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Effects of the Leachates of Essential and Non - Essential Inorganic Materials From Mined Clay Deposits and Landfills On the Environment: A Review

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Abstract

This study is designed to review studies on the effects of leaching from mined clay deposits and landfills on the environment. Thus, literature report showed that inorganic minerals such as goethite (FeO.OH), hematite (Fe_2O_3), kaolinite ($Al_2Si_2O_5(OH)_4$, Montmorillonite ($S_{i12}O_{30}Mg_8(OH)_4(H_2O_4{\times}8H_2O$), the heavy metals, including arsenic, cadmium, lead and their complexes are regarded as indicators; which makes it possible to identify the routes of various minerals and contaminants in the environments. This is because they can be distributed over far distances and get settled far away from their original source of deposits through diverse means, including leaching by rain and streams. However, from reviewed articles, it was observed that leaching of toxic substances such as arsenic, lead, cadmium, mercury, industrial dyes, agrochemicals etc into the ecosystem enhances environmental problems; because they will percolate into the ground and cause severe pollution of the environment; since clay soil is susceptible to alterations in physical and chemical properties when contaminated with leachates, hence, preventing the biochemical processes of lives in that environment when get absorbed.

Keywords: Clay deposit, environment, inorganic materials, leachate, mineral elements, pollution.

Introduction

Mineral elements such as potassium, copper, magnesium, calcium, aluminum, iron etc are regarded as the essential mineral elements, because they are required by human beings, animals, plants, aquatic lives etc for growth and metabolic processes, based on the recommended quantities by the international standard agencies, example, Food and Agriculture Organization (FAO) and World Health organization (WHO), while cadmium, lead, arsenic, mercury are regarded as non-essential elements, because they are toxic as could bioaccumulate in the body, thereby, causing severe harm to the tissues and organs in the body [1].

However, these mineral elements occur naturally in the earth crust. Nevertheless, the complex form of these mineral elements in clay deposits such as goethite (FeO.OH), hematite (Fe_2O_3), kaolinite ($Al_2Si_2O_5(OH)_4$, Montmorillonite ($Si_{12}O_{30}Mg_8(OH)_4(H_2O_4{\times}8H_2O)$ [2], also occur based on their respective geological processes involved.

Clay on the other hand are finely grained [3] natural rock or soil materials that combines with one or more clay minerals as well as traces of quartz (SiO_2), metal oxides such as AI_2O_3, MgO [4] and organic matter. Clay may also be refers to materials with particle size of less than 2 micrometer [3] as well as the materials with minerals that have similar chemical composition and common crystal structural characteristics. Studies from around the world confirmed the fact that clay contains numerous type of mineral elements and at different concentrations based on their location [2]. However, from reviewed literature, it was observed that minerals indicate various environmental conditions taking place during their formation. In other words, mineral genesis explained the formation of different types of mineral deposited within the earth crust. Hence, serve as indicators [5] which make it possible to know the transport pathway of various minerals including the pollutants in the environments because they can be distributed over far distances and get settled far away from their original source of deposits.

However, clay is formed either as a product of chemical weathering [6] of pre-existing granitic rocks and feldspar minerals mostly in warm tropical and subtropical regions of the world or as a product of hydrothermal alteration of granitic [7] rocks, riverbanks [4] and lakes. In Nigeria, clay is widely distributed and their deposits are found in places including lkot Ebom Itam [9] in Akwa Ibom State, in Abeokuta [10], in Benue State [11] etc. However, some of the largest deposits are located in the United States, China, Russia, India, and Greece. Another country with significant deposits include Brazil [12].

Clays from different sources contains numerous minerals including potassium, sodium, calcium, magnesium, iron etc with varying properties and their properties have the potential to affect the applications of clay industrially, medically, pharmaceutically etc. In other words, different types of clay mineral have unique properties and are used in a wide range of applications. Hence, their choices in diverse field depends on the desired properties of the material. However, due to high adsorption capacity of clays [13], they are used in treating and purifying wastewater [14]. The surface of clay minerals attracts water molecules greatly. Thus, when a small quantity of clay is added to water, a slurry forms because the clay distributes itself evenly throughout the water. Therefore, this potential property qualify the use of clay as colour pigments by the paint industry to disperse colour effectively throughout a paint [15].

Other vital uses include emulsifying [16],thickening, isotonic, anticaking agents,

catalyst, diluents, binders and decolorizing agent [17]. Clay materials have been used for other purposes, such as toothpaste, insecticides etc [18]. They are also use as skin care products such as facials powders and soaps [19]. It is also used as an excipient in pharmaceutical preparation [20]. The relatively high specific surface areas (26-43 m^2 g^{-1}) give the clays a good adsorption potentials [14] Therefore, they may be used in the treatment of certain poisonous trapping toxins, pesticides, gas, microorganisms and food allergy thus limiting their actions [21].Clay with high cation exchange (CEC) capacity being one of the important properties of clay makes it useful as adsorbent[17] or as a binding agent [16] e.g in drilling muds, which allows it to stabilized the borehole walls, thus, preventing them from collapsing. It can also impact soil fertility, plant growth, nutrient retention as well as other important factors that are essential for sustainable agriculture and environmental health development.

Bentonite is another type of clay minerals and there are several types which differ in their mineral composition, physical properties as well as industrial applications [22].

However, the variability in mineral distribution in the environments including the clay deposit calls for mineral evaluations, because leaching of mined solid wastes from the mined clay deposits may affect the environment by transporting concentrations of toxic materials into the surface and ground water around the environment [23] which is a threat to public health [24]. Leaching, however, is the natural process of removing both the essential and non essential substances out of the earth (soil, clay, rock etc) by rain through percolation into water bodies and around the environment. However, leaching from the landfill into the ground can contaminate ground water, soil, plants with heavy metals, [25] as well as inorganic and organic substances [26]. Nevertheless, altering the natural quality of the environment including surface and groundwater is dangerous because water is very important to human being, animal and plants for effective functioning of the biochemical processes.

However, studies have proven that industrial chemicals including synthetic dyes, agrochemicals such as fertilizer, pesticides, herbicides are deleterious to health and when the non-biodegradable ones are present in wastewater and the environment, they become a threat to lives in the ecosystem; thus, inhibits the proper functioning of their cells, tissues and organs, which consequently bring down the economic, social and cultural progress of the community concern.

Several studies have proven that there are variability in the distribution of the essential and non essential substances including the inorganic materials such as heavy metals and other toxic substances in the environment due to several reasons including the geological history of the region. In other words, the geography of the land (mineral composition) and the topography of the land (elevation, mountains, valleys, slope etc). However, Ike et al. [27], reported the mineralogical

variability in clay samples within the study area. Thus, the samples were analyzed using the X-ray diffraction and x-ray fluorescence. The results of the analysis showed the concentrations of the mineral elements and the oxides present. Literature review on the analysis of heavy metals constituent of sediments in Utibete River in eastern Obolo, Akwa Ibom State, Nigeria was carried out and the particle induced x-ray emission (PIXE) technique was used to determine the heavy metals including titanium, Chromium, Manganese, Iron, Copper, Zinc, Rhodium, Lead, Strongium, Zirconium, Silicon, the results showed variable concentrations of these heavy metals [28].

Furthermore, findings by [18] on the analysis of clay mineral content of clay samples from Ijesha-Ijebu North East Local Government Area of Ogun State was carried out using the X-ray diffraction technique and inductive coupled plasma-mass spectrophotometer for the analysis.

Literature report by Munoz et al., [12] on the variability of chemical, mineralogical and morphological of the clay-rich soils from different areas of Curitiba and the metropolitan region were analyzed by using the X-ray fluorescence spectrometry (XRF) for chemical analysis, while X-ray diffraction (XRD) was used for mineralogical composition and the microstructure were determined by scanning electron microscopy (SEM) . The results showed variable compositions of these parameters in the samples. However, their composition, properties, quantity as well as the quality varies depending on certain factors such as the geological history about the processes involved during its formation.

Climate, soil organic matter and particle size are also factors which causes variable chemical composition of the soil. However, soil does not necessarily indicate contamination, rather the long-term and extensive use of land for agriculture with frequent application of agricultural chemicals including fertilizer, herbicides, pesticides is one of the major causes of accumulation of toxic substances in the soil as well as unauthorized disposal of chemically reactive industrial wastes, whereby, their mobility, distribution in ecosystems and their bioavailability to living organisms and potential contamination of wide range of natural environment is a cause for concern.

Literature review by [25] has shown that mining activities had led to diverse environmental problems, including vegetation reduction as shown in Table 1 [29], soil degradation, water and air pollution [30]. However, leachates from mined solid wastes and landfills containing the frequently applied agrochemicals such as fertilizer, herbicides, pesticides as well as other toxic substances like cadmium, lead and mercury, percolating into the ground get distributed around the environmental compartment and cause severe pollution to the environment. However, several reports have shown the distribution of minerals and their impacts on the environmental compartment such as a report on mineral distributions on Mars through a 3-D Monte Caslo as a result of impact induced hydrothermally melting of subsurface ice [31.

The distribution of the essential and non-essential inorganic substances in clay deposits and the ecosystems may enhance or degrade the environment depending on the type and the concentration as shown in Table 2 [32]. Furthermore, most of the essential mineral elements poses severe environmental and health hazard because they are toxic and bioaccumulate when the normal threshold is exceeded. However, due to the pollution of the environment, vegetations has lost their natural potentials; groundwater also has lost its potentials as consumable water. Furthermore, the deficiency and over-concentration of the trace metals in human beings are characterized by certain syndrome which indicates the deleterous effect of the mineral metabolism [33].The non-essential heavy metals including cadmium, lead, mercury etc are regarded as toxic even in trace quantity and the reviewed literature reported on their presence in leachate solids as shown in Table 3 [25]. Thus, cadmium toxicity symptoms in human and animal include gastrointestinal disorders, pulmonary edema,heart diseases etc [34]. Consequently, this menace brings down the economic, social and cultural progress of the community concern because of the negative effect on the environments.

Table 1: Impact of Mining activity on vegetations within proximity of mines between 0-1km [29]

Vegetation	**Mechanized**	**Spesify**	**Open pit**	**Total**
Trees	2	2.5	2.6	2.3
Shrubs	2.5	2.5	2.3	2.4
Grass	3	1	1.8	2.2
Animal life	3.7	3.5	3.5	3.6

(Scale 1-5) 1=non (bare ground), 2=sparse, 3=moderate and 1ush, 4=dense and lush, 5=very dense and green.

Table 2: Leachate Composition (Oyediran et al., 2020)[32]

Parameters	**Landfill leachate composite**
Colour	Dark Brown
Odour	Malodorous Smell
pH	8.52
K^+	3210.01
Na^+	1505.11
Mg^{2+}	82.56
Ca^{2+}	100.10
Dissolved Aluminium	3.87
Dissolved Arsenic	<1
Dissolved Barium	0.23
Dissolved Mercury	0.010
Dissolved Boron	8.00
Dissolved Cadmium	0.002
Dissolved Manganese	1.77
Dissolved Zinc	0.27
Chromium	0.090

Cobalt	0.065
Nickel	0.12
Copper	<1
Iron	7.56
Lead	<1
Lithium	0.075
Chloride	1.52
Fluoride	5.90
Nitrate	<0.1
Sulphate	472

Table 3: Pearson's correlation among the heavy metal and metalloids of leachate solids (Hredoy et al. 2022)[25]

Parameter	**Lead (Pb)**	**Cadmium (Cd)**	**Chromium (Cr)**	**Cobalt (Co)**	**Nickel(Ni)**	**Arsenic (As)**
Pb	1					
Cd	0.533	1				
Cr	0.858	0.146	1			
Co	0.831	0.188	0.823	1		
Ni	0.861	0.180	0.854	0.995	1	
As	0.830	0.178	0.822	0.978	0.983	1

Conclusion

This study reviews the effects of leachates of the essential, non-essential inorganic materials and other toxic substances from mined clay deposits and landfill to the environment. The study showed that leachates from landfill and mined clay deposits are among the major sources of contaminants in the environment. This because toxic substances can percolate into the water bodies as well as plants and constitute pollutants to the ecosystem, thereby altering their natural quality, hence, threat to lives. Therefore, adequate investigative measures should be applied to monitor and mitigate the contaminants in the environment.

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