Comparative Assessment of Soil and Selected Crop in Cement Dust Contaminated Environment in OkpellaArea of Edo North, Nigeria

Abstract

The research was designed to compare the degree of contamination of soil and selected crops by cement dust generated during cement industry activities. Two types of soils were investigated. Soil obtained near the cement industry (OS1) and the soil obtained in a location far from the site of the cement industry (AS2). Only cassava was studied, rather one crop at two locations. The result showed that the percentage of P (28.6±0.01) and K in AS2 was higher than in OS1 (21.6±0.07). The OM in AS2 (2.34±0.01) was higher than in OS1 (2.17±0.01). The values obtained for EC were OS1 (145.7±0.01) and AS2 (115.4±0.28). The concentration of the selected elements did not exceed the maximum allowable amount. Fe has the highest concentration in soil and crop samples. The obtained value for ash content in OC1 was 4.62±0.00 and AC2 was 2.39±0.01. Carbohydrate has 74.4±0.01 in OC1 and 83.4±0.05 in AC2, however moisture content in OC1 was 7.17±0.03 and 6.86±0.03 in AC2. The results also showed the presence of various functional groups and revealed the types of minerals in the samples.

Keywords: Environment, soil, cassava, cement dust, heavy metals

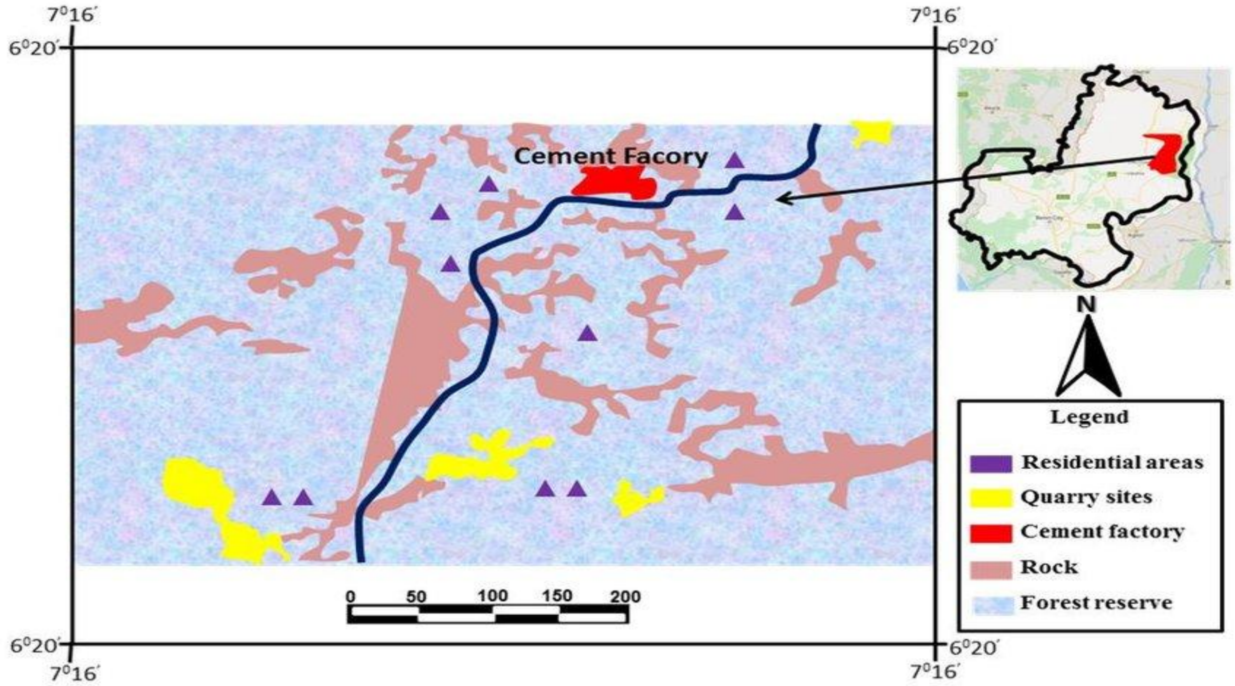
Introduction

Industrial environments are associated with the emission of toxic elements, particularly heavy metals, as a result of industrial activities and attendant environmental pollution, which in turn contributes significantly to human health challenges. It is known that the industries emit dust particles of various sizes, volatile substances and hazardous metals during cement production. The cement industries contribute to the environmental imbalances by altering the composition of the environment, resulting in pollution. Since the advent of human search for innovation, the development activities of industries and their effluents have been a primary concern in the environment and the activities of cement over the years have threatened the survival of our ecosystem. Plants and animals in the industrial areas, water, air and land are polluted by these obnoxious substances released into the environment by the cement plants. Ramesh, Ahmed, and Koperuncholan, 2014 have reported that pollutants and other toxic effluents released from the cement and mining industries and processes of raw materials including limestone, dolomite are sources of environmental pollution and toxic substances. The contamination of the major environmental components, including air, land, and water, has resulted from the presence of these toxic substances. Malthotra (2002) estimated that the cement manufacturing industries in Poland contributes to about 7 % of the overall greenhouse gases emissions that are released into the earth's atmosphere. High concentration of greenhouse gases has led to global warming.This warming has led to various adverse consequences, including the melting of polar ice, more frequent instances of flooding and drought, and alterations to the natural habitats of plants and animals (OlatunbosunSawa, Jibrin, Ilori, 2020). In addition, gaseous substances including carbon oxides (CO and CO_2), nitrogen oxides (NO_x), sulphur dioxide (SO_2), and dust are discharged into the atmosphere by the cement manufacturing industries as reported by Kampa and Castanas, 2008, Pregger and Friedrich, 2009. In the twenty-first century, the release of potentially dangerous metals and resulting risk of food safety have become major environmental concerns (Hailu Reta and Leta Damo (2020). Elements classified as heavy metals have specific densities more than 5 g/cm^3. Metals with this property have the potential to cause harm or destroy properties, living organisms and the ecosystem at large (Järup, 2003). As a consequence of their non-biodegradable nature, heavy metals readily accumulate in soil that has been contaminated, posing a risk to human health through the ingestion of contaminated crops and vegetables.

Materials and method

Studylocation

The study location is the immediate environment of the BUA (no abbreviation in first) cement plant situated in Okpella.Okpella is a town situated along the Federal highway that connects Abuja and Benin. Based on the latest census figures, the town has a population of 20,562 and one of the three major towns that constitute Etsako Local Government Area in Edo State. Okpella is known for its natural mineral resources based on sedimentary rocks including marble, calcium granite, feldspar, soap stone, clay, and limestone. The indigenous people are predominantly farmers. They engage in substantial production or cultivation of yams, cassava, tomatoes and ogbono. Okpella lies between 7^o 16^1 to 12^o N latitude and 6^o 20^1 to 46^o E longitude



Pic 1. Study location

SamplesCollection

Soil sample was collected from the industrial study area at a depth of 0 to 15 cmusingastainlesssteelspade.Cropsample(cassava tubers) wascollectedatthesame. Soilandcrop (cassava)sampleswerecollectedusingthesamemethodat non-industrial study area. The samples were collected into polyethylene bagslabeledandproperlytied.All the samples were collected during rainy season. Analytical grade chemicals and reagents were used in this study.

PreparationofSample

Soilsampleswereair-driedfor three days inthelaboratoryatambienttemperatureandthendriedfor 2hoursat105^{o}Cin an oven.Thedriedsampleswereground to pass through 100 µmmesh sieve and stored in a close air-tight container forfurther analysis. The soil sample collected from the industrial site at Okpella waslabelled OS1 while the soil sample collected from non-industrial site at AuchiwaslabelledAS2,which correspond to the control.

The crop samples were also air-dried for seven days and then oven-dried at105 ^{o}C for 2 hours. The dried samples were ground to pass through 100 µmmesh sieve and storedinacloseair-tightcontainerforfurtheranalysis.Moreover,thecassavapowder prepared from cassava tuber collected from industrial site at Okpella was labelledOC1whilecassava collectedfromnon-industrialsiteatAuchi waslabelledAC2.

Characterization of Samples

The samples were characterized using the following instruments; (1) FT-IR (Infrared Spectrometer Varian 660 MidIR Dual MCT/DTGS Bundle with ATR), (2) X-ray Diffractometer (XRD) and Atomic Absorption Spectroscopy (AAS). The XRD was used to determine the mineral compositions, while the FTIR Spectroscopy was used to investigate the presence of functional groups in the samples.AAS was used to determine the concentration of the heavy metals in the samples. The proximate compositions of the samples were determined according to the methodologies outlined in the AOAC 2009 report.

ResultsandDiscussion

Table 1 showsthat the physio-chemical properties of soil such as organic matter,electricalconductivity,soilpHandmoisturecontent influence the concentration of potentially toxic metals in the soil in a largequantities as well as on the bio availability and bio accumulation in plant. Thesoilorganicmatterobtainedfromthisstudyshowedthatthevalueis between2.17±0.01and2.340±0.01in the OS1andAS2respectively. The value (2.17±0.01) obtained in OS1 could be due to the decay of microorganisms as a result of industrial activities.Low level of organic matter can increase soil erosion processes whilehigh level of organic matter could affect the pH by lowering its level (Kekane*et al.*, 2015).

The pH values of the soil samples isbetween 6.60±0.06 and 6.83±0.03. AS2 sample has the highest pH value (6.83±0.03). Elaborate N P K values separately for different locations. The results show that nutrients availabilitywas higher in AS2thanOS1except for nitrogen (N) which was higher in OS1. The study showed thatOS1 and AS2 pHvalues were within the standardrange (6.5to8.5) set by the World Health Organization (WHO). Theelectrical conductivity(EC)ofthesoilsamples isbetween115.4±0.28and145.7±0.01/cm.SoilECisanimportantindicatorofsoilsalinityandameasure of the amount of salt in the soil but does not indicate the specific salt or ions thatmight be present. It is an indicator of salts such as sodium (Na), potassium (K),chloride(Cl^-), Sulphate(S), (Ullman, 2013). The result showed that the EC of OS1 and AS2 is low becauseEC of soils is less than200 µs/cmdoes not contain sufficientnutrientsforplantsandcouldhaveadisinfectedsoil withlow microbialactivity,(Verma*etal.*,2015).

A total of nine heavy metals were analyzed in the soil and crop samples for this research. The heavy metal concentration in OS1 was between 0.001± 0.00 to 228.6±0.03. Thelowestconcentration was found for mercury (Hg 0.001±0.00) while the highestconcentrationwasfound for iron (Fe 228.6±0.03).InAS2which correspond tothecontrolsample,theconcentration of heavy metals rangefrom 0.001±0.00 to 252.03±0.15. Mercury(Hg,0.001±0.00)hasthelowestconcentrationwhileiron(Fe,252.03±0.15)hasthehighest concentration.It showsthattheconcentrationofIron(Fe)wasthehighest in OS1 and AS2. The lowest concentrations were recorded for Mercury (Hg) in OS1 and AS2.

Table1:Thephysicochemical propertiesof OS1andAS2.

Parameter	OS1	AS2
N (%)	0.55±0.01	0.29±0.00
OM (%)	2.17±0.01	2.34±0.01
P (%)	23.6±0.01	28.6±0.01
K (%)	18.4±0.14	21.6±0.07
EC (%)	145.7±0.01	115.4±0.28
MC (%)	6.62±0.01	6.56±0.04
BD	1.09±0.00	1.10±0.03
pH	6.60±0.06	6.83±0.03

Theobtainedvaluesareaverages±standarddeviationofduplicatedetermination

The accumulation of heavy metals in the soil was presented in Table 2. The concentration order for OS1 was as follows; Hg<Co<Cu<Pb <Mn < Cr < Zn < Fe while AS2 was in the order Hg < Co < Ni < Pb < Cu <Mn<Cr<Zn <Fe. The findings indicate that iron (Fe)has the highest concentration in OS1 and AS2 (228.6±0.03 and 252.0±0.15 respectively while OC1 and AC2 (2.32±0.01 and 1.97±0.00).The results showed that Co and Hg were below detection limit.It isobservedthatthepollutionisnotsevereasalltheselectedelementsdonotexceed the maximum amount allowed. Based on World Health Organization (WHO) /FoodandAgricultureOrganization(FAO)guidelines.Althoughthehighestobtained value for iron (Fe) could be due to its occurrence presence in the earth's crust, this justifies its use as reference metal in the computation of enrichment factor(Alam*etal.*, 2013).

Table2.HeavyMetalsconcentration

	concentrations(ppm)			
Metals	OS1	AS2	OC1	AC2
Mn	0.370	0.490	0.190	0.210
Cu	0.310	0.270	0.120	0.170
Cr	0.820	0.820	0.070	0.100
Co	0.010	0.000	0.000	0.000
Hg	0.000	0.000	0.000	0.000
Ni	0.040	0.060	0.000	0.010

Fe	228.600	252.000	2.320	1.970
Pb	0.320	0.270	0.000	0.010
Zn	0.960	1.450	0.610	0.400
mean value	25.714	28.373	0.368	0.319

Theobtainedvaluesareaverages±standarddeviationofduplicatedetermination

Theresultoftheproximatecompositionanalysisof OC1 and AC2 are presentedin the table 3. A greater concentration of moisture was detected in OC1.The values showed that moisture content of thesamplewasmoderate,suggesting thatitcanbeconvenientlystoredforalongperiodoftimeasthiswillpreventsthegrowthofmicroorganisms and thus extends the shelf- life. The values obtained are acceptable for theestablished aim, achieve a stable shelf -life (< 20 % moisture) and agree with the valuespreviously reported by Kayisu*et al*., 1981, Gwenfogbe*et al*., 1988, Daramola andOsanyinlusi, 2006.

Ash refers to the concentration of minerals or inorganic residue that remainsafter either ignition or complete oxidation of organic matter in a food stuff. It isused for nutritional assessment .The percentage ash content in OC1 and AC2 is between 2.39±0.01 and 4.62±0.00. The low value found in OC1could be due toevaporationofsomeofvolatile mineralsdue toheat.

Carbohydrates are important in food as a major source of energy, to influencingcrucialtexturalpropertiesanddietaryfiberwhichaffectsphysiologicallyprocesses. The result of carbohydrates obtained from the samples by differenceshowed that AC2 was higher (83.4±0.05)while OC1 was(74.4±0.01)

Fats refer to those lipids that are solid at room temperature. Analysisoffatsinfoodsisimportantforaccuratenutritionallabelling,to determinewhetherthefoodmeetsthestandardofidentityandtoensurethattheproduct meetsmanufacturer'sspecifications.FatsvaluesobtainedforOC1,AC2 were (4.54±0.07) and (2.36±0.00)respectively.Fiber is essentially the sum of the indigestible components of food or food product. The fiber content of both samples range was (1.61±0.00) and(2.16±0.35). Protein are abundant components of all cells and are important forbiologicalfunctionsandcellstructureexceptthestorageproteins. The range of crude protein percentage is 3.37±0.02in AC2 and 7.15±0.01in OC1

Table3. ProximateAnalysis of OC1 and AC2

Parameters	OC1	AC2
Moisture Content	7.17±0.03	6.86±0.03
Ash Content	4.62±0.00	2.39±0.01
Fat	4.54±0.07	2.36±0.00

Fiber	2.16±0.35	1.61±0.00
protein	7.15±0.01	3.37±0.02
CHO	74.4±0.01	83.4±0.05

Theobtainedvaluesareaverages±standarddeviationofduplicatedetermination

Figure1istheFTIRspectrumofOC1.Thepeakappearingat3926.4cm^{-1}isduetoO-Hstretchingvibrationofhydroxylgroup.Thepeakat3312.65cm^{-1} correspondstothestretchingvibrationof OHwhiletheabsorptionpeakat2927.50cm^{-1}isduetothe stretchingvibrationof CH_2 of the alkylgroupoftheammoniumsaltpresentin the sample. The peak at 2850.31 cm^{-1} is as a result of the presence of OHstretching vibration hydroxyl group due to the water molecule adsorbed in thesample.Theabsorptionpeakat2312.88cm^{-1}isduetothe CO_3^{2-} (calcite)stretchingof carbonates compounds while the peak at 1650.03 cm^{-1}indicates thepresenceofasymmetricOHstretchinghydroxylgroupofwater molecule.Theabsorption peak at 1510.61 cm^{-1} shows the presence of asymmetric Si-O silicatestretching vibration while the peak at 1450.77 cm^{-1} is due to Si- O-Si stretchingsilicates.However theabsorptionpeakat1250.57cm^{-1}indicatesthepresenceAl-OHvibrationdue to aluminum deformation.Thepeakat1050.55cm-$^{-1}$isduetothe stretching vibration of Si-O (silicates plane).The absorption peak at 850.44 cm^{-1} shows thepresence of O-H deformation due to hydroxyl/aluminum while the peak at 618.33 cm^{-1}is dueto theAl-O(silicatesaluminum Sigroup).

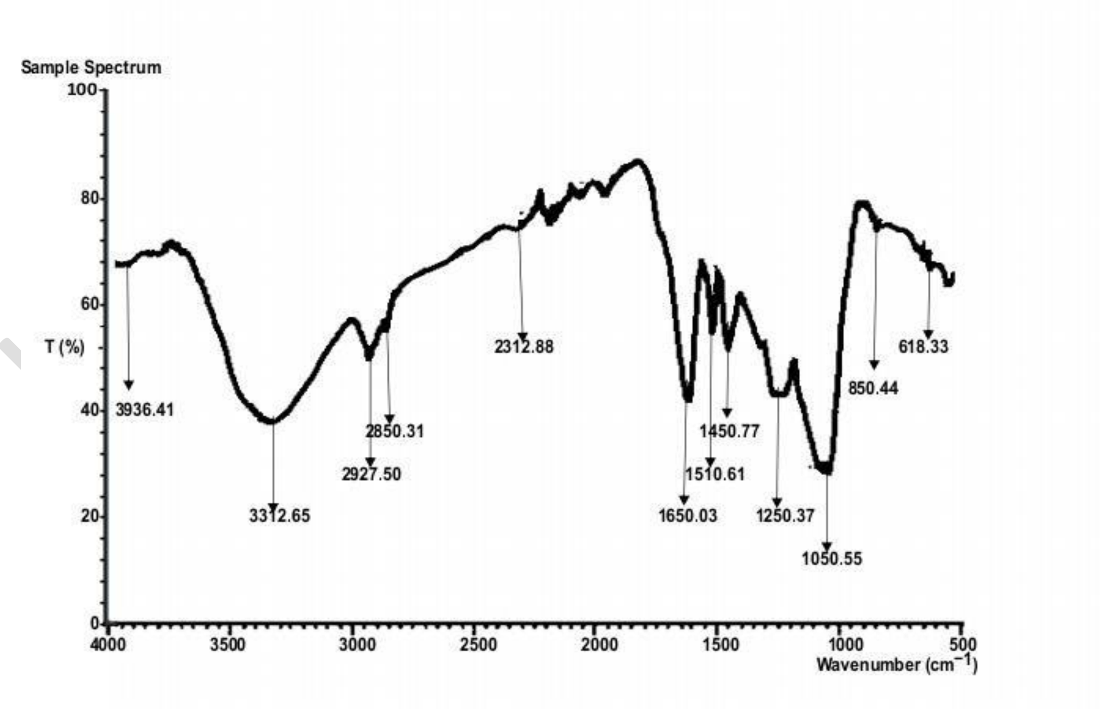


Figure1:FTIRSpectrumofOC1

Figure2showstheFTIRspectrumofAC2.Theabsorptionpeakat3775.10 cm^{-1} is due to the presence of the OH stretching vibration of the hydroxyl group. Thepeakappearingat3350.19cm^{-1}indicatesthe Si-OHstretchingvibration of silanolgroupwhile the absorption peak at 2775.84 cm^{-1} is due to the stretching vibration of CH_2 (alkanes). The appearance of a peak at 1250.78 cm^{-1}indicates H-O-Hbending vibration (hydroxyl group). The absorption peak at 1150.13 cm^{-1} is due to the stretching of silicate vibration (Si-O)whilethepeakat1051.42cm^{-1}isduetoSi-O- Si stretching vibrations (silicates compounds). The peak that appears in thespectrum at 974.82 cm^{-1} corresponds to Al-OH-Al (aluminates). The absorptionpeakat800.64cm^{-1}indicatesthepresenceofSi-OandSi-O-Al(silicates/aluminates). However the absorption band at 550.30 cm^{-1} is due to the stretching vibration of Si-O-Al (silicates/aluminates).

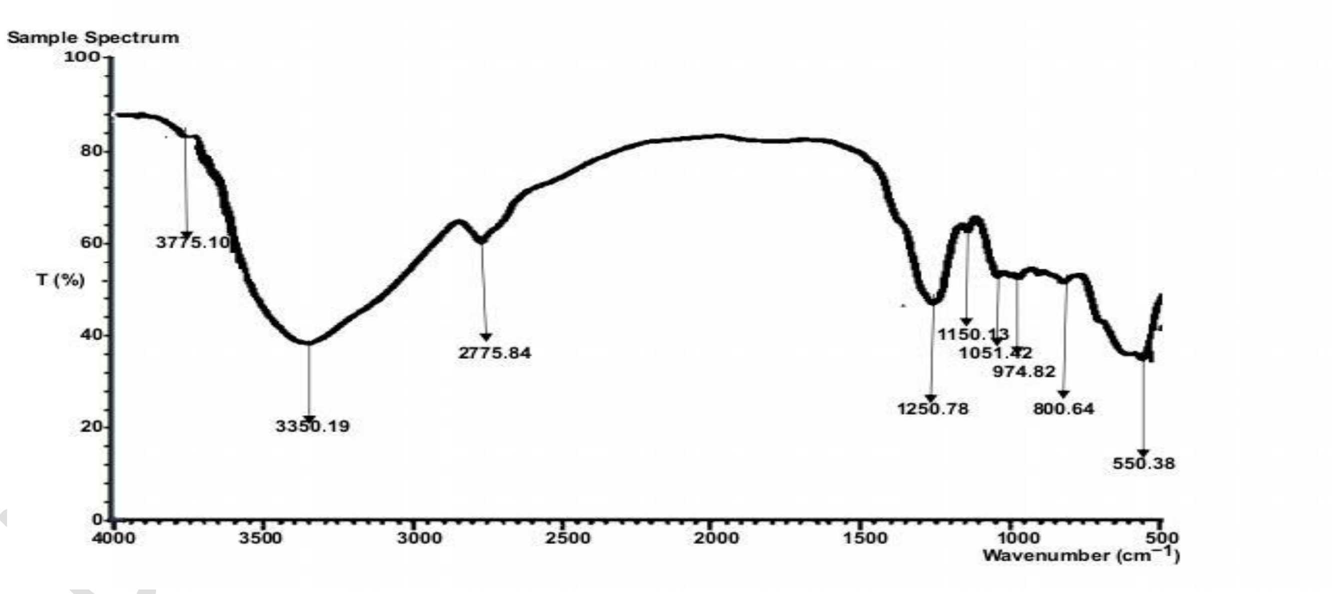


Figure2:FTIRSpectrumofAC2

Figure3istheFTIRspectrumofOS1. 3 Thepeakappearing at 3750.12cm^{-1} indicatesthepresenceofO-Hstretchingvibrationofhydroxylgroup,whilethepeak at 3350.19 cm^{-1} corresponds to OH stretching vibration of hydroxyl group. A peakat1960.33 cm^{-1} correspondstothe stretching vibration of CH_2 (alkanes). Theabsorption bandat1600.85cm^{-1}isthe region correspondingtothe stretching vibration of OHduetothepresence of adsorbedwaterin the sample(hydroxylgroup).The peak at 1300.28 cm^{-1} is due to the oscillation of the CO_3^{2-} stretching carbonates (calcite). Theabsorption band 1150.03 cm^{-1} shows the presence of sym bonds while the peak at1000.36 cm^{-1} correspondsthe asymmetric stretching vibration of the Si-O silicate. Theabsorption peak at 892.57 cm^{-1} is due to the vibration of the Si- O-Si stretching silicates andat750.14cm^{-1},thepeakcorrespondstoAl-OHdeformationofthe aluminumcompounds. The peak appearing at 618.33 cm^{-1}indicates the presence of OHbendingvibrationof the hydroxylgroup.Theabsorptionbandat550.28cm^{-1}isdue to the presence of O-Si-O/O-Al-O bending and silicates/ aluminates stretchingvibration

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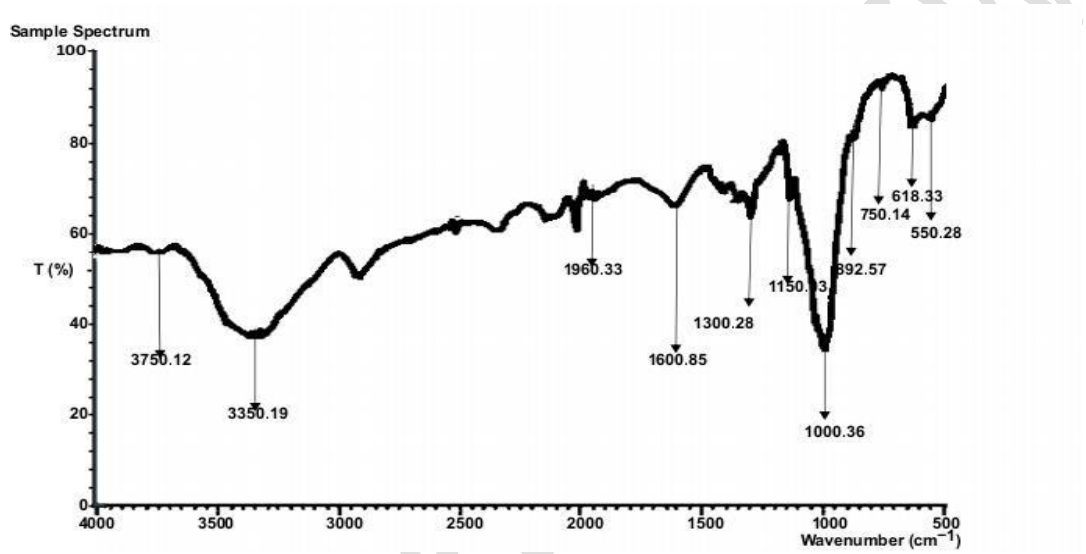

Figure3:FTIR SpectrumofOS1

Figure 4 is the spectrum of AS2. The absorption peaks at 3312.65, 2927.50and 2850.31cm^{-1} correspond to the stretching of OH, OH vibration elongationdue to hydroxyl group in the di-octahedral part of the mineral, OH stretchingvibration(hydroxylgroup)duetotheadsorbedwaterpresenceinthe samplerespectively.The peak at1711.85cm^{-1}isduetothe asymmetricstretching vibration of the OH hydroxylgroupofwaterwhilethepeakat1594.18cm^{-1}indicatesthepresenceof asymmetric stretching vibration of Si-O silicates. The absorption peak at1500.29 cm^{-1}indicates the presence of calcite-CO_3^{2-} stretching carbonatevibrationin the soil sample. The peak at 1442.63 $cm^{-1}$is attributed to the vibration of Si-O-Si stretching silicateswhile the absorption peak at 1206.16 cm^{-1}corresponds to the vibration of Al-OHaluminum compounds. However, the peak at 1050.55 cm^{-1}shows thepresenceofstretching vibration of

Si-O(silicates)andtheabsorptionbandappearingat800.03cm^{-1}isdueto thepresenceofOHdeformation modeofhydroxyl/aluminates(Al-Al-OHorAl-OH-Al)

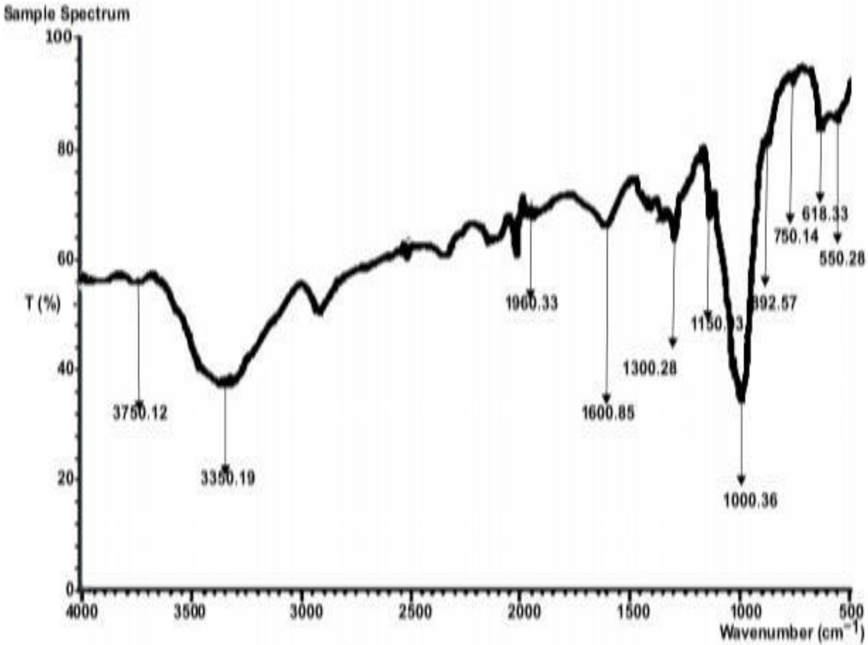

Figure4:FTIRSpectrumofAS2

XRDSpectrums

X-raydiffraction(XRD)wasusedtoanalyzeforthemineralogicalcomposition of the samples and the representative XRD patterns are shown below.TheXRDindicatescrystallineorthogonal phases.Thebackgroundandpeakspositionswereidentifiedandbasedonthepeakpositionsandintensities.Figure 5 is the diffractogram pattern of the OS1. The composition of the intensities inpercentage and thecorrespondingmineralsat20degreearelistedbelow.14.00(3.30),26.50(21.81),27.62(15.85),30.41(5.27),33.00(4.41),34.00(3.61), 38.97(11.43),41.00(9.53),46.00(2.64),55.62(5.29),65.00(3.52),67.00(4.40),and 78.00(4.01)wereforQuartz,Quartz,Hematite,Anatase,kaolinite,Quartz,kaolinite,Muscovite, Microcline,Calcite,kaolinite,kaolinite,andkaoliniterespectively. The result showed Quartz to be more abundant (21.81 %), followedby kaolinite (16.34%), Hematite (15.85%).

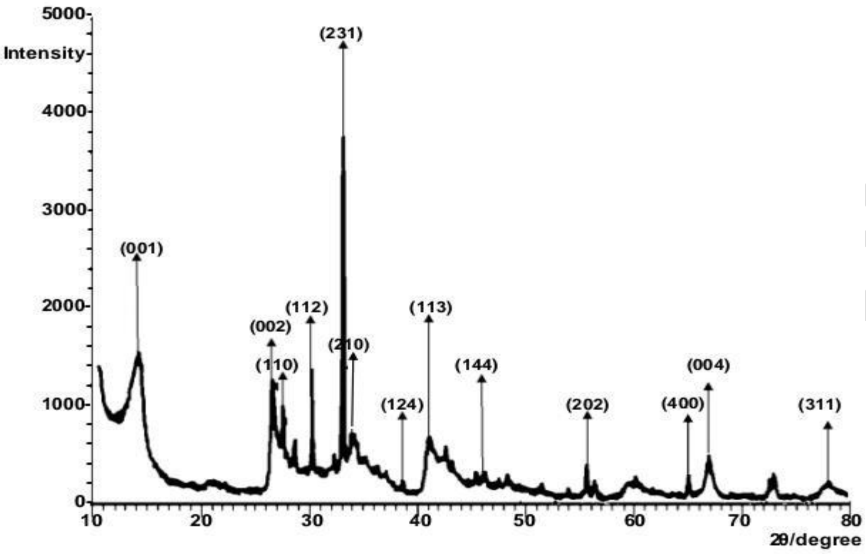

Figure5:XRDSpectrumofOS1

Figure6isthediffractogramofAS2.Theintensitiesat20degreecorresponding to the sample and the corresponding minerals are listed below. Theintensitiesat13.29,22.00,27.64,35.50,37.21,43.00,50.71,60.20,68.79and78.00 wererecordedforkaolinite,Quartz,Quartz,kaolinite,Quartz,Muscovite,Microcline,Cristobalite, Calcite,and Halloysite respectively.

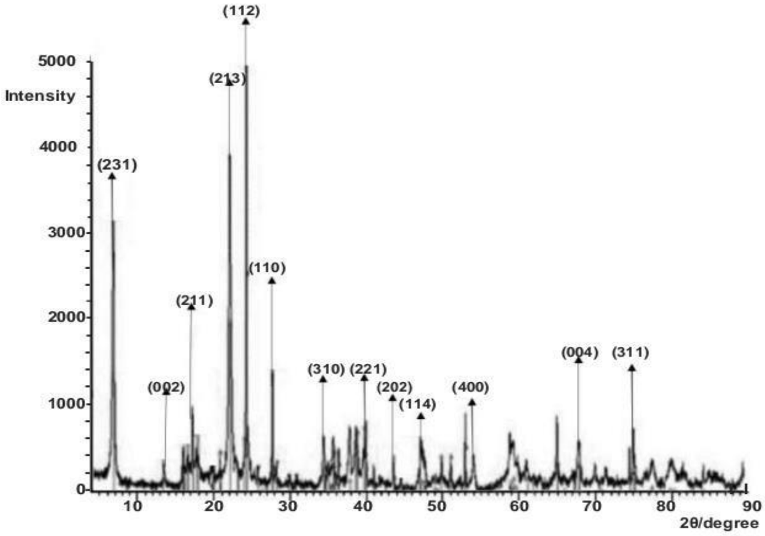

Figure6:XRDSpectrumofAS2

Figure 7 is the diffractogram of AC2. The intensities at 20 degree are asfollowsandthecomposition(%)inparentheses;13.00(3.30),16.50(21.81),28.61(15.85),29.94(5.27),31.10(4.41),36.23(3.61),37.40(11?43),39.94(9.53), 44.23(2.64),50.37(5.29),58.00(3.52),62.50(4.40)and76.00(4.01)wererecorded forQuartz,Quartz,Hematite,Anatase,Quartz,Quartz,kaolinite,Muscovite,Microcline,Calcite,Anatase,Quartz,kaoliniterespectively.Theresultindicates that Quartz was much in abundance (21.81 %) followed by Hematite, (15.85 %),kaolinite (11.43%).

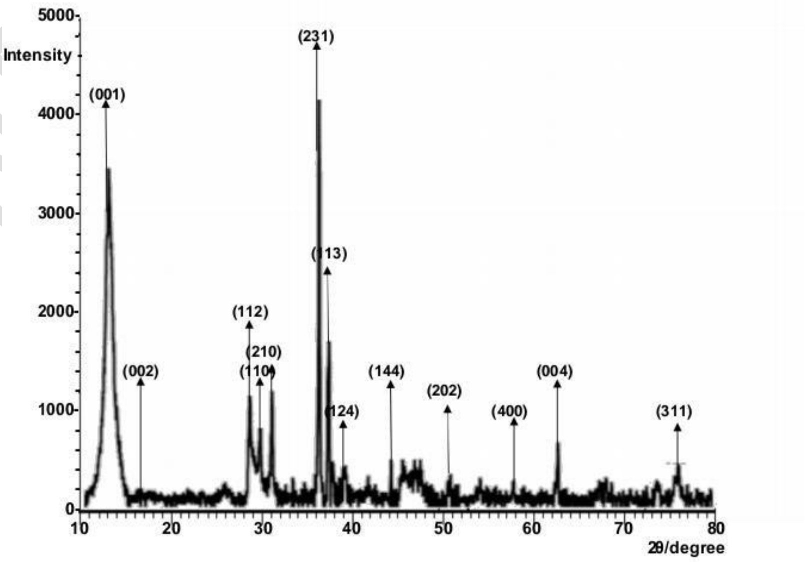

Figure7:XRDSpectrumofAC2

Figure 8 is the diffractogram of OC1. The intensities are recorded at 20 degree. The intensities are listed below with their composition and corresponding minerals. 11.98(3.81), 20.64(10.89), 26.50 (24.64), 34.50 (2.09), 36.43 (20.92), 42.50(5.15), 50.14(17.74), 60.20(4.84), 68.79(3.66), and 78.00(6.29) were kaolinite, Quartz, Quartz, kaolinite, Quartz, Muscovite, Microcline, Cristobalite, and Halloysite respectively. The result shows that the sample was much in Quartz.

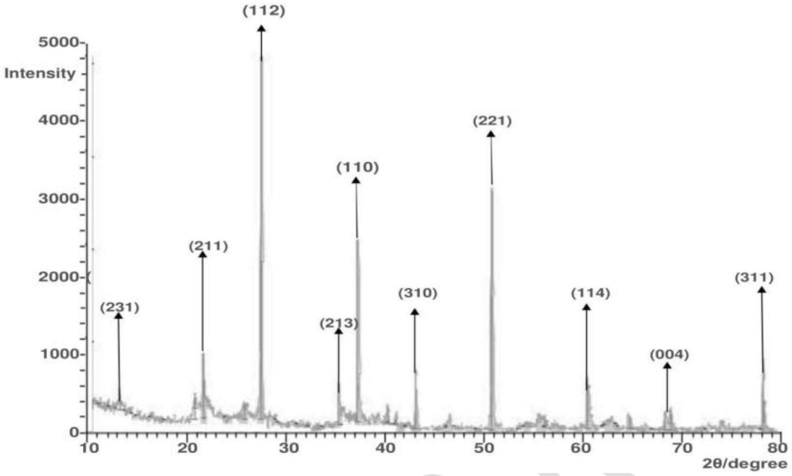

Figure8:XRDSpectrumofOC1

Conclusion

Heavy metals are potential pollutants which are commonly found in manufacturing industries particularly in cement industries. The study investigated the level of heavy metal contamination in the soil and selected crop near a cement industry and another soil and crop samples far from cement industry location. The concentration of the elements did not exceed the maximum allowable amount. The study found that nutrients availability were much in AS2 and the pH was within the standard range in both samples. The moisture content in OC1 and AC2 was moderate indicating that the samples can be stored for a long period of time, with potential to inhibit the growth of microorganisms and thus extending the shell life. In generally, the outcome of the research could be due to factors such as the season of sampling, climate, and the nature of soil which could be responsible for the concentration of the selected heavy metals and other parameters in the samples (soil and crops). Further research may be conducted at different times and seasons that vary from the current research conditions and factors.

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