Original Research

Seasonal effect of temperature on soil microbial respiration in Jaba area Kano Nigeria

Abstract

The planet's soil releases about 60 billion tons of carbon into the atmosphere each year, which is far more than that released by burning fossil fuels. This enormous release of carbon is balanced by carbon coming into the soil system from falling leaves and other plant matter. The study aimed at evaluating the effect of soil temperature on soil respiration. Ten samples were collected in dry and wet season from 0 – 25 cm depth using composite sampling method and then analysed for Cr, Cd, Pb, pH, temperature and soil respiration using standard laboratory procedures. The results shows 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 is high (26^0C). However Cd (4.37±0.6), Cr (64.8±10.12) and Pb (43.61±3.77) were found to be higher in dry season where the pH and temperature is low. The correlation analyses shows that soil respiration was negatively correlated with temperature and Cr (r = -0.5). The results also revealed that soil pH and temperature have significant effect on rate of soil microbial activities because soil respiration is higher in the wet season where pH and temperature are high. Soil temperature and pH significantly affect the soil respiration in the area. Increase of organic matter and avoid use of contaminated water for irrigation were recommended in the area.

Key words: soil, microbes, respiration, Carbon dioxide and temperature

INTRODUCTION

One of the major uncertainties in climate change prediction is the response of soil respiration to increased atmospheric temperature. Several studies show 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). The 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 belowground 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 belowground 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 (qCO2) is a sensitive indicator of soil pollution by heavy metals (Nwuche and Ugoji, 2008). Some research experiments have shown an increase in q CO_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 an ecological factors distressing the microbial growth and activities. Therefore to clearly recognize the nature 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 organism are the main group of living thing producing carbon dioxide (CO2) during decomposition of organic materials (Pietikainen *et al*., 2004).This paper assessed the effect of temperature and some physicochemical properties of soil on 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 used water from River

Getsi and Jakara. The crops grown in the area include cabbage, lettuce, onion, carrot, cucumber and tomatoes.

Materials and Method

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 – 15 cm depth in irrigated land. The samples collected were placed into polythene bags, labelled appropriate, air dried, and then taken to the laboratory for further analyses.

Experimental procedure

Determination of Soil Reaction (pH): Ten grammes (10g) of soil sample was placed in a 50 ml beaker and 25 ml of 1.0 (N) KCl was added and 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 was used and the temperature compensation knob 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 weighted in a clean 300 ml calibrated digestion tube and 5ml of concentrated sulpharic 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 millilitre (5ml) 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 racks 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 instrument was set up at a wavelength for each analyte. Adjustment was made to achieve the most sensitive line for the metals that was analysed. 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).

Calculation:

Heavy metal $= \frac{\frac{X}{Y} X\ V.F\ X 100}{1000\ X\ W.T}$………………………………………………………………… ii

Where, X is absurbance, Y is a Slope, V.F is equal to 100 and 10g is the weight of soil sample

Soil respiration: Soil respiration was analysed using incubation in a closed container 1- 3 days and 3 – 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 ml plastic beaker. A small beaker containing 10 ml 1.0 M NaOH solution was placed into that 1000 ml plastic beaker containing 200g pre-incubated soil. The beaker was then covered with polyethylene sheet, made airtight with a rubber band and kept in an incubator at 25^{o}C for 3 days. At the same time, a blank was run (without soil) to assess the CO_2 entering from air following the above procedure. After 3 days, the beaker containing 10 ml NaOH solution was removed and titrated against 1.0 M HCl after the addition of 5 ml of saturated $BaCl_2$ solution and a few drops of phenolphthalein indicator. The CO_2 evolved was calculated from the amount of NaOH consumed during 3 days of incubation.

RESULTS AND DISCUSSION

The mean values of some selected physicochemical properties of soil and soil respiration is presented in Table 1. High values of Cr, Cd and Pb corresponds with period where there is high value of soil respiration. The values of Cr, Cd, and Pb obtained in this research are higher than the values obtained by Bichi and Bello (2013) this indicates that there is gradual accumulation of heavy metals in the study area. The pH values (table 1) is slightly alkaline but it is optimum for some crops (Brady and Weil, 2014).

Table 1: Mean values of physicochemical properties of soil and soil respiration

	Physicochemical properties of soil and soil respiration					
	CO2	Cr	Cd	Pb	pH	Temp
Season	(µg NH4-N g-1)	(mg/kg)	(mg/kg)	(mg/kg)	(KCl_2)	(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

Source: Field work, 2015

Fig. 1 shows that Cr, Cd, and Pb were found to be higher in dry season than that of wet season which 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. This is agreed by Delbari and Kulkarni (2011) who explained in their findings that high concentration of heavy metals in wet season is due to redox reaction, runoff and leaching which are facilitated 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.

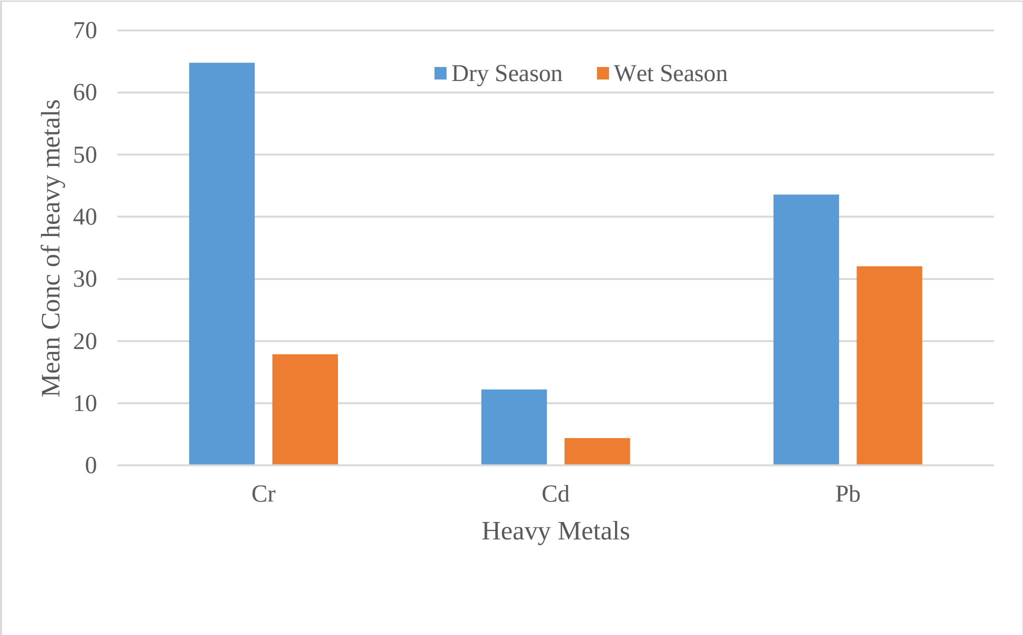


Figure 1: Distribution of some chemical properties of soil

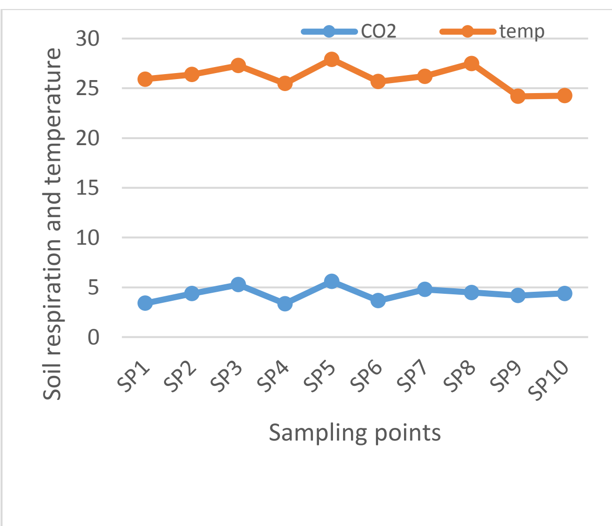
The mean values soil respiration is found to be higher in wet season than dry season. This shows that soil respiration responds more to seasonal change and consequently be an early and sensitive indicators of soil quality change. Seasonal change in temperature and carbon input from crop root, crop residue 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).

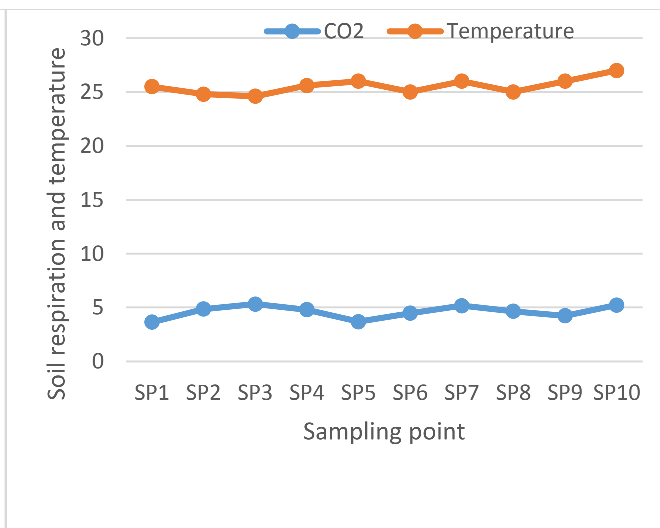
The soil pH found to be higher in wet season (table 1) which implies that Hydrogen (H^+) and Hydroxyl (OH^-) ions were freely released from the bound form thereby exchange complex of the soil in wet season is highly dominated by exchangeable cation and other base forming cation. This is explained by 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.

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 were found to be higher and the heavy metals were found to be 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 distribution of soil respiration and temperature in dry and wet season (Fig. 2) shows the nature of the trend which shows that most of the sample points with high temperature have high soil respiration in in the study area. This indicates that increase in soil temperature increases the microbial respiration in the study area.





a. b.

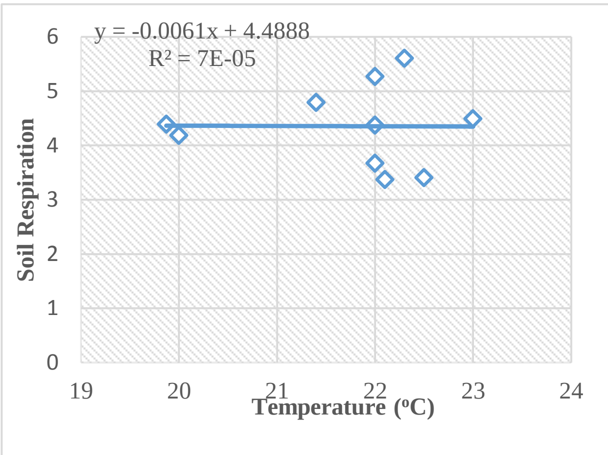
Figure 2 trend in soil respiration and temperature in the area a. Dry season b. Wet season

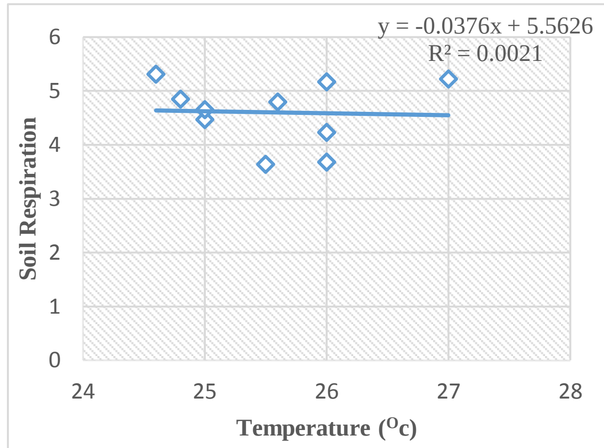
The trend in microbial soil respiration and temperature indicates the effect of temperature on soil respiration which is due to the fact that at high temperature the activities of soil microbes (soil respiration inclusive) would be high because it enhance their activity to the certain level.

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 influence 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 developed 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 analyses also shows that soil respiration was negatively correlated with organic carbon (r = -0.81) and was positively correlated and 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.

The analyses also shows 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 season respectively. This implies that decreases in soil temperature will decreases 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 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.





a. b.

Figure 3. Regression Model between soil respiration and Temperature: a. Dry Season b Wet Season

CONCLUSION AND RECOMMENDATION

From the findings it was concluded that rainfall facilitates the dilution and leaching of heavy metals results in low values of heavy metals in wet season. Heavy metal level 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 can mitigate the rate of carbon dioxide production from soil ecosystem. It was recommended that leaving crops biomass in soil, reduction of soil pollution through treating the waste before discharge will enhance the microbial activities which store more carbon in soil for longer period.

REFERENCES

Adamu, G.K. (2014). An Assessment of the Characteristics and Potentials of Fadama Soils in The Reaches of Two Major Stream in Kano State, Nigeria, *Unpublished Ph.D. Thesis,* Department of Geography Bayero University Kano, Nigeria, 6 – 19

Alef, R. and Nannipieri, P. (1995). *Methods in Applied Soil Microbiology and Biochemistry.* London Academic Press Ltd, London. 350 – 351

Allison SD (2005) Cheaters, diffusion and nutrients constrain decomposition by microbial enzymes in spatially structured environments. *Ecology Letters,* 8, 626–635.

Bichi, M. H. and Bello, F. U. (2013). Heavy metals in soils used for irrigation of crops along River Tatsawarki in Kano, *International Journal of Engineering Research and Development,* 8 (4): 01-017

Brady, N. C. and Weil, R. R. (2014). *Nature and Properties of Soils;* Fourteenth Edition, Pearson Education Inc; Upper Saddle River New

Bonnaeu, M. and Sauchier, B. (1982). *Constituents and Properties of Soil.* Academic Press Inc, III Fifth Avenue, New York, 419 – 465

Chander, K. J., Dyckmans, H., Hoeper, R. G., Joergensen, B. and Meyer, M. R. (2001). Long- term effects on soil microbial properties of heavy metals from industrial exhaust deposition, *Journal of Plant, Nutrition and Soil Sci*ence, (164): 657-663

Cox P.M., Betts R.A., Jones C.D., Spall S.A. and Totterdell I.J. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature* 408: 184–187.

Delbari, S. A and Kulkarni, D. K. (2011). Seasonal Variation in Heavy Metals Concentration Agricultural Soils In Teheran, Iran. *Bioscience Discovery.* 2 (3): 333

Fernandez-Calviño, D. Soler-Rovira, P. Polo, A. Diaz-Raviña, M. Arias-Estevez, M. and Plaza, C. (2010). Enzyme Activities in Vineyard Soils Long-Term Treated With Copper- Based Fungicides, *Soil Biology and Biochemistry,* (42): 2119-2127

Friedal, J. K., Langer, T., Siebe, C. and Stahr, K. (2000). Effect of long–term wastewater irrigation on soil organic matter, soil microbial biomass and its activities in Central Mexico, *Biology and Fertile Soils,* 31: 414-421

Khan, K. S. and Joergenesen, R. G. (2006). Decomposition of heavy metal contaminated Nettles (Urtica dioica L.) in soils subjected to heavy metal pollution by River sediments. *Chemosphere*. (65): 981-987

Koper, J., Piotrowska, A. and Siwik-Ziomek, A. (2003). Influence of mineral-organic fertilization on the value of the biological index of soil fertility, *Zesz. Probl. Post Nauk Roln,* 4 (94): 207-213

Lal, R. (2006). *Encyclopedia of Soil Science (2nd Edition)*. The Ohio State University Colombus, Ohio, U.S.A. Newyork London. (1 and 2): 817 – 1813.Tailor and Francis group

Liao, M., Chen, C. L. and Huang, C. Y (2005). Effect of heavy metals on soil microbial activity and diversity in a reclaimed mining wasteland of red soil area, *Journal of Environmental Sciences* (17): 832–837

Marschner, B., Kalbitz, K. (2003). Control of bioavailability and biodegradation of dissolved organic matter in soils, *Geoderma,* 113 (3-4): 211-235

Mikanova, O. (2006). Effects of heavy metals on some soil biological parameters, *Journal of Geochemical Exploration,* 8 (8): 220–223

Mohammed, M.A. (2010). An Assessment of Heavy Metals Pollution in Soils Under urban and Peri-Urban Irrigation in Kano Metropolis. *Unpublished M.Sc Thesis*, Geography Department, Bayero University Kano- Nigeria, 45 – 58

Mondal, N. K., Pal, K.C., Dey, M., Ghosh, S., Das, C. and Datta, J., K. (2015). Seasonal Variation Variation of Soil Enzyes in Areas of Florida Strees in Birbhum District West Bengal, India. *Journal of Taibah University for Science.* (9): 133-142

Nwuche, C. O. and Ugoji, E. O. (2008). Effects of Heavy Metal Pollution on The Soil Microbial Activity, *International Journal of Environmental, Science and Technology*, 5*(3): 409-414*

Pietikainen, P., Pettersson, M., Baath, E. (2004). Comparison of temperature effects on soil respiration and bacterial and fungal growth rates, *FEMS microbiology ecology*, 52 (20050): 49 – 58

Sarkar, D. and Haldar, A. (2005). *Physical and Chemical Methods in Soil Analysis* Fundamental Concepts of Analytical Chemistry and Instruental Technique, Newage International, Publishers, 4835/24, Ansari Road, Daryaganji, New Delhi-India

Smejkalova, M. Mikanova, O. and Boruvka, L. (2003). Effects of Heavy Metal Concentrations on Biological Activity Of Soil Micro-Organisms. Faculty of Biological Sciences, University of South Bohemia in Ceske Budejovice, Czech Republic: *J. of Research Institute of Crop Production, Prague, Czech Republic*. 49 (7): 321–326

Tobor-Kapłon M.A., Bloem J., Rőmkens P. F. A.M., Ruiter P. C. (2005). *Functional Stability of Microbial Communities in Contaminated Soils. Oikos*, 119–129.