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Original Research Article

Effect of Prolonged Exposure to Generator Fumes on Selected Soil Microbial Enzymes

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Abstract

This study therefore sought to evaluate the effect of prolonged exposure to generator fumes on selected soil microbial enzymes. Soil samples used for this study were collected from different locations in Federal University of Technology Owerri (FUTO) in Ihiagwa/North-West local government area of Imo State, Nigeria. The selected areas for this investigation were areas with high traffic and business activities. These areas were busy within the hours of 8.00 am – 5.30 pm at the close of work and business activities. Four sample points were chosen in each of the locations in order to capture concentration of pollutants within that location. The soil sample used for enzyme identification was stored in polyethylene plastic bags at a temperature below 15 ^{o}C to avoid the loss of moisture, inhibition of microbial activities and enzymatic reactions. Activities of soil microbial enzymes were assayed using standard methods. The results of this study showed increased activities of the soil microbial enzymes - following exposure to generator fumes when compared with those from the control site. Overall, increases in soil microbial enzyme activities were indications of the corresponding impact of pollutants on the soil ecosystems.

Keywords: Soil microbial enzymes, Pollution, Generator fumes

INTRODUCTION

The use of generators in recent years has raised and continues to raise tremendous safety questions. This is because users and the environment are exposed to fumes, whose effects depend on their frequencies, durations and intensity. Fumes are by-products of combustion and are made up of different components (Jande, 2005). The compositions of fumes are derived from the material subjected to combust. Generator fumes produced as a result of generating power through the combustion of petrol or diesel is made up of two parts; gases and soot. Each of these in turn is made up of different substances. The gaseous portion of the generator exhaust is mostly carbon monoxide, nitric oxide, nitrogen dioxide, sulphuroxides and polycyclic aromatic hydrocarbons (PAHs). The soot which is particulate in nature is made up of carbon, organic materials (including PAHs) and traces of metallic compounds (Hemming, 1977). Fumes generated from an original source such as diesel and burning of this diesel leads to the production of pollutants such as oxides of nitrogen (NO, NO_2), oxides of sulphur (SO_2), carbon monoxide (CO), ammonia (NH_3), hydrogen sulphide (H_2S), Suspended Particulate matter (SPM), heavy metals such as lead (Pb) and polycyclic aromatic hydrocarbons that are carcinogenic (benzo(a)pyrene and 1-hydroxypyrene) in form of soot. All these are known as 'byproducts of generator fumes (Hoyle et al., 1995).

There are vast scientific, epidemiological and medical researches that affirm that exposure to generator fumes; both low and prolonged levels can have profound effects on biological systems. Numerous epidemiological studies have also shown that exposure to a large amount of petroleum related particles causes an increase in morbidity and mortality which often arises from respiratory diseases and their negative impact on human health and its environment (Kandeler, 1996; Karigar and Rao, 2011). Researchers have also proven that both solid organic matter and gaseous volatile organic

compounds in petroleum related particles can trigger the mutation of cells, resulting in teratogenesis and other hazards (Lindstrom et al., 1991; Okolo et al., 2005). Generator fumes contain many known or suspected carcinogens or mutagens such as benzo(a)pyrene and 1-hydroxypyrene (Okolo et al., 2005).

A better understanding of the role of these soil microbial enzyme activities in the ecosystem will potentially provide a unique opportunity for an integrated biological assessment of soils due to their crucial role in several soil biological activities, their ease of measurement, and their rapid response to changes in soil management practices (Dick and Tabatabai, 1992; Bandick and Dick, 1999). Soil microbial enzymes are used as pollution indicators by many researchers due to agricultural practices and organic pollution (Gianfreda et al., 2005), irrigation by polluted water (Henry and Heinke, 2005; Barton et al., 2000), sewage sludge, municipal waste application and industrial activities (Fernandes et al., 2005; Kizilkaya and Hepsen, 2004). This study therefore sought to evaluate the effect of prolonged exposure to generator fumes on selected soil microbial enzymes

MATERIALS AND METHODS

Study area

Soil samples used for this study were collected from different locations in Federal University of Technology Owerri (FUTO) in ihiagwa/North-West local government area of Imo State, Nigeria. The selected areas for this investigation were areas with high traffic and business activities. These areas were busy within the hours of 8.00am –5.30pm at the close of work and business activities. Four sample points were chosen in each of the locations in order to capture concentration of pollutants within that location.

Location one (1) was the Public procurement office with latitude 05^0 22.808'N and longitude 006^0 59.803' E with 224.0ft elevation. Location two (2) was BJ Business centre with latitude 05^0 22.772' N and latitude 006^0 59.792'E with 202.5ft elevation. Location three (3) was Mr. Umunnakwe business center with latitude 05^0 22.773'N and longitude 006^0 59.774'E with 195.9ft elevation and Location four (4) was the business center behind the old registry with latitude 05^0 22.729' N and latitude 006^0 59.840'E with elevation 210.6ft for 5 days(13^{th} -17^{th} June,2016) at morning and evening sessions. Location one (1) known as the public procurement office is characterized by offices. Location two (2) otherwise known as BJ business services is characterized with offices (administrative and internet services), shops with regular use of generators and other gasoline-powered equipment. The sale of food is also noticed around the site and it has around it a T-junction and a mini-park for cars and motorcycles. Location three (3) is an enclosure that houses a business (mainly administrative work) center and stationary shops. Location four is an enclosure that houses a business centre. It also had around it a football viewing center and the sale of food was carried out there.

Twenty–seven (27) different soil samples were also collected from generator fume polluted site at location two (2) known as BJ business centre: 9 different soil samples from the top soil, 9 different soil samples from 1m depth sub soil and 9 different soil samples from 1m depth sub-sub soil. BJ business centre is situated at the northern apex area of Federal University of Technology Owerri (FUTO) between latitude 05^0 22.772' N and longitude 006^0 59.792' E. This location was characterized by high population density, high energy demand and erratic power supply. Thus, making it a suitable location for this study. The control was collected from the Department of Biochemistry surroundings at Federal University of Technology, Owerri (FUTO), which was regarded as an unpolluted site. All these areas lie entirely within Imo State in Southeastern Nigeria. The soil samples were labeled accordingly.

Preparation of soil samples

The soil sample used for enzyme identification was stored in polyethylene plastic bags at a temperature below 15^0C to avoid the loss of moisture, inhibition of microbial activities and enzymatic reactions.

Assay of Enzymatic Activities

Catalase activity was assayed according to the previously described method of Cohen et al. (1970). Lipase activity was determined according to the methods of Lorentz (Lorentz, 1998). Activities of acid phosphatase and alkaline phosphatase were assayed using the methods of Kind and King (Kind and King, 1954).

Statistical Analysis

The data collected was subjected to statistical analysis using the graph pad prism software version 5.0. One Way ANOVA was used in the analyses with a significant level set at $p \leq 0.05$.

RESULTS AND DISCUSSION

Effects of soil pollution on enzyme activities are complex. The response of different enzymes to the same pollutant may vary greatly and the same enzyme may respond

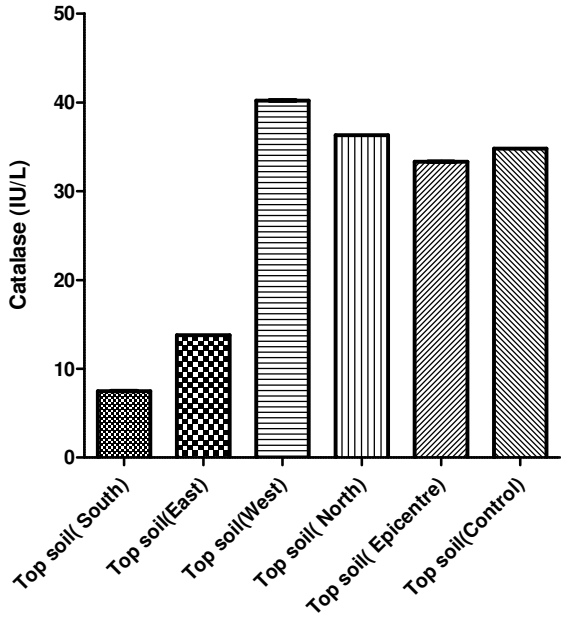

Figure 1. Effect of prolonged exposure to generator fumes on soil catalase activity in topsoil (1m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

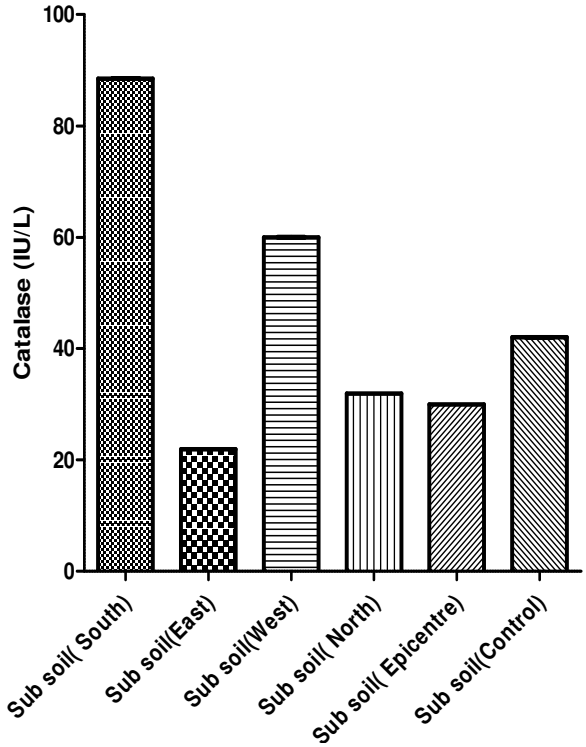

Figure 2. Effect of prolonged exposure to generator fumes on soil catalase activity in Subsoil (1m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

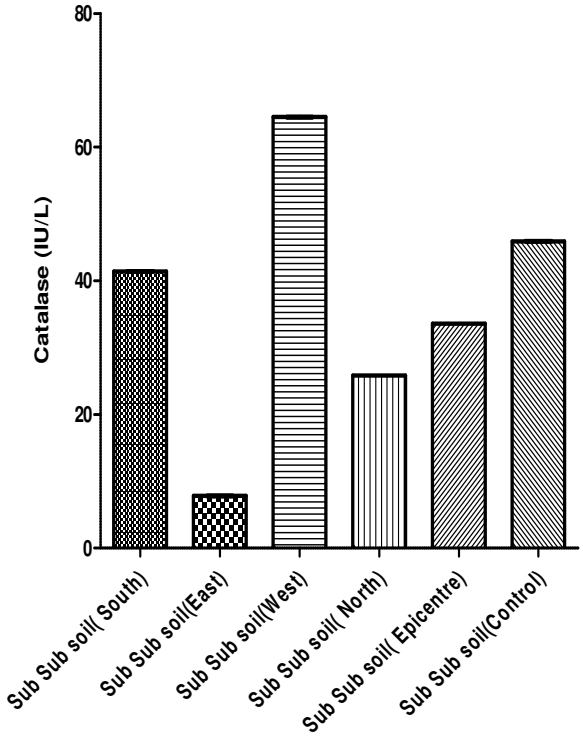

Figure 3. Effect of prolonged exposure to generator fumes on soil catalase activity in sub-sub soil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

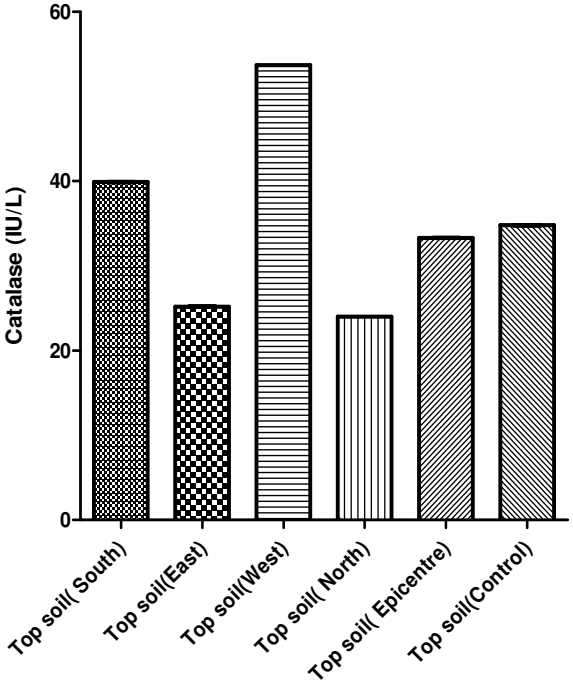

Figure 4. Effect of prolonged exposure to generator fumes on soil catalase activity in topsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

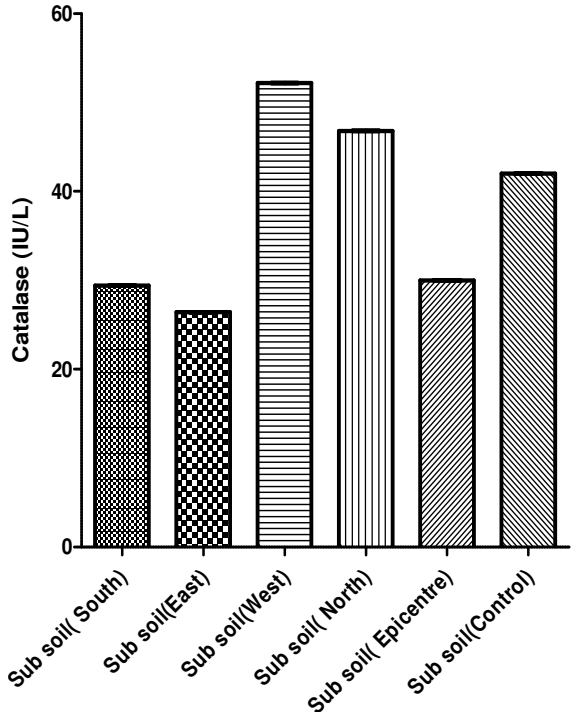

Figure 5. Effect of prolonged exposure to generator fumes on soil catalase activity in subsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at p< 0.05.

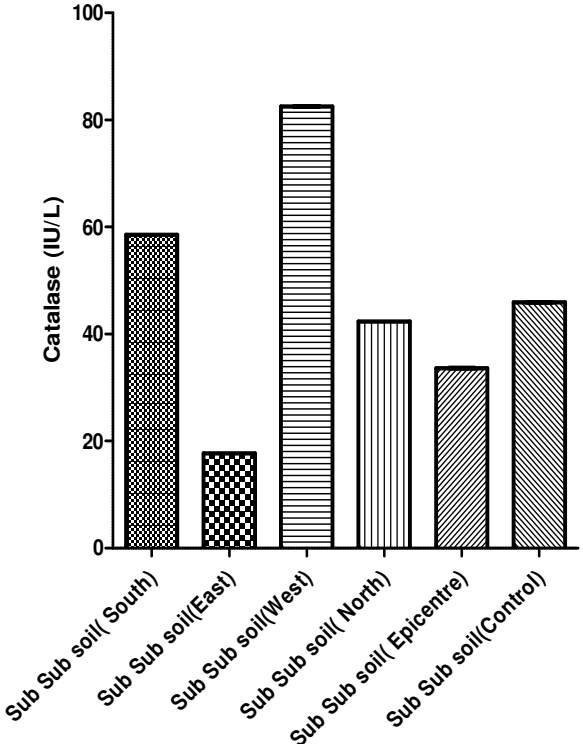

Figure 6. Effect of prolonged exposure to generator fumes on soil catalase activity in sub-sub soil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at p< 0.05.

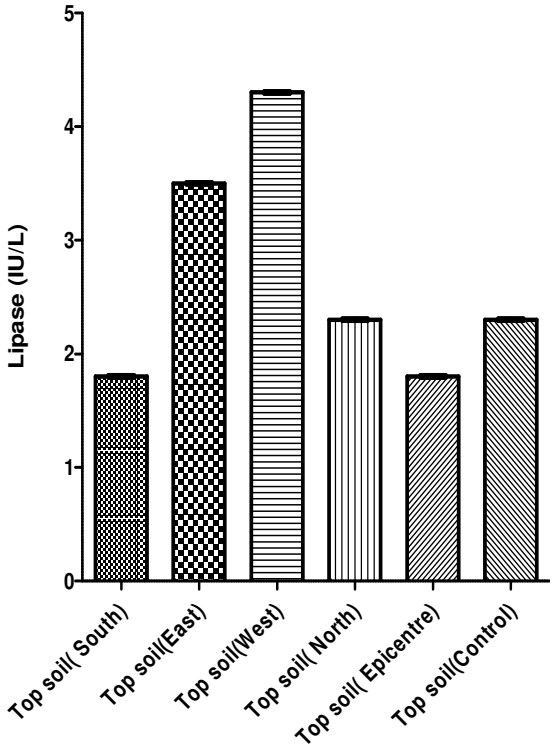

Figure 7. Effect of prolonged exposure to generator fumes on soil lipase activity in top soil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

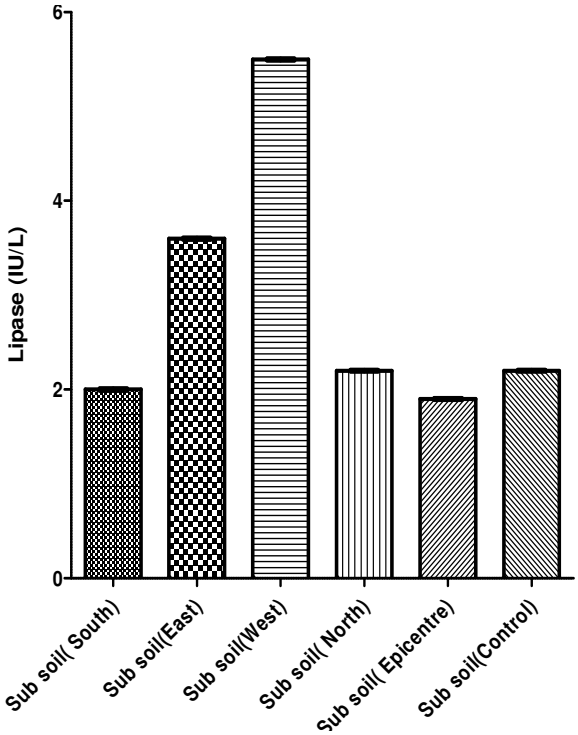

Figure 8. Effect of prolonged exposure to generator fumes on soil lipase activity in sub soil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

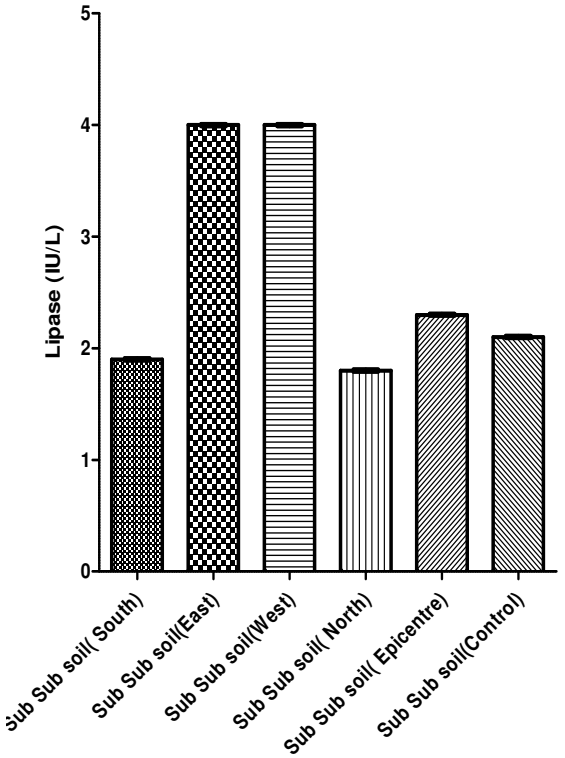

Figure 9. Effect of prolonged exposure to generator fumes on soil lipase activity in sub-sub soil (1m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

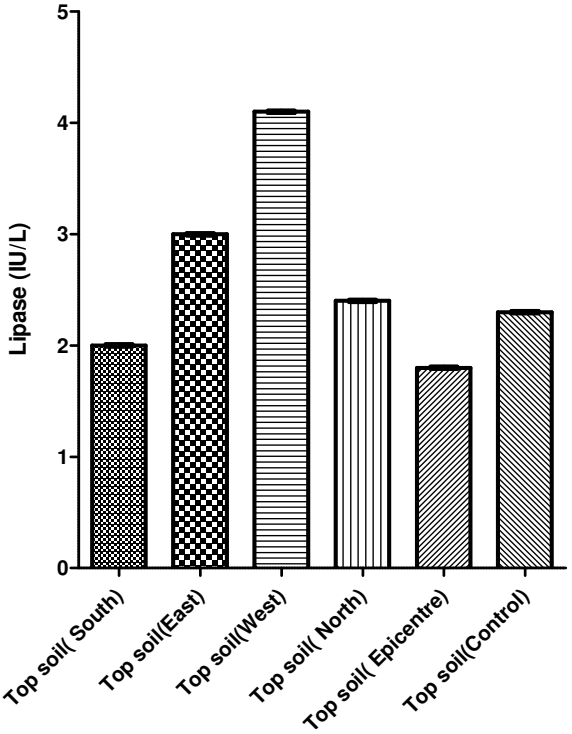

Figure 10. Effect of prolonged exposure to generator fumes on soil lipase activity in topsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

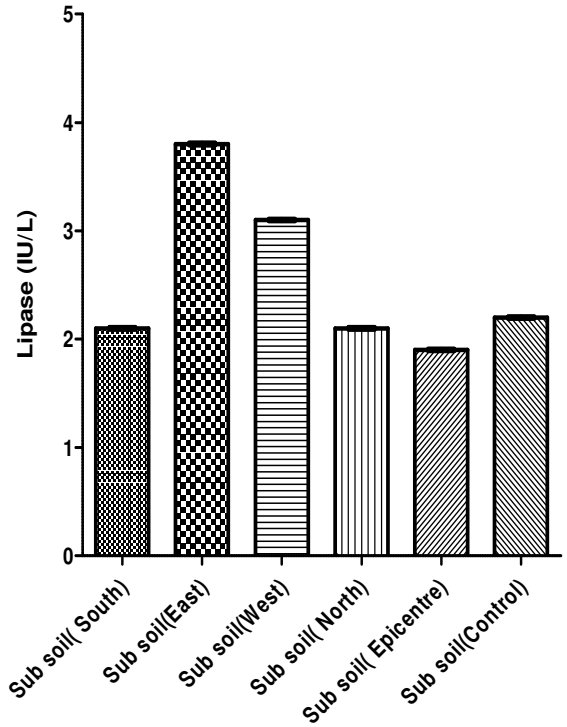

Figure 11. Effect of prolonged exposure to generator fumes on soil lipase activity in sub soil (2m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

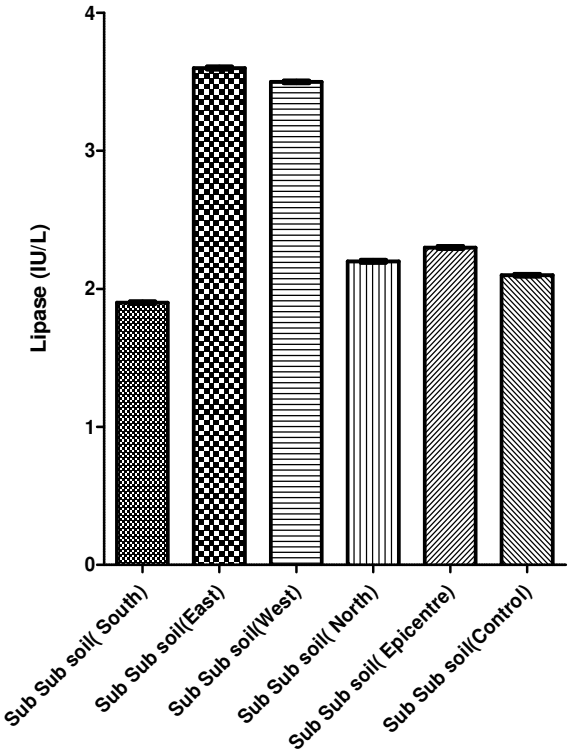

Figure 12. Effect of prolonged exposure to generator fumes on soil lipase activity in sub-sub soil (2m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

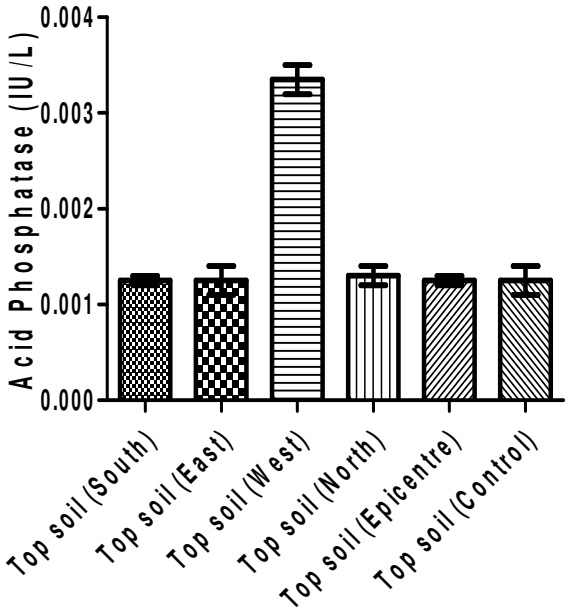

Figure 13. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in topsoil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

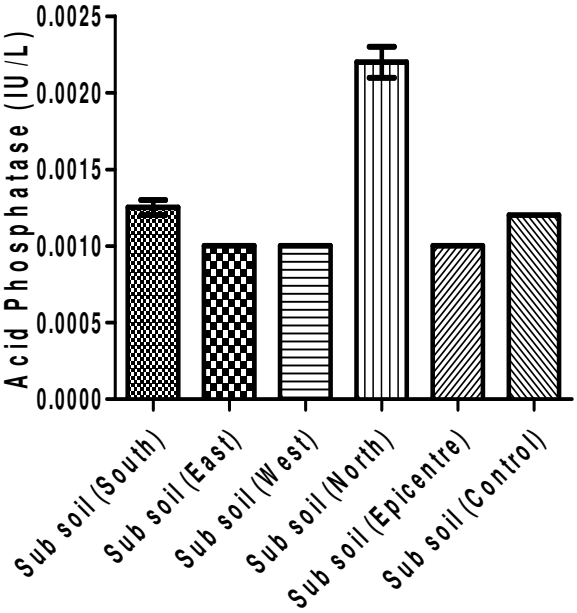

Figure 14. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in subsoil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

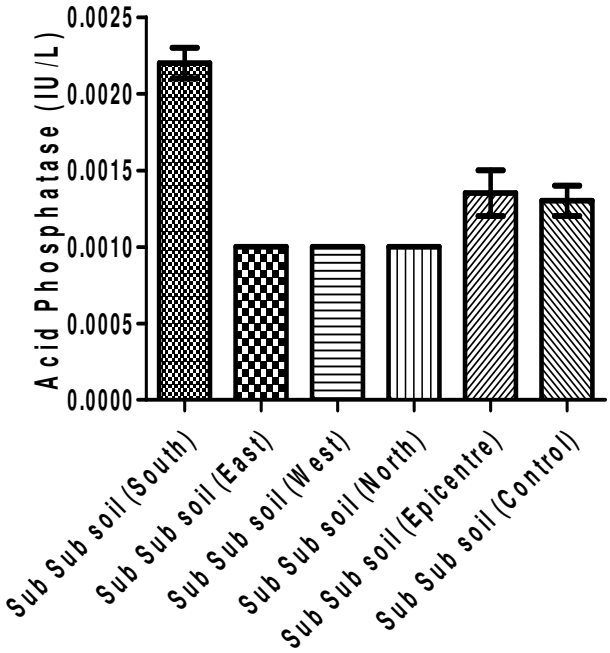

Figure 15. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in sub-sub soil (1m apart). Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

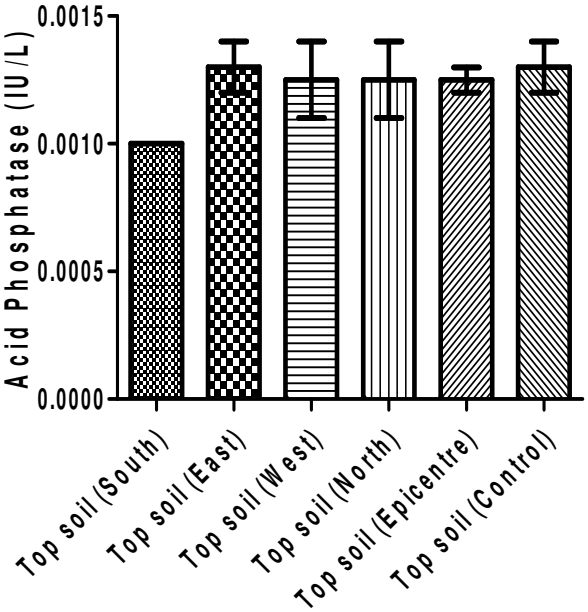

Figure 16. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in topsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

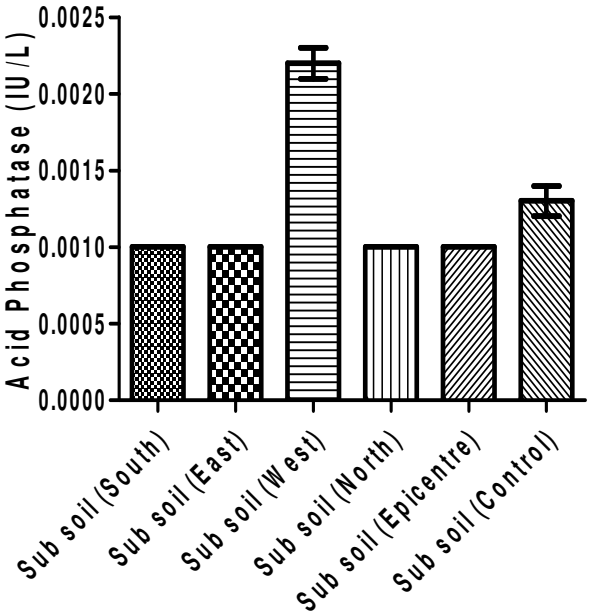

Figure 17. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in sub soil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

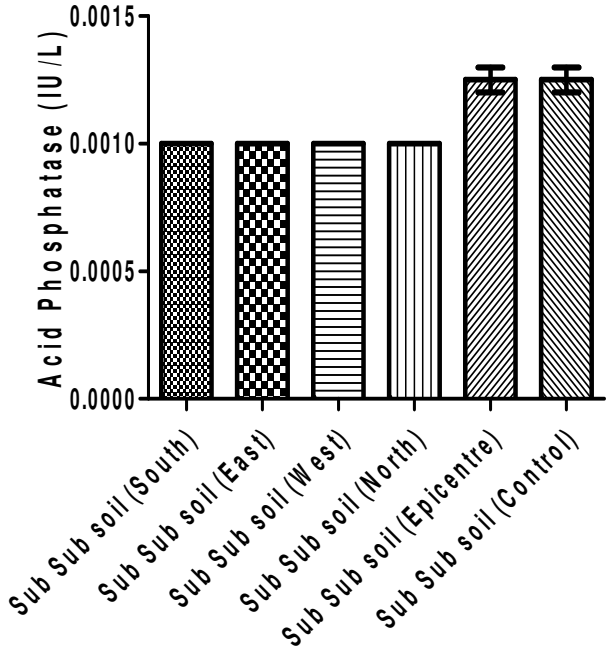

Figure 18. Effect of prolonged exposure to generator fumes on soil acid phosphatase activity in sub-sub soil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

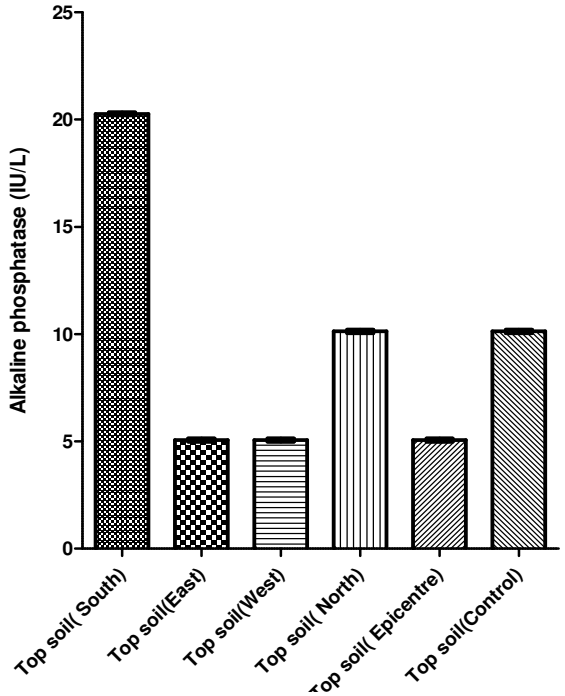

Figure 19. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in topsoil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

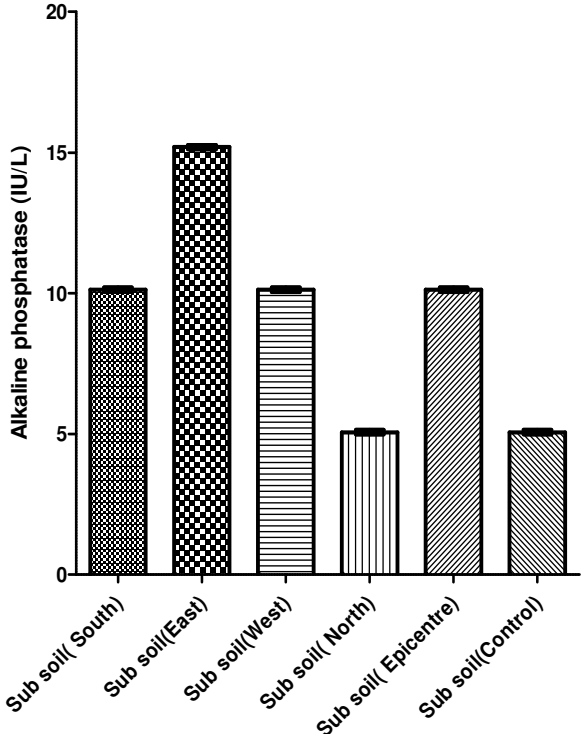

Figure 20. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in subsoil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

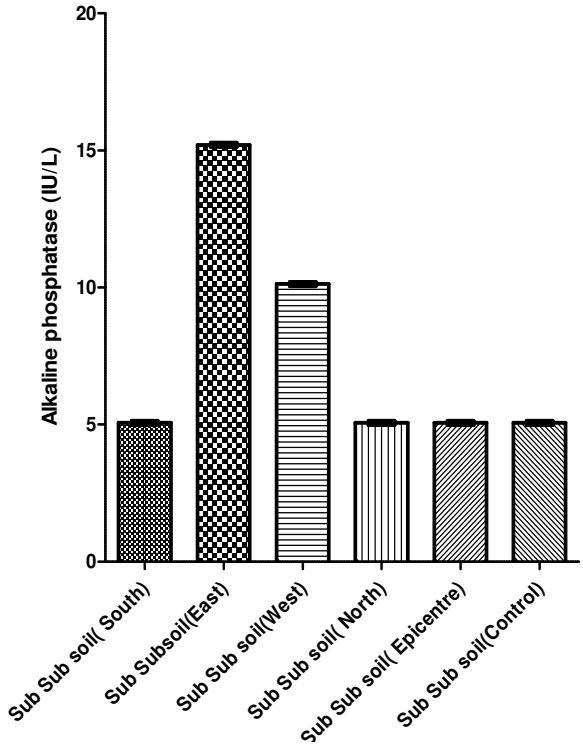

Figure 21. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in sub-sub soil (1m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

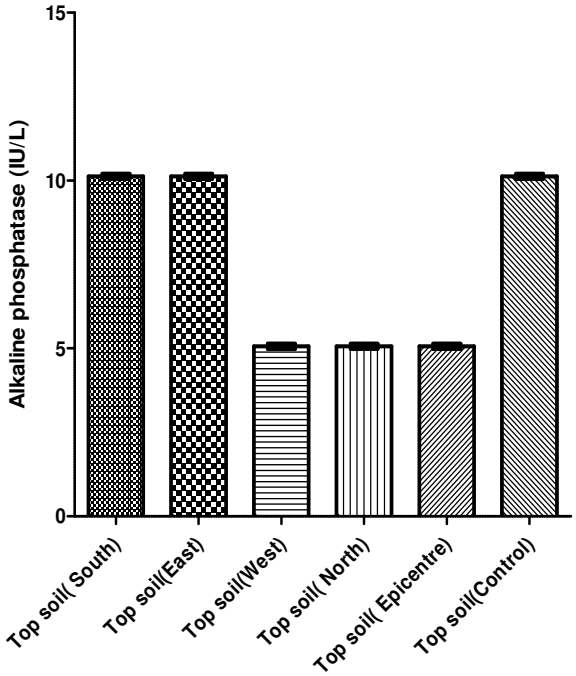

Figure 22. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in topsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

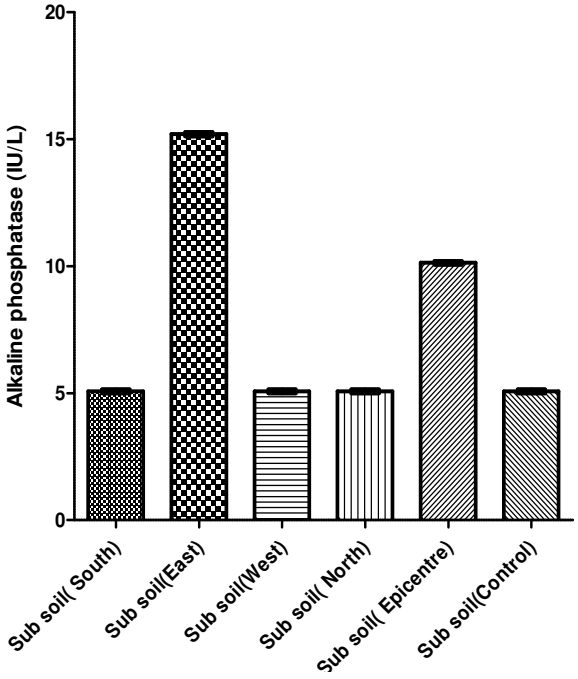

Figure 23. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in subsoil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

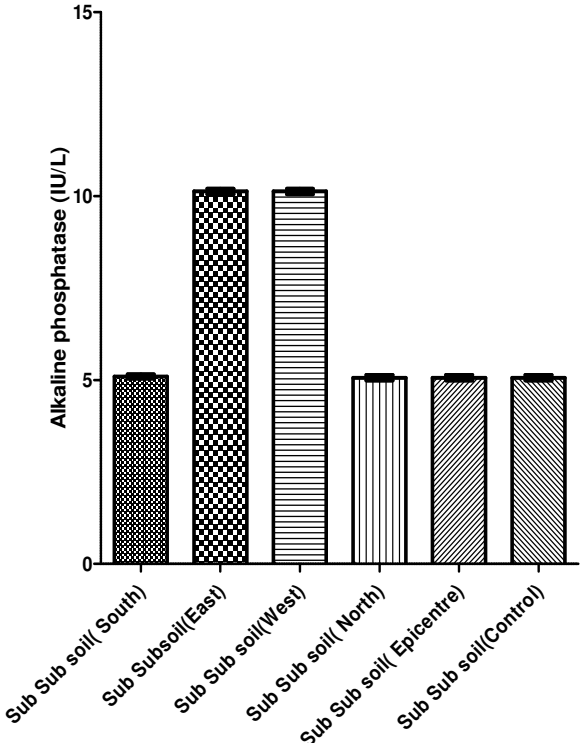

Figure 24. Effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity in sub-sub soil (2m apart).
Bars are presented as means± standard errors of mean (SEM) of triplicate determinations at $p< 0.05$.

differently to different pollutants (He et al., 2003). Various contaminants such as generator fumes and heavy metals have been found to alter soil biochemical equilibrium and energy balance. Their presence causes alterations in soil pH, oxygen and nutrient availability (Atuanya, 1987; Odjegba and Sadiq, 2002) and their exudates (pH, enzymes).

Microorganisms are known to release extracellular enzymes to mineralize organic compounds to elemental minerals (Nannipieri et al., 1990). It is important to underline that these enzymes attached at the outer microbial cells initiate the hydrolysis, and oxidation of high molecular weight substrates such as hydrocarbons to mineral elements (Nannipieri et al., 1990).

Catalase (EC. 1.11.1.6) is a common enzyme found in nearly all living organisms that are exposed to oxygen, where it catalyzes the decomposition of hydrogen peroxide to water and oxygen (Airaodion et al., 2020). Generally speaking, there was hydrogen peroxide of high concentration in soil and the activity of catalase decreased with corresponding increase in the concentration of the generator fumes (Yu, 2008). Catalase enzyme is widely present in nature, which accounts for its diverse activities in soil.

The prolonged exposure to generator fumes (pollutant) altered soil catalase activity significantly at $p< 0.05$. In figure 1 (top soil-1m away), there was significant increase ($p< 0.05$) in the activity of catalase on polluted soils (locW(west) when compared with control (unpolluted) site. Also, there was a significant reduction at $p<0.05$ at locS(south), E(east) and no significant different at $p < 0.05$ at loc N(north) and Epi(epicenter) when compared with control (unpolluted) site.In figure 4 (top soil-2m away), there was significant increase at $p< 0.05$ at loc W, S, and significant reduction at $p<0.05$ at loc E and N when compared with control (unpolluted soil). No significant-difference at loc epi.

In figure 2 (sub soil-1m), there was significant increase at $p< 0.05$ at loc S, W and significant reduction at $p< 0.05$ at loc E, N & epi when compared with the control. In figure 5 (sub soil -2ms), there was a significant difference (increase) at $p<0.05$ at W, N and significant reduction at $p<0.05$ at loc S, E & epi when compared with the control (unpolluted) soil.

In figure 3 (sub-sub soil -1m apart), there was a significant difference (increase) at $p<0.05$ at loc W and a significant reduction at $p<0.05$ at loc S, E, N, epi when compared with the unpolluted soil (control). In figure 6 (sub-sub soil-2meters apart), there was a significant increase at $p<0.05$ at loc W, S and a significant reduction at $p<0.05$ at loc E, N, & epi when compared with the control (unpolluted) soil. As shown in figures above at top soil loc S, E, at 1m and E & N at 2ms, Sub soil at loc E, N, & epi at 1m, E & N at 2ms, Sub-sub soil at loc S, E, N & epi at 1m & E, N,& epi at 2ms the catalase activities were decreased which indicate that petroleum hydrocarbon inhibited the catalase activity, that is the toxic action during petroleum hydrocarbon degradation which led to decrease the catalase activity.

The result of the activity of catalase observed in this study corresponds to that of Achuba and Okoh (Achuba and Okoh, 2014), which found that there was altered catalase activity as a result of the petroleum hydrocarbon. However, its activity increased as a result of the increased microbial activity towards biodegradation of available petroleum hydrocarbon. Achuba and Peretiemo-Clarke (Achuba and Peretiemo-Clarke, 2008) also asserted that the initial reduction at the top soil of catalase activity could be because being an enzyme; its activity is altered by unfavorable conditions, such as hypoxia, unavailability of nutrient and changes in pH. This finding puts catalase as a useful biomarker for indicating the onset of biodegradation process in the soil (Ajao et al., 2011).

The comparatively high level of sub soil catalase activity from polluted soil appeared to suggest the presence of a high quantity of biodegradable substrates in this soil type (Megwas et al., 2021). Additionally, it has been proposed that soil catalase activity increased with increase in concentrations of hydrocarbon pollutants. In an *in vivo* study, Airaodion et al. (2019) reported that feeding Wistar rats with a hydrocarbon contaminated diet significantly increased the activity of catalase.

This result is in accordance with the report of Nwaogu et al. (2012). The prolonged exposure to generator fumes to these sites brought changes in its soil condition such as pH, hypoxia as well as reduction in the number and activities of soil microorganisms (Maila and Cloete, 2005). These changes also caused the fertile soil to lose its productive potential (Margesin and Schinner, 1999). Catalase have been found only to be useful for indicating the onset of the biodegradation process as it exhibits decrease in its activities after the rate of biodegradation of petroleum has decreased as seen in sub-sub soil (Van der Waarde et al., 1995; Jaeger et al., 1994).

Lipase is secreted to the environment by plant roots and microorganisms. It is an important hydrolytic enzyme which catalyzes hydrolysis of oils and fats under physiological conditions (Nelson and Cox, 2004). Soil lipase can be used in monitoring bioremediation of hydrocarbons (Margesin and Schinner, 1999). An indicator of lipase may be attributed to the appearance of products released from oil degradation which may be substrate for lipase (Margesin and Schinner, 1999).

In figure 7 (top soil (1m apart), there was significant different at $p< 0.05$ when control (unpolluted soil) was compared with locS(South), E(East), W(West) and epi(epicenter) but no significant different at $P>0.05$ when compared with loc N(North). There was significant increase at $p<0.05$ at loc E, W, S and epi. In figure 10 (2m apart -top soil), there was a significant increase at $p <0.05$at loc E, W, significant reduction at $p< 0.05$ at loc epi and no significant different at $p > 0.05$ at loc S, N when compared with control (unpolluted soil).

In figure 8 (Sub soil -1m apart), there was significant different (increase) at p< 0.05 at locloc E, W, epi when compared with control (unpolluted soil). There was a significant reduction at p < 0.05 at loc epi and no significant difference at p> 0.05 at loc N & S when compared with control (unpolluted soil). In figure 11 (2meters apart- subsoil, there was significant difference (increase) at p< 0.05 at loc E, W when compared with control (unpolluted soil). There was also a significant reduction at p < 0.05 at loc epi.

In figure 9 (Sub-Sub soil -1m apart), there was significant different(increase) at p <0.05 at loc E, W, Epi when compared with control (unpolluted soil). Also, there was a significant reduction at p < 0.05 at loc S, N. In figure 12 (sub-sub soil-2 meters apart, there was a significant increase at p < 0.05 at E, W, Epi, N and significant reduction at p < 0.05 at loc S when compared with the control (unpolluted soil).

The lipase activity increased at p< 0.05 as the volume of the contaminant (fumes components) increased, however the increment was more pronounced in loc W and E of the top soil, sub and sub-sub soil. This finding corroborates studies by Margesin et al. (2000) and Van der Waarde et al. (1995) were it was found that increasing contaminant concentration increased microbial extracellular lipase activity, thus fronting lipase as a good option for study of contaminated soil bioremediation. The increase also at the sub, sub-sub soil was as a result of no colloidal suspension (unrecovered oil) that prevents the triacylglycerol and other substrate of lipase from getting to the sub soil or sub-sub soil. This increase of lipase activity in these hydrocarbon polluted locations might be the consequence of stimulation of the growth of microorganisms brought about by oily substances contained in petroleum contaminants. It was also observed that there was significant (P < 0.05) reduction in the concentration of lipase at top soil loc S, Epi at 1meter and 2meters apart, Sub soil at Epi at 1m and 2ms apart, Sub-sub soil at loc Epi at 1m and S at 2ms apart. A similar study by Lin et al. (2005) recorded that it was observed that lipase activity in a petroleum polluted site decreased after bioremediation, other works (Margesin et al., 2000; Riffaldi et al., 2006) have shown that lipase is closely related with the organic pollutants present in the soil.

Lipase activity has also been reported to be the reason behind the drastic reduction of total hydrocarbon from contaminated soil and its activity has been found to be a very useful indicator parameter for testing hydrocarbon degradation in soil (Margesin and Schinner, 1999; Ruiz-Duenas et al., 2007). Lipase degrades lipids and other lipid-like compounds derived from a large variety of microorganisms, animals, plants. Lipid catalyzes various reactions such as hydrolysis, interesterification, esterification, alcoholysis, aminolysis of organic pollutants laying credence to their avowed role in bioremediation (Ruiz-Duenas et al., 2007).

The prolonged exposure to generator fumes (pollutant) altered the lipase activity. This could arise from unfavorable conditions such as hypoxia and a reduction in pH which occurred in the oil polluted environment indicating that oil biodegradation by microorganisms and metabolic enzymes could lead to production of organic acids. It could also imply that the amino acids at the active sites of soil lipase (such as serine, histidine and aspartate) are irritable to hypoxic conditions and pH decrease, and any condition that creates oxygen tension with a rise in acidic environment adversely affected the activity. This finding is in consonant with the report of Margesin and Schinner (Margesin and Schinner, 1999) as well as that of Van der Waarde et al. (1995) on the inhibition of the activity of soil lipase following an insult of soil ecosystem with spent oil.

Phosphatases are inducible enzymes regulated by end-product inhibition. Plant roots and microbes will increase the excretion of phosphatases into soils when available phosphate does not meet their demands (Salimon, 2007). Soil acid phosphatase plays a vital role in controlling phosphate mineralization, and its activity reflects the capacity of organic phosphate mineralization potential in soils.

In figure 13 (top soil -1m apart), there was significant difference (increase) at P< 0.05 when control (unpolluted soil) was compared with sample loc W but no significant difference at p>0.05 at loc S, E, N and epi. In figure 16 (top soil-2ms apart, there was a significant reduction at p<0.05 when sample location S was compared with control (unpolluted soil) but no significant difference at p> 0.05 at sample loc E, W, N and epi.

In figure 14 (sub soil -1m apart), there was significant difference (increase) at P< 0.05 with sample location N and a significant decrease at p< 0.05 with sample location E, W, epi when compared with the control (unpolluted soil). No significant difference at p> 0.05 with sample loc S when compared with the control.In figure 17 (sub soil-2ms apart, there was a significant increase at p<0.05 at loc W and a significant reduction at p<0.05 at loc S, E, N, epi.

In figure 15 (sub -sub soil -1m apart), there was a significant different(increase) at p<0.05 at loc S, a significant reduction at p<0.05 at loc E, W, N and no significant different at p>0.05 at loc epi when compared with the control (unpolluted soil). In figure 18 (sub sub-2ms apart, there was a significant reduction(p<0.05) at loc S, E, W, N, when compared with control (unpolluted soil). No significant different at p> 0.05 at loc epi when compared with control.

Results showed that driven by seasonal variation, changes in soil acid phosphatase activities coincided with the seasonal climate pattern. Since this research was conducted in the month of June (wet season), it is expected that soil acid phosphatase activity would be clearly greater in the wet season than the dry season, a

seasonal pattern observed by Sardnas and Penuelas (Sardnas and Penuelas, 2005). Actually, in the wet season, plants grow fast, and microbial biomass is always high (Daniel-Kalio and Braide, 2004). This increasing enzyme activity would respond to meet the increasing P demand by plant and microbe growth in the wet season. Since heavy rain in the wet season often leads to nutrient loss, low available P detected in the wet season further intensifies the completion for P in ecosystems in the growing season.

Moreover, soil available P was relatively high to meet the biological demands because of the accumulation of nutrients released from litter decomposition and low soil nutrient diffusion (Reddy and Faza, 1989). Soil acid phosphatase activity is more dependent on soil available P in the growing season than in the least biologically active season (dry season).

The decrease in the soil acid phosphatase activity could be produced by drought which might result in a reduction of P supply to plants and further aggravate the pressure of P limitation in this study area in the long term. Apart from the decrease in soil moisture, the increasing acidity of soil accompanied by prolonged drought conditions during the time of research might be one of the mechanisms involved in the reduction of soil acid phosphatase activity. Also, reduction of the soil acid phosphatase activity could be as a result of doubled rainfall which brought about more available N input into the ecosystems because excessive available N input would result in a nutrient imbalance which is deleterious to microbial growth that requires balanced nutrient proportions (Perez-de-Mora et al., 2006).

The prolonged exposure to generator fumes which lowers the soil pH, would inhibit plant root growth and nutrient absorption (Sardnas and Penuelas, 2005). This factor would go against acid phosphatase since it is closely bound up with microbe, root growth and plant demand for P (Panara et al., 1990).

The effect of prolonged exposure to generator fumes on soil alkaline phosphatase activity was significantly ($p<0.05$) different. In figure 19 (top soil -1m apart), there was a significant different (increase) at $p<0.05$ at sample loc S and a significant reduction at $p<0.05$ at loc E, W and epi when compared with control (polluted soil). No significant difference at $p>0.05$ at loc N. In figure 22 (top soil-2ms apart, there was a significant difference (reduction) at $p<0.05$ at loc W, N and epi when compared with control (unpolluted soil). Also, no significant difference at $p< 0.05$ at loc S and E when compared with the control.

In figure 20 (sub soil -1m apart), there was a significant difference (increase) at $p< 0.05$ at sample loc E, a significant reduction at $p<0.05$ at sample loc N when compared with the control. No significant difference at $p< 0.05$ at loc S, N and epi when compared with the control (unpolluted soil). In figure 23 (sub soil-2ms apart, there was a significant different (reduction) at $p<0.05$ at sample loc W, N and epi, also no significant difference at $p<0.05$ at sample loc S & E when compared with the control(unpolluted) site.

In figure 21 (sub-sub soil -1m apart), there was a significant difference (increase) at $p< 0.05$ at loc E and W when compared with control. No significant difference at $p<0.05$ at sample loc S, N and epi. In figure 24 (sub -sub soil - 2ms apart, there was a significant difference (increase) at $p<0.05$ at sample loc E & W when compared with control. No significant different at $p<0.05$ at sample loc S, N and epi when compared with the control. The increase in soil alkaline phosphatase in this study also showed that prolonged exposure of soil to generator fumes is toxic to the soil.

CONCLUSION

Lipase, Catalase, Acid and Alkaline Phosphatases activities have been shown from this study to vary with fume pollution relative to soil depth. These selected microbial enzymes are effective in degrading the fume components as seen in their variations in the different polluted soil samples. Nevertheless, overall variability in soil microbial enzyme activities of soil strata from different polluted sites, for the most part, defined the pattern of soil contamination, which could serve as biomarkers for ascertaining level of soil pollution as well monitoring indices for bioremediation. Overall, increases in soil microbial enzyme activities were indications of corresponding impact of pollutant on the soil ecosystems.

Ethical Approval: Not applicable

Consent for Publication: Not applicable

Availability of Data and Material

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request

Competing Interests

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