NILU OR: 85/92

NILU OR : 85/92
REFERENCE : O-92047
DATE : DECEMBER 1992
ISBN : 82-425-0435-0

The Helwan Environmental Study Meteorology and Air Quality

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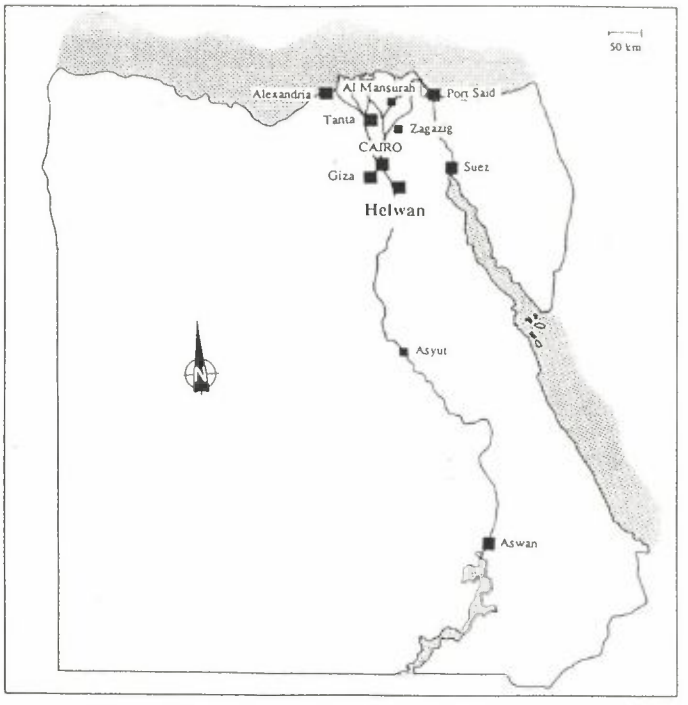

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PREFACE

This report represents the NILU contribution to an Environmental Assessment and Screening of the Helwan Area in Egypt carried out for the World Bank by Norconsult International a.s. in co-operation with the Tebbin Institute for Metallurgical Studies (TIMS). The Norwegian Institute for Air Research (NILU) has supported the project team and contributed to the study on meteorology and air quality measurements, analyses, modelling and evaluation.

The following NILU personnel have contributed to the work: Hans Nyberg (passive samplers and analyses), Astrid Røstad (statistical analyses) and Sam E. Walker (modelling).

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SUMMARY

The Norwegian Institute for Air Research supported Norconsult International a.s. to perform an environmental study of the heavily polluted Helwan area, south of Cairo in Egypt.

Earlier studies as well as this study show that the dustfall in the Helwan area frequently exceeds international standards. In the area dust fall values above 100 $g/m^2 \cdot 30d$, which is tentimes the European standards can be found. The highest values were found down wind from the three cement plants and the three process industries in the southern part of the area. High concentrations of heavy metals were found in some areas down wind from the smelter industries in the southern part of the area.

The concentrations of total suspended particles in the air exceeded 100 $\mu g/m^3$, which is more than eight times the proposed WHO guideline value, at three out of six selected sampling sites. Then sites are located down wind from Tourah and Helwan cement plants and down wind from the Iron & Steel plant.

The concentration of inhalable particles also exceeded international guideline values. Especially serious was the lead concentrations down wind from General Metals. These values exceeded the WHO recommeuded guideline values by a factor of fifty.

The highest concentrations of sulphur dioxide (SO_2) were found in the area south of El Nasr Coke, Iron & Steel, General Metals and El Tebbin power plant, and in the area down wind from South Cairo power plant. In all areas the concentrations were less than the WHO guideline values. The concentrations of nitrogen oxides were far below the WHO guideline values.

THE HELWAN ENVIRONMENTAL STUDY
METEOROLOGY AND AIR QUALITY

1 INTRODUCTION

The Government of Egypt is considering a project on Pollution Control and Energy Conservation (PCEC) of the three cement plants located in Helwan. One of the objectives of the project is to reduce industrial pollution and energy consumption in the Helwan cement plants; a second objective is to determine the most serious polluters among the non-cement plants so that during project implementation an action plan to reduce their pollution levels can be developed. To help design the proposed project to achieve these objectives, the Japanese Government has provided a grant to the Egyptian Government to carry out an Environmental Study. The World Bank was the executing agency for this grant.

Norconsult International a.s. (NI) has been appointed as the responsible international consultant for the Helwan Environmental Study. NI has included support from other companies in Norway. The Norwegian Institute for Air Research (NILU) was asked to be responsible for the studies on meteorology and air quality.

NILU has been responsible for collecting existing information on air quality and meteorology, and to design a short term monitoring programme for mabient air, included suspended particulate matter, dustfall and gaseous pollutants. Also measurements of wind, temperatures, stability and precipitation had to be undertaken, checked and evaluated. NILU was asked to contribute to the report on the final evaluation and findings as to climate meteorology and air pollution and also include a chapter on studies or measurements needed as a basis for preparing an action plan.

2 THE AREA

The study area, Helwan, is situated 30 km south of Cairo. For the purpose of this study, the boundaries of the Helwan area are defined east of the river Nile with Maadi in the north, and Tibbin in the south (see Figure 1).

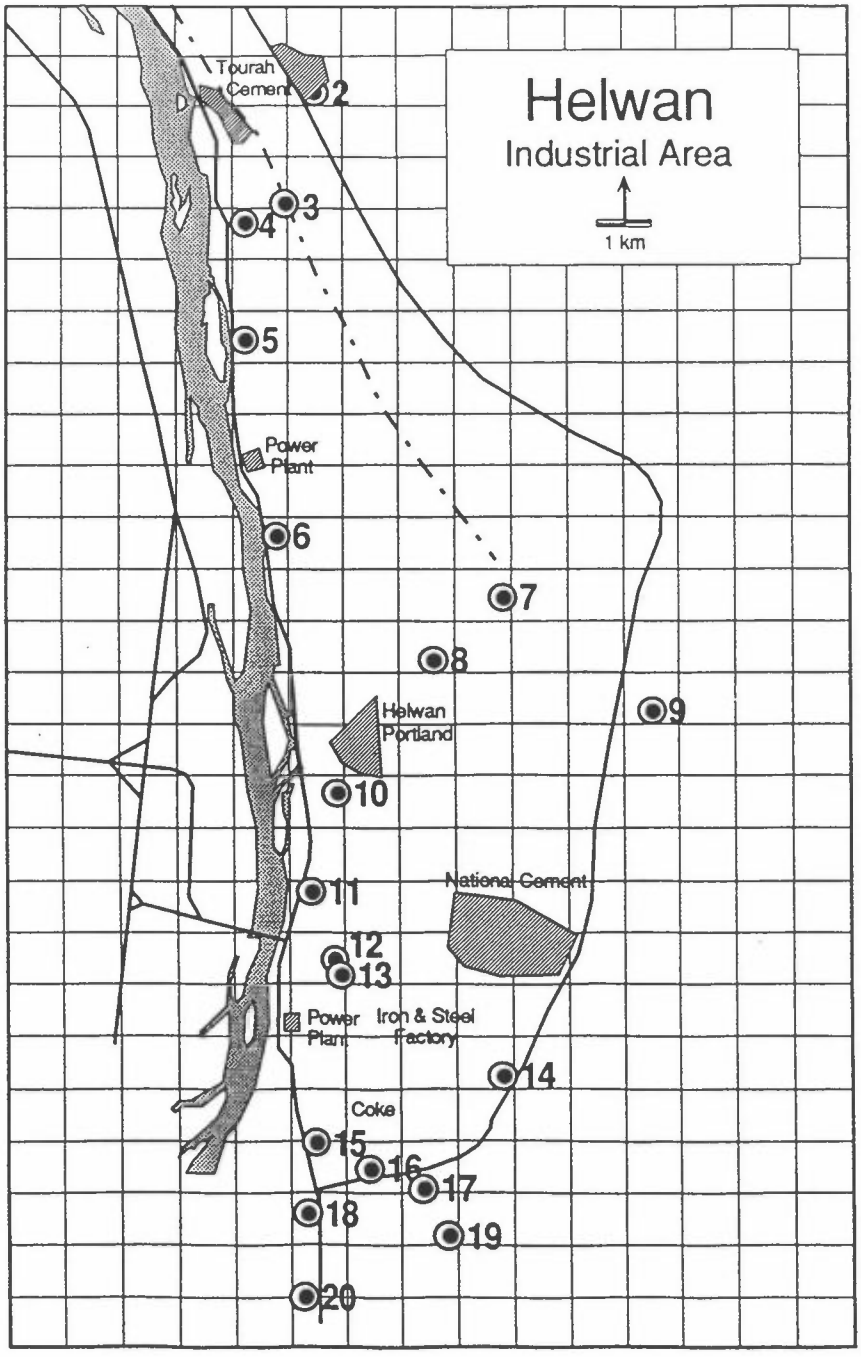

Figure 1: Map of the study area with 1 km grid system based upon UTM references. Sites for monitors are indicated.

Of particular interest is a 25 km strip, bordering along the east bank of the Nile on which the major polluting industries are concentrated. These industries can be grouped into: (i) cement industries, comprising the three cement factories, Tourah, National and Helwan, currently operating under the Ministry of Housing, Reconstruction and New Communities; and (ii) non-cement industries, such as Iron & Steel Complex, the El Nasr Coke Chemicals Co., General Metals Co., Helwan Spinning and Weaving, Helwan refractories, Nasr Automative Co., military factories for heavy and light industries and South Cairo and El Tibbin electric power stations. A number of brick factories burning heavy fuel oil are located within and just outside the study area. Open air burning and backyard burning of waste also results in local air polution problems. Helwan is also characterized by a relatively large number of persisting, stgnant water pools caused by deficiencies in the water and sewage systems as well as water logging.

The Helwan area was known during the first half of this century for its mild climate and the low humidity (mild and arid climate) beside the sulphur springs which gave the area of Helwan a worldwide reputation that attracts those seeking relaxation and tourists seeking medical therapy.

In the second half of the fifties a great industrial activity started in the area. It reached its peak in the middle of the sixties. Several industries were built like the iron and steel industry and the chemical industry. Expansion were also made in the cement industry and in others. Unfortunately the planning of the area was carried out where industries and residential areas were located with absolute no environmental awareness. Houses were built beside plants resulting in several problems in connection with the deterioration of the atmospheric environment. Gases and dust spread in the Helwan air resulting in a great increase of chest diseases for its residents. The area lost its touristic reputation and its air choked with pollutants. At that time the State became aware of the problem and initiated studies for assessing the size of the problem.

The first air quality measurement started in 1966 (Nasralla, 1968). Other studies were financed since 1967 by the General Organisation for Industrialisation and the Cairo Planning Agency in co-operation with the Air Pollution Unit at the National Research Center (Abd El Salam, 1968; 1969). The aim was to assess the size of the problem and improve the replanning process.

But unfortunately no serious or integrated steps were taken to face the problem resulting in a serious augmentation of the problem to an extent which we shall elaborate in the following. Several studies have demanded that no new industries are to be built or existing ones to be expanded in Helwan before its pollutants are controlled or its environment is planned for. Yet several industries were expanded resulting in an increase of its productive power like the cement industry, the iron and steel industry and to this the building of the fertilizers industry and the capacity increase of the electric power station.

Subsequently the use of fuel increased and especially the heavy parts of petroleum, which contained high percentages of sulphur. This has doubled the size of the problem and the industrial area of Helwan is faced with many environmental problems which are difficult to solve. Yet an earnest attitude must be adopted in order to face those problems.

3 MEASUREMENT PROGRAMMES

A measurement programme for meteorology and air quality was designed during a site visit to the area in March 1992 (Sivertsen, 1992).

3.1 METEOROLOGICAL MEASUREMENTS

The most important series of data available for studying meteorology and climatology of the Helwan area has been the observations collected by the Directorate of Meteorology near the Helwan Observatory.

Data have been collected on a routine basis every 3 hour for several years. Standard meteorological equipment as recommended by the World Health Organization (WHO) has been used.

Meteorological observations were also taken at the roof of the Tibbins Institute for Metallurgical Studies (TIMS). An automatic weather station, Weathermeasure type climatological wind sensor by Qualimetric Inc., was installed in 1988.

The measurements included wind direction and speed, temperature, solar radiation, relative humidity, barometric pressure, and precipitation. The data aquisition system includes a programable microprocessor and a data tape recorder with a standby battery. Reading and printing the recorded data are obtained by the IBM-PC and the associated printer.

The frequent cut-off of the electric power for long periods of time and the lack of regular follow up have caused a loss of data from 15 March 1992.

The environmental conditions, especially dusty weather, affect the performance of the relative humidity sensor and the solar radiation measurements. The recommended calibration process of the measuring systems have not been regularly conducted and documented.

3.2 AIR QUALITY MEASUREMENTS

Twenty monitoring sites were selected in March 1992 for measurement of dustfall, suspended particulate (TSP), sulphur

dioxide (SO_2), nitrogenoxide (NO_x) and nitrogendioxide (NO_2). Locations of the monitoring sites are shown in Figure 1.

Table 1: Monitoring stations in the Helwan industrial area March-June 1992.

St. no.	UTM Ref. X	UTM Ref. Y	Name (area)	Sampling D	PS	PN	HV	SO_2 m	NO_x m	DAS	DAI
1	333.5	315.2	Maadi south	X	X	X					
2	336.2	312.3	New Tourak Cement, south	X						X	X
3	335.6	310.3	El Maasarat east	X	X	X	X	X	X		
4	334.8	309.8	El Maasarat central	X							
5	334.77	307.75	Ezbet West	X							
6	335.16	304.60	Poultry farm	X	X	X	X	X	X		X
7	339.5	303.3	Helwan City Club	X	X	X					
8	307.0	301.6	Arab Rashed	X							
9	342.5	301.0	15 May City	X	X	X					
10	336.0	299.75	Kafr el Allou north	X						X	X
11	335.8	298.1	Egypal	X	X	X	X	X	X		
12	336.4	296.3	TIMS ground level	X							
13	336.4	296.2	TIMS roof level	X	X	X	X	X	X		X
14	339.4	294.5	Power switching stat.	X	X	X	X	X	X		X
15	335.7	293.3	Ind. & Trading Co.	X						X	X
16	336.8	292.8	Abusaid school area	X	X	X					X
17	337.8	292.5	Power distribution	X			X	X	X		X
18	335.6	292.1	Ottaiat area north	X	X	X	X	X			
19	338.1	291.6	Water treatment plant	X							
20	335.5	290.4	Ottaiat south	X	X	X					

D = Dustfall, NILU gauge
PS = Passive SO_2 sampler
PN = Passive NO_2 sampler
HV = Andersson Hi Vol sampler
SO_2M = Contin. SO_2 by Monitor Lab
NO_xM = Contin. NO_x by Monitor Lab
DAI = Analysis of elements in insoluble dustfall
DAS = Analysis of elements in soluble dustfall

A special programme was designed for collecting of suspended dust (TSP) with an Anderson type high volume sampler. Both glass fibre filters (for gravimetric analyses) and quarts filters (for element analyses) were included in this programme.

Continuous measurements of SO_2 and NO_x with Monitor Lab. type

instruments were to undergo the same sampling programme (site selection and sampling periods) as the Anderson type high volume sampler.

A sampling programme for passive samplers for SO_2 and NO_2 was established. Two sets of samples were collected:

a) short term exposure (8-9 days)
b) long term exposure (month)

Eleven sites were selected for these samplers. The analyses of these samples were performed at NILU.

The monitoring programme started on 2 April 1992 and ended on 26 May 1992.

3.2.1 The passive SO_2 and NO_2 sampler

A sensitive diffusional sampler for sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in ambient air was used in the Helwan study. These samplers were developed by the Swedish Environmental Research Institute (IVL). The sampler includes an impregnated filter inside a small plastic tube. To avoid turbulent diffusion inside the sampler, the inlet is covered by a thin porous membrane filter. Gases are also transported by molecular diffusion in the laminar boundary layer in front of the membrane. The thicknes of this layer is not negligible in comparison with the length of the sampler. The sampler has been tested for three gases. For SO_2, the measuring ranges are approximately 0.1-80 ppb for a sampling period of one month. The equivalent range for NO_2 is 0.02-40 ppb. In the Helwan study we designed it for sampling periods of 9 days and one month.

Filters were impregnated and the complete samplers were assembled at NILU. The concentrations of SO_2 were analyzed as sulphate using ion chromatography.

3.2.2 The NILU two-filter particle sampler

Aerodynamic behaviour and fate (e.g. dispersion, transport and removal), chemical nature, and health and various other environmental effects of airborne particles are largely aerodynamic size-dependent. To assess these important aerosol properties, it is desirable to separate the particles in at least two size fractions, usually referred to as "coarse" and "fine". The two-filter method has this capability, but has been possible only after the so-called Nuclepore filters (NP) became available.

The two-filter method (referred to as NILU-2F) in concept is as simple as its name implies: two filters, arranged in series, each collect a different size range of particles. Consequently, it has been variously referred to in the literature as "two-stage", "sequential", "tandem" and "stacked" filter (SFU) method.

The first filter, a large-pore NP with appropriate filtration characteristics, fractionates the aerosol in the sample airstream and retains the coarse particles. The second collects the penetrating fine particles. Any type of filter may be used for this, provided the filtration efficiency for fine particles is adequate and the medium is compatible with the subsequent analytical procedure.

The sampling head for the NILU-2F sampler is usually a dual, open face filter holder of appropriate diameter. The filter holder must be leak-proof, and of a design that keeps the two filters physically separated.

The realization that sample air inlets of known "intake effectiveness" characteristics are essential in ambient aerosol measurement is relatively recent, and came mainly after the concept of "inhalable particles" had gained momentum (Vitols, 1981). The air inlet provides a defined upper particle size cut-point, such that only particles penetrating the inlet make

up the "aerosol sample", which then may be subsequently fractionated in fine and coarse fractions by, for example, the 2F head. When sampling "inhalable particles" the particle-size cut-point of the inlet is at 10μm equivalent aerodynamic diameter (EAD). The second filter collect fine particles with typical EAD of 2.5 μm or less.

The NILU-2F sampler operates at a flowrate of 9 l/min (or 0.54 m^3/h). The comparatively simple features and possibly lower cost of the two-filter sampler makes it an attractive candidate for routine field monitoring of airborne fine and coarse particle concentrations. A comparison study has been undertaken to ascertain the feasibility of using the two-filer sampler as an alternative to the current U.S. reference method for gravimetric determination of coarse and fine aerosol fractions.

The NILU-2F sampler with the Sierra-Anderson (S-A) inlet gave on the average a 6% larger inhalable particle concentration than the DICHO. Statistically, this difference was not significantly different from zero, at a 95% confidence level (24 samples).

In the Helwan study the NILU 2F sampler was used with the S-A inlet.

We feel that the two-filter method, as described here, is an acceptable alternative to the DICHO method to provide an inexpensive assessment of exposure to inhalable particles, and separation of those into fine and coarse particle fractions as defined in the DICHO method.

4 METEOROLOGY

4.1 CLIMATE OF THE AREA

Egypt occupies the extreme Northeastern corner of Africa. The climate of Egypt is determined basically by the following factors:

1. The semi-permanent pressure system in each season such as the cold Siberian anticyclone in winter, the heat lows at Africa in spring and autumn and the huge low over Southwest Asia (Monzoon) in summer. These systems are air mass source regions in their respective season.

2. The travelling depression and associated weather in winter and transitional seasons.

3. The Meditteranean and, to much lesser extent, the Red Sea as sources of water vapour, in addition to their being positive or negative thermal sources.

4. Orography plays a small role in the general climate but has a local effect.

Figure 2 shows the mean seasonal pressure patterns of northern Africa (after K.H. Soliman).

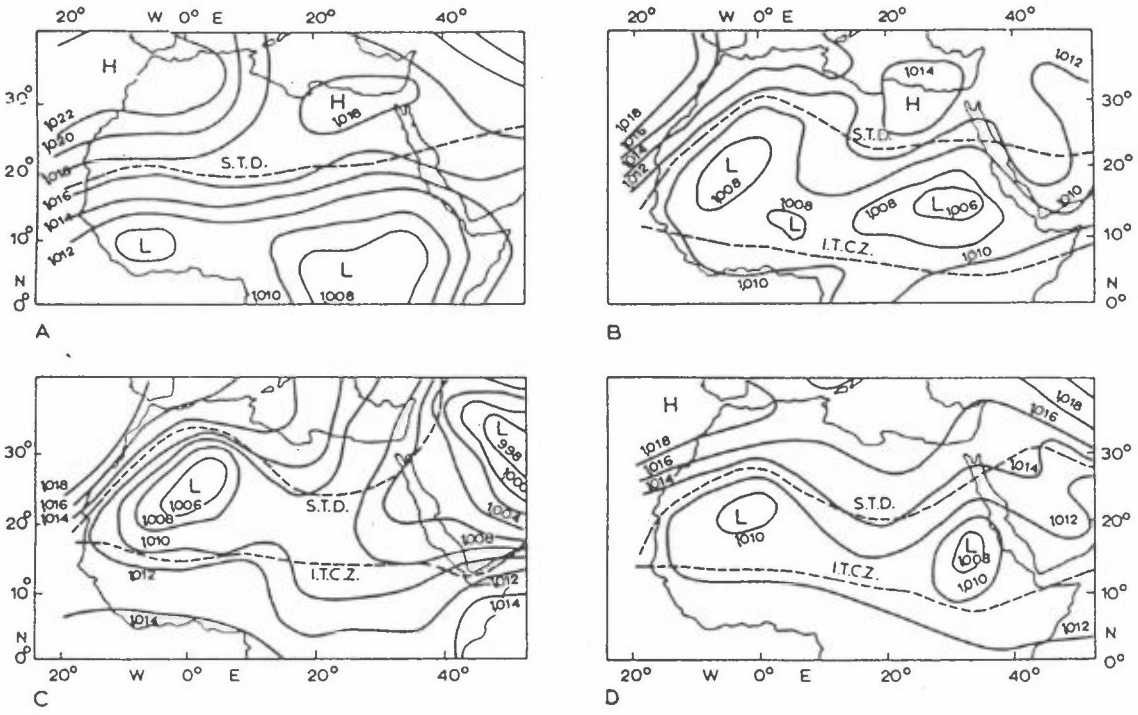

Figure 2: Mean seasonal pressure patterns during: a) Winter, b) Spring, c) Summer and d) Autumn.

Winter (December-February)

In winter the Mediterranean becomes the theatre for consecutive passage of depressions. They are the main cause of the weather in this season.

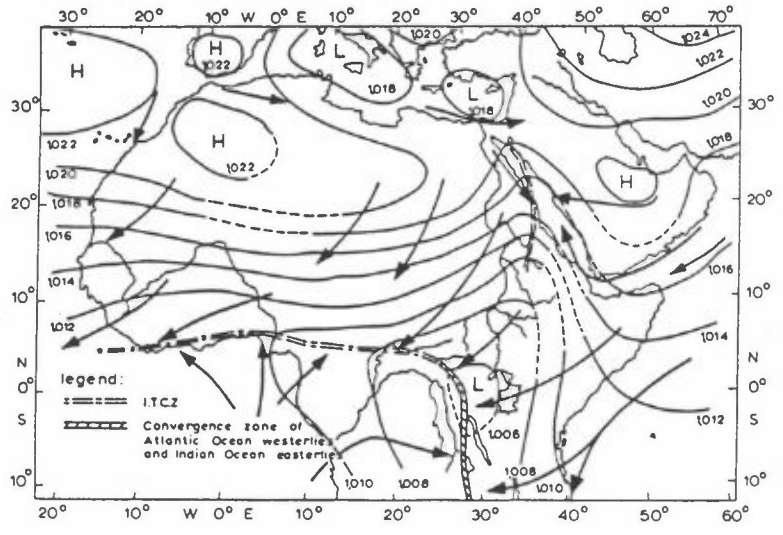

Figure 3: Mean daily pressure pattern and air flow for January.

In front of these depressions southerly winds blow across Egypt with almost clear skies and low relative humidity. This is the meain reason that the highest frequency of accurrence of the southerly wind is during winter. When the depression reaches the eastern Mediterranean cold, moist, north-westerly winds blow over Egypt and convection clouds appear during the day-time. When an upper cold low or steep through exists above the depression cloud and rain, sometimes accompanied by thunder, might occur over northern Egypt. The depression may stay for two or three days over the eastern Mediterranean. The warm Mediterranean water play an important part in supplying enormous amount of water vapour to the polar air masses moving south towards Egypt. If the Siberian anticyclone extends westwards to cover the Balkans during the above synoptic conditions, the coldest spells experienced in Egypt. When the depressions are deep the southwest winds may reach gale force and cause severe sand storms. The north-northwesterly winds in the rear of these depressions may also reach gale force, especially at the coast, but dust raised much less than southwesterly winds.

Between the passage of consecutive depressions, high pressure covers the eastern Mediterranean. This situation is responsible for the flow of northeasterly winds over north Egypt, a condition that favours the formation of radiation fog in the early morning, dispersing a few hours after sunrise.

Spring (March-May)

The main feature in this season is the southward shift of the depression trajectories. The centres of the depressions move either along the coast line of North Africa or further south, where they are known as desert or "Khamsin" depressions.

The frequency of these depressions may vary between one to six per month. These depressions usually are associated with Khamsin conditions which are the hot, dry, dust laden and

southerly winds. The scale is smaller than the winter Mediterranean depressions and they may be associated with more high and medium clouds but less rain.

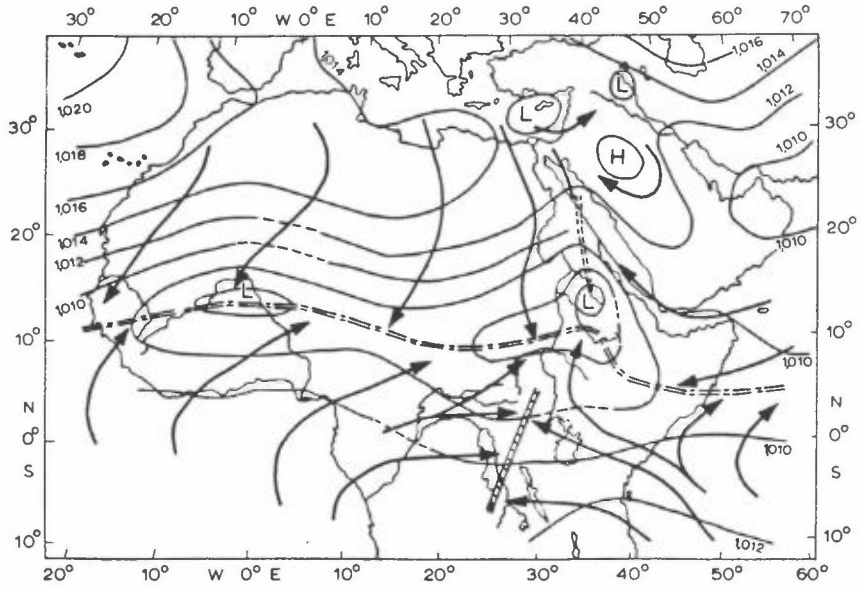

Figure 4: Mean daily pressure pattern and air flow for April.

The depression can be vigorous and cause severe sandstorms. The maximum temperature may be as large as 45 °C. The sand is raised by the strong southerly winds in front of the depression, especially at the passage of the cold front or even few hours ahead.

These depressions are often associated with large amounts of high and medium clouds which can give showers of rain and in some cases hail. Clouds and precipitation are also attributed to givestorms, which oscillates in close and intimate relationship with the depression, occupying a position a little further to the north. The role played by the Mediterranean water in this season in producing instability and supplying moisture to cold air masses is obviously less pronounced than in winter. Many of the rain showers in this season originates from mid-tropospheric instability clouds. This fact explains why some of the showers are charcterized by very large water drops which actually is melted hail.

In spring, as in autumn, the Sudan trough sometimes extends north wards to cover Egypt. The hot, southeasterly current of Arabia turns northwestwards over Egypt and heat waves are then experienced. The air is hot and dry, except in the surface layers where it picks up moisture from the Mediterranean, a feature that sometimes leads to the formation of early morning radiation fog over North Egypt. The Sudan trough may extend northward to cover not only the Red Sea but also the east Mediterranean Basin. In such cases there is usually an upper cold trough or low over the eastern Mediterranean area. Thunderstorms which may occur in such situations are due to the instability coming from the hot moist air near the surface and the cold low aloft.

Summer (June-August)

The spring conditions may extend a week or 10 days into June but afterwards summer conditions prevail.

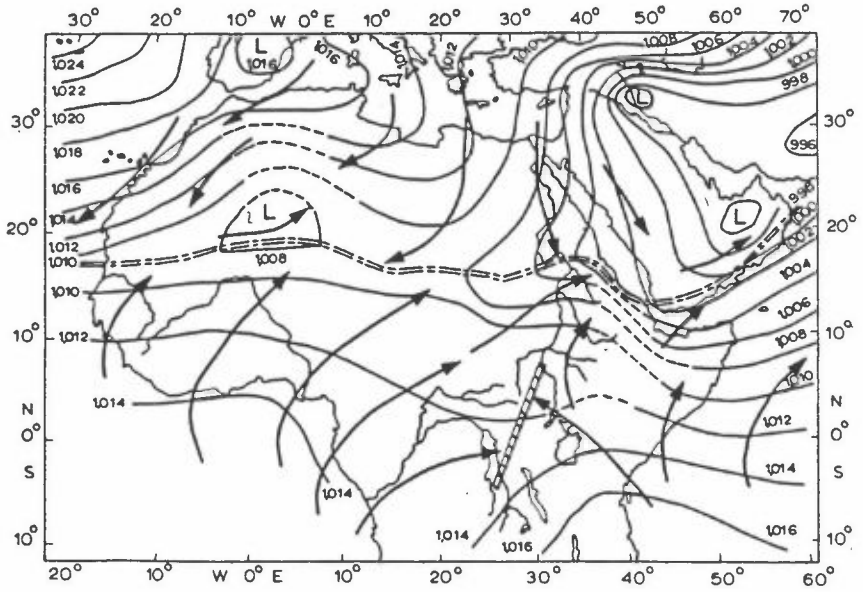

Figure 5: Mean daily pressure pattern and air flow for July.

The general climate is hot and rainless. Clear skies prevail, except for some coastal fair weather cumulus or early morning

stratus clouds or mist which form over north Egypt and disperse a few hours after sunrise. In this season depression cease to move across Egypt and weather becomes settled. Egypt is under the influence of both the huge Asiatic low centered over northwestern India and the subtropical high centred over Atlantic ocean and extends towards east. The temperature and wind, in this season, are controlled by the oscillation of this system. When the system moves towards the northwest, the north easterly winds blow from the Asian low. Temperature increases and very high temperature and humidity may form fog.

The movement of the system towards the southeast will turn the wind to be northwest and temperature and humidity decreases.

Autumn (September-November)

The climate in season is similar to that in spring for it is another transitional season.

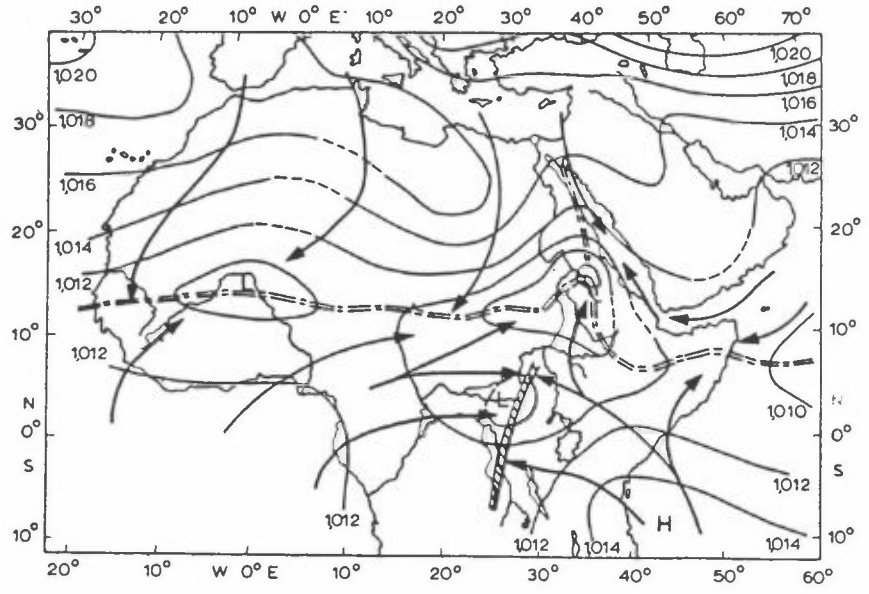

Figure 6: Mean daily pressure pattern and air flow for October.

Khamsin like depression begins to cross Egypt during late October and cause a breakdown of the settled summer regime. Early depressions in September are infrequent and usually die out on arriving Egypt from the west. The depressions at this time are much less vigourous than in the spring and are slower in their eastward movement. On the other hand, the higher humidity in this season favours greater frequency of thunderstorms and heavier precipitation, a fact especially true in November. The northeast wind and early morning radiation fog are more frequent than in the spring, while heat waves are less common and less severe than spring.

4.2 LOCAL METEOROLOGY

4.2.1 Temperature and relative humidity

Table 2 presents a statistical summary of temperatures and relativ humidities measured in Helwan during a ten year period 1981-1990.

Table 2: Temperatures and relative humidities measured at Helwan observatory (29 52 N, 31 20 E) during 1981-1990.

Month	Temperature					Relative Humidity		
	Mean	Monthly maximum		Monthly minimum		Mean	0300 hrs	1200 hrs
		Mean	Highest	Mean	Lowest			
1	12.84	18.7	31.3	9.2	5.2	65.12	79.4	47.2
2	13.94	20.1	32.0	9.9	3.6	61.15	77.3	42.2
3	16.56	23.0	35.5	11.6	5.2	58.17	77.0	37.8
4	21.50	28.4	41.4	15.2	9.4	51.17	72.4	30.5
5	24.70	31.9	44.4	17.9	13.0	49.13	73.7	28.0
6	27.23	34.6	44.6	20.9	16.0	50.69	76.6	29.6
7	27.86	34.9	42.1	22.4	19.0	58.63	83.6	35.8
8	27.69	34.5	41.9	22.7	20.0	62.01	85.1	38.0
9	26.13	33.0	40.0	21.1	18.2	62.49	85.5	37.9
10	22.91	29.4	39.8	18.0	13.6	63.97	84.7	41.0
11	18.31	24.4	35.4	13.7	11.0	64.87	81.4	44.2
12	14.52	20.5	30.0	10.5	8.8	67.17	82.0	47.6
Annual	19.0	27.8	44.6	16.1	3.6	59.5	79.9	38.3

The highest value of the mean maximum temperature (34.9 °C) occures in August. The extreme maximum, exceeding 40 °C, occurs usually during the spring season when Helwan is affected with the heat waves associated with the desert depressions. The lowest mean minimum temperature (9.2 °C) is measured during January, while the extreme minimum occurs in February, when the Mediterranean becomes colder and the Siberian anticyclone extends westwards to cover the Balkans. The polar continental air reaches Egypt with north westerly wind in the rear of the depressions.

The relative humidity has its minimum values during late spring and maximum values during early winter. The radiative cooling during clear nights, give high values of relative humidity at night time (0300) in summer and early winter.

The mean monthly annual variations of humidity are much less than the diurnal variations. The difference between the maximum monthly values and the minimum values ranges between 13.1% at 0300 to 19.6% at 1200 with mean values 18%, while the lowest value of diurnal variation, during January is 32.2% and maximum one in August is 47.8%.

4.2.2 Surface wind speeds and directions

The prevailing wind direction, all over the year is from around north. More than 57% of the winds are from between 320° and 040° on an annual basis as shown in the wind rose, Figure 7a.

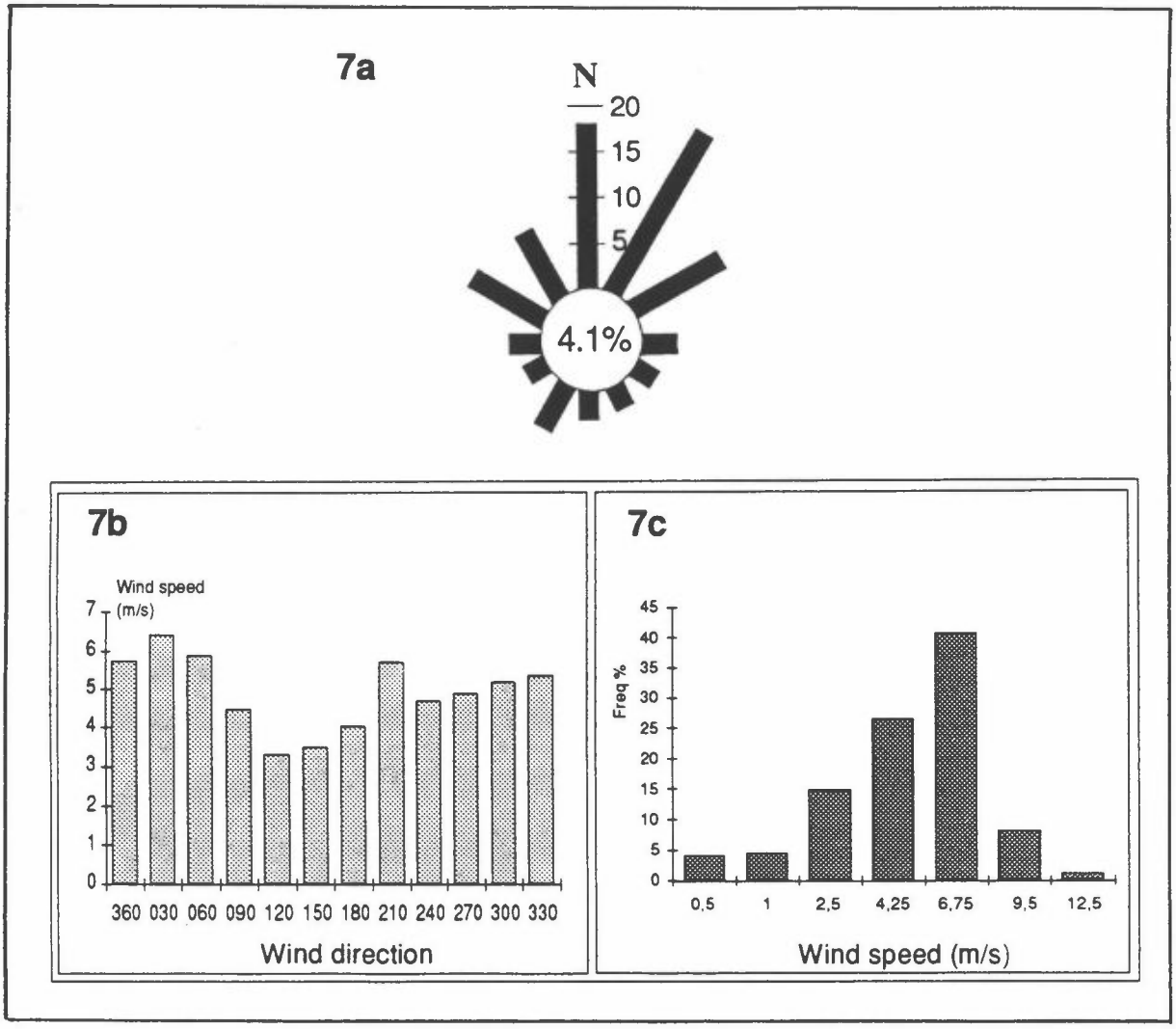

Figure 7: Wind direction and wind speeds at Helwan observatory,
a) wind rose 1981-90,
b) wind speed/wind direction,
c) frequency of wind speeds.

Southerly winds, between 140° and 230°, only occurred in 8.2% of the time. Most of these southerly winds occured between November and early May when the tracks of the depressions are near the coast line. In front of these depressions the winds are mostly southerly. These southerly winds are often light except in some cases during spring when they are strong and associated with dust storms.

The northerly winds have a mean wind volocity of about 6 m/s, while the southerly winds have an average wind speed of 4 m/s, as shown in Figure 7.

The mean annual wind speed is 5.2 m/s. More than 90% of the cases are equal or less than 8 m/s. Only 1.2% of the wind speeds exceeded 10 m/s.

4.2.3 Atmospheric stability

Measurements of vertical temperature gradients either by radiosondes or along tall masts represent a measure for the stability in the surface layer. This stability is important for the vertical spread and diffusion of air pollutants emitted in the lowest hundred metres of the atmosphere.

Few analyses are available of the stability distribution in the Helwan area.

Most important for the occurrance of high air pollution concentrations in the surface layer is the probability for surface based or low level inversions. One study of inversion statistics based upon data from the Helwan meteorological observatory has been published by Hassanein et. al (1976).

Monthly frequencies of surface based inversions and all inversions with base lower than 1 200 m is shown in Figure 8.

Monthly frequencies of surface based inversions and all inversions with base lower than 1 200 m is shown in Figure 8.

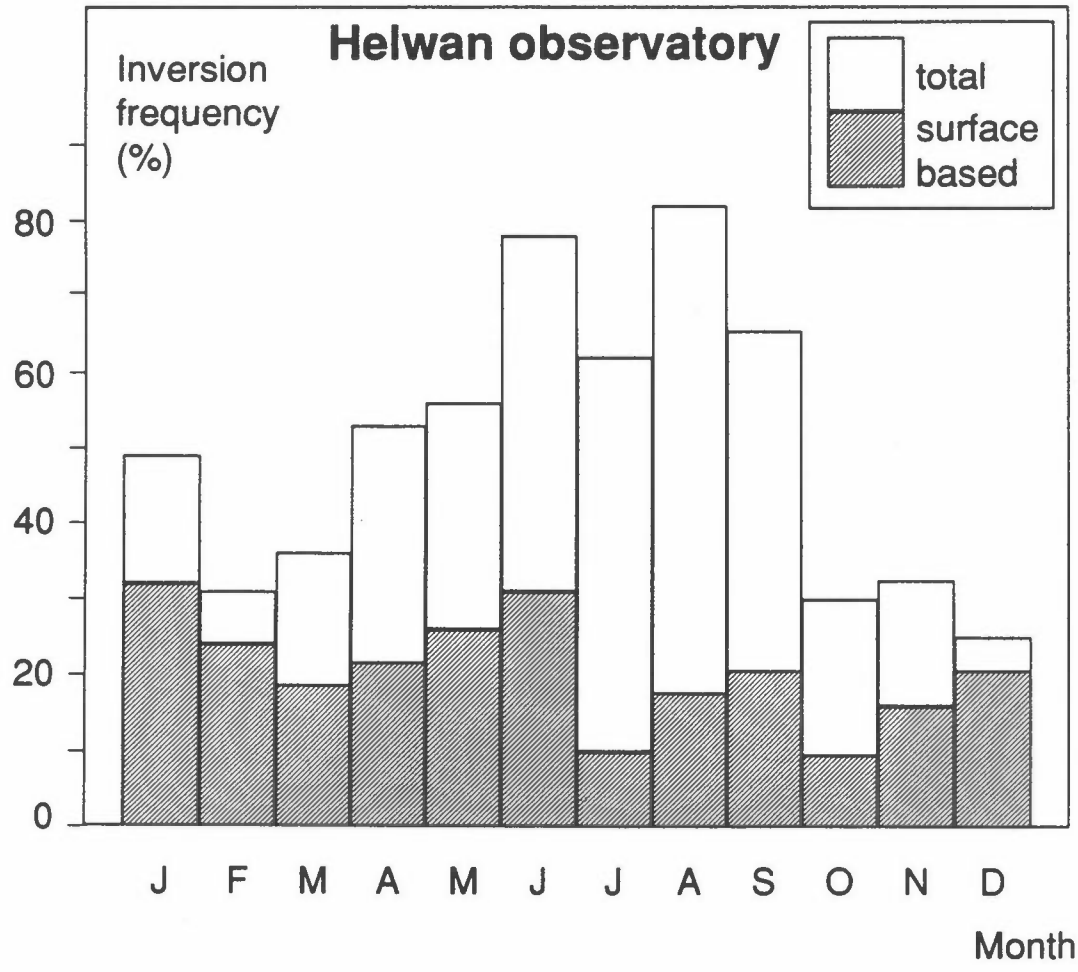

Figure 8: Monthly frequencies of: Surface based inversions, and all inversions with base < 1 200 m measured at 0000 hrs GMT. Data from Helwan, December 1965-November 1970.

From the conclusions drawn by Hassanein et.al the surface based inversion intensity is higher in winter than in summer. At night surface based inversions occur between 10 and 35% of the time, most often in winter and less often in the late summer season. Elevated inversions most often occur during the summer season. This might cause problems of fumigation which will bring dust and smoke from tall stacks rapidly down to the surface.

At daytime and in the afternoon elevated inversions with height less than 1 200 m occurs most often in the winter season. Surface based inversions rarely occurs in the afternoon. The seasonal variation of surface based inversions is shown in Table 3.

Table 3: Seasonal distribution of surface based inversions (per cent) at Helwan, 1956-1970.

	00:00 GMT	12:00 GMT
Winter	75	1
Spring	58	0
Summer	30	0
Autumn	50	1

4.2.4 Rain fall

Rain falls mainly in the cold season at Helwan.

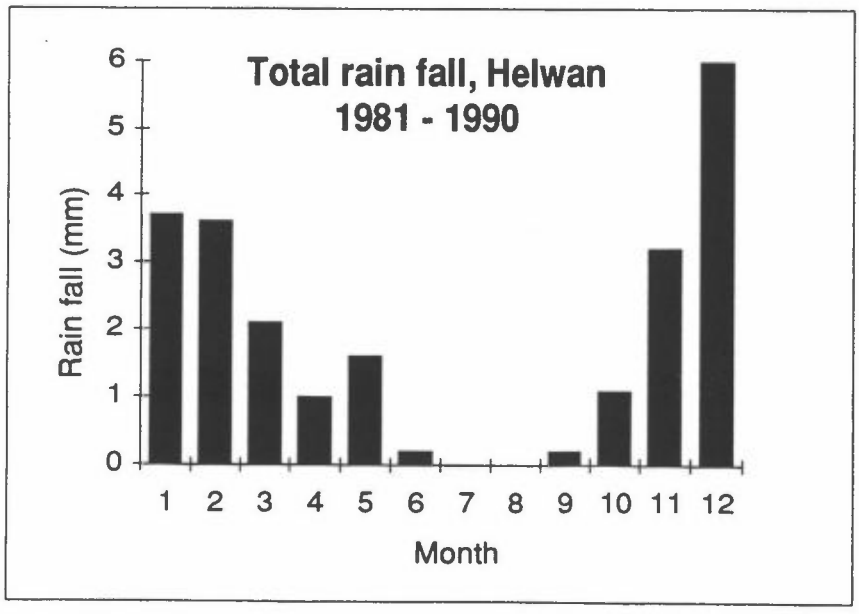

Figure 9: Monthly average total rain fall at Helwan (mm) for 1981-1990.

About 60% of the annual total (22.3 mm) falls in the months of December, January and February. December is the rainiest month. Summer and early autumn (June-September) are absolutely dry months, with no observed precipitation.

4.2.5 Cloud cover

As would be expected in a sub-tropical semi arid country, the mean monthly total cloud amount does not exceed 3 octas. The mean monthly cloud cover reaches a maximum in winter (2.5 octas) and a minimum in the summer (0.5 octas) as seen in Figure 10.

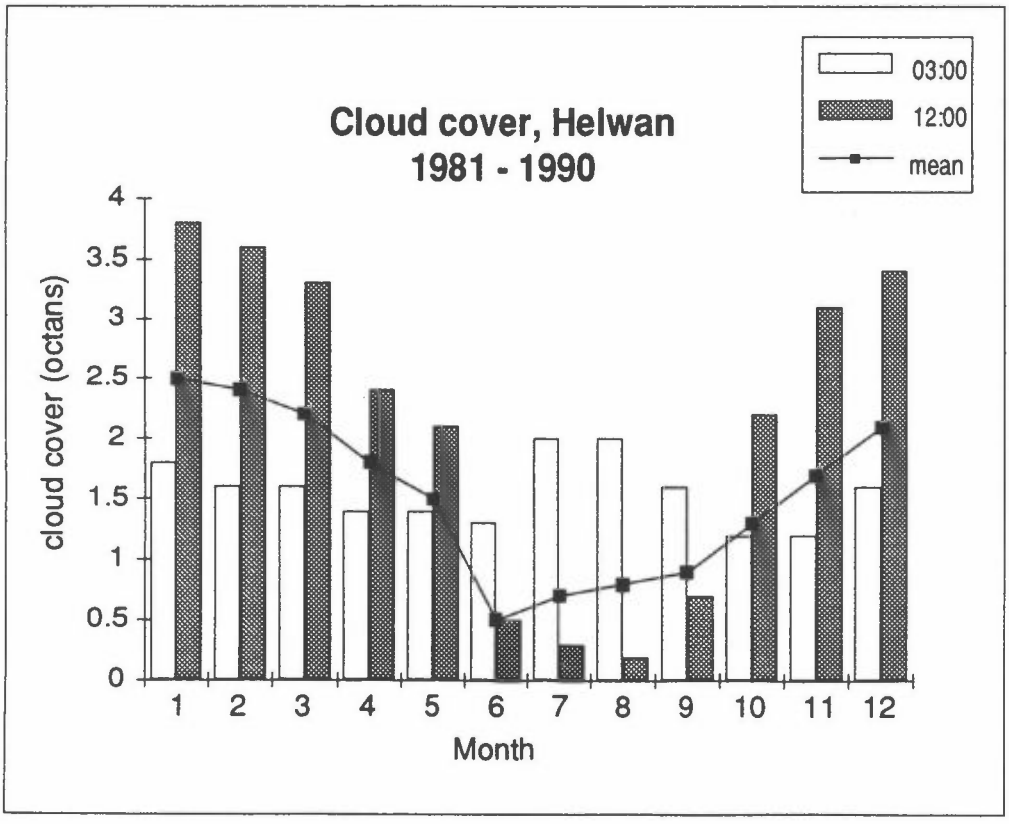

Figure 10: Monthly average cloud cover at Helwan (in octas) observed during 1981-1990.

In general, there is a noticeable diurnal variation of cloudiness. The observations show more clouds by day than by night. In summer there is a particular pattern of diurnal variation,

when cloudiness has its maximum amount at early morning. On many summer days, early morning low stratus forms. The sky is completely covered and the cloud cover frequently reaches 8/8, with cloud heights of about 300-600 m. This formation is due to radiation loss and turbulence in the humid surface layer, and usually disperses from two to four hours after the sunrise leaving clear sky until the next morning.

4.2.6 Solar radiation and sunshine

The strong relationship between global radiation and sunshine duration is illustrated in Figure 11.

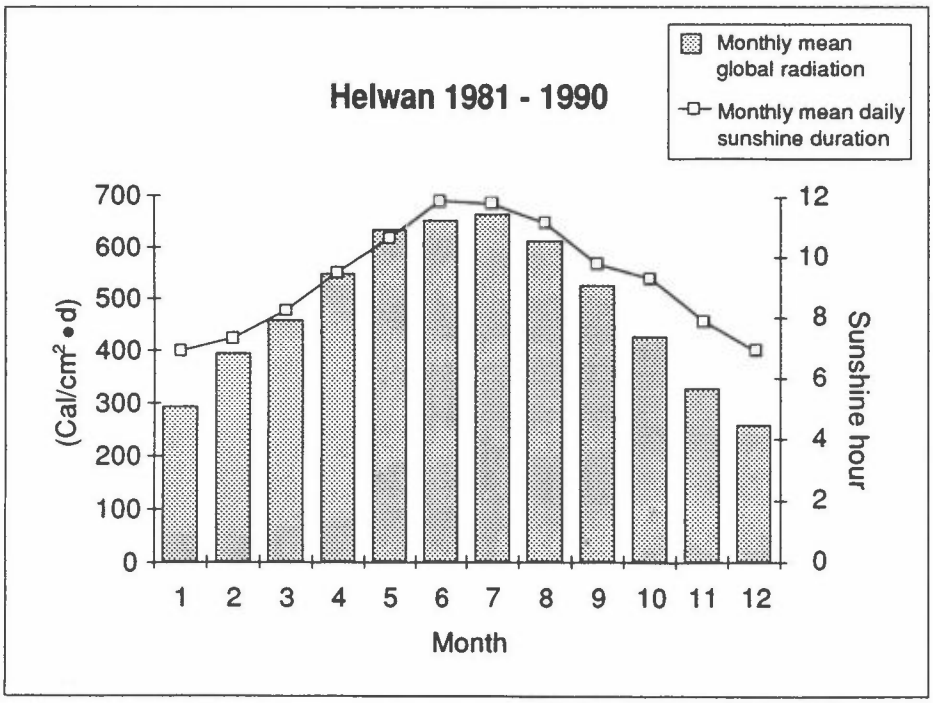

Figure 11: Monthly average values of global radiation (cal/cm^2 day) and sunshine duration (hrs).

Maximum values occures during summer and minimum during winter. One should expect that cloudiness might have some effects on global radiation during summer.

4.2.7 Dust storm

Among different weather phenomena which occur not only in Egypt but also in the rest of Northern Africa, one is certainly polluted and most unpleasant for the population. This phenomenon most frequently appears as strong southerly hot, dry and dust laden winds causing occasionally severe dust storm. This wind is usually named as Kahmsin in Egypt. Khamsin means in arabic language "fifty", referring to the period of fifty days in spring - from late March to early May - when it is considered that this weather most frequently occurs. (Figure 12).

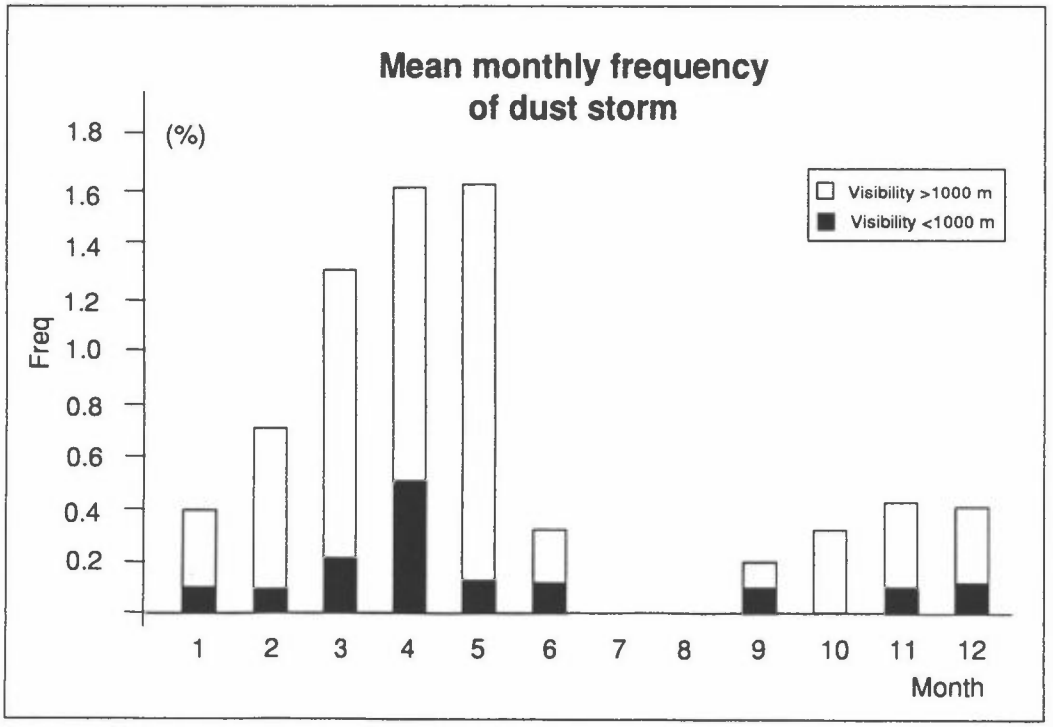

Figure: 12: The mean monthly frequency of dust storms "Khamsin".

Dust storms may also occur during autumn and winter, but with less frequency. The later cases are usually associated the cold fronts and with lower temperature and more humid air than the former one.

4.3 AIR QUALITY

4.3.1 Air pollution sources in Helwan

The area of Helwan is considered as one of the most concentrated industrial areas. The area's boundaries in which the industries lie reach up to 40 km^2 to the south of Cairo. Its main centre lies in the north south alongside of the Nile river. The industrial area starts about 8 km from the south border of the city of Cairo. It reaches up to about 17.5 km. The area is about 350 m broad in its northern part. The southern part is about 8 km broad. The population in the area amounts to approximately 400 000 inhabitants. More than 100 000 workers are occupied in the industries. A number of these live in the same industrial area, whereby others live in the city of Cairo.

The industries vary in the area including engineering industries, construction industries, textile industries, chemical industries, electric power stations and others. Most of the industries are located in the southern part of the area. The

The industries emit a variety of pollutants into the air. Table 1 defines the most significant industries and types of main air pollutants emitted.

Table 4: Major industries in the Helwan area and types of air pollutants emitted.

INDUSTRY	TYPE OF EMISSIONS
Portland Cement Co. Tourah	Solid particles (dust), sulphur oxides, nitrogen oxides
Sigwart Asbestos Co. automotive industry	Solid particles, sulphur and nitrogen oxides
Portland Cement Helwan	Solid particles, sulphur and nitrogen oxides
Iron and Steel	Solid particles, sulphur oxides, nitrogen oxides and carbon monoxide
Steel Works	Solid particles
Ceramics & Porcelain	Solid particles and sulphur oxides
National Cement Co.	Solid particles, sulphur and nitrogen oxides
Pottery Industries	Solid particles, sulphur and nitrogen oxides
Metal/Metallurg. Ind. Co.	Solid particles (containing lead and cadmium) and sulphur nitrogen oxides
Steel Pipes	Solid particles, sulphur and nitrogen oxides
Power Station Tebeen	Sulphur oxides, nitrogen oxide and smoke
South Cairo Power Station	Sulphur oxides, nitrogen oxide and smoke
Coke, Chemicals & Fertilizers	Sulphur oxides, fume, hydro carbons, nitrogen oxides, ammonia, hydrogen sulphid, particulates

The impact of pollutants became apparent through the factors of soiling and the increase in annoyance and disturbances to inhabitants of the area. In addition a decrease in crop productivity reached more than 70% in a number of cases (Mahmoud Nasralla et al., 1990; Dr. Esmat Ali et al., 1990). The decrease in visibility and in the incoming solar radiation reaching the earth surface was reported (Abd El Salam et al.,

1979). It was furthermore established that the rates of chest diseases surpass those similar to such in other Egyptian cities (Amal Saad El Din, 1986). The average growth of children (11-15 years of age) has decreased compared with the growth average in other areas in Egypt. To this there is the accumulation of toxic elements in some parts of the soil especially in the southern part of the area (Esmat Ali et al., 1991).

4.3.2 Dustfall in the Helwan industrial district

A study was conducted to investigate the rates of dustfall over the industrial area of Helwan during the years 1966 and 1967 and the years 1988 and 1989, i.e. with a difference of more than 20 years. This provides the possibility of evaluating the extent of deterioration in the area, thus establishing the extent of success or failure of any attempt made to improve the environmental conditions in the area of Helwan during this period.

Figure 13 indicates deposition rates during the year 1966 (Mahmoud Nasralla, 1968). There are clearly three areas where the dust fall reach limits that can by no means be accepted. These are the areas surrounding the Portland Cement Co. in Helwan reaching 168 $g/m^2 \cdot 30$ d during the year 1966. The second site with the highest deposition rates was concentrated around the two companies of iron and steel, coke and chemicals. There the deposition rate reached a yearly average of 115 $g/m^3 \cdot 30$ d during the year 1966. The third area established with high rates of dust deposition is the northern area around Tourah Cement Co. (38 $g/m^2 \cdot 30$ d).

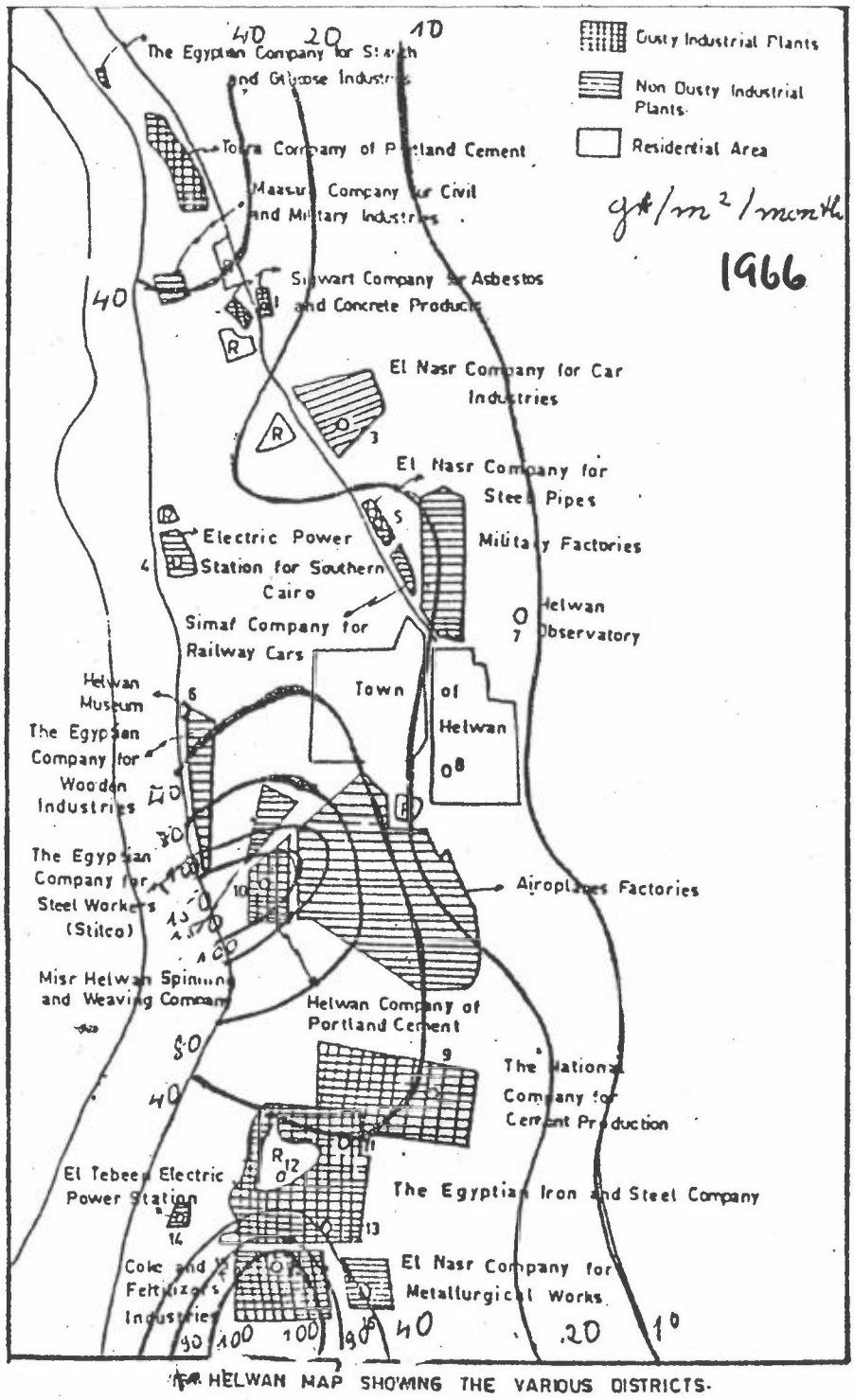

Figure 13: Average dustfall over the area during 1966.

These dust fall values can be compared with those recorded during 1989 (Nasralla et al., 1989; 1992) in order to see the changes that have been present during 20 years. Figure 14 illustrates the distribution of the highly polluted areas during the year 1989. The most recent studies indicate mainly the same distribution of dust deposition in the heavily polluted areas compared to the year 1966. This proves the role of those industries emitting dusts as being the main sources. We also see an unexpected increase in all areas and especially the areas of the cement industry (National, Portland and Tourah). This study indicates the existence of three areas with very high dustfall rates:

1. The area surrounding the National Cement Co. with a deposition rate that has reached a yearly average of 304 g/ $m^2 \cdot 30$ d in 1989 with a sevenfold increase compared to the deposition rate found near the company in 1966. This area reaches out to include the area surrounding the Portland Cement Co. in Helwan with a yearly deposition rate reaching up to 210 $g/m^2 \cdot 30$ d in 1989 with an increase of about 42 $g/m^2 \cdot 30$ d compared with the year 1966.

2. The area surrounding the Tourah Portland Co. where the deposition rate over the neighbouring residential areas reach up to 116 $g/m^2 \cdot 30$ d (1989) as compared to the annual average during 1966 which was 38 g/ $m^2 \cdot 30$ d.

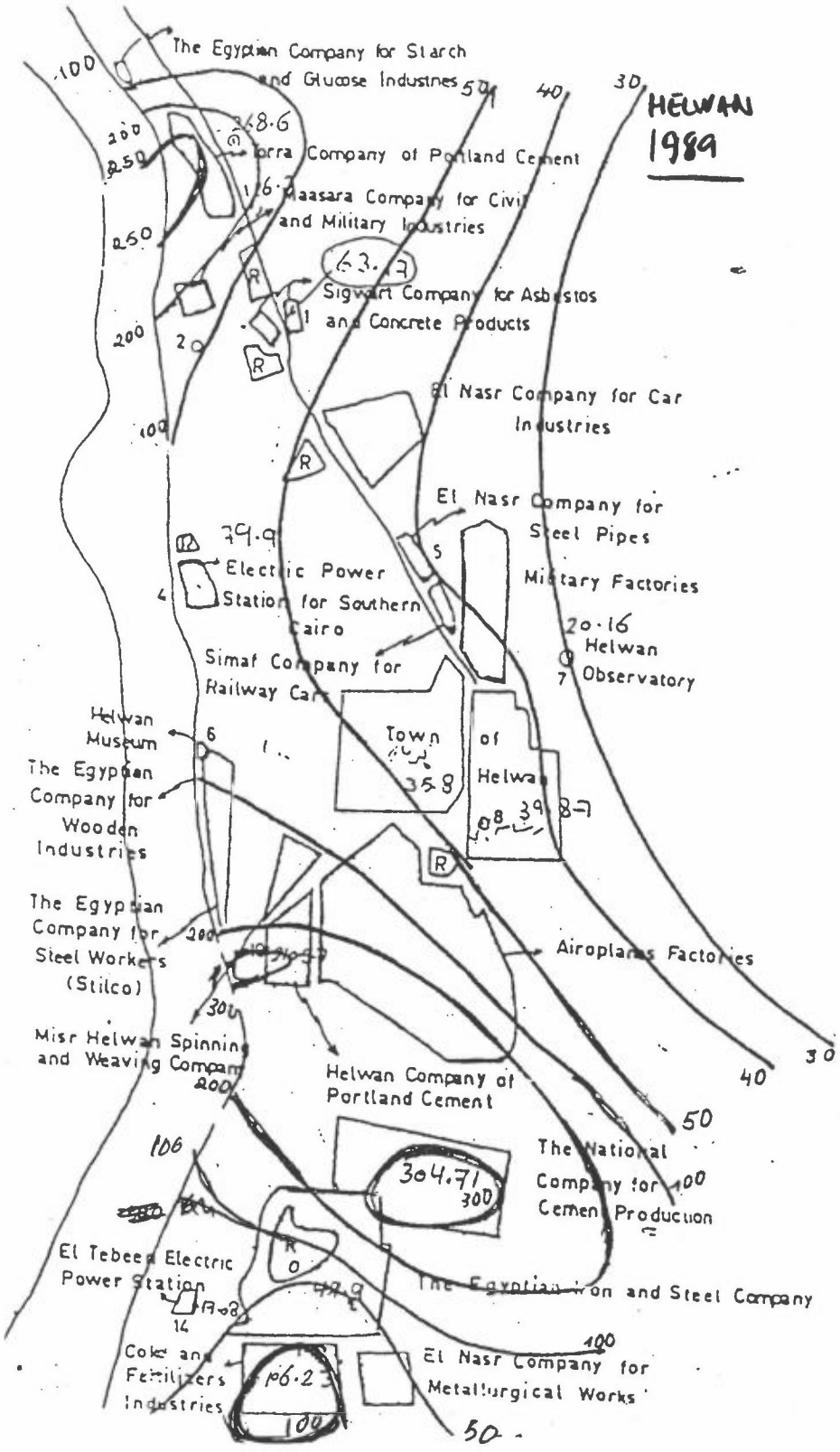

Figure 14: Annual mean rates of dustfall over the area during 1989.

3. The third area with high deposition rates is the area surrounding the iron and steel plant and the company of Coke and Chemicals. The dustfall rates during 1989 reached 49 g/ $m^2 \cdot 30$ d in the vicinity of the Iron and Steel Co. and 106 g/ $m^2 \cdot 30$ d in the vicinity of Coke and essential Chemicals Co. These are levels that do not differ much from those recorded during 1966 despite of expansion in the industry of iron and steel.

The unexpected increase in dustfall reflects the extent of expansion in the cement industry without any control or consideration for the surrounding environment. The relative stability of the dustfall rates in the vicinity of the Coke and the Iron and Steel Co. indicates that the overall emission rates emerging from both plants remained almost stable during the last twenty years inspite of expansion in the industry of iron and steel. This might have been a result of decrease of dust emission per ton of product. Yet its surrounding area is still suffering from this unacceptable rate of dustfall.

Comparing dustfall rates around cement plants with deposition rates in neighbouring areas of the Helwan Observatory, as a control site far from the effects of industrial processes for this area, the most pollutant areas reach up to 10-15 fold the 20 g/ $m^2 \cdot 30$ d annual mean of dustfall over the Observatory. Dustfall values collected at the Observatory also show an increase during the last twenty years; from 11 g/$m^2 \cdot 30$ d to 20 g/$m^2 \cdot 30$ d. This is a result of increased amounts of dusts carried from the industrial areas. If we consider that the deposition rate measured at the Observatory in 1966 is the highest rate of natural dusts in the area, then this means that the dustfall rates in the vicinity of the cement companies have reached 20-30 fold their natural background values. Added to this is the fact that these dust deposition rates are much higher than any air quality standard set for dustfall.

A summary of dustfall rates measured in 1966 and 1989 is presented in Table 5.

Table 5: Summary of dustfall rates ($g/m^2 \cdot 30$ d) over the Helwan area, measured in 1966 and 1989.

Location	Annual average dustfall ($g/m^2 \cdot 30$ d)		Monthly average dustfall ($g/m^2 \cdot 30$ d)	
	1966	1989	min.	max.
Tourak	-	268.6	196.8	387.0
El Balad (Tourak)	29.6	116.3	71.9	180.2
Sigwart	33.2	63.2	58.0	74.4
El Hawamdeya	-	45.2	23.2	82.2
South Cairo Power	20.8	79.9	42.0	101.3
Cabitage, Helwan City	-	35.8	19.6	65.3
Helwan municip.	16.2	39.9	11.3	72.3
Observatory	11.2	20.2	3.4	42.0
Helwan Portland	168.2	210.6	164.5	256.2
National Cement	39.0	304.7	231.6	432.0
Near Iron & Steel	32.9	49.9	22.0	80.0
El Tibbin power	21.4	47.1	20.9	58.0
Near Coke co.	115.3	106.2	64.2	180.8
El Sheweh village	-	67.1	37.0	111.1

A monthly average dustfall rate for the whole area (based upon 16 sites) is presented in Figure 15.

The average dustfall over the whole area (16 sites) were 61 $g/m^2 \cdot 30$ d. In the residential areas the dust deposition were ranging between 32 and 116 $g/m^2 \cdot 30$ d. These are up to 23 fold the maximum permissible limit of dustfall over residential and commercial city districts in the USA (5.2 $g/m^2 \cdot 30$ d).

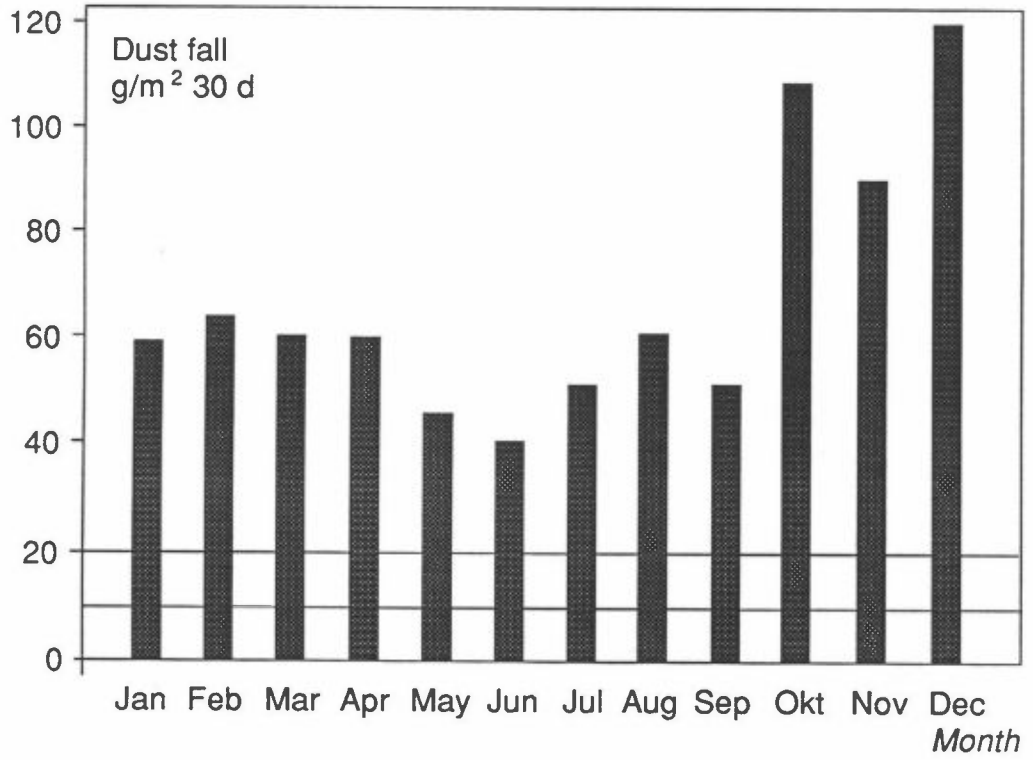

Figure 15: Montly dustfall rates averaged over the Helwan area (16 sites) during 1989.

The average rates of dustfall over the entire Helwan area, starting from Tourah in the north and reaching El Tebeen in the south, those have increased from 40 $g/m^2 \cdot 30$ d in 1966 to 107 $g/m^2 \cdot 30$ d in 1989. That means that dustfall over the Helwan area has increased 167% in twenty years, i.e. with an annual rate of about 7.5%. This increase in dust fall rates was clearly reflected on the extent of industrial growth and especially concerning the cement industry in Helwan. It also clearly reflects the absence of any kind of environmental planning or any efforts for the protection of the environment over the last twenty years.

The maximum dustfall rate over the Helwan industrial area is

found to be during the months of October-December. The lowest dustfall rates were those of the summer and spring seasons. The expected reason for the lowest dustfall rates during the summer season is the active north winds, the clear sky, the absence of rain and the relative decrease in humidity, which minimises the falling of dusts emitted into the air. Yet unexpected is the decrease of dustfall rates in the spring season too, with the "Rhamasin Duststorms" loaded with dusts and sand swirled up from the desert, covering almost the entire cities of the Republic. It was established from previous studies in 1963 in Cairo and in 1966 in Helwan that the highest dustfall rates were measured during the spring season. In 1989 it was found that dustfall rates during the spring seasons are the least. The role of the well known sand and dust storms that occur in Egypt in the spring season vanish during the eighties as result of the high dust emissions from cement companies and other industries in the Helwan area.

4.3.3 Chemical composition of dustfall over Helwan

Table 6 indicates that the chemical composition differs from one area to the other in Helwan. This is due to:

1. The nature of activities in each area and accordingly the type of emissions.

2. The size of different size particles and composition differ greatly and the amount of pollution reaching different areas differs accordingly.

Table 6: Chemical composition of dustfall over different areas in Helwan.

	Water soluble materials				Insoluble materials		
	Total	Calcium	Chloride	Sulphates	Tar	Ash	Combustible
Near dusty industries	14.8	1.99	0.8	1.19	0.61	61.04	23.52
Near non-dusty industries	18.39	1.71	1.45	2.01	0.7	59.1	21.8
Residential areas	18.7	3.5	1.19	0.89	0.16	58.2	21.8
Residential industrial areas	17.9	4.3	1.4	1.3	0.8	62.3	21.4

Ash reaches its maximum concentration, as expected, in dusty industrial areas and residential industrial areas, since it is always associated with particles of big sizes. As for soluble materials of micro size they travel great distances and thus reach their maximum concentration in residential areas. It is well known that soluble materials contain various harmful materials in addition to their susceptibility of being absorbed through the skin and the respiratory system much faster than other non-soluble materials.

Table 7: Average concentration of different elements in dustfall over the Helwan industrial area (16 locations) (1989).

Element	Average concentrations (1989)
	Percentage of dusts
Sodium	0.68
Magnesium	1.77
Potassium	0.47
Calcium	11.57
Iron	3.32
Zinc	0.06
Chromium	0.003
Manganese	0.02
Cobolt	0.01
Nickel	0.01
Copper	0.02
Cadmium	0.005
Lead	0.02

Analyses of the dustfall indicated the following:

1. Increase in percentage of sodium, potassium and calcium which form the main compounds of dusts released from cement factories.

2. The elements of cobolt, nickel, cadmium, vanadium and lead are found in concentrations reaching sometimes up to 200 ppm nickel and 600 ppm lead. The highest concentrations are due to the metallurgical industries in the area in addition to the fuel combustion, especially heavy oil used in industries and electric power stations.

It is apparent that the main reason for dust pollution in the Helwan area is industries of construction, pottery and porcelain, iron and steel, coke and chemicals resulting in dustfall averages exceeding 100 $g/m^2 \cdot 30$ d.

Nasralla et al. (1985) suggested the installation of a control device of more than 99% efficiency or establishing buffer zones of about 5 km around the three cement companies if they are going to release the same rates of dust emissions without any further control steps. The later solution necessitate the immigration of the population of the whole area (Figure 15).

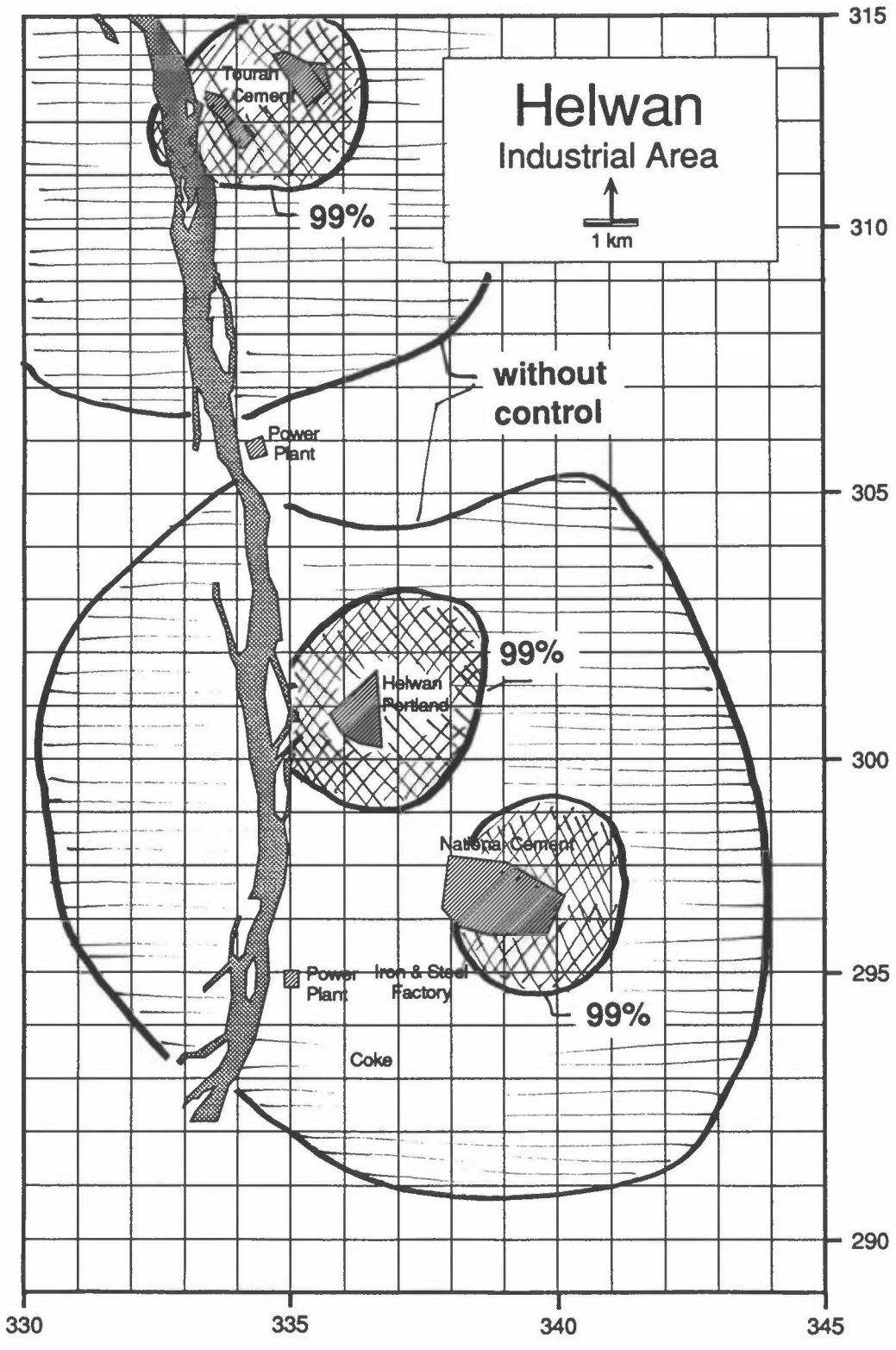

Figure 15: Polluted areas and suggested buffer zones around cement factories at present and upon control 99% control.

4.3.4 Suspended particulate matter

In 1983 and 1988 studies were undertaken focusing on suspended dusts and smoke in the industrial area of Helwan. The study was undertaken by the Air Pollution Department (Dr. Esmat Abd El Shakour and Mahmoud Nasralla). The study was made in the city of Helwan (the residential area). The average concentration of suspended dusts was found to reach 738 $\mu g/m^3$ at the same site in 1988. Daily concentrations of suspended dusts were between (average 24 hours) 325 and 1576 $\mu g/m^3$. Those concentrations for a residential area cannot be accepted by any recognized air quality criteria.

Table 8 illustrates the most significant concentrations found in Helwan City (residential area) for the two years 1983 and 1988 (Esmat Ali, 1987; M. Nasralla & E. Ali, 1992).

Table 8: The most significant concentrations of suspended dusts and smoke measured in Helwan City near the Cabritage (in $\mu g/m^3$).

Security	Concentration of suspended dusts		Smoke	
	1983	1988	1983	1988
Annual average	738	819	75	89
Max. monthly concentration	1030	1050	115	125
Max. 24 hr concentration	1800	1576	170	295

The official results of total suspended particulate (TSP) measurements performed by the Ministry of Health, National Air Pollution Network, in 1988 and 1990 is presented in Figure 16.

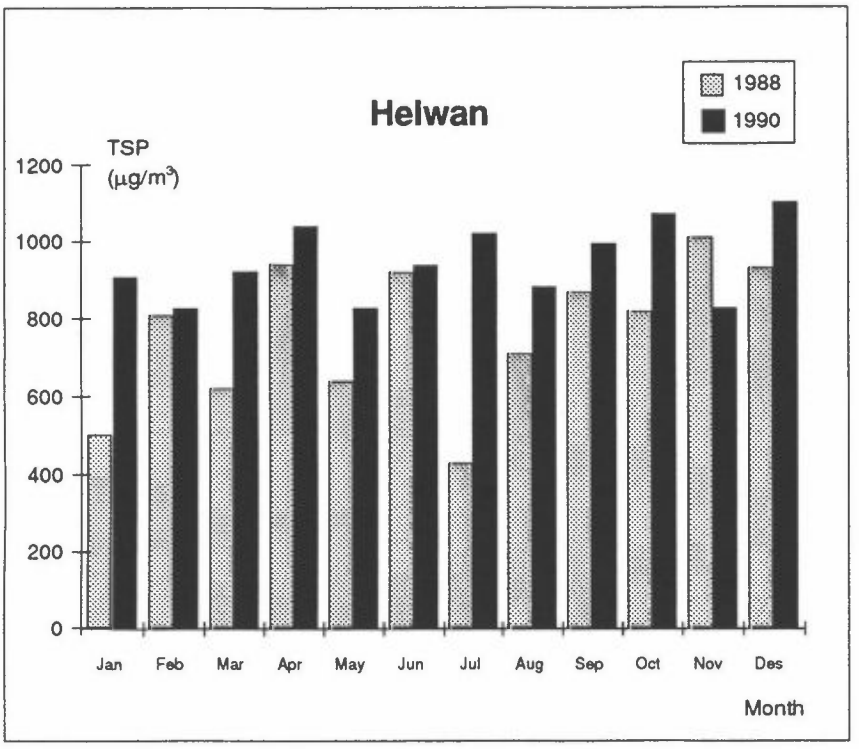

Figure 16: Monthly average of suspended particulates in Helwan City for 1988 and 1990.

Other measurements of suspended dust concentrations in the residential city of Helwan has resulted in an annual average of 738 $\mu g/m^3$ in 1983. Concentrations in the city centre of Helwan, at the Health Bureau, were between 503 and 1473 $\mu g/m^3$ as 24 hour concentration averages (Egyptian Ministry of Health). This average reached in 1989 a high of 1104 $\mu g/m^3$. The highest 24 hour level concentration was 2166 $\mu g/m^3$ compared with the maximum permissible limit of 150 $\mu g/m^3$ as a 24 hour average.

Table 9: Concentrations of smoke and suspended dust in 1989 at the residential city of Helwan.

Month	Smoke $\mu g/m^3$		Suspended dust $\mu g/m^3$	
	Highest concentration	Average	Highest concentration	Average
January	182	83	1048	1021
February	182	98	1128	1070
March	201	111	1023	927
April	216	130	1021	944
May	201	118	1103	1005
June	201	94	1042	962
July	201	96	2166	1788
August	201	95	1367	992
September	125	81	1642	1172
October	125	78	2053	1422
November	74	42	1221	1054
December	93	36	914	894
Annual average		88.9		1104.3
Highest conc. (24 hr)	216		2166	

4.3.5 Smoke

Smoke is known as "Black minutes suspended particles basically carbon (soot). They generate mainly from the process of incomplete fuel combustion. They furthermore contain several hydrocarbons and a number of heavy metals."

During the year 1977 the Air Pollution Department (El Tayeb, 1981) has undertaken a study on smoke in different areas of Helwan city. Table 10 illustrates high smoke concentrations near fuel combustion sources at electric power stations and different industries. Smoke concentration has reached about 90 $\mu g/m^3$ in the vicinity of the electricity power station and the iron and steel company. Concentrations in the Cabritage Area reached 77 $\mu g/m^3$ as an annual average.

Table 10: Monthly smoke concentrations ($\mu g/m^3$) in the Helwan area (El Tayeb, 1981).

Month	South Cairo power	Iron & Steel Plant	Cabritage
October 1976	79.4	87.6	68.9
November	85.4	109.4	97.1
December	132.5	114.5	101.5
January 1977	163.0	134.6	117.1
February	87.3	99.7	95.3
March	58.5	66.6	50.4
April	69.3	73.0	49.7
May	56.8	72.3	53.2
June	-	78.5	71.4
July	-	89.2	85.3
August	-	58.5	64.9
Average	91.5	89.4	77.7

The air quality guidelines given by WHO specify that together with SO_2 smoke concentration as a 6 month average should not exceed 40-60 $\mu g/m^3$.

Measurements performed by the Air Pollution Department in 1983 and 1988 in the Helwan residential area have shown that the average smoke concentration in 1983 was 75 $\mu g/m^3$ and has reached 89 $\mu g/m^3$ in 1988. This confirms an increase in the concentrations of this pollution in the Helwan City (measured by the Ministry of Health) as shown in Figure 17.

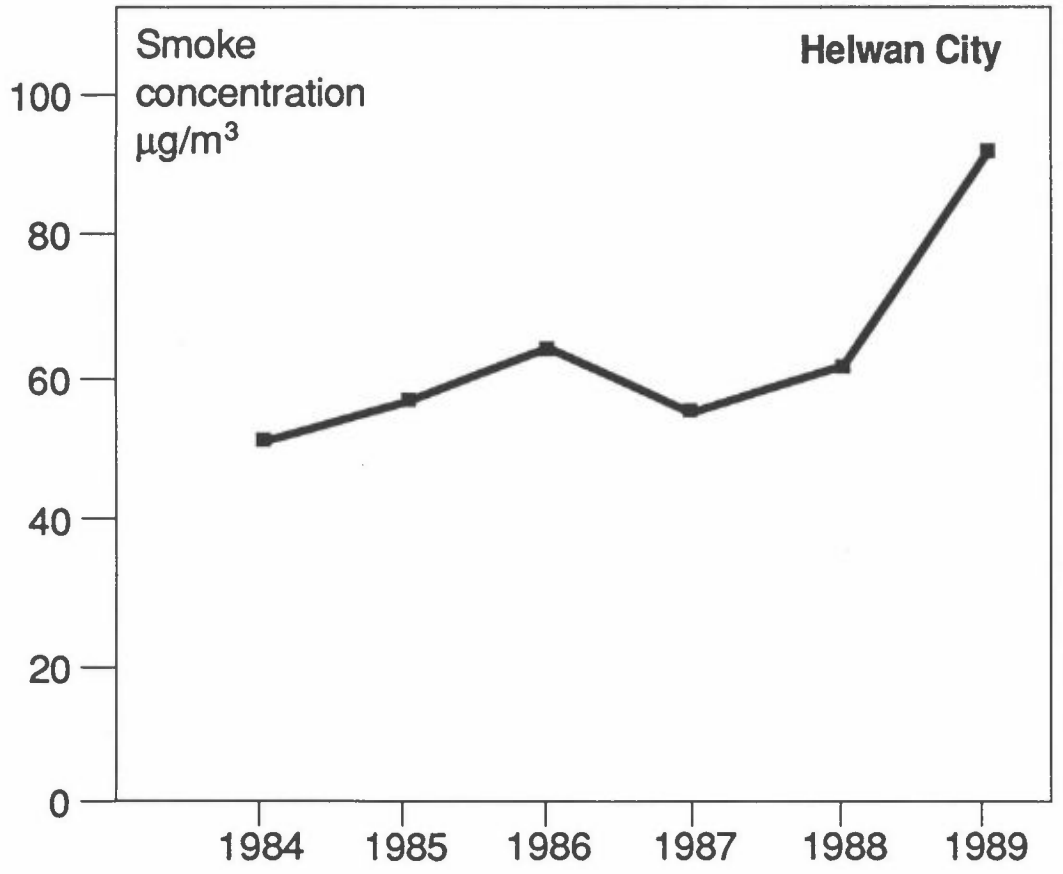

Figure 17: Annual average smoke concentrations in the residential city of Helwan.

Smoke measurements from El Masara indicate in Table 11 smoke levels somewhat higher than in Helwan City.

Table 11: Smoke concentrations at El Masara (measuring of Ministry of Health).

Month	Smoke in $\mu g/m^3$ highest concentration	average
January	101	71
February	254	139
March	177	91
April	190	103
May	164	108
June	190	102
July	190	142
August	190	117
September	164	106
October	164	93
November	232	176
December	117	62
Annual average		157.4
Highest concentration	254	

The high concentrations of dustfall and total suspended dust generating from the Helwan industries have been focussed. Smoke (or soot) concentrations, however, contains contaminants which might be more harmful to the health. Thus one should be aware of the increased fuel combustion without any technical control to limit emissions of these pollutants. It can also be apparent when observing stacks of industrial facilities (beside the cement industry) and chimneys of electrical power stations from which black smoke is apparent.

4.3.6 Gaseous pollutants

The Ministry of Health takes measures of sulphur dioxide (SO_2) in numerous areas in the Republic. Results reached by the Ministry of Health indicate that concentrations of sulphur dioxide are low both in Cairo and Helwan. Worth mentioning is, however, the fact that the measuring methods used by the Ministry of Health were proven to be useless as concerning measuring sulphur dioxide in the Egyptian atmospheres.

SO_2 measurements performed in Egypt were studied thoroughly and published in the Chemical Engineering Magazine (Nasralla et al., 1984). This study has recommended other methods that can measure sulphur dioxide without any interference of other elements that give totally wrong results. The study has recommended that any results reached according to this method (verification over hydrogen oxide upon air being absorbed in it) should not be trusted.

Therefore sulphur dioxide was measured using the colorimetric accurate method by the Air Pollution Department, NRC.

Table 12 shows a summary of concentrations of gaseous air pollutants measured in Helwan.

Table 12: Concentrations of gaseous air pollutants measured in Helwan (Cabritage), 1990 (Nasralla et al., 1992).

Pollutant	Averaging time	Measured conc. (ppb)	Max. permissible level (ppb)
Sulphur dioxide (SO_2)	Annual	30	20
Nitrogen oxides (NO_x)	"	60	-
Ozone (O_3)	One hour	40-140	100

The concentration levels of the gases shown in Table 12 (SO_2, NO_x and O_3) are low compared to levels normally found in urban areas. Gaseous air pollution seems not to be the major air pollution problem of the area compared to the dust levels represented by small and large particles and by elements, sulphate and other toxic substances related to the aerosol composition.

Consequently, it may be concluded that the problem of air pollution in Helwan has reached a serious stage. The environmental deterioration is continuing and increasing. This con-

firms the absence of a serious programme and underline the needs for establishing a modern and good surveillance programme. Immediate implementation should take place for treating pollution problems and monitoring the condition in this area. No new industries are to be built without preventing further deterioration of the Helwan area.

5 MEASUREMENTS TAKEN DURING THE STUDY PERIOD 1992

A measurement programme for air quality and meteorology was designed especially for this study in the Helwan area.

5.1 METEOROLOGICAL MEASUREMENTS

During the study period meteorological observations were collected from the Helwan Observatory of the Directorate of Meteorology in Egypt. Observations of wind speeds, wind directions, temperatures and relative humidities were taken every 3 hour. The wind recorder at the roof of the Tibbins Institute for Metallurgical Studies (TIMS) was out of order during the measuring period.

Manual observations of winds were also collected during the different field measurements. A plot of wind directions, wind speeds and temperatures is shown in Figure 18.

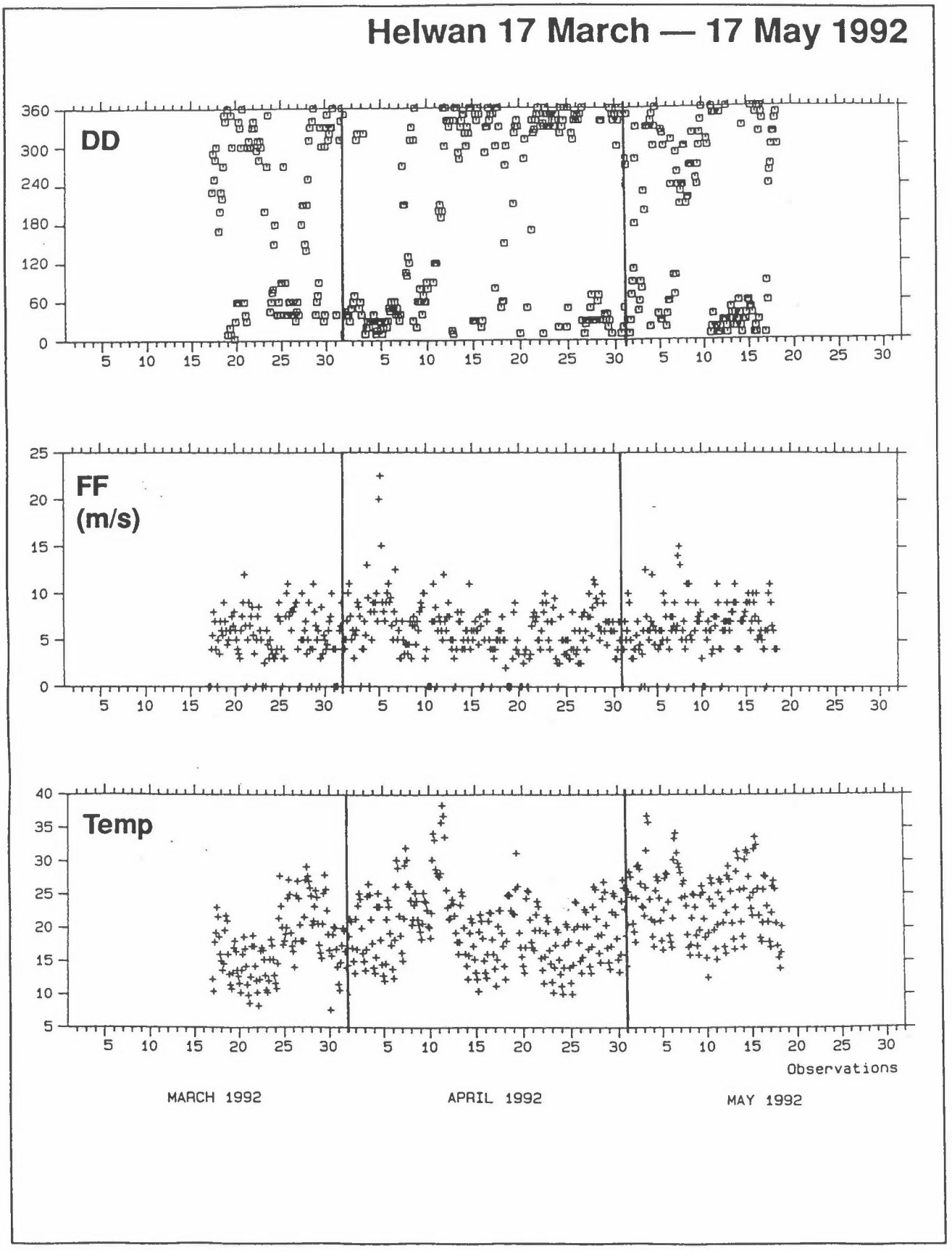

Figure 18: Records of wind direction (DD), wind speed (FF, m/s) and temperatures (°C) at Helwan Observatory for 17 March - 17 May 1992.

5.1.1 Wind frequency distributions

The wind direction frequency distribution for the Helwan observatory is shown for the study period i Figure 19.

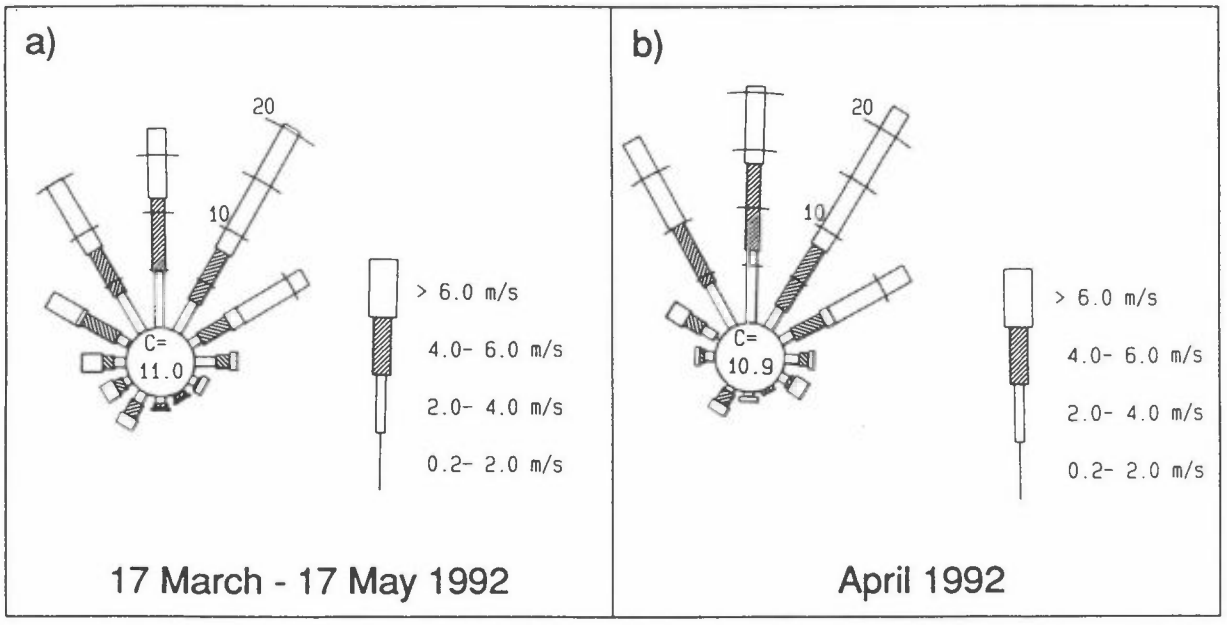

Figure 19: Wind direction frequencies (wind roses) for Helwan for a) 17 March-17 May 1992,
b) April 1992.

The predominant wind directions were from around north (N$\pm$45°), with north-northeast (NNE) as the most frequent 30 degree sector. The winds occurred in 23% of the time in this sector. During more than 60% of the time the wind blew from north $\pm$45°.

A more detailed frequency distribution for each third hour of the day and for the measuring period 17 March-17 May 1992 is presented in Table 13.

Table 13: The frequency (in %) of wind directions every three hour and the diurnal average (windrose) for Helwan, Kairo.

Wind direction*)	Diurnal variation of wind directions (%)								Wind rose
	0300 hrs	0600 hrs	0900 hrs	1200 hrs	1500 hrs	1800 hrs	2100 hrs	2400 hrs	
30	22.2	14.3	16.1	16.4	17.7	21.0	32.3	22.2	20.3
60	15.9	11.1	6.5	3.3	1.6	14.5	17.7	20.6	11.4
90	7.9	3.2	1.6	1.6	1.6	1.6	3.2	7.9	3.6
120	3.2	1.6	.0	.0	.0	1.6	1.6	3.2	1.4
150	.0	1.6	1.6	.0	.0	1.6	1.6	.0	.8
180	1.6	1.6	4.8	.0	1.6	.0	.0	.0	1.2
210	1.6	4.8	6.5	8.2	3.2	1.6	.0	1.6	3.4
240	1.6	3.2	9.7	1.6	3.2	1.6	.0	.0	2.6
270	1.6	.0	4.8	13.1	8.1	3.2	.0	.0	3.8
300	.0	4.8	9.7	14.8	19.4	4.8	4.8	6.3	8.0
330	7.9	11.1	12.9	26.2	22.6	16.1	17.7	6.3	15.1
360	17.5	11.1	14.5	11.5	17.7	30.6	17.7	17.5	17.3
Calm	19.0	31.7	11.3	3.3	3.2	1.6	3.2	14.3	11.0
No. of observations	63	63	62	61	62	62	62	63	498
Mean wind speed m/s	4.6	3.8	5.4	6.4	6.5	7.3	7.0	5.3	5.8

Classes of wind speed assigned to wind speed (%)

Class I : Wind speed .3 - 2.0 m/s
Class II : Wind speed 2.1 - 4.0 m/s
Class III: Wind speed 4.1 - 6.0 m/s
Class IV : Wind speed > 6.0 m/s

Wind direction*)	Classes				Total	No. of observations	Mean wind speed (m/s)
	I	II	III	IV			
30	.0	3.0	5.0	12.2	20.3	101	7.2
60	.0	1.0	2.8	7.6	11.4	57	7.4
90	.0	1.8	1.2	.6	3.6	18	4.7
120	.0	.6	.2	.6	1.4	7	5.9
150	.0	.2	.4	.2	.8	4	5.2
180	.0	.6	.4	.2	1.2	6	4.4
210	.0	1.0	1.4	1.0	3.4	17	6.2
240	.0	.6	.8	1.2	2.6	13	7.1
270	.0	1.0	1.0	1.8	3.8	19	6.4
300	.2	1.0	3.4	3.4	8.0	40	6.4
330	.0	3.8	4.4	6.8	15.1	75	6.0
360	.0	4.8	6.4	6.0	17.3	86	6.0
Calm					11.0	55	
Total	.2	19.5	27.5	41.8	100.0	498	
Mean wind speed (m/s)	2.0	3.6	5.4	8.5			5.8

*) The number gives the centre of the wind sector

An illustration of the diurnal variation of wind directions in shown in Figure 20.

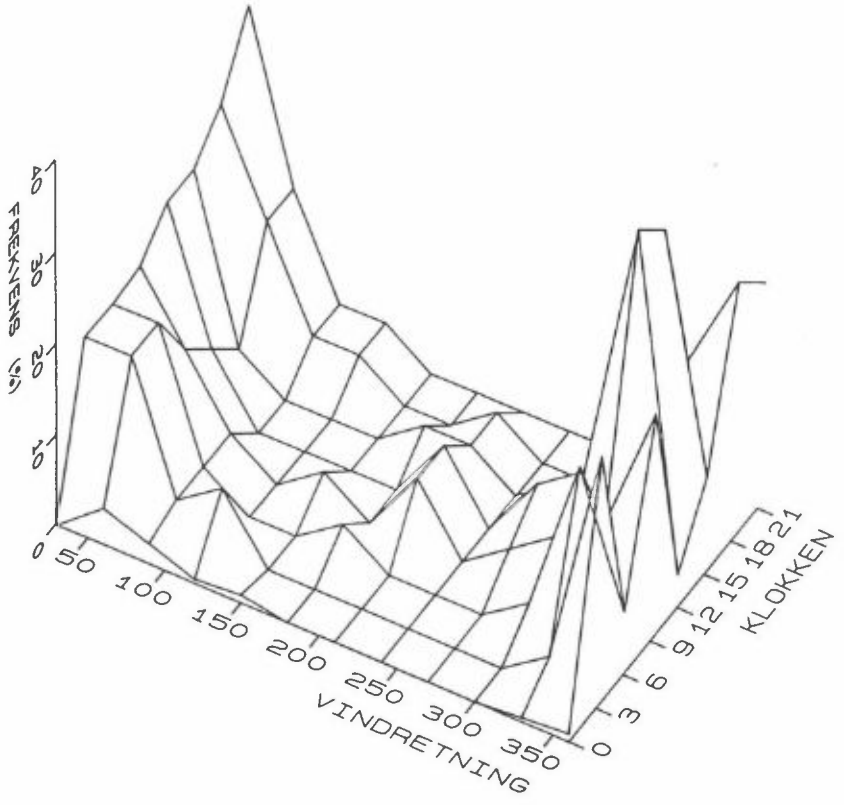

Figure 20: Diurnal variation of the wind direction frequency distribution at Helwan, April 1992.

Winds from north and north-northeast most frequently occurred in the late afternoon till around midnight, while winds from north and north-northwest occurred most often in the morning and at midday.

Winds from around south occurred most often between 0900 and 1600 hours in April 1992.

The average wind speed for the period was 5.8 m/s. The highest winds occurred when it was blowing from around northeast (NE$\pm$30°) (see Figure 21).

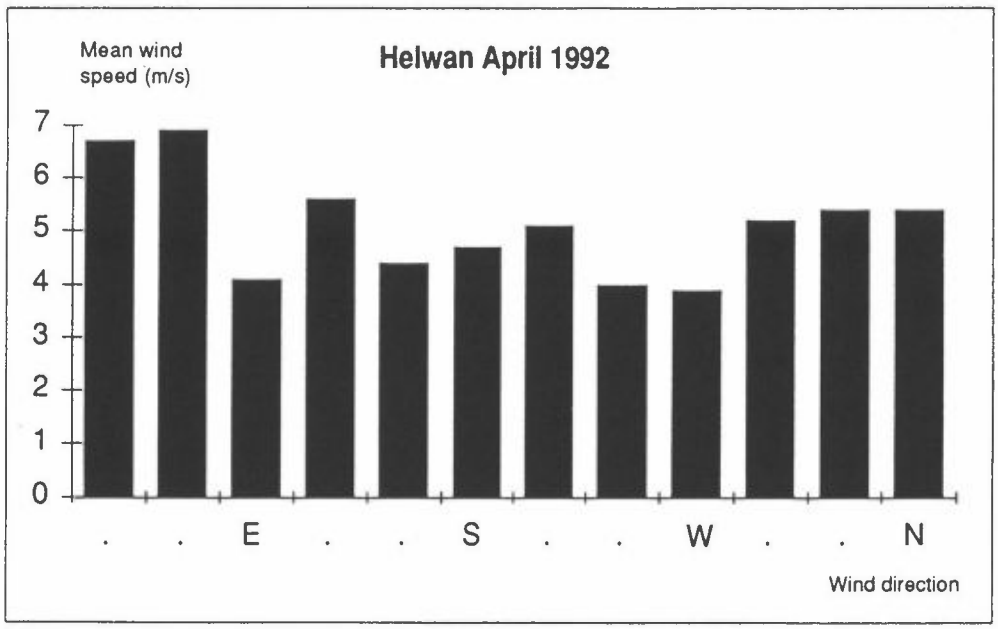

Figure 21: Average wind speeds as a function of wind directions at Helwan, April 1992.

The cumulative wind speed frequency distribution in Figure 22 shows a median wind speed of 5.3 m/s.

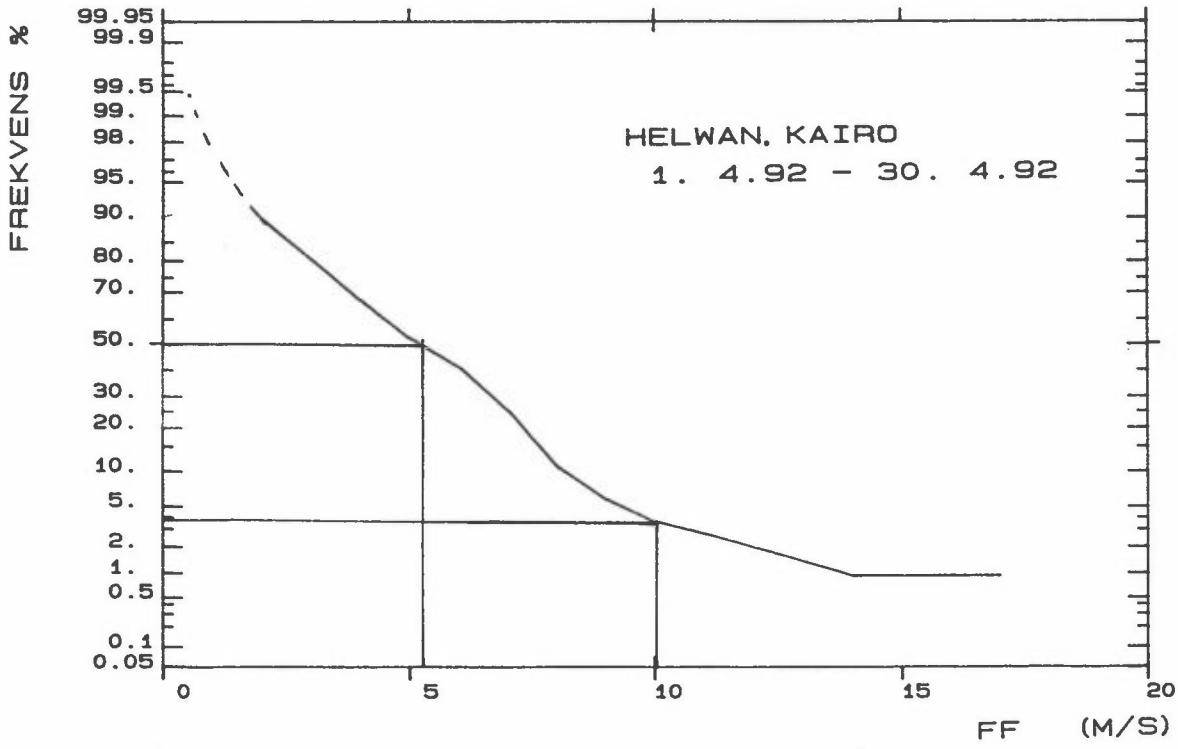

Figure 22: Cumulative wind speed distribution at Helwan, April 1992.

The diurnal variation of wind speeds show, in Figure 23 that during March to May 1992, the highest wind speeds occurred during night time hours.

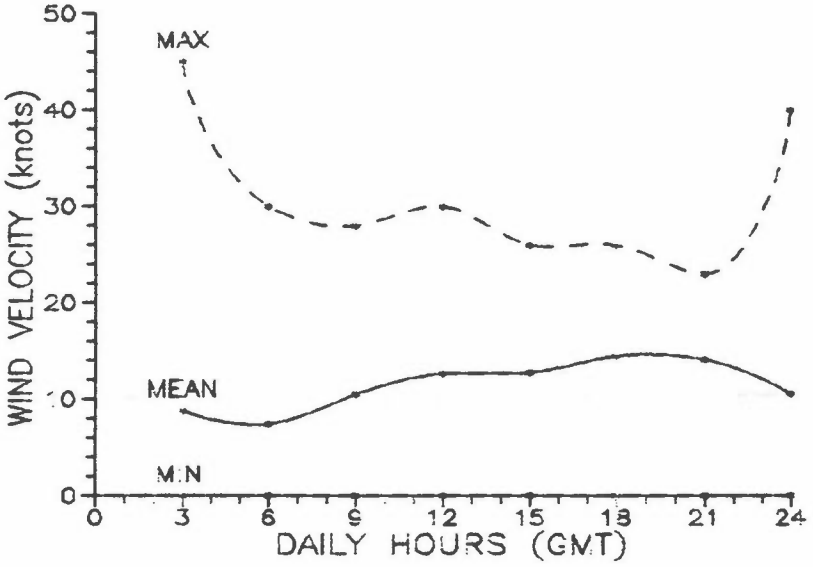

Figure 23: Diurnal variation of maximum and mean wind speed at Helwan, 17 March-17 May 1992.

On the average, the highest winds usually occur in the late afternoon and evening.

Only 3.5% of the wind was higher than 10 m/s. These high winds occurred at night from northeast.

5.1.2 Temperatures and stability

Temperature data for the measurement period 17 March- 17 May 1992 is presented in Figure 18. The average temperature for the period was 21^0C. Diurnal variations of minimum, mean and maximum temperatures measured during March-May 1992 is presented in Figure 24.

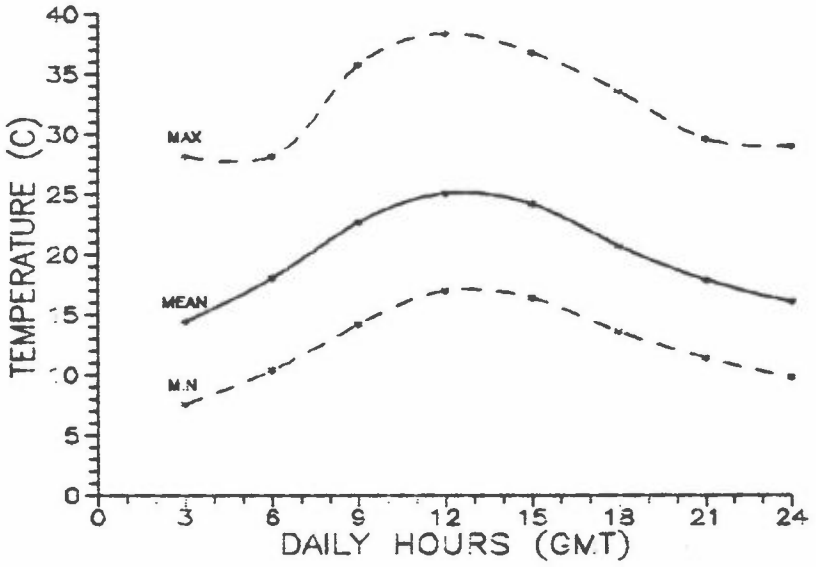

Figure 24: Diurnal variations of minimum, mean and maximum temperatures at Helwan, 17 March-17 May 1992.

The maximum temperature, 38.4°C, was measured on 11 April 1992 at 1400 hrs local time. The average temperature at noon was about 23°C for this measuring period.

Information about the stability of the surface layer has not been available during March-May 1992. For dispersion estimates data on surface based inversion as reported by Hassenein et al. (1976) (see chapter 4.2.3) has been used to estimate the frequency of 4 stability classes as a function of wind speeds.

Table 14: Estimated frequencies of four stability classes in four classes of wind speeds for Helwan.
(Data: Wind, spring 1992, stability for radiosondes 1965-70).

Wind speed class (m/s)	Stability occurrance (%)			
	Unstable	Neutral	Light stable	Stable
<2.0	5.0	0.5	6.5	2.0
2.1-4.0	6.5	9.0	7.0	1.5
4.1-6.0	9.0	15.5	3.5	0
>6.0	7.0	27.0	0	0
Total	27.5	52.0	17.0	3.5

Stable conditions occurred mostly during night time, at low wind speeds.

When using climatological dispersion models for long term average concentration distribution estimates, a frequency distribution of wind directions, wind speeds and stabilites has to be established. The data presented above for the study period 17 March-17 May 1992 has been used to establish this distribution.

5.1.3 Relative humidity

The highest relative humidities are measured at night time due to a fall in temperature.

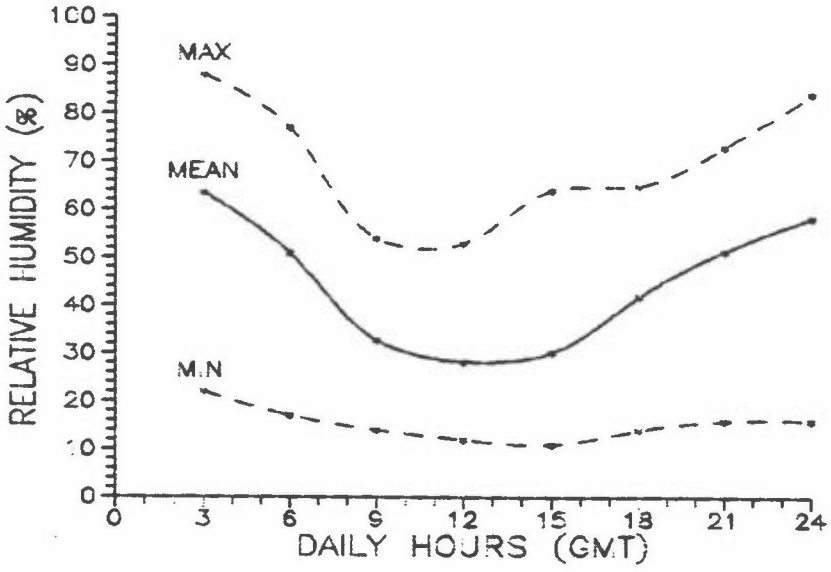

Figure 25: Diurnal variation of relative humidities at Helwan, 17 March-17 May 1992.

During daytime the typical average relative humidities are 30 per cent, at midnight the typical average values are 60-65 per cent.

5.2 AIR QUALITY MEASUREMENTS

5.2.1 Dustfall

A summary of dustfall values measured at 20 sites in the Helwan area is presented in Table 15.

Table 15: Summary of dustfall measured in the Helwan area, April 1992.

St.	UTM Ref.		DUSTFALL ($g/m^2 \cdot 30$ d) Measured values			
	X	Y	2.4-11.4	13.4-22.4	26.4-3.5	April
1	333.5	315.2	141	27	28	65
2	336.2	312.3	65	103	56	75
3	335.6	310.3	61	71	93	75
4	334.8	309.8	116	103	76	101
5	334.77	307.75	93	260	210	188
6	335.16	304.60	29	30	29	30
7	339.5	303.3	47	25	31	33
8	337	301.6	-	115	37	71
9	342.5	301.0	23	22	26	24
10	336.0	299.75	326	395	440	387
11	335.8	298.1	355	94	118	189
12	336.4	296.3	63	62	58	61
13	336.4	296.2	76	80	77	78
14	339.4	294.5	43	44	55	47
15	335.7	293.3	59	76	67	67
16	336.8	292.8	43	35	45	41
17	337.8	292.5	-	(360)	26	26
18	335.6	292.1	46	32	36	38
19	338.1	291.6	30	22	18	23
20	335.5	290.4	32	25	18	25

The highest dustfall rate of 387 $g/m^3 \cdot 30$ d was measured at a site less than 1 km south of the Helwan Portland Cement Factory. At sites 4 and 5, 1.5 and 3 km south of Tourah, and at site 11, 2.5 km south of Helwan Portland, the dustfall rate also exceeded 100 $g/m^2 \cdot 30$ d.

The general dustfall level varied from around 25 $g/m^2 \cdot 30$ d at sampling sites more than 6 km from any cement plant till 60-80 $g/m^2 \cdot 30$ d in residential areas of the Helwan region. A "natural background" level of falling dust has previously been estimated to about 20 $g/m^2 \cdot 20$ d for this part of Egypt.

Within a few kilometers from the cement plants, providing the measurements were taken in the prevailing wind direction, the dustfall rates observed in April 1992 were 10 to 40 times the values considered acceptable for residential areas in Europe (10 $g/m^2 \cdot 30$ d).

The total areas covered by dustfall rates in excess of 100 $g/m^2 \cdot 30$ d have been estimated to about 25 km^2.

The total dustfall rates for April are also shown on a map for the area in Figure 26.

Dustfall measured from 6 May to 15 May 1992 revealed a similar pattern as in April. Somewhat higher values were found south of Tourah (148-210 $g/m^2 \cdot 30$ d) and at site 10 (behind Helwan) 411 $g/m^2 \cdot 30$ d. Also the dustfall rates in the southern part of the area were higher than in April, ranging between 60 and 130 $g/m^2 \cdot 30$ d.

The amount of soluble, insoluble ash content and combustible dustfall is presented in Appendix A.

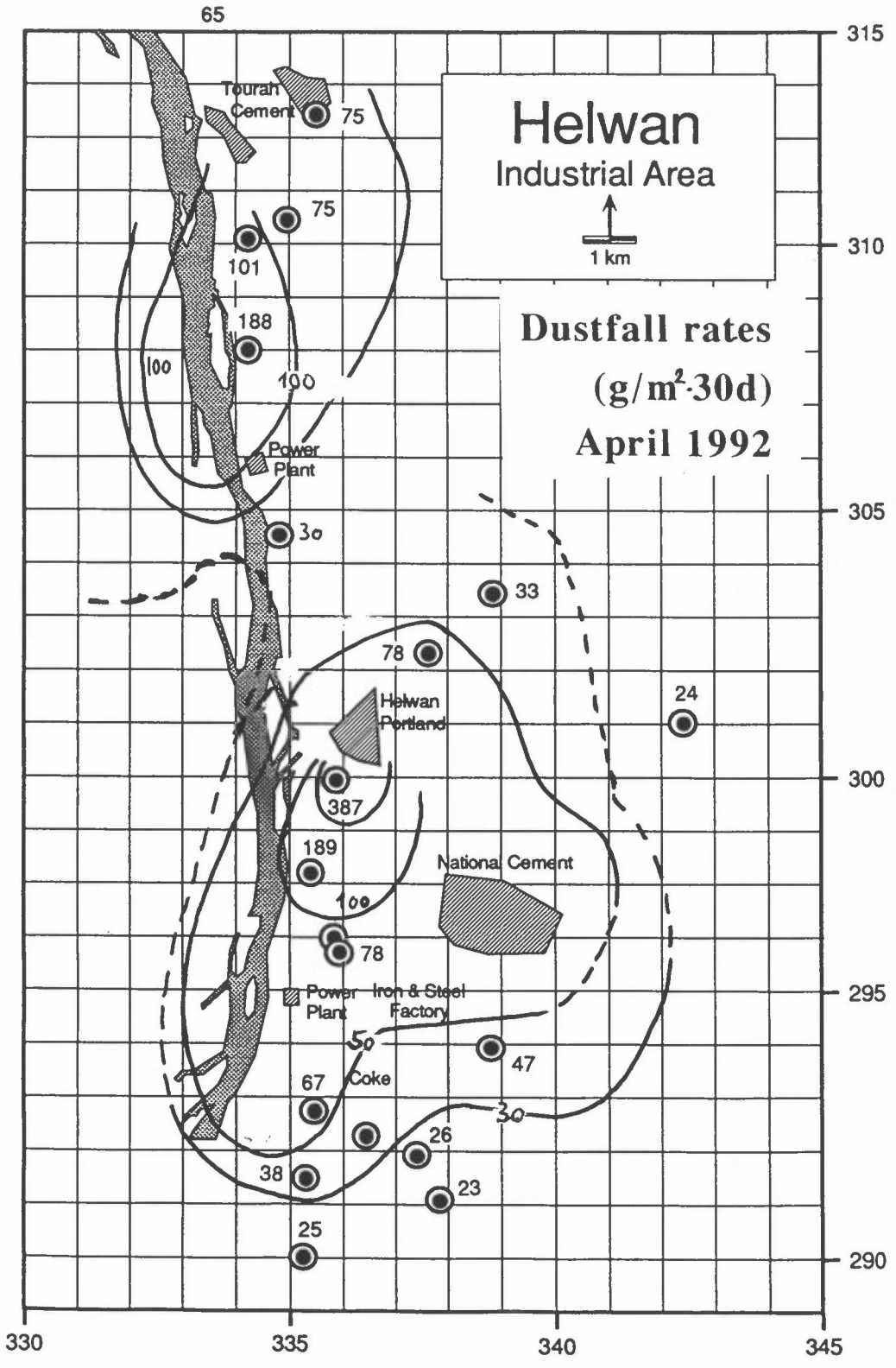

Figure 26: Dustfall rates measured in the Helwan area in April 1992 ($g/m^2 \cdot 30$ d).

A summary of typical values is given in Table 16.

Table 16: The content (in %) of insoluble particles, ash and combustible dust in dustfall at different types of sites in the Helwan area, April 1992.

Site type	Insoluble (%)	Ash (%)	Combustible (%)
Background	78-94	29-77	2-49
Residential	53-65	49-51	3-25
Cement industry	88-92	52-64	12-25
Other industry	65-77	60-71	6-15

Chemical analyses of the content of elements in dustfall have been undertaken for selected samples. A summary of analyses for insoluble dust at 8 sites and for soluble dust at 3 sites is presented in Table 17. More complete tables of analyses results are presented in Appendix A.

Table 17: The monthly deposition rate ($\mu g/m^2 \cdot 30$ d) for different elements measured in the Helwan area, April 1992.

	Site No.	Deposition rate $\mu g/m^2 \cdot 30$ d Fe	Ca	Pb	Mn	Zn	Cr	Ni	Cu	V
INSOLUBLE	2	1670	16100	6.8	17.7	25.2	4.2	4.0	3.8	2.5
	6	420	3982	3.26	8.25	15.29	4.73	3.65	1.66	0.3
	10	5263	66538	20.8	180.4	35.3	11.6	11.2	30.6	0.63
	13	1763	12098	4.6	16.4	25.3	2.3	2.5	4.2	0.21
	14	2073	8143	2.6	16.1	10.5	2.8	2.2	2.6	0.9
	15	3341	7774	5.8	76.8	18.3	4.0	4.15	5.7	0.9
	16	1569	3967	7.7	20.2	10.1	1.8	1.91	7.9	0.36
	17	1349	3892	1.6	6.4	9.2	1.56	1.3	1.8	0.05
SOLUBLE	2	135	2247	0.88	0.4	0.82	0.79	0.6	0.75	0.15
	10	296	6811	1.25	0.62	1.42	0.84	2.25	1.96	0.29
	15	93.8	2738	0.72	0.53	0.45	1.48	0.46	0.96	0.106

The highest deposition rates of elements (in $\mu g/m^2$) were found down wind from the Helwan Portland Cement Plant (site 10), where also the total deposition rates were by far the highest.

High values of iron, manganese and zinc were also found down wind from the iron and steel factory.

The highest concentrations of elements in dustfall are generally found down wind from the smelter industries in the southern part of the Helwan area and, for some elements, down wind from the power plants. A summary is presented in Table 18.

Table 18: The two sites with the highest concentrations of elements in insoluble dustfall in the Helwan area, April 1992.

Element	Sites no. with Highest conc.	Second highest	Down wind from:
Fe	15	16	Iron steel, smelter
Ca	2	10	Cement
Pb	16	6	Iron/steel, power plant, traffic
Mn	15	(16)	Iron/steel, smelter
Zn	6	15	Power, smelter, coke
Cr	6	15	Power, smelter, coke
Ni	6	15	Power, smelter, coke
Cu	16	15	Iron/steel, smelter
V	2	14	Cement

5.2.2 Suspended particulate matter

Total suspended particulate matter (TSP) was measured with the Andersen high volume sampler at the mobile station. Data from 6 selected sites; 3, 6, 11, 14, and 18 are presented in Appendix B.

A summary of TSP concentrations is presented in Table 19.

Table 19: Typical 24 h average concentrations of total suspended particles (TSP) measured at 6 sites in the Helwan area during 30 April-13 May 1992.

Site	Number of sampling days	TSP concentration ($\mu g/m^3$) range	average
1	5	480-1430	1373
6	2	125- 227	176
11	7	850-1600	1169
14	3	275- 490	416
17	4	470-1500	882
18	5	1320-1980	1463

The TSP concentrations measured about 3 km away from the cement factories at Tourah (site 3) and Helwan (site 11) show 24 h-average concentrations in excess of 1000 $\mu g/m^3$. This is more than 8 times the guideline values of 120 $\mu g/m^3$ given by WHO for assessing combined exposure to sulphur dioxide and particulate matter. A 24 h average maximum TSP concent[illegible] of 120 $\mu g/m^3$ is a tentative proposal by WHO. Concer[illegible] 1000 $\mu g/m^3$ or more is far above what should be acce[illegible]

Also at the sites 17 and 18, which is about 3 km [illegible] the iron and steel industry , smelters, chemical [illegible] tories, the 24 h-average TSP concentra[illegible] 1000 $\mu g/m^3$. The average concentration of 5 day[illegible] site 18, in the predominant wind direction 3.5 km [illegible] sinter stack, was 1463 $\mu g/m^3$. This is an unacceptable high concentration of suspended dust compared to international guidelines and regulations.

Analyses of elements in selected samples of suspended dust is tabulated in Appendix B.

Very high concentrations of lead, manganese and zink were found at site 17 and 18 down wind from the iron and steel industries. The highest concentrations of copper were found at site 3 and down wind from Tourah. High values of manganese were also found

at sites 11 and 14 down wind from Helwan and National Cement factories.

5.2.3 Inhalable particles (PM_{10})

Nine samples were collected with the NILU-2F sampler in May 1992 to study inhalable (equivalent aerodynamic diameter (EAD) less than 10 μm) and respirable particles (EAD less than 2.5 μm). The results of these analyses are shown in Table 20 for sites mainly influenced by the cement factories and in Table 21 for sites also influenced by emissions from smelters, coak and chemical industry.

Table 20: Concentrations of air borne particles less than 10μm (coarse) and less than 2.5 μm (fine) at sites influenced by emissions from cement industries in Helwan, 10-11 May 1992.

	Cement industries				Cement and other sources			
	Site 2		Site 10		Site 14		Site 13	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Particles ($\mu g/m^3$)	111	451	147	887	38	103	68	199
Pb (ng/m^3)	148	75	662	321	48	26	1344	623
Cd "	-	-		54	4	4	-	-
Zn "	212	196	383	415	87	86	196	121
Cr "	-	401	195	410	-	166	-	43
Ca "	13694	145300	12680	213600	2385	43360	-	11250
Fe "	-	10118	3500	23180	-	3956	580	5141
Mn "	25	159	39	374	20	124	28	175
V "	30	23		47	2	27	18	17
Sb "	-		15	1	-	-	22	8

- = below detection limit (short sampling time)

Table 21: Concentrations of air borne particles less than 10μ (coarse) and less than 2.5 μm (fine at sites influenced by emissions from smelters, iron, steel and chemical industries.

	General metals a		General metals b		Iron, steel and chemical industries Site 15		Site 16		Site 17	
	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse
Particles (μg/m^3)	138	497	145	127	58	154	70	148	59	248
Pb (ng/m^3)	56060	5392	45980	81800	100	65	233	114	252	115
Cd "	-	-	-	-	4	-	-	-	2	157
Zu "	-	71	44	114	-	9	11	11	11	22
Zn "	770	217	1442	392	1054	622	433	243	327	212
Cr "	-	660	-	-	-	142	91	151	-	86
Ca "	-	59300	-	27874	-	20900	2125	26600	1380	35500
Fe "	-	11837	-	1315	2613	19420	1636	10340	1187	11690
Mn "	53	179	39	78	185	854	107	315	78	315
V "	70	73	160	54	13	12	11	23	9	29
Sb	542	29	802	287	0.9	0.3	1.1	1.3	2.0	0.7

- = below detection limit (short sampling time)

The concentrations of inhalable particles with EAD less than 10 μm (PM_{10}) ranged from 140 to 1030 μg/m^3. The highest values, measured south of Helwan Portland Cement factory, was about 15 times the air quality guidelines value of 70 μg/m^3 given for PM_{10} by WHO. All concentrations of PM_{10} measured in the Helwan area during May 1992 were more than twice the WHO guideline value. Near the cement industries more than 80% of the PM_{10} particles were larger than 2.5 μm and about one fourth were calsium particles. About 3 km down wind from National Cement about one third of the PM_{10} particles were measured as calsium.

Two samples were collected about 500 m down wind from the General Metals industry. The PM_{10} concentrations were 272 and and 635 μg/m^3. Extremely high concentrations of lead were found in the fine fraction of these samples: 46 and 56 μg/m^3. This is more than fifty times the WHO recommended criteria of 0.5-1 μg/m^3 for lead concentration measured as an annual average value.

The measured concentrations were representative for averaging times of 2-5 hours. Concentration statistics and an evaluation of wind direction frequency distributions in the area indicate that the expected annual lead concentrations at these distances

from the smelter could be as high as 8 to 10 µg/m^3, which is still ten times the WHO recommended criteria.

At these sites also high concentrations of vanadium (V) and antimony (Sb) were found. This might be due to emissions from the oil fired power plant at Tibbin, which was located less than 1 km up wind from these sampling points. These areas might yield adverse impacts due to the toxic composition of respirable particles.

The sampling sites 15, 16 and 17 were located 1 to 2 km south of the industrial complex with iron, steel and chemical industries, in the southern end of the Helwan area. The PM_{10} concentrations were not the highest measured. However, PM_{10} concentrations ranging from 200 to 300 µg/m^3 and the composition of elements indicate that these southern areas are adversely impacted by fine dust from all types of industrial sources.

Relatively high concentrations of the elements Fe. Mn and Zn were found in these samples, which confirm the influence of the iron steel industries.

In summary the inhalable particles measured in the Helwan area, might be of concern to the health of people living in the area. Especially in the southern part of the area where a majority of small particles less than 2.5 µm (respirable) containing toxic elements were found.

5.2.4 Sulphur dioxide (SO_2)

Measurements undertaken with integrated passive filter samplers and with continuous monitors in the Helwan area during April and May 1992, shown that sulphur dioxide (SO_2) is a much less problem than dust.

Table 22 summarizes the integrated SO_2 samples taken at 15 sites in the Helwan area.

Table 22: Sulphur dioxide (SO_2) concentrations ($\mu g/m^3$) measured with passive samplers in the Helwan area during 2 April-3 May 1992.

	Sampling periods			
Sampling site	2-11 April	13-22 April	26 April-3 May	2 April 3 May
1	18.8	21.3	17.4	22.3
3	24.5	26.8	26.2	25.4
6	36.5	42.6	54.3	46.5
7	21.0	22.7	20.3	18.3 (21)
9	15.8	17.3	17.6	16.9
10	32.5			37.2
11	30.8	29.6*	32.6	32.7
13	48.6	34.1	35.4	29.9 (39)
14	30.0	30.0	39.0	32.4
15	51.0			51.9
16	53.4	76.3	73.0	64.3 (67)
17	31.4			49.8
18	36.5	37.5	52.9	41.8
19	33.2			38.5
20	40.0	51.9	73.1	48.1 (55)

The highest monthly SO_2 concentrations in April 1992 occurred south of the iron and steel industrial complex in the southern part of the Helwan area. Figure 4.1.1.11 shows a maximum area of 5-6 km^2 exceeding 50 $\mu g/m^3$ as a monthly average down wind from these industries.

Analyses performed on SO_2 samples collected in May 1992 show concentrations ranging from 5-6 $\mu g/m^3$ at site 1 and 9 to 30 $\mu g/m^3$ at site 16.

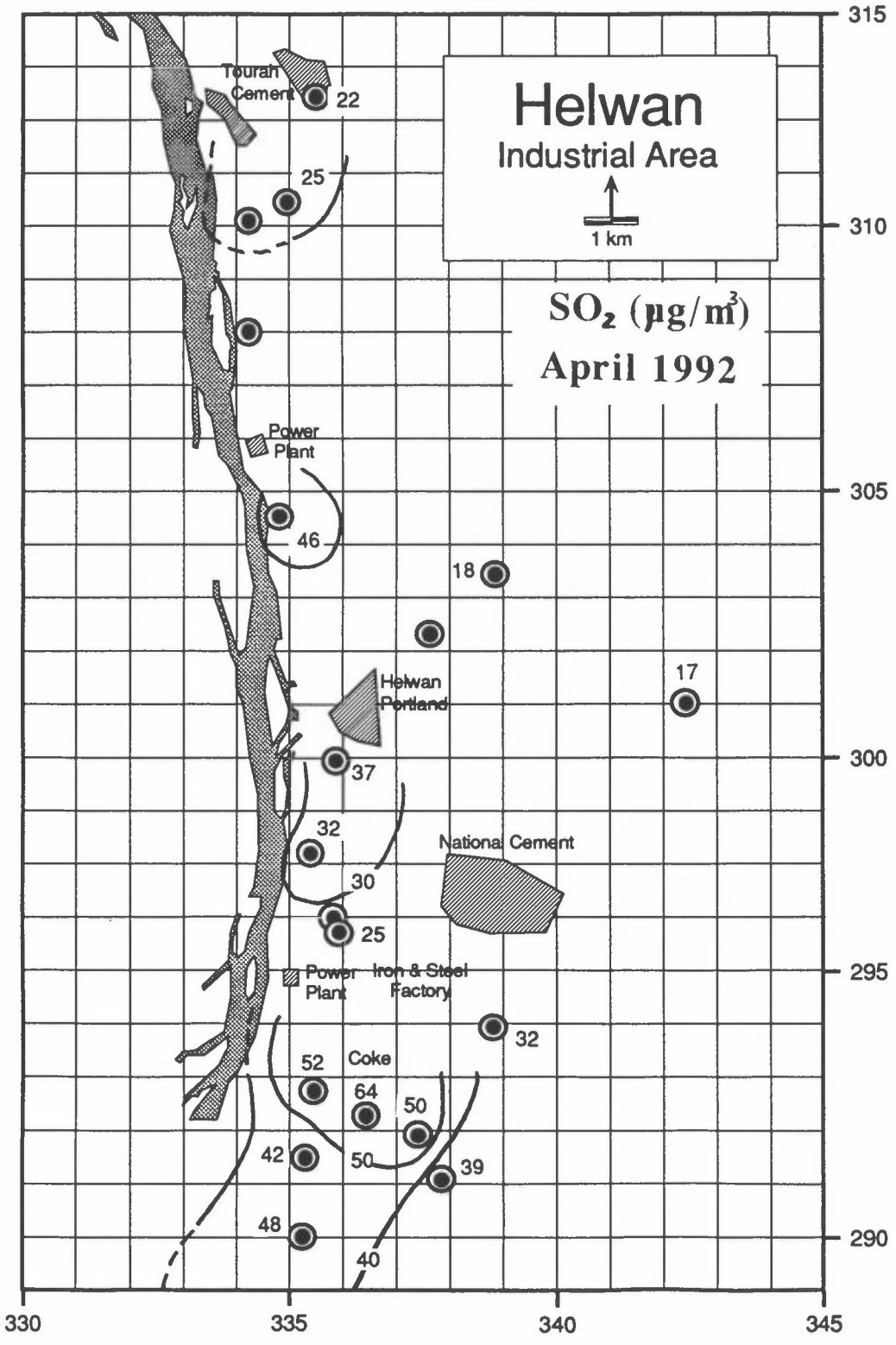

Figure 27: Monthly average SO_2 concentrations measured with passive samplers in the Helwan area, April 1992.

In comparison the World Health Organization (WHO) air quality guideline values for combined exposure to SO_2 and particulate matter specify that the annual average concentration should not exceed 50 $\mu g/m^3$. In the southern part of the Helwan area it is probable that these WHO guidelines might be exceeded.

Continuous records of SO_2 concentrations measured at selected sites in the area using the Monitor Lab instrument in a mobile van has been evaluated. Short term peak concentrations and maximum 1 h average concentrations are presented in Table 23.

Table 23: Maximum measured SO_2 concentrations at selected sampling sites during April-May 1992.

Site no.	UTM-ref		Number of measurement days	SO_2-concentrations ($\mu g/m^3$)	
	X	Y		Highest instantan.	Highest 1-h av.
3	335.6	310.3	5	66	46
6	335.2	304.6	2	274	114
9	342.5	301.0	2	29	15
11	335.8	298.0	7	206	85
14	339.4	294.5	3	292	200
17	337.8	292.5	4	360	72
18	335.6	292.1	5	157	126

At site 9, in the 15 May City, typical background values of SO_2 have been measured. Down wind from the industrial complex south in Helwan 1 h-average concentrations of up to 126 $\mu g/m^3$ was recorded (during the 4 days that the mobile station was located here!). The highest 1 h-average concentration recorded during the whole period was 200 $\mu g/m^3$ at site 14. The WHO guideline value for 1 h-average SO_2 is 350 $\mu g/m^3$.

Figure 28 shows a typical record from site 17 on 30 April 1992 from 1000 to 1600 hrs. A sharp peak reaching 126 ppb (360 $\mu g/m^3$) occurred at 12:25 hrs. This peak lasted for only a few minutes.

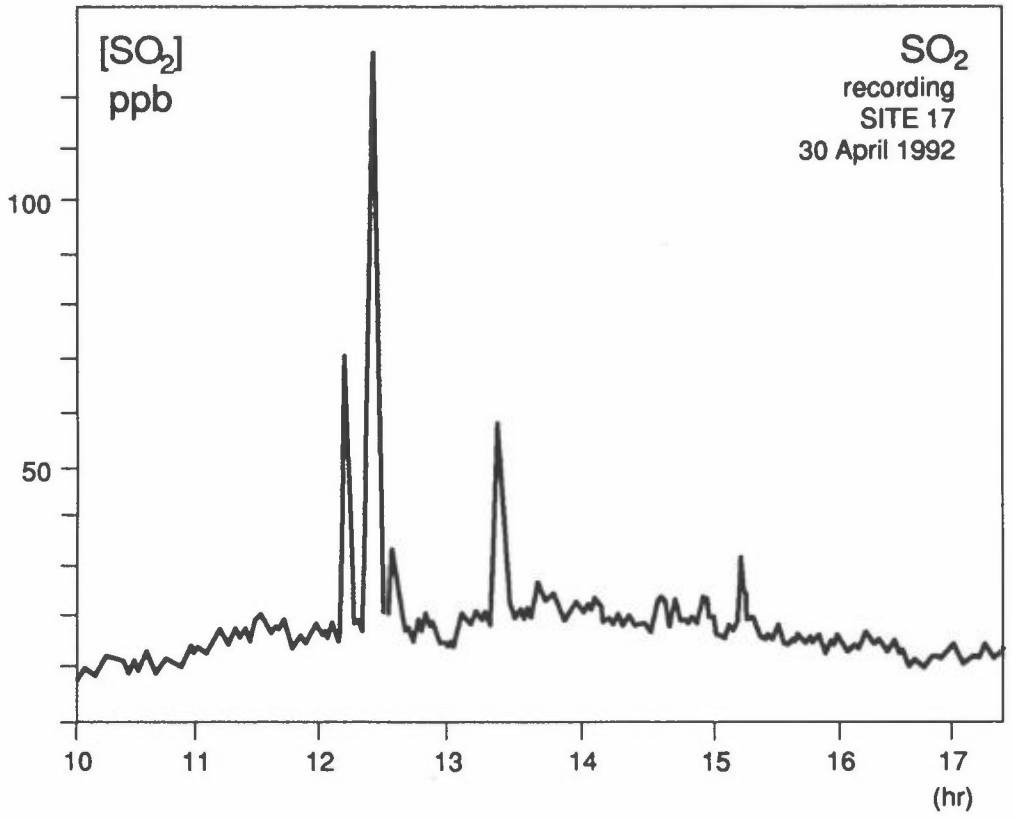

Figure 28: Continuous record of SO_2-concentrations measured at site 17 on 30 April 1992.

The wind during these hours were from around north at 7 m/s.

The SO_2 peaks must be caused by emissions from the smelter- and chemical industry north of the site.

5.2.5 Nitrogen oxides

The concentrations of nitrogen oxides (NO_x) and nitrogen dioxide (NO_2) measured continuously and with integrated passive samplers, show low values all over the Helwan area. The concentrations are far below any international guideline values for NO_x / NO_2.

The highest instantaneous concentration recorded of NO_x during the few days the mobile station was measuring, was a 30 min average found at site 11 at 200 ppb on 9 April 1992 at 0900-0930 hrs. Strong wind from northeast was observed at this hour.

The highest 10 min average concentrations are shown in Table 24.

Table 24: The highest NO_x concentrations recorded with the mobile van during April-May 1992.

Site	NO_x concentration (ppb)	
	highest instant.	highest 10 min av.
3	165	100
6	100	-
11	170	90
14	250	200
17	95	50
18	125	75

6 AIR QUALITY MODELLING

6.1 MODEL DESCRIPTION

A large number of different mathematical models have been developed and used by NILU. The different models treat the various elements of modelling differently. For the Helwan area, it has been important to model the cement factories and the different types of particle emission sources as adequate as possible.

For this purpose we have modified a multiple source Gaussian type model ("CONDEP") for the Helwan area. This model is primarily designed for estimates of long term average concentration distribution, and it treats both suspended and falling dusts. Input to the model is a meteorological frequency distribution of wind and stability and detailed information about the dust emissions.

6.1.1 Long term average concentrations and deposition

"CONDEP" calculates long term average concentrations including the effects of dry deposition and plume tilting. The model in this case is a sector model, where it is assumed that there is no horizontal crosswind variation in concentration within an angular sector equal to the resolution of the wind-direction data. The formula for ground level concentration from a number p of continuous point sources within a number r sectors of arbitrary angular width $2\pi/r$ (in radians) is as follows:

$$C(x,y,0) = (r/2\pi) \sum_{i=1}^{p} \sum_{l=1}^{4} \sum_{m=1}^{4} f(k_i,l,m)\, Q_i\, D(x_i,u,l)/x_i$$

where the dispersion function $D(x_i,u,l)$ is defined as:

$$D(x_i,u,l) = \sqrt{\frac{2}{\pi}} \left[\left(\frac{1+\alpha}{2}\right) \exp\left(-\frac{1}{2}\left(\frac{H'}{\sigma_z}\right)^2\right) + \sum_{n=1}^{3} \exp\left(-\frac{1}{2}\left(\frac{H'+2nL}{\sigma_z}\right)^2\right) + \exp\left(-\frac{1}{2}\left(\frac{H'-2nL}{\sigma_z}\right)^2\right) \right] / (u\sigma_z)$$

where $f(k,l,m)$ = joint frequency function

k_i = index identifying the wind sector appropriate for the ith point source

l = index identifying the wind speed class

m = index identifying the stability class

α = reflection coefficient due to deposition

$H' = H - \frac{V_t x}{u}$ = effective height including tilting of the plume.

V_t = gravitational settling speed of coarse particles.

L = the mixing height

The height dependency of the wind speed is described by a power law:

$$\bar{u}(z) = \bar{u}(z_0) \left(\frac{z}{z_0}\right)^m$$

with z = height above ground,

z_0 = reference height above ground,

$\bar{u}$ = time average wind speed

m = wind profile exponent.

The mean transport speed representative of an appropriate height range, e.g. from the effective source height (H) to ground level (for dispersion calculations), may then be calculated by integration:

$$\bar{u} = \frac{1}{\Delta z} \int \bar{u}(z)\, dz = \frac{1}{(z_2 - z_1)} \int_{z_1}^{z_2} \bar{u}(z_0) \cdot \left(\frac{z}{z_0}\right)^m dz.$$

The stability of the Helwan area has been classified according to measurements of inversion frequencies and assumption of daytime instable conditions. Usually temperature gradient measurements are used.

The stability classes are defined as:

Stability class	Temperature gradient dT (deg/100 m)	Corresponds to:	
		Pasquill	Brookhaven
Unstable	$dT < -1$	A + B + C	$B_1 + B_2$
Neutral	$-1 \leq dT < 0$	D	C
Slightly stable	$0 \leq dT < 1$	E	-
Stable	$dT \leq 1$	F	D

The diffusion parameters σ_y and σ_z are defined as the standard deviations of the concentration distributions in the lateral and vertical, respectively. They are functions of the down wind distance from the emission source and of the stability of the atmosphere. The standard deviations have been determined from tracer experiments carried out during different wind and turbulence conditions.

6.1.2 Dispersion parameters

The following form of diffusion parameters is used:

$$\sigma_y(x) = ax^p, \quad \sigma_z(x) = bx^q.$$

The most commonly used coefficients used for the Helwan area are listed in Table 25 below:

Table 25: Commonly used dispersion coefficients applicable for different source types and surface roughness.

Source and surface specifications	Coefficients	Un-stable	Neu-tral	Sl. stable	Stable
Surface and low sources, rough surface, urban area. Ref.: McElroy, J.L., Pooler, F. (1968)	a	1.7	0.91	1.02	-
	p	0.72	0.73	0.65	-
	b	0.08	0.91	1.93	-
	q	1.2	0.70	0.47	-
High stacks, smooth to medium rough surface Ref.: Smith, M. (1968)	a	0.36	0.32	0.31	0.31
	p	0.86	0.78	0.74	0.71
	b	0.33	0.22	0.16	0.06
	q	0.86	0.78	0.74	0.71

The model includes effects of stack downwash in cases of low effluent velocities. It also calculates plume rise due to momentum and buoyancy using algorithms presented by Briggs.

6.1.3 Plume rise

The plume rise is calculated as follows:

$$\Delta H_m = 3D_s W_s / U.$$

This equation is most applicable when W_s/U is greater than 4. Since momentum rise occurs quite close to the point of release, the distance to final rise is set equal to zero.

The buoyance dominated plume rise (hot plumes).

The value of the buoyancy flux parameter, F (m^4/s^3), is needed for computing the distance to final rise and the plume rise.

$$F = (gW_s D^2{}_s \Delta T)/(4T_s),$$

where $\Delta T = T_s - T_a$, T_s is the stack gas temperature (K), and T_a is the ambient air temperature (K).

The distance to final rise x_f (in kilometres) is the distance at which atmospheric turbulence begins to dominate entrainment.

For F less than 55: $x_f = 0.049F^{5/8}$.

For F equal to or greater than 55, $x_f = 0.119F^{2/5}$.

The plume rise, ΔH (in metres) is determined from the equations:

For F less than 55, $\Delta H_b = 21.425F^{3/4}/U$.

For F equal to or greater than 55, $\Delta H_b = 38.71F^{3/5}/U$.

If the neutral-unstable momentum rise is higher than the neutral-unstable buoyancy rise calculated here, momentum rise applies and the distance to final rise is set equal to zero.

For stable situations, a stability parameter s is introduced to estimate a reduced plume rise, given by:

$$\Delta H_b = 2.6\ [F/(U \cdot s)]^{1/3}$$

Also effects of building induced turbulence and plume penetration through elevated inversion layers are included in the model. The model can handle topography in a simplified form.

6.1.4 Dry deposition

Dry deposition has been an important part of the model established for Helwan. Adverse effects of deposition are mainly caused by long term values of dry deposition and gravitational fall out of large particles.

The deposition method used in the model CONDEP is the "partial reflection" model. This theory includes a reflection coefficient, α, on the image source term in the Gaussian dispersion formula, which thus is a fraction of the strength of the real source. This coefficient is determined by setting the deposition flux equal to the difference in fluxes from the real and the image terms. The plume is also allowed to "tilt" to incorporate gravitational settling of large particles, as described in the sector average Gaussian formula.

The reflection coefficient, $\alpha(X_G)$, are computed by solving an implicit relation for X_G, the distance to where the plume reach the ground:

$$\left[H - \frac{v_t \cdot X_G}{u}\right] \frac{\sigma_z(x)}{\sigma_z(X_G)} = z + H - \frac{v_t x}{u}$$

and the following equation for $\alpha(x)$:

$$\alpha(x) = 1 - 2v_d / (v_t + v_d + (uH - v_t x)\sigma_z^{-1} \ (d\sigma_z/dx))$$

where

v_d = deposition velocity for the effluent
v_t = gravitational settling speed for coarse particles

the other parameters are as described earlier.

For dust emissions from the cement factories in Helwan, we have assumed a particle size distribution as follows:

Equiv. aerodyn. diam. (EAD) (μm)	%
0-10	25
10-20	25
20-50	25
>50	25

6.2 EMISSION DATA

Emission data have been estimated for each of the cement factory based upon:

- measured emission rates at selected stacks and vents performed during this study by TIMS.

- data from the BMO study for prevention of dust emissions from Egyptian cement plants.

- field studies on building structures, stack height and plant layouts.

Different emission rates have been applied to verify the model performance compared with measured data for suspended dust and dustfall rates. Final estimates have not been performed within the short time frame available.

6.2.1 Emission verification using model estimates

An example of an estimate performed for model verification purposes is shown in Figure 29.

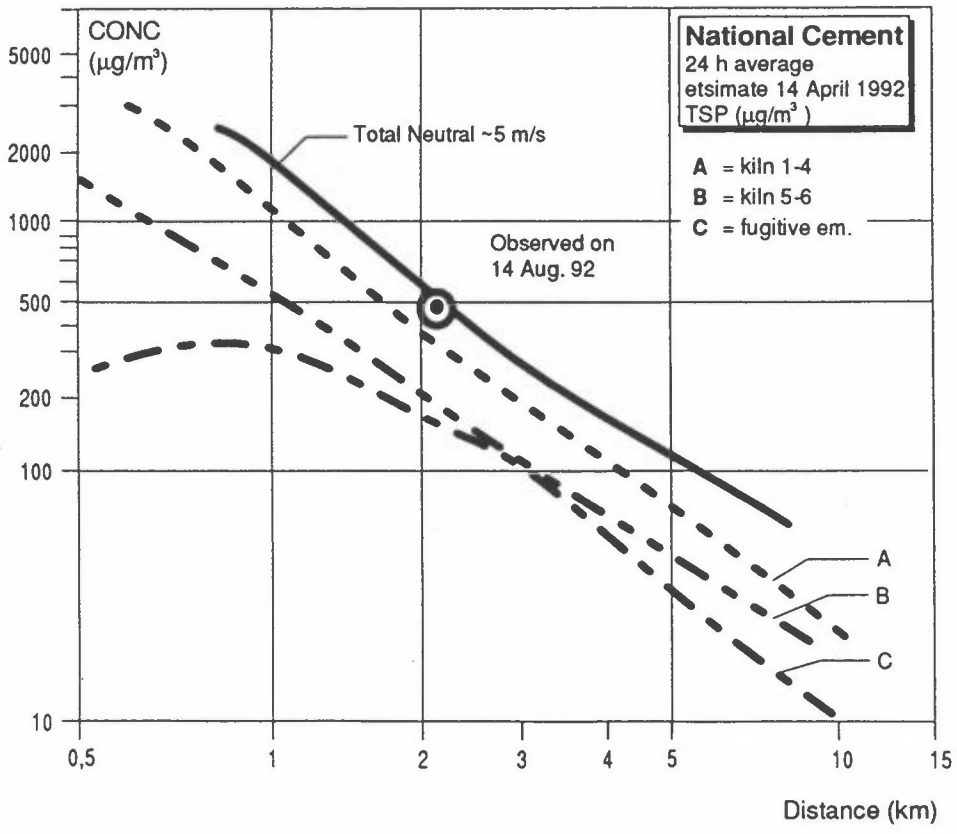

Figure 29: Estimated TSP concentrations for the meteorological conditions observed on 14 April 1992.
Assumed emissions: 500 g/s from kiln 1-4
450 " " " 5-6
200 " " " from fugitive emissions

Measurements of total suspended particulate matter (TSP) was performed at site 14, about 2.2 km south of National Cement, between 14 April at 11:00 hrs and 15 April at 10:00 hrs. The 24 h average concentration was 491 $\mu g/m^3$. During this period the wind was steadily blowing from around north (360 deg) at 4 to 6 m/s (a short period at night had ~ 10 m/s).

The NILU single source version of "CONDEP" which is a Gaussian type dispersion model CONSX was used to estimate the average concentration at site 14 with the relevant meteorology. The following simplified emission assumption were made:

Sources	Emission rate (g/s)	Stack height (m)
All kiln 1-4	500	50
All kiln 5-6	450	85
Fugitive	200	0

A total dust emission of 4140 kg/h was thus input to the model, which estimated wind profiles, plume rise and vertical diffusion within a neutral to unstable boundary layer of 1 km depth.

Figure 4.1.2.2 shows the result of down wind contributions from the three source types and the total suspended dust concentrations for a near neutral atmosphere and 5 m/s wind.

The observed 491 $\mu g/m^3$ at 2.2 km distance fits well into the estimated values. It is thus relevant to assume that the assumed average emission values are reasonable.

6.3 METEOROLOGICAL DATA

A joint frequency distribution of wind speeds, wind directions and stability classes have been established based upon wind data from Helwan for 1981-90, and for April 1992 and data on inversion frequencies collected during 1965-70 (see ch. 4.2).

Table 26 presents the frequency matrix used for the estimates in Helwan.

Table 26: Joint frequency distribution of stability, wind speed and -direction.

Stability classes: 1: Unstable
2: Neutral
3: Light stable
4: Stable

FF	1.0 m/s				3.0 m/s				5.0 m/s				7.5 m/s			
DD	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
30	1.0	.5	1.0	.5	1.0	2.0	.5	.5	2.0	3.0	1.0	.0	2.0	9.0	.0	.0
60	.5	.0	.5	.0	.5	.5	.5	.5	1.0	3.0	.0	.0	2.0	4.0	.0	.0
90	.0	.0	.0	.0	.5	1.0	.5	.0	.0	.5	.0	.0	.0	5.0	.0	.0
120	.0	.0	.0	.0	.5	.5	.5	.0	.5	1.0	.0	.0	.0	3.0	.0	.0
150	.0	.0	.5	.0	.0	.0	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0
180	.5	.0	.5	.0	.0	.0	.0	.0	.0	.5	.0	.0	.0	.0	.0	.0
210	.5	.0	.5	.0	.5	.5	.0	.0	.5	.5	.0	.0	.0	1.0	.0	.0
240	.0	.0	.0	.0	.5	1.0	.5	.0	.5	1.0	.5	.0	.0	2.0	.0	.0
270	.0	.0	.5	.0	.0	.5	.5	.0	.5	.5	.0	.0	.0	.5	.0	.0
300	.5	.0	1.0	.5	.0	.5	.5	.0	.5	1.0	.5	.0	.0	1.0	.0	.0
330	1.0	.0	1.0	1.0	1.0	.5	1.0	.5	2.0	2.0	1.0	.0	2.0	6.0	.0	.0
360	1.0	.0	1.0	.0	2.0	2.0	2.0	.0	2.0	3.0	1.0	.0	1.0	5.0	.0	.0

6.4 RESULTS

The air quality model established for the Helwan area can estimate monthly, seasonal and annual concentration distributions of dust. At present only emissions from the cement factories are included, which involve that only the cement factory contribution to the dust in Helwan is included.

It has not been possible, during the short weeks available, to include a complete emission inventory for all industries, incineration and traffic in the area. This is, however, possible and should be elaborated in future studies.

Figure 30 shows an example of estimated dustfall contribution to the whole area from the cement industry.

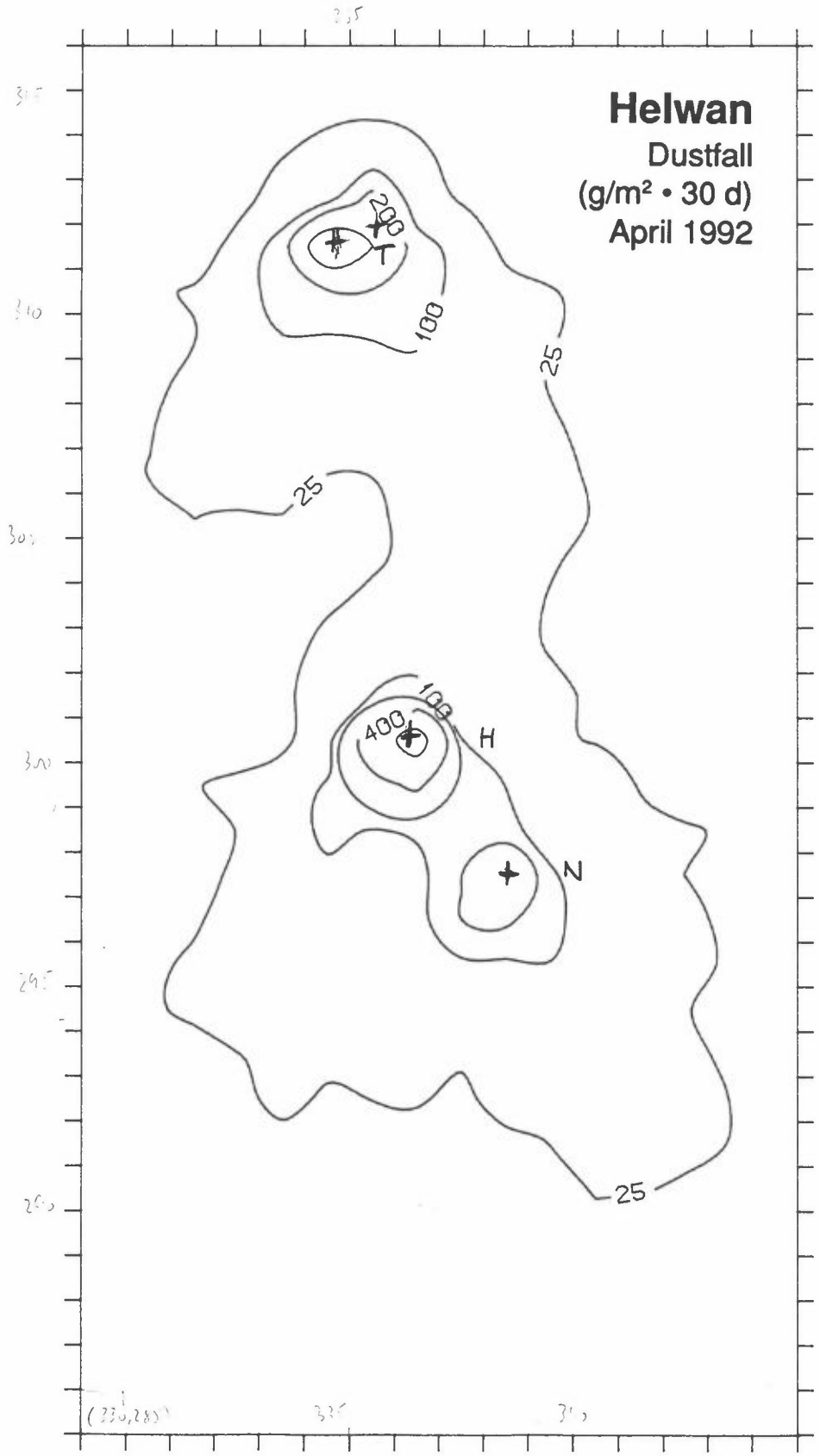

Figure 30: Estimated dust fall rates ($g/m^2 \cdot 30$ d) for April 1992 based upon assumption of dust emissions from the cement industry in the Helwan area.

Figure 31 and Figure 32 show the estimated concentrations of suspended dust (TSP and PM_{10}) for April 1992.

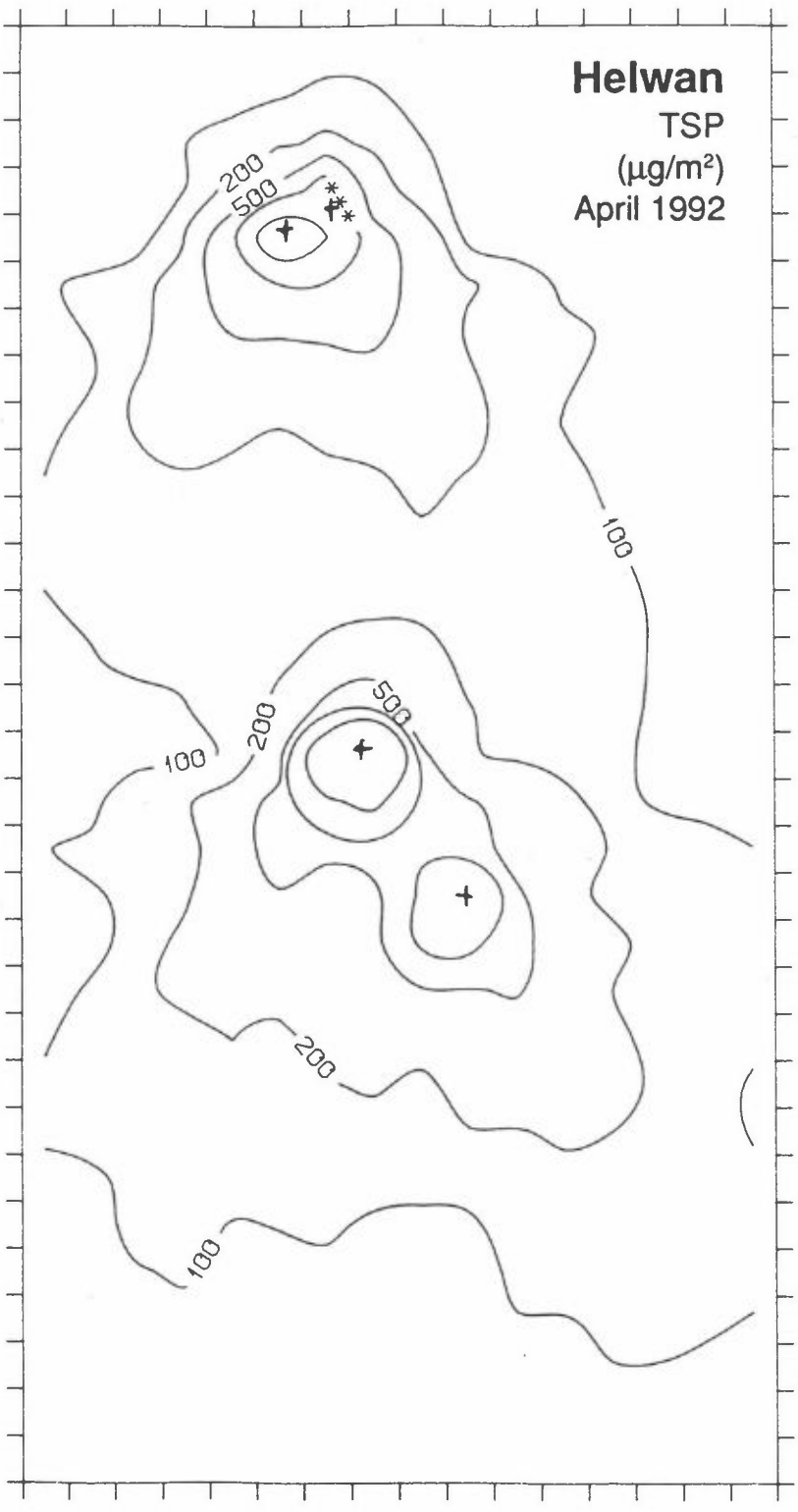

Figure 31: Estimated concentrations of suspended particulate matter (TSP) in air (µg/m³) for April 1992 based upon assumption of dust emission from the cement industry in the Helwan area.

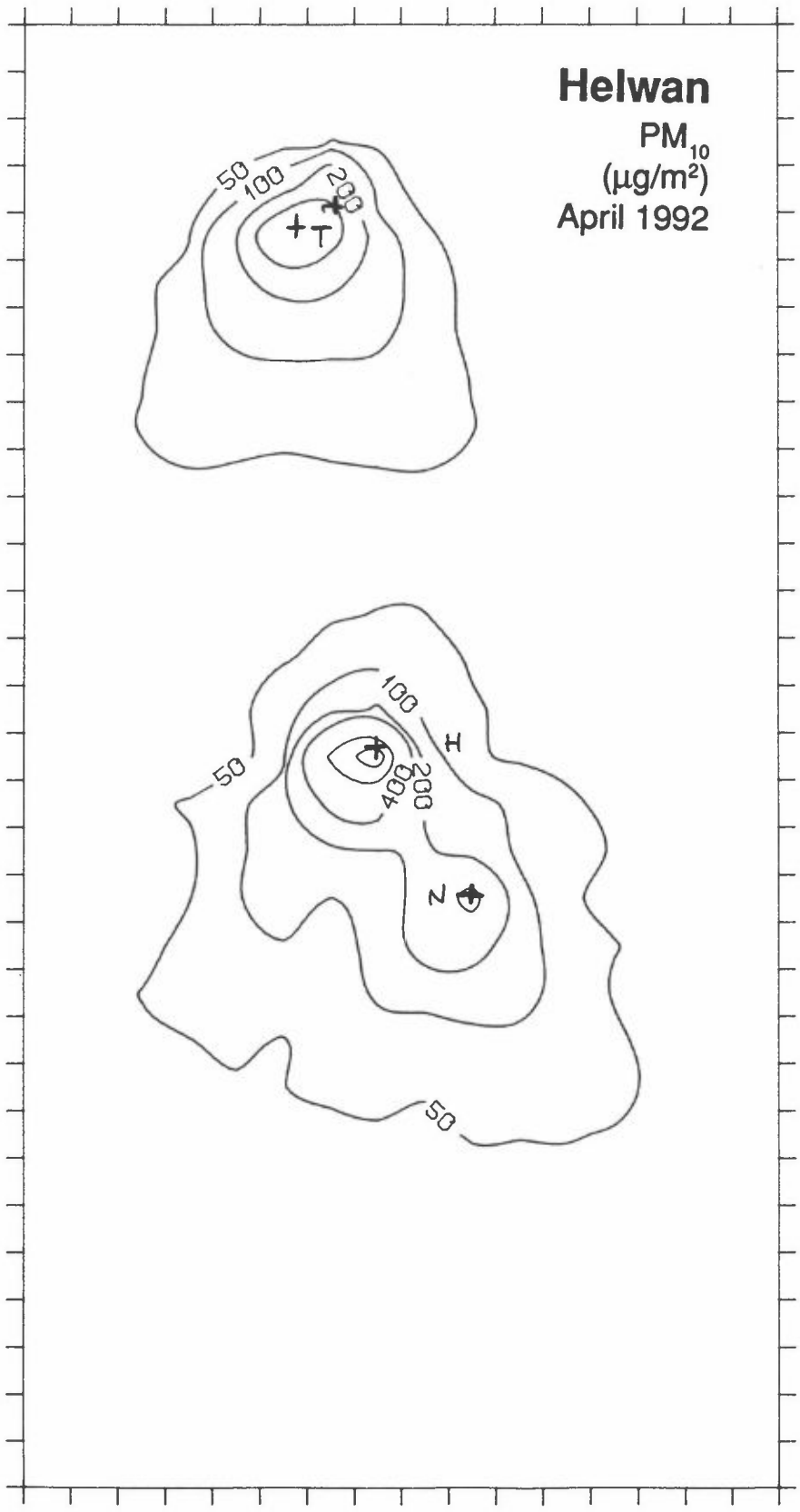

Figure 32: Estimated PM_{10} concentrations in air ($\mu g/m^3$) for April 1992, as a result of estimated emission rates from the cement industry.

For these estimates we have assumed emission rates from the cement factories as given in Table 27.

Table 27: Estimated emissions of dust from the cement factories used for modelling purposes.

	Emission rates (kg/h	
	High stacks	Low stacks and fugitive
Tourah old	5040	1800
Tourah new	2880	2520
Helwan Portland	5000	5900
National Cement	2950	1840

Using emission data available, the concentration distributions of TSP and dustfall show its highest impact down wind from the cement factories.

The estimated dustfall rates have been compared to measurement data for April 1992 in Figure 33.

As can be seen from Figure 33 the estimated dustfall rates close to Tourah were over estimated. This might be caused by:

- over-estimated dust emission at low sources (more dust from tall stacks).

- too many large particles.
- errors in dustfall measurement.

At site 2 and 3 the latter seems logical, as the results for 6-15 May 1992 show dustfall rates more than twice the April values.

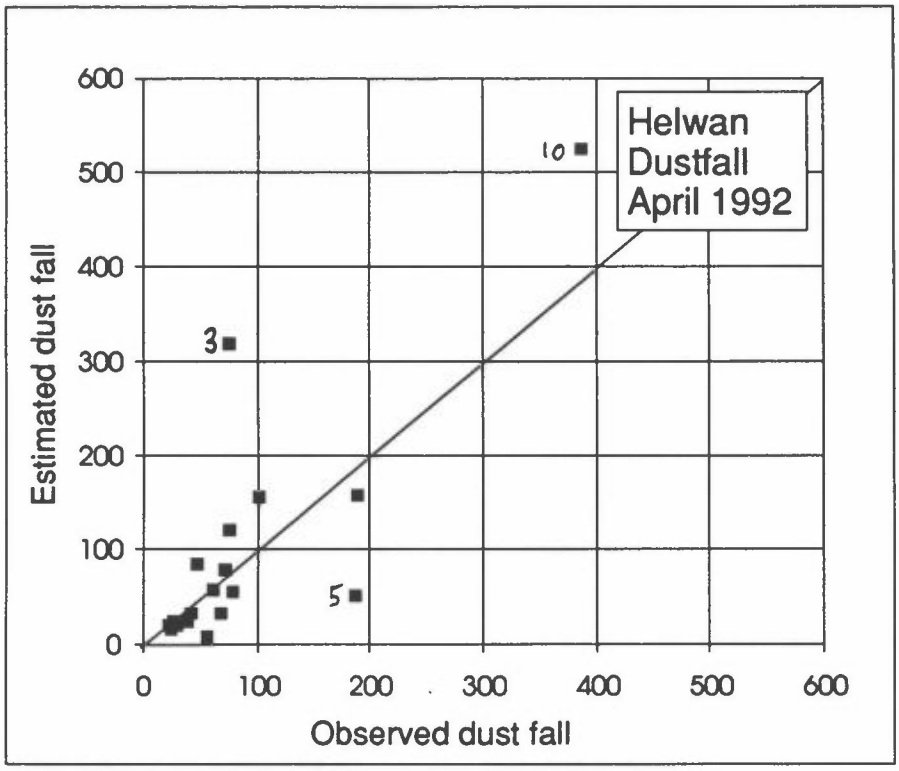

Figure 33: Model estimated dust fall rates at 20 selected sites in the Helwan area compared to measured dustfall at the same sites.

In the southern part of Helwan the dustfall rates are under estimated compared to measurements. This is due to the fact that only emission from the cement plants are included in the model.

It is further possible to use the model for estimating the relative importance of the different sources and in future to estimate the impact of air pollution reduction measures.

6.5 ESTIMATES FOR DIFFERENT SCENARIOS

The dispersion model established for the Helwan area for estimating suspended and deposited dust has not been fully verified with measurement data. The reason for this has been time limitations and the fact that not all sources have been included in

the emission inventory. At present the model only estimates the contribution from the 3 cement factories in the area. To obtain a complete picture of the dust load, emissions from other industries, traffic, cooking, backyard burning and wind blown sand dust have to be included in the model. However, we believe that close to the cement factories down wind in the predominant wind directions, the cement factories will by far be the most important sources to suspended dust and dustfall.

Meteorological data collected during April 1992 have been used to estimate the dustfall rates for 3 scenarios of emissions from the 3 cement factories in the Helwan area:

- Normal operation conditions.
- Best operation conditions.
- Worst operation conditions.

The results of these estimates can be compared with measured dustfall rates analysed for April 1992 in Table 28.

Table 28: Model estimated dustfall rates ($g/m^2 \cdot 30$ d) at 20 selected sites in the Helwan area compared to measured dustfall at the same sites. Calculations have been performed for the normal, best and worst case scenarios and also or the equipment shutdown scenarios.

Site	Observed April 1992	Estimated present emissions			Future shutdown scenario		
		Normal	Best	Worst	Normal 2	Best 2	Worst 2
1	65	7	2	20	4	0	15
2	75	44	8	238	33	5	222
3	75	305	45	825	171	15	627
4	101	127	19	356	73	7	276
5	188	37	7	114	22	2	91
6	30	18	6	47	9	1	35
7	33	24	8	66	13	2	50
8	71	70	38	149	28	3	90
9	24	16	6	42	8	2	33
10	387	592	268	1220	300	1	817
11	189	130	59	295	68	4	212
12	61	66	41	161	33	10	122
13	78	64	40	156	32	10	118
14	47	119	84	293	57	25	225
15	67	47	32	116	23	10	90
16	41	47	32	116	23	10	91
17	26	30	20	75	15	6	58
18	38	34	23	86	17	7	67
19	23	24	15	59	12	4	46
20	25	24	16	60	12	5	47

Estimates have been performed for the assumed present emissions from the cement factories and for emissions at a future equipment shutdown.

The total annual emission rates from the 3 factories for the different scenarios are presented in Table 29.

Table 29: Total annual emission rates (tonnes) of dust from the cement factories in the Helwan area for 3 of the scenarios estimated.

	Factory	Present condition (estimates)		
		Normal	Best	Worst
Stack	Tourah	51473	9042	157832
	Helwan	60214	28863	140185
	National	54716	43407	148031
Diffuse	Tourah	15441	2712	47349
	Helwan	18064	8658	42055
	National	16414	13022	44409

The distribution of total dustfall rates estimated for the six scenarios are presented in Appendix D.

As can be seen from Table 28, the estimated present normal conditions at the cement factories fairly well reproduce the measured dustfall rates at 20 monitoring sites in the area. Considering that dust from other sources, included natural background, has not been included in the estimates, it is seen that our "normal condition" emission rates slightly over-estimates the measured values. At Tourah the distribution with distance measured during April 1992 was different from that estimated, indicating that the portion of emissions from high stacks were higher in April 1992. It was less emission from the low sources. Down wind from Helwan Portland the estimates are well within the uncertainty of the measured values. If anything, the contribution estimated close to Helwan might be over-estimated. Down wind from National Cement it was not possible to locate samplers close to the factories. However, site 14 indicate that the normal emission rates estimated at National might be an over-estimate by a factor of two.

The total deposition values estimated are, as for the measured values, far above international guideline values for dustfall. The dustfall value considered acceptable for residential areas in Europe; 10 $g/m^2 \cdot 30$ d, has been exceeded by a factor of 10 to 50 down wind from all cement factories.

The present best case scenarios also show that the estimated dustfall rates exceed the acceptable limits by a factor of 4 to 25 down wind from the factories. The greatest improvements are around Tourah where an area of about 4 km^2 will have dustfall rates in excess of 25 $g/m^2 \cdot 30$ d. Around Helwan and National more than 50 km^2 still have dustfall rates in excess of 25 $g/m^2 \cdot 30$ d.

The future normal conditions introducing shutdown scenarios will give dustfall rates which are not much lower than those measured during April 1992. Improvements can be seen in the whole area, but the dustfall levels at the first few kilometres from the cement factories are still 6 to 30 times the acceptable level of 10 $g/m^2 \cdot 30$ d. More or less the whole Helwan industrial area will still be exposed to dustfall rates above 10 $g/m^2 \cdot 30$ d only as a result of cement factory emissions.

The best operation condition including shutdown scenarios will almost solve the large dustfall problem of the Helwan area. In this case 10 $g/m^2 \cdot 30$ d will only be exceeded very close to the factories. An area of about 7 km^2 surrounding the National Cement plant will still have dustfall rates in excess of 25 $g/m^2 \cdot 30 \cdot$ d. However, in most of the Helwan area the contribution from the cement factories to the total dustfall rates will be less than 10 $g/m^2 \cdot 30$ d.

7 RECOMMENDATIONS FOR A FUTURE MONITORING PROGRAMME

An air quality monitoring and surveillance programme should be established for the area including:

- continuous recording of meteorology
- dustfall measurements
- suspended particles
- gaseous pollutants
- modelling explanatory reasons

The programme should concentrate on 24 h average samples of air quality and 1 h average data for meteorology. Additional short term measurement campaigns should be added to study the air pollution plumes from specific sources or source areas.

Main objectives

The main objectives of a measurement programme should be to:

a) Establish a sound knowledge about the levels of air pollutants in the Helwan industrial area, and compare these with internationally or nationally recognized air quality guideline values.

b) Evaluate the impact on the ground level concentration of dust and gases from the different sources of the area.

c) Establish the monthly, seasonal and annual concentration distributions of air pollutants, to evaluate the exposure to the population living in the area.

d) Evaluate trends and development in time of the air pollution situation, and specify monitor and estimate the impact of source emission changes and improvement.

e) Estimate the impact of the air pollution sources of the Helwan area to the surrounding areas like Giza, Sukkara and the city of Cairo.

7.1 METEOROLOGICAL MEASUREMENTS

At TIMS

An automatic weather station should be established at the roof of TIMS. The institute already installed a Weathermeasure type climatological wind sensor by Qualimetric Inc. Data are recorded on magnetic casette tapes. During the study period

March-May 1992 the sensor did not operate properly. We will suggest that this instrument will be repaired and if possible linked directly to a data logger. Regular daily followup of the data aquisition system, especially the data recorder, would reduce the data losses to the minimum. Weekly maintenance and cleaning of the station sensors according to the recommended procedures Regular calibration of the measuring system should be performed as specified. Full and accurate documentation of maintenance and calibration processes is of most importance for reliable data collection and analysis. The relative humidity and solar radiation measuring systems should be revised by authorized specialists.

7.2 DUSTFALL MEASUREMENTS

Dust fall is at present a major air quality problem of the Helwan area. A large number of inexpensive dustfall collectors (NILU type, international standard) should be located down wind and up wind from the major sources of dust in the area.

Taking the predominant wind directions into account, which are from the north (N $\pm$ 45°), the dust fall monitoring programme established during the first period 1992 should be continued.

The dustfall samples should be analyzed according to standard: Total dustfall, soluble and insoluble part and pH-values.

7.3 SUSPENDED PARTICULATE MATTER

TSP and PM_{10} should be measured in the populated areas of El Maasra, Helwan City, Kafr El Allou and Abusaid. Simple NILU-2F samplers could be used to collect 24 h samples randomly with a frequency of one sample per week. This will enable seasonal and annual averages to be estimated.

Meteorological data have to be used together with these measurements for explanatory reasons.

8 CONCLUSIONS

Earlier studies as well as this study show that the dustfall in the Helwan are far exceeds international standards. The total Helwan area has a dustfall in excess of 100 $g/m^2 \cdot 30$ days which is ten times the European standard. The highest values are found down wind of the three cement plants and the three process industries in the southern part of the area. The concentration of total suspended particles in the air exceed 1000 $\mu g/m^3$, more than eight times the WHO proposed limit, at three out of six sampling sites. These sites are located down wind from Tourah and Helwan cement plants and down wind from the Iron & Steel plant.

The concentrations of inhalable particles also exceed international guideline values. Especially serious is that the lead content in the air down wind from General Metals by more than fifty times exceeds the WHO recommended criteria.

The highest concentrations of sulphur dioxide are found in the area south of El Nasr Coke, Iron & Steel, General Metals and El Tebbin power plant, and in the area down wind from South Cairo power plant. In these areas the concentrations lie within the WHO guideline value. The concentrations of nitrogen oxides are far below the WHO limits.

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APPENDIX A

DUSTFALL ANALYSES

DUST-FALL RESULTS ANALYSIS

(Period No. (1))

April.02.92 - April.11.92

Site No.	PH	Conc., g/m^2*30d	Soluble %	Insoluble %	Ash %	Carb. %
1	7.32	141.33	5.79	94.21	77.30	16.91
2	8.25	65.25	13.00	87.00	64.40	22.60
3	8.25	60.91	14.49	85.91	61.70	24.21
4	8.25	115.77	11.40	88.55	60.20	25.71
5	8.25	93.39	15.55	84.45	60.50	23.95
6	7.95	29.11	39.78	60.22	50.20	10.02
7	8.22	46.85	46.19	53.81	51.50	3.31
9	7.21	23.37	21.76	78.24	28.60	49.64
10	7.05	326.13	8.10	91.90	80.22	11.68
11	7.95	355.20	8.50	91.50	71.40	20.10
12	8.29	63.09	11.84	88.16	80.30	7.86
13	8.80	77.59	10.60	89.40	64.90	24.5
14	8.82	42.96	11.34	88.66	76.30	12.36
15	8.18	59.30	22.81	77.19	70.80	6.39
16	7.94	43.38	30.17	69.83	62.70	7.13
17	lost	lost	lost	lost	lost	lost
18	7.86	46.21	22.48	77.52	70.50	7.02
19	8.12	30.29	29.64	70.36	63.70	6.66
20	7.95	31.59	28.92	71.08	62.30	8.78

* Analysit : Chemist . H.Hamed.

DUST-FALL RESULTS ANALYSIS

(Period No. (2))

April.13.92 - April.22.92

Site No.	PH	Conc., g/m^2*30d	Soluble %	Insoluble %	Ash %	Carb. %
1	8.02	26.73	16.94	83.06	81.19	1.86
2	9.24	103.32	9.32	90.68	64.56	26.11
3	8.59	71.07	12.48	87.52	83.94	3.58
4	8.18	102.57	6.96	93.04	74.52	18.51
5	8.49	259.59	7.88	92.12	63.69	29.53
6	8.21	29.97	19.20	80.80	55.60	25.20
7	9.74	25.20	19.36	80.64	76.22	4.42
8	8.42	115.02	30.48	69.52	34.30	35.22
9	8.84	22.19	16.95	83.05	58.31	24.74
10	7.96	394.80	10.26	89.74	51.90	37.84
11	8.71	94.02	9.40	90.60	87.03	3.56
12	8.46	62.10	12.54	87.46	81.45	6.00
13	8.73	80.01	13.19	86.82	60.21	26.61
14	8.38	44.28	18.73	81.27	55.64	25.63
15	8.40	75.99	14.05	85.95	63.57	22.38
16	8.18	34.94	36.01	63.99	48.63	15.36
17	8.02	(360.00) *	6.45	93.55	82.73	10.82
18	8.02	31.20	23.73	76.27	71.83	4.44
19	8.09	21.96	30.15	69.85	55.51	14.34
20	8.04	24.66	25.44	74.56	50.08	24.48

* Analysit : Chemist . H.Hamed.

* contaminated ?

DUST-FALL RESULTS ANALYSIS

(Period No. (3))

April.26.92 - May. 03.92

Site No.	PH	Conc., g/m^2*30d	Soluble %	Insoluble %	Ash %	Carb. %
1	8.99	27.83	33.00	67.00	48.50	18.50
2	9.35	56.16	13.73	86.27	60.50	25.77
3	8.77	93.17	13.28	86.72	73.09	13.63
4	8.65	75.79	23.84	76.16	44.35	31.81
5	8.64	210.39	18.84	81.16	77.66	3.50
6	9.41	28.66	31.46	68.54	50.58	17.96
7	8.98	30.61	34.50	65.50	49.54	15.96
8	9.32	36.60	16.60	83.40	73.00	10.40
9	8.81	26.06	35.93	64.07	59.10	4.97
10	8.79	440.72	10.97	89.03	56.85	32.18
11	9.26	118.23	9.77	90.23	61.81	28.42
12	9.31	58.44	14.81	85.19	50.81	34.38
13	8.32	77.30	14.94	85.06	62.97	22.09
14	9.16	54.88	19.95	80.05	57.07	22.98
15	9.24	67.47	14.81	85.02	56.77	28.47
16	9.03	45.22	24.98	75.02	44.27	30.75
17	8.96	25.53	36.95	63.05	59.83	3.22
18	8.43	35.75	22.30	77.70	68.04	6.66
19	8.82	17.72	36.40	63.60	53.06	10.54
20	9.02	18.03	32.14	67.86	56.58	11.28

* Analysit : Chemist . H.Hamed.

DUST-FALL RESULTS ANALYSIS

(Period No. (4))

May. 6.92 - May. 15.92

Site No.	PH	Conc., g/m^2*30d	Soluble %	Insoluble %	Ash %	Carb. %
1	8.40	53.65	9.84	90.16	70.00	20.16
2	8.71	147.59	8.10	91.90	74.61	17.29
3	8.28	105.54	9.69	90.31	66.01	24.30
4	9.55	210.49	7.36	92.64	64.22	28.42
5	8.85	208.85	8.13	91.87	70.31	21.56
6	7.55	58.76	14.70	85.30	66.70	18.60
7	8.78	121.43	12.94	87.06	63.99	23.07
8	8.53	194.06	7.32	92.68	45.50	47.18
9	8.60	73.46	10.90	89.10	66.44	22.66
10	7.31	411.24	10.71	89.29	64.98	24.31
11	8.45	110.74	7.69	92.31	68.96	23.35
12	8.35	94.88	10.25	89.75	66.10	23.65
13	8.45	131.05	10.00	90.00	67.19	22.81
14	8.01	127.59	12.98	87.02	63.25	23.77
15	7.75	130.17	12.32	87.68	67.63	20.05
16	7.97	67.11	17.48	82.52	64.05	18.47
17	8.06	105.01	15.57	84.43	67.72	16.71
18	8.02	75.31	15.55	84.45	69.81	14.64
19	8.09	87.22	13.82	86.18	48.33	37.85
20	8.00	60.26	17.65	82.35	67.01	15.34

* Analysit : Chemist . H.Hamed.

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements
In

Period No. (1)
April 02. April 11.1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	2.52	20.81	86.24	271.97	298.51	54.73	44.78	49.75	38.14	10.22
6	1.30	11.70	148.70	334.57	706.32	29.74	96.65	48.33	7.43	20.91
10	1.33	10.72	46.86	270.20	79.30	20.22	40.18	50.21	1.33	14.50
13	2.09	8.62	52.60	119.94	260.81	2.79	19.53	16.74	1.39	20.34
14	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost
15	3.65	6.11	118.61	434.31	237.23	45.62	36.50	63.8	16.42	17.18
16	3.49	7.23	234.41	281.80	179.55	12.47	34.91	264.40	4.99	23.74
17	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost	Lost

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements

Period No. (1)
April 02. April 11.1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	0.10	4.97	16.58	9.95	14.93	9.95	4.98	4.98	0.95	0.20
10	0.07	1.46	1.69	1.66	2.99	2.32	5.31	4.31	0.66	0.18
15	0.15	6.02	16.42	3.65	9.12	23.72	5.47	14.59	0.30	0.44

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements
In

Period No.(2)
April 13. April 22.1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	1.89	20.25	80.33	209.49	194.92	45.07	24.09	38.76	28.19	10.15
6	1.73	11.62	120.14	202.17	288.80	361.01	79.42	83.03	10.83	25.16
10	1.27	21.92	60.40	822.23	89.07	31.24	7.95	161.36	1.92	9.13
13	2.46	16.49	60.86	300.24	256.97	31.10	22.99	72.66	4.06	17.22
14	2.89	16.19	46.47	278.79	200.54	51.35	24.46	53.80	19.56	20.43
15	5.41	12.41	90.61	900.81	294.70	54.07	44.13	135.25	11.39	18.00
16	4.97	10.55	168.28	353.81	211.05	52.76	37.24	235.88	12.41	26.80
17	5.04	9.02	70.20	102.77	48.38	16.52	9.62	19.32	2.05	20.50

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements

Period No.(2)
April 13. April 22.1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	0.04	1.65	6.28	1.05	3.14	9.43	2.09	5.24	3.10	0.18
10	0.05	1.17	3.56	1.92	3.29	1.64	5.48	5.48	0.82	0.60
15	0.06	2.90	7.42	5.69	2.85	34.16	2.85	9.97	2.85	1.50

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements
In

Period No. (3)
April 26. May.03 .1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	2.28	23.24	104.06	227.95	515.36	69.38	89.20	64.42		15.15
6	1.17	16.50	58.25	288.16	533.98	82.52	189.32	34.69		27.20
10	1.48	18.94	53.67	306.25	105.14	38.52	38.83	25.57		12.63
13	2.23	21.42	63.00	210.62	455.86	54.05	52.20	72.00		18.20
14	5.93	18.46	63.39	405.68	245.94	68.46	68.46	58.32		23.71
15	5.90	16.29	51.56	2103.00	288.72	78.37	105.18	57.74		14.30
16	3.03	11.95	160.00	846.15	347.69	64.62	67.69	76.92		30.16
17	5.34	20.92	54.50	386.96	659.40	103.54	92.64	119.89		10.21

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements

Period No. (3)
April 26. May .03 .1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	0.40	2.37	12.39	4.96	14.87	12.39	17.34	19.82		0.15
10	0.11	2.65	4.42	1.26	4.74	2.53	6.63	5.37		0.20
15	0.21	3.34	8.25	14.24	8.25	8.25	12.37	18.56		0.88

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements
In

Period No. (4)
May. 06. May.15 .1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	2.87	18.33	63.06	328.52	425.31	46.93	67.46	31.53		13.20
6	3.94	14.42	82.30	302.08	180.51	58.94	75.52	22.26		38.68
10	1.45	17.63	58.42	278.96	442.11	30.79	44.47	23.16		11.32
13	2.51	15.69	234.53	644.15	693.70	33.38	72.67	51.20		22.30
14	2.58	11.88	139.11	763.42	458.05	51.74	64.41	40.72		23.75
15	4.57	9.98	290.02	1230.46	814.76	70.00	57.37	44.06		21.62
16	5.13	8.10	461.22	656.35	741.82	72.57	67.73	59.66		37.09
17	3.56	8.97	90.69	474.08	700.81	57.71	51.53	30.92		25.77

Total D-F Analysis
Elemental Constituent Concentration
of Soluble elements

Period No. (4)
May 06. May .15 .1992

Analysit:Chem.H.Hamed

Site No.	Fe %	Ca %	Pb ug/g	Mn ug/g	Zn ug/g	Cr ug/g	Ni ug/g	Cu ug/g	V ug/g	Cd ug/g
2	0.09	6.60	8.47	2.20	2.93	7.39	1.54	2.93		0.22
10	0.05	2.03	2.63	1.84	2.63	1.45	2.16	3.42		0.79
15	0.13	2.49	7.48	3.33	4.16	12.14	7.07	6.65		2.33

APPENDIX B

TOTAL SUSPENDED PARTICULATES -
ELEMENT ANALYSES

CONC.OF T.S.P

Site No.	Date	Time	Sampling		Conc. $\mu g/m^3$	Remarkes
			On	Off		
6	30/3/92	24	14:00	14:00	125	
6	1/4/92	28	15:00	19:00	227.2	
6	2/4/92	8	20:25	4:25	626.2	
11	7/4/92	25	1:00	2:00	1594.00	
11	8/4/92	19	2:45	21:45	941.1	
14	13/4/92	24	13:00	13:00	484.00	
14	14/4/92	24	14:30	14:30	490.70	
14	15/4/92	24	16:00	16:00	275.4	
14	16/4/92	7	20:00	3:00	288.60	

CONC.OF T.S.P

Site No.	Date	Time	Sampling		Conc.	Remarkes
			On	Off	µg/m3	
11	18/4/92	22	11:30	9:30	1088.6	
11	19/4/92	24	10:00	10:00	1333.8	
11	20/4/92	23	11:30	10:30	853	
11	22/4/92	24	11:00	11:00	1341	
11	23/4/92	24	12:00	12:00	1034.2	
17	25/4/92	16	17:00	9:00	1487.6	
17	26/4/92	16	16:00	8:00	470.3	
17	27/4/92	24	16:00	16:00	697.4	
17	29/4/92	25	20:00	21:00	877.3	

CONC.OF T.S.P

Site No.	Date	Time	Sampling		Conc. Mg/m3	Remarkes
			On	Off		
18	2/5/92	24	11:30	11:30	1395.4	
18	3/5/92	24	11:30	11:30	1284.7	
18	4/5/92	24	11:30	11:30	1312.6	
18	5/5/92	20	3:30	3:30	1346.3	off 4 hr
18	6/5/92	16	18:30	10:30	1980.3	
3	9/5/92	24	17:00	17:00	578.7	
3	10/5/92	24	17:00	17:00	1326.0	
3	11/5/92	22:30	17:00	17:00	1377.7	off 1:30
3	12/5/92	24	17:00	17:00	780.5	
3	13/5/92	22:30	17:00	17:00	1432.0	off 1:00

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO.3		Remarkes
		10/5/92	12/5/92	
fe	%	6.000	4.000	
Ca	%	22.000	26.000	
Cu	ug/g	1814.900	5438.060	
V	ug/g			
Pb	ug/g	981.030	377.600	
Ni	ug/g	8.180	18.800	µg/m³
Mn	ug/g	498.600	302.100	
Cd	ug/g	16.000	56.000	
Cr	ug/g	81.700	18.800	
Zn	ug/g	555.900	399.800	

CONSTITUENT of T.S.P AND METALS IN AIR

Element	Unit	Site No.3		Remarkes
		10/5/92	12/5/92	
fe	ug/m	79.60	31.220	
Ca	ug/m	291.70	202.800	
Cu	ug/m	2.40	4.200	
V	ug/m			
Pb	ug/m	1.30	0.290	µg/m³
Ni	ug/m	0.01	0.014	\
Mn	ug/m	0.66	0.230	
Cd	ug/m	0.02	0.040	
Cr	ug/m	0.11	0.014	
Zn	ug/m	0.74	0.310	

CONSTITUENT OF T.S.P AND METALS IN AIR

Element	Unit	Site No.6		Remarkes
		30/3/92	2/4/92	
Fe	µg/m³	5.4	9.08	
Ca	µg/m³	8.6	15	
Cu	µg/m³	0.0189	0.08	
V	µg/m³	0.0120	0.04	
Pb	µg/m³	0.0370	0.16	
Ni	µg/m³	0.0240	0.01	
Mn	µg/m³	0.0244	0.08	
Cd	µg/m³	0.00	0.00	
Cr	µg/m³	0.00	0.01	

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO.6		Remarkes
		30/3/92	2/4/92	
Fe	%	4.32	1.45	
Ca	%	6.88	2.39	
Cu	µg/g	150	120	
V	µg/g	90	60	
Pb	µg/g	290	250	
Ni	µg/g	190	15	
Mn	µg/g	192	127.7	
Cd	µg/g	_	_	
Cr	µg/g	_	15	

(o)

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO. 11		Remarkes
		19/4/92	23/4/92	
fe	%	3.60	4.20	
Ca	%	9.50	10.40	
Cu	ug/g	342.80	726.93	
V	ug/g			
Pb	ug/g	1318.50	1580.28	µg/g
Ni	ug/g	290.08	1042.98	
Mn	ug/g	2215.18	1074.50	
Cd	ug/g	25.40	158.03	
Cr	ug/g	25.40	63.20	
Zn	ug/g	1555.90	4424.70	

CONSTITUENT OF T.S.P AND METALS IN AIR

Element	Unit	Site NO. 11		Remarkes
		19/4/92	23/4/92	
fe	µg/m^3	48.00	43.40	
Ca	ug/m^3	126.70	107.50	
Cu	ug/m^3	0.47	0.75	
V	ug/m^3			
Pb	ug/m^3	1.75	1.63	µg/m^3
Ni	ug/m^3	0.39	1.08	
Mn	ug/m^3	2.95	1.11	
Cd	ug/m^3	0.03	0.16	
Cr	ug/m^3	0.03	0.07	
Zn	ug/m^3	2.08	4.58	

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO. 14		Remarkes
		14/4/92	16/4/92	
fe	%	4.92	2.64	
Ca	%	21.10	15.80	
Cu	ug/g	209.10	166.01	
V	ug/g	30.00	43.20	
Pb	ug/g	184.501	396.04	
Ni	ug/g	50.430	264.02	µg/g
Mn	ug/g	221.40	1518.15	
Cd	ug/g	6.1500	26.40	
Cr	ug/g	24.600	92.41	

CONSTITUENT OF T.S.P AND METALS IN AIR

Element	Unit	Site NO. 14		Remarkes
		14/4/92	16/4/92	
fe	ug/m	24.100	7.500	
Ca	ug/m	103.300	45.500	
Cu	ug/m	0.100	0.050	
V	ug/m	0.014	0.012	
Pb	ug/m	0.090	0.114	µg/m^3
Ni	ug/m	0.024	0.076	
Mn	ug/m	0.109	0.430	
Cd	ug/m	0.003	0.007	
Cr	ug/m	0.012	0.026	

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO. 17		Remarkes
		25/4/92	27/4/92	
fe	%	2.40	4.00	
Ca	%	11.20	12.00	
Cu	ug/g	852.40	405.00	
V	ug/g			
Pb	ug/g	6586.60	2252.20	
Ni	ug/g	193.70	45.04	µg/g
Mn	ug/g	4300.64	1351.30	
Cd	ug/g	116.20	135.10	
Cr	ug/g	271.20	450.40	
Zn	ug/g	1975.90	2252.20	

CONSTITUENT OF T.S.P AND METALS IN AIR

Element	Unit	Site NO. 17		Remarkes
		25/4/92	27/4/92	
fe	ug/m^3	35.70	27.90	
Ca	ug/m^3	166.60	83.70	
Cu	ug/m^3	1.26	0.28	
V	ug/m^3			
Pb	ug/m^3	9.80	1.57	
Ni	ug/m^3	0.29	0.03	µg/m^3
Mn	ug/m^3	6.40	0.94	
Cd	ug/m^3	0.17	0.09	
Cr	ug/m^3	0.40	0.31	
Zn	ug/m^3	2.90	1.57	

METALIC CONSTITUENT OF SUSPENDED DUST

Element	Unit	Site NO. 18		Remarkes
		2/5/92	6/5/92	
fe	%	6.00	7.10	
Ca	%	28.10	15.00	
Cu	ug/g	1351.30	533.90	
V	ug/g			
Pb	ug/g	3800.60	106.70	
Ni	ug/g	8.40	5.30	µg/g
Mn	ug/g	819.20	683.40	
Cd	ug/g	25.10	21.30	
Cr	ug/g	50.60	10.60	
Zn	ug/g	979.73	218.90	

CONSTITUENT OF T.S.P AND METALS IN AIR

Element	Unit	Site NO. 18		Remarkes
		2/5/92	6/5/92	
fe	ug/m	78.70	138.60	
Ca	ug/m	368.00	297.00	
Cu	ug/m	1.77	1.05	
V	ug/m			
Pb	ug/m	4.98	0.21	
Ni	ug/m	0.01	0.01	µg/m^3
Mn	ug/m	1.07	1.35	
Cd	ug/m	0.03	0.04	
Cr	ug/m	0.06	0.02	
Zn	ug/m	1.29	0.43	

APPENDIX C

INPUT DATA FOR MODEL ESTIMATES

Emission & Meteorological Data, EONDEP

```
1500,1000,600,300              Mixing Heights
1.0,3.0,5.0,7.5                Mean windspeed
720,300.0                      DT,TA
25,25, 8,17,25                 QFREQ in % (<10,10-20,20-30,30-50,>50)
0.000,0.02,0.10,0.10,0.40      VT
0.001,0.01,0.05,0.05,0.20      VD
HELWAN TOTAL, APR92,           DUST
  30 1.0  .5 1.0  .5 1.0 2.0  .5  .5 2.0 3.0 1.0  .0 2.0 9.0  .0  .0
  60  .5  .0  .5  .0  .5  .5  .5  .5 1.0 3.0  .0  .0 2.0 4.0  .0  .0
  90  .0  .0  .0  .0  .5 1.0  .5  .0  .0  .5  .0  .0  .0  .5  .0  .0
 120  .0  .0  .0  .0  .5  .5  .5  .0  .5 1.0  .0  .0  .0 3.0  .0  .0
 150  .0  .0  .5  .0  .0  .0  .5  .0  .0  .0  .0  .0  .0  .0  .0  .0
 180  .5  .0  .5  .0  .0  .5  .0  .0  .0  .5  .0  .0  .0  .0  .0  .0
 210  .5  .0  .5  .0  .5  .5  .0  .0  .5  .5  .0  .0  .0 1.0  .0  .0
 240  .0  .0  .0  .0  .5 1.0  .5  .0  .5 1.0  .5  .0  .0 2.0  .0  .0
 270  .0  .0  .5  .0  .0  .5  .5  .0  .5  .5  .0  .0  .0  .5  .0  .0
 300  .5  .0 1.0  .5  .0  .5  .5  .0  .5 1.0  .5  .0  .0 1.0  .0  .0
 330 1.0  .0 1.0 1.0 1.0  .5 1.0  .5 2.0 2.0 1.0  .0 2.0 6.0  .0  .0
 360 1.0  .0 1.0  .0 2.0 2.0 2.0  .0 2.0 3.0 1.0  .0 1.0 5.0  .0  .0
1
0
330000,285000,345000,315000,1000, Grid
0
28, Number of sources
```

Met. data →

Q h_s T_g

Tourah old	1,334700,311600,	1000.0,80.0,420.0,20.0,1.6,40, 40,KILN2-6
	1,334800,311300,	400.0,80.0,410.0,20.0,2.8,40, 40,KILN7
	1,334700,311400,	300.0,25.0,360.0,20.0,0.5,20,100,CM
	1,334600,311500,	200.0, 5.0,300.0, .1,1.0,30,100,DIFFUSE
Tourah new	1,336000,311700,	800.0,60.0,420.0,20.0,1.0,40, 50,KILN8-9
	1,335900,311700,	500.0,25.0,400.0,20.0, .6,20,100,CM
	1,336000,311700,	200.0, 5.0,300.0, .1,1.0,40,100,DIFFUSE
Helwan	1,336400,300600,	400.0,50.0,450.0,20.0,1.3,20, 50,WETKILN1-6
	1,336400,300600,	40.0,20.0,370.0,10.0,0.6,20, 50,COOLERS
	1,336400,300600,	100.0, 5.0,300.0, .1,1.0,30,100,DIFFUSE
	1,336450,300640,	150.0,30.0,320.0,10.0,0.6,20, 50,CM1-6
	1,336450,300640,	100.0, 5.0,300.0, .1,1.0,20,100,DIFFUSE
	1,336410,300240,	200.0,60.0,400.0,20.0,3.0,50, 50,RM1-2
	1,336400,300200,	100.0, 5.0,300.0, .1,1.0,20,100,DIFFUSE
	1,336600,300300,	300.0,60.0,400.0,20.0,4.0,50, 50,RM3-4
	1,336600,300300,	100.0, 5.0,300.0, .1,1.0,20,100,DIFFUSE
	1,336410,300240,	240.0,60.0,400.0,20.0,3.8,50, 50,BYPASSKILN1
	1,336410,300240,	240.0,60.0,400.0,20.0,3.8,50, 50,BYPASSKILN2
	1,336400,300200,	50.0, 5.0,300.0, .1,1.0,20,100,DIFFUSE
	1,336600,300300,	800.0,30.0,300.0,20.0,0.5,20, 50,CM1-9
	1,336600,300300,	200.0, 5.0,300.0, .1,1.0,40,100,DIFFUSE
National	1,338700,297000,	300.0, 47.0,420.0, 8.0,0.5,30, 50,KILN1-3
	1,338900,297500,	200.0,120.0,500.0, 3.0,5.0,50, 50,KILN4
	1,338600,297100,	200.0, 50.0,400.0,10.0,1.0,30, 50,RM123
	1,339100,297600,	200.0, 85.0,365.0,10.0,3.9,30,100,KILN5-6
	1,338600,297600,	220.0, 50.0,400.0,10.0,1.0,30, 50,RM5-6
	1,338700,297600,	30.0, 30.0,300.0, 3.0,1.0,25,100,CM1-9
	1,338600,297400,	180.0, 5.0,300.0, .1,1.0,30,300,DIFFUSE

```
0, No halls
1, Fieldfile(0:No,1:Yes)
dusdep0.fld
DUST TOT. UG/M3
```

APPENDIX D

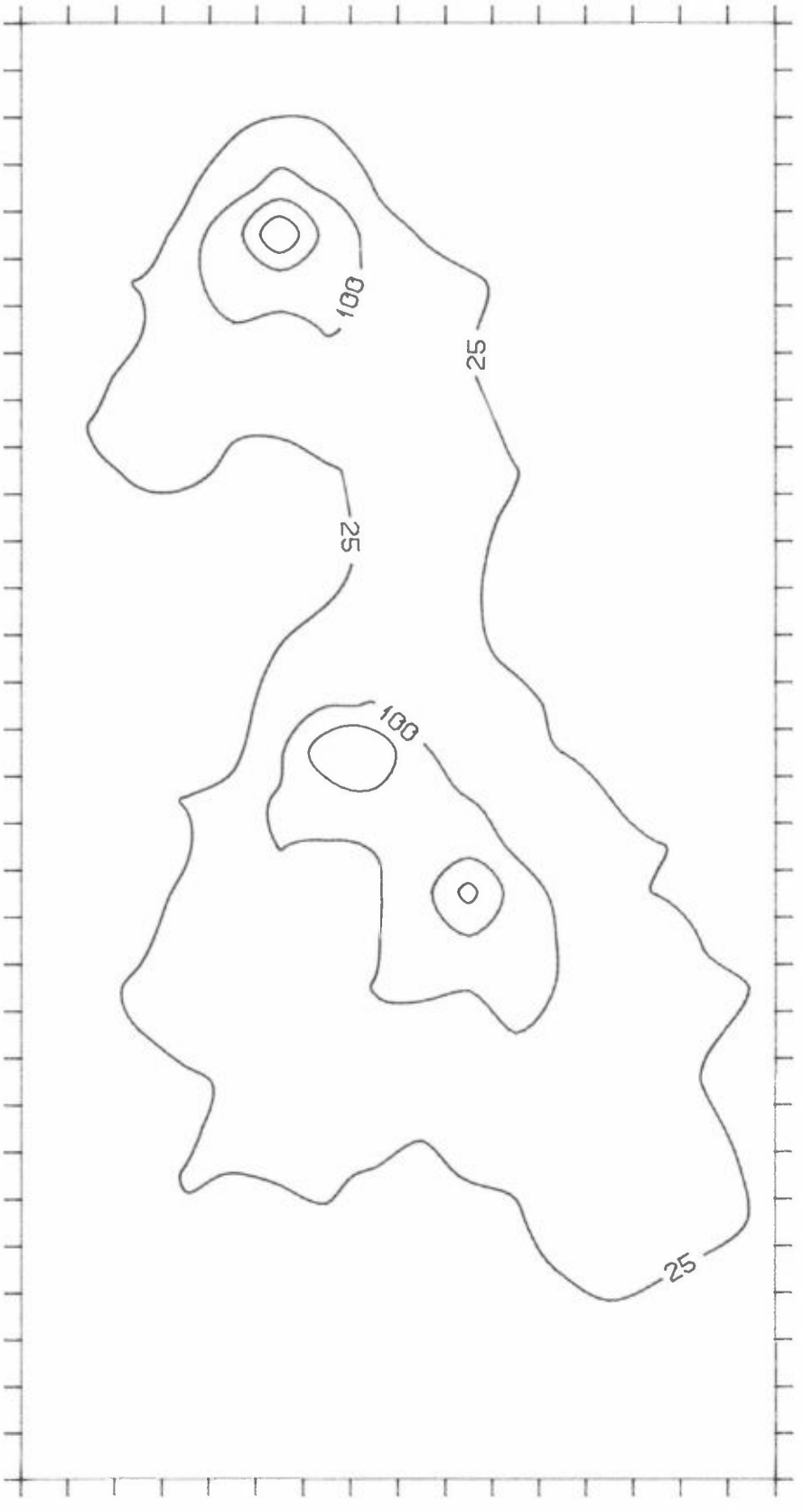
RESULTS OF MODEL ESTIMATES FOR FUTURE SCENARIOS

FELT NR. 2 PÅ FIL DUSDEPO-NO:FELT

MAX= 1.219E+03

DUST TOT. G/M2

D1:
Normal case



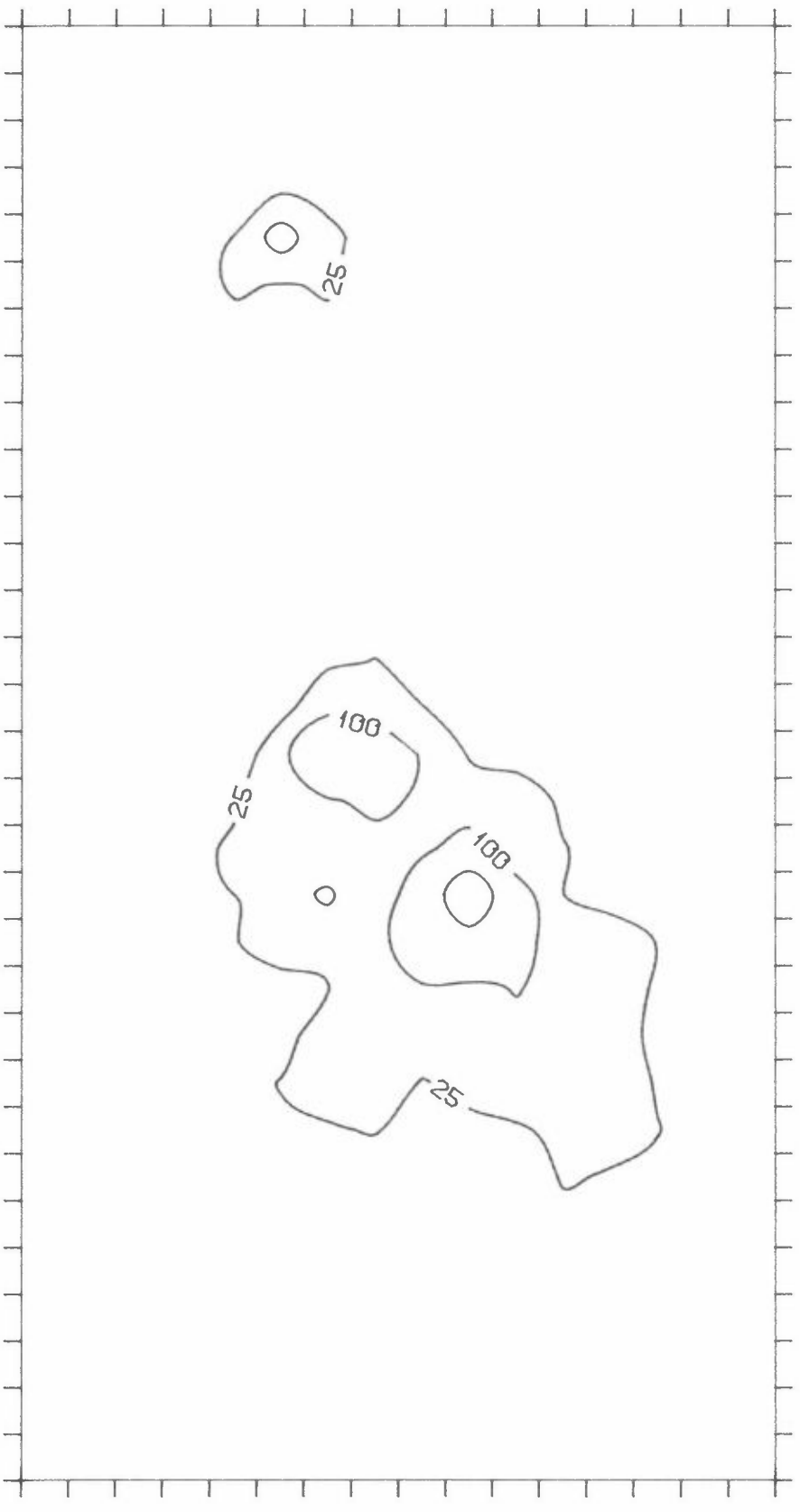
FELT NR. 2 PÅ FIL DUSDEPO-BO:FELT

MAX= 6.749E+02

DUST TOT. G/M2

D2:

Best Case

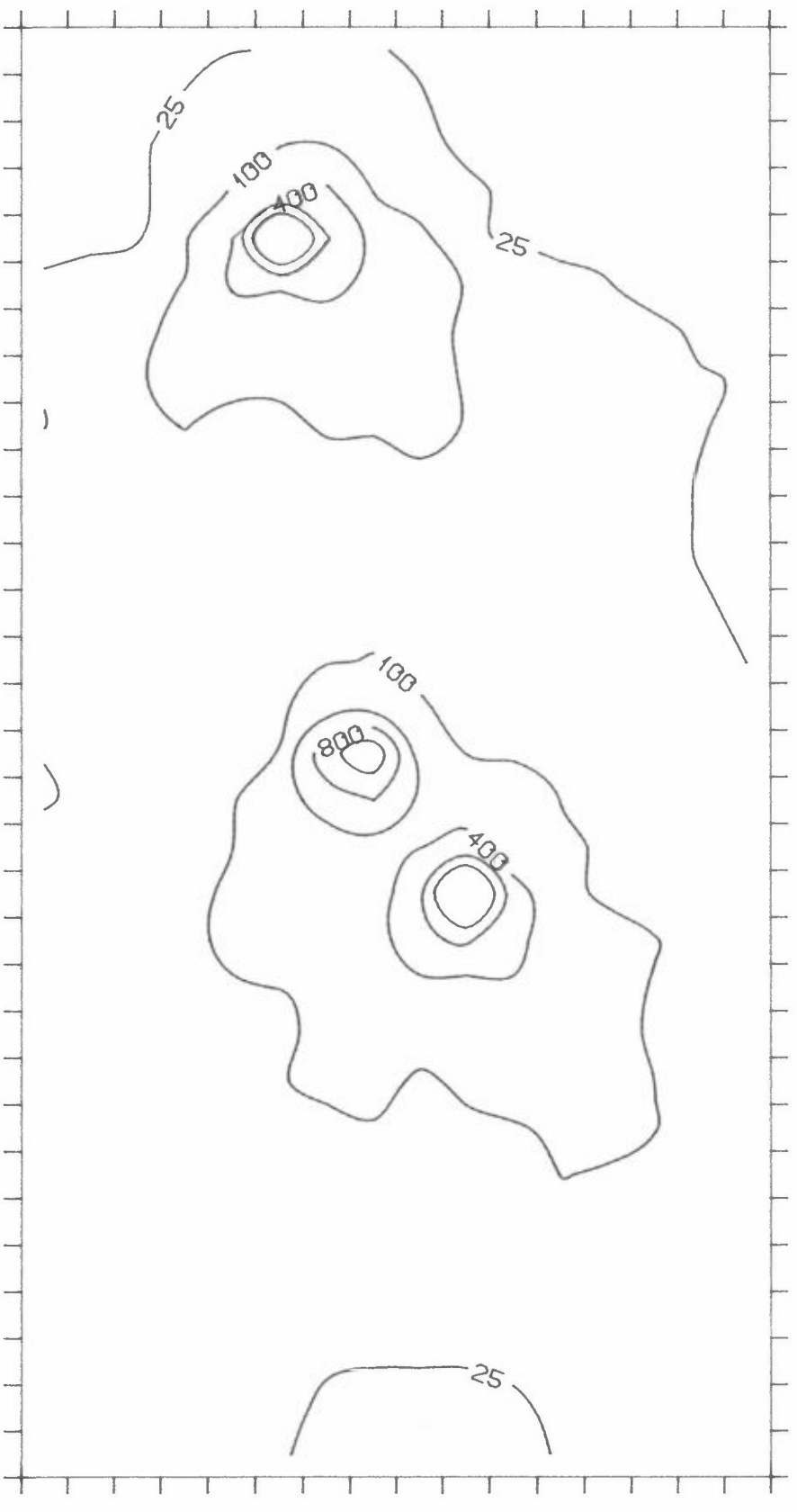


FELT NR. 2 PÅ FIL DUSDEPO-WO:FELT

MAX= 2.234E+03

DUST TOT. G/M2

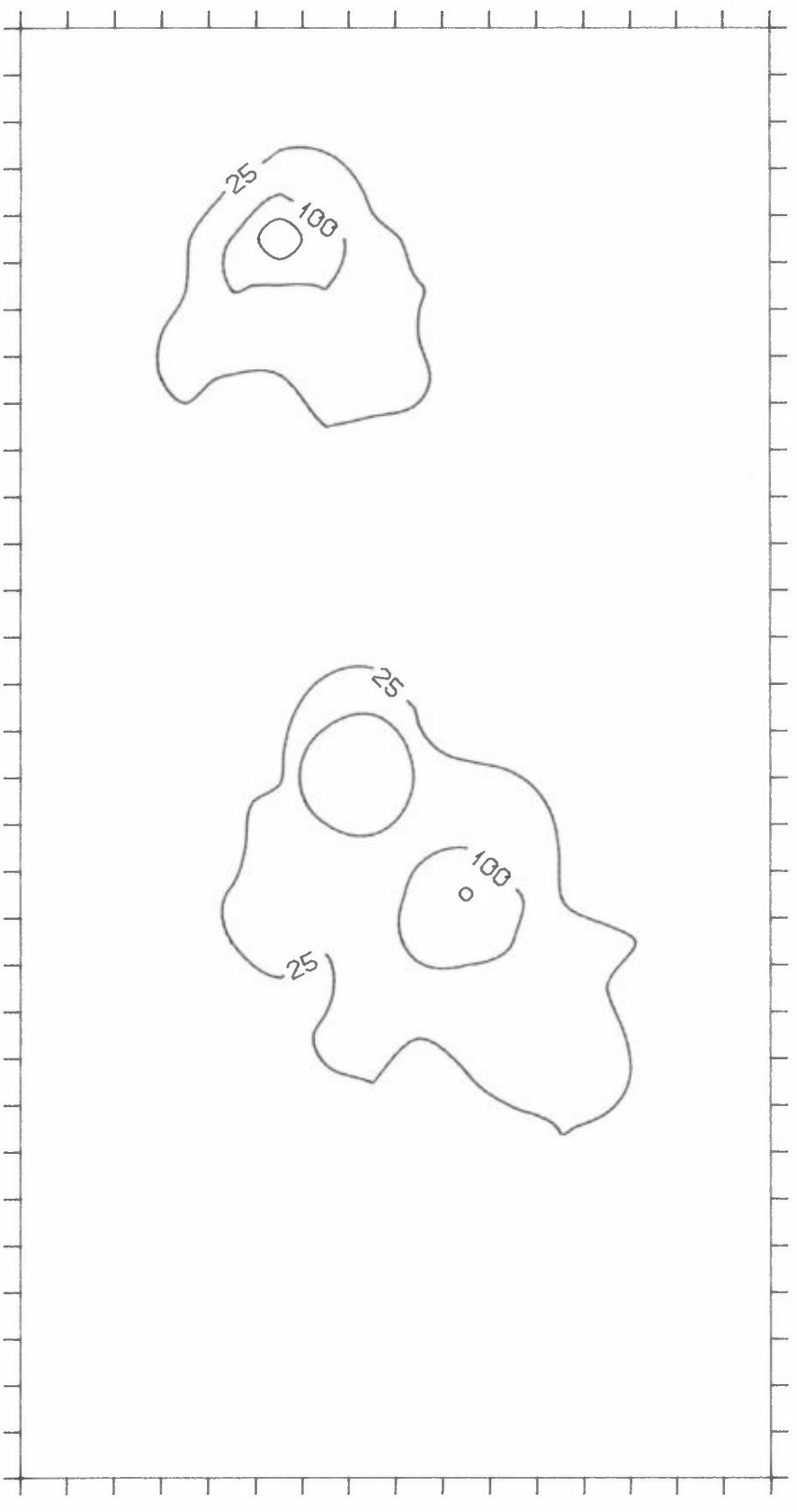
D3:
Worst case



FELT NR. 2 PÅ FIL DUSDEPO-NO2:FELT

MAX= 6.438E+02

DUST TOT. G/M2

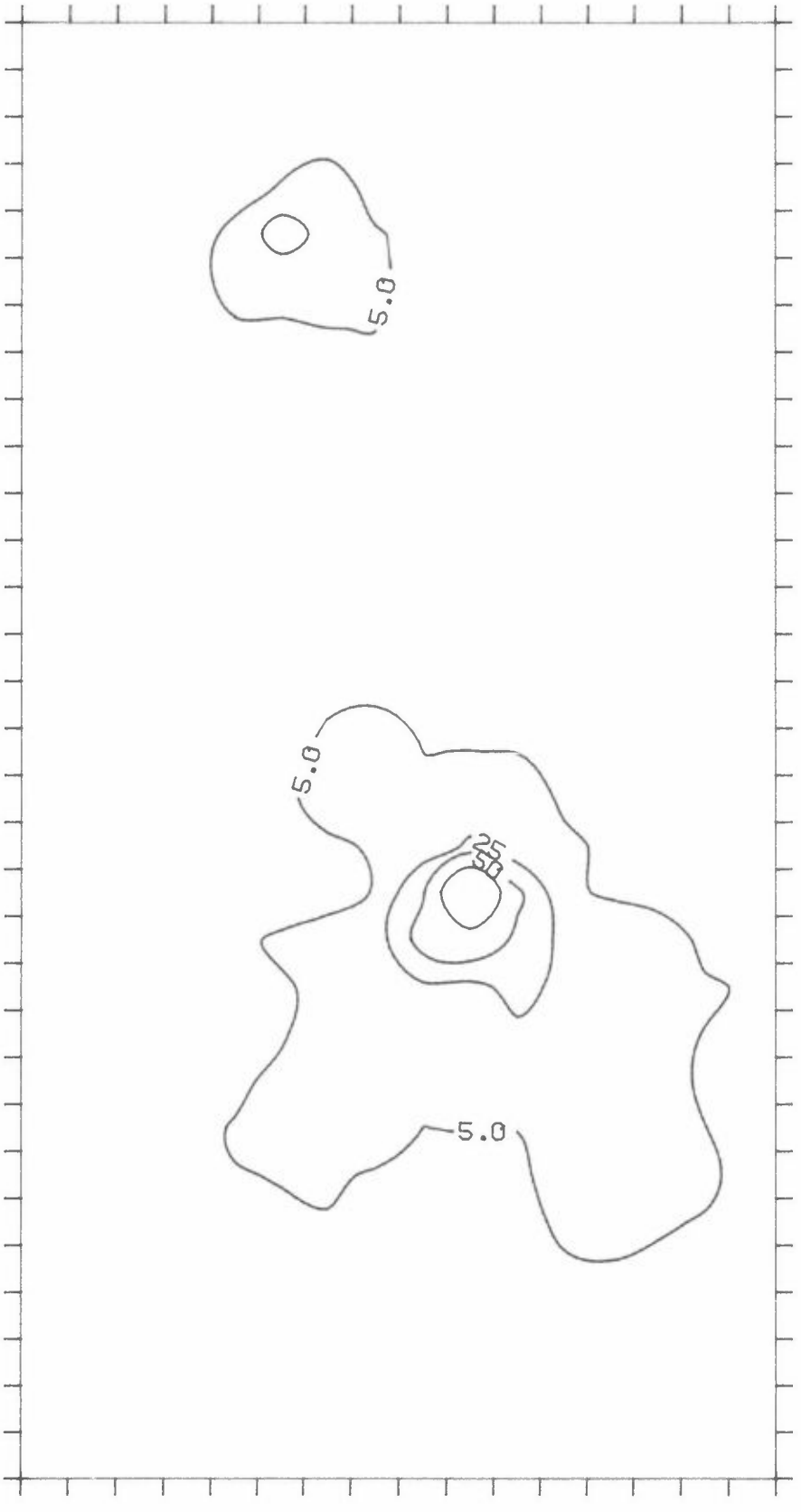


D4:
Normal case
with shutdown
equipment

FELT NR. 2 PÅ FIL DUSDEP0-B02:FELT

MAX= 1.849E+02

DUST TOT. G/M2



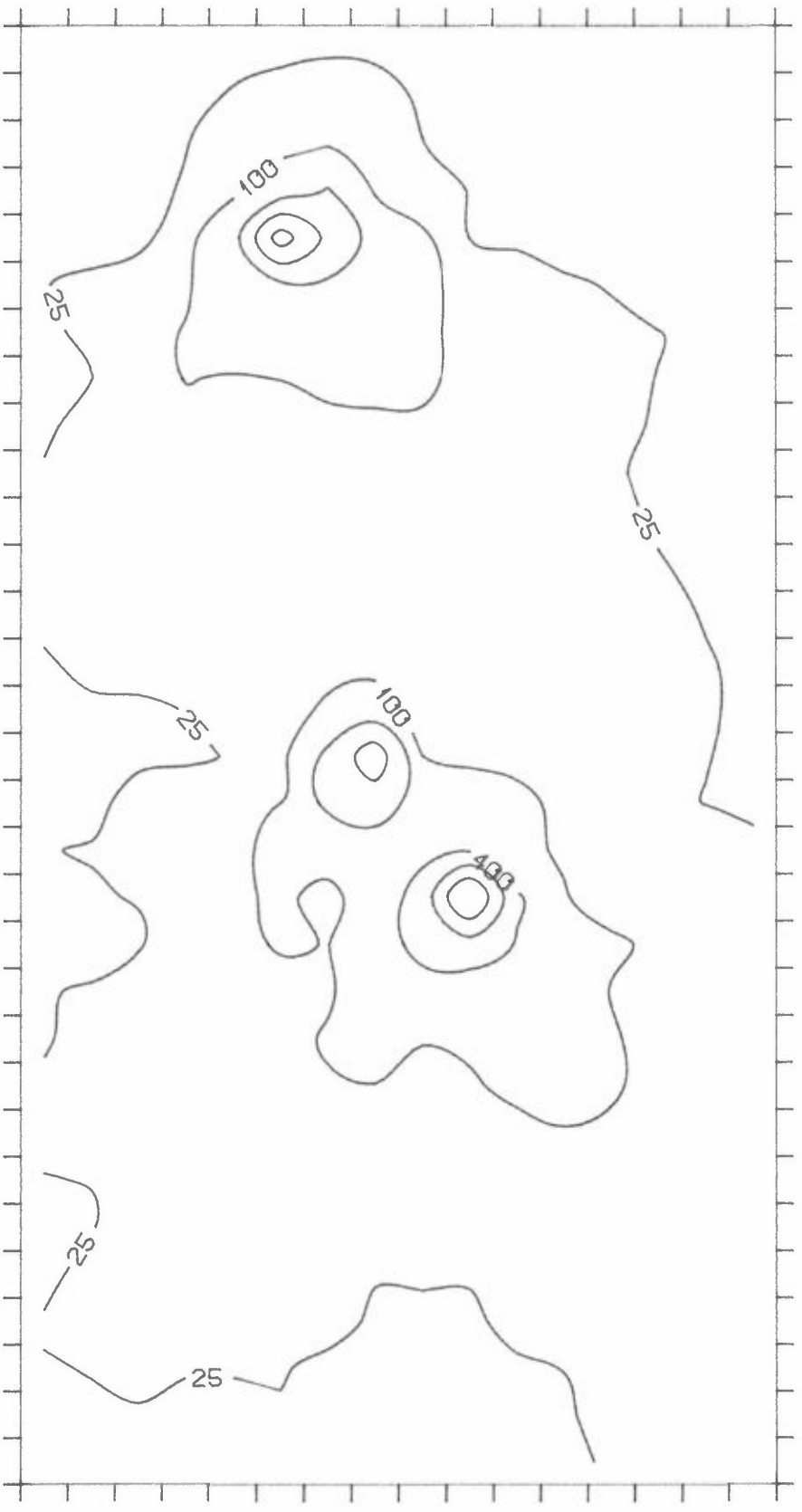
D5:

Best case with shut down equipment

FELT NR. 2 PÅ FIL DUSDEP0-W02:FELT

MAX= 1.727E+03

DUST TOT. G/M2



D 6.

Worst case

with shutdown

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RAPPORTTYPE OPPDRAGSRAPPORT	RAPPORTNR. OR 85/92	ISBN-82-425-0435-0	
DATO 16.12.1992	ANSV. SIGN. Ø Overland	ANT. SIDER 130	PRIS NOK 180,-

TITTEL THE HELWAN ENVIRONMENTAL STUDY METEOROLOGY AND AIR QUALITY	PROSJEKTLEDER NILU PROSJEKT NR. O-92047
FORFATTER(E) B. Sivertsen	TILGJENGELIGHET * A OPPDRAGSGIVERS REF.

OPPDRAGSGIVER (NAVN OG ADRESSE)
The World Bank via Norconsult International a.s

STIKKORD
Environmental | Impact | Industrial area

REFERAT

TITLE

ABSTRACT
An environmental impact study performed by NILU for Norconsult International a.s show that dust fall and suspended dust are by for the largest enviromental problem in the highty industrialized area of Helwan, south of Cairo in Egypt. Dust fall values more than ten Times European standards and total suspended dust of eight times the WHO air quality guideline values were frequently found.

* Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C