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Impact of Acrylic-Based Paints effluent on the Physicochemical and Bacteriological quality of soil in Ado-Ekiti, Nigeria

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Abstract

Paint manufacturing has grown in recent years in response to the increasing demand for high quality paints. Consequently, large amount of wastes are released into the environment. This study investigated the impact of acrylic-based paints effluent on the physicochemical and bacteriological compositions of the receiving soil around paint production factories within Ado-Ekiti using standard techniques. The paint effluent increased the receiving soil's pH, bulk density, particle size, temperature, moisture, electrical conductivity, but lowered the cation-exchange capacity (CEC), organic matter, nitrogen, and phosphorus content. These effects were significant ($P<0.01$) when compared with the control. Similarly, the total bacteria counts reduced in paint contaminated, but not significantly different from control ($P>0.01$). A total of 29 bacteria was characterized and distributed among 10 genera, namely; *Bacillus* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Arthrobacter* spp., *Aeromonas* spp., *Cirobacter* spp., *Alcaligenes* spp., *Flavobacterium* spp., *Enterobacter* spp. and *Micrococcus* spp. *Bacillus* spp. (24.1%) had the highest frequency and was followed by *Pseudomonas* spp. (17.2%) and *Flavobacterium* spp. (10.3%). The rest isolates had 6.9%. The predominant bacteria, *Bacillus* spp., *Pseudomonas* spp., and *Flavobacterium* could be more favoured in paint impacted soils and thus could be considered as paint effluent treatment agents.

1. Introduction

Soil is one of the major natural resources as important as water and air. It sustains the existence of plants, animals, and most importantly humans because; they derive their food from it. This natural resource determines the distribution of plant species and provides a home for wide varieties of organisms. It also controls the cycling of water and chemical substances between the atmosphere and the earth, and acts as both a source and reservoir for atmospheric gases such as oxygen and carbon dioxide) [1]. A good arable soil, according to environmentalists is characterized by adequate proportion of active organisms (microorganisms), soil water, soil air and mineral compounds in the right proportion. A destabilization in the proportion of soil composition, usually leads to unhealthy soil. One of the major factors affecting soil health and quality is environmental pollution, particularly resulting from increasing industrialization, rising population growth and over reliance on chemical products [2]. Soil is an efficient self-purifying medium with a great ability to receive and decompose wastes and pollutants of different kinds. According to Jolly *et al*. [3], soil has the capacity to filter out suspended matter, decompose organic matter by its microbial flora and mineralize essential nutrients. However, if the input of the

pollutants exceeds the soil purifying limit, the effectiveness of soil microorganism activity is reduced substantially, and this could lead to marked alteration in the soil physico-chemical and microbiological properties. As a result, the growth and development of the crop plants become adversely affected [3].

In Nigeria and other developing countries, one of the major pollutants of soil is industrial waste water [4]. Previous studies have shown that such poorly treated effluent adversely affect the ecosystem. One of the industrial wastes that is scarcely reported is effluents from paint industry. Globally, paint manufacturing has grown in recent years in response to the increasing demand for high quality paints by the general public [4]. The major problem associated with such industry is management of waste water that accompanies the production process. In Nigeria, Olaoye and Oladeji [4] reported that paint production utilizes large volume of water without adequate wastewater treatment plant, and consequently, large quantities of both hazardous and non-hazardous wastes are inherently released to the soil and water environment, thereby leading to potential health related problems, ecological imbalance and bioaccumulations in aquatic organisms. water-based or emulsion paints, such as Latex paint, which is one of most common trending paints, generally, consist of organic and inorganic pigments and dyestuffs, extenders, cellulosic and non-cellulosic thickeners, latexes, emulsifying agents, anti-foaming agents, preservatives, solvents and coalescing agents. These organic and inorganic chemical compounds, when not properly treated before disposal could damage the chemistry and biology environment [3, 5]. Comparing the importance of the industrial effluents, Chidozie and Nwakanma [5] reported that pollutants discharged by a paint industry are by far the most significant, especially with respect to heavy metal compositions. The health and environment effects of heavy metals cannot be over emphasized. Some of the major health hazards associated with exposure to heavy metals include genetic mutation, deformation, cancer, kidney damge [3, 6].

Microorganisms are the key components of the soil. They carry out basic biodegradation and mineral cycling activities in the soil, which keeps the soil fertility and structure intact. Several microorganisms exist in topsoil, where nutrient sources are abundant than in subsoil [3]. They are especially abundant in the area immediately next to plant roots (called the rhizosphere), where sloughed-off cells and chemicals released by roots provide ready food sources. These organisms are the basic decomposers of organic matter. They also play other important roles in the soil, such as provide nitrogen through fixation to help growing plants, detoxify harmful chemicals (toxins), suppress disease organisms, and produce products that might stimulate plant growth [7]. Soil microbes also have other benefits to humans, and have been found to be vital reservoir for antibiotic-producing organisms used to fight diseases [8]. Among the group of soil microorganisms, bacteria have been reported to be the most abundant with a population of about $3.0 \times 10^6 - 5.0 \times 10^8$ per gram of soil [9, 10]. However, the population and optimal activities of soil microbes depends largely on the prevailing environmental factors, such as nutrients availability, moisture availability, degree of aeration, pH, and temperature. Bacteria make up the most abundant soil flora, and are also the key players in various biochemical cycles and are responsible for the recycling of organic compounds [9, 10]. It is therefore, pertinent to monitor the population of these microorganisms so as to keep the health of the soil. Information on the prevailing physicochemical quality of the soil will go a long way in understanding the status of soil pollution. This study was therefore done to determine the impact of paint effluent on the physicochemical and bacteriological qualities of the receiving soil environment.

2. Materials and method

2.1. Sampling location

The sampling locations are paint effluents contaminated sites around the production unit of two famous factories (A and B) both located in Ado Ekiti, the State capital of Ekiti, South Western part of Nigeria.

Geographically, Ado-Ekiti is situated between latitude 7.667° N and longitude 5.250° E and bounded in the north by Kwara State and Kogi State while Osun State occupies the west and Ondo State lies in the south and extends to the eastern part (Fig. 1). The population of the indigenes is about 2,384,212 and the inhabitants of the state are mainly farmers, artisans, traders, civil and public servants [11].

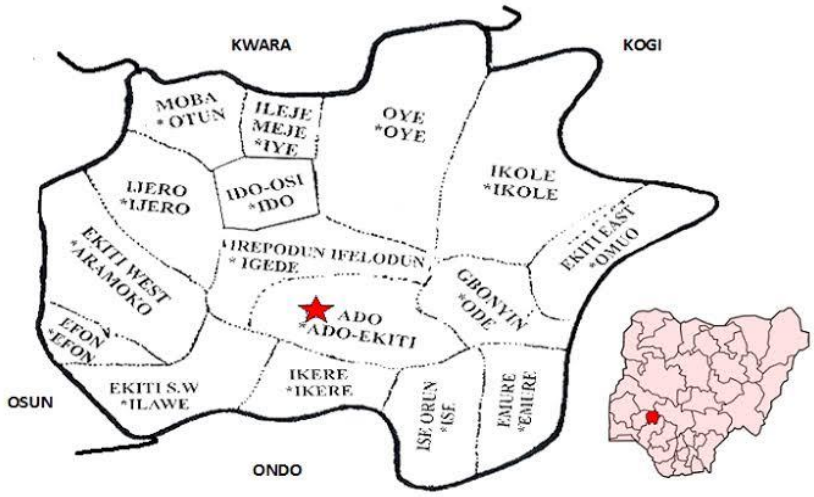

Fig. 1: The map of Nigeria with location of Ekiti State in red [11].

2.2. Sample collection

Soil samples from visibly discoloured acrylic paint polluted were collected from acrylic-paint impacted soil particles found inside the active paint production warehouse facility (indoor) and acrylic-paint impacted soils from outside the active paint production facility (outdoor) according to the procedure of Wieser *et al.* [12]. Indoor samples were collected by scraping-off and gently transferring into clean plastic containers, while the outdoor samples were collected by scrapping-off the top soil aerobically exposed up to a depth of 10 mm and gently placing in clean plastic containers before transportation to the laboratory for further work.

2.3. Physicochemical analyses of soil samples

Analyses of the physicochemical properties of the soil samples were carried out according to modifications of the methods adopted by Mahawar and Akhtar [13].

2.3.1. Determination of pH values

The pH of the soil samples was measured on site using a portable pH meter (Model: HI 8314 HANNA instruments). The glass electrode was thoroughly wetted with distilled water. The pH meter was then switched on and was standardized. The pH meter was standardized with buffer solutions (pH 4 and 9). About 2g of soil sample each was weighed and 50 mL of distilled water was added and stirred, the pH meter was then inserted in each sample and readings were taken.

2.3.2. Determination of Electrical Conductivity

Determination of electrical conductivity was carried out using a conductivity meter. The electrode of the meter was wetted thoroughly and then plugged into the conductivity meter before it was inserted into a 250 mL beaker containing distilled water. The conductivity meter was then switched on, and zero error was corrected. The distilled water was replaced with raw water samples and the reading was recorded. 2g of sample each was weighed and 50 mL of distilled water was added and stirred, the conductivity meter was inserted into each sample and readings were recorded.

2.3.3. Determination of moisture content

Five grams of each of the soil samples were weighed into pre-weighed crucible. The crucible and the content were weighed again. This was then put in the oven at 110°C for 3hrs to a constant weight after which it was removed, cooled and weighed. The following expression was used to calculate the moisture content.

$$Moisture\ content\ (\%) = \frac{Weight\ of\ Sample - dry\ weight}{Weight\ of\ sample} \times 100$$

2.3.4. Determination of Bulk density

The oven dry weight of the sample was divided by the volume of the undisturbed sample at filled moisture condition and the oven dry weight of the entire soil calculated.

$$Bulk\ density = \frac{Weight\ of\ oven\ dried\ soil}{Volume\ of Oven\ dried\ soil}$$

2.3.5. Determination of Particle

Density Specific density bottle was used in this method; a clean dry 50mL specific gravity bottle was weighed in air (Wa), some quantities of the air dried soil was added to the flask. The body of the specific gravity bottle was cleaned to remove the dust that spilled during the transfer of the soil to the flask and the content with the flask was weighed (Ws). Previously boiled and cooled distilled water was added to the flask with content little at a time and stirring was done gently to remove air between the particles (Wsw). After which the temperature of the contents was determined using the thermometer. The soil was further removed from the flask and the flask was filled with boiled cooled distilled water at the same temperature as former while the outside of the flask was dried with filter paper. The weight was known and recorded. Density of the water was determined.

$$Density\ (dW) = \frac{Ww - Wa}{50}$$

$$Particle\ density\ (DP) = \frac{dw\ (Ws - Wa)}{(Ws - Wa) - \ (Wsw - Ww)}$$

2.3.6. Determination of Total Porosity

This is determined from bulk density (Db) and particle density (DP). It is an index of the relative volume of pores. It is influenced by the structure and texture of soil. It is calculated using the following formula;

$$Porosity = \left[1 - \left(\frac{Db}{Dp}\right)\right] x\ 100$$

2.3.7. Determination of Organic Matter content

The walkley-black wet oxidation method, procedures measure active or decomposable organic matter in the soil. Oxidizable matter in a soil sample is oxidized by $Cr_2O_7^{2-}$ and the reaction is facilitated by the heat generated when 2 volumes of concentrated H_2SO_4 are mixed with 1 volume of 0.167M $K_2Cr_2O_7$ solution. The excess $Cr_2O_7^{2-}$ is determined by titration with standard $FeSO_4$ solution and the quantity of substance oxidized is calculated from the amount of $Cr_2O_7^{2-}$ reduced using orthophenanthroline-ferrous complex indicator (ferroin) which gives a colour change from orange to dark green to light green and finally to maroon red. Precisely 1g of already grinded soil sample was weighed and transferred to 250mL conical flask, 2.457g of potassium dichromate was weighed and made up to 50 mL with distilled water. 19.61g of Iron (II) ammonium sulphate was weighed and made up to 100 mL with distilled water. 0.1487

of orthophenanthroline ferrous complex indicator was also weighed and 0.0695g of Iron (II) sulphate was weighed. The indicator and Iron (II) sulphate were added together and made up to 100 mL with distilled water. 10mL of potassium dichromate was added to the soil in the 250 mL conical flask, 20 mL of concentrated sulphuric acid was added to the content rapidly and the flask was swirled immediately and gently until the soil and reagent are mixed properly. The swirling continued more vigorously for one minute then the flask was rotated and allowed to stand on a sheet for about 30 mins. After standing for 30 mins, 100mL of distilled water was added as well as the addition of 3-4 drops of ferroin indicator, thereafter, titration was done with 0.5M iron (II) ammonium sulphate which takes greenish cast and then changes to dark green. At this point, colour changes sharply from green to brownish red. Blank titration was made in the same manner. The titre values were recorded.

$$\% \text{ Organic carbon} = (B\text{-}T) \times M \times 0.003 \times 1.33 \times 100/\text{weight of sample}$$

B = Blank titre value, T = Sample titre value and M = Molarity of $(NH_4)_2\,Fe(SO_4)_2.6H_2O$

$$\% \text{ Organic matter} = \% \text{ organic carbon} \times 1.724$$

2.4. Heavy metal analyses of soil samples

The presence of metals within the soil samples in their elemental form was detected using Atomic Absorption Spectrophotometer (AAS Buck Scientific Model 210 VGP) and Flame Photometer FP 902

2.5. Enumeration and isolation of bacteria from sample

Soil samples collected were processed based on the technique adopted by Phulpoto *et al.* [14] with slight modifications. Precisely 1g of each sample collected from each site was dissolved in 50 mL of sterile distilled water and placed in flasks (250 mL capacity). The sample containing flasks were then incubated at 37 ^oC for 2 h. After incubation, approximately 5 mL of each sample was used as an inoculum for enrichment procedure. The isolation medium was an enrichment technique, mineral salt media (MSM), containing 0.5 g/L $MgSO_4$, 0.2 g/L $CaCl_2$, 13.6 g/L KH_2PO_4, 5 g/L $(NH_4)_2.SO_4$, 0.05 g/L $FeSO_4.7H_2O$, 15 g/L Na_2HPO_4 [14]. The soil suspension (5 mL) was aseptically added into flasks containing 100 mL of prepared MSM broth enriched with acrylic paint (Finecoat® Acrylic Emulsion Paints) as carbon source in concentrations of 1% v/v. The experimental set-ups were incubated at 37 ^oC for 10 days under agitation (150 rpm). The total microbial growth absorbance was measured in 3 days intervals at 600 nm. Experimental set-ups with the highest absorbance values connoting higher microbial presence was used for microbial isolation. Primary isolation of bacteria was carried out using nutrient agar by plating out 0.1 mL of samples on appropriately prepared culture using pour plate technique. Pure cultures that were determined were maintained on 2% (w/v) Nutrient agar, and stored at 4°C in a refrigerator. Pure cultures were sub-cultured onto fresh sterile medium slants every 2-3 weeks to ensure viability. Phenotypic identification of bacterial isolates was carried out with focus on gram staining reactions, spore test, motility, hydrogen sulphide production, growth on differential media, indole production, catalase production, citrate utilization, oxidase production, Methyl Red and Voges Proskauer reactions, coagulase production, urease production, nitrate reduction, and sugar fermentation tests. The Bergey's manual of Determinative Bacteriology was used as a guide and reference.

2.6. Statistical analyses

Statistical methods documented by Paulson [15] were adopted throughout the research work. Experiments were carried out in triplicates and values were expressed as mean ± standard deviation. Results were presented in tabular and graphical formats. Where necessary, data obtained were statistically analysed using different Analysis of variance (ANOVA) adopting probability levels below 5%. Difference in means were analysed using the Duncan's Multiple Range Test.

3. Results

The effects of acrylic-based paints on some other physicochemical properties of impacted soils in comparison with the controls were recorded in Table 1. Values of Electrical conductivity (EC) tested showed that electrical conductivity of the acrylic paints were higher than the electrical conductivities of the test soil samples. EC values of the samples from the Factory B were significantly higher than their controls. The same observation was made for EC samples from Factory A, which showed EC values significantly higher than that of their control. Nitrogen and phosphorus contents of the emulsion paints were lower compared with the test soil samples. With respect to nitrogen content, the values obtained for both Factories A and B were lower than that of their respective controls. Similar trend was observed for the test of phosphorus content, as the Phosphorus values obtained for the test soil samples were higher than the values obtained for the acrylic paints. The Phosphorus contents of the test soil samples were also lower than their respective controls. The cation-exchange capacity (CEC) tested for the soil samples showed a range of between 10.31% and 16.59%. Values of CEC for both Factories A and B were more than values of their controls. However, for total organic carbon (TOC), they were lower than in the controls samples.

Table 1: Comparative assessment of effects of acrylic-based paints on selected soil physicochemical properties of impacted soils in comparison with the controls

Test Samples	EC (µS/cm)	P (%)	N (%)	CEC (%)	Organic matter (%)
Emulsion Paint (White)	170.07^{b}±0.07	0.18^{h}±0.00	0.10^{g}±0.00	N/A	N/A
Emulsion Paint (Coloured)	214.1^{a}±0.46	0.19^{g}±0.00	0.11^{f} ±0.00	N/A	N/A
Inside the Factory	106.27^{e}±0.12	0.38^{f}±0.00	0.12^{f}±0.00	10.31^{f}±0.00	1.94^{f}±0.01
Outside the Factory A	82.2^{f}±0.10	0.41^{e}±0.00	0.17^{e}±0.00	14.51^{d} ±0.01	2.97^{e}±0.00
Control (Factory A)	71.2^{g}±0.17	0.61^{b}±0.00	0.20^{d}±0.00	15.33^{c}±0.00	4.28^{c}±0.02
Inside the Factory B	150.33^{c}±0.03	0.49^{d}±0.00	0.22^{c}±0.00	13.13^{e}±0.00	3.48^{d}±0.01
Outside the Factory B	115.73^{d}±0.15	0.58^{c}±0.00	0.25^{b}±0.00	16.59^{b}±0.02	5.48^{b}±0.01
Control (Factory A)	106.1^{e}±0.15	0.74^{a}±0.00	0.28^{a}±0.00	20.11^{a}±0.00	5.69^{a}±0.00
P-value	**P<0.01	**P<0.01	**P<0.01	**P<0.01	**P<0.01

Note: different letter across the row showed that there is a significant difference across the sampling sites when compared to the Controls. P<0.01, EC – Electrical conductivity; P – Phosphorus; N – Nitrogen; CEC – Cation-Exchange capacity; TOC – Total Organic Carbon; NA – Not applicable

Table 2 shows the assessment of physical properties of acrylic paints and soils of acrylic paint-impacted soils tested. The pH of the actual paint samples were slightly alkaline when compared with the pH ranges for the test samples and their controls. Moisture contents were also obviously less in the test soil samples compared with the actual paint samples. Moisture contents of the samples from Factory B were slightly more than the control, while moisture contents from the Factory A were less than the control. Particle size analyses of the test samples showed a particle size range of between 0.13 mm and 0.5 mm for all the samples tested. The test samples had a soil porosity range of 22.33 % to 30.67%, and a bulk density range of between 1.37 g/cm^3 and 2.37 g/cm^3. All values from samples tested were statistically significant when compared with their respective controls (Table 2). The soil samples from the two sites evaluated harboured varying numbers of acrylic-paint utilizing bacterial cells as determined by the total bacterial counts from the different samples. Table 3 shows the numbers of the culturable bacterial present in the two sampling sites. For the individual sites, values of bacterial counts from soils collected from outside the active production facility but within the production compound (precisely at outdoor paint impacted sites) showed a higher count of bacteria compared with the values of bacterial counts obtained from with the active production sites. Overall, Factory A sites harboured more bacterial counts (up to 6.2 x 10^8 CFU/g) than the Factory B sites (7.6 x 10^7 CFU/g). Bacterial counts for the paint samples from both factories were zero (Table 3).

Table 2: Physical properties of acrylic paints and soils of acrylic paint-impacted sites

Test Samples	pH (%)	Moisture (%) (mm)	Particle Size (%)	Soil porosity (%)	Bulk Density (g/cm^3)
Emulsion Paint (White)	8.72^{a}±0.01	89.03^{b}±0.23	N/A	N/A	N/A
Emulsion Paint (Coloured)	8.36^{b}±0.02	91.53^{a}±0.03	N/A	N/A	N/A
Inside the Factory A	7.80^{e}±0.06	16.83^{e}±0.07	0.25^{b}±0.00	29.33^{b}±0.67	2.37^{a}±0.09
Outside the Factory A	7.19^{g}±0.00	17.2^{d}±0.06	0.2^{c}±0.00	22.33^{e}±0.33	2.97^{e}±0.00
Control (Factory A)	6.6^{h}±0.06	15.9^{f}±0.10	0.2^{c}±0.00	26.33^{c}±0.33	1.73^{b}±0.09
Inside the Factory B	8.08^{c}±0.02	15.53^{g}±0.09	0.5^{a}±0.00	30.67^{a}±0.67	1.87^{b}±0.07
Outside the Factory B	7.64^{d}±0.01	14.8^{h}±0.06	0.2^{c}±0.00	25.0^{d}±0.00	1.37^{c}±0.09
Control (Factory A)	7.39^{f} ±0.01	18.17^{c}±0.09	0.13^{d}±0.00	25.0^{d}±0.00	1.53^{c}±0.03
P-value	**P<0.01	**P<0.01	**P<0.01	**P<0.01	**P<0.01

Note: different letter across the row showed that there is a significant difference across the sampling sites when compared to the Controls. P<0.01, NA- Not applicable

Table 3: Total heterotrophic counts of acrylic-paint utilising bacteria from different test sites

Test Sites	Test Sample	Total Heterotrophic Bacterial counts
Factory A	Indoor Soil	1.4 x 10^6 CFU/g
	Outdoor Soil	6.2 x 10^8 CFU/g
	Paint Sample	Nil
Factory B	Indoor Soil	2.3 x 10^5 CFU/g
	Outdoor Soil	7.6 x 10^7 CFU/g
	Paint Sample	Nil

A total of 29 bacterial colonies from the acrylic-enriched medium was recovered and characterized (Table 4). The bacterial isolates were coded based on their source of isolation. Exactly 16 (55.2%) of the isolates were from samples from Factory A, while, 13 (44.8%) of the isolates were from samples from Factory B environment. The 29 bacterial characterized were distributed among ten (10) genera, namely; *Bacillus* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Arthrobacter* spp., *Aeromonas* spp., *Cirobacter* spp., *Alcaligenes* spp., *Flavobacterium* spp., *Enterobacter* spp. *Micrococcus* spp. *Bacillus* spp. (24.1%) had the highest frequency and was followed by *Pseudomonas* spp. (17.2%) and *Flavobacterium* spp. (10.3%). All the remaining isolates had the least frequency (6.9%). (Table 4).

Table 4: Frequency of occurrence of the bacteria isolates from both paint factories

Bacterial isolates	Factory A sample	Factory B sample	Total (%)
Bacillus spp.	4	3	7 (24.1)
Pseudomonas spp.	2	3	5 (17.2)
Staphylococcus spp.	2	0	2 (6.9)
Arthrobacter spp.	2	0	2 (6.9)
Aeromonas spp.	1	1	2 (6.9)
Cirobacter spp.	2	0	2 (6.9)
Alcaligenes spp.	1	1	2 (6.9)
Flavobacterium spp.	2	1	3 (10.3)
Enterobacter spp.	0	2	2 (6.9)
Micrococcus spp.	0	2	2 (6.9)
Total (%)	16 (55.2)	13 (44.8)	29 (100)

4. Discussion

Acrylates and acrylic-containing chemicals are important industrial commodities as they are used in the production of adhesives, printing inks/printing paste, thickening agents in automotive sprays, as paper colourants, in lubrication of crude oil drilling bits to reduce friction during drilling, as emulsions in paints for buildings and other forms of application [16]. During industrial production and application,

there is a large tendency that acrylates and acrylic-containing compounds can be released into the environment as wastes thereby contaminating surface water bodies and soil systems. According to a report by the US EPA in 1994 on toxic chemical release inventory, the integrated risk of acrylic-containing compounds led to the determination of the impact of acrylic pollution on surface water quality, underground sediments, and land sites. Weideborg *et al*. [17] and Chang *et al*. [18] also further stated that acrylate concentrations of 0.3 ppb to 5 ppm have been detected in terrestrial and aquatic ecosystems as a result of the applications of these chemicals in sewer grouting with acrylates found to be stable in the water samples for more than 2 months. This has necessitated the need to investigate the physicochemical and bacteriological quality of paint waste impacted soil systems.

The proliferation of microorganisms within very many environmental sites is usually dependent on a variety of physicochemical factors, as such factors govern microbial physiological functionalities [33]. Soil-borne bacteria most importantly are affected by factors like electrical conductivity, inorganic matter, moisture content, and pH [19]. The sites studied in this work presented unique properties with respect to their physicochemical characterisation. The acrylic paint manufacturing companies selected had significant spillage of acrylic paint on the immediate soil environment. These impacted on the soil properties and were directly indicative of microbial proliferation tendencies within the soils. With the exposure of soils at these sites to acrylic paints, it was observed that electrical conductivities were higher in the test samples than in the control. This could be due to the unique characteristics of acrylic paints as possessing functional electrically charged ionic groups due to their chemical structure [20]. The electrical conductivities have been determined as a factor that could affect bacteria growth and proliferation in defined ecosystems and has formed a component part of analytical chemistry of environmental samples over years of research [21]. It is important to note that cellular functionalities with respect to ionic flow and membrane-bound respiration, have been proven to be a major point of interaction by cells with their environments [22]. Nitrogen and Phosphorus contents on the other hand were found to be higher in the acrylic paints than in the acrylic paint laden soil samples tested. This could largely be because of the uptake of nitrogen and phosphorus from the acrylic paints by the microbial flora. Possible microbial utilization system would have been established for evolutionary adaptations of the microbial species for the acrylic paints spilled onto the test sites over time [23]. Different kinds of adaptation mechanisms exist, however adaptation due to nutritional circumventions depending on the kind of nutrients existing within the chemicals impacting the soil samples is one of the main routes microorganisms especially bacteria adapt to their environment [24].

The reduction in inorganic nutrients like nitrogen and phosphorus within acrylic-paint impacted soil samples tested in comparison with the actual acrylic paints is also a good indicator of the presence and growth of acrylic paint utilizing bacteria within the test sites [23]. There was a functional increase in the cation-exchange capacity of the tested acrylic paint-impacted soil samples in comparison with the acrylic paint control. This could be attributed to the actual release of cations from metabolic activities of soil-borne autochthonous bacteria [19]. Such activities are based on the mineral transformations occurring within the test samples as bacteria utilize the components of acrylic paints [25]. This factor also goes further to interplay on the pH values of the acrylic paint-exposed soils compared to the pH of the actual acrylic paints. It was observed that the pH range of the acrylic paint was relatively higher when compared with the pH of the paint-exposed soils. This could similarly be tied to the mineralization and free cation exchange potentials occurring within the samples of acrylic paints metabolized by the soil autochthonous bacteria [26]. The pH is also indicative of the bacterial growth preference for proliferation. It is evident that the bacteria growth within lower pH values could be directly caused by the secretion of volatile fatty acids resultant from the bacterial tri-carboxylic acid cycle or Kreb's cycle

and free cationic conditions that similarly maintain the soil environment in the optimum proliferation potentials for the inherent bacteria [27]. Due to the difference in the physical properties of test soil samples (solids) and the acrylic paints (liquids) their moisture content properties were evidently different. However, comparing the moisture contents of the acrylic paint-impacted samples obtained from different paint company sites, there were observed differences. This could be attributed to the soil structures of the different sites. The variations in soil properties were also evident in differences between values for the particles sizes, bulk densities, soil porosity, and organic matter content recorded. Earlier explanations have been put forward that soil samples from different sites possessed different physical properties and this greatly affected the attachment potentials of individual cells of autochthonous bacteria in the form of biofilms and cell clumps within the soil samples [28]. The rate of cell clumping and agglutination within the soil samples can be influenced my moisture, soil porosity and particle sizes of the soil samples, and this in turn plays out on the organic matter within the soil which is a direct correlation with the microbial loads within such sites.

With respect to the bacterial counts within the test samples, due to the nature of the sites and their physicochemical properties, there were bacterial counts ranging between 10^5 and 10^8. Following quality control procedures that would have been adopted in the paint production, the acrylic paint samples had no bacterial load, as counts were zero. This is in line with proper good manufacturing processes and as a result has reduced the burden of paint spoilage in the finished product. Paint industries are expected to observe acceptable quality control/assurance practices in their processing lines to aid in the production of high quality products and the longevity of the applied products on the materials they are painted upon [29]. On the part of the acrylic paint impacted soil samples; overall, outdoor soil sampling sites yielded marginally higher bacterial counts than indoor soil sampling sites. As earlier described, the variations in the bacterial counts between the outdoor and indoor environments showed that there were impacts of environmental factors that allowed much more bacterial proliferation in the outdoor sites compare to the indoor site [28]. The reduction in bacterial counts within the indoor environments could also be as a result of consistent cleaning of the indoor environment which might have reduced bacterial presence in comparison with the outdoor environment. Soil particles harbour clumps of bacteria in large communities within certain ecological niches, with average bacterial counts ranging from 10^2 to 10^8 depending on the soil type and the environmental factors [30]. It is also important to note that unique bacterial interactions like mutualism, commensalism, amensalism, and parasitism are also inherent within such sites, therefore a key influential factor for bacterial growth and proliferation within such sites is in the particular nutrients present within such sites [31]. This is so because nutrient type influences selection of specific bacterial species that can metabolise such nutrients in a competitive selection above other bacteria that lack the physiological machinery for breaking down the nutrient substrates found within the sites. In this work acrylic paint was used to enrich the soil before the actual isolation of the bacteria, thereby ensuring that acrylic paint utilizing bacteria were mostly isolated. Enrichment technique had been exploited in isolation of unique bacteria in a selective format thereby giving the target physiological group of bacteria some selective advantage over others within the environment [32]. Applying that in this research, acrylic paint was used as a sole carbon source in preparing a medium for growth and then the soil samples were mixed with the acrylic-paint medium and pre-incubated, leading to the extant out-growth of the acrylic paint utilizing bacteria. The 29 bacterial characterized were distributed among ten (10) genera, namely; *Bacillus* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Arthrobacter* spp., *Aeromonas* spp., *Cirobacter* spp., *Alcaligenes* spp., *Flavobacterium* spp., *Enterobacter* spp. And *Micrococcus* spp. Some of these bacteria had been reported to possess versatile enzymatic machinery needed for organic and inorganic matter bioremediation [8,

14, 19, 29, 31]. Hence, they could be exploited as axenic or consortia culture in bioremediation processes of polluted sites [33].

Conclusion

This study has shown that acrylic paint impacted soil possessed unique physicochemical properties that favoured the proliferation of certain bacterial species within them. The knowledge of the soil bacteriology and chemistry in this study could be applied in soil treatment and reclamation. Also, the bacteria isolates could be employed as bio-treatment agents for paint effluents prior to disposal. However, furthers studies on the biodegradation kinetics of each or a mixture of the efficient isolates is vital to select the most efficient species for biotechnological purposes.

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