MONITORING OF SUSPENDED PARTICULATE MATTER (SPM), HEAVY METALS AND OTHER PARAMETERS IN SOME WORKPLACES

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Abstract *-*

This report presents results of measurements of sound levels, chemical analysis of air particulate matter and soil samples from two factories in Nairobi. A preliminary assessment of suspended particulate matter (SPM) in a residential site and its possible impacts on acute respiratory infections (ARI) of children under five years of age is also reported.

Our investigations show that for Factory A, the Soil pH measurements within the Factory were more basic (pH = 8.5) than those collected near a complainant's residence (pH = 7.2). The sound level measurements showed that the maximum noise level recorded was 90 dB. This was at a distance of about 0.5m from the main exhaust vent of the Factory (20 m above ground level). There was a strong "detergent-perfume" odour within and outside the Factory premises especially towards the complainant's side. However, the odour fluctuated. There was also no smoke emissions noticed during the site visits when the factory was operational.

For Factory B, the major source of environmental degradation was drainage and management of the factory effluents. The BOD and COD levels for effluents samples analyzed (<350 mg/L, <450mg/L respectively) are considered high for direct disposal into the municipal sewer system. The wastewater was heavily loaded with particulate matter-total dissolved solids (TDS) (1240-1550) mg/L and the total suspended solids (TSS) (1170-3732) mg/L. All these levels are higher than the recommended Kenyan standards for BOD (<20mg/L), COD (<50mg/L), TDS (<1200mg/L) and TSS (<30mg/L). The soil and sediment samples analyzed contained heavy metals such as chromium, lead, copper, zinc and possible organic compounds. The sediment samples from the bottom of the disposal underground waste tank were contaminated with lead (250-300 μg/g), copper (3.56-4.04)%, total chromium (0.91-0.94)% and zinc (847-940μg/g). The proposed remedy for cleaning up the soil at this site was to remove and stabilize the contaminants in order to reduce the potential for migration of contaminants from soil to ground water, public exposure to contamination and inhalation of dust, direct contact with, or ingestion of contaminated soil particles.

The assessment of suspended particulate matter (SPM) in a residential site was done at Kibera. The SPM data collected over an eight-month period (May-December 1998) had the coarse particles (8.0μm) ranging from 62.4-107.5μm/m^3 whereas the fine particles ranged from 16.2-24.4μm/m^3. The prevalence of ARI cases in 1998 ranged between 29.9% in January to the highest level of 59.6% in June. The total number of children who presented themselves throughout the study period, January-December 1998, was 146. A parallel study of dust sampling was also carried out from January to December 1998 in a typical office environment. Dust levels recorded from the working office environment at the Institute of Nuclear Science was found to range from 0.44 -1.79 μg/cm^2/day.

1. INTRODUCTION

The inappropriate and careless handling of municipal and industrial wastes, including those that are hazardous have often created problems related to human health and environmental degradation. The effective control is therefore of paramount importance for the proper health, environmental protection and natural resources management. This report seeks to identify suspected areas of manufacturing contamination in Nairobi and recommends among others the treatment of the pollutants found. It also presents some preliminary results of suspended particulate matter measurements and their possible effects in acute respiratory incidences in Kibera, Nairobi.

Industrial activities in Nairobi include the following: food and beverages, textiles and clothing, leather products, paper and paper products, printing and publishing, industrial chemicals and plastics, petroleum products, cement, aluminum, iron and steel works, non-ferrous metal works, fabricated metal products, electrical machinery, transport equipment and other miscellaneous products.

A number of government departments handle various components of environmental issues. Consequently, the resources on environmental issues involve cooperation and coordination among different Ministries and intergovernmental bodies. The following presents current local situation:

i) Water pollution regulations are administered by departments of the Ministry of Water Resources. Specific monitoring and enforcement is done by urban municipal authorities. The Ministry is also responsible for ground water exploration and exploitation.

ii) Air pollution studies including outside air quality and vehicle emissions are done on a regular basis by the Institute of Nuclear Science (INS), University of Nairobi. Currently, there are no regulations governing the emission from polluting sources. The INS has been operating air monitoring stations that have provided some data on the status of air quality in Nairobi through IAEA coordinated projects. For these activities, INS has been collaborating with Kenya Meteorological Department (KMD), and the Kenya Medical Research Institute (KEMRI).

iii) Waste management services are provided by the urban municipal authorities. Strict monitoring of industrial effluents is lacking and as such there are no strong mechanisms for enforcement.

iv) The Ministry of Agriculture is responsible for pesticides and other agricultural products used for improving the crop yields. The Ministry has the power to approve or ban usage of pesticides.

v) Occupational health regulations are enforced by the Ministry of Labour. The strict monitoring of chemical exposure is lacking.

vi) Environmental impact assessments for major projects are evaluated by various accredited organizations including NGO's in collaboration with the parent Government Ministries.

Some reported environmental degradation cases include:

- Many factories discharging their industrial waste waters in the domestic water sewerage system or water causes. They also dump their solid wastes at the municipal land fill, open fields but the volume and composition is not known. The present law requires no measurement and analysis of these wastes.

- Occupational health related diseases have been reported in various studies.
- Cases of waterborne diseases have also been reported as a result of inadequate treatment facilitates and contamination of water supply.

2. METHODS

2.1. Sampling

(i) Factory A

Soil samples (n= 7 for Na level measurements; n=4 for pH measurements) were collected (0-15cm depth) randomly within and outside the factory premises and towards the complainant's house (inside the factory, 10m outside the factory perimeter wall towards the complainant's house; 10m away from the boundary of the complainant's residence and also within his residential compound (near the boundary fence with the factory). Polyethylene plastic bags were used for sample storage and transfer to the laboratory. Plastic spatulas were used to avoid trace metal contamination.

Air particulate samples were collected through the PM-10 system [1]. Two filters (0.4 and 8 microns pore diameter) were used to trap the dust particles in the air. The collection sites were within the factory at the packing bay area, conveyor belt/drier area and outside the premises.

Noise level measurements were performed within the Factory at the packing bay area, conveyor belt/drier area, main exhaust stack outlet and outside the premises towards the complainant's homestead. The prevailing weather conditions were also noted.

(ii) Factory B

Sampling was done on the 18th and 28th November 1998 and 10th December 1998 respectively. Samples collected included soil, sediments, swaps, chemical deposits and liquid effluent samples as described below:

(a) *Liquid Samples*

These were collected from an open trench in the open field after being pumped from an overflowing underground waste storage tank. Five (5) samples were collected at 10m intervals within a stretch of about 100m. A further 4 samples were collected during the second visit to the site.

(b) Sediment Samples

Seven (7) soil/sediment samples were collected from the same sites as the liquid samples (MKI/SI -S5/98/18) and a further 4 samples from diverse sites during the second visit namely; MKI/S1/98/28, MKI/S3/98/28, MKI/S5/98/28 and MKI/S6/98/28 from the similar sites of the first visit. Four (4) sediment samples (MKI/SB2, SB3, SB4, and SB5/98/10) were sampled from the bottom of the underground waste storage tank on the 10th December 1998.

(c) Soil samples

These were collected (~500g) randomly from various sites within the factory.

(iii) Suspended Particulate Matter (SPM) Monitoring

(a) Kibera

There were five sampling sites designated A-E covering the lower and the upper part of the area. All the sampling sites were located on the small open spaces between the housing units except for site C at Olympic Primary School which was located on compound partly covered by grass on one side and paved road on the other side. Sampling was done using the "Gent" Stacked Filter Unit (SFU). Fine (0.4μm pore filter) and coarse (8.0μm pore filter) nucleopore membranes were used. Sampling was done for an average of eight hours per day starting at between 8.00 and 9.00 a. m. in the morning and ending at around 4.00 to 5.00 p.m. in the evening. Hence only one sample could be collected in a day. Sampling was started in May and the results are reported up to December 1998. On average two sets of samples were collected per month for all the sites except for site B and E whose frequency was increased to four from September 1998. With each sample the following information was recorded- a number code, type of filter membrane used and month of sampling. For example, sample E185 was collected at site E. One (1) refers to the first sample for that month, 8 refers to the coarse filter (i.e., 8.0 micron pore filter) and 5 refers to the month of May. Other parameters included the start and end time of sampling, the initial and final volume (as read from the meter); rotameter flow rate at the beginning and end of sampling; initial and final pressure (as read from the pressure gauge); weather conditions (i.e., sunny, cloudy etc). After every two weeks of sampling, the SFU was dismantled into the various parts and cleaned thoroughly with ethanol. This was necessary to remove any particles, which may have accumulated.

(b) Dust fallout in a typical office environment

Sampling of dust fallout was done at the Institute of Nuclear Science offices at University of Nairobi. Placing coarse filter (i.e., 8.0-micron filter) in a petri dish, which was thoroughly cleaned with ethanol. The set-ups were left at the top of cabinets in various offices for 34 days for the month of January to April 1998 but from May 1998, the days of exposure were reduced to 20 days.

2.2. Sample Preparations

The samples preparation included oven drying to constant weight at 100°C for 48 hrs, grinding to fine powder of particle size less than 50μm. For each sample, three thin pellets weighing~200mg were prepared for energy dispersive x-ray fluorescence analysis [2-4] while the pH measurements were done through water solution method [5].

2.3. Analysis

(i) Gravimetric Determination of SPM

Filters were weighed in an air-conditioned laboratory using 1 μg sensitivity (Ainsworth Type 24N) weighing balance before and after sampling. The balance pan was wiped clean with a piece of cotton wool soaked in ethanol. This was necessary to ensure the filters were not contaminated by dust particles, which may have accumulated. Prior to weighing all filters were left to equilibrate for 24 hours in the weighing room and irradiated with ^{241}Am α-emitting source (5μCi) to remove the static build up before and after sampling. Filter loading on the SFU was done indoor (i.e., in the air-conditioned laboratory). Loaded filters were stored prior to analysis in thoroughly cleaned Millipore petri dishes. The method provides satisfactory results, with less than 1% loss of the material [1]. All the filter handling

was done using plastic tweezers to avoid contamination by grease from fingers and by heavy metals if metallic tweezers were used.

(ii) Heavy metal Determination by X-ray fluorescence analysis

Solid sample materials (soil and air particulate) were analyzed by energy dispersive X-ray fluorescence (EDXRF) method after appropriate sample preparation [1,4]. The x-ray fluorescence spectrometer used consists of: Canberra Si (Li) detector, radioisotope excitation sources- ^{109}Cd (4.8mCi-1/8/97), ^{55}Fe (0.08mCi-1/8/97) and associated electronics interfaced to a personal computer with appropriate software for spectral data storage and quantitative analysis [2,4]. The detector resolution was 190 eV for the Mn-K_α line at 5.9 KeV. Evaluation of the elemental concentration was done according to fundamental parameter technique algorithm [3]. A Canberra S-100 PC based multi-channel analyser (MCA) was used for spectral data acquisition and storage. Both the coarse and fine loaded filters were irradiated at between 50, 00 to 60,000 seconds using ^{109}Cd source to give reasonable statistical accuracy. The loaded filters were placed on the sample holder such that the loaded side faced the source of radiation as per the recommended method [3]. Spectrum data analysis was done using the IAEA software, Analysis of X-rays by Iterative Least square fitting (AXIL) which is based on a non-linear least square fitting procedure for optimization of the fitting model (energy and resolution calibration, peak intensities and background parameters) for each spectrum. Quantitative analysis was done using quantitative analysis of environmental samples (QAES) software, which relates the spectral intensities with the elemental concentrations, based on the fundamental parameter technique [3].

(iii) Noise Measurements

These were performed by use of a Precision Sound level Meter, Type 2206, with weighting "A" so as to mimic the human ear frequency set on fast response [8]. The prevailing weather conditions such as temperature, wind direction and rain were also recorded.

(iv) Total dissolved solids were determined as residue after evaporation of the sample at 105^0C.

(v) Total suspended solids were determined on the original crude sample after filtering on ashless Whatman #42 filter from the residue at 105^0C.

(vi) BOD and COD determination

BOD is a parameter of organic pollution applied to wastewater and surface water. This determination involves measurement of the dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter at the sampling and after 5 days incubation period. COD is the measure for organic matter in industrial and municipal wastes that contain compounds, which are toxic to biological life.

3. RESULTS AND DISCUSSIONS

The results of Factory A are shown in Tables I and II.

TABLE I. COMPARISON OF WHO MAXIMUM ALLOWED VALUES FOR AIR QUALITY WITH THOSE OBTAINED FROM FACTORY A AND FROM A SELECTED SITE IN NAIROBI INDUSTRIAL AREA

Element	Factory A (Outside the Factory, μgm^{-3}) 0.4μm	8μm	Values obtained for Nairobi Industrial Aerosols(μgm^{-3}) [1]	WHO max. values for Air Quality (μgm^{-3}) [9]
V	<200	<200	-	1.0
Ca	704 ± 100	738 ± 100	0.033-4.15	-
Cr	<50	<30	-	1.0
Mn	<30	<30	0.004-0.089	1.0
Fe	55.8 ± 10	76.6 ± 10	0.094-1.58	-
Ni	<10	<30	-	1.0
Cu	<10	<30	0.007-0.074	-
Zn	<10	<30	0.008-0.072	-
Br	<10	<16.2 ± 4	0.008-0.098	-
Pb	35.9 ± 5.0	<30	0.031-0.465	-
Cd	-	-	-	0.01-0.02
TSP	0.016	0.013	30-80	-

These values are within the WHO (1987) Guidelines [9]. The high calcium level is attributed to the activities (quarrying and cement production) found in the surrounding area where the main raw material used is limestone.

3.1. Soil Samples

The results of EDXRF analysis are shown in Table II.

TABLE II: EDXRF ANALYSIS OF SOIL SAMPLES (VALUES IN PPM)

Element	Sample 1* (n=3)	Sample 2** (n=3)
Na***	605 ± 19[a]	718 ± 13
K	10800 ± 2000	15600 ± 400
Ca	14500 ± 200	10900 ± 500
Ti	4400 ± 200	4900 ± 100
V	<2.0	<59
Cr	<18	<59
Mn	3300 ± 100	4100 ± 100
Fe	37400 ± 800	41100 ± 400
Ni	<3.0	<5.6
Cu	11.9 ± 1.8	12.6 ± 0.9
Zn	143 ± 2	155 ± 7
Ga	33.9 ± 3.0	30.3 ± 3.0
As	<1	<4
Se	<1	<1
Pb	31.7 ± 3.1	21.8 ± 0.4
Br	4.0 ± 0.3	4.4 ± 0.4
Rb	87 ± 1	86 ± 3
Sr	102 ± 8	91 ± 3
Th	20.8 ± 1.7	17.3 ± 1.5
Y	98.9 ± 2.3	95.8 ± 1.8
Zr	726 ± 11	728 ± 12
Nb	185 ± 1	183 ± 2
Mo	<1	<1

a (n = 4)
* collected within the Factory near the Sulphonation Plant
** collected near the complainant's homestead.
*** analysis by Flame photometry

3.2. Noise Level Measurements

The results of these measurements are shown in Figure 1.

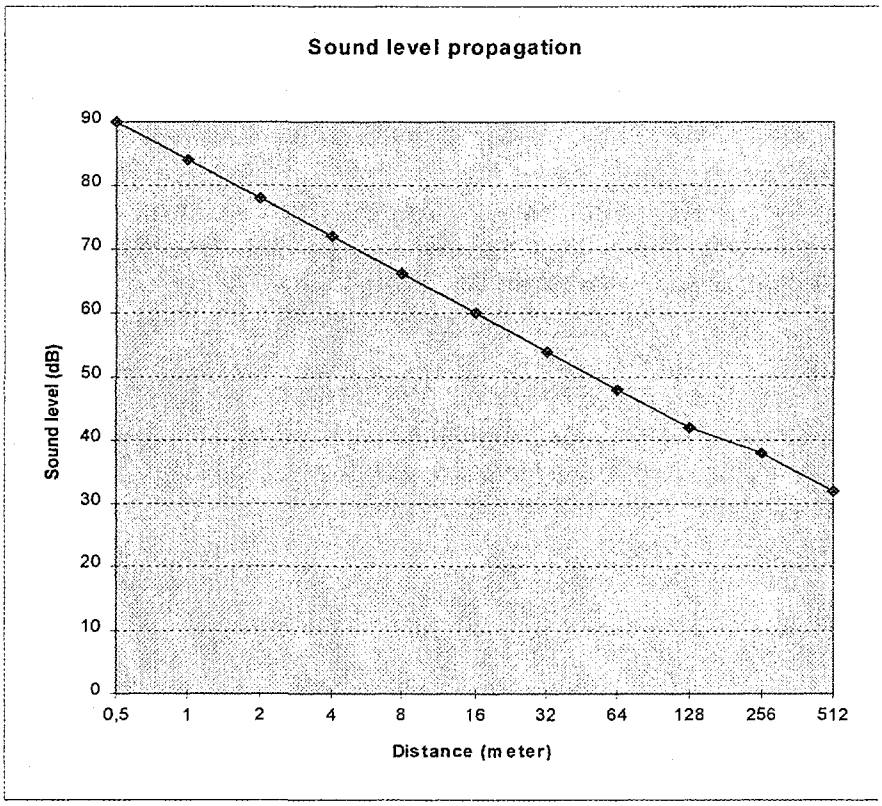


Figure 1: Noise Level Distribution

TABLE III: THE DECIBEL SCALE [10]

Type of Sound	**dB**
near threshold of pain	130
under airport exit	120
noisy traffic	100
loud passage from orchestra	90
noisy office	70
medium traffic	60
busy restaurant	50
ordinary conversation	40
quiet domestic interior	30 - 20
rustle of leaves and human breathing	10
threshold of hearing	0

Based on the above results, physical observations and other information availed to the team, we made the following conclusions:

Factory A:

a) From the noise data recorded and considering international standards on noise control criteria, there is **NO** sound or noise pollution outside the Factory. In fact from the complainant's residence, it is possible to hear the noise produced by the traffic along the Mombasa road, which is at the north-eastern boundary and at about 800 m away.

b) The levels realized above (noise, heavy metals in air particulate and soils) are within the World Health Organization (WHO) Guidelines (1987) [9], proposed Kenyan Standards [6] and the decibel scale, Table III [7].

Factory B:

a) In this study we noted the following major source of environmental degradation: drainage and management of the factory effluents.

b) The BOD and COD levels for effluents samples analyzed (<350 mg/l, <450mg/l, respectively) are considered high for direct disposal into the municipal sewer system.

c) The waste waters are also heavily loaded with particulate matter: total dissolved solids (TDS) (1240-1550) mg/L and the total suspended solids (TSS) (1170-3732) mg/L. All these levels are higher than the recommended Kenyan standards for BOD (<20mg/L), COD (<50mg/L), TDS (< 1200mg/L) and TSS (< 30mg/L).

d) The primary contaminants of concern affecting the soils and sediment samples analyzed are heavy metals such as chromium, lead, copper and zinc and a possibility of organic compounds. The sediment samples are contaminated with lead (250-300 μg/g), copper (0.11-2.59)% and total chromium (0.24-0.94)%.

e) For the soil samples analyzed results indicate that particle sizes corresponding to 98.9% of the soil particles were less than 60μm and 34% were less than 1.7μm. By implication this category of the soil is considered clay. The soil permeability was 2.8 x 10^{-5}mm/sec which is considered low to enable the ease movement of contaminants. It is therefore possible that the contaminants are confined to the top soil.

f) This study found that there is soil contamination from the industrial effluents of Factory B. Therefore, a proposed remedy for cleaning up the soil at this site should first aim to remove and stabilize the contaminants to reduce the potential for migration of contamination from soil to ground water, public exposure to contamination and inhalation of dust, direct contact with, or ingestion of contaminated soil particles. Secondly, the sewerage system of the building should be connected to the main trunk sewer to Dandora or Athi River.

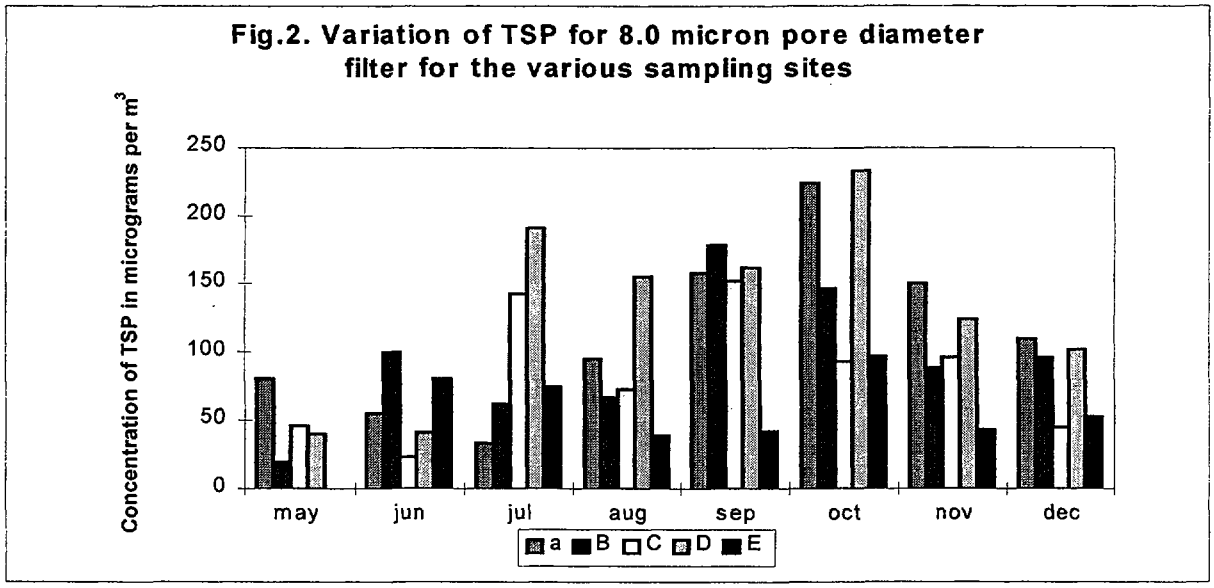
3.4. Suspended Particulate Matter (SPM) in Kibera

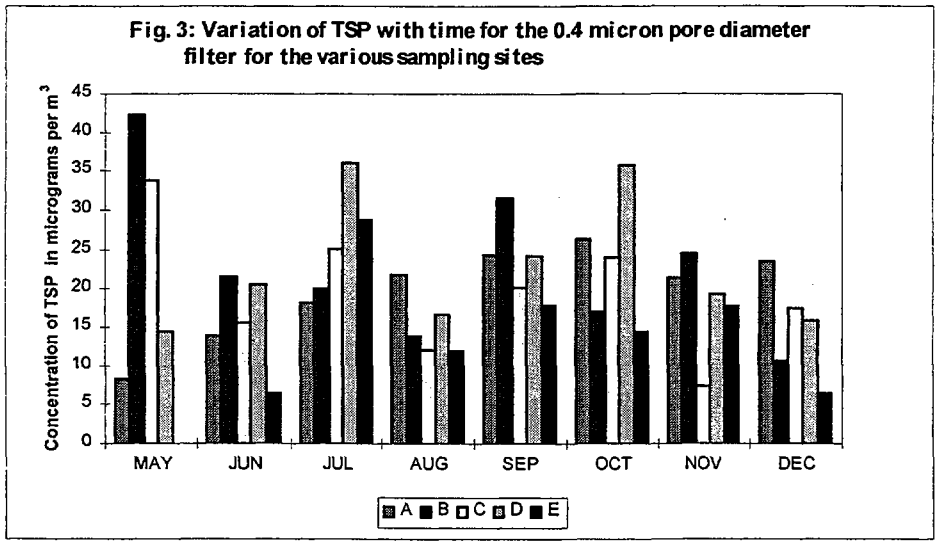
3.4.1. SPM Level changes

The PM_{10} levels for the various sites (Fig 2 & 3 and Table 4a and b). The PM_{10} levels were found to follow a seasonal trend for all the sites. Rainfall pattern during the year 1998 is shown in Fig 4. Variation from the general trend occurred for some sites due to the changes in the weather parameters mainly humidity, temperature and rainfall. For the coarse particles, levels were low in May and June. These were the months characterised by heavy rainfall (long rains) and high humidity (Fig 5). The zone levels then increases from July to August 1998. These months are characterised by cold conditions and high humidity. The high levels of SPM were

attributed to the increased emissions from residential burning of fuels. This was followed by rapid increase in September and October. These months are usually characterised by a dry spell.but during the previous increase it was attributed to the high level of soil dust.

The SPM levels decreased in November and December 1998. These months are also characterised by a dry spell but it should be noted that for the month of December, the SFU was at a higher height (4 m) unlike the sampling of May to November 1998, which was done at 2 m from the ground.





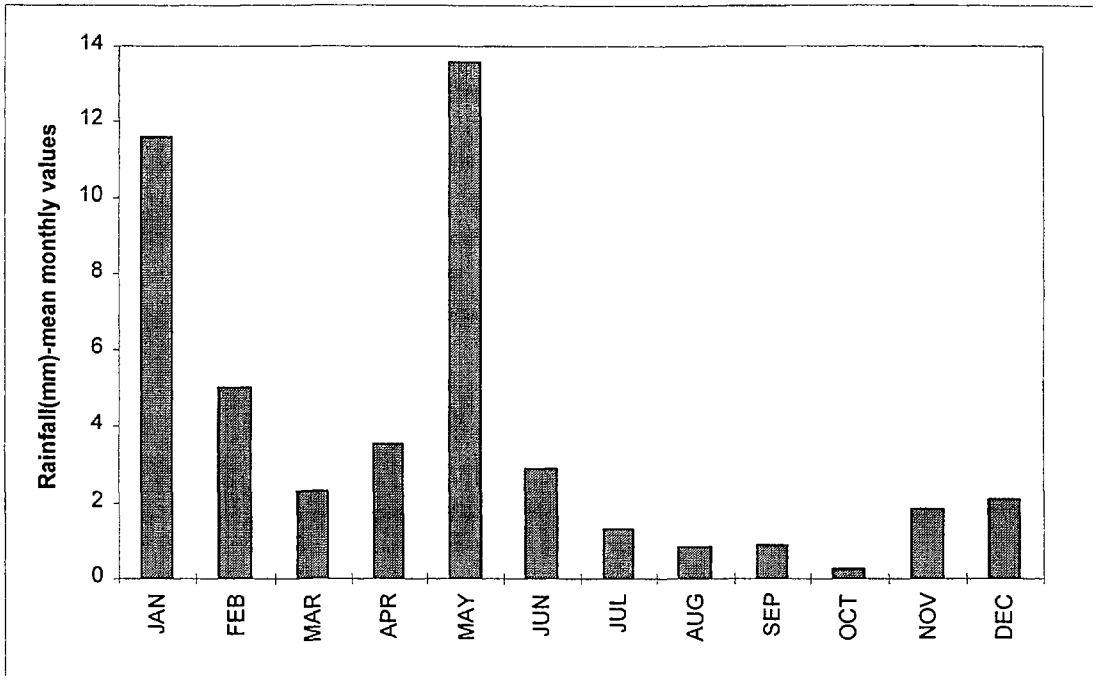


Fig 4: Rainfall pattern in Dagoretti [11]

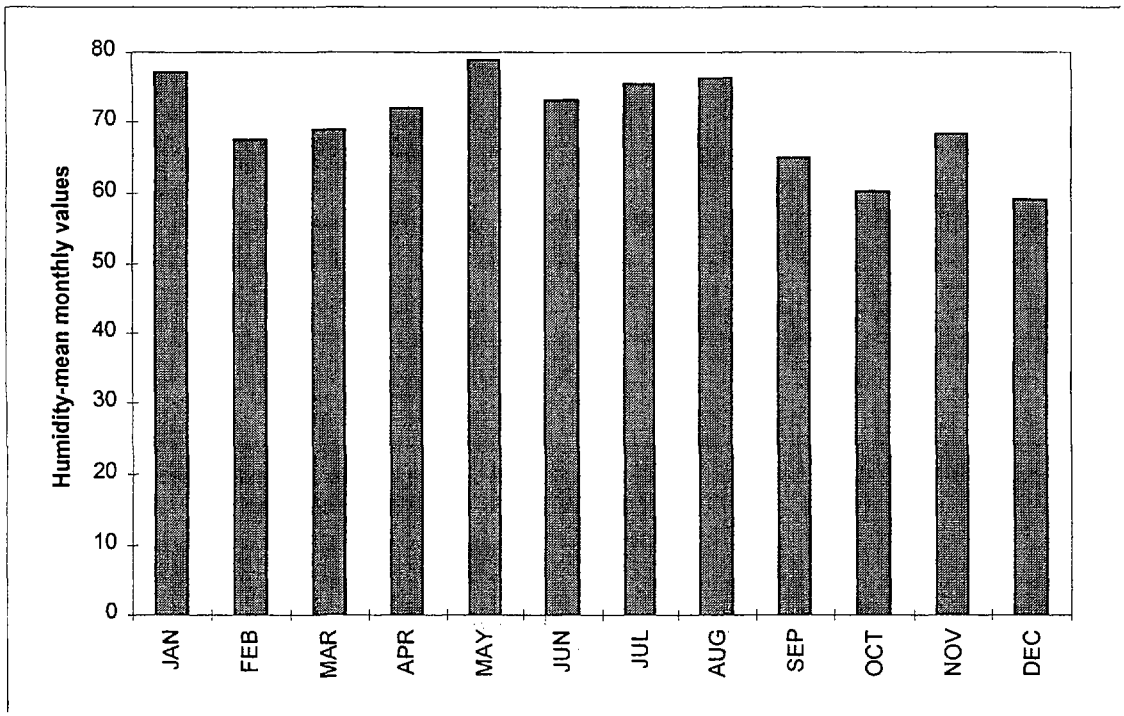


Fig 5: Variation of Humidity in Nairobi [11]

3.5. Elemental concentrations

Elemental concentration results for samples collected from May to November 1998 are shown in Table IV. The results presented are for the months of June to November 1998.

The data on SPM collected over the eight-month period (May-December) had the coarse particles (8.0μm) ranging from 62.4-107.5μm/m^3 whereas the fine particles ranged from 16.2-24.4μm/m^3.

3.6. Acute Respiratory Infections

Results of ARI Monitoring are shown in Table V. The point prevalence of ARI in 1998 ranged between 29.9% in January to the highest level of 59.6% in June. The total number of children who presented themselves continuously under surveillance throughout the study period, January-December 1998, was 146. The average ARI incidence was found to be 8.5±4.0 episodes per child per year. Throughout the year, the ARI point prevalence showed a seasonal variation with the cold months of May-August, having the highest percentages (57.9, 59.6, 54.0 and 44.1 respectively).

TABLE V. CHILDREN CONTACTED AND % OF THE ARI EPISODES PER MONTH FOR 1998*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Children #	724	754	781	808	836	857	661	624	651	621	661	646
Visit (%) 1	23.2	36.6	30.7	36.1	41.5	37.1	36.9	37.5	35.9	28.7	28.6	21.7
2	5.7	9.0	9.4	13.7	16.4	22.5	17.1	6.6	13.4	13.5	15.6	8.2
3									4.0	5.0	4.1	2.0
4									2.0	1.8	0.3	-
Total (%)	29.9	45.6	40.1	49.8	57.9	59.6	54.0	44.1	55.3	49.0	48.6	31.9

* ARI progress reports [12]
nb: % refers to the number of children with ARI on examination

Actual and Predicted cases of ARI for Site B and E with respect to PM_{10} and $PM_{2.0}$ from May through December 1998 are shown below (Table VI).

TABLE VI. ACTUAL AND PREDICTED ARI CASES

	Site B (n=8)				**Site E** (n=7)			
	PM_{10}		**$PM_{2.0}$**		**PM_{10}**		**$PM_{2.0}$**	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
May	57.9	49.0	57.9	62.4	ND	ND	ND	ND
Jun	59.6	50.2	59.6	49.3	59.6	48.6	59.6	45.3
Jul	54.0	49.4	54.0	48.5	54.0	51.9	54.0	54.9
Aug	44.1	49.4	44.1	44.5	44.1	44.7	44.1	47.7
Sept	55.3	52.0	55.3	55.7	55.3	46.5	55.3	50.2
Oct	49.0	51.0	49.0	46.6	49.0	53.8	49.0	48.7
Nov	48.6	50.1	48.6	51.3	48.6	45.9	48.6	50.2
Dec	31.9	49.9	42.6	40.2	31.9	45.7	31.9	45.4

Nd – not determined

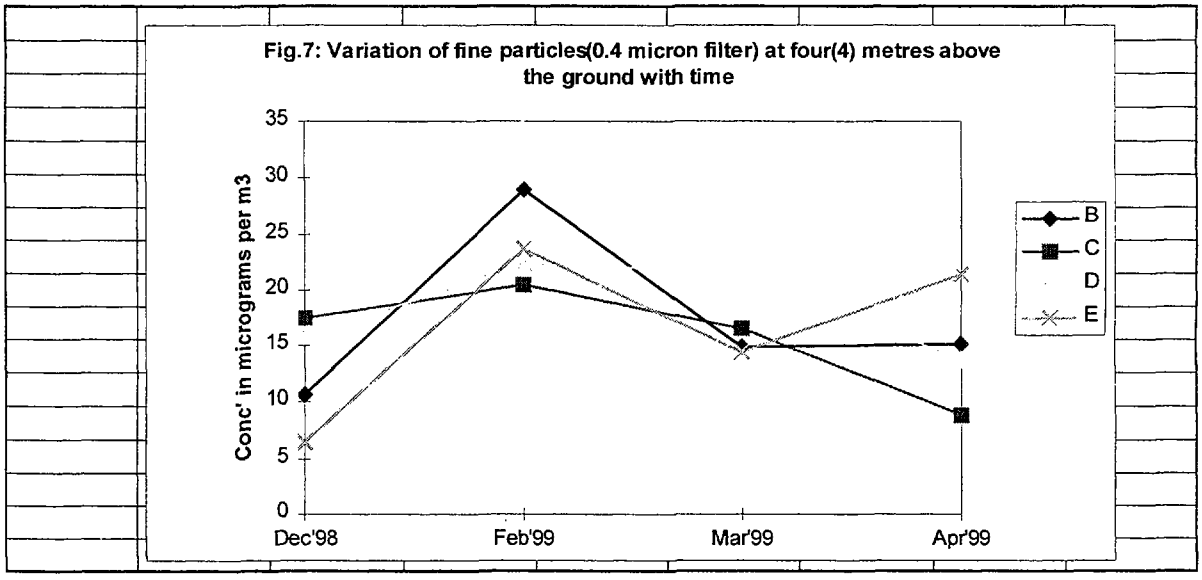
TABLE VII: MEAN MONTHLY CONCENTRATION (μG/M³) OF COARSE PARTICLES (8.0μM PORE FILTER) FOR THE PERIOD DEC. 1998 TO APRIL 1999.

Site	December 1998	February 1999	March 1999	April 1999
B	95.4 ±42.6	98.5 ±23.6	45.0 ±44.9	23.3 ±14.8
C	45.3 ±8.50	128.9 ±56.5	68.95 ±47.2	13.9 ±14.2
D	101.1 ±46.5	184.0 ±36.8	155.5 ±109.5	46.7 ±24.9
E	53.1	28.2	70.2	29.0

	±18.9	±15.0	±17.0	±10.5

TABLE VIII: MEAN MONTHLY CONCENTRATION (μG/M³) OF FINE PARTICLES (0.4μM PORE FILTER) FOR THE PERIOD DECEMBER 1998 TO APRIL 1999.

Site	Dec'98	Feb'99	Mar'99	Apr'99
B	10.7 ±4.9	29.0 ±1.27	14.9 ±4.45	15.1 ±2.26
C	17.5 ±2.8	20.5 ±1.20	16.55 ±1.06	8.85 ±1.77
D	15.8 ±2.9	22.4 ±2.80	21.60 ±19.6	13.7 ±5.09
E	6.5 ±7.73	23.7 ±0.28	14.4 ±2.55	21.45 ±14.8



PLANS FOR FUTURE WORK

The following are our future plans:

(i) Continue with the epidemiological case studies at Kibera, Nairobi.
(ii) Characterisation and Transport of Atmospheric Aerosols at Mt Kenya.
(iii) Radon and its daughter products contamination in residential houses in Taita-Taveta, Kenya
(iv) Soil studies
- determination of organic mater content
- cation exchange capacity (CEC)
- chromium speciation
- hydrogeologic and soil characteristics of the site in terms of the extent of contamination.
- determination of cyanide in soils and sediment samples

(v) Monitoring the quality of ground water in Nairobi.
(vi) Inventory of the air pollution sources in Nairobi.
(vi) Noise pollution studies in Nairobi.
(vii) Continue participating in intercomparison exercises.

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