RIVERS STATE UNIVERSITY
PORT HARCOURT

RESOLVING THE RISKS ASSOCIATED WITH HUMAN AND ENVIRONMENT INTERACTIONS USING *IN VITRO* BIOACCESSIBILITY TESTS

AN INAUGURAL LECTURE

BY

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DEDICATION

This Inaugural Lecture is dedicated to Almighty God

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The Vice-Chancellor and Chairman of this occasion
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Heads of Departments and Units
Distinguished Professors and Members of Senate
Academic, Administrative and Technical Staff
Graduate and Undergraduate students
Ministers of God
Your Royal Majesties and highnesses
All invited Dignitaries
Distinguished Ladies and Gentlemen

1.0 HUMAN AND ENVIRONMENT INTERACTIONS

1.1 ORIGIN OF HUMAN AND ENVIRONMENT INTERACTIONS

There are several theories about the origin of man and nature or man and environment in published literatures. They include special creation (concept of God), spontaneous generation (concept of originating from non-living matter), steady-state (the concept of no explainable origin), cosmozoan (the concept of aliens from another planet) and biochemical evolution (the concept of originating from chemical and physical processes).

As a bible student the focus here will be that of special creation; which emphasizes that God created the world/universe (human and environment). The details of the Christian account of creation can be found in Genesis (1:1-26). The notion that human race and the earth, and all other animal and plant species were created in six days. God also created light, day and night, land, surface and ground waters, seasons. At the end of creation God observed that creation was very good before He ordered human race to have dominion over the environment. However, can we assert that have sustained God's creation?

The assessment of the nature of interactions and anticipated impacts have been presented at several local and international platforms by professional environmental groups and advocacy groups. However, some presentations havepainted over-simplified picture of interactions and impacts, far from the very complex interactions (Fig 1.1). As a result of the several complex interactions, projected impacts are sometime under-estimated or over-estimated. These complex interactions and their projected impacts have resulted in several unexplainable impacts.

The pattern of interactions between human with his environment has elicited varying inferences. A school of thought has raised alarm about the negative impact of our exploitation of the environment. Contrary to this posture others have suggested that the impacts, if any, are not as bad as escalated. This presentation will attempt to provide some scientific evidence to clarify the real situation, and highlight uncertainties where they existand report deliberate researches conducted to resolved some of such uncertainties.

1.2 UNSUSTAINABLE EXPLOITATION OF THE ENVIRONMENT

Human desire for civilization and better life has triggered unsustainable exploitation of environmental resources. The unsustainable exploitation commenced with the shift from hunting and gathering of farm produce to a system of mechanized farming. Industrial revolution demanded more feedstock from the environment.Also, man's desire for economic enhancement and nation's interest for posterity have been indicted as drivers of unsustainable exploitation of the environment.

The excessive pressure of human actions on the limited resources of the environment has led to imbalance of the ecosystem. The imbalanceresults from our desire for food to cater for large populations, fuel for transportation, natural resources for electrical power to sustain the built environment and industries, our desire for jewelries, and the desire for effective national security.

The impact on environmental resources includes, mechanized tilling of land resources, application chemical enhancers and overgrazing of vegetation that have led to sedimentation, deforestation and the pollution of land and surface water resources. Our desire for more energy has prompted the excessive exploitation for fossil fuel in the form crude petroleum and mining for coal with known adverse impact on environment. Transportation also adds pressure to demand for crude petroleum and coal. The high street value of gold and other geological resources has driven the mining sector and left behind its adverse legacies. The use of modern transportation vehicles has added to the pollution of surface waters, land and the atmosphere. The unregulated exploitation of environmental resources has been described as unsustainable development.

1.3 ENVIRONMENTAL PROTECTION AND SUSTAINABILITY

The impacts of unregulated exploitation of environmental resources have been highlighted and escalated at numerous fora at national, continental and global levels. As a result of the anticipated impacts governments and global agencies have initiated at several times processes and policies to protect the environment. In Nigeria agencies likes, National Oil Spill Detection and Response Agency (NOSDRA), National Environmental Standard and Regulation Enforcement Agency (NESREA), are saddled with the responsibility. Popular global agencies include United States Environmental Protection Agency (USEPA), Scottish Environmental Protection Agency (SEPA), and Environment Agency – GOV.UK (EA).

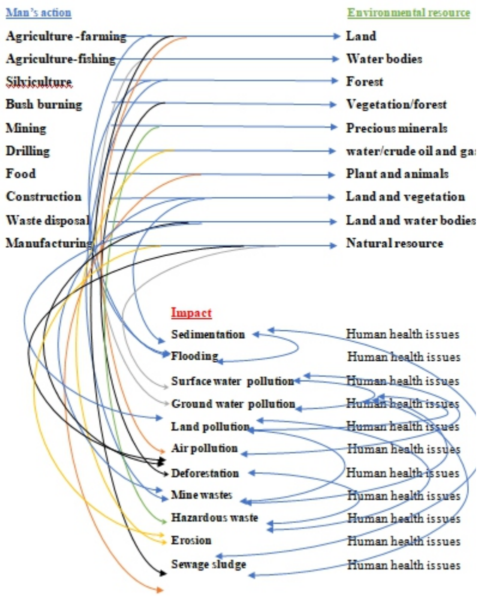


Figure 1.1: Man, and Environment Interactions

Sustainability is the process of meeting present human needs in a manner that do not adversely impact future generations and environment. After several years ofunregulated exploitation of environmental resource, human race realized an imbalance and commenced the process of normalization of the human and environment interactions. The deliberate attempts to normalize by human race is christened "sustainable development". The process requires that we placate simultaneously the social, economic and environmental needs.

Today in Nigeria we our struggling to meet our energy and food needs, suggesting we are less likely to implement sustainability in our desperate attempt to meet our food and energy targets. Currently our national approach to monitoring and regulating the environment is skewed. The country is so big that most of us in southern part of the country believe that the main natural resource is crude petroleum, however, the country also blessed with valuable mineral resources like gold, lead, tin, gemstones and lithium. In spite of large solid minerals that are mined in eastern, western and northern Nigeria, there are no dedicated environmental agencies to cater for mining. The government, however has theNational Oil Spill Detection and Response Agency (NOSDRA) dedicated to handle mining and refining of crude petroleum resource. The establishment of an environmental agency dedicated to solid mineral mining and process is long overdue. Because of the absence such dedicated regulated agency several adverse human and ecological incidents (eg. Infants death in Zamfara State) are over looked.

1.4 RELATED RESEARCH OUTPUT

In 2011Boisa**,** *et al***., (**2023**)**inquired about cause of lead poisoning of children of Mitrovica, Kosovo. The research design required sampling of surface soils, human hair and mine wastes. Analysis were conducted for As, Cd, Cu, Pb and Zn. Results indicated concentrations above 1000 mg/kg, 10 mg/kg, 1000 mg/kg, 1500 mg/kg and 10000 mg/kg for As, Cd, Cu, Pb and Zn, respectively. These observed levels were above Dutch target value and UK CLEA soil guideline value. In a related study Boisa *et al*., (2020) investigated two mining communities in Nigeria. A lead mining town, Enyigba in Ebonyi State and a gemstone mining town, Eggon in Nasarawa State. For both town road, mine, residential and street samples were investigated. Results indicated As concentration range of 13.4 – 56. 1 mg/kg and 111.8 – 143.1 mg/kg were reported for gemstone and lead mining towns, respectively. While Pb concentration range of 77.6 – 461.8 mg/kg and 750.2 – 8630.5 mg/kg were reported for Eggon and Enyigba, respectively. The finding of both studies highlights how human activities excavates potentially toxic elements that were originally beneath the earth surface to the surface in loose form with a likelihood to harm both human and ecology.

Boisa and Gogonte, (2017) conducted an assessment of the impact crude petroleum spill on wetland sediments in eleven Andoni communities. The communities include Inyogorog, Asarama, Alalanga, Nbikibgi. Opokiri, Ajakajak, Okputumbi, Ererekiri, Nkoro, Ataba and Yeregbeni. The focus was to assess the impact of massive crude petroleum spills on wetland sediments, a matrix that previous studies have overlooked. The results indicated that the typically acidic wetland sedimentswere gradually becoming less acidic. The study also highlighted the elevated concentration (2.2 - 21.12 mg/kg) of Cd.

Boisa and Falodun,(2017) conducted a study to compare the relative impacts of human activities like,auto-mechanic, crude petroleum refining and solid mineral mining on the distribution of heavy metals in surface soils. The results are depicted in the Table 1.1. The results highlighted the relatively low concentrations of toxic elements exposed crude petroleum spills when compared to lead mining activities. In a related study conducted by Boisa and Eric,(2017) to assess the concentrations of lead in surface soils exposed auto-mechanic spills in Port Harcourt city indicated a range of 40 to 411 mg/kg. Both studies indicated lead concentrations that exceeded the State regulatory limit of 200 mg/kg set by RSMenv. These data also highlight how man's activities elevates levels of inorganic contaminants in the environment.The elevated concentrations reported by Boisa and Falodun (2017) were also reported in a study by

Boisa and Odagwe (2019) for deposited dust in the built environment for rural gas flare community in Delta State. The range of concentration reported for Cd and Pb were 3.0 – 6.2 mg/kg and 79.5 – 132.4 mg/kg, respectively.

Table1.1:The distribution of heavy metals in surface soils exposed to different human activities

Element	Crude petroleum	Auto-mechanic	Mining
	Boisa and Falodun, (2017)		
As (mg/kg)	37.8	25.0	55.2
Cd (mg/kg)	7.4	7.7	18.4
Pb (mg/kg)	404.0	401.4	4939.0
Zn (mg/kg)	109.2	1983.0	2220.0
	Boisa and Eric, (2017)		
Pb (mg/kg)	411		

The desire to have a better understanding of air quality of Port Harcourt city black soot impact prompted a study conducted by Akinfolarin et al.,(2017) titled "Assessment of Particulate Matter-Based Air Quality index in Port Harcourt, Nigeria". The design covered four locations, namely; Rumuolumeni, Oginigba, Eleme and Omuanwa. The summary of the results is presented in Table 1.2. In a related study by Okeh-Wokeh et al., (2020)., designed to assess atmospheric particulates in Aba, Port Harcourt and Elele Alimini the results indicated elevated concentrations of PM10 sized particulates in the dry season for all locations (Table 1.2). Also, the urban areas indicated more particulate matter than the rural areas (Table 1.2).To further understand the likely primary sources of particulates in our atmosphere Gogonte et al.,(2021) developed a novel method of sampling fly ash from multiple matrices. The design has gone on exhibitions to represent this University and is currently awaiting patent.

Tanle 1.2: PM_{10} levels in studies conducted by Akinfolarin *et al* (2017) and Okeh-Wokeh *et al.*, (2020)

Location	Dry season (m^3)	Wet season (m^3)
Akinfolarin *et al* (2017)		
Rumuolumini	1139.6	54.2
Oginigba	1199.4	50.4
Eleme	1053.9	78.9
Omuanwa	516,7	11.4
Okeh-Wokeh *et al.*, (2020)		
Aba	635.7	55.6
Port Harcourt	555.3	48.6
Elele Alimini	191.9	22.3

As a result of our current limitations in solid wastes management in the areas of containment and treatment a few studies were also conducted with others. Iyama*et al.*, (2018) assessed nutrient (NO_3^-, PO_4^{2-}, SO_4^{2-} and NH_4^+) status of leachates from selected dumpsites in Port Harcourt. The results indicated highly elevated concentrations of the nutrients and authors suggested the nutrients enriches surrounding surface soils and the have capacity to pollute surrounding surface water bodies.

The human and environment interactions do not only impact the environment, there are also situations when the natural environment adversely impacts human subjects. In an attempt to beautify self, we search through the environment resources that can aid our desire. In northern Nigeria there is geological stone locally called Tiro (facial eye liner) that women use for both lip and eye lining. Boisa and Ogbede (2016) investigated different brands of traditional eye liner for its toxic heavy metal content. The results obtained indicated the following ranges. For Cd, 26 – 2430 mg/kg, for Cr, 111-296 mg/kg, for Pb, 650 – 671000 mg/kg and for Zn, 296 – 2710 mg/kg. The concentrations for Cd and Pb are more hundred times above limits set for safe use of cosmetic. These results have highlighted how the environment can adversely affect humans.

Man, traditionally depended on nature for medicine. One of the early reports was the consumption of clay for management of ailments. Boisa et al., (2017) and Boisa et al., (2023) investigated different indigenous lick soils that are deliberately ingested mostly by women in Nigeria for their and nutrients and toxic elemental contents. The list of claysof clays investigated and their alleged medicinal effects are provided in Table 1.3a. The results for their nutrient and potentially toxic elements are indicated in Table 1.3b.

Table 1.3a: Different lick soils consumed in Nigeria and their alleged medicinal effects

Name of Lick soil	Medicinal effect
Ajanzu	Tooth ache
Biter Bitter	Stomach problem
Black stone	Asthma and diabetes
Nzunwa	Pregnancy issues
Nzuobi	Heart problem
nzuokkpukpo	Bone problem
Nzuike	Convulsion and skin rashes

Table 1.3b: Contents of potentially toxic elements and nutrients in lick soils

Element	Range (mg/kg)
	Potentially toxic elements
As	14.4 – 89.3
Cd	3.2 – 29.2
Cr	21.8 – 123.8
Fe	667.0 – 70858
Pb	30.0 – 152.0
Mn	832.0 – 3673.0
Zn	23.4 – 410.1
	Nutrients
Na	56.9 – 436.8
K	Bd - 60.0
Mg	Bd – 387.3
Ca	122.9 – 373.7

2.0 RISK ASSESSMENT

2.1 RISK

Risk is a measure of the probability that a harmful event arising exposure to a chemical may occur under certain specific conditions during its use or during disposal according to IUPAC. No chemical whether man made or natural is completely free from toxic effects. The possibility of potential risk is always certain irrespective of how the chemical is handled.

Environmental risk assessment of polluted sites traditionally was conducted by comparing environmental concentration with regulatory limits. This trend is still obtainable in most developing countries. The modern trend involves inputting environmental data into risk assessment models to predict exposure doses and the likelihood of occurrence of specific disease conditions. There is need for Nigerian professionals to update themselves for modern risk assessment.

The job of a chemical risk assessor is to obtain data relevant to a given chemical substance and estimate its potential hazard and provide information to the public in user friendly manner. At a supervisorylevel in industry and construction the assessor is expected to lower the possibility of exposure of staff members to harmful substances by insisting on safety protocols while handle chemicals.

As a nation our acceptance that risk exist is less likely in our daily handling of chemicals because most of us are beclouded by our believe that God will take care of us in every situation. This notion exposes us to avoidable risks in our daily handing of chemicals. Our non-implementation of protocols designed to minimize exposure to risk has translated into several reported human disaster at the state and national levels. Examples include, explosion of domestic and industrial gas pipeline in Lagos, explosion of national trunk crude petroleum and refined products pipelines, and the explosion of military ordinances in Lagos.

2.2 RISK ASSESSMENT PROTOCOL

The classical practice of environmental scientist involves initial pre-field survey, field trips for sampling, sample pre-treatment, analytical sample treatment, analysis of treated samples and data analysis. The data analysis is typically conducted to ascertain the trueness, precision and patterns. The data generated at the end are then compared with regulatory limits.

Modern practice emphasizes that a risk assessment is conducted. Today the marriage of environmental, public health and toxicology data and their subsequent analysis has yielded algebraic equations relating relevant variables. The resulting algebraic equation following is known as mathematic models. Most models of chemical phenomena require that some criteria are satisfied before their successful applications.

Countries like the United State, United Kingdom, Italy and Dutch over the years have generated large environmental, public health and toxicological database and used same to develop easy-to-use risk assessment models. Examples include the USEPA soil ingestion exposure assessment tool;

DI = (EC x SIR x ED) / BW

Where EC is the environmental concentration of a given chemical contaminant in the soil, SIR is the soil ingestion rate (mg/d) with the default set at 100 mg/d for 2-6 year old US children, ED is the exposure duration as is mostly estimated as 1, and the BW is the body weight (kg).

The UK version is called the Contaminated Land Exposure assessment (CLEA) tool to assess the risk of contaminated land exposure for human health. With the CLEA software tool the following can be achieved;

Derivation of generic soil assessment criteria

Derivation of site-specific soil assessment criteria

Assessment of whether a measured concentration in soil would present a potential risk to human health for a given circumstance.

Currently, there is lack of a published Nigerian risk assessment tool for the soil environment. To reverse this trend, we need to deliberately generate quality generic and site-specific soil data for the Nigerian environment. However, even some existing data will be unusable due to the non-application of something as basic as dilution factor. An agency at the state or federal level need to be saddled with responsibility of collating acceptable data for the development of a future risk assessment tool.

Typical procedures of risk assessment involve the following five steps;

Hazard assessment

Dose-response assessment

Exposure assessment

Risk characterization

Risk communication

Hazard assessment involve steps taken to identify potential and danger. During this step you attempt to answer question like "how much damage can be done?". Dose-response assessment requires the generation of data for the attainment of quantitative prediction human risk. Exposure assessment involves the estimation of how much exposure, who is likely? and under what circumstance? Risk characterization is the integration of data from hazard assessment, dose-response assessment and exposure assessment to identify dependence of the individual assessment on each other. The output from such integration will aid decision makers. The communication decision to the effected local population is essential for ultimate protection. The process of communicating findings to local or global population is the known as the risk communication. The implementation of the procedure is layered; meaning if no hazard is identified all the latter steps will be suspended. It is however important to highlight the fact that sometimes model outputs may not superimpose with clinical data on ground.

2.3 RELATED RESEARCH OUTPUT

Boisa *et al*., (2013) conducted the soil exposure assessment for children exposed to mine wastes contaminated dust in Mitrovica, Kosovo using the USEPA tool. The quantification of the potential human exposure risk associated with the ingestion of contaminated soils indicated daily ingestion Asdoes of (0.38 μgkg^{-1} BWd^{-1}) and Pb (14.4 μgkg^{-1} BWd^{-1}) with both doses exceeding acceptable threshold daily doses. In a related study at the same location Boisa *et al*., (2014) also quantified potential human exposure through the inhalation pathway and reported significant but lower Pb doses of (0.0005 – 1.284 μgkg^{-1} BWd^{-1}). The findings from both studies indicating high soil-Pb ingestion andinhalation doses was validated by the elevated blood Pb-levels in children at Mitrovica.

In 2020 Bamidele *et al*. conducted risk assessment for children exposed to indoor dust twenty-two local Government areas; Oshodi, Agege, Ibeju-Lekki, Badagry,, Shomolu, Lagos, Mainland, Moshin, Apapa, Ifako Ijaiye, Ikorodu, Amuwo odofin, Epe, Ikeja, Ojo, Eti-Osa, Lagos Island, Kosofe, Ajeromi, Surulere and Alimosho. Results indicated the daily doses for ingestion, inhalation and dermal pathways. The potentially toxic elements investigated wee As, Cu, Cr, Pb and Zn, and none indicated doses above threshold values. The ingestion pathway indicated the highest doses in all the local government areasinvestigated. The study however indicates that significant quantities of potentially toxic elements are taken in on daily basis and they also have the potential to bioaccumulate in our body.The As daily dose range for the state for childrenwere $5.44 \times 10^{-5} – 6.31 \times 10^{-5}$ µgkg^{-1} BWd^{-1}, $1.52 \times 10^{-9} – 2.05 \times 10^{-9}$µgkg^{-1} BWd^{-1} and $1.52 \times 10^{-7} – 5.30 \times 10^{-6}$µgkg^{-1} BWd^{-1}for ingestion, inhalation and dermal pathways, respectively.The Pb daily dose range for the state for children were $1.43 \times 10^{-6} – 7.37 \times 10^{-5}$ µgkg^{-1} BWd^{-1}, $3.98 \times 10^{-11} – 1.69 \times 10^{-9}$ µgkg^{-1} BWd^{-1} and $3.99 \times 10^{-9} – 3.47 \times 10^{-7}$ µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. For both As and Pb the exposure doses were more for the ingestion pathway. Shomolu and Lagos Mainland local Government areas indicated the highest total lifetime cancer risk for children. In a similar study by Oko-jaja *et al.,* (2023) conducted for the 23 local governments areas of Rivers State, risk, ingestion of indoor dust particles was the main exposure pathway route of heavy metals followed by dermal and inhalation. The As daily dose range for RiversState for children were 1.20 x 10^{-3} – 3.51 x 10^{-3} µgkg^{-1} BWd^{-1}, 3.70 x 10^{-8} – 1.45 x 10^{-7} µgkg^{-1} BWd^{-1} and 2.71 x 10^{-6} – 1.20 x 10^{-5} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. The Pb daily dose range for the Rivers State for children were 3.20 x 10^{-4} – 1.27 x 103^{-3} µgkg^{-1} BWd^{-1},.8.99 x 10^{-9} – 3.32 x 10^{-8} µgkg^{-1} BWd^{-1} and 8.11 x 10^{-7} – 2.83. x 10^{-6} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. The result showed that As was more contacted followed by Pb in which children were more exposed to these elements than adults in Rivers State. The result also reveals that residents in Bonny LGA were more exposed to indoor dust followed by Opobo/Nkoro LGA, Abua/Odual LGA, Asari-Toru LGA and Khana LGA while least was recorded in Ahoada West LGA.

Boisa *et al.,* (2024) conducted human health risk assessment for children exposed to indoor dusts at some primary schools in Port Harcourt. The contaminants of interest were, As, Cd, Cr, Fe, Mn and Pb. Before we commenced field sampling, permission was sought from Rivers State Ministry of Education and approval was granted. In total 25 primary schools were selected for the study and the locations were; Diobu, Amadi Ama, Abuloma, Ozuboko, Olu Obansanjo Road, Port Harcourt Township, D-line, Borokiri, Old GRA and New GRA.The Pb daily dose range for the state for children were 1.72 x 10^{-5} – 7.99

x 10^{-5} µgkg^{-1} BWd^{-1}, 4.82 x 10^{-11} – 2.23 x 10^{-9} µgkg^{-1} BWd^{-1} and 4.83 x 10^{-8} – 2.24 x 10^{-7} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively.The Mn daily dose range for the state for children were 9.58 x 10^{-4} – 3.63 x 103^{5} µgkg^{-1} BWd^{-1}, 2.68 x 108^{9} – 9.27 x 10^{-9} µgkg^{-1} BWd^{-1}and 1.02 x 10^{-6} – 8.84 x 10^{-6} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively.The Cr daily doses range for the state for children were 9.81 x 10^{-6} – 4.32 x 10^{-5} µgkg^{-1} BWd^{-1}, 9.08 x 10^{-10} – 6.74 x 10^{-9} µgkg^{-1} BWd^{-1} and 9.32 x 10^{-8} – 1.22 x 10^{-7} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. The Cd daily dose range for the state for children were 5.26 x 10^{-7} – 2.22 x 10^{-6} µgkg^{-1} BWd^{-1}, 1.47 x 10^{-11} – 8.39 x 10^{-11} µgkg^{-1} BWd^{-1} and 8.41 x 10^{-10} – 6.21 x 10^{-9} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. The As daily dose range for the state for children were 1.37 x 10^{-5} – 8.13 x 10^{-5} µgkg^{-1} BWd^{-1}, 1.40 x 10^{-10} – 2.27 x 10^{-9} µgkg^{-1} BWd^{-1} and 5.05 x 10^{-7} – 6.83 x 10^{-6} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. Fe daily dose range for the state for children were 7.27 x 10^{-2} – 1.97 x 10^{-1} µgkg^{-1} BWd^{-1}, 2.03 x 10^{-6} – 4.52 x 106^{9} µgkg^{-1} BWd^{-1}and 2.04 x 10^{-4} – 4.72 x 10^{-4} µgkg^{-1} BWd^{-1} for ingestion, inhalation and dermal pathways, respectively. Only As indicated doses were predicted to indicate the possibility of cancer incidence. The output from the risk assessment suggests that As indicates the highest possibility of non-carcinogenic risks. Thus, the health risks of As in indoor dust of these primary schools, is a source of concern. The health consequences of arsenic exposure include respiratory, hepatic, renal, gastrointestinal, skin, hematological, neurological and immunological effects, as well as damaging effects on the central nervous system and cognitive development in children Boisa and Falodun (2017) conducted soil ingestion exposure assessment for surface soil areas exposed to three different anthropogenic activities, namely; auto-mechanic, crude petroleum spills and mining. The metals investigated were As, Cd, Pb, Mn and Zn. Mining and auto-mechanic activities indicated daily intake doses for Pb (Table 2.1) above acceptable level.

Table2.1: Daily intake doses for mechanic, mining and crude petroleum impacted surface soils

Activity	**As** (μgg^{-1} BWd^{-1})	**Pb**(μgg^{-1} BWd^{-1})
Auto-mechanic	0.35	58.1
Mining		2.85
Reference dose		**1.9**

In a related study investigating Pb exposure risk assessment for surface soils and deposited dusts by Boisa and Eric (2017) at auto-mechanic workshops in Port Harcourt. The results indicated daily intake dose range of 0.39 – 5.11 μgg^{-1} BWd^{-1} with the upper limit exceeding the threshold of 1.9 μgg^{-1} BWd^{-1}.Also risk assessment was conducted by Boisa and Odagwe (2017) for deposited dust on surfaces in homes at a rural town, Ebedei, Delta State, hosting a gas flare facility. The findings indicated the presence of Cd, Pb and Mn, though the predicted daily doses were below the threshold values for ingestion, inhalation and dermal pathways.

To assess the health status of human population at two mining towns, Eggon in Nasarawa State and Enyigba in Ebonyi State mining for gemstone and lead respectively, a study was initiated by Boisa *et al*., (2020). The predicted doses are listed in Table 2.2. The results indicated a likelihood of Pb poisoning at the mining town, Enyigba. However, no published cases of Pb poisoning has been reported for children at the site. The lack of reported Pb poisoning cases highlights the uncertainties that are associated with risk assessment models.

Table 2.2: predicted daily intake doses for Eggon and Eyingba population exposed to surface soils

Elements	**Eggon**	**Enyigba**	**Tolerable dose**
As $\mu g g^{-1}$ BWd^{-1}	0.03 – 0.63	0.22 – 1.61	
Cd $\mu g g^{-1}$ BWd^{-1}	0.05 – 0.12	0.02 – 0.12	
Pb $\mu g g^{-1}$ BWd^{-1}	0.50 – 1.63	8.43 – 48.48	1.9

Using the USEPA Integrated Exposure Uptake Biokinetic (IEUBK) model Boisa *et al*., (2012) predicted the blood Pb levels of children (2 – 6 years) exposed surface soils contaminated by mine wastes and smelter wastes. Most of the samples indicated Pb concentrations above acceptable levels for soils. The model was originally tailored for atmospheric Pb concentrations, but was modified after Arditsoglou and Samara

(2005). The predicted blood Pb concentration were mostly above empirical blood Pb concentrations for the children and also overshot the blood Pb level of concern (10 μgdL^{-1}) for long-term health risk. The inconsistency between the predicted and measured blood Pb levels is a source of uncertainty in health risk assessments.

3.0 RISK UNCERTAINTY AND ACCEPTABILITY

3.1UNCERTAINTIES IN RISK ASSESSMENT

The ideal expectation of users of risk assessment frameworks and models is that the experimental or predicted output equates reality in public health or human clinical examination status. Uncertainties have resulted due to limited knowledge on contaminant behavior in different environmental matrices and biological systems.Uncertainties manifest in existing risk assessment tools. Uncertainties can arise while doing dose extrapolation and during the process of identifying carcinogens. They also arise due to differences between test species and other species we extrapolate to. Data limitations and baseline assumption made during model development is also a contributor.Uncertainties cannot be completely eliminated, what we can do, is to identify them as we acquire more knowledge about the properties of contaminants and manage their influence. Uncertainties in human health risk assessment can occur during all the steps, namely, hazard identification, exposure assessment, dose-response assessment and risk characterization.

The focus here will be uncertainties associated with exposure assessments. Exposure assessment revolves from source point to biomonitoring. Specifics considered during exposure assessments are duration estimation, frequency estimation, magnitude estimation and quantification of substance of interest in environmental matrices or in biological systems. Uncertainties can also result from the following variables;

Population type

Spatial information

Temporal information

Population activity

Pathways

Sample pre-treatment and treatment stages

Data analysis

Existing exposure assessment models were developed using archived data obtained from previous studies, and the quality of such data can be a source of uncertainty. Typical data employed for the development of model may also include default bioavalability/bioaccessibility factors, body mass of individual, skin surface area, respiration rate (resting or active), volume of air inhaled, and fluid/food consumption rate.Exposure assessment uncertainties can be characterized into four tiers; tier 0 (screening level), tier 1 (qualitative level), tier 2 (deterministic level), and tier 3 (probalistic level).

3.2 RISK ACCEPTABILITY

In recent times risk assessment has been criticized by industrialist, multinational organizations and sometimes nations depending on their interests. They have suggested that expectations from regulatory agencies are too strict or unachievable in some cases. Risk assessment toolshave also been criticized by environmentalist, on the basis that science cannot effectively estimate effects of exposure for a given substance when in real situation we are exposed multiple substances simultaneously. They also argue that risk to a given population is usually underestimated giving the exposed population a false sense of safety. In spite of the highlighted short falls, there is still need for risk assessment tools and frameworks because in worst case scenario, they provide approximations of actual risk. The highlighted short falls has fueled research activities in the subject area.In our daily activities, we consider some aspect as safe but they are actually low-risk activities. In life nothing can be said to be absolutely safe. The relativity of risk and the shortfalls that have been highlighted and escalated by critics has emboldened some sections of the population to ignore risk.

Risk acceptability is a measure of how acceptable a known harm is to a given population group. Risk acceptability is influenced strongly by our perceptions which are not static, they actually vary with time. Acceptability is also influenced by our level of awareness, which also gets altered with the emergence of new data. Another factor that can influence acceptability are the perceived benefits accruable from the risky activity. As a group of the population anticipate much benefits, it will enhance their acceptance of even obvious risk. The potential risk-benefit analysis determines risk acceptability.

However, if the anticipated risks are not greater those presented by nature, the population will naturally accept the risk. Some people expressly have the desire to die, consequently if the activity indicate a potential to cause death, it may not deter that population group. In situations, were a given population was previously exposed to a risk that is more severe that what is anticipated from an intended activity, there will be no justifiable reason to prevent the implementation of the new activity.

3.3 RELATED RESEARCH OUTPUT

As a researcher it has not always been easy closing up initial hypotheses because of gaps observed between actual and generated data. For science to continue to provide answers to challenges confronting man we need to take stock of such gaps and endeavor to minimize them. Examples of some such uncertainties encountered during the studies I have been involved in are provided in Table 3.1.

Table 3.1: Case studies of uncertainties encountered during some research works

Research finding	**uncertainty**	**Reference**
The IEUBK model for predicting children blood Pb level based on environmental concentration was used to simulate blood Pb levels for children exposed to mine wastes contaminated surface soils.	The predicted blood Pb level were exceptionally higher than the measured blood Pb levels for the children	Boisa *et al*., (2012)
Exposure r isk assessment for children exposed to surface soils with elevated As and Pb concentrations was conducted and the model predicted likelihood of As and Pb poisoning.	Clinical data for children only indicat ed incidence of Pb poisoning. The study focused on only the ingestion pathway.	Boisa *et al*., (2013)
Analysis of local eyeliner (Tiro) indicated very high concentrations potentially toxic elements that exceeded tolerable level for facial cosmetics.	No repo rted adverse effects resulting from the use of Tiro	Boisa *et al*., (2016)
A study investigated concentrations of some potentially toxic elements at auto -mechanic, mining and crude petroleum spills contaminated surface soils and unacceptable levels Pb at au to-mechanic and mining locations.	No reported adverse effects for children at the study locations	Boisa and Falodun, (2017)
Investigated the status of particulate matter in Port Harcourt during the black soot crisis period and reported concentrations that exceeded regulatory limit of 150 µg/m3 during the dry season	There is data explaining how the particulates will behave inside human lungs	Akinfolarin *et al* ., (2017)
Deposited dust samples in the built environment of 23 local government areas of	There was no published data explaining what	Wemedo *et al* .,

4.0 RISK UNCERTAINTY RESOLUTIONS

4.1 RESOLUTION OF UNCERTAINTIES USING ANALYTICAL METHODS

The quality of risk assessment model outputs is influenced by quality of analytical methods employed to generate site-specific environmental data inputted into models. The methods include, sampling, sample pre-treatment and treatment. Any of the method not conducted following robust analytical protocol can be a source of uncertainty. Sampling of micron-sized solid sample is challenging and complicated even with modern expensive ambient atmospheric particulate samplers. Ambient atmospheric samplers indicate obvious limitation in obtaining sufficient quantity of samples for post-sampling analytical tests. Deposited dusts and surface soil of micron-sized samples are achieved usually using appropriate sieves. When the sieve sizes are below 100 micron, it's difficult to achieve sufficient sample volumes. When < 10 micron is desired from contaminated solid samples additional problem of exposure to hazardous substance may arise.

To resolve highlighted challenges associated with sampling PM_{10} sized samples from surface soils and deposited dust, a novel, simple, low-cost approach for generating < 10 μm fraction from soils and other related materials was developed by Boisa *et al*., (2014). The developed method was based on the principles of Stoke's law. The equation describing the motion of the fine particulates is given as;

$$Fd = 6\pi\mu Vd$$

Where Fd is the drag force of fluid on a suspended sphere,
μ is the fluid viscosity,
V is the velocity of the suspended sphere through the fluid,
and d is the diameter of the suspended sphere.
Three forces, buoyancy effect of displacing fluid, the viscous drag on the sphere by the fluid and gravitational attraction are involved. The integration of all three forces can be expressed as;

$$T = \frac{6.3\ x\ 10^{9}\eta log10(R/S)}{N^{3}D^{2}\Delta s}$$

Where T is the time for sedimentation in min
ŋ is the viscosity at fixed temperature
R is the distance (cm) from centre point of the centrifuge head to the top of the sediment in the tube when the wall of the container is perpendicular to the rotation axis,
S is the distance from axis of rotation to the top of suspension,
N is the number of revolutions per minute,
D is the particle diameter (μm),
Δs is the difference in specific gravity between the solvated particle and water.
Details of the steps developed to achieve the extraction of PM_{10}

fraction from surface soils are depicted in Fig 4.1. Into a 100 ml measuring cylinder 2.00 g of < 63 μm fraction of surface soil was suspended in 100 ml of deionized water and dispersed with the aid of a magnetic stirrer and allowed to stand for 10 min (step 1). A pipette was then inserted to the 50 ml mark and 50 ml volume siphoned off (step 2). Some portion of the siphoned was submitted for particle size analysis. The siphoned suspension was transferred into a centrifuge tube and later centrifuged at 4000 rpm to obtain the desired < 10 μm sized fraction of the soil (steps 3 - 6). The sedimented solid was later dried and weighed before use.Results indicated 84.7 – 87.3 % of the extracted fraction was < 10 μm particles.

During the black soot crisis period in Rivers State several suggestions were made regarding the primary source of the black particulates in the atmosphere. Some of the suggestions were actually based on empirical data obtained from sampled ambient particulates or settled sediments on experimental surfaces. However, because of the multiple incineration sources that contribute to atmospheric particulates, what they sampled may not provide analytical robust data. To qualify to make a strong judgement you require finger-print fly ash samples from as many incineration sources as possible. The finger-print samples can then be compared with ambient atmospheric samples for proper source apportionment.

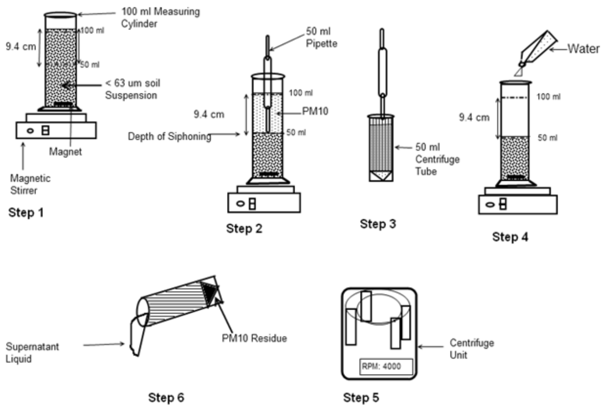


Figure 4.1: Schematic diagram of steps employed in extracting PM_{10} from soils

Toresolve gap of absence of pure incinerated source fly ash samples, Gogonte et al., (2021) developed a method for sampling pure fly ash from commonly incinerated local materials. The research scope included conceptualization, design and fabrication of a new mini incinerator for the generation of pure fly ash (Fig 4.2). The unique feature of the design was a frustum to accelerate a laminar flow of fly ash into the chimney. The method allowed the generation of fly ash from any desired material so long as the material is flammable. With the pure fly ash samples finger-printing is now possible. Also controlled toxicological studies can now be conducted with pure fly ash sample. The developed equipment has facilitatedsome studies in atmospheric chemistry.

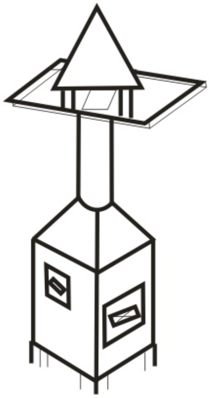


Figure 4.2: Developed mini incinerator

4.2 RESOLUTION OF UNCERTAINTIES USING *IN VITRO* BIOACCESSIBILITY TESTS

Soil Generic Assessment Criteria studies encourages the comparison of contaminants concentrations in environmental matrices with soil guideline values, and consequently a judgement is made if there is the possibility of risk to human population at that location. Uncertainties have emerged from just comparing total environmental concentrations with acceptable limits. We have instances when risk assessment output based this method had predicted deaths, but no deaths are reported empirically. To minimize such uncertainties *in vitro* and *in vivo* assays have been conducted to determine intake doses and potential toxicities. Intake doses of contaminants are influenced by their solubilities in pathway lining fluids. The fraction of a given contaminant concentration that is available for absorption into living organisms, including human is referred to as bioavailabilty. However, when the absorption is through the digestive or inhalation systems that is referred to as bioaccessibility (Nathanail *et al*., 2005).

Workers believe that part of the answers required to address the uncertainties associated intake dose estimation that is responsible the over-estimation of human health risks following exposure may be provided by the application of bioaccessibility tests. Some modern risk assessment models have incorporated into them default bioavailability/bioaccessibility factors, and example is the USEPA Integrated Exposure Uptake Biokinetic (IEUBK) model for predicting blood Pb levels for exposed population using Pb concentrations in environmental samples. The IEUBK model was built with a default 30 % bioavailability factor.The model however provided the flexibility of the user replacing the factor with site-specific Pb bioaccessibility.

Several robust ingestion pathway bioaccessibility testing protocols exist in published literature, but same cannot be said for the inhalation pathway. To bridge the gap a novel inhalation bioaccessbility testing protocol was developed for testing inhalable (< 10 µm) particle sizes by Boisa *et al*., (2014). The authors achieved this by first critically reviewing published human epithelial lung fluid compositions, focusing on the extracellular fraction (Fig 4.3).The protocol attempts to mimic the interaction of inhalable particles with the respiratory tract lining fluid and the subsequent dissolution and uptake (Fig 4.3). After the review significant components that were omitted were considered and added to complement gaps. The Simulated Epithelial Lung Fluid (SELF) composition developed by Boisa *et al*., (2014)is reflected in Table 4.1. The authors applied the fluid to surface soil related PM_{10} samples obtained from a mining town, Mitrovica, Kosovo. Since the publication of the protocol several workers have adopted it for testing inhalable particulates for the prediction of potential risk to humans. Google scholar citation for the publication is currently reading over 150.

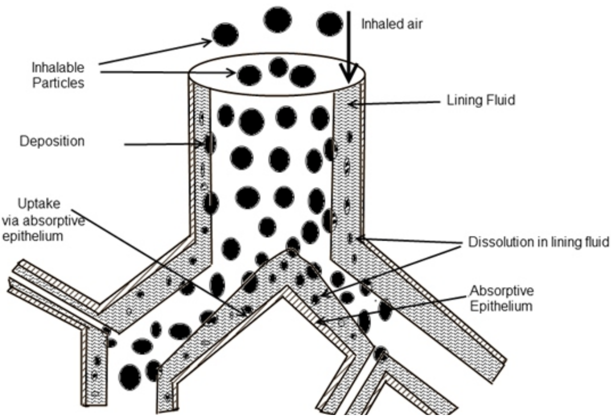
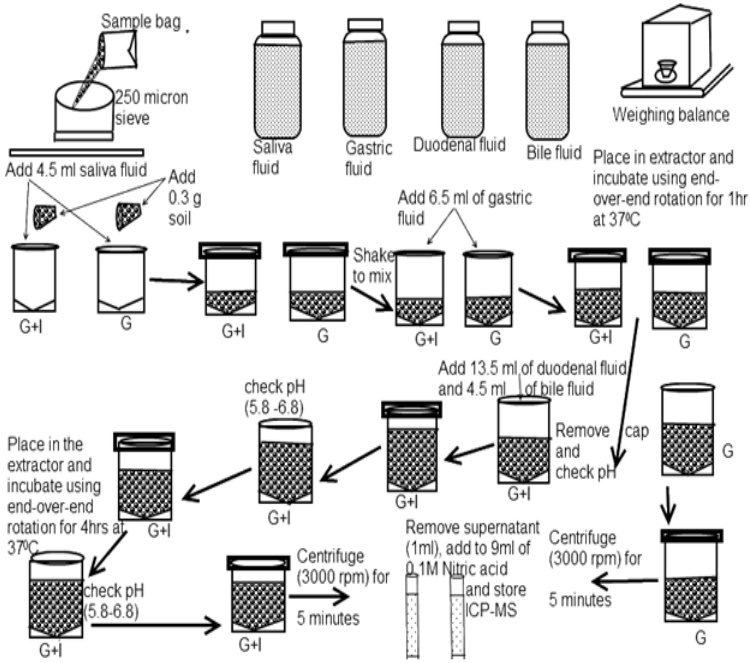


Figure 4.3: Deposition and dissolution of xenobiotics in the tracheobronchial region

Table 4.1: Recipe for synthetic tracheobronchial fluid

Reagent	**Concentration (mg/ L)**
Inorganic salts	
NaCl	6020
$CaCl_2$	256
Na_2HPO_4	150
$NaHCO_3$	2700
KCl	298
$MgCl_2$	200
Na_2SO_4	72
Surfactant lipid	
DPPC	100
Large-molecular-mass proteins	
Albumin	260
Mucin	500
Low-molecular-mass antioxidants	
Ascorbic acid	18
Uric acid	16
Glutathione	30
Organic acids	
Glycine	376
Cysteine	122



G – Gastric phase and G+I – Gastrointestinal phases

Figure 4.4: Sketch of the steps involved in the oral bioaccessibility test

Several bioaccessibility testing protocols (Wragg and Cave, 2003; Wragg and Klinck 2007; Juhasz et al., 2009; Wragg *et al.,* 2009; Broadway *et al.,* 2010; Meunier et al., 2010) have been developed for the ingestion pathway. The Bioaccessibility Research Group of Europe (BARGE) adopted the Unified Bioaccessibility Method (UBM). Details of steps involved in the UBM protocol are provided in Figure 4.4. The UBM protocol is an additional line of evidence in the assessment of contaminated site for potential to exposed humans. Data obtained from oral bioaccessibility tests will aid minimization of uncertainties in exposure risk assessment. The UBM was also adopted by Boisa and other workers to screen contaminated sites to get data with minimal uncertainties, between environmental concentrations and intake doses, and details of their applications and findings are provided in Table 4.2. The table highlights the titles of the studies conducted where bioaccessibilty testing was employed to minimize gaps between predicted risk and empirical site data.

Table 4.2: Depicting tittles, findings and references of studies that bioaccessibility data aided resolution of uncertainties

Title of publication	Findings	References
Empirical and Model simulations (IEUBK) of blood Pb levels in children exposed to Pb contaminated soil/dust at Mitrovica, Kosovo	Model default bioaccessibility was modified with site-specific bioaccessibility data obtained following the application of the UBM protocol. Simulations were performed using both the default and sit-specific gastric phase bioaccessibility factor. The predicted blood Pb levels using site-specific ABA better superimposed with measured blood Pb data.	Boisa *et al.*, (2012)
Potentially harmful elements (PHE) in scalp hair, soil and metallurgical wastes in Mitrovica, Kosovo. The role of oral bioaccessibility and mineralogy in human PHE exposure	Results indicated mean bioaccessibility of 22 %, 55 %., 22 %, 61 % and 41 % in gastric phase for As, Cd, Cr, Pb and Zn, respectively. Gastro-intestinal phase indicated 25 %, 18 %, 28 %, 13 % and 7 % for As, Cd, Cr, Pb and Zn, respectively. The only empirical risk reported was for Pb, but most of the elements also indicated levels above acceptable limit. The elevated bioaccessibility reported for Pb in both phases justifies the occurrence of Pb poisoning at the site	Boisa *et al.*, (2013)
In vitro oral bioaccessibility and levels of some heavy metals in indigenous lick soils ingested in Nigeria	Gastric phase bioaccessibility range for Cd, Fe, Pb and Mn were 3.4 – 100 %, 0.3 – 5.2 %, 12.7 – 33.8 % and 0.3 – 15.2 %, respectively. The ranges for the gastro-intestinal phase were 1.0 – 52.7 %, 0.1 – 6.1 %, 4.5 – 16.3 % and 0.5 – 4.5 % for Cd, Fe, Pb and Mn, respectively. These	Boisa *et al.*, (2017)

	results are significant because the quantities of different lick soils (Nzu) consumed are not regulated by NAFDAC. Although obvious adverse health indication for Pb now and may due to the very low (maximum 6.1%) bioaccessibility observed in this study.	
Bioaccessibility of selected heavy metals from soils contaminated by auto-mechanic, mining and crude oil refining activities	Mean Gastric phase bioaccessibility for As were 8.8 %, 3.6 % and 11.0 % for auto-mechanic, mine and crude oil spill sites, respectively. For Pb were 37.2 %, 14.4 % and 14.4 % auto-mechanic, mine and crude oil spill sites, respectively. Mean gastro-intestinal phase bioaccessibility for As were 25.1 %, 8.3 % and 18.5 % for auto-mechanic, mine and crude oil spill sites, respectively. For Pb were 12.3 %,and 4.4 % for auto-mechanic and mine sites, respectively. The mine site bioaccessibility obtained for Pb in Enyigba, Ebonyi State is relatively about 50 % of the value indicated at Mitrovica, Kosovo, and this may explain the absence of recorded Pb poisoning cases at the Nigerian site.	Boisa *et al*., (2018)
Concentrations and human health risk assessment of polycyclic aromatic hydrocarbons and toxic elements in tyres and petroleum products fly ash	Fly ash bioaccessibility were reported for different matrices. Mean Asgastric bioaccessibility were 17.8 %, 10.7 %, 29.7 %, 3.4 %, 3.9 % and 6.3 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Pb gastric	Boisa *et al*., (2023)

	bioaccessibility were 14.5 %, 16.1 %, 10.1 %, 1.5 %, 1.8 % and 0.4 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Hg gastric bioaccessibility were 24.3 %, 32.5 %, 25.4 %, 10.4 %, 5.3 % and 6.3 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Ni gastric bioaccessibility were 4.3 %, 4.0 %, 11.1 %, 0.8 %, 0.6 % and 1.1 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. For the gastro-intestinal phase, mean As bioaccessibility were 50.2 %, 48.4 %, 67.4 %, 43.2 %, 44.6 % and 50.0 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Pb bioaccessibility were 15.8 %, 12.7 %, 21.2 %, 16.8 %, 13.5 % and 18.8 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Hg bioaccessibility were 44.8 %, 60.9 %, 32.1 %, 29.4 %, 25.2 % and 29.0 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively. Mean Ni	

	results are significant because the quantities of different lick soils (Nzu) consumed are not regulated by NAFDAC. Although obvious adverse health indication for Pb now and may due to the very low (maximum 6.1%) bioaccessibility observed in this study.	
Bioaccessibility of selected heavy metals from soils contaminated by auto-mechanic, mining and crude oil refining activities	Mean Gastric phase bioaccessibility for As were 8.8 %, 3.6 % and 11.0 % for auto-mechanic, mine and crude oil spill sites, respectively. For Pb were 37.2 %, 14.4 % and 14.4 % auto-mechanic, mine and crude oil spill sites, respectively. Mean gastro-intestinal phase bioaccessibility for As were 25.1 %, 8.3 % and 18.5 % for auto-mechanic, mine and crude oil spill sites, respectively. For Pb were 12.3 %,and 4.4 % for auto-mechanic and mine sites, respectively. The mine site bioaccessibility obtained for Pb in Enyigba, Ebonyi State is relatively about 50 % of the value indicated at Mitrovica, Kosovo, and this may explain the absence of recorded Pb poisoning cases at the Nigerian site.	Boisa *et al*., (2018)
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	bioaccessibility were 0.8 %, 0.8 %, 1.8 %, 1.0 %, 0.9 % and 1.5 % for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres, respectively.These fly ash gastric and gastro-intestinal bioaccessibility data reported for crude oil, crude oil residue, refined diesel, artisanal diesel, used engine oil and waste tyres matrices have not been previously published. The bioaccessibility data has indicated relatively higher values for As and Hg in both digestive phases, hence suggesting that fly ash-bound As and Hg can pose health risk to human. The data is for ingestion pathway not inhalation. There is a likelihood that exposed food and water can provide a platform for the deposition of these fly ash material before we later ingest same.	

Entwistle *et al*., (2015) presented a paper titled "what drives bioaccessibility? A multi-technique approach to investigate the Pb -phases which control the overall solubility of Pb in top soil and metalliferous wastes". The paper attempted to draw attention to the large variance of Pb bioaccessibility reported for surface soils contaminated by similar anthropogenic activities (e.g. Pb mining). Different techniques have been applied in the search for answers and they include, x-ray diffraction (XRD), computer-controlled scanning electron microscopy (CCSEM).
Boisa *et al*., (2013) employed XRD test to aid the interpretation of bioaccessibility data and found that the solid-Pb phases were in very different mineralogical forms. The minerals include beudantile, anglesite, cerussite, larnarkite and coronadite. The minerals have Pb in different strengths of encapsulation and it influences the solubility in the UBM fluid. It is important to highlight that some of the Pb particle are in isolated forms. To investigate the individual particle (IP) in soil, CCSEM was employed. Results from the CCSEM analysis indicated that Pb associated with elements of higher atomic numbers had lower solubility and those associated elements of lower atomic numbers indicated higher solubilities. The varying solubilities may be the due to the elements associated with Pb types associated with Pb in its solid phase.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Vice Chancellor Sir, as a trained Environmental-Analytical chemist, my research is supposed to focus on monitoring impacts resulting from human and environmental interactions, either from human or the environment. I have spent time looking at human self-inflicted impacts resulting from our desire for precious mineral resources buried underground both in Nigeria and Europe. Impacts were assessed using data resulting from laboratory works that were subsequently inputted into risk assessments models for analysis. These analyses yielded predicted contaminants doses that humans are expected to be exposed to. The doses were subsequently employed in predicted adverse human health effects based on existing toxicological data.

In some instances, predicted impacts were not superimposing with field empirical human health data. The lack of agreement between predicted impacts and real data indicated uncertainties. Some of the uncertainties resulted from limitations in existing laboratory methods. Consequently, novel analytical methods were developed to address the gaps. Novel methods were developed to address gaps in sampling of pure fly ash samples and extraction of PM10 samples from soil matrices. Also, to address absence of robust *in vitro* methods for inhalation bioaccessibility testing, a new synthetic fluid was formulated and a testing protocol developed.

There were uncertainties in the interpretation of impacts monitoring and bioaccessibility testing data. To address the challenges default variables employed in the building of risk assessment models were in some cases modified before use. For the interpretation of bioaccessibility data, mineralogical data were generated usingcutting edge technologies like XRD and CCSEM. The mineralogical data further enhance our understanding of the dissolution of contaminant in human systems.

We are impacted by several natural and anthropogenic events in this country that requires both resources and skilled environmental scientist to manage. However, most of the ongoing researches in environmental science are not tailored to addressing challenges confronting us. Sometimes you feel discouraged when your professional colleagues don't see what see. There are still a lot left undone. I have highlighted the little have been able to achieved in our difficult research environment. Thank you.

5.2 RECOMMENDATIONS

1. Environmental professionals should be encouraged to design their researches towards solving environmental challenges that are confronting us locally.

2. Environmental intervention agencies should not just patronize imported technologies, they fund the development indigenous technologies. This will lead to sustainability.
3. Institutions in Nigeria should encourage *in vitro* testing options. This is the global trend. Compliance will facilitate Trans-Atlantic collaborations.
4. There is need to establish an intervention agency to address the of impacts that may result from solid mineral mining. If we fail, what we are currently managing in Ogoniland will be a child's play for mining communities.
5. NAFDAC should commence the regulation of processes involved in the production and consumption of lick soils
6. Government should invest in the monitoring of our atmosphere regularly and provide funds to generate data that can aid our understanding of the dynamic status of the atmosphere.
7. Hospital data relating to inhalation challenging should be monitored, stored and provided we needed for validation of risk assessment studies. Also, sudden surge in a specific inhalation challenge should be integrated with environmental data. The integration will

search for associations between the two data-set.

8. Departments of geology in Nigeria should be equipped with cutting-edge XRD instruments to aid in mineralogy analysis.
9. Government should adopt risk assessment as a decision-making tool in environmental management.

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