Available online at http://www.ajol.info/index.php/njbas/index
Nigerian Journal of Basic and Applied Science (March, 2012), 20(1): 73-77 ISSN 0794-5698

Full Length Research Article

Distribution of Sulphur in Soils Formed from Different Parent Materials in Southern Nigeria

***J.S. Ogeh, F. Uzu and O.D. Obi-Ijeh**
Department of Soil Science, Faculty of Agriculture, University of Benin, PMB 1154, Benin City, Edo State, Nigeria
[*Corresponding author: E-mail: sogeh2@yahoo.com; ☏: +234(0) 8023569846]

ABSTRACT: A study on the profile distribution of sulphate - sulphur (SO_4-S) and the relationship with some soil properties was carried out in three soils namely, Oxic paleudalfs in Akure area, Rhodic paleudults in Benin area and Arenic paleudults in Sapele area of Southern Nigeria. Six depths in each profile were considered (0-15, 15-30, 30-45, 45-60, 60-75 and, 75-90cm).Results showed that the range of sulphate - sulphur in the soil profiles was 2.11 – 5.28 mg kg^{-1} in oxic paleustalfs , 0.47-1.55 mg kg^{-1} in the Rhodic Paleudults and 3.75 – 12.36 mg kg^{-1} in the Arenic paleudults. The Oxic paleustalfs and Rhodic paleudults were found to be deficient in SO_4-S assuming 8.50mgkg^{-1} S as critical level in surface horizon. Sulphate sulpur (SO_4-S) decreased as depth increased but at 45-60 and 60-75cm there was a slight increase in Oxic paleustalfs. In Rhodic paleudults SO_4-S decreased from the surface up to 75 – 90 cm. However in Arenic paleudults SO_4-S increased in depth up to 30 – 45 cm before a decrease was experienced. The highest value for SO_4-S was recorded in Arenic paleudults at 30-45cm with a value of 12.36mg kg^{-1}. Correlations analysis revealed that SO_4-S correlates with organic carbon in Oxic paleustalfs ($r = 0.805$); Na in Oxic paleustalfs and Rhodic paleudults ($r = 0.803$ and $r = 0.893$ respectively) and Mg in Rhodic paleudults ($r = 0.795$).
Keywords: Sulphur, soils, distribution, parent material, profile

INTRODUCTION

Sulphur is a non-metal element which reacts with several cations to produce sulphides and eventually sulphates. It can also react with non metals like fluorine and chlorine. It is one of the secondary essential elements needed by plants and animals including some microbes. Sulphates can be changed to sulphides under anaerobic conditions and are therefore seen in organic soils. Several studies have been carried out in the temperate and subtropical climatic zones on its occurrence and regional distribution (David *et al*., 1995 and Brady and Weil, 2002) but there is a dearth of information about sulphur and its compounds particularly in Nigeria. This is because emphasis is laid on N, P and K with the assumption that S can be added in the form of fertilizer like superphosphate and organic manure. If this trend continues there is the tendency that sulphur may become a limiting element in soils of southern Nigeria since there is still a missing gap in the documentation so far on it's distribution.

The main source of sulphate in soils is through clay content and organic matter addition from plant and animal sources and inorganic fertilizes. Sulphur can also enter the atmosphere by both natural processes and man's activities, some of which are industrial wastes and fossil fuel burnings which help to contribute a great amount of sulphur to the atmosphere (Somnath and Ghosh, 2009). Sulphur however finds its way into the soil system through atmospheric depositions (wet and dry). The wet deposition is dissolved in rain while the dry deposition involves compounds containing sulphur e.g. parent materials.

The sulphur attributable through these system may be lost in the soil through many ways either by run-off, leaching, burning, microbial and plant uptake and a larger proportion of it may be unavailable (fixed) to plant (Brady and Weil, 2002). Sulphur exists primarily as organic and inorganic form in the soil. Most farmers employ the use of inorganic fertilizers due to its quick release of nutrients and ease of application when compared to its organic counterpart although, the organic sulphur appeared to be more superior. In a well drained, well aerated soil, most of the inorganic form of sulphur occur as sulphates and the amount of reduced sulphur compounds are generally less than 1% . Under anaerobic conditions, particularly in tidal swamps and poorly drained or water logged soils, the main form of inorganic sulphur in soil is sulphide and often elemental sulphur (Zhang *et al*., 1996). Hence, the easily absorbed form of sulphur by plants is the sulphates form. Sulphate-sulphur interactions with the soil solid phase influences not only its availability but also its distribution (Barrow, 1985). The factors that influence the adsorption of sulphates are also responsible for its distribution down the soil profile. These factors however include oxides of Iron and Aluminum, content and nature of organic matter, pH and the presence of other ions.

The presence of other ions may influence sulphate adsorption as it has been shown in studies involving New Zealand soils and Brazillian soils (Randall, 1988). In the soils it was verified that as adsorbed calcium increased it leads to increase in sulfate adsorption and on the other hand, phosphate adsorption decreases the sulphate adsorption (Randall, 1988). Most studies demonstrate that the organic ions are preferentially adsorbed over sulphate by clay minerals and oxides. In view of this, it can be concluded that surface soils may present unfavorable condition for sulphate adsorption due to additions of phosphate as well as the adoption of practices that increase the soil organic content or increase in sulphate leaching (Dalvinderjit and Chhiba 2001). Therefore, the need to study the distribution of sulphate sulphur becomes necessary to find out the amount of this element in subsurface soil samples.

Since Sulphur is hardly applied directly as fertilizer the study of its distribution in selected soils of southern Nigeria where rainfall is high and the soils very prone to leaching and consequent loss of organic materials becomes important. Based on this facts, it is assumed the element could be deficient in the soil. This is because in southern Nigeria SO_4-S is easily leached as a result of displacement by phosphate ions and can be lost in the surface soils. The objective of the study was to determine the soil factors that influence the occurrence and distribution of sulphur within the soil, its availability and management in some selected soils of southern Nigeria.

MATERIALS AND METHODS

Three soil profiles were dug in three different locations viz: Akure on Lat. 5° 15' N and Long. 7° 18' E; Benin City on Lat. 5° 45' N and Long. 6°20' E and Sapele on Lat. 5° 40' N and Long. 5° 50' E. Six different sampling intervals of 0-15, 15-30, 30-45,45-60, 60-75, 75-90 cm were used. Soil samples were collected from the soil profile at the various depths specified above.

After sample collection the samples were air dried, sieved with a 2mm sieve and analysed. The following parameters were determined using the physical and chemical analyses.

Particle size distribution was determined by the use of hydrometer method (Bouyocous, 1951) as modified by Day (1965). Soil pH was determined in distilled water (1:1 soil:water) using the glass electrode pH meter. Organic Carbon was determined by the Potassium dichromate wet oxidation method of Walkley and Black (1934). Total Nitrogen was determined by the micro-kjeldhal digestion method. Available Phosphorus was determined using Bray 1 method (Bray and Kurtz, 1945). Exchangable acidity was determined by leaching soil samples with neutral molar solution of KCl and the acidity estimated by titrating with 0.02M NaOH solution using phenolphthalein as indicator (Mclean, 1965). Exchangeable bases (Ca, Mg, K and Na) of the soils were extracted using 1N neutral ammonium acetate (NH_4OAC) and Ca and Mg was determined using atomic absorption spectrophotometer while Sodium and Potassium ions were determined by flame photometry. Extractable Sulphate Sulphur was determined by the procedure of Tabatabai (1974).

RESULTS AND DISCUSSION

The soils from Akure are derived from Quaternary undifferentiated basement complex and classified as Alfisols while those from Benin and Sapele are derived from PreCambrian coastal plain sands and classified as Ultisols at order level (USDA 1999). At suborder level the soils of Akure are classified as Oxic Paleustalf, Benin as Rhodic Paleudults and Arenic Paleudults in Sapele. The physical and chemical properties of the soils in Akure, Benin and Sapele areas are presented in Tables 1, 2 and 3 respectively. Total Nitrogen ranged from 0.21– 1.32 g/kg at Akure, trace level of N to 0.76 g/kg in Benin and trace level of N to 1.22 g/kg in Sapele. This element was more at the top soil and decreased with depth in the three profiles. P, K, Ca, Mg and Na also followed the same trend as N in the three locations. The textural class at Akure was sandy loam at the top soil to sandy clay loam and sandy clay at the subsoil. At Benin the textural class was loamy sand and sandy loam in the top soil and sandy clay loam in the sub soil while at Sapele the textural class was loamy sand in the top soil and loamy sand and sand in the subsoil.

Sulphate- Sulphur, pH, organic carbon and exchange acidity at Oxic paleustalfs, Rhodic paleudults and Arenic paleudults are presented in Tables 4, 5 and 6. Extracted sulphur in Akure area ranged from 2.11 – 5.28 $mgkg^{-1}$ with a mean of 3.33 $mgkg^{-1}$ and a CV of 5.43% . In Benin area the range was 0.47 – 1.55 $mgkg^{-1}$ with a mean of 1.00 $mgkg^{-1}$ and a CV of 5.37% while in Sapele area amount of sulphur ranged from 3.75 – 12.36 $mgkg^{-1}$ with a mean of 8.61 $mgkg^{-1}$ and CV of 5.41%. However, the values recorded were lower than the critical level of 8.50 $mgkg^{-1}$ as established by Kang and Osiname (1976) except at

Sapele where the values were above 8.50 $mgkg^{-1}$ in the top soil.

pH, at Akure ranged from 5.38 – 6.45 with a mean of 5.74 and a CV of 5.39% . At Benin the range was 4.80 – 5.41 with a mean of 5.11 and a CV of 5.48% while at Sapele pH range was from 4.22 – 4.75 with a mean of 4.44 and CV of 4.44%. Organic carbon at Akure ranged from 3.5 – 29.1 gkg^{-1} with a mean of 9.72gkg^{-1} and a CV of 4.99% . At Benin the range was from trace to 12.3 gkg^{-1} with a mean of 4.22 gkg^{-1} and a CV of 4.89% while at Sapele organic carbon ranged from trace to 19.6 gkg^{-1} with a mean of 5.65 gkg^{-1} and CV of 4.67%. Exchangeable acidity at Akure ranged from 0.26 – 0.72 $cmol+kg^{-1}$ with a mean of 0.55 $cmol+kg^{-1}$ and a CV of 5.43% . At Benin the range was 3.61 – 4.08 $cmol+kg^{-1}$ with a mean of 3.92 $cmol+kg^{-1}$ and a CV of 5.48% while at Sapele the values ranged from 4.67 – 5.71 $cmol+kg^{-1}$ with a mean of 4.94 $cmol+kg^{-1}$ and CV of 5.47%.

There was a negative correlation between SO_4–S and depth (Table 7) for all the three soil studied. There was a positive correlation between SO_4–S and pH for Akure and Benin soils. This was in line with the findings of Zhang and Yu (1997). In their own finding, soil pH was inversely correlated to sulfate adsorption. SO_4–S correlated positively with organic carbon and Na in the Oxic Paleustalfs while SO_4–S correlated with Na and Mg in the Rhodic Paleudults at 0.05 level of significant only.

Table 1: Physical and chemical properties of Oxic paleustalfs in Akure area

	Soil Depth (cm)					
Soil Properties	0 -15	15 -30	30 – 45	45 – 60	60 – 75	75 – 90
N (gkg^{-1})	1.32	0.68	0.53	0.35	0.34	0.21
P ($mgkg^{-1}$)	12.76	5.13	5.00	3.26	3.00	0.48
K ($cmol+kg^{-1}$)	0.25	0.18	0.20	0.20	0.16	0.13
Ca ($cmol+kg^{-1}$)	5.04	4.69	4.72	4.61	4.85	4.93
Mg ($cmol+kg^{-1}$)	0.62	0.40	0.42	0.31	0.37	0.44
Na ($cmol+kg^{-1}$)	0.10	0.70	0. 60	0.50	0.50	0.30
Sand (gkg^{-1})	680	668	660	592	520	521
Silt (gkg^{-1})	160	155	150	122	96	96
Clay (gkg^{-1})	160	182	190	286	384	383
Textural Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Clay Loam	Sandy Clay	Sandy Clay

Table 2: Physical and chemical properties of Rhodic paleudults in Benin area.

	Soil Depth (cm)					
Soil Properties	0 -15	15 -30	30 – 45	45 – 60	60 - 75	75 - 90
N (gkg^{-1})	0.76	0.61	0.29	0.28	0.00	0.00
P ($mgkg^{-1}$)	4.75	3.82	2.96	1.42	0.69	0.18
K ($cmol+kg^{-1}$)	0.11	0.09	0.06	0.06	0.04	0.03
Ca ($cmol+kg^{-1}$)	1.55	1.53	0.98	0.96	0.54	0.47
Mg ($cmol+kg^{-1}$)	0.42	0.48	0.47	0.43	0.22	0.16
Na ($cmol+kg^{-1}$)	0.07	0.03	0.05	0.05	0.03	0.02
Sand (gkg^{-1})	850	832	800	728	657	639
Silt (gkg^{-1})	40	30	20	20	18	10
Clay (gkg^{-1})	110	138	180	252	325	351
Textural Class	Loamy Sand	Loamy Sand	Sandy Loam	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam

Table 3: Physical and chemical properties of Arenic paleudults in Sapele area

	Soil Depth (cm)					
Soil Properties	0 -15	15 -30	30 – 45	45 – 60	60 - 75	75 – 90
N (gkg^{-1})	1.22	0.51	0.33	0.15	0.07	0.00
P ($mgkg^{-1}$)	5.66	1.38	1.02	0.46	0.15	0.14
K ($cmol+kg^{-1}$)	0.08	0.09	0.07	0.10	0.10	0.10
Ca ($cmol+kg^{-1}$)	0.88	0.75	0.49	0.50	0.42	0.40
Mg ($cmol+kg^{-1}$)	0.21	0.20	0.16	0.15	0.15	0.14
Na ($cmol+kg^{-1}$)	0.11	0.07	0.06	0.06	0.05	0.05
Sand (gkg^{-1})	880	840	862	890	908	908
Silt (gkg^{-1})	40	40	30	23	22	20
Clay (gkg^{-1})	80	120	108	87	70	72
Textural Class	Loamy Sand	Loamy Sand	Loamy Sand	Loamy Sand	Sand	Sand

Table 4: Some soil properties and sulphate-sulphur at different depths in Oxic Paleustalfs Akure area

Depth (cm)	Extracted SO_4 ($mgkg^{-1}$)	pH (1:1 H_2O)	Organic Carbon (gkg^{-1})	Exch. Acidity ($cmol+kg^{-1}$)
0 -15	5.28	6.45	29.1	0.58
15 – 30	2.74	5.71	9.6	0.42
30 – 45	2.81	5.79	8.5	0.63
45 – 60	3.22	5.69	3.9	0.69
60 – 75	3.79	5.42	3.7	0.72
75 – 90	2.11	5.38	3.5	0.26
Mean	3.33	5.74	9.72	0.55
Range	2.11 - 5.28	5.38 - 6.45	3.5 - 29.1	0.26 – 0.72
CV (%)	5.43	5.39	4.99	5.43

Table 5: Some soil properties and sulphate-sulphur at different depths in Rhodic Paleudults in Benin area

Depth (cm)	Extracted SO_4 ($mgkg^{-1}$)	pH (1:1 H_2O)	Organic Carbon (gkg^{-1})	Exch. Acidity ($cmol+kg^{-1}$)
0 -15	1.55	5.41	12.3	3.82
15 – 30	1.53	5.40	7.2	3.92
30 – 45	0.98	5.16	2.5	4.07
45 – 60	0.96	5.07	2.1	4.08
60 – 75	0.54	4.82	1.2	4.00
75 – 90	0.47	4.8	0.0	3.61
Mean	1.00	5.11	4.22	3.92
Range	0.47 – 1.55	4.8 – 5.41	0.00 – 12.3	3.61 – 4.08
CV (%)	5.37	5.48	4.89	5.48

Table 6: Some soil properties and sulphate-sulphur at different depths in Arenic Paleudults in Sapele area

Depth (cm)	Extracted SO_4 ($mgkg^{-1}$)	pH (1:1 H_2O)	Organic Carbon (gkg^{-1})	Exch. Acidity ($cmol+kg^{-1}$)
0 -15	7.37	4.74	19.6	5.71
15 – 30	12.15	4.40	6.9	4.67
30 – 45	12.36	4.25	3.9	4.82
45 – 60	9.44	4.50	2.2	4.19
60 – 75	6.58	4.53	1.3	5.06
75 – 90	3.75	4.22	0.0	5.18
Mean	8.61	4.44	5.65	4.94
Range	3.75 – 12.36	4.22 – 4.75	0.00 – 19.6	4.67 – 5.71
CV (%)	5.41	4.44	4.67	5.47

Table 7: Correlation Coefficient (r) of Sulphate-sulphur and some other soil factors of soil samples collected from Akure, Benin and Sapele.

	Location		
	Akure	Benin	Sapele
SO_4-S (mgkg^{-1})	1.00**	1.00**	1.00**
Depth (cm)	-0.593	-0.746	-0.600
pH (1:1 H_2O)	0.785	0.733	-0.089
Organic Carbon (gkg^{-1})	0.805*	0.638	0.115
Na (cmol+kg^{-1})	0.803*	0.8930**	0.256
Mg (cmol+kg^{-1})	0.631	0.795*	0.673
K (cmol+kg^{-1})	0.778	0.748	0.097
Exch. Acidity	0.520	0.404	-0.509

*= $p<0.05$ level of significant.
** = $p<0.01$ level of significant.

The depth distribution of Sulphate Sulphur in the three soils studied is in the order of Sapele > Akure > Benin.

CONCLUSION

From the results of the study it could be concluded that there is a deficiency of sulphur in the soils studied. From the findings of this work, the plough layer of soils is very low in sulphur. The soils of these locations will therefore be expected to show response to sulphur fertilization. However to ensure a relative amount of sulphate-sulphur content in the soils good management such as the return of crop residues and careful addition of fertilizers should be also adhered to.

REFERENCES

Barrow, N.J. (1985). Reaction of anions and cations with variable charge soils. Advances in. Agronomy **381:**183-232.

Bouyoucous, G.H. (1951). A Re-calibration of the hydrometer method for making mechanical analysis of soil. *Agronomy Journal*. **43:** 434-438.

Brady N.C. and Weil, R.R. (2002). The Nature and Properties of Soils, 13th Edition. Macmillan, New York. 683p

Bray, R.H. and Kurtz, L.T. (1945). Determination of Total Organic and Available Forms of Phosphorus in Soils. *Soil Science* **59:** 39-45

Dalvinderjit, S.B. and Chhibba, I.M. (2001). Sulphur Status of soils and crop in submontane Tract of Northwestern India. *International Journal of Agriculture and Biology* **3(4):** 348 – 350

David M.B., Vance, G.F. and Krzyszowska, A.J. (1995). Carbon controls on Spodosols: Nitrogen, sulphur, and phosphorus cycling in carbon forms and functions in forest soils. J.M. Kelly and W.W. McFee. (Eds). Soil Sci Soc. of America, Madison W I, 329-352.

Day, Y.R. (1965). Experimental confirmation of the hydrometer theory. America Society of Agronomy, Wisconsin, U.S.A. (re-use of sodium hexametaphosphate introduced)

Kang, B.T. and Osiname, O.A. (1976) Sulphur response of maize in Western Nigeria. *Agronomy Journal* **68:** 333 - 336

Mclean, E.O. (1965). Aluminium. In: Methods of Soil Analysis. Agronomy 9,Part II C.A. Black (Ed.). American Society of Agronomy. Madison, Wisconsin pp978 – 998

Randall, P.J. (1988). Evaluation of the sulphur status of soils and plant. Techniques and Interpretation. Proc. of TSI-FAI Sump. S India Agriculture March 9-11, 1988. New Delhi, pp 1-15.

Somnath C. and Gosh, G.K. (2009). Vertical distribution of forms of Sulphur in some profiles of Birbhum district of West Bengal. *Journal of Interacademicia,* **13(1):** 28 - 35

Tabatabai, M.A. (1974). Determination of Sulphate in Water Samples. *Soil Science Society America. Journal,* **10:**11-15.

USDA (1999). Soil Taxonomy- A basic system of soil classification for making and interpreting soil surveys. USDA Agricultural Handbook. No. 436. Second Edition. U.S. Government Printing Office, Washington D.C. 869pp

Walkley, A. and Black, I.A. (!934). An examination of the degtejareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37:** 29 – 38

Zhang, G.Y., Brummer, G.M. and Zhang, X.N. (1996). Effect of perchlorate, Nitrate, chloride and pH on SO_4 adsorption by variable charge soils. *Geoderma* **73:** 217-229.

Zhang, G.Y. and Yu, T.R. (1997), Coordination adsorption of anions In: Yu, T.R. (Ed) Chemistry of variable charge soils. Oxford Univ. Press. New York.