ATMOSPHERIC SULPHUR DIOXIDE POLLUTION IN MALTA: A PRELIMINARY STUDY

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ABSTRACT

The results of a preliminary survey of the air quality in Malta during May-December 1990 with respect to sulphur dioxide are presented. One-hour-average SO_2 concentrations as high as 320 ug m^{-3} have been measured from areas proximate to the Marsa power station. The concentration of SO_2 in ambient air was found to be strongly dependent on atmospheric conditions and especially on wind direction. At Paola, measured concentrations varied from below the detection limit of 25 ug m^{-3} to about 160 ug m^{-3}. These preliminary results suggest that specific areas in Malta which are close to the Marsa power station may have an air pollution problem which is significantly more pronounced than that in other areas. The results also indicate the need for a thorough air monitoring programme which would allow the pollution problem to be assessed more accurately and to be followed continually.

Keywords: sulphur dioxide, air, pollution, Malta, environment.

INTRODUCTION

There is a great paucity of data relating to parameters which define environmental quality in Malta. Laboratories of state or parastatal institutions are involved in the routine measurement of sea and drinking water quality parameters, but the data is not published. Three recent papers (1, 2, 3) have addressed flouride, nitrate and salt levels in drinking water respectively, but nothing has yet been published on the quality of the air in the Islands.

This paper presents preliminary data on sulphur dioxide concentrations in ambient air at ground level measured from five different localities in Malta during 1990. The significance of the data and its implications for public health will be discussed.

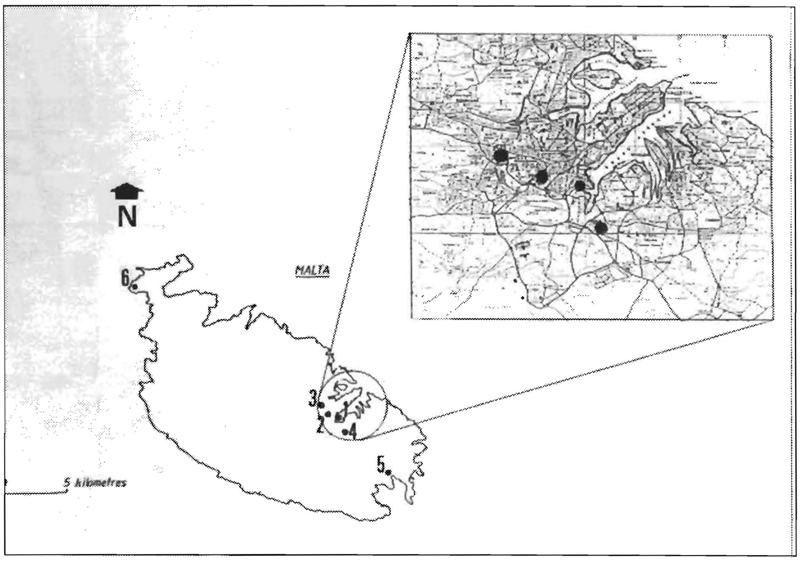

FIGURE 1: *Map of sites which have been sampled in this study and their relation to Marsa Power Station.*

MATERIALS AND METHODS

The concentration of sulphur dioxide in air was determined by the method of West-Gaeke (4). The procedure involves aspirating a measured volume of air through a solution containing tetrachloromercurate (II) ion resulting in the formation of a dichlorosulphitomercurate (II) complex which is then determined quantitatively by spectrophotometry at 540 nm.

The impinger was made from a 25cm^3 boiling tube with side arm to which a glass delivery tube was fitted by a ground glass joint. This tube was drawn out to a jet with diameter 1 mm which extended to within 4 mm from the bottom of the boiling tube. Air was aspirated through the impinger using a portable pump (Casella Model SN 19855) which was calibrated and adjusted to give a flow

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rate of 0.5 litres per minute. A silica gel trap was placed in line between the pump and the air inlet to prevent moisture accumulating in the pump and affecting the flow rate. The impinger was immersed in a bath at 25°C and was protected from sunlight by an aluminium foil cover. The impinged samples were stored under refrigeration (<5°C) prior to analysis.

A sulphite solution, freshly standardized iodometrically, was used as calibrant. Spectrophotometry was performed using a Milton Roy Spectronic 20 single beam instrument. The calibration curve is linear over the working range of about 0.10 to 1.3 ug SO_2 mL^{-1}. It was established that the minimum atmospheric sulphur dioxide concentration that was detectable by this method was 25ug m^{-3}.

Air sampling was performed at ground level with the impinger placed 1m above street level. The sites chosen for analysis were Marsa, Hamrun (Blata l-Bajda area), Paola, Marsaxlokk and Cirkewwa (Figure 1). These sites were selected to represent, respectively, areas which are geographically close to the Marsa power station (Marsa, Hamrun and Paola) and others (Cirkewwa and Marsaxlokk) which are in areas situated away from this pollution source and in opposite directions. In 1990, the new power plant at Delimara had not yet been commissioned.

In all cases, sampling was performed on pavements along main roads. On each occasion, the sampling time period was one hour and air samples were taken during daytime, mostly in the mornings. Sampling dates were spread over a period of eight months chosen to represent different climate regimes.

The air temperature was calculated as an average of three readings taken on site over the 1-hour sampling period;

TABLE I: SULPHUR DIOXIDE CONCENTRATIONS IN MALTA AIR
MAY-DECEMBER 1990

DATE	TIME	LOCATION	WIND DIRECTION SPEED (KNOTS)	SO_2 CONCENTRATION (ug m^{-3})
01/05	10:00	Paola	E/21	<25
07/05	11:05	M'Xlokk	SE/12	<25
15/05	10:30	Hamrun	SE/6	97
31/05	10:25	Paola	NW/14	161
03/06	10:15	Hamrun	SSE/10	108
16/06	09:34	M'Xlokk	NW/11	<25
20/06	11:04	Marsa	NE/12	193
27/06	13:30	Marsa	NE/10	285
24/07	10:36	Paola	NW/11	136
27/07	09:34	Paola	N/7	<25
01/08	09:32	Cirkewwa	NW/8	<25
02/08	10:20	M'Xlokk	E/8	<25
06/08	10:30	M'Xlokk	SSE/8	<25
07/08	09:58	Cirkewwa	SE/12	<25
08/08	09:00	Hamrun	E/7	<25
10/08	08:52	Marsa	NNE/10	322
16/08	09:13	Marsa	SW/14	<25
16/08	10:37	Hamrun	SW/13	<25
02/09	11:30	Paola	S14	<25
11/09	13:08	Paola	NW/16	103
18/09	16:08	Cirkewwa	SW/12	<25
24/09	14:23	Marsa	SW/15	<25
30/09	06:50	Marsa	NNE/10	206
16/10	17:30	Hamrun	SE/12	218
17/10	18:20	Marsa	ESE/11	99
18/10	18:24	Marsa	S/2	<25
25/10	18:22	Paola	calm	<25
26/10	10:31	Marsa	E/9	<25
31/10	17:35	Paola	S/7	<25
02/11	10:31	Marsa	NW/11	<25
06/11	16:20	Marsa	NW/8	<25
03/12	06:30	Cirkewwa	NW/10	<25
16/12	07:00	Marsa	SW/15	<25
19/12	15:30	Hamrun	NNW/8	<25
23/12	18:07	Marsa	E/21	42
29/12	10:05	M'Xlokk	NNW/6	<25

the barometric pressure, wind speed and direction were obtained from the hourly reports of the Luqa Meteorological Office. The standard air volume used for analysis was 30.0 +/- 0.5L.

RESULTS

One-hour average concentrations of sulphur dioxide in air obtained on each of 36 monitoring sessions are given in Table I. The Table includes the location, date of sampling, time at the start of sample collection, wind direction and speed, barometric pressure and temperature.

DISCUSSION

Sulphur dioxide is one of three major pollutants known to degrade the quality of ambient air, the other two pollutants being nitrogen oxides and suspended particulate matter. In the absence of industry like sulphide ore smeltering, SO_2 in air originates largely from the combustion of sulphur-bearing fossil fuels. Indeed, the regulation of sulphur content in fuels is a widely used measure in policies designed to control sulphur emission in the ECE region (5).

Currently, the major point source emitters of sulphur dioxide into the Maltese environment are the chimney stacks of the two power stations at Marsa and Delimara respectively; during 1990, however, the latter utility had not yet come on stream. From published information (6) on the amount of coal and fuel oil consumed during that year and considering the average percentage sulphur content of each fuel, we estimate an output of about 17,000 tonnes SO_2 from the Marsa plant during that year. Automotive traffic, especially that powered by diesel engines, contributes somewhat to sulphur dioxide pollution. Gas oil (diesel fuel) has a sulphur content of about 0.2 to 0.3%; this is about one tenth of the sulphur content of fuel oil. Petrol typically contains about 0.02% sulphur. On the basis of the amounts of these fuels consumed during 1990 (6), we estimate that about 600 tonnes of SO_2 were formed from the combustion of petrol and gas oil during that year. Hence, the contribution to the atmospheric sulphur dioxide load by automotive traffic in Malta in 1990 was less than 4% of the total; also, unlike that originating from the electrical utility, this type of air pollution is not localised.

For a localised point source, the smoke plume issuing from the chimney stack of the source moves with the prevailing wind and disperses outwards in a manner which depends on a number of factors including meteorological conditions, nature of the terrain, topography and distance travelled (7). In Malta, the most prevalent winds blow from the North West (8) (Figure 2) and these winds direct the pollution plume onto Paola, the major town nearest the power station in this direction. On the three separate occasions when air was sampled from Paola with a NW wind blowing, value of sulphur dioxide concentrations >100 ug m^{-3} were measured. This SO_2 concentration is below the World Health Organization (WHO) guideline value for the pollutant when the air is free from particulate matter but above the guideline value when the gas is also accompanied by particulate material (Table II) (9).

The health effects of sulphur dioxide are known to be much more pronounced when the gas is accompanied by suspended particles and water vapour (10). Laboratory studies on volunteers have shown that changes in lung function are not evident when sulphur dioxide is the sole pollutant in the air until it reaches concentrations around 2000 ug m^{-3}. However in ambient air containing water and particulate matter as well as other substances, reactions may take place to produce compounds to which the respiratory system is much more sensitive. It has been shown that in the presence of 135 ug m^{-3} total suspended particles (TSP), even SO_2 concentrations lower than 25 ug m^{-3} have resulted in increased frequency of acute lower respiratory tract disease; at 180 ug m^{-3} TSP, 55 ug m^{-3} SO_2 have been found to cause a higher rate of respiratory symptoms and decreased lung function (11).

The process of coal combustion favours the formation of smoke and particulate matter and the synergistic effects described will be operative especially when coal firing is in progress. Since this occurs routinely at the Marsa plant and since for about 30% of the time, northwesterlies blow over the island (Figure II), we conclude that the air quality in the Paola area may frequently be conducive to adverse health effects due to sulphur dioxide pollution.

TABLE II:
AIR QUALITY GUIDELINES FOR SULPHUR DIOXIDE POLLUTION ACCORDING TO WHO (9)

CONDITION *	SO_2 Concentration / ug m^{-3}
Short term exposure with no particulate matter	500
Long term exposure with no particulate matter	350
Short term exposure combined with particulate matter	125
Long term exposure combined with particulate matter	50

(*) *In this table, "short term" exposure refers to a time period of the order of an hour. It is believed that inhalation of sulphur dioxide in concentrations and for exposure times below these guideline values will not have adverse effects on health.*

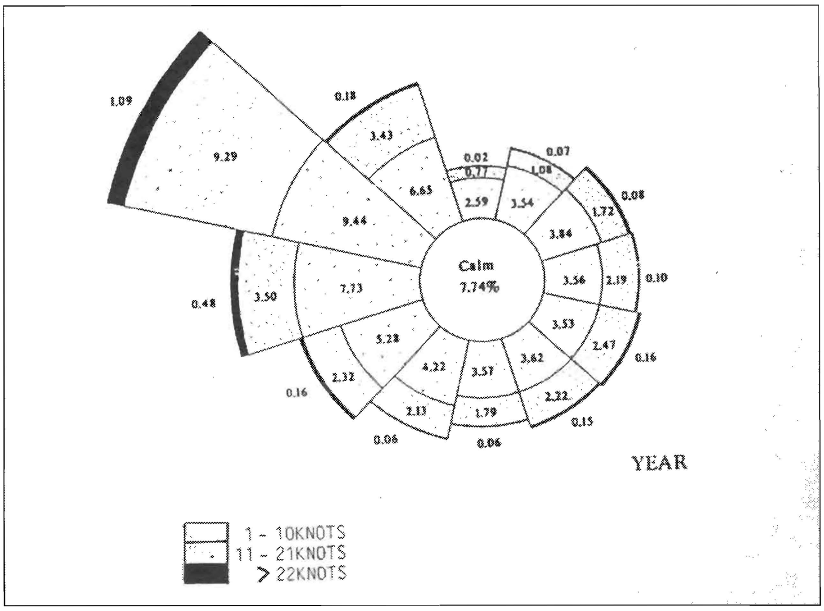

FIGURE II: *Percentage frequencies of wind direction and speed within specified ranges for the period 1958 - 1987; based on data collected by Luqa Meteorological Office, and reproduced, by permission, from reference (8).*

The results in Table 1 also suggest that the northwesterlies apparently succeed in blowing away from Marsa, home town of the polluting source, most of the air pollution related to the power station. Indeed, under these conditions, the ambient SO_2 levels are <25 ug m^{-3}, well within the accepted WHO limits. Low SO_2 levels were also found in Marsa during a southwesterly wind. These are interesting results which seem to suggest that the heavy vehicular traffic passing through the area is not contributing greatly to air pollution by SO_2 in Marsa. This finding is consistent with the fact that the sulphur content of petrol and gas oil is significantly lower than that of heavier oils used as fuels in the power staion. However, the situation with regard to other pollutants emitted by vehicle exhausts, and notably that due to nitrogen oxides and partiuclate matter, including lead compounds, may be very different and certainly needs to be addressed.

The effect of northeasterly winds on the air quality in Marsa is very dramatic. Sulphur dioxide levels ranging from about 200 to 300 ug m^{-3} were measured on four such occasions. These SO_2 concentrations are clearly well above the WHO guideline values although they actually compare favourably with maximum 24-hour averages measured in residential areas in Brussels (411 ug m^{-3}), Rome (413 ug m^{-3}), London (425 ug m^{-3}) and Calcutta (773 ug m^{-3}) (12).

Judging from the present results, the air at Cirkewwa, 19km away from Marsa, is apparently always clean of sulphur dioxide pollution, even when southeasterly winds blow polluted air in this direction. The same appeared to have been true for Marsaxlokk, which is only 6 km away from Marsa and prone to pollution effects carried by northwesterly winds. Obviously, with the commissioning of the new power station at Delimara, the air quality at Marsaxlokk needs to be assessed again. With respect to pollution from this new source, it is to be noted that the most prevalent winds from the NW would disperse the air pollutants out to sea.

A theoretical technique has been developed which attempts to predict dispersal modes of gaseous emissions from stationary sources (13). On the basis of this so-called Gaussian plume model, pollutant is delivered to surrounding areas downwind from the source to form an elliptical pollution footprint at ground level: outside of this footprint, pollutant concentrations remain finite but with much lower magnitude. Within the footprint, the pollutant concentration varies continuously and the lowest value may be different from the highest by a factor of three or four, depending on the position. This means that in any monitoring situation based on measurement from a single collector the values obtained may not represent the highest or even the most prevalent concentrations affecting the locality being monitored. Thus, for example it is possible that the unexpectedly low SO_2 concentration value of 42 ug m^{-3} measured at Marsa on 23/12/90 with wind blowing from the east may have represented the pollution situation just outside the footprint; alternatively, the high wind speed of 21 knots may have shifted the footprint further east towards Qormi. Clearly, such a problem could have been resolved given more data.

The Gaussian plume model has been used to predict concentrations of SO_2 and other air pollutants expected from the full-scale operation of the new power station at Delimara in a study aimed at assessing environmental impact of the station (14). Similar calculations based on this model could also be employed for the Marsa plant, except that, in this case, the model would probably be a rather poor predictor in view of the circumstances obtaining at Marsa. A major problem involves the topography of the terrain surrounding the station. Also, the presence of several juxtaposed chimneys of widely different heights further complicates matters: indeed, under certain conditions, simultaneous emission of smoke from these chimneys may greatly exacerbate the pollution problem at ground level downwind from the station.

These considerations tend to discourage attempts at modelling air pollution originating from the Marsa station and emphasise, instead, the need for a thorough and long-term experimental monitoring programme. Ideally, such a programme would be implemented using automatic measuring devices as currently employed by several environmental agencies. Such a study, which could also include measurements of other priority pollutants such as suspended particulate matter, nitrogen oxides, volatile organic compound and ozone, would permit the delineation of polluted zones and could provide a basis for comparative epidemiological studies concerning specific health problems related to ambient air quality.

CONCLUSIONS

The results presented in this work indicate that the air quality in Marsa, Hamrun and Paola, i.e. areas proximate to the Marsa power station, is being adversely affected by the emission of sulphur dioxide from the stacks of the power station. The data seem to suggest that air pollution in these areas is quite dependent on wind direction and also on wind speed.

Atmospheric sulphur dioxide concentrations at Marsaxlokk and Cirkewwa are shown to have been invariably below the detection limit of 25 ug m^{-3}. For Marsaxlokk, this datum serves as an important reference baseline for possible future work connected with the air pollution status of this village, now already under the influence of the Delimara power station effluents.

In view of the limited size of the data set, this study can only be regarded as preliminary in nature. The results obtained suggest that a thorough air monitoring programme of sufficient duration is called for which would allow the air pollution status of Malta and Gozo towns to be assessed more accuratley and to be followed continually.

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