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ORIGINAL ARTICLE

Chemical composition of wet precipitation in ambient environment of Ilorin, north central Nigeria

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Abstract The physico-chemical quality of rainwater in the atmospheric environment of Ilorin in the north central Nigeria has been evaluated. Rainwater samples were collected at every rainy day between March and October 2008. Samples were analysed for pH value, conductivity and water-soluble cations and anions: Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{3+}, Pb^{2+}, NO_3^-, SO_4^{2-}, PO_4^{3-}, and Cl^-. The average monthly pH ranged between 6.6 and 7.4 with the highest value recorded during the early months of precipitation while the average annual pH value ranged between 6.68 and 7.04. The average annual conductivity ranged between 108.8 μS cm^{-1} and 219.6 μS cm^{-1} with the highest and lowest values recorded at highly urbanized areas and a low density residential area. High levels of Ca^{2+} and NO_3^- ions were observed and together constituted 55% of the total ion mass. Ca^{2+} ion is crustal element and it alone contributed 56% to the total cations while NO_3^- a by-product of atmospheric oxidation of particulate from fossil fuel combustion constituted 53% of total anions measured. Generally speaking, the ionic abundance in precipitation (μg L^{-1}) showed the general trend: $NO_3^- > Cl^- > SO_4^{2-} > PO_4^{3-}$ for anions and $Ca^{2+} > K^+ > Na^+ > Fe^{2+} > Mg^{2+} > $ -Pb^{2+} for cations. The average annual SO_4^{2-} concentration ranges between 12.9 and 27.6 μg L^{-1} while the cumulative average for Ilorin was 17.3 μg L^{-1}. The statistical analysis of physico-chemical parameters revealed a strong correlation ($p < 0.01$ and $p < 0.05$) among some sites which was an indication of a common source of inputs of these parameters. Results of the present study suggested that both natural and anthropogenic inputs influence the changes of chemical compositions that occurred during the wet precipitation.

1. Introduction

The understanding of the chemical composition of the atmospheric aerosols is significant due to its short and long term effects on human health and the ecosystems (Kanellopoulou, 2001; Steinnea, 1990). Automobile, industrial and agrochemical

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particulate emissions are air-borne chemicals and are constantly transported in the air over a long distance from the point of emissions. When it rains, these aerosols come down as chemicals dissolved in the rain (Smirnioudi et al., 1998) and form the damaging constituents of the rain. The presence of heavy metals in the atmosphere is essentially due to the combine effects of waste incineration, fossil fuels and fire-burning. Industrialization, urban growth and low level of hydro-power generation and distribution have led to heavy reliance on fossil fuels (petroleum products and coal) as alternative to power supply. This has caused greater emissions of atmospheric pollutants such as SO_2, NO_x, VOCs and aerosols (Teixiera et al., 2008).

A great percentage of metals as a result of their relative masses, fall through the rain at the place of their production (Nurnberg et al., 1984). But the lighter aerosols, which have a very small falling velocity, are easily transported by the wind and could be deposited through the rain at long distances away from the point of their emissions (Smirnioudi et al., 1998). Therefore, it is expected that the acid components, anions, cations and heavy metals which constitute the chemical components in the rainwater can significantly produce damaging effects on the environment (surface waters, plants, animals and human beings).

The urban areas are more prone to anthropogenic pollution than the rural areas, due to high traffic volume and level of industrialization. Vehicular emission which is due to aging of moving parts, releases heavy metals such as Zn from tyres, Cu from brake linings and Mn from moving parts (Preciado and Li, 2006). Concentrations of industries and industrial processes and mining operations are known to produce the largest emission of As, Cd, Cu, Mn and Zn (Allen et al., 2001). SO_4^{2-}, NO_3^-, PO_4^{3-} are present in the atmosphere partly due to oxidation of SO_2, NO_x from automobile exhaust or mining of phosphate rocks. Atmospheric deposition could be an important source of plant nutrient input to the ecosystem (Kellman et al., 1982).

This paper presents 8 months study of wet precipitation composition carried out on each rainy day in the sites chosen. The average concentrations of the parameters determined were discussed in relation to their environmental fates.

2. Materials and methods

2.1. Study areas

This study was conducted in Ilorin metropolis in the north central region of Nigeria. It is located at latitude 6°29′N and longitude 4°32′E. The climate is characterized by 4–5 months of dry season. The city is located in an agricultural region but fast growing in commercial and industrial activities. Its population was estimated at 1178,420 according to National Population Commission, 2006. The choice of the sampling sites was based on commercial, industrial, traffic volume, or residential lay out. Ten (10) sampling points were selected (Table 1 and Fig. 1) and randomly spaced within the city. The choice was to capture the various anthropogenic activities which may represent the inputs into the precipitation quality of the area.

2.2. Sampling methods

The sampler is made up of a wooden stand of about 6ft tall with an opening at the top that can conveniently hold the 5 L collecting plastic buckets. A small hole was pierced on the bucket lid which was just sufficient to hold in place a large funnel. The containers and funnels were washed with hot soapy water and rinsed several times with deionized water prior to precipitation as a quality control measure. The funnels were covered with sieves to prevent foreign materials and dry precipitation from the collection buckets. The buckets were removed immediately after precipitation and water transferred into a 2.5 L plastic bottles. Hence, the sample collected was wet and not bulk precipitation (Montes and San Jose, 1989).

Field measurement of pH value and electrical conductivity was done immediately after the rain. Samples were colorimetrically analysed for water-soluble macro-nutrients: PO_4-P, NO_3-N, SO_4-S using Spectronic 20. Phosphate determination involved the formation of an antimony–phospho–molybdate complex and an intense blue coloured complex using ascorbic acid (EPA, 1979). Cadmium reduction method was used to convert nitrate to nitrite. The nitrite in the acidic medium reacts with sulphanilic acid to form an amber colour product (Andrew et al., 1975; EPA, 1979). Sulphate was obtained by turbidimetric method involving $BaCl_2$ and colour developed using a conditioning agent (Andrew et al., 1975). Chloride was determined by Volhard method (Andrew et al., 1975). Prior to metal analysis, water samples were acid digested (Adekola et al., 2010). Ca and Mg were obtained by complexometric titration using EDTA, Na and K were determined using flame photometric method while Fe and Pb were determined using Alpha 4 AnalTech Atomic Absorption Spectrometer.

3. Results and discussions

There was variability in the amount of monthly precipitation and consequently the physico-chemical parameters recorded. On the basis of monthly average pH value, site B had the high-

Table 1 Sampling sites' description.

S/No.	Sample label	Site description	Easting's	Northing's
1	A	Eyenkorin Junction	662,780	930,200
2	B	Mandate Housing Estate/Lubcon	665,300	937,240
3	C	Near Gerialimi Roundabout	667,220	935,760
4	D	Ipata Market	671,740	940,000
5	E	Near Maraba Junction	673,180	939,650
6	F	Sango Area	675,540	942,410
7	G	Oloje Housing Estate	665,540	941,540
8	H	University Senior Staff Quarters	678,300	937,540
9	I	Asa Dam Industrial Layout	669,290	934,560
10	J	Taiwo Road/Oko-Erin Junction	670,000	937,900