Acidification in Tropical Countries
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CHAPTER 9

Acidification Potential in the Nigerian Environment

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9.1 INTRODUCTION

Nigeria is located between about 3° and 15° E longitude and between 4° and 16° N latitude and has an area of 924,000 km^2 with an estimated population of 100 million. The country cannot currently be regarded as industrialized but increased national revenue from petroleum has resulted in rapid industrialization and urbanization since the 1970s. Like most developing countries, consideration has not been given to the environmental pollution that is usually the side effect of industrialization, urbanization, and related economic activities. Simmons (1974) notes:

acceptability of the pollutant by-products of economic activity varies with affluence. Poor countries and the poorer regions of the industrialized nations are prepared to tolerate the effects of pollution if their living standard is raised by operation of the earlier parts of the resource process.

The inability of developing countries to tackle pollution problems for economic reasons is a fact of life. In addition, due to the lack of knowledge in Nigeria about the environment, it is difficult to ascribe environmental changes to particular factors. Therefore, in viewing acidification caused by sulfur dioxide and oxides of nitrogen in Nigeria, the first problem is to identify the relationship between acidification and prevailing economic activities, based on the experience of the developed world.

9.2 SOURCES OF ACIDIFICATION

9.2.1 Power Generation

Nigeria's power generating plants are shown in Table 9.1 and Figure 9.1. Total installed capacity is 4,700 megawatts (MW) of which 1,300 is hydro-generated while 3,400 MW are generated from thermal stations fired mainly by natural gas. However, the installed capacity is seldom reached; in 1982, 2,900 MW were generated from the thermal stations. Some of the gas pipelines to the thermal stations have not been completed so oil is used.

Table 9.1 Power generating stations in Nigeria (Oyekunle, 1985)

Station	Power generated (MW)	Total capacity (MW)	Extension (MW)
Hydro			
1. Kainji	360	760	–
2. Jebba	200	540	–
3. Shiroro*		450	–
Thermal			
1. Sapele	300	1,020	300
2. Afam (Port Harcourt)	400	700	450
3. Ijora (Lagos)	30	60	–
4. Delta (Ughelli)	160	312	800
5. Oji	–	–	–
6. Egbin (Lagos)	200	1,320	

* Still under construction.

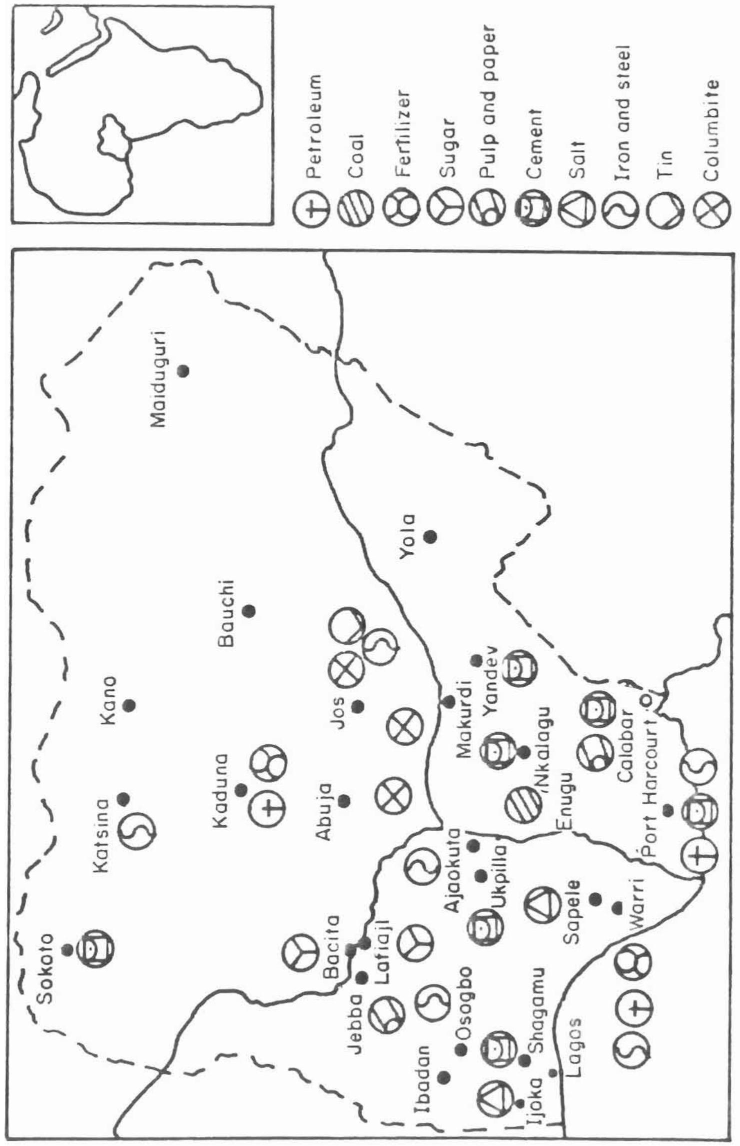


Figure 9.1 Principal industrial cities in Nigeria (Patel and Onwuka, 1978)

In 1984 about 1 billion m^3 of gas were used for energy generation. Coal is much less common; in 1982 less than 6,000 tons were used in energy generation.

Nigerian natural gas contains 0.58% nitrogen (Osaigbovo and Jegbefume, 1985), and most of the annual production is flared. The patterns of production and utilization over the years (Figure 9.2) show that the cumulative production from 1958 to 1982 was 274 billion m^3, of which 12 billion m^3 (4.3%) were used for energy generation and industrial purposes. The balance was flared (Okoroji, 1985). The proportion utilized is increasing. In 1981, 3 billion m^3 of a total production of 18 billion m^3 (Okoroji, 1985) was utilized. Natural gas combustion—that is, flaring and other uses—will increase the quantity of nitrogen oxides emitted into the atmosphere.

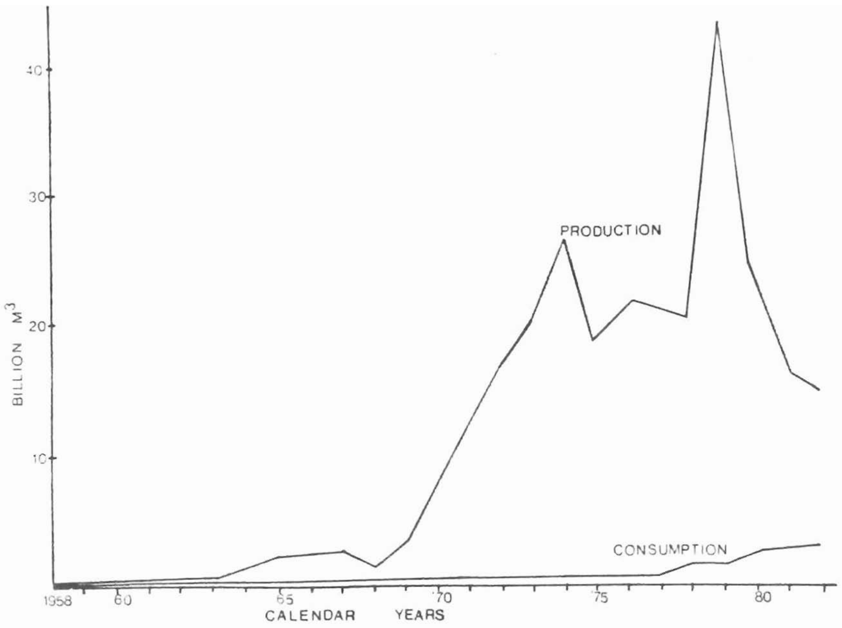


Figure 9.2 Production and consumption of natural gas in Nigeria, 1958–1982 (Okoroji, 1985)

An analysis of Nigerian coal shows it to contain 1.2–2.3% nitrogen and 0.4–1.7% sulfur (Sijuade, 1978). Coal consumption has been dwindling and in 1982 a total of 19,000 tons were used locally, but there are plans to use bituminous Lafia coal for making steel. This coal is said to have sulfur content of up to 6%.

9.2.2 Refineries

Nigeria has three oil refineries located in Port Harcourt, Kaduna, and Warri with respective refining capacities (and comissioning dates) of 67,000 (1962), 88,000 (1980), and 100,000 (1978) barrels of oil a day (Figure 9.1). A fourth refinery is planned for Port Harcourt. Most Nigerian crude oils have a sulfur content of 0.1–0.2%. A measurement in April 1984 around the Warri refinery showed no detectable nitrogen oxides and less than 0.05 mg/m^3 SO_2 in the air around the refinery (Nriagu *et al.*, 1985).

9.2.3 Metal Industries

Nigeria's one direct-reduction, electric-arc furnace steel plant (commissioned in 1982), with a liquid steel capacity of one million tons, is located at Aladja near Warri (Figure 9.1). The plant utilizes ore imported from Liberia and Brazil. There is also blast furnace steel plant with a capacity of 1.3 million tons at Ajaokuta which will be utilizing locally available ore when fully operational. There are steel rolling mills at Jos, Katsina, and Oshogbo that utilize billets from the two steel plants: each has a capacity of 210,000 tons. There are also mills at Enugu and Kano that make use of scraps and have a total combined capacity of 270,000 tons.

Nriagu *et al.* (1985) estimate that the Ajaokuta steel plant will emit 5,600 tons of SO_2 per year when completed. At Aladja, however, the ores are preroasted and less SO_2 emission is expected from the smelting. For example, less then 0.05 mg/m^3 SO_2 was recorded in air samples taken from 10 locations within a radius of 20 km around the Aladja steel complex in March–April 1984 (Nriagu *et al.*, 1985). Nitrogen dioxide (NO_2) measurements ranged from 0.05 to 1.20 mg/m^3. The highest value of 1.20 was recorded in a steel melting shop. The values then decreased until they became undetectable at 20 km distance.

Nigeria has produced less than 10,000 tons of tin ore annually in recent years. Most of the ore is mined around Jos and smelted locally at the Makeri plant. Ore smelting plants are probable contributors to the level of acidity in the atmosphere (Roth *et al.*, 1985). Various companies in Nigeria imported 10,700 tons of non-ferrous base ores in 1982.

9.2.4 Fertilizer Plants

There is a single superphosphate fertilizer plant in Kaduna with a capacity for 100,000 tons NPK fertilizer. Another plant that will utilize natural gas is under construction at Onne near Port Harcourt. The Onne plant will have a capacity of 1,000 tons/day of ammonia, 1,500 tons/day of urea, and 1,000 tons/day of NPK when completed. According to Grundy (1972) phosphate fertilizer plants primarily emit particulates so no acidifying gaseous pollutants are expected from the Kaduna plant. The Onne plant, which uses the Haber-Bosch process, is probably emitting oxides of nitrogen (NO_x).

9.2.5 Pulp and Paper Industries

A newsprint manufacturing plant with an installed capacity of 100,000 tons/year is located in Cross River state, and another plant that will have a capacity of 60,000 tons is under construction at Iwopin in Ogun state. The Jebba plant has been in production since 1963 and has a capacity of 130,000 tons. The paper manufacturing process results in SO_2 emissions (Grundy, 1972).

9.2.6 Chemicals

The *Nigerian Industrial Directory* (1980) has 12 unspecified establishments listed as producing basic industrial chemicals. Ten are located in the Lagos area. These and other manufacturing concerns imported about 2,900 tons of sulfur and unroasted iron pyrites in 1982.

9.2.7 Transportation

The number of vehicles on Nigerian roads has grown tremendously during the past three decades. As of 1976, there were 431,000 cars and trucks in Nigeria (Oluwande, 1979) and assuming that cars and trucks make up two-thirds of vehicles, and motor cycles one-third, a total of 700,000 vehicles were operational. The oil boom of the 1970s greatly encouraged the sale of motor vehicles. An estimated 1 million motor vehicles are on Nigerian roads. Nationally, the estimated total vehicle mileage was 50 billion in 1985, 80 times the value reported for 1955 (Oluduro, 1985). Most of the growth in vehicle numbers was in the major cities. Traffic volumes on Lagos roads showed increases ranging from 130% to 250% between 1966 and 1975, depending on location. In addition, many roads during this period in the metropolis experienced average 24-hour traffic volumes of between 40,000 and 100,000 vehicles (Federal Ministry of Works, 1976). Current rates can only be imagined with the estimated population in Lagos at 7 million people (see Figure 9.3 for map of population distribution).

In Ibadan, Nigeria's largest metropolis, central city locations showed 24-hour traffic volumes of 2,500 to 15,000 vehicles (Oluwande, 1979). The location that had the highest traffic volume recorded a mean daytime (6 a.m.–6 p.m.) SO_2 concentration of 0.28 ppm (742 $\mu g/m^3$). The annual mean for this location in 1976–1977 was 0.10 ppm (265 $\mu g/m^3$) which is far greater than the World Health Organization recommended mean of 0.02 ppm (figures from Oluwande, 1979).

9.2.8 Emissions From Burning and Agricultural Waste

9.2.8.1 *Vegetation Burning*

Most of the subhumid savanna of Nigeria (Figure 9.4) is burned annually in the dry season, generally by pastoralists and subsistence farmers. This area includes Derived, Southern Guinea, and Northern Guinea zones (Keay, 1959) and covers more than 60 million hectares; 20.7 million hectares are grazing lands (UNESCO, 1979) and are usually burned annually. Isichei and Sanford (1980) estimate that 12–15 kg nitrogen/ha is lost to the atmosphere in annual fires. These values are not based on air measurements but on the total nitrogen content of savanna plants just before burning and are close to values arrived at on the Ivory Coast (Delmas, 1982). Ekeleme (1986), who obtained a value of 12.33 kg/ha total nitrogen and 1.74 kg/ha nitrate nitrogen in rainfall in southwestern Nigeria, has observed that most of the nitrogen is found in the early rainy season showers preceding the fires. Due to increasing degradation and the spread of the perennial weed *Chromolaena odorata*, forest fires are becoming commonplace in the semi-deciduous forest of southern Nigeria. No estimates of nitrogen emissions have been made in this area.

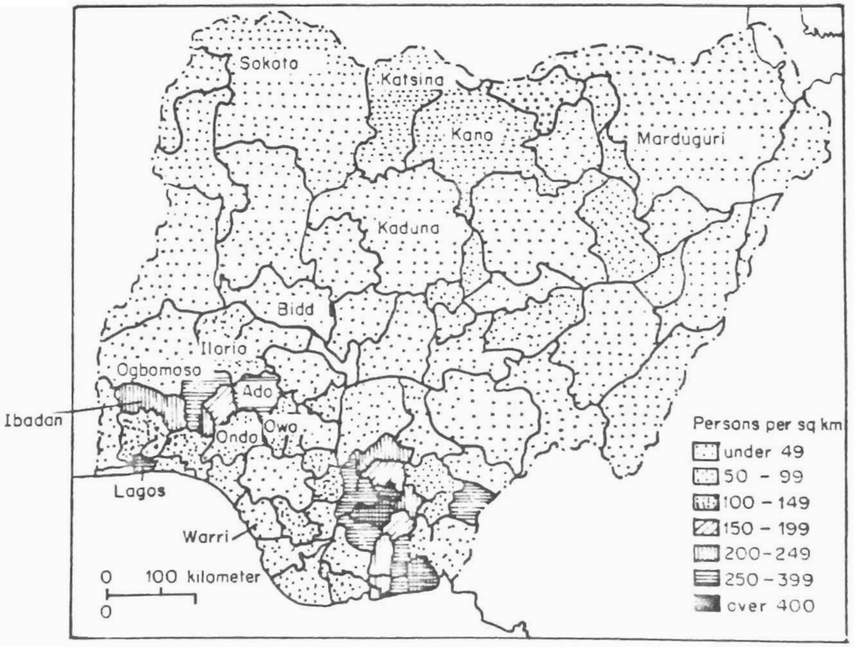


Figure 9.3 Population distribution in Nigeria, 1963 census

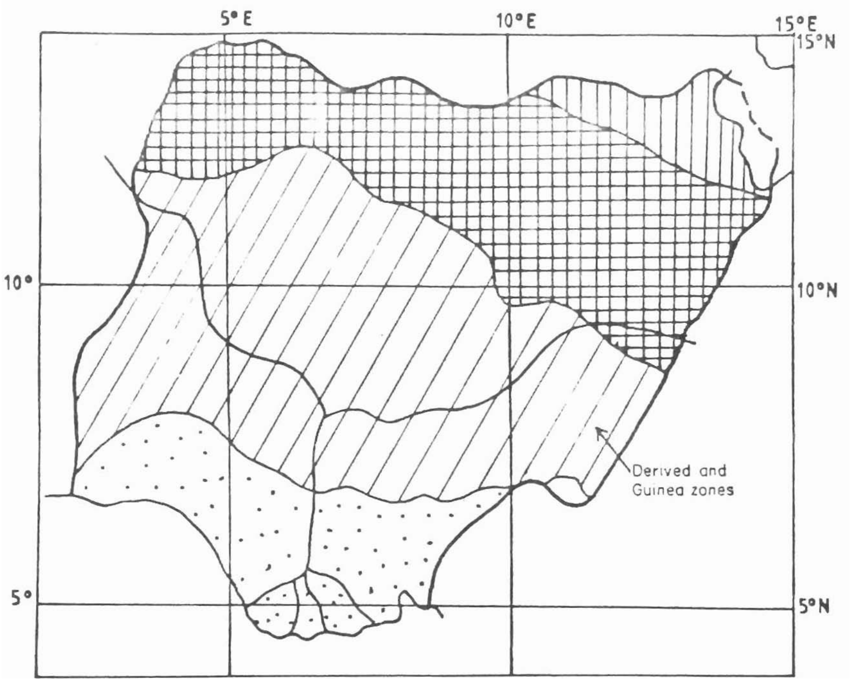


Figure 9.4 Locations of the Derived and Guinea savanna zones in Nigeria, where most vegetation burning occurs

9.2.8.2 Fertilizer Nitrogen

Bremner and Blackmer (1978) reported that there are emissions of N_2O from soils spread with ammonium sulfate and urea fertilizers. Emissions were insignificant when potassium nitrate was used. It has been assumed that 10% of nitrate nitrogen fertilizer is lost as a result of volatilization during storage and use in Nigeria (Singh and Balasubramanian, 1980).

For the 1986 planting season Nigeria imported about 590,000 tons of fertilizers, mostly 15–15–15 NPK and urea (*The Guardian Newspaper*, 1986). Most (70%) was used in the northern parts of the country, particularly in Kano and Kaduna. Northern Nigeria also has most of the country's livestock zones, which emit ammonia (Soderlund and Svensson, 1976).

Extensive fertilizer use is a relatively new phenomenon in Nigerian agriculture. It became popular in the 1970s and its use will likely double well before the end of the century. No direct estimates are available for emissions resulting from this use.

9.2.9 Natural Background Emissions

Delmas and Servant (1983) reported an emission figure of 15 kg/ha sulfur per year from the equatorial forest of the Ivory Coast. This type of emission might also be expected from the Niger Delta area of Nigeria. Delmas *et al.* (1980) earlier reported hydrogen sulfide emissions of between 30 and 300 $\mu g/m^2/hr$ from the swamps of the Ivory Coast. They concluded these were a nonnegligible contribution to the sulfur cycle: the values were 5–10 times those obtained for temperate regions of France. Atmospheric concentration in that zone of the Ivory Coast ranged from 0.10 to 8.7 $\mu g/m^3$, and Delmas *et al.* (1980) suggest that hydrogen sulfide is an important source of atmospheric sulfur when oxidized.

The Niger Delta, with an area of 21,000 km^2, has many oil spills and well blowouts that kill vegetation and result in rapid turnover of organic matter. Nriagu *et al.* (1985) obtained pH values as low as 2.8 in mangrove soils. This acidity can be attributed to the production of hydrogen sulfide (H_2S) during vegetation decomposition and the subsequent reaction of the H_2S with iron compounds to form pyrites which, when oxidized, result in the formation of sulfuric acid. Emissions are not expected from other wetland soils in Nigeria because of their fairly high pH (Okusami, personal communications).

Servant *et al.* (1984) report atmospheric concentrations of 1.4 $\mu g/m^3$ for NO_3^- and 0.64 for NH_4^+ in aerosol particles over the tropical rainforest of the Ivory Coast. They observed that ammonium ions occur on particles that are submicronic in size with 60% less than 0.4 μm in diameter and are therefore not likely to be dry deposited by sedimentation. Nitrate particulates on the other hand, ranged in size from 0 to 10 μg, suggesting dry deposition in the absence of rainfall scavenging. It should be noted that ecological conditions on the Ivory Coast are applicable to Nigeria.

Table 9.2 provides a summary of all emission processes, including rough quantitative estimates. Emissions of nitrogen oxides are clearly dominated by biomass burning. For sulfur compounds both burning and natural emissions from forests seem to be important. Industrial emissions in both cases represent only a small fraction of the total. It should be emphasized, however, that these quantitative estimates are extremely uncertain.

9.3 ATMOSPHERIC DISPERSION OF POLLUTANTS

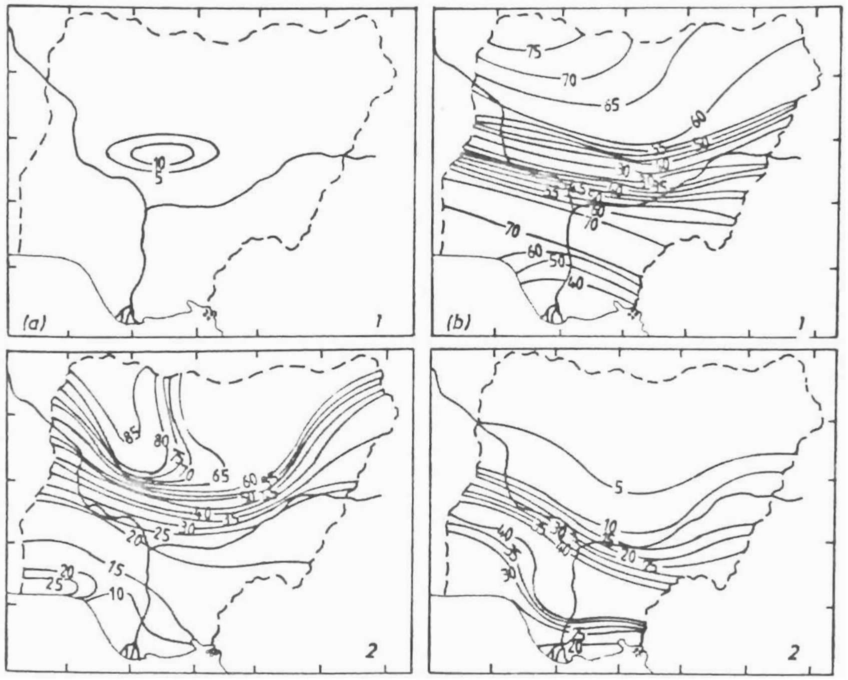
Nigeria has two climatic seasons, wet and dry, which are determined by the prevailing air masses. The southwesterly winds bearing rain originate in the Atlantic, and the dry northeast trade winds (called Harmattan) come from the Sahara Desert. The point of convergence of these two air masses at any time of the year is termed the Intertropical Zone of Discontinuity (ITD) and determines which season a particular area experiences. Areas south of

Table 9.2 Estimate of nitrogen and sulfur emissions in Nigeria

Estimated emission	Source	Locality most affected	Reliability of projection	References
Nitrogen (10^6kg/year)				
44	Natural gas burning, energy generation, industries and flaring	Southern Nigeria where most oil fields and installations are located	Reliable	Osaighovo and Jeghefume, 1985; Okoroji, 1985; Robertson and Rosswall, 1986
20.4	Gasoline use	Throughout the country	Reliable	NNPC, 1982; Robertson and Rosswall, 1986
269	Savanna annual burning	Throughout the country	Reliable	Isichei and Sanford, 1980; UNESCO, 1979
1,000	Burning of semi-deciduous forest	Mid-regions of Nigeria	Fairly reliable	UNESCO, 1978; Robertson and Rosswall, 1986
26	Soil NO_x	Throughout the country	Fairly reliable Estimates extrapolated from West African figures	Robertson and Rosswall, 1986
36	NH_3 volatilization from soil	Throughout the country	Fairly reliable Estimates extrapolated from West African figures	Robertson and Rosswall, 1986
190	Denitrification in soil	Throughout the country	Fairly reliable Estimates extrapolated from West African figures	Robertson and Rosswall, 1986
Sulfur (10^3 kg)				
1,000	Paper mill	Locations of paper mills	Not reliable	Grundy, 1972; Nigerian Industrial Directory, 1980
76	Petroleum refining	Refinery location	Not reliable	Grundy, 1972; Nigerian Industrial Directory, 1980
1,000	Sulfuric acid plant	Lagos area	Not reliable	Grundy, 1972; Nigerian Industrial Directory, 1980
32,000	Savanna burning	Savanna regions	Fairly reliable (Ivory Coast figure used)	Delmas, 1982
3,000	Natural emissions from forests	Niger Delta	Fairly reliable (Ivory Coast figure used)	Delmas and Servant, 1983

the ITD experience rainfall while those to the north are exposed to the dry northeast trades and have dry weather. The ITD is mobile and its position varies from the coastal areas at the peak of the dry season to the extreme north during the middle of the rainy period (Figure 9.5). At the local level most tropical areas experience great turbulence at the beginning and end of the rainy season (Ojo, 1977). During the dry season Harmattan winds have been observed to travel at up to 30 km/hour (McTainsh and Walker, 1982).

Due to limited data it is difficult to estimate transport and deposition rates of NO_x and SO_2 in Nigeria. It is likely that acidic depositions are mainly of the wet type because of the high humidity year round, especially in the south. In the rainy season there are also frequent mists. Rough estimates of the deposition of nitrogen are included in section 9.5.



(a) Northeasterly and easterly winds *(b) Southwesterly and westerly winds*

Figure 9.5 Percentage frequency of wind direction in (1) July, and (2) January (Ojo, 1977). Reprinted by permission of Heinemann Educational Publishers, Ltd

Another climatic phenomenon that may influence dispersion and deposition is Harmattan dust. The Harmattan dust in Nigeria originates in the Bodele Depression around Faya Largeau in northern Chad and blows in a

west-southwest direction. The average particle size of the deposited dust decreases from more than 50 μm in the source area to <2 μm in the Atlantic (McTainsh and Walker, 1982). During the dry season all parts of Nigeria are affected: depositions in Kano averaged 162 tons/km^2/year between 1976 and 1979 (McTainsh, 1985). Depositions further south are much less, but McTainsh (1985) observed that the soils in the middle portions of Nigeria may have been formed from Quaternary dust depositions. Harmattan dust particles may be important as centers of condensation of atmospheric droplets. Their mineralogical and chemical composition may also affect acidity.

9.4 THE PRESENT LEVEL OF ACIDIFICATION IN WATERS AND SOILS IN NIGERIA

9.4.1 Rivers

Surface water acidification is probably not yet a problem in Nigeria (Ajayi, 1986). This assertion is supported by evidence obtained from measurements of pH in several Nigerian rivers. In a study of 26 rivers on the western side of Nigeria, primarily in the industrialized oil production areas, Ajayi and Osibanjo (1981) found that pollution by solid waste was more important than acidification. The lowest pH recorded was 5.4 with most values close to 7.0. The mean pH for the 26 rivers was 6.52. Okwuobi and Ohagi (1982) also obtained a range of 5.6 to 7.0 in Ikpoba River near Benin in southwestern Nigeria. The five rivers surveyed by Oluwande *et al.* (1983) were basic due to solid waste pollution.

The Warri River, which is adjacent to the Aladja steel plant, showed pH values of 6.5–6.8, sulfate concentrations between 0.7 and 5.5 mg/liter, and nitrate concentrations of 1.9–3.1 mg/liter (Nriagu *et al.*, 1985). Nriagu *et al.* gave the pH of rainfall in five locations around Warri as 5.16–5.87. Sulfate concentrations in the five locations were always less than 0.20 mg/liter while nitrate concentrations ranged from 0.12 to 0.52 mg/liter. Effluents and waste water from the steel plants showed elevated pH with a sulfate concentration of between 3.3 and 36 mg/liter. The pH of River Niger was close to neutral (Nriagu et al., 1985). Anion concentrations in rainfall near the Ajaokuta steel plant showed sulfate concentrations of 0.20–0.53 mg/liter and nitrate concentrations of 0.62–2.17 mg/liter.

9.4.2 Soils

There are two major groups of soils in Nigeria: ferralitic (Oxisols) and tropical ferruginous (Alfisol) types (Jones and Wild, 1975). The tropical ferruginous type is most common and is usually formed from basement complex rocks (mainly metamorphic) of Precambrian age. During the process of leaching in an equatorial climate (Figure 9.6), silica and bases are lost and aluminum and iron tend to accumulate. This is particularly true in ferralitic soils. In ferruginous soils some of the original minerals and neo-formed ones may remain. This effect of climate on parent rock material results in low soil pH.

Jones and Wild (1975) give the mean pH values of 245 ferruginous surface soil samples as 6.0 with a range of 4.8–8.2, and a mean of 6.0 and a range of 4.8–7.3 for 33 ferralitic samples. Measurements in the Warri area by Nriagu *et al.* (1985) show that mangrove soils have a pH range of 2.6–4.2 while upland soils have a range of 3.9–5.1. One can say with certainty that soil pH in Nigeria increases northward just as the amount of rainfall decreases. Southern Nigeria, which is more prone to acidification, has naturally acid soils. Due to high humidity, acid depositions there are likely to be wet.

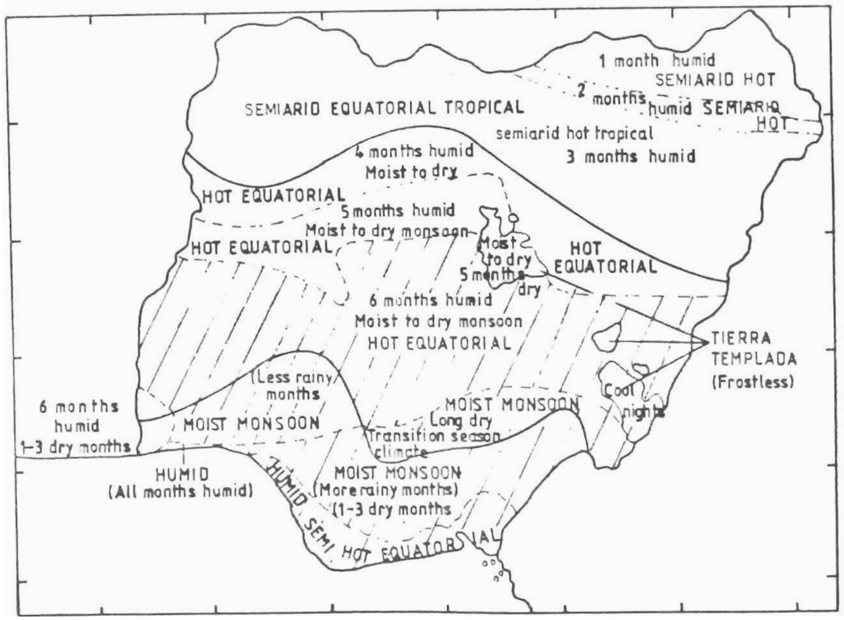


Figure 9.6 The climates of Nigeria; lined area indicates soil prone to acidity (Papadakis, 1961)

9.5 EMISSION PROJECTIONS AND POTENTIAL PROBLEM AREAS

From the few available measurements in rivers and soils, the current level of acidification in the Nigerian environment appears to be low. Nevertheless,

in view of rapid industrialization and inadequate monitoring, it is important to examine possibilities and trends as a safeguard for the future.

Projections of emissions based on available data show that some parts of Nigeria could experience high levels of acidification in the near future. The natural gas consumption rate of 3×10^9 m^3 and the gas flaring at about three times this value are expected to result in emissions of 44×10^6 kg N/year from the oil-producing areas of southern Nigeria. This is assuming an emission factor of 2.9 g N per m^3 of gas (Robertson and Rosswall, 1986). Using a factor of 5.1 g N/kg gasoline (again as in Robertson and Rosswall), not less than 20.4×10^6 kg N is emitted through gasoline consumption: 4×10^9 kg gasoline was used in Nigeria in 1982 (NNPC, 1982) (Figure 9.7). Probably half of this value is emitted through the use of kerosene and fuel oil.

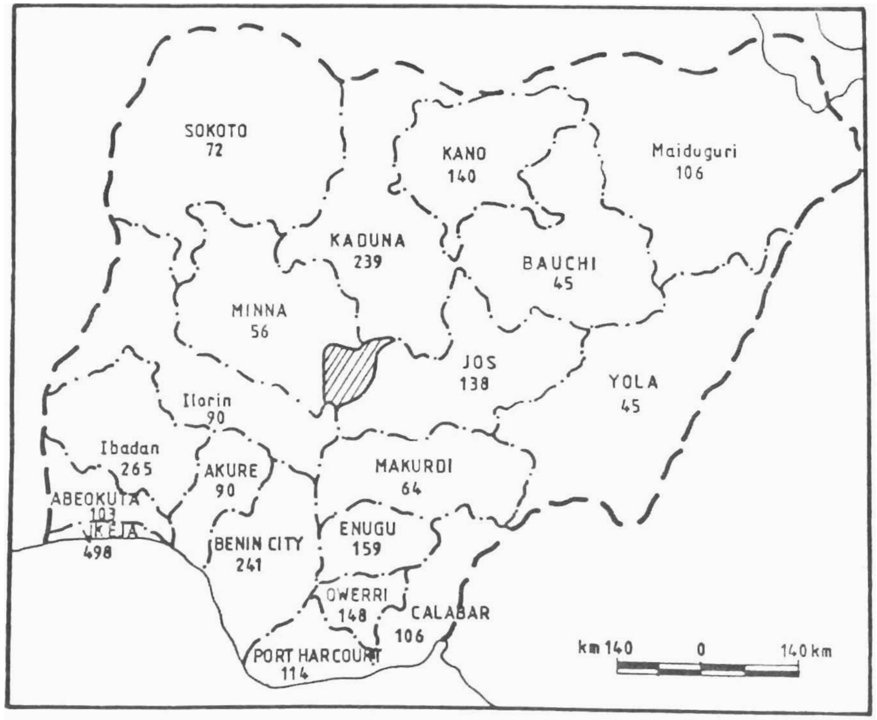


Figure 9.7 Major cities of Nigeria, showing estimated concentrations of SO_2 in air ($\mu g/m^3$) based on 1982 gasoline consumption rates (Oluwande, 1979)

From the 12–15 kg/ha nitrogen emission values reported by Isichei and Sanford (1980) for savanna burning, an estimated 269 × 10^6 kg N is lost from 20.7 × 10^6 ha of annually burned savanna in Nigeria. If it is assumed that semi-deciduous forest occupies 10 × 10^6 ha, this represents one-third of all forest and woodland in Nigeria. Assuming further that just one-fifth of this semi-deciduous forest is burned, then an additional 1,000 × 10^6 kg N is lost through burning. This reasoning is based on 500 kg N/ha for this vegetation type (Robertson and Rosswall, 1986). Robertson and Rosswall (1986) noted the prominent role fire-caused emissions play in the nitrogen cycle in West Africa. The area brought under fire is spreading from the savanna zone to the drier forests and the implications of this change for the nitrogen cycle must be considered.

Other emissions include 26 × 10^6 kg NO_x from soil, 36 × 10^6 kg NH_3 from volatilization and 190 × 10^6 kg N from denitrification. The values (Robertson and Rosswall, 1986) are based on the assumption that Nigeria's land area is one-sixth that of West Africa and that climatic and vegetation patterns are uniform for the West African region. These three figures include emissions caused by fertilizer use and livestock.

No industrial emission figures for nitrogen can be given now. One major source in the future, the ammonia fertilizer plant, has yet to begin production.

Closed forest, open woodland, and scrub (31 × 10^6 ha in total) receive some 460 × 10^6 kg N in the annual rainfall of 1,200–2,000 mm assuming 15 kg/ha as the amount of N returned in rainfall. The rest of the country receives about 300 × 10^6 kg N per year, assuming 5 kg/ha as the amount of N returned in rainfall (Robertson and Rosswall, 1986).

Robertson and Rosswall (1986) estimate that a total of 1.5 × 10^9 kg N/year is lost through leaching, run-off, and erosion in West Africa, based on River Niger fluxes. About 50% of the area drained by the Niger (excluding deserts and sub-deserts) is in Nigeria (NEDECO, 1959). When the areas drained by Nigeria's second largest river, the Benue, and other major rivers are combined, a total river discharge of 1,000 × 10^6 kg N can be estimated for Nigeria.

Data concerning sulfur emission and deposition are even more limited than that for nitrogen. Consequently, any projections will be much less reliable. However, in order to meet the objective of guiding future monitoring, some projections may be made. Over a thousand tons of sulfur dioxide may be emitted from the 290,000 ton (total capacity) paper mills in Nigeria; the emission rates used by Grundy (1972) are applied. The petroleum refineries in Nigeria should emit 76,000 tons of SO_2 per year if, again, Grundy's rates are used. The only known sulfuric acid plant in Nigeria, located in Lagos with a capacity of 40,000 tons, is expected to emit about 1,000 tons SO_2.

Sulfur emissions from transportation will vary from place to place and,

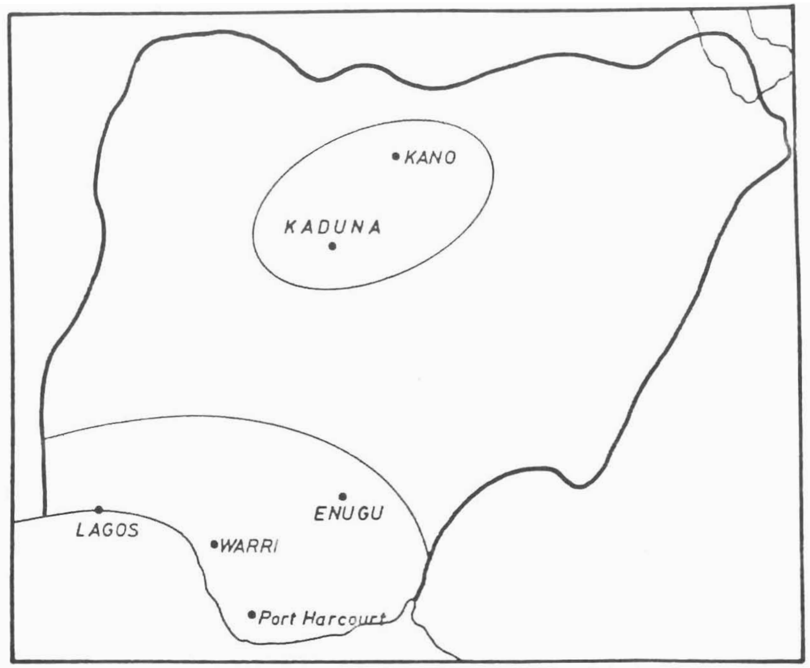


Figure 9.8 Areas of Nigeria susceptible to acidification

based on the single-vehicle, traffic-related atmospheric concentration measurement from Ibadan, the expected concentrations in the capital cities of the 19 states are shown in Figure 9.7. These values are based on 1982 gasoline consumption rates as well as on the assumption that the largest city in each state (the capital) consumes the same proportion of the state's gasoline as Ibadan does in its state. The six southern states of Nigeria consumed 64% of the national gasoline in 1982.

Delmas (1982) obtained an emission value of 1.4 kg S/ha from savanna burning in the Ivory Coast. Applied to Nigeria this would result in a value of 32 × 10^6 kg sulfur emitted over 20.7 × 10^6 ha grazing land (usually burned annually) and 2 × 10^6 ha of burned semi-deciduous forest. Delmas and Servant (1983) further report a natural gaseous emission of 15 kg S/ha from the equatorial forest zone of the Ivory Coast. The same type of forest in the Niger Delta occupies 2 × 10^6 ha and should, at the same rate, emit 30 × 10^6 kg S/year.

It thus seems likely that natural emissions, including burning, are more important than anthropogenic emissions of sulfur. More measurements of the acid-buffering capacities of Nigerian soils, especially in the southern region, are necessary as soil and water are the best indicators of acidification.

The status of the above estimations for nitrogen and sulfur is summarized in Table 9.2. Locations in southern Nigeria and on the Kano–Kaduna axis will be most affected by acidification due to industrialization and oil-related activities. These areas are shown in Figure 9.8. A glaring need exists for air concentration and deposition measurements of NO_x and SO_2.

Considering the projected emissions, acidification may well become a problem in Nigeria in the future. Acidification resulting from industrialization may not yet be evident, partly because most industrial concerns are only recently established. However, burning of forests and other biomass clearly represents a major source of air pollution in the country. Acidification of water may be masked by the presence of effluents, which decrease acidity. There is obviously a strong need for more research and monitoring of the acidification process in Nigeria.

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