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Investigation of Edaphic Variability and Properties for Suitability of Post- Bitumen Mining Reclamation Work

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Abstract
A study to evaluate the pre-mining conditions of the overburden soils in the bituminous sand deposit area located at Gbelejuloda community of Ondo State, Nigeria and their suitability for post-mining reclamation and restoration programme was undertaken in this research. A total of eleven (11) soil samples; each weighing approximately 1-2kg were obtained from selected locations in the study area at depths varying between 0-20cm and 80-100cm respectively. The samples were put in polythene bags and transferred to the laboratory for analyses of soil particle size, bulk density, pH and the constituent macro and micro elements essential for proper plant growth. The obtained soil nutrients values were compared with the Food and Agricultural Organization (FAO) and USDA soil quality standards to ascertain the soils viability and suitability as growth media for natural process of re-vegetation. The analyses revealed a range of soil organic matter between (0.14 - 2.79) %, nitrogen (0.07-1.40) %, phosphorous (2.60-39.55)mg/kg and potassium (0.07-0.51) Cmol/kg respectively. The study showed that the study area is made up of soil of four textural classes with clay-loam forming the largest proportion of 54.5%. Also, the research found that most of the soil nutrients essential for plant growth were adequate in the sampled soils to encourage restoration of cleared vegetation when embarking on post-open pit mining reclamation programme as- an integral part of environmental conservation mining plan.

Keywords: reclamation, soil, properties, mining, vegetation, analysis, open-pit.

INTRODUCTION

Open pit mining entails the removal in partial or total of the overburden (overlying) materials covering the mineral deposit. Generally, mining causes damage and destruction to the original soil in the process of removing the desired mineral (Bradshaw, 1997). In open pits, mine reclamation is an integral part of the mineral development process. It is designed to restore to an acceptable state, the physical, chemical, and biological qualities of land and water regimes disturbed by mining. The plan of reclamation needs to remain flexible and adaptable to changes in site characteristics, mine plans, geology, and long term end land use changes. Such plans should be practical, achievable and be prepared in conjunction with community input.

The overall objective of a reclamation plan is to produce a landscape that is safe, stable and compatible with the surrounding landscape and final land use. While recognizing that each mine site has unique characteristics, there are principles that are applicable to all surface mining operations and serve as the foundation for planning and implementing reclamation plans for surface bitumen mines. According to Bradshaw (1984) no effective reclamation can be achieved without the proper knowledge of the ecology of the site and the material to be used.

Mining operations are temporary land use activities and should be conducted with understanding and respect for the environment. Use of reclamation planning and environmental management that aim at sustainability should be encouraged in all aspects of reclamation planning, design and implementations. Plans must be science-based, comprehensive in scope and militate against safety hazards and environmental effects. Reclamation should be conducted as the operation proceeds (Song and Yang, 2006).

The central purpose in reclamation planning should be to promote the ecological integrity of each site and surrounding landscapes (Oboh *et al*., 2006). The application of ecological restoration principles requires that plans are developed consistent with regional or landscape level ecological objectives. At the local scale, this involves an examination of surrounding landscapes, in combination with determining predicted succession trends of vegetation communities appropriate to enhance local and regional ecosystems. At the site level, emphasis is placed on reclamation techniques such as land-form replication and planting species that will promote site stability and sustainability. Re-vegetation should use native species that contribute most to the compatibility of the local ecology (Akande and Akinbinu, 2005).

The technical and socio-economic factors associated with the post mine land use must be evaluated and the proposed land use, such as natural conservation and development of the ecological succession of plants and animal within the study area, is also very necessary before the mine closure, in order to establish self-sustaining re-vegetation (Cooke and Johnson, 2002; DeFries *et al.* 2004; Jeffery *et al.,* 2008).The detailed cost estimate associated with reclamation should be considered and compared with the cost of production, and if the cost of reclamation is been high and uneconomical the rule of thumb will be used, in such a case it is advisable to amend the soil and allow it to naturally regenerate which is possible as a result of the soil study carried out within the study area.

One of the key elements required for mined land reclamation is soil. Soils vary widely from place to place. Many factors determine the chemical composition and physical structure of the soil at any given location. The different kinds of rocks, minerals, and other geologic materials from which the soil originally formed affect the soil formation. The kinds of plants or other vegetation that grow in the soil are also important. Virgin soil usually contains adequate amounts of all the elements required for proper plant nutrition (Erin et al., 1994).

GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION OF THE STUDY AREA

Gbelejuloda, the study area is a community located on coordinates E004^0 48-49' and N06^0 34-36' and situated within the Nigerian bitumen belt lying on the shore areas of Eastern Dahomey (Benin) Basin. The probable reserve of bitumen and heavy oil in the entire Nigerian bitumen belt is about 120 x 4.3km (Adegoke and Ibe, 1982; Oboh et al., 2006), stretching from Lagos, Ogun, Ondo up to Edo State.

MATERIALS AND METHODS

Soil Sample Collection

Soil samples were randomly obtained from eleven (11) locations within the study area using soil auger. Top and subsoil samples were taken from (0-20) cm and (80-100) cm depth respectively. The samples were put inside polythene bags labelled according to locations and then transferred to the laboratory for analysis.

Methods

Particle Size Analysis

The particle size analysis involved two basic steps namely, the separation of all particles from each other; known as "dispersion" and the measurement of the quantities of each size group also referred to as "fractionation". From each soil sample, 50g oven-dried soil was weighed into 250ml water and 100ml sodium hexametaphosphate (calgon) were added. It was allowed to soak for 30mins, after which it was transferred to mechanical stirrer cup and stirred for 30mins. The soil suspension was transferred quantitatively to sedimentation cylinder and made up to 1 litre. After 40secs, hydrometer in the suspension was read and temperature was also taken.

The stem of the hydrometer reads directly in grams of soil per litre of suspension. To correct the hydrometer reading for temperature 0.36g per litre was added for every 1^{o}C above 20^{o}C and 0.36g was subtracted for every 1^{o}C below 20 ^{o}C.

$$\%\,(\text{Silt} + \text{Clay}) = \frac{\text{Corrected 40secs.Hydrometer reading} \times 100}{50} \quad (1)$$

$$\%\,\text{clay} = \frac{\text{Corrected 2hrs.Hydrometer reading} \times 100}{50} \quad (2)$$

$$\%\,\text{Silt} = \%\,(\text{Silt} + \text{Clay}) - \%\,\text{Clay} \quad (3)$$

$$\%\,\text{Sand} = 100 - \%\,(\text{Silt} + \text{Clay}) \quad (4)$$

Determination of Soil pH

From each air-dried and sieved soil sample, 10g were weighed into 100ml cleaned beaker. 20ml of distilled water were added and stirred several times within a period of 30minutes. The pH meter was standardized with buffer solutions after which the pH of the soil suspension was determined by immersing the glass electrode into the soil sample suspension

Determination Organic Matter

One gramme of finely ground soil sample was weighed into 250ml conical flask. 10ml of 0.5M $k_2Cr_2O_7$ was pipetted into it and 20ml of concentrated H_2SO_4 was added rapidly. The solution was allowed to stand for 30mins after which 100ml of distilled water was added with 3 drops of ferroine indicator and titrated against 0.5M ammonium ion (H) Sulphate. The colour changed from orange to dark green to light green and finally to maroon red. The blank titration was made in the same manner.

$$\%\,\text{Organic carbon} = \frac{(Vb - Vs) \times M \times 0.399}{Wt} \quad (5)$$

Where:

M= Molarity of Ferrous Ammonium Sulphate (FAS)

V_b= Vol of FAS used for blank

V_s= Vol of FAS used for Sample

W_t = Weight of soil sample

% Organic matter = % Organic carbon x 1.724 (6)

$$\%\,\text{Organic Nitrogen} = \frac{\%\,\text{Total carbon}}{20} \quad (7)$$

Soil Extraction - Exchangeable Bases (Na, K, Ca and Mg)

From each ground soil sample, 10g were weighed into extracting tube; 100ml of 1M neutral ammonium acetate were added. The mixture was stirred on mechanical shaker for one hour and then filtered. Sodium and potassium standards were aspirated into flame photometer. The emissions were recorded and plotted against concentrations. Soil extracts were also aspirated and emission of potassium and recorded concentration evaluated from the graph.

K or Na(Mg/kg) = curve gradient x E x 100/10 x D (8)

where; E = emission

D = dilution factor

Determination of Bulk Density

The diameter (d) of a regular bulk density mould was measured and recorded. The radius was then calculated with formula (r =d/2). The height (h) of the mould was also measured and recorded. Mathematically the volume of the mould was calculated as $V = \pi r^2 h$.

The mould was used to obtain the topsoil samples and density was calculated as the dry weight of soil divided by its volume. This volume included the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed g/cm^3 (Tagar and Bhatti, 2001).

RESULTS

Table 1: Some Essential Elemental Composition of Soil Samples

Sample	pH in H_2O 01:02	O/C %	O/M %	N %	P mg/kg	K^+ cmol/kg	Na^+ cmol/kg	Ca^{2+} cmol/kg	Mg^{2+} cmol/kg
S_1	5.31	0.98	1.68	0.07	3.13	0.09	0.07	0.09	0.07
S_2	5.36	1.10	1.89	0.11	8.65	0.10	0.08	1.0	0.8
S_3	5.49	0.36	0.62	0.18	15.73	0.12	0.10	1.2	0.9
S_4	6.28	2.79	4.82	1.4	39.55	0.51	0.67	5.3	3.7
Sample	pH in H_2O 01:02	O/C %	O/M %	N %	P mg/kg	K^+ cmol/kg	Na^+ cmol/kg	Ca^{2+} cmol/kg	Mg^{2+} cmol/kg
S_5	5.22	0.04	0.07	0.05	2.6	0.07	0.05	0.8	0.5
S_6	5.90	1.24	2.14	0.62	26.41	0.28	0.15	1.8	1.1
S_7	5.36	0.20	0.35	0.10	13.65	0.10	0.07	1.0	0.8
S_8	5.84	0.82	1.41	0.41	23.88	0.24	0.12	1.4	1.0
S_9	5.72	0.64	1.10	0.32	19.08	0.15	0.10	1.2	0.9
S_{10}	5.78	0.76	1.31	0.38	23.75	0.15	0.11	1.4	0.8
S_{11}	5.63	0.93	1.62	0.22	16.77	0.14	0.10	1.2	0.9

Table 2: Classification of Soil Macro and Micro Nutrients (Adapted from FAO Soil Bulletin No.63)

Soil Chemical Properties	**Low**	**Medium**	**High**
pH(H_2O)	6	6-7	>7
pH(1MKCl)	7	5-6.5	>6.5
Organic Matter(O/M) %	1.5	1.5-3	>3
Organic Nitrogen(O/N) %	0.08	0.08-0.15	0.15
P Bray-1mg/kg	7	7-20	20
K (CH_3COONH_3)(mg/kg) K^+(Cmol/kg)	59 0.15	59-160 0.15-0.3	120 0.30
K (CH_3COONH_3)(mg/kg) Na^+(Cmol/kg)	60 0.10	60-120 0.1-0.3	120 0.30
Ca (CH_3COONH_3)(mg/kg) Ca^{2+}(Cmol/kg)	380 2.0	1150-3500 2.0-5.0	3500 5.0
Cu(HCl)mg/kg	2	2-6	6
Fe(HCl)mg/kg	2.3	90	360
Mn((HCl)mg/kg	4	14	50
Pb(HCl)mg/kg	2	2-6	6
Zn(CH_3COONH_3)mg/kg	2	4	10
Mg^{2+}(Cmol/kg)	0.3	0.3-1.0	1.0
CEC(Cmol/Kg)	6	6-12	12

Table 3: Sampled Soil Bulk Density

Samples	Mass (gram)	Density (g/cm^3)
S_1	70.9	2.63
S_2	72.3	2.68
S_3	76.1	2.82
S_4	52.2	1.93
S_5	71.0	2.63
S_6	81.8	2.03
S_7	59.8	2.21
S_8	74.6	2.76
S_9	63.5	2.35
S_{10}	72.6	2.69
S_{11}	52.2	1.93

Table 4: Textural Classification of Sampled Soils

Sample	Sand (%)	Clay (%)	Silt (%)	Textural Class
S_1	60	35	5	Sandy clay
S_2	57	36	7	Sandy clay
S_3	57	35	8	Clay loam
S_4	49	28	23	Loam
S_5	69	29	2	Sandy clay loam
S_6	57	33	10	Clay loam
S_7	59	37	4	Clay loam
S_8	57	33	10	Clay loam
S_9	57	31	12	Clay loam
S_{10}	57	34	9	Clay loam

Note: S_1- S_{11}: Soil Sample designations based on Locations

The results presented in Tables 1 shows that the percentage organic matter present in the soil samples could be rated low, medium and high based on the FAO classification in Table 2. Six of the obtained samples were observed to have medium organic matter; four were low while the last one was high. Organic matter is the most essential nutrient for plant growth formed from residue of plants or remains of plant root deep within the soil. It has a strong, positive effect on infiltration of water into soils due mainly to a decrease in bulk density and improvements in aggregation and structure (MacRae and Mehuys, 1985). Since more than 60% of the sampled soils were moderately rich in organic matter, the soils in this area could be adjudged suitable as earth cover during reclamation programme of the area. The ability of organic matter-rich soils to retain nutrients, stabilize soil aggregation and act as cation exchange medium for plants (Mbah and Onweremadu, 2009) would particularly be of an advantage in this reclamation process.

The case may somewhat be different from other four locations with low level organic matter. These would require a measure of treatment before being utilized for same purpose as their present states if used could slow or inhibit the course of natural plant re-growth (Enwezor, *et al*.,1990).

Bulk density has direct correlation with compacted stress, if compacted layers are present in the soil; the risk of soil erosion is increased. The movement of water into and through the soil is reduced resulting in greater overland flow and subsequent surface erosion. However, the incorporation of organic matter in a compacted soil lowers the bulk density, increases electric charge thus increasing repulsive forces between soil particles and improves soil aggregate strength Soane (1990) in (Naeem *et* al. 2007).

The positively charged bases (cations) include calcium, magnesium, potassium, sodium, ammonium, nitrogen, and several trace minerals. When optimum ratios of these bases exist, the soil is believed to support high biological activity, becomes resistant to leaching, and has optimal physical properties (water intake and aggregation). The plants growing on such soils are also balanced in mineral levels and are nutritious to humans and animals alike (Preston, 1999). On the contrary, the excessive concentration of a particular nutrient in the soil may have undesirable effect over other ones.

The pH values obtained from the soil test ranged from pH 5.22 to pH 6.28 (Table 1), indicating that majority of the samples were moderately acidic with the exception of sample S_4 which is slightly acid according to Table 5. Generally, this range of Soil pH values is well suited for availability of most essential macro nutrients as depicted in Figure 1. Some nutrients become 'tied up' in the soil at certain pH levels. For example, excess phosphorus is known to tie up zinc; while extremely acidic soils could lead to deficiencies of phosphorus, calcium, magnesium and molybdenum, as well as toxic levels of manganese and aluminum. Alkaline soils on the other hand may lead to deficiencies in iron, manganese, boron, copper and zinc (Figure 1) (USDA, 1998; Harald, 2010).

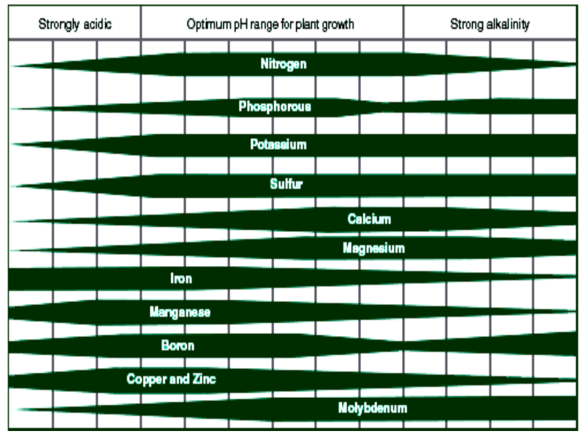

Figure 1. Nutrient Availability and Soil pH (after USDA, 1998)

Table 5: Common Classes of pH(after USDA, 1998)

Extremely acid	3.5-4.4
Very strongly acidic	4.5-5.0
Strongly acidic	5.1-5.5
Moderately acidic	5.6-6.0
Slightly acidic	6.1-6.5
Neutral	6.6-7.3
Slightly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0

The mean bulk density of the analyzed soil samples in Table 3 is 2.42 g/cm^3. Bulk density as a measure of the degree of compaction of the soil material is dependent on soil texture and the densities of soil mineral (sand, silt, and clay) and organic matter particles, as well as their packing arrangement (USDA, 2008). Ghose (2004) observed that high density has serious implication on subsequent change of soil properties due to tightly packed soil particles which could impede the flow of water and gases within the soil matrix. One of the implications of bulk density on the tested soils is its influence on restriction of plant growth and the volume the soil would occupy during back-filling of the cut out areas after full bitumen extraction. The more compact the soil, the less its volume required during reclamation.

Particle size analysis is one of the most stable soil properties hence; it is used as basis of soil textural classification. It is very essential in the study of morphology, genesis, classification and mapping of soils. It influences many physical, chemical and biological properties of soils such as soil drainage (water holding capacity), aeration and susceptibility to erosion and thus, it is a vital aid in soil management. The relative size of the soil particles is expressed by the term texture, which refers to the fineness or coarseness of the soil. The soil texture contracts with soil structure which refers to how well soil particles are aggregated together (Passioura, 1991). The rate and extent of many physical and chemical reactions in plant that aid growth are governed by texture because it determines the amount of surface where the reaction occurs.

The textural classification of the analyzed soil samples revealed that the study area falls into various textural classes as shown in Table 4. Generally, the area is predominantly clay-loam. The clay portion of the soil is usually with high density due to the presence of various matters in it such as decomposed plant remains, the remains of insects and animals. It possesses a moderate water retention capacity, an ability to form mould and support plant growth. Many clay minerals found in soils have the ability to develop a net negative charge which is satisfied through the electrostatic adsorption of cations. Hence, higher percentage of clay in soil boosts its cation exchange capacity and the pH buffering. Likewise, a soil with a large amount of fine particles (silt and clay) will have smaller pore diameters and a higher penetration resistance at a lower bulk density than a soil with a large amount of coarse particles (Richard and Gordon, 1983). A careful observation of the vegetation in the studied area shows that the soil in the area supports vegetative growth; hence, there is a high tendency for the stripped surface to return to its natural form if the conditions of the initial stripped soils are restored.

According to Table 4, the obtained field samples are more of clay-loam, a few are sandy while only one of the samples is mainly loam. Loam is the best type of soil that contains the required quantity and quality of plant nutrients that enhance plant growth. However, clay-loam which is predominant in the sampled area is good and could also be used to support plant regeneration. Due to the microscopic grain-sized and flake-like shape of clay particles, their aggregate surface area is much greater than their thickness and this allows them to take up large amounts of water by adhesion (Schaetzi and Anderson, 2005).

LIMITATION

Specific assessment to determine which of the native plants and or tree species would be able to adapt and thrive as soil cover should a significant change in the mineralogical composition of the essential soil nutrients occur when stripped off and stockpiled could not be carried out in the study. The authors consider this also an important aspect of ecological engineering for vegetative recovery.

CONCLUSION

The study observed based on textural analysis of the obtained soil samples that the study area is mainly dominated by Clay - loam soil having good properties and soil nutrients capable of sustaining wealthy plant growth. Other soil types found in the study area are a mixture of sandy-clay and loamy soils. The soil in the area is therefore classified viable with a high tendency to promote natural re-vegetation after the bitumen extraction has been carried out and the initial state of surface soil restored to an appropriate depth below the surface.

REFERENCES

Adegoke, O. S. and Ibe, E. C. (1982): The Tar Sand and Heavy Crude Resources of Nigeria. Proc. 2nd Inter. *Conf. on Heavy Crude and Tarsands, Caracas, Venezuela, ch* 32: 280-285

Akande, J. M. and Akinbinu, V. A. (2005): Impact Assessment of Bitumen Mining on the Water and Soil Characterization of Mining Area of Ondo State. *J. Sci. Eng. Technol* 12:2

Bradshaw,A.D. (1984): Ecological Principle and Land Reclamation Practice, Elsevier.

Bradshaw,A.D. (1997):Restoration of Mined Lands- Using Natural Processes. *Engineering Ecology, volume 8, Issue4 pp 255-268.*

Cooke, J.A. and Johnson, M.S. (2002): Ecological Restoration of Land with Particular Reference to the Mining of Metals and Industrial Minerals: A Review of Theory and Practice, Environ. Rev. Vol. 10, pp 41–71.

DeFries, R. S., J. A. Foley, and G. P. Asner (2004): Land-use Choices: Balancing Human Needs and Ecosystem Function. Frontiers in Ecology and the Environment 2:249–257.

Enwezor, W.C., Ohiri, A.C. Opuwaribo, F.E. and Udu, J.E. (1990): Literature Review on Soil Fertility Investigations in Nigeria. Fertilizer Procurement and Distribution Division (FPDD), Federal Ministry of Agriculture and Natural Resource, Nigeria.

Erin et al., (1994): Successful Organic Gardening. Mineral Nutrition and Applied Science 2(10):pp10-25.

Ghose, M. K. (2004): Effects of Open Cast Mine on Soil Fertility, Journal of Scientific Industrial Research, vol. 63 pp 1006-1009

Harald, H. (2010): Soil pH and Plant Health in the Home Garden, Western Australian Agriculture Authority pp 1-4.

Jeffrey A. S., William S. C, Keith N. E.,Karen, k., Susan, M. Tim,. N., Bob, R. P. and Carolyn. T.(2008): Forest to Reclaimed Mine Land Use Change Leads to Altered Ecosystem Structure and Function, Ecological Applications, 18(1), 2008, pp. 104–118.

MacRae, R. J. and G. R. Mehuys, (1985): The Effect of Green Manuring on the Physical Properties of Temperate Area Soils. Advan. *Soil Sci*., 3: 71–94

Mbah, C.N and Onweremadu, E.U. (2009) : Effect of Organic and Mineral Fertilizer Inputs on Soil and Maize Grain Yield in an Acid Ultisol in Abakaliki-South Eastern Nigeria, American-Eurasian Journal of Agronomy 2 (1): 07-12

Naeem A., Fayyaz-ul-H. and Ghulam Q. (2007): Effect of Subsurface Soil Compaction and Improvement Measures on Soil Properties *Int. J. Agri.& Biol., Vol. 9, No. 3,*

Oboh, O. B., Ilori, M. O., Akinyemi, J. O. and Adebusoye S. A. (2006): Hydrocarbon Degrading Potentials of Bacteria Isolated from a Nigerian Bitumen (Tarsand) Deposit. *Nature and Sci.* 4(3): 51-58.

Passioura, J.B. (1991): Soil Structure and Plant Growth, *Australian Journal of Soil Research* 26(6)pp717-728.

Preston, S. (1999): Sustainable Soil Management-Soil System Guide, Appropriate Technology Transfer for Rural Areas <http://www.soilandhealth.org/index.html> assessed 10th February, 2012.

Richard L. D. and Gordon E. W.(1983): Growth-Limiting Soil Bulk Densities as Influenced by Soil Texture, Watershed Systems Development Group, USDA Forest Service, Colorado.

Schaetzi, R.J. and Anderson, S. (2005): Soils: Genesis and Geomorphology, Cambridge University Press, New York, pp84-85.

Song, W. and Yang, L. (2006): Research on the Principle and Methodology of Open Pit Dumping Area Ecological Restoration and Rebuilding. In: Promoting Land Administration and Good Governance, Proceedings of the 5th FIG Regional Conference, March 8-11th, 2006, Accra, Ghana

Tagar, S. and A. Bhatti, (2001): Physical Properties of Soil. In: “Soil Science” (2nd ed.), pp: 130–4. N.B.F. Islamabad.

USDA (1998): Soil Quality Indicators: pH, Soil Quality Information Sheet, U.S. Department of Agriculture. p 2

USDA (2008): Soil Quality Indicators- Bulk Density, U.S. Department of Agriculture. p 2