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Elemental Composition Analysis of Soil Samples from Bayelsa State in the Niger Delta Region of Nigeria

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ABSTRACT: This study analysis the elemental composition and concentration of elements in the soils of the study area to ascertain degree of elemental enhancement in the soil resulting from anthropogenic activities with possible soil contamination, human health and environmental detriment. The study area was divided into eight grids and two soil samples per grid from over burden to a depth of 900mm was collected randomly in each grid. The samples were prepared using standard methods and analyzed with a linear accelerator. The number of detectable elements and their quantitative information was extracted from the elemental spectral signatures. . The result showed a high concentration value in some elements in the soil samples above values of elemental concentrations in soils from other reported studied region. In addition, Aluminium, Strontium, Barium, Gallium etc also showed an extremely high value in their concentration that exceeds the world wide mean range upper limit values in crustal soil study published. The study indicates some degree of potential contamination and therefore necessitate a regular periodic monitoring study to reduce potential health detriment to humans and the environment to as low as reasonably possible.

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All soils are formed from physical, biological and chemical weathering processes of crustal rocks, as such, possesses a characteristic physical and chemical property which shares a relationship to the source rocks/crustal rocks from which they were formed. An important factor that affects the total number of elements in the soil and the quantity of each element (i.e., Chemical property of the soil) described as the 'elemental composition' measured in parts per million (PPM), is the location of the source rock, pathway of travel during weathering and environment in which the soil formation occurred. The elemental composition of Soils formed from crustal rocks weathered from an igneous environment, are known to be different from soils formed from a metamorphic rock environment. Likewise, soils formed in either of these two environments (igneous and Metamorphic) are reported to be different from soils formed in a sedimentary environment (Igbinigie and Ogbamihumi, 2022; Parker and Fleischer, 1967). Anthropogenic factors (either domestic or industrial) are also considered as a major factor that leads to substantial alteration of soil elemental compositional nature, for example, the application of NPK fertilizers to soil to increase cultivation plant yield and productivity in agriculture, results in the increase of the soil composition in PPM in that localised soil environment, in each of the constituent elements - Nitrogen (N), Phosphorus (P) and Potassium (K)). In cassava processing for food, the effects of cassava waste water disposal on the alteration of concentrations of some heavy metals on the soil of the disposal site were reported by Izonfuo *et*

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al (2013). Also some degree of detriment to the environment and human health from elevated levels of elemental composition of the topsoil or increased heavy metals levels is reported by Olayinka *et al* (2017); Elevated heavy metals in municipal waste disposal dumpsites is reported by Musa *et al* (2020);The elevation or enhancement of naturally occurring radioactive materials/primordial radionuclides (radioisotopes) like Uranium-238(^{238}U), Thorium-232(^{232}Th) and their decay series besides Potassium-40 (^{40}K) in soil more especially in minerals mining operations have been extensively reported (IAEA, 2016) since their enhancement in soil have been shown to be detrimental to human health and environment (UNSCEAR 2000; ICRP, 2007; IAEA, 2016).

Numerous research has shown that, alteration of the composition of the natural compositional natures of the soil or alteration in elemental compositional/ radionuclide composition of the soil leads to enhancement of these elements or radionuclides threshold resulting to soil contamination. Contaminated soils as reported by Olayinka *et al(2017)* on the field and laboratory effects of elevated level of metals study, presented by Tylor *et al* possesses an undesirable property as such enhancement in heavy metals and radionuclides results in soil contamination that affects soil functionality, micro-organism growth, groundwater contamination etc. and consequently human health as the enhanced heavy metals or radionuclides finds their way into the food chain of humans. Several potential effects of these enhanced heavy metals and radionuclides found in soils have been studied and reported by numerous researchers. In the work conducted by Abdulsalam *et al*(2021) they reported that an increased in nickel uptake in plants results in significant reduction of plants photosynthesis pigments, Also the effects of nickel on fungi and bacteria growth is study and reported by Wanjala *et al*(2021). The Carcinogenic effects of heavy metals uptake or ingestion by humans through pathways as defined in the study is reported by Beyersmann and Hartwig (2008), and Adesuyi *et al* (2021). Bayelsa state of Nigeria is characterised by mangrove vegetation as a deltaic region and clastic lithologies. The global trend of expanding land demand for use due to Urbanization and industrialization have also resulted in numerous anthropogenic activity within the locality. Certain industrial activity like mining of sand and clay for construction and exploration and production of Oil etc. have become very predominant industrial activities. These anthropogenic activities will potentially affect the elemental compositional nature of the area causing contamination from oil spills, heavy metal enhancement from beneficiation of these mineral sands and mining operations, enhancement of radionuclides from sludges from oil operations, contamination of ground water from seepage and water bodies from runoffs. Therefore, there is a critical need to monitor the degree of variation or alteration of the human activities on the environment. The aim of the study is to determine the quantitative distribution of elements in the soil, evaluate their variation with published values from other regions and their consistency with worldwide crustal published mean range values. As part of an approach in the proper monitoring and management of the environment.

MATERIALS AND METHODS

Study Area: The study was conducted in Bayelsa State, bounded between longitude 4.7710^{0}N and latitude 6.0699^{0}E; a region within the Niger Delta of Nigeria. The area is characterised by brackish water and associated vegetation in the north, north-east areas and salty water, mangrove vegetation down the south, south-east areas and bounded in the south-south by the Atlantic Ocean.

Sample Collection: The state area was subdivided into 8 grids with each grid representing a local government area (LGA). Samples of soil was collected in 2 locations in each grid totalling 16 samples. Core samples from over burden to 900mm using hand field auger was collected from each location applying grid random sampling approach, with selection criteria predominately of soil mining sites for building, road, and other construction purposes as presented in the IAEA TECHDOC 1415. (2004). The soil samples were packed and stored in polyethylene bags and sealed with plastic polypropylene sellotape. And each bag label outside with a paper tape marked with an ink marker of the location and soil type for easy sample identification. According to location and sample type.

Sample Preparation: The samples were dried individually in an oven at 60^{0}C for a period of 24, hours to reduce water moisture. Each sample is then briquetted to establish homogeneity in particle size and mixed thoroughly in a plastic container. A representative sample of 500 grammes of each sample was then collected and place into a labelled Marinelli beaker with lid and sealed with plastic transparent Sellotape tape. According to soil type and location from which samples was collected.

Sample testing and Analysis: A representative sample of 50 grammes are collected from the labelled Marinelli beaker into a labelled polyethylene sachet for the analytical test which is conducted to determine each of the sample elemental compositional nature expressed in parts per million (PPM) deduced from their spectral signature using a linear accelerator at the Center of Energy Research and Development in Ife, Ile -Ife. Nigeria

RESULTS AND DISCUSSIONS

The elemental composition of the collected samples from the different locations of the study area was determined. The results obtained from the analysis of the samples using a linear accelerator is presented in Tables 1 and 2; the Tables show that all the samples contain high level of Silicon (Si), Aluminium (Al), Sodium (Na), Magnesium (Mg), Potassium(K) and Iron (Fe). Within the limit of detection, also observed are trace elements and heavy metals like Cr, Zr, Ti, Co, Zn, Cu, and Mn, in varying proportions whose concentration in samples vary with samples and with sample locations. It is also observed that the most abundant element in the samples vary from sample to sample. The Na, Al, Mg, Fe, Si, and k, elements whose degree of concentration depends on location, also have an observed variability between clay and sand samples. For example, between the 16 samples, the Si element value varies from 264,825.7 – 498,781.9 mg/kg; Na ranges from 821.9 - 6967.5 mg/kg, Al values ranges from 5,217.3 – 102,374.4mg/kg, Mg ranges from 487.2 – 10512.2mg/kg, Fe values ranges from 4295.2 – 63663.0 mg/ kg and K ranges from 4,189.9 -23,106.5. Certain elements detected, are observed to be location dependent while others are sample type dependent. Elements such as Br, Ba, Ga are observed in very low concentration and from analytical results are only in sand samples. Other heavy metals with considerable concentration in the samples including Zr, Rb, Sr, Zn, were mostly observed in considerable concentration in the clay samples. In general, the 16 samples from the different location and soil type are laden with differing concentration of heavy metals, alkali metals, alkali earth metals amongst other elements in trace amounts.

From Table 3, it is observed that most of the elements presented in Tables 1 and 2 have concentration of elements that are relatively high when compared to the values reported by Towett *et al* (2015); for example, the mean concentration value in ppm of Aluminium (Al) from the study area (mean SA) is 46562.7 ppm as against 37564.8 ppm (mean VR1). While the value reported, mean (VR1) fall within the worldwide reported range WR (VR3) values of 10,000 – 40,000 ppm, the mean values of the study area (mean SA) exceeded the maximum boundary value of WR (VR3). Also, the values of phosphorus a major constituent of the earth crust from the study area is much greater than values reported with a value of 653.8 ppm (mean SA) as against 143.9 ppm from reported mean value (mean VR1). Potassium has values also higher in the study area with a concentration of 13017.5ppm (mean SA) as against 10893.0 ppm from Mean (RV1). Two notable deviation is observed in the Table 3, with elements such as Iron (Fe) and calcium (Ca) observed to be higher in the reported values of concentration than the study area. For example, the Fe value in the study area is 22040.8ppm (mean SA) which is lower than 27954.0 ppm from the reported value (mean VR1), and also with values of calcium been 2268.3 ppm from the study area (mean SA) and 9780.0ppm (mean VR1) from the values reported by Towett et al (2015). In addition, values from Table 3 also shows that some heavy metals and trace elements have values that are comparatively higher in the reported values mean concentration (RV1) than the study area mean concentrations (mean SA), as seen in the values of Ti, Cr, Mn etc.

Table 1: Composition and concentration of light elements and iron in soil samples

Sample	**Concentrations of Major Elements of Soil Samples of Study Area (mg/kg)**									
ID	Na	Mg	Al	Si	P	Cl	S	K	Ca	Fe
S1	6967.5	10512,2	85238.9	304507.6	736.7	-	8823.6	19998.2	5343.2	35386.3
S2	1077.0	606.6	6090.4	395002.6	-	-	-	4238.7	404.1	6274.0
S3	4056.0	6423.2	82865.3	273680.3	607.0	-	-	20182.5	4915.3	40934.6
S4	1349.7	591.9	7286.3	356830.2	-	-	-	5604.6	439.3	5096.1
S5	3199.3	7555.8	102374.4	264825.7	706.7	64.0	-	20739.6	4412.2	63663.0
S6	1197.0	487.2	6077.3	327545.1	-	-	-	4691.0	468.8	4295.2
S7	5116.8	6913.5	68396.4	372109.9	699.8	-	5326.6	17021.2	3419.6	22295.1
S8	2665.7	644.9	9378.4	379649.2	-	-	-	6370.1	1207.3	5796.4
S9	4476.3	6649.8	83463.1	283891.5	761.7	138.7	-	23106.5	4359.0	44725.1
S10	1617.9	644.9	8486.0	376237.8	-	-	-	6271.3	833.0	5730.3
S11	3859.5	6171.8	77776.8	273414.2	812.6	88.6	-	21163.9	3783.5	28175.3
S12	821.9	537.9	5217.3	392892.8	-	77.1	-	4189.9	324.4	6,135.92
S13	3366.3	5173.2	89133.0	276204.4	516.9	-	-	20932.1	2703.0	27446.6
S14	2807.7	810.6	11529.9	420349.4	589.9	-	-	6864.2	1024.5	7358.7
S15	2629.2	5811.1	91981.1	274867.9	479.9	65.5		20182.2	1909.7	42490.7
S16	1928.9	647.3	9707.8	498781.9	627.1			6724.4	745.9	6848.6
Max Value	6967.5	10512,2	102374.4	98781.9	812.6	138.7	8823.6	23106.5	5343.2	63663.0
Min Value	821.9	487.2	5217.3	264825.7	479.9	64.0	5326.6	4189.9	324.4	4295.2
Mean Value	2946.044	3311.313	46562.65	341924.4	653.83	86.78	7075.1	13017.53	2268.3	22040.75

Table 2: Concentration of Heavy Metals and Trace elements in soil sample

Sample ID	Concentrations of Heavy Metals & Trace Elements of Soil Samples of Study Area (mg/kg)											
	Ti	Cr	Mn	Co	Cu	Zn	Rb	Zr	V	Sr	Ba	Ga
S1	4329.4	10.7	447.9	3.5	9.5	18.3	78.9	1483.0	-	-	-	-
S2	371.0	66.2	66.5	-	9.7	-	-	116.2	-	-	-	-
S3	5794.7	10.5	1044.3	_	10.5	60.1	116.3	939.5	-	105.9	-	-
S4	283.4	49.6	58.7	-	5.9	35.4	-	-	764.5	-	96751.8	14247.3
S5	7574.3	13.9	1989.1	6.2	-	-	201.3	-	-	45323.3	-	-
S6	311.2	51.9	60.9	-	5.4	-	-	-	1285.9	-	-	-
S7	2823.5	7.8	309.9	-	13.1	54.4	-	-	-	-	-	-
S8	358.6	72.6	60.7	-	16.0	55.3	-	269.7	1495.8	-	-	-
S9	5612.6	13.4	1261.3	-	11.9	51.6	56.0	583.7	70.0	-	-	-
S10	576.1	55,5	103.3	-	4.8	-	-	-	281.7	-	-	-
S11	6030.1	12.9	421.4		10.8	52.8	49.2	550.0		79.4		
S12	205.7	66.0	34.6	-	6.8	33.0	-	-	167.1	-	-	-
S13	8317.3	13.4	248.8	-	5.9	73.9	131.8	591.0	-	-	-	-
S14	711.9	61.8	105.2	-	16.3	-	-	-	1144.2	-	-	-
S15	7398.6	8.5	397.8	-	5.6	77.8	113.1	703.0	-	-	-	-
S16	270.8	80.8	-	-	14.7	-	-	-	1345.6	-	134830.1	-
Min Value	205.7	7.8	34.6	3.5	4.8	18.3	49.2	116.2	70	79.4	96751.8	14247.3
Max Value	8317.3	80.8	1989.1	6.2	16.3	77.8	201.3	1483	1495.8	45323.3	134830.1	14247.3
Mean Values	3185.575	36	440.6933	4.85	9.793333	51.26	106.6571	654.5125	819.35	15169.53	115791	14247.3

Table 3. Concentration of Elements in Study Area and Reported Values from Other Study Locations (Mean RV1 reported values and Mean RV3 - reported worldwide range values, from Towett, et al (2015); while Mean (RV2) are reported values from Olabanji, et al (2015))

Element	Max(SA)	Min(SA)	Mean(SA)	Mean(RV1)	Mean(RV2)	WR(RV3)
Na	6967.5	821.9	2946.0	-	-	
Mg	10512,2	487.2	3311.3	-	9247.2	
Al	102374.4	5217.3	46562.7	33927.0	37564.8	10,000-40,000
Si	98781.9	264825.7	341924.4	-	143791.3	
P	812.6	479.9	653.8	143.0	-	-
Cl	138.7	64.0	86.8	-	88.7	
S	8823.6	5326.6	7075.1	-	-	
K	23106.5	4189.9	13017.5	10893.0	9687.5	-
Ca	5343.2	324.4	2268.3	9780.0	130744.0	-
Fe	63663.0	4295.2	22040.8	27954.0	20591.6	-
Ti	8317.3	205.7	3185.6	4264.0	2409.7	200-24000
Cr	80.8	7.8	36	64.0	63.0	1-1500
Mn	1989.1	34.6	440.7	466.0	512.6	<7-9000
Co	6.2	3.5	4.9	-	-	
Cu	16.3	4.8	9.8	17.0	-	1-250
Zn	77.8	18.3	51.3	29.0	79.8	10-602
Rb	201.3	49.2	106.7	-	42.2	
Zr	1483	116.2	654.5	-	149.5	
V	1495.8	70	819.4	37.0	-	5 – 500
Sr	45323.3	79.4	15169.5	118.0	90.0	32 - > 1000
Ba	134830.1	96751.8	115791	-	-	
Ga	14247.3	14247.3	14247.3	8.0	-	0.4 – 70

Min (SA) = Minimum value of study area; Max (SA) = maximum value of study area; Mean (SA) = Mean value of study area (SA); mean (RV1) = mean of reported value 1; Mean RV2 = Mean of reported value2; WR (RV3) = Worldwide Range reported value.

For example, Ti has a mean concentration value of 4,264.0 ppm (mean VR1) as against 3185.6 ppm (mean SA), Cr mean concentration value of 64.0 ppm (mean VR1) in reported values(mean VR1)as against 36 ppm in study area mean concentration(mean SA) and Mn with mean concentration value of 466.0ppm (mean VR1) compared to 440.7ppm(mean SA). However, the values of Ti, Cr, and Mn from the study area (mean SA) and reported values as presented in (mean RV1) are all in consonance with reported worldwide range values WR(VR3) which are 200-24000ppm, 1-1500ppm, and <7-9000ppm respectively. A reversal in degree of concentrations is evidently observed in other heavy metals as well as trace elements; for example, Vanadium (V), Strontium (Sr), Barium (Ba), and Gallium (Ga) show significant high mean concentration in the study area with mean concentration values of 819.4 ppm, 15169.5 ppm, 11,5791ppm, and 14247.3ppm which are higher than the values as in the reported mean values (mean VR1) of 37.0 ppm for V, 118.0ppm for Sr, 8.0ppm for Ga. These mean concentration values are also observed to not be within the mean concentration range in the reported worldwide range values WR (VR3). It can be observed that in the comparative analysis between the mean concentration values of the study area (mean SA) and extracted values from the study on soil elemental composition analysis published by Olaqbami et al (2014) as presented in table 3, the concentration of elements like Mg has concentration values that are higher than those observed in the study area. For example, the reported mean concentration value (mean RV2) of Mg is 9247.2 ppm, the value from the study area (mean SA) is lower with a value of 3,311.3 ppm. Also, the values for Al, Si, K, Ca, Fe for the study area is observed to be higher than the values of the reported studied soil samples analyzed by Olaqbami et al (2014). The mean values of these elements in the study area (mean AS) in the soil samples are 46562.7 ppm for Al, 341924.4 ppm for Si , 13017.5 ppm for K, 2268.3 ppm for Ca, 22040.8 ppm for Fe as compared with the reported values of mean concentration (mean VR2) of 37564.8 ppm for Al, 143791.3 ppm for Si, 9687.5 ppm for K, 130744.0 ppm for Ca and 20591.6 ppm for Fe respectively. For the heavy metals and trace elements Ti, Cr, Mn and Zn the values for mean concentration (mean VR2) as reported are observed to be higher in concentrations to those of the study area mean concentration values(mean SA) of these elements .The values of these elements are also observed to fall within the worldwide mean range values in the reported case studies for the variability of elements in environmental , agricultural and contamination soils.

Conclusion: The elemental concentration of some elements in the soil studied are noticed to be higher than soil elemental concentration from other regions. The studied site soil concentration of some elements is also observed to be higher than world wide mean concentration range found in soil. This indicates some degree of potential contamination in the studied locations resulting to anthropogenic activities. Therefore, regular monitoring of the studied locations on a periodic basis is desirable to prevent potential health detriment from heavy metal and radionuclides.

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