Acta Scientific Microbiology (ISSN: 2581-3226)

Volume 1 Issue 7 July 2018

Research Article

Distribution of Bacteria in Lead Contaminated Soil in Anka Local Government Area, Zamfara State, Nigeria

Mustapha Bashir Kazaure*

Department of Science Laboratory Technology, College of Science and Technology, Jigawa State Polytechnic Dutse, Nigeria

***Corresponding Author:** Mustapha Bashir Kazaure, Department of Science Laboratory Technology, College of Science and Technology, Jigawa State Polytechnic Dutse, Nigeria.

Received: April 25, 2018; **Published:** June 21, 2018

Abstract

This study was to determine the distribution of bacteria in lead contaminated soil of Anka Local Government Area of Zamfara State, Nigeria. Soil samples were collected from five different places of the local government which include Abare, Bagega (BGG), Dan Kamfani (DNK), Dareta (DRT) and Anka town (ANT) where illegal gold mining activities is taking place. The samples were collected for the period of three months (November, December and January). The physicochemical and bacteriological parameters of the soil samples were analyzed. The soil samples were serially diluted and 0.1ml of 10^6 dilution factors was inoculated into nutrient agar and incubated for 24 hours at 37^0C. The highest concentrations recorded for lead was 57 × 101mg/kg from the DNK. Soil from ANT had the highest total bacterial counts of 6.9 × 10^6cfu/g, 5.5 × 10^6 cfu/g and 7.2 × 10^6 cfu/g for November, December and January respectively. The predominant bacterial isolates were identified as species of *Bacillus, Proteus, Achromobacter, Citrobacter, Corynebacerium, Alcaligenes, Pseudomonas, Staphylococcus, Klebsiella, Escherichia, Agrobacterium, Enterobacter* and *Diplococcus. Bacillus* species had the highest frequency of occurrence (45.67%). *Achromobacter, Agrobacterium, Enterobacter* and *Diplococcus* species had a very low frequency of occurrence (0.79%).

Keywords: Bacteria; Lead; Contaminated; Soil

Introduction

Anthropogenic activities have resulted in localized ecosystem contamination with heavy metals that serve no known biological purpose such as mercury, arsenic, cadmium, and lead [1]. Anthropogenic sources of heavy metal pollution include but not limited to mining, iron smelting, fossil burning and municipal and industrial waste disposal. Illegal mining activities in Zamfara, Northern Nigeria were reported to have killed hundreds of people, mostly children in 2010 [2]. Heavy metal contamination is a major environmental threat worldwide due to their adverse effects (toxicity) on natural biota and humans which is manifested as DNA damage, lipid peroxidation, binding to -SH groups of essential proteins and enzymes and generation of reactive oxygen species [3]. Heavy metals present in soils pose serious threat to human and animal health. Neither are they neutral to plants microorganisms [4]. They can have inhibitory effect on the development of bacteria, fungi and actinomycetes [5,6]. Heavy metals reduce the biomass of microorganisms and lower their soil activity [5,7] and even if they do not reduce their number, they depress their biodiversity [8].

Lead, a ubiquitous and versatile metal, has been used since prehistoric times. It has become widely distributed and mobilized in the environment and human exposure to and uptakes of this non-essential element have consequently increased [9]. At high levels of human exposure there is damage to almost all organs and organ systems, most importantly the central nervous system, kidneys and blood, culminating in death at excessive levels. At low levels, haeme synthesis and other biochemical processes are affected, psychological and neuro behavioral functions are impaired, and there is a range of other effects [10,11], collectively known as lead poisoning [12]. There is a long history of public exposure to lead in food and drink. Lead poisoning was common in Roman times because of the use of lead in water pipes and earthenware containers, and in wine storage. Lead poisoning associated with occupational exposure was first reported in 370 BC [13]. It became common among industrial workers in the 19th and early 20th centuries, when workers were exposed to lead in smelting, painting, plumbing, printing and many other industrial activities. In 1767, Franklin obtained a list of patients in La Charite´ Hospital in Paris who had been admitted because of symptoms, which, although not recognized then, were evidently those of lead poisoning. All the patients were engaged in occupations that exposed them to lead [9,13].

Exposure of human populations to environmental lead was relatively low before the industrial revolution but has increased with industrialization and large-scale mining. Lead contamination of the environment is high relative to that of other nonessential elements [14]. Globally, the extensive processing of lead ores is estimated to have released about 300 million tonnes of lead into the environment over the past five millennia, mostly within the past 500 years. The concentrations of heavy metals in soils are associated with biological and geochemical cycles and are influenced by anthropogenic activities, such as agricultural practices, transport, industrial activities and waste disposal [14].

Soil contains a variety of microorganisms including bacteria that can be found in any natural ecosystem. Microorganisms play an important role on nutritional chains that are an important part of the biological balance in the life in our planet. Where, bacteria are essential for the closing of nutrient and geochemical cycles such as the carbon, nitrogen, sulfur and phosphorous cycle. Without bacteria, soil would not be fertile and organic matter such as straw or leaves would accumulate within a short time [15]. The establishment of the strong binding between soil particulates and bacteria is probably a gradual process, involving a variety of binding mechanisms [16]. Soil bacteria and fungi play pivotal roles in various biogeochemical cycles (BGC) and are responsible for the cycling of organic compounds. Soil microorganisms also influence above-ground ecosystems by contributing to plant nutrition, plant health, soil structure and soil fertility [17]. Soils normally contain low background levels of heavy metals. However, in areas where agricultural, industrial or municipal wastes are land-applied as fertilizer, concentrations may be much higher. Excessive levels of heavy metals can be hazardous to man, animals and plants. Although most organisms have detoxification abilities (i.e. mineralization, transformation and/or immobilization of pollutants), particularly, bacteria play a crucial role in biogeochemical cycles and in sustainable development of the biosphere [18].

Materials and Methods

Experimental Design and Sample Collection

The study area includes four different villages of Anka Local Government Area of Zamfara State, Nigeria. These are Abare (ABR), Bagega (BGG), Dan Kamfani (DNK), Dareta (DRT) and Anka town (ANT). The soil from Anka town where no mining activity is taking place was used as control. Purposive and random sampling method was also applied to each mining site. In each of the locations, ten soil samples were randomly collected in triplicates from the top 0 - 20 cm of the soil with the aid of soil auger and bulked into polythene bags. The soil samples were transported to the Usmanu Danfodiyo University, Sokoto Postgraduate Microbiology Research Laboratory for analysis. The soil samples were collected at after one-month interval for the months of November, December [2013] and January [2014] respectively.

Characterization and Identification of Isolates

Pure isolates of bacteria were identified based on colonial, morphological Gram staining properties and biochemical characteristics following the guidelines outlined by Barrow and Feltham [19] as well as Prescott and Harley [20]. Some of the biochemical tests employed are Triple sugar iron test, Urease production test, Methyl red reaction test, Voges-Proskauer test, Indole production test, Citrate utilization test, Catalase, Oxidase and Starch hydrolysis.

The data generated from the experiments were analyzed by analysis of variance (ANOVA) using INSTAT statistical package at 95% statistical significance.

Results

Physicochemical Analysis of Soil

Results obtained from the study of the physicochemical parameters were shown on table 1. Soil pH was observed to be slightly acidic, ranging from 5.6 to 6.3. Highest pH (6.3) was recorded in Abare (ABR) soil and least pH (5.6) was also recorded in DNK. DRT soil had the highest organic carbon (OC) (1.12%) and organic matter (OM) (1.93%) content. BGG samples were poorest in both the organic carbon (OC) and organic matter (OM) 0.14 and 0.24 respectively. The ANT had moderate amount of both the parameters 0.34% and 0.59% respectively. Nitrogen and phosphorus contents of the soils were shown to differ although without statistical significance ($p \geq 0.05$). Soil from DRT, ABR and DNK had higher nitrogen content 0.109%, 0.095% and 0.067% respectively. Similarly, ABR, DRT and BGG soils recorded 0.95 ppm, 0.86 ppm and 0.82 ppm of phosphorus respectively. Moreover, DRT soil was shown to contain more calcium (1.75 cmol/kg), potassium (1.62 cmol/kg), sodium (0.70 cmol/kg) and cation exchange capacity (9.64 cmol/kg) than the other soils except for magnesium where ABR soil had higher content (1.06 cmol/kg).

The lowest quantities of Potassium K, Sodium Na, and Cation Exchange Capacity CEC) were observed in the Soil of ANT with potassium (K), 0.82 cmol/kg, sodium (Na), 0.39 cmol/kg and Cation Exchange Capacity (CEC), 7.74 cmol/kg). DNK had the lowest magnesium (Mg) content of 0.65 cmol/kg.

Site	Parameter (mean ± SD)									
	Ph	OC (%)	OM (%)	N (%)	P (ppm)	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	CEC (cmol/kg)
ABR	6.3	0.40	0.69	0.095	0.95	1.30	1.15	1.23	0.57	8.50
BGG	5.7	0.14	0.24	0.032	0.82	1.65	0.90	1.44	0.65	9.36
DNC	5.6	0.46	0.79	0.067	0.79	0.80	0.65	1.15	0.48	8.66
DRT	5.9	1.12	1.93	0.109	0.86	1.75	1.05	1.62	0.70	9.64
SAT	6.0	0.34	0.59	0.056	0.77	0.70	0.90	0.82	0.39	7.74

Table 1: Monthly Physicochemical Parameters of the Soil Sample.

SD: Standard Deviation; ABR: Abare; BGG: Bagega; DNC: Dan Company; DRT: Dareta; SAT: Soil from Anka Town; OC: Organic Carbon; OM: Organic Matter; N: Nitrogen; P: Phosphorus; Ca: Calcium; Mg: Magnesium; K: Potassium; Na: Sodium; CEC: Cation Exchange Capacity.

Enumeration of Bacteria in Soil Samples

The soil samples from Anka Town (ANT) which was used as control had the highest number of the bacterial counts in all the three months. The mean counts were recorded as 6.9 × 10^6 cfu/g, 5.5 × 10^6 cfu/g and 7.2 × 10^6 cfu/g for the months of November, December and January respectively. The mean counts of ABR followed that of ANT in the months of November and January as 5.6 × 10^6 cfu/g and 4.3 × 10^6 cfu/g respectively, however the mean value recorded for the month of December was 1.3 × 10^6 cfu/g. Dareta (DRT) is having next to the least mean of bacterial count in November and January as 2.0 × 10^6 cfu/g and 1.7 × 10^6 cfu/g respectively, while in December it had the least mean bacterial count of 1.0 × 10^6 cfu/g. Bagega (BGG) followed ABR mean of the total of bacterial count in November and January as 4.7 × 10^6 cfu/g and 1.7 × 10^6 cfu/g respectively, while in December the mean total of bacterial count was recorded as 3.9 × 10^6 cfu/g followed that of Soil from Anka Town (SAT). Dan Company (DNC) had the least mean of the total of bacterial count in November and January as 1.1 × 10^6 cfu/g and 1.1 × 10^6 cfu/g respectively.

Sampling site	Mean Count (cfu/g) × 10^6*		
	November	December	January
SAT	6.9^a	5.5^a	7.2^a
ABR	5.6	1.3^{abcd}	4.3
DRT	2.0	1.0^b	1.7^a
BGG	4.7	3.87^c	1.7^a
DNC	1.1^a	1.7^d	1.1^a

Table 2: Total Aerobic Heterotrophic Bacterial Count.

*Values with the same superscript in a column are significantly different p ≤ 0.05.

While in December the mean total of bacterial count of DNC was recorded as 1.7 × 10^6 cfu/g followed that of BGG. Table 3 showed the bacterial isolates in the soil samples. *Bacillus* species had the highest frequency of occurrence than the rest of the isolates. *Achromobacter, Agrobacterium, Enterobacter* and *Diplococcus* species are having a least frequency of occurrence with (0.79%). Other isolates have their frequencies of occurrence ranging from 7.87% to 1.57%.

Concentration of Lead in Soil Sample Collected from Lead Contaminated Sites

Results obtained from the study of the lead concentration in the soil were shown on Table 4. Soil samples from DNK had the highest level of lead (0.57 ppm) whereas that from Bagega (BGG) had the least (0.16 ppm) in the month November. Soil sample from Dan Company (DNC) also had the highest level of lead (0.51 ppm) and the soil sample from Bagega (BGG) had the least (0.13 ppm) in the month of December. In the month of January also the soil sample from Dan Company had the highest level of lead and soil from Bagega BGG still have least lead level that were recorded as 0.63 ppm and 0.10 ppm respectively. Abare (ABR) soil lead level followed that of soil from Anka town with 0.35 ppm, 0.39 ppm and 0.30 ppm for the month of November, December and January respectively.

Discussion

The pH of the soils was weakly acidic (Table 1). The acidity may be attributed to microbial activities as found by Hamza [21], who recognized microbial activities, root respiration and exudation as important causes of soil acidity. This is also in accordance with the findings of Stephen and Ijah [22], where acidic soil pH was observed in phytoremediation studies. Some pH parameters of the soil in rainy season slightly changed to basic that is closed to neutral and this agrees with the finding of Asraf and Adam [23] who worked on the effect of heavy metals on the soil microbial community.

Bacteria species	Occurrence (%)					Total
	SAT	DRT	BGG	DCN	ABR	
Bacillus species	8 (27.59)	12 (42.86)	21 (80.80)	9 (50.00)	8 (30.77)	58 (45.67)
Proteus species	4 (13.79)	3 (10.71)	2 (7.69)	3 (16.67)	3 (11.54)	15 (11.81)
Achromobacter species	1 (3.45)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.79)
Citrobacter freundii	0 (0)	2 (7.14)	0 (0)	0 (0)	1 (3.85)	3 (2.36)
Corynebacterium species	5 (17.24)	1 (3.57)	0 (0)	0 (0)	1 (3.85)	7 (5.51)
Alcaligenes species	1 (3.45)	0 (0)	0 (0)	0 (0)	1 (3.85)	2 (1.57)
Pseudomonas species	4 (13.79)	4 (14.29)	0 (0)	1 (5.56)	5 (19.23)	14 (11.02)
Staphylococcus species	1 (3.45)	3 (10.71)	0 (0)	2 (11.11)	4 (15.38)	10 (7.87)
Klebsiella species	3 (10.34)	2 (7.14)	1 (3.85)	0 (0)	3 (11.54)	9 (7.09)
Escherichia species	2 (6.90)	1 (3.57)	2 (7.69)	0 (0)	0 (0)	5 (3.94)
Agrobacterium species	0 (0)	0 (0)	0 (0)	1 (5.56)	0 (0)	1 (0.79)
Enerobacter species	0 (0)	0 (0)	0 (0)	1 (5.56)	0 (0)	1 (0.79)
Diplococcus species	0 (0)	0 (0)	0 (0)	1 (5.56)	0 (0)	1 (0.79)
Total	29 (22.83)	28 (22.05)	26 (20.47)	18 (14.17)	26 (20.47)	127 (100)

Table 3: Frequency of Occurrence of the Distribution of Aerobic Heterotrophic Bacteria in Lead Contaminated Soil.
KEY: SAT: Soil Sample from Anka Town; DRT: Dareta; BGG: Bagega; ABR: Abare; DNC: Dan Company.

Site	Lead concentration (ppm)			Mean ± SD*
	November	December	January	
SAT	0.19	0.25	0.22	0.22 ± 0.03^{ab}
ABR	0.36	0.39	0.30	0.35 ± 0.05^{acd}
DRT	0.28	0.26	0.24	0.26 ± 0.02^{ef}
BGG	0.16	0.13	0.10	$0.13 \pm 0.03^{c\,eg}$
DNC	0.57	0.51	0.63	0.57 ± 0.06^{bdfg}

Table 4: Levels of Lead in soils collected from lead contaminated site.
KEY: *Values with the same superscript are statistically significant $p \leq 0.05$.
Soil SAT: Sample from Anka Town; DRT: Dareta; BGG: Bagega; ABR: Abare; DNC: Dan Company.

The mean bacterial counts of the two seasons show that Soil from Anka Town (SAT) had the highest mean total in both seasons. It had 6.9×10^6cfu/g, 5.5×10^6 cfu/g and 7.2×10^6 cfu/g of November, December and January respectively for the dry season. It also had 8.1×10^6 cfu/g, 6.1×10^6 cfu/g and 5.5×10^6 cfu/g of July, August and September respectively for raining season. The highest number of the bacterial count has to do with less concentration of the lead in the soil sample when compared to many of the soil sample used. The standard level of lead concentration in sediment and water was reported to be 0.01mg/l and 0.05 mg/l respectively by Ezejiofor., *et al.* [24] and the levels of lead concentration from the soil sample SAT which was used as control was found to exceed the above standards with little less than one figures. This may be due to the fact that the Anka town soil is surrounded by villages where the local gold mining activities is taking place and the possibility of the Anka soil to have lead content is revealed. The mean levels of lead concentration in soil of SAT were recorded as 0.19 ppm, 0.25 ppm and 0.22 ppm for November, December and January respectively. Also, the mean levels of lead in soil of SAT were recorded as 0.25 ppm, 0.19 ppm and 0.20 ppm for July, August and September respectively. The more the lead concentration in a soil samples the less the number of bacterial count and vice versa. This finding agrees with work of Wyszkowska., *et al.* [5] where he reported that "In a soil contaminated by higher doses of heavy metals regardless of the soil use, cadmium, copper and lead significantly reduced the count of heterotrophic bacteria".

The soil from DNC was found to have the highest lead concentration and lowest bacterial counts when compared to all the five places in both the dry and rainy seasons. The least bacterial count of DNC soil was probably due to the high concentration of the lead as it agrees with the findings of McGrath., *et al* [25]. This low bacterial count in relation to high heavy metal concentration was also reported by Wyszkowska., *et al.* [5], where their work revealed that heavy metal contamination of soil adversely affects the abundance and activity of microorganisms involved in organic decomposition and nutrient recycling.

The most predominant bacteria among the isolates ware *Bacillus* species which occupied 45.67% of the isolates. This may be attributed to their ability to resist harsh environmental conditions and heavy metal contamination in soils. *Bacillus* species are known to produce spores that enable them with stand environmental harshness. This agrees with Laugauskas., *et al.* [6], where he found *Bacillus* species as the most bacteria in the soils contaminated with lead. This finding is also in agreement with Ezejiofor., *et al.* [24], where he reported Bacillus species among the organisms that resist lead highest in his findings. Next to the *Bacillus* species, the species of *Pseudomonas, Proteus, Staphylococcus, Klebsiella, Corynebacterium* and *Escherichia* are found to have moderate distribution among the bacteria isolated in the five places of the lead contaminated areas of Anka Local Government Area [26-92].

Conclusion

The result of this study revealed the distribution of bacteria in lead contaminated soils of Anka local Government Area Zamfara State which provided the baseline information for the bacteria present in lead contaminated soils of five places, the bacteria resisting lead and the possible candidates for bioremediation of the affected polluted places. The *Bacillus* species were found to be best survivours of the lead contaminated soils. The result of this work also shows high lead level in all the soil samples collected.

Acknowledgement

I wish to express my profound gratitude to my father for his encouragement, patience, tolerance and continuous guidance throughout the conduct of this work.

Also, my profound gratitude to Bello M Hassan, Usman Sani Usman Naziru Usman Bello, may Allah help and guide them in their undertaking amen.

Bibliography

1. Dej RN., *et al*. "Tolerance to various toxicants by marine bacteria highly resistant to mercury". *Journal of Mercury Biotechnology* 5.2 (2003): 185-193.
2. NNP. New Nigerian Politics. Lead poison kills 400 infants in Zamfara. March 7th, 2011.
3. Milind MN., *et al*. "Laboratory of Bacterial Genetics and Environmental Biotechnology". Department of Microbiology, Goa University, Taleigao Plateau, Goa, India 403 (2012): 206.
4. Wyszkowska J., *et al*. "Effect of interaction of cadium with other heavy metals and its influence on the soil biochemical properties". *Pollution Journal of Environmental Studies* 15.2a (2007): 559-568.
5. Wyszkowska J., *et al*. "Enzymatic activity of nickel contaminated soil". *Journal of Elementology* 13.1 (2008): 139-151.
6. Lugauskas A., *et al*. "Effect of copper, zinc and lead acetates on microorganisms in soil". *Ekologija* 1 (2005): 61-69.
7. Min L., *et al*. "Toxicity of cadmium to soil microbial biomass and its activity: Effect of incubation time on Cd ecological dose in a paddy soil". *Journal of Zhejiang University Science* 6.5 (2005): 324-330.
8. Moffett BF., *et al*. "Zinc contamination decreases the bacterial diversity of agricultural soil". *Microbial Ecological Journal* 43 (2003): 13-19.
9. Smith MA. "Lead in history". In: Lansdown, R, Yule, W, eds. The lead debate: The environmental toxicology and child health. London, Croom Helm, (1984): 7-24.
10. WHO. "Inorganic lead". World Health Organization, Geneva, Environmental Health Criteria, No. 165 (1995).
11. WHO. Lead. In: Guidelines for drinking-water quality. Volume 2: Health criteria and other supporting information. World Health Organization, Geneva (1995).
12. European Union (EU). "European Union Regulation Setting Maximum Level for Certain Contaminant in food stuffs". Commission Regulation (EC) No 1881 (2006).
13. Kazantzis G. "Lead: ancient metal-modern menace?" In: Smith MA, Grant LD, Sors A.I., (editors). Lead exposure and child development: an international assessment. Lancaster, England, MTP Press, (1989): 119-128.
14. Abollino O., *et al*. "Heavy metals in agricultural soils from piedmont, Italy. Distribution, speciation and chemometric data treatment". *Chemosphere* 49.22 (2002): 545-557.
15. Kummerer K. "Resistance in the environment". *Journal of Antimicrobial Chemotherapy* 54.2 (2004): 311-320.
16. Bakken LR and Lindahl V. "Recovery of bacterial cells from soil". In: Nucleic Acids in the Environment: Methods and Applications (van Elsas, J.D. and Trevors, J.T., Editors.). Springer, Berlin-Heidelberg-New York-Tokyo (1995): 9-27.
17. Kirk JL., *et al*. "Methods of studying soil microbial diversity". *Journal of Microbiology Methods* 58.2 (2004): 169-188.
18. Diaz E. "Bacterial degradation of aromatic pollutants: A paradigm of metabolic versatility". *International Microbiology* 7 (2004): 173-180.
19. Barrow GI and Feltham KA. "Cowan and Steel's Manual for Identification of Medical Bacteria". 3rd edition. Cambridge University Press, London (1993).

20. Prescott LM and Harley JP. "Laboratory Exercise in Microbiology". 5th edition, McGraw-Hill Companies, NewYork (2002).

21. Hamza MA. "Understanding Soil Analysis Data". Resource Management Technical Report 327, Department of Agriculture and Food, Government of Australia (2008).

22. Stephen E and Ijah UJJ. "Comparison of Glycine Max and Sida Acuta in the Phytoremediation of Waste Lubricating Oil Polluted Soil". *Nature and Science* 9.8 (2011): 190-193.

23. Ashraf R and Adam TA. "Effect of Heavy Metal on Soil Microbial Community and Mung Beans Seed Germination". *Pakistan Journal of Botany* 39.2 (2007): 629-636.

24. Ezejiofor TIN., *et al*. "Environmental metals pollutants load of a densely populated and heavily industrialized commercial city of Aba, Nigeria". *Journal of Toxicology and Environmental Health Sciences* 5.1 (2013): 1-11.

25. McGrath SP., *et al*. "Long-term effects of metals in sewage sludges on soils, microorganisms and plants". *Journal of Industrial Microbiology* 14.2 (1995): 94-104.

26. Environment Protection Authority (EPA). "Guidelines on the Management of Lead Contamination in Home Maintenance, Renovation and Demolition Practices". A Guide for Councils. NSW Environment Protection Authority, Sydney (2003): 59-61.

27. Flegal AR and Smith DR. "Current needs for increased accuracy and precision in measurements of low levels of lead in blood". *Environmental Research Journal* 58.2 (1992): 125-133.

28. Anyanwu CU and Nwachukwu ON. "Heavy Metal Resistance in Bacteria Isolated from Contaminated and Uncontaminated Soil". *International Journal of Research in Chemistry and Environment* 1.1 (2011): 173-178.

29. Abadin AM., *et al*. "Toxicological profile for lead". U.S. Department of Health and Human Services Public Health Service Agency for Toxic Substances and Disease Registry (2007).

30. Abou-Shanab RAI., *et al*. "Bacterial inoculants affecting nickel uptake by Alyssum murale from low, moderate and high Ni soils". *Soil Biology and Biochemistry* 38.9 (2006): 2882-2889.

31. Adeniyi AA and Owoade OJ. "Total petroleum hydrocarbons and trace heavy metals in roadside soils along the Lagos-Badagry express way, Nigeria". *Environmental Monitory Assessment* 167.1-4 (2010): 625-630.

32. Aiyesanmi AF, *et al*. "Lead accumulation in Siam weed (Chromolaena odorata), Node weed (Synedrella nodiflora) and Water leaf (Talinum triangulare): Potential phytoremediators". *Archives of Applied Science Research* 4.1 (2012): 360-371.

33. Alexander M. "Introduction to Soil Microbiology". 2nd Edition. John Willey and Sons, New York (1977).

34. Ashok K., *et al*. "Biosorption of Heavy Metals by four acclimated microbial species, Bacillus spp., Pseudomonas spp., Staphylococcus spp. and Aspergillus niger". *Journal of Biological and Environmental Science* 4.12 (2010): 97-108.

35. Atuanya EI., *et al*. "Microbial studies and lead tolerance levels of microbes in lead accumulator dumps". *Journal of Environmental Science and Health* 2.1 (1999): 8-13.

36. Baath E. "Effects of heavy metals in soil on microbial processes and populations". *Water, Air and Soil Pollution Journal* 47.3-4 (1989): 335-379.

37. Babula P., *et al*. "Uncommon heavy metals, metalloids and their plant toxicity: a review". *Environmental Chemistry Letters* 6.4 (2008): 189-213.

38. Baya AM., *et al*. "Coincident plasmids and antimicrobial resistance in marine bacteria isolated from polluted and unpolluted Atlantic Ocean samples". *Applied and Environmental Microbiology* 51.6 (1986): 1285-1292.

39. Benka-Coker MO. "Studies on the Effects of Crude Oil and the Microbial Populations at the Kokori Flare Site, Bendel State, Nigeria". Ph.D. Thesis, University of Benin, Benin City, (1991): 83.

40. Benson M. "Microbiological Applications Laboratory Manual". Eighth edition, McGraw-Hill Companies, New York (2001).

41. Blacksmith Institute (BI). UNICEF Progrmme Coperation Agreement. Environmental Remediation - Lead poisoning in Zamfara. Final Report (2011): 57.

42. Bleasdale M. "Children bath in a pond likely highly contaminated with lead in Bagega village, Zamfara State, Nigeria". VII copy right for Human Rights (2011).

43. Cánovas D., *et al*. "Heavy metal tolerance and metal homeostasis in Pseudomonas putida as revealed by complete genome analysis". *Environmental Journal of Microbiology* 5.12 (2003): 1242-1256.

44. Cervantes C., *et al*. "Resistance to arsenic compounds in microorganisms". *FEMS Microbiology Reviews* 15.4 (1994): 355-367.

45. Chen Y., *et al*. "Residues and source identification of persistent organic pollutants in farmland soils irrigated by effluents from biological treatment plants". *Environment International* 31.6 (2005): 778-783.

46. Chesworth W. "Encyclopedia of Soil Science, Dordrecht, Netherlands". Springer 14 (2008).

47. Choudhury R and Srivastava S. "Zinc resistance mechanisms in bacteria". *Current Science* 81.7 (2001): 768-775.

48. Daland RJ and Gilbert LR. "Lead and human health". Prepared for the American Council on Science and Health (ACSH) second edition (2000).

49. De-Miguel E., *et al*. "Risk -Based evaluation of the exposure of children to trace elements in play round in Madrid (Spain)". *Chemosphere* 66 (2007): 505-513.

50. Derek HW and Sharon RL. "The Sinorhizobium meliloti stringent response affects multiple aspects of symbiosis". *Molecular Microbiology* 43.5 (2002): 1115-1127.

51. Dukhuizen DE. "Santa Rosalia revisited: why are there so many species of bacteria?" Antonie van Leeuwenhoek, 73 (1998): 25-33.

52. Duxbury T and Bicknell B. "Metal-tolerant bacterial populations from natural and metal-polluted soils". *Soil Biology and Biochemistry* 15 (1983): 243-250.

53. Eze S and Hilary M. "Evaluation of Heavy Metals Pollution of Soils Around the Derelict Enyigba Mines and Their Sources". *International Journal of Applied Environmental Science* 13.3 (2008): 4.

54. Ene A., *et al*. "Determination of heavy metal in soil using XRF techniques". *Rommania Journal of Physics* 7-8 (2010): 815-820.

55. Ezekiel AK., *et al*. "Determination of Heavy Metals in Soil Sample of Selected Sawmills in Ekiti State, Nigeria". *Journal of Scientific Research and Reports* 2.2 (2013): 513-521.

56. Fage OE and Adetutu EM. "Lead solubilizaiton and accumulation by two strains of Pseudomonas species obtained from a battery manufacturing factory's effluent". *Nigerian Journal of Microbiology* 13 (1999): 39-46.

57. Fatoki OS. "Lead, Calcium and Zinc Accumulation in Soil and Vegetation among some Selected Major Roads of Eastern Cape". *International Journal of Environmental Studies* 6.2 (2003): 199-204.

58. Filip Z. "International approach to assessing soil quality by ecologically-related biological parameters". *Agriculture Ecosystem and Environment* 88.2 (2002): 169-174.

59. Friedlova M. "The influence of heavy metals on soil biological and chemical properties". *Soil and Water Resources* 5.1 (2010): 21-27.

60. Galadima A., *et al*. "Domestic Water Pollution among Local Communities in Nigeria, Causes and Consequences". *European. Journal of Scientific Research* 52.4 (2011): 592-603.

61. Govil PK., *et al*. "Soil Contamination of Heavy Metals in the Katedan Industrial Development Area, Hyderabad, India". *Environment Monitoring Assessment* 140.1-3 (2008): 313-323.

62. Goyer RA. "Transplacental transport of lead". Conference on Advances in Lead Research: Implications for Environmental Health. *Environmental Health Perspect* 89 (1990): 101-106.

63. Goyer RA. "Toxic effects of metals In Casarett and Doull's Toxicology: The Basic Science of Poisons". 5th edition. C.D. Klaassen, Ed. McGraw-Hill, New York (1996).

64. Hada HS and Sizemore RK. "Incidence of plasmids in marine Vibrio spp. isolated from an oil field in the northwestern Gulf of Mexico". *Applied and Environmental Microbiology* 41.1 (1981): 199-202.

65. Hardman DJ., *et al*. "Large plasmids from soil bacteria enriched on halogenated alkanoic acids". *Applied and Environmental Microbiology* 51 (1986): 44-51.

66. Hoormaan JJ and Rafiq I. "Understanding soil microbes and nutrient recycling". *Factsheet of Agriculture and Natural Extension* Ohio State University (2010).

67. International Institute of Tropical Agriculture (IITA). Selected Methods for Soil and Plant Analysis. Manual No. 1. International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria (1979).

68. Jankiewicz B., *et al*. "Spectrophotometric Determination of Iron (ii) in Soil of Selected Allotment Gardens in Lodz". *Polish Journal of Environmental Studies* 11.6 (2002): 745-749.

69. Johnston DT., *et al*. "Sulfur isotope insights into microbial sulfate reduction: when microbes meet models". *Geochimica et Cosmochimica Acta* 71.16 (2007): 3929-3947.

70. Jang YC., *et al*. "Leaching of Arsenic, chromium and copper in a contaminated soil at a wood preserving site". *Bulletin of Environmental Contamination and Toxicology* 69.6 (2002): 808-816.

71. Knight B., *et al*. "Biomass carbon measurements and substrate utilization patterns of microbial populations from soils amended with cadmium, copper, or zinc". *Applied and Environmental Microbiology* 63.1 (1997): 39-43.

72. Kozdroj J and Van-Elsas JD. "Response of the bacterial community to root exudates in soil polluted with heavy metals assessed by molecular and cultural approaches". *Soil Biology and Biochemistry* 32.10 (2000): 1405-1417.

73. Lee E and Matsumotok L. "Analysis of Lead Content in Herbal Preparations in Malaysia". *Human and Experimental Toxicology* 22.8 (2003): 445-451.

74. Liang J., *et al*. "Assessment of Heavy Metal Pollution in Soil and Plants from Dunhua Sewage Irrigation Area". *International Journal of Electrochemical Science* 6 (2011): 5314-5324.

75. Lloyd JR and Lovely DR. "Microbial detoxification of metals and radionuclides". *Current Opinion Biotechnology Journal* 12.3 (2001): 248-253.

76. Lloyd JR. "Bioremediation of metals, the application of micro-organisms that make and break minerals". *Microbiology* 29 (2002): 67-69.

77. Macur RE., *et al*. "Bacterial populations associated with the oxidation and reduction of arsenic in an unsaturated soil". *Environmental Science and Technology* 38.1 (2004): 104-111.

78. Malik A and Ahmed M. "Seasonal variation in bacterial flora of the wastewater and soil in the vicinity of industrial area". *Environmental Monitoring and Assessment* 73.3 (2002): 263 -273.

79. Okunola OJ., *et al*. "Levels of Trace Metals in Soils and Vegetation Along Major Roads in Metropolitan City of Kaduna, Nigeria". *African Journal of Biotechnology* 6.14 (2007): 1703-1709.

80. Page AL., *et al*. "Methods of soil analysis-chemical and microbiological properties". Part-2. 11th edition. *American Society of Agronomy* Madison, Wisconsin, USA (1982).

81. Peters RW and Shem L. "Adsorption/desorption characteristics of lead on various types of soil". *Environmental Progress Journal* 11.3 (1992): 234-240.

82. Pichtel J., *et al*. "Distribution of Pb, Cd and Ba in soils and plants of two contaminated sites". *Environmental Pollution Journal* 110 (2000): 171-178.

83. Reber HH. "Simultaneous estimates of the diversity and degradative capability of heavy metal affected soil bacterial communities". *Biology and Fertility of Soils* 13.3 (1992):181-186.

84. Shi W., *et al*. "Long term effects of chromium and lead upon the activity of soil microbial communities". *Applied Soil Ecology* 21.2 (2002): 169-177.

85. Soon YK and Abboud KS. "Cadmium, Chromium, Lead, and Nickel". In: M.R.Carter (editor.) Soil Sampling and Methods of Analysis. Canadian Society of Soil Science, Lewis, Canada (1993): 101-108.

86. Trasar-Cepeda C., *et al*. "Towards a biochemical quality index for soils: an expression relating several biological and biochemical properties". *Biology and Fertility of Soils* 26.2 (1997): 100-106.

87. Voroney RP. "The Soil Habitat". Soil Microbiology, Ecology and Biochemistry. Third Edition, Paul E. A. (editor) Academic Press, UK (2007).

88. Wei BG and Yang LS. "A review of Heavy Metals Contamination in Urban soils, Urban Road dusts and Agricultural soils from China". *Micro-Chemical Journal* 94.2 (2010): 99-107.

89. Wickham GS., *et al*. "Plasmid frequency fluctuations in bacterial population from chemically stressed soil communities". *Applied and Environmental Microbiology* 54.9 (1988): 2192-2196.

90. Wuertz S and Mergeay M. "The impact of heavy metals on soil microbial communities and their activities". In: van Elsas, J.D., Trevors, J.T., Wellington, E.M.H. (Editors.), Modern Soil Microbiology. Marcel Dekker, New York, (1997): 607-639.

91. Yao H., *et al*. "Substrate utilization pattern, biomass and activity of microbial communities in a sequence of heavy metal-polluted paddy soils". *Geoderma* 115.1-2 (2003):139-148.

92. Yusuf AA., *et al*. "Assessment of lead contamination of farmlands in Abare village, Zamfara State". In: Hassan WA., *et al*. (Editorss). Mobilizing Agricultural Research Towards Attaining Food Security and Industrial Growth in Nigeria. Proceedings of the 45th Annual Conference of the Agricultural Society of Nigeria, (2011): 487-491.

Volume 1 Issue 7 July 2018