

# State of the Environment Report for Malta 2002

Ministry for Home Affairs and the Environment

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State of the Environment Report for Malta 2002

9

# Air Quality

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## 9.1 Introduction

Since the writing of the first State of Environment Report in 1998, significant progress has been made in the generation of detailed knowledge regarding urban air quality in Malta. This was mainly due to the fact that, in 1999, the Environment Protection Department (EPD) initiated a National Air Monitoring Programme with the aims of providing an assessment of air quality based on scientific criteria and enabling urban air pollution mapping in the Maltese Islands.

The monitoring programme addressed both the determination of the spatial distribution of air pollutants as well as their temporal variation (i.e. to establish how pollutant levels or concentrations changed with time in any given place). For spatial distribution mapping, diffusion tubes are used that are exposed for a period in selected areas in Malta and Gozo.

Thirty-one sites, including four in Gozo were selected for such monitoring as shown in **Table 9.1** and **Figure 9.1**. Four streets in each locality were chosen and the average value of the pollutant concentrations in each of these was taken as representative of the area. The air pollutants measured by this technique were sulphur dioxide, nitrogen dioxide, ozone and the hydrocarbons benzene, toluene, ethylbenzene and xylenes (BTEX). The diffusion tube samplers are exposed at the sites for a measured period and are then collected and sent to an analytical laboratory for chemical work up. This technique provides average concentrations over the measurement period. For temporal variation measurements, a mobile air pollution station was used equipped with apparatus that allows measurement of the following pollutants: sulphur dioxide, nitrogen monoxide and nitrogen dioxide (collectively referred to as NO<sub>x</sub>), ozone, carbon monoxide and also airborne particulate matter with aerodynamic diameter less than 10 micrometres (PM<sub>10</sub>). The mobile station is placed in a particular street for a period of one week where it collects readings of the five pollutants continuously for the duration of the period. The station is then moved to another street and more data is similarly collected. The mobile station was used to measure pollutants in similar localities to those involved in the diffusion tube measurements.

**Table 9.1: Stations selected for monitoring air quality using diffusion tubes**

Station number	Locality	Station number	Locality
1	Valetta	16	Fgura
2	Floriana	17	Zabbar
3	Pieta'	18	Cospicua
4	Hamrun	19	Luqa
5	Marsa	20	Gudja
6	Qormi	21	Zejtun
7	Mosta	22	Marsaxlokk
8	Birkirkara	23	Birzebbugia
9	Siggiewi	24	Mellieha
10	Sliema	25	Ghajn Tuffieha
11	San Gwann	26	Rabat / Mdina
12	Swieqi	27	Dingli
13	Msida	28	Victoria (Gozo)
14	Gzira	29	Marsalforn
15	Paola	30	Xlendi
		31	Mgarr (Gozo)



Figure 9.1 Map showing diffusion tube air monitoring stations

Figure 9.2 is a map of the sites visited by the mobile station: locations are chosen from the north, central and south sectors of Malta and these are shown in different colours, namely, red for northern, green for central and blue for southern sites. Over 188,000 samples were taken between September of 1999 and January of 2001 and the monitoring programme continues to date.



Figure 9.2: Map showing locations where the mobile station collects data on air pollutants

Other measurements on local air quality were also conducted by two Departments of the Faculty of Science of the University of Malta, namely, the Physics Department where continuous measurements of background ozone and carbon monoxide are measured at a remote station in Gozo (Tal-Gordan Lighthouse) and the Chemistry Department where a number of measurement campaigns each lasting

about 6 months were undertaken over the period 1998 to 2001 for BTEX hydrocarbons and methyl tributyl ether (MTBE) in both urban street air as well as inside air.

There was also an investigation of the presence of polyaromatic hydrocarbons in aerosols and street dusts as well as an investigation of the chemical composition of black dustfalls affecting southern regions of Malta. Work at the Physics Department was initially performed in connection with a doctoral thesis and is currently ongoing as departmental research in collaboration with German research partners while work from the Chemistry Department was the subject of final year student projects.

## 9.2 Sulphur Dioxide

Sulphur dioxide (SO<sub>2</sub>) is a colorless gas which has a pungent odour in high concentrations. It is produced in the combustion of sulphur-containing fossil fuels such as coal and oil and it is also a byproduct of ore smelting; it is used in many industrial processes. In Malta, there is no industry which releases into the air any significant amounts of sulphur dioxide and the presence of the gas in local air is ascribable mainly to combustion of fuels, including those used for vehicular transport.

Once released into the atmosphere, the gas is transformed into sulphur trioxide and later sulphuric acid and sulfate particles at a rate of about one percent per hour. Sulphur dioxide impairs human health. Due to its high solubility, the gas acts directly upon the mucous membranes of eyes and the upper respiratory tract. In heavy concentrations or intense inhalation, it can effect the lower respiratory tract. Asthmatics are at considerably higher risk than healthy persons.

Sulphur dioxide affects plants in a complex manner: direct damage to the leaves and needles occurs in the gaseous and aqueous forms. The effects of sulphur dioxide on forests are well known as is that concerning the acidification of water bodies such as lakes and rivers. In Malta, a more important effect is that which acidic sulphur dioxide exerts on materials, buildings and cultural heritage in limestone.

In Malta, the prospected legal limits of SO<sub>2</sub> concentrations in air are those prescribed in Council Directive 1999/30/EC. This guideline has been adopted as national law (Legal Notice 224 of 2001) within the newly enacted Environment Protection Act XX of 2001.

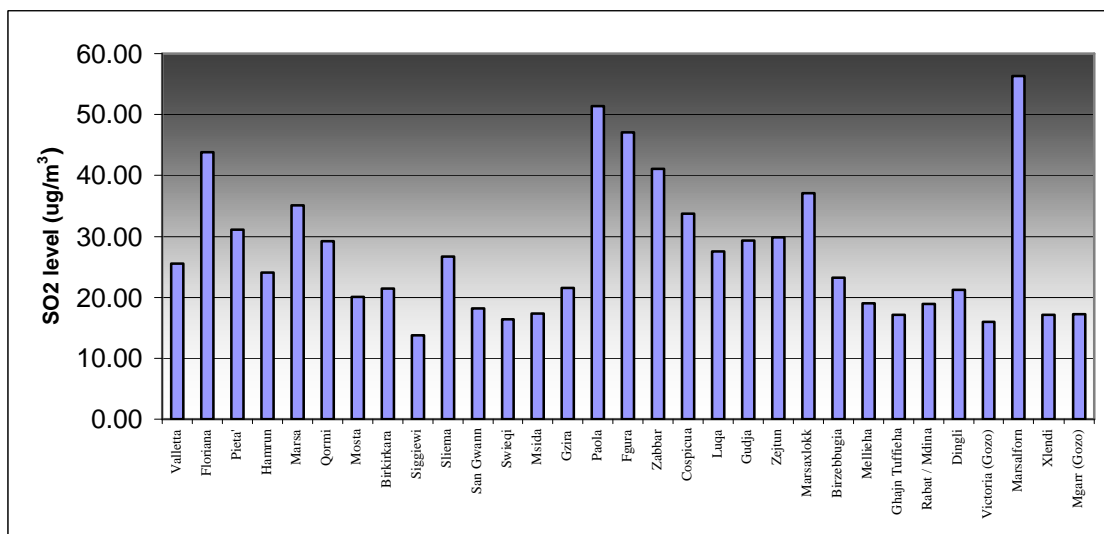
Pollution limit values refer to concentration levels fixed on the basis of scientific knowledge with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole; with regards to environmental damage, such limits take into account the vulnerability of ecosystems which must be maintained if the long-term capacity of the natural balance is to be guaranteed.

The EC Guideline for sulphur dioxide requires that the gas concentration in air must not exceed the value of 125 µg/m<sup>3</sup> as a 24-h average on more than 3 times per year; the hourly average concentrations must not exceed 350 µg/m<sup>3</sup> on more than 24 occasions per year with a 43% margin of tolerance on 1 January 2001, this tolerance reducing by equal annual percentages to reach 0% tolerance by 1 Jan 2005. The directive also requires that if 500 µg/m<sup>3</sup> is measured over three consecutive hours at locations that are representative of an entire zone, an alert threshold is to be issued to citizens that must contain specific information such as the reason for the occurrence, any forecasts of change and/or duration, the precautions to be taken etc.

The WHO Air quality guidelines for health safety recommend an *annual* average of 50 µg/m<sup>3</sup>.

The sulphur dioxide data collected on the basis of diffusion tube measurements yields 576 hour (24 day) averages. This data, converted to yearly averages for the period March 2000 – March 2001, is shown in **Figure 9.3**. The values can be compared with the WHO annual average guideline (50 µg/m<sup>3</sup>).





**Figure 9.3 Sulphur dioxide annual averages (mg/m<sup>3</sup>) for the period Mar. 2000 to Mar. 2001.**

On the basis of this data, it is seen that three zones can be identified, namely, those which appear to have a significant exposure to SO<sub>2</sub>, defined here as being an area for which the annual average is greater than 40 µg/m<sup>3</sup>, a zone for regions where the SO<sub>2</sub> concentrations lie between 20 and 40 µg/m<sup>3</sup> (medium exposure, but probably without significant health implications) and the low exposure sites defined by SO<sub>2</sub> average concentrations less than 20 µg/m<sup>3</sup>. Using this zoning classification, the localities would appear as shown in **Table 9.2**.

**Table 9.2 Sulphur dioxide impact zones**

Significant Exposure (> 40 mg/m <sup>3</sup> )	Medium Exposure (20 – 40 mg/m <sup>3</sup> )	Low Exposure (< 20 mg/m <sup>3</sup> )
Floriana	Valletta	Siggiewi
Paola	Pieta'	San Gwann
Fgura	Hamrun	Swieqi
Zabbar	Marsa	Msida
Marsalforn	Qormi	Mellieha
	Mosta	Ghajn Tuffieha
	Birkirkara	Rabat/Mdina
	Sliema	Victoria
	Gzira	Xlendi
	Cospicua	Mgarr (Gozo)
	Luqa	
	Gudja	
	Zejtun	
	Marsaxlokk	
	Birzebbugia	
	Dingli	

Since sulphur dioxide is derived mainly from the combustion of sulphur-bearing fuels, localities, which are downwind from the power stations and/or under the influence of heavy vehicular traffic, would be expected to be the most severely affected. Paola and Fgura are both downwind from the Marsa Power

Station and are also on important arterial roads. Besides, these localities are sited at an altitude, which places them in an unfavorable position with regards to the smoke plume from the highest chimneys at the Marsa powerhouse. This probably explains the significant impact these localities have from sulphur dioxide pollution.

Marsa ( $35 \mu\text{g}/\text{m}^3$ ) and Marsaxlokk ( $37 \mu\text{g}/\text{m}^3$ ), 'homes' of the respective power stations, are less exposed to damaging sulphur dioxide pollution probably because the plumes issuing from the (tall) chimneys vent at height with respect to these localities and smoke-derived sulphur dioxide is not frequently incident at ground level. Clearly, the type of data in **Figure 9.3** does not reveal the occurrence of incidents of high sulphur dioxide levels as might arise due to unfavourable meteorological conditions. Such occurrences are revealed by measurements in real time of pollutants using the sensors of the mobile station. **Figure 9.4**, an example of such information, shows the temporal variation of sulphur dioxide from three localities, namely Mellieha, Marsa and Zabbar, typifying the north, central and south regions, calculated as 8 day averages in a recent study by Galea (2001).

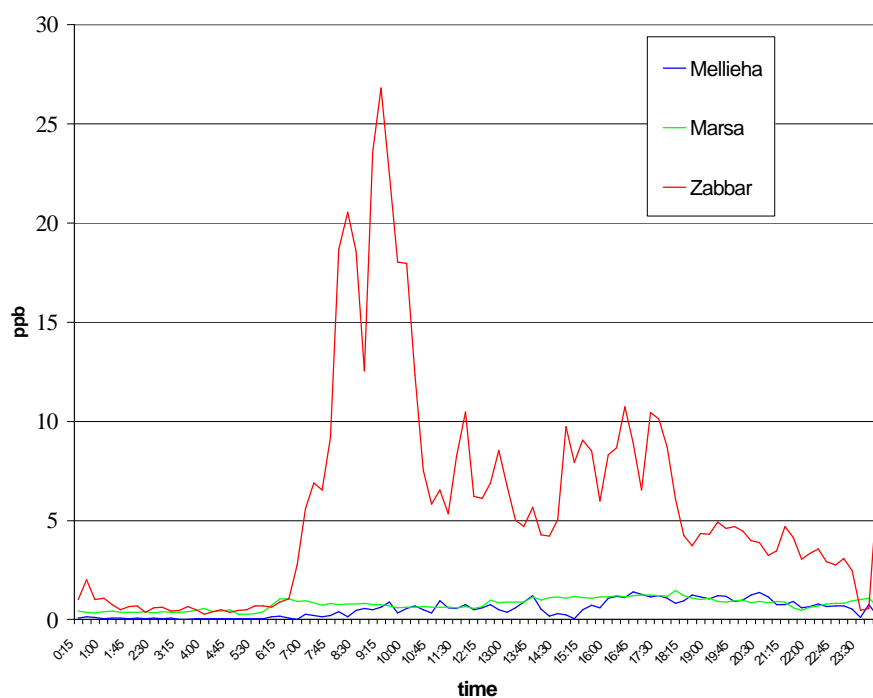
The EPD publishes regular summary reports of air quality which appear on its website<sup>1</sup>. During the period of review of this report (January 2000 to December 2001), the EPD declared three exceedances of the limit value for  $\text{SO}_2$  ( $115 \mu\text{g}/\text{m}^3$  as 24 h average) as occurring in Marsa during 50 days of monitoring between 2 May to 20 Aug 2000. During the same period, one exceedance of the 'alert threshold' ( $558 \mu\text{g}/\text{m}^3$  hourly average over 3 consecutive hours) was recorded again in Marsa; during this period, the peak concentration measured was  $1069 \mu\text{g}/\text{m}^3$ . There were no exceedances of  $\text{SO}_2$  observed at Marsa during a later monitoring period held between 15 Oct and 9 Nov 2001. No exceedances for  $\text{SO}_2$  were reported for the 'significant exposure' zones Floriana, Paola, Fgura and Zabbar when these were monitored for total periods ranging from 3 (Paola) to 11 days (Zabbar): clearly, the data is still insufficient and further monitoring is required to assess the situation properly. On the other hand, in view of the exceedances found at Marsa, it would appear appropriate to install a permanent real-time sensor for sulphur dioxide in this locality and to broadcast alerts when necessary using radio and television, giving advice to affected citizens on how to take evasive measures.

The elevated sulphur dioxide impact at Marsalforn is, in our view, rather anomalous: it cannot be related to power house emissions: not only is the site too far away from the power stations but also the other Gozo sites that were measured (Xlendi, Victoria and Mgarr) had practically identical average sulphur dioxide levels ( $16 - 17 \mu\text{g}/\text{m}^3$ ) which are about a third of the Marsalforn value and typical of low- $\text{SO}_2$  Malta sites, e.g. Mellieha ( $19 \mu\text{g}/\text{m}^3$ ), Ghajn Tuffieha ( $17 \mu\text{g}/\text{m}^3$ ) and Siggiewi ( $13 \mu\text{g}/\text{m}^3$ ). It is also unlikely that the anomalous sulphur dioxide value is caused by motor traffic impact. This is because the hydrocarbon levels at Marsalforn are actually below those present in the other Gozo sites which levels, in turn, reflect the density of motor traffic that visits the localities. The impact from sulphur dioxide at Marsalforn requires further investigation.

It is possible to calculate  $\text{SO}_2$  emissions from the quantities of fuels used and their respective sulphur contents. **Table 9.3** gives values of  $\text{SO}_2$  emissions for the years 1998 – 2001 based on fuel consumption data published by Enemalta Corporation<sup>2</sup>.

<sup>1</sup> <http://www.environment.gov.mt/publications/airq/>

<sup>2</sup> Based on respective Annual Reports



**Figure 9.4** Variation in mean sulphur dioxide concentration (ppb) with time in Marsa, Zabbar and Meliieha (N.B. For conversion into  $\text{mg}/\text{m}^3$ , values should be multiplied by 2.62)

**Table 9.3** Sulphur dioxide emissions from fuel combustion

Year	1998/9	1999/2000	2000/1
Sulphur dioxide (Tonnes)	26377	24729	24302

The reduction in sulphur dioxide emissions in 1999/2000 was mainly due to decreased consumption of sulphur-rich heavy fuel oil (2.45 %S); during 2000/1, heavy fuel oil consumption increased somewhat but a net further reduction in sulphur emissions was due to (1) introduction of low sulphur (0.05%) diesel fuel that replaced higher sulphur gas oil (0.3% S) for transportation and (2) a reduction of about 36% in overall gas oil use, presumably from lower industrial need.

Neither of the two power stations are equipped with technologies (e.g. flue gas desulphurization equipment) that can mitigate sulphur dioxide emissions. These emissions can only be reduced locally through use of more expensive low sulphur fuels and/or increased efficiency in energy production and use (e.g. combined cycle technology). It is likely that, in future, Malta would be faced with the need to reduce considerably emissions of  $\text{SO}_2$  from its stationary sources (e.g. the power houses) in order to comply with its international obligations.

### 9.3 Nitrogen oxides

Nitrogen oxides ( $\text{NO}_x$ ) refer mainly to nitrogen monoxide  $\text{NO}$  and nitrogen dioxide,  $\text{NO}_2$  although other oxides of nitrogen, e.g. dinitrogen monoxide  $\text{N}_2\text{O}$ , are also found in air. The gaseous oxides are or can convert into acidic gases which damage human health and vegetation, as well as buildings and

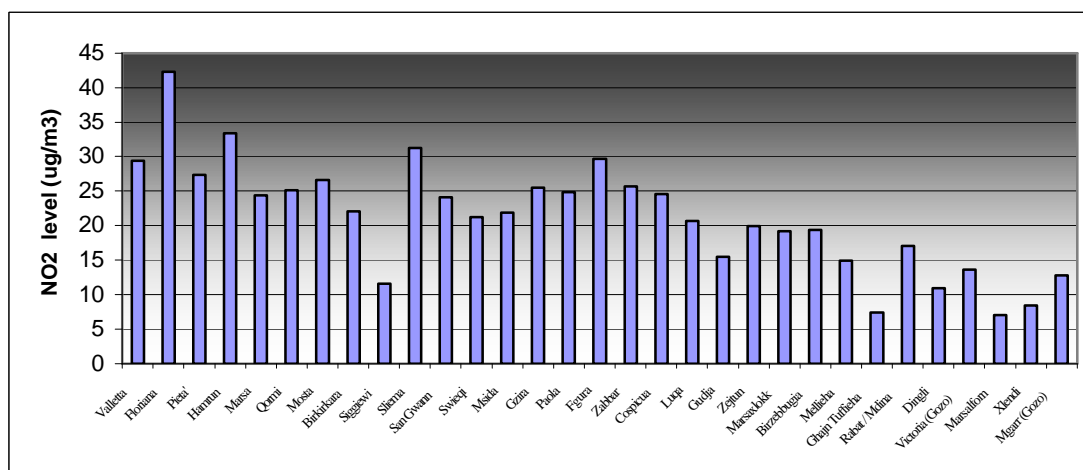
monuments. Nitrogen oxides are essential contributors to the excessive formation of ozone and other health-endangering oxidants during the summer heat periods.

Nitrogen oxides and particularly **nitrogen dioxide, NO<sub>2</sub>**, affect persons and animals. Nitrogen dioxide causes irritation to the mucous membranes in the respiratory tract and can increase the risk of infection. Various epidemiological investigations have shown a connection between deterioration of the lung function, respiratory tract symptoms and increased nitrogen dioxide concentration.

Nitrogen oxides are predominantly emitted from combustion sources including vehicle exhausts and electrical energy production and in certain types of industry. Nitrogen oxides form from the chemical combination of nitrogen and oxygen of the combustion air and to a lesser extent also from the oxidation of nitrogen-containing compounds in the fuel. The formation of nitrogen oxides greatly increases with the combustion temperature.

Nitrogen monoxide comprises more than 90 % of nitrogen oxide emissions. The reaction of NO with ozone in the atmosphere forms nitrogen dioxide NO<sub>2</sub> which is much more damaging to human health than NO. Besides direct reactions with ozone, interaction with hydrocarbon molecules also contributes to the transformation of nitrogen monoxide into nitrogen dioxide. Through further oxidation and combination with hydrocarbon molecules acidic aerosols develop from nitrogen dioxide, which deposit on surfaces and/or precipitate from the atmosphere as acid rain.

The EU guideline value for human health expressed as an annual mean NO<sub>2</sub> concentration is 40 µg/m<sup>3</sup>. **Figure 9.5** presents data obtained by diffusion tube measurements for nitrogen dioxide. On the basis of this data, it is seen that air pollution with respect to nitrogen dioxide actually exceeds the EU guideline in only one locality, namely Floriana; however for Hamrun, Fgura and Sliema the annual average concentrations are within 75% of this guideline value. If we define zones of “high”, “medium” and “low” exposure to nitrogen dioxide based on annual mean NO<sub>2</sub> concentrations of respectively >30, 16-30 and <16 µg/m<sup>3</sup>, the localities studied would classify as shown in **Table 9.4**.



**Figure 9.5 Nitrogen dioxide annual concentrations (in mg/m<sup>3</sup>) for 2000-1**

A comparison of **Table 9.4** with **Table 9.2** shows that the majority of localities (65%) which suffer an impact from NO<sub>2</sub> also experience significant air pollution from sulphur dioxide; the localities which plot in different ‘impact zones’ for these two pollutants are shown with an asterisk in **Table 9.4**. Thus, while Sliema is at medium risk from SO<sub>2</sub>, presumably in view of the distance of this town from the main point source emitter (at Marsa), traffic-generated nitrogen dioxide does not spare this area. A similar “promotion” in terms of pollution impact is evident for Msida, San Gwann, Swieqi and Rabat/Mdina: in all cases, these localities plot in the “medium exposure” zone for nitrogen dioxide but

are in the “low exposure” zone for SO<sub>2</sub>. Conversely, Paola, Fgura, Zabbar<sup>3</sup> which plot in the “high exposure” area with respect to sulphur dioxide are located in the “medium exposure” zone in regards to nitrogen dioxide: clearly these areas, traversed by major traffic corridors in the southern part of the island, experience a significant impact from NO<sub>2</sub> pollution in addition to that from the power station.

In view of the serious concern about the toxic effects of this gas on the health of the population, in addition to the annual mean value, the European Community has also determined a limit value for nitrogen dioxide of 200 µg/m<sup>3</sup> expressed as an hourly average not to be exceeded more than 18 times per year<sup>4</sup> and an alert threshold of 400 µg/m<sup>3</sup> measured over 3 consecutive hours (CD 1999/30/EC). Measurements using the mobile station (Galea, 2001), show that although air concentrations can reach very high maxima for short periods (e.g. a value of 405 µg m<sup>-3</sup> was measured in Qormi at 13:45 on Nov 2000), nitrogen dioxide pollution was contained below the alert threshold values. Indeed, the EPD website report does not record any exceedances of nitrogen dioxide during the period of review.

**Table 9.4. Nitrogen dioxide impact zones**

High Risk of Exposure (> 30 mg/m <sup>3</sup> )	Medium Risk of Exposure (16 – 30 mg/m <sup>3</sup> )	Low Risk of Exposure (< 16 mg/m <sup>3</sup> )
Floriana	Valletta	Siggiewi
Hamrun	Pieta'	Dingli(*)
Sliema (*)	San Gwann (*)	Gudja (*)
	Marsa	Ghajn Tuffieha
	Qormi	Mellieha
	Mosta	Marsalforn (*)
	Birkirkara	Victoria
	Swieqi (*)	Mgarr (Gozo)
	Gzira	Xlendi
	Msida(*)	
	Cospicua	
	Luqa	
	Fgura (*)	
	Zejtun	
	Zabbar (*)	
	Marsaxlokk	
	Birzebbugia	
	Paola (*)	
	Rabat/Mdina (*)	

(\*) For a discussion of values with an asterisk, see text.

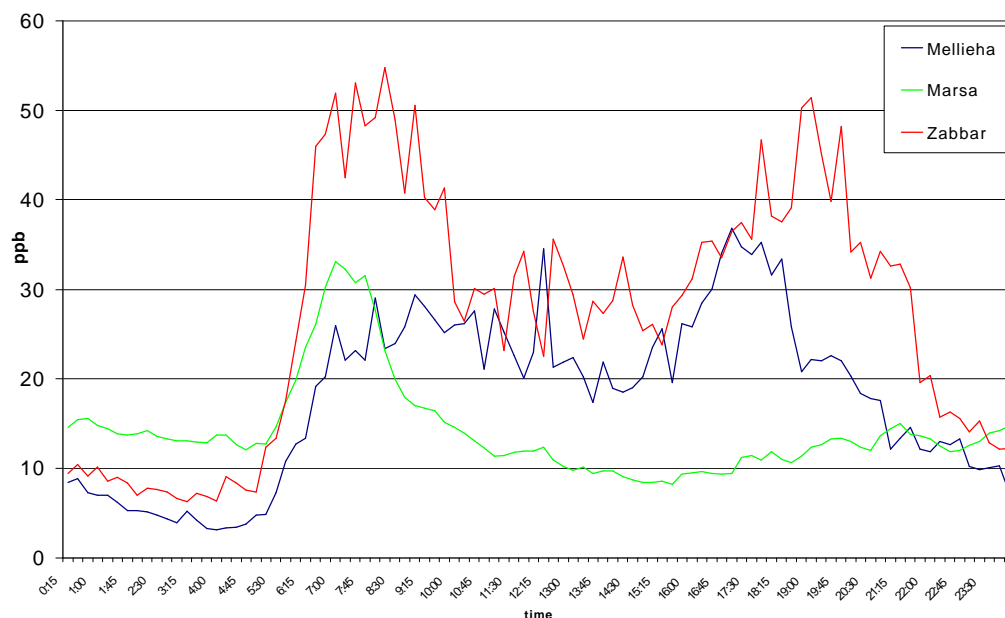
**Figure 9.6** (Galea, 2001) shows how the average nitrogen dioxide air concentrations vary during 24 hours in Mellieha, Marsa and Zabbar: this data was generated from measurements conducted during an observation period of two weeks for each locality as follows: Mellieha (G. Borg Olivier St), monitored during December 1999 and February 2000; Marsa (Azzopardi St), monitored during May 2000 and August 2000 and Zabbar (Triq ic-Cawqli), monitored during November 1999 and March 2000.

Inspection of **Figure 9.6** shows that even for Zabbar, which registered the highest concentrations of the gas (for the chosen monitoring periods), neither the WHO 24 h NO<sub>2</sub> average (80 ppb = 150µg/m<sup>3</sup>) nor the hourly average (200 ppb = 400 µg/m<sup>3</sup>) were exceeded (at least during the two weeks of continuous observation for each site). Moreover, at all three sites, the data clearly indicates significant temporal variation in NO<sub>2</sub> concentration, as would be expected for this particular air pollutant. Thus, in the street air where these measurements were made, concentrations of the gas are medium to low (< 30

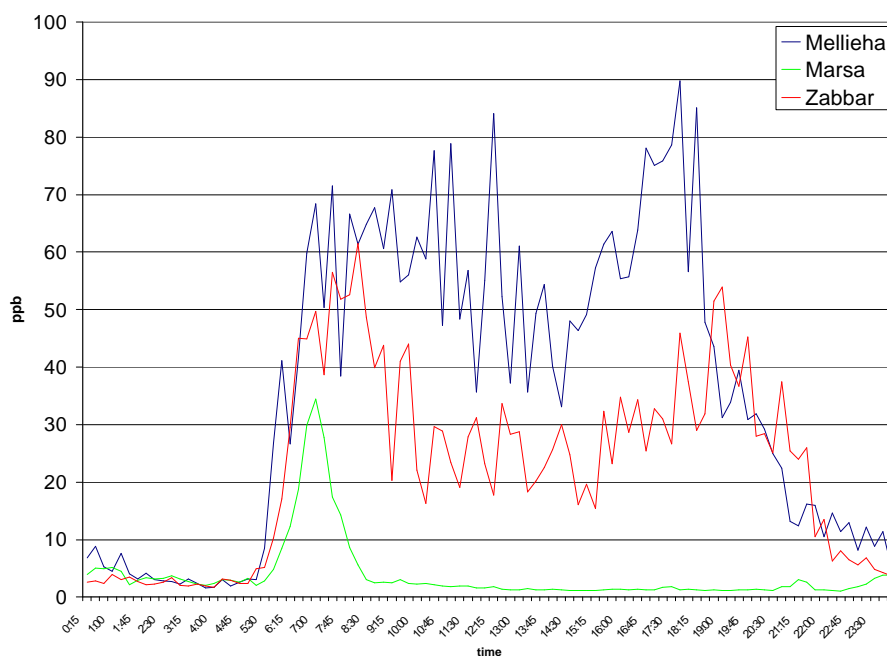
<sup>3</sup> Marsalforn is also in this category except that for this sea side resort town, annual nitrogen dioxide is in the low impact zone (at 7 mg/m<sup>3</sup>). The value of Marsalforn annual sulphur dioxide air concentration is anomalous; see earlier discussion in text.

<sup>4</sup> With a margin of tolerance of 50% on entry into force (1<sup>st</sup> Jan 2001) reducing to 0% by 1<sup>st</sup> Jan 2010.

to  $10 \mu\text{g}/\text{m}^3$ ) during the night time (from about 9.00 pm to 6.00 am) and then increase and reach peak values during the period 7:00 am - 8:00 am. This happens in response to the formation of the gas from its precursor substance, namely nitrogen monoxide, a primary pollutant found in motor traffic exhaust which is formed in air as motor traffic passes through the towns on the way to work. The relation between nitrogen monoxide (NO) and  $\text{NO}_2$  at these three sites can be appreciated by consideration of the data for nitrogen monoxide measured simultaneously with nitrogen dioxide and shown in **Figure 9.7** (from Galea, 2001).



**Figure 9.6** Variation in mean nitrogen dioxide concentration (ppb) with time in Marsa, Zabbar and Mellieha (N.B. For conversion into  $\text{mg}/\text{m}^3$ , values should be multiplied by 1.92)



**Figure 9.7** Variation in mean nitrogen monoxide concentration (ppb) with time in Marsa, Zabbar and Mellieha (N.B. For conversion into  $\text{mg}/\text{m}^3$ , values should be multiplied by 2.94)

It is seen that the surge in NO concentration begins to occur before the upsurge in NO<sub>2</sub> concentrations. At Marsa, the NO concentrations decrease rapidly to the background levels shortly after the morning rush hour. On the contrary, for both roads in Mellieha and Zabbar, NO levels remain steadily high until the late evening. The higher values at Mellieha may reflect the fact that G. Borg Olivier Street is a steep narrow and congested street where vehicles are forced to drive in low gear which thus increases exhaust emissions.

The reason why NO<sub>2</sub> concentrations peak during the period 7:00 am - 8:00 am is because the conversion of NO to NO<sub>2</sub> is catalysed by the presence of sunlight; the conversion is also assisted by the presence of hydrocarbons and other volatile organic compounds (VOCs) found in car exhaust and emitted in quantity during the morning rush hour. Absence of sunlight during the evening rush hour presumably explains why there is a subdued second maximum in NO<sub>2</sub> concentration at Zabbar and Mellieha (but not evident at Marsa) during the time interval 19:00 – 20:00.

In addition to its effect on human health, nitrogen dioxide, and indeed NO<sub>x</sub> gases in general, are also known to cause damage to plant life. These oxides and their by-products cause manifold effects on forest ecosystems and research in this area has led to the establishment of the notion of critical levels and critical loads which have to be respected if the ecosystem is to survive in a sustainable manner. The EU (and WHO) air quality guideline value for protection of vegetative life has been set at 30 µg/m<sup>3</sup> as a yearly average value. It is interesting to note that in Malta, this ecological guideline is exceeded but only in built-up areas whereas the quality of countryside air (e.g. at Ghajn Tuffieha, Xlendi, Rabat/Mdina, Siggiewi) with respect to NO<sub>2</sub> is presumably well below this guideline value. However, the distinction between rural and urban sites in Malta may be rather tenuous in view of the small size of the territory. Further discussion on probable ecological effects from air pollution in Malta is included in Section 9.9.

## 9.4 Ozone

Ozone is a natural trace gas in the atmosphere and is related to oxygen gas in that it consists of molecules containing three atoms of oxygen (O<sub>3</sub>) instead of two as for atmospheric oxygen gas (O<sub>2</sub>). Whereas the air contains about 20 % O<sub>2</sub>, ozone occurs in very much smaller concentrations. In comparison to atmospheric oxygen, the ozone content is subject to very large temporal and spatial fluctuations caused by the generation and decomposition of ozone.

Ozone formation depends on the splitting of one oxygen atom from either atmospheric oxygen or other oxygen-containing molecules resulting from the action of electrical discharges (e.g. lightning) or high energy (solar) radiation (UV light) as is available in the upper layer of the atmosphere, i.e., the stratosphere at 12-40 km altitude. A considerable part of the hazardous UV radiation is consumed there in the formation of ozone from dioxygen, O<sub>2</sub>. The ozone itself absorbs a further part. Thus, the presence of an 'ozone layer' in the stratosphere is crucial for the existence of life on our planet. The ozone layer is endangered through anthropogenic emission of materials into the atmosphere, which serve to shift the sensitive chemical balance between ozone formation and decomposition in favour of ozone destruction. This is the reason why countries, including Malta, strive to limit the production and use of the so-called ozone depleting substances (ODS's) and this is discussed further below (Section 9.11).

In the lower part of the atmosphere, known as the troposphere, ozone formation from dioxygen is no longer possible because of the lack of high-energy radiation. The less energetic part of UV radiation, which manages to penetrate the ozone layer and reach the earth's surface is still capable of forming ozone by reaction with nitrogen oxides and hydrocarbons present in air as pollutants. The ozone formed in the lower troposphere decomposes upon contact with materials on the ground. In the atmosphere, ozone causes other trace substances, such as sulphur dioxide, carbon monoxide and nitrogen oxides to oxidize to form reaction products such as aerosols, which lead to the haze in the atmosphere and are washed out with the rain. Ozone in the troposphere also plays a further role as a greenhouse gas where it absorbs, just like carbon dioxide, a part of the thermal radiation emitted from the ground and contributes to the warming of the atmosphere.

The great chemical reactivity of ozone can cause adverse effects on surfaces which come in contact with the gas at elevated concentrations. Ozone exercises a corroding effect on the surface of metal parts. It attacks the leaf of plants and needle surfaces. Ozone can damage the corresponding protective layer and/or the leaf tissue itself. Increased parasite attack and a decrease in plant growth can be the consequence. Various plant kinds react very differently to ozone. Increased ozone concentrations especially during summer are considered to have the capacity of causing negative health effects on persons and animals, especially on the respiratory tract because ozone is not water-soluble and can therefore penetrate the lung and cause damage to lung tissue. High ozone concentrations can also cause environmental damage to trees and forests.

Motor vehicle traffic is the main cause of the primary emissions responsible for ozone formation. Nitrogen oxides are present in vehicle exhaust being produced during fuel combustion in the motor; hydrocarbons are also emitted as a result of incomplete or failed combustion of the fuel. Nitrogen oxides are also emitted from power plants, industrial furnaces and domestic heaters etc. Another important source of hydrocarbon emission is that from the evaporation of solvents from paints and varnishes, as well as different processes in certain industries (e.g. where solvents are used to clean electronic components). Natural hydrocarbon emissions occur from vegetation and the oceans. The quantities of volatile hydrocarbons emitted from natural sources exceed, on a worldwide scale, the anthropogenic emissions although on the local scale, the effects from industrial and vehicular sources can be very significant.

In EU countries<sup>5</sup>, the ozone threshold value for human health protection is  $110 \mu\text{g}/\text{m}^3$  expressed as an 8 h average: this limit indicates the concentration, which should not be exceeded in case of long continuing loads. The same applies for the threshold values for the protection of vegetation in excess of which damage to plants can occur. The threshold value for notifying the public,  $180 \mu\text{g}/\text{m}^3$  ozone as the median value over an hour, is to be seen as the threshold at which persons who are especially sensitive to ozone can be effected. The responsible authorities in these countries are then to recommend that particularly unusual and strenuous exertion outdoors in the afternoon be avoided. At  $360 \mu\text{g}/\text{m}^3$ , an identical warning is directed to the entire population. At these and higher concentrations irreversible damage of the lung can occur. Irritation of the pharynx and tears in the eyes can be observed under these circumstances although these effects are not due to ozone itself, but to other substances (e.g. peroxyacetyl nitrate, PAN) which form from the effect of sunlight on a cocktail of pollution gases including ozone, NO<sub>x</sub> and VOCs.

**Figure 9.8** shows the annual average concentrations obtained for ozone from diffusion tube experiments during the period 2000 –2001. Guideline concentrations for ozone expressed as average values from long-term monitoring periods are not available either from EC or WHO sources; the longest averaging period is that of 24 hours pertaining to EC 92/72 (and the WHO 1988 Critical Level guideline) threshold value of  $65 \mu\text{g}/\text{m}^3$  for the protection of vegetation. Thus, the locally generated diffusion tube ozone data are not directly comparable to any of the available international standards (based on 1h or 8h averages). The fact that the long-term average values are so high, ranging between 70 and  $120 \mu\text{g}/\text{m}^3$ , may suggest that ground level ozone in most areas in Malta are probably not low and could be of some concern. However, the EPD has routinely also measured ozone using the mobile station and it has not recorded any exceedances of the  $180 \mu\text{g}/\text{m}^3$  (90 ppb) hourly average standard.

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<sup>5</sup> CD 1992/72/EC



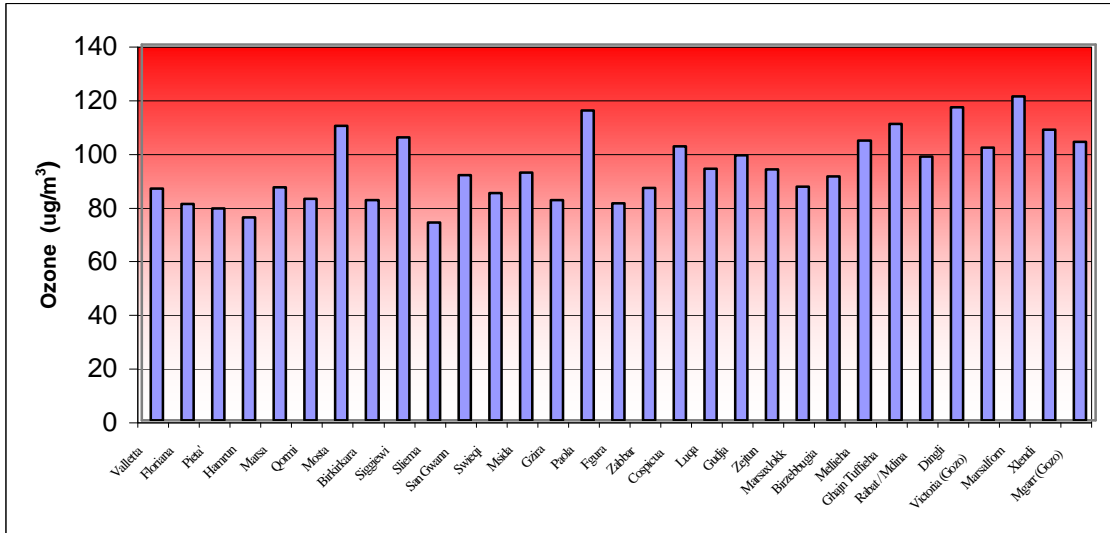


Figure 9.8 Ozone annual average concentrations, in mg/m<sup>3</sup>, for 2000-1

Figure 9.9 gives a picture of the temporal variation of ozone (weekly averages) at the three sites Mellieha, Marsa and Zabbar recalculated from mobile station measurements (Galea, 2001).

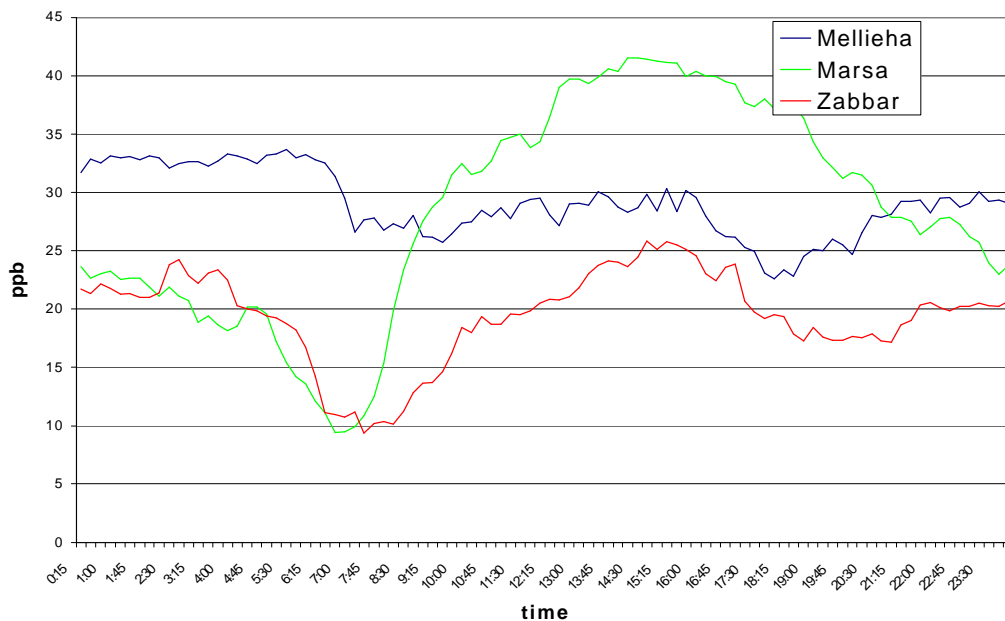


Figure 9.9 Variation in mean ozone concentration (ppb) with time in Marsa, Zabbar and Mellieha (N.B. For conversion into mg/m<sup>3</sup>, values should be multiplied by 2)

Especially at Marsa and Zabbar, the plots in Fig. 4.2 show marked minima in ozone levels occurring at about 7:00 am: this occurs because the influx of considerable quantities of primary air pollutants from passing traffic (NO, CO) is reactive to and consumes the ambient ozone. Later on in the day, photochemical action on accumulating NO<sub>2</sub> and VOCs-rich air pollution results in a significant rise in ozone level (and a decrease in NO<sub>2</sub>); ozone levels wane again as evening approaches to reach minima during the nighttime, the cycle repeating itself on the next day.

At this point, one has to note that although ozone can form as a result of pollution originating from local sources (mainly motor traffic exhaust), there is evidence to show that a significant fraction of ozone in near-ground Malta air may be imported as transboundary atmospheric pollution. The air monitoring station at Gordan Lighthouse in Gozo run by the Atmospheric Research Unit of the Department of Physics (University of Malta) has been measuring on a continuous basis background ozone concentrations since 1997. Work by this unit<sup>6</sup> has established (Nolle, 2001) that background ozone reaching the island from overseas sources is among the highest ever observed in coastal areas, with maximum monthly average values of about 110  $\mu\text{g}/\text{m}^3$  and minimum values of 88  $\mu\text{g}/\text{m}^3$ . The minimum values are about double those typically observed on the continent. It was also found that air masses that approach the Gordan station from the north show generally higher ozone concentrations and this polluted air has been ascribed to photo-smog originating possibly from oil-refinery-polluted air in southern Sicily. Such conclusions are indeed highly interesting and might suggest that it will probably be difficult to achieve effective local control of ozone concentrations if it is confirmed that a substantial component of the pollutant is of a transboundary nature.

## 9.5 Carbon monoxide

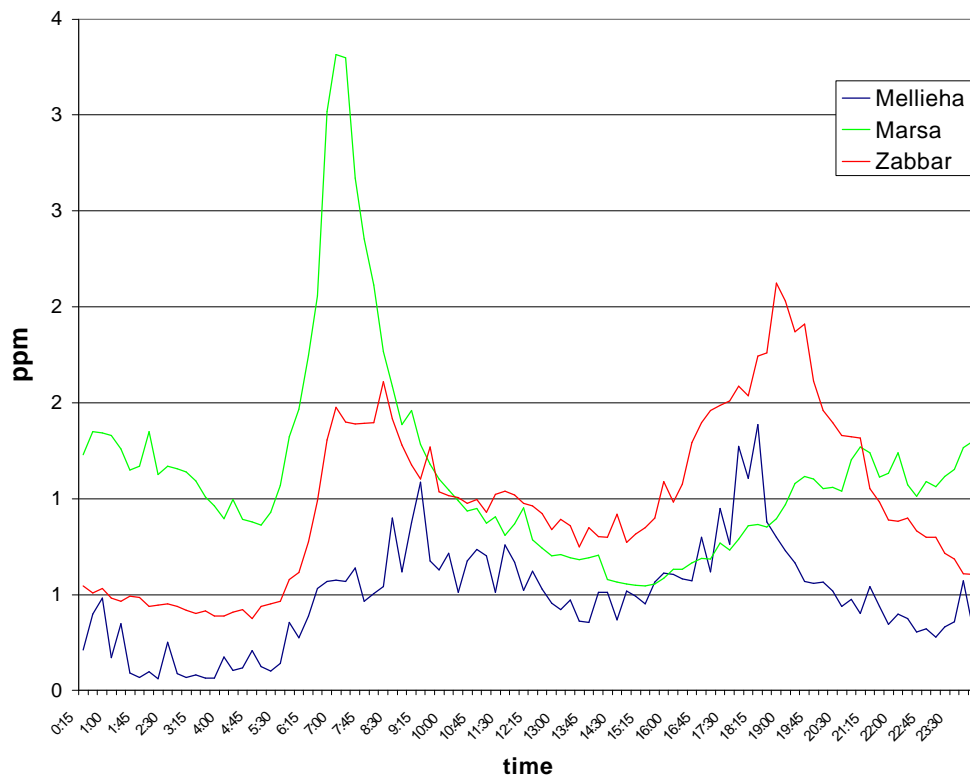
Carbon monoxide, a colourless, odourless and tasteless gas, is a trace constituent of the troposphere, produced by both natural processes and human activities. Plants can both metabolize and produce carbon monoxide and therefore trace levels are considered as normal constituents of the natural environment. Recent data on global trends in tropospheric carbon monoxide indicate a decrease over the last decade: global background levels fall in the range of 60–140  $\mu\text{g}/\text{m}^3$  (50–120 ppb) and are higher in the northern hemisphere than in the southern hemisphere. Average background concentrations also fluctuate seasonally being higher in the winter months and lower in summer. About 60% of carbon monoxide found in the non-urban troposphere is attributed to human activities, both directly from combustion processes and indirectly through the oxidation of hydrocarbons and methane that, in turn, arise from agricultural activities, landfills and other similar sources. Atmospheric reactions involving carbon monoxide can produce ozone in the troposphere.

Although ambient concentrations of carbon monoxide in the vicinity of urban and industrial areas can substantially exceed global background levels, there are no reports of currently measured levels of carbon monoxide producing any adverse effects on plants or microorganisms (WHO, 1999a). Ambient concentrations of carbon monoxide, however, can be detrimental to human health and welfare, depending on the levels that occur in areas where humans live and work and on the susceptibility of exposed individuals to potentially adverse effects. The WHO report (*ibid.*) states that trends in air quality data from fixed-site monitoring stations show a general decline in carbon monoxide concentrations, which reflects the efficacy of emission control systems on newer vehicles.

Carbon monoxide has a reasonably long lifetime in the atmosphere, eventually oxidizing to carbon dioxide; hence air masses which are polluted with CO can travel long distances to create transboundary pollution, as discussed earlier for ozone. Indeed, in Malta, during 1997 to 2000, the Atmospheric Pollution Station in Gozo has measured monthly average values of CO ranging from 157  $\mu\text{g}/\text{m}^3$  in July to 261  $\mu\text{g}/\text{m}^3$  in February (Nolle, 2001), which are higher by about 30% than those observed typically from maritime stations. Highest CO concentrations (up to 467  $\mu\text{g}/\text{m}^3$ ) were measured when air from the Maltese mainland moved in Gozo's direction (*ibid.*).

Normally, in urban areas, concentrations of carbon monoxide are highest near street intersections, in congested traffic and in poorly ventilated areas such as road tunnels or parking garages. **Figure 9.10** shows the average carbon monoxide concentrations measured at Mellieha, Marsa and Zabbar over a 2-week period (Galea, 2001).

<sup>6</sup> Under the direction of Dr. R. Ellul, Department of Physics.



**Figure 9.10** Variation in mean Carbon monoxide concentration (ppm) with time in Marsa, Zabbar and Mellieha (N.B. For conversion into  $\text{mg}/\text{m}^3$ , values should be multiplied by 1.17)

The significant increase of CO concentration during the period 7:00 to 8:00 am and again during 4:30 to 5:30 pm are obvious effects of the morning and the evening rush hours respectively. One notes how the carbon monoxide maximum originating from the morning traffic high corresponds to a similar peak observed for nitrogen dioxide (**Figure 9.5**); it is interesting to note how the  $\text{NO}_2$  peak materializes about an hour after the CO peak since it requires time and sunlight to achieve the conversion of NO (emitted simultaneously with CO in tail pipe exhaust) into  $\text{NO}_2$ .

According to WHO, if a healthy subject is exposed to an average  $10 \text{ mg}/\text{m}^3$  (9 ppm) of CO for 8 h, the carboxyhaemoglobin blood level of the subject does not exceed 2.5%, even if the subject engages in light or moderate exercise: this is the basis of the guideline value for this pollutant which is employed by the EPD for reporting exceedances of CO.

There were no reported exceedances of carbon monoxide during the period of review covered by this report. Even though the highest concentration measured by the mobile station was 16.6 ppm (during August 2000, at Swieqi), this peak value did not last for a sufficient period to constitute an exceedance of the limit value.

#### *Carbon monoxide in indoor air*

Indoor air concentrations of carbon monoxide are a function of outdoor concentrations, indoor sources, infiltration, ventilation and air mixing between and within rooms. In residences without sources, average carbon monoxide concentrations are approximately equal to average outdoor levels. The highest indoor carbon monoxide concentrations are associated with combustion sources and are typically found in enclosed parking garages, service stations and restaurants. The lowest indoor carbon monoxide concentrations are found in homes, churches and health care facilities. Exposure studies show that passive cigarette smoke is associated with increasing a non-smoker's exposure by an average of about  $1.7 \text{ mg}/\text{m}^3$  (1.5 ppm) and that use of a gas cooking range at home is associated with an

increase of about  $2.9 \text{ mg/m}^3$  (2.5 ppm). Other sources that may contribute to carbon monoxide in the home include combustion space and water heaters and wood-burning stoves.

No data is currently available for carbon monoxide in indoor air of public and institutional buildings in Malta where smoking is not prohibited (e.g. the Law Courts); in such places, it is reasonably expected that the gas could assume concentrations that might exert adverse health effects. Besides being a source of carbon monoxide for smokers as well as non-smokers, tobacco smoke is also a source of other chemicals with which environmental carbon monoxide could interact. Available data strongly suggest that acute and chronic carbon monoxide exposure attributed to tobacco smoke can affect the cardiopulmonary system, but the potential interaction of carbon monoxide with other products of tobacco smoke confounds the results (WHO, 1999a).

## 9.6 Benzene and other hydrocarbons

It is increasingly apparent that in Malta motor vehicle traffic is the main source of air pollution that is capable of affecting most of the national territory. According to a recent report (Planning Authority, 2001), during the 1990's there was a net average increase of 7000 new private cars per annum (from a total of 10 000 new vehicles per annum) that resulted in a level of 1.36 cars per household in 1998. Even by international standards, car ownership in Malta (i.e. number of vehicles per 1000 persons) is high, being, for example significantly higher than that in the UK, Greece or Ireland. In 2000 the total number of vehicles using the roads was approximately a quarter of a million.

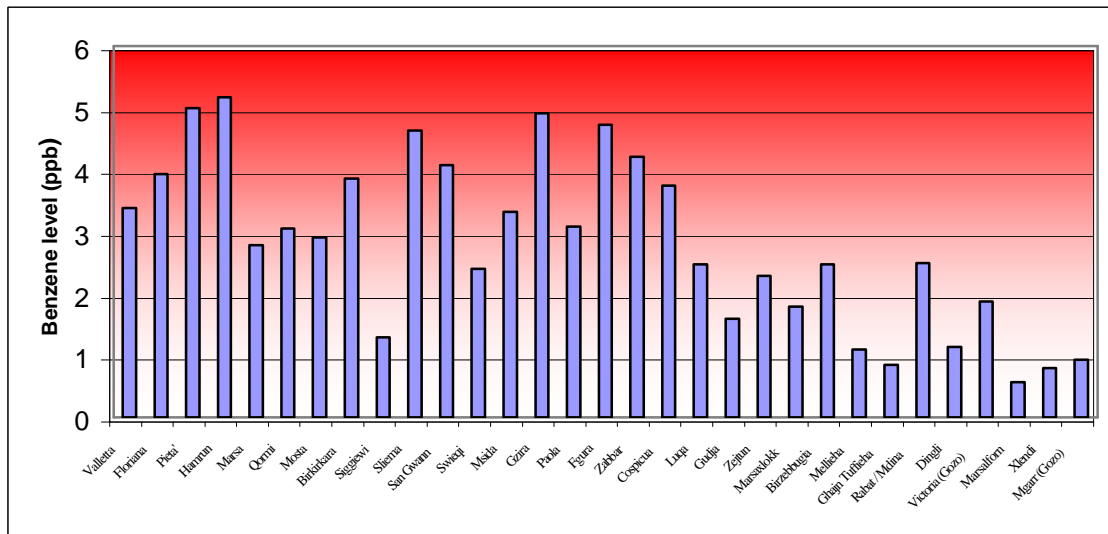
The most significant pollutants emitted by motor vehicles in terms of quantity are carbon monoxide, hydrocarbons, nitrogen oxide and carbon dioxide. Other air pollutants are also emitted but in relatively smaller quantities; these are airborne fine particulate matter from diesel fuel combustion, particles from tyre abrasion and VOCs, of which benzene is of particular concern. These air pollutants are important because of their significant and negative effects on human health. As already indicated earlier in this report, hydrocarbons, along with nitrogen oxides, play a significant role as ozone precursors. Hydrocarbons are released through the exhaust when fuel is unburned or incompletely burned. Considerable amounts also reach the atmosphere due to fuel evaporation. Hydrocarbons evaporate from the fuel tank and other fuel feed elements, such as the carburettor, etc. Petrol-derived hydrocarbons also vaporize when fuel station storage depots and motor vehicle tanks are filled during replenishment as well as during ship to shore transfer of fuel.

Some of the hydrocarbons, e.g. benzene, require particular attention because of their toxic effects. Benzene has been proven to cause bone marrow damage, leukemia, and lymphomas in human subjects. Petrol is a source of benzene and for this reason, EC Directive 98/70/EEC limits to 1% by volume the benzene content of petrol. Benzene is also formed by the "cracking" of other aromatic compounds in petrol in motor vehicle engines and exhausts; this, rather than petrol evaporation, is typically the largest and most widespread source of benzene in the ambient atmosphere (Dept. of Environment, UK, 1993).

Since benzene is a carcinogen, there is no really 'safe level' of human exposure for the substance. Different authors come to similar conclusions about estimates of myeloid leukaemia cases increment among populations exposed to benzene vapour. On the basis of these findings, WHO states a risk level of between 4.4 and 7.5 cases per million people exposed continuously to  $1 \text{ } \mu\text{g/m}^3$ . The risk criterion proposed by WHO which considers as "socially acceptable" the risk of 22 to 37 additional cases of leukaemia every million people is equivalent to a concentration of  $5 \text{ } \mu\text{g/m}^3$ : this was thus stated as the limit concentration for urban air (Macbeth Programme, 1999). German federal regulations require that as from July 1998, the yearly (arithmetical) average concentration of benzene in air be limited to  $10 \text{ } \mu\text{g/m}^3$ , down from  $15 \text{ } \mu\text{g/m}^3$  as set in 1995. These levels are equivalent to about 3 and 5 parts per billion (ppb) respectively for the substance while the WHO limit guideline is 1.5 ppb. EC Council Directive 2000/69/EC requires that as from 2005, the target limit value for benzene will be that currently prescribed by WHO (i.e. 1.5 ppb or  $5 \text{ } \mu\text{g/m}^3$ ).

The first indications that benzene levels in Malta air were high resulted from a first study published by Vella and Gaerty (1998) where 1h average concentrations were determined and found to range from non-detectable in rural places to highs of 70 to  $80 \text{ } \mu\text{g/m}^3$  in urban streets. These values were short term

averages and cannot be directly compared to the guideline levels mentioned earlier. However, longer term and comparable data has indeed been compiled by the EPD during their continuous campaign of measurements: values of yearly average benzene concentrations (for 2000-1) in parts per billion (ppb) measured in street air using diffusion tubes is shown in **Figure 9.11**.



**Figure 9.11 Benzene yearly average concentrations for 2000-1**

(N.B. For conversion into  $\mu\text{g}/\text{m}^3$ , values should be multiplied by 3.3)

Inspection of the raw data from which these averages are computed reveals that for nearly all of the Malta sites, the monthly averages reached peak values during the months of October and November 2000 and January 2001: during these periods, the monthly average values were as high as two to five times the annual mean. The highest measured concentration was obtained from Floriana (St Ann Street) in October 2000 where  $69 \mu\text{g}/\text{m}^3$  (21 ppb) of benzene were measured. In Hamrun (St Joseph High Street), during the same period,  $43 \mu\text{g}/\text{m}^3$  (13 ppb) were measured which increased to  $53 \mu\text{g}/\text{m}^3$  (16 ppb) in November 2000. A similar phenomenon was not observed for the Gozo stations.

These figures confirm the preliminary results of the first study and portray a rather alarming picture of air quality with regards to this extremely noxious compound: the findings are certainly cause for concern. Forty five per cent of the sites measured exceed the  $10 \mu\text{g}/\text{m}^3$  (3 ppb) (German) guideline value and at Hamrun, the benzene average concentration even exceeds the  $15 \mu\text{g}/\text{m}^3$  (5 ppb) (earlier) guideline. *Seventy eight percent of sites exceed the WHO limit value of  $5 \mu\text{g}/\text{m}^3$  (1.5 ppb)*. In other countries, the air in those regions regarded as constituting “urban background”, i.e. areas that are distant from major traffic corridors, are known to have benzene levels of  $1 \mu\text{g}/\text{m}^3$  (0.3 ppb) or less; on the other hand, air pollution in urban or industrial hot spots is about 5 times that value or even higher. Such hot spots are usually found in streets busy with motor traffic and the pollution is exacerbated by so-called “street canyon” effects, involving stagnation of polluted air by high buildings fronting the traffic corridors. **Table 9.5** compares benzene concentrations measured in urban background areas as well as in urban hot spots. Data is taken from a Position Paper written by the Working Group on Benzene for the European Commission (1998).

**Table 9.5 Benzene in air in urban background areas and hot spots (street canyons) in Malta and other European cities (annual means, mg/m<sup>3</sup>)**

<b>City: urban background</b> <i>Benzene</i> <b>mg/m<sup>3</sup></b>	<b>Dingli</b> 3.7	Munich (16 sites) 1.8 - 3.2	Berlin (3 sites) 2.1 - 2.8	Florence (Boboli) 6.0	Uppsala 2.0
<b>City: hot spot</b> <i>Benzene</i> <b>mg/m<sup>3</sup></b>	<b>Hamrun</b> 17.1	Wiesbaden 11.0	Berlin (27 sites) 3.3 – 9.6	Florence (Rosselli) 32.0	Goteborg 11.0

These (and other) figures suggest that the levels of air pollution in Malta with respect to benzene are amongst the worst in Europe (although still apparently much better than in certain European cities). Thus, hot spot areas in Paris measure typically 20 to 54  $\mu\text{g}/\text{m}^3$  during the morning hours; in Floriana, comparable values (1 h averages) measured in 1997 (Vella and Gaerty, 1998) hovered between 60 to 70  $\mu\text{g}/\text{m}^3$ , in Sliema 40 to 74  $\mu\text{g}/\text{m}^3$  and in San Gwann 80 to 84  $\mu\text{g}/\text{m}^3$ . Also, the lowest annual mean benzene concentrations (during 2000-1) were (in  $\mu\text{g}/\text{m}^3$ ) 1.88 (Marsalforn), 2.64 (Xlendi), 2.80 (Ghajn Tuffieha). In contrast, in Sweden, most of the urban background areas had annual mean concentrations less than 2  $\mu\text{g}/\text{m}^3$  during 1997/8 and the hot spots did not exceed 14  $\mu\text{g}/\text{m}^3$  but were mostly in the range 6 to 9  $\mu\text{g}/\text{m}^3$ . In Malta, the situation is more alarming because a sizeable bulk of the population is being exposed to the hot spot concentrations since residential areas are frequently close or even within busy traffic lanes.

Unpublished studies carried out at the Department of Chemistry (Zammit, 1999; Saliba 2001) have shown that in streets where there is present a service station, the air in the proximity of the station contains a significantly higher concentration of petrol-derived VOCs, including benzene. From two to tenfold increases in benzene have been measured and this is due mainly to evaporative loss of petrol during underground tank refill and dispensing of petrol to vehicles. Locally-imported leaded petrol has a benzene content of 6 to 8% by volume<sup>7</sup> which is much higher than the 1% benzene allowed for use in Europe and this factor may be exacerbating both the service station as well as the general benzene problem.

It is worth noting that imported unleaded petrol has a much lower benzene content and a phase-out of leaded petrol should therefore conduce to lower atmospheric concentrations of benzene assuming the quality of unleaded fuel with regards to this substance is strictly controlled. Moreover, installation of fuel vapour recovery systems, which in Europe have been required by law for several years, would also help mitigate the general VOC problem. There was no legislation in Malta related to evaporative emissions prior to 2001 although Legal Notice 214 of 2001 concerns this very matter. According to this legal notice, service stations with an annual throughput of more than 100 m<sup>3</sup> of petrol per year will have to control VOC emissions released during storage and fuel transfer. This legal notice, however, has not yet been put into effect. Also, ship to shore petrol transfers remain uncontrolled, despite the considerable impact especially to the locality of Birzebbugia.

The findings on the quality of air with respect to benzene suggest that serious consideration should be given for taking other immediate mitigation measures aimed at improving the air quality. The fitting of catalytic converters to cars has been shown to reduce benzene emissions from tail pipe exhausts by up to 90% (8) and EC directive 91/441/EEC requires the installation of three-way catalytic converters to all petrol-engine cars as from 1<sup>st</sup> January 1991. Such vehicles can only be run on unleaded petrol. Catalysts are only effective once they have warmed up and hence any improvement in air quality in a particular area will depend on the impact of "cold start" emissions in that area. Short travel distances as are typical to Malta will tend to exacerbate problems of cold-start emissions and may possibly not allow full benefit to be derived from these devices. However, this is hardly a case for discouraging their use. Indeed, there appear to be strong reasons for taking the following actions: (1) stopping the use of

<sup>7</sup> According to analyses of the fuels in the laboratory of Professor AJ Vella.

leaded petrol as quickly as possible and (2) imposing an immediate prohibition of the importation of petrol-engine vehicles not equipped with catalytic converters. Action (1) will require the simultaneous availability for a period of a leaded petrol substitute to cater for the old fleet which, in Malta, is a substantial fraction of the total vehicle population.

Information on other hydrocarbons in Malta air is available from the EPD monitoring campaigns, for example, on toluene, ethylbenzene and xylenes: these materials are not known to be carcinogenic; on the other hand, unfortunately, there is currently no information on another air pollutant known as 1,3-butadiene, a substance formed from the incomplete combustion of petrol, which is classified<sup>8</sup> as a category 2 carcinogen (i.e. one that should be regarded as if it were carcinogenic to man). This substance should be considered for inclusion in the diffusive sample monitoring campaign.

### ***Benzene in indoor air***

An investigation on the quality of inside air for VOCs was conducted at the Department of Chemistry (Schivagnotis, 2000) where it was found that the concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) tended to be higher indoors than in the corresponding outdoors. The concentrations of indoor benzene and xylenes correlated very well with those outside domestic residences although toluene and ethylbenzene both gave weak correlations.

The influence of smoking in households was not found to affect the air quality inside the home significantly and this is probably due to frequent ventilation to remove stale odours caused by the smoke. In public places, i.e. offices and bars, the air quality was however found to be significantly affected by smoking. In one of the experiments, two bars situated in the same street in St Julians were chosen for investigation: bar A was equipped with extractor fans while bar B had no similar ventilation; also, B had a larger clientele. The average concentration of benzene measured inside the bars during a typical Saturday night – Sunday morning session were as follows: 18.5 µg/m<sup>3</sup> in A; 726 µg/m<sup>3</sup> in B. The concentrations of the other hydrocarbons inside the bars were found to range from about 25 to 95 µg/m<sup>3</sup>. The alarming levels of benzene in environments similar especially to those found in bar B must present significant health risks for both customers and especially staff and should raise concerns on public health and safety connected with this aspect of the leisure industry. Serious consideration should be given to enforcing controls on smoking and/or to provide adequate ventilation to these places of entertainment in order to protect patrons from an insidious and considerable danger.

Another study on the presence of benzene (and other air pollutants) in indoor air was commissioned by the Department of Public Health and concerned the air quality inside Government primary schools in eight different localities. This study covered the period April 2001 to March 2002 and the report has not yet been published. The data made available to the authors appear to support the general conclusion mentioned above, namely, that indoor air quality in schools, as in domestic residences, is greatly affected by that of the surrounding area; also, the highest benzene concentrations found inside school rooms are far below the values quoted for bars and are more similar to outside concentrations in urban areas away from hot spots.

## **9.7 Airborne particulate matter (dusts)**

Particulate matter or dust is a form of air pollution which is perceptible to everyone without needing a special monitoring device. A basic distinction is made between airborne (or floating) particulates and dust deposits. Dust deposits are easily evident on smooth horizontal surfaces while floating particulate matter is visible as a turbidity of the atmosphere. Dust particles are of diverse origin, their size varies widely and they are composed of a wide range of substances.

For airborne dust, the particles are predominantly 10 µm (about 1/7 the width of a human hair) or smaller in size (so called PM<sub>10</sub>). Airborne particulates are divided into primary aerosols, which are emitted directly as dust particles, and secondary aerosols, which are first emitted as gases and later convert to particles in the atmosphere. Dust has a detrimental effect on humans and the environment.

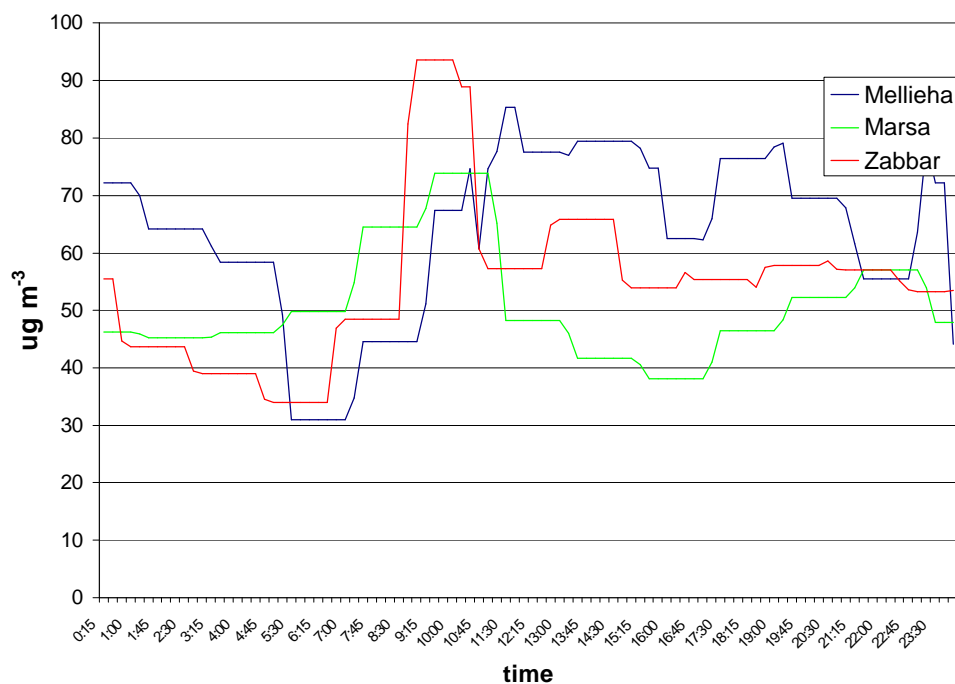
<sup>8</sup> On the basis of EC Dangerous Substance Directive 67/548/EEC

Air pollution in the form of floating dust irritates the human bronchial system. The type and degree of damage caused is dependent on the quantity and composition of the dust. The finer fraction of airborne dust, known as  $PM_{2.5}$ , is believed to be even more damaging than larger particles. Long-term strain on the self-purification system of the respiratory tract can lead to cell or tissue damage and this is particularly the case when floating dust combines with other air pollutants, e.g. sulphur dioxide.

According to a recent WHO review (WHO, 1999b) the composition of ambient air  $PM_{10}$  varies substantially between various locations. Secondary inorganic particles formed from gaseous pollutants (and containing ammonium, sulfate and nitrate ions) can contribute between 25 to 50% of the total mass. Elemental carbon and organic compounds account for 25 to 30%, the latter including bio-aerosols, often contributing to more than 8% of the total particle mass. The remaining particles are of both anthropogenic and natural origin, e.g. material from the earth's crust and/or sea salt. In urban environments, the main anthropogenic contributors to fine airborne particulates are usually power plants, domestic fuel combustion and transportation. The coarser part of floating dust is typically of a similar composition to the finer fraction but with a higher proportion of material from the earth's crust.

Power station emissions (sulphur dioxide and nitrogen oxides), motor vehicle exhausts (nitrogen oxides) and agriculture, which contributes a significant proportion of ammonia emissions, are precursors of airborne dust. The processes whereby these gases change into particles proceed at the rate of two to six percent per hour depending on the meteorological conditions. Therefore, particles in Malta air could, in part, also originate from sources outside of the national boundaries. The brown dustfalls carried periodically by the southern winds are a spectacular manifestation of transboundary dust transport originating from the African desert. In Malta, the burning of fireworks during the long *festa* season is another as yet unquantified and possibly important contributor to airborne dust.

**Figure 9.12** illustrates the calculated average daily variation of  $PM_{10}$  observed at three localities (Marsa, Mellieha and Zabbar) during 1999-2000 as studied by Galea (2001).



**Figure 9.12** Variation in mean  $PM_{10}$  concentration (in  $mg/m^3$ ) with time in Marsa, Zabbar and Mellieha



There is a clear increase in concentration of fine dust that occurs at around 9.00 am possibly related to morning traffic although it is to be noted that these maxima are reached rather late during the morning; also, for all three sites, the values remain near or above the guideline concentration for most of the day and night.

**Table 9.6** shows results for typical 24-h averages of PM<sub>10</sub> for other localities (Galea, 2001).

Using statistical calculations, Galea (2001) showed that there were significant differences in particle concentrations between different localities and also in the same locality between different months. The temporal differences could possibly be related, in part, to meteorological causes (e.g. rainfall, which cleanses the atmosphere by scavenging of dusts) but this is not discussed in the study.

The EU standard for PM<sub>10</sub> according to Directive 1999/30/EC is 50 µg/m<sup>3</sup> measured as a 24-hour average which is not to be exceeded more than 35 times a year. The annual limit value is 40 µg/m<sup>3</sup> (both limit values to be met by 2005). The short term limit value for particulate pollution has been frequently exceeded. Indeed, this is the only air pollutant other than benzene (Section 9.6) which has been consistently found to be present in air in excess of values that are regarded as safe for human health.

Using the median values in **Table 9.6**, the air pollution level with respect to fine dusts in those areas monitored where the concentrations exceeded the guideline value, could be described as ranging from moderate (50 – 74) to high (75 – 99)<sup>9</sup>. Moreover, the exceedances are found to occur at most sites and there does not seem to be any correlation between the presence of this pollutant and possible and clearly identified sources of dust although the type of information as is available does not yet permit a sound assessment. This is because no fixed analysers for airborne particles are available for long term monitoring and they are missing especially in background areas that measure transboundary dusts. It is known that the Sahara can be a substantial source of airborne fine dust in the Mediterranean area (WHO, 1999b) and such background measurements can help resolve whether the locally high PM<sub>10</sub>'s are derived from this source.

**Table 9.6 Concentrations of PM<sub>10</sub> in (mg/m<sup>3</sup>) measured in various localities during Sep 1999-Jan 2001**

<i>Locality</i>	<i>Median</i>	<i>Minimum</i>	<i>Maximum</i>
Dingli	39	31	64
Fgura	50	35	100
Ghajnsielem	46	22	130
Hamrun	65	35	114
Kalkara (Mar 00)	60	34	113
Kalkara (Nov 00)	43	26	80
Marsa (Aug 00)	48	38	73
Marsa (May 00)	72	54	120
Mellieha (Dec 99)	30	17	41
Mellieha (Feb 00)	66	31	85
Mosta	53	17	93
Munxar	26	13	59
Paola	58	32	73
Qormi (Mar 00)	38	22	73
Qormi (Nov 00)	51	34	137
Rabat	34	28	49
Siggiewi	46	22	96
Swieqi	17	7	24
Vittoriosa	45	38	82
Zabbar (Mar 00)	55	34	93
Zabbar (Nov 00)	89	57	222

<sup>9</sup> Based on categories proposed by the UK Department of the Environment, Transport and the Regions.

Particulate air pollution exerts an adverse effect on human health, affecting lung function and modifying the body's immune response, causing allergies. In a survey on respiratory health (Balzan and Bonnici, 2001) conducted on the basis of a questionnaire sent to residents of Fgura and Zejtun, the authors claimed the incidence of asthma and hay fever or nasal allergies in these towns are comparable to or higher than the highest levels recorded internationally and that Fgura residents had higher problems of respiratory problems related to airborne particles. The authors speculate that the differences observed between the two towns may reflect differences in PM<sub>10</sub> levels although no data is presented to corroborate this conclusion.

Recurrent dustfalls occurring over the Fgura-Paola area and causing consternation among residents were shown to originate from Marsa power station in a study conducted by Spiteri (2000) at the Chemistry Department of the University of Malta.

In another local study conducted in 1999, airborne particles were analysed for their content of the polyaromatic hydrocarbon benzo(a)pyrene (BaP), (Said Pullicino, 1999). This substance is a carcinogenic material known to form as a result of incomplete combustion of fuels, especially that of cyclic hydrocarbons found in diesel and fuel oil but also from incineration and uncontrolled refuse burning. Seven towns were investigated, the air quality being analysed on two (or three) separate occasions during which 8 h samples were collected during the daytime. The results are given in **Table 9.7**.

**Table 9.7 Concentrations of benzo(a)pyrene (8 h average) in airborne particulate matter (from Said Pullicino, 1999)**

Locality	Date of test (1999)	Benzo(a)pyrene, ng/m <sup>3</sup>	Degree of Pollution*
Marsa (Balbi St)	1/3; 3/3	nd ; nd	Low
Paola (Valletta Rd)	5/3; 8/3	nd; 1.5	Low - Moderate
Mdina (Rue D'Argens)	16/2; 13/3; 7/3	2.5; 2.9; 6.1	Considerable
Floriana (St Ann's St)	11/3; 12/3	6.0; 5.1	Considerable
Mqabba (Zurrieq Rd)	27/2; 6/3	nd; nd	Low
Bugibba (Tourist St)	22/3; 24/3	0.1; 0.1	Low
Mosta (Delu St)	19/3; 20/3	0.5; 0.4	Low

(\*) Based on the following suggested scheme: for BaP concentrations (ng/m<sup>3</sup>) <1: low; 1-3: moderate; 4-10: considerable; > 10: high. The WHO does not provide any guideline values for this carcinogenic substance.

The considerable presence of BaP found in the Floriana and Msida streets analysed, both of which being major traffic corridors, clearly indicates that the pollutant is mainly derived from traffic exhaust, especially from the black soot of diesel engines. It is to be noted that the streets in Marsa and Paola chosen for monitoring are not located on arterial roads: their proximity to the power station does not appear to markedly affect the air quality with respect to this pollutant. It is worth noting that this component of airborne dust constitutes only about 0.01% of the PM<sub>10</sub> load in the most polluted sites, although BaP is among the most toxic materials found in these dusts.

Another component of Malta airborne dust is the metal lead. The presence this toxic metal in local dust is well established and was discussed in the first State of Environment Report (1998): the main source of lead salts in dust is petrol-driven motor-vehicle traffic. With the reduction in use of leaded petrol and its eventual abolition from the local market, the concentration of lead in Malta air is expected to decrease significantly. Judging from results in other countries where leaded petrol has been phased out, it may be anticipated that airborne lead particles will not disappear immediately with the cessation of use of leaded petrol. In any case, monitoring for lead in air is required by Council Directive 1999/30 and considering the elevated blood lead levels of the Maltese population, it would appear appropriate to generate this data on a regular basis in order to establish the state of pollution with respect to this toxic heavy metal. No such data is available for the period under review.

## 9.8 Ammonia

The source of ammonia gas in the atmosphere is mainly agricultural land where the gas is released from fertilizers applied to soils. Among other things, and as mentioned earlier, ammonia can be a source of particulate matter in the form of salt crystals that can form when ammonia combines with acidic air pollutants. There is currently no data available on ammonia emissions or concentrations in air. This air pollutant is subject of Council Directive 2001/81/EC which obliges European member states to set national emissions ceilings on ammonia (and other gases<sup>10</sup>) by 2010.

## 9.9 Effects of air pollutants on vegetation

It is generally accepted that air pollution can cause injury to crops and plants. This has led to the adoption of air quality standards that are applicable to crops and vegetation and such standards are indeed significantly lower than those prescribed for human health.

Air pollutants elicit an increase in the size of the shoot relative to the roots of plants so that the root-to-shoot ratio is a good indicator of environmental stress. A recent local study has investigated such effects on the potato plant (*Solanum tuberosum*) (Callus, 2000). At Mellieha and Qormi, root-to-shoot ratios of potato plants were significantly lower than those grown at Zabbar and Kalkara. Levels of ozone at Mellieha were significantly higher than those recorded at the other sites, whereas sulphur dioxide levels were significantly higher at Qormi. The lower root-to-shoot ratios found at Mellieha were attributed to effects caused by ozone while the lower root-to-shoot ratios observed on plants at Qormi were thought to be the result of a synergism between sulphur dioxide and ozone, since levels of SO<sub>2</sub> were significantly higher at this site when compared with other sites. A very significant correlation was obtained with respect to the combined effects of sulphur dioxide and nitrogen oxides suggesting that while SO<sub>2</sub> was adversely affecting the root-to-shoot ratio, nitrogen oxides were actually promoting the transfer of assimilate from the shoot to the root.

Other factors besides air pollution can affect root-to-shoot ratios, e.g. type of soil and its fertility status: in this study, nitrate-nitrogen in the soils were found to be very low and the nitrogen oxides appear to have actually served as foliar fertilisers to replenish the potato plants with nitrate.

## 9.10 Odours

Odours are the most easily recognized air pollutants and are typically the most frequent cause of complaint to environment protection authorities worldwide. Odours cause concern and, frequently, also fear in people who experience them. While some odours are known to be caused by specific chemical agents such as hydrogen sulfide, carbon disulfide or mercaptans, others are difficult to define chemically. While odorous poisonous gases do exist that can be fatal if inhaled at sufficiently high concentration (hydrogen sulfide is a prime example), not all perceptible malodours are necessarily damaging to health. Nevertheless, due to their aesthetic problem, such malodours are not and should not be tolerated especially for prolonged periods.

The Sant'Antnin municipal solid waste composting plant at Marsascala was Malta's main cause of complaint from malodours until about 1998. With the introduction, during that year, of a new composting method (the "Ecopod system"), which largely prevents formation of low molecular weight organic acids from anaerobic fermentation, the number of complaints from residents neighbouring the plant have practically disappeared.

Complaints of sulphurous odours from the waste oils recycling facility at Marsa were also lodged during the initial phase of operations of this plant: subsequent action by the operators which included, among other actions, the installation of charcoal filters to the heating tanks of the facility have

<sup>10</sup> Namely sulphur dioxide, NO<sub>x</sub> and VOCs.

mitigated this problem significantly. However, complaints from bad odours originating in the Menqa area of Marsa, continue to recur periodically and it is assumed that these smells may accompany fuel oil transfer operations from ship to shore connected with the power station at Marsa. Similar complaints, however, are not lodged by residents of Marsaxlokk in connection with the power station at Delimara. During the period of review, children from one particular school at Marsa have had to be evacuated on a number of occasions due to anxiety and distress caused by smells drifting into the school premises from the direction of the harbour. The EPD has not been able to ascertain with confidence the source(s) of such odours. Other complaints from odours (mainly fuel-related) were lodged by residents of Sliema, Bugibba, Mqabba, Cospicua, Kalkara (Rinella), Fgura and Qormi.

## 9.11 Ozone Depleting Substances

International concern over the accelerated depletion of stratospheric ozone in the mid-70s and early 80s, led in 1985 to the Vienna Convention for the Protection of the Ozone Layer. Accelerated depletion of the ozone layer was linked to widespread use of certain categories of halogenated alkanes which are produced by human activities and which are collectively termed ozone depleting substances (ODS).

The Vienna Convention was followed by a protocol, adopted in Montreal in 1987, for co-operation among nations in introducing measures to drastically reduce and restrict the use of these ODS. The protocol embodied a definite 'timetable' for the phase-out of the consumption and production of ODS, together with restrictions on their manufacture, export and import. Four major amendments to the Montreal protocol have since been promulgated.

The protocol classifies ODS into lists which are contained in annexes A, B, C and E of the protocol. Annexes A and B incorporate substances with the highest ozone depleting potential: these were therefore to be phased out as rapidly as possible. Since a number of countries abiding with the convention, particularly developing ones, found difficulties adhering to the Montreal provisions, a system was devised whereby countries with an annual consumption of less than 0.3 kg per capita chlorofluorocarbons (CFC's) were permitted a delay in satisfying the adopted restrictions until 1999. These countries were termed Article 5 member parties.

Malta became signatory to the Vienna Convention and the Montreal protocol on 15<sup>th</sup> September 1988 and party to the protocol on 29<sup>th</sup> December of the same year. It ratified the London Amendment in February 1994 but has not to date accepted any subsequent amendments. The Pollution Control Co-ordinating unit (PCCU) within EPD formulated an action plan to identify quantities of imported ODS (via investigation of import licenses) thus creating a comprehensive database for the annual consumption of ODS. Malta is presently an Article 5 member party and is following the following phase-out schedule, as agreed by the parties to the Protocol at their 9<sup>th</sup> Meeting of the Parties (15-17<sup>th</sup> September 1997). The timetable is given in **Table 9.8**.

Malta presently imports the ozone depleting substances shown in **Table 9.9** which gives information on their respective use. **Table 9.10** shows imports (in metric tons) of ODS for the period 1989 to 2001. It should be noted that some of the imported substances (halons) indicated in the table could have been re-exported.

Carbon tetrachloride (CCl<sub>4</sub>) and 1,1,1-trichloroethane (CH<sub>3</sub>CCl<sub>3</sub>) contributed to Malta's imports of ODS up to 1995 and 1997 respectively. The consumption of CCl<sub>4</sub> was never high, mainly as a result of its toxic properties: it was used as a solvent for degreasing purposes. 1,1,1-Trichloroethane is used primarily in the manufacture of polyurethane foams. As from 1997, no further importation was permitted. Local needs were met via existing stock.

**Table 9.8: Timetable for phase-out of Ozone Depleting Substances**

Date	Phase-out obligations
1 July 1999	Freeze of Annex A Group I CFCs at 1995-97 average levels
1 January 2002	Freeze of Halons at 1995-97 average levels  Freeze of methyl bromide at 1995-98 average levels
1 January 2003	Reduction by 20% of 1998-2000 consumption levels of Annex B CFCs.  Freeze of methyl chloroform at 1998-2000 average level
1 January 2005	50% reduction of annex A CFCs with respect to 1995-97 average levels  50% reduction of Halons with respect to 1995-97 average levels  85% reduction of carbon tetrachloride (CCl <sub>4</sub> ) with respect to 1998-2000 average levels  30% reduction of 1,1,1- trichloroethane with respect to 1998-2000 levels
1 January 2007	85% reduction of Annex A CFCs with respect to 1995-97 average levels  85% reduction of Annex B CFCs with respect to 1998-2000 average levels
1 January 2010	100% phase-out CFCs, Halons and CCl <sub>4</sub> .  70% reduction of methyl chloroform with respect to 1998-2000 average level
1 January 2015	100% phase-out methyl chloroform and methyl bromide
1 January 2016	Freeze of Annex C HCFC's at 2015 average levels
1 January 2040	100% reduction of HCFC's

**Table 9.9 Imported Ozone Depleting Substances and their use***Annex A Group I*

Substance code	Chemical Formula	Use
CFC-11	CCl <sub>3</sub> F	Refrigeration
CFC-12	CCl <sub>2</sub> F <sub>2</sub>	Refrigeration
CFC-113	CCl <sub>3</sub> CF <sub>3</sub>	Degreasing processes
CFC-115*	CClF <sub>2</sub> CF <sub>3</sub>	Refrigeration

*Annex A Group II*

Halon 1211	CBrClF <sub>2</sub>	Fire extinguishers
Halon 1301	CBrF <sub>3</sub>	Fire extinguishers

*Annex C Group I*

HCFC 22	CHClF <sub>2</sub>	Refrigeration and air conditioning
HCFC 141b	CH <sub>3</sub> CCl <sub>2</sub> F	Foam blowing/metal cleaning

*Annex E Group I*

Methyl Bromide	CH <sub>3</sub> Br	Agricultural/industrial fumigant
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(\*) As R 502 which is a 50:50 mixture of CFC-115 and HCFC-22.

**Table 9.10 – Importation of ozone depleting substances for the period 1989 to 2001**

Substance	Amount in metric tons per year												
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
R-11	125	n/a	26	4	7	5	9	0	0	7.7	4.1	7.25	8.38
R-12	230	n/a	28	25	36	21	20	30.1	33.3	65.6	65.7	33.2	28.5
R-113	15	n/a	34	40	16	40	40	50	40	40	30.08	30.08	30
R-115	1	n/a	3	6	9	5	1	0	1.5	2.33	5.49	5.34	3.79
Halon 1211	n/a	n/a	5.33	2	1	0	0	0	0.046	0.05	10	10	10
Halon 1301	n/a	n/a	0.03	0.3	0.2	0	0	0	0.106	0.036	10	10	10
CCl <sub>4</sub>	0.04	n/a	0.04	0.025	0.04	0.02	0	0	0	0	0	0	0
R-22	25	25	25	26	28	58	70	11	57.8	192.5	118.8	167	204.8
R-141b	n/a	n/a	n/a	n/a	n/a	10	30	62	55	45	6.5	43	39
1,1,1-Trichloroethane	30	30	26	25	28	18	24	2	0	0	0	0	0
Methyl bromide	n/a	40	40	40	40	110	62	39	40	35.52	40	30	26.9
Total CFCs	371	0	91	75	68	71	70	80.1	74.8	115.5	105.4	75.88	70.62
Total HCFCs	25	25	25	26	28	68	100	73	112.8	237.5	125.3	210	243.8
Total Halons	0	0	5.36	2.3	1.2	0	0	0	0.152	0.086	20	20	20

### *Phase-out of CFCs*

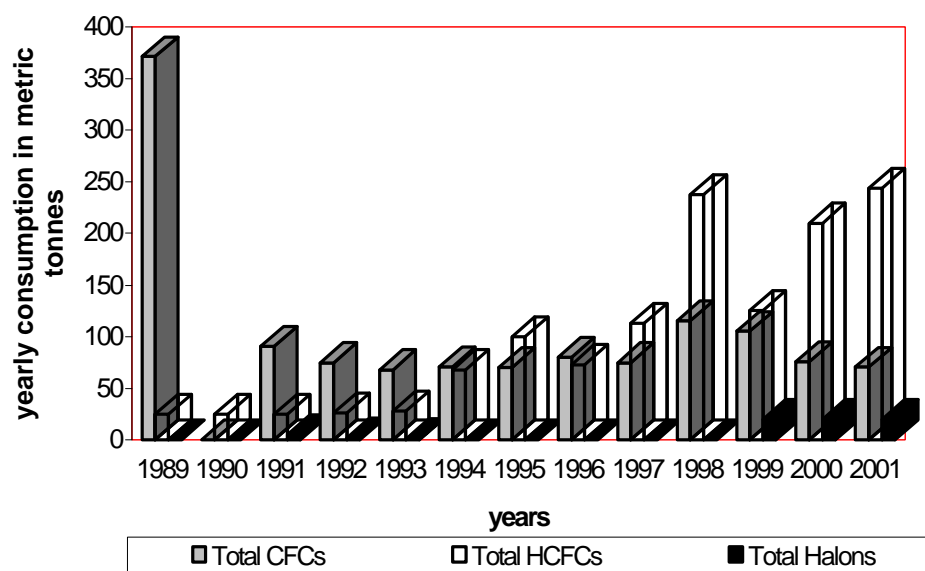
In accordance with the phase-out timetable for Annex A substances (*see* Table 9.7), 1999 marked a freeze in the consumption of CFCs with the following years seeing the level fall to 1995-97 average values. **Table 9.11** compares consumption of Annex A group I ODS for the years 1999, 2000 and 2001 with 1995-97 calculated average values<sup>11</sup>. Results indicate that consumption of these CFCs during 2000 and 2001 was within stipulated limits; the value for 1999 is higher than the average stipulated value by ca. 50%. This however does not conflict with the phase-out provision since the 1999 freeze went into force on the 7<sup>th</sup> month of that year and abiding countries were given a 6 month period to stockpile.

<sup>11</sup> These were calculated by multiplying the yearly importation quantity for the particular annex A CFC by its corresponding Ozone-Depleting Potential number and adding up for all CFCs as per article 3 of the Montreal Protocol.

**Table 9.11. Consumption of Annex A Group I ODS during 1999-2001 compared to 1995-97 (in ODP-tonnes)**

	Amount ODP- tons /yr
Calculated average consumption over the period 1995-97	66
Calculated consumption for the year 1999	97
Calculated consumption for the year 2000	68
Calculated consumption for the year 2001	63

**Figure 9.13** compares yearly quantities in metric tons for total Annex A group I CFCs and Annex C HCFC's for the period 1989 to 2001. While the trend for the importation quantities of CFCs has at first decreased and then eventually leveled out, that for hydrochlorofluorocarbons (HCFC's) has risen substantially from 25 tons in 1989 to 243 tons in 2001.

**Figure 9.13 Importation of total CFC's, HCFC's and Halons in Malta for the period 1989 – 2001**

HCFC's have a much lower ozone depleting potential and are at present the only economically-viable alternative to Annex A CFCs; eventually, these compounds too will fall under protocol regulatory control. Figure 9.13 also shows that consumption of halons during the period 1999-2001 has remained stable at 20 metric tons per year. The bulk of halons was actually re-exported. Consumption of methyl bromide has decreased from 40 tons to 27 tons. Both methyl bromide and halons shall be subject to a freeze in importation levels as of the 1<sup>st</sup> of January 2002.

## 9.12 International Obligations

Under the Convention for the Long Range Transport of Air Pollution, Malta has a number of obligations amongst which is the need to submit yearly inventories for emissions of specific air pollutants, to include also projections for the years 2010 and 2020. No data has been prepared in connection with this convention and the country is currently in default of several obligations under this

convention (e.g. no participation in any of the International Cooperative Programmes on effects of air pollutants on vegetation and crops, historic monuments, ecosystems, etc.).

Malta also signed the UN Framework Convention on Climate Change in 1994 and in 2001 ratified the Kyoto Protocol. As a candidate country, Malta should have submitted communications regarding the emissions of carbon dioxide and other greenhouse gases (GHG) such as methane, nitrous oxide, sulphur hexafluoride etc. In 1999, a National Board on Climate Change Affairs was set up to formulate policy and more recently, the EPD has commissioned experts from the University of Malta to prepare the first National Communication as required by Articles 3 and 12 of the said convention. The communication will include: a national inventory of anthropogenic GHG emissions; a national strategy and a general description of the steps taken or envisaged for the implementation of the obligations under the convention and any other relevant information relating to mitigation strategies such as energy saving schemes etc. This communication is currently in preparation.

### 9.13 Sustainability Indicators for Air Quality

Mallia (2002) has recently proposed and discussed the adoption of a set of air quality sustainability indicators for Malta following practice established by UNEP's Blue Plan (2000). The indicators identified are shown in **Table 9.12**.

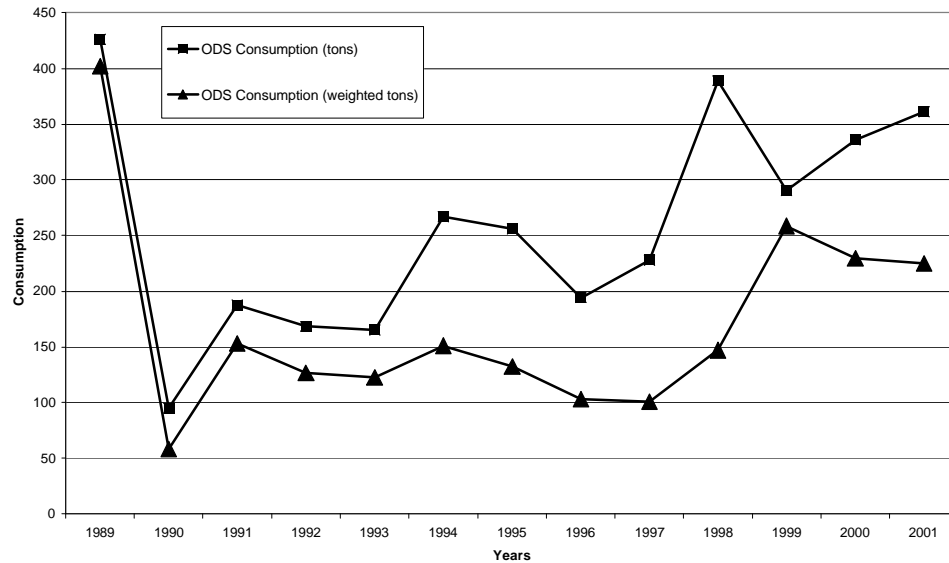
**Table 9.12 Air quality sustainability indicators for Malta (from Mallia, 2002)**

UNEP Indicator Number	Title of Indicator
110	Emissions of Greenhouse Gases
111	Emissions of Sulphur Oxides
112	Emissions of Nitrogen Oxides
113	<i>Consumption of Ozone Depleting Substances</i>
114	Frequency of Excess Over Air Standard (Ozone)
115	Expenditure on Air Pollution Abatement
116	Share of Clean Fuels Consumption in Total Motor Fuels
117	Share of Agglomerations over 100,000 Inhabitants Equipped with an Air Pollution Monitoring Network

Indicators 110, 111 and 112 are based on calculated emissions of specific pollutants as performed using standard techniques (e.g. CORINAIR inventory) for which data exists only for the years 1990, 1994 and 1997 as discussed by Vella and Bugeja in the State of Environment Report for 1998. Once the information required to compute these emissions is collected, then the indicators can be calculated for the period under current review. The data presented in Table 9.3 (this report) is relevant to indicator 111 on sulphur oxides: although not comprehensive, the data certainly include main sources of SO<sub>2</sub> emission, *i.e.* those pertaining to combustion of sulphur-containing fossil fuels. The data suggest that sulphur dioxide emissions may have decreased somewhat over the period of review but that possibly the reduction in emissions may be levelling off.

Data currently available also allow the computation of indicator 113 pertaining to consumption of ozone depleting substances: the information is shown in Figure 9.14 both as total tonnage of ODS as well as amount in ODP-weighted-tonnes. The two curves are parallel to each other up to about 1991 when they then diverge, indicating a favourable switch from use of the more ozone-damaging CFCs to that of ozone-friendlier HCFCs.





**Figure 9.14 Total consumption of ODS showing data both in tonnes and in ODP-tonnes (from Mallia, 2002). Cf. Table 9.9**

Indicator 114 on the frequency of exceedances of tropospheric ozone cannot currently be adopted in a rigorous manner since no fixed stations measuring the gas continuously in real time are yet available<sup>12</sup>. The diffusive samplers for ozone do not provide the necessary information and neither does the mobile station, unless possibly the latter is used in a different mode to the present.

Indicator 115 on 'expenditure on air pollution abatement' is defined as investment and current expenditure incurred to prevent, reduce and eliminate air pollution. The indicator includes expenditure by the public sector as well as the private sector. In the case of the public sector, expenditure related to general administration, as well as the monitoring of the environment are included. Measurement of this indicator is quite complex since it takes into account a wide range of activities and sectors, as well as capital and recurrent costs, including subsidies and taxes. The fact that national accounting does not currently cater for environmental measures makes impossible the computation of this sustainability indicator.

Indicator 116 on 'share of clean fuels consumption in total motor fuels' is defined as the proportion of 'clean fuels' consumed by the motor vehicle fleet, where clean fuels refer to unleaded petrol, liquefied petroleum gas (LPG) and pressurised gas. In Malta, the only clean fuel in use is unleaded petrol. The percentage clean fuel use for the years 1998 through to 2001 are shown in **Table 9.13**.

<sup>12</sup> Except that measuring background levels at the University Atmospheric Station in Gozo, which is not appropriate for this type of use.

**Table 9.13 Share of unleaded petrol consumption in total motor fuels for the period 1997 – 2001 (from Mallia, 2002)**

Year	1997	1998	1999	2000	2001
% share of unleaded petrol	6.71	9.2	7.74	11.2	13.9

Clean fuel use has increased steadily over these years although it is expected to stabilize in future once leaded petrol is phased out, unless LPG becomes a permitted motor fuel when further increases in this indicator value would be possible.

Sustainability indicator number 117 pertaining to ‘the share of agglomerations of over 100 000 inhabitants equipped with an air pollution monitoring network’ is probably not applicable to Malta in view of the size of the population and the distribution of the main urban centres over the national territory.

Finally, in our opinion, consideration should be given to the adoption of another sustainability indicator, namely, *frequency of excess over air standard of benzene* pertaining to the percentage of air monitoring stations registering an exceedance of benzene levels in air over the yearly average value of  $5 \mu\text{g}/\text{m}^3$  (or 1.5 ppb). The indicator value would then vary from 0%, the optimal value, to 100%, if all stations measure excess benzene; the number of measuring stations, N, would need to be cited in quoting the indicator. For the 12-month period of measurement during 2000-1, the frequency of excess over air standard of benzene for Malta was 78% (N = 31). Even though this sustainability indicator does not form part of the set of indicators identified in UNEP’s Blue Plan for Mediterranean countries, it is highly relevant to Malta’s situation and may arguably be more important than the excess ozone indicator in view of the following considerations: (a) the extent of pollution from this carcinogenic compound and (b) the probability that unlike ozone, for which a transboundary component appears to be important, the main sources for benzene are local (mainly motor traffic exhaust) and therefore, in principle, the problem admits management solutions taken at the local level.

## 9.14 Data Availability

As already stated, the volume of data currently available on the air quality in Malta is considerable and this in sharp contrast with the situation in 1998. The EPD has generated the bulk of the data although it is also clear that resources within the department (including human) are not nearly sufficient to ensure continuation of this effort coupled with proper evaluation of the incoming data. No difficulty was encountered in accessing air quality data from EPD or other Government Departments. Information from research studies conducted at the University was equally easy to acquire.

## 9.15 Conclusions and Recommendations

The main recommendations and conclusions identified in this chapter are summarized below:

1. Significant progress has been achieved in the generation of knowledge about the quality of air in Malta: this is mainly due to the work of the Environment Protection Department which however needs to be further supported by additional resources, including manpower, and probably another mobile station.
2. The impact from short term but high level sulphur dioxide pollution at Marsa warrants installation of a permanent monitor and a prompt alerting system to safeguard people from this pollutant. The situation in other areas where exposure may be as significant if not higher than that at Marsa needs to be more closely monitored using the mobile station.

3. Although emissions of sulphur dioxide between 1998 and 2001 decreased somewhat (8%), in future, such emissions from stationary sources will need to be reduced considerably if Malta is to abide by its international obligations.
4. Nitrogen dioxide, a highly irritant gas formed from motor vehicle exhaust, was found present in Floriana air at levels that exceed health limits: the gas was also present in other areas where traffic density is high although at somewhat lower concentrations. The highest levels are formed in urban air during the morning rush hour.
5. Ozone, another toxic air pollutant which forms from traffic exhaust, is also present at considerable concentration in Malta air although it appears that part of the ozone load could originate from overseas countries to our north, e.g. Sicily.
6. There were no reported exceedances of carbon monoxide levels in air, although no information on the state of pollution of indoors air by this gas are available.
7. Air pollution caused by the presence of the carcinogenic compound benzene is of great concern since this substance is found at considerable to high concentration in most places where motor traffic is abundant; in Malta, benzene pollution could be amongst the worst in Europe.
8. Benzene and other volatile organic compounds emitted from vehicular exhaust can be stopped by installation of catalytic converters and these devices should be made mandatory. The emission of toxic volatile organic compounds, including benzene, resulting from commerce in petrol is currently uncontrolled and needs to be addressed.
9. The presence of very high concentrations of benzene in indoor air in places of entertainment has been established: proper ventilation and control of smoking would reduce this insidious problem significantly.
10. Airborne fine dust has been found to be consistently present in air in most localities in Malta in excess of values that are regarded as safe for human health. Motor traffic adds to the fine dust content of air, contributing the very toxic component benzo(a)pyrene found in black smoke from diesel engines. However, there may be other sources of airborne dust that are unknown at the present time.
11. Fixed analysers for airborne dusts and additional research are required in order to identify the source(s) of Malta's high dust levels.
12. Monitoring for the presence of lead in airborne particles should be performed not only because of our international obligations but also as a means of assessing the status of environmental pollution with respect to this toxic element.
13. Knowledge of the type and quantity of air pollutants generated by agriculture, e.g. ammonia, and establishing any effects which air pollutants exert on vegetation should be future objectives for environmental assessment in Malta.
14. With respect to global effects of air pollution, in particular, the control of consumption of ozone-depleting substances, Malta is complying with Montreal Protocol obligations.
15. Sustainability indicators for air quality as suggested by UNEP's Blue Plan for Mediterranean countries could be adopted, except possibly for indicator 117 which appears inappropriate for Malta. Quantification of some of these indicators is currently hindered either by lack of knowledge from non-collection of available necessary data or, more seriously, lack of appropriate public (and private) accounting procedures as related to spending on air pollution abatement actions.
16. It is recommended that a sustainability indicator based on exceedances of levels of benzene in air be adopted locally in view of the extent of pollution from this carcinogenic compound.

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