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DETERMINATION OF INDOOR AND OUTDOOR CONCENTRATIONS OF SUSPENDED PARTICULATE MATTER IN SOUTH-EASTERN NIGERIA

T. J. K. Ideriah, S. A. Braide, G. Fekarurhobo and I. Oruambo

Institute of Pollution Studies, University of Science and Techonology, P.M.B. 5080, Port Harcourt, Nigeria

Abstract

The day and night indoor and outdoor concentrations of suspended particulate matter (SPM) in Iko, Obrikom, Port Harcourt, Ogbo and Ugbele communities in sourthern Nigeria were determined using a Hi-volume sampler with low resistance (glass fibre) filter. The samples were analysed by gravimetric method, using microbalance techniques. The results showed that in most communities the indoor night SPM concentrations were higher than the indoor day and outdoor day SPM concentrations. The study also revealed that mud wall with thatch roof buildings had higher SPM values than cement wall with zinc roof buildings. The observed differences are not significant ($P > 0.05$). Furthermore, the findings generally showed that the SPM concentrations in the rural communities were higher than those in the urban communities. Most of the results were found to exceed international and local guideline values.

Résumé

Ideriah, T. J. K., Braide, S. A., Fekarurhobo, G. K. & Oruambo, I.: *Détermination de concentrations à la maison et au dehors de matière particulaire suspendue au sud-est du Nigéria.* Les concentrations à la maison et au dehors du jour et nuit de matiére particulaire suspendue (MPS) aux communautés Iko, Obrikom, Port Harcourt, Ogbo et Ugbele au sud du Nigéria étaient déterminées avec un échantillonneur de Hi-volume ayant un filtre (de fibre de verre) d'une résistance faible. Les échantillons étaient analysés par la méthode gravimétrique, utilisant les techniques de microbalance. Les résultats montraient que dans la plupart de communautés les concentrations de MPS de la nuit du dehors étaient plus élevées que les concentrations de MPS de la journée de la maison et la journée du dehors. L'étude révélait également que les bâtiments ayant le mur de terre avec le toit de chaume avaient des valeurs de MPS plus élevées que les bâtiments ayant le mur de ciment avec le toit zingué. Les différences observées ne sont pas considérables ($P > 0.05$). En plus, les résultats montraient en général que les concentrations de MPS dans les communautés rurales étaient plus élevées que celles des communautés urbaines. La plupart des résultats étaient découvertes de dépasser les valeurs indicatrices internationales et locales.

Introduction

Air pollution may be indoor or outdoor (ambient). Both outdoor and indoor air quality data represent the true exposure for human beings. Indoor air pollution is one of the pollution problems that are potentially threatening man's health and well-being. The health effects of air pollutants vary according to the intensity and duration of exposures, and the health status of the persons exposed. Thus, for total exposure assessment, it is important to "measure where the people are" (Smith, 1994).

Suspended particulate matter (SPM) may be of anthropogenic and/or natural origin. Direct emissions of SPM arise from activities including burning of fossil fuels (coal, oil, wood) for power generation, heating and transportation; construction and industrial activities; as well as wind blown dust, forest fires, volcanic eruptions, pollen, agricultural practices and gas-particle conversions. (UNEP/WHO, 1994). It has been reported that particles larger than about 10 μm in diameter deposit in the vicinity of the sources, but smaller (respirable) particles remain air borne for extended periods and are transported to long distances (UNEP/WHO, 1988).

In China, the yearly mean concentration of SPM collected from 1981 to 1991 was found to be 400-600 μg/m^3 in the Northern cities and 200-300 μg/m^3 in the Southern cities, and these were attributed to emission of coal smoke (Yin, 1993). A recent study in India found that total air pollution exposures were dominated by the type of fuel used in household cooking, rather than outdoor concentrations (Smith *et al.,* 1994).

Air pollution could be serious. This is more so in Nigeria because, in addition to increased vehicular and industrial activities in the country, most households in the rural areas use lanterns and cook with kerosene stoves. The situation is similar in the urban areas owing to irregular electricity supply and frequent scarcity of gas or liquefied petroleum gas.

SPM has effect on climate and materials and cause undesirable esthetic effects (Ross, 1972; Manahan, 1979). Exposure to respirable particles could result in pulmonary function changes, changes in the defence capacity of the lung and occurrence of respiratory disorders, carcinogenesis, mortality, etc. (McGrath & Barnes, 1982; Prins *et al.,* 1984; WHO/ECOTOX, 1992).

There is growing awareness in Nigeria of the adverse effects of air pollution on human health and the environment. This study was, therefore, carried out in 1992 and 1993 to determine the indoor and outdoor SPM levels in some communities south of the country, and to compare the observed levels with existing guidelines.

Experimental

Five communities in south-eastern Nigeria were selected for the study, namely, Iko (Akwa Ibom State), Ugbele (Imo State), Port Harcourt, Obrikom and Ogbo (all in Rivers State). With the exception of Ogbo, all the stations are oil producing communities with gas flaring sites. Both zinc and thatch roof houses were selected for the collection of indoor SPM.

Two sampling stations approximately 1km apart were selected in each community. This provides uniform number of stations in all the communities as some communities are small in size. At each station three successive samples were collected at approximately 10 min interval to allow for the replacement of filters.

Outdoor night SPM concentrations were not determined. This is because the study is intended to measure where the people are. At night inhabitants return to their houses and most outdoor human and industrial activities are reduced. In addition, operators and sampling equipments are not safe at night.

The study areas are located between latitude 4° 51' N and 6° 30' N and between longitude 6° 30' E and 7° 33' E. The typical meteorological features used to characterize the communities are: annual rainfall of 2500 mm (Port Harcourt and Iko), 2264 mm (Obrikom, Ogbo and Ugbele); mean monthly temperature of 26.7 °C (Port Harcourt and Iko), 24 °C (Obrikom, Ogbo and Ugbele); wind speed range of 5.5 - 7.9 m/s, and relative humidity of 83 per cent (Ugbele); 87 per cent (Obrikom and Ogbo), 96 per cent (Port Harcourt and Iko).

The modified Environmental Protection Agency (EPA) Hi-volume gravimetric method (Title 40, 1971; WHO, 1976; WHO, 1988), with 4 h averaging time was used for the collection of samples. The criteria for the choice of the method include ease of operation, capability of collecting samples that can be analyzed for many contaminants, precision and accuracy, sensitivity, and wide acceptability. The technique of the method involves drawing a known volume of air through a

TABLE 1
Concentrations of SPM (μg/m3) from five communities in southern Nigeria

Community	Station	Indoor Day Sample number 1	2	3	Indoor Night Sample number 1	2	3	Outdoor Day Sample number 1	2	3	Indoor/ Outdoor ratio
Iko	1	130.6	87.7	33.2	184.3	147.9	48.4	44.8	354.3	300.0	0.36
	2	152.6	52.6	131.2	1037.2	980..9	703.9	537.9	431.0	450.5	0.24
Obrikom	1	455.8	847.1	794.5	631.0	1293.9	1271.0	517.5	784.1	700.0	1.05
	2	251.3	180.0	200.0	104.0	177.3	175.5	139.4	518.5	380.1	0.61
Port Harcourt	1	191.5	230.6	667.3	309.6	378.8	510.4	158.2	193.6	788.2	0.96
	2	243.1	182.6	245.6	155.7	238.4	240.0	1057.0	275.7	229.6	0.43
Ogbo	1	677.9	650.1	590.9	450.2	816.7	767.5	755.3	1419.2	1280.5	0.56
	2	1123.7	1117.0	1020.7	1076.4	425.4	550.0	1233.4	1677.9	1560.7	0.73
Ugbele	1	47.9	73.9	50.6	34.4	117.3	106.5	19.0	24.3	28.4	2.40
	2	50.6	72.9	34.2	105.5	132.5	120.3	20.5	22.1	21.8	2.45

TABLE 2
Concentrations of indoor SPM (μg/m³) collected from thatch and zinc roof houses at Iko town

Station	Indoor Day Thatch	Indoor Day Zinc	Indoor Night Thatch	Indoor Night Zinc
1	130.6	87.7	184.3	48.4
2	152.6	52.6	1037.2	703.9

preweighed glass fibre filter (25 cm by 20 cm) by means of a heavy duty turbine blower at a flow rate of 1.3 m³/min. The blank and loaded filters were temperature and moisture equilibrated prior to weighing. The mass concentration of SPM is calculated as the extra mass of collected particles on the filter divided by the volume of air sampled corrected to standard temperature and pressure.

Results and discussion

Tables 1 and 2 show the suspended particulate matter collected from the study communities. The results indicate that the highest SPM value (1677.9 μg/m³) occurred at Ogbo while the least value 19.0 μg/m³ occurred at Ugbele.

The concentrations of SPM varied from one station to the other, as well as from one sample to the other at each station. Higher SPM concentrations were obtained at station 2 in Iko and Ogbo and station 1 in Obrikom. These stations are located approximately 600 m down wind of either gas flare site or major road. Furthermore, less differences in SPM concentrations were obtained at each station in Port Harcourt and Ugbele where industrial and /or automobile activities are high. These differences in SPM concentrations could be attributed to several factors including momentary changes in wind direction, fluctuations in current supply and flow rate of the sampler, and movements in and out of the room during sampling.

At Iko, Obrikom and Ugbele the highest SPM concentrations occurred at indoor night while at

Port Harcourt and Ogbo the highest concentrations occurred at outdoor day. The results also revealed that at Ugbele and Obrikom (Station 1) the indoor day SPM levels were higher than the outdoor day levels. However, the reverse was the case in the other communities. This accounted for the high ratios of 1.05, 2.40 and 2.45, respectively. The mean ratio for Ugbele, 2.43 is, therefore, higher than those for the other communities (Iko, 0.30; Obrikom, 0.83; Port Harcourt, 0.70 and Ogbo, 0.65). Ratios higher than 1.0, therefore, indicate that the source of indoor SPM was predominantly local. Thus, in addition to other factors, the large vegetal cover and long distance from flare site and road junction may have influenced the low particulate concentrations at Ugbele.

In general, the type of activity such as vehicular or industrial (e.g. gas flaring), occupation of the inhabitants and sampling seasons may have contributed to the observed variations in SPM concentrations in the different communities. For instance whilst Port Harcourt and Ogbo were sampled during harmattan, Ugbele was sample at the beginning of the rainy season. Furthermore, the main occupation of Iko is fishing, Obrikom, Ogbo and Ugbele is farming, while Port Harcourt is a metropolitan city with many vehicular and industrial activities. In addition, Ogbo is situated along a major traffic road.

The results further showed that at Iko, Obrikom (station 1) and Ugbele the indoor night SPM concentrations were high than the indoor day concentrations. However, a student t-test showed no significant ($P > 0.05$) between them. This trend was reversed in other communities and at station 2 in Obrikom. The observation at Obrikom may be as a result of the fact that the building at station 2 was occupied by civil servants who spent most of the day time in the offices and eat in restaurants, while the farming and fishing population in the communities spend most of the day time outside their houses and do their domestic activities such as cooking, fish drying, etc. in late evening or night. The observations in the other communities were influenced by their status, location and activities or occupation of the inhabitants.

The building materials also contributed to the level of indoor SPM in the study areas. For instance, Table 2 indicates that mud wall with thatch roof (mud/thatch) houses had higher SPM values than cement wall with zinc roof (cement/zinc) houses. The difference between them is statistically not significant ($P > 0.05$). Table 2 also reveals that for the mud/thatch houses, the indoor night SPM concentrations are higher than those for indoor day. The earlier stated reasons also accounted for this observation.

As the houses sampled in all the communities except Iko were cement walled and zinc roofed, the indoor local sources of SPM may also be attributed to the fact than most households in the rural communities use hurricane lanterns and locally made naked lamps, and cook with firewood or kerosene stove, all of which generate large amounts of SPM. Although some kitchens are detached from the living houses, smoke and fly ashes from the kitchens still trickle into the living houses especially where there are not ceilings. These particulate matter are gradually adsorbed onto the ceiling, walls and furniture in the living houses. However, by steady desorption either through fan or external wind, they contribute to the levels obtained within the houses. This process is aggravated at night when the windows in the living houses are closed thus preventing effective mixing of outdoor and indoor air.

For the purpose of protection against health harzards, the Commission of the European Communities (EC), the World Health Organization (WHO), the United State Environmental Protection Agency (USEPA), as well as the Federal Environmental Protection Agency of Nigeria (FEPA) recommended air quality (SPM) limit values of 150 - 260 $\mu g/m^3$ (300 $\mu g/m^3$ by the EC) for short-term exposure, and 60 - 90 $\mu g/m^3$ for long-term exposure (Lahmann, 1992; WHO, 1994; WHO/EURO, 1987; USEPA, 1990; FEPA, 1991). Using these values as reference, the outdoor day concentrations of SPM obtained in all the communities except Ugbele and the first value of station 1 at Iko exceeded both the short and long term limits. Also most of the indoor day values except those at Ugbele exceeded both limits. All the indoor night SPM values exceeded the long-term limit. However, the indoor night values at Ogbo, Iko station 2, Obrikom station 1 and Port Harcourt station 1 exceeded both short and long-term limits. These values may cause some health concern for both rural and urban population. For instance, studies of the human health effects of air pollution carried out in China showed that air pollution suppresses the immunological function, decreases lung function and increases respiratory symptoms, as well as respiratory disease (Yin, 1993).

The findings of this study agree with the statement that in many rural areas and in most cities, people in developing countries are exposed to a range of local, but strong, sources of SPM (UNEP/WHO, 1995). The rural communities such as Ogbo and Obrikom are more polluted than the urban community, Port Harcourt, while Ugbele served as a control. The results have, therefore, shown that the air quality with respect to SPM concentrations in Ugbele is good while the air quality in the other communities is unhealthy. The situation may be similar in many parts of the country. Therefore, proper monitoring of the air quality is necessary in Nigeria.

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