

AIR POLLUTION STUDIES. II: MONITORING OF SULPHUR (IV) OXIDE EMISSION BY MOTOR VEHICLES AT A BUSY ROUND-ABOUT IN ILORIN, NIGERIA.

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ABSTRACT: Sulphur (IV) Oxide concentrations at a busy round-about in the city of Ilorin versus time of day were measured on 4 different days staggered throughout the month for 12 months of the year. The results showed that the highest peaks occurred at 8-9a.m. and 3-4p.m. each day. These two time periods corresponded to the busy hours when workers were going to their offices and returning home respectively. Comparison of the values obtained at the round-about with those at a remote rural area suggests that the relatively high SO_2 concentration at the round-about came from motor vehicles. While the measured SO_2 levels are within the range that is tolerable for human beings, the low levels obtained might be harmful to children, the elderly and people with chronic respiratory problems.

INTRODUCTION

Sulphur oxide (IV) oxide, SO_2 , is one of the most important and common pollutants in the atmosphere. Its major sources into the air are fuel combustion in transportation, stationery heating, industrial processes and other miscellaneous human activities (U. S. Environmental Protection Agency (USEPA), 1973). In addition, about 200 million tons of SO_2 per year are generated within the atmosphere as a result of the oxidation of H_2S from the decay of organic matter and biological reduction of sulphates by anaerobic bacteria (Manahan, 1993). While most of the anthropogenic SO_2 comes from the combustion of coal, a significant amount of it comes from the burning of petrol in internal combustion engines of motor vehicles. This SO_2 comes from the sulphur compounds which constitute anywhere from 0.1 to 6% in petroleum (Kutepov *et al*, 1988).

The main worry about SO_2 pollution of the air is the health effects the gas has on human beings. It readily affects the respiratory tract causing a sore throat, chest pain, constriction, burning and tearing of eyes, vomiting, nausea, excessive nasal discharge as well as breathlessness (Calabrese, 1976). In fact, SO_2 has been implicated in some acute incidents of air pollution in which many people died. Apart from the effects on man, corrosion rates of moist metals are accelerated by SO_2 pollution. It attacks a wide variety of building materials containing carbonates in the form of marble, limestone, roofing slate and mortar, converting them to water-soluble sulphates (Stoker and Seager, 1992).

Sulphur (IV) oxide causes the problems mentioned above because the gas is converted to the corrosive sulphuric acid in the form of aerosols in the air. Experiment shows that animals exposed to various amounts of H_2SO_4 aerosol developed narrowed air passages caused by bronchiosterosis, mucosal swelling or increased secretion. As a result, people who already have difficulty in breathing, such as the old, asthmatic or heart patients, can die, not by the direct corrosive quantities of H_2SO_4 , but by the respiratory strain that H_2SO_4 places on the already stressed people (Maddalone *et al*, 1976).

Transportation is one of the major contributors to primary atmospheric pollutants. Five major pollutants in the air are carbon monoxide, oxides of nitrogen, hydrocarbons, oxides of sulphur and particulate matter. It has been documented for example that transportation alone contributed over fifty percent of the total amount of these pollutants in the U. S. in 1970. (Manahan, 1993). It is therefore evident that a round-about with heavy traffic volume for most of the day will be highly polluted. In view of this, it was decided to monitor the concentrations of SO_2 in a busy round-about at the Emir's

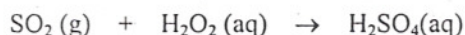
market in the city of Ilorin, Nigeria, so as to see if the level of SO₂ there is safe for human beings without causing health problems.

MATERIALS AND METHODS

Air samples were taken for a period of 12 months, that is, January to December of 1994. The periods chosen for the runs were 6-7a.m., 8-9a.m., 12-1p.m., 3-4p.m. and 6-7p.m. each day the runs were made. This choice of intervals was used in order to show the variation of SO₂ concentrations with time of the day.

Specifically, between 6 and 7a.m., most people are still at home getting ready to go to their offices. Between 8 and 9a.m., a lot of vehicles are already on the streets. Around 12-1p.m., most people are in their offices so traffic volume is reduced. However, from 3-4p.m., workers are returning home in their vehicles, so one can expect more pollutant emissions. By 6-7 p.m., most people are back at home and there is a great reduction in traffic volume. Samples were taken at each of these five time periods for 4 days spaced throughout every month.

The procedure used for the collection of air samples was impingement in liquid method (Hamilton *et al*, 1967). The air sampler used is shown in Fig. 1. The boiling tube contained 0.3M H₂O₂ solution buffered at a pH of 5. The set-up was airtight. At the start of the run, the aspirator was filled with water to the upper limit and the tap at the bottom of the aspirator was opened creating a partial vacuum in the aspirator. This caused air to rush into the boiling tube and bubbled through the 20cm³ of 0.3M H₂O₂. The flow rate was low (about 1000cm³/min) to ensure that the SO₂ in the air was given enough time to dissolve in the H₂O₂ solution. The volume of water displaced from the upper to the lower limits of the aspirator was 20dm³ and that was equal to the volume of air, which bubbled through the sampling H₂O₂ solution. 20dm³ of air was bubbled through the H₂O₂ solution 2 times for each run, which means that 40 dm³ of air was sampled for each run. This procedure was used for air sampling throughout the study period. The H₂O₂ solution was buffered at pH of 5 to prevent the dissolution of atmospheric CO₂, which does not dissolve in water at pH of 5 and below (Manahan, 1993). The SO₂ in the sampled air reacted with the H₂O₂ as follows:



The conductance of the H₂SO₄ solution was used to read off the concentration of H₂SO₄ formed by using a reference graph of conductance versus H₂SO₄ concentration (Moore and Moore, 1976). This is a standard method for SO₂ measurement. The concentrations thus obtained were expressed as micrograms per cubic meter (µg/m³) of air.

The above reaction between SO₂ and H₂O₂ shows that one mole of SO₂ produces one mole of H₂SO₄. Therefore, the concentration of H₂SO₄ produced is the same as that of SO₂ in the sampled air since the H₂O₂ concentration is in a whopping excess over SO₂ concentration. For example, the SO₂ concentration will have to be at least 0.5ppm for one to smell it (Stoker and Seager, 1992). The concentration of a 0.3M H₂O₂ solution is 10,200ppm, which is over 20,000 times that of the SO₂. Of course the SO₂ concentration in regular polluted air is always far below 0.5ppm and the slow speed at which air was bubbled also enhances the chances that all the SO₂ would react with the H₂O₂.

RESULTS AND DISCUSSION

Table 1 is a summary of the data obtained for 12 months. Each date point on the table represents the average of 4 measurements taken on 4 different days staggered throughout each month. Blank runs were made by measuring the conductance of 0.3M H₂O₂ solution through which no air was bubbled. Values of the blank runs were subtracted from the readings got for the samples so as to obtain what was due to the SO₂ in the air.

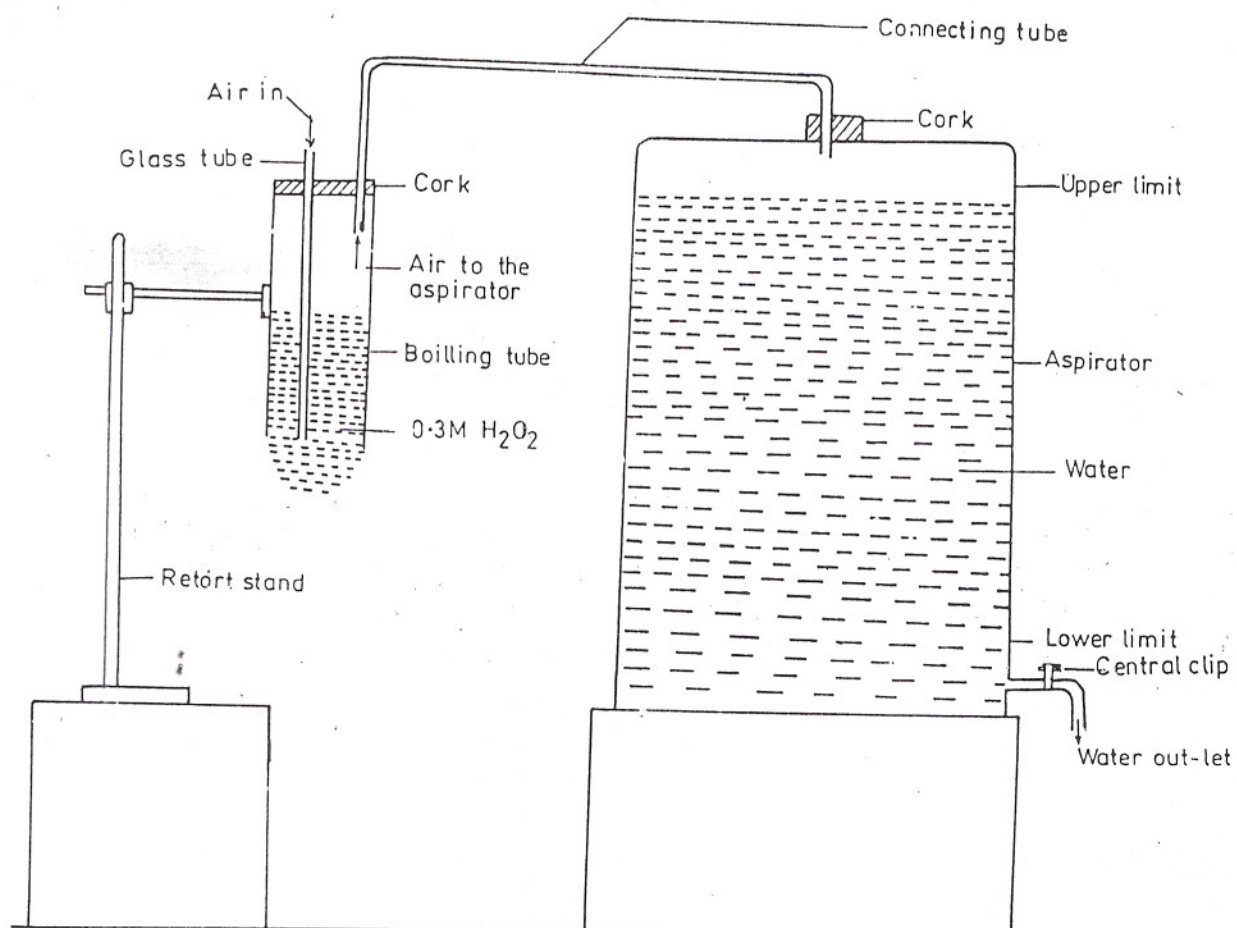


Fig. 1. Set up of the Sampler

In order to find out whether or not the SO₂ concentrations were really different during the dry and wet seasons, the t test was used (Haynes, 1982). The averages of the data for January, February and March were used to calculate the dry season values while the data for the months of July, August and September were used for the wet season. Our calculations showed that the observed t values for SO₂ concentrations at 6-7a.m., 8-8a.m., 12-1p.m., 3-4p.m. and 6-7p.m., ranged from 6.950 to 16.562. From

Table 1. Summary of Monthly Averages of Sulphur (IV) Oxide Concentrations ($\mu\text{g}/\text{m}^3$) for 1994

Month	[SO ₂] at 6-7a.m.	[SO ₂] at 8-9a.m.	[SO ₂] at 12-1p.m.	[SO ₂] at 3-4p.m.	[SO ₂] at 6-7p.m.
January	373 $\pm$ 15.0	524 $\pm$ 23.7	459 $\pm$ 30.7	574 $\pm$ 31.1	539 $\pm$ 18.2
February	381 $\pm$ 11.0	600 $\pm$ 28.2	485 $\pm$ 46.2	636 $\pm$ 17.7	592 $\pm$ 7.8
March	375 $\pm$ 8.9	581 $\pm$ 33.9	493 $\pm$ 33.1	636 $\pm$ 27.2	584 $\pm$ 19.8
April	342 $\pm$ 11.6	498 $\pm$ 27.7	428 $\pm$ 28.4	545 $\pm$ 5.5	519 $\pm$ 12.6
May	282 $\pm$ 3.8	373 $\pm$ 3.9	326 $\pm$ 2.2	381 $\pm$ 3.9	360 $\pm$ 6.1
June	272 $\pm$ 2.2	360 $\pm$ 3.9	331 $\pm$ 2.0	370 $\pm$ 3.2	347 $\pm$ 2.4
July	279 $\pm$ 4.0	365 $\pm$ 1.5	331 $\pm$ 3.1	373 $\pm$ 1.5	339 $\pm$ 10.9
August	274 $\pm$ 1.7	344 $\pm$ 5.7	331 $\pm$ 3.0	357 $\pm$ 5.4	339 $\pm$ 8.4
September	263 $\pm$ 8.7	318 $\pm$ 17.0	308 $\pm$ 20.9	328 $\pm$ 13.1	321 $\pm$ 14.4
October	263 $\pm$ 4.5	295 $\pm$ 10.2	282 $\pm$ 11.1	315 $\pm$ 6.2	295 $\pm$ 8.3
November	300 $\pm$ 17.1	383 $\pm$ 27.9	352 $\pm$ 17.0	404 $\pm$ 34.4	381 $\pm$ 34.8
December	375 $\pm$ 2.8	568 $\pm$ 23.0	516 $\pm$ 7.1	615 $\pm$ 18.9	576 $\pm$ 15.3

Note: Each data point listed on the table represents 4 measurements taken on 4 different days staggered throughout the month.

the standard statistical table, the critical t value with significant level of 0.05 was 2.776. The fact that the critical t value is much lower than the calculated values confirms that the SO₂ concentrations in the air during the two seasons were significantly different.

A careful look at the data shows that on a daily basis, the concentrations of SO₂ vary with time of day. This regular pattern is also maintained for each of the 12 months of the year. The concentration of SO₂ rises steeply from 6a.m. to a maximum around 8-9a.m. By 12-1p.m., SO₂ has decreased appreciably only to rise to a second maximum around 3-4p.m. By 6-7p.m., it starts falling again. The peak at 3-4p.m. is higher than the one at 8-9a.m. The behaviour observed here for SO₂ concentration versus time of the day is similar to what was obtained on a New York street when the variation of carbon monoxide concentration against time of the day was studied (Wolf, 1971). The two peaks for carbon monoxide were found to occur at 8a.m. and 4pm. The explanation for these two peaks is as follows: Between 8 and 9a.m., most workers have already driven their vehicles on the streets or are still there in motion. Other vehicles such as taxi cabs, buses and other commercial vehicles cause traffic volume on the streets to be at its highest around this time. Since SO₂ is one of the pollutants emitted from the exhaust pipes of motor vehicles, the concentration of this gas can be expected to be very high between 8 and 9a.m. The same explanation goes for the second peak around 3-4p.m., but this time, the workers are returning home.

When one compares dry season SO₂ concentration values with those of the rainy season, one would find that the rainy season values are much lower. For example, at 8-9a.m. in February, the average SO₂ concentration was 600 $\mu\text{g}/\text{m}^3$ compared to 295 $\mu\text{g}/\text{m}^3$ for the same time in October. Since the volume of traffic does not decrease significantly because of the rains, the lower SO₂ concentration in the wet season could not be due to lower emission but to the washout by rains.

In order to find out if the SO₂ measured at the busy spot in the city was due to traffic, measurements were taken for 2 days in a rural area, which was about 20km away from the city. The site chosen was inaccessible to motor vehicles. The average SO₂ Concentrations are given in Table 2. The Time intervals used, which coincided in the two tables, are 12-1p.m. and 3-4p.m. Comparing the two values from the tables, one finds that the SO₂ concentrations down town range from about 5 to 10 times the values in the rural area. Since the only difference between the busy round-about in the city and the rural area in terms of pollution is the heavy traffic volume, it seems reasonable to associate the SO₂ at the round-about to motor vehicle exhaust.

Table 2. Averages of Sulphur (IV) Oxide concentrations ($\mu\text{g}/\text{m}^3$) in the air of a rural area on 20/6/94 and 22/6/94.

[SO ₂] at 10-11a.m.	[SO ₂] at 12-1p.m.	[SO ₂] at 2-3p.m.	[SO ₂] at 3-4p.m.	[SO ₂] at 4-5p.m.	[SO ₂] at 5-6p.m.
15 $\pm$ 0.6	31 $\pm$ 0.8	70 $\pm$ 1.0	76 $\pm$ 0.5	70 $\pm$ 1.8	63 $\pm$ 1.6

Another aspect that is obvious in Table 2 is the behaviour of SO₂ concentration versus time of the day, which follows the pattern observed downtown. In rural areas, one source of SO₂ is the decay of organic matter such as weeds, which emit H₂S. The H₂S can be oxidized to SO₂:



This reaction is rapid (Kellogg et al, 1972). Apart from the fact that this reaction is not likely to result in the type of pattern observed in table 2 with respect to the time of day, the concentrations are not likely to be this high. Similar studies have shown that concentrations of atmospheric pollutants in rural areas are significantly in excess of natural background levels. It has been shown that these high values can be caused by air masses transporting pollutants from cities to the rural areas. In addition to that, precursors for the formation of a particular pollutant may be carried by air masses to rural areas where these precursors react to form the pollutant under study (Chameides and Stedman, 1976). We believe that these two processes or at least one of them was responsible for the similarity in behaviour of the data on the two tables and the relatively high values got for the rural area.

From Table 1, it can be seen that the highest SO₂ concentration recorded for the whole year was 636 $\mu\text{g}/\text{m}^3$, which occurred in February and March. This value is higher than the lowest concentration for inducing conditioned reflexes centered in the brain cortex, that is, 521 $\mu\text{g}/\text{m}^3$ (USEPA, 1973). On the other hand, the highest value obtained is far less than 1304 $\mu\text{g}/\text{m}^3$, which is the threshold limit for odour detection. Therefore, the main worry here is the effects of low levels of SO₂ on human beings. Long-term effects resulting from extended exposure to low levels of SO₂ are known. Studies carried out by the U. S. Environmental Protection Agency (USEPA, 1973) show a definite correlation between the incidence of respiratory infection in children and the level of SO₂ pollution in their environment. The frequency of infection and diminished lung function increased with an increase in residence time of a child in polluted areas, according to the findings. Since the round-about studied here is always busy with traffic, it means that the children living around it are likely to suffer from the long-term effects of their constant exposure to the low levels of SO₂ pollution.

In conclusion, the fact that SO₂ concentrations found at this site are much higher than in rural areas, is an indication that other places where traffic volume is high will be similarly polluted with SO₂. However, since the SO₂ levels at this round-about are fairly low, only children, the elderly and people with chronic respiratory problems might be affected (USEPA, 1973). In terms of air quality, the dry season air is of much lower quality than the wet season air as far as SO₂ pollution is concerned.

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