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RESEARCH PAPER

Bioremediation of arable soil using Nitrogen, Phosforus, Potassium fertilizer treatment

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Abstract. This study seeks to examine *"in situ"* remediation effectiveness of NPK fertilizer treatment as a viable biostimulation-based bioremediation technology for soil remediation by evaluating data obtained from soil physicochemical properties before and after initiation of bioremediation. Bioremediation was initiated by stimulating indigenous microorganisms in soil by NPK application, while remediation was determined by soil physicochemical condition after nutrient amendment and changes observed in plant height after 60, 90, 120, 150, 180 and 210 days of planting. Rhizomes of turmeric were planted in soil treated with NPK fertilizer and control in a randomized complete block design (RCBD) with three replications. Data generated from soil physicochemical parameters in laboratory and field was analyzed before and after treatment. Study showed increase in available potassium, available phosphorus, total nitrogen, pH, cation exchange capacity (CEC) and organic carbon. However, there was decrease in aluminium, soil organic matter and acidity. Sand, silt and clay also decreased slightly. Study revealed significant increase in plant height from plants that benefitted from nutrient amendment.

Keywords: physicochemical properties, indigenous microorganisms, soil remediation

1. Introduction

Many countries face environmental challenges orchestrated by soil degradation and fertility loss due to agricultural practices which in the past have been largely prevented by the use of less intensive farming methods (Arden-Clarke & Hodges, 1987; Chambers & Garwood, 2000). Although agriculture has flourished over the years, research has shown the negative effect it has on soil physicochemical characteristics when not controlled. Also, it is appropriate to note that the role of Nitrogen (N), Phosphorus (P), Potassium (K) fertilizer and the adverse effects on continuous use of high dose on soil is known hence, researchers are now showing considerable inclination towards adopting the most suitable and feasible bioremediation response option in returning polluted soil back to its original condition since there is no single bioremediation

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technique to restore polluted sites. Over the years, there has been an increase in population while available land resources is under intense pressure from various industrial activities, agricultural practices etc (Eze & Okpokwasili, 2010). Human activities such as deforestation, indiscriminate dumping of generated waste, agricultural practices and unregulated disposal of untreated wastes from industries cause soil pollution and subsequently loss of fertility. Therefore to increase yield, farmers had to resort to use of pesticides, chemical fertilizers etc even though these practices have adverse effects on soil physicochemical conditions. Interestingly, soil can be returned to use and bioremediation looks more feasible towards achieving this feat. Timmis et al. (1998) argued that environmental degradation from oil exploration and production, agricultural activities, ill-advised bush clearing and other health related concerns resulting from oil pollution have justified the need for more studies into bioremediation of polluted environment.

2. Literature review

2.1. Principle of bioremediation

Sasikumar and Papinazeth (2003) defined bioremediation as a technology for removing pollutants from the environment thus restoring the original natural environment. It can occur via natural attenuation or can be enhanced with addition of fertilizers and microorganisms. Over the last 25 years, various bioremediation techniques have been developed. However, there are two main techniques to remediating polluted sites and these are biostimulation (addition of nutrients to stimulate growth of indigenous bacteria) and bioaugmentation (addition of bacteria to supplement existing microbial population) (Cerniglia, 1993). Studies on bioremediation have shown that when pollutant lies 1m below ground surface, bioremediation might proceed without excavation however, pollutant lying 1.7m below ground surface needs to be transported to the surface for bioremediation to be effectively enhanced (Nikolopoulou et al., 2013). Another study by Walker et al. (1976) revealed that nutrient amendment with nitrogen and phosphorus yielded positive result as a countermeasure to combat oil spills in marine environment. Land farming bioremediation technique which incorporates tillage often involves irrigation, aeration and nutrient amendment as its major operations. This stimulates activities of indigenous microorganisms to enhance the process of bioremediation.

2.2. In situ bioremediation techniques

In situ bioremediation technique involves treating polluted substances at the site of pollution. This technique is less expensive when compared to ex situ bioremediation technique because excavation cost is not required. In situ bioremediation techniques can be enhanced (biostimulation, bioaugumentation, bioventing, biosparging and phytoremediation) while others might proceed without any form of enhancement (intrinsic bioremediation or natural attenuation). In situ bioremediation techniques have been successfully used to treat chlorinated solvents, dyes, heavy metals and hydrocarbons polluted sites (Kim et al., 2014; Roy et al., 2015). For a successful in situ bioremediation to be achieved (Philp & Atlas, 2005) reported that the following environmental conditions must be considered; temperature, pH, nutrient availability and moisture content.

2.2.1. Enhanced in situ bioremediation

(a) Biostimulation (addition of nutrients)

Basically biostimulation involves stimulation of indigenous microbes in soil or groundwater by providing necessary nutrient supplement. Studies have shown that fertilization with nitrogen and phosphorus offers great promise as a countermeasure to combat oil spills in the marine environment (Walker et al., 1976).

(b) Bioaugumentation

Bioaugumentation involves addition of bacteria to supplement already existing microbial population (Cerniglia, 1993). In this technique, organisms with high degradation abilities are applied to contaminated site to augment indigenous microorganisms in soil.

(c) Bioventing

This technique involves injecting oxygen to the vdose zone to enhance bioremediation by facilitating indigenous microbial activities. Aside air injection, biostimulation technique is also applied to facilitate microbial transformation of pollutants to non- toxic products (Philp & Atlas, 2005).

(d) Bioslurping

Bioslurping remediation technique can be used to remediate soil contaminated with volatile and semi-volatile organic compounds in saturated and vadose zones. The technique combines bioventing, soil vapour extraction and vacuumed pumping (Gidarakos & Aivalioti, 2007).

(e) Biosparging

Biosparging system of remediation involves injecting air into the saturated zone to stimulate microbial activities which will in turn facilitate pollutant removal. Philp and Atlas (2005) reported that for biosparging to be effective, soil permeability, pollutant bioavailability to microorganisms and pollutant biodegradability are factors that should be considered.

(f) Phytoremediation

This technique uses plant to mitigate the effect of toxic pollutants on the soil. Some phytoremediation mechanisms include rhizoremediation, accumulation, extraction and filtration. Lee (2013) reported that plant to be used for phytoremediation should be resistant to diseases and pests.

2.2.2. Intrinsic bioremediation (natural attenuation)

Intrinsic bioremediation technique is an in situ remediation technology which involves remediation of polluted sites without human intervention. It is a process that occurs naturally hence the name “natural attenuation”. Intrinsic bioremediation relies on existing aerobic and anaerobic bacteria to biodegrade pollutants to non-toxic substances. According to Philp and Atlas (2005) the following three criteria must be met in order to establish that intrinsic bioremediation is ongoing: proof of biodegradation potentials in field, evidence of detoxification from contaminated sites and proof from laboratory analysis that microorganisms isolated from contaminated sites have the ability to biodegrade pollutants.

3. Methodology

3.1. Materials

This study was carried out in Ihiagwa located at latitude 5°24'0" N and longitude 7°1'0" E south-east Nigeria. According to Köppen's climate classification, the study region has tropical climate with highest average annual temperature of 26.4°C while the driest month is January with 18mm of rainfall. Field experiments were conducted during 2018 planting season (February 2018 to January 2019). The study area was chosen because it is an agrarian community and can easily be monitored and controlled without any form of interference. Table 1 shows soil condition of study area before cultivation and NPK fertilizer application.

Table 1. Soil condition before NPK application/cultivation

Soil parameters	Status
Chemical properties	
K^+ (cmol/100g soil)	0.05±0.01
P (ppm)	5.84±0.10
Total N (%)	0.11±0.01
Organic matter (%)	10.53±0.01
Al^{3+} (cmol/100g soil)	2.42±0.01
Acidity	0.70±0.01
pH (H_2O)	6.32±0.01
CEC (cmol/kg soil)	7.55±0.01
Organic carbon (g/kg)	1.45±0.02
Texture	
Silt (%)	4.04±0.02
Sand (%)	9.12±0.03
Clay (%)	12.02±0.01

Data represented are means ± standard error (SE)

Already established agronomic practices were applied according to guidelines outlined by International Institute of Tropical Agriculture (IITA, 1979) before cultivation. The 2.5 gram of NPK fertilizer was added to 500 gram of soil and tagged (N) to indicate treatment applied on it while control was tagged (C). Turmeric rhizome was planted at depth ranging between 7.0 cm – 10.0 cm. Treatments were assigned to ridges in a randomized complete block design (RCBD) with three replications.

3.2. Laboratory analysis of soil samples

Soil samples were randomly collected at depth 0 – 35 cm below ground surface using cylindrical auger to test for selected physicochemical characteristics in the laboratory. According to United Nations Environment Progrmme (2011) report on the environmental assessment of Ogoniland, microbial degradative activities facilitate the process of bioremediation at this depth. Soil samples were collected before and after NPK fertilizer treatment and then transferred to the laboratory for analysis using methods outlined by International Institute of Tropical Agriculture (IITA). Cation exchange capacity (CEC), total nitrogen, sand, silt, clay, available phosphorus, pH, available potassium, organic matter content, available phosphorus, organic carbon and soil acidity were the selected physicochemical properties examined in this study. Available phosphorus (P_2O_5) in soil was determined by Lancaster method. Organic carbon was determined using procedures described by Walkey Black. Total nitrogen content was determined by Micro-Kjeldahl method. Soil pH was determined by electrometric method. Organic matter was obtained by determination of ash content. Aluminium was determined by colorimetric platinum cobalt method. Cation of K^+ was determined by flame emission spectrophotometry (FES). Soil acidity (H^+) was determined by percolation method while CEC was determined by ammonium saturation. Soil texture was determined using mechanical sieve shaker.

Data generated in this study was statistically analyzed using analysis of variance (ANOVA) while significant difference among treatments was tested using least significant difference (LSD).

4. Results

4.1. Soil physicochemical status

Results of physicochemical analysis of soil from experimental site show that the textural content of soil is sandy with a decline in silt and clay. Soil that benefitted from NPK fertilizer treatment increased pH value. This pH value is in tandem with findings by Vidali (2001) who reported that the optimum pH range for microbial activities necessary to initiate bioremediation is between 5.5-8.8. Foght and Westlake (1987) reported that bacterial degradation is at its peak under slightly alkaline condition. The increase in pH value in this study could be as a result of direct application of NPK chemical fertilizer to the soil. Study showed organic carbon content increased in treated plots. Numerous studies have been carried out on soil organic carbon in relation to soil physicochemical characteristics. This was corroborated when Lal (1994) reported that soil organic carbon has the capability of affecting soil structure and physicochemical conditions. On the other hand, Nambiar and Abrol (1989) observed the devastating effects of low concentration of soil organic carbon. Organic carbon content in this study had mean value of 8.53 g/kg as against 14.67 g/kg reported by Achi et al. (2011). The high organic carbon content in this study could be due to high organic matter content of the soil which was influenced by the use of NPK (Singh & Nambiar, 1986). The estimation obtained for organic carbon could be because NPK provides instant nutrient and energy to soil microorganisms which in turn facilitate mineralization of soil organic compound.

Study showed there was an increase in CEC. Awode et al. (2008) reported that soil CEC is influenced by organic matter content of soil therefore, this could be the reason for CEC estimation. Study revealed that total nitrogen content increased in soil. This is in tandem with earlier findings by Saha (1988) who reported a significant increase in N after treatment with NPK. This may be due to the fact that NPK fertilizer releases nitrogen directly to the soil and makes it readily available without necessarily undergoing complex chemical reactions. The high concentration of N is capable of biostimulating microbes to initiate biodegradation process since N is a source of nutrient for microorganism. Available P status in this study increased. The increase in P provide adequate nutrient for microbial metabolic activities. This is in agreement with previous work by Jeremiah (2008). Study revealed a significant increase in K concentration in soil samples. The increase in K could be as a result of direct application of NPK chemical fertilizer to soil. Similar findings were also reported by Jeremiah (2008). There was an increase in soil acidity in NPK treated plots as compared to control. This might be as a result of high percentage of N present in the NPK fertilizer used in this study which produces H^+ during nitrification process. These results are in accordance with earlier studies by Sharma et al. (2002). Study revealed a reduction in Al^{3+} in treated soil. This may be because of the involvement of manure in degradation reaction as reported by Singh (2007). Table 2 shows comparison of soil status before and after treatment/cultivation.

Tabel 2. Comparison of soil physicochemical status before treatment/cultivation and after treatment/cultivation

Parameters	Before Treatment/Cultivation	After Treatment/Cultivation	
		NPK	Control
Chemical Properties			
K^+ (cmol/100g soil)	0.05±0.01	21.01±0.02	8.23±0.01
P (ppm)	5.84±0.10	7.20±0.01	1.17±0.00
Total N (%)	0.11±0.01	0.65±0.01	0.22±0.01
Organic matter (%)	10.53±0.01	4.83±0.01	5.04±0.01
Al^{3+} (cmol/100 g soil)	2.42±0.01	1.52±0.01	1.61±0.01
Acidity	0.70±0.01	0.83±0.01	0.41±0.01
pH (H_2O)	6.32±0.01	7.12±0.01	6.29±0.00
CEC (cmol/kg soil)	7.55±0.01	10.50±0.01	8.03±0.01
Organic carbon (g/kg)	1.45±0.02	8.53±0.01	4.04±0.01
Texture			
Silt (%)	4.04±0.02	3.74±0.01	1.29±0.01
Sand (%)	9.12±0.03	9.10±0.01	8.50±0.01
Clay (%)	12.02±0.01	11.57±0.01	10.23±0.01

Data represented are means ± standard error (SE). Means having same letter are statistically significant at 0.05 *p*-level

4.2. Plant observations

4.2.1. Plant height

Generally, soil treated with NPK fertilizer gave better results as plants grew significantly taller than that of control (Fig. 1). Turmeric height was measured at 60, 90, 120, 150, 180 and 210 days after planting. Figure 1 clearly shows that turmeric cultivated on NPK treated plots recorded maximum mean height of 24 cm as at 60 days after planting and maximum mean height of 98 cm as at 210 days after planting. On the other hand, maximum mean height of 21cm was recorded for turmeric cultivated on control plots as at 60 days after planting while maximum mean height of 36 cm was recorded as at 210 days after planting. The significant increase in height as seen in turmeric plant that benefitted from nutrient amendment in this study is in agreement with previous work by Singh (2007). The rapid growth of turmeric in treated plots could be as a result of available essential nutrients in soil necessary for its growth and metabolism which was influenced by NPK application.

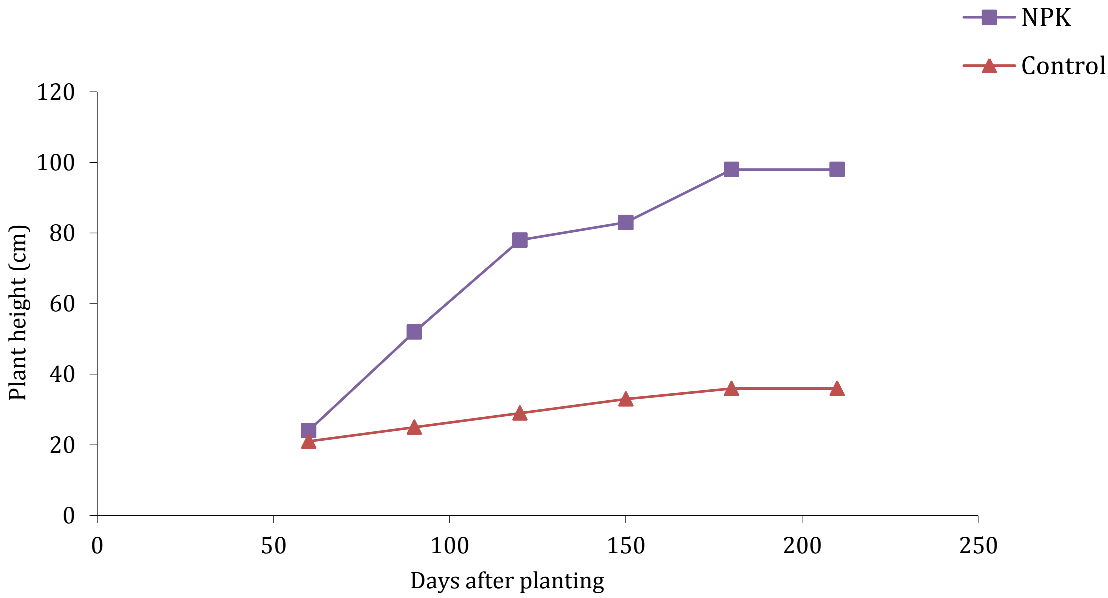

Figure 1. Graph showing plant height (cm) at different days after planting turmeric (*Curcuma longa*)

5. Conclusions

The bioremediation technology applied in this study was simple. The study revealed that NPK fertilizer and control treatments showed variations with yield and yield-contributing characters of turmeric but NPK gave better results. It also revealed that soil samples that benefitted from NPK treatment showed improvement in physicochemical status thereby enhancing soil fertility. This study concludes that controlled use of NPK fertilizer as nutrient supplement can be an effective biostimulation-based bioremediation strategy in restoring the soil back to its natural condition.

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References

Achi, M., Uzairu, A., Gimba, C. E., & Okunola, J. O. (2011). Chemical fractionation of heavy metals in soils around the vicinity of automobile mechanic workshops in Kaduna Metropolis. *Nigeria Journal of Environmental Chemistry and Ecotoxicology*, *3*(7), 184–194.

Arden-Clarke, C., & Hodges, R. D. (1987). The Environmental Effects of Conventional and Organic / Biological Farming Systems . I . Soil Erosion , with Special Reference to Britain *. *Biological Agriculture and Horticulture*, *4*(1986), 309–357.

Awode, U. ., Uzairu, A., Balarabe, M. L., Harrison, G. F. ., & Okunola, O. . (2008). Assessment of peppers and soils for some heavy metals from irrigated farmlands on the banks of river Challawa, Nigeria. *Pakistan Journal of Nutrition*, *7*(2), 244–248.

Cerniglia, C. E. (1993). Biodegradation of polycyclic aromatic hydrocarbons. *Biodegradation of Polycyclic Aromatic Hydrocarbons. Current Opinion in Biotechnology*, *4*(3), 331–338.

Chambers, B. ., & Garwood, T. W. D. (2000). Monitoring of water erosion on arable farms in England and Wales.1990^94. *Soil Use and Management*, *16*(16), 93–99.

Eze, V. C., & Okpokwasili, G. C. (2010). Microbial and other related changes in a Niger Delta River sediment receiving industrial effluents. *Continental Journal of Microbiology*, *14*, 15–21.

Foght, J. M., & Westlake, D. W. S. (1987). Biodegradation of hydrocarbons in freshwater. In Vandermeulen & Hrudey (Eds.), *Oil in Freshwater: Chemistry, Biology, Countermeasure Technology* (pp. 217–230). New York: Pergamon Press.

Gidarakos, E., & Aivalioti, M. (2007). Large scale and long term application of bioslurping: the case of a Greek petroleum refinery site. *Journal of Hazard Mater*, *149*, 574–581.

International Institute of Tropical Agriculture (IITA). (1979). Selected methods in Soil and Plant Analysis. Manual Series No 1. Retrieved from https://hdl.handle.net/10568/97963

Kim, S., Krajmalnik-Brown, R., Kim, J. O., & Chung, J. (2014). Remediation of petroleum hydrocarbon-contaminated sites by DNA diagnosis-based bioslurping technology. *Science of the Total Environment*, *497*, 250–259.

Lal, R. (1994). Methods and guidelines for assessing sustainable use of soil and water resources in the tropics.

Lee, J. H. (2013). An overview of phytoremediation as a potentially promising technology for environmental pollution control. *Biotechnol Bioprocess Eng*, *18*, 431–439.

M.I. Jeremiah. (2008). *Bioremediation of oil contaminated soil using emulsifier (liquid soap), NPK fertilizer and microbial (Bacillus sp) treatment*. Ahmadu Bello University, Zaria, Nigeria.

Nambiar, K. K. ., & Abrol, L. . (1989). Long term fertilizer experiments in India. An overview. *Fertilizer*, *34*, 11–19.

Nikolopoulou, M., Pasadakis, N., Norf, H., & Kalogerakis, N. (2013). Enhanced ex situ bioremediation of crude oil contaminated beach sand by supplementation with nutrients and rhamnolipids. *Marine Pollution Bulletin*, *77*(1–2), 37–44.

Philp, J. C., & Atlas, R. . (2005). Bioremediation of contaminated soils and aquifers. In A. R.M (Ed.), *Bioremediation: applied microbial solutions for real-world environmental cleanup* (pp. 139–236). Washington: American Society for Microbiology (ASM) Press.

Roy, M., Giri, A. K., Dutta, S., & Mukherjee, P. (2015). Integrated phytobial remediation for sustainable management of arsenic in soil and water. *Environment International*, *75*, 180–198.

Saha, A. K. (1988). Note on response of turmeric to manure and source of N and P under terrace conditions of mid- altitude Mizoram. *Indian Journal of Horticulture*, *45*, 139–140.

Sasikumar, C. S., & Papinazath, T. (2003). Environmental management: bioremediation of polluted environment. In *Proceedings of the Third International Conference on Environment and Health* (pp. 265–269). New York: Department of Geography, University of Madras, Chennai and Faculty of Environmental Studies, York University.

Sharma, S. P., Subehia, S. K., & Sharma, P. K. (2002). Long term effects of chemical fertilizers on soil quality, crop productivity and sustainability. Palampur: Department of Soil Science. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyataya.

Singh, D. (2007). *Integrated Nutrient Management Studies on Yield and Quality of Turmeric (Curcuma longa L.) in an Acid Alfisol*. Retrieved from http://hdl.handle.net/10603/9785

Singh, G. B., & Nambiar, K. (1986). Crop productivity and fertility under intensive use of chemical fertilizer in long term field experiments. *Indian Journal of Agronomy*, *31*, 115–117.

Timmis, K. N., Yakimov, M. M., & Golyshin, P. N. (1998). Hydrocarbonoclastic Bacteria: Novel Marine Bacteria that grow only on oil. *Scientific Annual Report, German National Research Centre for Biotechnology (GBF)*, 21–26.

United Nations Environmen Programme (UNEP). (2011). *Environmental Assessment of Ogoniland*. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/%0A
25282/ogoniland_chapter1_UNEP_OEA.pdf?sequence=1&isAllowed=y%0A

Vidali, M. (2001). Bioremediation. An overview. *Pure and Applied Chemistry*, *73*(7), 1163–1172.

Walker, J. D., Colwell, R. R., & Petrakis, L. (1976). Biodegradation rates of components of petroleum. *Canadian Journal of Microbiology*, *22*(8), 1209–1213.