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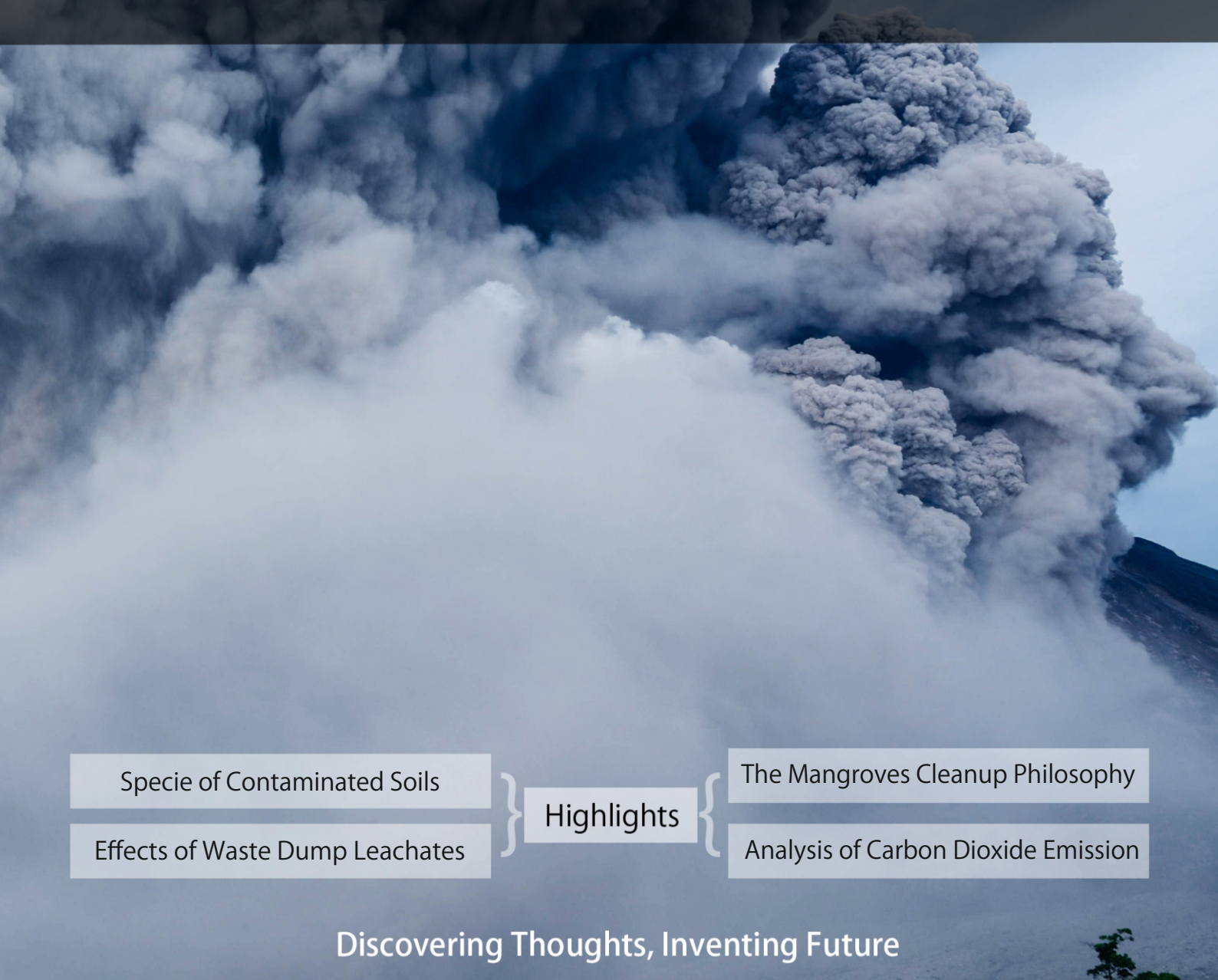

Specie of Contaminated Soils

Effects of Waste Dump Leachates

Highlights

The Mangroves Cleanup Philosophy

Analysis of Carbon Dioxide Emission

Discovering Thoughts, Inventing Future

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Ailanthus Altissima (Mill.) Swingle, Bioacumulated Specie of Contaminated Soils

By Corral Ribera, M., De Soto García, I.S., Fidalgo Hijano, C., & García Giménez, R.
Universidad Autónoma de Madrid

Abstract- *Ailanthus altissima* (Mill.) Swingle) is one of the most widespread invasive alien species on a global scale. Its current distribution is clearly linked to anthropized environments, where concentrations of heavy metals or trace elements in their soils can reach levels of toxicity to other plant organisms. The present research carried out in environments of the Community of Madrid (Spain) focuses on the relationship between the presence in soil components such as arsenic (As), copper (Cu), chromium (Cr), boron (B), vanadium (V), cobalt (Co), etc., harmful to some plant organisms, and the existence of *Ailanthus altissima*. The results obtained identify that the species modifies the content of some minority elements, a fact that must be taken into account for future soil fertility studies. Secondly, ailanto is capable of absorbing toxic elements present in the soil environment, which shows its value as a phytoremediator of contaminated soils.

Keywords: *ailanthus altissima, soil contamination, heavy metals, bioconcentration, phytoremediation, fertility.*

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Ailanthus Altissima (Mill.) Swingle, Bioacumulated Specie of Contaminated Soils

Corral Ribera, M. [α], De Soto García, I.S. [σ], Fidalgo Hijano, C. [ρ], & García Giménez, R. [ω]

Abstract- ***Ailanthus altissima*** **(Mill.) Swingle) is one of the most widespread invasive alien species on a global scale. Its current distribution is clearly linked to anthropized environments, where concentrations of heavy metals or trace elements in their soils can reach levels of toxicity to other plant organisms. The present research carried out in environments of the Community of Madrid (Spain) focuses on the relationship between the presence in soil components such as arsenic (As), copper (Cu), chromium (Cr), boron (B), vanadium (V), cobalt (Co), etc., harmful to some plant organisms, and the existence of *Ailanthus altissima.* The results obtained identify that the species modifies the content of some minority elements, a fact that must be taken into account for future soil fertility studies. Secondly, ailanto is capable of absorbing toxic elements present in the soil environment, which shows its value as a phytoremediator of contaminated soils.**

Keywords: ailanthus altissima, soil contamination, heavy metals, bioconcentration, phytoremediation, fertility.

I. Introduction

The last centuries are characterized by the increase in the quantity, typology and dangerousness of the waste that ends up being incorporated into the soil. The soil transformation of certain chemical compounds causes, on numerous occasions, its disturbance. This translates into a loss of quality and suitability for certain uses, unless the soil is subjected to phytoremediation treatments (Porta-Casanellas *et al.* 1999).

Among the chemical contaminants of the soil component, heavy metals such as copper (Cu), chromium (Cr), vanadium (V), cobalt (Co), among others, stand out. Although these elements are natural components, in high concentrations, they are potentially harmful to the natural environment. Without forgetting that the incorporation of contaminants into the soil implies an increase in the concentrations of trace elements that can be toxic and cause irreversible damage to plant organisms (Kumar, 2013; Kleckerova and Dočekalová, 2014).

In this context *Ailanthus altissima* (Mill.) Swingle could be used as an indicator species and bioaccumulator of harmful elements in disturbed environments. Hu *et al.* (2014) determines that in the city of Yan'an (Loess Plateau, China) ailanthus acts as a signifier bioaccumulating species of lead, copper and cadmium. In addition, it also has the capacity to store, in its aerial part, chromium and zinc.

Lin *et al.* (2017) establishes that, in different of Beijing, *A. altissima absorbs* a large number of toxic elements (highlighting metals) in its leaf surface.

In the same sense, recent research shows that the existence or degree of concentration of certain chemical substances in the soil is related to the proliferation of *Ailanthus altissima* (Corral, 2022).

These investigations identify the importance that the use of *Ailanthus altissima* as a remedying species of contaminated soils may have.

Considering the capacity of *Ailanthus altissima* to bioaccumulate toxic elements in its leaves, which will then be returned to the soil after the loss of the leaf surface, the present research has as a preliminary hypothesis the study of the soil composition modification in which this species develops. Previous research (Corral, 2021; Corral, 2022; Corral *et al.,* 2022) seem to indicate the importance of the existence of a significant number of specimens of *Ailanthus altissima* to be able to originate this modification.

Therefore, the objective of this article is to study the possible differences between soils with the presence and absence of *Ailanthus altissima* and to study the possible modifications into the soil due to the presence of this plant species.

II. *Ailanthus Altissima* as Bioaccumulating Species

Plant organisms play a major role as bioaccumulators of chemicals, transferring harmful elements from the abiotic environment to their plant tissues (Alcoba *et al.* 2014; Martínez-López *et al.* 2014). It is important to define the concept of bioaccumulator species as that organism that stores heavy metals or other environmental pollutants in its tissues. These pollutants are absorbed from the environment when species perform their biological functions.

Plant organisms present two adaptive strategies against soil contamination:

- On the one hand, exclusion strategies, which prevent the assimilation of the element, restrict its transport to the plant itself, produce exudates by the

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roots and/or reduce the concentration of the element taking advantage of the leaf fall.

- On the other hand, accumulation strategies that allow the plant to store toxic elements in different plant tissues (Baker & Walter, 1990; Verkleij & Schat, 1990). Positive relationships have been identified between the deposition of heavy metals in the soil and concentrations of the same in plants (Ugulu *et al*. 2012). Different plant species are able to absorb and accumulate significant amounts of potentially toxic substances (Piczak *et al*. 2003).

Thus, trees and shrubs play a significant role in removing heavy metals and other soil contaminants (McDonald *et al.* 2007, Dzierżanowski *et al.* 2011,). As well, different plant organisms are often used to measure environmental quality and possible environmental impacts (Piczak *et al.* 2003, Nowak *et al.* 2006).

In relation to the increase in chemical contaminants in soils, three types of plants have been differentiated:

- *Accumulative Plants:* those where the element (metal) is concentrated in the stem and leaves. Within this group, those that have the ability to grow in environments with high concentrations of toxic elements and, in addition, accumulate a large concentration of them in their tissues stand out. These plants are called hyperaccumulators.
- *Indicator Plants:* those where the absorption and transport of the chemical element are regulated in the way in which the concentrations in the plant are reflected in the aerial part of it (leaves, buds or fruits).
- *Exclusionary Plants:* in which the concentration of the element in the stem and leaves is constant, it happens as long as the concentration of the metal in the soil does not exceed the tolerance limits by the plant.

In this context, knowledge and use of plant species tolerant to anthropogenic environments are essential for the design of remedial measures to reduce soil pollution (Dzierżanowski *et al.* 2011).

Ailanthus altissima (Mill.) Swingle is one of the most widespread invasive alien species on a global scale. Its natural range is the geographical regions of Eastern China and Northern Vietnam. From these nuclei of origin, it has been progressively colonizing various spaces (natural and anthropized) of the rest of the continents (Köwarik & Säumel 2007).

In the regions of origin, *Ailanthus altissima* is considered as a colonizing species of habitats or spaces altered by anthropic actions, where ruderal vegetation or species associated with stages of substitution of natural formations prevail. In addition, it has been introduced ornamentally in green spaces of cities (Hu, 1979; Liu *et al.* 2015; Huang *et al.* 2015; Knüsel *et al.* 2019).

In relation to its area of distribution, Ailanthus altissima has colonized numerous and diverse territories between 35º and 60º latitude in the Northern Hemisphere and between 30º and 60º latitude in the South (Meusel & Jäger, 1992; Köwarik & Säumel, 2007; Gassó *et al.* 2012).

Its high adapting plasticity allows its growth in both anthropized and natural places. However, its secondary area of distribution is subject to spaces with some degree of disturbance; either anthropic (pollution, deterioration of urban and rural space, constructions, etc.), or natural disturbances that lead to the loss of tree cover (fires, thinning, phytosanitary diseases, among others) (Köwarik & Säumel, 2007).

In Europe, ailanto presents a wide dispersion in green areas, margins of communication routes, playhground or private gardens of the urban centers. This distribution is highly correlated with its introduction for ornamental purposes (Köwarik & Böcker, 1984; Kowarik & Säumel, 2007; Petrovi *et al.* 2011; Maslo, 2016; Corral, 2021)

In the Community of Madrid (Spain) broadly speaking, the expansion of ailanto is radial and linear, following a distribution correlated with the main communication routes (Enríquez, 2020). Corral's research (2021) analyzes in different regions of the Community of Madrid the dispersion of *Ailanthus altissima*, corroborating the potential distribution in communication routes, but expanding to a detailed scale new colonized habitats highlighting significantly deteriorated environments such as dumps, landfills, abandoned plots or slopes, among others.

Table 1: Research determining A. altissima as a bioaccumulator and bioaccumulated compounds

Author/s and year	Element bioaccumulated by *Ailanthus altissima*
Porter (1968)	Fe, Cu, Zn, Ti, K, Cl
Hu *et al.* (2014)	Pb, Cu, Cr, Zn,
Filippou et al,. (2014)	SnO
Ranieri & Gikas (2014).	Cr
Lin *et al.* (2017)	suspended particles (PM1, PM2,5, PM10)
Ashraf *et al.* (2017)	Cr
Abbaslou & Bakhtiari (2017)	Cu, Mn, Fe, Zn, Cd, Pb
Nabi *et al.* (2019)	NO, SnO
Roy *et al.* (2020)	Cd, Cr, Cu, Mn, Ni, Pb, Zn
Corral (2022)	Ni, Cu, MgO, Sr, B, CaO, Sn

In addition to the ability to bioaccumulate these substances, *Ailanthus altissima* returns to the soil the toxic components it absorbs, serving as a favorable strategy for their proliferation.

With all the above, it is evident that the existence or degree of concentration of certain chemical

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compounds in soils is closely related to the proliferation of *Ailanthus altissima*.

III. Methodology

This research was carried out in different habitats of the Community of Madrid (Spain). The variability of physical-environmental components of the region forced to define an area large enough and with differentiated features that would allow reaching the objectives set. Regions with different physiography, lithology, soil science, altitude, thermo-rainfall regime and uses and uses of the territory were selected.

The successive field campaigns were carried out between March to October of the years 2019 and 2020. These months were chosen for the optimal state of foliar growth and flowering of the species; ending just before the onset of autumn and leaf loss (Sæbø *et al.* 2012). Samples were taken in four different environments with the presence of *A. altissima* (dump, natural space, communication route and urban green area).

a) Sampling and Laboratory Analysis

250.0 g of soil were collected with an auger at a depth between 0.5 cm to 0.5 m. Subsequently, the sample was dried at room temperature for 7 days (drying at room temperature has been used because the increase in drying speed limits changes due to microbial activity). Once the sample was dry, 2.0 g of soil was separated for the calcination of organic matter in laboratory muffle at 300°C for 12 hours (this temperature and scale time have been used to avoid the destruction of clay minerals in the soil).

The sample (previously treated in the oven) was then ground in agate mortar to a fine size (<20µm). After soil treatment, values for pH, electrical conductivity (EC), organic matter, texture and mineralogical composition were obtained.

For the study of the content of the chemical elements, an elementary semi-quantitative analysis of the samples was carried out, which encompasses the vast majority of the periodic table, except of noble gases and other elements such as carbon (C), hydrogen (H) and several halides. The chemical determination was by Mass Spectroscopy with Inductively Coupled Plasma (ICP-MS) with argon flame. The spectrometer used has been ICP-MS Elan 6000 Perkin Elmer Sciex with AS91 autosampler.

To perform the calibration curve, the values 0.1, 1 and 10 mg/l are taken, except for the Na, Mg and Ca in which values 0.1, 1, 10 and 100 will be used. The measurement of Na and K has been made by emission flame photometry, with Perkin Elmer 2280 equipment.

b) Statistical Analysis

With the chemical data of the soil, a statistical studywas done with the statistical program SPSS version 27. A discriminant study has been carried out with the content of minority elements.

The initial hypothesis of the research is that invasive species such as this plant can change soil fertility and nutrient cycles (Gutiérrez López, *et al.* 2014, Medina-Villar *et al.* 2015, 2016), so this statistical study can provide very valuable information about the influence of the plant on the soils analyzed.

Complementary to this analysis, the coefficients of bioaccumulation or bioconcentration factor (FBC = concentration of metal in the root/concentration of metal in the soil) have been calculated. The coefficient determines the transfer of metal from the soil to the plant. A value, >1, means that there are mechanisms that concentrate the element in the leaves. On the other hand, the transfer factor FT= (metal concentration in the leaf/metal concentration in the root) was calculated to indicate the type of response (accumulation, indicator, exclusion) of the plant to the metal (Abreu *et al.* 2012).

The coefficient establishes that, if the ratio <1, there is a restriction of metal transport between root and leaf. If it is >1, the metal is transferred to the aerial part of the plant organism.

IV. Results

The analysis has established that the presence of minority elements in the soil samples is related to the number of specimens of *Ailanthus altissima*. In this way, the samples are grouped in the statistical study according to the number of existing specimens. So, the existence of this plant species can alter the content of minority elements of the soil.

Figure 1 shows the result of the statistical study of discriminant with the minor concentration of the minority elements and in which the samples have been grouped, initially, according to the number of plants that appeared at each sampling point in an area of $1m^2$.

The following initial groups were made for this study: soils without plant, soils with 1 to 50 individuals, soils with 51-150 individuals and soils with more than 150 individuals (see figure 1).

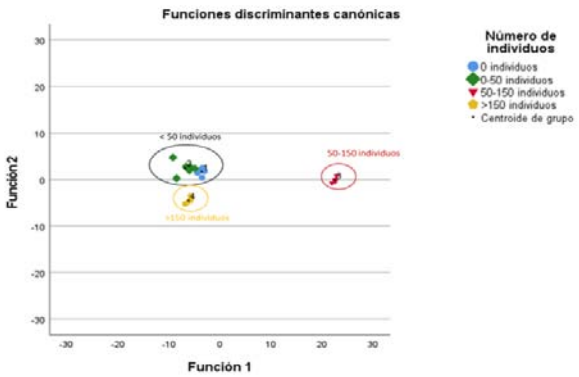

Fig. 1: Statistical analysis of the discriminant according to the number of individuals and their content in minority elements

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A grouping of the samples in the following subgroups has been obtained according to their content in the following minority elements:

- *Samples from 0 to 50 individuals* present similar contents of Be, Cr, Cu, Cr and S.
- *Samples from 51 to 150 individuals* present similar contents of As, B, Co and V.
- *Samples from > 150 individuals* present similar contents of Be, Cr, Cu, V, As and B.

In view of these results, a second statistical study of the discriminant was carried out, in order to study in more detail the samples that presented up to 50 individuals in an area of 1m2 (Figure 2).

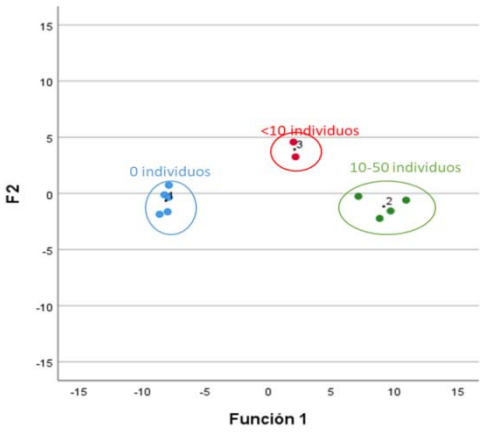

Fig. 2: Result of the statistical analysis of the discriminant of soils with less than 50 individuals based on their content in minority elements.

The samples are grouped into the following subgroups.

- *Soil samples without plants:* Similar contents of Cr, B and Li.
- *Soil samples with less than 10 individuals:* Similar contents of Be, V, P and S.
- *Soil samples with 10 to 50 individuals:* Similar contents of Cr, B, Li, Be, P and V.

According to the bioaccumulation capacity of *Ailanthus altissima*, B, Cu, Sn and Sr are the elements that can be considered bioaccumulated by the leaves of *A. altissima* since its bioconcentration factor (FBC) is higher than the unit (FBC ≥1). In addition to the aforementioned elements, other compounds such as Cu and Ni can be considered to have a certain cumulative character, since their bioconcentration factor is ≥0.5 (Table 2).

Table 2: Bioconcentration factor values (FBC).

Element	Average concentration in leaves (ppm)	Average concentration in soil (ppm)	FBC
Sn	41	8	5,06
B	174	148	1,18
Sr	108	92	1,17
Cu	22	24	0,92
Ni	6	12	0,51
Mn	102	213	0,48
Zn	31	70	0,45
Cr	4	11	0,34
Ce	4	16	0,25
Sc	1	3	0,25
Zr	7	39	0,18
As	1	8	0,12
Ba	40	375	0,11
V	3	30	0,11
Ga	1	14	0,09
Rb	10	127	0,08
Li	3	51	0,07
Pb	2	39	0,06

They have differentiated:

- *Elements not accumulated in the leaves:* They have bioconcentration factor less than 0.5 (FBC ≤ 0.5). Among these elements are As, Ba, Ce, Cr, Ga, Li, Mn, Pb, Rb, Sc, Zn and Zr.
- *Possible bioaccumulated elements:* These are those that present a bioconcentration factor (FBC ≥ 0.5). Cu and Ni.
- *Bioaccumulated elements:* Those whose bioconcentration factor is equal to or greater than the unit (FBC ≥ 1), B and Sr.
- *Potentially accumulated elements:* Those elements whose concentration in the leaves is significantly higher than in soils. In research, the only element with this characteristic is the Sn (FBC >5).

V. Discusion

The processes of industrialization, urban development, change in land uses and other anthropic actions contribute to the increase in the concentration of chemical substances (heavy metals or trace elements) that can be harmful to plant organisms.

The toxicity of metals in plants depends on the tolerance of each species tolerance, the chemical element in question and/or the physicochemical characteristics of the soil. Thus, certain metals are considered essential for the growth and development of plant organisms, such as Cu and Zn that activate enzymatic reactions and participate in the Redox reactions of plants. Or the Cu that acts in the photosynthetic process (Mahmood & Islam, 2006; Chatterjee *et al.* 2006). Zn is essential for ribosomes. Co

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is an indispensable element for vitamin B12 (Nagajyoti *et al.* 2010).

In the soil of anthropized environments it is common to find non-essential elements that are considered toxic to plant organisms such as Hg, Ag, Pb, Ni. In addition, in anthropized spaces, trace elements such as Fe, Cu, Zn, Mn or Co, among others, usually occur in high concentrations, harmful to the development of most plant species (Nagajyoti *et al.* 2010). However, species such as *Ailanthus altissima* have the ability to develop in soils with toxic concentrations of these metal elements (Corral, 2022).

This species shows a clear and marked expansion in habitats significantly disturbed by anthropic actions. Thus, the species has been considered one of the most tolerant to air pollution, being highly resistant to SO2 and other compounds harmful to most plant organisms, being highly resistant to SO2 and other compounds harmful to most plant organisms. This tolerance is due, among other characters, to the high antioxidant capacity of its leaves. In addition, it has a great capacity for detoxification (Kovacs *et al.* 1982).

According to the results *Ailanthus altissima* has the ability to bioaccumulate in its plant tissues elements such as B, Cu, Sn and Sr (Table 2), which will be returned to the soil surface with the loss of the leaf surface.

The loss of the leaves implies that *Ailanthus altissima* has modified the content of minority elements of the soils studied. This change is related to the number of individuals existing in the same soil surface.

This fact is important when studying soil fertility, since there are changes in the phosphorus content of the soil. Before this study, changes in soil fertility have been observed due to the presence of *Ailanthus altissima* (Gutiérrez López *et al.* 2014, Medina-Villar *et al.* 2015, 2016), so this fact should be consider in future work, since there is very little research on the influence of the plant on soil fertility.

It has been observed that the samples are grouped according to the number of individuals and their content in some toxic elements and soil contaminants such as Cr, V, As, Co and Cu (Figures 1 and 2).

These results are of crucial importance, since such elements have been considered as toxic, according to the list of toxic substances made by the Agency for Toxic Substances and disease Registry (ATSDR) in 2019, where the Ace, ranks first.

There are studies about the ability of the plant to reduce the concentration of heavy metals in soils (phytoremediation). In these cases, *ailanthus* retain toxic elements of the soil, such as heavy metals, in its roots and leaves (Hu *et al.* 2014; Ranieri *et al.* 2016; Abbaslou and Bakhtiari, 2017; Ashraf *et al.* 2017; Lin *et al.* 2017; Popoviciu and Negreanu-Pîrjol, 2017) who demonstrated the effectiveness of ailanto as a phytoremediation plant to extract Cr, among other metals.

A recent study (Lebrun *et al.* 2020) has shown that *Ailanthus altissima* remove As and Pb from the soil, in such a way that the As is absorbed, mainly, in the roots due to its similarity with P, with very low amounts in the leaves, while Pb is restricted only to the root surface. More recently, the success of the plant in remedying a soil with Pb and Ni contamination has been demonstrated, this efficiency being clearer when the soils were treated with organic amendments and the plant (Mohebzadeh *et al.* 2021).

In a short period of time, *Ailanthus altissima* has the ability to retain these minority elements of the soils, an also, to changeits concentration in the soil. The statistical study has demonstrated its capacity as a phytoremediator. Thus, this should be considered in future works, taking into account that currently in the European Union it is estimated that there may be up to 2.8 million places where polluting activities are developed or have been developed (Payá Pérez & Rodríguez Eugenio, 2018).

VI. Conclusions

Ailanthus altissima presents a clear and marked expansion in habitats significantly disturbed by anthropic actions. Thus, the species has been considered one of the most tolerant to air and soil pollution. Being highly resistant to SO2, heavy metals and other compounds harmful to most plant organisms It has been shown that the existence or degree of concentration of certain chemical substances in soils is closely related to the proliferation of *Ailanthus altissima*.

According to our initial hypothesis and the specific objective of this research, the results of the statistical study conclude that *Ailanthus altissima* produces a change in the content of minor elements content, a fact that must be consider for future studies of soil fertility and heavy metal contamination.

Therefore, it is interesting to study those plant organisms that have high tolerance and ability to absorb harmful components of urban soils, in order to manage green areas. In addition, it is important to consider that those species are capable of surviving and growing without constant irrigation and they are sustainable and disturb natural spaces as little as possible and use species without risk of future Invasions.

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Clustering of Fine-Grained Tropical Soils using Data Science Tools Applied to their Geotechnical Properties

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Abstract- The characterization of fine-grained tropical soils for use in pavements has evolved since the 1980s, however, even today these soils are still discarded or underused in infrastructure works because they do not fully meet the requirements established by traditional classification methodologies or even by the CBR. Tropical soils present peculiarities of geotechnical behavior regarding elastic and plastic deformability, as many authors have already observed. This article contributes to this distinction by analyzing the grouping of thirteen fine-grained soils from northeastern Brazil through the application of data science tools to the results of geotechnical tests. More than fifty geotechnical parameters obtained in the laboratory were considered. By means of simple and multiple linear regressions, they were analyzed in a hierarchical cluster, using Ward's linkage method and Euclidean distance. The results showed that the mechanical behavior of soil compaction and the granulometry, especially the quantities of silt and fine sand, were decisive for the initial division of soils into clusters.

Keywords: *tropical soils. geotechnical properties. geotechnical behavior. cluster analysis. data science.*

GJHSS-B Classification: *DDC Code: 418.007 LCC Code: P53*



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Clustering of Fine-Grained Tropical Soils using Data Science Tools Applied to their Geotechnical Properties

Mayssa Alves Da Silva Sousa [α], Roberto Quental Coutinho [σ] & Laura Maria Goretti Da Motta [ρ]

Abstract- The characterization of fine-grained tropical soils for use in pavements has evolved since the 1980s, however, even today these soils are still discarded or underused in infrastructure works because they do not fully meet the requirements established by traditional classification methodologies or even by the CBR. Tropical soils present peculiarities of geotechnical behavior regarding elastic and plastic deformability, as many authors have already observed. This article contributes to this distinction by analyzing the grouping of thirteen fine-grained soils from northeastern Brazil through the application of data science tools to the results of geotechnical tests. More than fifty geotechnical parameters obtained in the laboratory were considered. By means of simple and multiple linear regressions, they were analyzed in a hierarchical cluster, using Ward's linkage method and Euclidean distance. The results showed that the mechanical behavior of soil compaction and the granulometry, especially the quantities of silt and fine sand, were decisive for the initial division of soils into clusters. For refining the clusters, we considered the different types of geotechnical parameters (physical, chemical and mechanical) in order to highlight other important variables in the distinction of the behavior of these materials. Additionally, microscopic images were compared also using data science techniques and the results corroborated those obtained in cluster analysis, indicating that soil mineralogical characteristics are associated with with the results of laboratory geotechnical tests.

Keywords: tropical soils. geotechnical properties. geotechnical behavior. cluster analysis. data science.

I. Introduction

In Brazil, the study of the behavior of fine-grained tropical soils, in the perspective of pavement engineering, began several decades ago, especially with the works of Nogami and Villibor, 1991, 1995), which introduced the classification called MCT. These are soils typical of the tropical environment that, according to the concept adopted by the *Committee on Tropical Soils of the International Society of Soil Mechanics and Foundation Engineering - ISSMFE* in 1985, present "peculiarities of properties and behavior, in relation to non-tropical soils, due to the performance in the same geological and/or pedological processes, typical of humid tropical regions".

It is also emphasized that the introduction of repeated load tests for the determination of the resilient modulus and permanent deformation of this type of soil (Medina and Preussler, 1980; Svenson, 1980) consolidated the appropriate mechanical characteristics of fine-grained tropical soils, complementing the MCT methodology.

Due to fine granulation, most of these soils are usually discarded or underused in infrastructure works because they do not present geotechnical parameters that fit the traditional selection criteria (*Transportation Research Board - TRB and California Bearing Ratio - CBR*). However, it has been demonstrated by several surveys (Nogami and Villibor, 1991; Guimarães, 2009; Medina and Motta, 2015; Sousa, 2016; Dalla Roza and Motta, 2018; Lima, Motta and Guimarães, 2017; Lima et al., 2020; Guimarães, Motta and Castro, 2019; Guimarães, Silva Filho and Castro, 2021; among several others) that, regardless of granulometry, consistency indexes and CBR, many of the fine-grained tropical soils have excellent mechanical performance in terms of resilience and plastic deformability, justifying their use in road and railway pavements.

Currently, many laboratory tests are carried out to expand knowledge about soil behavior for geotechnical purposes, determining their physical, mechanical, chemical and mineralogical characteristics. The joint analysis of the results obtained by these tests can be performed by means of clustering techniques and can provide valuable information to understand the behavior of soils considering several variables at the same time, by a multivariate analysis.

In this context, Frank and Todeschini (1994) define Cluster Analysis as a set of multivariate exploratory methods that seek to find clusters, based on some criterion of similarity between objects (or variables), and that the result of clustering depends greatly on the method used, the standardization of variables and the measure of similarity chosen. The main premise is that the groups or "clusters" formed should be as homogeneous as possible and the differences between the various clusters as large as possible.

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In data science, cluster analysis is part of unsupervised Machine Learning technology that encompasses a set of tools for creating clusters with homogeneous properties from a large number of heterogeneous samples.

Data science according to VanderPlas (2016) is difficult to define, but can be considered as an interdisciplinary set of skills that are becoming increasingly important in many applications in industry and academia and comprises the intercession of three distinct overlapping areas: 1 – *Math & Statistics Knowledge*, to model and summarize data sets; 2 – *Hacking Skills*, to design and use algorithms to store, process and visualize this data efficiently and, 3 – *Substantive Expertise*, knowledge necessary to interpret the results.

For the application of Data Science it is common to use programming languages such as R and Python (among others) through the implementation of codes and sets of functions (libraries) that allow to manipulate and treat data, as well as generate relevant information about the data in seconds.

It is noteworthy that the Python programming language has established itself as one of the most popular languages for scientific computing due to its interactive nature and its system of maturation of scientific libraries, being an attractive choice for the development of algorithms and exploratory data analysis (Millman and Aivazis, 2011).

There are several libraries with several modules with different functionalities and are used at different stages of the analysis in Data Science with Python, whose focus varies according to the analyst's objective. Thus, to deepen the knowledge about the main libraries and modules, the following references are recommended (not limited to these): Millman and Aivazis (2011); Pedregosa (2011); Harris et al., (2020) and Virtanen et al., (2020) and the book "Data Science of Zero" by Joel Grus (2016) that present concepts and details on the subject.

There are several clustering methods as shown Hastie, Tibshirani and Friedman (2009), Hair et al., (2009), Härdle and Simar (2015), Forsyth (2018), among others. The hierarchical method is the one used in this article, because it is the most frequently applied in practice. Härdle and Simar (2015), indicates that it starts with the best possible structure, calculates the distance matrix for the clusters, and joins the clusters that have the shortest distance.

However, it should be emphasized that clustering techniques in general, and especially hierarchical clustering, is an exploratory analysis of data, and different combinations may reveal different characteristics of the data set, as analyzed by Chen et al., (2007).

Härdle and Simar (2015) say that cluster analysis can be divided into two fundamental steps: 1 – Choice of proximity measure (each pair of observations is verified as to the similarity of their values) and, 2 – Choice of the cluster creation algorithm (based on proximity measurements, objects are assigned to clusters so that the differences between them become large and observations within the cluster become as approximate as possible).

The proximity between the data is measured by a distance or matrix of similarity distances whose components provide the coefficient of similarity or the distance between two points. There is a variety of distance measurements for the various types of data, and for quantitative variables, the most used are the Euclidean (used in this article), generalized/weighted, and Minkowski distance.

There is also a variety of cluster linkage methods, the main ones are indicated in the Table 1. Hair et al., (2009) state that, combined with the chosen measure of similarity, the clustering algorithm provides the means to represent the similarity between clusters with multiple members. However, according to Härdle and Simar (2015), Metz (2006) and Frank and Todeschini (1994) there is no "correct" combination of distance measurement and linkage method.

Table 1: Linkage methods in cluster analysis

Linkage methods	Clustering shapes	Comment
Single linkage	Defines the distance between two groups as the shortest distance between an element of one group to an element of the other group, also called the Nearest Neighbour algorithm.	Tends to produce large clumps, weakly linked and with little internal cohesion.
Complete linkage	The distance between two clusters is calculated as the greatest distance between two objects in opposite clusters, also called the Farthest Neighbour algorithm.	Tends to produce well separated and small clumps.
Average linkage	The distance between two clusters is calculated as the average of the distances between all pairs of objects in opposite clusters.	It proposes a compromise between the two previous algorithms.

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Centroid linkage	The distance between two clusters is calculated as the distance between their centroids.	Each cluster is represented by its centroid.
Ward method	The distance between two clusters is calculated by summing the squared deviations of each object from the centroid of its own cluster, joining two clusters that result in the smallest increase in the sum of squares of the total error within the group, also called the least variance method.	Unlike the other methods, brings together groups that do not dramatically increase heterogeneity, in this way, it unifies the groups so that the variation within these groups is minimized, groups created as homogeneous as possible.

Note: developed on the basis of Frank and Todeschini (1994) and Härdle and Simar (2015).

Another important detail for cluster analysis includes the standardization of the variables, since most cluster analyses using distance measurements are very sensitive to different scales or magnitudes between variables. In general, variables with higher dispersion (higher standard deviations) have a greater impact on the final similarity value. The most common form of standardization is the conversion of each variable into standard scores (Z scores) by subtraction of the mean and division by the standard deviation for each variable. The process converts each initial data score into a standardized value with an average of 0 and a standard deviation of 1, eliminating the bias that is introduced by the differences in the scales of the various attributes or variables used in the analysis (Hair et al., 2009).

The result of Cluster Analysis can be presented in the form of a graph, called dendrogram, where the observations, the sequence of the clusters and the distances between the clusters are presented. Hastie, Tibshirani and Friedman (2009) state that a dendrogram provides a complete interpretative description of the hierarchical cluster in a graphical format and that this is one of the main reasons for the popularity of this clustering method.

The main objective of this article is to analyze the clustering of fine-grained tropical soils in relation to their geotechnical properties in association with physical, mechanical, chemical and mineralogical characteristics, using data science tools (the Python programming language). In addition to the analysis and discussion of the hierarchical cluster dendrogram, the article compares microscopic images of soils in order to identify the similarity between them in mineralogical terms, verifying the similarity of the comparison with the result of the cluster analysis.

II. Materials and Methods

a) *Tropical Soils Studied*

Thirteen fine-grained soils were studied (with maximum of 10% of retained material in the no. 10 sieve - with a 2.0 mm opening, according to the criteria of the MCT Methodology: M - Miniature, C - Compacted, T - Tropical), collected in horizon B of road or deposit areas available in the Metropolitan Region of Recife, which is composed of 15 municipalities (including the capital – Recife), as indicated in Figure 1.

The MCT Methodology, created by Job Shuji Nogami and Douglas Fadul Villibor in 1980, allows the initial classification of soils into two large groups (lateritic behavior - L and Non-lateritic - N) and the categorization of these into the classes: LA - Lateritic Sand; LA' - Lateritic Sandy Soil; LG' – Lateritic Clay soil; NA - Non-Lateritic Sand; NA' - Non-Lateritic Sandy Soil; NS' – Non-Lateritic Silty Soil and NG' – Non-Lateritic Clay soil, more detailed in Villibor and Nogami (2009).

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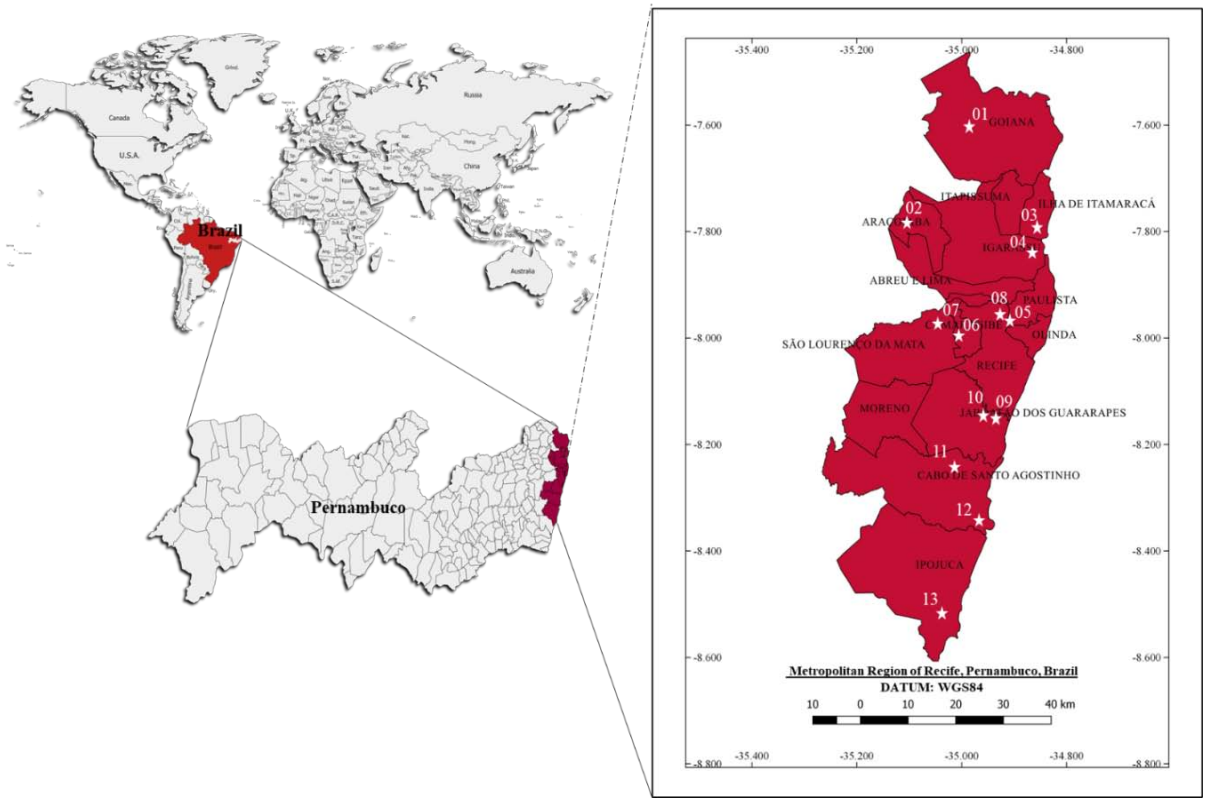

Figure 1: Location of the soils in the Metropolitan Region of Recife - Pernambuco, Brazil

The characteristic climate of the region is marked by large volumes of rainfall (1,500 to 2,000 mm per year) and high temperatures (> 20°C), according to the Agência Pernambucana de Água e Clima (APAC), a typical condition of tropical environments according to CHESWORTH et al., (2008).

Most of the selected materials are from the Barreiras Geological Formation which is formed by unconsolidated sediments with diversified particle size, observing the predominance of clay and sandy clay sediments and, less frequently, sandy, and may also present ferruginous concretions and pebbles (CPRM, 2014 and Coutinho et al., 2019).

In terms of pedology, the predominant soils are yellow acrisols and yellow latosols (in the Brazilian classification), which in the international soil classification system of the Food and Agriculture Organization of the United Nations (FAO) can comprehend the classes of ferralsols and acrisols.

They are soils that have suffered a lot from weathering processes and often present the phenomenon of natural cohesion/cementation, which is a strong pedogenetic hardening of the soil when it reaches the dry state (reversible in the wet state) due to the high concentrations of Fe hydroxides and Al oxides (CPRM, 2014; Guimarães, Silva Filho and Castro, 2021; Sousa et al., 2021; Coutinho and Sousa, 2021), as was clearly identified in the soils studied in this article (examples in Figure 2).



(a) 12SU-LG'

(b) 13IP-LA'

Figure 2: Examples of the natural cementation of the thin tropical soils of this research

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b) Geotechnical Tests And Parameters

The geotechnical parameters of the soils were obtained by physical, mechanical, chemical and mineralogical tests in the laboratory following, whenever possible, the Brazilian standards of the National Department of Transport Infrastructure (DNIT, formerly DNER). In all, 57 variables were considered, and Table 2 presents a list of the tests performed with an indication of which of the parameters obtained through them were used as the basis for the generation of soil clustering, including their respective units, as well as the standards and manuals that served as a reference for the execution of each test.

Table 2: Performed tests, obtained geotechnical parameters and reference standards/manuals

Test	Parameters	Standards
Real Particle Density	Real Particle Density (δ, g/cm³)	DNER-ME 093/94
Atterberg limits	Liquid Limit (LL, %), Plastic Limit (PL, %), Plasticity Index (PI, %)	DNER-ME 122/94; DNER-ME 082/94
Granulometric analysis (with deflocculant)	%Clay, %Silt, %Sand, %Fine Sand (%FS), %Medium Sand (%MS), % Coarse Sand (%CS), %Gravel(%Grav)	DNER-ME 051/94
MCT Classification	Coefficients c' and d', e' index, Immersion Mass Loss (PMI, %), Immersion Mass Loss – specimen with optimal soil moisture (PMIwo, %)	DNER-ME 258/94; DNER-ME 256/94
Compaction	Apparent dry specific weight ($\rho_{dmáx}$, g/cm³) and optimal moisture content (w_o, %)	DNIT 164/2013-ME
California Bearing Ratio	CBR (%) and expansion (Exp., %) at the optimal moisture content	DNIT 172/2016-ME
Chemical tests	hydrogen potential in: water (pH_{H2O}) and KCl (pH_{KCl}), ΔpH (pH_{KCl} - do pH_{H2O}), Organic Matter (M.O., $g.kg^{-1}$), Base saturation (V, %), Aluminum saturation (S, %), Cation Exchange Capacity (CEC, $cmol_c dm^{-3}$)	EMBRAPA (2017)
Soil-Water Characteristic Curve	Soil suction at optimal moisture contente (S_{wo}, kPa), saturation humidity (θs, %), residual moisture (θ_r, %), suction obtained in the resilient module specimens (SMR, kPa) and parameters of Model's Gitirana Jr. and Fredlund (2004) - Ψb1, Ψres1, Sres1, Ψb2, Sb, Ψres2, Sres2	ASTM D5298 – 16
Resilient Modulus	Resilient Modulus medium (MR_{medium}, MPa), regression coefficients of linear models as a function of stresses: confining stress (K1TC e K2TC) and deviator (K1TD e K2TD), Composite model parameters (K1MC, K2MC e K3MC)	DNIT 134/2018-ME
Permanent Deformation	Maximum permanente deformation (ε_p, mm) obtained under confining stress - σ_3 (120 kPa) and deviator stress - σ_d (360 kPa), Parameters of the Guimaraes Model (2009) - Ψ1, Ψ2, Ψ3 and Ψ4	DNIT 179/2018-IE

The LL and PL tests were performed both with samples previously dried in the air and destroyed (standard procedure) and without previous drying, and the parameters obtained were identified as follows: without previous drying - LL1, PL1 and PI1 and, with drying and destruction: LL2, PL2 and PI2.

The test of the soil-water characteristic curve was performed using the filter paper method, with the specimen compacted on the intermediate Proctor energy and considering a drying and wetting mixed trajectory. The model adjustment parameters of Gitirana Jr. and Fredlund (2004) follow equation 1, applicable to soils with bimodal behavior commonly identified in lateritic tropical soils. The coefficients of determination (R^2) obtained were all very close to 1 (>0.91) showing suitability of the model to the soil behavior of this article.

$$S_e = \frac{S_1 - S_2}{1+\left(\frac{\psi}{\sqrt{\psi_{b1}\psi_{res1}}}\right)^{d1}} + \frac{S_2 - S_3}{1+\left(\frac{\psi}{\sqrt{\psi_{res1}\psi_{b2}}}\right)^{d2}} + \frac{S_3 - S_4}{1+\left(\frac{\psi}{\sqrt{\psi_{b2}\psi_{res2}}}\right)^{d3}} \quad (1)$$

Where: S = degree of saturation; = suction obtained in the laboratory test;b = suction at the air inlet point; res = residual suction and d1, d2, d3 = model's parameters.

Mechanical compaction, CBR, resilient modulus (MR) and permanent deformation tests were performed on the intermediate Proctor energy. The equations that were used to model resilient behaviors and permanent soil deformation are indicated in Table 3.

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Table 3: Models used to express the resilient behavior and permanent deformation of the soils of this research

References	Equation	Variables	Parameters
Hicks and Monismith (1970)	MR=k13k2	3	k1 and k2
Svenson (1980)	MR=k1dk2	d	k1 and k2
Macêdo (1996)	MR=k13k2dk3	3;d	k1, k2 and k3
Guimarães (2009)	p(%)=1302d03N4	3;d and N	1, Ψ2, 3 and 4

Notation: 3 = confining stress; d= deviator stress; p(%) = Specific permanent deformation, N = number of loading cycles and, k1, k2, k3, 1, Ψ2, 3 and 4 are regression parameters, 0 = reference stress, considered with the atmospheric pressure of 100 kPa.

c) *Data Science Tools For Cluster Analysis*

The implementation of the codes required for the analyses was carried out in the Python programming language (version 3) available in the Anaconda virtual environment (https://www.anaconda.com/). In addition to the standard Python library, modules and functions from other libraries were used as indicated in Table 4, which explains the general objectives of each (in the application column) and in the column "functions and modules" is the specific indication of the main tools that were used.

Table 4: Main Libraries, modules and functions used in the analysis with Python in this research

Libraies	Aplication	Modules and functions
Pandas https://pandas.pydata.org/	Data manipulation and analysis: structures and operations to manipulate numerical tables and time series.	read_excel, drop, set_index, head, shape
Numpy https://numpy.org/	Data analysis: mathematical functions, random number generators, linear algebra routines, Fourier transformations, etc.	Array, arrange, mean, std, argsort
Scipy https://www.scipy.org/	Data modeling: fundamental algorithms for statistical functions (probability distributions, hypothesis testing, frequency statistics, correlation functions, etc.).	scipy.cluster, hierarchy, hierarchy.linkage (method='ward',metric='euclidean'), hierarchy.dendrogram
Scikit-learn https://scikit-learn.org/	Data Modeling: Machine learning algorithms, supervised and unsupervised (Classification, Regression, Clustering, Model Selection, etc.)	sklearn.preprocessing, StandardScaler, transform
Scikit-image https://scikit-image.org/	Image processing: functions for manipulating scientific, specific or general-purpose images, operations on Numpy matrices, manipulation of exposure and color channels, detection and segmentation of objects.	Feature
Imageio https://pypi.org/project/imageio/	Image manipulation: reading and writing image data, including animated images, volumetric data, and scientific formats.	imread
Matplotlib https://matplotlib.org/	Data presentation and exploration: creating graphs and general data visualization	plot.figure, plot.title, plot.xlabel, , plot.yabel, subplot , imshow

For the analysis of data clusters through the hierarchical method and implementation via codes and libraries in Python, the data were standardized by applying the Z-score Normalization Method, and for this an array was created through the "array" function of the Numpy library and the functions "StandardScaler" and "transform" of the Scikit-learn library were applied.

Then, to obtain hierarchical cluster of the (standardized) datasets, the hierarchy function of the Cluster module of the SciPy library was imported. The implementation was made considering Ward's linkage method and Euclidean distance.

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d) Image Comparison

As a complementary analysis and a way of using data science tools for image analysis, images were separated from the fine-earth fraction of soils (in this case the material passing in sieve no. 10 and retained in no. 200) made in the Stereo Microscope Zeiss Discovery V8 in order to compare the soils to each other and to verify some similarity with the results obtained in the clustering.

The mineralogy of the fraction passing in sieve no. 200 was studied by performing the X-ray Diffraction test and images of the coarse fraction of the soil (retained in sieve no. 10) were also extracted, but were not considered in the analyses of this article.

In summary, the process of comparing images in Python is done by implementing a function that receives the image and processes it by transforming it into vectors. The function applied in this article was the BIC (Border-Interior Pixel Classification), which transforms and rescales the image, and finally computes two color histograms: one for the "interior" pixels and the other for the "border" pixels (edges of the image), then normalizes the histograms and concatenates them into a single vector. Vectors represent the frequencies of colors in the image, which allows, with the aid of a distance measurement, to compare images for color similarity.

To make the comparison, you must set an image as a reference so that the distance of the other images related to it is calculated. In this part of the analysis, we chose to use the same distance measurement used in the cluster analysis that was the Euclidean distance.

III. Results and Discussion

a) Geotechnical Parameters

Table 5 presents part of the database of the studied soils: geotechnical classifications (TRB, USCS and MCT), MCT classification, real density, Atterberg limits, granulometry, mechanical compaction parameters, CBR (and expansion), MR, DP and chemical data. Table 6 presents the continuity of the database with parameters associated with the characteristic curve of the soils. The units of measurement of each parameter were presented in Table 2.

Regarding the USCS class, five samples were classified as ML (silt soils of low compressibility), four were classified as SC (clay sand), and two as SM (silty sand). Soil 03 was classified as SM-SC and soil 13 was classified as CL (clay soil of low compressibility).

Table 5: Classification database, true density, consistency limits, granulometry, compaction, CBR, expansion, MR, DP and chemical data from soils studied in this research

Soil	1	2	3	4	5	6	7	8	9	10	11	12	13
MCT	LG'	LG'	NA'	LG'	LA'	LA'	NA'	LA'	LA'	LA'	LA'	LG'	LA'
TRB	A-6	A-7-6	A-4	A-6	A-6	A-6	A-6	A-4	A-4	A-7-6	A-7-5	A-6	A-6
USCS	ML	ML	SM-SC	SC	SC	SM	ML	ML	SM	SC	ML	SC	CL
d'	247	139	133	87	131	140	147	107	109	217	188	150	154
e'	0,94	0,62	1,19	0,93	0,62	0,62	1,16	0,84	0,91	0,87	0,84	0,81	0,81
c'	2,0	1,9	1,2	1,7	1,4	1,05	1,05	1,29	0,92	1,05	1,0	1,67	1,1
PMI	75	10	153	58	9	10	143	40	58	56	49	40	40
PMI_{wo}	75	0	98	38	9	0	34	0	0	0	0	39	42
δ	2,63	2,67	2,65	2,63	2,64	2,67	2,69	2,70	2,68	2,68	2,68	2,67	2,68
LL1	32,2	33,7	22,0	26,2	30,0	28,5	32,2	34,5	27,4	27,5	33,9	27,8	28,7
PL1	22,8	25,9	18,0	20,3	20,4	20,4	24,4	26,5	19,3	19,8	30,4	18,7	19,8
PI1	9,4	7,8	4,0	5,9	9,6	8,1	7,8	8,0	8,1	7,7	3,5	9,1	8,9
LL2	35,6	41,3	24,1	33,4	37,9	39,9	39,9	39,5	34,7	40,5	46,6	34,8	35,9
PL2	25,0	27,9	17,4	21,7	23,1	26,5	28,5	32,4	24,9	25,4	30,1	21,4	24,2
PI2	10,6	13,4	6,7	11,7	14,8	13,4	11,4	7,1	9,8	15,1	16,5	13,4	11,7
%Clay	50,2	47,8	32,3	38,8	41,7	42,6	46,5	47,0	42,0	40,3	45,5	34,9	44,7
%Silt	14,2	19,0	5,6	6,6	4,8	5,2	13,6	19,3	5,7	8,1	6,8	4,4	8,4
%FS	25,3	18,7	55,9	36,2	31,5	31,1	27,3	21,8	35,3	29,9	25,9	33,6	25,5
%MS	10,0	11,2	6,1	17,3	18,2	20,6	12,3	11,5	16,7	20,2	20,9	25,7	20,5
%CS	0,3	1,2	0,1	0,8	2,1	0,6	0,3	0,3	0,3	0,8	0,9	0,9	0,9
%Grav	0,1	2,1	0,0	0,2	1,7	0,1	0,0	0,1	0,0	0,8	0,1	0,4	0,1
$\rho_{dmáx}$	1,79	1,75	1,97	1,91	1,94	1,88	1,78	1,69	1,90	1,87	1,86	1,94	1,86
W_o	17,4	18,4	10,6	13,1	13,7	13,8	16,5	19,0	12,7	12,7	15,6	11,2	13,2

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CBR	12,8	15,0	35,0	15,4	25,0	17,0	21,0	15,2	30,0	16,0	27,5	29,0	23,0
Exp.	0,05	0,00	0,15	0,60	0,00	0,00	0,05	0,10	0,00	0,20	0,00	0,20	0,00
MR_{medium}	416	394	865	477	425	667	557	394	507	611	487	478	689
K1TC	222	144	200	175	153	164	231	214	519	345	222	359	227
K2TC	-0,24	-0,33	-0,48	-0,32	-0,33	-0,49	-0,28	-0,2	0,01	-0,19	-0,25	-0,09	-0,34
K1TD	205	144	246	171	146	177	227	197	405	327	202	297	243
K2TD	-0,33	-0,41	-0,52	-0,42	-0,44	-0,60	-0,36	-0,29	-0,09	-0,26	-0,36	-0,20	-0,41
K1MC	354	282	289	295	263	168	384	342	650	462	403	483	341
K2MC	0,33	0,32	0,03	0,25	0,35	0,02	0,29	0,30	0,34	0,21	0,39	0,35	0,14
K3MC	-0,51	-0,53	-0,50	-0,52	-0,62	-0,64	-0,51	-0,43	-0,32	-0,39	-0,55	-0,43	-0,47
ε_p	6,52	6,59	2,93	7,19	1,63	6,66	4,18	3,63	0,78	3,37	3,15	1,30	6,40
$\Psi 1$	0,21	0,28	0,13	0,46	0,07	0,02	0,03	0,01	0,08	0,10	0,04	0,09	0,47
$\Psi 2$	-0,45	0,79	0,25	-0,51	0,07	-2,31	-1,86	-1,22	0,04	0,17	-0,53	-0,27	1,09
$\Psi 3$	1,73	1,30	1,24	1,30	0,07	3,90	2,98	3,96	0,91	1,42	2,39	1,07	0,95
$\Psi 4$	0,06	0,06	0,06	0,05	0,07	0,05	0,06	0,08	0,05	0,07	0,06	0,05	0,05
pH_{H2O}	4,7	4,9	4,9	4,8	4,6	4,6	4,4	4,6	4,6	4,5	4,4	4,8	4,7
pH_{KCl}	4,0	4,1	4,0	3,9	3,9	4,0	4,1	4,1	4,0	3,9	4,0	4,0	4,0
ΔpH	-0,7	-0,8	-0,9	-0,9	-0,7	-0,6	-0,3	-0,5	-0,6	-0,6	-0,4	-0,8	-0,7
M.O.	7,59	7,12	3,85	5,53	5,11	4,37	4,32	7,19	5,68	6,25	6,67	5,94	4,43
CEC	4,63	4,55	2,80	3,55	3,75	3,85	3,84	4,40	5,42	5,74	4,46	4,07	4,64
S	36,6	28,4	43,4	61,5	79,1	54,3	41,4	53,2	73,1	69,0	56,6	86,3	55,5
V	25,1	30,6	28,9	19,4	8,8	17,9	17,7	13,4	7,2	9,4	10,3	3,9	15,7

In the TRB classification, three samples were classified as A-4 (non-plastic silt soils to moderately plastic), seven as A-6 (plastic clay soils), one (soil 11) as A-7-5 (PI moderate in relation to LL, and may be elastic and subject to high volume variation) and two (02 and 10) as A-7-6 (high PI in relation to LL and are subject to extremely high volume changes).

According to the TRB classification, all soils of the research would present poor to bad behavior as a subbed layer of pavements, however, considering the results of the Resilient Modulus (MR) and Permanent Deformation (PD) trials, the studied soils present excellent behaviors regarding these aspects, evidencing that fine-grained tropical soils present peculiar behavior, as noted in several works already mentioned.

Regarding the MCT classification, it is verified that in general, the samples further north of the metropolitan region of Recife present clayey behavior, except for sample 03 (fine sandy soil), moving to a more sandy behavior when collected in the south region (except for sample 12).

It is observed that the coefficient d', which is associated with the inclination of the dry branch of the Mini-MCV compaction curve (in MCT), presents important variation between the samples, indicating different behaviors. Villibor and Nogami (2009) specify that d' values above 20 indicate soils of lateritic behavior and above 100 (very high) refers to the typical behavior of fine clayey sands. It is noted that most of the samples evaluated present these characteristics in this aspect and also granulometric and mineralogical.

Regarding Mass Loss by Immersion (PMI_{wo}), the values obtained for specimens (CP) molded in optimum moisture were 0% to almost 50% of the soils, even after 24 hours of immersion. The e' index, which associates the MLI and the coefficient d', reflects the lateritic or non-lateritic behavior of the analyzed soil. Soils with low mass loss and high d' values result in lower values of e' and more evident lateritic behavior: 02, 05, 06, 08 to 13.

As for the values of c', which is associated with the slope of the soil deformability curve, it is understood that the higher the value of c', the more deformable the soil is, since there are steeper reductions in the CP height as the blows are applied in the Mini-MCV compaction test. Thus, the soil with the highest deformability was soil 01 (c' = 2.0) indicating the behavior of a clay soil (c'>1.5 according to Nogami and Villibor (2009)), and soil 09 presented the lowest c' value showing typical behavior of non-plastic sands and silts (c'<1.0, according to Nogami and Villibor (2009)). In the permanent deformation tests, soil 09 showed the lowest deformation and soil 01 was the most notable deformation.

Regarding granulometry, we stress that other parameters associated with granulometry were also considered, but deleted from the table in order to optimize the presentation of the data. The variables in this case were: % of total sand, % of passing material in sieve no. 10, % of material retained in sieve no. 10 and percentage of passing material in no. 200.

All soils presented appreciable content of clay (between 32.28% and 50.17%) and fine sand (between

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18.66% and 55.85%), and low percentage of coarse material (retained in sieve no. 10 – between 0.12% and 3.76%). Regarding the consistency indexes (LL, PL and PI) it is observed that for all soils there was an increase in values with drying. The actual density values of the grains obtained were between 2.629 – 2.699 g/cm^3 which is approximate, according to Gidigasu (1976), to the quartz mineral (2.65 to 2.66 g/cm^3) and the clay mineral kaolinite (2.60 to 2.68 g/cm^3), which is coherent since most of the soils studied are composed of sand and clay fractions.

The results of maximum dry specific mass (ρ_{dmax}, g/cm^3) and optimum moisture (W_{or}, %) ranged between 1.69 - 1.97 g/cm^3 and between 10.6 - 19%, respectively, and showed some correspondence with the granulometry. Soil 03, for example, has a large percentage of fine sand in its composition, which is reflected in the compaction curve (low optimum moisture and high specific dry mass), while soil 08, with the highest percentage of silt, compared to the other soils, presented higher moisture and lower specific mass.

Six soils presented CBR values below 20%, which is, according to the paving manual of the Brazilian Department of Transport Infrastructure (DNIT, 2006), the minimum allowed for application in subbase layers, considering the empirical sizing method. The other soils presented values higher than 20%, reaching a maximum of 35% (sample 03), which according to the mentioned guidelines could be recommended for subbase layer and none of the soils would be recommended for the base layer since CBR>60% is required. Regarding expansion, six soils showed an expansion of 0% after 96 hours of immersion in water, and the other 7 samples showed low expansion values. The values of $_{mean}$ MR of all soils were above 400 MPa, considered a high value for fine-grained soils, comparable to the values of boulder soils.

As for permanent deformation, all soils presented low total deformation values (ε_p, mm) for all stress levels applied in the test. According to The National Pavement Sizing Method (MeDiNa), the sum of the contribution of all layers and subgrade to the sinking of the wheel track should be a maximum of 10 mm for Main Arterial Route, for example.

Almost half of the soils exhibit opposite behavior in relation to the parameter Ψ_2 of the expression of permanent deformation, associated with the confining stress. Soils with negative values of Ψ_2 show a reduction in permanent deformation with increased confining stress. All values of Ψ_3 are positive indicating that the variation of the deviation stress increases permanent deformation, which is expected.

The pH measurement reflects the active acidity of the soil, and the results obtained (< 5) represent soils with high acidity, which is expected for lateritic soils. Specifically in water, values between 4.4 and 4.7 were obtained indicating the presence of exchangeable aluminum (Sobral et al., 2015), which suggests possible gains in chemical stabilization processes. ΔpH is associated with the predominance of clay minerals such as kaolinite and illite, (Farias, 2012 and Camapum de Carvalho et al., 2015).

The CEC presented low values (between 2.8 – 5.74 cmol$_c$dm^{-3}) indicating predominance of 1:1 clay such as kaolinite (Gidigasu, 1976; Das, 2008 and Sobral et al., 2015). Regarding Organic Matter (OM), all soils have a low content (< 15 g.kg^{-1}) according to Prezotti (2013). For all soils, the percentage of base saturation (V, %) is considered "low" (< 50%) according to Prezotti, 2013). Aluminum saturation (S, %) was in the "low" class (< 50%) in soils 01, 02, 03 and 07, "middle" class (50% - 70%), in 04, 06, 08, 10, 11 and 13, and, "high" class (>70%) in soils 05, 09 and 12, according to Prezotti, (2013).

Table 6: Data of the characteristic curve of the studied soils (Continuation of the database in Table 5)

Soil	S_{Wo}	θ_s	θ_r	SMR	Ψ_{b1}	Ψ_{res1}	S_{res1}	Ψ_{b2}	S_b	Ψ_{res2}	S_{res2}
01	200	20,58	1,47	198,59	3,5	5,0	0,84	10000	0,82	26800	0,02
02	800	20,67	0,00	760,23	3,0	6,0	0,89	7500	0,85	22500	0,08
03	30	34,34	0,06	1071,43	2,5	16,0	0,70	8000	0,62	21500	0,02
04	30	17,64	0,00	487,86	4,0	5,5	0,74	10000	0,59	23000	0,03
05	300	14,35	0,26	434,80	3,4	6,5	0,78	8700	0,72	27000	0,03
06	50	29,31	0,99	372,62	4,8	6,5	0,84	18000	0,77	36000	0,10
07	6	23,60	1,01	430,23	6,0	9,0	0,89	14000	0,83	20000	0,05
08	100	22,26	0,00	485,99	3,8	10,0	0,91	12000	0,87	48000	0,07
09	400	13,49	0,26	1088,10	1,2	11,0	0,75	14000	0,72	30000	0,04
10	25	23,91	0,45	1527,01	2,1	20,0	0,74	15000	0,66	25000	0,04
11	40	33,60	0,17	1673,32	3,8	20,0	0,79	13500	0,71	22500	0,04
12	1000	17,20	0,00	1147,13	2,0	11,0	0,69	5500	0,66	24000	0,04
13	40	26,85	0,60	275,91	3,5	6,5	0,73	13800	0,65	30000	0,04

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Table 6 presents the results of the modeling of the soil-water characteristic curves. The characteristic curves of the studied soils present high suction values and air intake points, since the more weathered the soil, the higher the presented suction values are (Boszczowski and Ligocki, 2012). The shape of the curves suggests a bimodal behavior, indicating that both micropores and macropores control water inlet and outlet flows (Feuerharmel et al., 2006).

The high suction values obtained are also similar to those obtained by Marinho and Stuermer (2000) when they studied a mature residual soil of Gnaisse (45% clay), compacted in normal and modified Proctor energies, obtaining air intake values ranging between 1000 and 2000 kPa and residual suction of 15,000kPa.

b) Cluster Analysis

The dendrogram created by processing the codes in Python resulted in the hierarchical structure presented in Figure 3. Seeking to understand how the algorithm effectively grouped the data, a top-down dendrogram analysis was carried out, i.e., noting which geotechnical variable or variables may have been used as a soil divider in each Cluster. For this, three cut-off points were defined in the dendrogram, as highlighted in the figure, and the clusters created were identified. It is emphasized that the clusterization obtained went through a much more complex process than is described here, since more than fifty geotechnical attributes were considered.

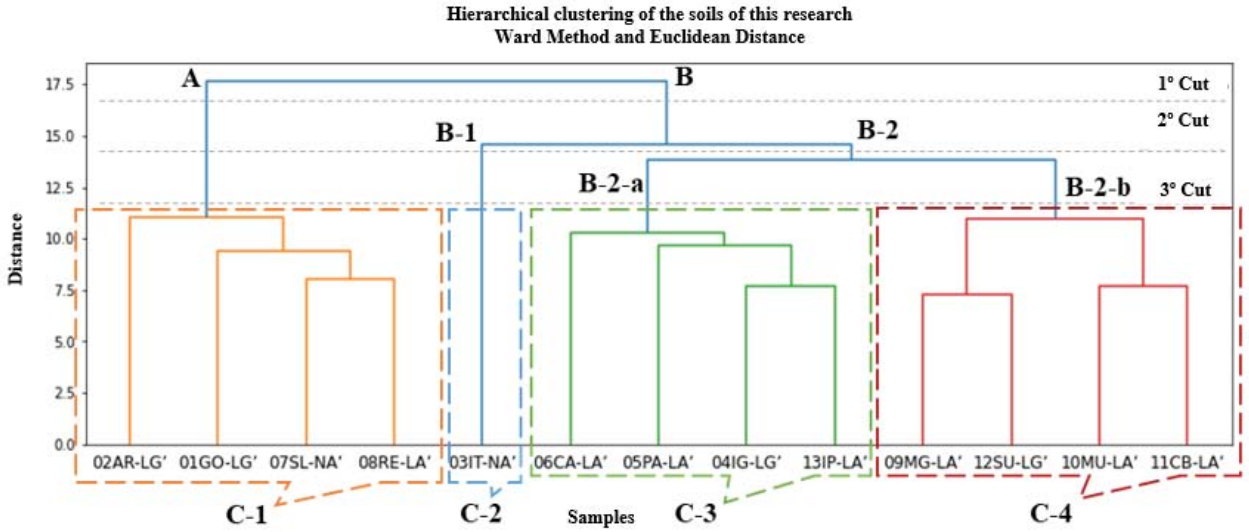

Figure 3: Analysis of the dendrogram of the hierarchical clustering of the soils of this research

Initially, in the first cut-off point, the algorithm divided the soils into two large groups (A and B), which may have been formed considering the results of the compaction test (optimum moisture and maximum dry apparent specific mass), since, as can be seen in the graph of Figure 4, there is a clear division of these groups through the compaction curves. Thus, it is observed that group A is composed of soils with higher values of optimum moisture (Wo > 16%) and lower values of ρ_{dmax} (< 1,8 g/cm³) and group B of soils with Wo < 16% and ρ_{dmax} >1,8 g/cm³), It was also noted that group A is composed entirely of USCS's ML class soils that take into account LL and PI.

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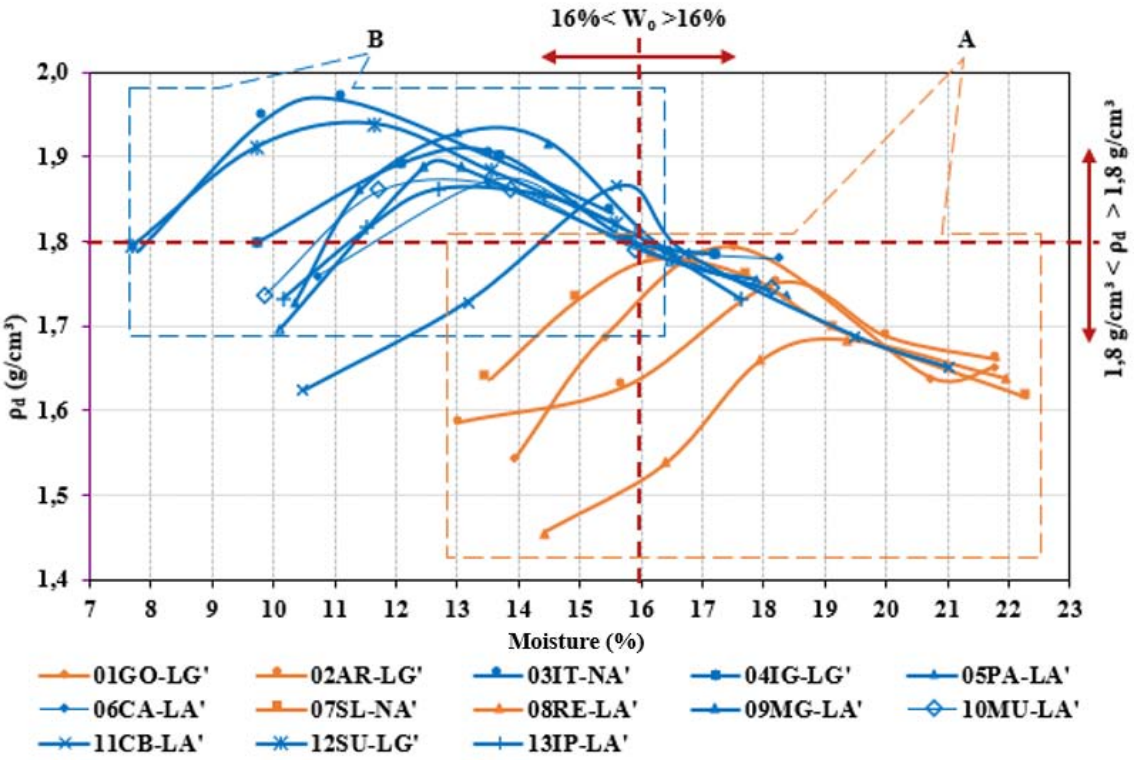

Figure 4: Division of groups A and B by the soil compaction curves of this research

In the second cut-off point, it is observed that group B is subdivided into two other groups (B-1 and B-2), while group A remains the same (showing that the soils of this group have more homogeneous characteristics than the soils of group B). This part of the clustering may have been made based on the granulometric composition, especially by the silt and fine sand fractions of the soils. The subdivision of group B into B-1 and B-2 was due to the high % of fine soil sand 03IT-NA' (55.85%), which differentiated it from the other soils of the group, as can be seen in the graph of Figure 5.

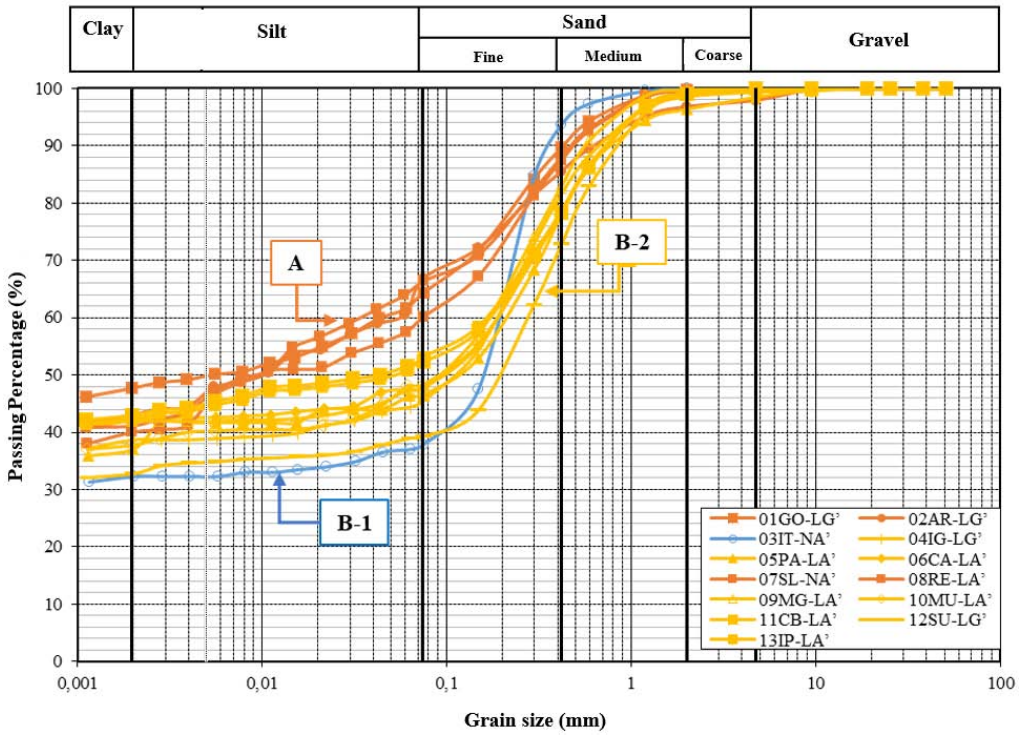

Figure 5: Division of groups A, B1 and B2 by the granulometric curves

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In the third and last cut-off point, group A again remained homogeneous. Because group B-1 was composed only of soil 03IT-NA', it also had no alterations (and will not have). group B-2, however, was subdivided into two subgroups (B-2-a and B-2-b), whose division may have been carried out as a function of the organic matter content found in the soils, as shown in Figure 6 (B-2-a: O.M. between 4.37 – 5.53 g/kg; B-2-b: 5.68 – 6.67 g/kg), but may also be associated with the behavior of several other variables that, despite presenting a certain "overlap" of values between groups tend, to present lower or higher results such as: ε_p - B-2-a: between 1.63 – 7.19 mm; B-2-b: 0.78 – 3.37 mm; ψ_{b1} - B-2-a: between 3.4 – 4.8 kPa; B-2-b: 1.2 – 3.8 kPa.

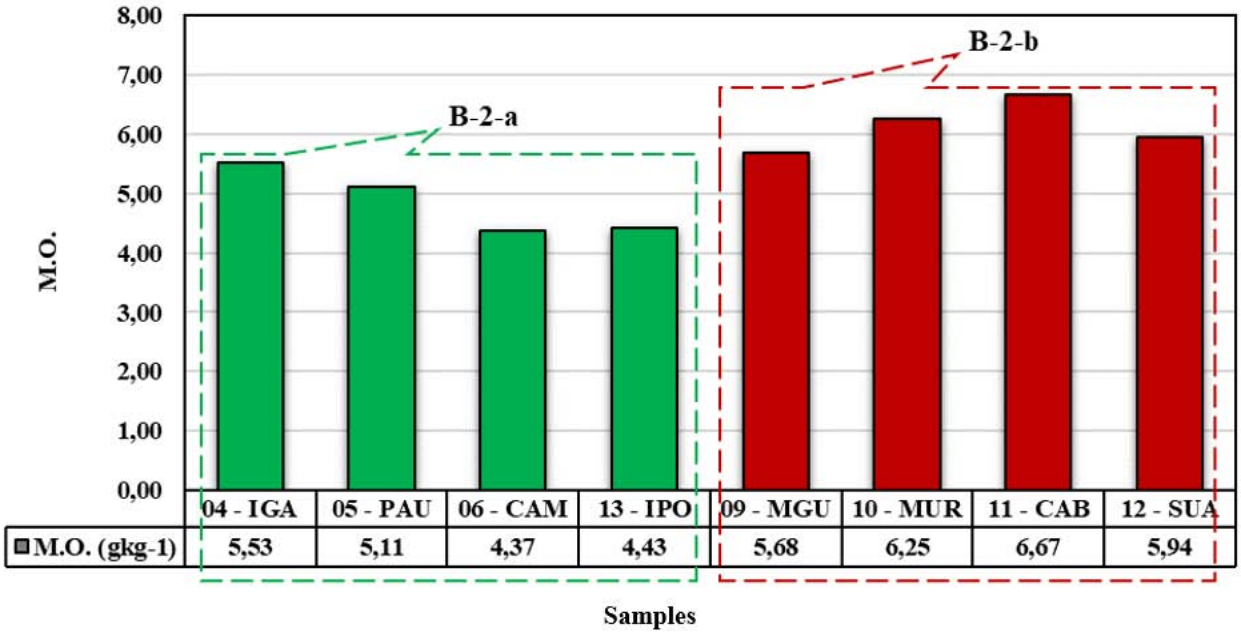

Figure 6: Division of groups B-2-a and B-2-b considering the organic matter content of the soils of this research

The final interpretation of the group allows the division of the studied soils into four different clusters (C-1 to C4) in the dendrogram, cluster 1 (C-1) composed of 4 soils of group A (01GO-LG', 02AR-LG', 07SL-NA' and 08RE-LA'), Cluster 2 (C-2) composed of the soil of group B-1 (03IT-NA'), Cluster 3 (C-3) formed by 4 soils of subgroup B-2-a (04IG-LG', 05PA-LA', 06CA-LA' and 13IP-LA') and Cluster 4 (C-4) composed of 4 soils of subgroup B-2-b (09MG-LA', 10MU-LA', 11CB-LA' and 12SULG'). From each cluster, greater similarities were identified between some pairs of soils, namely: c-1 - 07SL-NA' and 08RE-LA', C-3 - 04IG-LG' and 13IP-LA' and C-4 - 10MU-LA' and 11CB-LA'.

Soils 07SL-NA' and 08RE-LA', despite being of different MCT classes, are of identical USCS class and have similar values of liquidity limit, %clay, pH_{KCl}, δ, ε_p and S_b. Soils 04IG-LG' and 13IP-LA', though also of different MCT classes, are of the same TRB class (A-6) and have analogous values of PI, optimum moisture, K2TC, K2TD, ε_p, U'_{b1} and S_{res1}. The soils 10MU-LA' and 11CB-LA' are of the same MCT class with similar values of c', e', % silt, PI, ε_p and Ψ_{res1}.

It was also observed that the classification of aluminum saturation indicated by Prezotti (2013) may also be related to general soil grouping, since only one soil in each saturation class (low, medium and high) is distant from the formed group, which is certainly due to the other variables considered.

c) Stereo Miscroscope Image Comparison

Figures 7, 8 and 9 present the images that are most similar to the images of the 04IG-LG', 08RE-LA' and 12SU-LG' samples, respectively (a sample of each cluster obtained in the hierarchical cluster, with the exception of the cluster composed of the sample 03IT-NA because it is a group with a single element). The numbers presented next to each ranked image refers to the Euclidean distance in relation to the reference image.

The soils with color distribution most similar to soil 04IG-LG' are soils 07SL-NA', 13IP-LA', 11CB-LA', 10MU-LA' and 03IT-NA', and it is noted that, with the exception of sample 07SL-NA', the indicated soils are part of the same large hierarchical group (B) and, in addition, the 13IP-LA' soil coincides with the soil closest to 04IG-LG' in cluster C3/B-2-a. Visual similarity regarding the predominance of quartz particles is noted.

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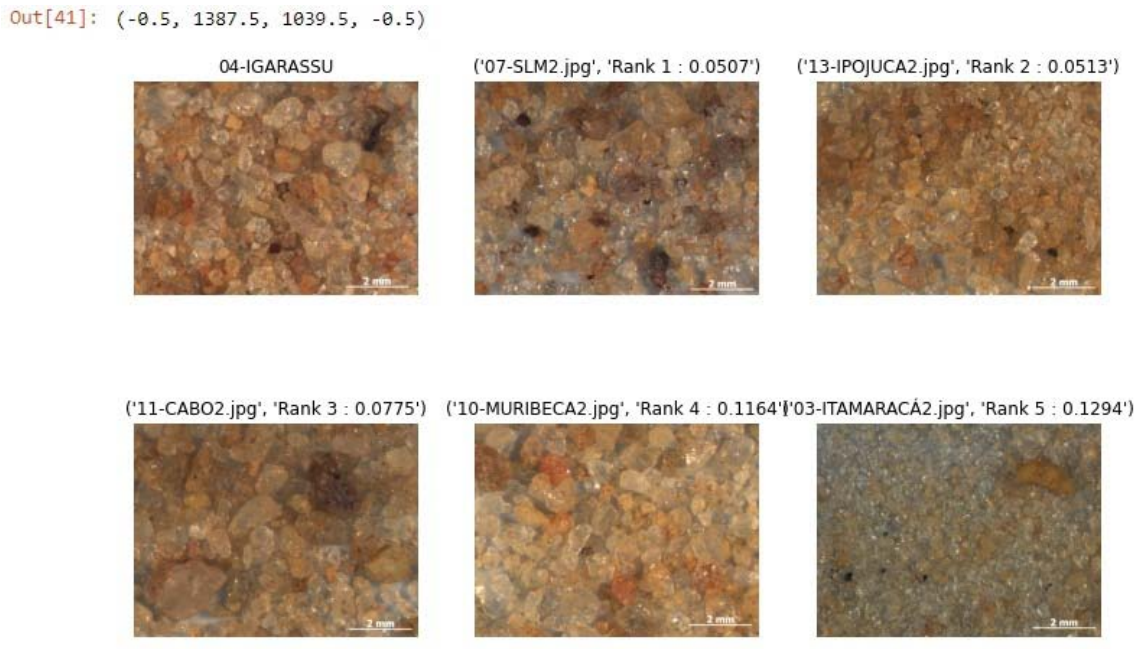

Figure 7: Images similar to sample image 04IG-LG', fine fraction

The soils with color distribution most similar to soil 08RE-LA' are soils 01GO-LG', 06CA-LA', 02AR-LG', 09MG-LA' and 12SU-LG', and it is noted that with the exception of sample 06CA-NA', the two closest soils are soils 01GO-LG' and 02AR-LG' which are part of the same large hierarchical group (A/Cluster C1). Visual similarity is also noted in relation to the presence of iron oxides (limonite).

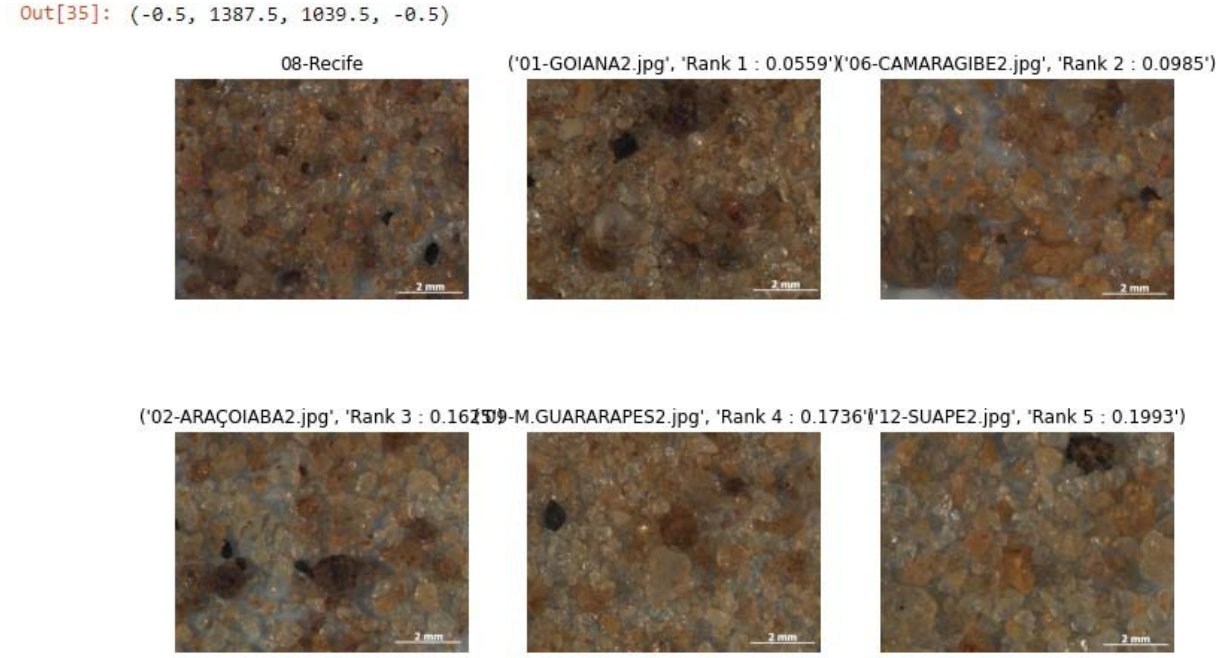

Figure 8: Images similar to sample image 08RE-LA', fine fraction

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Figure 9: Images similar to the 12SU-LG sample image,' fine fraction of this research

The soils with color distribution most similar to soil 12SU-LG' are soils 09MG-LA', 02AR-LG', 05PA-LA', 06CA-LA' and 01GO-LG'. It is noted that the closest soil (09MG-LA') coincides with the result of the cluster analysis, and, with the exception of soils 01GO-LG' and 02AR-LG', the other soils indicated as close are part of the same large group and subgroup (B and B-2).

In view of the obtained results, the comparison of soils through images using the techniques of data science can be considered promising, since the obtained results were near the cluster obtained with cluster analysis. The results using these two techniques, even though the same parameters were not used, showed correspondence between the mineralogical characteristics visualized in the images (iron oxides, rock fragments, quartz grains, etc.) with the results of geotechnical tests. The few variations found can be attributed to the methods themselves, since each technique used can provide different results (distance measurements, linkage methods, image descriptor, etc.).

As mentioned in the topic of Materials and Methods, for the acquisition of images, a Stereo Microscope Zeiss Discovery V8 available in the Paleontology laboratory of the Department of Geology of Federal University of Pernambuco was used. Although not trivial, it is believed that access to this type of equipment in universities is not very difficult, since it is an essential equipment in geology laboratories, biology and medicine. It can be noted that to use the Data Science tools presented here, it is not required that the images be obtained by this type of specific microscope, in fact, the important thing is that the images are of good quality and that they are obtained using minimum standards (process of obtaining samples, fraction of material, approximations, etc.) in order to obtain reliable results.

IV. Conclusion

The thirteen tropical soils of fine granulation examined in this study, originating from the northeastern region of Brazil, were characterized as materials with physical and mechanical behavior varying between clayey and sandy, having been labeled into different classes of fine soils according to the considered Classification systems (MCT, TRB and USCS). They presented high values of resilient modulus, low levels of permanent deformation, unsaturated behavior of the bimodal type in all soil-water characteristic curves, as well as chemical and mineralogical characteristics indicative of typically lateritic soils.

Multivariate analyses, such as cluster analysis applied in this article, consider three or more variables to characterize the behavior of the analyzed object, so it is understood that several geotechnical parameters were used at the same time to form the groups with the most homogeneous characteristics.

In this sense, other clusters were tested excluding, for example, the parameters of the two-dimensional models of resilient behavior (keeping only those associated with the composite model that presented the best framework for most soils), and it was observed that by excluding only the data associated with the model, or due to the deviation stress or the confining stress, there is no change in the dendrogram, however, by removing all the parameters associated with the two models, a dendrogram with another cluster

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structure is obtained, evidencing the association that the algorithm makes between the many variables.

Still, it was possible to notice that the mechanical characteristics of soil compaction (ρ_{dmax} and W_o) were decisive for the initial division of the groups, as well as the granulometry (mainly the percentage of silt). The chemical classification of aluminum saturation (S, %) indicated by Prezotti (2013) also showed a relationship with the clustering of the soils, indicating that the clustering considered, in fact, different types of characteristics of fine-grained tropical soils (physical, mechanical and chemical).

It was also noted that soils with mechanical clayey behavior (higher optimum moisture and lower dry apparent density) showed a more homogeneous behavior forming a cluster composed entirely of soils of the ML class (from the USCS classification, which is based on the LL and the PI) and with very similar characteristics of granulometry (percentage of silt and fine sand), in addition to the geotechnical compaction characteristics indicated.

In the group formed by soils of sandy behavior (B), the subdivision was done also by considering, in addition to the parameters considered in group A, the organic matter content, and it was noticed that the association between several other variables was also considered, since there was a tendency towards lower or higher values in some parameters, for example: in terms of total permanent deformation (ε_p) in subgroup - B-2-a: soils with ε_p larger (1.63 – 7.19 mm) than those of group B-2-b (ε_p between 0.78 – 3.37 mm) were included; the suction in the first at the air intake point associated with macropores (ψ_{b1}) tended to be slightly higher in the soils of group B-2-a (3.4 – 4.8 kPa) when compared to B-2-b (1.2 – 3.8 kPa).

The recognition of the similarity between some pairs of soils proved the validity of the hierarchical clustering technique since several variables with similar values were identified between them, even though they were of a different nature (physical, chemical and mechanical), the most recurrent being: LL, PI, %Clay, % silt, c', e', pH_{KCl}, δ, S_b, Ψ_{b1}, Ψ_{res1}, S_{res1}, W_o, K2TC, K2TD, ε_p.

The comparison of images applying the techniques of data science also corroborated, since satisfactory results were obtained, congruent with those obtained in cluster analysis, with rare exceptions. It is assumed, therefore, that there is correspondence between the mineralogical characteristics visualized in the images (iron oxides, rock fragments, quartz grains, etc.) with the results of geotechnical tests.

Finally, it is concluded that the application of cluster analysis by hierarchical method, as well as the comparison of microscopic images, using the tools of Data Science, showed useful techniques and tools for the cluster analysis of fine-grained tropical soils since it portrayed the similarity of behavior of different soils considering several geotechnical aspects.

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Oil Spills Cleanup Operations on Land and Inland Waters – The Mangroves Cleanup Philosophy

By Etuk Etiese Akpan

Abstract- *The Niger Delta region has witnessed several environmental pollutions arising from oil exploration and production activities* Though crude oil production has its attendant high risks, it is one of the largest and most profitable businesses in the world, and in fact the main economic sustenance for Nigeria (Onayemi 2004,). From its development phase to production phase, many disasters are bound to occur in the industries. Oil spill is the most important type of environmental disaster, which usually occurs. It has impact on humans as wells as on plants and wild life, including birds, fish and mammals.

Sources of spill ranges from equipment failures, human errors, accidents, sabotage and illegal bunkering activities on the production facilities. (Oil theft, sabotage and spills).

Good Industry operating and maintenance procedures is key to reducing incidents of oil spills in the environment.

Prompt spill response management is a key success factor in reducing escalation of the attendant negative impacts on the environment by deploying a workable contingency plan suitable to the specific environment of importance.

Keywords: *oil spills; sources; impacts; niger delta region, mangroves, cleanup, land, water.*

GJHSS-B Classification: *DDC Code: 363.7382 LCC Code: KF27*



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I. Introduction

Oil spill cleanup generally refers to the removal of spilled oil from the environment to protect and preserve the ecosystem where the incident had occurred. These may include containment, recovery, evacuation and remediation of the polluted area. Oil spill cleanup helps in facilitating speedy recovery and resuscitation of the polluted environment.

Oil spill incidents are inevitable events in the areas where oil is explored, drilled and produced. These could occur either by willful damage by hoodlums, human errors, equipment failure and by an act of nature.

The incidence of oil spillage constitutes serious economic and soil degradation in the Niger Delta. The area currently faces series of ecosystem depletion as most soil flora and fauna are destroyed. Oil spills from the activities in the oil industry in the region affect the environment in the operational areas, right of ways (ROW) and third party areas. These result from equipment failures, leaks from corroded equipment and vandalisation (sabotage). The spilled crude oil from the source, through a plausible transport mechanism and exposure pathway, gets to the receptors - soil, vegetation, surface and ground water, marine environment, animals and humans - and pollute the environmental media. Soil fertility, measured by physical, chemical and biological parameters, is adversely affected. Also the livelihood of the inhabitant of the area

What ever the cause is, it is the corporate social responsibilities of the government and the oil operating companies to cleanup the areas impacted by crude oil as a result of their production activities.

a) *Statement of Problem*

Oil spills from several different sources are stigma to the environment and cause of concerns to all. The impact on the environment is massive with great degradation in the past decades. Areas of such impacts include contamination of water bodies, danger to aquatic life, destruction of flora and farmlands which includes resort centers, destruction of properties, loss of lives and many more.

b) *Objectives*

To maintain a better sustainable and viable environment through timely, effective and systematic cleanup operations when spills occur.

c) *The Scope*

The scope covers cleanup operations generally with emphasis on land spill cleanup, inland water spill cleanup and mangroves spill cleanup options.

II. Literature Review

Oil, as a significant factor affecting economic development and human life of most countries in the world. (Prendergast & Gschwend, 2014) has increased attendant risks associated with its production, however with significant benefits also for diverse locales, regions, and nations.

Transportation, equipment failures, willful damages, aged equipment amongst others have been the major sources of oil spill into the environment. According to ITOPF (2021) statistical data report, statistics on tanker spills more than 7 tones have showed a substantial decline over the last half-century. However, tanker collisions resulted in roughly 10,000 tons of oil being lost to the environment in 2021. This is a significant increase over the prior two years, owing mostly to the one large occurrence oil spill accident reported. Nonetheless, despite significant technological

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advancements aimed at ensuring the safety of navigation in order to minimize the likelihood of oil leakage (Bucelli et al., 2018), the possibility and severity of oil spills on land and water body cannot be completely ruled out, as evidenced by several recent severe accidents (Bonvicini et al., 2022; Wang et al., 2022). To mitigate these consequences, preparedness and response to any oil spill are always necessary and important for sensitive resources, including observation, detection, mitigation, response, and remediation of oil pollution (Li et al., 2016; Hung et al., 2018). Despite the devastating effects of oil spills on the ecosystems, social and economic life, and worldwide policies encouraging scientific research on the subject, the peer reviewed literature on oil spill response systems is expected to widen in the future years (Neves et al., 2015; Murphy et al., 2016). Although many studies and equipment exist that support oil spill response planning, because of this issue there remains a need for a comprehensive uderstanding and review of oil spills and their consequences.



Figure 1: Leaking Pipeline

Oil spills change the dynamic of the ecosystems and therefore emphasize the importance of rapid response technology capable of mitigating potential damage (Prendergast & Gschwend, 2014; Chen et al., 2020). To mitigate the negative consequences of an oil spill, it is also vital to manage spilled oil in an orderly and timely manner (Mohammadiun et al., 2021; Yang et al., 2021). This requires the development of both short and long-term contingency strategies (Chang et al., 2014; Wang et al., 2022). A range of response methods are included in the oil spill control strategy/contingency, with the purpose of limiting possible damage to human health and the environment by maintaining a timely and coordinated response (Li et al., 2016). Effective monitoring techniques can help with spill cleanup by detecting slicks early and specifying oil characteristics, estimating spill volume, and predicting oil movement (Robbe & Hengstermann, 2006).

III. Methodology

Removal of spilled oil on land, inland water and the coast could be achieved with combination of options with the use of selected response equipment and manually, which requires the involvement of a large labour force over an extended period. Although its chemical composition changes over time, residual oil remnants still contain various toxic chemicals, which must be dealt with caution for the sake of the health of the clean-up workers.

a) On Land Spills Cleanup

These operations involve the containment, recovery, evacuation and remediation of the impacted soil to resuscitate the impacted soil. Spilled oil on land prevents water absorption by the soil, spills on agricultural locations or grasslands have the effect of choking off plant life. There is also high probability of soil infiltration of the oil with the attendant risks of ground water contamination or entering waterways as run-off.

Lined Berms and trenches are some of the best ways to contain the spill on the land, as long as their use does not allow the oil to leach into the soil. Where there is no danger to the water table, the contaminated area can be flooded, which “floats” the oil or moves it to the water’s surface, as it is typically lighter than water. This technique allows for recovery via mechanical means such as vacuums and skimmers. Other possible techniques include mechanical removal of contaminated soil, in-situ burning, sorbents, and bioremediation.

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Figure 2: Linned Trench for Containment



Figure 3: Temporary Storage Facilities for Recovered Spilled Oil

Additional strategies may include:

a. *Removal of gross contamination including removal of surface and subsurface pollution (beached oil)*
b. *Manual and Mechanical removal of spilled oil*
c. *Removal of debris*
d. *Segregation of generated waste*
e. *Low pressure flushing*
f. *Final Polish*
g. *Shoreline walk*
h. *Grading*
i. *Cleaning*
j. *Replanting*
k. *Replacement materials if required*
l. *Removal of equipment*



Figure 4: Right of Way Spill Clean up

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Spill on Land Cleanup Options:

Table 1: Best Cleanup Option for On Land Spill

Preferred Method	Avoid
Co-ordinated manual recovery	Removing clean sediment
Mechanical transfer of oiled sand	Vehicles mixing oil with clean sand
Water flushing stranded oil	Removal of any vegetation bordering the beach
Consider restricting public access if possible	Use of chemical dispersants
	High Pressure washing



Figure 5: On land Spill Cleanup Operations

b) Inland Water Spills Cleanup

This operations involve the containment, recovery, evacuation of spilled oil on the surface of impacted in land water body.

In managing inland water spill incident and for effective clean-up of inland oil spills the knowledge of the probable sources, volume, flow direction, current, sensitive habitats, weather conditions, accessibility of spills are key delivery factors. Prior planning and preparation for adequate resources and coordinated approach are drivers for effective cleanup operations.

The widespread use of oil for industrial, commercial, and domestic purposes results in frequent small inland oil spills particularly as a result of incidents during delivery to and storage at user premises. Less frequent accidents involving large quantities of oil have occurred at oil storage installations or during bulk movements of oil but there are few reported incidents of significant pollution damage to ground or surface water. Oil companies, local and national government agencies, by developing elaborate emergency plans and providing equipment and training to ensure that the plans can be effectively carried out, have done much to minimise the damage caused by inland oil spills. Close cooperation between industry and government has also helped to make these plans particularly effective.

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Figure 6: In land Spill Cleanup Operations

In most cases, oil released in inland waters is subject to the natural hydrologic flow as well as any man-made changes, of which there are many, to the hydrologic system. For example, the banks can be armored, stream flow is directed through culvert systems, or dams of all sizes and uses turn riverine systems into lakes. Another confounding and risky issue is flooding upon oil spills, where waterways leave their banks and/or change courses. The potential for surface water, vegetation and groundwater contamination is often a primary public health concern.

The goal of any spill response be it coastal or inland, should be to select the response methods and endpoints that will result in the most rapid recovery of the environment (Michel and Benggio, 1999). For inland spill response, there are often two perspectives that have to be resolved: 1) Remove all of the spilled oil from the environment versus; 2) Remove as much oil as possible without damaging or slowing the overall habitat/resource recovery. Cleanup endpoints for spills in coastal and marine settings seldom have endpoints as rigorous as "No oil observed" though these can be used for amenity beaches. Most of the time, cleanup endpoints in coastal and marine settings are based on acknowledgement that any residual oil will weather or degrade over time, sped by natural removal processes in areas exposed to waves and currents.

Removing oil to the extent that soil, sediment, and water meet state regulatory limits agreed as the cleanup endpoint could require additional extensive efforts.

Consequently, cleanup endpoints are needed to:

- Define the conditions beyond which further active treatment is likely to provide no net environmental benefit and may delay, rather than accelerate, recovery of impacted habitats and natural resources;
- Define the target conditions that must be achieved before active treatment may cease. As such, these criteria signal the transition from active response-related cleanup to passive, maintenance and monitoring, or final sign-off;
- Provide Operations with clear targets for when treatment activities are done;
- Provide Shoreline Cleanup Assessment Technique (SCAT) Teams with criteria with which to inform their recommendations of the most appropriate treatment options and evaluate results of treatment activities; and
- Provide those responsible for the follow-up remediation with guidelines that are consistent with those provided to emergency responders.

There are generally four types of cleanup endpoints (Sergy and Owens, 2007, 2008; NOAA 2013): 1) Quantitative endpoints that build on the terminology of the SCAT process and use metrics related to the percent oil distribution, the oil thicknesses, the oil type, etc. (e.g., no more than 10% Stain); 2) Qualitative endpoints that describe the presence and character of oil (e.g., does not rub off on contact); 3) Analytical criteria for sediment and water quality and 4) Interpretive impact endpoints (e.g., removal to the point when further treatment will result in excessive habitat disruption). At this point, no further treatment (NFT) is recommended due to a net environmental benefit consideration. This last endpoint is applied mostly to sensitive habitats when meeting one of the first three endpoints would cause greater harm than leaving the oil to attenuate naturally.

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Figure 7: Inland Water Spill Due Cut Pipeline by Sabotage



Figure 8: Recovery Progress in Inland Water Spill



Figure 9: Oil Containment and Recovery in Progress

c) Oiled Mangroves Spills Cleanup

Several studies frown against aggressive removal of oil from sensitive habitats such as marshes and mangroves because the action can slow the overall recovery of the habitat. (Hoff, 2010). Therefore, in mangrove cleanup response, evaluating the relative

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environmental risks, using the concept of net environmental benefit analysis is key to safe management of the mangrove ecosystem and to establish the safe cleanup endpoints for the mangrove ecosystem.

In cleaning oiled mangrove forest shoreline, extreme caution must be exercised in selecting cleanup activities. Potential benefits of oil removal must be weighed against the risks of potential additional harmful impacts from the cleanup technique on the mangroves habitat. This is because the mangrove ecosystem are:

- *High degree bio-diversity & ecological sensitivity to hydrocarbons.*
- *Easily damaged by physical presence of shoreline clean-up teams.*
- *Priority sites for protection booming*
- *Requires expert advice & guidance if clean-up is to be attempted.*

Cleanup options are best selected from the list of available techniques taking into consideration the above highlighted points.

- No Action/Natural Recovery

When it is appropriate to do nothing. When cleanup would cause more harm than benefit to mangroves or other associated habitats, or when shorelines are inaccessible

- Barrier Methods

Several forms of barriers can deflect or contain oil, including booms, sediment berms, dams, and filter fences. Barriers can be used along mangrove shorelines and inlets to prevent oil entry. Proper strategic boom deployment is highly effective in trapping large quantities of mobile oil and reducing oil impact to interior mangroves.

- Manual Oil Removal

Manual removal, using hand tools and manual labor, is often conducted to remove bulk oiling by heavier oils, such as crude oil or Bunker oil, stranded in mangroves. Manual removal can help prevent other mangroves from contamination.

- Passive Collection with Sorbents

Sorbent boom or other sorbent materials can be placed at the fringe of oiled mangrove forests to passively recover any mobile oil, including sheens. Sorbents are oleophilic and either absorb or adsorb oil.

- Vacuuming

Vacuuming can remove pooled oil or thick oil accumulations from the sediment surface, depressions, and channels. Vacuum equipment ranges from small units to large suction devices mounted on dredges, usually used outside vegetated areas.

- Ambient Water Flooding (Deluge) and Low-Pressure High Volume Ambient Water Flushing

Low-pressure flushing with ambient seawater can wash fluid, loosely adhered oil from the sediment surface and mangrove vegetation into areas where it can be collected, as long as it can be done without resulting in significant physical disturbance of the sediment.

- Nutrient Addition/Bioremediation

Microbes and essential nutrients for oil degradation generally are not limited in mangrove habitats, but nutrient enrichment may not offer much benefit.

- NO NO Response Techniques for Mangroves Cleanup,

Under no circumstances should live mangrove vegetation be cut or burned. Both techniques will destroy trees and mangrove habitat. Mangrove trees are slow growing and take decades to be replaced by mature vegetation.



Figure 10: The Mangrove Ecosystem Impacted with Spilled Oil

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Figure 11: The Mangrove Ecosystem



Figure 12: Low Pressure – High Volume Flushing of the Mangrove Ecosystem

Mangroves Spill Cleanup Options:

Table 2: Best Cleanup Option for Mangroves Spill

Preferred Method	Avoid
If possible leave to degrade naturally (NEBA)	Driving oil further down in to sub-strate
Closely controlled manual recovery (LP flushing & sorbents)	Use of heavy plant & machinery
Pruning of heavily contaminated vegetation	Completely removing oiled vegetation
Priority case for protection booming	Cosmetic clean-up

General Spills Clean-Up Methods

a. Using Oil Booms.
b. Using Skimmers.
c. Using Sorbents.
d. Burning In-situ.

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Figure 13: In Situ Burning of Spilled Oil

e. Using Dispersants.
f. Hot Water and High-Pressure Washing.
g. Using Manual Labour.
h. Bioremediation.

IV. Conclusion

Recalling that mangroves are important players in some of the greatest challenges facing the world today. They provide a defense between land and sea, absorb carbon, contribute to economic and food security, and are home to some of the most rare and colorful species.

However, mangroves are disappearing at an accelerating rate consequent on many factors including oil pollution of the marine ecosystem.

Only with healthy ecosystems can we enhance people's livelihoods, counteract climate change, and stop the collapse of biodiversity.

UNEP research shows that mangrove ecosystems underpin global and local economies, by supporting fisheries, providing other food sources and protecting coastlines.

They are also important protectors – sheltering land and coastal communities from storms, tsunamis, rising sea levels and erosion. In addition, with the world at risk of a temperature rise of over 3°C this century, mangroves are an invaluable ally in the race to adapt. They extract up to five times more carbon from the atmosphere than forests on land, and protecting mangroves is 1000 times less expensive, per kilometer, than building seawalls.

Clearing mangrove forests to create space for buildings, and to farm fish and shrimp – is the main driver of mangrove loss. Worldwide, this has caused the loss of 20 per cent of mangrove ecosystems.

Before planting new mangroves, it is important to understand the cause of forest degradation or disappearance. In the case of pollution, over-harvesting or other causes that can be eliminated, mangroves can recover naturally.

When recovery requires human intervention, it is important to follow key steps, like involving local communities, selecting native seedlings and establishing a functioning nursery

Contingency planning and readiness for the management of oil spill incidents as they occur is very important to effectively protect the environment from extensive damages consequent on the spills. It is strongly recommended that prompt cleanup be effected upon any spill incident using the most appropriate selected techniques to protect and preserve sensitive habitats such as the mangrove habitat.

While there is no 100% assurances of complete resuscitation of the ecosystem after effective cleanup, proactive measures to ensure preparedness must be put in place for prompt response in an emergency situation.

Timely response to cleaning up the spill will not only reduce the negative impact on sensitive habitats in the ecosystem, but will guarantee sustainable co-existence in the ecosystem.

Continuous monitoring and evaluation is required after the cleanup to assure quick recovery of the impacted ecosystem.

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Assessment Household Vulnerability to Flood Disaster: A Study of Oweto Community in Agatu Local Government Area of Benue State, Nigeria

By Patricia Ali, Monday Akpegi Onah, Odeh Adimanyi & Paul Tarzoho
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Abstract- Flood disasters are anticipated to happen more frequently in the future due to climate change, unplanned rapid urbanization, change in land use pattern, poor watershed management with attendant impact and vulnerability. This study therefore assessed household vulnerability to flood disasters in Oweto community, Agatu Local Government of Benue State, Nigeria. The study sampled 400 respondents for the purpose of data collection on vulnerability factors and indicators using structured questionnaire. Principal Component Analysis was used to generate weights of vulnerability factors (Exposure, Adaptive Capacity and Sensitivity) and their corresponding indicators so as to avoid the uncertainty of equal weighting given the diversity of indicators used. The result indicates that Oweto community is very vulnerable to flood disasters with a Composite Flood Vulnerability Index (CFVI) of -0.347. In terms of individual vulnerability factors, the result indicates a moderate adaptive capacity index of 4.513; high sensitivity or susceptibility index of 3.655 and relatively high exposure index of 1.205 respectively. The study recommends that concerted efforts be made to relocate households living in close proximity to River Benue and its tributaries so as to reduce flood risks and impact resulting from high exposure and sensitivity levels.

Keywords: *climate change, disaster, flood, household, vulnerability.*

GJHSS-B Classification: *DDC Code: 363.11966 LCC Code: TP155.5*

ASSESSMENTHOUSEHOLDVULNERABILITYTOFLOODDISASTERASTUDYOFOWETOCOMMUNITYINAGATULOCALGOVERNMENTAREAOFBENUESTATENIGERIA

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Keywords: climate change, disaster, flood, household, vulnerability.

I. Introduction

Floods are anticipated to happen more frequently in the future because of climate change, unplanned rapid urbanization, change in land use pattern, poor watershed management and decline in recharge of groundwater by extension of impermeable surfaces particularly in urban areas (Hajar, Mohd and Thamer. 2016). This follows that, many communities living close to rivers and on wetlands (urban or rural communities) globally are at the risk of flood disasters with attendant adverse impacts resulting from varying degrees of vulnerability (Hajar, Mohd and Thamer. 2016; Ali, 2018, Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, 2022).

Managing floods with the objectives of ensuring safety and wellbeing of people, and reducing risks and impacts on livelihoods would require adequate knowledge of vulnerability. This is because flood vulnerability is defined in probability terms which shows the degree of susceptibility and exposure to damage resulting from disaster in an area or population, as well as the human ability to resist or adapt. In other words, against a flood occurrence, the amount of damage depends on the area's characteristics and demographic makeup (Mohammad, Hesam, Mohsenand Hossein, 2020), which is defined by the level of exposure and susceptibility and the resilience capacity.

The need to assess flood vulnerability is further underscored by the fact that it is usually location dependent since vulnerability to flood disaster varies over time in places due to environmental conditions, human activities, and the culture of affected society (Ahmad and Simonovic, 2013; Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, 2022).

Over the last 20 years, Flood Vulnerability Index (FVI) has proven to be a useful tool in assessing or analysing vulnerability to flood disasters by households and communities. This is because Flood Vulnerability Index (FVI) indicates the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (UNESCO-IHE, 2022). Also, according to UNESCO-IHE (2022), human population worldwide is vulnerable to natural disasters, and in recent years, the impacts of floods have gained importance because of the increasing amount of people who are exposed to its adverse effects. Therefore the aim of vulnerability studies is to recognize correct actions that can be taken to reduce vulnerability before the possible harm is experience. FVI is a powerful tool for policy and decision-makers to prioritize investments and makes the decision making process more transparent. Identifying areas with high flood vulnerability and understanding the extent of vulnerability may guide the decision making process towards a better way of dealing with floods by societies.

Oweto is an important agrarian community in Agutu Local Government Area of Benue State, Nigeria and is reputed for massive production of rice due to its location on vast floodplains of the River Benue. Inspite of its agricultural significance in terms of rice production and fishing, floods of varying magnitudes and severity have been a yearly event which underscores the need to assess the extent of vulnerability. This will no doubt help in targeted interventions that would reduce flood risks and impact in the study area. Moreover, efforts have not

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been made in determining the extent of household vulnerability to flood disasters in this area. Previous studies on flood in Benue State focused on flood damage; rainfall pattern and its implication on flood frequency; and social impact and people's perception of flooding all in Makurdi town (Ali, 2018, 2006; Ologunorisa and Tersoo, 2006; Ocheri and Okele, 2012). Similarly Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, (2022) assessed household vulnerability to flood also in Makurdi town which suggests that flood studies in this area are concentrated in urban areas, while little is little has been reported in the literature on vulnerability of households to flooding in flood prone rural communities of Benue State including Oweto. It is in view of the above that this study assessed household vulnerability to flood disasters in Oweto, a rural area in Agatu Local Government Area of Benue State.

II. Material and Methods

a) Study Area

Oweto is an agrarian community in Usha Council Ward in Agatu Local Government Area of Benue State. Oweto is located between Latitudes 7^0 49'15''N and 7^0 49'45''N and Longitudes 7^0 57'55''E and 7^0 58'10''E at the Lower Benue River floodplains (Figure 1). Oweto shares boundary with the River Benue to the North, Utugolugwu village to the East, Olegada'Akolo village to the West and Ugba village to the South, all in Agatu Local Government Area.

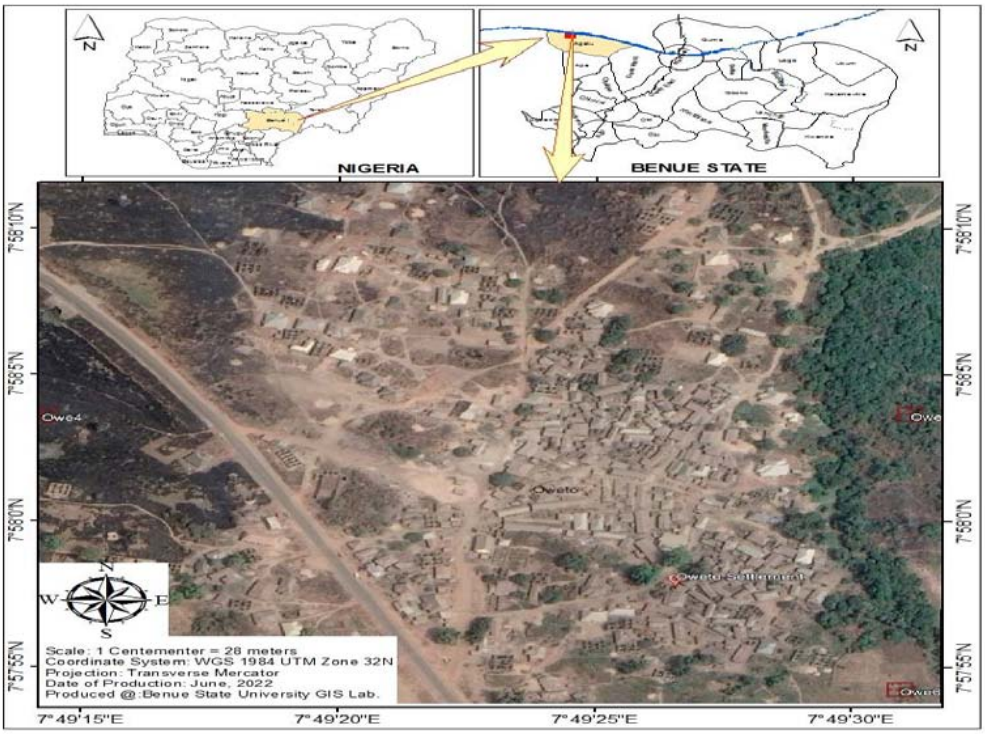

Figure 1: Oweto Community, Aguta Local Government Area, Benue State, Nigeria

The relief is generally low-lying averaging 92 metres above sea level, while the geology of the area is basically composed of sedimentary rocks, with sandstones as the dominant rock type. This area is mainly cretaceous of fluvio-deltaic sediments with well – embedded sandstone which are of hydrological significance in terms of ground water yield and exploitation. (Ali, (2018, 2006; Uchua and Nduke, 2011; Ocheri, Ali and Eba, 2014; Ocheri and Onah, 2015). Oweto is situated completely on one side of the river and the Ajiba river flows into it and drains into the River Benue as tributary.

Oweto has an average temperature of 27.9^0 C and a rainfall average of 1370mm (Moro and Onoja, 2006). Temperatures are high throughout the year with February and March occurring as the hottest months. Though the vegetation of the area is generally classified as the guinea savannah type with scattered woodland, shrubs and grasses, Oweto also has a riverine forest vegetation, a remarkable vegetation similar to that of a typical rain forest belt of Nigeria. This unique vegetation within the Savannah was home to buffaloes, elephants, gorillas and different species of monkeys. There was preponderance therefore of tall trees and luxuriant vegetation.

b) Methods

i. Sampling

The study employed both direct field measurements and questionnaire for data collection on vulnerability factors and indicators. For the purpose of questionnaire administration, a total of 400 sample size

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was determined using Yamane (1967) formula. The study sampled 400 households using simple random sampling technique. Respondents were selected based on the criteria of being household members of the community and on their ability to respond to questions put to them appropriately. In doing this priority was given to the heads of the households in responding to questions as contained in the questionnaire, however, where the household head was indisposed, the most elderly with the ability to respond to questions was selected.

ii. *Computation of Flood Vulnerability index (FVI) Using PCA*

The following steps were followed in determining FVI using PCA.

Step I: In computing FVI, the first step was to quantify the various vulnerability indices as specified on Table 1.

Step II: The weights of these indicators were determined using PCA and the component loading of the first component was used. This was consistent with the method used by Akukwe and Ogbodo (2015) Ali 2018 and Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna (2022). In their studies, PCA was run on the variables, and the weights were attached to the indicators using the first principal component scores of the indicators. The reason for assigning the weights determined by PCA to indicators was to avoid the uncertainty of equal weighting given the diversity of indicators used (Akukwe and Ogbodo, 2015; and Deressa, Hassan and Ringler, 2008; Ali, 2018, Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, 2022). Thus, for the determination of the vulnerability indices, the selected indicators of sensitivity and exposure were negatively associated with their first principal component because it was assumed that areas with higher frequencies of flooding were subjected to higher sensitivity due to the adverse effects of flooding as well as being more exposed (Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, 2022). On the other hand, adaptive capacity was positively associated with the first principal components because it is assumed that people with higher adaptive capacity were less sensitive to damages caused by flooding, holding exposure level constant. Thus, higher values of the vulnerability indices show less vulnerability and vice *versa* (Akukwe and Ogbodo, 2015; Deressa et al., 2008; and Madu, 2011; Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, 2022).

Step III: Consequently, vulnerability to flood was computed according to Deressa et al., (2008); and Akukwe and Ogbodo, (2015) as follow:

$$\text{FVI} = /\text{Adaptive Capacity}/ - / \text{Sensitivity} + \text{Exposure}/ \quad (1)$$

Ali, 2018, Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, (2022) explained the adoption of this formula, maintaining that this equation was adopted because flooding is one of the consequences of climate.
Equation (1) was expanded as follows:

$$\text{FVI} = (wAC_1 + wAC_2 + wAC_3 + \ldots wAC_n) - (wS_1 + wS_2 + wS_3 + \ldots wS_n) + (wE_1 + wE_2 + wE_3 + \ldots wE_n) \quad (2)$$

Where *FVI* is vulnerability index, *w* are weights of first components scores, $AC_1 \ldots AC_n$ are adaptive capacity variables, $S_1 \ldots S_n$ are sensitivity Variables, and $E_1 \ldots E_n$ are the exposure variables.

Note: AC = Adaptive Capacity; S = Sensitivity; and E = Exposure

Table 1: Vulnerability, Units of Measurement, and Their Relationship Vulnerability

Determinant of vulnerability	Vulnerability indicator	Description of each indicator	Units of Measurement	Relationship between indicator and Vulnerability
Adaptive or Resilience Capacity	Wealth	Average Annual income Receipt of assistance/relief	% of total population who earned more than N500,000.00 per annum % of population who received assistance	The higher the % of total population more than N500,000.00 per annum, who receive, who are educated, who are employed outside primary production sector like farming, the lesser the vulnerability.
	Literacy rate	Educational qualification	% population who are educated	
	Employment status	Occupation	% of population that are less vulnerable	
Sensitivity or Susceptibility	Flood characteristics	Length of stay - The number of years of residence	% of population that have stayed longer than 10 years	The higher the frequency, the more the vulnerability. The higher the numbers the higher the vulnerability.

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		Frequency of Flood occurrence	Frequency of Flood occurrence in a year	The higher the extent of coverage/magnitude, the higher the vulnerability
		Period of flood occurrence in a year	Number of months with flood in a year	
		Severity	Extent of coverage	
	Flood perception	Pre-flood awareness	% of population with pre-flood awareness	
	Flood experience	Past flood experience	% population who had experience flood	
Exposure	Proximity to water body	Average Distance from River	The average distance to flood prone areas	The shorter the average distance to water body, the higher the vulnerability
	Flood duration	Number of days it takes for flood to recede	Number of days with flood water	The longer it takes for flood to recede the higher the vulnerability

Source: Adapted from Ali, 2018, Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, (2022).

III. Results and Discussion

a) *Flooding Vulnerability Level at Oweto Community*

The results of the flooding vulnerability level as shown by PCA and composite vulnerability index for study area are presented in Tables 2 and 3. The result of the PCA is presented in Table 2. The shows that first principal component explained most of the variation in the flood vulnerability indicators with an eigen value of 10.450 and the percentage variance explanation of 38.705%. This component shows high loadings on the adaptive capacity indicators such as nature of source of assistance; impact on businesses and sensitivity indicators such as pre-flood awareness, past flood experience and flood duration. Since more factors loaded were on adaptive capacity indicators, the first component is named *Adaptive Capacity Component,* which is an indication that the study has relatively moderate to high resilience capacity to cope with flood disaster.

The second component which has an eigen value of 6.154 with percentage explanation of 22.793% is named *Socio-economic Component*. This is because the second component is highly loaded on socio-economic variables such as nature of business, annual income, sex and educational attainment which are part of adaptive capacity factors.

The third component with an eigen value of 4.139 accounted for 15.328% explanation in the variation in the flood vulnerability indicator. The component is highly loaded in the period of flood occurrence and frequency of flood occurrence. Therefore the component is named *Sensitivity Indicators Component.* This suggests that even though the study area has relatively highly adaptive capacity, the sensitivity factor is relatively high thereby making households highly vulnerable.

In the same vein, the fourth component with an eigen value of 3.048 and 11.290% explanation is highly loaded on variables such as relocation, flood losses and other source of income. Therefore the component is called *flood adaption and impact component.* Overall, the total percentage explanation of 88.117% substantially accounted for the variation in the vulnerability indicators of adaptive capacity, sensitivity and exposure factors.

Table 2: Rotated Component Matrix

Variable	Component			
	1	2	3	4
Sex	.162	***.879***	.162	.130
Length of stay	***.862***	.444	.021	.001
Ethnic group	***.700***	.176	.460	.418
Age	.508	.451	.324	.587
Educational qualification	.513	***.774***	.255	.189
Occupation	***.831***	.409	.132	.224
Marital status	.461	.398	.566	.492
Distance from river	.493	***.758***	.269	.330

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Period of flood occurrence	.300	.002	***.819***	.158
Frequency of flood occurrence	.126	.231	***.933***	.341
Extent of coverage	.677	.501	.169	.392
Days flood water recede	***.712***	.537	.212	.303
Nature of business	.203	***.784***	.422	.362
Keep you from business	***.855***	.295	.111	.007
If yes how long	***.831***	.230	.164	.384
Quantify your annual income	.503	***.814***	.131	.078
Flood loss in momentary terms	.439	.458	.504	***.511***
Flood render you homeless	.678	***.644***	.011	-.159
How long do your relocate	.702	.189	.458	.407
Why have you not relocated	.912	.233	.007	***.563***
Other source of income	.399	.471	.322	***.630***
Coping strategy	.750	.486	.278	.159
Assistance by groups	.216	-.021	-.104	***.596***
Nature of assistance	***.837***	.346	-.024	.232
Who has helped you	***.891***	.351	.113	.212
Pre-flood awareness	***.881***	.128	.164	.256
Past flood experience	***.809***	.251	.103	.469
Total Eigenvalues	*10.450*	*6.154*	*4.139*	*3.048*
% of Variance	*38.705*	*22.793*	*15.328*	*11.290*
Cumulative %	*38.705*	*61.498*	*76.826*	*88.117*

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization
a. *Rotation converged in 9 iterations.*

The first principal component which explained the majority of the variation in the data set as shown in Table 2 was taken (that is, it served as the weight) and used in the computation of the vulnerability indices for the study area presented in Table 3.

The result indicates that households in Oweto community are highly vulnerable with Composite Flood Vulnerability Index (CFVI) of -0.347. The level of vulnerability is as shown in the result is very high due to exposure and sensitivity levels. This is because Oweto is located right at the floodplain of River Benue and one of the major tributaries river Ajiba.

Table 3: Computed Weight of Flood Vulnerability Indicators

Variables	Components Weights
Adaptive Capacity or Resilience Indicators	
Education	0.513
Occupation	0.813
Average annual Income	0.503
Coping Strategies	0.750
Assistance	0.216
Nature of assistance	0.837
Source(s) of assistance	0.881
Total Weight	**4.513**
Sensitivity or susceptibility Indicators	
Length of stay	0.862
Period of flood occurrence in a year	0.300
Frequency of Flood occurrence	0.126
Extent of coverage	0.677
Pre-flood awareness	0.881
Past flood experience	0.809
Total Weight	**3.655**
Exposure Indicators	
Average Distance from River	0.493
Flood duration	0.712
Total Weight	**1.205**

Source: Computed from First Principal Component Scores

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From Table 3 above, Flood Composite Vulnerability Index (CFVI) is computed as follows: FVI = 4.513 - 3.655 + 1.205 = - 0.347

In terms of total weight of individual vulnerability indicators, the result on Table 4 revealed that Oweto has a relatively moderate adaptive capacity or resilience index of 4.513. Adaptive capacity has an inverse relationship with vulnerability, which means that the higher the adaptive capacity, the lower the vulnerability. This is so because, adaptive capacity has to do with the economic and social capital or resources base of individuals and communities of flood affected areas. This also follows that the higher the socio-economic capital, the higher the resilience of individuals/ communities during flood events. To this end, the result of Oweto residents with lower socio-economic assets is very weak in their capacity to cope with flood disaster. This is evident in the fact that Oweto residents engage predominantly in agriculture (farming and Fishing) which is more vulnerable to flood disaster than other livelihood options.

The result of sensitivity or susceptibility shows that Oweto is equally highly susceptible to flooding with the index of 3.655. Generally, the higher the susceptibility index, the higher the vulnerability. This implies that Oweto community, as far as sensitivity index is concerned, is highly vulnerable to flooding; moreso that Oweto possesses weak socio-economic capital to deal with flood disasters in face of high susceptibility.

Similarly, the result on the level of exposure to flooding indicates that Oweto is very exposed with exposure index of 1.205. Just like the sensitivity indices, the higher the exposure of a place to flood, the higher the vulnerability. This implies that the percentage of those leaving in close proximity to the river in the study area is higher. Also, the flood duration in terms of the numbers of days flood takes to recede is equally very high in Oweto. Consequently, the cumulative effect of high sensitivity and exposure as against weak adaptive capacity led to very high flood vulnerability as shown in the very low (even negative) CFVI in Oweto community.

Overall, the observed negative vulnerability index of Oweto could be connected to the fact that Oweto is rural agrarian community with inadequate social amenities and low income generation ability largely from engaging in primary production.

b) Discussion

The result of this study is similar to those of Ali, Onah, Mage, Yiyeh, Tarzoho, and Iorhuna, (2022), in their study of "Principal Component Analysis of Household Vulnerability to Flood Disaster in Makurdi Metropolis, Benue State, Nigeria" where the author reported low vulnerability index of 0.443 as against a very low index of 0.347 for Oweto. This suggests that both Makurdi and Oweto communities in Benue State are vulnerable, however Oweto is extremely more vulnerable than Makurdi due to higher adaptive capacity in Makurdi and low or weak adaptive capacity in Oweto. Similarly, Abdulhamid (2016) also reported that 67.79% of residents of Lokoja metropolis lived in neighbourhoods with low vulnerability to flooding, while 13.64% lived in areas with vulnerability. This result is however, at variance with the findings of this study due to their rural-urban differences. In all these studies however, high level of exposure and sensitivity resulting from close proximity to water bodies, long flood duration and short frequency were the major vulnerability factors. This suggests that any effective intervention targeted at reducing flood risks and impacts should be focused on addressing these critical determinants of vulnerability to flood disasters in these areas.

Elsewhere in Narmada river basin districts in Central India, Shefali, Mukulm andMudit (2021) reports that 76% of the districts in the Narmada river basin remain highly vulnerable to flood-risk, while the socio-economic parameters and physical sizes of districts and their resources play crucial roles in the vulnerability level. This result agrees to a large extent with the findings of this study especially in term of weak socio-economic factor which translates to weak adaptive capacity as reported in these studies. To this end, strengthening of adaptive capacity by diversifying households' livelihood options, improved education and early warning mechanisms would contribute to reducing vulnerability.

IV. Conclusion and Recommendations

The study concludes that households in Oweto community, Agatu Local Government of Benue State are highly vulnerable to flood disasters due to high level of exposure and susceptibility and also weak adaptive capacity to cope with flood hazards, risks and impacts. Consequently, the study recommends that concerted efforts be make to relocate households living in close proximity to River Benue and its tributaries. Also, exploring other livelihood options in addition to agriculture would help boost their resilience capacity to cope with flood impacts and its associated vulnerability. Activation of early warning system should be strengthened in order to scale down the level of households' susceptibility and exposure to flood disasters in Oweto community.

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Analysis of Carbon Dioxide Emission from Transportation Sector using Panel Data Method

By Ahmed Derbel
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Abstract- CO2 emissions and climate change have become a topic of global importance for the international community, which should have led to immediate action to remedy this dangerous situation. The main objective of this work is to identify the causes and factors that can contribute to the reduction of CO2 emissions in the transportation sector. The estimation method based on Panel data for 25 countries around the world has shown that the density of the urban population and the heavy use of private vehicles in many metropolitans are the main causes of CO2 emissions. We have demonstrated that the development of renewable energies, the development of collective transport systems and sustainable forest management practices are concrete and practical solutions to fight against CO2 emissions in megalopolises.

Keywords: co2 emissions, panel data, atmospheric pollution, data science.

GJHSS-B Classification: DDC Code: 363.73874 LCC Code: QC879.8



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Analysis of Carbon Dioxide Emission from Transportation Sector using Panel Data Method

Ahmed Derbel

Abstract- CO2 emissions and climate change have become a topic of global importance for the international community, which should have led to immediate action to remedy this dangerous situation. The main objective of this work is to identify the causes and factors that can contribute to the reduction of CO2 emissions in the transportation sector. The estimation method based on Panel data for 25 countries around the world has shown that the density of the urban population and the heavy use of private vehicles in many metropolitans are the main causes of CO2 emissions. We have demonstrated that the development of renewable energies, the development of collective transport systems and sustainable forest management practices are concrete and practical solutions to fight against CO2 emissions in megalopolises.

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I. Introduction

Each year, several tones of CO2 (carbon dioxide) are released into the atmosphere, accelerating the rise in temperatures around the world. These greenhouse gas emissions are mainly due to the consumption of fossil fuels, oils, gases and which are linked to various human activities. The transport sector is the second largest contributor to the increase in the atmospheric concentration of CO2. The use of transport requires the combustion of fossil fuels, which increases the volume of carbon dioxide emitted into the atmosphere. Several factors are taken into account to determine the carbon footprint of land transport such as population density, urbanization, and distance traveled, type of journey and number of passengers. According to the study conducted by the OECD (Organization for Economic Co-operation and Development) in 2018, transport accounts for 24.4% of the share of global emissions behind the production of heating and electricity, which represents 41.5% of emissions from greenhouse gas around the world. The figures show that CO2 emissions from the transport sector have steadily increased over the past decade despite tangible efforts by some countries to reduce pollution and environmental impact. This development is likely to continue if we have not found an alternative to fight against this scourge. To curb the increase in CO2 emissions in the transport sector, the public authorities are obliged to take more determined action to improve the current situation. The main objective of this work is to identify the causes and factors that can assist in reducing the production of CO2 emissions and to contribute in proposing recommendations that could be applied to future programming.

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II. Literature Review

The increase in greenhouse gas emissions, especially CO2 emissions, is the cause of global warming. However, when we analyze the growth curve of CO2 in the atmosphere, we observed a very rapid growth, which began in the 2000s. Indeed, the reduction of CO2 emissions from transport is a subject of concern. This subject has been deeply analyzed at the scientific level. For example, the researchers have shown that CO2 emissions from freight transport can be analyzed using 7 key indicators; the modal split, the number of handling operations in the transport chain (handling factor), the distance of the trip (length of haul), the weight of the load (payload on laden trips), the proportion of empty trips (proportion of km run empty), energy efficiency (energy efficiency), the carbon intensity of the energy used (carbon intensity of the energy source). These parameters could be used as a basis for developing and implementing policy measures towards global efforts to reduce CO2 emissions from freight transport. The author also proposed measures such as reducing the number of handling operations, reducing the distance of the journey to reduce freight demand, developing less carbon-intensive modes of transport, improving the filling rate; increase the energy efficiency of road transport [1]. In addition, for the world to stay within the safe threshold of a 2 ° C increase in average temperature agreed to by virtually all governments, the transport sector must be carbon-free. The author has shown that the two main obstacles that have prevented CO2 emissions reductions are the absence of a legally binding global agreement and the high relative cost of clean vehicle/energy techniques [2]. Furthermore, researchers have shown that the transportation sector is a major contributor to greenhouse gas emissions, accounting for about 20 percent of all carbon dioxide emissions globally, and road transport accounts for the vast majority of these emissions [3]. Global warming and climate change have been two hotly debated topics lately due to their malicious consequences not only on ecosystems, but also on the human race. The levels of CO2 emissions are on the rise again and the objectives set at the

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COP21 Paris 2015 are becoming almost impossible to achieve [4]. In 1990, CO2 levels in the atmosphere were 354.4 ppm, but by 2018 this level had risen to 408.5 ppm. This means, the CO2 emissions levels from fossil fuels reached a record high of 37.1 gigatones. To reach the Paris target of 2 ° C, global carbon emissions will need to be reduced by 50% by 2030 and to zero by 2050. Over time, to meet the set targets at the macro level, the state could use public instruments and resources such as taxes, the pricing system, develop the modal shift by favoring soft modes, the establishment of standards relating to pollution and noise, encouraging the uptake of eco-labels and to promote sustainable forest management [5].

III. Research Methodology

The specificity of our work lies in the choice of developing countries and developed countries as the field of investigation, 25 countries were selected to analyze the impact of urbanization variables, population and the transport system on emissions of CO2 from transport over a 49-year period (1970 to 2018). The choice of countries depends on the availability and reliability of quality data.

We have selected European countries and territories such as; Belgium: BEL, Switzerland: CHE, Germany: DEU, France: FRA, Turkey: TUR.

African countries; Angola: AGO, Cote d'Ivoire: CIV, Cameroon: CMR, Algeria: DZA, Morocco: MAR, Tunisia: TUN.

America countries; Argentina: ARG, Bolivia: BOL, Brazil: BRA, Canada: CAN, Chile: CHL, Cuba: CUB, United States: USA.

Asian countries; United Arab Emirates: ARE, India: IND, Japan: JPN, Malaysia: MYS, Saudi Arabia: SAU, China: CHN.

And finally Australia: AUS.

Three variables are needed to assess the CO2 emissions from transport. First, the population is a key factor in determining the assessment of CO2 from transportation. Cities concentrate economic activity, and energy consumption for housing, transport, infrastructure. More than half of the world population lives in cities, the metropolises contribute more CO2 emissions at the planetary level. Urbanization and population continues at an accelerated pace, particularly in developing countries, but also with the expansion of urbanized territories. Two indicators were used to measure the evolution of urbanization and population, such as population density and urban population growth. Subsequently, we proposed that the urban planning reorganization and the town planning structure could reduce the percentage of CO2 emissions. We have proposed that the possible contributions of the green areas can combat CO2 emissions. In our case, two indicators were used to measure the contribution of agriculture and forestry such as forest area and agricultural land. Finally, the use of private transport is a direct source for a growing share of CO2 emissions produced by the combustion of energy. On the other hand, an efficiently designed and implemented a public transport system offers a practical mode of travel that reduces the need for private vehicles, and thus reduces CO2 emissions per passenger-km traveled. Two indicators were used to measure the evolution of the transport system such as the number of travelers by road and the number of travelers by railway transport services. Table 1 shows all the variables and indicators used in our context.

Table 1: The Variables used in the Panel model

Indicator (unit)	Explication	Source
CO2 emissions from transport (% of total fuel combustion)	CO2 emissions from transport contains emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation [6].	https://donnees.banquemondiale.org/indicator/EN.CO2.TRAN.ZS
Population density (people per sq. km of land area)	Population density is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status [6].	https://data.worldbank.org/indicator/EN.POP.DNST
Agricultural land (% of land area)	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures [6].	https://data.worldbank.org/indicator/AG.LND.AGRI.ZS
Forest area (% of land area)	Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural [6].	https://data.worldbank.org/indicator/AG.LND.FRST. ZS

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Road passengers (million passenger-kilometers)	Passenger transport refers to the total movement of passengers using inland transport on a given network. Data are expressed in million passenger-kilometers, which represents the transport of a passenger for one kilometer. [6].	https://data.oecd.org/transport/passenger-transport. htm
Railways passengers (million passenger-km)	Passengers carried by railway are the number of passengers transported by rail times kilometers traveled [6].	https://data.worldbank.org/indicator/IS.RRS.PASG. KM
Urban population growth (annual %)	Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects [6].	https://data.worldbank.org/indicator/SP.URB.GROW

Our study takes place over a long period (1970-2018) and based on a large number of observations (1225 for the sample with 49 observations for each indicator and for each country). This data collection is essential to analyze the behavior of countries and measure the impact of each variable with the use of artificial intelligence and more precisely with the Panel data method. The Panel data model has a number of advantages. The double dimension of the data (individual: country and temporal: years) makes it possible to implement a monitoring algorithm which simultaneously takes into account the dynamics of behaviors and their possible heterogeneity between the countries. It constitutes an advantage over other types of method such as time series and analytic data.

IV. Panel Data

The data used in artificial intelligence are most often provided by a time series. Furthermore, it is possible to have instantaneous cross-sectional data relating to a given period. Therefore, the panel data model is written as a double index (*i*: individual and *t*: temporal) model which takes the following form Eq1:

$$Yit = \alpha + \beta Xit + \varepsilon it \quad (1)$$

- *Yit* is the dependent variable (CO2 emissions from transportation)
- α is the intercept
- β is the regression coefficient*Xit* is the independent variable (Population density, Agricultural land, Forest area, Road passengers, Railways passengers and Urban population)
- ε is the error term

The dual dimension offered by panel data is a major advantage. Indeed, while time series data allow us to study the evolution of relationships over time, they do not allow us to control for unobserved heterogeneity related to individuals. Conversely, cross-sectional data make it possible to analyze the heterogeneity between individuals, but they cannot take into account the dynamic behavior. Thus, by using panel data, we can exploit the two sources of variation in statistical information: Temporal where intra-individual variability (within) Individual or inter-individual variability (Between) The increase in the number of observations makes it possible to guarantee better precision of the estimators, to reduce the risks of multi-collinearity and to widen the scope of the investigation. The panel considered is not necessarily complete (balanced data) where all statistical units are observed during the period considered. This may be an incomplete, unbalanced panel where individuals are not observed over the entire period of analysis due to the input/output problem.

V. Result and Discussion

Between 1970 and 2018, global CO2 emissions from transport increased by 45% as indicated in Figure 1 and can be expected to increase by around by 70%. This trend is particularly marked in developing countries and emerging economies compared to developed countries. For example Brazil, Bolivia and Ivory Coast have more CO2 emissions due to transport compared to Australia and Canada.

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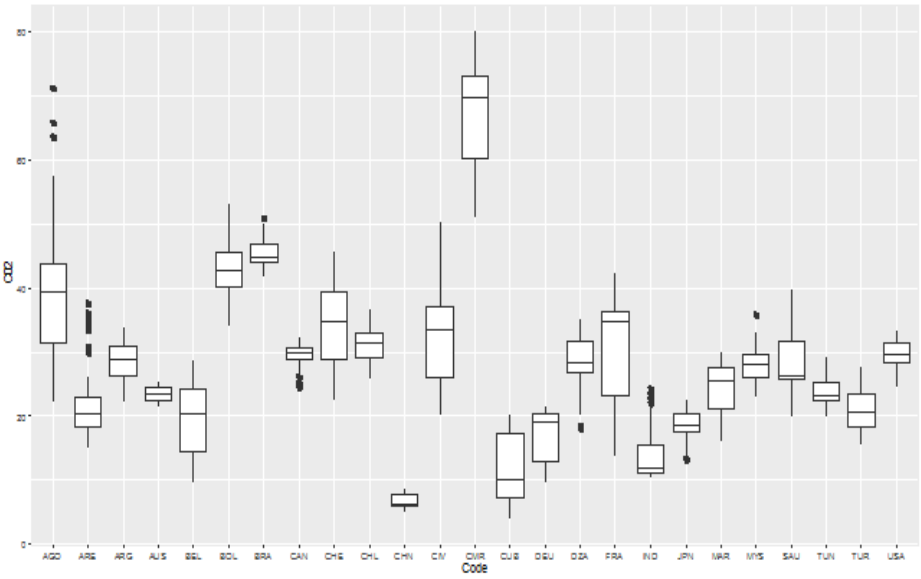

Fig. 1: The evolution of C02 emissions in the world for the period (1970 to 2018).

Figure 2 illustrates the distribution of population density for all selected countries. The figures show that the high population density of the countries combined with the dynamics of urbanization will translate into strong growth in demand for travel. Urban mobility here represents a significant part of this growth perspective. The high density is noticed especially in the developed countries compared to the developing countries. For example, we have noticed a high density of the urban population in France, Japan and Belgium.

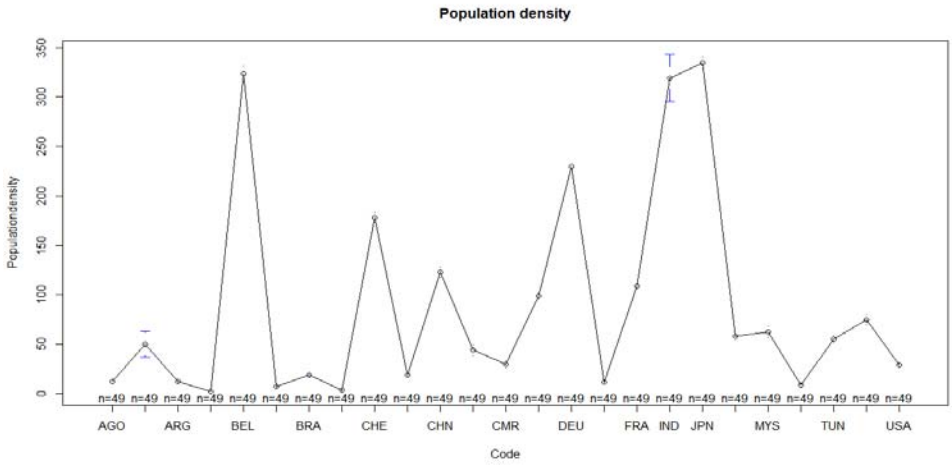

Fig. 2: The evolution of urban population in the world for the period (1970 to 2018).

The results of the panel model are shown in Table 2. We noticed that the population density exerted a positive impact (z-value> 0) and significant at 95%, this indicates that an increase in the population density recorded an increase in CO2 to 0.89% (coefficient of regression). Population growth to be the cause of environmental damage and CO2 emissions. This relationship is very obvious. Lifestyles are constantly changing, especially under the dynamic impetus of population, including higher living standards, technical progress and urbanization, in this case, the movement of displacement can become more and more polluting. Usually, the emphasis is precisely on technical progress to assert that the population growth and urban density of the population can be attributed largely to an increase in polluting emissions. In other words, an increase in population and an increase in population growth of 1% generate an increase of approximately 1.2% in CO2 emissions. Data for 25 countries between 1970 and 2018 show that the elasticity of carbon dioxide to population growth and population density is between 1.2 and 0.89.

In most cases, the rapid expansion of cities occurs in the absence of a land use planning strategy. Human pressure, thus generates extremely harmful effects on forests and landscapes, as well as on green spaces in cities. The environmental impacts of urbanization are often exacerbated by climate change

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and lead to increased pollution, decreased food and available resources and the frequency of extreme climate events.

We also noticed that the agricultural land and forest area variables had a negative and significant impact. For this reason, we have shown that planting green areas and trees can reduce CO2 emissions from transport by 1%. Tree planting projects, less expensive and easy to implement, have become very common to the point that all actors (companies, associations, local authorities, institutions, etc.) can reduce polluting activities and waste emissions from the transportation sector. The forests and wooded areas in cities (rows of trees, isolated trees, urban forests, etc.) are urban ecosystems providing various ecosystem services. Urban trees can help mitigate negative effects and social consequences of urbanization, and therefore make cities more resilient to these changes. In this sense, they constitute multifunctional spaces and can also be considered as natural actions to fight against environmental risks and adapt to climate change. In addition, these ecosystems can provide other services such as the contribution of biodiversity (animal and plant), the improvement of the living environment, the offer of recreational activities and the structuring of the landscape.

Finally, we have shown that the use of private vehicles in an exhaustive way can increase CO2 emissions to 3% and the use of public transport such as the train for example can reduce CO2 emissions by up to 0.14%. This implies that the two main environmental nuisances of the automobile are air pollution and the emission of greenhouse gases. In addition to air pollution, there is noise pollution, which would also have a significant impact on health [7]. An efficiently designed and implemented public transport system offers a practical mode of travel that reduces the need for private vehicles, thus reduces CO2 emissions, and the emissions produced per passenger-km traveled. Therefore, public transport promotes urban densification and also serves to reduce the distances should be traveled.

Table 2: The result of panel data

Coefficients:	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	2.9881e+01	4.8012e+00	+6.2237	4.856e-10 ***
Population density	8.9329e-02	1.2889e-02	+6.9306	4.190e-12 ***
Population growth	1.2953e+00	3.6041e-01	+3.5940	0.0003256 ***
Agricultural land	-6.2576e-01	6.6513e-02	-9.4081	< 2.2e-16 ***
Forest area	-3.3879e-01	1.2460e-01	-2.7191	0.0065459 **
Railways passengers	-1.4761e-01	6.0694e-06	-2.4321	0.0150113 *
Road passengers	3.2020e+00	3.2912e-07	+0.9729	0.0330594*

*Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*

VI. The Performance of the Panel Model

The panel method makes it possible to take into account any unobservable factors specific to each pair of countries (so-called individual or specific effects). The Hausman test is used to test whether or not there is a correlation between the specific effects and the explanatory variables of the model. This makes it possible to choose between the fixed effects model and the random effects model [8]. The result of the Husman test showed that the test is significant (p-value 5%), for this reason, we retained the estimators of the fixed-effects model which is presented in table 2, thus envisaging the errors are not correlated with the regression coefficient. This statistic is asymptotically distributed according to a chi-square equal to 2289.8 with 6 degrees of freedom, it is the number of variable introduced in the model.

VII. Recommendations

a) Ecological driving and Fuel tax

The most promising CO2 emission reduction measures in the transport sector are those aimed at promoting fuel-efficient driving through training and by encouraging the installation of on-board driving assessment systems. This is based on those characteristics that encourage motorists to choose vehicles with lower emissions in countries with very strict emission standards. Therefore, the fuel tax, the standards applicable to vehicles and their components, the modulation of taxes on vehicles and ecological driving are measures used to encourage environment and energy development and aimed at reducing consumption that offer the best prospects for reducing CO2 emissions in the short and medium term. The integration of transport policy and land use planning could, in the long term contain the demand for mobility and the proportion of private vehicles. Ultimately, it will be necessary to resort to much more expensive energy

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sources, including clean energies such as hydrogen and electricity from renewable sources or fossil fuels with carbon capture and storage, to reduce more CO2 emissions produced by transport. Bringing these technologies to commercial viability will require a significant research and development effort.

b) Improve the performance of public transport system

The International reports on the reduction of CO2 emissions mention the measures taken to promote walking and the use of bicycles. Furthermore, an efficiently designed and implemented a public transport system offers a practical mode of travel that reduces the need for private vehicles, and thus reduces CO2 emissions produced per passenger-km traveled. Public transit promotes urban densification and also serves to reduce the distances to be traveled and provides a convenient travel mode that reduces the need for individual vehicles [9].

c) Traffic management and town planning

International governments are obliged to create traffic management measures (congestion tolls, vehicle guidance systems, and parking regulations) to reduce CO2 emissions. Indeed, the same is true of the efforts made to integrate regional planning and transport policy, an essential step to control the growth in traffic and CO2 emissions. This omission seems to be attributable to the sharing of responsibilities between the central power and the local communities. It therefore seems justified to assess the role that local authorities can play in reducing CO2 emissions produced by transport, even if energy efficiency must remain one of the major objectives of national policy.

VIII. Conclusion

Road transportation is the biggest contributor to CO2 emissions, and the second largest source of growth in these emissions in the world. It should be an integral part of any strategy to reduce CO2 emissions. There is no magic solution to the problem of sustainable mobility, but there is a set of tools and measures, which, if deployed in a consistent manner, can help us to reduce CO2 emissions from transport and improve life quality for the various populations. The panel data approach leads to the following conclusion. The restriction of CO2 emissions measured by changes in population density and the massive use of private vehicles. Referring to the empirical study of the 25 countries in the world, the establishment of a green zone and efficient public transport networks can reduce CO2 emissions from the transportation sector. To do this, the world should start planning and investing now in the future to target transformations in urban planning, electrified public transport infrastructure and networks, and the infrastructure necessary for electric vehicles and their location.

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Similarity Principle and its Acoustical Verification

By Lintao Liu, Guocheng Wang, Huiwen Hu, Cong Shen, Zhonghua Li, Zhimin Shi, Yu Xiao, Xuepeng Sun, Heng Sun & Yanji Yao

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Abstract- This study finds a similarity principle: the waves emanated from the same source are similar, as long as two wave receivers are close enough. The closer the wave receivers are, the more similar the received waves are. We define the similarity mathematically and verify the similarity principle by acoustical experiments.

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Similarity Principle and its Acoustical Verification

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Abstract- **This study finds a similarity principle: the waves emanated from the same source are similar, as long as two wave receivers are close enough. The closer the wave receivers are, the more similar the received waves are. We define the similarity mathematically and verify the similarity principle by acoustical experiments.**

I. Introduction

A man has two ears (acoustical receivers), which are not very close. When a cicada is singing, the two ears should hear high similar sounds, which makes the man feel that there is only one cicada singing. When many cicadas are singing, the two ears should listen to low similar sounds, which makes the man think that there are many cicadas singing. An interesting question is: what will happen if the distance between two ears becomes shorter or longer?

Gravitational waves have been observed at two stations (H and L stations)[1,2]. Our studies (unpublished) show that gravitational waves received at two stations are highly similar. Such high similarity can verify the existence of the gravitational wave and the uniqueness of the gravitational wave origin. One should note that the distance between gravitational wave receivers (though several thousand miles) is very short compared to the remote distance of gravitational wave propagation.

When dealing with the seismic wave data (recorded by one seismometer) caused by the two consecutive big blasts at Tianjin China in 2015, we found that the time-frequency similarity of the two seismic waves reached 96%[3]. Such a similarity is high enough to make us sure that, only according to the seismic wave data, the two blasts took place at the same site even though the equivalent magnitudes of the two blasts are several times different. Here, we emphasize that high similarity can help us verify the uniqueness of wave origin. So, one can imagine: would low similarity means the multi-origin of waves? Our answer to this question is nearly positive, concluded by the acoustical experiments in this study.

The waves, such as acoustical, electromagnetic, seismic, and gravitational ones, if emanated from the same source, might show similarity to some degree, no matter what the wave transmission medium is. This study will show that the similarity varies with the distance between two wave receivers. In Section 2, a similarity principle is given. Section 3 defines the similarity function mathematically. We verify the similarity principle by the acoustical experiments in Section 4. Finally, we will have some discussions.

II. Similarity Principle

1. The waves emanated from the same source are similar, as long as two wave receivers are close enough. The closer the receivers are, the more similar the received waves are.
2. When a proper distance between the wave receivers is fixed, the high similarity of received waves means a unique origin of the waves. In contrast, the low similarity means multi-origins of the waves.

III. Mathematical Definition of Similarity

There are many ways to measure the similarity of two variables[4, 5]. Most reflect the degree of linearity, like the Pearson correlation coefficient[6], where a high value figured out means the two variables are linear while a low value means nonlinear. Based on the condition, we will choose a suitable measurement to calculate the similarity[7]. The similarity is a tool, by which we can research kinds of scientific problems. In the principal component analysis, the principal component can be extracted by the correlation coefficient which could be regarded as similarity[8]. The similarity can be used to analyze two images for spatial concordance[9], and also used in Complex Network Graphs[10].

Here, similarity refers to the degree of limit correlation of the concerned oscillating information in two time data sets, and its value interval is $[-1,1]$. The similarity makes it feasible to estimate the time delay between the two datasets. If the two datasets are not disturbed by noise, then the similarity is determined by a formula similar to the correlation coefficient's, by which the corresponding delay estimation can be worked out directly.

Generally, assuming that there are two closely separated observation stations, respectively recording the infinite oscillation time datasets $f_1(t) \in R$ and $f_2(t) \in R$, the similarity between the oscillating

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information in the two datasets can be measured by the following equation.

$$\rho(l,s)=\frac{\int_{D+l} f_1(t)f_2(t+s)dt}{\sqrt{\int_{D+l} f_1^2(t)dt\int_{D+l} f_2^2(t+s)dt}} \quad l\in R, s\in\Delta \tag{1}$$

This function is called the similarity function, where *D* represents an integral time period, showing the length of the information concerned; *D+l* means the period *D* translates rightly by *l* time; *s* denotes the delay time index; Δ denotes a time interval.

We call

$$\gamma(l)=\rho\left(l,s^{'}\right) \tag{2}$$

as Similarity Coefficient between the concerned oscillating information around *l* time, if

$$\left|\rho\left(l,s^{'}\right)\right|=(|\rho(l,s)|) \tag{3}$$

Here, $s^{'}$ can be regarded as the delay of the oscillating information in $f_2(t)$ to that in $f_1(t)$. The similarity coefficient takes the positive value when the oscillating information is positive phase correlated, and it takes the negative value when the oscillating information is reverse-phase correlated.

If time series $f_1(t)\in R$ and $f_2(t)\in R$ are disturbed by noises, the similarity function (1) can be substituted by[11]

$$\rho(l,s)=\frac{\iint_{S+l} Re\left(\Psi f_1(\tau,\varpi)\right)Re\left(\Psi f_2(\tau+s,\varpi)\right)d\tau d\varpi}{\sqrt{\iint_{S+l} Re^2\left(\Psi f_1(\tau,\varpi)\right)d\tau d\varpi\iint_{S+l} Re^2\left(\Psi f_2(\tau+s,\varpi)\right)d\tau d\varpi}} \quad l\in R, s\in\Delta \tag{4}$$

where Ψ denotes a normal time_frequency transform (NTFT)[12, 13], in which τ and ϖ denote time and frequency respectively; Re denotes the real part. *S* denotes the time-frequency area concerned; *S+l* denotes area S translating rightly by *l* time.

IV. Acoustical Experiments

To verify the above similarity principle, two acoustical experiments have been done in our work. The first experiment is one sound source test, and the other three sound sources test. We use two microphones to receive the sounds. In each experiment, a series of distances (0.008m, 0.2m, 0.415m, 1.5m, and 4.3m.) between two microphones have been set, reflecting how the Similarity Coefficient varies with the distance. Every recording time series lasts about 30 seconds with a sampling frequency 128KHz.

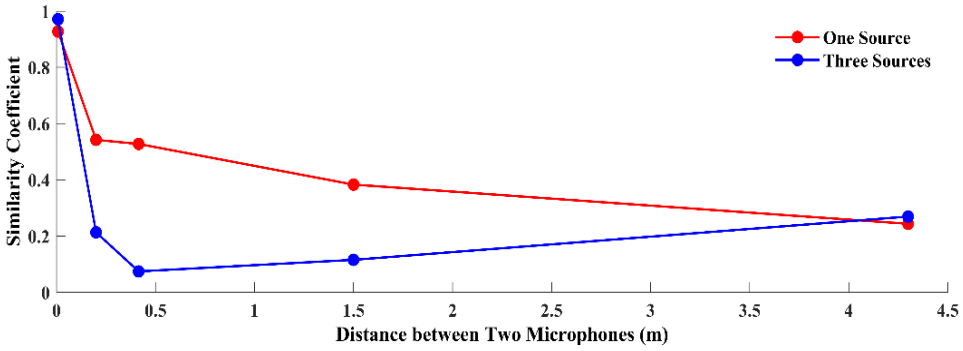

Figure 1: The Similarity Coefficient in Two Experiments

Fig.1 shows the result of the two experiments. Each line shows the Similarity Coefficient varies over the distance between two microphones. In fact, the Similarity Coefficient is averaged along the time. The red line corresponds to one source and the blue line to three sources. Figure 1 shows that the Similarity Coefficient decreases with the increasing distance based on the red line. The blue line shows some difference in this phenomenon. When the distance is close, its trend is the same compared to the red line. When the distance is far, the Similarity Coefficient shows a little increase. We conjecture it may be caused by the position distribution of two microphones and three sources, which requires further research. However, despite the close or far distance between two microphones, the Similarity Coefficient is larger than 0.9 in an enough close distance (it can be 0.008m in our experiments). On the contrary, less than 0.3 in a far distance (4.3m). It can be concluded that if the distance between two microphones is not close enough, the Similarity Coefficient is down sharply. The two acoustical experiments are sufficient to verify Similarity Principle I that the closer distance between the two receivers, the higher similarity of the two received waves.

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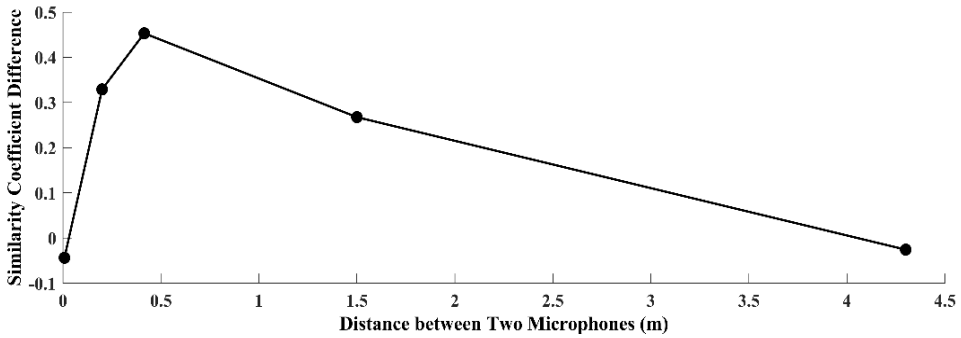

Figure 2: The Similarity Coefficient Difference

Comparing the difference in the Similarity Coefficient in two experiments at a distance between two microphones, the result is shown in Figure 2. The difference approximates 0, which indicates the two degrees of similarity are almost the same, then is significant, and lastly goes back to be near-zero value. It suggests an interval of distance in which the Similarity Coefficient is significantly different for one source against three sources. This case agrees with Similarity Principle II. A suitable distance (0.2m) between two microphones can be found, where the Similarity Coefficient is high in one source but low in three sources. According to the principle, it is possible to judge whether there is only one source or two more by making two receivers be arranged at a proper distance.

V. Discussion

This study shows a physical principle, the similarity principle, verified by acoustical experiments. In the traditional sense, waves emanated from the same source should be highly similar, and similarity should be little related to the distance between two receivers. However, Similarity Principle I negates this traditional sense. Similarity Principle II suggests that the distance between man's two ears should result from evolution. Such a distance is proper for a man to judge whether the sounds come from the same source or not.

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Abatement of Polluting Effects of Waste Dump Leachates using Different Coagulants

By Oso, S., Taiwo, A.M., Bamgbose, O., Olayinka, O., Terebo, O. & Soyingbe, A.A.
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Abstract- This study assessed the effectiveness of different coagulants for treating leachates before their release into the environment. Three inorganic coagulants (ferric chloride, ferrous sulphate and alum) and one organic coagulant [Moringer Oleifera seed (MOS)] were used in a jar test to determine the optimum pH and dosage for the coagulants. Raw and treated leachates were analysed for physiochemical parameters such as pH, chemical oxygen demand, Total solids, Pb and Cr. The optimum pH for ferric chloride, ferrous sulphate, alum and MOS was 7, 7,6 and 10 respectively. While the optimum dosage for each coagulant was 3g/L, 3g/L, 5g/L and 5g/L respectively. The analysis of the raw leachate sample showed that it was highly polluted (Dry season: COD – 3000mg/L, TSS – 2369mg/L, Cr – 0.075mg/L, Pb – 0.25mg/L and Mn – 0.29mg/L; Wet season: COD – 3000mg/L, TSS – 2369mg/L, Cr – 0.075mg/L, Pb – 0.25mg/L and Mn – 0.29mg/L). Coagulants removal efficiency (RE) for COD ranges from 12% to 41% with ferric chloride having the highest removal efficiency.

Keywords: leachates, coagulants, jar test, removal efficiency, seasonality.

GJHSS-B Classification: DDC Code: 616.157 LCC Code: RC647.C55



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Abatement of Polluting Effects of Waste Dump Leachates using Different Coagulants

Oso, S.[α], Taiwo, A.M.[σ], Bamgbose, O.[ρ], Olayinka, O.[ω], Terebo, O.[¥], & Soyingbe, A.A.[§]

Abstract- This study assessed the effectiveness of different coagulants for treating leachates before their release into the environment. Three inorganic coagulants (ferric chloride, ferrous sulphate and alum) and one organic coagulant [*Moringer Oleifera* seed (MOS)] were used in a jar test to determine the optimum pH and dosage for the coagulants. Raw and treated leachates were analysed for physiochemical parameters such as pH, chemical oxygen demand, Total solids, Pb and Cr. The optimum pH for ferric chloride, ferrous sulphate, alum and MOS was 7, 7,6 and 10 respectively. While the optimum dosage for each coagulant was 3g/L, 3g/L, 5g/L and 5g/L respectively. The analysis of the raw leachate sample showed that it was highly polluted (Dry season: COD – 3000mg/L, TSS – 2369mg/L, Cr – 0.075mg/L, Pb – 0.25mg/L and Mn – 0.29mg/L; Wet season: COD – 3000mg/L, TSS – 2369mg/L, Cr – 0.075mg/L, Pb – 0.25mg/L and Mn – 0.29mg/L).Coagulants removal efficiency (RE) for COD ranges from 12% to 41% with ferric chloride having the highest removal efficiency. All the coagulants were efficient in reducing the level of heavy metals in the sample leachate. The RE ranges from 55% to 95.6% with MOS having the highest RE of 95.6% for lead. The coagulants showed significant difference (at $P < 0.05$) in their RE for some of the parameters treated. The inorganic coagulants (ferric chloride, ferrous sulphate and alum) showed no significant difference ($P > 0.05$) in the removal of COD, while the organic coagulant (MOS) was significantly different at $P < 0.05$ from the inorganic coagulants. Over all, Alum showed to be a better coagulant than other coagulants in reducing the physiochemical parameters of leachates while MOS is a suitable substitute for alum. It was also observed that there was no significance ($P > 0.05$) in the removal efficiency of the coagulants in both dry and wet seasons. Seasonality has no effect on the effectiveness of the coagulants.

Keywords: leachates, coagulants, jar test, removal efficiency, seasonality.

I. Introduction

The continuous growth in population and industrialization globally has led to increases in solid waste generation and the problem of its management. Solid waste collection and disposal are among the most serious threats to waste management in most cities in developing countries (Donevska *et.al.,* 2006). Solid waste is any material, which is not in liquid form, and has no value to the person who is responsible for it (Zurbrugg, 2003). Babatola (2008) described waste as any material lacking direct value to the user and so must be disposed of.

The poor management of solid wastes constitutes a disaster for human health and leads to environmental degradation (Achankeng, 2003). One of the most important issues of concern in open dump or landfill waste disposal method is the issue of leachate generation and its potential for downgrading water resources systems (Sartaj *et.al.,* 2010). Leachates are defined as the aqueous effluent generated as a consequence of rainwater percolation through wastes, biochemical processes in waste's cells and the inherent water content of wastes themselves (Lee *et.al.,* 2012). The generated leachate can cause significant environmental damage, becoming a major pollution hazard when it comes into contact with the surrounding soil, ground or surface waters. This leachate often contains a high concentration of organic matter and inorganic ions, including ammoniacal nitrogen and heavy metals; posing great treat to human (Zouboulis *et al.,* 2008).

The quality of leachate is affected by factors such as dumpsite age, precipitation, seasonal weather variation, waste type and composition. Treatment methods are highly dependent on leachate characteristics and tolerance of the method against changes in leachate quality such a variable nature along with other factors. The leachate treatments success depends also on the characteristics of the leachate and age of the landfill. Therefore, in order to avoid environmental damage, landfill leachate must be collected and appropriately treated before being discharged into any water body (Oh *et.al*., 2007).

Coagulation is widely used for wastewater treatment. This treatment is efficient to operate and the operating cost is low (Wang *et.al*., 2008). It has many factors that can influence the efficiency, such as the type and dosage of coagulant, pH, mixing speed and time and retention time.The optimization of these factors may influence the efficiency (Wangand Bank, 2007). Coagulation destabilizes the colloidal suspension of the particles with coagulants and then causing the particles to agglomerate with flocculants. After that,it will accelerate separation and thereby makes the effluents clearer (Gnandi *et.al*., 2005).

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There are two kinds of coagulants; inorganic and organic coagulants. Inorganic coagulants (such as Alum, Ferric chloride etc.) are the most commonly used in coagulation treatment of leachate. The use of organic coagulants (M. oleifera seed, Phaseolusvulgaris seed, etc.) is not as common as the inorganic coagulants. The Moringa Oleifera tree grows in tropical and subtropical regions around the world and its seeds have been used in drinking water treatment in small scale in Sudan and India for generations. Coagulation studies are usually carried out using jar test equipment. The jar test has been the typical technique used in wastewater and drinking water industry to improve the addition of coagulant and flocculants (Silver *et.al*., 2004).

This paper seeks to investigate the efficiency of M. oleifera and compare the differences in the removal efficiency of alum, ferrous sulphate and ferric chloride to *M. oleifera* as coagulants in removing physicochemical parameters of leachate. Also to assess the effect of pH on the effectiveness of coagulants in leachate treatment and determine the pollution level of leachate samples by determination of water quality parameters.

II. Materials and Methods

a) Study Area

The study area Saje is located in Abeokuta North Local Government of Abeokuta, the capital of Ogun State, South-West Nigeria. Abeokuta covers an approximate area of about 40.63 km^2. Saje dumpsite lies between latitude 7^0 09' N – 7^0 19' N and longitudes 3^0 29' E – 3^0 41' E (Ufoegbune *et.al.,* 2008).

The Saje dumpsite (figure 1) established in 2006 was formerly a quarry, where mining was done over a long period of time for granites. In order to reclaim the site the state government decided to use the quarry as dumpsite. The dumpsite is the only major dumpsite used in Abeokuta metropolis and is about 4 ha in area. Saje area was formally an outskirt of Abeokuta town but due to increased population of the metropolis, houses have encroached the site of the dump site (Badejo *et.al.,* 2013).

The location coordinate of the dumpsite was obtained with a hand held Global Positioning System (GPS, Garmin MAP 76CSx model made in Taipei County, Taiwan) with position accuracy of less than 3m. The choice of the sampling points within the dumpsite was considered using the following criteria: location, accessibility and availability of leachate.

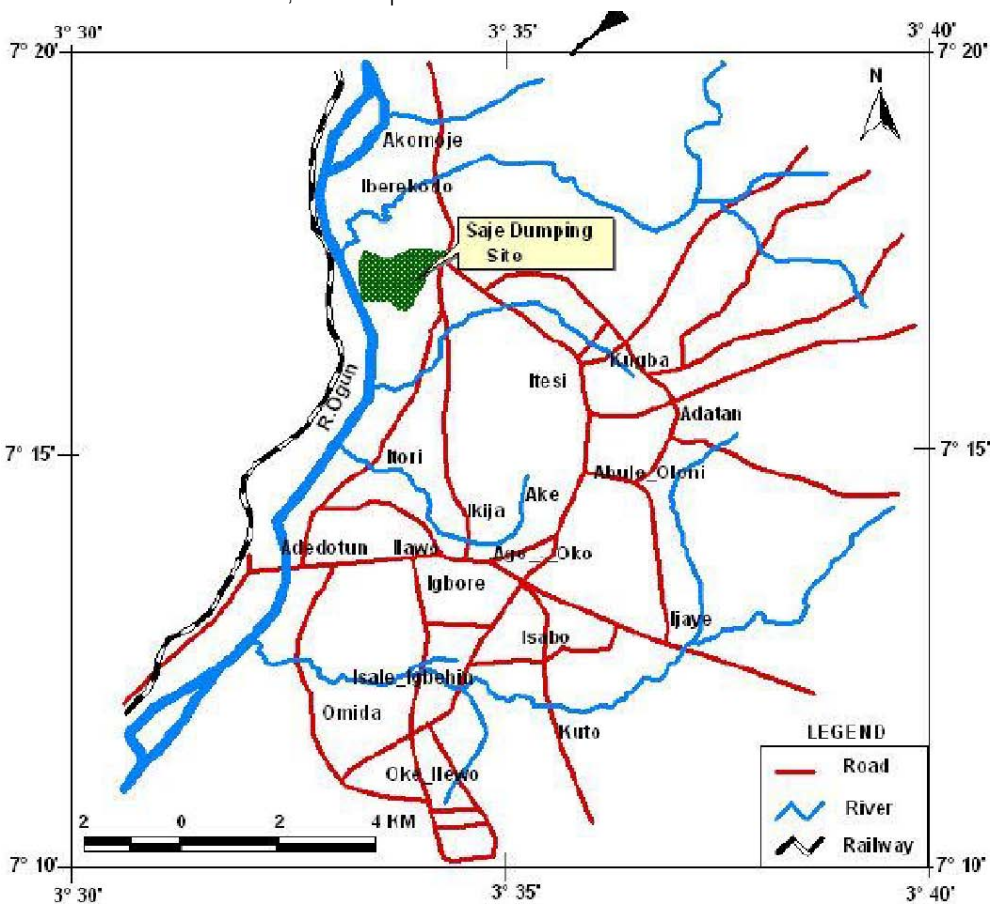

Figure 1: Saje Dumpsite Location within Abeokuta City, Ogun State, Nigeria.

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b) Sampling Procedures

Leachate: Leachate samples were collected from Saje dump site (figure 1) in Abeokuta, Ogun State during wet and dry seasons using standard methods. Samples were collected in 15 L plastic containers, transported to the laboratory and stored in a refrigerator at 4°C. The samples were removed from the refrigerator and left under room temperature for at least 2 hours. Then, the samples were thoroughly stirred to agitate settled solids before any tests were conducted on the leachate samples.



Figure 2: Leachate collection point from Saje dumpsite

c) Reagents

In this study, Ferric Chloride ($FeCl_3.6H_2O$), Ferrous Sulphate ($Fe(SO_4).7H_2O$) and Aluminum Chloride ($Al_2(SO_4)_3.18H_2O$) were used as inorganic coagulants. *Moringa oleifera* Seed (MOS) was used as organic coagulant. MOS 10% Stock solution was prepared daily by dissolving 30g of MOS powder into 270ml of distilled water, and the solution was well mixed.

d) Analysis Techniques

The physical and chemical parameters were determined using APHA Standard Methods (2005) for testing water and waste water. pH was assessed by glass electrode method with a calibrated pH meter, while temperature EC and TDS was determined using HM Digital Meter COM-100. Total alkalinity, total hardness, Acidity, chloride, were determined by titrimetric method. A total suspended solid was determined by gravimetric method. Chemical oxygen demand (COD) was determined by open reflux method. Nitrate Phosphate and Sulphate were measured by UV-Visible spectrophotometer. The heavy metal analysis was carried out using Atomic Absorption Spectrophotometer (AAS) Model 210 VGP of the Buck Scientific AAS series.

e) Experimental Procedure

Chemical coagulation was performed using beakers and stirrer as Jar test apparatus. The experimental process consisted of three subsequent stages: initial rapid mixing at 160 rpm for 10 min, followed by slow mixing for 20 min at 30 rpm, the final settling time for 1 h.

First, the optimum pH was determined by varying the pH of the sample using HCl and NaOH at constant coagulant concentration. The pH with the highest removal efficiency was the optimum pH.

About 2L beakers of equal volume were used to examine the different coagulants at their respective optimum pH. A known mass of (1g, 2g, 3g, 4g and 5g) of each coagulants was added to a jar containing 1liter of leachate samples at optimum pH using the jar test procedure. To determine the efficiency of coagulant dose, the supernatant was withdrawn by using a pipette from a point about 2 cm below the top of liquid level of the beaker and the supernatant was assessed for TSS, COD, Mn, Pb and Cr.

f) Data Analysis

Data collected were evaluated for descriptive and inferential statistics using the Statistical Package for Social Sciences (SPSS) for windows version 20.The removal efficiency (RE) of the coagulants was determined for each parameter by using the equation:

$$\text{RE}\ (\%) = \frac{Ci - Cf}{Ci} \ x\ 100 \frac{Ci - Cf}{Ci} \ x\ 100$$

Where, C_i and C_t are the initial and final concentrations of the parameters.

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III. Results and Discussion

a) Characteristics of Landfill Leacahte

The results of the physiochemical analysis of the untreated leachate samples from the dumpsite during dry and wet seasons are presented in Table 1.

The Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solid (TDS), Chloride, Chromium, Lead and Manganese of the untreated leachate samples from the dumpsites exceeded the limiting values recommended by the WHO and the FMENV. The values of all other parameters were within the allowable limits as specified. The high level of Pb and Mn is due to the dumping of metals such as cans, used batteries, iron etc in the dumpsite.

Table 1: Characteristic of raw leachate sample for wet and dry seasons

Parameters	Dry (mg/L)	Wet (mg/L)	T value
*pH	7.50±0.10	7.70±0.20	0.011
Alkalinity	47.00±1.00	49.00±1.00	0.007
COD	2900±101	3000.0±100	0.01
Acidity	50.00±10.10	47.00±3.0	0.006
Hardness	2240±201	2280.0±102	0.01
**EC	5790±120	8740.0±90.0	0.02
TDS	3110±110	4720.0±96.0	0.004
TSS	2333.0±120.00	2333.0±20.0	0.001
Chloride	870.0±65.00	910.0±202	0.01
Nitrate	0.73±0.00	0.31±0.00	0.01
Phosphate	0.49±0.00	0.32±0.00	0.012
Sulphate	204.51±2.52	174.84±10.0	0.01
Chromium	0.07±0.01	0.08±0.01	0.013
Lead	0.25±0.0	0.25±0.03	0.013
Manganese	0.29±0.02	0.30±0.02	0.014

**No units **µS/cm*

b) Coagulants optimum pH

Results for the optimum pH obtained from the coagulation of leachate samples using Ferric Chloride, Ferrous Sulphate, Aluminum Chloride and MOS at varying pH values (4,6,7,8, and 10) to evaluate COD and TSS concentrations in the samples are shown in Figure 3 and 4. All the coagulants were kept at 2g/L in all the runs. The pH with the highest removal efficiency (ER) was taken as the optimum pH for the coagulant. It was noticed that all the coagulants gave different results at different pH. $FeCl_3$ and $FeSO_4$ had optimum pH of 7 and Alum had optimum pH of 6, while MOS had its optimum pH at a pH value of 10.

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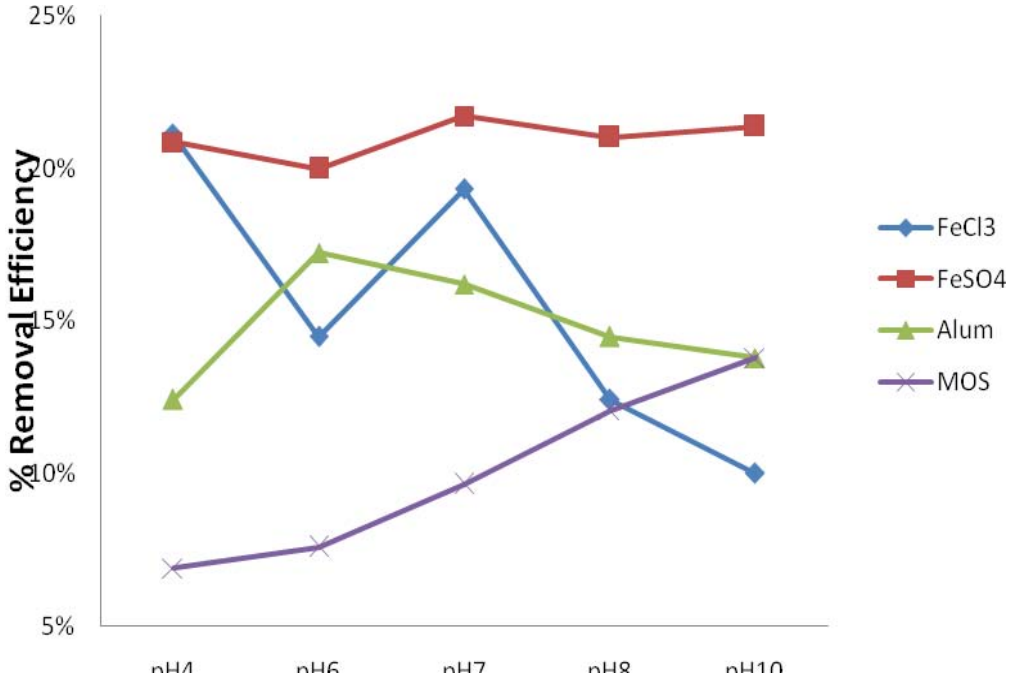

Figure 3: Effects of varying pH at constant coagulant dosage on COD

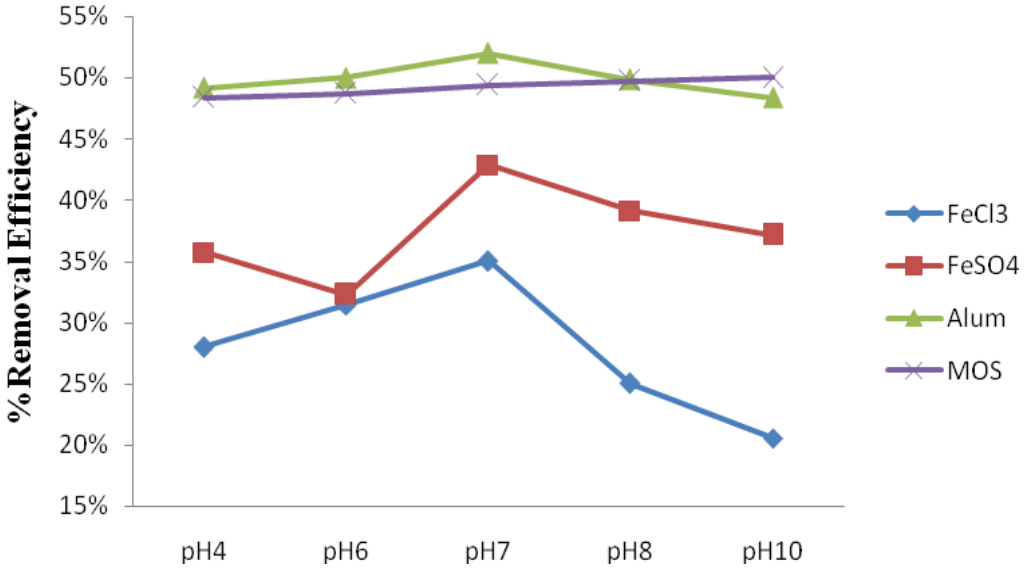

Figure 4: Effects of varying pH at constant coagulant dosage on TSS

c) Effects of Different Coagulant Concentrations in Coagulation Treatment

To observe the effect of coagulant dose, the experimental runs were conducted at different doses (1, 2, 3, 4 and 5 g/L). The percentage removal efficiency at each dose was compared. Depending on the coagulants, the optimal dose varied with the various coagulants used.

$FeCl_3$ removal efficiency for heavy metals ranged from 55% to 85% (Figure 5), this is in line with the reported work of Lee *et.al*. (2012) where $FeCl_3$ was reported to remove 75% of Pb. Amuda and Alade (2006) also gave a report in this range. $FeCl_3$ removed Cr better than Pb and Mn. $FeCl_3$ was not as efficient in removing COD, the value ranged from 19% to 40% (Figure 6). Other studies also reported low RE of $FeCl_3$ for COD (Ibrahim *et.al*., 2012; Lee *et.al.,* 2012). The optimum dosage for $FeCl_3$was determined to be 3 g/L, the RE dropped beyond this dosage.

$FeSO_4$ removal efficiency for heavy metals ranged from 65% to 85% as shown in Figure 7. $FeSO_4$ also removed more of Cr when compared to Pb and Mn, following the trend of $FeCl_3$. It was also not as efficient in removing COD, the value ranges from 21% to 37% (Figure 8) this was in accordance with the work of Ibrahim *et.al*. (2012). $FeSO_4$also had optimum dosage of 3 g/L. Additional concentration above the optimum dosage reduced the efficiency of the coagulant.

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Alum had a higher RE for heavy metals compared to $FeCl_3$ and $FeSO_4$. Its values ranged from 72% - 94.28%. Like in other Coagulants, Cr has the highest RE of 94.28%. This was closely followed by Pb (92.8%) and Mn (87.9%) as presented in Figure 9. The maximum COD removal of 41.72% (Figure 10) resulted at 5 g/L coagulant dose. The COD removal increased with alum dosage increase. Zazouli and Yousefi (2008), Bila *et.al*. (2005) also reported RE of Alum for heavy metals in the range of 71% - 96% and COD in the range of 27% - 40% in their reports. Meanwhile, Trebouet *et.al*. (2001) reported a much lower maximum RE of 66% for heavy metals.

MOS had the best range of RE for heavy metals of all the four coagulants with a minimum of 72.4% and maximum of 95.6% (Figure 11). It removed more of Pb, than Mn and Cr had the least RE. Ravikumar and Sheeja, (2013) reported a 93% RE for Pb and 70% RE for Cr in their work. Both Alum and MOS increased there RE for heavy metals with increase in concentration. Figure 12 showed that MOS treated samples had increased COD concentrations, giving a negative RE. This is similar to the report in previous studies (Arnoldsson and Bergman, 2007).

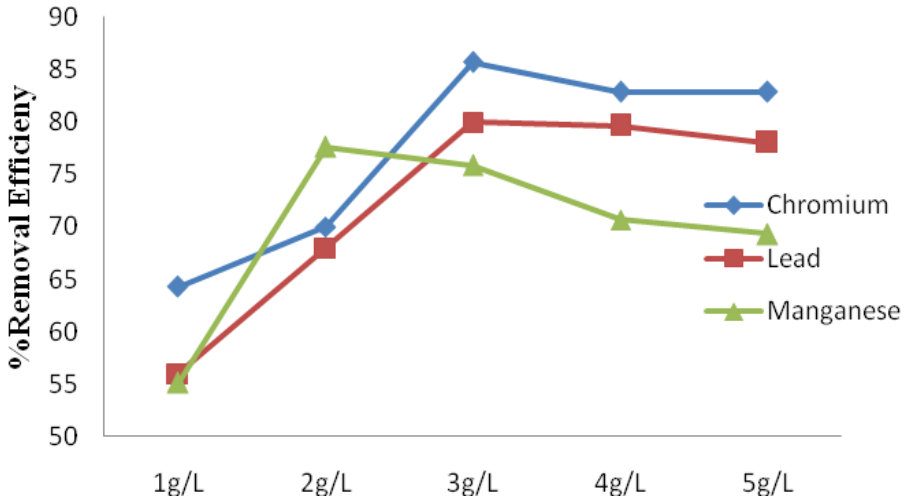

Figure 5: $FeCl_3$ percentage removal efficiency for Cr, Pb and Mn

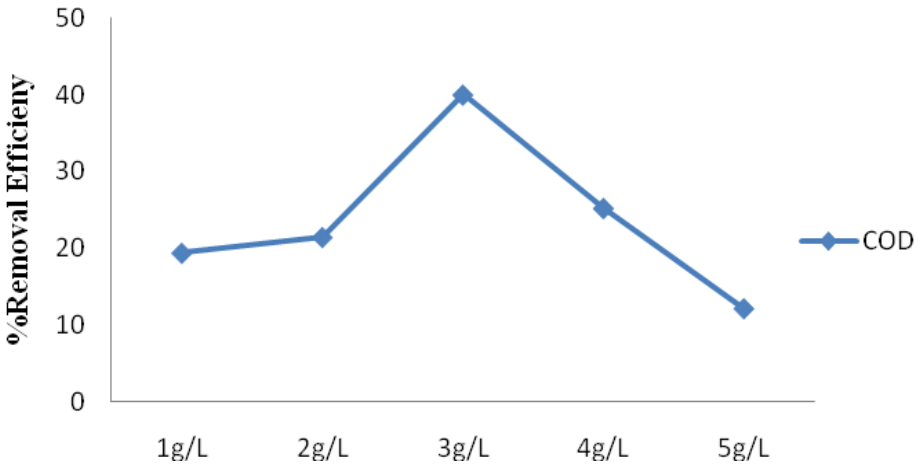

Figure 6: $FeCl_3$ percentage removal for COD

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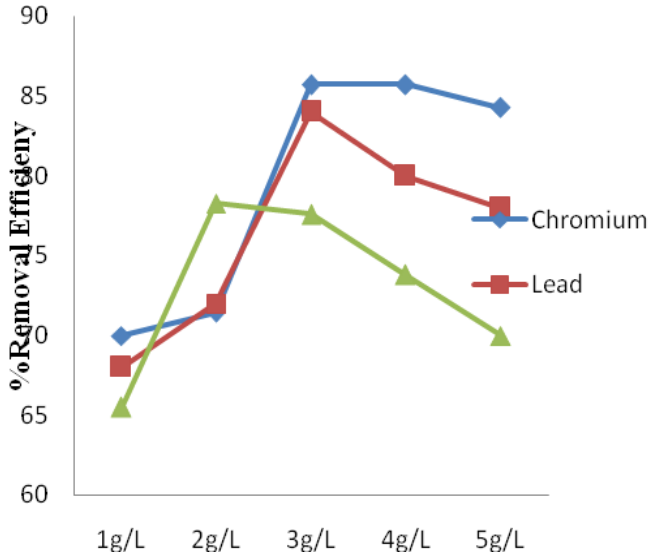

Figure 7: $FeSO_4$ percentage removal efficiency for Cr, Pb and Mn

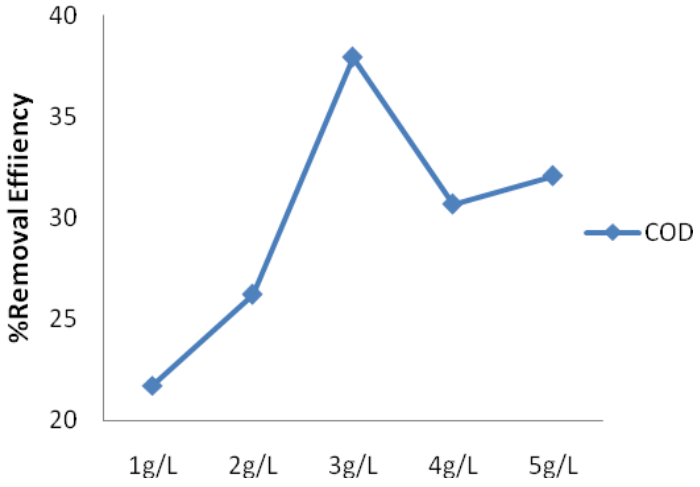

Figure 8: $FeSO_4$ percentage removal efficiency for COD

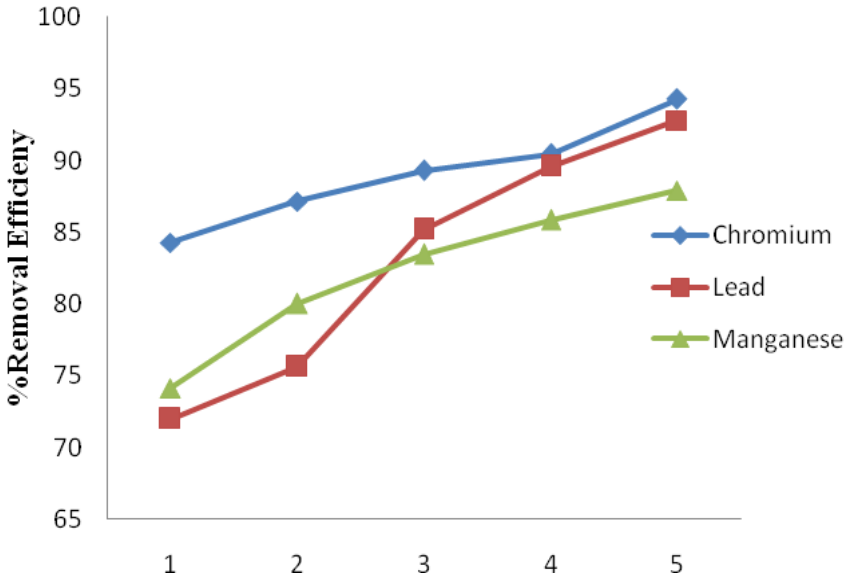

Figure 9: Alum percentage removal efficiency for Cr, Pb and Mn

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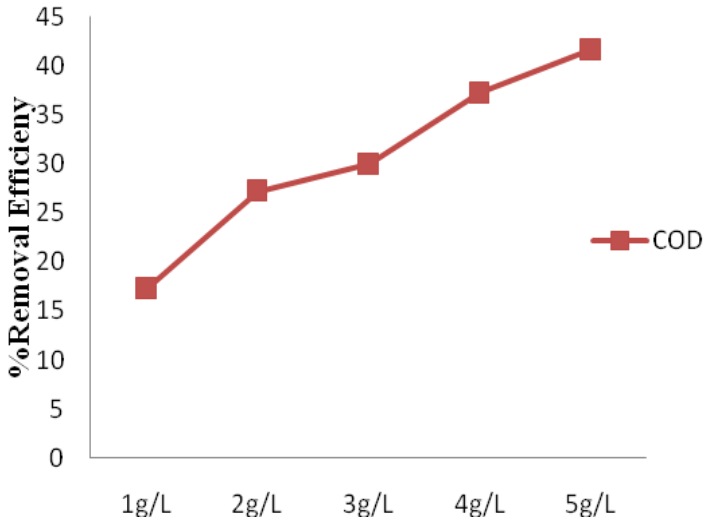

Figure 10: Alum percentage removal efficiency for COD

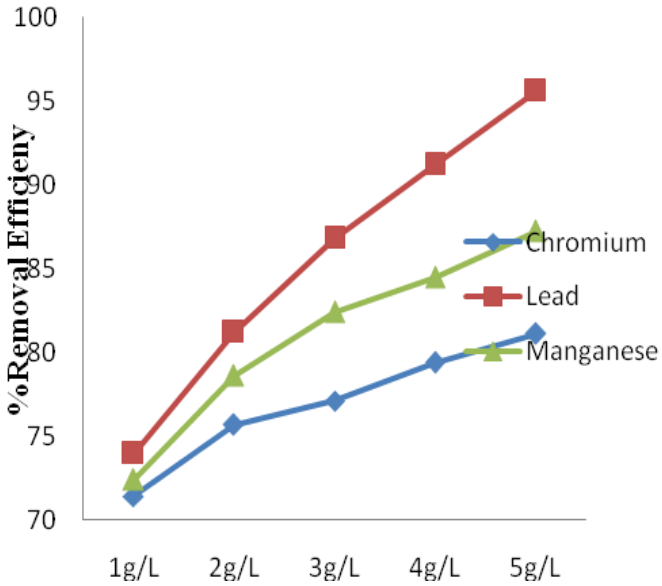

Figure 11: MOS percentage removal efficiency for Cr, Pb and Mn

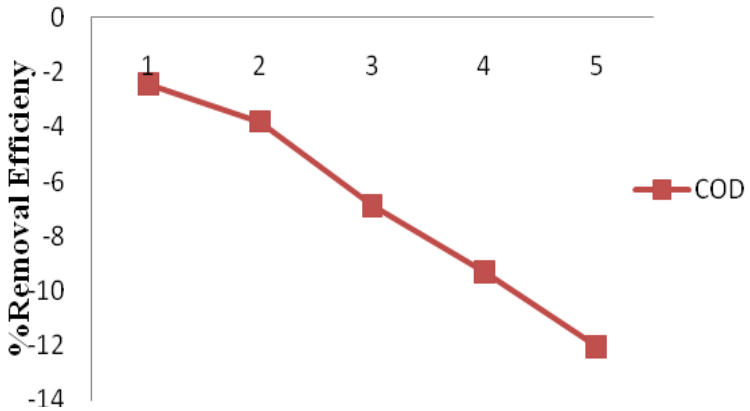

Figure 12: MOS percentage removal efficiency for COD

Alum exhibited a good performance in the sample parameters compare to other coagulants. Table 2 shows that the coagulants were able to reduce heavy metals from the leachates samples to level below standard limits but COD and TSS still had values higher than the recommended standards.

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Table 2: Summary of comparison of coagulants optimum dosage parameters

Parameters	Raw	$FeCl_3$(3g/L)	FeSO4(3g/L)	ALUM(5g/L)	MOS(5g/L)	WHO Standard	FMENV Limit For Discharge To The Environment
COD (mg/L)	3000	1770	1875	1730	0	60.9	60.9
TSS (mg/L)	2369	207	1637	368	1047.5	25	25
Chromium (mg/L)	0.0750	0.0105	0.0105	0.0045	0.0133	0.0500	0.0500
Lead (mg/L)	0.2500	0.0490	0.0395	0.0175	0.0110	0.0500	0.0500
Manganese (mg/L)	0.2950	0.0705	0.0645	0.0355	0.0365	0.0500	-

Over all, Alum was a better coagulant than the three other coagulants in reducing the physical and chemical parameters of leachates.

d) Seasonal Variations of Leachate Concentration

The test was carried out both in the dry and wet seasons to determine effect of season on the efficiency of coagulants. Table 4 and 5 is a summary of the physical and chemical properties of the raw and treated leachate samples for dry and wet seasons.

It was shown that the physical and chemical properties of the leachates are higher in the wet season than in the dry season. This can be attributed to the fact that rainfall is a crucial factor in the formation of leachate and the characteristic of the leachate.

Season has no effect on the efficiency of coagulants. The trend of the removal efficiency of each coagulants tested in dry season is similar to that of the wet season.

Table 4: Summary of Physical and Chemical Parameters of Raw Leachates and Treated Leachate in the Dry Season

	Raw Leachate	After treatment $FeCl_3$	After treatment $FeSO_4$	After treatment Alum	After treatment MOS
COD (mg/L)	2900.0 ± 100.50^{b}	2216.0 ± 274.32^{a}	2038.0 ± 177.68^{a}	2010.0 ± 274.32^{a}	3100.0 ± 268.23^{b}
TSS (mg/L)	2333.0 ± 120.00^{c}	1037.9 ± 295.90^{a}	1726.5 ± 383.22^{b}	717.56 ± 295.90^{a}	1246.5 ± 159.15^{ab}
Cr (mg/L)	0.07 ± 0.01^{c}	0.02 ± 0.00^{b}	0.01 ± 0.01^{ab}	0.01 ± 0.00^{a}	0.02 ± 0.00^{b}
Pb (mg/L)	0.25 ± 0.03^{c}	0.07 ± 0.02^{b}	0.06 ± 0.02^{ab}	0.04 ± 0.02^{a}	0.04 ± 0.02^{a}
Mn (mg/L)	0.29 ± 0.02^{c}	0.09 ± 0.02^{b}	0.08 ± 0.02^{b}	0.05 ± 0.02^{a}	0.06 ± 0.02^{a}

Table 5: Summary of Physical and Chemical Parameters of Raw Leachates and Treated Leachate in the Wet Season

	Raw Leachate	After treatment $FeCl_3$	After treatment $FeSO_4$	After treatment Alum	After treatment MOS
COD (mg/L)	3000.0 ± 100^{b}	2350.0 ± 288.57^{a}	2170.0 ± 163.25^{a}	2122.0 ± 288.57^{a}	3270.00 ± 279.52^{b}
TSS (mg/L)	2333.0 ± 20.0^{c}	1074.2 ± 295.98^{a}	1591.0 ± 136.38^{b}	717.6 ± 295.98^{a}	1246.6 ± 159.21^{ab}
Cr (mg/L)	0.08 ± 0.01^{c}	0.02 ± 0.00^{b}	0.02 ± 0.01^{ab}	0.01 ± 0.00^{a}	0.02 ± 0.00^{b}
Pb (mg/L)	0.25 ± 0.03^{c}	0.07 ± 0.02^{b}	0.06 ± 0.02^{ab}	0.04 ± 0.02^{a}	0.04 ± 0.02^{a}
Mn (mg/L)	0.30 ± 0.02^{c}	0.09 ± 0.02^{b}	0.08 ± 0.02^{b}	0.05 ± 0.02^{a}	0.06 ± 0.02^{a}

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IV. Conclusion

The application of coagulation treatment for raw leachate collected from Saje dumpsite showed the leachate was characterized by low pH and high concentration of pollutants; especially that of organic matter as observed in the COD level and high level of heavy metals which are all above the WHO and the FMEnv limit for waste water. The study showed that the leachate from the dumpsite is polluted and there is need for it to be treated before it is released into environment.

The study showed that coagulation treatment is efficient in ameliorating the polluting potential of dumpsite leachates. All the four coagulants; ferric chloride, ferrous sulphate, alum and MOS were able to reduce the heavy metals in the leachate by over 55% and MOS removing as high as 95.6%. MOS was better than the other coagulants in terms of removal efficiency for heavy metal. The coagulants were not as effective against COD, with alum giving the highest removal efficiency of 41.7% and MOS increased the COD concentration. None of the coagulants was able to bring the COD level down to below the FMEnv standard limit.

This study also revealed pH as an important factor in coagulation. It was established that each coagulant has the pH at which it works best; to remove contaminants. This pH isreferred to as the optimum pH. In this study the optimum pH for Ferric chloride and ferrous sulphate was 7.0, Alum was 6.0 and MOS was 10.0.

This study had determined the optimum dosage of each coagulant to get the best use of them. It was observed that the optimum dosage for ferric chloride, ferrous sulphate, alum and MOS were 3.0g/L, 3.0g/L, 5.0g/L and 5.0g/L respectively. From the results Alum was the best coagulant for treating leachates, closely followed by ferric chloride, MOS and ferrous sulphate in that order.

This study has shown little or no seasonal variation in the concentration of leachate. The season did not have significant effect on the efficiency of the coagulants

Moringa Oleifera showed good coagulating properties, and has many advantages compared to aluminium sulphate. It did not affect the pH, alkalinity or conductivity of the water, and it can be produced locally at low cost. *Moringa oleifera* is an environmentally-friendly natural coagulant that can be used to replace alum and other inorganic coagulants particularly in treating drinking water. It is a method that certainly can be considered as a good, sustainable and cheap solution for smaller waterworks, if the supply of Moringa seeds can be guaranteed.

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Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

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Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

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Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

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A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

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One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

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Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

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Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

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Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

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Tips for writing a good quality Social Science Research Paper

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1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

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5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

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9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

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11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.
Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

19. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

20. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

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22. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

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Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

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To make a paper clear: Adhere to recommended page limits.



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- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

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Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.



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Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
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- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

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Put figures and tables, appropriately numbered, in order at the end of the report.

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If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

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- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

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Describe generally acknowledged facts and main beliefs in present tense.

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Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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