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Microbiological and Physicochemical Characteristics of Soil Receiving Palm Oil Mill Effluent in Umuahia, Abia State, Nigeria

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Abstract
The microbiological and physicochemical characteristics of soil receiving palm oil mill effluent (POME) in Umuahia were investigated. A total of 20 samples were analyzed for total heterotrophic bacterial count, fungal count, hydrocarbon-utilizing bacterial count, hydrocarbon-utilizing fungal count and nitrifying bacterial count. The pour plate technique was used for the isolation of the organisms. The mean total heterotrophic bacterial count ranged from 6.00 ± 0.07Log_{10}cfu/g to 6.13 ± 0.06Log_{10}cfu/g while the effluent and control soil sample were 5.80 ± 0.05Log_{10}cfu/mL and 6.19 ± 0.04Log_{10}cfu/g respectively. The fungal mean count ranged from 3.53 ± 0.02Log_{10}cfu/g to 4.03 ± 0.01Log_{10}cfu/g for contaminated soil and 3.69 ± 0.01Log_{10}cfu/mL for effluent. The mean count for the hydrocarbon-utilizing bacteria ranged from 5.34 ± 0.3Log_{10}cfu/g to 5.96 ± 0.2Log_{10}cfu/g for soil and 5.77 ± 0.06Log_{10}cfu/mL for effluent. Hydrocarbon-utilizing fungal count for the soil ranged from 2.95 ± 0.1Log_{10}cfu/g to 3.23 ± 0.01Log_{10}cfu/g and 3.00 ± 0.00Logcfu/mL for the effluent. The mean count for nitrifying bacteria ranged from 2.90 ± 0.2Log_{10}cfu/g to 3.42 ± 0.1Log_{10}cfu/g for soil and 4.38 ± 0.2Log_{10}cfu/mL for effluent. Results of the physicochemical analysis showed that the pH recorded for contaminated soil and control was 6.1 and 5.5 respectively and 7.2 for the effluent. The mean values for conductivity, oil and grease, phosphate, nitrate, sulphate, calcium, sodium, potassium, magnesium, in contaminated soil were 63.8 ± 5.0µs/cm, 8.1 ± 0.6mg/kg, 3.84 ± 0.1%, 1.50 ± 0.05mg/kg, 0.59 ± 0.01mg/kg, 27 ± 3.0mg/kg, 219 ± 15.0mg/kg, 116 ± 10.0mg/kg, 6.0 ± 0.5mg/kg, 0.85 ± 0.02mg/kg respectively. The mean values for conductivity, oil and grease, phosphate, nitrate, sulphate, calcium, sodium, potassium, magnesium, for the control soil were 46.7 ± 6.0µs/cm, 1.0 ± 0.04mg/kg, 0.93 ± 0.02%, 0.62 ± 0.01mg/kg, 0.33 ± 0.01mg/kg, 13.0 ± 2.0mg/kg,156 ± 10.0mg/kg, 83 ± 4.0mg/kg, 3 ± 0.6mg/kg, 0.52 ± 0.03mg/kg. The mean values of the conductivity, oil and grease, turbidity, chloride, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total suspended solids, total dissolved solids, ammonia, phosphate, nitrate and sulphate for the raw effluent were 26.5 ± 3.0µs/cm, 12.3 ± 2.0, 55.0 ± 3.0NTU, 10 ± 1.0mg/L, 1.8 ± 0.2mg/L, 25 ± 2.0mg/L, 60 ± 4.0mg/L, 32 ± 1.0mg/L, 0.35 ± 0.02mg/L, 0.40 ± 0.01mg/L, 0.21 ± 0.01mg/kg, 0.55 ± 0.02mg/kg, 2.0 ± 0.3mg/kg respectively. The results shows that the POME impacts on the soil
Key words: Microbiological, physicochemical, characteristics, soil, palm oil, mill, effluent

1. Introduction

Palm oil mill effluent is a wastewater generated from palm oil milling activities which requires effective treatment before discharge into water courses due to its highly polluting properties (Phaik, Wei-Jin, & Mei, 2010).

Palm oil mill effluent is the voluminous liquid waste that comes from the sterilization and clarification sections of the oil palm milling process. The raw effluent contains 90-95% water and includes residual oil, soil particles and suspended solids. The fact that the effect of chronic palm oil mill effluent discharged on our agricultural soil has not been given the proper attention it deserves, may be due to lack of knowledge of its effect. (Zakaria, 2002).

The palm oil industry is a major agro based one in Africa especially in the Western part where palm oil trees are found both in the wild and plantations. Palm tree (*Elaeis guineensis*) is a tropical forest palm native to West and Central Africa. It produces 3–8 times more oil from a given area than any other tropical or temperate oil crop when grown in plantations. Oil can be extracted from the fruit and the seed, crude palm oil from the outer mesocarp and palm-kernel oil from the endosperm. (Wahid, Abdullah, & Henson, 2005). The palm thrives in disturbed forest and near rivers; it does not grow well under closed canopies (Corley & Tinker, 2003). As long as it is well watered Oil palm is tolerant to a wide range of soil types (NewCROP, 1996). Under 'good' conditions, the majority of bunches are female and can lead to high fruit yields. Drought stress increases the proportion of male flowers. Once the female flowers are pollinated, the plum-shaped fruits develop in clusters of 200–300 on short stems (pedicels) close to the trunk. Each fruit is about 3.5 cm long and 2 cm wide, and weighs about 3.5 g. The fruit comprises outer oily flesh or pericarp (made up of exo-, meso- and endocarp) and an oil-rich seed or kernel (endosperm).

During processing of the ripe fruit to extract the cooking oil, a lot of wastewater (Palm Oil Mill Effluent- POME) is generated. Much of the POME results from water used in processing. Observations show that most of the POME is not treated before discharged into the surrounding environment especially by the small scale mills, causing pollution problems.

In Umuahia, palm oil production is one of the major socioeconomic activities of inhabitants in the area due to the abundance of palm trees as well as other palm families, as such large quantities of palm fruit are harvested and processed weekly and most times daily. During processing, large quantities of palm oil effluents are discharged onto the soil. This has been the practice of the people for decades, but little do the people know of the ameliorating effect of this effluent or waste on their soil. Studies have shown that the application of organic wastes (such as effluents, compost and sewage sludge) to soils increases plant growth, and that organic wastes contain considerable amounts of plant nutrients including micronutrients whose benefits to plant growth. However, since POME is organic in nature, it may have tremendous effects on the supply of nutrient elements to the soil. According to Odu and Mba (1991), inorganic fertilizers supply nutrient elements through microbial assistance but also help in the improvement of soil physical properties.

The characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production processes in palm oil mills (Osemwota, 2010).

This work is therefore aimed at determining the microbiological and physicochemical characteristics of the soil receiving palm oil mill effluent.

2. Materials and Methods

2.1 Sample Collection

Soil samples were collected using the grab method at Uzoakoli Abia State, Nigeria. Twenty soil samples were collected from the effluent dump at different sites and the control sample was collected about 10yards away from the effluent site. Freshly processed raw effluent was also collected. The dump site (POME site) was bare without vegetation, clammy and dark brown in color, while the non-POME site was covered with vegetation (trees and grasses), dry and greenish in color. All sites have similar soil parent material, topography and climate. The soil samples were put in a polythene bags and the raw effluent in a sealed tight container with labels, and taken to the laboratory less than 6hours of collection, where it is air dried and passed through a 2mm sieve in order to separate the soil from the stones. Thereafter, the microbial and physicochemical properties determined, within 24hours of collection.

2.2 Chemical Reagents

The chemical reagents used in the study were of analytical grade and were products of BDH Chemicals, Poole's, England and Sigma Chemical Company, St. Louis Missouri, USA. The microbiological media used were products of Oxoid and Difco Laboratories, England. They included nutrient agar used for the estimation of total heterotrophic aerobic bacteria, purification of hydrocarbon-utilizers and for pure culture; Sabouraud dextrose agar (SDA) used for the isolation of fungi. The modified mineral salt agar was used for the isolation of hydrocarbon-utilizing bacteria while the modified mineral salt agar plus antibiotics was used for the isolation of hydrocarbon-utilizing fungi.

2.3 Enumeration of Total Heterotrophic Bacteria and Fungi

Samples of the polluted soils were serially diluted in ten folds. Total viable heterotrophic aerobic counts were determined by plating in duplicate using pour plate technique. Then molten nutrient agar at 45^0C was poured into the Petri-dishes containing 1mL of the appropriate dilution for the isolation of the total heterotrophic bacteria and fungi respectively. They were swirled to mix and colony counts were taken after incubating the plates at room temperatures for 48h.

2.4 Enumeration of Hydrocarbon-Utilizing Bacteria and Fungi

The hydrocarbon-utilizing bacteria and fungi were determined. The mineral salt agar of Mills, Breuil & Colwell., (1978) as modified by Okpokwasili & Amanchukwu (1988) comprising per litre of distilled water NaCl, l0g; $MgSO_4.7H_2O$, 0.42g; KCL, 0.29g; K_2HPO_4, 1.2g; KH_2PO_4, 0.83; $NaNO_3$, 0.42g; agar,15g; pH 7.2 was used.

To 990mL of the mineral salt medium in conical flasks was added 10mL of palm oil which served as sources of carbon. However, for the hydrocarbon-utilizing fungi, the medium was supplemented with an antibiotic chloramphenicol. The hydrocarbon-utilizers were then enumerated after plating in duplicate using pour plate technique, 1mL of the appropriate dilutions of the samples on Petri dishes. The molten mineral salt agar medium and the ones containing antibiotic at 45^0C were poured into the Petri dishes for the isolation of hydrocarbon-utilizing bacteria and fungi respectively. These were swirled to mix, allowed to solidify and incubated. Enumeration of the hydrocarbon-utilizers was performed after incubation at 30^OC for 7 days.

Colonies of the hydrocarbon-utilizing bacteria growing on the agar plates were counted, isolated, purified by streaking on nutrient agar plates and kept on nutrient agar slants as stock cultures for characterization and identifications. In the case of hydrocarbon-utilizing fungi, the isolates were streaked to purify onto Sabouraud

dextrose agar plates and kept on Sabouraud and agar slants as stock cultures for characterization and identification.

2.5 Characterization and Identification of Hydrocarbon-utilizing Isolates

Bacterial isolates were characterized and identified after studying their Gram reaction as well as cell micro morphology. Other tests performed were spore formation, motility, and catalase production. Citrate utilization, oxidative/fermentative utilization of glucose, indole production, methyl red - Voges Proskauer reaction, urease and coagulase production, starch hydrolysis, production of H_2S from triple sugar iron (TSI) agar and sugar fermentation. The tests were carried according to the methods described by (Azu, 2004; Cheesborough, 2005; Adeoye, 2007; Agwung-Fobellah & Kemajou, 2007; Ochei & Kolhatkar, 2008) Microbial identification was performed using the keys provided in the *Bergey's Manual of Determinative Bacteriology,* 1994.

Fungal isolates were examined macroscopically and microscopically using the needle mounts technique. Their identification was performed according to the scheme of Barnett & Hunter (1972) and Larone (1986).

2.6 Determination of the Physiochemical Parameters

A number of physicochemical parameters of the contaminated soil samples were determined. They included pH, conductivity, nitrate, phosphate, sulphate. Others included oil and grease, total organic carbon heavy metals and exchangeable cations. The pH was measured using Hach pH meter (Model EC1O); conductivity was measured using Hach conductivity meter (Model CO150). Sulphate, nitrate and phosphate were determined using Barium chloride (Turbidimetric), Cadmium reduction and Ascorbic acid methods respectively. All analyses were in accordance with APHA, 2005.

2.7 Determination of oil and grease

The method was adopted from ASTM, 2003. The soil samples were air dried and sieved. Ten grams of the air dried sieved samples were weighed into 60ml glass bottles and 20ml of tetrachloroethylene was poured into the glass bottles. These bottles were placed into a shaker maintained at room temperature. The system was allowed to into a 20ml glass bottle using a glass funnel stuffed with cotton wool on which anhydrous sodium sulphate was placed. Analysis of the samples was done using Hach DR4000 spectrophotometer.

2.8 Determination of total organic carbon

The method used was adopted from ASTM, 2003. One gram each of the air-dried samples was weighed out in duplicate and transferred to 250ml Erlenmeyer flask. Ten millimeters of 1N potassium dichromate solution and 20ml concentrated sulphuric acid was added and the flasks swirled until the soil and reagents were mixed. The flasks were allowed to stand on the sheet of asbestos for about 30minutes after 100ml of distilled water was added. Three drops of indicator was added and then titrated with 0.5N ferrous sulphate solution. The endpoint was observed when the colour changed sharply from blue to red (maroon colour) in reflected light against a white background.

2.9 Determination of Exchangeable Cations

The method for the determination was adopted from APHA, 2005. The soil samples were first extracted using IN ammonium acetate solution. This was done by weighing 5g of sieved air dried samples and adding to 30ml of the extracting solution in a tube. This was shaken on a mechanical shaker for two hours. They were then centrifuged for five minutes and the supernatant carefully decanted into a 100ml volumetric flask. This was then made up to the mark with the extracting solution. The exchangeable cations (Na, K, Ca^{2+}, Mg^{2+}) of the extract were determined using Unicam Atomic Absorption Spectrophotometer, Model 969.

3. Results

The results of the microbiological and physicochemical characteristics of soil receiving palm oil effluent are shown in Tables 1-3. Table 1 shows the mean microbial counts of the different contaminated soil sites, control soil and raw effluent. The mean total heterotrophic bacterial count ranged from $6.00 \pm 0.07 Log_{10}$cfu/g to $6.13 \pm 0.06 Log_{10}$cfu/g for the contaminated soil while the effluent and control soil sample were $5.80 \pm 0.05 Log_{10}$cfu/mL and $6.19 \pm 0.04 Log_{10}$cfu/g respectively. Site 1 had the highest count of $6.13 \pm 0.06 Log_{10}$cfu/g while site3 had the least count of $6.00 \pm 0.07 Log_{10}$cfu/g. The ANOVA, $P > 0.05$ showed that there was no significant difference in the mean total heterotrophic bacterial count among the sites. The fungal mean count ranged from $3.53 \pm 0.02 Log_{10}$cfu/g to $4.03 \pm 0.01 Log_{10}$cfu/g for contaminated soil and $3.69 \pm 0.01 Log_{10}$cfu/mL for effluent. The mean count for the hydrocarbon-utilizing bacteria ranged from $5.34 \pm 0.3 Log_{10}$cfu/g to $5.96 \pm 0.2 Log_{10}$cfu/g for the contaminated soil and $5.77 \pm 0.06 Log_{10}$cfu/mL for effluent. Hydrocarbon-utilizing fungal count for the soil ranged from $2.95 \pm 0.1 Log_{10}$cfu/g to $3.23 \pm 0.01 Log_{10}$cfu/g and 3.00 ± 0.00Logcfu/mL for the effluent. The mean count for nitrifying bacteria ranged from $2.90 \pm 0.2 Log_{10}$cfu/g to $3.42 \pm 0.1 Log_{10}$cfu/g for soil and $4.38 \pm 0.2 Log_{10}$cfu/mL for effluent. The ANOVA, $P < 0.05$ showed that there was significant difference in the mean counts of the nitrifying bacteria among the sites.

Table 2 shows the microorganisms isolated and their percentage occurrence. The highest in occurrence among the bacteria isolates is the *Pseudomonas aeruginosa* (27%), *Staphylococcus aureus* (17%) and *Klebsiella*

species (17%), while *Proteus* species, *Bacillus* species, *Citrobacter* species have the lowest percentage occurrence of 6%. For the fungi isolates, the *Rhizopus* species and *Aspergillus* species have the highest percentage occurrence of 21% and 24% respectively, while the *Geotricum* species and *Mucor* species have the lowest percentage occurrence of 10% and 12% respectively.

Table 3 shows the physicochemical characteristics of soil and effluent samples. There is increase of the physicochemical parameters of the contaminated soil when compared with the control. The mean pH values recorded for contaminated soil and control were 6.1 ± 0.2 and 5.5 ± 0.3 respectively and 7.2 ± 0.5 for the effluent. The mean values for conductivity, oil and grease, phosphate, nitrate, sulphate, calcium, sodium, potassium, magnesium, in contaminated soil were 63.8 ± 5.0µs/cm, 8.1 ± 0.6mg/kg, 3.84 ± 0.1%, 1.50 ± 0.05mg/kg, 0.59 ± 0.01mg/kg, 27 ± 3.0mg/kg, 219 ± 15.0mg/kg, 116 ± 10.0mg/kg, 6.0 ± 0.5mg/kg, 0.85 ± 0.02mg/kg respectively. The mean values for conductivity, oil and grease, phosphate, nitrate, sulphate, calcium, sodium, potassium, magnesium, for the control soil were 46.7 ± 6.0µs/cm, 1.0 ± 0.04mg/kg, 0.93 ± 0.02%, 0.62 ± 0.01mg/kg, 0.33 ± 0.01mg/kg, 13.0 ± 2.0mg/kg,156 ± 10.0mg/kg, 83 ± 4.0mg/kg, 3 ± 0.6mg/kg, 0.52 ± 0.03mg/kg. The mean values of the conductivity, oil and grease, turbidity, chloride, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total suspended solids, total dissolved solids, ammonia, phosphate, nitrate and sulphate for the raw effluent were 26.5 ± 3.0µs/cm, 12.3 ± 2.0, 55.0 ± 3.0NTU, 10 ± 1.0mg/L, 1.8 ± 0.2mg/L, 25 ± 2.0mg/L, 60 ± 4.0mg/L, 32 ± 1.0mg/L, 0.35 ± 0.02mg/L, 0.40 ± 0.01mg/L, 0.21 ± 0.01mg/kg, 0.55 ± 0.02mg/kg, 2.0 ± 0.3mg/kg respectively. The alteration of the contaminated soil when compared with the control is due to the deposition of the raw effluent in the soil.

4. Discussion

It was observed that there was an increase in the hydrocarbon-utilizing bacterial and hydrocarbon-utilizing fungal counts from the soil contaminated with palm oil mill effluent when compared with the control. This increase was due to the increased hydrocarbon content from the palm oil mill effluent. This is in agreement with the findings of (Amadi & Odu, 1993; Okerentugba & Ezeronye, 2003; Obire & Nwanbet, 2002, Eze & Okpokwasili, 2008), who reported gradual increase in microbial population in contaminated soil.

The three different sites of soils from palm oil mill effluent dump sites and the non-POME site and raw-effluent from Uzuakoli, Umuahia, were analyzed for microbiological and physicochemical qualities. The most predominant hydrocarbon degrading bacteria found belong to the following genera *Pseudomonas*, *Bacillus*, *streptococcus*, *Citrobacter*, *Staphylococcus*, *Klebsiella*, and *Enterobacter*. The bacteria genera found are in line with the previous reports (Bossert & Bartha, 1984; Okpokwasili & James, 1995, Eze, Okwulume, & Agwung, 2006). The genera identified are wide spread and many of the individual species have been shown to be able grow on petroleum hydrocarbon (Singer & Finnerty, 1984; Okpokwasili & Nnorom, 1990, Okpokwasili & Okorie, 1991). Atlas and Cerniglia, 1995 also reported that the most prevalent bacteria genera that degrade hydrocarbon include *Pseudomonas, Bacillus* and *Micrococcus.*

The hydrocarbon-utilizing fungi identified included the following genera *Mucor*, *Aspergillus*, *Fusarium*, *Rhizopus*, *Trichoderma*, *Penicillium* and *Geotrichum*. These were in line with works of (Bossert & Bartha, 1984; Amanchukwu,Obafemi, & Okpokwasili, 1989, Eze & Okpokwasili, 2010).

The data generated showed that the physicochemical properties of soil at the POME dump site were altered. This shows that POME is biodegradable and non-toxic as its disposal on the soil does not cause any damage, but significantly and substantially increases the soil nutrient levels needed for plant growth (Hemming, 1977; Bek-Nelson, Singh, & Toh, 1999). It is also shown that POME raises the levels of organic carbon, total nitrogen, phosphorus, potassium and magnesium, and most especially the pH level of the soil to the range of maximum nutrient availability. This is in line with the earlier reports of (Habib, Yusoff, Phang, Kamarudin & Mohmed, 1998; Khalid & Mustafa, 1992; Rupani, Singh, Ibrahim, & Esa, 2010) when they observed that since no chemicals are added during the oil extraction process, POME is considered non toxic because it contains substantial amounts of Na, P, K, and Ca which are vital nutrient elements for plant growth. It has been reported that when raw POME is discharged the pH is acidic (Hemming, 1977) but seems to gradually increase to alkaline as biodegradation takes place. The increase in the content of available phosphorus according to Huan, 1987 is as a result of the high absorption in the soil or a possible precipitation of phosphate in the soil, as well as the gradual biodegradation of POME, which leads to a delay effect on the soil. The increase in the contents of Available Phosphorus in POME soil is therefore attributed to the rise in pH level to the range of nutrient availability. The increment in the proportions of Ca, Mg, K and Na in POME soil compared to the control shows enrichment of the soil. Okwute & Isu, 2007; Huan, 1987 reported similar result and attributed the increase to the addition of POME onto the soil which increased the levels of exchangeable bases. Due to its non toxic and fertilizing properties, POME can be used as fertilizer or animal feed substitute in terms of providing sufficient mineral requirements. But because palm oil mill effluent tends to concentrate major minerals and trace elements, the levels of these elements can increase to toxic levels and their use in ruminant feed should therefore be

assessed carefully for potential mineral toxicity (Bamikole, & Ikhatua, 2009; Seephueak, Ngampoogsai, & Changula, 2011). It can also be used as supplements (organic manure) to improve soil fertility. POME has been shown to be acidic in nature and it is advisable that it undergoes some form of treatment or decomposition before application as manure or on land taking into consideration the physicochemical properties of the land in that particular environment. When properly treated and packaged, it can be used by farmers both in rural and urban areas to improve soil fertility thereby increasing the agricultural productivity for global, national and regional food demands. The treatment helps in avoiding the initial harsh effects of POME on soil meant for agriculture.

The only noticeable problem of POME is its clogging and water logging nature which leads to the death of vegetation in contact. The first impression that could be got from the POME soil environment was that of barrenness and a wasted land. POME was said not to respond to ordinary treatment as in the case of municipal or domestic effluents because of the high density of suspended soils (Thilaimutu, 1976). The application of POME by sprinkles suppresses or kills soft weeds on the ground within few days and takes about 2-3 months to regenerate (Huan, 1987). However, Wood, Pillai, & Rajaratnam, 1979 noted that this can be overcome by controlling the discharge or application of small quantities of POME at a time. The state of the soil in that environment will determine the best treatment for the effluent to be dumped on it. Environmental pollution considerations in small-scale palm oil milling need better attention as this industrial segment assumes greater importance.

5. Conclusion

The effects POME has on soil properties would help farmers mostly in rural areas to improve food production through expanding their understanding on the importance of POME as well as educating them on the application of required quantities of POME to the soil during farming operation prior to planting. It is also necessary that POME should be properly treated before discharge into the environment to avoid impacting negatively on the environment
and due to it's acidic content and a very high biochemical oxygen demand and also to improve the soil fertility.

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Table 1: Mean count of microorganisms isolated from the contaminated control soil and effluent samples

	Log_{10}cfu/g / Log_{10}cfu/mL				
Sample location	THBC	HUB	THFC	HUF	NB
Site 1	6.13 ± 0.06	5.96 ± 0.2	4.03 ± 0.01	3.23 ± 0.03	2.95 ± 0.1
Site 2	6.09 ± 0.02	5.34 ± 0.3	3.60 ± 0.10	2.95 ± 0.10	2.90 ± 0.20
Site 3	6.00 ± 0.02	3.79 ± 0.01	3.53 ± 0.02	3.15 ± 0.20	3.41 ± 0.03
Control	6.19 ± 0.04	2.00 ± 0.01	5.23 ± 0.09	2.90 ± 0.01	3.30 ± 0.08
Raw effluent	5.80 ± 0.05	5.77 ± 0.06	3.69 ± 0.07	3.00 ± 0.02	4.38 ± 0.2

Legend: THBC= Total heterotrophic bacterial count; HUB= Hydrocarbon-utilizing bacteria; THFC= Total heterotrophic fungal count; HUF= Hydrocarbon-utilizing fungal count; NBC= Nitrifying bacterial count

Table 2: Microorganisms isolated and their percentage occurrence

Microorganism	Number of isolates	% Occurrence
Bacteria		
Proteus species	1	4.0
Bacillus species	5	20.0
Pseudomonas aeruginosa	8	32.0
Streptococcus species	2	8.0
Citrobacter species	1	4.0
Staphylococcus aureus	3	12.0
Klebsiella species	3	12.0
Enterobacter aerogenes	2	8.0
Fungi		
Fusarium species	2	5.0
Aspergillus species	9	21.0
Rhizopus species	10	24.0
Trichoderma species	6	14.0
Penicillium species	6	14.0
Mucor species	5	12.0
Geotricum species	4	10.0

Table3: The mean values of the physicochemical parameters of the contaminated and control soil and effluent

	Samples		
Parameter	**Contaminated Soil**	**Control Soil**	**Effluent**
pH	6.1 ± 0.2	5.5 ± 0.3	7.2 ± 0.5
Conductivity (µS/cm)	63.8 ± 5.0	46.7 ± 6.0	26.5 ± 3.0
Oil and grease (mg/Kg)	8.1 ± 0.6	1.0 ± 0.04	12.3 ± 2.0
Total organic carbon (%)	3.84 ± 0.1	0.93 ± 0.02	NN
Phosphate (mg/Kg)	1.50 ± 0.05	0.62 ± 0.01	0.21 ± 0.01
Nitrate (mg/Kg)	0.59 ± 0.01	0.33 ± 0.01	0.55 ± 0.02
Sulphate (mg/Kg)	27.0 ± 3.0	13.0 ± 2.0	2.0 ± 0.3
Calcium (mg/Kg)	219.0 ± 15.0	156.0 ± 10.0	NN
Sodium (mg/Kg)	116.0 ± 10.0	83.0 ± 4.0	NN
Potassium (mg/Kg)	6.0 ± 0.5	3.0 ± 0.6	NN
Magnesium (mg/Kg)	0.85 ± 0.02	0.52 ± 0.03	NN
Turbidity (NTU)	NN	NN	55.0 ± 3.0
Chloride (mg/Kg)	NN	NN	10.0 ± 1.0
Dissolved oxygen (mg/L)	NN	NN	1.8 ± 0.2
Biochemical oxygen demand (mg/L)	NN	NN	25.0 ± 2.0
Chemical oxygen demand (mg/L)	NN	NN	60.0 ± 4.0
Total suspended solid (mg/L)	NN	NN	32.0 ± 1.0
Total dissolved solids (mg/L)	NN	NN	0.35 ± 0.02
Ammonia (mg/L)	NN	NN	0.40 ± 0.01

Legend: NN = Not Necessary