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Effect of some Physicochemical Properties of Soil on Microbial Respiration along River Jakara, Kano State, Nigeria

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ABSTRACT
This study aimed at evaluating the effect of soil temperature on soil respiration. Ten soil samples were collected along the irrigated land in dry and wet seasons from 0 – 15 cm depth using composite sampling method and then analysed for Cr, Cd, Pb, pH, temperature and soil respiration using standard laboratory procedures. The results showed that soil pH (7.65 ±0.57), and soil respiration (5.67±0.87) were found to be higher in wet season where the temperature was high (26^{0}C). However, Cd (4.37 mg/kg ±0.6), Cr (64.8 mg/kg±10.12) and Pb (43.61 mg/kg±3.77) were found to be higher in dry season where the pH and temperature were low. The correlation analyses showed that soil respiration was negatively correlated with temperature and Cr (r = -0.5). The results also revealed that soil pH and temperature have significant effects on rate of soil microbial activities because soil respiration is higher in the wet season where pH and temperature were high. Soil temperature and pH significantly affect the soil respiration in the study areas.

Keywords: Carbon dioxide, Microbes, Respiration, Soil, Temperature

INTRODUCTION
One of the major uncertainties in climate change prediction is the response of soil respiration to increased atmospheric temperature. Several studies showed that increased soil temperature accelerates rate of microbial decomposition, thereby increasing carbon dioxide (CO_2) emitted by soil respiration and producing positive feedback to global warming (Allison *et al.*, 2010). Soil is the largest terrestrial carbon (C) pool, therefore stored soil C results from an imbalance between organic matter produced by plants and its decomposition back into the atmosphere as CO_2. The large pool of C in the soil is vulnerable to climatic warming and its potential loss may amplify further warming (Cox *et al.*, 2000). Among the factors affecting soil microbial respiration are temperature, pH and pollutants are perhaps the most relevant. Regarding the temperature sensitivity of decomposition, kinetic theory predicts that temperature sensitivity of soil respiration should increase as the degree of substrate complexity and microbial activities increases. Changes in the below-ground carbon pools can have a major impact on carbon storage in terrestrial ecosystems and change carbon flux to the atmosphere. CO_2 efflux from the litter surface originating as plant and microbial respiration reflects this large below-ground activity.

The soil respiration rate has been among the most widely studied microbial parameters in heavy metal polluted soils (Liao *et al.*, 2005). This includes measurements in contaminated soils around smelters, roads, in the field and laboratory experiments involving metal addition via sewage sludge, wastewater, sawdust or inorganic and organic salts. It is accredited as an indirect indicator of the activity of total soil microbial populations (Koper *et al.*, 2003). Because of its relationship to soil biology, ease of measurement and rapid response to changes in soil management, it has been suggested as a potential indicator of soil quality (Fernandes *et al.*, 2005). Tobor-Kapłon *et al.* (2005) stated that under stress, more resistant organisms respond by an increased respiration activity as oxygen consumption increases with ongoing decontamination processes, while more sensitive organisms are characterized by reduced respiration. Mikanova(2006) attributed the different results of individual studies to different properties of available substrate in soil which is mineralized at the time when respiration activity is measured.
Specific respiration (qCO_2) is a sensitive indicator of soil pollution by heavy metals (Nwuche and Ugoji, 2008). Some research experiments have shown an increase in qCO_2 (Clemente *et al.*, 2007) whereas some others exhibited a decrease in qCO_2 in highly contaminated soils (Liao *et al.*, 2005). Friedal *et al.* (2001) noticed that in wastewater-irrigated fields, qCO_2 decreased in plots with less metals pollution, and it increased in plots with high metal contamination. Liao *et al.* (2005) observed that the soil respiration was negatively affected by elevated levels of heavy metals in soils and that the qCO2 was closely correlated to the heavy metal

stress. Chander *et al.* (2001) reported that values of qCO_2 were constantly lower in soils polluted by river sediments than in the soils amended with Zn-enriched sewage sludge. They further indicated that low qCO_2 values were due to the large proportion of older organisms being in a resting state.

Soil moisture, temperature, and some soil properties were considered as ecological factors distressing the microbial growth and activities. Therefore to clearly recognize the nature and variation of microbial activities a trustworthy evaluation of temperature and some soil properties is necessary. The significance of soil microbes reliance on temperature has been momentously accentuated recently due to global climatic dynamics meanwhile soil organisms are the main group of living thing producing carbon dioxide (CO_2) during decomposition of organic materials (Pietikainen *et al*., 2004).This paper assessed the effect of temperature, some physicochemical properties and heavy metals on soil microbial respiration.

MATERIALS AND METHODS

Study Area

The study was carried out along the irrigated land of Jaba village located between latitude 12^0 10ˈ N to 12^o 21ˈN and longitude 8^o 46ˈE to 8^o 53ˈE and the area is situated in Ungogo local government area Kano state of Nigeria (Mohammed, 2010). The farmers in the area normally use water from River Getsi and Jakara for irrigation. The soil of the area is dominated by ferruginous type with hydromorphic soil along the flood plain of the river where by crops grown in the area include cabbage, lettuce, onion, carrot, cucumber and tomatoes.

Materials

The materials used in this study include spade soil auger for sampling the soil, Global Navigation System (GNS), pH meter for measuring soil pH. Ten soil samples were randomly collected form 0 – 15cm depth from irrigated land. The samples collected were placed into polythene bags, labelled appropriately, air dried, and then analyzed in the laboratory.

Experimental procedure

Determination of pH: Ten grams (10g) of soil sample was placed in a 50 cm^3 beaker and 25 cm^3 of 1.0 N, KCl was added and the suspension was stirred at regular intervals for 1 hour. The suspension was stirred well just before immersing the electrode. The pH meter was switched on at least 15 minutes for the pH meter to warm up and standardized the glass electrode. The standard buffers were used and the temperature compensation knobs to the temperature of the test solution were adjusted. The electrode was rinsed with distilled water after each determination and a blotting paper was used for water removal from its surface. The standardization process was checked after every ten determinations.

Determination of Some Heavy metals in the Soil

Ten grams soil was weighed in a clean $300cm^3$ calibrated digestion tube and 5ml of concentrated sulphuric acid (H_2SO_4) was added in the fume hood and swirled carefully and the tubes were placed in the tubes racks and then placed in the block-digester. Gradually, the temperature setting was increased from 60^oC to 145^oC for one hour. Five centimeter cube ($5cm^3$) of tri-acid mixtures (HNO_3, H_2SO_4 and HCl) were added and then heated to 240^oC for further one hour. The tubes racks were removed out of the block-digester and carefully placed on a rack holder and allowed to cool at room temperature and then filtered through Whatman No. 42 filter papers and stored in pre-cleaned polythene bottles for further analysis. Atomic Absorption Spectrophotometer (AAS, 210 VGP, American Model) was used. The digested and filtered samples were aspirated and the results were dispensed on the read out unit of atomic absorption spectrophotometer (Sarkar and Haldar, 2005).

Soil respiration

Soil respiration was determined using incubation in a closed container 1 to 7 days testing period as described by Alef and Nannipieri (1995) and Khan and Joergensen (2006). Two hundred grams of soil was transferred to a 1000 cm^3 plastic beaker. A small beaker containing 10 ml 1.0 M NaOH solution was placed into the 1000 cm^3 plastic beaker containing 200g pre-incubated soil. The beaker was covered with polyethylene sheet, made airtight with a rubber band and kept in an incubator at 25^oC for 3 days. At the same time, a blank was run (without soil) to assess the amount of CO_2 entering. After 3 days, the beaker containing 10 cm^3 NaOH solution was removed and titrated against 1.0 M HCl after the addition of 5 cm^3 of saturated $BaCl_2$ solution and a few drops of phenolphthalein indicator. The CO_2 evolved was calculated from the amount of NaOH consumed.

RESULTS AND DISCUSSION

The mean values of the selected physicochemical properties of soil and soil respiration is presented in Table 1 which showed that the mean values of Cr, Cd and Pb were found to be higher in dry season than wet season. High mean values of Cr, Cd, and Pb in dry season is probably attributed to the effect of rainfall which facilitates the dilution of soil minerals, redox reaction, leaching and run off which are capable of removing heavy metals from subsurface soil.

Table 1: Mean values of heavy metals, CO_2, pH of soil

Season	CO_2 (µg NH4-N g-1)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	pH	Temp (^oC)
Dry	4.35	64.81	12.2	43.61	7.65	21.71
Wet	4.6	17.89	4.37	32.04	7.94	25.55

This is agreed with Delbari and Kulkarni (2011) who explained in their findings that low concentration of heavy metals in soil at wet season is due to redox reaction, runoff and leaching which are expedited by rainfall. This is contended by Lal (2006) who explained that seasonal variation of heavy metals in the soil influenced by runoff and leaching of dissolved heavy metals which is facilitated by rainfall. The values of Cr, Cd, and Pb obtained in this work are higher than the values obtained by Bichi and Bello (2013) which indicated that there is gradual accumulation of heavy metals in the study area. The pH values (Table 1) are slightly alkaline but it is optimum for some crops (Brady and Weil, 2014).

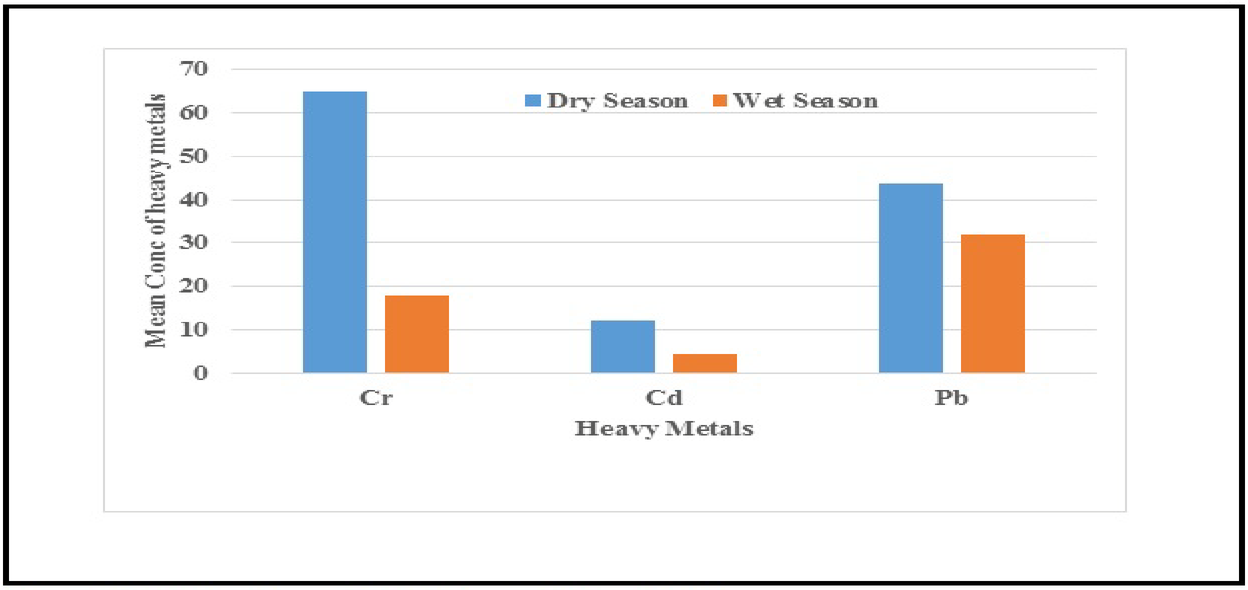

Fig. 1: Distribution of Cr, Cd and Pb of Soil

The mean values of soil respiration was found to be higher in wet season than dry season. This shows that soil respiration responds more to seasonal change and consequently sensitive indicator of soil quality change. Seasonal change in temperature and carbon input from crop root, crop residue and rhizosphere have significant effect on soil respiration which in turn affect the ability of soil to supply nutrient to plant through organic matter turn over (Boerner *et al.*,2005). High mean values of soil microbial respiration in wet season is probably attributed to the favorable condition for microbial population growth and activities due to rainfall, temperature and rapid mineralization rate in wet season (Mondal *et al.*, 2015).

The soil pH found to be higher in wet season (Table 1) which implies that Hydrogen (H^+) and Hydroxyl (OH^-) ions were freely released from the bound form thereby exchange complex of the soil in wet season is highly dominated by exchangeable cation and other base forming cations. This was explained by Brady and Weil (2014) who explained that at high pH, the Aluminium and Hydroxyl ions have been replaced by H^+ more in to the soil solution.

Spatial Distribution of Soil Temperature and respiration

The spatial distribution of soil temperature and respiration was evaluated and presented in Figures 2 and 3. The distribution of soil temperature shows that the eastern part, north-eastern and south-eastern part of the area recorded 21.3 to 22.23^{o}C which demarcated by the strip of land running north to south with 22.24 to 23.16 and the remaining part which comprises of north, north west and south west recorded 32.17 to 24. 07^{o}C. However, some patches of land around the southern and some around northern part recorded the highest temperature of 24.08 to 25°C.

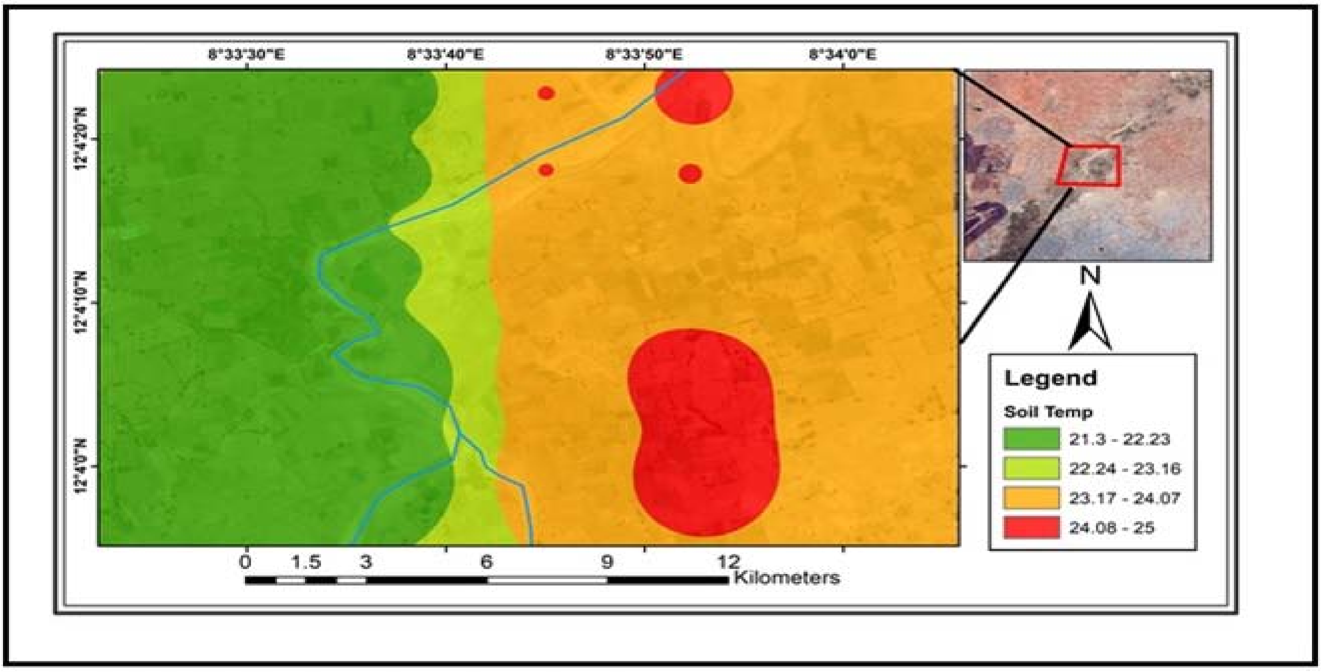

Fig. 2: Distribution of Soil Temperature

The spatial distribution of soil respiration shows that small spots of land in the extreme north and very small one at extreme south-east and central part respectively recorded 2.75 to 3.68°C as the smallest ranges among the classes. It was discovered that the smallest range (2.75 to 3.66°C) where surrounded by 3.69 to 4.6°C range with small spot at the central part of the area. The remaining land coverage which is the largest recorded rang of 4.61 to 5.53°C and is the area with second highest soil respiration values. However, the eastern part running to the north-east with some patches at the extreme south, central part and very small spot at the south western part covered with soil respiration ranges from 5.54 to 6.45°C and considered the highest range among the soil respiration of the area. This implies that there is bumpy distribution of soil temperature and respiration in the area and therefore, micro variability were discovered in the area.

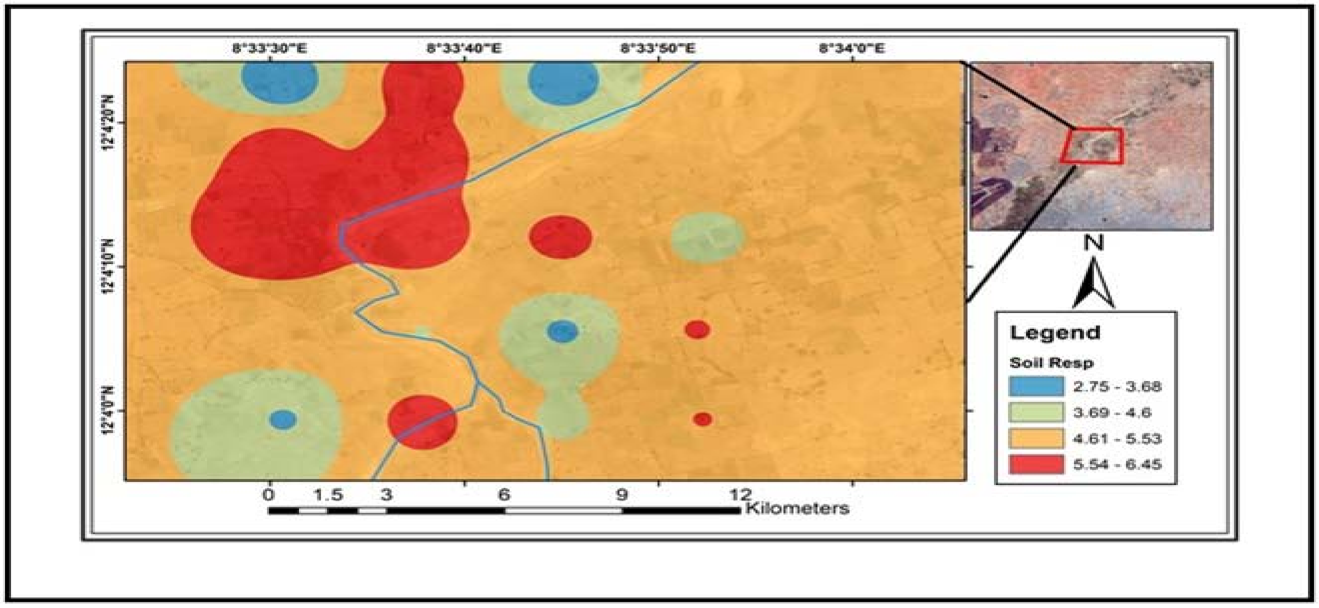

Fig. 3: Distribution of Soil Respiration

Temperature and physicochemical response to Soil Respiration

The mean values of soil respiration was found to be higher in wet season where the temperature (Fig. 2) and pH are higher and also the heavy metals are low, this indicates that soil respiration is affected by temperature, pH and some heavy metals because respiration activities are characterized by the process of mineralization of organic matter in soil and other metabolic process in which CO_2 is released by soil respiration (Tobor-Kaplon *et al.*, 2005). The trend of soil respiration and temperature in dry and wet season (Fig. 4) shows that most of the sampling points with high temperature have high soil respiration in the study area. This indicates that increase in soil temperature increases the microbial respiration in the study area.

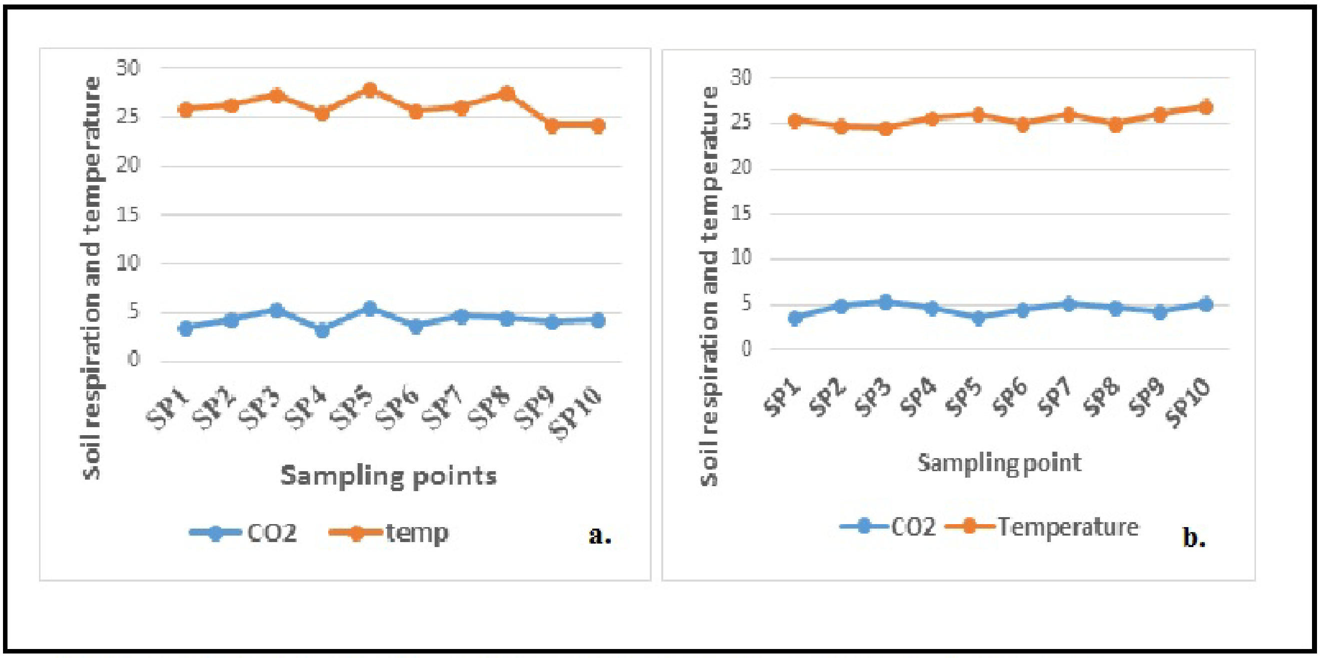

Fig.4: Trend of soil respiration and temperature in the area a. Dry season b. Wet season

The trend in microbial soil respiration and temperature indicates how temperature affect soil respiration which is because at high temperature, the activities of soil microbes (soil respiration inclusive) would increase since temperature enhance the activity of soil microbes particularly soil respiration.

The correlation analyses shows that Cr (r = 0.55), Cd (r = 0.24) and Pb (r = 0.05) were positively correlated with soil respiration, this indicates that changes in soil respiration in the area is not significantly associated with Cr, Cd and Pb. This is probably attributed to the pH level in the area which influenced the solubility, availability and toxicity of heavy metal to soil microbes. This is explained by Lal (2006) that availability, solubility and toxicity of heavy metals decreases as soil pH increases, this is due to the increase in negative charges on the variable charge surface in soil and the propensity for these heavy metals to precipitates as springy soluble compound as soil pH increase. This is further supported by Marschner and Kalbitz (2003) who reported that low pH soil may contain high level of heavy metals without any sign of toxicity to soil microbial activities whereas toxicity may develop with certain organisms at much lower heavy metals level in acidic soil. The results is in line with the findings obtained by Smejkalova *et al.* (2005) who reported positive correlation between soil respiration and some heavy metals. This is probably due to the high pH and temperature in the area which influence the soil microbes to resist the toxicity effect of heavy metals.

The relationship between soil respiration and temperature in all the seasons (Figure 5) was evaluated and the results shows that soil respiration was negatively correlated with organic carbon (r = -0.81) and was positively correlated with pH (r = 0.37). This implies that decreases on organic carbon would decrease the soil respiration of the area and increase in soil pH would also increase the soil respiration in the area. This trend is probably due to the fact that under high pH all pollutants that inhabits soil microbial respiration would be reduced if not hindered completely (Brady and Weill, 2014).

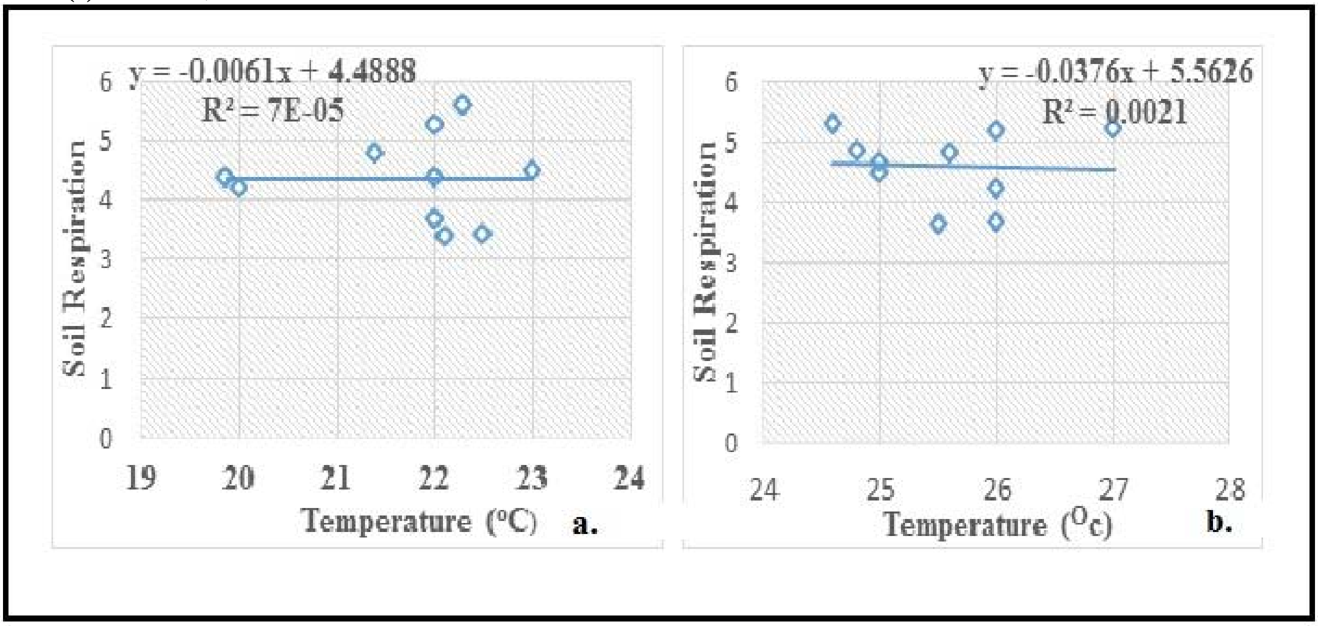

Fig.5 : Relationship between Soil temperature and Respiration a. Dry and b. wet Seasons

The analyses also showed that soil respiration is negatively correlated with temperature where the correlation coefficient values are: r = - 0.05, p = 0.98 and r = – 0.14 and p = 0.90 for dry and wet seasons respectively. This implies that decrease in soil temperature will decrease the rate of soil respiration in the soil of the area. This is contended by Brady and Weil (2014) who explained that soil microbial respiration is influenced by temperature change, their activity normally cease below 5^{o}C and the rate of soil microbial respiration typically more than double for every 10^{o}C raised in temperature up to the optimum of about 35^{o}C to 40^{o}C. Figure 3 shows the regression analyses between soil respiration and soil temperature where the regression equation and coefficient of determination (r^2) values for the relationship. The nature of this relationship between soil respiration and temperature indicates the dependency of soil microbial respiration on warm soil has important roles for soil pore space and aeration.

CONCLUSION

From the findings of this work it can be concluded that heavy metals levels in the soil affect the soil respiration of the area and also high pH and temperature significantly enhanced the microbial diversity and activities which influence the soil respiration in the area. Soil pollution management could mitigate the rate of carbon dioxide production from soil ecosystem.

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