Tropical Built Environment Journal. Volume 11, No. 1, 31-53, 2025 www.tbejournal.com
ISSN: 1118-1790

IMPACTS OF CONSTRUCTION DEBRIS FROM BUILDING COLLAPSE ON THE SOIL PHYSICO CHEMICAL PROPERTIES IN EBONYI STATE, NIGERIA.

[1]Irem, C. O.; [2]Okoye, C. O. and [1]Onuoha, D. C.
[1]Department of Environmental Management, Faculty of Environmental Sciences
Nnamdi Azikiwe University,
P.M.B 5025, Awka.
[2]Department of Urban and Regional Planning, Faculty of Environmental Sciences
Nnamdi Azikiwe University,
Corresponding Author's Email: remscolexcel@gmail.com ; **Phone: +2348038744113**

ABSTRACT
Building collapse generates waste in form of debris; the management of which could lead to soil and groundwater contamination that negatively impacts local ecosystem and biodiversity. The aim of this study is to evaluate the impacts of construction debris from building collapse on soil physicochemical properties in Ebonyi State, Nigeria. Adopting purposive sampling method, 12 sample sites in 6 L.G.A$_s$ were selected and samples collected using CRD, for 3 years at uniform depths of 0-30cm, Ebonyi State University alley crop farm as control. Laboratory analyzes were carried on Soil samples for physicochemical and heavy metals properties. Results showed a predominantly sandy soil; unusually high physicochemical properties and heavy metals, (f-ratios - 232,944 and 4.62 & p-values-0.000 & 0.012 respectively; $p<0.05$), agriculturally unsupportive, and poor in load-bearing. The study concluded that waste from building collapse had deleteriously impacted on soil physicochemical properties, in Ebonyi State, Nigeria. Recommended therefore to policy-makers, environmental agencies and builders included: comprehensive waste management and remediation strategy for construction debris, eco-friendly innovations, advanced building construction, etc.

Keywords: Construction Debris from Building Collapse, Soil Physicochemical Properties, Heavy Metals, Environmental Pollution, Ebonyi State.

1.0 Introduction

1.1 Background to the Study

Construction debris from building collapse includes materials like concrete, metals, wood, and hazardous substances such as asbestos, lead, and arsenic. It poses serious environmental hazards, including soil and groundwater contamination, thereby negatively impacting the local ecosystem and biodiversity (Zhou et al., 2019). This is primarily a result of improper waste management practices. Soil primarily receives the contaminants, becomes polluted, and loses nutrients such as soil organic carbon, nitrogen, phosphorus, potassium contents, and soil pH (Aluko et al., 2021). A change in soil properties may impact heavy metal availability and mobility, and heavy metal accumulation can alter physical and chemical properties, leading to soil degradation, reduced fertility, and environmental risk (Yin et al., 2020). Ebonyi State records a high rate of building collapse. Dumps of the collapsed building wastes or abandoned collapse debris/rubble are seen in several parts of the state including agricultural and residential areas.

According to works by several authors, the parent material of the soil influences the

physicochemical and biological properties of the soil, hence its susceptibility to wastes contamination. In order to assess soil potential for contamination and develop effective strategies for soil protection, parent material of the soil is important (Brady & Well, 2008; Singer, 2006).
It has also been reported that poor exchangeable bases leads to poor soil cohesion and accelerated acidification causes structural collapse (Olanitori, 2011, Olagunyi *et al.,* 2013; Blevins and Frye 2013). Also, recorded is increase in heavy metals concentration on soils within collapsed structure and their dump sites. According to the following authors; { Adagunodo *et al.* (2017), Toth *et al.* (2016) and Obodoh *et al.* (2019)}, improper waste management is also capable of triggering further building collapse. It has also been discovered that, management of debris from building collapses can overwhelm local waste systems, leading to groundwater contamination that further harm the environment {Oyinloye and Olanrewaju, (2015); Essay UK, (2017) and Bala, (2017)}.

Building collapse has continued to generate high volumes of wastes which dumped or abandoned indiscriminately, in Ebonyi State. Unfortunately, no local research has considered the state despite its deteriorating state due to impacts of waste from building collapse even with the growing concerns raised by stakeholders, globally. It is therefore expedient that the physico-chemical properties of the soil within the immediate environments of collapsed building sites or their dumps in Ebonyi State, Nigeria, be analyzed for a thorough evaluation of the impacts of wastes from building collapse. This will help to ascertain the extent to which the soil of Ebonyi State has been affected wastes from building collapse, thereby addressing a significant gap in existing research on this topic.

1.2 Statement of Problem

Building collapse has become a persistent and distressing issue in Ebonyi State, Nigeria, leading not only to structural and economic losses but also to severe environmental degradation. The debris from such collapses, comprising concrete, metals, paints, plastics, asbestos, and other hazardous materials, is often indiscriminately dumped on agricultural lands and within residential areas (Ogunsemi & Jagboro, 2006). This improper disposal practice introduces a complex mix of pollutants into the soil, which in turn alters key physicochemical properties such as pH, organic matter content, nutrient levels, and heavy metal concentrations (Aluko et al., 2021).

These changes are particularly alarming because soil serves as a critical medium for food production and ecological balance. The presence of construction debris can decrease soil fertility, disrupt microbial activities, and increase the bioavailability of toxic elements such as lead, cadmium, and arsenic, which may pose direct threats to human health and biodiversity (Yin et al., 2020; Ayolabi et al., 2015). In Ebonyi State, where agriculture is a principal livelihood, contamination of soil due to uncontrolled debris dumping could exacerbate food insecurity and rural poverty.

Furthermore, several building collapses in the state have occurred on reclaimed land or areas already impacted by prior waste deposition, compounding the environmental burden over time. Despite the increasing frequency of such collapses and the environmental concerns they raise, there is a striking lack of empirical research analyzing the specific impacts of construction debris from building collapse on

the physicochemical properties of soil in Ebonyi State. This knowledge gap is critical, as soil degradation has long-term implications for sustainable land use and environmental policy (Nwankwoala, 2011).

Therefore, this study is necessitated by the urgent need to assess the extent of soil alteration due to construction debris in Ebonyi State.

1.3 Aim and Objectives

The aim of this study was to evaluate the impact of construction debris from building collapse on soil physicochemical properties in Ebonyi State, Nigeria.

The specific objectives were:

1. to assess the physicochemical properties of soil in areas affected by Construction debris from building collapse in Ebonyi State, Nigeria.
2. to evaluate the impact of Construction debris from building collapses on soil physicochemical properties, including, pH, nutrient availability and heavy metal concentrations
3. to determine the levels and types of pollutants in soil samples in areas affected by Construction debris from building collapse in Ebonyi State, Nigeria.
4. to provide recommendations for mitigating the impact of waste on soil physicochemical properties and promoting sustainable waste management practices in Ebonyi State, Nigeria.

1.4 The Study Area

The study was carried out in Ebonyi state

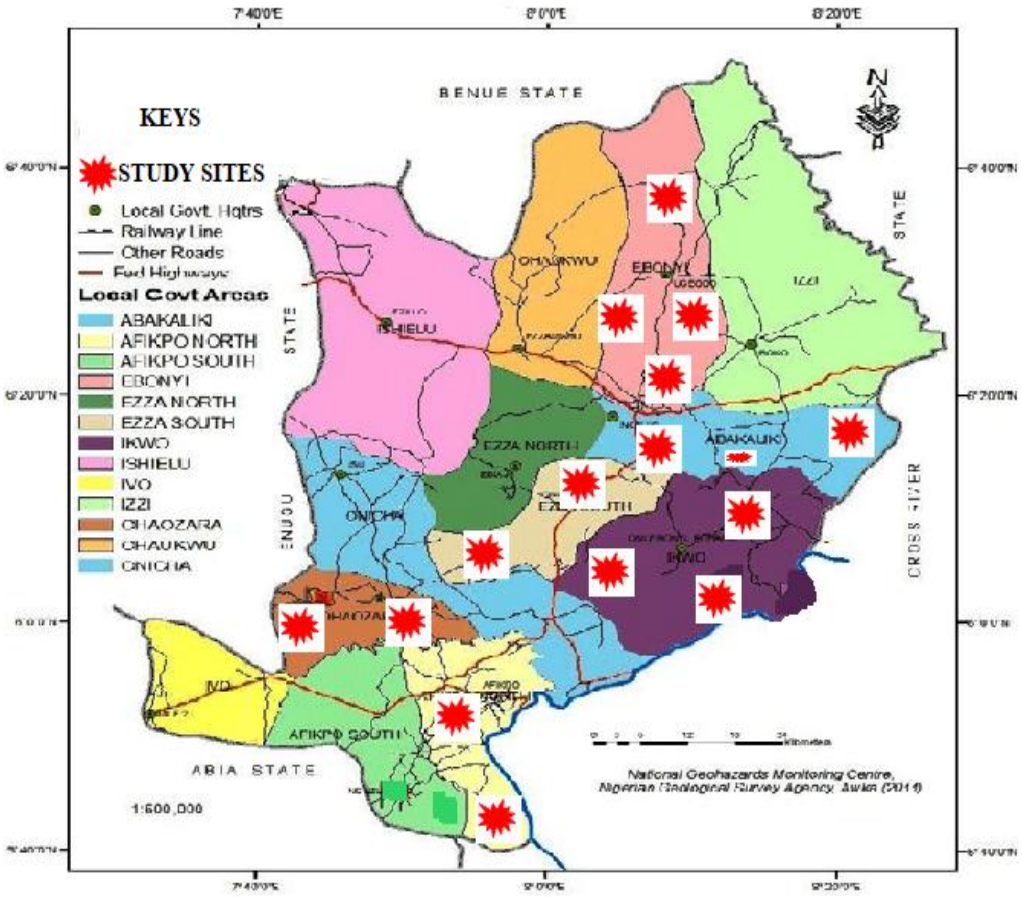


Figure 1: Map of Ebonyi State Showing the Study Sites
Source: National Geohazards Monitoring Centre, Nigerian Geological Survey.

Ebonyi state lies approximately on latitude 6º15' 00" N and longitude 8º 05' 00'' E and located in Southeast, Nigeria. It is made up of thirteen (13) local government areas, which were divided into three (3) zones, namely: Ebonyi North, Ebonyi Central and Ebonyi South. The state has land mass of approximately 5,932 square kilometers; bound in the East by Cross River State, in the North by Benue State, in the West by Enugu State, and in the South by Abia State (EBMOI, 2005). Ebonyi State has a population of about 2.1 million people (NPC, 2006). The vegetation of the state is a mixture of Savanna and Semi-tropical forest with agriculture as the main economic activity. It lies in an area of moderate relief of between 125 metres and 245 meters above sea level. The soil is texturally sandy loam, fairly to poorly drain with gravely subsoil in some locations especially the upland adjacent to lowland areas. Two main seasons prevail in the area-the rainy (wet) season, which starts from early April to early November, and the dry season which lasts from late November to early April, with a short dry spell termed the August break, usually experienced during the month of August, (Ekpe *et al.,* 2005).

Site Selection: The study purposively selected Ebonyi States due to the statistics of building collapse occurrence across the state, as stated in Table 1 as culled from Ebonyi State Emergency Management Agency (EBSEMA) (2019).

Table 1: Statistics of Building Collapse in Ebonyi State from 2015 to 2019

S/N	Type of building	Location	Affected buildings	No. of Peoples Affected
1	Residential/commercial	Abakaliki	64	2700
2	Residential/commercial	Afikpo North	12	400
3	Residential/commercial	Afikpo South	8	300
4	Residential/commercial	Ebonyi	45	4800
5	Residential/commercial	EzzaNorth	22	800
6	Residential/commercial	EzzaSuuth	30	1960
7	Residential/commercial	Ikwo	40	5730
8	Residential/commercial	Ishielu	19	150
9	Residential/commercial	Ivo	-	402
10	Residential/commercial	Izzi	34	4380
11	Residential/commercial	Ohaozara	9	500
12	Residential/commercial	Ohaukwu	20	230
13	Residential/commercial	Onicha	10	170

Source: ***Ebonyi State Emergency Management Agency (EBSEMA), (2019)***

In view of the above criterion, two local government areas from each zone were purposively selected because of their high incidence of building collapse. Thus, in Ebonyi North zone; Abakaliki, and Ebonyi local government areas were selected. In Central zone; Ikwo and Ezza Ssouth were selected, then in South zone; Afikpo and Ohaozara were selected.

Furthermore, two villages with higher records of building collapse were also purposively from the selected local government areas. The villages included: Elunwovu and Gunning road, in Abakaliki local government area; Amaike Aba and Ntezi Aba in Ebonyi local government area. Others included: Onyikwa Alike and Ohankwu, in Ikwo local government; Ameka, and Onueke, in Ezza-South local government area. Similarly, Amuro-Ngbom and Ibii, were selected in Afikpo local government, while Isu and Okposi were picked from Ohaozara, local government area.

2.0 Conceptual and Theoretical Frameworks

2.1 Concept of Drivers, Pressure, State, Impacts and Response (DPSIR): The Drivers, Pressure, State, Impacts and Response (DPSIR) concept according to Ganobi (2017), is more widely adopted by the European Environmental Agency for environmental reporting in order to establish the relationship between "indicators" such as environmental pressures (the human activities leading to a stress), states of the

environment affected by the activities e.g., physical, chemical and biological change in characteristics of soil, and the response in form of regulation adopted to resolve the problem and achieve the intended goals. Ganobi (2017) further modified DPSIR. to a chain of casual links starting with "driving forces" (human activities) through "pressure" (waste) to "states" (physical, chemical and biological) and "impacts" on ecosystems, humans, and functions, eventually adding to political "responses" (prioritization, target setting, indicators). Describing the casual chain from driving forces to impacts and responses is a complex task, which Ganobi (2017) intended to be break down into sub-tasks, for example, by considering the pressure-state relationship in Figure 2 (Ganobi, 2017).

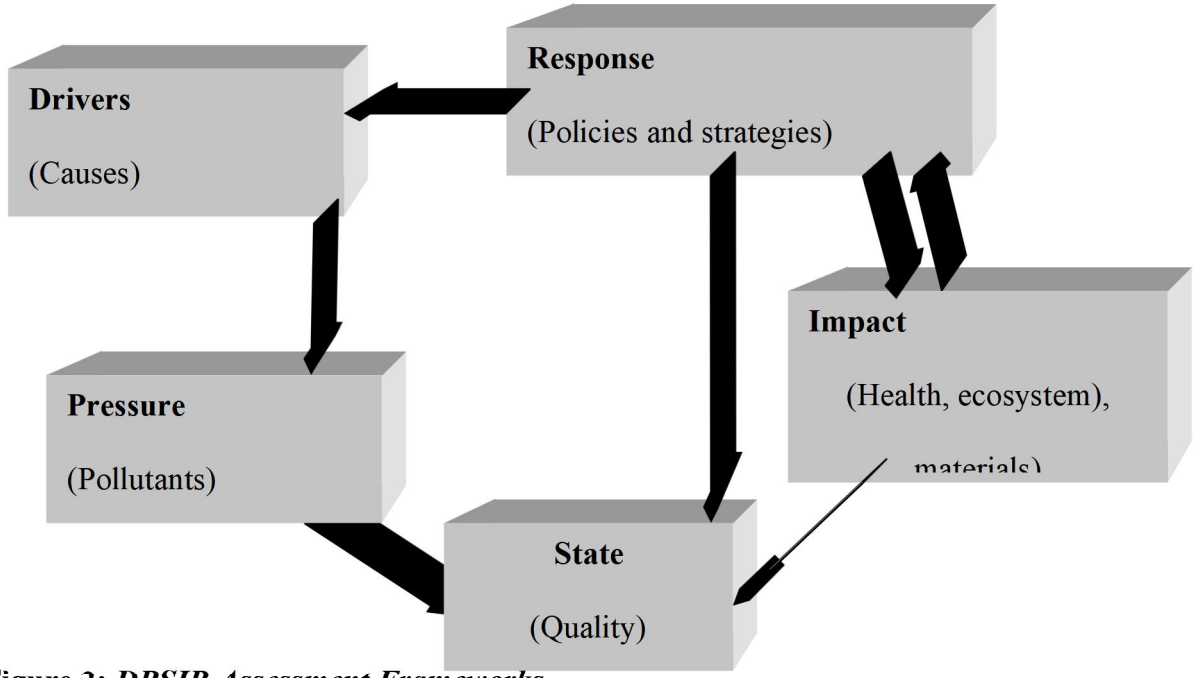


Figure 2: ***DPSIR Assessment Frameworks***
Source: ***(Adapted from Ganobi, 2017).***

The DPSIR was adopted as a means for assessing effects of industrial waste discharge on soil and the livelihood of human inhabitants of the environment. In the context of industrial pollutants wastes discharged by drivers such as industries caused pressure into the receiving land systems In that study, it was assumed that industrial waste discharge is influenced by anthropogenic drivers such as industries. This driver among others has caused pollutant pressure on the environment such as heavy metals accumulation (Mweogha and Kihampa, 2010 in Ganobi, 2017). Ganobi, (2010), therefore opines that the state of the environment included reduced quality of soil, and other resources which made it unsuitable for livelihood. In order to reduce the severity of the effects, various mitigation measures, such as industrial waste management in the industrial sites and improved information were recommended for adoption.

Applying this DPSIR framework to this research as part of the adopted concept is very suitable because building collapse

could be likened to an environmental force representing the 'Drivers' emanating from construction which is anthropogenic activity capable of mounting 'Pressure' in form of physical and chemical pollutant wastes and heavy metals, loss of resources, loss of lives and environmental pollution. These 'pressure' could alter the physical, chemical and biological (environmental) 'State' of the soil in contact with the contaminants. The resultant 'Impact' could be a reduced quality of soil, giving rise to low agricultural productivity. The 'Response' represents the intervention policies and strategies towards ameliorating the impact of Construction debris from building collapses on the soil physicochemical properties.

2.2 Theory of Ecological Modernization: Ecological modernization theory (EMT), first introduced in the 1980s by sociologists Arthur P. Mol and Gert Spaargaren is a sociological and environmental theory that suggests that economic growth and environmental protection can go hand in hand through the adoption of sustainable practices and technologies. This was recently employed by Janicle, M, and Jorgens, H. (2023) and Dias, R. R. and Sylva P. P., (2020). It proposes that society can address environmental problems by transitioning towards more sustainable production and consumption patterns, which will ultimately lead to improved environmental quality. The theory argues that industrial societies could reconcile economic development with environmental protection. They proposed that there is a possibility for industries to adopt cleaner technologies and develop new forms of production that are more environmentally friendly. It also suggests that through a combination of technological innovation, policy interventions, and societal change, societies can achieve economic prosperity while minimizing their environmental impacts. This theory provides a reliable perspective on how waste from building collapse can be managed to align with sustainability goals and environmental protection. It emphasizes the use of advanced waste management practices, sustainable building techniques, and comprehensive regulations to minimize the negative impact of these incidents on the environment.

Applying the concept in the study of impact of waste from building collapse on soil physicochemical properties is apt in several ways. Through its 'Waste management practices', 'Sustainable building practices', and 'Environmental regulations' components, building collapse which is a product economic growth/development can be forestalled through adoption of: (i) proper waste management practices like adoption of cleaner technology, timely collection and application of the 3-R_s of environmental management (Reduce, Recycle and Reuse (ii) sustainable building practices such as new production technology (use of eco-friendly materials and adoption of movable or detachable/demountable architecture) and (iii) environmental regulations like waste management policies and strategies, building codes, etc.

3.0 Materials and Methods

The materials employed for the samples collection were soil auger, core sampler, trowel, enamel tray, sieves, masking tape, marker, safety boots, cutlass, and hand gloves shovel, nose mask, measuring tape and ruler, sample bags, a pen and jotting pad.

3.1 Methodology of Study

The methodology of study is as discussed

3.2 Sampling Design: The study utilized a purposive sampling technique to select Abakaliki, Ebonyi, Ikwo, Ezza-South, Afikpo, and Ohaozara local government areas in Ebonyi State, due to a record of number of incidents of building collapses. A completely randomized design (CRD) was employed to collect soil samples at uniform depths of 0-30cm from the 12 locations which gave a total of 36 composites samples used for the study with the alley crop farm at Ebonyi State University serving as a control.

3.3 Sample Collection: Core and auger soil samples were collected at uniform depth of 0-30cm randomly from the locations per site; totaling in all, 36 composite samples. Composite in this context means, soil samples were randomly collected at three different points in each site and later composited to a single sample. The Core samples from the different sites were used to determine physical parameters while that of auger soil samples, were air-dried at room temperature and passed through a 2mm sieve and used for determination of some selected soil chemical properties.

3.4 Laboratory Analysis: The well processed core and auger samples were subsequently subjected to laboratory analyses. For the physical parameters; the bulk density, total porosity, gravimetric moisture content, and hydraulic conductivity were respectively measured using the core method in Stolt (1997), Carter and Ball (1993) method, direct method in Obi, (2000) and Reynoyds (1993) method, the The chemical parameters (soil pH in water (1:2.5 soil water ratio); Total Nitrogen, organic carbon, Available Phosphorus, Exchangeable bases and ECEC) on the other hand were measured by the following methods: glass electrode meter as described by McLean, (1982), modified Kjedahl digestion procedure in Bremmer and Mulvancy, (1982), Walkley-Black method, the Bray II method, the complexiometric titration method, in knudsental, (1982), the titration method (Tel, and Hagarty, 1984) and the summation of exchangeable bases and total exchangeable acidity values.

4.0 Data Presentation and Analysis

Soil Texture: Table 2 presents textural class of the soil across the study locations

Table 2: Textural Class at the Different Study Sites

Items	% Sand	% Silt	% Clay	Textural Class
Control	87.00	7.40	5.60	Loamy sand
Ebonyi North				
Abakaliki	93.00	3.40	3.60	Sand
Ebonyi	93.00	3.40	3.60	Sand
Ebonyi Central				
Ikwo	93.00	2.40	4.60	Sand
Ezza South	92.00	2.40	5.60	Sand
Ebonyi South				
Afikpo	91.00	6.40	2.60	Sand
Ohaozara	92.00	5.40	2.60	Sand

Source: Researchers field works, 2019-2021

It shows that whereas the control site was loamy sand (with sand-silt-clay ratio of 87%: 7.4: 5.6), textural class of the study locations, was sandy soil, with sand-silt-clay ratio of between 91-93%: 2.4-6.4%: .6-5.6%.

Physical Properties: Table 3 shows physical properties of the soil across the study sites.

Table 3: Soil Physical Properties in Study Sites between 2019 and 2021

Locations	2019			2020			2021		
	Bd	TP	GMC	Bd	TP	GMC	Bd	TP	GMC
Control	1.28	52	23.5	1.27	52	23	1.22	54	44
Ebonyi North									
Abakaliki	1.34	49	23	1.39	48	41.5	1.37	48	52.5
Ebonyi	1.39	48	20.5	1.43	46	27.5	1.48	44	37.5
Ebonyi Central									
Ikwo	1.48	44	20.5	1.57	41.5	36.5	1.51	43	46.5
EzzaSouth	1.54	42	20	1.64	38.5	26.5	1.59	40	36.5
Ebonyi South									
Afikpo	1.58	40	20.5	1.63	38	31	1.65	38	41
Ohaozara	1.62	39	22.5	1.68	37.5	27	1.68	37	37
FLSD(0.05)	0.02	2.43	ns	0.01	1.89	1.75	0.01	1.77	5.80

Bd=bulk density, TP= total porosity, GMC=gravitational moisture content, SE=standard error, FLSD = Fishers Least Significant difference, ns = not significant

Source: Author's Field surveys; 2019-2021

The table shows an average value range of Bd of 1.66 and 1.36 increasing from 1.62 to 1.68 for highest values and 1.34 to 1.37 for lowest values over control of 1.25 for the 3-year study period, precisely at Ohaozara and Abakaliki precisely. For the TP, the average lowest value was 37.5 and highest value, 48.3 for also at Ohaozara and Abakaliki repectively. On the other hand, GMC averaged, 39 increasing from 23 to 52.5 at Abakaliki and lowest at 22.8 increasing between 22.5 and 37 at Ohaozara. It will deduced from Table 7.2 that there was a remarkable increase in the bulk densities (Bd) and gravimetric moisture content (GMC) with decrease in total porosity (TP) of the soil in study area across the study period. In both situations, the variations were significant ($p<0.05$) 5% probability level compared to the control as revealed by their FLSD values.

Chemical Properties: Tables 4 and 5 show range of values of the chemical properties and heavy metals concentration across the 3-year study period. Table 5 shows the results of the analyses of the chemical properties in Ebonyi State. Similarly, the results of statistical analysis showed that the parameters studied varied significantly ($p<0.05$) at 5% probability level as shown by their FLSD values.

Also as shown on Table 5, the concentration of acid varied from 5.6 to 4.10 in 2019 and 2021 respectively, compared to control with study sites pH values ranging between 5.1, and 5.2, all varying significantly, ($p<0.05$) at 5% probability level as shown by their FLSD values, Table 5 also shows that the available phosphorus varied significantly ($p<0.05$) at 5% probability level with the concentration ranging from 47.70mg/kg, and 22.60mg/kg at the control site, while the

study sites recorded between 46.7mg/kg and 9.10 mg/kg, signifying a continuous drop in the concentration of available phosphorus also. Again, Total Nitrogen varied from 0.04% to 0.06% compared to the control value of 0.07% with a significant value of $p<0.05$, Organic Carbon (OC); ranging from 0.87% to 0.25% over control value of 0.99 and Organic Matter (OM); ranging from 0.8% to 0.13% over control value of 1.71.

Table 4: Soil chemical Properties for 3 years (2019-2021)

Locations	pH (H_20)	Av. P	Total N	OC	OM	Ca	Mg	K	Na	EA	ECEC	BS
Control	**5.20-5-1**	**47.70**	**0.08**	**0.99**	**1.71**	**2.40**	**0.90**	**0.04**	**0.25**	**2.88**	**5.69**	**95.00**
Ebonyi North												
Abakaliki	**4.8-4.4**	**36.2-10.2**	**0.06-0.10**	**0.61-0.24**	**1.05-.41**	**1.60-2.2**	**0.8-1.5**	**0.03-.04**	**0.17-.07**	**2.06-0.7**	**5.400-4.11**	**48.0-84**
Ebonyi	**5.6-4.3**	**31.5-9.8**	**0.08-0.05**	**0.87-0.42**	**1.5-0.72**	**2.40-1.6**	**2.2-0.5**	**0.12-.03**	**0.17-0.03**	**0.72-0.32**	**5.31-3.19**	**86.00-70**
Ebonyi Central												
Ikwo	**4.9-4.4**	**46.7-14.8**	**0.05-0.03**	**0.48-0.09**	**0.83-0.2**	**2.00-4.0**	**0.40-1.3**	**0.03-0.7**	**0.12-.11**	**1.04-.0.56**	**3.24-6.18**	**71.0-58**
Ezza South	**5.10-4.3**	**46'7-9.1**	**0.03-0.09**	**0.40-0.06**	**0.69-0.1**	**1.5-2.1**	**0.80-0.3**	**0.06-.03**	**0.07-.11**	**0.56-0.8**	**3.50-4.95**	**84.00-52**
Ebonyi South												
Afikpo	**5.40-4.1**	**35.50-16.5**	**0.06**	**0.16-0.44**	**0.17-0.8**	**4.0-1.4**	**0.40-0.8**	**0.23-.13**	**0.23-0.10**	**0.64-0.82**	**3.21-8.77**	**84.00-62**
Ohaozara	**5.60-4.2**	**35.5-12.4**	**0.04-0.09**	**0.28-0.10**	**0.48-0.2**	**3.60-1.8**	**2.20-0.4**	**0.04-.06**	**0.07-0.23**	**0.72-0.40**	**6.76-3.04**	**91.00-68**
FLSD	**0.24***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***	**3.99***

Table 5: Soil heavy metals

	2019 →			2020 mg.kg^{-1}			← 2021		
Locations	**Cd**	**Pb**	**Ar**	**Cd**	**Pb**	**Ar**	**Cd**	**Pb**	**Ar**
Control	**0.02**	**1.78**	**1.34**	**0.02**	**1.79**	**1.35**	**0.03**	**2.58**	**2.21**
Ebonyi north									
Abakaliki	**0.03**	**19.21**	**2.20**	**0.04**	**20.89**	**1.70**	**0.07**	**23.13**	**2.70**
Ebonyi	**0.05**	**30.90**	**2.50**	**0.06**	**25.88**	**2.40**	**0.09**	**26.16**	**3.50**
Ebonyi Central									
Ikwo	**0.03**	**18.99**	**1.60**	**0.05**	**19.01**	**2.28**	**0.07**	**20.21**	**4.58**
EzzaSouth	**0.04**	**19.13**	**1.70**	**0.06**	**19.78**	**2.43**	**0.08**	**21.36**	**5.03**
Ebonyi South									
Afikpo	**0.03**	**40.15**	**2.00**	**0.04**	**30.07**	**2.70**	**0.05**	**33.43**	**4.87**
Ohaozara	**0.06**	**43.89**	**3.50**	**0.07**	**31.63**	**3.70**	**0.08**	**34.06**	**5.43**
Threshold Limit	**1.00**	**60.00**	**5.00**	**1.00**	**60.00**	**5.00**	**1.00**	**60.00**	**5.00**

Note: pH = podus Hydrogenium, Av.P =Available Phosphorus *cmol.kg^{-1}*, N = Nitrogen *cmol.kg^{-1}*, OC = Organic Carbon *cmol.kg^{-1}*, OM = Organic Matter *cmol.kg^{-1}*, Ca = Calcium, Mg = Magnesium, K= Potassium, Na = Sodium, EA= Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity, BS = Base Saturation %, FLSD = Fishers Least Significant Difference, * = Significant, **Cd=**Cadmium *mg.kg^{-1}*, Pb=Lead, Ar=Arsenic.
Source: Researchers field works, (2019-2021)

Equally Table 4 shows that exchangeable bases such as calcium (Ca) magnesium, potassium, and sodium showed significant ($p<0.05$) changes in the soil affected by wastes from building collapse in the study area. From table 3, Calcium (Ca) varied from 0.40 cmol.kg-1 to 1.20cmol.kg-1 compared to control with 1.50cmol.kg-1. Magnesium value was between 0.40cmol.kg-1 and 1.20cmol.kg-1 compared to control 0.90. Potassium varied from 0.03cmol.kg-1 to 0.12 cmol.kg-1 compared with control value of 0.08cmol.kg-1. Sodium (Na) varied between 0.07cmol.kg-1 to 0.23cmol.kg-1 compared with control (0.15cmol.kg-1). In the same vein, the table shows that the exchangeable acidity (EA) ranged between 0.48cmol.kg^{-1} and 2.82cmol.kg^{-1} compared to the control 0.88cmol.kg^{-1} of .2020 for all the years; while the effective cation exchange capacity (ECEC) ranged between 8.77cmol.kg^{-1} at Afikpo and 3.19 cmol.kg^{-1} lower at Ebonyi location compared to the control with 3.05cmol.kg^{-1}. The BS varied increasingly, from 84% at Afikpo to 48% at Abakaliki; over the control sample with 81%, and (98%) at a significant ($p<0.05$).

Lastly, concentration of the heavy metals: cadmium, lead and arsenic significantly ($p<0.05$) increased on yearly basis compared to the threshold limits such that cadmium recorded 0.03 and 0.04mg.kg-1 in 2019 precisely in Ikwo and Ezza South, respectively over the control; 25 and 42% increase in 2020 and 2021, respectively. Similarly, lead recorded 19.21 and 30.90 mg.kg-1 in 2019 over the control. Furthermore, arsenic recorded 2.20 and 2.50 mg.kg-1 in 2019. This variation resulted to 29 and 37% between 2019 and 2021 (See Table 4). In 2020 and 2021, the concentration of cadmium, lead, and arsenic were below the threshold limits of heavy metal concentration in soil (Table 5).

4.0 Results

Soil Texture: Having sand-silt-clay ratio of between 91-93%: 2.4-6.4%: .6-5.6%., the affected soil was said to be sand while the control was found to be loamy-sand.

Physical properties: Having a medium bulk density (Bd) of between 1.34 and 1.68, the studied soil was suitable for low rise to medium rise buildings as its bulk density falls within the standard range of 1.4 g/cm^3-1.8 g/cm^3. As such, high rise building might collapse in the area due to the nature of its soil bulk density. This is consistent with the findings of Essoka and Esu (2001) who reported that the bulk densities of soils around collapsed building varies between 1.0 and 2.0 g/cm3 bulk density and as such, bulk densities less than 1.8 g/cm3 might not offer mechanical impedance to structures and might not support agricultural production effectively.

The result from table 4 shows that higher bulk density resulted in the lower porosity and lower GMC observed in the studied sites. This is consistent with the findings of Lal and Singh (2018) that the relationship between bulk density, total porosity and GMC would determine the structural carrying capacity of the soil and Hassan *et al*. (2016), who established that the bearing capacity of the underlying soil in collapsed site was 17.5% below the load intensity exerted on it.

Chemical properties

PH value of 4.1 to 5.6, implies that the soil range between moderately acidic and acidic. Available Phosphorus ranging between 9.1 and 46.7 implies low available phosphorus observed in soil affected by wastes from building collapse when compared with control.

The values of exchangeable acidity, ECEC and base saturation indicated a continuous loss in soil nutrients and biota due to

severity of Construction debris from building collapses. These were in line with the findings of Emmanuel (2006) who reported a decrease in exchangeable cations, EA and ECEC of soils with substantial proportion of its occupation of cation exchange site of soils at low soil pH which suggests unavailability of plant essential nutrients. These phenomena were also observed by Arpita and Ingrid (2012), Mbah et al., (2013); Daggupati et al., (2014) and Feng et al., (2015) who reported Low ECEC and EA in the eroding sites as could be explained by building collapse-induced changes in organic matter and clay content of the soil.

These implies that increase in the concentration of heavy metals in the studied soils of different locations in Ebonyi State due Construction debris from building collapses.

The increase could be attributed to the illuviation processes of the constituents of the collapsed structure into the soils in earlier mentioned processes. This agrees with Adagunodo et al. (2017), Toth et al. (2016) and Obodoh et al. (2019) who reported increase in heavy metals concentration on soils within a collapsed structure and the environments due to the wastes generated due to collapse.

In a nutshell, the physical properties (bulk density) of the affected soil increased with decreased total porosity and gravimetric moisture content at a constant trend for all the years of this study. Also, the values of the chemical properties of the soil (pH, Av.P, N, OC, OM, Ca, Mg K, Na, EA, CEC, and BS) were low to the extent that the soil was no longer fit for agricultural production and might not support heavy buildings as shown by the significant ($p<0.05$) F-ratio value of 232,944 and 4.62 and p-values of 0.000 and 0.012 for physicochemical and heavy metals concentrations respectively.

5.0 Discussion

The findings of this study underscore the significant impacts of construction debris from building collapse on the physicochemical properties of soil in Ebonyi State, Nigeria. A comparative analysis between affected locations and the control site reveals substantial alterations in soil texture, physical structure, nutrient availability, and heavy metal accumulation.

Soil Texture and Physical Properties

The study sites were predominantly sandy, with sand contents ranging from 91% to 93%, in contrast to the control site, which exhibited a loamy sand texture. This texture difference is critical because sandy soils typically have low nutrient-holding capacity and poor water retention (Lal & Singh, 2018). The elevated bulk density (1.34–1.68 g/cm³) across the sites—higher than the control value of 1.22 g/cm³—indicates soil compaction, possibly resulting from prolonged deposition of debris materials. Increased bulk density is directly correlated with reduced total porosity and gravimetric moisture content, as observed in this study, which aligns with findings from Hassan et al. (2016) and Essoka & Esu (2001), who noted that compacted soils around collapsed buildings often display limited structural support and poor agricultural suitability.

Chemical Properties and Nutrient Depletion

Chemically, the affected soils exhibited acidic pH values (4.1–5.6), significantly lower than the control (5.1–5.2), likely due to the leaching of acidic compounds from the debris into the soil (Emmanuel, 2006). The decline in essential macronutrients—such as Available Phosphorus (9.1–46.7 mg/kg), Total Nitrogen (0.03–0.09%), Organic Carbon (0.25–0.87%), and Organic Matter (0.13–0.80%)—confirms the deterioration of soil fertility. These values

fell below those of the control site and indicate poor soil quality, which is inadequate for productive agriculture.

Furthermore, the exchangeable bases (Ca, Mg, K, Na) and base saturation (BS) decreased substantially in the study sites, indicating nutrient depletion. This finding is consistent with Arpita & Ingrid (2012) and Mbah et al. (2013), who reported nutrient leaching and reduced cation exchange capacity in soils exposed to construction and demolition waste. The significant decline in effective cation exchange capacity (ECEC) supports the claim that the soils have lost their ability to retain and exchange nutrients effectively.

Heavy Metal Accumulation

The study revealed an alarming increase in heavy metals—Cadmium (Cd), Lead (Pb), and Arsenic (As)—over the three-year period. For instance, Pb concentrations reached up to 43.89 mg/kg in Ohaozara in 2021 compared to 1.78 mg/kg at the control. These values, although below the threshold limits, show a rising trend that poses long-term ecological and health risks. The accumulation is attributed to the illuviation of contaminants from collapsed structures, echoing the observations by Adagunodo et al. (2017) and Tóth et al. (2016), who linked heavy metal proliferation to debris pollution in urban environments.

Statistical analyses confirmed these findings, with F-ratios of 232.944 and 4.62 and p-values of 0.000 and 0.012, indicating that both physicochemical and heavy metal variations were significant at $p < 0.05$.

6.1 Conclusion

This study establishes a clear link between construction debris from building collapse and the degradation of soil physicochemical properties in Ebonyi State. The consistent trends of increased bulk density, reduced porosity, nutrient depletion, and rising heavy metal concentrations paint a stark picture of environmental stress induced by unmanaged construction waste. These changes compromise the soil's capacity to support both agriculture and infrastructure, thereby posing a dual risk to food security and structural safety in affected communities.

Given the significant statistical evidence and the environmental implications observed, it is evident that building collapse debris contributes to severe soil degradation. Urgent intervention is needed to implement effective waste management practices, establish zoning laws that prevent illegal dumping, and develop land restoration programs for affected sites.

Finally, the study addresses a significant research gap by providing empirical data from Ebonyi State and supports the call for evidence-based policymaking to mitigate the growing environmental and public health threats in the region.

6.2 Recommendations

The following recommendations were made from the result of the study: comprehensive waste management and remediation strategy tailored specifically tor handling construction debris and hazardous materials to be developed and implemented by the Ministry of Environment of Ebonyi State, Eco-friendly architecture to be adopted by both building and environmental professionals and advanced building construction technology to be adopted by building material companies and building professionals. Adoption of light-weight and collapsible/demountable structures on soil that are already affected pending remediation actions.

REFERENCES

Abimbola O; Adebayo, S. O. and Windapo K (2012) Improving building techniques, *Proceedings of a Workshop on Building Collapse: Causes, Prevention and Remedies.* The Nigerian Institute of Building, Lagos State Chapter, April.

Adagunodo.T.A., Sunmonu.L.A., Adabanija M.A., Suleiman E.A., Odetunmibi O.A., ((2017)) Geo-exploration of radio element's datasets in a flood plain of crystalline bedrock, *Data Brief*, 15: 809–820.

Adebowale, P. A. (2016) "Building collapse in Nigeria: issues and challenges". *Proceedings of the International Journal of Art and Sciences*. pp. 99–108.

Adhikari D and Hartemink, G. (2016). Minimizing the Collapse of Buildings in Lagos State. *Proceedings of the National Seminar on effective Contract Management in Construction Industry,* Nigerian Institute of Building, 22-23August, pp 174-187.

Agwu, D. (2014). *Principles of emergency planning and management*. Harpended: Terra Publishing.

Akande, B. F., (2016). Effective sites and services scheme as a means of solving Low-income housing need in Nigeria cities. *Journal of Economics and International Business Management* vol. 2(3), pp. 50-58, September 2014. Science-web Publishing.

Akintola, O. O., Adeyemi, G. O., Olokeogun, O. S., and Bodede, I. A. (2021). Impact of wastes on some properties of soil around an Active Dumpsite in Ibadan, Southwestern Nigeria, *Journal of Bioresource Management*, 8 (3): 27-40

Akujieze O. O and Irabor O. (2014). Causes, Effects and remedies to the incessant building collapse in Lagos State, Nigeria. *International Journal of Basic & Applied Sciences*: 16 (04): 12-29

Allman. O.O. Amakiri S Aminu D and Aluko (2015). Building collapse in Nigeria: architects' perspective. *International Journal of Engineering and Engineering Technology*, Federal university of Technology Akure, 6(2): 90-96.

Anchal S, Ashok K. G, and Rajiv G (2018) Impact of open dumping of municipal solid waste on soil properties in mountainous region. *Journal of Rock Mechanics and Geotechnical Engineering*, 10: 725-739

Arpita N and Ingrid L (2012). Collapsed structures dumpsite related changes to physicochemical properties of ultisols distributed on calcareous sedimentary rocks. *Journal of Sustainable Development;* 5(8): 52-68

Azuka, C. V., and Ezeme, C. (2023). Influence of municipal solid waste dumpsite on soil physicochemical properties and vertical distribution of heavy Metals, *Journal of Bioresource Management*, 10 (3): 104-118

Bala, K. (2017) "Building collapse in Nigeria: challenges and remediation". *11th Annual Lecture/ Conference. Faculty of Environmental Sciences, Nnamdi Azikiwe University,* Awka, Nigeria. 5th – 7th June, 2017

Battye, W., Aneja, V. P. and Roelle, P. A. (2003). Evaluation and improvement of ammonia emission inventories. *Atmos. Environ*. 37:3873-3883

Blevins, R.L., and Frye, W.W., (2013). The effects of building collapsed waste on soil properties. pp. 99-110.

Brady, N.C and Well, R.R (2008). *The nature and properties of soils*. Pearson Prentice Hall.

Bremner, J.M and Mulvancy, J.W (1982) Total nitrogen in Page A.L., Miller, R.H and Keeny,D.R eds Methods of soil analysis .Part 1: *ASA*,No.9 Madison.

Carter, M.R. and Ball, M.C. (1993). Soil Porosity in: soil sampling and methods of soil analysis. Carter, M.R. (ed), *Cannadian Society of Soil Science*, Lewis Publication, Boca. Raton, USA, Pp18-20

Chabbi, G Sheehan, S. W and Obi, N.I. (2017). Building collapse in Nigeria: the causes, effects, consequences and remedies, *International Journal of Civil Engineering Construction and Estate Management.* 3(4). 14-15.

Chendo I.G. and Obi N. I. (2015). Building collapse in Nigeria: the causes, effects, consequences and remedies. *International Journal of Civil Engineering, Construction and Estate Management* 3(4): 41-49

City of Minneapolis (2008). Building Design, Buildability and site production. *Proceedings of A Workshop on Building Collapse: Causes, Prevention and Remedies,* The Nigerian Institute of Building, Ondo State, 23-24October.

Dhere AM, Chandrasekhar BP, Pratapsingh BP, and Dhanraj AP. (2018) Municipal solid waste disposal in Pune city: An analysis of air and groundwater pollution. *Current Science*; 95:773-777.

Directorate of Irrigation Research and development (DIRD) (2009). Laboratory testing procedure for soil and water sample analysis, *Pune*

Ebehikhalu N. N, and Dawan P; (2014) Spatial analysis of building collapse in Nigeria: a study of the causes and problems. *Journal of Economics and sustainable Development.* 5(2).

EBMOI (2005), Ebonyi state ministry of Information: A publication of the ministry in 2005: *Diary of the ministry.* Pp 17-23

EBSEMA Annual Reports; (2019). "Incessant incidents of building collapse in Ebonyi state: a challenge to stakeholders 10(4)75 – 84.

Ede, A. N. (2010) Building Collapse in Nigeria: The trend of casualties in the last decade. *Chennai India.Proceeding Booklet,* 122–131.

Ede, A. N. (2017) Strategies for enhancing the local governments roles in minimizing the collapse of Buildings. *Proceedings of the National Conference on Effective Contract Management in the Construction Industry.* Nigerian Institute of Building, 22-23August, pp188-200

Ekeu-wei, I. T. K. I. Azuma and Ogunmuyiwa F. B. B. (2018). Assessment of environmental impact of solid waste dumpsites using remote sensing in Benin City, Nigeria, *Nigerian Journal of Technology***,** 37(1): 275 – 285

Ekpe E R, Ghezzehei, T.A., and D. Or. (2005). Dynamics of soil aggregate coalescence governed by capillary and geological processes. Water Re- in field conditions the soils can be wetted at different *sour. Res*. 36:367–379.

Eshcer, K., (2011). Assessment of heavy metals in a municipal solid waste dumpsite. Workshop on sustainable landfill management. *Chennai India. Proceeding Booklet,* 139–145.

Essay UK, (2017) Quality management implementation in the Egyptian construction. *Journal of Management in Engineering*; 24(3):156–161.

Essoka, A. N. and Esu, I. E. (2001). Physical properties of inland valley soils of Central Cross River State, Nigeria. In Management of Wetland Soils for Sustainable Agriculture and Environment, *Proceedings of the 27th Annual Conference of the Soil Science Society of Nigeria*, University of Calabar, Calabar.

Famoroti, F. (2005, March 30). Before the next building collapse. *The Punch* (p. 9)

Feng, T., Chen, H., Polyakov, V. O., Wang, K., Zhang, X., and Zhang, W (2015).: Soil erosion rates in two karst peak-cluster depression basins of northwest guangxi, china: comparison of the Rusle model with 137cs measurements, *Geomorphology*., 253: 217-224.

Flores M, Famoroti, J. and Arokoyu S. B (2011). The Egan report - *rethinking construction. Report of the Construction Industry Task Force* to the Deputy Prime Minister. Rertievedfrom http://www.ciob.org.cn/Resources/.

Francis K. M (2013). Influence of solid waste management practices on the socioeconomic lives of Karai residents in Naivasha municipality, Nakuru County, Kenya *Master degree dissertation.* Department of Economics and Management of the University of Nairobi.

Ganobi, J.A. (2017). An assessment of building regulations and standards and the implications for building collapse in Nigeria. *Proceedings of a workshop on building collapse: causes, prevention and remedies*. The Nigeria institute of building, Ondo State, 23-24 October

Gavett S. H., (2006). Effect of phosphate rock sources on biological nitrogen fixation by soybean. *Fertilizer Research* 34, 153-159

Hassan B I, Olsson, and A. Bahri Hawken, D.R. (2016) *Quality handbook for the Architectural, Engineering and Construction Community* (Milwaukee, WI, ASQC Quality Press)

Hatfield, A.B., Stanissious, T. D., Okwulehie, K. and Princewill, U. (2017). Comparative Analysis and Factors of Building Collapse in Notable Cities of a nation. *International Journal of Research and Scientific Innovation (IJRSI), 8(8):73-79.*

Ibrahim, S. O. (2013). Factors Influencing Solid Waste Management in Garissa Municipality. *Waste Management* 3(2): 23–29.

Ichipi, E.B.; and Senekane, M.F. (2023) An evaluation of the impact of illegal dumping of solid Waste on Public Health in Nigeria: A Case Study of Lagos State. *Int. J. Environ. Res. Public Health*, 20: 7069.

Igwe C.A (2012) Gully Erosion in Southeastern Nigeria: role of Soil Properties and Environmental Factors *http://dx.doi.org/10.5772/51020* visited 22/12/2018

Ijaodola, A.G; Weje, Ikezam I; and Wachukwu, F.C (2024). Socio-economic effects of open saste Dumpsite on Residents of Selected Communities in Rivers State, Nigeria. *International Journal of Innovative Science and Research Technology* 9(1): 292-304

Kabiru P (2021) in Lattery, Katharine. *The Igbo People- Origin and History* www.faculty.ucr.edu. School of English, Queen's University of Belfast. Retrieved April 20, 2022

Knudsental, H (1982). Methods for the determination of ECEC and exchangeable bases in calcareous soils. *Agrochimica* 54 (2):103-114

Ku, B., Jeppesen, E., Conley, D.J., Sondergaard, M., Larsen, S.E., Ovesen, N.B. and Castensen, J. (2015). Nutrient pressures and ecological responses to nutrient loading reductions in Danish Streams Lakes and coastal Waters *Journal of Hydrol*ogy, 304, 274–288.

Kumar M, Prakash V (2020) A review on solid waste: its impact on air and water quality. *J Pollut Eff Cont* 8 (4): 1-3

Lal, R. and B.R. Singh. (2016). Effect of soil pollution on crop productivity in East Africa. *Journal of Sustainable Agriculture* 13(1): 15-41

Lal H. and Singh, L (2018).*Project Quality Management: Why, What and How*. Fort Lauderdale, Florida: J. Ross Publishing. p. 41. ISBN 1-932159-48-7

Lazola B, Hlekani M.K, Oseni A, Motebang D.V. Nakinb and Zendy M (2023). Impacts of illegal solid waste dumping on the water quality of the Mthatha River. *Water Practice & Technology*, 18(5):

Mansaray- Pearce, S. (2019). Envionmental and Socio-economic effect of Solid Waste on Local Livelihood in Sierra Leone. A Case Study of Freetown Municipality. International *Journal of Research in Business Studies and Management*, 6(7),:14- 22.

Massreshaw A.A (2017). Social impact of solid waste temporary storage area in Addis Ababa City. *International Journal of Scientific Engineering and Science, 1(10): 1-6,*

Mbah, C.N., E. E. Attoe and U.F. Nwagu (2013). Influence of different soil management practices on soil properties and its implication on soil productivity. *Journal of Agriculture and Veterinary Science.* 5(1): 19-22

Mbah, C.N., Njoku, C., Okolo, C. C., Attoe, E. and Osakwe, U.C. (2017). Amelioration of a degraded Ultisol with hardwood biochar: Effects on soil physicochemical properties and yield of cucumber (Cucumis sativus L). *African Journal of Agricultural Research.* 12 (21), 1781 – 1792.

McLean, E.O. (1982). Soil pH and Lime Requirements in: Page, A.L. Methods of soil analysis. Part2 chemical and microbiological properties, Second ed. *Agronomy no.9 ASA*. SSSA. Madison. WI. USA

Mitsuo Y (2018) Technical and social factors of dumpsite collapse in developing countries and its consequences: case studies in Mozambique and Sri Lanka *APLAS TOKYO 2018 The 10th Asia-Pacific Landfill Symposium - The tenth anniversary - 24 - 26 November 2018.* Pp 23-28

Mweogha M, and Kihampa M (2010) Swell-shrink behavior of expansive soils, damage and control. Electr J Geotech Eng 17:2673–2682

MWMO (2008). The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century. *Report of the IUCN Renowned Thinkers Meeting*,

29–31January 2006. Retrieved on: 2009-02-16.

Nelson, D.W. and Sommer, L.E. (1996). Total carbon, organic carbon and organic matter. in: Spark, D.L; Ed., Method of soil analysis, Part 3, *American Society of Agronomy* Vol. 34, and 961-1010.

Nwite, J.N, Okolo and Okonkwo, C.I (2018) Evaluation of productivity of a degraded ultisol amended with animal wastes in Abakaliki, Southeastern, Nigeria. *Elixir Agriculture* 71 (2014) 25167-25172

Nwite, J. N. and Okolo, C. C. (2020). Organic carbon dynamics and changes in some physical properties of soil and their effect on grain yield of maize under conservative tillage practices in Abakaliki, Nigeria. *African Journal of Agricultural Research*, 12(26): 2215-2222.

Obi, M.E. (2000). Soil physics. *A compendium of lectures*. Atlanto Publishers, Nsukka, Nigeria, 28p

Obodoh D., Amade B., Obodoh C. and Igwe C. (2019). Assessment of the effects of building collapse risks on Nigerian built environment. *Nigerian Journal of Technology,* 37(3): 222– 312

Obodoh D., B. Amade, C. Obodoh and C. Igwe (2021) Effects of building collapse risks on the stakeholders in the Nigerian built environment. *Nigerian Journal of Technology (NIJOTECH), 38(4). 822– 831*

Odum, E.N., Ogunbajo, R.A and Oke, A.O (2011) Assessment and management strategies for the receding watersheds of Ebonyi State, Southeast Nigeria. *Journal of Environment and Earth Scienc*e, VOL.3, No.3, 2011).

Okonkwo B.C.N., Okore, I.K., Chukwu, G.O., Okonkwo, J.C., Olejede, A.O. (2019). Agronomic potentials of poultry manure and defatted palm kernel cake in sweet potato production on Typic Paleudult. *Proceedings of the 43th Annual Conference of the Agricultural society of Nigeria,* Abuja, pp. 56-59.

Okonkwo, C.I. (2010). Effect of urning and Cultivation on soil properties and microbial Population of Four Different Land Use Systems in Abakaliki. *Research Journal of Agriculture and Biological Sciences*, 6(6): 1007-1014.

Okoye, C.O., Irem, C.O., and Tafiwa, H.Y (2017). Environmental and economic effects of Abakaliki rice mill company ltd on Amagu Community-Ebonyi State, Nigeria. *Environmental Review,* Vol. 6, N0 1, 2017. Unizik, Awka.

Oladeji, S.O, Ajayi, O.T, Akala, V.T, Leramo, G.F and Odole, O.B. (2021). Socio economic impact of indiscriminate dumping of solid wastes on the inhabitants of Akure and Ibadan Metropolitan areas, Nigeria. *Proceedings of the 4th edition of world environmental conservation conference* 5th June, 2021

Olagunyi, K.C., Ugochukwu, S.C and Ezeokoli, F.O., (2013) Addressing the building collapse problem in Nigeria: exploring the builder's potentials, the builders' Liability Insurance Option and the Health ans Safety Management Plan. *Environmental Review,* Vol. 6, N0 1, 2017. Unizik, Awka.

Olanitori L.M. (2011). Causes of structural failures in a Building: case study of a building at Oba-Ile, Akure. *Journal of building Appraisal*. 6, (3-4): 277-284.

Olawale H.S, Adedotun T.A, Abiodun S A, Oluwatoyosi Ol S, and Biola K B (2017) Impact of dumpsites on the quality of soil and groundwater in Satellite Towns of the Federal Capital Territory, Abuja, Nigeria. *J Health Pollution 14: 15-22*

Oleghe, E.E. and Chokor, J.U. (2014). Effect of gully erosion on soil properties in some soils of Edo State, Nigeria. *National Journal of Soil Science* 24(1):174-180

Oluwatoyin R.N. (2022). Soil Aggregate Stability and Erodibility in different gully sites in Parts of Kaduna State, Nigeria. *Ethiopian Journal of Environmental Studies & Management* 7(2): 188 – 196

Onwudike S.U, Asawalam D.O, and Ano AO. (2016) Comparative evaluation of burnt and unburnt agro-wastes on soil properties and growth performance of cocoyam in a humid environment. *Asian J. Agric. Res.;* 9:276-292.

Onwuka, N O Olusola, K.O., Ata, O. and Ayangade, J.A. (2012). Quality and structural strength of sandcrete blocks produced in Ile-Ife: A preliminary Investigation. *Journal of Environmental Technology, Federal University of Technology, Akure*, 1 (1&2):136-142

Oseghale, G.E and Ikpo, I.J., and Ajayi, O. D. (2021) Causes and effects of building collapse in Lagos State, Nigeria, *Civil and Environmental Research*, 7 (4), 1- 11

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences of the United States of America* 104(39):15181–15187

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science* 325 (5939):419–422.

Ostrom, E., and M. Cox. (2010) Moving beyond panaceas: a multitier diagnostic approach for social-ecological analysis. *Environmental Conservation* 37(4):451–463.

Owuamalam, R.A., (2012). An assessment of housing Maintenance and Management in Federal Housing Estates in Abuja, Nigeria. *Journal of the Nigerian Institution of Estate Surveyors and Valuers 38(1) 65-77*

Oyedele, P. O., (2018). "Physicochemical changes associated with soil receiving Cassava Mill Effluent". *Journal of Chemical Society of Nigeria*. 31(1):69-73.

Oyinloye, A. O and Olanrewaju J.O. (2015). Contemporary issues in building collapse and its implications for sustainable development. *Buildings* 2: 283-299

Page, A. L., Olsen, S.R. and Sommer, L.E. (1982). Phosphorus n. method of soil analysis. part2 ed. Miller, R.H., Keeny, D.R. and Madison, W.I. *American Society of Agronomy*. P 1572

Phillips, J. D. (2002) Designing matched band-pass and azimuthal filters for the separation of potential field anomalies by source region and source type. In: 15th geophysical conference and exhibition, *Australian Society of Exploration Geophysicists*, extended abstract, pp. 1–4

Rakesh N, Sutton,M. A, Zhang, M and Narayanan DS. (2012) Impact of solid waste effect on ground water and soil quality nearer to Pallavaram solid

waste landfill site in Chennai, Rasayan J Chem.;4:828-836.

Sam-uroupa, E.R; and Ogbeibu, A.E (2020) Effects of solid waste disposal on the receiving soil quality in Benin Metropolis, Nigeria. *J. Appl. Sci.* Environ. Manage, 24 (2) 393-401

Sev, A. (2009). How can the construction industry contribute to sustainable development? A conceptual framework. *Sustain. Dev.*, *17*, 161–173.

Shanmuganathan, A.A and Rajendran, J.A. (2018). Incessant building collapse: a case of a Hotel in Akure, Nigeria. *Journal of Building Appraisal.* Vol 6. Pp 241-248. *The World Gazetteer*. Retrieved 2007-04-03.

Shivanna, A.; and Nagendrappa, R.A. (2014). Comparison of climate forcing due to chlorofluorocarbons and Carbon Monoxide; *Geophys. Res. Lett.*, *23,* 65-68.

Sholadoye M, Tomori A.A,Oyeleke R.B, Jimoh Y. A (2018) Economic impact appraisal of municipal solid waste dumpsite on nearby properties using HEDONIC Model. *International Journal of Advanced Research in Science, Engineering and Technology*5 (6): 6165-6173

Singer, M.J., and Munns, D. N. (2006). *Soils: an introduction*. Pearson Prentice Hall.

Singh E, Tiwari S, and Agrawal M. (2019) Effects of elevated ozone on photosynthesis and stomatal conductance of two Soybean varieties: A case study to Assess Impacts of One Component of Predicted Global Climate Change. *Plant Biol Stuttg* Ger11 (Suppl. 1):101–8.

Solanki, P. and Chavda, F. J. (2012). Accumulation of Cr, Pb, Cu, Ni, Zn and Cd in soil following irrigation with untreated urban effluents in Australia. *Environmental Pollution,* 94 (3), 317–323.

Steel, R.G.D. and Torrie, J.A. (1980). *Principle and procedures of statistics: a biological Approach,* McGraw-Hill Companies, Inc. New York, USA. 73.

Steve, D.L (2008). Effect of past soil erosion on crop productivity in *I*ndiana. J. Soil Water Conserv. 44, 604–608.

Stolt M.J. (1997) Soil erodibility indices under different land uses in Llwer Shiwaliks with the revised universal soil loss equation RUSLE, USDA Handbook; 703, *United States Department of Agriculture* (USDA), Washington, D.C.

Tchounwou P.B., Yedjou C.G., Patlolla A.K.,and Sulton D.J., (2012) Heavy metals toxicity and the environment,*EXS*,10(1): 133–164.

Tel, D.A. and Hagarty, M (1984). Soil and plant analyses. Study guide for agricultural laboratory directors and technologists working in tropical regions; printed by *International Institute of tropical Agriculture (IITA), Ibadan, Nigeria* in conjunction with the *University of Gueiph, Gueiph, Canada*. 277p

Toth G.,T. Hermann,M.R.and DaSilva,L.M (2016) Heavy metals in agricultural soils of the European Union with implications for food safety,*Environ.Int.*88: 299–309.

UNEP (2013), Environmental risks and challenges of anthropogenic metals flows and cycles, in E. vander-Voet, R. Salminen, M. Eckelman, G. Mudd, T. Norgate, R. Hischier (Eds.), A Report of the Working Group on the Global

Metal Flows to the *International Resource Panel*, ,p.231.

Uwadiegwu B. O. and K. E. Chukwu (2013). Strategies for effective urban solid waste management in Nigeria. *European Scientific Journal.* 9(8): 296-308

Wardle, D.A.; Bardgett, R.D.; Klironomos, J.N.; Setala, H.; van der Putten, W.H.; Wall, D.H.(2006). Ecological Linkages between above ground and belowground biota. *Science* 304, 1629–1633

Windapo, A.O and Rotimi (2012) Contemporary issues in building collapse and its implications for sustainable development. *www.mdipi.com.journal/buildings.Visited/12/08/2019*

Zhang, H. M., Moore, D., He, P., Ritsema, C.J., and Geissen,V.(2011). Extension of a GIS procedure for calculating the RUSLE equation LS factor. *Journal of Computers Geosciences,* 52: 77–188.