

This was analyzed according to the method adopted by Havlin et al. (2020). This method ensures precise quantification of exchangeable cations, which influence soil fertility and plant growth. The concentrations of exchangeable cations (K a Na) in soil (cmol(+)/kg) was calculated using the Equation 3.

$$\text{Exchangeable Cation } \left(\frac{\text{cmol}}{\text{kg}}\right) = \frac{\text{C x V}}{\text{W x 100}} \qquad \text{Eqn 3}$$

Where:

C = Concentration of the cation from the calibration curve (mg/L)

V = Volume of extractant used (mL) (50mL)

W = Weight of soil sample used (g) (5g)

100 = Conversion factor to express result in cmol/kg

Soil temperature determination

This was be done using mercury in bulb thermometer. The bulb of the thermometer will be inserted into the soil at the depth of 0-20cm at the site and allowed to stand for 5 minutes before taking the reading in degree Celsius while still in place.

Soil pH determination

The pH determination was done by mixing 5.0 g of the soil sample with de-ionized water in a ratio of 1: 2.5 and properly mixed for 5 minutes; the pH will be read with the Jenway HANA 1910 multipurpose tester.

Determination of Organic Carbon in Soil Samples.

This will be determined by Walkley and Black method (1934). This method is based on the reduction of $Cr_2O_7^{2-}$ ion by organic matter and the unreduced $Cr_2O_5^{2-}$ ion will be measured by titration.

Determination of Electrical Conductivity in Soil Samples.

10g of air-dried soil sample was mixed with 20ml of distilled water and placed on a mechanical shaker for 15 minutes. It was allowed to stand for at least an hour and returned to the shaker for 2 hours. The mixture was then centrifuged and the supernatant decanted. Then, conductivity was measured using the conductivity meter.

RESULTS

Table 1: Frequency of Microbial Isolates from the Soil

S/NO.	ISOLATES	FREQUENCY	PERCENTAGE (%)
1	Bacillus species	20	50.8
2	Pseudomonas species	12	36.5
3	Micrococcus species	11	35.9
4	Staphylococcus species	8	31.7
5	Aeromonas species	6	27

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6	Flavobacterium species	5	24
7	Aspergillus species	17	59.7
8	Penicillium species	14	55.9
9	Mucor species	6	33.3
10	Fusarium species	5	25.6

Table 2: Mean Heterotrophic Count (Thc) of the Bacterial and Fungal Isolates from the Soil.

S/NO	DISTANCE (M)	BACTERIA (10^4 cfu/ml)	FUNGI (10^4 cfu/ml)
1	0	8.65 ± 4.51	8.07 ± 1.37
2	100	6.06 ± 5.50	7.7 ± 1.04
3	200	4.04 ± 4.46	6.75 ± 1.87
4	500	3.50 ± 2.02	3.08 ± 2.13

Results expressed in mean ± standard deviation of triplicate determination

Table 3: physicochemical properties of the soil

S/no	Distance (m)	pH	Available phosphorus (mg/l)	Total nitrogen	Organic carbon	EC (us/cm)
1	0	8.55 ± 0.18	7.44 ± 0.90	10.01 ± 0.71	0.94 ± 0.50	123.52 ± 1.13
2	100	8.68 ± 0.12	6.69 ±0.10	8.76 ± 0.14	0.76 ± 0.40	98.31 ± 0.85
3	200	7.34 ± 0.70	7.20 ± 0.12	8.01 ± 0.00	0.88 ± 0.20	83.56 ± 0.95
4	500	8.02 ± 0.10	6.15 ± 0.94	8.71 ± 0.53	0.66 ± 0.00	89.01 ± 1.70

Results expressed in mean ± standard deviation of triplicate determination

DISCUSSION

The microscopic and biochemical analysis of microbial isolates from the soil identified species such as Bacillus spp., Pseudomonas spp., Micrococcus spp., Staphylococcus spp., Aspergillus spp. and Penicillium spp. These findings are consistent with the study of Okafor et al. (2022) that also reported the presence of Aspergillus and Penicillium species in paint industry effluents. However, Chimagalam et al. (2022) also isolated Fusarium and Rhizopus species—with Rhizopus being particularly dominant—these were not detected in the current study.

The discharge of fresh paint waste appears to have negatively impacted the soil microflora, as soils in nearby control areas—untouched by the effluent—did not exhibit similar reductions in microbial count and diversity. These results align with the observations of Chimagalam et al. (2022), who suggested that prolonged exposure to effluents can lead to microbial acclimatization and adaptation, ultimately enhancing microbial populations in such environments. Paint effluents typically contain high levels of organic matter, which microorganisms can break down, enriching the soil with nutrients and creating a more favourable microenvironment. According to the Public Library of Science (2018), paint effluents can offer optimal conditions for resilient microbes, thereby increasing the potential for microbial degradation. However, most studies have focused only on selected microbial groups present in paint-contaminated substrates, rather than capturing the full diversity of microbial communities. The composition of soil microbial populations is known to vary greatly depending on environmental conditions.

In alkaline soils (pH > 7.5), the availability of micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) decreases due to the formation of insoluble hydroxides and carbonates. This can lead to deficiencies in these essential nutrients, manifesting as chlorosis and other deficiency symptoms in plants. Phosphorus availability is also reduced in alkaline conditions as it precipitates as calcium phosphate. The optimal pH range for nutrient availability is typically between 6.0 and 7.0. Within this range, most essential nutrients are in their most soluble forms and can be readily absorbed by plant roots (Khaled and Sayed, 2023).

The health and environmental impacts of paint are diverse, with one of the most significant concerns being the release of volatile organic compounds (VOCs). The breakdown of paint materials can create favourable

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conditions for microbial growth, and human contact with such contaminated surfaces may result in bacterial or fungal infections (Padmini & Kiran, 2020). Additionally, moisture-related problems like dampness and mold can increase the risk of upper respiratory issues, including coughing, wheezing, and asthma (Mendell, 2007).

To mitigate these risks, it is recommended that effective antimicrobial agents be incorporated into paint formulations. Doing so would help limit microbial proliferation at sites where paint effluents are discharged and support broader efforts to protect environmental health.

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