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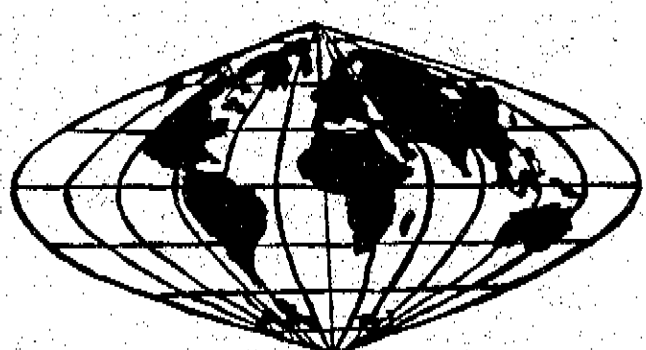
HUMAN EXPOSURE ASSESSMENT LOCATION

HEAL PROJECT

INDOOR AIR QUALITY IN THE BASSE AREA, THE GAMBIA



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SUMMARY

An indoor air pollution study was carried out in the Basse area, The Gambia, in coordination with the MRC laboratories in that country. Part of the study was implemented during the dry season (January 1987), the other part during the rainy season (July/August 1987). The project was linked to a study on Acute Respiratory Infections (ARI) among children in the Basse area. It was the second field study in a WHO programme on indoor air quality related to biomass fuel combustion. The first field study was carried out in the Maragua area, Kenya in 1986 (WHO, 1987).

Repeated 24-hour measurements of suspended particulate matter and nitrogen dioxide were carried out in 18 randomly selected kitchens where most of the cooking was done over traditional open fires using wood as fuel. A similar programme was repeated during the rainy season. In the dry season also hourly measurements were made, in three kitchens, between 6 a.m. and 8 p.m., to observe the daily pollution pattern. During the measurements observations were made on presence of mothers and children near the fire.

The geometric mean of the 24-hour average suspended particulate matter (inspirable fraction) concentrations, in the dry and rainy season, were respectively about 2000 and 2100 ug/m^3, which is higher than the level of 1400 ug/m^3, which was found in the Kenya study. However, it was shown that in The Gambia a substantial proportion of suspended suspended particulate matter comprised larger particles due to a source other than wood smoke, probably sand dust. The concentrations of wood smoke were very high and likely to cause adverse health effects. For nitrogen dioxide similar concentrations were found in The Gambia as in Kenya. The recorded levels of nitrogen dioxide and suspended particles indicate that suspended particles represent a larger health hazard than nitrogen dioxide. Also, the concentrations of selected polycyclic aromatic hydrocarbons in the suspended particulate matter were found to be high.

The air pollution data showed more variance in the rainy season than in the dry season, probably because of varying weather conditions. Analysis of variance showed that, in both seasons the suspended particulate matter concentrations were homogeneously distributed among the kitchens with little variance between the kitchens. Analysis of covariance indicated a relationship between hours of burning and area of ventilation openings and level of air pollution. There was no relationship between season and level of air pollution.

CONTENTS

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2. PREFACE

A review made by WHO some years ago of the scientific literature on indoor air pollution caused by burning biomass fuels for cooking and heating showed that this is a relatively serious problem (WHO, 1984). Not only are the levels of different air pollutants in rural kitchens high but this problem exists in rural areas in Asia, Africa and Latin America and is therefore widespread. It is conservatively estimated that some 500 million persons, mostly women and children, are exposed to levels of indoor air pollution that are well above those considered safe.

The extent and severity of health effects associated with biomass fuel combustion is not well defined and WHO is undertaking a number of field surveys to provide better information and data in this area. To accomplish these surveys, cooperation was developed between the Respiratory Infections Programme and the Unit for Prevention of Environmental Pollution. The indoor air pollution surveys are being carried out in different countries where Acute Respiratory Infection (ARI) studies in children are in progress in order to be able to correlate the data and information produced.

The first field study was carried out in the Maragua district, Kenya in 1986 (WHO, 1987). Houses with corrugated iron or thatched roofs and with internal or detached kitchen arrangements were included in the study. Average levels of respirable suspended particles (RSP) exceeded by 20-fold the recommended level for the general population. The RSP exposure was very homogeneously distributed among the population, so that no differences could be detected in ARI incidence between the children in relation to RSP exposure.

In this document the results of the second WHO study, which comprised air quality measurements made both during the dry and rainy seasons in the Basse area, The Gambia, are reported. The study involved the cooperation of the MRC unit in The Gambia and of the Wageningen Agricultural University, The Netherlands, which carried out the field work.

The ultimate purpose of the field surveys is to consider and evaluate in more detail the health implications of indoor air pollution and to engage the health sector in advocating solutions to eliminate or prevent this type of problem. Such activities will involve the preparation of guideline documents, training of rural health workers and cooperation in international efforts to bring about technological changes such as the introduction of clean stoves, improved housing design and community participation in implementing these changes.

3. INTRODUCTION

Indoor air pollution is being associated increasingly with acute respiratory infections in children. In developing countries, indoor air pollution is mainly due to biomass fuel combustion in dwellings that are often poorly ventilated. Air pollutants from biomass fuel combustion include carbon monoxide (CO), nitrogen dioxide (NO_2), formaldehyde (HCHO) and suspended particulate matter (SPM). The SPM contains polycyclic aromatic hydrocarbons (PAH), some of which are known to be carcinogenic (WHO, 1984).

This indoor air pollution survey was implemented in the Basse area, The Gambia, within the area of a study on the epidemiology and aetiology of Acute Respiratory Infections (ARI), being carried out by the MRC laboratories. One of the objectives of this study is to determine risk factors for ARI (smoke from cooking, nutritional status, vaccination, socio-economic status) among children in a rural community. Three villages and four hamlets about 10 km from Basse have been identified, comprising 500 under 5 year old children (total population about 3000) and representing the two major ethnic groups in the region, Mandinkas and Fullas. The population has been fully censused and nutritional status, vaccination and socio-economic data have been collected. Each child is visited weekly by a resident field worker and a morbidity questionnaire is completed. Children suspected of having an ARI episode are referred to the project physician at Basse. All villages and hamlets consist of a number of compounds, each usually inhabited by one family. Each compound consists of several traditional huts, one of which is used as kitchen. A typical example of a compound is given in figure 1.

Figure 1 Typical example of a compound

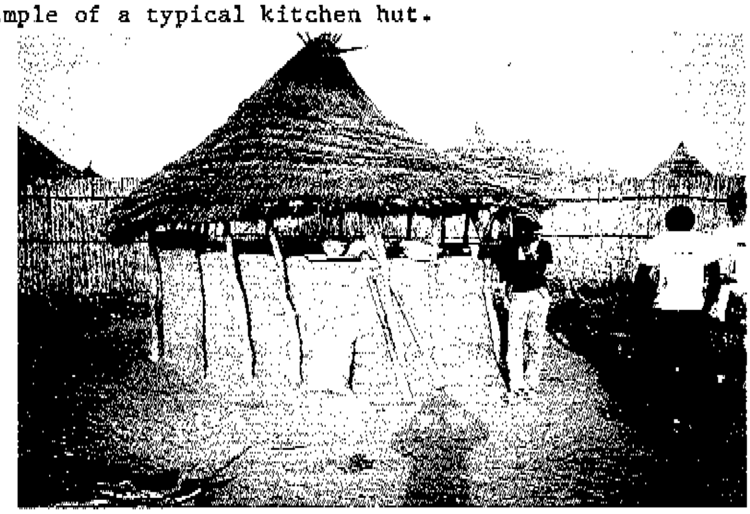
Some data of the villages which were included in the indoor air pollution study are given in table 1.

Table 1 Villages included in the indoor air pollution study

Village	number compounds	number huts	number inhabitants
Tamba-sensan	71	189	950
Kundam-demba	11	118	264
Badari	22	134	448

The kitchen huts generally have dirt floors, mud walls and thatched roofs with a ventilation gap between the wall and the roof. An example of a cooking hut is given in figure 2.

Figure 2 Example of a typical kitchen hut.



All cooking is done on traditional three stones fires using wood for fuel. During the dry season about two thirds of the cooking is done inside, while during the rainy season almost all cooking is carried out inside. The wives of the family take turns preparing food for the whole family. An infant is only near the fire when carried on the back of the mother. Older children generally are not allowed to enter the kitchen. During the rainy season, however, children were sometimes observed in the kitchen.

4. OBJECTIVES OF THE STUDY

- Measure various air pollutants associated with biomass fuel combustion as indicators of air pollution levels in a representative number of kitchens;
- Evaluate the main factors contributing to high indoor air pollution exposure for children aged below five years; and women
- Explore the feasibility of assessment of the relationship between the level of indoor air pollution and the incidence of Acute Respiratory Infections in children.

5. SELECTION OF THE KITCHENS

In the dry season after an initial visit to all villages and hamlets which were included in the ARI study, 3 villages, considered to be representative and to have enough families, were selected. The villages were Tamba-sensan and Badari, both belonging to the Mandinka tribe and Kundam-demba belonging to the Fulla tribe. In each village 6 kitchens were chosen randomly. In the rainy season the same or comparable (three cases) kitchens were selected.

6. STUDY DESIGN

The air pollution survey in the dry season had two components, 24-hour average measurements and daily polution pattern measurements. The survey in the rainy season only had the first component.

6.1. 24-hour average measurements

In all 18 kitchens 24-hour average measurements for suspended particulate matter and nitrogen dioxide were performed twice with an interval between the two measurements of about one week. For measuring the suspended particulate matter the pump/filter technique followed by weighing was used. Dupont P2500 constant flow units were used as pumps. These pumps have an electronic flow correction to compensate for increasing resistance due to filter loading. Extra batteries were installed (5V, 4Ah) to allow a sampling time of 24 hours. The flow of the pumps was checked with a Brooks flowrator (type R-6-15-A, glass), at the beginning and at the end of each sampling period. The flowrator was calibrated against a soapbubble meter.

PAS-6 filter holders were used as sampling heads with glass fibre filters (Whatman GF/A, 2.5 cm diameter) and a flow of 2 liters per minute. The PAS-6 sampling head measures particles in the inspirable range that have a 50 % cut off diameter of about 30 um (ISO, 1981, 1983). For comparison 6 measurements were performed with a 10 mm Casella cyclone as sampling head, which measures the respirable particles. Respirable particles are defined as having a 50% cut off diameter of 5 um (ISO, 1981, 1983). Weighing of the filters before and after sampling was performed with a digital microbalance.

The pump and extra battery were installed in a wooden box for protection and noise reduction. Attached to this box was an aluminium pole through which the sampling tube was led to the filter holder. The sampling heigth was 80 cm, corresponding with breathing height of women during the preparation of the meal.

In 13 filters sampled during the dry season, the amount of polycyclic aromatic hydrocarbons (PAHs) was determined by the Dutch standard method (NVN 2798, 1986). The filters were kept in the dark at ambient temperatures for about two weeks before they were put in a refrigerator at -18 C for a period of about 4 weeks before analysis. The filters were extracted in cyclohexane under ultrasonification. Aliquots of the extracts were injected into a liquid chromatograph with a Vydac 201 TP-B5 column and the PAHs were detected by fluorescence (254 nm). Only the less volatile PAHs (4 rings or more) have been analysed as the more volatile ones tend to evaporate from the filters and carcinogenicity for the individual compounds is only found for the less volatile PAH (IARC, 1983).

The NO_2 was measured with Palmes diffusion tubes used in duplicate pairs. During sampling atmospheric NO_2 is transferred from the open end of the tube to the absorbent triethanolamine at the closed end by molecular diffusion. After adding "Saltzmann" reagent the solution is analysed spectrophotometrically (540 nm). The method has been described in detail by Boleij et al. (1986). The tubes were placed on the same support to which the PAS-6 filterholder was attached and at the same measuring height.

During the 24-hour measuring period two families were observed by one field worker to record the presence of the mothers and children aged under five near the fire. Finally, some characteristics of the kitchens, like surface area and ventilation openings (door, window and gap between wall and roof), were recorded.

6.2. Daily pollution pattern measurements

To observe the variations in concentrations during the day, measurements of carbon monoxide, carbon dioxide and respirable particles were carried out in three kitchens each hour between 6 a.m. and 8 p.m. during the dry season. In addition, observations on people´s activities were made.

The respirable particles were measured using a direct reading piezobalance instrument (Thermo Systems Inc., model 3500 Respirable Aerosol Mass Monitor). The principle of this instrument is based on a change in vibration frequency of a crystal after loading with particles from a known amount of air. The particles are precipitated electrostatically on the cristal after pre-separation by a cyclone.

The carbon monoxide and carbon dioxide concentrations were measured with Drager indicator tubes and a hand operated pump (CO: CH25601, CO_2: CH 30801). With the pump a fixed amount of air can be pulled through the tube filled with an absorbent and a reagent giving a colour reaction. For direct reading a scale has been printed on the tubes. The relative standard deviation of the method is 10-20 percent. Occasionally, during the dry season, the same measurements were performed during the house visits for the 24-hour average measurements.

6.3. Quality Control

For measuring suspended particulate matter constant flow pumps were used. The flow was checked at the beginning and the end of the measurements. After 24 hours all flows were within 10 % of the original flows. To evaluate the precision of the suspended particle measurements, duplicate amples were taken in 7 kitchens during the dry and rainy seasons. This resulted in total coefficients of variation (CV_t) of respectively 6.5 and 5.2 %.

Based on six duplicate measurements (including sampling) of the various PAH, an average CV_t of 30% was found (see also table 6).

All NO_2 measurements were done in duplicate, which resulted in an overall CV_t of 6 and 11 % respectively for the dry and rainy seasons.

7. FIELDWORK

The equipment was prepared, charged and stored in a laboratory at the MRC field station, Basse, from where the fieldwork of the ARI study was carried out. Filters and Palmes tubes were also stored there after sampling. The local ARI field workers, who work in these villages, made the necessary arrangements with the families prior to the first installation of the equipment. They also assisted with the fieldwork and especially with collecting information on the duration of the fire, the time the mother spent cooking and the time that children were near the fire. The field workers stayed in the villages during the 24 hours that the measurements were being made. For the 24-hour average measurements measuring units were placed in six kitchens one day, and collected the next day. This was done by one team worker of the Wageningen Agricultural University, with generally the assistance of two local field workers. The time schedules for the dry and rainy season are given in tables 2a and 2b.

Table 2a Time schedule for the field work during the dry season

	1st visit	2nd visit
Placing equipment in 6 kitchens in Kundam-demba	Fr 30/01/87	Th 12/01/87
Collecting equipment from 6 kitchens in Kundam-demba	Sa 31/01/87	Fr 13/02/87
Placing equipment in 6 kitchens in Badari	Su 01/02/87	Tu 10/02/87
Collecting equipment from 6 kitchens in Badari	Mo 02/02/87	We 11/02/87
Placing equipment in 6 kitchens in Tamba-sensan	Tu 03/02/87	Sa 07/02/87
Collecting equipment from 6 kitchens in Tamba-sensan	We 04/02/87	Su 08/02/87

Table 2b Time schedule for the field work during the rainy season

	1st visit	2nd visit
Placing equipment in 6 kitchens in Kundam-demba	Fr 10/07/87	Fr 17/07/87
Collecting equipment from 6 kitchens in Kundam-demba	Sa 11/07/87	Sa 18/07/87
Placing equipment in 6 kitchens in Badari	Wo 15/07/87	Wo 22/07/87
Collecting equipment from 6 kitchens in Badari	Th 16/07/87	Th 23/07/87
Placing equipment in 6 kitchens in Tamba-sensan	Mo 20/07/87	Th 30/07/87
Collecting equipment from 6 kitchens in Tamba-sensan	Tu 21/07/87	Fr 31/07/87

In this way a total of 18 kitchens was monitored twice, once in the dry and once during the rainy season.

8. RESULTS

Detailed information on the characteristics of the kitchen, the family, the time budgets and the individual measurements of the 24-hour program are given in appendix I. A summary of this information is presented in table 3.

Table 3 Summary of characteristics of the kitchen, the family and exposure time

Characteristics	Season (1)	Mean	Standard Deviation
Door and window area (m^2)	Dry	1.2	0.4
	Wet	1.2	0.3
Ventilation gap between wall and roof(m^2)	Dry	2.9	2.5
	Wet	2.7	2.6
Kitchen area (m^2)	Dry	11.0	3.1
	Wet	10.6	2.8
Number of huts in the compound	Dry	7.4	5.8
	Wet	6.4	3.3
Number of persons in the compound	Dry	19.2	13.3
	Wet	17.5	10.3
Number of children in the compound participating in the ARI study	Dry	2.8	2.2
	Wet	2.4	2.0
Burning hours	Dry	7.8	2.2
	Wet	7.0	2.0
Presence mother near fire (h) (2)	Dry	4.1	1.5
	Wet	3.3	1.3
Presence child near fire (h) (3)	Dry	1.8	1.2
	Wet	1.5	0.9

(1) In the rainy season in three cases different kitchens were selected
(2) Mostly different persons for each season
(3) Means are calculated without the 14 and 9 cases,respectively, for the dry and wet season without any children near the fire

8.1 24-hour average suspended particles data

8.1.1 Comparison between respirable and inspirable particle measurements

For this study all particle measurements were made using the PAS-6 method, which samples a fairly wide range of inspirable particles (less than 30 um cut off). In terms of respiratory health effects it is also the most relevant fraction. For comparison, however, a small sample of respirable particle (less than 5 um cut off) measurements were made, as combustion sources generally emit particles in that size range. In the dry and rainy season respectively 6 and 12 randomly selected 24-hour measurements were performed. The results are given in tables 4a and 4b.

Table 4a Comparison between inspirable and respirable measurements in 6 kitchens during the dry season.

House number	Inspirable particles conc. (ug/m^3)	Respirable particles conc. (ug/m^3)	ratio
148	4843	1926	0.40
142	3196	2523	0.79
150	1716	660	0.38
135	1493	741	0.50
322	1898	1234	0.65
210	1135	400	0.35

Table 4b Comparison between inspirable and respirable measurements in 12 kitchens during the rainy season.

House number	Inspirable particles conc. (ug/m^3)	Respirable particle conc. (ug/m^3)	ratio
128	1173	718	0.61
130	1561	860	0.55
135	1009	757	0.75
201	1861	963	0.52
201	2392	1241	0.52
203	2188	1266	0.58
209	1198	808	0.67
308	1461	1154	0.79
313	2742	1764	0.64
314	1600	732	0.46
314	2621	840	0.32
320	1235	467	0.38

The results in tables 4a and 4b show:

- the inspirable fractions are greater than the respirable fractions indicating that at The Gambia location particle sources other than combustion are present. In the Kenyan study (WHO, 1987) it was shown that all particles were in the respirable range;
- as might be expected, particle concentrations in the air are generally higher during the dry season;
- particle concentrations are well above the acceptable norms for the protection of health.

8.1.2. Summary statistics and analysis of variance

Complete data sets of repeated measurements are available for all 18 kitchens. The results of the dry and rainy season are summarized in tables 5a and 5b. The individual data are given in appendix I.

Table 5a Results of 24-hour average particle measurements of suspended particles (inspirable fraction) in 18 kitchens during the dry season (in ug/m^3).

	n	AM	SD	GM	GSD	min	max
all kitchens	36	2013	783	1860	1.5	675	3444
visit 1	18	2124	767	1992	1.5	1097	3444
visit 2	18	1901	806	1736	1.6	675	3361
Tamba-sensan	12	2264	618	2184	1.3	1205	3444
Kundam-demba	12	945	942	1733	1.7	675	3427
Badari	12	1828	757	1700	1.5	1026	3361

Table 5b Results of 24-hour average particle measurements of suspended particles (inspirable fraction) in 18 kitchens during the rainy season (in ug/m^3).

	n	AM	SD	GM	GSD	min	max
all kitchens	36	2112	1264	1761	2.1	152	6209
visit 1	18	2105	1147	1843	1.7	734	4392
visit 2	18	2136	1406	1683	2.3	152	6209
Tamba-sensan	12	1884	1448	1588	1.8	734	6209
Kundam-demba	12	2371	1213	2053	1.8	742	4392
Badari	12	2107	1178	*	*	152	4088

n = number
AM = Arithmetic mean
SD = Standard deviation of the AM
GM = Geometric mean
GSD = Geometric Standard Deviation
max = maximum
min = minimum
* = not lognormally distributed

The results presented in tables 5a and 5b show that:

- average particle concentrations tend to be about the same, around 2000 ug/m^3, during both the dry and the rainy season;

- extreme concentrations, both the minimum and maximum levels are very different in the two seasons. During the rainy season lows of around 150 ug/m^3 are reached while the highs attain values of around 6200 ug/m^3. During the dry season extreme values range from around 600 to 3500 ug/m^3.

The statistical analysis SAS Institute Inc. 1985) showed the suspended particle concentrations to be log-normally distributed during the dry season but not during the rainy season. During the rainy season, however, concentrations were log-normally distributed if the measurements with zero burning hours were eliminated. Analysis of the log-transformed data from the two seasons indicated that only about 30% of the total variance was caused by differences among the kitchens and about 70% was due to differences between days.

8.1.3 Chemical analysis of suspended particles

Thirteen randomly chosen filters collected during the dry season loaded with suspended particles were analysed for PAH content. The results are summarized in table 6.

Table 6 Average PAH concentrations of 13 suspended particle samples

			filter load		air concentrations (1)		
Compound	CV_t (2)	n	AM (ug/g)	SD	AM (ng/m^3)	min (ng/m^3)	max (ng/m^3)
1 Fluoranthene	28	13	81	74	163	55	279
2 Pyrene	4	12	160	153	322	108	551
3 Benzo(a)anthracene	26	12	147	104	296	99	506
4 Chrysene	17	13	113	69	227	76	389
5 Benzo (b fluoranthene	40	13	74	43	149	50	255
6 Benzo (k) fluoranthene	27	13	34	17	68	23	117
7 Benzo (a) pyrene	32	13	102	48	205	69	351
8 Benzo (ghi) perylene	33	13	246	239	495	166	847
9 Dibenzo (a,h) anthracene	36	13	149	145	300	101	513
10 Indeno (1,2,3-cd) pyrene	60	13	69	66	139	47	238

(1) Air concentrations were calculated on the basis of the m an PAH content of the 13 loaded filters and the mean, maximum a d minimum of the complete data set of suspended particle concentrations.

(2) Total coefficient of variation on the basis of six duplicate measurements (including sampling).

8.2 24-hour average NO_2 data

Complete data sets were available for all 18 kitchens. The results of the dry and rainy seasons are summarized in tables 7a and 7b. Individual data are given in appendix I.

Table 7a Results of 24-hour average measurements of NO_2 in 18 kitchens (in ug/m^3) during the dry season

	n	AM	SD	GM	GSD	min	max
all kitchens	36	132	70	114	1,8	20	338
visit 1	18	133	60	120	1,6	47	270
visit 2	18	131	81	108	2,0	20	338
Tamba-sensan	12	137	55	129	1,4	78	270
Kundam-demba	12	141	88	114	2,1	20	338
Badari	12	117	67	101	1,8	43	262

Table 7b Results of 24-hour average measurements of NO_2 in 18 kitchens (in ug/m^3) during the rainy season.

	n	AM	SD	GM	GSD	min	max
all kitchens	36	160	113	125	2.1	15	494
visit 1	18	162	114	134	1.8	52	494
visit 2	18	156	113	116	2.4	15	432
Tamba-sensan	12	159	97	141	1.6	86	432
Kundam-demba	12	224	138	117	2.2	51	494
Badari	12	96	61	77	2.1	15	203

n = number
AM = Arithmetic mean
SD = Standard deviation of the AM
GM = Geometric mean
GSD = Geometric standard deviation
max = maximum
min = minimum

The results presented in tables 7a and 7b indicate that:

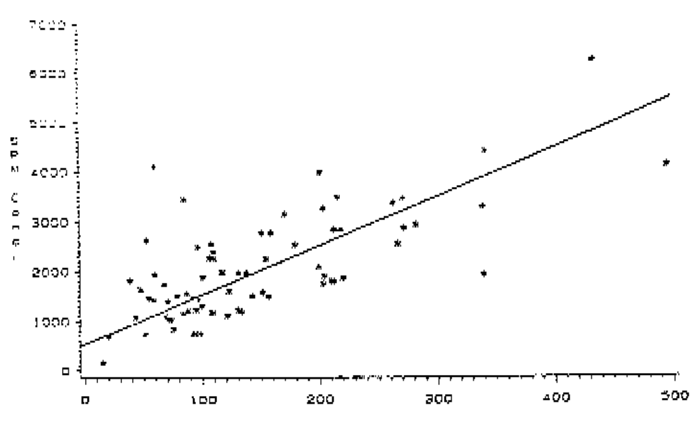
- average NO_2 concentrations in kitchens tend to be slightly higher during the rainy season when compared with the data obtained during the dry season;

- the minimum and maximum values are somwehat further apart during the rainy season but this situation is not as extreme as for the suspended particles (section 8.1.2).

Statistical analysis SAS Institute Inc., 1985) showed that NO_2 concentrations during the dry and rainy seasons to be lognormally distributed. Analysis of variance of the logtransformed data showed that during the dry season 22% of the total variance was due to diffeerences between kitchens while during the rainy season it is 66%. The remainder in each case, 78% and 34% was caused by differences between days.

8.3 Correlation between suspended particle (inspirable fraction) and NO_2 concentrations

Figure 3. Relation between suspended particle and NO_2 concentrations (both ug/m^3)



Regression analysis of the logtransformed data showed a correlation coefficent of 0.70. Based on the relation between suspended particle and NO_2 concentrations, a predicted value can be calculated for the suspended particle concentration from NO_2 measurements. The predicted value and the 95 percent prediction interval for the suspended particle concentration based on 1 and 10 NO_2 measurements for the lowest and highest NO_2 level, in this study, are given in table 8.

Table 8 Predicted value and 95 percent prediction interval for the suspended particle concentration based on 1 and 10 NO_2 measurements (in ug/m^3) for the highest and lowest NO_2 level in this study.

NO_2 level	n	predicted value	95 % prediction interval for the suspended particle concentration
15	1	540	100 - 2926
494	1	4151	292 - 58927
15	10	540	124 - 2475
494	10	4151	1492 - 12123

n = number of measurements

8.4 Daily pollution pattern measurements

During the dry season hourly measurements and observations were made in three kitchens in the village Tamba-sensan. The results of one kitchen are given in table 9. The results of the other two kitchens are similar.

Table 9 Results of hourly measurements and observations in a kitchen in Tamba-sensan

Time of day	fire condition	presence mother and child	food prepared	CO (ppm)	CO_2 (%)	suspended particles (ug/m^3)
6.00	no	-	-	-	-	180
7.10	high	-	coos	7	0.04	800
8.05	low	m	-	5	0.05	220
9.05	low	-	-	-	0.05	360
10.00	low	-	-	4	0.05	230
11.05	no	-	-	0	0.04	90
12.00	high	m/c	beans	7	0.10	1650
13.05	low	-	-	5	0.09	1060
14.00	low	m	water	-	0.06	850
16.00	high	m	groundnuts	5	0.20	1740
17.05	high	m	-	10	0.12	300
18.05	high	m	coos	5	0.04	660
19.00	moderate	-	sauce	10	0.08	270

The results shown in table 9 are quite similar to those obtained in Kenya (WHO, 1986). The CO and CO_2 concentrations, although somewhat elevated, are not much above normal background levels. The suspended particulate matter levels are also quite similar reaching higher levels when the fire is burning vigorously. The levels of suspended particulate matter are high and are liable to cause adverse health effects.

8.5 Correlation between 24-hour average pollution levels and other characteristics.

Analysis of covariance (SAS Insitute Inc., 1985) was performed with the logtransformed suspended particle and NO_2 concentrations as dependent variables in various models with the following characteristics as independent variables: village (3 levels), visit (2 levels), burning hours, season, total ventilation area (doors, windows and gap between roof and wall), kitchen area, number of huts in the compound, number of persons in the compound and number of children in the compound. Only burning hours and total ventilation area showed significant relationships with airpollution levels. Also, for NO_2 the dependent variable village showed a significant effect. The intercept, regression coefficients, standard errors and confidence levels are given in tables 10a and 10b for the model of suspended particle and NO_2 concentration with village, burning hours and total ventilation area.

Table 10a Differences in mean logtransformed suspended particle concentration, of the combined dry and rainy season data, for village 1 (Tamba-sensan) and village 2 (Kundam-demba) as compared to village 3 (Badari) and regression coefficients (b), standard errors (SEb) and confidence levels for burning hours and total ventilation area (Df=67, F=6.16, R^2=0.28, p=0.003).

	b	SEb	p
intercept	2.934	0.104	<0.01
village 1	0.171	0.095	0.08
village 2	0.032	0.013	0.61
burning hours	0.058	0.018	<0.01
ventilation area	-0.048	0.018	<0.05

Table 10b Differences in mean logtransformed NO_2 concentration, of the combined dry and rainy season data, for village 1 (Tamba-sensan) and village 2 (Kundam-demba) as compared to village 3 (Badari) and regression coefficients (b), standard errors (SEb) and confidence levels for burning hours and total ventilation area (Df=67, F=10.03 R^2=0.39, p=0.0001).

	b	SEb	p
intercept	1.588	0.114	<0.01
village 1	0.331	0.104	<0.01
village 2	0.186	0.069	<0.01
burning hours	0.072	0.014	<0.01
ventilation area	-0.052	0.020	0.01

9. DISCUSSION AND CONCLUSIONS

The results of the indoor air pollution measurements carried out by WHO are summarized in table 11.

Table 11. Indoor air pollution concentrations in Kenya (WHO 1987) and The Gambia

Country	Season	Susp. Part. Mean Conc. (ug/m^3)	NO_2 Mean Conc. (ug/m^3)
Kenya	Rainy	1397	169
The Gambia	Dry	2013	132
The Gambia	Rainy	2112	160

The data compiled in table 11 show that indoor NO_2 levels in Kenya and The Gambia are quite similar, in the order of 150 ug/m^3. Judged against the WHO maximum 24-hour guideline of 150 ug/m^3, this is quite high and may cause difficulties to sensitive segments of the population. The indoor suspended particulate matter levels are higher in The Gambia. This is most probably due to the presence of higher levels of naturally occurring dust in the air in The Gambia. The levels of respirable dust, caused by combustion of fuel, are about equal in Kenya and The Gambia. The upper limit for black smoke, as defined by the appropriate WHO guideline, is 100-150 ug/m^3. Although not entirely applicable, comparison with this guideline shows that suspended particulate matter levels in The Gambia, as well as in Kenya, frequently exceed this guideline more than tenfold.

The daily pollution pattern measurements, in the dry season, showed the highest concentrations under high burning conditions of the cooking fires. This is significant because it is the time when the women and children are likely to be near the fire and thus exposed to peak concentrations. The observations of the fieldworkers during the 24-hour measuring period for each kitchen, in the dry and rainy season, showed an average presence for the women attending the fire of 4.1 and 3.3 hours per day, respectively. Because more women were available in each compound and they took their turns preparing the food, women were not exposed as constantly as was the case in the Kenyan study (WHO, 1987) where they were exposed for about 4 hours each day. In the dry and rainy season in respectively 61 and 74% of the 24-hour measuring periods children were observed in the kitchen. The average presence of children near the fire was 1.8 and 1.5 hours per day respectively. This also represents a lower exposure than in the Kenya study where each child under the age of 5 was exposed for about 4 hours each day.

The CO concentrations found during cooking are much lower than recorded in other studies in developing countries (WHO, 1984, p.19). This might be due to differences in sampling locations. We were able to measure much higher concentrations directly above the fire in the smoke plume. However, these concentrations are not likely to be inhaled as people tend to avoid direct inhalation of smoke. The CO_2 concentrations were between 0.04 % and 0.20 %, which is similar to the Kenya situation (WHO, 1987). This indicates a relatively high ventilation rate.

Analysis of covariance for NO_2 and suspended particles showed an influence of burning hours and total ventilation area on air pollution concentrations. There is no relationship between season and level of air pollution. Several kitchens had no or only a small gap between the wall and the roof. As the negative influence of the ventilation area could be demonstrated, it is advisable to have a large gap because this will result in lower concentrations. For example, when in the village Tamba-sensam the ventilation area is increased from 1 (small gap) to 6 m^2 (large gap) the suspended particle concentration is reduced from 3318 to 1910 ug/m^3 (8 burning hours).

Generally, the PAH concentrations, in the dry season, were very high. Concentrations for some PAH were somewhat lower, for others somewhat higher than in the Kenyan study. This might be due to the different kind of wood which is used as fuel in The Gambia.

There is evidence that the measured PAH (substances 3, 5, 6, 7, 9, 10) are carcinogenic to experimental animals (IARC, 1983). All measured PAH are major components of the total content of PAH in soot. The human carcinogenicity of soot in the form of lung cancer is demonstrated by several cohort studies of mortality among chimneysweeps (IARC, 1985). Although a thorough evaluation of the carcinogenic risk is not possible as all studies so far have been performed in western societies, the levels observed in this survey can be considered as a potential threat to the population.

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Many thanks are due to all employees of the MRC field station in Basse. Fieldworkers, drivers, data-entry clercs and the mechanic made the field work of this project an easy job, the cooperation was extremely good.

Special thanks are due to Harry Campbell, who is in charge of the ARI study. He had arranged the field station to a smoothly running organisation which was completely at our disposal. His advice on the field work and the organisation of it, and his knowledge of the villages and their inhabitants were invaluable.

Of course, we are very grateful to the families that were included in the indoor air pollution study. Their cooperation was perfect and their hospitality great.

Many thanks are also due to the MRC laboratories in Fajara and their director Dr Brian Greenwood, for his stimulating discussions. His staff and especially Richard Bush and Kaity Hill who managed to get us and our equipment transported to Basse after arrival at the airport in Banjul.

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APPENDIX I DRY SEASON

household number	village number	visit number	nitrogendioxide concentration ug/m3	suspended particulate matter conc. ug/m3	burning hours	door/window area m2	ventilation gap m2	kitchen area m2	number of huts	number of persons	number of children	presence mother near fire hr	presence child near fire hr
128	1	1	270	3444	7.8	1.3	0.0	13.0	4	9	2	3.9	1.9
128	1	2	170	3122	8.8	1.3	0.0	13.0	4	9	2	2.2	1.5
123	1	1	130	1964	9.0	0.7	5.0	8.0	4	6	0	4.0	2.0
123	1	2	199	2475	6.7	0.7	5.0	8.0	4	6	0	1.7	1.0
130	1	1	109	2389	6.0	0.7	7.2	9.6	6	18	4	3.0	0.5
130	1	2	109	2249	9.1	0.7	7.2	9.6	6	18	4	2.3	1.0
131	1	1	87	1205	6.5	0.7	5.8	9.1	4	9	2	3.2	0.8
131	1	2	96	2480	6.6	0.7	5.8	9.1	4	9	2	1.6	0.0
134	1	1	107	2547	8.0	1.4	6.3	12.6	1	17	3	4.0	4.0
134	1	2	137	1963	11.0	1.4	6.3	12.6	1	17	3	2.7	0.0
135	1	1	78	1493	8.8	0.7	7.0	10.9	6	19	5	2.2	2.0
135	1	2	154	2238	9.9	0.7	7.0	10.9	6	19	5	4.9	2.5
201	2	1	218	2835	6.9	1.1	4.7	19.6	25	50	7	5.0	0.0
201	2	2	58	1413	7.0	1.1	4.7	19.6	25	59	7	3.5	0.0
203	2	1	212	2838	8.7	1.2	1.3	12.6	14	24	4	4.3	0.0
203	2	2	338	3267	7.1	1.2	1.3	12.6	14	24	4	3.5	1.8
205	2	1	210	1797	10.6	0.8	3.8	12.6	16	53	8	6.4	5.5
205	2	2	20	675	0.0	0.8	3.8	12.6	16	53	8	3.6	0.9
206	2	1	130	1209	8.6	1.4	0.6	9.6	5	6	0	5.7	3.2
206	2	2	133	1177	7.4	1.4	0.6	9.6	5	6	0	5.9	0.0
209	2	1	99	1302	6.0	0.9	0.6	9.6	7	16	0	5.3	0.0
209	2	2	106	2266	8.2	0.3	0.6	9.6	7	16	0	7.5	0.0
210	2	1	84	3427	9.0	1.4	1.1	9.6	11	26	2	6.8	0.0
210	2	2	83	1135	7.5	1.4	1.1	9.6	11	26	2	3.8	0.0
309	3	1	59	1932	6.2	1.3	0.6	9.6	4	13	2	4.5	0.0
308	3	2	43	1069	4.4	1.3	0.6	9.6	4	13	2	3.9	2.3
309	3	1	158	2760	6.8	1.3	0.5	7.1	4	9	2	4.3	0.0
309	3	2	262	3361	4.2	1.3	0.5	7.1	4	9	2	2.5	0.0
315	3	1	122	1604	9.3	1.5	1.4	10.2	5	11	1	6.0	0.3
315	3	2	96	1427	6.6	1.5	1.4	10.2	5	11	1	3.8	1.0
316	3	1	121	1097	11.6	2.4	0.8	16.0	8	26	4	5.8	0.3
316	3	2	73	1026	7.5	2.4	0.8	16.0	8	26	4	3.8	1.9
320	3	1	47	1636	6.0	1.6	2.6	8.3	4	15	2	2.0	0.0
320	3	2	70	1376	9.3	1.6	2.6	8.3	4	15	2	4.0	2.0
322	3	1	150	2756	10.8	1.7	2.7	9.4	5	18	3	6.0	0.8
322	3	2	204	1898	11.2	1.7	2.7	9.4	5	18	3	6.2	1.5

village number: 1='Tamba-sensan' 2='Kundam-demba' 3='Badari'

CONTINUATION OF APPENDIX I RAINY SEASON

household number	village number	visit number	nitrogendioxide concentration ug/m3	suspended particulate matter conc. ug/m3	burning hours	door/window area m2	ventilation gap m2	kitchen area m2	number of huts	number of persons	number of children	presence mother near fire hr	presence child near fire hr
128	1	1	203	1745	5.6	.	.	.	4	9	2	2.3	0.5
128	1	2	108	1173	6.2	.	.	.	4	9	2	2.4	0.9
129	1	1	100	1367	9.0	.	.	.	2	6	0	2.0	2.0
129	1	2	179	2513	6.0	.	.	.	2	6	0	3.0	5.2
130	1	1	151	1561	7.1	0.7	7.2	9.6	6	18	4	3.6	0.6
130	1	2	212	1792	7.1	0.7	7.2	9.6	6	18	4	3.5	0.7
131	1	1	94	1220	7.4	0.7	5.8	9.1	4	9	2	3.6	2.1
131	1	2	86	1555	6.4	0.7	5.8	9.1	4	9	2	4.3	1.9
134	1	1	156	1485	7.4	1.4	6.3	12.6	6	18	3	4.6	1.6
134	1	2	432	6209	8.4	1.4	6.3	12.6	6	18	3	4.1	1.7
135	1	1	92	734	5.8	0.7	7.0	10.9	6	19	5	3.2	2.1
135	1	2	98	743	7.8	0.7	7.0	10.9	6	19	5	5.0	2.2
201	2	1	215	3467	12.9	1.1	4.7	19.6	13	50	7	7.0	0.0
201	2	2	220	1861	9.2	1.1	4.7	19.6	13	50	7	4.3	3.2
203	2	1	340	4392	7.2	1.2	1.3	12.6	14	25	4	4.3	1.9
203	2	2	271	2854	8.3	1.2	1.3	12.6	14	25	4	2.2	1.9
206	2	1	75	832	4.8	1.4	0.6	9.6	4	6	0	2.0	0.0
206	2	2	51	742	7.1	1.4	0.6	9.6	4	6	0	3.8	0.0
207	2	1	67	1740	7.6	1.0	1.9	9.5	9	18	.	4.3	3.1
207	2	2	68	1110	4.2	1.0	1.9	9.5	9	18	.	3.0	2.1
209	2	1	494	4064	7.7	0.9	0.6	9.6	7	18	0	4.7	0.0
209	2	2	266	2542	6.7	0.9	0.6	9.6	7	18	0	2.4	0.0
210	2	1	281	2917	9.4	1.4	1.1	9.6	11	27	2	5.9	3.6
210	2	2	339	1930	7.3	1.4	1.1	9.6	11	27	2	2.2	1.3
308	3	1	91	1461	7.0	1.3	0.6	9.6	5	13	2	1.8	1.1
308	3	2	59	4088	6.4	1.3	0.6	9.6	5	13	2	2.2	0.0
309	3	1	116	1993	5.5	1.3	0.5	7.1	4	9	2	2.9	0.3
309	3	2	142	1498	6.3	1.3	0.5	7.1	4	9	2	3.5	0.9
313	3	1	200	2966	9.1	1.8	0.0	11.9	5	26	.	4.8	1.7
313	3	2	203	3247	6.4	1.8	0.0	11.9	5	26	.	2.9	0.9
314	3	1	70	1026	5.8	0.9	1.8	10.5	6	17	.	2.6	0.0
314	3	2	52	2621	5.3	0.9	1.8	10.5	6	17	.	1.9	0.0
315	3	1	116	1975	6.7	1.5	1.4	10.2	5	12	1	3.0	1.0
315	3	2	15	152	0.0	1.5	1.4	10.2	5	12	1	0.0	0.0
320	3	1	54	1457	7.1	1.6	2.6	8.3	4	15	2	2.7	1.1
320	3	2	38	1812	7.7	1.6	2.6	8.3	4	15	2	4.5	0.9

village number: 1='Tamba-sensan' 2='Kundam-demba' 3='Badari'

CONTINUATION OF APPENDIX I RAINY SEASON

household number	village number	visit number	nitrogendioxide concentration ug/m3	suspended particulate matter conc. ug/m3	burning hours	door/window area m2	ventilation gap m2	kitchen area m2	number of huts	number of persons	number of children	presence mother near fire hr	presence child near fire hr
128	1	1	203	1745	5.5	.	.	.	4	3	2	2.2	1.5
128	1	2	105	1173	6.6	.	.	.	4	3	2	2.4	0.3
129	1	1	100	1987	9.0	.	.	.	2	6	0	2.0	0.4
129	1	2	179	2512	6.0	.	.	.	2	6	0	3.0	0.4
130	1	1	151	1561	7.1	0.7	7.2	9.6	6	18	4	3.6	0.6
130	1	2	212	1792	7.1	0.7	7.2	9.6	6	18	4	3.5	0.7
131	1	1	94	1220	7.4	0.7	5.8	9.1	4	9	2	3.6	2.1
131	1	2	86	1555	6.4	0.7	5.8	9.1	4	9	2	4.3	1.9
134	1	1	156	1465	7.4	1.4	6.3	12.6	6	18	3	4.6	1.6
134	1	2	432	6209	8.4	1.4	6.3	12.6	6	18	3	4.1	1.7
135	1	1	92	754	5.9	0.7	7.0	10.9	6	19	5	3.3	2.1
135	1	2	96	743	7.8	0.7	7.0	10.9	6	19	5	5.0	2.2
201	2	1	215	3467	12.9	1.1	4.7	19.6	13	50	7	7.0	0.0
201	2	2	220	1863	9.2	1.1	4.7	19.6	13	50	7	4.3	3.2
203	2	1	340	4292	7.2	1.2	1.3	12.6	14	25	4	4.3	1.8
203	2	2	271	2254	8.3	1.2	1.3	12.6	14	25	4	2.2	1.9
206	2	1	75	832	4.8	1.4	0.6	9.6	4	6	0	2.0	0.0
206	2	2	51	742	7.1	1.4	0.6	9.6	4	6	0	3.8	0.0
207	2	1	67	1740	7.6	1.0	1.9	9.5	9	18	.	4.3	2.1
207	2	2	63	1110	4.2	1.0	1.9	9.5	9	18	.	3.0	2.1
209	2	1	494	4064	7.7	0.9	0.6	9.6	7	18	0	4.7	0.0
209	2	2	266	2542	6.7	0.9	0.6	9.6	7	18	0	2.4	0.0
210	2	1	281	2917	9.4	1.4	1.1	9.6	11	27	2	5.9	2.6
210	2	2	379	1930	7.9	1.4	1.1	9.6	11	27	2	2.2	1.3
308	3	1	91	1461	7.0	1.3	0.6	9.6	5	13	2	1.8	1.1
308	3	2	59	4088	6.4	1.3	0.6	9.6	5	13	2	2.2	0.0
309	3	1	116	1993	5.5	1.3	0.5	7.1	4	9	2	2.9	0.3
309	3	2	142	1498	6.3	1.3	0.5	7.1	4	9	2	3.5	0.9
313	3	1	200	3966	9.1	1.8	0.0	11.9	5	26	.	4.8	1.7
313	3	2	203	3247	6.4	1.8	0.0	11.9	5	26	.	2.9	0.9
314	3	1	70	1026	5.8	0.9	1.8	10.5	6	17	.	2.6	0.0
314	3	2	52	2621	5.3	0.9	1.8	10.5	6	17	.	1.8	0.0
315	3	1	116	1975	6.7	1.5	1.4	10.2	5	12	1	3.0	1.0
315	3	2	15	152	0.0	1.5	1.4	10.2	5	12	1	0.0	0.0
320	3	1	54	1457	7.1	1.6	2.6	3.3	4	15	2	2.7	1.1
320	3	2	38	1312	7.7	1.6	2.6	3.3	4	15	2	4.5	0.9

village number 1='Tamba-sensan' 2='Kundam-demba' 3='Dadari'

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