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Nitrate, Sulphate, Phosphate and Chloride Status of Staple Food Crops, Soils and Water as Indicator of Environmental Base Anion Pollution Load in Ebonyi State, Nigeria

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Abstract: The levels of anions (NO_3^- , SO_4^{2-} , PO_4^{3-} and Cl^-) in staple food crops (yam, cassava, rice, maize, cowpea and African yambean); soils and water sources in Ebonyi State, Southeastern Nigeria has been quantitatively determined spectrophotometrically. The results indicate that there were significant variations in the concentrations of anions in the staple food crops across the localities with regards to SO_4^{2-} ($p < 0.001$). No significant location effect in the nitrate contents of the staple food crops was observed while chloride was not detected. The anions level in the soils and surface water depicts significant correlations ($p < 0.000$) and that between soils and underground water is ($p < 0.002$). However, it was observed that the phosphate concentrations of the staple foods, soils and underground water sources exceeded the internationally acceptable limit while the sulphate, nitrate and chloride levels are within the international acceptable limit. The observed high levels of phosphate in the study areas calls for concern as it may render the staple food crops and water sources unsuitable for human, livestock and for industrial uses. Also, if not checked, soils may be unsuitable for agricultural purposes.

Key words: Staple food, water, spectrophotometrically, anions

INTRODUCTION

Staple food crops require anions such as nitrate (NO_3^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}) and chloride (Cl^-) (Berardi, 2003). The major source of anions is the soil, which under favourable conditions make them available to plants and then humans via diets. They require active transport across the plasmalemma of the plant root cells for uptake (Rubio *et al.*, 2005). Anions occur usually in the form of metallic salts and may be supplied in the inorganic forms as potassium chloride (KCl), zinc sulphate (ZnSO_4), potassium nitrate (KNO_3) and polyphosphates or in the form of mixed fertilizer (AFRR, 2000).

Factors that affect anion uptake by plants, like other micronutrients include: availability to root soil interface (i.e. the rhizosphere), specific and sufficient root cell plasma membrane absorption mechanism (i.e. transporters and ion channels), interaction with other elements. Soil moisture, temperature and soil pH are also other factors that affect availability of anions to plants (Peles *et al.*, 1998; Chen *et al.*, 1997).

Nevertheless, dietary anions have many biochemical effects both in the physiology of plants and man. In plants, some anions are involved in the control of water loss (salt effect), maintaining of turgor and transportation of cations such as potassium (K), calcium (Ca),

magnesium (Mg), within the plants. Some anions assist in reducing the disease incidence in roots and leaves. Their deficiency may cause wilting, restricted growth and diseases (Grist, 1986). Some anions such as chloride (Cl^-), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) are acidic and when taken in high concentrations can alter the acid-base load of the body and obviously manifest as net acid load if the diet source does not provide basic cations (K, Ca, Mg) that could balance it (Berardi, 2003). This tends to produce low grade chronic metabolic acidosis and hence hypercalcuria, calcium is released from the bone and osteoclastic activity sets in (Berardi, 2003). It is also known that excess nitrate load in the biological system undergoes biotransformation resulting in the formation of metabolites (e.g. nitrosamine), which has been implicated as an excellent candidate in carcinogenesis, teratogenesis and infantile methaemoglobinaemia (McKnight *et al.*, 1999; Ezeonu *et al.*, 1996, 1994, 1992; Egboka and Ezeonu, 1990; Edeogu and Fidelis, 1999; Bassir and Maduagwu, 1978; Okonkwo *et al.*, 1981; Low, 1974). Tajtakova *et al.* (2000) reported that nitrate contaminated drinking water from private wells has an impact on the size and functional state of thyroid gland in school children.

However, dietary anions have important physiological effects in man such as electrolyte balance and constituent of gastric juice (e.g. Cl^-), maintenance of pH (e.g. PO_4^{3-}), cell signaling, potent vasodilator

(Moncada and Higgs, 1993), platelet aggregation inhibitor (Radomski *et al.*, 1991) and bacteriocidal activity (Hogg *et al.*, 1992).

They are essential constituents of the human body, not only in the bone and teeth but also in many enzyme systems (FASEB, 1981). They play vital roles in carbohydrate, fat and protein metabolism (e.g PO_4^{3-}) (FASEB, 1975, 1981).

However, the objective of the present research is to evaluate the level of these anions in stable food crops, soils, surface and underground water sources in the food producing rural areas of Ebonyi State, Southeastern Nigeria. The result is envisaged to be of uttermost importance, serving as a measuring indicator of environmental pollution load of anions in the study areas.

MATERIALS AND METHODS

Location of the study area The study areas are located in Ebonyi State, in the eastern part of Nigeria. However, the project sites are Abakaliki, Afikpo North, Ohaukwu, Ohaozara and Ikwo Local Government Areas.

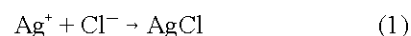
These areas lie within the Cross River Basin which is in the humid zone with climatic condition characteristic of the tropical zone; i.e, wet-hot and rainy. The major inland water body of these areas is: Cross River-system, Ebonyi-River system and Azu-River system.

Materials: The materials used for this work are staple food crops: cereals (maize and rice); legumes (African yambean and cowpea); root tubers (yam and cassava); composite soil samples which are collected with a metal auger from the sample sites at the depth of 0-15 cm using random sampling technique as reported by Onyeike *et al.* (2002) while the Water samples were collected randomly from the available sources closest to the study areas. Two streams, three underground for Ikwo, Ohaukwu, Ohaozara, Abakaliki and Afikpo Local Government Areas of Ebonyi State were collected at regular intervals of one week for 2 months from 25 different sources then stored in stopper plastic bottles in a freezer until the analysis was done colorimetrically.

Equipments: The equipment used are Buck Scientific Atomic Absorption/Emission spectrophotometer (AAS): Buck Scientific Atomic Absorption/Emission Spectrophotometer 205 Model which is high sensitive, accurate and precision equipment; the pH meter: Pye Unicam Model; water bath made by Gram Instruments Cambridge Limited; weighing balance: Metal Hdw Balance, centrifuge: Mse Minor 35, oven by B and T A Searle Company; Muffle furnace: IMF 4 Carbolite Sheffield England etc.

Methods: Basically in food crops, common acid radicals present include: chloride, phosphate, nitrate and sulphate; each with its own unique way of determining its level in any given food crop sample.

Determination of chloride: The chloride level was determined titrimetrically according to AOAC (1984). This method employs silver nitrate as titrant and potassium chromate as the end point indicator and the ion present in the sample is precipitated as white silver chloride:



The procedure involves the weighing of 0.50 g of the slurry sample into a washed and dried crucible and then ashed in a furnace at 500°C for 3h. This is allowed to cool at room temperature and then dissolved in 10 mL of nitric acid (HNO_3). About 5 mL of ash (aliquot) was pipetted into conical flask and was titrated with 0.1 N silver nitrate (AgNO_3) using potassium chromate as indicator (K_2CrO_4). The appearance of brown reddish precipitate marked the end point or titre value which is noted. The chloride concentration (mg L^{-1}) is thus calculated as:

$$C_c = T_v \times 35.5 \quad (2)$$

where C_c is the chloride concentration and T_v is the titre value.

Determination of nitrate: The status of the nitrate was determined from the samples using colorimetric method as adapted by AOAC (1980). Here, in the presence of sodium salicylate, nitrate ions react to give yellow sodium par-nitrosalicylate, which can be determined colorimetrically. Again, 0.5 g of unashed sample was weighed into a washed and dried crucible. Five millileter of sodium salicylate was added to the sample and made up to 50 mL using distilled water. About 1 mL of this solution was pipetted into a test tube and 10 mL of distilled water added and allowed to stand for about 20 min then the absorbance was read at 415 nm in spectrophotometer using distilled water as blank. The value was read off from the nitrate standard calibration graph (Fig. 1). Then, the concentration of the nitrate ion (NO_3^-) in mg L^{-1} calculated thus:

$$C_N = A_b \times G_{mg} \quad (3)$$

where C_N is the concentration of the nitrate ion, A_b is the absorbance and G_{mg} is the gradient of the standard nitrate calibration graph.

Determination of sulphate: The status of sulphate was determined turbidimetrically according to AOAC (1984). This method is based on the fact that barium chloride (BaCl_2) precipitates sulphate (SO_4^{2-}) in its solution to form barium sulphate (BaSO_4) which is insoluble in water and the turbidity measured spectrometrically. The procedure is: 0.50 g of the slurry sample is weighed into a clean dried crucible, then ashed in a muffle furnace at 500°C for 3 h. The set up is allowed to cool at room temperature which is then digested with 5 mL of HNO_3 . This was made up to 50 mL using distilled water. Again, about 5mL of the filtrate was then pipetted into a test tube and a pinch of BaCl_2 crystal added which was allowed to stand for one and half hours. The absorbance was then read off spectrometrically at wavelength of 425 nm. The value was read off from the sulphate standard calibration graph (Fig. 2). The concentration of the sulphate ion (SO_4^{2-}) in mg L^{-1} is thus calculated:

$$C_s = A_b \times G_{\text{ssg}} \quad (4)$$

where C_s is the concentration of the sulphate ion, A_b is the absorbance and G_{ssg} is the gradient from the standard sulphate calibration graph.

Determination of phosphate: The phosphate status was determined colorimetrically (AOAC, 1984).

0.5 g of the slurry sample was weighed into a well washed and dried crucible. The sample was ashed in muffle furnace at 500°C for 3 h and then allowed to cool. It was digested with 5 mL of HNO_3 and the volume made up to 50 mL with distilled water. Approximately 5 mL of the diluted sample was pipetted into a test tube and 2 mL ammonium molybdate and 10N sulphuric acid solution was added. The mixture was swirled and allowed for 10 min. The absorbance was read at 420 nm using distilled water as blank. The standard solutions were treated as test sample. The calibration graph for the phosphate standard (Fig. 3) was used to read off the concentration of the phosphate:

$$C_p = A_b \times G_{\text{spg}} \quad (5)$$

where C_p is the concentration of the phosphate, A_b is the absorbance and G_{spg} is the gradient from the standard plot of the phosphate concentration.

Determination of anion in soil and water samples: The anions in soil and water samples were determined by the same procedure (AOAC, 1984), except that the water samples were not ashed but membrane filtered before the

analysis. The analytical chemicals used for this work was provided by sigma Aldrich chemical Company, St. Louis, Mo, USA.

RESULTS AND DISCUSSION

Figure 1, 2 and 3 are the calibration graph of the standard curve for the determination of the concentration of nitrate, sulphate and phosphate respectively. The results of the anions distribution in staple food crops, surface water, underground water and soils are as shown in tables 1 to 9. Table 1 depicts the concentration of anions (mg g^{-1}) in rice; Table 2 shows the concentration of anions (mg g^{-1}) in maize; Table 3 shows the concentration of anions (mg g^{-1}) in yam; Table 4 shows the concentration of anions (mg g^{-1}) in cassava;

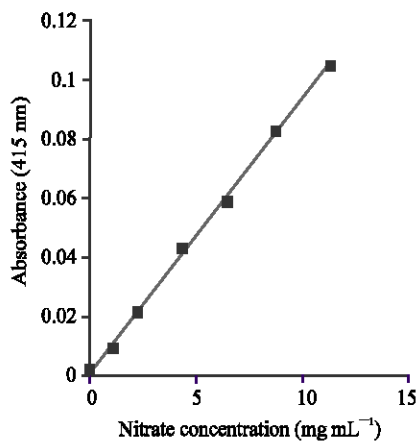


Fig. 1: Standard curve for the determination of nitrate (NO_3^-) concentration

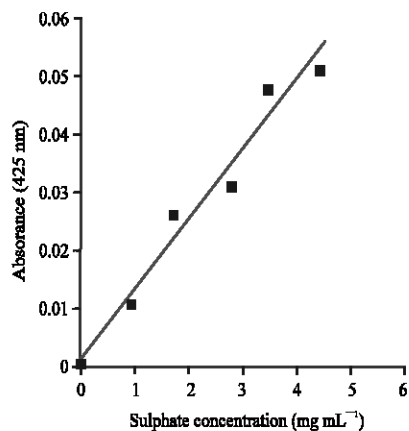


Fig. 2: Standard curve for the determination of sulphate (SO_4^{2-}) concentration

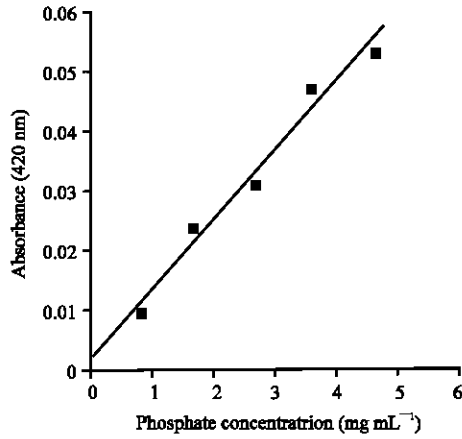


Fig. 3: Standard curve for the determination of phosphate concentration

Table 1: Concentration of anions (mg g⁻¹) in rice

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	6.50±0.14	36.25±1.91	43.70±1.41	-
Afikpo	5.05±0.21	5.35±0.07	40.75±0.78	-
Ikwo	6.45±0.21	4.80±0.14	37.60±1.41	-
Ohaozara	5.25±0.21	4.80±0.14	37.30±0.85	-
Ohaukwu	3.85±0.07	5.50±0.14	37.60±0.00	-
Mean values	5.42±0.17	11.34±0.48	39.39±0.89	-

Table 2: Concentration of anions (mg g⁻¹) in maize

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	6.30±0.28	15.65±0.35	61.25±0.29	-
Afikpo	4.10±0.14	5.50±0.14	46.00±1.69	-
Ikwo	9.45±0.21	4.45±0.35	37.10±0.42	-
Ohaozara	6.80±0.14	6.20±0.14	49.85±1.06	-
Ohaukwu	4.35±0.07	8.75±0.07	36.90±0.00	-
Mean values	6.20±0.17	8.11±0.21	46.22±0.69	-

Table 3: Concentration of anions (mg g⁻¹) in yam

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	4.50±0.14	15.10±0.28	62.35±0.64	-
Afikpo	4.40±0.14	4.05±0.07	32.30±1.92	-
Ikwo	4.45±0.49	6.85±0.07	40.95±1.20	-
Ohaozara	4.70±0.14	6.70±0.14	27.75±0.21	-
Ohaukwu	3.70±0.14	12.55±0.07	58.55±0.07	-
Mean values	4.35±0.21	9.05±0.13	44.38±0.81	-

Table 5 shows the concentration of anions (mg g⁻¹) in cowpea; Table 6 shows the concentration of anions (mg g⁻¹) in African yambean; Table 7 shows the concentration of anions (mg L⁻¹) in surface water; Table 8 shows the concentration of anions (mg L⁻¹) in underground water while Table 9 shows the concentration of anions (mg g⁻¹) in soil.

Table 4: Concentration of anions (mg g⁻¹) in cassava

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	6.30±0.28	15.65±0.35	61.25±0.91	-
Afikpo	4.10±0.14	5.50±0.14	6.00±1.69	-
Ikwo	9.45±0.21	4.45±0.35	37.10±0.42	-
Ohaozara	6.80±0.14	6.20±0.14	49.85±1.06	-
Ohaukwu	4.35±0.07	8.75±0.07	36.90±0.00	-
Mean values	6.20±0.17	8.11±0.21	46.22±0.82	-

Table 5: Concentration of anions (mg g⁻¹) in cowpea

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	8.15±0.21	8.05±0.07	51.05±0.49	-
Afikpo	8.75±0.21	13.35±0.78	42.95±0.21	-
Ikwo	4.15±0.21	9.50±0.14	37.80±0.14	-
Ohaozara	8.55±0.35	8.65±0.21	50.35±0.07	-
Ohaukwu	9.65±0.77	7.50±0.42	46.05±0.07	-
Mean values	7.85±0.35	9.41±0.32	45.64±0.19	-

Table 6: Concentration of anions (mg g⁻¹) in African yambean

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	9.25±0.21	8.70±0.14	52.15±0.64	-
Afikpo	10.00±0.28	8.40±0.14	51.50±0.28	-
Ikwo	11.65±0.21	9.70±0.28	41.85±0.77	-
Ohaozara	9.90±0.14	7.25±0.21	46.65±0.17	-
Ohaukwu	5.90±0.14	9.50±0.14	47.30±0.56	-
Mean values	9.34±0.19	8.71±0.18	47.85±0.48	-

Table 7: Concentration of anions (mg L⁻¹) in surface water

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	4.45±0.21	9.45±0.21	23.20±0.57	63.20±0.71
Afikpo	4.70±0.14	7.05±0.07	10.85±1.06	20.95±0.49
Ikwo	4.15±0.07	10.20±0.57	17.65±0.07	21.65±1.34
Ohaozara	4.40±0.14	7.45±0.07	22.25±0.64	62.95±0.07
Ohaukwu	5.65±0.07	8.70±0.14	11.75±0.07	21.40±0.42
Mean values	4.67±0.13	8.57±0.21	17.14±0.48	38.03±0.61

Table 8: Concentration of anions (mg L⁻¹) in underground water

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	4.45±0.07	9.50±0.42	22.45±0.49	55.60±1.84
Afikpo	5.75±0.07	7.25±0.07	12.45±0.42	29.20±0.42
Ikwo	4.30±0.00	9.30±0.28	16.40±0.70	24.00±0.14
Ohaozara	3.65±0.07	7.45±0.21	19.25±0.49	51.25±1.76
Ohaukwu	4.15±0.07	8.35±0.07	10.80±0.14	21.20±0.57
Mean values	4.38±0.06	8.37±0.21	16.27±0.45	36.25±0.95

DISCUSSION

The results in Table 1 and 2 show that phosphate had the highest concentrations in cereals in all the areas studied. Abakaliki rice recorded the highest levels (43.70 mg g⁻¹) of phosphate followed by Afikpo

Table 9: Concentrations of anions (mg g⁻¹) in soil

Study area	Anion			
	Nitrate (NO ₃ ⁻)	Sulphate (SO ₄ ²⁻)	Phosphate (PO ₄ ³⁻)	Chloride (Cl ⁻)
Abakaliki	2.05±0.07	10.75±0.21	14.45±0.21	2.75±0.21
Afikpo	2.80±0.14	2.80±0.14	2.60±0.28	3.55±0.07
Ikwo	1.45±0.49	8.85±10.35	4.44±0.35	2.65±0.21
Ohaozara	1.50±0.14	9.45±0.21	6.70±0.14	2.15±0.07
Ohaukwu	2.20±0.28	6.86±0.07	9.00±0.57	2.60±0.14
Mean values	2.00±0.22	7.74±0.19	7.44±0.31	2.74±10.14

(40.75 mg g⁻¹) and Ohaozara had the least value of phosphate (37.30 mg g⁻¹). The same pattern of anions distribution was maintained in maize (Table 2).

The levels of sulphate were highest in Abakaliki rice (36.25 mg g⁻¹), Ohaozara and Ikwo had the least values of sulphate in rice (Table 1). The concentration of nitrate in the cereals is in the order Abakaliki > Ikwo > Ohaozara > Afikpo > Ohaukwu for rice. For maize, the NO₃⁻ levels is in the order Ikwo > Ohaozara > Abakaliki > Ohaukwu > Afikpo (Table 2). For tubers and legumes the anions level maintained the same pattern of distributions as shown in tables 3, 4 and 5 respectively.

Phosphate had the highest concentrations in tubers and legumes with a range of values 27.75 to 62.35 mg g⁻¹ 36.90 to 61.25 mg g⁻¹; 46.05 to 57.05 mg g⁻¹ and 41.85 to 52.15 mg g⁻¹ for yam, cassava, cowpea and African yambean respectively (Table 3, 4, 5 and 6). Chloride was not detected in all the staple food crops analyzed.

The highest level of chloride was obtained in surface water (63.20 mg L⁻¹) and underground water (55.60 mg L⁻¹) from Abakaliki. This is followed by Ohaozara that recorded (62.20 mg L⁻¹) in surface water and (51.25 mg L⁻¹) in underground water (Table 7 and 8). Phosphate had the second highest concentrations in surface and underground water in Abakaliki and Ohaozara respectively. The least values of the anions in surface and underground water were nitrate in all the study areas with a range of values 4.15 to 5.65 mg L⁻¹ for surface water and 3.65 to 5.75 mg L⁻¹ for underground water (Table 7 and 8).

Phosphate had the highest concentrations in the soil with a range of values 2.60 to 14.45 mg g⁻¹ and a mean of 7.44±0.31 mg g⁻¹ (Table 9). Abakaliki soil had the highest value of phosphate (14.45 mg L⁻¹) followed by Ohaukwu soil (9.00 mg L⁻¹). The least value of phosphate was recorded in Afikpo soil (Table 9). The mean concentrations of anions in surface water, underground water and soil indicate that surface water had the highest concentration of chloride.

Significant variations exist in the concentrations of the anions in staple food crops across the localities with respect to sulphate and phosphate (p<0.001). This may be attributed to differences in the environmental factors such

as the physiography of the soil, pH, temperature and the availability of other elements. This result is in agreement with the findings of Purselove (1991) and Edeogu *et al.* (2006) that chemical compositions of food vary according to the type and nature of the environment.

The staple food crops from the areas studied did not accumulate chloride ions. Chloride ions are derived from chlorine, which is a halogen. Halogens (chlorine, bromine) are obligatorily functional elements in plants physiology. They are not structural elements but they play vital roles in plant metabolism (Campbell, 1979). Furthermore, chloride ions are very soluble and are not easily obtained in food crop analysis because of their ionization. These facts may be responsible for absence of chloride in the food crops studied. This result agrees with Edeogu *et al.* (2006).

Significant differences exist between surface water and soil anion levels with respect to nitrate and phosphate (p<0.000). These differences in the anion levels may be attributable to nitrate and phosphate overload through fertilizer applications. The result is that the fertilizer load exceeds the absorption capacity of the crops and accumulates in soil and is leached as soluble nitrate and phosphate into the surface and ground water environment where they pollute shallow and deep aquifers. This accounts for the levels of NO₃⁻ and PO₄³⁻ in surface water and soils in the areas studied. This result is in agreement with earlier report that during rainfall, excess fertilizers are washed off as part of runoff into streams, lakes and rivers (Egboka and Ezeonu, 1990). Some of the nitrate and phosphate are leached into the soil zone where they may be taken up by plants through soil water and concentrate them in their edible tissues to be consumed later by man (Egboka and Ezeonu, 1990).

The significant differences between underground water and soil in Ebonyi State with respect to nitrate and phosphate is in line with the report of Ritter and Chirnside (1987) on their work in Kent and Sussex that in over 200 bore-hole water analyzed, nitrate was found to be consistent with the agricultural practice of the areas. The occurrence of high levels of anions in underground water than soil samples could be as a result of existence of the anions free in solution than soils where they are neutralized with only the excess remaining as negatively charged micelle (Greenwood, 1984).

The high levels of chloride ions recorded in surface and underground water sources from Abakaliki and Ohaozara Local government Areas of Ebonyi State was not surprising. This is because there is Uburu salt lake in Ohaozara and Izzi salt lake in Abakaliki local government area. What was unexpected is the low levels of the chloride ions in Ikwo L.G.A. which has salt lake at

Echialike, Ikwo. The low chloride ions level in Ikwo may be due to absence of major River systems, which are tributaries to Abakaliki and Ohaozara (Corie, 2003).

The World Health Organization maximum permissible limits for NO_3^- , SO_4^{2-} , PO_4^{3-} and Cl^- are 10-50 mg L^{-1} , 200.00 mg L^{-1} , 0.40 mg L^{-1} and 250 mg L^{-1} respectively (WHO, 1983; Ministry of Agriculture, Fisheries and Food, 1987). From these permissible limits, the concentrations of nitrate, sulphate and chloride in soils, surface water and underground water from Ebonyi State are within acceptable limits for domestic and industrial purposes and therefore pose no threat to health on consumption. Same can be said of the levels of nitrate and sulphate in the staple food crops. However, the levels of phosphate in food crops, soils, surface and underground water exceed the internationally acceptable limit. This indicates that food crops, soils, surface water and underground water in Ebonyi State are polluted with phosphate. The use of super phosphate fertilizers adjudged as one of the best fertilizers for tuber and cereal crops productivity by the local farmers in these areas may be responsible for the high load of phosphate in all the samples analyzed.

High levels of phosphate in drinking water and staple food crops are deleterious to animals and humans on consumption. It causes increase in plasma phosphorus level and decrease in serum calcium (Anderson, 1977). The resulting hypocalcaemia stimulates secretion of parathyroid hormone, which in turn increases the rate of bone resorption (Anderson, 1977). Studies from animal models suggest that ingestion of high levels of phosphorus salt during organogenesis is teratogenic (Verrett, 1980).

CONCLUSION

The presence of anions (NO_3^- , SO_4^{2-} , PO_4^{3-} and Cl^-) in the staple food crops, soils, surface and underground water in Ebonyi State was detected. However Cl^- was absent or not detected in any of the food crops analysed.

The concentrations of NO_3^- , SO_4^{2-} and Cl^- in soils, surface and underground water in Ebonyi State are within the World Health Organization permissible limits of the anions. Same can be said of the levels of NO_3^- and SO_4^{2-} in the staple food crops.

The levels of phosphate in the staple food crops, soils, surface and underground water exceed the WHO maximum permissible limit. This indicates that food crops, soils, surface and underground water in Ebonyi State are polluted with phosphate.

The existence of high levels of anion (PO_4^{3-}) in the staple food crops, soils, surface and underground water

sources in Ebonyi State imposes health problems not only among the inhabitants of the study areas but other parts of the globe where these food crops may be exported. As the study area is a high agricultural belt of south eastern Nigeria, high levels of this anion may render the soils unsuitable for agricultural purposes.

I, therefore, recommend that the Government of Ebonyi State should undertake a survey on the health status of both the occupationally and non-occupationally exposed inhabitants of the study areas. A more comprehensive environmental audit, health screening and monitoring is recommended to ascertain the occupational and environmental diseases to which the people of the study areas may be exposed as they depend on these staple food crops and water sources for their daily use. Preliminary study on the bioremediation of the study areas by Ezeonu *et al.* (2005) revealed that the process has a great promise in cleaning areas contaminated by anions. Therefore, planting hyper-anion accumulator plants will be of great importance in addressing the contamination profile of the study areas.

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