The deposition of sulphur in the rainwater in Northern Nigeria

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ABSTRACT

The concentrations and amounts of SO_4–S were measured at eleven sites, situated between 350 and 880 kilometres from the sea, during two rainy seasons in Northern Nigeria. In both years, concentration showed a similar pattern at each site, being greatest at the beginning and end and smallest at the peak of the rains. The presence of anthropogenic atmospheric-S at the start of the rains, and of harmattan dust and lower precipitation at the beginning and end of the rains account for the concentration pattern observed. Amounts of S deposited ranged from 0.49–1.89, mean 1.14 kg S/ha. An estimate of dry deposition of S was made from the intercept on the y axis of a plot of amount deposited against rainfall. The dry deposition rates were 0.26 and 0.43×10^{-12} g S/cm^2/s respectively. The agricultural importance of the deposition is briefly discussed.

Introduction

Amounts of sulphur deposited in rain, in particulate material, and sorbed directly in gaseous form, from the air by soils and plants, are known to be sufficient for crops grown in industrially polluted areas (Buchner, 1958). In non-industrial areas amounts of sulphur deposited are much less (Hesse, 1957) and decrease inland (Hutton & Leslie, 1958). In non-industrial areas remote from the sea fertilizer-S is needed, but, the exact amounts depend upon crop requirement, the amount derived from natural sources and whether the soil retains the sulphate ion.

The work reported here is part of a study designed to determine the total atmospheric-S additions to a non-industrial area distant from the sea.

Climate

The study area (Fig. 1) contained eleven sites, whose average rainfalls ranged from 640 mm (Maradi) to over 1 300 mm (Kaduna), located between 350 (Mokwa) and 880 (Maradi) kilometres from the coast. The rainfall pattern over the area results from the circulation of two air masses: (1) the monsoon, a moist, cool air mass originating over the south Atlantic and blowing from the south west, and (2) the harmattan, a dry, hot air mass blowing from the north east, often dust laden, and having a long history of desert tracking. Where these two air masses meet they form a belt of unstable ascending air known as the Inter Tropical Convergence Zone (I.T.C.Z.). The I.T.C.Z. oscillates northward over Nigeria between February and August and southward from September to January. The rains advance northward behind and retreat southward before the I.T.C.Z. The amount of rain and length of rainy season (Fig. 1) decrease from south to North.

Materials and Method

Rainwater collection. Deposition gauges conforming to BS. 1747, Part 1, 1961 were modified for tropical use by fitting 30 litre polythene collection bottles. The neck of the collection bottle was slightly above the outlet of the plastic collecting bowls and this junction was sealed with washed cotton cloth. A 1 mm mesh nylon thimble was inserted into the collecting bowl outlet to exlude insects and plant debris from the collecting bottle. Each collecting bottle was treated initially, and after each sampling, with a 1% w/v solution of penta-chloro-phenol in

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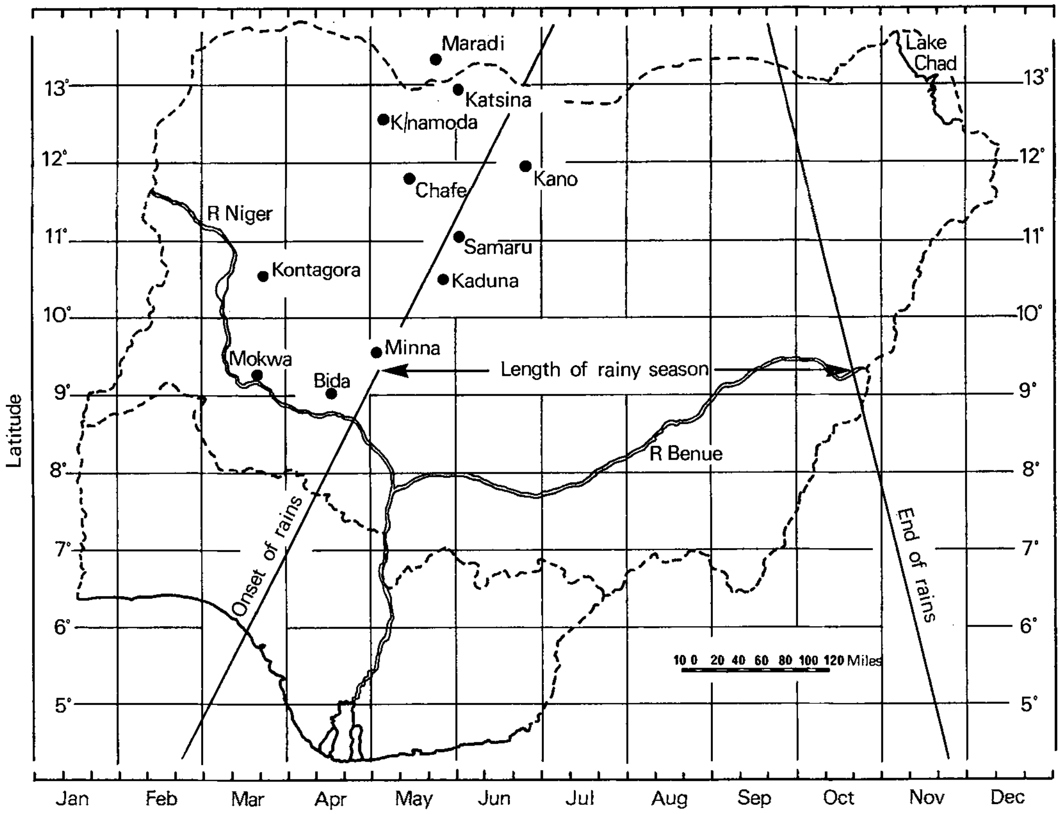


Fig. 1. The onset of rains, their termination and the length of the rainy season. ●, Collecting sites (adapted from Kowal & Knabe, 1972).

ethanol to prevent algal and bacterial growth. The gauges were all visited within a five day period at the end of each calendar month. The rainwater collected was measured and an aliquot taken for chemical analysis. The same polythene aliquot collection bottle was used for each site and an "internal standard" of distilled water in a similar collection bottle was used to check possible contamination.

Chemical analysis. A total of 200 ml of rainwater was evaporated to dryness without boiling, in a 25 ml reduction flask on a sandbath. After cooling S was determined (error ± 1.3 μg S/determination) by the reduction procedure previously described (Bromfield, 1972) using 3 ml of the chilled reduction acid mixture. Rainwater collected at both beginning and end of the rainy season was turbid and was left to settle before the 200 ml aliquot was taken. The S determined was SO_4–S plus any soluble and easily reducible organic-S components.

Results and Discussion

The concentration of S in the rainwater followed a similar pattern at each site, being highest in April and October and lowest in the August collection period, when rainfall was highest. The pooled results for 1970 and 1971, Fig. 2, show that the maximum concentration of 1.37 ppm S in April was higher than October concentration of 0.53 ppm S and the minimum was 0.09 ppm S in August. Rainwater collected at the beginning and end of the rains was turbid and the colour of harmattan dust (buff) rather than of the local topsoils (grey or red). Early and late in the rainy season the oscillations of the I.T.C.Z. bring alternately rainstorms and dust storms to the area, this alternation being more marked at the beginning than at the end of the rains. The water soluble SO_4–S in the harmattan dust is approximately 20 times that in the local topsoils and this plus the fact that

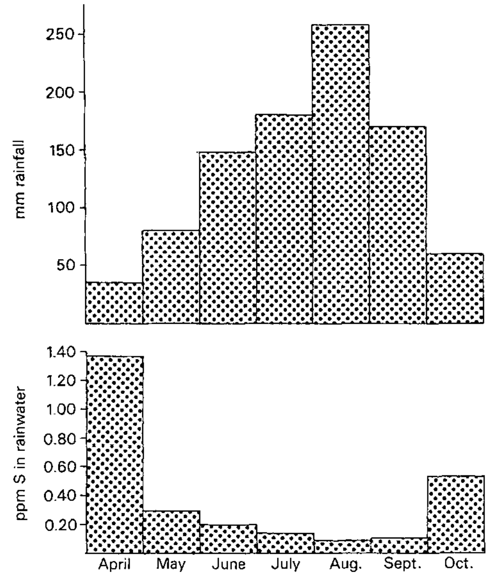


Fig. 2

rainfall is least during April and October collection periods, probably accounts for the higher concentrations of S.

Another factor affecting the April rainwater-S concentration is that anthropogenic-S in the form of ash and gaseous-S is released just before the onset of the rains by farmers clearing and burning natural fallows for planting. Ash and carbonaceous material were found in the gauges at the April collection in both years.

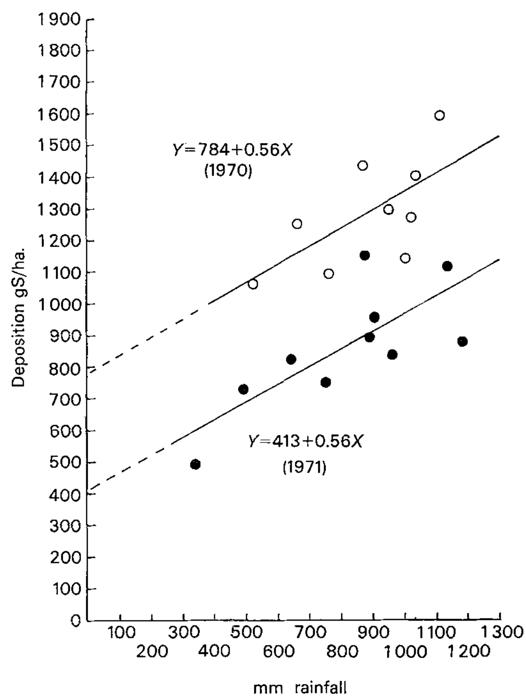
The mean concentration for the July, August and September collection periods, when both dust and anthropogenic-S were least, was 0.11 ppm S (0.11 mg/l) and may be compared to background estimates of 1 to 2 ppm S in Europe and America (Selezneva, 1972).

The mean concentrations of rainwater-S at each site (Table 1) for the whole collection period were generally greater at the sites receiving less precipitation. The Kaduna site appeared in both years to have a higher amount of S relative to its precipitation and this may reflect a higher concentration of S in the air of the area due to the proximity of an airport, textile mills and a brewery.

Linear regressions between the amount of S deposited in the rain and the rainfall (Graph 1), omitting Kaduna, gave a positive intercept on the *y* axis. This was presumed by Munn & Rodhe (1971), who used a curvilinear relationship (not possible with the small amount of data in this study) to be a measure of particulate and gaseous-S deposited, or sorbed, on the collection gauge in the dry periods between storms. The intercept values here were 784 and 413 g S/ha for 1970 and 1971 accounting for 45 and 58 % of the total-S deposition respectively.

Dividing by the mean gauge exposure time and expressing the dry deposition rate per cm^2 we calculate 0.43×10^{-12} and 0.26×10^{-12} g S/cm^2/s^{-1} respectively. The atmospheric-S measured at Samaru during the 1971 collection period averaged 0.72 μg S/m^3. The vertical deposition velocity constant (Vg) calculated from this is 0.36 cm/s which, although including all forms of dry deposition, agrees with those values measured for SO_2 under controlled conditions at greater gaseous-S concentrations but comparable humidities (Spedding, 1969), and suggests that taking the intercept gives a reasonable approximation of dry deposition in the rainy season.

Amounts of S deposited (Table 1) ranged from 0.49 to 1.89 kg S/ha, mean for 1970 plus 1971 being 1.14 kg S/ha, and may be compared



Graph 1

Table 1. *The deposition of S, rainfall and the S concentration in rainwater at eleven sites for 1970 and 1971 in northern Nigeria*

	Rainwater – S (kg/ha^{-1})		Rainfall (mm)		Concentration (ppm)	
	1970	1971	1970	1971	1970	1971
Samaru	1.30	0.89	948	884	0.14	0.10
Bida	1.14	0.88	1 007	1 181	0.11	0.08
Minna	1.58	1.12	1 110	1 131	0.14	0.10
Chafe	1.57	1.15	932	874	0.17	0.13
Mokwa	1.27	0.89	1 024	958	0.12	0.09
Katsina	1.25	0.73	662	489	0.19	0.15
K'namoda	1.10	0.75	757	750	0.15	0.10
Kano	1.44	0.82	864	637	0.17	0.13
K'gora	1.40	0.96	1 036	903	0.14	0.11
Kaduna	1.89	1.51	1 273	1 038	0.18	0.12
Maradi	1.06	0.49	521	339	0.20	0.14
Mean	1.36	0.92	897	856	0.15	0.11
Mean (1970+71)	1.14		877		0.13	
Range	0.49 – 1.89		339 –1 273		0.08 – 0.20	

to the values of 2.78, 4.52 and 7.02 kg/ha obtained in 1958 for the stations of Binza, Yangambi and Mulunga respectively in Zaire quoted by Eriksson (1966), of ca. 1 kg S/ha obtained by Hesse (Hesse, 1957) in Kenya, and the range of 1.36 to 6.69 kg S/ha found by Drover (1960) in Western Australia.

Much of the rainwater-S deposited on non-sorbing soils before crop germination would be lost by leaching, whereas that deposited on sorbing soils would all be held in the sub-soil and some taken up by plants later in the growing season.

The mean amount deposited in the rainy season 1.14 kg S/ha, is sufficient completely to replace the amount of S removed by a yield of 650 kg/ha of groundnuts (kernels plus shells but excluding haulm) which is about the yield obtained by local farmers not using fertilizers.

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ОТЛОЖЕНИЯ СЕРЫ ДОЖДЕВОЙ ВОДОЙ В СЕВЕРНОЙ НИГЕРИИ

В течение двух дождливых сезонов в Северной Нигерии в 11 местах, расположенных на расстояниях от 350 до 880 километров от моря, измерялись концентрации и количества SO_4–S. В оба года концентрация вела себя аналогично в каждом месте, будучи наибольшей в начале и конце сезона и наименьшей в пике дождей. Наблюдаемое поведение может быть объяснено присутствием антропогенной серы в атмосфере в начале дождей и наличием пыли из пустыни и меньшими осадками в начале и конце сезона. Поступление серы колебалось в пределах 0,49–1,89 *кг/га* со средним значением 1,14 *кг/га*. Поступление серы в сухом состоянии было оценено по положению пересечения оси y кривой количества отлагаемой серы в зависимости от количества осадков. Скорости поступления серы были, соответственно, 0,26 и $0{,}43 \cdot 10^{-12}$ *г/см²*/сек. Кратко обсуждается значение отложения серы для сельского хозяйства.