

**AEAT in Confidence**

Version 1

# **Preliminary assessment of air quality in Malta**

B Stacey

T Bush

August 2002

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# Executive Summary

A preliminary assessment of air quality within Malta has been conducted for the pollutants regulated by the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> Daughter Directives on ambient air quality. A requirement for Member States to conduct a preliminary assessment of air quality is specified by *Article 5* of The Framework Directive (Council Directive 96/62/EC).

The objective of the preliminary assessment is to establish estimates for the overall distribution and levels of pollutants, and to identify monitoring necessary to fulfil obligations to The Framework and subsequent Daughter Directives.

Measurements of air pollutants, derived from monitoring surveys and the national emissions inventory data, have been utilised in this preliminary assessment. These data originated from measurement campaigns commissioned by the Maltese Pollution Control and Co-ordination Unit (PCCU). The data used in this assessment are as follows:

1. Diffusive sampler measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> and benzene, March 2000 – May 2001
2. Short-term automatic measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, CO and PM10, 1999-2002
3. The Atmospheric Emission Inventory for Malta 1997

Based upon these measurements/surrogate information and guidance provided by the Directives, it has been established that levels of air pollution in Malta are above or, where measurements are not available, likely to be above thresholds which require fixed measurements to be made for compliance with the Daughter and Framework Directives. These observations apply both for an agglomeration zone identified within Malta (the Valletta and Sliema agglomeration, population >250,000 inhabitants) and for areas outside of this agglomeration (the Malta zone).

As a result, the following fixed monitoring is recommended for minimum compliance with the three Daughter Directives and the Framework Directive.

## Fixed monitoring requirements for minimum compliance with the 1<sup>st</sup> - 3<sup>rd</sup> Daughter Directives within Malta

Zone/agglomeration	Pollutants to be monitored	Generic location of monitoring effort
<b>Valletta/Sliema agglomeration</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM10, lead, O <sub>3</sub> , CO, benzene	At roadside location in Valletta
	NO <sub>x</sub> , SO <sub>2</sub> , PM10, lead, O <sub>3</sub> , benzene	At urban background location in Valletta, Sliema or environs
	NO <sub>x</sub> , SO <sub>2</sub> , PM10	At point of max. ground level concentration for plume from Marsa power station
<b>Malta zone</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM10, lead, O <sub>3</sub> , CO, benzene	At urban background location in zone

These recommendations recognise:

1. Road transport as the main emissions source of pollution effecting the majority of the Maltese population;
2. The potential impacts upon resident populations resulting from the plume touch down of key point sources to the south west of the Valletta and Sliema agglomeration;
3. Fixed, long-term measurements of pollutants regulated by 1<sup>st</sup> – 3<sup>rd</sup> Daughter Directives have as yet not been made;
4. Measurements of airborne lead levels have not, as yet, been made within Malta;
5. That, given the limited historical measurement data and surrogate information from emissions inventories, there is little scope to reduce the monitoring burden via supplementary information; and
6. A strategic need to characterise roadside, urban background and industrial components of air pollution with view to developing modelling capabilities and for development of national plans to improve air quality.

A further recommendation- the commissioning of a rural background monitoring station measuring NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, ozone and meteorological- is also made with the specific aim of:

1. Protecting sensitive ecosystems not governed on Malta by the Daughter Directives;
2. Assessment of contributions from transboundary pollution particularly for PM<sub>10</sub> and ozone;
3. Facilitating the development of national plans to improve air quality by identifying components of air pollution which are not directly controllable locally.

We also recommend the continued assessment of additional air pollution issues in Malta through:

- Rationalised diffusive sampler surveys
- Development of spatially disaggregated emissions inventory
- Dispersion modelling studies of point sources and
- Utilisation of the mobile laboratory

Information is also provided in this report on the following topics specified by the terms of reference:

1. Development of plans to improve air quality;
2. Instruments available for reducing emissions;
3. Emissions standards for the reduction of air pollution
  - i. Emissions from the transport sector
  - ii. Emissions from power generation and stationary sources
4. Modelling and prediction requirements
  - i. Basic requirements for modelling and prediction of emissions and ambient concentrations
5. Approaches to Air Quality Monitoring

- i. Types of Monitoring stations
  - ii. Mobile laboratory vs. fixed sites
  - iii. Instrumentation
  - iv. Costs
  - v. Pollutant Measurement Methods
6. Principle of Operation of Automatic Analysers;
  7. Quality Assurance and Quality Control (QA/QC);
  8. Personnel requirements and training;
  9. Public Information.



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# 1 Introduction

EU Council Directive 96/62/EC, (commonly known as The Framework Directive<sup>1</sup>), has established a coherent framework under which the limit values or target values regulating specified ambient air pollutants will be set within Europe. The objectives of the Directive are described in *Article 1* of the Directive as follows:

“...to define the basic principles of a common strategy to:

- Define and establish objectives for ambient air quality in the Community designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole
- Assess the ambient air quality in Member States on the basis of common methods and criteria
- Obtain adequate information on ambient air quality and ensure that this is made available to the public, *inter alia* by means of alert thresholds
- Maintain ambient air quality where it is good and improve it where it is bad.”

Under *Article 5* of The Framework Directive, a requirement has been placed upon Member States to undertake a preliminary investigation of ambient air quality prior to the implementation of subsequent ‘Daughter Directives’<sup>234</sup> setting limit values referred to in *Article 4* of the Framework Directive.

The objective of the preliminary assessment detailed in this report is to establish estimates for the overall distribution and levels of pollutants, and to identify monitoring requirements in line with the guidance provided by the Daughter Directives; these will be necessary in order to fulfil obligations to The Framework and subsequent Daughter Directives by their transposition dates.

## 1.1 SCOPE OF THIS REPORT

Sections 1-4 of this report aim to provide a *preliminary assessment of air quality* in relation to pollutants regulated by the Framework Directive and the 1<sup>st</sup> 2<sup>nd</sup> and 3<sup>rd</sup> Daughter Directives.

As part of the preliminary assessment, recommendations will be made for options available to achieve formal compliance with the monitoring requirements of the Daughter Directives. In addition, recommendations will be made for the monitoring that will fulfil:

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<sup>1</sup> The Framework Directive – Council Directive 96/62/EC of 27 September 1996 on ambient air quality and assessment.

<sup>2</sup> 1<sup>st</sup> Daughter Directive - Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

<sup>3</sup> 2<sup>nd</sup> Daughter Directive - Council Directive 2000/69/EC relating to limit values for benzene and carbon monoxide in ambient air.

<sup>4</sup> 3<sup>rd</sup> Daughter Directive – Council Directive 2002/3/EC relating to ozone in ambient air.

- Malta's obligation to the Convention on Long-Range Transboundary Air Pollution
- Protection of sensitive ecosystems not explicitly protected by the 1<sup>st</sup> and 2<sup>nd</sup> Daughter Directives
- Strategic monitoring from development of modelling capabilities and source apportionment of air pollution

Section 5- 11 of the report aim to provide information and advice on

- Instrumentation required following the recommendations of the preliminary assessment and estimate running costs
- Specifications for procurement of monitoring equipment
- Quality assurance and control issues
- The relative merits and demerits of in-house or out-sourcing of services
- Modelling and air quality prediction
- Data dissemination to the public
- Plans to improve air quality
- Institutional and training needs for regulatory and enforcement activities

## 2 General Approach

Our approach to the assessment of air quality for pollutants regulated by Daughter Directives 1-3, has been to utilise recent historical measurements and emissions inventory data. These data have been derived from measurement campaigns commissioned by the Maltese Pollution Control and Co-ordination Unit (PCCU). The data used in this assessment are as follows

- Diffusive sampler measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> and benzene, March 2000 – May 2001
- Short-term automatic measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, CO and PM10 from 1999-2002
- The 1997 Atmospheric Emission Inventory for Malta

Measurement data from these surveys have been compared with appropriate Upper and Lower Assessment Thresholds (UAT and LAT), Target Values and Long-term Objectives presented in the relevant Directives. A requirement to monitor pollutants with the zones and agglomerations identified for Malta is triggered by the exceedence of the LAT for pollutants regulated by Daughter Directives 1-2 and by the exceedence of the long-term objectives for ozone. Guidance on the number of fixed monitoring stations required for minimum compliance is provided in the relevant Directive and incorporates reference to population of the of zones and agglomerations being assessed.

## **2.1 KEY ASSUMPTIONS INFLUENCING THE MINIMUM MONITORING REQUIREMENTS**

The following assumptions and definitions have been utilised for the purposes of this preliminary assessment.

1. Malta is comprised of one agglomeration (>250,000 inhabitants) and one zone (<250,000 inhabitants), see section 2.2;
2. There are no areas of Malta to which the ecosystem and vegetation Limit Values and assessment thresholds apply (see section 2.2);
3. There are currently no fixed measurements of pollutants regulated by Daughter Directives 1-3;
4. There is limited scope for 'other sources of information' to reduce the monitoring requirement within Malta.

It should be noted that formal demonstration of exceedence or compliance with a LAT or UAT, based on guidance from the Directives, can only be demonstrated using at least five years of contiguous and continuous monitoring data. Clearly, for Malta this guidance cannot strictly be conformed with, owing to the duration of the campaigns and surveys so far undertaken. Hence, for the purpose of this preliminary assessment, a single exceedence of the LAT will trigger a requirement to monitor. For the following reasons, this strategy is not likely to be significantly detrimental in over-prescribing the monitoring requirements for Malta:

- Car ownership and therefore road traffic emissions of pollutants within Malta is increasing;
- Recent European fuel standards regulating sulphur and benzene content of petrol and diesel have not as yet been adopted within Malta;
- There have been no recent improvements to the abatement mechanisms on significant point sources that may impact upon ambient air quality in the main agglomerations of Malta;
- The vehicle fleet is old in comparison with many European countries and any impact upon emissions from this fleet as a result of fleet renewal will have significant lead times.

Hence, it is probable that if an exceedence of a relevant threshold is identified in measurement data outlined above, it is likely to have also been recorded in the previous four years had measurements taken place. Moreover, such an exceedence is likely to be recorded in the future as a result of increasing road traffic emission under a 'business as usual' policy scenario.

## **2.2 DEFINITION OF ZONES, AGGLOMERATIONS AND ECOSYSTEM/VEGETATION AREAS**

For the purpose of implementing the Framework and Daughter Directives, Member States are required to declare the extent of zones and agglomerations within which ambient air quality is to be assessed. In addition, there is a

requirement to identify the extent of ecosystem and vegetation areas where the Limit Values (LVs) for the protection of ecosystems and vegetation may apply.

### **2.2.1 Zones and agglomerations in Malta**

The general topography of urban areas within Malta is more densely populated than those in the UK or other European countries. The island as a whole is listed as the 9<sup>th</sup> most densely populated territory in the world. Within the main cities and urban areas, there is a clear absence of the suburban fringe demographic characteristics of many European cities. As a result, there is the potential for significant numbers of the population to be exposed to health risks from air pollution exposure.

In order to delineate the extent of the zones and agglomerations within Malta, the main urban areas and archipelago coastline was assessed within a Geographical Information System (see Figure 1). A UK-based approach to theineation of continuous urban areas has been applied to Maltese urban areas. This technique attempts to identify continuous urban land by applying a 100m buffer zone to all urban areas (see Figure 2). Hence, urban areas separated by less than 200m can be highlighted as part of the same continuous urban area. After completion of this analysis, it was identified that the most significant continuous urban area in Malta was comprised of Valletta, Sliema districts and some surrounding environs (see Figure 3). This urban area has been identified as the Maltese agglomeration and is assumed to have a population of greater than 250,000 inhabitants.

All other territories and urban areas outside of this agglomeration form part of the Maltese zone.

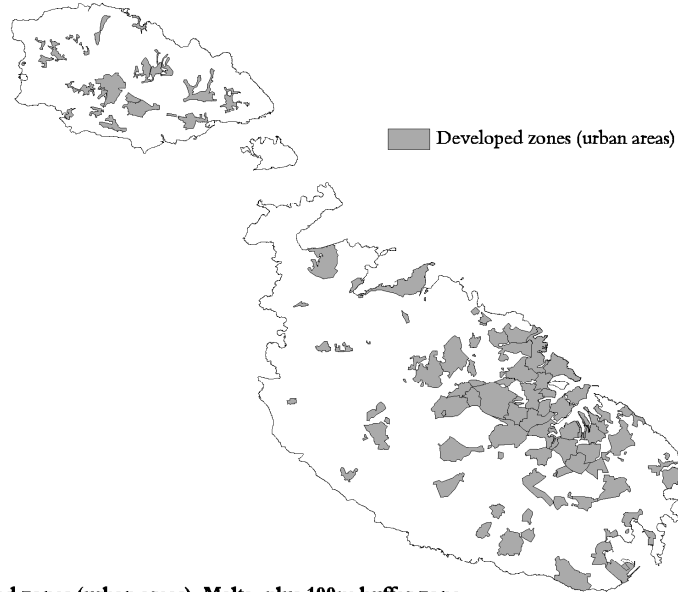
### **2.2.2 Ecosystem and assessment areas within Malta**

The 1<sup>st</sup> Daughter Directive provides Limit Values for NO<sub>x</sub> and SO<sub>2</sub> for the protection of ecosystems and vegetation. However, in recognition that these LVs are unlikely to be attainable close to urban area, major roads, point sources and agglomerations guidance is provided on the areas to which these LVs should apply. The Directive indicates that LVs for ecosystems should only apply:

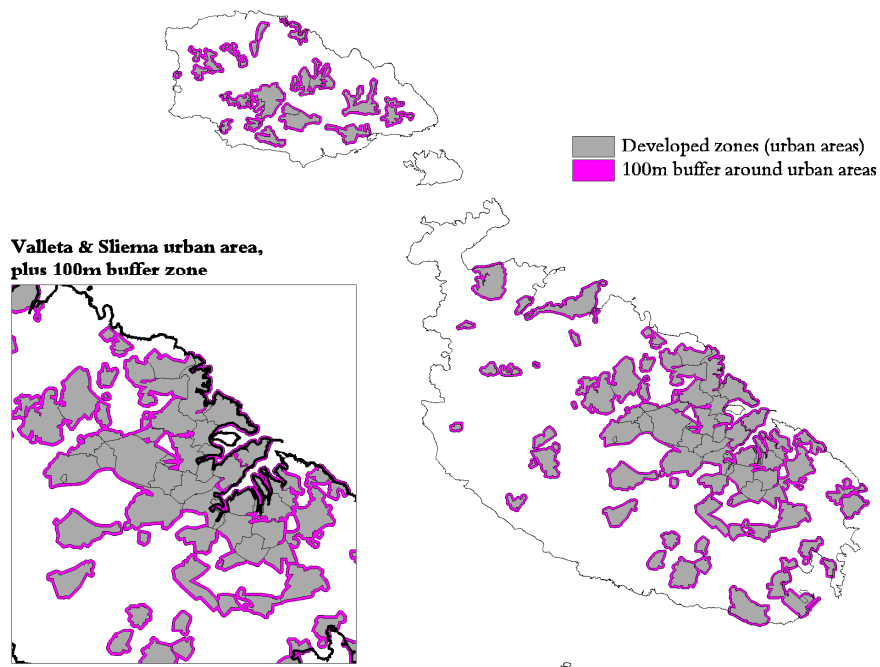
- At a distance of 5km from urban areas, motorways and major points sources
- At a distance of 20km from agglomerations

Figure 4 shows the effect of applying a 5km buffer to the urban areas of Malta and clearly shows that, under the specific definitions presented by the Directive, the ecosystems and vegetation LVs should not be obligatory within Malta. However, in recognition of the need to assess air quality upon islands and protect natural ecosystem and sensitive areas, it is our recommendation that these should be regarded as applicable to the assessment of these pollutants in sensitive areas.

**Figure 1 Developed zones (urban areas), Malta**

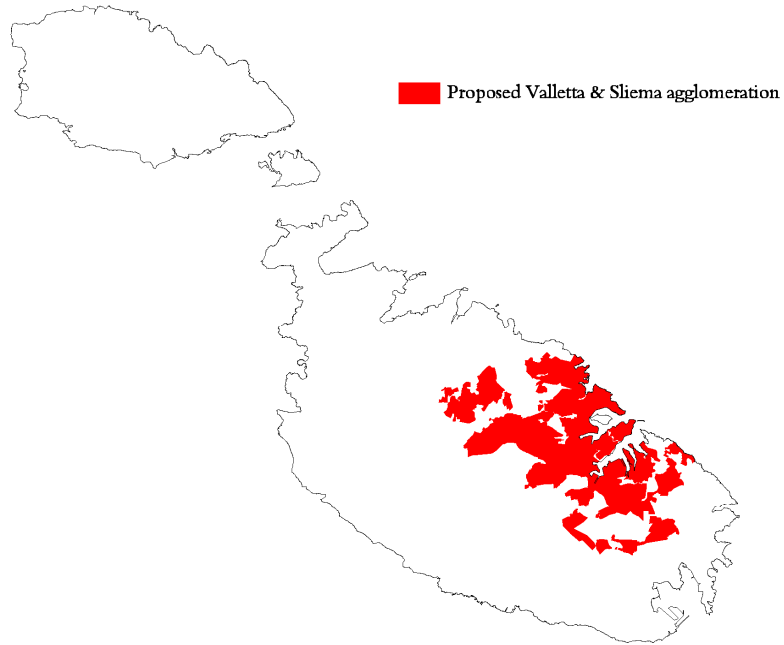


**Figure 2 Developed zones (urban areas), Malta, plus 100m buffer zone to delineate continuous urban areas with <200m separation**

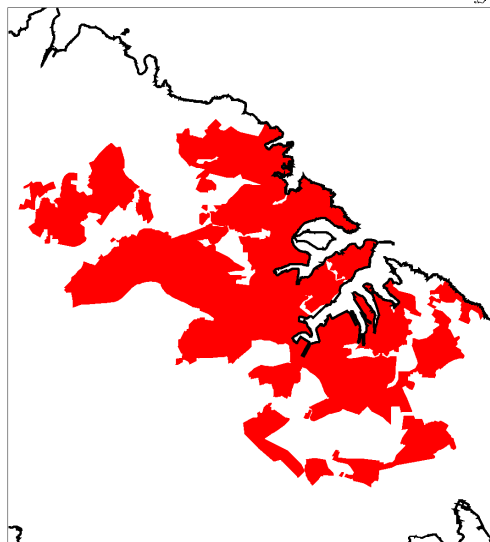




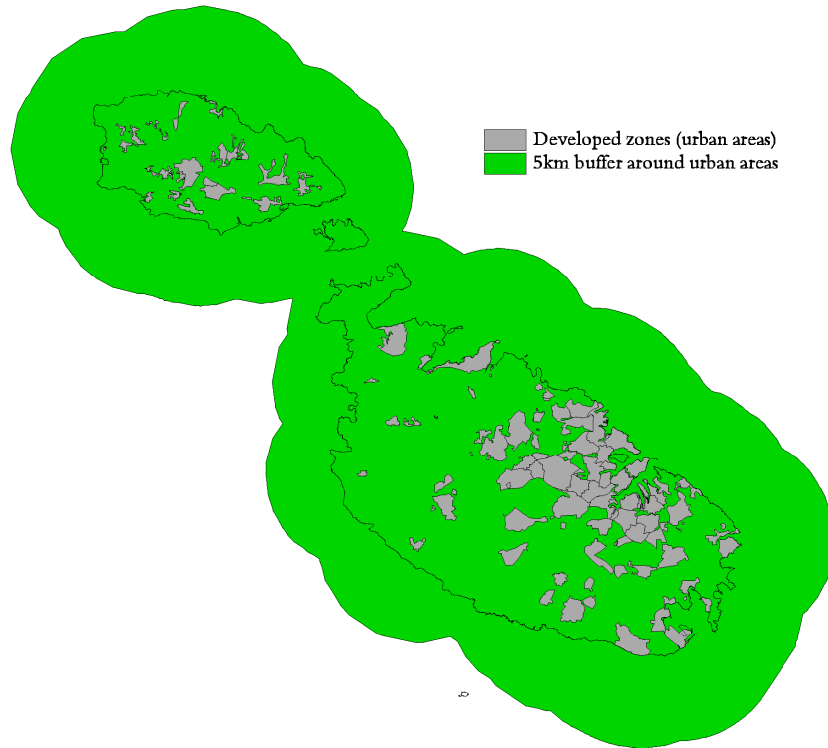
**Figure 3 Proposed Valletta & Sliema agglomeration based on continuous urban fabric (urban areas separated by less than 200 metres)**



**Proposed Valleta & Sliema agglomeration**



**Figure 4 A 5 km buffer on urban areas indicating absence of ecosystem and vegetation areas on Malta, Gozo and Comino**



### 3 Preliminary assessment of air quality

#### 3.1 MAIN SOURCES OF AIR POLLUTION IN MALTA

Information from the Malta emissions inventory for 1997 provides a good estimate of the key sources of air pollutants regulated by 1<sup>st</sup> and 2<sup>nd</sup> Daughter Directives. Table 1 below presents a list of the emission sectors responsible for the majority of emissions of NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub> (dust), lead, benzene and CO within Malta.

**Table 1 Key emissions sources of pollutants regulated by Daughter Directives 1-2**

Pollutant	Total emission (tonnes)	Sectors responsible	Percentage of total emission	Height of emission
<b>NO<sub>x</sub></b>	10,001	Combustion in energy and transformation	50% (4,993 tonnes)	High
		Road transport	34% (3,441 tonnes)	Low
<b>SO<sub>2</sub></b>	32,624	Combustion in energy and transformation	94% (30,683 tonnes)	High
		Combustion in manufacturing industry	2 % (713 tonnes)	Medium
		Road transport	2% (684 tonnes)	Low
<b>Dust (PM<sub>10</sub>)</b>	2980	Combustion in energy and transformation	90% (2,691 tonnes)	High
		Road transport	7% (202 tonnes)	Low
		Resuspension	Unquantified	Low
		Transboundary	Unquantified	Low
<b>Lead</b>	20,235	Road transport	97% (20,000 tonnes)	Low
<b>NM VOC</b>	26,886	Solvent and other product use	68% (18,400 tonnes)	Low
		Road transport	27% (7,205 tonnes)	Low
<b>Benzene (estimate d)<sup>5</sup></b>	n/a	Solvent and other product use	184 tonnes	Low
		Road transport	360 tonnes	Low
<b>CO</b>	22,553	Road transport	97% (21,817 tonnes)	Low

Table 1 indicates that the road transport sector is an important source of low-level emissions for all pollutants, particularly lead, benzene and CO. For NO<sub>x</sub>, SO<sub>2</sub> and Dusts (PM<sub>10</sub>), the contribution from stationary sources, (combustion in

<sup>5</sup> Benzene emission estimated from the NMVOC emission inventory. Benzene fraction of solvent use and road transport assumed to be 1% and 5% respectively of NMVOC emission, (*pers comm* N Passant, UK National Atmospheric Emission Inventory, 2002).

energy and transformation and manufacturing) is significantly higher than that from road transport. It should be noted however, that under normal operating conditions within Europe the contribution from such sources to ground level concentrations would be mitigated by emission at a suitable elevation to ensure effective dispersion. Local information from the Malta PCCU, together with previous assessment work<sup>6</sup>, indicates that the dispersion of emissions from point sources in the central Sliema and Valletta agglomeration may not be sufficiently effective. It is likely, therefore, that these sources will contribute significantly to short-term pollutant concentrations as a result of plume grounding and advection.

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<sup>6</sup> Air quality in Malta. UNDP contract MAT/97/002, July 1998. J Bower and J Lampert.

### 3.1.1 Data utilised in the preliminary assessment of air quality

Table 2 presents the air quality data utilised by the preliminary assessment of air quality. There are currently no fixed monitoring stations providing representative measurements of the pollutant levels regulated the three Daughter Directives.

Between 1999 and 2001, the Malta PCCU commissioned a series of short-term measurement campaigns at 21 different roadside localities within Malta. Measurements were undertaken using automatic techniques housed in a mobile laboratory.

In addition, an extensive diffusive sampler survey was commissioned between March 2000- May 2001. This survey measured four pollutant species at a total of 28 localities within Malta and Gozo and at three representative location types within these localities (roadside, urban intermediate and urban background).

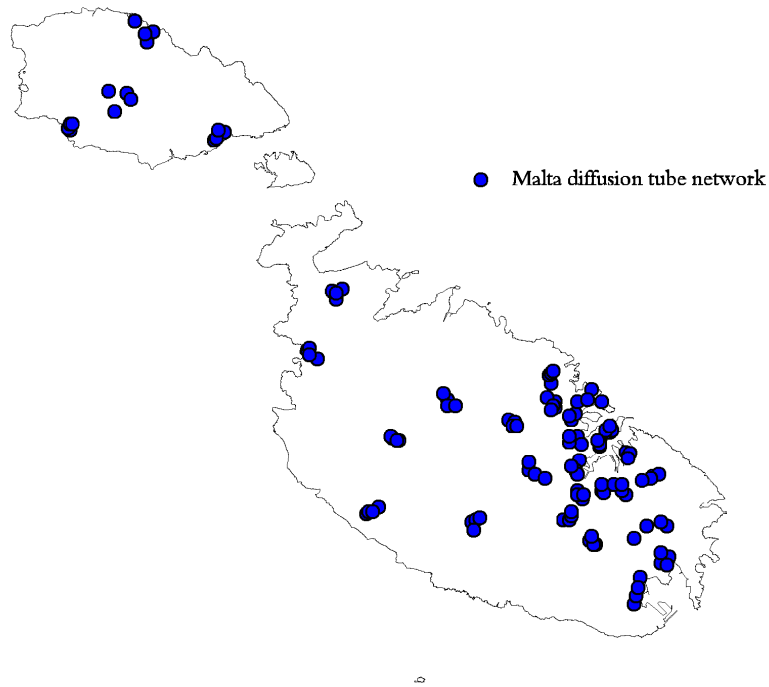
Figures 5 and 6 present the coverage of Malta and Gozo provided by the sampler and automatic monitoring surveys.

**Table 2 Air quality information utilised by the preliminary assessment**

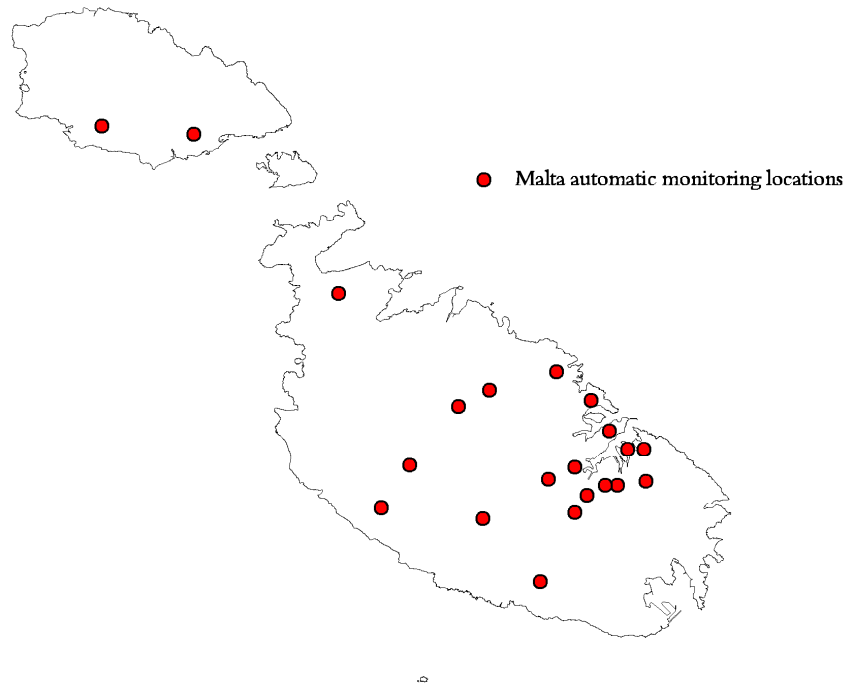
Source of information	Pollutants covered	Localities measured	Techniques used	Location types
Diffusive sampler survey March 2000 to May 2001	NO <sub>2</sub> , SO <sub>2</sub> , benzene, O <sub>3</sub>	28	Palms type tubes - NO <sub>2</sub> , SO <sub>2</sub> , O <sub>3</sub> Perkin-Elmer type sorbent tubes - benzene	1 roadside, 1 urban intermediate and 2 urban background per locality
Automatic monitoring campaign  September 1999 to February 2002	NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> , PM10	21	NO <sub>x</sub> – chemiluminescence SO <sub>2</sub> – UV fluorescence CO – IR absorption O <sub>3</sub> – UV absorption PM10 – beta attenuation	1 roadside location per locality
Emissions inventory for Malta (1997)	NO <sub>x</sub> , SO <sub>2</sub> , CO, lead, Dust, NMVOC	n/a	Collector software	n/a

The emissions inventory for Malta has been used to provide surrogate information on the potential for elevated pollutant concentrations, particularly for species that were not measured in the surveys described above.

**Figure 5 Coverage of Malta and Gozo provided by diffusive sampler survey**



**Figure 6 Coverage of Malta and Gozo provided by automatic monitoring campaign**



## 3.2 NITROGEN DIOXIDE

### 3.2.1 Methodology

Exceedences of the annual average assessment thresholds for nitrogen dioxide have been estimated using annual average data derived from the diffusion tube survey. The extensive coverage of key towns and cities within Malta has also enabled these data to be interpolated; the resulting maps provide an indication of the spatial distribution of this pollutant.

Exceedence of the hourly assessment threshold for nitrogen dioxide has been estimated using the automatic monitoring data. It should be noted that, owing to the short-term duration of the automatic monitoring campaigns, it is not possible to demonstrate formal compliance with the hourly assessment threshold. However, if the numbers of exceedences over the duration of each monitoring period are greater than that allowed by the Directive, it is possible to demonstrate exceedence.

Figure 6 presents measured annual mean NO<sub>2</sub> concentrations at locations in the diffusion tube-monitoring network. Measured concentrations have been colour coded to indicate exceedence of the UAT (32 µg/m<sup>3</sup>) and the LAT (26 µg/m<sup>3</sup>).

Figures 7a-d present bilinear interpolated plots of annual mean NO<sub>2</sub> concentrations. Interpolations have been prepared for sampler locations that are representative or broad sections of urban land within Malta (urban background and urban intermediate locations in the sampler network). Interpolated roadside measurements are not presented, as these measurements are only representative of very a limited spatial areas close to busy roads.

Figures 7a-d have been colour coded to estimate the likely extent of areas exceeding the LAT and UAT and also the overall spatial distribution of NO<sub>2</sub>.

### 3.2.2 Observations

#### ***Diffusive sampler network***

Figure 6 shows that measured annual mean NO<sub>2</sub> concentrations at roadside locations within the Valletta and Sliema agglomeration are routinely above the UAT. Within the Malta zone, concentrations at the roadside are generally below the LAT although exceedence of the UAT is indicated in Mellieha to the north of Malta and of the LAT in Marsaxlokk.

Intermediate locations in the Malta zone are shown to be routinely below the LAT. Within the Valletta and Sliema agglomeration, however, concentrations were generally above the LAT; within the in the Sliema, Valletta and Grand Harbour districts, concentrations were greater than the UAT. Background concentrations are shown to be below the LAT in most areas of the Malta zone and agglomeration with the exception of areas of Valletta and Grand Harbour district, where concentrations exceed the LAT and UAT. The interpolated plots presented in Figures 7a-b confirm these observations.

The overall spatial distribution of NO<sub>2</sub> concentrations is illustrated by Figure 7c-d. These present a bilinear interpolation of annual mean concentrations at background and intermediate sampler locations. Figure 7c-d clearly shows that highest concentrations are measured within the Valletta and Sliema agglomeration and other key urban areas with significant road transport NO<sub>x</sub> emissions.

The annual average Limit Value (40 µg/m<sup>3</sup>) and Margin of Tolerance (60 µg/m<sup>3</sup>) for 2000 were exceeded at roadside sites in the agglomeration. Sites exceeding include Sliema, Zabbar and Hamrun (> Limit Value) and Floriana and Mosta (>Margin of Tolerance).

### **Automatic monitoring campaign**

An analysis of hourly average data from the automatic monitoring campaign indicates that 9 sites exceeded the hourly average LAT and UAT within the Valletta and Sliema agglomeration. There were no identifiable exceedences within the Malta zone. Table 3 below identifies the sites within the Valletta and Sliema agglomeration where exceedences were measured.

**Table 3 Automatic monitoring locations measuring hourly average data greater than the LAT and UAT**

Site	Period of monitoring	N <sup>o</sup> . of exceedences of the hourly UAT	N <sup>o</sup> . of exceedences of the hourly LAT	Exceedence criteria
Hamrun	16.02.2001-03.03.2001	4	36	LAT
Kalkara	27.11.1999-9.12.1999	6	20	LAT
Luqa	23.11.2001-05.12.2001	13	24	LAT
Marsa	15.10.2001-09.11.2001	96	125	UAT
Marsa	02.05.2000-26.05.2000	1	35	LAT
Naxxar	1,07-15.01.2002, 22-28.02.2002	12	21	LAT
Swiegi	21.08.2000-07.09.2000	55	130	UAT
Valletta	15.09.2001-02.10.2001	51	82	UAT
Zabbar	11.03.2000-20.03.2000	2	33	LAT

LAT = Lower assessment threshold (26 µg/m<sup>3</sup>)

UAT = Upper assessment threshold (32 µg/m<sup>3</sup>)

It should be noted that although exceedence at other locations were not identified over the periods monitored, it is not possible to demonstrate compliance with the LAT and UAT owing to the limited sampling times.

### **3.2.3 Proposals**

Exceedence of either the annual average or hourly LAT and UAT have been identified within both the Malta zone and Valletta and Sliema agglomeration. It is



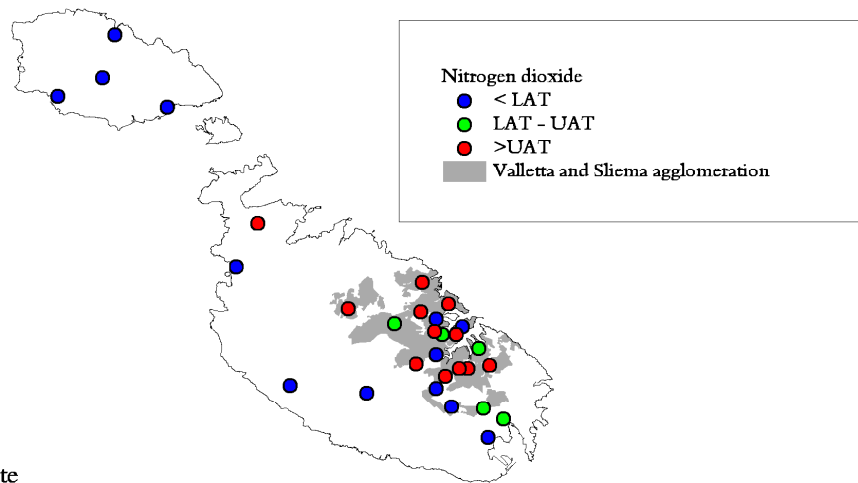
proposed, therefore, that monitoring for the protection of human health will be required within both zones for NO<sub>x</sub>.

Based on guidance provided by the Directive (Annex VII) and taking into account the population density of the Valletta and Sliema agglomeration, the population of the Malta zone and the measured exceedences, the following recommendations are made for minimum compliance with 1<sup>st</sup> Daughter Directive:

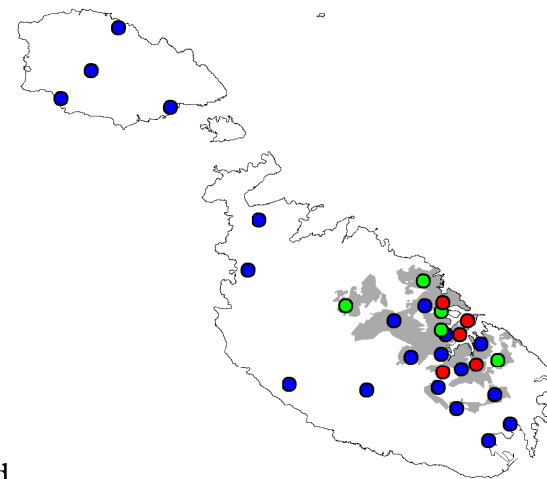
1. Two fixed NO<sub>2</sub> monitoring stations are required within the Valletta and Sliema agglomeration
2. One fixed NO<sub>2</sub> monitoring station is required within the Malta zone

**Figure 6 Annual average nitrogen dioxide concentration, Malta 2000-2001 ( $\mu\text{g}/\text{m}^3$ )**

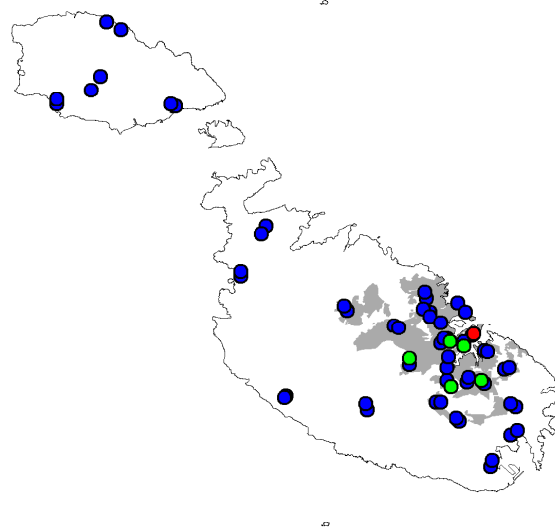
Roadside



Urban intermediate



Urban background



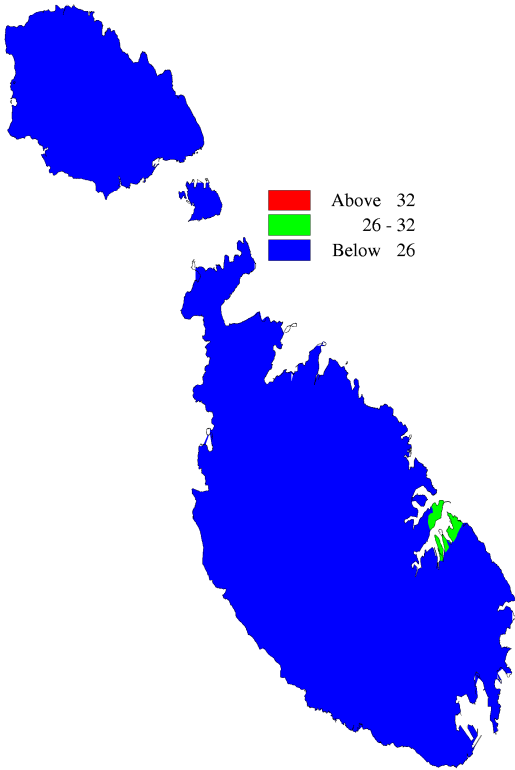


Figure 7a Annual average NO<sub>2</sub> concentrations relative to the UAT and LAT, Urban background (µg/m<sup>3</sup>)

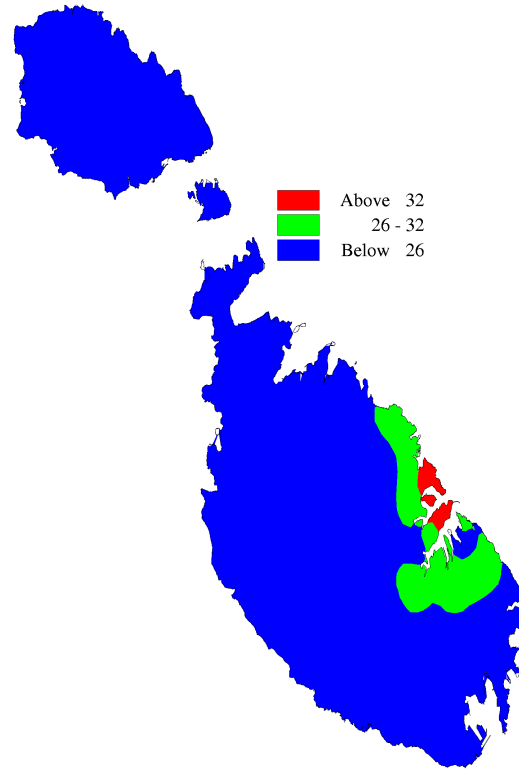


Figure 7b Annual average NO<sub>2</sub> concentrations relative to the UAT and LAT, Urban intermediate (µg/m<sup>3</sup>)

Figure 7c Spatial distribution of annual average NO<sub>2</sub> concentrations, Urban background (µg/m<sup>3</sup>)

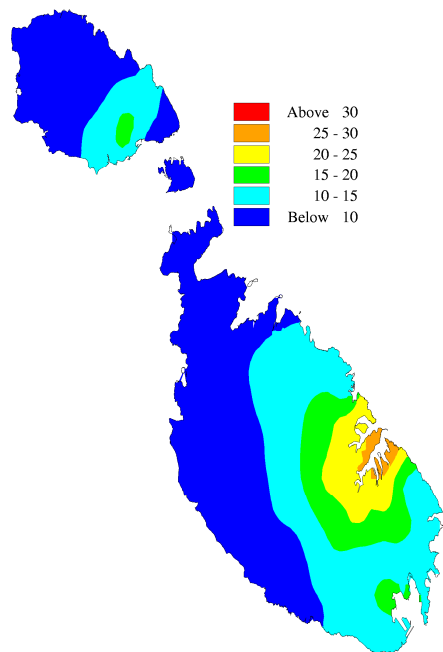
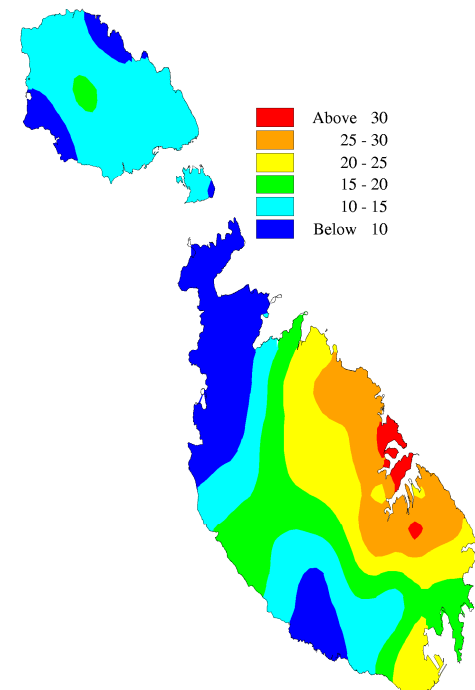


Figure 7d Spatial distribution of annual average NO<sub>2</sub> concentrations, Urban intermediate (µg/m<sup>3</sup>)



## 3.3 BENZENE

### 3.3.1 Methodology

Exceedences of the annual average assessment thresholds for benzene have been estimated using annual average data derived from diffusion tube measurements. The extensive coverage of key towns and cities within Malta has also enabled these data to be interpolated to provide an indication of the spatial distribution of this pollutant. Measurements of benzene levels were not made using automatic techniques.

Figures 8 present measured annual mean benzene concentrations at locations in the diffusion tube monitoring network. Measured concentrations have been colour coded to indicate exceedence of the UAT ( $3.5 \mu\text{g}/\text{m}^3$ ) and the LAT ( $2 \mu\text{g}/\text{m}^3$ ).

Figures 9a-d present bilinear interpolated plots of annual mean benzene concentrations. Interpolations have been prepared for sampler locations that are representative of broad sections of urban land within Malta (urban background and urban intermediate locations in the sampler network). Interpolated roadside measurements are not presented, as these measurements are only representative of very a limited spatial areas close to busy roads.

Figures 9a-d have been colour coded to estimate the likely extent of areas exceeding the LAT and UAT and also the overall spatial distribution of benzene.

### 3.3.2 Observations

#### *Diffusive sampler network*

Figure 8 shows that measured annual mean benzene concentrations at the roadside, intermediate and urban background locations in the Valletta and Sliema agglomeration and Malta zone are routinely above the LAT. Exceedences of the UAT were measured at roadside, intermediate and urban background within the Valletta and Sliema agglomeration. Within the Malta zone, exceedence of the UAT is limited to five urban areas, Marsaxlokk, Birzebbuga, Siggiewi and Mellieha.

The overall spatial distribution of benzene concentrations illustrated by Figures 9a-c. These interpolations indicate that, even away from busy roads, much of Malta is likely to have benzene concentrations that exceed the UAT. Highest concentrations are demonstrated to be in the Valletta and Sliema agglomeration. Given the significant car usage in this area, this observation is consistent with the most likely significant source of emission for this pollutant. Exceedences of the Limit Value ( $5 \mu\text{g}/\text{m}^3$ ) were measured at 70% of sites and of the Margin of Tolerance at 28% of sites.

### 3.3.3 Proposals

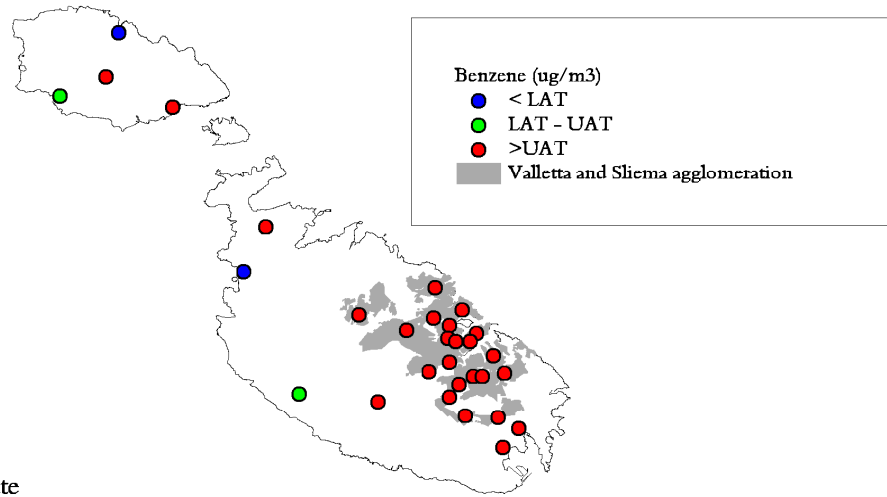
Exceedences of the annual average LAT and UAT for benzene have been identified within both the Malta zone and Valletta and Sliema agglomeration. It is proposed, therefore, that monitoring of this pollutant for the protection of human health is required within both zones.

Based on guidance provided by the Directive (Annex V) and taking into account the population density of the Valletta and Sliema agglomeration, the population of the Malta zone and the measured exceedences, the following recommendations are made for minimum compliance with 2<sup>nd</sup> Daughter Directive:

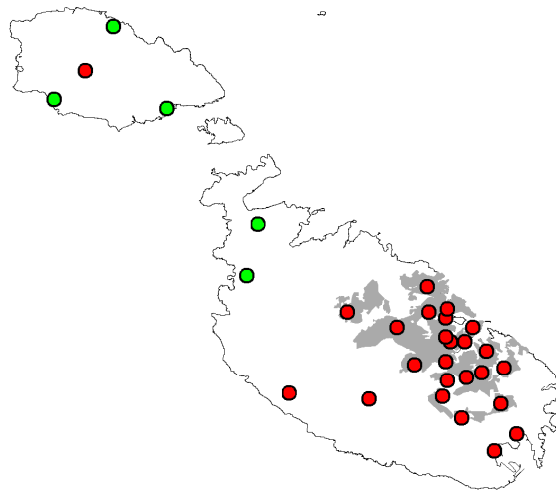
- Two fixed NO<sub>2</sub> monitoring stations are required within the Valletta and Sliema agglomeration
- One fixed NO<sub>2</sub> monitoring station is required within the Malta zone

**Figure 8 Annual average benzene concentrations, Malta 2000-2001 ( $\mu\text{g}/\text{m}^3$ )**

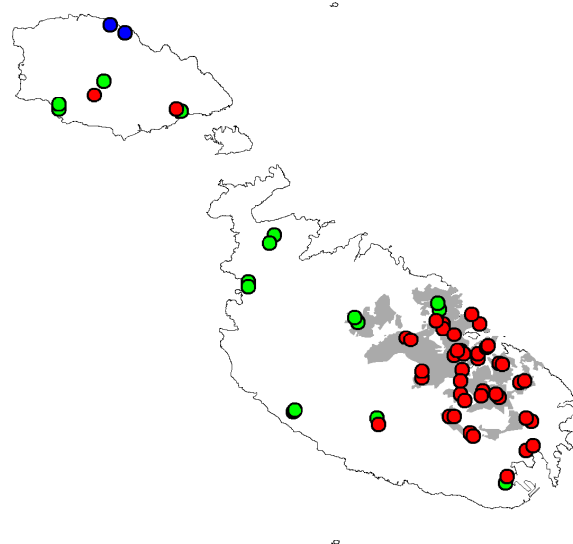
Roadside



Urban intermediate



Urban background



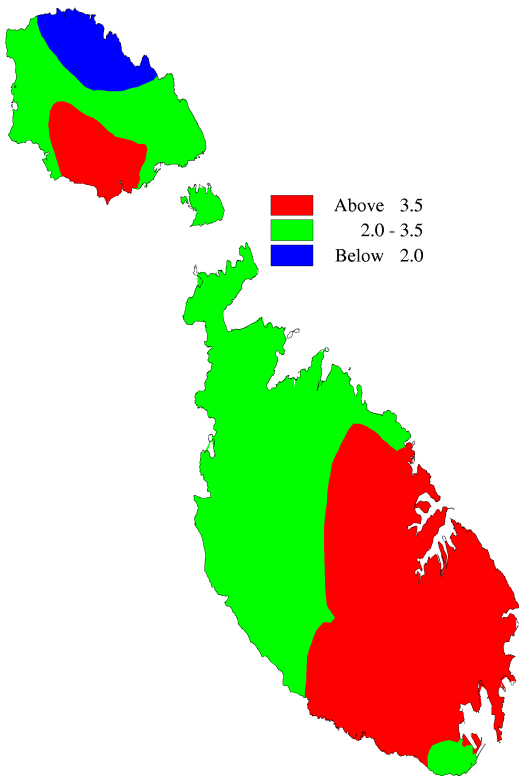


Figure 9a Annual average benzene concentrations relative to the UAT and LAT, Urban background ( $\mu\text{g}/\text{m}^3$ )

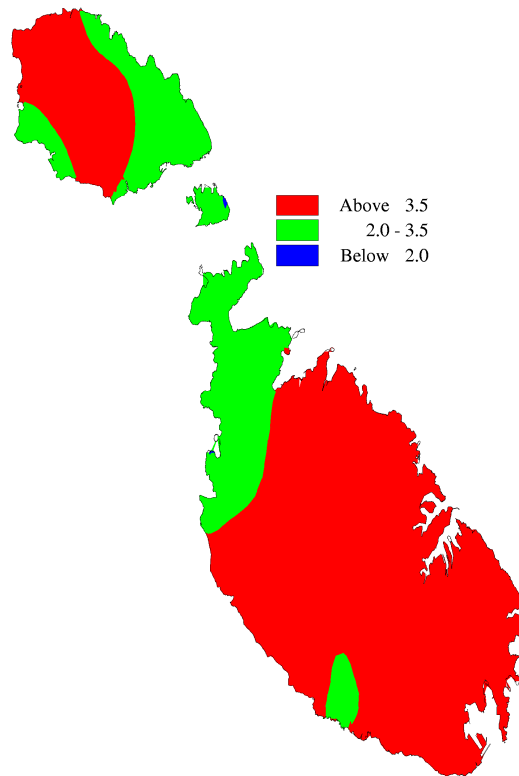


Figure 9b Annual average benzene concentrations relative to the UAT and LAT, Urban intermediate ( $\mu\text{g}/\text{m}^3$ )

Figure 9c Spatial distribution of annual average benzene concentrations, Urban background ( $\mu\text{g}/\text{m}^3$ )

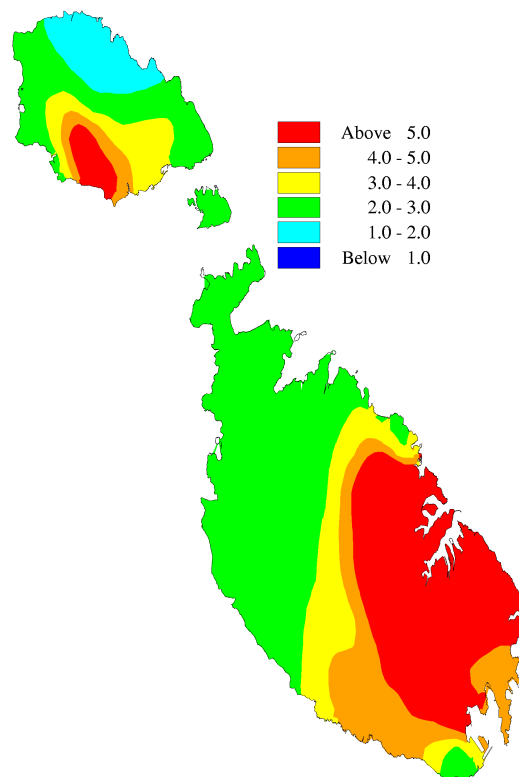
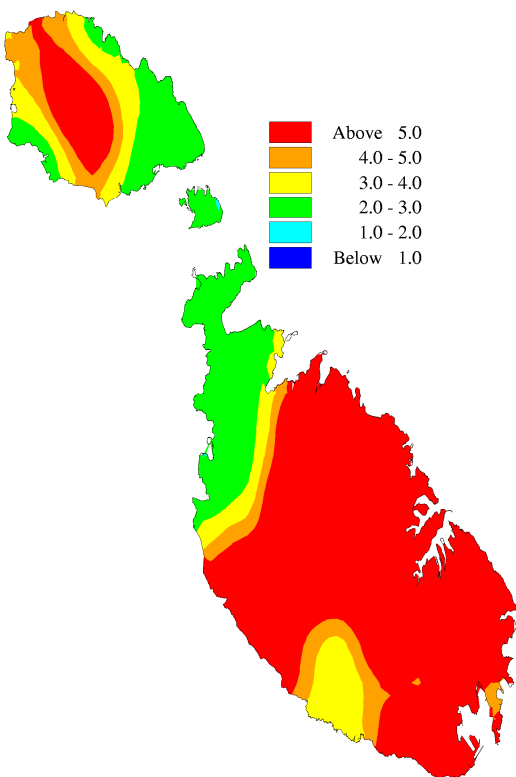


Figure 9d Spatial distribution of annual average benzene concentrations, Urban intermediate ( $\mu\text{g}/\text{m}^3$ )



## 3.4 SULPHUR DIOXIDE

### 3.4.1 Methodology

Formal compliance with the assessment thresholds for sulphur dioxide cannot be determined from diffusion tube measurements, owing to the averaging time specified by the Directive being incompatible with this measurement technique. However, local knowledge of the major sources of this pollutant has indicated that short-term sulphur dioxide concentrations may be a significant issue in Malta. As a result, the measured data provided by the diffusive sampler network provides useful information on likely hotspots and general distribution of this pollutant.

Exceedences of the hourly assessment threshold for sulphur dioxide have been estimated using the automatic monitoring data. It should be noted that, owing to the short-term duration of the automatic monitoring campaigns, it is not possible to demonstrate formal compliance with the hourly assessment threshold. However, if the numbers of exceedences over the duration of each monitoring period are greater than that allowed by the Directive, it is possible to demonstrate that exceedence.

Figure 10 presents measured annual mean SO<sub>2</sub> concentrations at locations in the diffusion tube-monitoring network. Figures 11a-c present bilinear interpolated plots of annual mean SO<sub>2</sub> concentrations. Interpolated maps have been prepared for sampler locations that are representative of broad sections of urban land within Malta- urban background and urban intermediate locations in the sampler network.

### 3.4.2 Observations

#### ***Diffusive sampler network***

Figure 10 shows that measured annual mean concentrations are highest at locations to the southeast of Marsa Power Station. The prevailing wind direction is northwesterly and will contribute to elevated concentrations to the south-east of the power station arising from plume touch down, advection and dispersion.

Highest concentrations are observed at roadside locations, identifying road transport as the most significant emissions source of this pollutant other than the Marsa power station.

The overall spatial distribution of SO<sub>2</sub> concentrations is illustrated by Figure 11a-c, which present bilinear interpolated of annual mean concentrations at intermediate and urban background sampler locations. These figures clearly show that the highest concentrations are measured within the Valletta and Sliema agglomeration, with a clearly identifiable area of elevated concentrations in close proximity to the Marsa power station.

#### ***Automatic monitoring campaign***

An analysis of hourly average data from the automatic monitoring campaign indicates that one site measured concentrations that exceeded the hourly average LAT and UAT. There were no identifiable exceedences at other



locations. Table 4 below identifies the site and corresponding exceedences identified from automatic monitoring.

**Table 4 Automatic monitoring locations measuring hourly average SO<sub>2</sub> data greater than the LAT and UAT**

Site	Period of monitoring	N <sup>o</sup> . of exceedences of the hourly UAT	N <sup>o</sup> . of exceedences of the hourly LAT	Exceedence criteria
Marsa	03.05.2000-26.05.2000	4	6	UAT

LAT = Lower assessment threshold (50 µg/m<sup>3</sup>)

UAT = Upper assessment threshold (75 µg/m<sup>3</sup>)

It should be noted that, although exceedence at other locations were not identified over the periods monitored, it is not possible to demonstrate compliance with the LAT and UAT owing to the limited sampling time.

### 3.4.3 Proposals

Exceedence of either the 24-hour LAT or UAT has been identified within the Valletta and Sliema agglomeration. Given the continued use of high sulphur automotive fuels, the potential for exceedences elsewhere, particularly in locations close to busy roads, remains an issue for concern. The diffusive sampler network has identified elevated concentration close to busy roads but, owing to an incompatible averaging period, these measurements are not capable of identifying formal exceedences of the assessment thresholds at these locations.

It is proposed therefore that monitoring for the protection of human health is required within both the Valletta and Sliema agglomeration and the Malta zone. In addition, in order to assess the impact of point sources in the Valletta and Sliema agglomeration, a monitoring station is recommended at the likely location of maximum ground level concentration arising point.

Based on guidance provided by the Directive (Annex VII) and taking into account the population density of the Valletta and Sliema agglomeration, the population of the Malta zone and the measured exceedences, the following recommendations are made for minimum compliance with 1<sup>st</sup> Daughter Directive

- Two fixed SO<sub>2</sub> monitoring stations are required within the Valletta and Sliema agglomeration;
- One fixed SO<sub>2</sub> monitoring station is required within the Malta zone at a point identified as the location of maximum ground level concentration arising from Marsa power station.

**Figure 10 Annual average sulphur dioxide concentrations, Malta 2000-2001 ( $\mu\text{g}/\text{m}^3$ )**

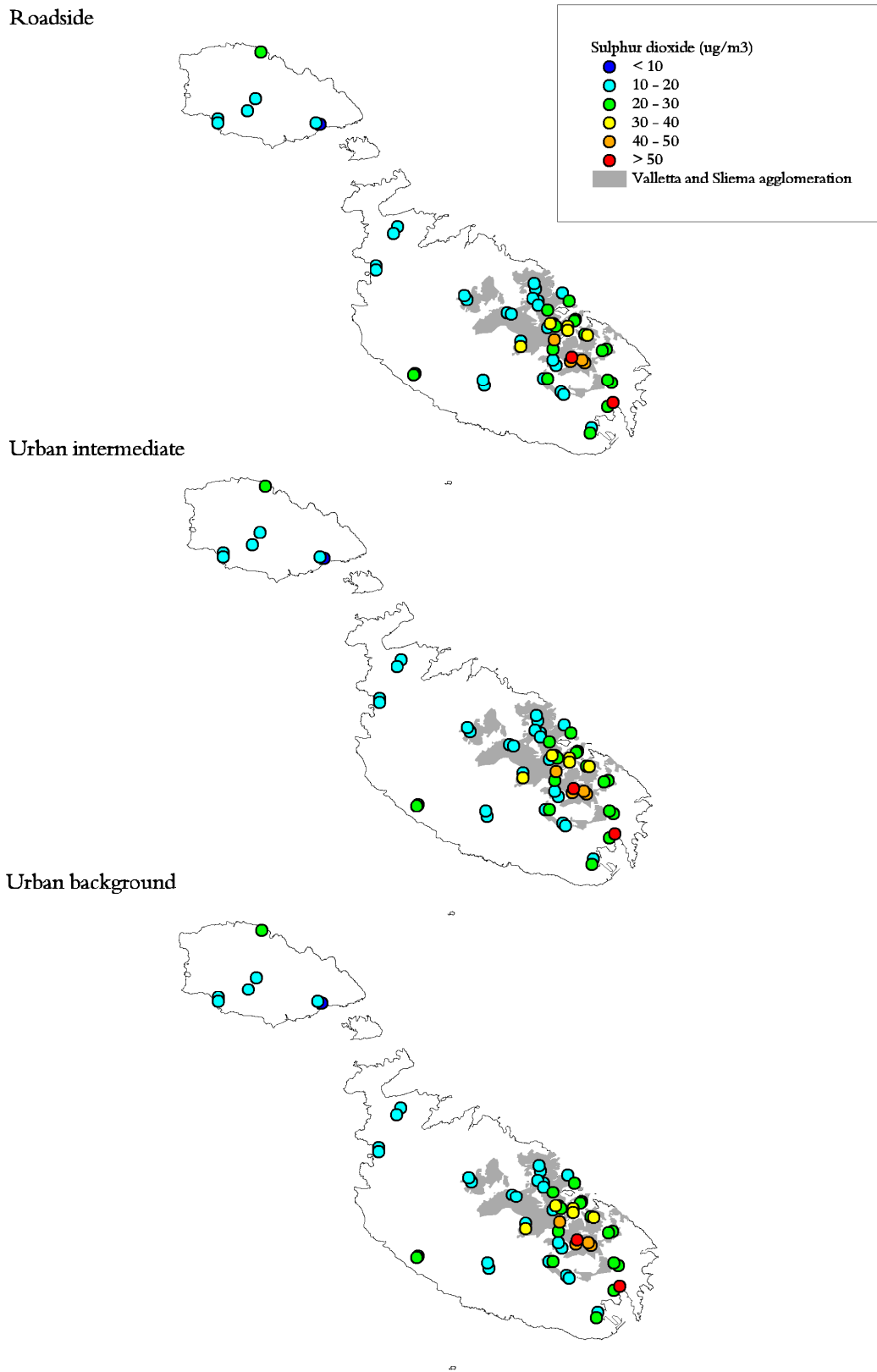


Figure 11a Spatial distribution of annual average SO<sub>2</sub> concentrations, Urban background (µg/m<sup>3</sup>)

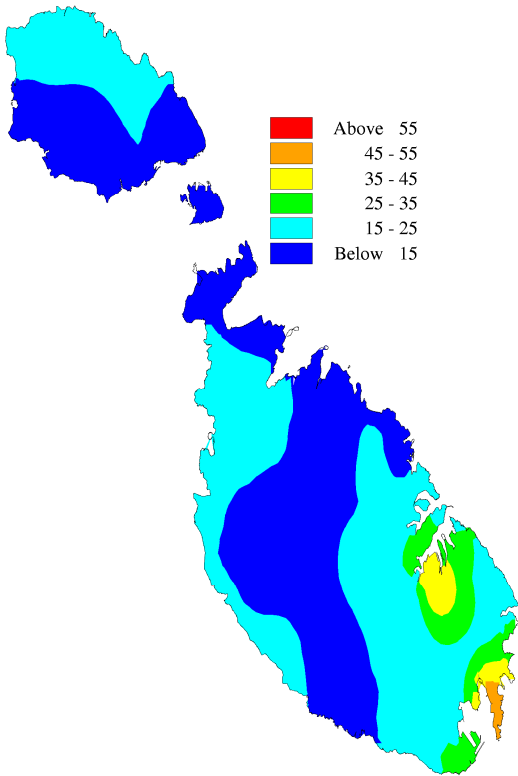


Figure 11b Spatial distribution of annual average SO<sub>2</sub> concentrations, Urban intermediate (µg/m<sup>3</sup>)

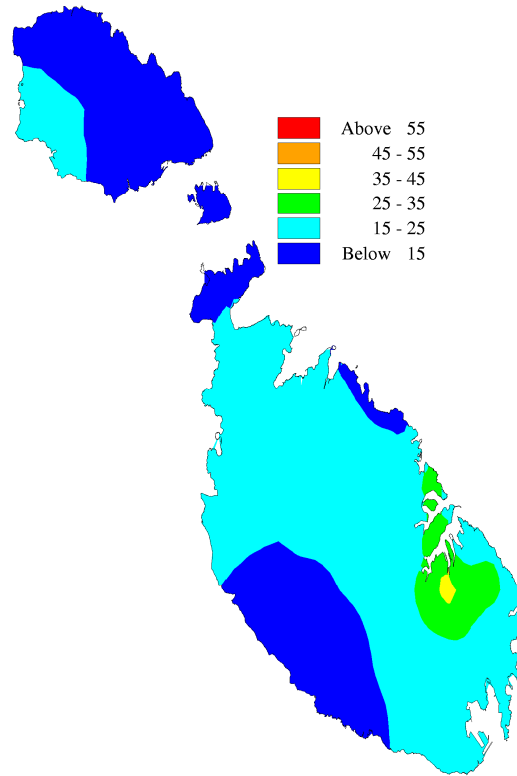
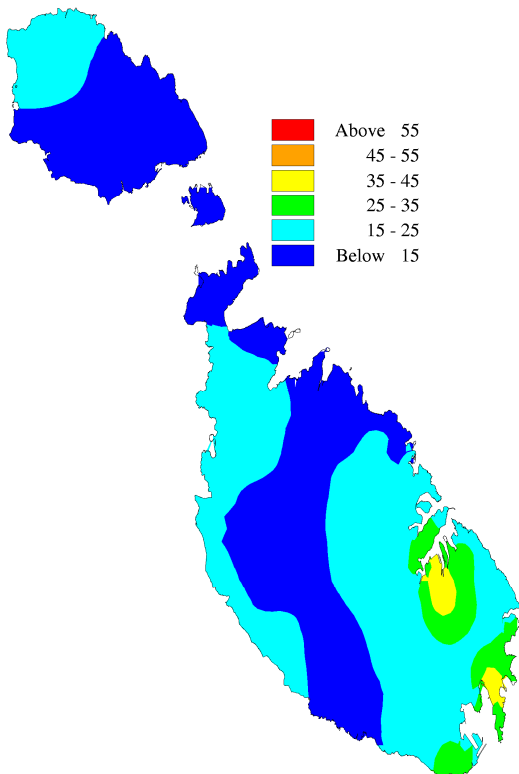


Figure 11c Spatial distribution of annual average SO<sub>2</sub> concentrations, Urban intermediate and background (µg/m<sup>3</sup>)



## 3.5 PM10

### 3.5.1 Methodology

Sampler-based techniques for measuring levels of PM10 are not available for the present assessment. For the purpose of this study, therefore, PM10 concentrations measured by an automatic beta-attenuation technique have been utilised.

Exceedences of the hourly and annual average assessment threshold for PM10 have been estimated using these automatic monitoring data. It should be noted that, owing to the short-term duration of the automatic monitoring campaigns, it is not possible to demonstrate formal compliance with these assessment threshold. However, if the numbers of exceedences over the duration of each monitoring period are greater than that allowed by the Directive, it is possible to demonstrate exceedence.

### 3.5.2 Observations

#### ***Automatic monitoring campaign***

An analysis the data from the automatic monitoring campaign indicates that all sites measured concentrations significantly above the annual average LAT and UAT. The average concentration from all sites where measurements took place was  $53 \mu\text{g}/\text{m}^3$  (standard deviation  $16.6 \mu\text{g}/\text{m}^3$ ), 379 % higher than the UAT. Clearly, it may be drawn from these measurements that there are some significant sources of PM10 in Malta.

An analysis of the 24-hour average PM10 concentrations measured by the automatic monitoring campaign shows that there were 8 monitoring sites in the Valletta and Sliema agglomeration which exceeded the 24-hour LAT and UAT for PM10. Within the Malta zone, a further 8 sites exceeded the 24-hour LAT and UAT. Table 5 identifies the sites and measured exceedences at each.

It should be noted that, although exceedence at other locations were not identified over the periods monitored, it is not possible to demonstrate compliance with the LAT and UAT owing to the limited sampling time. However, from the data available, it is reasonable to assume that difficulties in compliance with the Directive will be experienced in Malta.

**Table 5 Automatic monitoring locations measuring hourly average data greater than the LAT and UAT**

Site	Period of monitoring	N <sup>o</sup> . of exceedences of the hourly UAT	N <sup>o</sup> . of exceedences of the hourly LAT	Exceedence criteria
Dingli	8-27/9/00	13	20	UAT
Ghajnsielem	21/12/99 - 30/1/00	32	42	UAT
Hamrun	16/2 - 3/3/01	18	18	UAT
Kalkara	27/11 - 9/12/99	8	9	UAT
Luqa	23/11 - 5/12/01	10	12	UAT
Marsa	15/10 - 9/11/01	22	22	UAT
Marsa	1-20/8/00	20	20	UAT
Marsa	3-26/5/00	24	24	UAT
Mellieha	10-20/12/99	8	8	UAT
Naxxar	1, 7-15/1/02, 22-28/2/02	13	15	UAT
Qormi	22/2 - 5/3/00	9	10	UAT
Rabat	5-15/10/01	9	10	UAT
Rabat	15/4 - 2/5/00	11	15	UAT
Siggiewi	1-8/10/99	8	8	UAT
Swiegi	21/8 - 7/9/00	18	18	UAT
Valletta	15/9 - 2/10/01	16	17	UAT
Vittoriosa	6-30/9/99	23	23	UAT
Zabbar	11-20/3/00	9	9	UAT
Zurrieq	7/12/01 - 7/1/02	12	26	UAT

LAT = Lower assessment threshold (30 µg/m<sup>3</sup> not to be exceeded more than 7 times in a calendar year)

UAT = Upper assessment threshold (20 µg/m<sup>3</sup> not to be exceeded more than 7 times in a calendar year)

### 3.5.3 Proposals

Exceedences of either the 24-hour LAT or UAT have been identified within the Valletta and Sliema agglomeration and Malta zone. It is proposed, therefore, that monitoring for the protection of human health is required within both zones and at a point at likely maximum ground level concentration arising from plume touchdown from Marsa power station.

Based on guidance provided by the Directive (Annex VII), and taking into account the population density of the agglomeration, the population of the Malta zone, the measured exceedences, it is proposed that

- Two fixed NO<sub>2</sub> monitoring stations are required within the Valletta and Sliema agglomeration
- One fixed NO<sub>2</sub> monitoring station is required within the Malta zone at a point identified as the location of maximum ground level concentration arising from Marsa power station

## 3.6 LEAD

### 3.6.1 Methodology

There have been no measurements of ambient lead concentrations undertaken within the Malta. The emission inventory for Malta (1997) indicates that the main source of lead emissions to the air is from road transport, accounting for 99% of total emission. The per capita lead emission for Malta is approximately 55kg/person. Within the UK, road transport emissions also dominate emissions of lead to atmosphere, accounting for 68% of total emission in 1997<sup>7</sup>. The per capita emission rate of lead in the UK is approximately 20kg/person (1997). By comparing the emission rates for Malta and the UK, it can be shown that emissions on Malta are almost 300% higher than the UK.

The largest emissions source is likely to be the anti-knock additives for petrol. As these are emitted at a low level, therefore, the potential for exposure of the Maltese population to elevated lead levels is high.

### 3.6.2 Proposals

Given that there are no measurements of ambient lead concentrations within Malta, but having regard to the prevalence of cars and LGVs fuelled by leaded petrol and the significantly high per capita lead emission rate compared with the UK, it is proposed that the following monitoring is required for minimum compliance with the Directive.

- Two fixed NO<sub>2</sub> monitoring stations are required within the Valletta and Sliema agglomeration
- One fixed NO<sub>2</sub> monitoring station is required within the Malta zone

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<sup>7</sup> UK Emissions of Air Pollutants 1970-1999, November 2000. JWL Goodwin, AG Salway, TP Murrells, CJ Dore, NR Passant, KR King, PJ Coleman, MM Hobson, ST Pye, JD Watterson. A report for DEFRA, UK.

## 3.7 CARBON MONOXIDE

### 3.7.1 Methodology

Sampler-based techniques for measuring levels of CO are not available for this study. For the purpose of this assessment, CO concentrations measured by an automatic infrared absorption monitor have been utilised.

Exceedences of the maximum daily eight-hour average assessment threshold for CO have been estimated using the automatic monitoring data. It should be noted that, owing to the short-term duration of the automatic monitoring campaigns, it is not possible to demonstrate formal compliance with the assessment thresholds. However, if the numbers of exceedences over the duration of each monitoring period are greater than that allowed by the Directive, it is possible to demonstrate that exceedence.

### 3.7.2 Observations

#### **Automatic monitoring campaign**

An analysis the data from the automatic monitoring campaign indicates that the LAT was exceeded at one site in the Valletta and Sliema agglomeration. No exceedences of the UAT were identified. Table 6 below presents the site and exceedences identified from automatic monitoring.

**Table 6 Automatic monitoring locations measuring hourly average CO data greater than the LAT and UAT**

Site	Period of monitoring	Max. daily 8-hour mean (mg/m <sup>3</sup> )	Exceedence criteria
Swieg i	21.08.2000-07.09.2000	5.9	LAT

LAT = Lower assessment threshold (5 mg/m<sup>3</sup>)

UAT = Upper assessment threshold (7 mg/m<sup>3</sup>)

It should be noted that although exceedence at other locations were not identified over the periods monitored, it is not possible to demonstrate compliance with the LAT and UAT owing to the limited sampling time.

#### **Malta emissions inventory**

The emission inventory for Malta (1997) indicates that the main emission source of CO on Malta is road transport (representing 97% of total emission). During 1997, 21817 tonnes of CO were emitted by this sector, a per capita emission of approximately 62kg/person. Within the UK, during the same year, 3.7 Mega tonnes of CO were emitted by the road transport sector, equivalent to a per capita emission 59 kg/person. A comparison of the per capita emission rate therefore shows that emissions of CO in Malta are broadly consistent with those in the UK. It is assumed from this comparison that exceedences of the LAT and UAT in Malta are likely to be broadly consistent with those observed in the UK. Within UK, the extensive national monitoring networks have identified exceedence of the UAT and LAT close to busy roads and at urban centre

locations<sup>8</sup>. Within the UK, measured exceedences of the UAT and LAT have triggered a requirement to monitor CO in all zones and agglomerations.

Exceedence of the maximum 8-hour daily average LAT has been identified within the Valletta and Sliema agglomeration. It is proposed, therefore, that monitoring for the protection of human health is required within Valletta and Sliema agglomeration. Given the lack of long-term fixed monitoring within the Malta zone, it is proposed that, monitoring for the protection of human health is also required within this zone.

Based on guidance provided by the Directive (Annex V) and taking into account the population density of the Valletta and Sliema agglomeration, the population of the Malta zone, the measured exceedences and CO emissions in Malta, it is proposed that

- One fixed CO monitoring stations is required within the Valletta and Sliema agglomeration
- One fixed CO monitoring station is required within the Malta zone

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<sup>8</sup> Preliminary Assessment of benzene and carbon monoxide levels in the UK. T Bush, February 2002 (Draft). A report to Department for Environment, Food and Rural Affairs, the Scottish Executive, the National Assembly for Wales and the DoE for Northern Ireland. NETCEN, Culham.



## 3.8 OZONE

### 3.8.1 Methodology

A requirement to monitor ozone within zones and agglomerations is mandatory where concentrations are demonstrated to exceed the long-term objective ( $120 \mu\text{g}/\text{m}^3$  as a maximum daily 8-hour average within a calendar year or  $6,000 \mu\text{g}/\text{m}^3\cdot\text{h}$  as AOT40 within a calendar year). Formal compliance with these objectives for ozone cannot be determined from diffusion tube measurements, owing to incompatible averaging periods. However, the annual average concentrations derived from diffusive sampler campaigns provide an indicative assessment of the likely concentrations and for the potential for exceeding of the long-term objective.

An analysis of the maximum daily 8-hour average automatic data has been undertaken to identify exceedences of  $120 \mu\text{g}/\text{m}^3$ . It should be noted that, owing to the short-term duration of the automatic monitoring campaigns, it is not possible to demonstrate formal compliance with the long-term objective. However, if the numbers of exceedences over the duration of each monitoring period are greater than that allowed by the Directive, it is possible to demonstrate that exceedence.

Figures 12 present measured annual mean ozone concentrations at locations in the diffusion tube monitoring network. Figures 13a-c present bilinear interpolated plots of annual mean ozone concentrations. Interpolations have been prepared for sampler locations that are representative of broad sections of urban land within Malta - urban background and urban intermediate locations in the sampler network.

### 3.8.2 Observations

#### ***Diffusive sampler network***

Figures 12 show that measured annual mean ozone concentrations are consistently higher than  $100 \mu\text{g}/\text{m}^3$  in many urban background and intermediate locations in the Valletta and Sliema agglomeration and Malta zone. Concentrations at the roadside are observed to be far lower, and this is likely to be linked the ozone scavenging effect of localised nitric oxide emissions from road traffic.

The overall spatial distribution of ozone concentrations is presented by Figures 13a - 13b, which present interpolated plots of measured annual average concentrations at urban background and intermediate locations. An analysis of the average concentrations at each location type indicates that intermediate and urban background monitoring locations behave very similarly. Typically, ozone concentrations at the urban background are only approximately 10% higher than concentrations at urban intermediate locations. As a result, measurements at these locations have been combined in the interpolated map presented in 13c.

Figures 13a-c clearly show that annual average ozone concentrations are lowest in areas of highest ground level  $\text{NO}_x$  emission (the Valletta and Sliema agglomeration). Downwind of the agglomeration, there is a notable area of

elevated of ozone concentrations which may arise from the photochemistry in the urban plume. Concentrations in other areas more distant to NO<sub>x</sub> emissions (to the southwest around Dingli and to the north of Gozo) are also notably higher than those in the agglomeration.

### ***Automatic monitoring campaign***

No identifiable exceedences of the maximum daily 8-hour average long-term objective were shown by the automatic data. Assessment relative to the AOT40 objective was not possible owing to the limited time coverage at each location.

The absence of identifiable exceedences of the long-term objective is surprising, given the levels measured by the diffusive sampler network. A possible explanation may relate to the location types used for siting the automatic mobile laboratory. In general, the mobile laboratory was located close to busy roads and hence ozone levels at such locations are likely to be suppressed as a result of local NO<sub>x</sub> emissions. It should be noted however, that although exceedence of the long-term objective were not identified over the periods monitored, it is not possible to demonstrate compliance with this objective owing to the limited sampling time.

### **3.8.3 Proposals**

From the indicative measurements provided by the diffusive sampler network, it would appear likely, given the magnitude of the annual average data measured, that an exceedence the long-term objective for ozone is possible within both in the Valletta and Sliema agglomeration and the Malta zone. Concentrations are most likely to be highest, in episode conditions, at urban background locations downwind of the Valletta and Sliema districts.

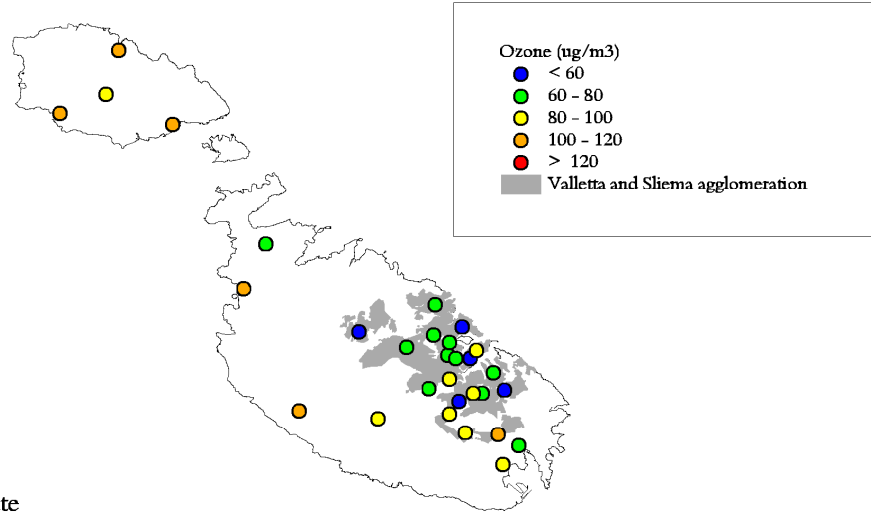
It is proposed, therefore, that monitoring for the protection of human health is required within both the Valletta and Sliema agglomeration and the Malta zone.

Based on guidance provided by the Directive (Annex V) and taking into account the population density of the agglomeration and the population of the Malta zone it is proposed that

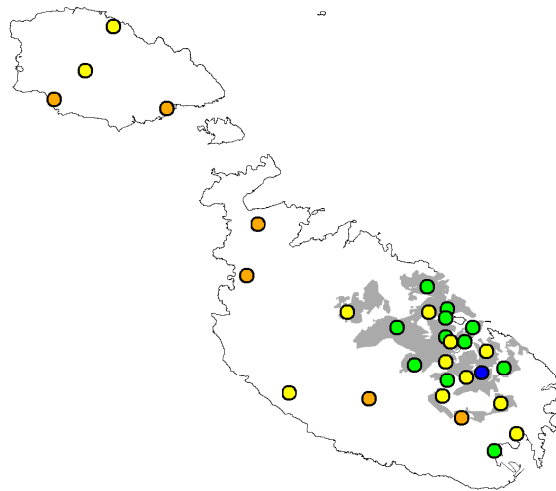
- One fixed ozone monitoring stations is required within the Valletta and Sliema agglomeration at an urban background/suburban location
- One fixed ozone monitoring station is required within the Malta zone at a suburban or rural location

**Figure 12 Annual average ozone concentrations, Malta ( $\mu\text{g}/\text{m}^3$ )**

Roadside



Urban intermediate



Urban background

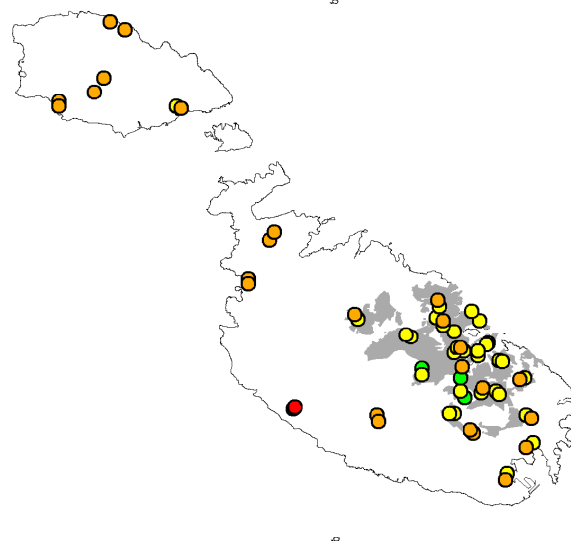


Figure 13a Spatial distribution of annual average ozone concentrations, Urban background ( $\mu\text{g}/\text{m}^3$ )

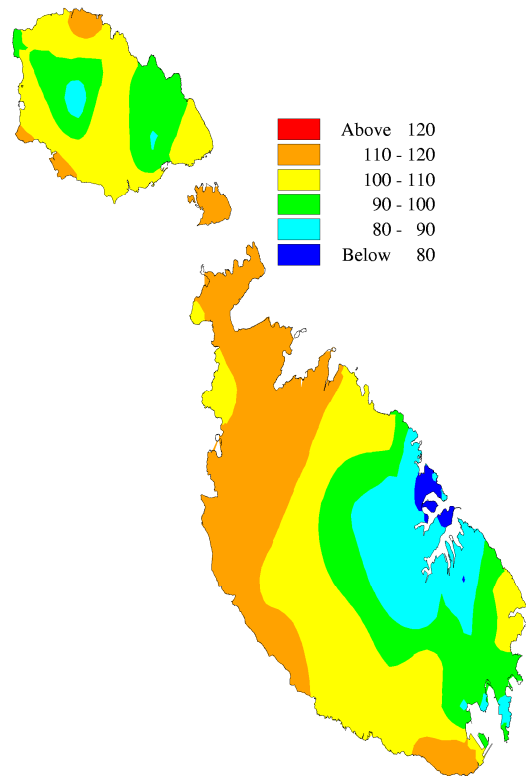


Figure 13b Spatial distribution of annual average ozone concentrations, Urban intermediate ( $\mu\text{g}/\text{m}^3$ )

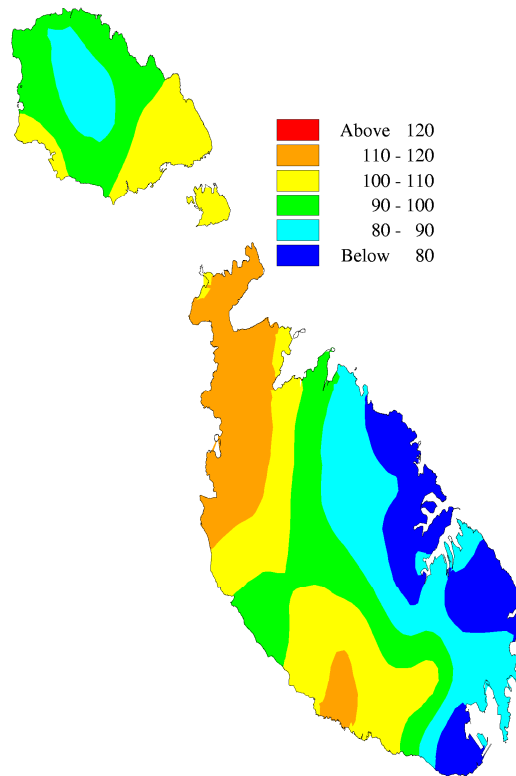
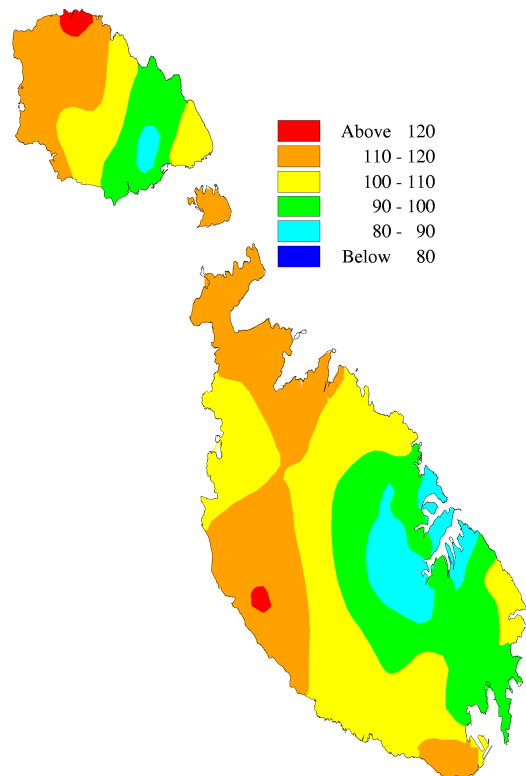


Figure 13c Spatial distribution of annual average ozone concentrations, Urban intermediate and background ( $\mu\text{g}/\text{m}^3$ )



## 4 Summary of Monitoring requirements for minimum compliance with Daughter Directives 1-3

Table 6 (overleaf) presents the maximum measured exceedence of the LAT, UAT and long-term objective statistics specified by the relevant Daughter Directives. A single exceedence of these assessment thresholds and objectives enforces a requirement to monitor the specified pollutant in that zone or agglomeration. Where no measurements have been made or exceedence statistics of the appropriate averaging period cannot be derived, it is assumed that a requirement to monitor is enforceable.

Given the exceedences presented in Table 6 and the analyses presented in previous sections, it is our recommendation that the monitoring effort presented and summarised in Table 7 will achieve minimum compliance with the 1<sup>st</sup> 2<sup>nd</sup> and 3<sup>rd</sup> Daughter Directives.

**Table 7 Minimum monitoring requirements for minimum compliance with the three Daughter Directives**

<b>Zone/agglomeration</b>	<b>Pollutants to be monitored</b>	<b>Generic location of monitoring effort</b>
<b>Valletta/Sliema agglomeration</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , CO, benzene	At roadside location in Valletta
	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , benzene	At urban background location in Valletta, Sliema or environs
	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub>	At point of max. ground level concentration for plume from Marsa power station
<b>Malta zone</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , CO, benzene	At urban background location in zone

### 4.1 RECOMMENDATIONS FOR ADDITIONAL MONITORING

The recommendations made above are sufficient for minimum compliance with Daughter Directives only. Given Malta’s topographical, climatological and geographical position and diversity, however, there are significant further considerations that need to be made.

#### ***Protection of sensitive ecosystems***

Owing to the distribution of urban areas within Malta, there are no areas of the islands that are protected by ecosystem and vegetation Limit Values (see Figure 5). It has been noted within the UK, that the approach to delineation of areas to be protected by ecosystem and vegetation Limit Values defined in Annex VI of the 1<sup>st</sup> Daughter Directive overlooks the likelihood of sensitive ecosystems existing closer to urban land than 5km. Exactly this issue has arisen within the

UK, where Sites of Special Scientific Interest (SSSIs) are effectively unprotected by the 1<sup>st</sup> Daughter Directive because of their proximity to an urban area, agglomeration, motorway or point source.

Within the UK, such issues are to be resolved as a matter of national policy based on ethical grounds. Likewise, in Malta, this approach may well be warranted. Given the limited knowledge of rural background concentrations of NO<sub>x</sub>, SO<sub>2</sub> and ozone, it would be useful to be able to characterise these concentrations for both the protection of sensitive areas and with a view to developing a modelling capability for Malta.

It should be noted that the vegetation and crops require the assessment of rural ozone concentrations by monitoring, in order to demonstrate compliance with the AOT40 targets and objectives.

### ***Assessment of Contributions from transboundary pollution***

There is significant potential within Malta for local PM<sub>10</sub> levels and, to a lesser extent, ozone levels to be effected by transboundary sources. It is anticipated that, in the future, Malta will be required to inform the Commission of an exceedence of a Limit Value or Margin of Tolerance for PM<sub>10</sub>. It is plausible also that a number of these exceedences will have resulted from natural events or sources out of the control of the Maltese authorities. In such cases, Member States are required to inform the Commission, providing necessary justification. In order to do so, it will be necessary to characterise both the meteorological conditions promoting long-range transport for the pollutant and the likely external origin.

### ***Development of action plans***

Where Limit Values or Margins of Tolerance are exceeded, Member States are required to develop action plans to reduce air pollution. In order to assess what is technically and financially viable, it is likely that contributions to measured concentrations from the rural background, urban background and roadside or point sources will be required.

On the basis of the issues presented above, it is therefore recommended that a rural background monitoring station- additional to the minimum Daughter Directive requirement of sites detailed in Table 7- be established to:

- Protect and monitor levels of pollution impacting upon sensitive ecosystems;
- Characterise transboundary pollution events and aid in dissemination of this information to the Commission;
- Aid in the source apportionment of pollution;
- Characterise rural background concentrations for future modelling exercises.

It is recommended that the rural background station would monitor the following pollutants:

*NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, ozone and meteorological data*

#### **4.1.1 Supplementary air quality information**

Further recommendations are made for providing the supplementary information on ambient air quality:

1. A reduced diffusive sampler network for ongoing characterisation of pollutant levels throughout Malta, (key pollutants of interest NO<sub>2</sub> and benzene)
2. Continuous annual updates to the emissions inventory for Malta and development of spatially disaggregated inventory
3. Dispersion modelling studies of significant point sources
4. Utilisation of a mobile laboratory for short-term hotspot monitoring
5. Development of a mapping/modelling capability

**Table 6 Highest identified exceedence statistics for pollutants regulated by Daughter Directives 1-3**

Pollutant	Parameter	Highest measured annual mean diffusion tube concentrations within proposed agglomerations and zones (ug/m3)								
		Proposed Malta agglomeration			Proposed Valletta agglomeration			Proposed zone		
		Roadside	Intermediate	Background	Roadside	Intermediate	Background	Roadside	Intermediate	Background
Nitrogen dioxide	Annual average	79	39	35	79	39	35	49	29	28
	Hourly average	96	n/a	n/a	96	n/a	n/a	13	n/a	n/a
Sulphur dioxide	24-hour average	4	n/a	n/a	4	n/a	n/a	n/a	n/a	n/a
PM10	Annual average	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	24-hour average	24	n/a	n/a	24	n/a	n/a	32	n/a	n/a
Lead	Annual average	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Benzene	Annual average	28	23	26	28	23	26	22	15	17
Carbon monoxide	Max 8-hour average	5.9	n/a	n/a	5.9	n/a	n/a	n/a	n/a	n/a
Ozone	Max daily 8-hour average	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	AOT40	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Type of exceedence identified from annual mean diffusion tube data (italics indicate estimated exceedence)										
		Proposed Malta agglomeration			Proposed Valletta agglomeration			Proposed zone		
		Roadside	Intermediate	Background	Roadside	Intermediate	Background	Roadside	Intermediate	Background
		UAT	UAT	UAT	UAT	UAT	UAT	UAT	LAT	LAT
	Nitrogen dioxide	UAT	UAT	UAT	UAT	UAT	UAT	UAT	LAT	LAT
	Sulphur dioxide	UAT	UAT	UAT	UAT	UAT	UAT	UAT	UAT	UAT
	PM10	UAT*	n/a	n/a	UAT*	n/a	n/a	UAT*	n/a	n/a
	Lead	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*
	Benzene	UAT	UAT	UAT	UAT	UAT	UAT	UAT	UAT	UAT
	Carbon monoxide	LAT	n/a	n/a	LAT	n/a	n/a	n/a	n/a	n/a
	Ozone	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*	UAT*

UAT – indicates exceedence of Upper Assessment Threshold

LAT – indicate exceedence of Lower Assessment Threshold

\* - indicates exceedence by default as a result of monitoring data unable to resolve to the averaging period of assessment threshold/objective or monitoring not undertaken



## **5 Development of plans to improve air quality**

From the preliminary assessment of air quality presented in Section 2 of this report, there are clearly air quality problems within Malta at the present time relative to the levels specified by the Daughter Directives. In addition, there is potential for air quality Limit Values and Margins of Tolerance set out in the Daughter Directives to be breached in the future if current 'business as usual policies' continue.

As a future Member State of the European Community, a breach of the Limits Values and Margins of Tolerance enforces a requirement for Malta to submit Action Plans which will lead to the improvement quality and attainment of Limit Values and objectives.

In considered the development of a local or national plan or strategy to improve air quality, the following key issues must be addressed:

- Options for reducing emissions
- Quantification of costs of abatement strategies
- Quantification of benefits of reducing emissions
- Quantification of benefits
- Comparison of benefits and costs

It is important that all the available options should be evaluated and that all relevant local/national professionals and departments should be involved from the start. The need for co-operation, partnership and commitment from all interested parties cannot be underestimated.

Action plans must be incorporated and integrated effectively into local/national policy in order for them to be sustainable. They therefore need to be part of local/national planning, especially so in the case of transport planning.

### **5.1 INSTRUMENTS AVAILABLE FOR REDUCING EMISSIONS**

There are various instruments available for reducing emissions and therefore meeting the objectives. These include:

- Traffic management
- Land-use planning
- Regulation of large industrial plant emissions
- Regulation of small industrial plant emissions
- Industrial smoke control
- Domestic smoke control
- New vehicle specifications
- Vehicle emission testing and control over stationary vehicles
- Fuel switching

- Tax incentives for the reduction of emissions from
  - Cars (renewal of the car fleet, fuel switching)
  - Large combustion plant
- Promotion of public transport system

It is important to ensure that statutory regulation and enforcement powers are implemented where appropriate.

The control measures contributing to the plan need to be determined in an objective, targeted and cost-effective way. The reductions in emissions required should depend both on the relative contribution of the sector and also the cost of reducing emissions. In other words control measures should be "relative, objective, cost effective and proportionate".

The subsequent sections consider the options available to reduce emissions and improve air quality. They have been developed for the UK case. However, these will in general transfer effectively to the development of an Action Plan for Malta.

### **5.1.1 Stationary Sources**

#### ***PM10 and NO2***

Strict enforcement of authorisation limits on large and small stationary sources, as specified by the Large Combustion Plant Directive or other enforcement mechanism, will be essential. Assessment of contributions to local PM10 levels from transboundary sources will, likewise, be necessary for proper application for derogations and exemptions.

#### ***SO<sub>2</sub>***

Strict enforcement of authorisation limits on large and small stationary sources, as specified by the Large Combustion Plant Directive or other enforcement mechanism, will be essential. Consideration also needs to be given to the impact of the Directive on Sulphur Content of Liquid Fuels and the New European Fuel Quality Directives. The potential for reductions in emissions will largely fall on industrial operators of oil and coal fired boiler plant and large industrial sites burning both coal and oil, along with refineries.

Generic technical options available include:

- End of pipe treatment
- Fuel switching
- Energy Efficiency (Best Practise)
- Limited changes in behaviour

Consideration needs to be given to the costs to industry and the public. Consequently, a combination of measures from the options available may be the best way proceeding

### **5.1.2 Transport**

There is a greater burden to assess the options and effects (including demand) of control of emissions from transport as a result of the potential

savings in emission. Other issues include the impact of future planning, noise and congestion.

Options for reducing emissions from transport tend to be classed in three main categories: technical; non-technical and management measures. The last two, although in many cases the most cost-effective, are often the most difficult to implement.

### **Technical options**

Appropriate technical options include the range of technical measures for private cars (requires national/EU legislation), cleaner public transport (new modes, alternative fuels, new stock) and cleaner vehicle fleets for both local authorities and local commerce and industry.

With regard to public transport and vehicle fleets the, following technical options are available:

- Tailpipe Treatments
- De-NOx catalyst for diesels
- Oxidation catalytic converters for buses
- Continuously regenerating traps (CRT)
- Alternative and Reformulated Fuel Types
- CNG vehicles
- LPG vehicles
- Low sulphur diesel
- Ethanol vehicles
- Methanol vehicles
- Alternative Drive Trains
- Fuel cell vehicles, electric vehicles, hybrids
- City diesel
- De NOx catalysts for diesel vehicles
- Alternative fuels (CNG, LPG)

The relative performance of these need to be evaluated on the cost per tonne of pollutant abated.

### **Non-Technical Options**

The main non-technical options include economic and fiscal measures (fuel tax, etc.), roadside checks, public information and driver awareness. It is generally believed that the first two offer the most significant potential reductions in emissions.

### **Traffic Management Options**

Local traffic management options include congestion reduction, traffic constraint and shifts to different modes of transport. However, their effectiveness and the impact on demand must be carefully assessed.

*Congestion Reduction and Traffic Constraint* - Congestion can be relieved by using systems such as red route parking, speed and urban traffic control in conjunction with other restraint measures like road pricing in urban areas and highways and traffic restriction measures such as licence plate permit entry, area bans and no-drive days.

*Encouraging Modal Shift* - Modal shift can be encouraged by the provision of:

- Park and ride facilities
- Parking restrictions
- New transport systems (e.g. tram, light rail)
- Bus priority measures
- Reduced public transfer fares
- Improvement of cycling and walking
- Encouraging high occupancy vehicles
- Employer based measures
- Land use planning

Studies- for example for central London in the UK- show that greater potential for emissions reductions is achieved with a careful combination of approaches.

### 5.1.3 Assessing costs

Care needs to be taken when assessing costs, in order to ensure that all cost estimates are presented in equivalent terms. This means that the equivalent annual costs of measures are used, that all costs are for the same year, same discount rate, and that the cost stream is annualised. Costs should be normalised to equivalent annual costs of each measure of emissions reduction (e.g. cost per tonne abated). An example of the ranking of relative costs in terms of cost per unit reduction of emissions is presented in Table 8 below. In this case, the most cost-effective option is fuel switching. Whilst there is a cost implication for small firms, case studies have shown that where favourable long-term contracts can be negotiated, actual cost savings can result.

**Table 8 Ranked costs of options**

SOURCE	CONTROL OPTION	£/tonne
Small Industrial - Coal	Fuel switching – High to Low Sulphur Coal	33
Domestic – Coal	Fuel switching – High to Low Sulphur Coal	33
ESI – Coal	Fuel switching – High to Low Sulphur Coal	89
Large Industrial – Coal	Fuel switching – High to Low Sulphur Coal	167
Iron & Steel – Coal	Fuel switching – High to Low Sulphur Coal	167
ESI – Oil	Fuel switching – Oil to Gas	197
Large Industrial – Oil	Fuel switching – Oil to Gas	197
Small Industrial – Oil	Fuel switching – Oil to Gas	197
Refineries – Oil	Fuel switching – Oil to Gas	197
Iron & Steel – Oil	Fuel switching – Oil to Gas	197
Domestic – Oil	Fuel switching – Oil to Gas	296
ESI – Oil	Fuel switching – High to Low Sulphur Oil	346
Large Industrial	Fuel switching – High to Low Sulphur Oil	346
Small Industrial – Oil	Fuel switching – High to Low Sulphur Oil	346
Refineries – Oil	Fuel switching – High to Low Sulphur Oil	346
Iron & Steel – Oil	Fuel switching – High to Low Sulphur Oil	346
Domestic – Oil	Fuel switching – High to Low Sulphur Oil	346
ESI – Oil	FGD – Lime Slurry Scrubbing/Spray Drying Process	354
Large Industrial – Oil	FGD – Lime Slurry Scrubbing/Spray Drying Process	354
Refineries – Oil	FGD – Lime Slurry Scrubbing/Spray Drying Process	354
Iron & Steel – Oil	FGD – Lime Slurry Scrubbing/Spray Drying Process	354

Less cost-data are available on non-technical measures to abate pollution from transport, and these tend to be very site specific. Non-technical measures usually offer the least- cost option. In some areas, to achieve

targets may require a combination of both technical and non-technical measures.

## 6 Emissions standards for the reduction of air pollution

Atmospheric pollutants, which enter the air from a wide variety of sources, can be subdivided into three broad categories:

- Emissions from mobile sources (transport industry)
- Emissions from immobile source (businesses, homes, farms and rubbish dumps)
- Emissions caused by power generation

The European Union has implemented a number of activities and Directives designed to control air pollution and its effects. The recommendation of specific emissions standards for individual sources within Malta lies beyond the scope of this report; However, the EU instruments outlined in the following sections propose emissions targets and standards for all major polluting sectors.

### 6.1 EMISSIONS FROM THE TRANSPORT SECTOR

Several directives have been adopted at Community level in order to limit pollution due to transport, set maximum emission limits for vehicles and other sources of pollution and introduce tax measures in the transport sector aimed at encouraging the consumer to act in a more environmentally friendly manner.

#### 6.1.1 The Auto-oil programme

In co-operation with the oil and motor vehicle industries, the Commission has devised a common "Auto-oil" programme to reduce exhaust gas emissions. The programme comprises two new directives (98/69<sup>9</sup> and 98/70<sup>10</sup> amending Directives 70/156<sup>11</sup> and 70/220<sup>12</sup>) dealing with the quality of petrol and diesel fuel and measures to tackle air pollution from motor-vehicle emissions.

- The new directive 98/70 reduces pollution emanating from car emissions by introducing new environmental specifications applicable to petrol and diesel fuels and it bans leaded petrol from the market

<sup>9</sup> Council Directive 98/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Council Directive 70/220/EEC.

<sup>10</sup> Council Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC

<sup>11</sup> Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers.

<sup>12</sup> Council Directive 70/220/EEC of 20 March 1970 on the approximation of the laws of the Member States on measures to be taken against air pollution by emissions from motor vehicles

- from the year 2000. It also provides for progressive improvements in the environmental quality of unleaded petrol and diesel fuel.
- The directive 98/69 lays down differing limit values for emissions, by petrol and diesel cars, which shall apply from 2000 and 2005, according to the type of vehicle. Tax incentives granted by Member States to encourage advance compliance with new limit values are permitted and after 28 September 1999, the new European test cycle provided by this directive shall apply.
  - The Directive 98/77<sup>13</sup> inserts new technical requirements into Directive 70/220 such as the EC approval of replacement catalytic converters as separate technical units, the EC approval of vehicles, which may operate on liquefied petroleum gas or natural gas, and the measurement of rolling resistance.

### **6.1.2 Light commercial vehicles**

On 26 June 1991, the Council adopted the consolidated emissions Directive 91/441<sup>14</sup>. This directive particularly concerns passenger vehicles with a maximum capacity of six passengers and a maximum weight of 2500 kg and regulates both tailpipe emissions (including a durability test) and evaporative emissions. It was amended by Directive 94/12.

### **6.1.3 Heavy goods vehicles**

On 1 October 1991, the Council adopted Directive 91/542<sup>15</sup>, reducing in two stages the limit values for gaseous emissions and particulate pollutants from diesel-engine and other heavy goods vehicles of over 3.5 tonnes.

### **6.1.4 Light commercial vehicles of up to 3 500 kg and heavy vehicles for more than six occupants**

These vehicles, with engine categories M and N, M1 and N1, are the subject of Directive 93/59<sup>16</sup>. It categorises vehicles according to differences in power and design: Class I, with a reference weight of up to 1 250 kg; Class II, with a reference weight from 1 250 kg to 1 700 kg; and Class III, with a reference weight of more than 1 700 kg.

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<sup>13</sup> Council Directive 98/77/EC of 2 October 1998 adapting to technical progress Council Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by emissions from motor vehicles

<sup>14</sup> Council Directive 91/441/EEC of 26 June 1991 amending Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by emissions from motor vehicles

<sup>15</sup> Council Directive 91/542/EEC of 1 October 1991 amending Directive 88/77/EEC on the approximation of the laws of the Member States relating to the measures to be taken against the emission of gaseous pollutants from diesel engines for use in vehicles

<sup>16</sup> Council Directive 93/59/EEC of 28 June 1993 amending Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by emissions from motor vehicles

### **6.1.5 Mobile machinery and equipment with internal combustion engines**

European Parliament and Council Directive 97/68<sup>17</sup> deals with gas emissions and polluting particles from mobile machines of this kind, such as bulldozers, excavators, rollers and harvesters. The directive introduces limit values for particulates, hydrocarbons, carbon monoxide and oxides of nitrogen from diesel motors of between 18 and 550 kW.

### **6.1.6 Motorcycles and mopeds**

The Commission is currently drawing up limit values for exhaust emissions from these vehicles based on the UN Economic Commission for Europe regulations.

### **6.1.7 Lead in petrol**

Since the compulsory introduction of unleaded petrol in October 1989, leaded petrol has been subject to restrictive measures and will virtually disappear from 1 January 2000 (Directive 98/70).

### **6.1.8 Sulphur in liquid fuels**

Directive 93/12<sup>18</sup> lays down two stages for reducing the sulphur content: since 1 October 1994, the maximum limit value for all liquid fuels including diesel has been 0.2%, and for diesel it has dropped to 0.05% from 1 October 1996. The new directive 98/70 further reduces sulphur dioxide emissions resulting from the combustion of heavy fuel oils and gas oils.

### **6.1.9 Volatile organic compounds (VOCs)**

In late 1994, the Council and Parliament adopted a directive controlling VOC emissions from the storage and distribution of petrol, Stage 1 (Directive 94/63/EC)<sup>19</sup>.

In March 1999, a new directive (99/13)<sup>20</sup> on the "limitation of emissions of volatile organic compounds due to the use of organic solvents in certain industrial activities and installations" was approved. It provides for a two-third reduction in the VOCs, which are released into the atmosphere through the use of solvents in industry and together with nitrogen oxide and sunlight, cause the notorious summer smog.

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<sup>17</sup> Council Directive 97/68/EC of the European Parliament and of the Council of 16 December 1997 on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery

<sup>18</sup> Council Directive 93/12/EEC of 23 March 1993 relating to the sulphur content of certain liquid fuels

<sup>19</sup> Council Directive 94/63/EC of 20 December 1994 on the control of volatile organic compound (VOC) emissions resulting from the storage of petrol and its distribution from terminals to service stations

<sup>20</sup> Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations



## 6.2 EMISSIONS FROM POWER GENERATION AND STATIONARY SOURCES

### 6.2.1 Revised Large Combustion Plants Directive

The Revised Large Combustion Plants Directive (LCPD, 2001/80/EC)<sup>21</sup> applies to combustion plants with a thermal output of greater than 50 MW. The LCPD aims to reduce acidification, ground level ozone and particles throughout Europe by controlling emissions of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and dust (particulate matter (PM)) from large combustion plants (LCPs). These include plants in power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid or gaseous fuel.

The revised LCPD takes into account advances in combustion and abatement technologies. It will replace the original LCPD (88/609/EEC)<sup>22</sup> adopted in November 1988. New combustion plant must meet the emission limit values (ELVs) given in the LCPD. For 'existing' plants (i.e. those in operation pre-1987), Member States can choose to meet the obligations by either:

- Complying with ELVs for NO<sub>x</sub>, SO<sub>2</sub>, and particles.
- Operating within a 'National Plan'. That would set an annual national level of emissions calculated by applying the ELV approach to existing plants, on the basis of those plants' average actual operating hours, fuel used and thermal input, over the 5 years to 2000.

### 6.2.2 The Integrated Pollution Prevention and Control Directive (IPPC)

The IPPC Directive 96/61/EC<sup>23</sup> 2001/80/EC<sup>24</sup> lays down a framework requiring Member States to issue operating permits for certain installations carrying on industrial activities described in its Annex 1. The Directive applies to new or substantially changed installations with effect from October 1999 and no later than October 2007 for existing installations. These permits must contain conditions based on best available techniques (BAT) as defined in the Article 2.11 of the Directive, to achieve a high level of protection of the environment as a whole.

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<sup>21</sup> Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants

<sup>22</sup> Council Directive 88/609/EEC of 24 November 1988 on the limitation of emissions of certain pollutants into the air from large combustion plants

<sup>23</sup> Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control

<sup>24</sup> Council Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants

### **6.2.3 The Emissions Ceiling Directive**

Directive 2001/81/EC<sup>25</sup>, the national emission ceilings directive, addresses acidification, tropospheric ozone and soil eutrophication as inter-related problems caused by emissions of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), volatile organic compounds (VOC) and ammonia (NH<sub>3</sub>). In order to cut emissions of these substances, the directive aims to differentiate for each individual Member State, limits for the total emissions in 2010 of the four pollutants.

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<sup>25</sup> Council Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants

## 7 Modelling and prediction requirements

No mandatory modelling and prediction requirements are presently specified by Daughter Directives. However, discharging responsibilities to improve air quality specified by Article 7 of the Framework Directive, will present a need for emissions predictions and air quality modelling capabilities. In addition, in the application for an authorisation to emit pollutants from stationary point sources, it is likely that a dispersion modelling assessment of the impacts of emission will be necessary.

### 7.1 BASIC REQUIREMENTS FOR MODELLING AND PREDICTION OF EMISSIONS AND AMBIENT CONCENTRATIONS

The following key facilities and capabilities will be required to identify baseline (business as usual) and alternative emissions scenarios for the reduction of air emissions. Information provided by these will feed into the development of national and local Action Plans to reduce air pollution.

*Key modelling and prediction facilities and capabilities required for identification of emissions scenarios and estimation of current and future ambient pollutant concentration*

- An accurate and regularly updated spatially disaggregated emissions inventory
- Projected emissions to at least 2010 based on estimates of future activity data (eg. Coal use, car ownership)
- Dispersion modelling facility to estimate contributions to ambient concentrations
- Accurate measurement for calibration or verification of model results.
- Source apportionment of pollutant concentrations to identified what fraction of the ambient concentration is controlled at national/local levels
- Information on air mass back trajectories to aid in source apportionment, transboundary pollution identification

## 8 Approaches to Air Quality Monitoring

### 8.1 TYPES OF MONITORING STATIONS

The Maltese Government has a number of technical options open to it in the determination of ambient air quality on the island. These generally fall into three distinct areas: passive monitoring techniques, active samplers and automatic monitoring techniques.

#### 8.1.1 Passive monitoring

This type of monitoring usually makes use of discreet plastic or metal tubes, which are fixed to street furniture. The tubes rely on diffusion of pollutants through the tube and absorption onto an impregnated material, over a long exposure period (typically 2-4 weeks). This technique has already been used to great effect in Malta.

The advantages of the technique are:

1. The tubes are cheap (typically £10-25GBP each). Thus large numbers of tubes can be deployed to provide cost-effective pollution datasets.
2. Use and handling of the tubes is very straightforward.
3. Most of the major gaseous pollutants can be measured using this technique.
4. The results give an excellent indication of spatial pollutant distribution, enabling the identification of pollution "hotspots"

However there are some disadvantages:

1. The tube results are long-term averages; it is not possible to reliably extrapolate this data into short-term indicators.
2. The results produced by the tubes are not normally of sufficient quality to be reported to EC.
3. The uncertainty of measurement for a diffusion tube is significantly higher than a well controlled automatic analyser.
4. There is a significant delay between exposure and production of results.

As a set of methodologies, passive monitoring techniques are best used to identify pollution hotspots and spatial distribution of pollutants, prior to investigation using more accurate techniques.

#### 8.1.2 Active samplers

These techniques usually trap the pollutant of interest onto a filter or in solution, by pumping sampled air through the system. The sample can be collected over days or weeks, depending upon the pollutant collected, before analysis is undertaken.

The advantages and disadvantages for these techniques are broadly similar to the passive techniques, although for some pollutants this is the only method available (for example metals and PAH's)

### **8.1.3 Automatic monitoring**

This type of monitoring usually involves the use of mains-powered equipment, which draws sampled air into a detection system that measures a response to a specific pollutant.

The advantages of this technique are:

1. Highly time-resolved data (can be as short as 1 minute averages).
2. The analysers give indications of short-term changes (say at a roadside, or during periods of high concentrations).
3. The analysers can be used to undertake source apportionment analyses during pollution episodes.
4. The data, once appropriate quality assurance and quality control procedures have been applied, can be used for comparison with any of the EC Directives.
5. Data can be published very rapidly, which could be of value in alerting the general public of pollution episodes.

The disadvantages of this technique are:

1. Analysers are relatively expensive (£5,000 to 20,000GBP), and have substantial ongoing running costs.
2. Analysers are complex to operate, and can be prone to breakdowns.
3. A high level of skill is required to produce meaningful data from the equipment.

Taking all of these factors into account, providing a cost-effective programme can be devised, the advantages offered by the use of continuous analysers far outweigh the shortcomings.

## **8.2 MOBILE LABORATORY VS. FIXED SITES**

Up until **netcen**'s assessment visit at Easter 2002, a mobile laboratory was used to assess levels of air pollution in Malta. The table below presents a summary of the data provided by PCCU.

Site	Date	Average CO, ppm	Maximum 8hour CO, ppm	Average NO <sub>2</sub> , ppb	Maximum hour NO <sub>2</sub> , ppb	Average O <sub>3</sub> , ppb	Maximum 8 hour O <sub>3</sub> , ppb	Maximum hour O <sub>3</sub> , ppb	Average PM <sub>10</sub> , µgm <sup>-3</sup>	Maximum 24 hour PM <sub>10</sub> , µgm <sup>-3</sup>	Average SO <sub>2</sub> , ppb	Maximum hour SO <sub>2</sub> , ppb
Dingli	8-27/9/00	0.2	1.2	9.6	132	26.6	46.7	51.5	41.3	131.5	0.6	20.5
Fgura	17-25/10/99			13.9	52	19.1	35.1	39.3	52	71.5	5.1	58.6
Ghajnsielem	21/12/99 - 30/1/00	0.4	3.3	12.2	60	27.2	38.5	39.4	50.3	293	0.8	11.4
Hamrun	16/2 - 3/3/01	1.2	3.4	18.6	100.3	14.5	33.8	36.7	66.3	111.7	1.2	17.6
Kalkara	6-10/3/00	1.3	2.7	34	83.1	18.1	36.8	41	65.5	81.3	7.5	79.8
Kalkara	27/11 - 9/12/99			15.8	69.5	22.2	39.9	42.1	44.6	79.5	2.1	42.3
Luqa	23/11 - 5/12/01	1.5	2.6	25.3	233	21.4	35.4	36.6	37.8	73.5	0.3	4
Marsa	15/10 - 9/11/01	1.7	3.5	41	216.6	14.2	33.4	37.9	58.8	92.1	0.2	17.7
Marsa	1-20/8/00	1.1	4	14.1	53.6	28.3	54.8	63.8	50.8	70	0.8	6.2
Marsa	3-26/5/00	1.8	5	23.7	76.3	18.8	37.6	42	74.3	122.7	16.3	255.3
Mellieha	11-21/2/00	0.3	2.1	3.6	26.1				29.9	46.4	0.4	11.2
Mellieha	10-20/12/99	0.6	1.6	18	56.2	22.5	31.9	34.1	64.9	95.8	0.5	6.4
Mosta	9-16/10/99			23.3	79				50.1	66.6	0.9	6.8
Munxar	6-9/2/00	0.9	2.9	13.8	44.9	23.5	32.3	35.4	27.6	33	0.8	2.9
Naxxar	1, 7-15/1/02, 22-28/2/02	1.2	2.6	16.9	129.9	21.3	41.2	43.9	39.9	98.7	1.7	11.9
Paola	27-31/10/99	0.6	2.1	18.3	62.2	24.8	40.2	43.4	58.1	64.6	0.6	4.5
Qormi	22/2 - 5/3/00	0.6	1.5	16.5	81.7	24.9	43.1	48.4	38.6	54.9	0.6	19
Qormi	18-26/11/99			21.9	141.7	17	29.4	32.8	65.1	108.6	3.6	21
Rabat	5-15/10/01	0.3	1.1	6.9	68.3	17.3	36.6	39.6	48.1	60.8	0.8	5.9
Rabat	15/4 - 2/5/00	0.6	2.4	9	77.6	36.8	46.6	50.6	35.4	67.6	1.2	14.2
Siggiewi	1-8/10/99			12.6	50.5	22.6	30.4	50.7	51.4	61.4	1.9	42.8
Sliema	27/6 - 5/7/01	1.8	2.5	13	108.5	36.6	49.8	52.9			2.4	14.4
Swieqi	21/8 - 7/9/00	1.4	5.9	40.8	151.6	16.9	40.9	42.7	89	191.8	1.8	20.5
Valletta	15/9 - 2/10/01	2.1	3	38.7	464.8	25.3	40.7	42.7	44.7	81.7	0.3	10.1
Vittoriosa	6-30/9/99			9.2	48.8	23.1	43.4	47.5	48.9	72.8	1.2	60.5
Zabbar	11-20/3/00	1	2.4	27	86.6	27	42.1	45.7	54.3	67.6	5.7	88.8
Zabbar	2-3/11/99			35.8	67	12.6	20.8	27.9	97.9	98.8	1	8.8
Zurrieq	7/12/01-7/1/02	0.8	2.9	9.8	52	27.7	45.8	50.9	35.5	150	1.1	14.5

It can be seen from the table that a large number of sites have been visited, but as a consequence, only a small amount of data collected at each location (usually 2 weeks maximum). As a result, it is not entirely appropriate to use the data collected to compare against long-term EC Directives.

This is the main problem of the use of a mobile laboratory - these can be very useful for investigating possible pollution hotspots, but data acquired in this way only be usefully compared against short-term Directives. In addition, equipment housed in mobile facilities tends to be more unreliable than identical analysers when placed in a fixed location.

In European monitoring networks, data submitted to the EC to demonstrate compliance comes overwhelmingly from fixed monitoring locations. There are many advantages to placing equipment in a fixed location:

- Data from long term fixed sites can be used to identify trends, to investigate the effectiveness of any control measures.
- It is easier to protect a fixed site from vandalism.
- As noted above, analysers that remain in a single location tend to be generally more reliable.

It is therefore recommended that any Maltese monitoring network be set up with fixed sites.

The existing mobile laboratory should continue to be maintained, for investigating complaints and potential hotspots. It could be operated in the grounds of the MEPA offices when it was not required elsewhere, where it could be used to trial new equipment and train new staff.

### **8.3 INSTRUMENTATION**

The selection of appropriate instruments is essential to the success of any monitoring network in achieving its stated objectives. The objectives of an Automatic Network require precise time-resolved measurements, necessitating the use of automatic analysers. It should be noted, however, that the advanced capabilities of such instruments are bought at the expense of increased capital, running and support costs, greater unreliability, and a higher skill requirement for routine operation. The choice of equipment to be used is as important as the decision to use automatic analysers. The quality of the equipment is one of the fundamental factors in determining final data quality. **netcen** has extensive knowledge of the various equipment brands commonly in use in European monitoring networks. These include:

- Thermo Electron
- Monitor Labs (Monitor Europe)
- Advanced Pollution Instrumentation (API)
- Horiba
- Signal Ambitech (Ambirak)
- Environnement SA
- Rupprecht and Patashnick (dust analysers)
- Dasibi

- Met One (dust analysers)
- Kleinfiltergerät
- GRIMM

**netcen** has written a comprehensive series of Local Site Operators instruction manuals, which provide background information and details of how to calibrate analysers. In addition, we devised and implemented the QA/QC methodologies used in the UK to process the data prior to submission to the EC. Excerpts from these documents are presented in Appendices to this report

From this background, we suggest the following points need to be carefully considered during the decision making process:

- Purchase prices
- Costs for service and maintenance
- Minimal turn-around time for repair
- Reliability of equipment
- Ease of use / acquisition of data
- High data capture

Inevitably, there is a balance to be struck between price and performance. By way of example, the analysers used in the **netcen** Calibration Laboratory cost between £9-10,000 GBP each. They are used to produce data that are quality critical, and are very reliable. These analysers represent the best that money can (currently) buy. At the other end of the market, analysers can be bought for as little as £5,000 GBP, but these can require more frequent attention to get the best out of them. It is therefore important to consider how quickly a faulty instrument will be repaired, when choosing equipment.

In the UK, there are over 350 individual analysers supplying data to the network. Equipment suppliers are tied to a 48-hour fix-or-replace contract, thus minimising data losses. With such a large number of analysers and tightly controlled service contracts, it is possible to make substantial savings by purchasing "mid-range" equipment. MEPA will need to assess the local situation, and decide accordingly.

**netcen** has undertaken a large number of instrument procurement exercises in the past, both for UK Government monitoring networks and for the establishment of networks in China and Hong Kong. Typical tender documents, which outline instrument specification and terms of service and maintenance contracts are presented for information in appendix 2

## 8.4 COSTS

The purchase of an air pollution monitoring station represents only a minor proportion of the costs that will be incurred. The following table presents an indication of the upfront and ongoing costs that need to be funded to operate a single, multi pollutant monitoring station in the UK:



<b>Description</b>	<b>Capital costs (approx. £GBP)</b>	<b>Ongoing Annual Costs (approx. £GBP)</b>
Equipment purchase (NOx, CO, SO2, O3, TEOM, enclosure + accessories)	60,000	
Service and maintenance contract		6,000
Running costs (site commissioning, electricity, phone etc)		2,000
Calibration Standards		5,000
Manpower: Site calibrations and call outs for equipment faults		15,000
Manpower: Data Acquisition, processing, ratification, QA/QC and management		15,000

A typical air pollution analyser can be expected to have an effective lifetime of between 7 - 10 years. So, assuming that the multi pollutant site described above runs for 10 years, the initial capital purchase of £60,000 will be dwarfed by the £280,000 required to operate the analysers for this period.

## 9 Pollutant Measurement Methods

There are a number of techniques that may be used for measurement of pollution. The selection of instruments must be based on specific and proven analytical techniques for the pollutants measured, as presented in the Table below:

### Recommended Operating Principles of Automatic Analysers

<b>Pollutant Measured</b>	<b>Operating Principle</b>
O <sub>3</sub>	UV Absorption
NO/NO <sub>2</sub>	Chemiluminescence
SO <sub>2</sub>	UV Fluorescence
CO	IR Absorption
PM <sub>10</sub>	TEOM (Tapered Element Oscillating Microbalance) Gravimetric Sampler

Ideally, the performance of the analysers should be assessed prior to purchase. This will ensure that they meet the data quality and performance criteria laid down for the network. A number of characteristics need to be measured and compared with the manufacturer's specifications. These include noise, linearity errors, precision and zero and span drifts.

The selection of analysers also has had regard to the spatial and temporal characteristics of the pollutants under study, particularly in the urban environment. As a result, analysers must have a fast response to changes in concentration and a wide concentration range. The analysers must also have a facility for remotely activated daily calibration, so that long-term performance can be monitored and faults detected rapidly.

The selection of analysers for a network ideally involves both in-field and laboratory type-testing. For the UK Automatic Network, in-service data on performance, reliability and after sales support has also been available to assist in the decision-making process.

A typical specification list that analysers should comply with is provided below:

**Typical specifications for Automatic Analysers**

<b>Pollutant measured by analyser</b>	<b>NO<sub>2</sub></b>	<b>SO<sub>2</sub></b>	<b>O<sub>3</sub></b>	<b>CO</b>
Lower detectable limit	2 ppb	2 ppb	2 ppb	100 ppb
Precision as % of upper range limit	< 1%	< 1%	< 1%	< 1%
Noise				
Zero	1 ppb	1 ppb	1 ppb	50 ppb
Span	3 ppb	3 ppb	3 ppb	200 ppb
24 hour drift				
Zero	2 ppb	2 ppb	2 ppb	500 ppb
Span	2% FS	2% FS	2% FS	2% FS
Linearity Error	2%	2%	2%	2%
95% Response Time (max)	180 secs	150 secs	150 secs	60 secs

**9.1 PRINCIPLE OF OPERATION OF AUTOMATIC ANALYSERS**

**9.1.1 UV Absorption Ozone Analyser**

Ozone concentrations are calculated from the absorption of ultra-violet light at 254 nanometres wavelength. The sample passes through a cell tube of length (l), and the absorption is measured using a UV detector. An ozone-removing scrubber is used to provide a zero reference intensity. The analyser alternately measures the absorption *I* of the air path with no ozone present and the

absorption  $I_1$  of the ambient sample. The concentration ( $c$ ) is calculated using the Beer-Lambert equation:

$$I_1 = I_0 e^{-alc}$$

where  $a$  = absorption coefficient at 254 nm

### 9.1.2 Chemiluminescent Oxides of Nitrogen Analyser

Nitric oxide (NO) in the sample air stream reacts with ozone ( $O_3$ ) in an evacuated chamber to produce activated nitrogen dioxide ( $NO_2^*$ ).



The intensity of the chemiluminescent radiation thereby produced is measured using a photomultiplier tube (PMT). The PMT tube output voltage is proportional to the NO concentration. The ambient air sample is divided into two streams ; in one, ambient  $NO_2$  is reduced to NO using a molybdenum catalyst before reaction. Separate measurements are made of total oxides of nitrogen  $NO_x$  ( $= NO + NO_2$ ) and NO. The ambient  $NO_2$  concentration is calculated from the difference ( $NO_2 = NO_x - NO$ ).

### 9.1.3 UV Fluorescence Sulphur Dioxide Analyser

Ambient air is exposed to UV light which excites  $SO_2$  molecules in the sample to higher but unstable excited states. These excited states decay, giving rise to the emission of secondary fluorescent radiation. The fluorescent radiation is detected by a photomultiplier tube, causing an output voltage proportional to  $SO_2$  concentration. A permeable membrane 'kicker' is used to remove interfering hydrocarbons before reaction.

### 9.1.4 IR Absorption Carbon Monoxide Analyser

CO concentration in the sample air is measured by the absorption of infrared radiation at 4.5 to 4.9 mm wavelength. A reference detection system is used to alternately measure absorption due to CO in the ambient air stream, and absorption by interfering species. An infra-red detector and amplification system produce output voltages proportional to the CO concentration. The concentration is derived from the Beer-Lambert relation described above.

### 9.1.5 Particulate Analysers

Particulate matter (commonly called "PM") is a term used to describe a multitude of components. Unlike conventional pollutants, such as carbon monoxide or nitrogen dioxide, PM can take many forms, ranging from wind blown dust, fine particles produced during combustion (e.g. vehicle exhausts), through to very small liquid droplets, called aerosols.

Elevated concentrations of particulate matter are of concern because of the risk of increased chronic health effects such as heart disease and respiratory difficulties. Of most concern are very fine particles, which can be inhaled deep into the lungs.

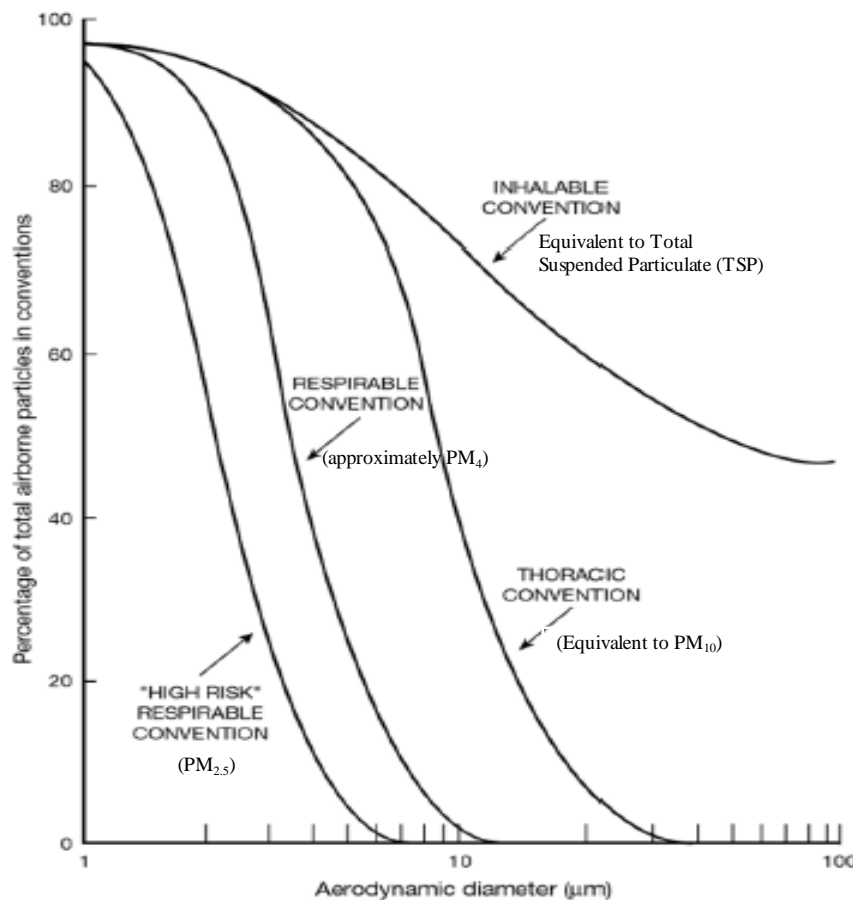
Based on experimental evidence, particle size fractions have been determined, which relate, in general terms, to how far particles can penetrate into the body. These are described below:

**Inhalable fraction** is the mass fraction of total airborne particles that are inhaled through the mouth and nose;

**Thoracic fraction** is the mass fraction of total airborne particle that is inhaled and penetrates beyond the larynx;

**Respirable fraction** is the mass fraction of total airborne particle that are inhaled, pass beyond the larynx and penetrate the unciliated airways (i.e. enter the lung).

The studies showed that particles that are inhaled have a variable probability of penetrating through the respiratory system, according to the figure below:



The plots show the probability profile for a range of particle sizes passing the various conventions. For each profile, it can be seen that larger particles are less likely to be inhaled than finer particles.

To illustrate this, for the thoracic convention, a particle of 30 microns in size is very unlikely to get through the respiratory system and be deposited into the thorax. However, a 1 micron particle has a near 100% chance. At 50% probability, the particle size is 10 microns, thus the particles that conform to this convention are called PM10. Similarly, the median particle size for the high risk respirable convention is 2.5 microns, and particles that conform to this convention are called PM2.5. From the plots above, it can be seen that PM2.5 particles are a subset of the PM10 particles, which in turn are a fraction of the inhalable particle mass.

A series of sampling adaptors have been designed to mimic the behaviour of the respiratory system, to assess PM concentrations in the thoracic and high risk respiratory conventions. These adaptors are placed on the inlets of PM sampling equipment and are called PM10 and PM2.5 "heads".

The main emphasis in ambient particulate monitoring is to determine the concentration of total particulates in the respirable and thoracic size ranges, since these have the greatest significance in relation to human health. Ambient air enters the particulate monitor through a sampling head, which has a maximum collection efficiency for particles with a mean aerodynamic size of 10 microns - the so called PM10 fraction. The PM10 size fraction encompasses a large proportion of respirable and thoracic particles.

#### **9.1.5.1 Gravimetric Samplers**

Particulate matter is trapped onto a pre-conditioned, pre-weighed filter. A measured volume of air is drawn through the filter for a 24 hour period, before the filter is re-conditioned and re-weighed. The mass concentration is calculated from the mass of dust deposited and the volume of air passing through the filter. The flow rate of air through the system is usually controlled using thermal mass flow controllers.

This is the approved reference method for determining compliance with EC Directives. It has the added advantage that exposed filters can be "bulked together", to permit analysis of other species (eg. lead, vanadium, mercury, cadmium etc.)

#### **9.1.5.2 TEOM (Tapered Element Oscillating Microbalance)**

The tapered element oscillating microbalance (TEOM) system determines particulate concentration by continuously weighing particles deposited on a filter. The filter is attached to a hollow tapered element, which vibrates at its natural frequency of oscillation ( $f$ ). As particles progressively collect on the filter, the frequency changes by an amount proportional to the mass deposited ( $m$ ).

$$m \propto k/f^2$$

**k** is a constant determined during calibration of the TEOM analyser.

The flow rate of air through the system is controlled using thermal mass flow controllers and automatically measured to determine mass concentration. The filter must be manually changed before the mass loading is at the maximum allowed by the system.

To ensure the reproducibility of the measurement principle, the physical environment around the filter (specifically temperature and humidity) needs to be carefully controlled. As a result, the method tends to underread with respect to gravimetric methods when volatile aerosols are present in the atmosphere. Extensive research has been undertaken to establish a relationship between the two methodologies, and TEOM data has been accepted as an equivalent to gravimetric data in the UK, when an adjustment factor of 1.3 is applied to the TEOM datasets.

### **9.1.5.3BAM (Beta Attenuation Mass Monitor)**

The mass density is measured using the technique of Beta attenuation. A small Beta source is coupled to a sensitive detector, which counts the Beta particles. As the mass of particles increases the Beta count is reduced. The relationship between the decrease in count and the particulate mass is computed according to a known equation (Beer-Lambert as above). In the UK, this technique is not used to submit data to the EC, as the measurement technique does not measure mass directly, and an correction factor to convert the data to "Gravimetric Equivalence" has not been agreed.

## **10 Quality Assurance and Quality Control (QA/QC)**

Above all other considerations, tight control of QA/QC is fundamental in the production of reliable, defensible datasets. Good QA/QC practice covers all aspects of network operation, including systems design and site selection, equipment evaluation, site operation, maintenance and calibration, data review and ratification. The successful implementation of each component of the QA/QC scheme is essential for the success of the programme.

The fundamental aims of a quality assurance/control programme are as follows:

- The data obtained from measurement systems should be representative of ambient concentrations existing in each urban area.
- Measurements must be accurate, precise and traceable.
- Data must be comparable and reproducible. Results from any monitoring network must be internally consistent and comparable with international and other accepted standards.

- Results must be consistent over time.
- In order for seasonally or annually averaged measurements to be meaningful, an appropriate level of data capture is required throughout the year.

Detailed guidance for the implementation of a typical QA/QC programme are provided in Appendix 4

## 10.1 PERSONNEL

There are four main areas where human input is required in the monitoring process:

1. Calibration of equipment
2. Data processing / ratification
3. Intercalibration exercises
4. Equipment servicing

**Calibrations.** Quite possibly, the most important components in the entire measurement chain in a monitoring network are the people that perform the regular calibrations of the equipment. It is the results from these calibrations that are used to turn raw numbers into scaled concentrations, so it can be argued that the data are only as good as the people that undertake the calibrations.

It is therefore essential that these people are knowledgeable and trained to a high standard. As the staff at MEPA already have experience in this field, it would be wholly appropriate to continue to use them to fulfil this function. Consideration should be given to undertaking a programme of additional training for MEPA staff in this field.

**Data processing and ratification.** These are the steps that turn mere numbers into pollution datasets. The actual procedures are presented in Appendix 5, and much of the work can be automated using PCs and dedicated telemetry links.

However, there is a considerable amount of "expert" interpretation and supervision required, to ensure reliable datasets are produced. As the staff at MEPA already have some experience in this field, it would be wholly appropriate to continue to use them to fulfil this function. Consideration should be given to undertaking a programme of additional training for MEPA staff in this field.

### **Intercalibration exercises.**

This process involves undertaking a series of performance tests on the network analysers at regular intervals (usually every 6 months). These tests are described in more detail in Appendix 6. The scope of work is somewhat more complex than a routine calibration, but could be undertaken by MEPA staff, given suitable training. This task could be undertaken by MEPA, or by hired

subcontractors. It is unlikely that the capability to undertake this aspect of work exists elsewhere in Malta.

### **Equipment Servicing.**

This task is essential in ensuring the continued reliability of the equipment in the network. Whilst some of the tasks could be undertaken locally, the vast majority of faults and servicing of analysers is best left to the equipment suppliers (as is the case in most European networks).

## **11 Public Information**

As the General Public will be a major stakeholder in the monitoring programme, it is very important that they have easy access to the information generated by the network. For this information to be useful it will, of course, be necessary to ensure that data generated are of appropriate quality, and there is a high level of data availability.

The data itself could be disseminated in a wide range of formats:

- Hourly alerts
- Daily bulletins
- Forecasts
- Monthly summaries
- Ratified Annual reports

... and to many different outlets:

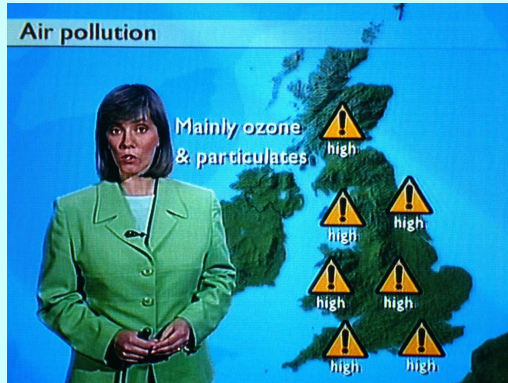
- Newspapers
- Radio
- Television
- Weather Forecasts
- World Wide Web
- Public Display Systems

The following figures overleaf in Box 1 illustrates the diversity of publication outlets used in the UK:



## Box 1- The UK Air Quality Information Service

This service, managed by AEA Technology, utilises a wide variety of media and electronic resources to disseminate the latest air quality data and forecasts:



**Bulletins**



**Teletext**



**Freephone Service**



**CD-ROMs**



**An award-winning website\***



**Written reports and brochures**

\*([www.airquality.co.uk](http://www.airquality.co.uk))

It can be seen that there is a huge quantity of information that can be made available to the General Public, ranging as follows:

1. Simple banding bulletins (e.g. "Air pollution today is LOW")
2. Current air pollution levels, coupled with 1. Above (e.g. teletext service)
3. Extensive archive information, with background information and current pollution datasets
4. Formal annual reports of ratified datasets

Consideration will need to be made as to what each of these datasets represents. For example, data that is broadcast to the general public on an hourly or daily basis is provisional at best, and should be marked as such. The ratified data in any annual report should be of an appropriate level of quality that it can be submitted to the EC / research institutions.

MEPA, as the local experts, will need to determine the most appropriate methodologies for disseminating information that will be of use to the Maltese population.

## 12 Summary and Conclusions

A preliminary assessment of air quality within Malta has been conducted for the pollutants regulated by the 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> Daughter Directives on ambient air quality. A requirement for Member States to conduct a preliminary assessment of air quality is specified by *Article 5* of The Framework Directive (Council Directive 96/62/EC).

The objective of the preliminary assessment is to establish estimates for the overall distribution and levels of pollutants, and to identify air quality monitoring activities necessary to fulfil obligations to The Framework and subsequent Daughter Directives.

Measurements of air pollutants, derived from monitoring surveys and the national emissions inventory data have been utilised in this preliminary assessment. These data were derived from measurement campaigns commissioned by the Maltese Pollution Control and Co-ordination Unit (PCCU). The data used in this assessment are as follows:

- Diffusive sampler measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub> and benzene, March 2000 – May 2001
- Short-term automatic measurement data for NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, CO and PM<sub>10</sub>, 1999-2002
- The Atmospheric Emission Inventory for Malta 1997

Based upon these measurements/surrogate information and guidance provided by the Directives, it has been established that levels of air pollution in Malta are above or, where measurements are not available, likely to be above thresholds which require fixed measurements to be made for compliance with the Daughter and Framework Directives. These observations apply both for an agglomeration zone identified within Malta (the Valletta and Sliema agglomeration, population >250,000 inhabitants) and for areas outside of this agglomeration (the Malta zone). If the Maltese Government decides to redefine the boundaries of the Zones and Agglomerations, the monitoring requirements will need to be redetermined.

On the basis of the agglomerations and zones here defined, however, the following fixed monitoring activities are recommended for minimum compliance with the three Daughter Directives and the Framework Directive.

### ***Fixed monitoring requirements for minimum compliance with the 1<sup>st</sup> - 3<sup>rd</sup> Daughter Directives within Malta***

<b>Zone/agglomeration</b>	<b>Pollutants to be monitored</b>	<b>Generic location of monitoring effort</b>
<b>Valletta/Sliema agglomeration</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , CO, benzene	At roadside location in Valletta
	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , benzene	At urban background location in Valletta, Sliema or environs
	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub>	At point of max. ground level concentration for plume from Marsa power station
<b>Malta zone</b>	NO <sub>x</sub> , SO <sub>2</sub> , PM <sub>10</sub> , lead, O <sub>3</sub> , CO, benzene	At urban background location in zone

These recommendations recognise:

- Road transport as the main emissions source of pollution effecting the majority of the Maltese population;
- The potential impacts upon resident populations resulting from the plume touch down of key point sources to the south west of the Valletta and Sliema agglomeration;
- Fixed, long-term measurements of pollutants regulated by 1<sup>st</sup> – 3<sup>rd</sup> Daughter Directives have as yet not been made;
- Measurements of airborne lead levels have not, as yet, been made within Malta;
- That, given the limited historical measurement data and surrogate information from emissions inventories, there is little scope to reduce the monitoring burden via supplementary information; and
- A strategic need to characterise roadside, urban background and industrial components of air pollution with view to developing modelling capabilities and for development of national plans to improve air quality.

A further recommendation- the commissioning of a rural background monitoring station measuring NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, ozone and meteorological- is also made with the specific aim of:

- Protecting sensitive ecosystems not governed on Malta by the Daughter Directives;
- Assessment of contributions from transboundary pollution particularly for PM<sub>10</sub> and ozone;
- Facilitating the development of national plans to improve air quality by identifying components of air pollution which are not directly controllable locally.

Continued assessment of Malta's air pollution is also recommended through rationalised diffusive sampler surveys, development of spatially disaggregated

emissions inventory, dispersion modelling studies of point sources and utilisation of its mobile laboratory.

Extensive information and recommendations are presented in the appropriate sections of the report on the following topics specified by the terms of reference:

- Development of plans to improve air quality;
- Instruments available for reducing emissions;
- Emissions standards for the reduction of air pollution
  - i. Emissions from the transport sector
  - ii. Emissions from power generation and stationary sources
- Modelling and prediction requirements
  - i. Requirements for modelling and prediction of emissions and ambient concentrations
- Approaches to Air Quality Monitoring
  - i. Types of Monitoring stations
  - ii. Mobile laboratory vs. fixed sites
  - iii. Instrumentation
  - iv. Costs
  - v. Pollutant Measurement Methods
- Principle of Operation of Automatic Analysers;
- Quality Assurance and Quality Control (QA/QC);
- Personnel requirements and training;
- Public Information.

# Appendices

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# **Appendix 1**

## **Example Specification for the Servicing and Maintenance of Air Quality Monitoring Equipment**

# Appendix 1 - Example Specification for the Servicing and Maintenance of Air Quality Monitoring Equipment

## 1. BACKGROUND

1.1 (company name) has been appointed by the (government) to act as the Management Unit (CMCU) for the Automatic Monitoring Networks (AURN). The CMCU is responsible for the overall management of the AURN, including site operations, data collection and data validation. Quality assurance is vested within an independent QA/QC Unit (netcen). Audit gases for the calibration of both Networks are provided by a certified supplier. Routine calibration and site checks are carried out by Local Site Operators (LSO) in each location.

1.2 As part of its CMCU responsibilities, (company name) wish to appoint XXXXX to act as an Equipment Support Units (ESU) to the Network. The ESU will be responsible for routine and emergency maintenance and repair of the monitoring and ancillary equipment at each site. The period of contract will be from XXXX to XXXX.

## 2. DESCRIPTION OF THE NETWORK

2.1 The monitoring stations comprise of analytical equipment to monitor continuously for one or more of the following pollutants:

- a) sulphur dioxide (SO<sub>2</sub>) UV fluorescence
- b) nitrogen oxides (NO<sub>x</sub>) Chemiluminescence
- c) carbon monoxide (CO) Infrared absorption
- d) ozone (O<sub>3</sub>) UV absorption
- e) suspended particles (PM<sub>10</sub>) Tapered Element Oscillating Microbalance

2.2 The monitoring stations are also equipped with remote station data loggers, modems, chart recorders, and suitable auto-calibration facilities. Depending upon the individual site location, the equipment is housed within purpose-built enclosures, or within existing premises. Many of the sites are equipped with air conditioning.

## 3. SPECIFICATION OF WORKS

3.1 A description of sites within the Network, their location, the equipment and pollutants monitored, is provided in Annex X. The ESU will be responsible for the service and maintenance of all analysers and ancillary equipment (including modems, loggers,



chart recorders, manifolds, calibration systems etc) at each monitoring station.

### **Routine Service and Maintenance**

3.2 It is a requirement of the AURN to achieve a minimum data capture of 90% for all pollutants across all sites, over the period of a calendar year. The service and maintenance procedures which are in place, and the resources dedicated to this, must be sufficient to guarantee the required data capture target.

3.3 Routine servicing of all instruments and equipment at each site is to be carried out on a 6-monthly basis. The service visits are to be conducted in co-ordination with the QA/QC intercalibration visits, and must be completed within a timetable determined by CMCU.

3.4 Routine service visits are to include full instrument servicing according to the manufacturers recommendations. On an annual basis, all equipment and supplies should be tested for electrical safety, and a suitable certificate issued and provided to CMCU. Where applicable, the sample manifold is to be completely dismantled and cleaned, and the manifold blower dismantled, cleaned and lubricated. All PTFE lines, which are exposed to ambient air, up to the first Sample Inlet Filter, are to be replaced. For sites within the Urban Network, the ESU will also be required to service and maintain the Zero Air Generator pumps (the QA/QC Unit will assume responsibility for replacement and regeneration of ZAG consumable supplies every 6 months). If requested by CMCU, the ESU will also be required to change the PTFE lines between the ZAG and the instruments. The Site Operator's Manuals that are provided by the Network QA/QC Units provide further guidance on the general scope of servicing to be undertaken. The need to undertake ozone photometer calibrations, NO<sub>x</sub> converter efficiency tests, and multi-point linearity checks should be noted.

3.5 All routine service visits are to be fully documented and completed in accordance with procedures described within the Site Operator's Manuals (issued by the QA/QC Units) and the ESU Procedure Manual (issued by CMCU). Documentation must describe in detail any necessary equipment adjustments, modifications or repairs. The relevant Pre and Post-Calibration Checklists are to be completed and faxed to both CMCU and the relevant QA/QC Unit at the earliest opportunity, and within 7 days at latest.

### **Emergency Service and Maintenance**

3.6 In the event of equipment malfunction between routine service visits, the appointed ESU will be required to carry out emergency repairs. The emergency call-out will be issued by the CMCU. During normal working hours (Mon-Fri, 0830-1730 hrs) emergency call-outs will be notified by telephone and confirmed by facsimile. Outside of these hours, the ESU will specify a means of receiving and logging calls from CMCU i.e. by message pager, mobile phone or answer machine.

3.7 It is a requirement that the ESU attends site and effects repairs within 48 hours after receiving notification from the CMCU. If the faulty equipment cannot be repaired within the required timescale, then a replacement unit should be fitted. Specific procedures related to emergency call-outs are detailed within the Site Operator's Manuals. This 48-hour response excludes weekends and Public Holidays. In all cases the ESU must confirm to the CMCU that they have received the call-out. It is a requirement that the ESU attends site and effects repairs within 48 hours of this confirmation.

3.8 As a general guide, the following circumstances may give rise to an emergency call-out:

- electronic or pneumatic instability of the instruments
- autocalibration checks outside of acceptable tolerances
- instruments operating outside of manufacturers specifications
- manual calibration checks outside of acceptable tolerances
- malfunctions identified with the sample manifold, data logging or gas calibration systems.

Whilst these criteria provide guidance on call-out procedures, emergency call-outs will be issued at the sole discretion of the CMCU.

3.9 All emergency call-out visits must be fully documented and describe all equipment malfunctions, repairs or replacements. In the event of any instrument adjustments that affect calibration, these must be agreed in advance with the CMCU, and be accompanied by the relevant Pre and Post-Calibration Checklists and Calibration Records. Documentation must be faxed to both CMCU and the relevant QA/QC Unit as soon as possible, **and within 7 days at latest.**

### **Supply of consumables**

3.10 The ESU will be required to provide and maintain adequate consumable supplies for all monitoring stations within the relevant part of the Network. This will include, for example,

supplies of chart paper, Sample Inlet Filters, TEOM filters, permeation tubes, degreasing agents for sample head cleaning (Decon 90) etc. Additional supplies of consumables are to be despatched to the relevant site LSO within 5 working days of notification by CMCU. The ESU will not be expected to supply calibration gases or consumables for the ZAGs.

### **Air Conditioning Units and Fire Extinguishers**

3.11 Many of the Network monitoring stations are equipped with air conditioning units (see Annex X). The ESU will provide for the service and maintenance of these units, to ensure adequate operation. Both routine (6-monthly) servicing and emergency call-out should be provided for. The ESU should include for the annual testing and replacement (if required) of fire extinguisher units within each site.

### **Spares and calibration equipment**

3.12 A list of spare equipment available for this contract is detailed in Annex X. Where spares are not available, the ESU will be expected to provide replacement equipment within the stated response timescale, should any equipment fault not be rectifiable.

3.13 Immediately before any repair, adjustment, or replacement of an analyser, it is essential that the instrument is calibrated in an 'as found' state using the on-site calibration gases. In the case of ozone analysers, this calibration must be completed against a reference photometer.

3.14 Photometers used within the AURN are required to be calibrated against the primary standard photometer at least every six months.

### **Equipment Inventories**

3.15 The ESU will assist the CMCU in preparing a detailed inventory of all equipment within the AURN. By January of each year, the ESU will have completed an inventory of all equipment at each monitoring station, together with a list of spares. The inventory will be provided in Microsoft Excel format.

# **Appendix 2**

## **Ambient air quality monitoring - equipment procurement**

## Appendix 2 - Ambient air quality monitoring - equipment procurement

Table 1 lists the types and methods of instruments/equipment to be procured for ambient air quality monitoring.

Table 1. – Ambient air quality monitoring equipment

Item	Description	Comments
1	Ambient NO <sub>x</sub> analyser	Chemiluminescence
2	Ambient SO <sub>2</sub> analyser	UV Fluorescence
3	Ambient CO analyser	IR absorption
4	Ambient O <sub>3</sub> analyser	UV photometry
5	Particulate (PM <sub>10</sub> ) analyser	TEOM / Gravimetric Sampler
6	Datalogging systems	Internal logging or central logger
7	Meteorological sensors	Wind speed & direction, ambient pressure, temperature and relative humidity.
8	Ambient air quality monitoring enclosure	To incorporate NO <sub>x</sub> , SO <sub>2</sub> , CO, O <sub>3</sub> and PM <sub>10</sub> analysers together with met. sensors.

### General requirements

- Unless noted otherwise, all mains operated instrumentation and other equipment is to be supplied to operate off 220 VAC supply. Suppliers of equipment operating from other power supplies or voltages shall supply a suitable voltage transformer.
- All equipment is to be supplied fit for purpose and compliant with Maltese and relevant EU health & safety, environmental, transport and other applicable regulations.
- All prices are to include delivery to the specified recipient and on-site commissioning (to include training of local operators) of the instrument/system. For administrative purposes the address of the project office in (*to be added*), shall be used as a first point of contact.

- Duplicate equipment manuals are to be provided in English or Maltese. Details of technical support and servicing costs and provision in Malta shall also be detailed.
- All certificates of compliance, quality control reports and manufacturers test reports are to be supplied.
- Wherever local subcontractors are to be used, these should be listed and their roles comprehensively detailed.
- All software supplied shall be original and complete with licence agreements (where required).
- All equipment shall be covered by warranty of no less than 12 months duration.
- All tenders are to include a complete breakdown of prices, as tailoring of the final requirements/specification may be necessary.

## PROCUREMENT AND DISTRIBUTION OF INSTRUMENTATION

The following equipment has been identified as priority requirements and as such represent the first phase of the procurement schedule.

**Automatic Monitoring Sites** – Maltese MEPA, to purchase **X** monitoring stations. Pollutant species to be measured are NO<sub>x</sub>, SO<sub>2</sub>, CO, O<sub>3</sub>, PM<sub>10</sub> and the meteorological parameters – wind speed and direction, ambient temperature, pressure and relative humidity, at the following sites:

Table 2 - Pollutants to be monitored

Site	Location ( <i>examples</i> )	Parameters to be monitored ( <i>examples</i> )
1	Valetta	NO <sub>x</sub> , PM <sub>10</sub>
2	Marsa	NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub>
3	Dingli	O <sub>3</sub>
4	Delimara	NO <sub>x</sub> , CO, SO <sub>2</sub> , PM <sub>10</sub> , WS, WD, Rain, T, RH, P, Sol

## AUTOMATIC MONITORING SITES

The Maltese Government are to set up a network of X air pollution monitoring stations, as detailed in Tables 1 and 2.

Instrumentation to be procured and installed (where applicable) are listed in Table 3 below, the technical specifications of these instruments are as for those listed elsewhere within this document.

Table 3.

NO <sub>x</sub> analyser	Data logging system
SO <sub>2</sub> analyser	Meteorological sensors
CO analyser	10 metre Met. mast
O <sub>3</sub> analyser	Gaseous analyser calibration system
Particulate (PM <sub>10</sub> ) analyser	Monitoring Enclosure

In addition the following features are to be included as part of the monitoring instrumentation:-

- *Temperature control.* The enclosure should be provided with an air conditioning unit capable of maintaining the internal temperature at  $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$  for the entire range of ambient temperatures experienced in Malta (typically 0 to  $+50^{\circ}\text{C}$ ).
- *Electrical installation.* It should have a safe electrical circuit installed to the requirements of the IEE wiring regulations 16<sup>th</sup> edition. There should be sufficient power outlet sockets for the complete range of analysers and ancillary equipment installed within the mobile laboratory, with at least six unused power outlet sockets. The electrical supply shall be split through a distribution panel with separate circuits for lighting, air conditioning, heating, analyser racks and power outlet sockets. Each circuit shall be protected by earth leakage circuit breakers. The electrical circuit shall be stabilised and protected from surges in mains supplies.
- *Noise.* The container shall have sufficient noise insulation in order that at a distance of 1m the noise measured should be less than 70 dB(A).
- *Security.* All efforts should be made in order to minimise the opportunity for unwarranted access to the interior of the enclosure. An internal security system (alarm) shall be fitted. All analyser inlets shall be protected from malicious damage by the use of shrouds (cages).
- *Telemetry.* Connection to the Maltese telephone network would be arranged by MEPA. Suitable connections to the telephony system must be supplied.
- *Service and maintenance.* Local arrangements for service and maintenance of the complete monitoring instrumentation shall be provided.
- *Consumables and spares.* Local arrangements for the provision of consumables and spares shall be provided.
- *Calibration systems.* A system shall be installed to introduce calibration gases to the analysers at atmospheric or near atmospheric pressure on a daily basis. The calibration gases will either be certified gas mixtures contained within cylinders or gases produced by permeation devices. Zero gas shall be provided either from a zero air generator that passes ambient air through chemical scrubbers, or from a certified zero air cylinder. The calibration system shall also have the facility of manual initiation from the operator.
- *Gas cylinder supports.* Secure cylinder supports shall be provided for a minimum of six 40 litre cylinders.
- *Data retrieval/processing.* In addition to the data storage facilities at the monitoring station, a computer system shall be supplied to retrieve data from the monitoring station. Additional software to process and analyse the data gathered shall be provided.
- *Internal installations.* Gaseous pollutant analysers should be securely mounted in instrument racks. The particulate analyser shall be



mounted on a sturdy platform in a position, which affords easy access for changing filters etc as necessary.

- *Inlet manifold system.* The inlet for gaseous pollutant analysers should be constructed from inert material (either PTFE or glass). The length of the manifold should be kept to a minimum in order to reduce the residence time of pollutants in the manifold. The maximum permissible residence time shall be 5 seconds. The manifold shall extend 0.5 metres above the level of the roof, thus enabling 360° unrestricted flow to the manifold. The inlet shall be protected from the ingress of rainwater. The sample inlet for the particulate analyser shall be separate from the gaseous analyser inlet and appropriate to the type of particulate analyser used.
- *Particulate ( $PM_{10}$ ) analyser.* In order to maintain comparability with  $PM_{10}$  monitoring undertaken within the EC, Gravimetric sampling or measurement with a TEOM, are the preferred measurement methods.
- *Roof access.* A ladder shall be provided to enable safe access to the roof of the monitoring enclosure. Ladder supports shall be attached to the enclosure to support the ladder when in use. The ladder shall be stored inside the monitoring enclosure.

## DETAILED SPECIFICATIONS OF EQUIPMENT REQUIRED

The following pages give detailed technical specifications of the monitoring equipment required to fulfil the ambient monitoring requirements. Any deviations from the listed specification should be clearly noted. All analysers are to be supplied complete with a minimum of one years consumables (i.e. sample filters). Any recommended additional/ancillary equipment for the laboratory instruments should be listed and priced separately.

### AMBIENT CHEMILUMINESCENT NO<sub>x</sub> ANALYSER

The NO<sub>x</sub> analysers are intended for measurements of ambient concentrations at a range of locations. The analysers will be incorporated into a system for the measurement of a range of ambient air pollutants, in common with the other analysers these instruments shall have the following features:-

- automated zero gas check facility
- automated span gas check facility (either by permeation device or reference gas mixture)
- pre-sample filtering
- Automatic pressure / temperature compensation

The supplier shall demonstrate compliance with relevant international approval schemes e.g. USEPA, UBA/TUV, UK DEFRA/NETCEN. the instrument shall also be compliant with ISO 7996:1985 Ambient Air – Determination of the mass concentration of nitrogen oxides – Chemiluminescence method.

The detailed technical requirements for the instrument are given below:-

Table 4.

Operational ranges	0-0.05/0.1/0.5/1/2/5 ppm
Lower detectable limit	1 ppb
Zero drift	< 1 ppb / day
Span drift	< 1 % FS / day
Linearity error	< 1% MV
Precision	± 1% FS
NO <sub>x</sub> converter efficiency	> 98%
Operational temperature range	5 – 40 °C
Operational humidity range (%RH)	20 - 80

Analogue voltage output	0 – 0.1/1/5/10 V
RS-232 interface	Standard

Key:

FS – Full scale response

MV – Measured value

## **AMBIENT UV FLUORESCENCE SO<sub>2</sub> ANALYSER**

The SO<sub>2</sub> analysers are intended for measurements of ambient concentrations at a range of locations. The analysers will be incorporated into a system for the measurement of a range of ambient air pollutants, in common with the other analysers these instruments shall have the following features:-

- automated zero gas check facility
- automated span gas check facility (either by permeation device or reference gas mixture)
- pre-sample filtering
- hydrocarbon removal system
- Automatic U.V energy / temperature / pressure compensation

The supplier shall demonstrate compliance with relevant international approval schemes e.g. USEPA, UBA/TUV, UK DEFRA/NETCEN.

The detailed technical requirements for the instrument are given below:-

Table 5.

Operational ranges	0-0.05/0.1/0.5/1/2/5 ppm
Lower detectable limit	1 ppb
Zero drift	< 1 ppb / day
Span drift	< 1 % FS / day
Linearity error	< 1% MV
Precision	± 1% FS
Response to hydrocarbon interferences	< 5 ppb for 1 ppm m-xylene
Operational temperature range	5 – 40 °C
Operational humidity range (%RH)	20 - 80
Analogue voltage output	0 – 0.1/1/5/10 V
RS-232 interface	Standard

Key:

FS – Full scale response

MV – Measured value

## AMBIENT GFC / NDIR CO ANALYSER

The CO analysers are intended for measurements of ambient concentrations at a range of locations. These analysers will be incorporated into a system for the measurement of a range of ambient air pollutants, in common with the other analysers these instruments shall have the following features:-

- automated zero gas check facility
- automated span gas check facility (either by permeation device or reference gas mixture)
- pre-sample filtering
- Automatic pressure / temperature compensation

The supplier shall demonstrate compliance with relevant international approval schemes e.g. USEPA, UBA/TUV, UK DEFRA/NETCEN. If employing the NDIR technique, then the instrument shall also be compliant with ISO/DIS 4224:2000 Ambient air -- Determination of carbon monoxide -- Non-dispersive infrared spectrometric method.

The detailed technical requirements for the instrument are given below:-

Table 6.

Operational ranges	0-10/25/50/200 ppm
Lower detectable limit	0.5 ppm
Zero drift	< 0.5 ppm / day
Span drift	< 1 % FS / day
Linearity error	< 1% MV
Precision	± 1% FS
Operational temperature range	5 – 40 °C
Operational humidity range (%RH)	20 - 80
Analogue voltage output	0 – 0.1/1/5/10 V
RS-232 interface	Standard

Key:

FS – Full scale response

MV – Measured value

## AMBIENT UV PHOTOMETRIC O<sub>3</sub> ANALYSER

The O<sub>3</sub> analyser is intended for measurements of ambient concentrations at a rural location. This analyser may be incorporated into a system for the measurement of a range of ambient air pollutants, in common with the other analysers this instrument shall have the following features:-

- automated zero gas check facility
- automated span gas check facility (either by permeation device or reference gas mixture)
- pre-sample filtering
- Automatic pressure / temperature compensation

The supplier shall demonstrate compliance with relevant international approval schemes e.g. USEPA, UBA/TUV, UK DEFRA/NETCEN. The instrument shall also be compliant with ISO 13964:1998 Air quality – Determination of ozone in ambient air – Ultraviolet photometric method.

The detailed technical requirements for the instrument are given below:-

Table 7.

Operational ranges	0-0.05/0.1/0.2/0.5/1/2/5 ppm
Lower detectable limit	1 ppb
Zero drift	< 1 ppb / day
Span drift	< 1 % FS / day
Linearity error	< 1% MV
Precision	± 1% FS
Operational temperature range	5 – 40 °C
Operational humidity range (%RH)	20 - 80
Analogue voltage output	0 – 0.1/1/5/10 V
RS-232 interface	Standard

Key:

FS – Full scale response

MV – Measured value

## AMBIENT PARTICULATE (PM<sub>10</sub>) ANALYSER

The particulate (PM<sub>10</sub>) analysers are intended for measurements of ambient concentrations at a range of locations. The methods of particulate measurement to be considered are:

- Gravimetric Sampler
- Tapered Element Oscillating Microbalance (TEOM)

The analysers will be incorporated into systems for the measurement of a range of ambient air pollutants.

While PM<sub>10</sub> is the preferred particulate fraction to be monitored, TSP and PM<sub>2.5</sub> inlets should also be available.

The supplier shall demonstrate compliance with relevant international approval schemes e.g. USEPA, UBA/TUV, UK DEFRA/NETCEN. The instrument shall also be compliant with ISO 12341 Ambient air – Measurement of the mass of particulate matter.

The detailed technical requirements for the instrument are given below:-

Table 8.

Operational ranges	0-10 mg/m <sup>3</sup>
Lower detectable limit	0.5 µg/m <sup>3</sup>
Operational temperature range	5 – 40 °C
Operational humidity range (%RH)	20 - 80
Analogue voltage output	0 – 0.1/1/5/10 V
RS-232 interface	Standard

## **DATALOGGING SYSTEM**

Two options are available for the logging and acquisition of monitored data. Either the analysers will have on-board data loggers, or a discreet data logger shall be procured. Due to the remote locations of some of the monitoring sites, data logging systems are required to be able to store a minimum of 30 days monitoring data. Data shall be stored as 5 minute average concentrations based on a sampling frequency of not more than 10 seconds. Data loggers shall be capable of connection to a modem and data transfer by telephone (or mobile telephone) to the data processing centre.

If a separate (discrete) data logger is supplied it should be capable of interfacing with analysers from other manufacturers through analogue voltage or current loop inputs. On board loggers should have the capacity for other (external) parameters to be logged i.e. meteorological data.

Whether a discrete logger or an analyser's on-board logger is used then it shall be capable of providing vector averages for the purpose of meteorological data logging.

## **DATA COLLECTION / ANALYSIS / REPORTING SOFTWARE**

A software system to collect monitoring data from the monitoring station via telemetry link; perform analysis of the dataset over operator defined timescales; and this report the data, is required. The ability for this software to interface with instrumentation supplied by other manufacturers would be advantageous. The software should operate under Windows 95/98/2000 and NT.

### **Data collection**

The collection of data from the monitoring station should be automatic (not needing operator intervention) and should be initiated at predetermined times throughout the course of the day, or manually by the operator as required.

### **Data analysis**

The data analysis functions required include:-



Data scaling	- the ability to manipulate datasets to account for drift in analyser responses
Time series plots multiple sites	- single and multiple pollutants, single and multiple sites
Calculation of averages	- hourly, 8-hourly, daily, annual
Wind rose analysis/plots speed	- plot of wind direction frequency and mean speed
Pollution rose analysis/plots	- frequency, mean and peak pollution concentrations against wind direction
Exceedence calculations	- listing of occurrences and dates/times of exceedences of user defined standards and limit values
Summary statistics	- list of mean, min, max, data capture etc for monthly, annual and user defined periods

### Data reporting

The data generated from the data analysis software should be easily ported to standard word processor and spreadsheet programs.

## METEOROLOGICAL SENSORS

The following meteorological parameters are to be measured:-

- wind speed
- wind direction
- ambient temperature/relative humidity

Systems for the measurement of the above parameters should be provided complete with 10m mast. Each parameter shall be represented by an analogue voltage, which will be presented to a data logger.

**Table 11. Wind speed sensor specification**

Range	0-50 m/s
Threshold	0.25 m/s
Linearity error	< 1%
Resolution	0.1 m/s or better
Accuracy	2%
Output	Analogue voltage and current loop

**Table 12. Wind direction sensors specification**

Threshold	0.3 m/s
Linearity error	< 1%
Resolution	0.5° or better
Accuracy	2%
Output	Analogue voltage and current loop

**Table 13. Temperature/relative humidity sensor specification**

	Temp.	RH
Range	-30 to +50°C	0 – 100%
Resolution	0.1°C or better	1%
Accuracy	0.25 °C	± 3%
Output	Analogue voltage and current loop	

**Table 14. Ambient pressure sensor specification**

Range	890 – 1050 mbar
Resolution	1 mbar
Accuracy	± 2 mbar
Output	Analogue voltage and current loop

## **MINIMUM PC SPECIFICATIONS FOR ALL SYSTEMS**

Processor – Pentium III 500 MHz

Memory – 128 MB

Storage/disk drives – 10 GB Hard Disk, 3.5" Floppy disk, 40X CD ROM drive

Graphics – SVGA

Monitor – 15"

Ports – parallel, serial, USB

Operating system – Windows 98/2000 or NT

## SUPPLIERS

Typical suppliers for equipment items 1 to 8.

Environnement SA 111, Boulevard Robespierre 78300 Poissy France	Enviro Technology Services plc Kingfisher Business Park London Road Stroud Gloucestershire, GL5 2BY UK
Thermo Electron Instruments Viking Way Bar Hill Cambridge, CB3 8EL UK	EMC Environment Engineering Imperial House 3 Montpelier Parade Cheltenham, GL50 1UA UK
Horiba Instruments Ltd Summerhouse Road Moulton Park Northampton, NN3 6FL UK	Signal Ambitech Regal Way Faringdon Oxfordshire, SN7 7BX UK

# **Appendix 3**

## **SITE OPERATIONAL PROCEDURES**

(example)

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## Appendix 3 - SITE OPERATIONAL PROCEDURES (example)

### 1 Introduction

A major factor in ensuring high quality from a monitoring network will be the regular visits to each monitoring site carried out by locally based personnel. These site visits will allow the following functions to be undertaken:

- (1) Precalibration checks;
- (2) Changing particulate monitor filter;
- (3) Calibration of analysers;
- (4) Postcalibration checks, safety and security inspection.

Together with these routine weekly functions, there will be instances when non-routine site visits will be necessary, in the event of apparent instrument or system malfunction.

Local site operators must be suitably trained in all aspects of normal equipment, and in the relevant calibration procedures. Operators must retain copies of instrument manuals at each site, and are required to familiarise themselves with normal operating principles and characteristics of the instrumentation.

Calibration procedures differ from instrument to instrument, but the basic principle is common to all analyser types, with the exception of the particulate analyser. Weekly calibrations will take the form of a simple two-point calibration.

Each analyser must be calibrated exactly *as found*. In this way, any instrumental drifts which may have occurred since the previous calibration will be exactly quantified, with there being no possibility that changes in response have been caused by any operator action.

Acting only in extreme circumstances, instrument adjustments may be performed to optimise analyser sensitivity. If such adjustments are found to be necessary, the instrument will be recalibrated after a suitable initial stabilisation period typically 15 minutes, so allowing the production of provisional revised calibration factors. However, full stabilisation of the instrument may take several hours and hence, ideally the instrument should be recalibrated after say a further 24 hours. The equipment supplier will advise on this. It is not anticipated that instrument adjustments of this sort will occur frequently.

The following sections of manual describe step-by-step procedures which must be followed during site visits. It is essential that the procedures are followed as written, for weekly and non-routine site visits, to ensure that reliable and accurate air quality measurements are made. However, the sequence in which zero and span calibrations are performed is not critical.

### 2 Preparation

1. Upon arrival at the site, check the pollutant levels on the front panel of each analyser and the chart trace to see if an episode is occurring i.e. pollution levels during the last hour are above, or close to, the trigger values (O<sub>3</sub> >~70 ppb, NO<sub>2</sub> >~75 ppb, SO<sub>2</sub> >~90 ppb and CO >~10 ppm). If an episode is occurring, seek advice before proceeding any further.
2. Take a new set of check and calibration sheets and enter Site, Date and Operator and Start Time.
3. Ensure the Operational Manual is to hand, and follow the instructions carefully.
4. Ensure that the toolkit supplied with the site is complete.

### 3 Precalibration Checks

In this section, a number of initial visible checks are made on the equipment. Some checks require a tick and some require a value to be recorded on the precalibration sheet. Complete all the checks for all the analysers and ancillary equipment. When all checks are complete, inform the MU if any are not correct, before proceeding with the calibration.

#### 3.1 CO Analyser

The API 300 CO analyser has a 2-line alphanumeric display and 3 status LED display lights on the front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", with the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on precalibration checklist.
2. If the red FAULT light is flashing, a warning message has been generated and is still active, due to some instrument operating parameter falling outside preset ranges. If the FAULT light is flashing, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on precalibration checklist. When all parameters on the precalibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

#### 3.2 NOx Analyser

The API 200 NOx analyser has a 2-line alphanumeric display and 3 status LED display lights on the front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", with the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on precalibration checklist.
2. If the red FAULT light is flashing, a warning message has been generated and is still active, due to some instrument operating parameter falling outside preset ranges. If the FAULT light is flashing, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on precalibration checklist. When all parameters on the precalibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

#### 3.3 SO2 Analyser

The API 100 SO2 analyser has a 2 line alphanumeric display and 3 status LED display lights on front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on precalibration checklist.
2. If the red FAULT light is flashing, a warning message has been generated and is still active, due to some instrument operating parameter falling outside of the preset levels. If the FAULT light is flashing, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on precalibration checklist. When all parameters on the precalibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

### 3.4 Ozone Analyser

The API 400 O<sub>3</sub> analyser has a 2 line alphanumeric display and 3 status LED display lights on front panel. The display is divided into 4 fields, Mode Field, Key Definition, Message and Concentration.

1. In normal operation, the Mode field will show "SAMPLE", the SAMPLE LED illuminated and the CAL and FAULT LEDs off. Check these and record on precalibration checklist.
2. If the red FAULT light is flashing, a warning message has been generated and is still active due to some instrument operating parameter falling outside of the preset levels. If the FAULT light is flashing, two additional buttons will be identified in the Key Definition area of the display, namely MSG (message) and CLR (clear). Press the message button and record the warning message given in the message area of the screen and press clear.
3. If the red "FAULT" light is off and a message display is visible, a fault has occurred, but has been automatically rectified. Record the message and press clear.
4. A number of instrument internal operational parameters can be accessed by pressing the test (left hand) button to obtain each parameter in turn. Press this and record the result displayed in the message area of the display against the appropriate parameter on precalibration checklist. When all parameters on the precalibration checklist have been noted, press the test button once more. This will display the current time on the instrument display.

### 3.5 TEOM Particulate Monitor

The R & P TEOM instrument has a 4 line display screen. The top line is fixed, and displays, from left to right, current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time. This top line is fixed, whilst the other 3 lines of the display can be used to scroll through a list of 16 information lines displaying various parameters. Use the cursor keys on the keypad to scroll up and down. Two lights marked "POWER" and "STATUS" are also visible on the front panel.

Record the following checks on the precalibration checklist.

1. In normal operation, the "POWER" switch will be on and the "STATUS" light off. Check these and record on the precalibration checklist.
2. Record current status code, current operating mode, percentage of filter lifetime used, current RS-232 mode and current time from the top line of the display.
3. Record the first three information lines in the appropriate space on the precalibration checklist.

4. Press ↓ to scroll through all information lines and record the information.
5. Press ↑ to return to the top of the information lines.

### 3.6 Air Sampling Manifold (where fitted)

Record the following checks on the precalibration checklist.

1. Check that the sample manifold is intact and shows no sign of possible leakage.
2. Check that the blower motor is operating by listening and feeling for vibration on the motor housing.
3. Check that the instrument sample inlet tubes are connected to the manifold and the sample inlet port at the back of the rack and that these connections are secure and leak-tight.

### 3.7 Modem (where fitted)

1. Check that the AA, TR and MR red lights are displayed on the modem and record on the precalibration checklist.

### 3.8 Chart Recorder (where fitted)

Perform the following visual check and record on the precalibration checklist.

1. Check that the orange RCD light is on.
2. Check that the 6 traces are clearly visible on the chart paper.
3. Inspect the chart paper to see that it is not jammed.
4. If BAT appears in the bottom right hand corner of the display then the battery back-up is low. Arrange for replacement as soon as possible.

### 3.9 Zero Air Generator

Check the condition of the scrubbers, two of which are self indicating; silica gel turns from blue to pink and purafil from purple to brown as it becomes exhausted.

1. Check that at least 25% of the silica gel is still blue. If less than 25% of the silica gel is blue proceed to section 11.3.11 - Changing the Silica Gel.
2. Check that at least 25% of the purafil is still purple. If less than 25% of the purafil is purple, note on the calibration record sheet, but continue with calibration.
3. Check that all connections are secure and tight.

### 3.10 Changing the Silica Gel

If it is necessary to change the silica gel proceed as follows.

NOTE: If no silica gel is available, proceed with the full calibration of all analysers as normal, noting the fact that the silica gel needs replacing on the record sheet. Inefficient silica gel will only affect the zero on the CO analyser.

1. Remove the canister containing the silica gel from the zero air assembly. Use two spanners to remove the swagelock compression fittings from the canister.
2. Remove the metal screw top, spring, metal and fabric spacer from the canister.
3. Empty the spent silica gel into a suitable container. The spent silica gel can be regenerated in an oven by the LSO. Take care not to breathe in any silica gel dust, as it is harmful.
4. Refill the canister with the fresh silica gel retained on site.



5. Replace the metal and fabric spacers. Replace the spring. Ensure that the rubber "O" ring is situated in the screw on top of the canister. Screw the metal top of the canister on to the canister.
6. Using two spanners, reconnect the swagelock compression fittings onto the canister. Take care not to crack the sides of the plastic canister by over-tightening the fittings.
7. Mark the date on the "Date of Change" sticker on the silica gel canister.
8. Reassemble the zero air generator assembly.

### 3.11 Completion of Precalibration Checks

If any of the above checks are not correct, seek advice before proceeding with calibration.  
If all correct, proceed to section 4.

## 4 TEOM Particulate Monitor

The TEOM particulate monitor filter cartridge must be changed either every 4 weeks or when the "percentage of filter lifetime used", as shown on the top line of the instrument display is 80% or greater. It is recommended that the TEOM filter cartridge box is stored in the sensor unit of the TEOM analyser so they are pre-conditioned before they are changed with existing filters.

Whenever the filter cartridge is changed, the PM10 head must be cleaned as detailed below. Since the analyser requires at least one hour to stabilise after filter cartridge changing, it is recommended that this operation be undertaken before the calibration of the gas analysers. Whenever the filter is changed, complete the TEOM Filter Cartridge record sheet.

### 4.1 Cleaning the PM10 Head

The PM10 head is located on the sample inlet tube above the roof of the monitoring station. Use the ladder, with due regard to personal safety, to gain access to the cabinet roof. Extra care should be taken if it is raining, as the roof of the cabinet may be slippery when wet.

The PM10 inlet needs to be cleaned each time the TEOM filter cartridge is changed to ensure optimal performance. The cleaning materials required are a small brush, lint free tissues, cotton buds, Decon 90 (1% in H<sub>2</sub>O), silicon grease, and distilled water. All components are to be cleaned by soaking Decon 90 on lint-free tissues or cotton buds as appropriate. The component should then be rinsed with distilled water to remove any Decon 90 and wiped dry with a lint-free tissue.

### 4.2 Removing the PM10 Head

1. Switch the TEOM "out of service" switch (where fitted) to ON. The control will show a red indicator when activated.
2. Carefully lift the complete PM10 head assembly from the TEOM inlet tube.
3. Protect the inlet tube so that rain or snow cannot enter at any time whilst the head is removed, and take the head inside the monitoring cabinet.
4. Separate the upper and lower inlet halves by unscrewing (counter-clockwise) the acceleration assembly from the collector assembly.

### 4.3 Cleaning the Acceleration Assembly

1. Mark the upper and lower plates of the assembly with a pencil so that the unit can be correctly aligned on reassembly.
2. Unscrew the four Philips screws from the top plate and remove the top plate and four spacers.
3. Clean the top plate, deflector cone, insect screen, internal walls and the underside plate.

4. Inspect the large diameter o-ring for wear and replace if necessary. Wipe any grease off with a tissue, and apply a thin coating of fresh silicon grease to the o-ring and the aluminium threads.
5. Careful reassemble, using the pencil marks to align the top and bottom plates.

#### 4.4 Cleaning the Collector Assembly

1. Clean the walls, the three vent tubes and the base of the assembly with a lint-free cloth soaked in Decon 90. Rinse with distilled water.
2. Use cotton buds and Decon 90 to clean the three vent tubes, base of the assembly and weep hole in the collector plate where the moisture runs out to the moisture trap. Rinse with distilled water.
3. Disconnect rain jar assembly from lower collector plate assembly. Clean inside brass tube with cotton buds and Decon 90. Rinse with distilled water.
4. Remove the rain jar and clean. For units with a cork sealing ring inside the cap of the jar, put a thin coating of silicon grease on the gasket and install the jar. If the sealing gasket is neoprene, no silicon grease is required.
5. Reconnect rain jar assembly to lower collector assembly. Ensure rain jar is sitting vertically.
6. Inspect the two inlet tube o-rings for wear and replace if necessary. Wipe off any grease present, and apply a thin coating of fresh silicon grease to the o-rings.
7. Clean the internal threads of the assembly with Decon 90 on a lint-free tissue.

#### 4.5 Replacing the Head

1. Screw the Acceleration and Collector assemblies together until the threads are hand tight. DO NOT OVER-TIGHTEN
2. Place the complete assembly back onto the TEOM inlet tube.

#### 4.6 Filter Cartridge Exchange Procedure

1. Refer to the manufacturer's operation manual when following the instructions for filter exchange. It is recommended that the TEOM filter cartridge box is stored in the sensor unit of the TEOM analyser so they are pre-conditioned before changing.
2. Check that the TEOM 'out of service' switch (where fitted) is ON. The control will show a red indicator when activated.
3. Open the door of the TEOM sensor unit.
4. Carefully lift the handle of the mass transducer to swing the transducer into its filter changing position and expose the filter.
5. Carefully insert the filter exchange tool under the filter cartridge so that the filter disk is between the fork and the upper plate of the tool (with the hub of the filter between the tines of the lower form). Gently lift the filter from the tapered element with a straight pull - DO NOT TWIST OR PULL SIDEWAYS.
6. Discard the exposed cartridge and wipe clean the exchange tool with a tissue.
7. Use the exchange tool to remove a new cartridge from the box - DO NOT TOUCH THE FILTER WITH YOUR FINGERS. Note that the box of new filters should be stored inside the TEOM sensor unit, to maintain them at a constant temperature.
8. Hold the new filter in line with the tapered element and lightly insert the hub of the filter onto the tip of the tapered element. Apply a downward pressure to set the filter firmly in place and then carefully retract the exchange tool. Problems with excessive response noise may be experienced if the filter is not seated correctly and firmly on the tip of the tapered element. The filter should, therefore, be positioned with particular care.
9. Gently move the horizontal handle downwards to close the mass transducer; allow the springs to pull it closed for the last centimetre.
10. Close the door of the TEOM sensor unit.

11. After 5 minutes, open the sensor unit and mass transducer again and push down on the filter with the base of the exchange tool. This is to ensure that no movement of the cartridge has occurred during heating of the transducer.
12. Close the door of the TEOM sensor unit.
13. Press <F1> on the TEOM control unit and allow one hour for system to reset.
14. Switch the TEOM 'out of service' switch to 'off'.
15. After one hour check that TEOM noise level on the chart recorder trace is within 60 mg/m<sup>3</sup> (~7 vertical chart divisions). If greater than this, attempt to re-seat the filter. Seek advice if the response is still excessively noisy.

## 5 Analyser Calibration Procedure

Results of the calibration will be taken from both the data logger display (where fitted) and the instrument's display and recorded on the calibration record sheets. The on-site chart recorder is to be used to determine that the instrument has fully stabilised in its response to the gas sample being introduced at its inlet.

When closing the gas cylinder valves care should be taken not to overtighten the valves on the gas regulator. Overtightening can damage the needle valve mechanism resulting in the outlet valve failing to open. The main valve on the top of each cylinder should, however, be tightly closed to avoid venting the cylinder.

In order to have a full and complete set of instructions for each analyser, instructions for opening gas cylinder valves are contained within the calibration procedure for each analyser. However, when all analysers are being calibrated, it will be advantageous for all cylinders to be opened at the same time, after ensuring that the needle valves in the cabinet are closed. All cylinders can then be closed at the same time at the end of the calibration session.

### 5.1 Instructions for Changing Chart Speed Prior to Calibrations (where chart present)

1. Open the chart recorder door to allow access to programming controls.
2. Press "SET" key at far left hand side of controls 3 times. The display should now show:  
IF SPEd 00010  
The indicator at the top right of the display should also show "mm/h". This indicates that chart speed selection mode has now been entered.
3. Press ">" key 5 times. The figure 1 should now be flashing.
4. Type figure "6" from the number pad. The indicated chart speed should now be 00060, with the trailing zero now flashing.
5. Press "ENT" to enter new chart speed, and "DISPLAY" key to return main display to normal channel cycling mode.

## 5.2 CO Analyser

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch CO "out of service" control (where fitted) to "on". The control will show a red indicator when turned on. This allows calibration data to be flagged.
3. (a) Uncap CO zero air inlet situated on the front of the instrument rack.  
(b) If fitted turn the CO inlet selection valve from "CO AMBIENT" to "CO WEEKLY ZERO / SPAN".
4. Connect the zero air generator to this zero air inlet. Plug in or switch on zero air generator. Check that flow indicator shows a flow of  $1.9 \pm 0.1$  litres per minute. Adjust if necessary using the tap on the output of the zero air generator.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred on the chart recorder, i.e. the CO recorder trace does not vary by more than 1 scale division in one centimetre along the time axis. The CO trace is channel 4 and is coloured blue.
6. Record three consecutive CO readings from the data logger and instrument display, i.e. after 3 ten second updates on the data logger display.
7. Switch off the zero air generator and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then with a spanner, tighten further by one quarter turn.
8. Open CO in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not attempt to use the cylinder if the pressure indicated is less than 300 psi.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) valve. Slowly open the regulator outlet (left hand) valve fully.
10. By gradually turning the CO calibration gas control valve inside the hut, adjust the flow through the flow meter to produce  $1.0 (\pm 0.1)$  litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute. Verify that stabilisation has taken place by examining the chart recorder, i.e. the CO recorder trace does not vary by more than 1 scale division in one centimetre along the time axis.
12. Record three consecutive CO readings from the data logger and instrument display. The signal should show a large deflection from the zero point previously obtained.
13. If fitted turn the CO inlet selection valve from "CO WEEKLY ZERO / SPAN" to "CO AMBIENT".
13. In the following order, fully close the CO calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system, and further action should be taken.
14. By considering previous calibration results and the chart recorder trace obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 25 mV ( $\sim 0.25$  ppm) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. Seek advice if the results of this are also unsatisfactory.
15. Change the CO sample inlet filter, following the instructions given in section 5.6.
16. Switch the CO out-of-service control to "off".

### 5.3 NOx Analyser

1. Record the instrument number and instrument running range on the calibration sheet.
2. Switch NOx analyser "out of service" control (where fitted) to on. The control will show a red indicator when turned on. This allows calibration data to be flagged.
3. Uncap NOx zero air inlet situated on the front of the instrument rack.
4. Connect the zero air generator to the zero air inlet of the nitrogen oxides analyser. Plug in or switch on zero air generator. Check that flow indicator shows a flow of  $1.9 \pm 0.1$  litres per minute. Adjust if necessary using the tap on the output of the zero air generator.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred on the chart recorder, i.e. the NO and NOx recorder traces do not vary by more than 1 scale division in one centimetre along the time axis. The NO and NOx traces are channels 2 and 1, and are coloured red and purple respectively.
6. Record three consecutive sets of NOx, NO and NO<sub>2</sub> readings from the data-logger (where fitted) and instrument display, i.e. after 3 ten second updates on the data logger display.
7. Switch off the zero air generator and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then, with a spanner, tighten further by one quarter turn.
8. Open NO in nitrogen cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not use the cylinder if the pressure indicated is less than 300 psi.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) valve. Slowly open the regulator outlet (left hand) valve fully.
10. By gradually turning the NO calibration gas control valve inside the hut, adjust the flow through the flow meter to produce  $1.0 (\pm 0.1)$  litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute. Verify that stabilisation has taken place by examining the chart recorder, i.e. the NO and NOx recorder traces do not vary by more than 1 scale division in one centimetre along the time axis.
12. Record three sets of NOx, NO and NO<sub>2</sub> readings from the data logger and instrument display. The readings should be taken as close as possible to each other, but need not be in consecutive 10 sec periods if this is not possible. The NO signal should be similar to the NOx signal, and show a large deflection from the zero point previously obtained. The NO<sub>2</sub> signal should be close to zero.
13. In the following order, fully close the NO calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system.
14. Turning now to the NO<sub>2</sub> in air calibration cylinder, repeat steps 8 to 11.
15. Record three sets of NOx, NO and NO<sub>2</sub> readings from the data logger and instrument display. The readings should be taken as close as possible to each other, but need not be in consecutive 10 sec periods if this is not possible. Verify that the readings are reasonable: the NO signal should be close to that obtained while performing the zero calibration, with the NOx and NO<sub>2</sub> signals showing approximately the same large deflection from this zero point.
16. Repeat step 13.
17. By considering previous calibration results and the chart recorder trace obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero values on all channels should not differ by more than 10 mV (~4 ppb) from the previous calibration. The span calibration values should not differ by more than 5% from those obtained during the previous calibration. If in doubt, repeat the relevant procedure. Seek advice if the results of this are also unsatisfactory.
18. Change the NOx analyser inlet filter following the instructions given in section 5.6.
19. Switch the NOx "out-of-service" control to "off".

## 5.4 SO<sub>2</sub> Analyser

1. Record the instrument number and instrument running range on the calibration record sheet.
2. Switch SO<sub>2</sub> "out of service" control (where fitted) to "on". The control will show a red indicator when turned on. This allows calibration data to be flagged.
3. Uncap SO<sub>2</sub> zero air inlet situated on the front of the instrument rack.
4. Connect the zero air generator to this zero air inlet. Plug in or switch on zero air generator. Check that flow indicator shows a flow of  $1.9 \pm 0.1$  litres per minute. Adjust if necessary using the tap on the output of the zero air generator.
5. Allow the analyser to stabilise on zero air for a period of not less than 10 minutes. Verify that stabilisation has occurred on the chart recorder, i.e. the SO<sub>2</sub> recorder trace does not vary by more than 1 scale division in one centimetre along the time axis. The SO<sub>2</sub> trace is channel 3 and is coloured green.
6. Record three consecutive SO<sub>2</sub> readings from the data logger (where fitted) and instrument display, i.e. after 3 ten second updates on the data logger display.
7. Switch off the zero air generator and disconnect it from the zero air port. Replace the cap on the zero air inlet and tighten until finger-tight. Then with a spanner, tighten further by one quarter turn.
8. Open SO<sub>2</sub> in air cylinder main valve by turning it fully anticlockwise. Read cylinder pressure from right hand dial and cylinder number from tag on cylinder, and enter these on the calibration record. Do not attempt to use the cylinder if the pressure indicated is less than 300 psi.
9. Adjust the regulator secondary pressure to 15 psi, as read from left hand dial, by turning regulator primary (right hand) value. Slowly open the regulator outlet (left hand) valve fully.
10. By gradually turning the SO<sub>2</sub> calibration gas control valve inside the hut, adjust the flow through the flow meter to produce  $1.0 (\pm 0.1)$  litres per minute.
11. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Ensure that the flow measured by the flow meter remains stable during this time. Adjust the flow, if necessary, to 1 litre per minute. Verify that stabilisation has taken place by examining the chart recorder, i.e. the SO<sub>2</sub> recorder trace does not vary by more than 1 scale division in one centimetre along the time axis.
12. Record three consecutive SO<sub>2</sub> readings from the data logger and instrument display. The signal should show a large deflection from the zero point previously obtained.
13. In the following order, fully close the SO<sub>2</sub> calibration gas control valve (in hut), the regulator outlet valve (do not overtighten), the main cylinder valve (tightly) and the primary regulator valve. This traps gas in the regulator, thus ensuring a positive pressure and hence, no ingress of ambient air. Note that the pressure regulator dials should remain at their previous setting, if a marked decrease is observed there is a leak in the system.
14. By considering previous calibration results and the chart recorder trace obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 20 mV ( $\sim 4$  ppb) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. Seek advice if the results of this are also unsatisfactory.
15. Change the SO<sub>2</sub> sample inlet filter, following the instructions given in section 5.6.
16. Switch the SO<sub>2</sub> out-of-service control to "off".

## 5.5 Ozone Analyser

1. Record the instrument number on the calibration record sheet.
2. Switch the O<sub>3</sub> "out-of-service" control (where fitted) to on. The control will show a red indicator when turned on. This allows calibration data to be flagged.
3. Press "CALZ" button and enter password (512). Press 'enter' button to start the zero calibration.
4. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Verify that stabilisation has occurred on the chart recorder, i.e. the O<sub>3</sub> recorder trace does not vary by more than 1 scale division in one centimetre along the time axis. The O<sub>3</sub> trace is channel 5 and is coloured brown.
5. (a) Record three consecutive O<sub>3</sub> readings from the data logger (where fitted) and instrument display.  
(b) To exit "ZERO" mode, press "EXIT" button twice.
6. Press "CAL S" button and enter password (512). Press 'enter' button to start the span calibration.
7. Allow the analyser to stabilise on this sample for a period of not less than 10 minutes. Verify that stabilisation has occurred on the chart recorder, i.e. the O<sub>3</sub> recorder trace does not vary by more than 1 scale division in one centimetre along the time axis.
8. (a) Record three consecutive O<sub>3</sub> readings from the data logger and instrument display.  
(b) To exit "SPAN" mode, press "EXIT" button twice.
9. By considering previous calibration results and the chart recorder trace obtained from the calibration just performed, satisfy yourself that the calibration has proceeded successfully. The zero value should not differ by more than 20 mV (~2 ppb) from the previous calibration. The span calibration value should not differ by more than 5% from that obtained during the previous calibration. If in doubt, repeat the relevant procedure. Seek advice if the results of this are also unsatisfactory.
10. Change the O<sub>3</sub> analyser inlet filter, following the instructions given in section 5.6.
11. Switch the O<sub>3</sub> "out-of-service" control to "off".

## 5.6 Changing Analyser Sample Inlet Filters

The analyser sample inlet filters situated on the front of the instrument rack will be changed on a weekly basis at all sites. In the event of a filter appearing badly soiled, the site operator shall inform the MU.

Detailed instructions for sample inlet filter changing:

1. Unscrew 2 brass nuts on filter holder.
2. Lift top cover of filter holder off bottom section.
3. Remove "O" ring and used filter.
4. Inspect filter for signs of excessive soiling and inspect "O" ring.
5. Take clean filter from box using the tweezers supplied and insert into base of filter holder.
6. Replace "O" ring in filter holder.
7. Replace top of filter holder and secure with brass nuts. The brass nuts should be hand tightened.
8. Check that teflon lines to filter holder are well secured.
9. Verify that the filter is seated correctly - and that the analyser is sampling through its inlet port - by performing a flow test. Remove the analyser sample line from the manifold arrangement and, by momentarily placing a finger over the end of the tubing, verify that there is suction. This test should not be performed for an excessive length of time as valve diaphragms or other components may become damaged. Record the result of this flow test on the calibration sheet.

## 5.7 Chart Recorder

### 5.7.1 Instructions for Changing Chart Speed After Calibration:

1. Open the chart recorder door to allow access to programming controls.
2. Press "SET" key at far left hand side of controls 3 times. The display should now show: IF SPED 00060

The indicator at the top right of the display should also show "mm/h". This indicates that chart speed selection mode has now been entered.

If 'SET' button is pressed more than three times, continue pressing the button. The display will cycle through a number of set-up parameters, and will eventually return to the "IF SPED 00060" display.

3. Press ">" key 5 times. The figure 6 should now be flashing.
4. Type figure "1" from the number pad. The indicated chart speed should now be 00010, with the trailing zero now flashing.
5. Press "ENT" key to enter new chart speed, and "DISPLAY" key to return main display to normal channel cycling mode.

If an error has been made in setting the speed to one outwith the possible limits, the entire display will flash on and off repeatedly. In this event, press 'enter'. The display will stay illuminated thus allowing step (3) to be repeated.

Check if the recorder chart paper needs to be replaced by following the instructions below.

### 5.7.2 Instructions on Inspecting Chart Paper Supply and Replacement of Paper

1. Open door of chart recorder.
  2. Press "RCD on/off" switch. The small yellow light in the top left corner of the display should go off, indicating that the chart recorder is no longer in record mode.
  3. Access the paper feed compartment by pulling the two edges into which the chart retaining bar is mounted.
  4. Inspect the paper supply and ensure that there is sufficient paper to last for at least two weeks. This can be done by considering the amount of paper used in the previous week. If supplies are adequate, go to step 9.
  5. If supplies are inadequate, remove chart retaining bar which runs across front of chart. This is spring loaded at one side. Store this bar safely.
  6. Remove entire chart from recorder.
  7. Take a new 20 metre chart from its packing and inspect for possible damage that may cause the chart to jam at a later date. Place chart on a surface and unfold the top 4 sections of paper. Place the main body of the chart paper in the paper supply compartment, and allow the 4 unfolded sections to drape down into the paper collection compartment. These sections should then be neatly folded into the collection compartment.
  8. Ensure that the chart feed sprockets protrude through the paper feed holes evenly on both sides of the paper. Replace the chart retaining bar into its original position.
  9. By firmly pushing the paper feed compartment, return it to its original position. You will hear two distinct clicks indicating that it is now secure.
  10. Press "CHART FEED" control and verify that the paper is running smoothly through the feed mechanism.
  11. Record the date, site name, time, and operator name on both the chart in the recorder and any that may have been removed.
  12. Press "RCD on/off" switch. The small yellow light in the top left corner of the display should go on, indicating that the YEW is in record mode.
- Check and reset if required the date and time of the chart recorder to agree with the data logger, following the instructions given below:



### 5.7.3 Instructions for resetting date/time

1. Open the chart recorder door to allow access to programming controls.
2. Press "SET" key at far left hand side of controls 4 times. The display should now show YY MM DD HH:MM
3. Press ">" or "<" keys to move to the digit that needs to be changed. This will then flash.
4. Enter the new value using the numeric keypad.
5. Press "ENT" key to enter the new date/time and "DISPLAY" key to return main display to normal channel cycling mode.

## 6 Postcalibration Checks, Safety and Security Inspection

As the network will report time-averaged concentration data, it is important that operators critically assess the operating condition of the analysers over the time scales used in making discrete measurements. Such assessments may not be possible by consideration of averaged data, as the averaging process may mask such factors as excessive noise or cyclic response changes etc. Information on analyser performance over very short time periods is important, as this will alert network managers as to whether instrumentation faults are developing.

Performing calibration checks at weekly intervals, as detailed previously, is an excellent means of assessing instrument performance characteristics. For instance, excessive rise or fall times, possibly due to flow constrictions having developed, will be easily noted by a simple calibration of the analyser. Similarly, "noisy" analyser outputs, which may be caused by inefficient photomultiplier tube cooling systems, will be immediately apparent by observing the analyser output while sampling zero air.

Operators will also be expected to examine backup chart recorder traces whilst on-site. These again may highlight problems that are not apparent by consideration of telemetry data. Considering each trace in turn, the operator should verify that the traces are as normally expected. The trace should show some degree of variation with time. For instance, in the case of primary pollutants such as NO<sub>x</sub> and CO, there should normally be a peak corresponding to the morning rush hour. Pollutants such as NO<sub>x</sub> and CO would be expected to rise and fall in phase with each other, whereas NO<sub>x</sub> and O<sub>3</sub> traces would generally be out of phase. The operator should verify that a continuous trace is being recorded i.e. there are not excessively high levels of instrument noise, and that the daily zero span autocalibration cycle has taken place. The chart traces for the autocalibrations should be examined closely to verify that the instrument fully stabilises on both zero and span gas during the autocalibration cycle. In addition, seemingly unimportant occurrences, such as an analyser air pump being noisy, may be indicative that the unit is liable to malfunction; this should be reported by the operator.

Obviously, the level to which these problems will be detected will depend upon the experience and familiarity with the equipment of each individual operator, but the operator must critically review the calibration he/she has undertaken and comment on any unusual or suspect results or occurrences. In addition, the postcalibration check sheet must be completed as follows:

1. All checks detailed in section 3 must now be repeated and recorded on the postcalibration check sheet as follows:
  - (i) CO Analyser
  - (ii) NO<sub>x</sub> Analyser
  - (iii) SO<sub>2</sub> Analyser
  - (iv) Ozone Analyser
  - (v) TEOM (not required when filter not changed)
  - (vi) Air Sampling Manifold (not required if precalibration was OK)
  - (vii) Modem
  - (viii) Chart Recorder

2. Complete the final check section of the postcalibration check sheet.
3. Complete the gas cylinder pressure table at the end of the calibration sheets.
4. Complete the calibration end time.
5. Inspect the cabinet inside and outside for security and safety purposes, paying particular attention to electrical and telephone connections. Check for any signs of vandalism, especially if this may affect safety or lead to a deterioration in data quality. Immediate action must be taken to rectify any situation that may lead to members of the public or monitoring personnel being at risk.
6. Check that the roof area and fittings are secure, that there are no loose items left on the roof and then stow the ladder safely inside the hut.
7. Check that all cylinders except the CO autocal cylinder are firmly closed and the cylinder store locked.
8. Ensure the cabinet is clean and tidy.
9. Upon completion of the calibration and on returning to your office, photocopy the entire check-lists and calibration sheets. Keep the originals at your office and when you next visit the site return the copies to the monitoring site. In this way a backup will be kept of the calibration history of all the instruments.

# **Appendix 4**

## **QUALITY ASSURANCE/CONTROL OBJECTIVES**

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## QUALITY ASSURANCE/CONTROL OBJECTIVES

Good data quality and high data capture rates are essential if a network is to achieve its objectives. To ensure that data are sufficiently accurate, reliable and comparable, consistent data quality assurance/control (qa/qc) procedures are applied throughout the network.

Good qa/qc practice covers all aspects of network operation, including systems design and site selection, equipment evaluation, site operation, maintenance and calibration, data review and ratification. The successful implementation of each component of the qa/qc scheme is essential for the success of the programme.

The fundamental aims of a quality assurance/control programme are as follows:

- The data obtained from measurement systems should be representative of ambient concentrations existing in each urban area.
- Measurements must be accurate, precise and traceable.
- Data must be comparable and reproducible. Results from this geographically extended network must be internally consistent and comparable with international and other accepted standards.
- Results must be consistent over time.
- In order for seasonally or annually averaged measurements to be meaningful, an appropriate level of data capture is required throughout the year.

In the UK the National Measurement System (NMS) exists to provide a formal infrastructure for all measurements in the United Kingdom. At its core are primary standards monitored by the National Physical Laboratory, together with appropriate absolute or traceable metrology standards maintained at other designated laboratories. Essential requirements for conformity with the NMS are:

- Measurement methods used must be of known performance and defined scope of application;
- All calibrations must be traceable through an unbroken chain to international standards (the SI system);
- Measurements should be made within a documented quality system;
- Where possible, measurements should be harmonised with those made by organisations both within and outside UK.

This appendix describes the procedures and record-keeping systems necessary to ensure that on-site network operations comply with the overall qa/qc programme objectives specified above, and are also compatible with the requirements of the UK National Measurement System.

Documenting procedures is, in itself, insufficient to ensure good practice. In order to ensure that on-site operations are compatible with the requirements of the QA/QC programme, full training should therefore be given to the LSO's. This training is intended to ensure that the site operators are fully conversant with the monitoring techniques involved and with the network procedures required to maintain a high standard of performance.

Compliance with documented procedures should be closely monitored, by undertaking audits of site operators and on-going data assessments.

## DATA REQUIREMENTS

Proper QA/QC practice is necessary to ensure data integrity and guarantee the data quality required for meeting the overall network monitoring objectives. Fundamental data requirements are:

1. Accuracy
2. Precision
3. Data capture rate
4. Traceability to national/international metrology standards
5. Long-term consistency
6. Intercomparability (for extended multi-site networks).

Points 1-3 are described in more detail below.

### Accuracy

Accuracy may be defined as 'the closeness of agreement between a single measured value and the actual air quality characteristic or its accepted reference value (from ISO 6879). The accuracy of any air pollution measurement depends on many factors encompassing the entire measurement chain. The accuracy of primary calibration methods (and of the physical constants underlying these), the resultant accuracy of transfer or secondary standards, together with the frequency and method of on-site instrument calibration are of prime importance; intrinsic characteristics of the instruments used, such as span drift or response, will also need to be considered. Other factors such as gas sampling errors or artefacts, sample loss in manifolds or in-line particulate filters, instrument pressurisation and interference effects may all affect overall accuracy. Many of the factors necessary for the rigorous determination of measurement accuracy are readily quantifiable, whilst others are more difficult to assess. Accuracy estimations, involving detailed review of the calibration chain and of measured instrumental characteristics (both in-service and in controlled laboratory situations) have been performed for gaseous measurements of O<sub>3</sub>, NO<sub>x</sub>, SO<sub>2</sub> and CO in existing national networks. Estimated accuracy figures for these pollutants range from 8% (CO) to 11% (O<sub>3</sub>) - see Table below:

Pollutant	Accuracy (2σ)	Precision (2σ)
SO <sub>2</sub>	± 10%	± 1.2 ppb
CO	± 8%	± 0.6 ppm
NO	± 10%	± 2.5 ppb
NO <sub>2</sub>	± 10-11%	± 3.5 ppb
O <sub>3</sub>	± 11%	± 2 ppb
PM <sub>10</sub>	unknown	± 4µg/m <sup>3</sup>

Accepting that the quality of measurements in the automatic urban network should be consistent with these figures, we recommend that a target accuracy of **±10%** as being appropriate and achievable for gaseous measurements undertaken in this programme. Corresponding accuracy estimations have not been made for continuous particulate analysers, although a range of these instruments is currently under evaluation. In practice, it appears that their accuracy is a function of factors such as flow rate and filter mass loading, so that this will need to be defined under clearly specified conditions. Until a primary standard for particulate matter is available, we therefore recommend a target accuracy of ±10% for such analysers.

### Precision

Precision is the 'closeness of agreement between mutually independent test results obtained

by repeating a measurement several times under stipulated conditions' (from ISO 6879). Precision figures, quantified from measured long-term variations in baseline response of in-service continuous gas analysers are summarised in the Table below. Accordingly, we propose the following as target precision requirements for a typical monitoring network:

<b>Pollutant</b>	<b>SO<sub>2</sub></b>	<b>CO</b>	<b>NO</b>	<b>NO<sub>2</sub></b>	<b>O<sub>3</sub></b>	<b>PM<sub>10</sub></b>
<b>Precision</b>	± 1 ppb	± 0.5 ppm	± 2 ppb	± 3 ppb	± 2 ppb	± 4 µg/m <sup>3</sup>

As with other sensitive air quality analysers, the overall precision of TEOM PM<sub>10</sub> measurements will depend on both the short term instrument noise and longer term baseline drift. An estimate of this precision can be determined by calculating the difference in concentrations measured by two TEOM analysers operating side-by-side. The California Clean Air Board (CARB) has undertaken this test and calculated a standard deviation of ± 2µg/m<sup>3</sup> for hourly average PM10 measurements. Working from this figure, a corresponding uncertainty in the instantaneous chart recorder output would be a peak-to-peak variation of 60µg/m<sup>3</sup>. Ratified hourly average PM10 data are quoted with a precision of ±2 standard deviations i.e. ±5 µg/m<sup>3</sup>. The overall uncertainty in any air quality measurement is the combination of accuracy and precision errors. Since accuracy is expressed as a percentage error, its significance for overall uncertainty increases at higher concentrations. At very low concentrations, close to the instrument baseline, the contribution of accuracy errors to total uncertainty is reduced and the overall uncertainty estimate is dominated by the precision error, which is constant at all concentrations.

### Data capture

Data capture rates provide a good indicator of overall network performance and the temporal representativeness of the information gathered. They should not be assessed in isolation, however, as there is a trade-off in the operation of any network between data quality and capture. Overly stringent quality requirements usually involve low capture rates while, conversely, capture rates can always be maximised by relaxing or removing data quality/acceptance criteria. An acceptable compromise is to seek data quality commensurate with the overall aims and objectives of the network and maximise data capture within the constraints thus set. Only if acceptable data quality and high capture rates are achieved can the performance of a network then be regarded as fully satisfactory. The current target data capture requirements for the automatic urban network is 90%. Data loss in any network can result from a number of factors. The most important in practice are:

- analyser breakdown
- poor servicing
- failure or leak of gas sampling system
- data acquisition system failure
- power cut or other site disruption
- telephone line breakdown
- operator error
- vandalism
- failure of quality assurance system
- data rejection (after failing qa/qc criteria)

It may be noted that, if properly designed and configured, daily automatic analyser calibrations should not result in loss of hourly average data. The calibration cycle can be arranged to occur across an hour. Provided that three of the 15 minute averages for the hour are of ambient data, the data can be considered valid.

In well-run networks, the major failure mode will be analyser breakdown: these instruments are complex and 100% reliability cannot reasonably be expected. Although some data loss due to analyser failure is unavoidable (short of deploying backup instruments), most other failure rates can be minimised by:

- efficient data telemetry (enabling on-site problems to be identified rapidly)
- backup data storage media on-site
- rapid service, maintenance and repair
- comprehensive and documented site operational protocols
- regular application of these protocols
- experienced site operators
- proven site infrastructure and system backup
- the deployment of proven analyser types

Data loss should, as far as possible, be evenly distributed throughout the year if meaningful annual or seasonal average estimates are to be derived from the data.





# **Appendix 5**

## **CALIBRATION SYSTEMS: PRINCIPLES**

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# CALIBRATION SYSTEMS: PRINCIPLES

## 1 Introduction

The production of meaningful data from the any monitoring network necessitates the regular calibration of all analyser types using traceable transfer gas calibration standards.

To ensure optimum data quality and capture, a three-tier system of calibration and analyser test procedures is employed in the UK Automatic Network. The major components of this system are briefly described below:

1. Daily automatic calibrations. These allow instrumental drifts to be examined, and act as a daily check on instrument performance. Results should not be used for data scaling, however.
2. Manual calibrations. These are performed by the local site operators, and are used by MU to scale raw pollution data (from the analysers) into meaningful concentration units. Instrument drifts are fully quantified by calibrating analysers manually with documented and traceable calibration standards. These calibrations will be carried out on a weekly or fortnightly basis.
3. Network intercalibrations. These exercises ensure that measurements from all network stations are completely representative and intercomparable. In some cases, such as for ozone analysers, the data are directly scaled according to the results obtained from the network intercalibration. The intercalibrations will also act as an independent audit of the system performance at each monitoring site. In this way, any site-specific problems that may have developed and remained undetected are fully quantified. It is recommended that these network intercalibrations are undertaken every 6-months.

This appendix will describe automatic calibration systems and techniques, as well as gas standards to be used by local site operators in their weekly site calibrations. The intercalibration exercises broadly follow similar procedures to those for weekly calibrations, but use recently calibrated traceable gas standards. Details of this exercise, as undertaken in the UK, are presented in Appendix Z.

## 2 Automatic Calibration Systems and Standards

Daily automatic calibrations provide valuable information on the routine performance of analysers and any long term response drifts. The calibrations, consisting of two point zero and span checks, are controlled automatically by the data logger or analyser software, and will not normally need any adjustment.

The principles of operation of automatic calibration zero and span (IZS) devices for each pollutant, are given below.

### 2.1 NO<sub>x</sub> Analyser

Zero air is generated by passing ambient air through purafil and charcoal scrubbers, before being passed into the reaction cell. With time, the quality of the zero air will eventually degrade, as the scrubbers become exhausted. These should, therefore, be replaced at every six monthly service.

Span gas is usually generated by an NO<sub>2</sub> permeation tube. Zero air at a constant flow rate is passed across the tube that contains a quantity of pure liquid NO<sub>2</sub>. The tube is enclosed in an oven maintained at constant temperature. Provided the flow rate and temperature are kept constant, the amount of NO<sub>2</sub> that permeates from the tube into the air stream will be

constant. This gas thus produced then passes into the reaction cell to provide a span calibration response.

Alternatively, span gas is supplied from a dedicated NO or NO<sub>2</sub> cylinder attached to the IZS span inlet on the equipment rack.

## **2.2 SO<sub>2</sub> Analyser**

Zero air is generated by passing ambient air through a charcoal scrubber, before entering the reaction cell.

Span gas is usually produced in a similar way to the NO<sub>x</sub> analyser, except an SO<sub>2</sub> permeation tube is used in the oven. Alternatively, span gas can be supplied from a dedicated SO<sub>2</sub> cylinder attached to the IZS span inlet on the equipment rack.

## **2.3 Ozone Analyser**

Zero air is produced by passing ambient air through a charcoal scrubber, before entering the reaction cell.

Span gas is produced by the action of UV light on the same zero airstream to produce ozone.

## **2.4 CO Analyser**

Zero air is generated by passing ambient air through a heated catalyst, before entering the reaction cell.

Span gas is supplied from a dedicated CO cylinder attached to the IZS span inlet on the equipment rack.

## **2.5 TEOM Particulate Analyser**

It is not possible to provide a system to carry out daily automatic calibrations on the particulate analyser.

## **3 Transfer Standard Calibration Systems**

As fortnightly manual calibrations are to be used to scale data into meaningful engineering units, it is most important that the calibration mixtures used are both stable and traceable to primary standards. The gas standards supplier is responsible for supply and calibration of on-site transfer standards. These standards are maintained and utilised by local site operators in accordance with the directions specified in this manual. The integrity of on-site standards can be verified the every 6 months, during an intercalibration exercise.

During every calibration visit, a two-point calibration will be performed. This involves determining the response of the analyser when the pollutant of interest has been:

1. Removed from the sample airstream, (zero response);
2. Is present at an accurately known concentration, (span response).

Data scaling factors are determined from these responses, and are used to convert raw voltage data into concentration units, as described in Section 4.

It is useful if the transfer standards that will be used during the weekly/fortnightly calibrations are completely independent from the daily autocalibration apparatus. In this way, the two systems will act as a check on each other. Similarly, the intercalibrations must employ a third, independent, standard to determine zero and span response. All three systems will, however, be inter-related during the intercalibration to quantify any drifts in autocalibration and on-site calibration standards that may have occurred during the preceding 6 month period. If standards are found to have undergone significant drifts, these will be replaced.

### **3.1 Production of Zero Air**

Zero air is produced for use at fortnightly site visits by catalytically removing pollutant species from a sample airstream. For this purpose, a zero air generator has been developed which consists of the following components.

1. Compressor to produce air sample.
2. Water drain to remove liquid water.
3. Needle valve to regulate airflow.
4. Silica gel to remove water vapour.
5. Hopcalite to remove CO
6. Purafil to remove NO
7. Activated charcoal to remove O<sub>3</sub>, NO<sub>2</sub> and SO<sub>2</sub>.
8. A particulate filter on the system outlet to ensure that no particulate matter, especially scrubber material, is "blown" into the analysers.

Using an "active" system, where air is forced through the scrubbers, as opposed to a "passive" system has the following advantages:

1. The system is far less susceptible to leaks due to the positive pressure caused by the compressor along the flow path.
2. The differences between output pressure and atmospheric pressure, i.e. overpressurisation in active and underpressurisation in passive systems, can be better regulated and controlled in an active system.

At some of the network sites, however, a "passive" scrubber system may be used, in which air is drawn through the scrubbers by the analyser.

The consumable components in the zero air generator will be changed routinely at six monthly intervals as part of any service/intercalibration exercise. This will only be done after comparison with transfer zero standard. Having replaced the scrubber components, this comparison will be repeated to ensure the effectiveness of the regenerated scrubber. The zero transfer standard used for these comparisons will previously have been compared to certified zero air cylinders. It may however be necessary for the LSO to regenerate or replace the silica gel component at more frequent intervals.

The date of any scrubber replacements and/or comparisons with transfer standard zero air will be clearly marked on the zero air generator.

### **3.2 Production of Span Calibration Gases**

The gas standards supplier will supply gas cylinders containing calibration gas mixtures of NO, NO<sub>2</sub>, SO<sub>2</sub>, and CO for calibration of the relevant analysers. These cylinders will be purchased from a supplier that has demonstrated compliance with all relevant quality control procedures in the preparation of gas mixtures.

The cylinders will be calibrated, prior to being installed on-site, at the gas standards supplier's gas calibration laboratory.

Each cylinder will be supplied with its own regulator. This will minimise the possibility of the cylinder becoming contaminated by the use of regulators that contain ambient air or other calibration gases. These regulators must not therefore, be removed from the cylinder under normal operating circumstances. Instructions on how to open and close cylinder/regulator supplies must be strictly adhered to if contamination of the cylinder contents is to be avoided.

The use of cylinders has health and safety implications. Provision must be made to securely strap cylinders to prevent them from falling; this is especially important as regulators are to be left connected.

To obtain the analyser calibration span points the following mixtures will be used:

Nitrogen oxides: Nitric oxide (NO) in nitrogen.  
Sulphur dioxide: Sulphur dioxide (SO<sub>2</sub>) in air.  
Carbon monoxide: Carbon monoxide (CO) in air.

A second span check may be undertaken on the nitrogen oxides analyser using a nitrogen dioxide (NO<sub>2</sub>) in air mixture.

For all analysers, the span checks will be undertaken on the analyser running range. This ensures that errors do not manifest themselves in the data scaling factors as a result of inconsistencies in analyser range ratios.

The concentration of each cylinder should be checked at 6 monthly intervals. This will ensure that no significant drifts have occurred in the cylinder concentration. In the event of an excessive drift having occurred, the cylinder will be returned to the supplier for further investigation.

As there is, at present, no reliable and proven system for performing simple on-site two point calibrations on O<sub>3</sub> and particulate analysers, all calibrations which produce data scaling factors for these instruments will be carried out using a reference standard photometer every 6 months.

#### **4 Utilisation of Calibration Data in Producing Scaled Pollution Data**

The two point calibration will quantify the analyser "zero" and "span" response. Where an analyser gives an analogue output in volts which is recorded and averaged by the data logger, it is vital that zero and span factors are also taken as voltage readings from the data logger and not solely by reading the instrument display.

The zero response, **V<sub>z</sub>**, is the response of the analyser when the pollutant species being measured is not present in the sample airstream. The span response, **V<sub>s</sub>** is the response of the analyser to an accurately known concentration, **c**, in ppb, (parts per billion (10<sup>-9</sup>)), of the pollutant species. Both the zero and span responses will be taken on the concentration range at which the instrument normally operates. Instrument zero and span factors are then calculated using these data as follows:

$$\text{Instrument zero} = V_z$$

$$\text{Instrument span, } F = c/(V_s - V_z)$$

Ambient pollution data are then calculated by applying these factors to logged output signals as follows:

$$\text{Pollutant concentration (ppb)} = F(V_a - V_z)$$

Where **V<sub>a</sub>** is the recorded signal from the analyser sampling ambient air. Application of calibration data in this way assumes that the instrument response is linear over the whole concentration/voltage range in use. The linearity of the instrument should be checked at six-monthly intervals.

The data scaling procedures detailed above will be used for pollutants for which reliable transfer standards exist. In the case of ozone, however, the UV measurement technique is inherently more stable than the production of ozone concentrations in the ambient range. The weekly/fortnightly calibration of ozone analysers does not, therefore, serve to produce data scaling factors.

Ambient NO/NO<sub>x</sub>/NO<sub>2</sub> data will be scaled from the calibration of the NO and NO<sub>x</sub> channels of the NO<sub>x</sub> analyser, using the NO in nitrogen transfer standard. This will directly output NO and NO<sub>x</sub> concentrations, with the NO<sub>2</sub> concentration being given by:

$$\text{NO}_2(\text{ppb}) = \text{NO}_x(\text{ppb}) - \text{NO}(\text{ppb})$$

An NO<sub>2</sub> in air calibration mixture will, however, be used as a cross-check on the NO<sub>x</sub> channel calibration and to ensure that the catalytic converter in the instrument efficiently reduces NO<sub>2</sub> to NO.

Exact procedures for instrument calibration are detailed in the Site Operations Procedures.

## 5 Use of Calibration Data over Extended Time Periods

All air pollution analysers will undergo some form of drift in sensitivity over time. This may be due to ageing of components such as photo-multiplier tubes, degradation of catalytic scrubbers, (e.g. ozone scrubbers), or drifts in electronic components.

The possibility exists to routinely adjust instrument sensitivities to align the instrument with the on-site transfer standard. For the following reasons, however, such routine adjustments should be avoided:

1. As all instruments in the network are to be checked on a fortnightly basis, any drifts will be easily quantified by consideration of the calibration history of the instruments. It is most important, therefore that this calibration history is not destroyed.
2. The transfer standards themselves may drift from their original value. If this were the case and both the analyser and on-site standard were drifting, it would be impossible - having altered the analyser response - to produce a final validated data set. Drifts in the on-site standard will be quantified during intercalibrations at 6 monthly intervals.
3. Routine instrument adjustments may lead to unreliable data being produced as the instrument stabilises. Stabilisation periods may take many hours from the time of the adjustment and, with sites being calibrated/adjusted fortnightly, this could lead to an appreciable proportion of data being degraded in quality.

**Calibration results therefore, serve only to scale ambient data. They will not be used to routinely adjust analyser response factors.**

As the instruments will not be adjusted, the instrument scaling factors - **Vz** and **F** - will have to be updated in any data processing system on a regular basis, following each calibration. For this reason, calibration records must be entered into the system immediately after each on-site manual calibration.

## **6 Calibration During High Pollution Episodes**

In order to prevent losing valuable pollution data, it is important to avoid calibrating the analysers during high pollution episodes. The following pre-calibration checks must be performed to confirm if any episode is occurring.

1. Examine the analyser front panel reading to see if the instantaneous concentrations are above, or close to, the trigger levels given for each pollutant in the Table below. The analyser front panel readings are not accurate but give an indication appropriate for this purpose.
2. Where applicable, inspect the chart recorder trace to see if the pollution concentrations have been consistently high during the last hour (approximately one chart division).
3. If the above criteria are met, advice should be sought before proceeding with the calibration.

<b>Pollutant</b>	<b>Episode Criteria</b>	<b>Trigger Level</b> (exceeded for ~ 1 hour)
O <sub>3</sub>	> ~70 ppb	
NO <sub>2</sub>	> ~ 75 ppb	
SO <sub>2</sub>	> ~ 90 ppb	
CO	> ~ 10 ppm	
PM <sub>10</sub>	> ~ 100 µg/m <sup>3</sup>	

# **Appendix 6**

## **NETWORK INTERCALIBRATION REPORT**

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# Network Intercalibration Report

## Introduction

AEA Technology's National Environmental Technology Centre (NETCEN) has undertaken an intercalibration of air quality monitoring sites in the Automatic Urban Network (AUN) in July to September 2001. These intercalibrations are used to complete a wide range of tests to evaluate the performance of each monitoring station. The following major checks are made:

1. **Analyser accuracy and precision**, as a basic check to ensure reliable datasets from the analysers.
2. **Instrument linearity**, to check that doubling a concentration of gas to the analyser results in a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
3. **Instrument signal noise**, to check for a stable analyser response to calibration gases.
4. **Analyser response time**, to check that the analyser responds quickly to a change in gas concentrations.
5. **Leak and flow checks**, to ensure that ambient air reaches the analysers, without being compromised in any way.
6. **NO<sub>x</sub> analyser converter efficiency**, to ensure reliable operation. This is the device that allows the publication of NO<sub>2</sub> datasets, so it must work acceptably.
7. **TEOM k<sub>0</sub> evaluation**. The analyser uses this factor to calculate mass concentrations, so the value is calculated to determine its accuracy.
8. **SO<sub>2</sub> analyser hydrocarbon interference**, as certain hydrocarbons are known to interfere with the SO<sub>2</sub> detector.
9. **Evaluation of site cylinder concentrations**, using a set of NPL certified cylinders that NETCEN take to all the sites. The concentrations of the site cylinders are used to scale pollution datasets, so it is important to ensure that the concentration of gas in the cylinder does not change.
10. **Competence of Local Site Operators (LSO)** in undertaking calibrations. Similarly, as it is the calibrations by the LSO's that are used to scale pollution datasets, it is important to check that these are undertaken competently.

In addition to the above tests, a "Network Intercomparison" is conducted. This exercise utilises audit gas cylinders transported to each site in the AUN. These cylinders have been recently calibrated by NPL, and allow us to examine how different site analysers respond when they are supplied with the same gas used at other sites.

The technique used to process the intercomparison results is broadly as follows:

- The analyser responses to audit gas are converted into concentrations, using provisional calibration factors obtained on the day of the intercalibration. This factor is also used for sending out provisional data to the web/teletext/Met Office.
- These individual results are tabulated, and statistical analyses undertaken (e.g. network average result, network standard deviation, deviation of individual sites from the network mean etc.)

These results are then used to pick out problem sites, or “outliers”, which are investigated further to determine reasons and investigate possible remedies for the outliers. The definition of an outlier is a site result that falls outside the following limits:

- $\pm 10\%$  of the network average for NO<sub>x</sub>, CO and SO<sub>2</sub> analysers,
- $\pm 5\%$  of the reference standard photometer for Ozone analysers,
- $\pm 2.5\%$  of the stated  $k_0$  value for TEOM analysers,
- $\pm 10\%$  for particulate analyser flow rates.

As stated, any outliers that are identified are rigorously checked to determine the cause, and corrective action taken, if necessary. Further details of the typical causes can be found in Section 2.

The procedures used to determine network performance are documented in AEA Technology Work Instructions. These methods are regularly updated and improved and have been evaluated by the United Kingdom Accreditation Service (UKAS). NETCEN holds UKAS accreditation for the on-site calibration of all the analyser types (NO<sub>x</sub>, CO, SO<sub>2</sub>, O<sub>3</sub> and PM<sub>10</sub>) used in the AUN. A UKAS Certificate of Calibration (Calibration Laboratory number 0401) for the urban sites in the AUN is appended to the report.

A total of 81 sites were audited in this exercise; direct funded sites at Dumfries, London Westminster and Inverness, and affiliated sites at Grangemouth, Cwmbrân, Bournemouth, Canterbury, Stockton-on-Tees Yarm, Wigan Leigh, Portsmouth and Northampton commenced operation during the previous six months. The 82<sup>nd</sup> site at Wrexham was vandalised immediately after installation, and is currently awaiting improved security measures before recommissioning.

This report presents the results for each pollutant, identifies analysers that did not meet performance standards, investigates the possible causes of these results and recommends any remedial action required to modify the datasets.

## Analyser Performance

As with the winter 2001 intercalibration report, individual analyser performance has been graded, to provide an indication of how data quality may be affected by the intercalibration results.

The performance grades are as follows:

1. **A** This grade is indicative of an analyser performing very well. All of the tests undertaken were within the required limits, and the quality of the ratified dataset produced by this instrument should be of a high standard. No data should be lost.
2. **B** This grade is indicative of an analyser performing well. The results of the tests have highlighted a minor outlier (for example as a result of minor drift in calibration factor, or a result slightly outside acceptance criteria). This type of outlier is not likely to be easily detected by the Local Site Operator or the CMCU. The quality of the ratified dataset produced by this analyser should be of a high standard. No data should be lost.

3. **C** This grade indicates an analyser performing acceptably. The results of the tests have highlighted a significant outlier (for example as a result of severe drift in calibration factor, or a result significantly outside acceptance criteria). Close examination of the performance history of the analyser may show that data could be retained, but may require substantial adjustments to the dataset to be performed. It is possible that this type of outlier could be detected by the LSO or CMCU during the scheduled calibrations, but it is likely that the fault will remain undetected until the network intercalibration visit. The LSO should compare the current results with those from previous visits, and carefully examine the progress of the current analyser calibration, to ensure "expected normal" behaviour. Any deviations from these patterns should be reported to CMCU immediately. The quality of the ratified dataset produced by this analyser should be of an acceptable standard. It is possible that some data could be rejected during the ratification process.
4. **D** This grade indicates a poorly performing analyser. The results of the tests have highlighted a serious fault or outlier (for example, a poor NOx converter result, or significant losses of calibration gas to the sampling system), which will have serious implications for the quality of the instrument dataset. Again, the LSO and CMCU might be able to detect this type of poorly performing analyser during the scheduled calibration visits, but it is possible that the fault remains undetected until the network intercalibration visit. The LSO should report any "abnormal" behaviour to the CMCU immediately, who will then decide whether any remedial action is required. Depending upon the cause of the outlier, it is possible that much of the dataset will be salvageable during ratification, but it is likely that significant portions of data will be rejected as a result.
5. **E** This grade indicates either a very poorly performing analyser, or that the analyser was not available for testing. The results of the tests have highlighted a very serious fault, or the analyser has completely malfunctioned during the course of the tests, preventing any meaningful results being obtained. Data from this type of analyser will be seriously compromised, and it will be clear to both the LSO and CMCU that there is a fault with the equipment. Depending upon the exact nature of the fault, it may be possible to save data from the analyser, but it is most likely that large portions of the dataset will need to be rejected.

To further aid the readability of the report, the grades are colour coded: GREEN for grade A and B analysers, YELLOW for grade C and D analysers, and RED for grade E analysers. The Table below presents a summary of the network intercalibration:

Date visited	Site	NOx	CO	SO <sub>2</sub>	O <sub>3</sub>	PM <sub>10</sub>
<b>Sites in Scotland</b>						
12/09/01	Aberdeen	D	A	A	-	A
10/09/01	Dumfries	A	-	-	-	-
23/07/01	Edinburgh Centre	A	A	A	A	A
24/07/01	Glasgow Centre	D	A	A	A	A
24/07/01	Glasgow City Chambers	A	A	-	-	-
24/07/01	Glasgow Kerbside	A	A	-	-	A

Date visited	Site	NOx	CO	SO <sub>2</sub>	O <sub>3</sub>	PM <sub>10</sub>
23/07/01	Grangemouth	A	-	A	-	A
11/09/01	Inverness	A	A	-	-	-
<b>Sites in Wales</b>						
22/08/01	Cardiff Centre	A	A	A	A	A
20/08/01	Cwmbrân	B	-	A	-	A
22/08/01	Port Talbot	A	-	A	A	A
21/07/01	Swansea	A	A	A	A	A
	Wrexham	-	-	-	-	-
<b>Sites in Northern Ireland</b>						
17/07/01	Belfast Centre	A	A	A	B	B
17/07/01	Belfast Clara St	-	-	-	-	A
17/07/01	Belfast East	-	-	A	-	-
18/07/01	Derry	C	A	B	A	A
<b>Sites in England</b>						
04/09/01	Barnsley 12	-	-	A	-	-
04/09/01	Barnsley Gawber	D	-	A	B	-
11/07/01	Bath Roadside	A	A	-	-	-
14/08/01	Billingham	A	-	-	-	-
23/07/01	Birmingham Centre	A	A	A	A	A
26/07/01	Birmingham East	A	A	A	A	A
31/07/01	Blackpool	A	A	A	A	A
11/07/01	Bolton	A	A	A	A	A
29/08/01	Bournemouth	A	-	A	-	-
06/09/01	Bradford Centre	A	B	A	A	A
30/08/01	Brighton Roadside	A	A	-	-	-
31/07/01	Bristol Centre	B	A	A	B	C
30/07/01	Bristol Old Market	B	A	-	-	-
10/07/01	Bury Roadside	A	A	A	A	A
17/07/01	Cambridge Roadside	A	-	-	-	-
06/08/01	Canterbury	A	-	-	-	A
12/07/01	Coventry Memorial Park	A	A	A	A	B
01/08/01	Exeter Roadside	A	A	A	B	-
30/08/01	Hove Roadside	A	A	A	-	-
20/08/01	Hull Centre	A	A	A	A	A
19/07/01	Leamington Spa	B	A	A	A	A
07/09/01	Leeds Centre	B	A	A	A	A
17/08/01	Leicester Centre	A	A	A	A	A
07/08/01	Liverpool Centre	A	A	B	-	A
04/07/01	London A3 Roadside	A	A	-	-	A
03/07/01	London Bexley	B	A	B	A	A
04/07/01	London Bloomsbury	E	A	B	B	C
16/07/01	London Brent	A	A	A	A	A
29/08/01	London Cromwell Road 2	A	A	A	-	-
02/07/01	London Hillingdon	A	A	A	A	A
08/08/01	London Westminster	B	A	A	A	A
01/08/01	Manchester Piccadilly	A	A	A	A	A
31/07/01	Manchester South	A	-	A	A	-
02/08/01	Manchester Town Hall	A	A	-	-	-
14/08/01	Middlesbrough	A	A	A	A	A
14/08/01	Newcastle Centre	B	A	A	A	A
09/07/01	Northampton	A	-	A	-	B
15/08/01	Norwich Centre	A	A	A	A	A
14/08/01	Norwich Roadside	D	-	-	-	-

Date visited	Site	NOx	CO	SO <sub>2</sub>	O <sub>3</sub>	PM <sub>10</sub>
21/08/01	Nottingham Centre	A	A	A	B	A
02/07/01	Oxford Centre	A	-	A	-	-
02/08/01	Plymouth Centre	B	A	A	A	A
10/07/01	Portsmouth	A	-	A	-	B
25/07/01	Preston	A	A	A	B	B
03/07/01	Reading	B	A	B	B	A
13/08/01	Redcar	B	A	A	B	A
05/09/01	Rotherham Centre	A	-	A	B	-
01/08/01	Salford Eccles	B	A	A	B	A
20/07/01	Sandwell West Bromwich	A	A	A	A	-
20/08/01	S'thorpe	-	-	A	-	A
03/09/01	Sheffield Centre	A	A	A	B	A
03/09/01	Sheffield Tinsley	A	A	-	-	-
05/07/01	Southampton Centre	A	A	A	B	A
07/08/01	Southend-on-Sea	A	A	A	A	A
12/07/01	Stockport	A	A	A	-	A
13/08/01	Stockton-on-Tees Yarm	A	-	-	-	A
09/07/01	Stoke-on-Trent Centre	A	A	A	A	A
15/08/01	Sunderland	-	-	A	-	-
07/08/01	Thurrock	A	D	A	A	-
05/09/01	Walsall Alumwell	A	-	-	-	-
16/07/01	Walsall Willenhall	B	-	-	-	-
29/08/01	West London	A	A	-	-	-
08/08/01	Wigan Leigh	A	-	C	-	-
24/07/01	Wirral Tranmere	B	A	A	A	A
30/07/01	Wolverhampton Centre	A	A	A	C	A

**Note: The Wrexham site was not audited due to vandalism.**

Grade	A	B	C	D	E	Not tested
<b>No of instruments</b>	<b>245</b>	<b>38</b>	<b>5</b>	<b>5</b>	<b>1</b>	<b>11</b>

From the above table, it is clear that the vast majority of analysers (283 of the 305 analysers, 93%) in the network are functioning well. This compares well with the winter exercise, where 92% of the analysers were grade A or B. Of the remaining analysers, it is possible that data from the majority can be retained, but some investigation into the causes of the outliers needs to be undertaken. The following sections consider each pollutant in turn.

## Ozone

The calibration of the ozone analysers was performed using NETCEN photometers certified against the Standard Reference Photometer (SRP), held at the National Physical Laboratory (NPL).

The results from 15 of the 47 analysers (32%) were found to be greater than 5% from the NETCEN standard at this intercalibration. The overall result is much better than the previous exercise, when 54% of the analysers were identified as outliers. Of the 15 outliers, 14 were minor grade B; the Wolverhampton analyser

was grade C. This was attributed to a large drift in the instrument response, which should be correctable during ratification.

Subsequent investigations revealed instrument response drift as the main reason for all of the other outlying analysers. Ratification of the data from these sites should be relatively straightforward.

The analyser at Liverpool was not tested due to a fault with the NETCEN photometer during the test.

Despite the fact that a large number of outliers were identified, all were relatively minor in nature. The ratification process should produce reliably scaled datasets, with only minimal consequences for data capture.

## Nitrogen Oxides

Twenty of the 77 analysers tested (26%) were identified as outliers, giving calculated values that were more than 10% from the network mean response. This result is much better than the previous intercalibration, when 43% of the analysers were found to be outliers.

Close investigation of the results showed that 14 of these outliers were of minor grade B, 1 of grade C 4 of grade D and 1 of grade E.

The grade B outliers were all seen as a result of minor drifts or step changes in analyser response between scheduled LSO calibrations, which will be easily corrected during ratification, without any loss of data.

The analyser at Derry seen to exhibit considerable differences in response when gas was introduced through the sample inlet, as opposed to the dedicated cylinder inlet. This may well have significant consequences for ambient data, as the results from the scheduled calibrations do not appear to accurately represent what the analyser samples from ambient air.

The analyser scaling factors at London Bexley appear to be incorrect, as supplied by CMCU. This is easily correctable, and will not affect data capture for the site.

The analyser at London Bloomsbury broke down during the audit visit; thus its performance could not be evaluated. It is unlikely that data will need to be rejected as a result of this finding.

Comparison of the network average results against the actual cylinder concentrations showed that the network overestimates NO concentrations by approximately 2% of actual concentrations, with a percentage standard deviation around this value of 3.9%. This is a very good result, which demonstrates that measurements are accurate, consistent and traceable to metrology standards.

The result of the network NO<sub>2</sub> intercomparison shows that the network appears to underestimate concentrations by an average of 2.8%, with a percentage standard deviation around this value of 4.1%. This is also a good result, which demonstrates that measurements of NO<sub>2</sub> are accurate, consistent and traceable to metrology standards.

The NOx converters at four sites (5%) were found to have fallen below the 95% acceptance limit:

- |                     |     |
|---------------------|-----|
| 1. Aberdeen         | 92% |
| 2. Barnsley Gawber  | 86% |
| 3. Glasgow Centre   | 91% |
| 4. Norwich Roadside | 85% |

The performance of the analysers at these sites will be closely scrutinised during ratification, and it is possible that some data will need to be rejected as a result. The ESUs should continue to undertake three monthly converter tests to ensure optimal performance.

**Recommendation: ESU to undertake three monthly converter tests at the above sites**

## Carbon Monoxide

Just one of the 60 analysers (2%) was identified as an outlier. This is much better than the previous exercise, when 14% of the analysers were found to be outside the acceptance limits.

The analyser at Oxford Centre was away for repair at the time of the audit visit; the analyser at Dumfries had not been commissioned prior to the audit.

The analyser at Thurrock was suffering from a truncated zero response at the time of the audit, resulting in an apparent underread. All available data will be used to review this result, but it is likely that significant portions of data will need to be rejected as a result of this finding.

Comparison of the network average results against the actual cylinder concentrations showed that, overall, the network continues to measure concentrations of CO to within 1% of actual values, with a percentage standard deviation of 3.4%. This is an excellent result, demonstrating that measurements are accurate, consistent and traceable to metrology standards.

## Sulphur Dioxide

The analysers at six of the 62 sites (10%) were identified as outliers, giving calculated values that were more than 10% from the network mean response. Of these outliers, 5 were grade B, 1 was grade C. This result is similar to the previous intercalibration, when seven analysers were found to be outliers.

The outliers at Derry, Liverpool Centre, London Bloomsbury and Reading were all seen as a result of minor drifts or step changes in analyser response between scheduled LSO calibrations, which will be easily corrected during ratification, without any loss of data.

The analyser scaling factor at London Bexley appears to be incorrect, as supplied by CMCU. This is easily correctable, and will not affect data capture for the site.

The analyser at Wigan Leigh was seen to drift significantly over the time between LSO calibration and the QA/QC audit. This should be correctable during ratification, with minimal consequences for data capture.

Comparison of the network average results against the actual audit cylinder concentrations showed that, overall, the network measures SO<sub>2</sub> concentrations to within 1%, with a percentage standard deviation of 4.2%. This is an excellent result, and demonstrates that measurements are accurate, consistent and traceable to metrology standards.

The efficiency of the hydrocarbon “kicker” was evaluated with a 1 ppm m-xylene cylinder. The kicker selectively removes hydrocarbons from the sample inlet prior to analysis. This is an important test, because m-xylene behaves in a similar manner to SO<sub>2</sub> when exposed to UV light, and could therefore interfere with the analyser response, if the kicker doesn’t function properly.

To pass the test, the analyser must not respond by more than 1% (10 ppb) of the m-xylene cylinder concentration. However, it should be noted that this particular test is very demanding; typical ambient hourly maximum concentrations of this pollutant rarely exceed 50 ppb, and annual concentrations rarely exceed 5 ppb.

The following 9 analysers were significantly outside the required standard:

- |                           |          |
|---------------------------|----------|
| 1. Belfast East           | (16 ppb) |
| 2. Bury Roadside          | (30 ppb) |
| 3. Coventry Memorial Park | (17 ppb) |
| 4. Derry                  | (24 ppb) |
| 5. Exeter Roadside        | (18 ppb) |
| 6. London Hillingdon      | (19 ppb) |
| 7. Manchester South       | (19 ppb) |
| 8. Nottingham Centre      | (20 ppb) |
| 9. Wolverhampton Centre   | (19 ppb) |

The kicker at Manchester South was also identified as an outlier at the previous exercise.

These results are the same as the previous intercalibration, when 9 analyser kickers were identified as outliers. However the magnitude of the responses to m-xylene was lower; none of these results give immediate cause for concern.

To put these results into perspective, at the expected maximum ambient concentrations of m-xylene (50ppb), the worst kicker would show an interference response of around 2 ppb.

In addition, there were 7 analysers that were just outside the 10ppb acceptance criteria (between 10 and 15ppb). These will be carefully checked at the next intercalibration, and remedial action recommended as necessary.



## Particulates

### TEOM ANALYSERS

Evaluation of the TEOM instrument  $k_0$  calibration constants, using a series of pre-weighed filters, showed that five analysers were outside the  $\pm 2.5\%$  acceptance limit:

- |                           |         |
|---------------------------|---------|
| 1. Belfast Centre         | (-3.2%) |
| 2. Coventry Memorial Park | (-4.6%) |
| 3. Northampton            | (-2.7%) |
| 4. Portsmouth             | (-2.9%) |
| 5. Preston                | (-6.2%) |

The analysers at Coventry Centre and Preston were repeat outliers, having been identified at the winter intercalibration. The Preston analyser had been adjusted at the winter intercalibration (as an outlier of  $-24\%$ ), but it seems that this adjustment has not been completely successful. It should be possible to rescale the data from these sites with no loss of data.

The remainder of the outliers were minor in magnitude, and it should be relatively straightforward to rescale the datasets.

These  $k_0$  results should be verified by the appropriate ESU, and remedial action taken as necessary

**Recommendation: ESUs to verify the results at the above sites, and take remedial action as necessary**

These results give some cause for concern: there are more outliers identified at this intercalibration exercise than have been recorded in total for the nine years of operation of the TEOM in the network. There do not appear to be any clear trends to identify reasons for these outliers; the analysers are a wide range of ages, types and direct funded/affiliated instruments. NETCEN is working closely with the ESU / manufacturer to resolve this position and particular attention will be paid to this test at the next intercalibration

The analyser at Thurrock was in the process of being repaired following water damage at the time of the audit.

The flow rates of the analysers at Bristol Centre and London Bloomsbury were found to be significantly below the required 16.67 l/min. Data from these instruments will be carefully examined, and it is possible that some data will need to be rejected as a result. No significant flow errors or leaks were found at any of the other sites.

### BAM ANALYSER

The flow rate of the analyser at Belfast Clara Street was found to be within acceptable limits.

## PARTISOL ANALYSERS

These gravimetric daily samplers have been or are being installed at the following sites in the network:

1. Dumfries (not commissioned at the time of the audit)
2. Inverness
3. Wrexham (yet to be commissioned)
4. Bournemouth (not tested at the audit)
5. Northampton (not operational at the time of the audit)
6. London Westminster (yet to be commissioned)

At the time of the Inverness intercalibration visit, the analyser reported a filter exchange fault, preventing a flow test being carried out.

## Site Cylinder Concentrations

During the intercalibration, the concentrations of the on-site cylinders were evaluated using the audit cylinder standards. The calculated results showed that 26 of the 274 cylinders (~9%) appear to be outside the  $\pm 10\%$  acceptance criterion. This is similar to the previous intercalibration, where 8% of the cylinders were found to be out of specification. The site cylinder evaluations are performed by calibrating the analysers with audit and site cylinder gas through the same inlet system, and using the conditioned site cylinder regulators, thus minimising any possible errors due to contaminated tubing or regulators.

4 NO cylinder outliers were identified. Of these, the cylinders at Cwmbrân, Glasgow Centre and Stockton-on-Tees Yarm are of most concern, as the NO concentrations alone have changed significantly, suggesting the cylinders may have become contaminated. These should be returned to NPL for replacement at the earliest opportunity.

**Recommendation: NPL to replace the Cwmbrân and Glasgow Centre NO cylinders**

21 NO<sub>2</sub> outliers were found. Of the outliers identified, only the cylinder at Aberdeen gives any cause for concern, as it was found to be 33% different from its certified value. However, as NO<sub>2</sub> cylinders are not routinely used to scale NO<sub>x</sub> data, the requirement for replacement is not urgent. The calculated concentration of this cylinder will be carefully checked at the next intercalibration.

Only one SO<sub>2</sub> outlier was identified. The calculated concentration of the cylinder at London Cromwell Road 2 appears to have drifted by 35% from its stated values. The calculated concentrations of this cylinder will be carefully checked at the next intercalibration.

As with earlier exercises, the site cylinder concentrations evaluated at the on-site audit are not used to update the cylinder databases. This is because the certified values provided by the Calibration Laboratories at NPL and NETCEN have much better uncertainties associated with their calculations. The field calculation is used as a check to identify possible outlier cylinders, which can be subsequently assessed by returning the cylinder for re-certification.

All of the revised calculations will be carefully assessed at the next intercalibration exercise, and any recurring outlier cylinders will be reported to NPL.

## **Assessment of sampling inlets**

During this intercomparison exercise, the potential losses of sample gas to the inlet systems were assessed, using audit cylinder gas.

At a scheduled fortnightly calibration, the LSO introduces gases into the analysers through dedicated, clean gas cylinder inlets. These calibrations are then used to scale raw data from the analysers.

Audit cylinder gases and site cylinder gases were introduced to the analysers at the sample inlet, and the responses compared to the previous LSO calibration, to determine any significant differences between the two methods.

In previous intercalibrations, affected analysers were seen to exhibit pressure sensitivity when audit gases were introduced into the sample inlets. This meant that if the excess flows to the analyser were increased, even by a small amount, the analyser responses would increase, and vice versa. As a result, it has proved extremely difficult to reliably estimate losses to the manifolds for the analysers at affected sites.

At this exercise, the vast majority of the sites showed losses of less than 10% to the sample inlet. Only the NO<sub>x</sub> analyser at Derry was seen to exhibit apparent losses to the sampling / calibration system. This is an encouraging result, continuing the trend of progressively fewer incidences of sample gas losses to the inlet manifold, since the phenomenon was first observed.

## **LSO Audits**

During the intercalibration, 32 of the 65 Local Site Operators were audited; to assess their performance in undertaking scheduled calibrations. As with previous audit exercises, the majority of LSO's undertake calibrations competently, and are very knowledgeable about the equipment used on site and procedures employed in the network. During the intercalibration, we have also undertaken a number of assessments of relatively new LSO's (for example at Inverness, Dumfries, Northampton and Cwmbrân), to ensure that their training has been successfully undertaken. These were very successful, with very few adjustments of their operating techniques required to fully conform to the Operator Manual.

This LSO audit exercise once again demonstrates that operators are generally competent, enthusiastic and knowledgeable about their sites, which is a major contributing factor in ensuring the continued high performance of the network.

## **Certification**

Appended to this report is the Network Certificate of Calibration. This certificate presents the results of the individual analyser scaling factors on the day of the audit visit, as calculated by NETCEN using the audit cylinder standards, in accordance with our UKAS accreditation.

## **Summary**

The intercalibration exercise has demonstrated its value as an effective tool in determining overall site performance and assessing the reliability and traceability of air quality measurements from a large scale network. The results from this intercalibration will be used to assess data quality during the ratification of the network datasets for the 6-month period January – June 2001.

# CERTIFICATE OF CALIBRATION

## AEA Technology Environment

Culham, Abingdon, Oxfordshire OX14 3ED. Telephone 01235 463099 Facsimile 01235 463011



Certificate No: 00606  
AEA Identification Number: 20568104

0401  
0401 S1  
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Approved Signatories:  K. Stevenson  
S. Eaton  
Signed: \_\_\_\_\_ Date: \_\_\_\_\_

Date of issue: 12 December 2001

Customer Name and Address: Mr Alan Irving  
AEQ Division  
Department for Environment, Food and Rural  
Affairs  
Ashdown House (Zone E14)  
123 Victoria Street  
London SW1E 6DE

Description: Calibration factors for monitoring stations in the Automatic Urban Monitoring Network

### 1. Carbon Monoxide

Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppm)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
<b>Scottish Sites</b>							
12/09	Aberdeen	10269	-45	0.3	0.010	3.0	0.9918
23/07	Edinburgh Centre	co11m-79	55	0.3	0.047	3.0	0.9974
24/07	Glasgow Centre	gra410-009	-2	0.3	0.049	3.0	0.9980
24/07	Glasgow City Chambers	m300-721	-9	0.3	0.047	4.0	0.9987
24/07	Glasgow Kerbside		9	0.3	0.054	4.7	0.9988
11/09	Inverness	300-1500	-28	0.3	0.010	3.0	0.9990
<b>Welsh Sites</b>							

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppm)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
22/08	Cardiff Centre	co11m080	30	0.3	0.052	3.0	1.0000
21/07	Swansea	m300-070	-4	0.3	0.050	3.0	0.9999
<b>N.Irish Sites</b>							
17/07	Belfast Centre	769	19	0.3	0.049	3.0	0.9999
18/07	Derry	J AR 009	0	0.3	0.054	3.0	1.0000

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppm)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
<b>English Sites</b>							
11/07	Bath Roadside	eti11388	-27	0.3	0.053	3.0	0.9987
23/07	Birmingham Centre	92376	45	0.3	0.051	3.0	0.9993
26/07	Birmingham East		-17	0.3	0.054	3.0	0.9997
31/07	Blackpool		2	0.3	0.046	3.0	0.9954
11/07	Bolton	2392	1	1.5	1.142	6.9	0.9987
06/09	Bradford Centre		-2	0.3	0.053	3.0	0.9999
30/08	Brighton Roadside	api300-14	20	0.3	0.049	3.0	0.9995
31/07	Bristol Centre	CO11 - 2	42	0.5	0.057	3.0	0.9994
30/07	Bristol Old Market	n121	20	0.3	0.054	3.0	0.9997
10/07	Bury Roadside	1357	0	0.3	0.972	5.0	0.9987
12/07	Coventry Memorial Park		-2	0.3	0.046	3.0	1.0000
01/08	Exeter Roadside	244	11	0.3	0.055	3.0	0.9998
30/08	Hove Roadside	1433	-28	0.3	0.053	3.0	0.9999
20/08	Hull Centre	co11m-77	128	1.0	0.048	6.5	0.9984
19/07	Leamington Spa	219b	61	0.3	0.052	3.0	0.9980
07/09	Leeds Centre		47	0.3	0.048	3.0	0.9999
17/08	Leicester Centre	c011m-104	103	0.3	0.049	3.0	0.9999

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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Date Year =200 1	Site	Analyser number	<sup>1</sup> Zero output	Uncert ainty (ppm)	<sup>2</sup> Calibrati on Factor	Uncertai nty (%)	*R <sup>2</sup>
07/0 8	Liverpool Centre	93097	50	0.3	0.051	3.9	0.9984
04/0 7	London A3 Roadside		-3	0.3	0.052	3.0	0.9991
03/0 7	London Bexley	M300- 079	19	0.3	0.051	3.0	0.9973
04/0 7	London Bloomsbury	159	67	0.3	0.047	3.0	0.9999
16/0 7	London Brent	9830- 33	66	0.7	0.055	3.8	0.9990
29/0 8	London Cromwell Road 2	10776	9	0.3	0.051	3.0	0.9992
02/0 7	London Hillingdon	410- 005	-3	0.3	0.047	3.0	0.9989
08/0 8	London Westminster	300- 867	5	0.3	0.050	3.0	0.9999
01/0 8	Manchester Piccadilly	gra0410 -0	15	0.7	0.052	3.9	0.9941
02/0 8	Manchester Town Hall	m300- 720	-1	0.3	0.047	3.0	0.9993
14/0 8	Middlesbrough	m300- 214	9	0.3	0.053	3.0	0.9998
14/0 8	Newcastle Centre	co11m- 91	45	0.3	0.053	3.0	0.9999
13/0 8	Norwich Centre		9	0.3	0.054	3.0	
21/0 8	Nottingham Centre		-39	0.3	0.047	3.0	0.9991
02/0 8	Plymouth Centre	410-200	37	0.3	0.006	3.0	0.9990
25/0 7	Preston		-7	0.3	0.051	3.0	0.9999
03/0 7	Reading		8	0.3	0.056	3.0	0.9999

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppm)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
13/08	Redcar	m300-610	10	0.3	0.050	3.0	0.9999
01/08	Salford Eccles	9830-43	0	0.3	0.995	5.0	0.9995
20/07	Sandwell West Bromwich	94603	7	0.3	0.053	3.0	0.9997
03/09	Sheffield Centre	0410-006	4	0.3	0.051	3.0	0.9998
03/09	Sheffield Tinsley	828	-2	0.3	0.047	3.0	0.9998
05/07	Southampton Centre	c011m-90	19	0.3	0.057	3.0	0.9998
07/08	Southend-on-Sea		-5	0.3	0.052	3.0	0.9999
12/07	Stockport	1701	21	0.3	0.052	3.0	0.9987
09/07	Stoke-on-Trent Centre	AR 003	-1	0.3	0.053	3.0	0.9994
07/08	Thurrock	300-262	2	0.3	0.060	3.0	0.9996
29/08	West London	92915	71	0.3	0.048	3.0	0.9996
24/07	Wirral Tranmere		-7	0.3	0.049	3.0	1.0000
30/07	Wolverhampton Centre	gra0410-007	-3	0.3	0.058	3.0	0.9983

## 2. Sulphur Dioxide

Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	m-xylene interference (ppb)
<b>Scottish Sites</b>								

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	m-xylene interference (ppb)
12/09	Aberdeen	12182	0	4	0.216	5.0	0.9978	2.2
23/07	Edinburgh Centre	m100-50	19	4.2	0.208	5.0	0.9987	6.4
24/07	Glasgow Centre	477-018	-48	4.9	0.244	5.0	0.9978	11.7
23/07	Grangemouth	703B-274	1	4.2	1.017	5.0	0.9987	5.1
<b>Welsh Sites</b>								
22/08	Cardiff Centre	m100-054	9	4.1	0.201	5.0	0.9933	2.8
20/08	Cwmbran	350e-4080	5	4.1	0.941	5.0	0.9917	5.6
22/08	Port Talbot	m100-943	1	4.3	1.073	5.0	0.9914	3.5
21/07	Swansea	m100-168	8	4	0.201	5.0	0.9968	3.0
<b>N.Irish Sites</b>								
17/07	Belfast Centre	m100-052	18	4	0.197	5.0	0.9994	7.9
17/07	Belfast East	703	3	4.2	0.802	5.0	0.9998	15.8
18/07	Derry	j-ar-009	0	4.1	0.838	5.0	0.9998	23.5
<b>English Sites</b>								
04/09	Barnsley 12	706	3	4.2	0.977	5.0	1.0000	4.9
04/09	Barnsley Gawber		92	5.9	1.276	5.0	0.9952	1.0
23/07	Birmingham Centre	92378	143	4.1	0.183	5.0	0.9998	0.5
26/07	Birmingham East		17	4.1	0.190	5.0	0.9996	8.8
31/07	Blackpool		17	10.6	3.018	5.0	0.9980	11.3

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	m-xylene interference (ppb)
11/07	Bolton	2344	0	4.2	1.037	5.0	0.9978	5.2
29/08	Bournemouth	API-1179	1	4.2	1.030	5.0	0.9983	7.6
06/09	Bradford Centre		242	4.7	1.095	5.0	0.9994	1.9
31/07	Bristol Centre	115	-29	4.5	0.199	5.0	0.9997	9.4
10/07	Bury Roadside	1581	38	4.6	0.911	5.0	0.9964	29.8
12/07	Coventry Memorial Park		248	4.4	1.308	5.0	0.997	17.0
01/08	Exeter Roadside	634(1835)	20	4.4	1.026	5.0	0.9998	18.0
30/08	Hove Roadside	1178	-28	4.4	0.984	5.0	0.9988	6.4
20/08	Hull Centre	m100-205	77	4.1	0.200	5.0	0.9960	1.6
19/07	Leamington Spa	1793	24	4.3	1.054	5.0	0.9986	9.5
07/09	Leeds Centre		20	4	0.193	5.0	0.9985	0.8
17/08	Leicester Centre	m100-204	-27	4.1	0.210	5.0	0.9911	7.2
07/08	Liverpool Centre	93099	10	4	0.224	5.0	0.9992	1.8
03/07	London Bexley	M100-066	1	4.5	1.186	5.0	0.9971	11.3
04/07	London Bloomsbury	92329	22	4.6	0.22	5.0	0.9997	4.0
16/07	London Brent	9850-63	21	4.2	1.002	5.0	0.9983	12.0

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	m-xylene interference (ppb)
29/08	London Cromwell Road 2	10779	1	4.2	1.065	5.0	1.0000	4.3
02/07	London Hillingdon	477-017	30	4	0.199	5.0	0.9974	18.5
08/08	London Westminster	100a-705	2	4.1	0.881	5.0	0.9999	7.9
01/08	Manchester Piccadilly	gra0477-0	6	5.4	0.211	5.0	0.9947	13.2
31/07	Manchester South	E4770104	-20	5.6	0.222	5.0	0.9990	19.4
14/08	Middlesbrough	m100-161	9	4.1	0.216	5.0	0.9997	7.3
14/08	Newcastle Centre	m100-116	-8	4.1	0.213	5.0	0.9995	5.9
09/07	Northampton	890563033	1	4.1	0.796	5.0	0.9977	1.6
13/08	Norwich Centre		104	5.7	1.102	5.0	0.9990	8.5
21/08	Nottingham Centre	477-016	360	10.5	0.463	5.0	0.9955	20.0
02/07	Oxford Centre	3768-161	103	4.1	0.961	5.0	0.9993	2.9
02/08	Plymouth Centre	356-89251	11	4.4	0.104	5.0	0.9998	14.2
10/07	Portsmouth	578323093	1	4.3	1.162	5.0	0.9969	1.2
25/07	Preston		63	4.4	1.351	5.0	0.9996	6.8
03/07	Reading		190	4.1	0.812	5.0	0.9999	8.1
05/09	Rotherham Centre	d4770109	-4	4.4	1.101	5.0	0.9999	-7.2

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	m-xylene interference (ppb)
01/08	Salford Eccles	9850-79	1	4.3	1.010	5.0	0.9987	12.6
20/07	Sandwell West Bromwich	93082	4	4.2	0.998	5.0	0.9993	4.0
20/08	Scunthorpe		-1	4.2	1.024	5.0	0.9999	8.2
03/09	Sheffield Centre	0477-015	-7	4.1	0.203	5.0	0.9998	1.6
05/07	Southampton Centre	m100-203	-16	4.1	0.188	5.0	0.9999	4.1
07/08	Southend-on-Sea		100	4.5	1.249	5.0	0.9999	6.6
12/07	Stockport	1690	19	4.8	0.998	5.0	0.9982	8.0
09/07	Stoke-on-Trent Centre	AR 003	252	11.7	1.063	5.0	0.9992	5.6
15/08	Sunderland	m100-508	-2	4.1	0.862	5.0	0.9999	5.2
07/08	Thurrock	100A-555	3	4.2	1.011	5.0	0.9999	6.1
08/08	Wigan Leigh		1	4.3	1.042	5.0	0.9991	6.5
24/07	Wirral Tranmere		151	6.8	1.092	5.0	0.9994	7.6
30/07	Wolverhampton Centre	gra477-014	8	7.8	0.206	5.0	0.9905	18.9

### 3. Ozone

Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
<b>Scottish Sites</b>							
23/07	Edinburgh Centre	m400-053	-13	3	0.096	3.2	0.9999

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Date Year =200 1	Site	Analyser number	<sup>1</sup> Zero output	Uncerta inty (ppb)	<sup>2</sup> Calibrat ion Factor	Uncertai nty (%)	*R <sup>2</sup>
24/0 7	Glasgow Centre	427-013	-10	3	0.201	3.4	0.9994
	<b>Welsh Sites</b>						
22/0 8	Cardiff Centre	m400- 057	29	3	0.102	3.1	1.0000
22/0 8	Port Talbot	api300- 83	2.5	3	0.497	3.1	1.0000
21/0 7	Swansea	api400- 156	14	3	0.097	3.1	1.0000
	<b>N.Irish Sites</b>						
17/0 7	Belfast Centre	m400- 051	8	3	0.094	3.1	1.0000
18/0 7	Derry	j-ar- 009	0	3	1.019	3.1	0.9999
	<b>English Sites</b>						
04/0 9	Barnsley Gawber		3	3	1.107	3.1	0.9998
23/0 7	Birmingham Centre	92379	23	3	0.105	3.1	1.0000
26/0 7	Birmingham East	92456	5	3	0.097	3.1	1.0000
31/0 7	Blackpool	l-ar- 010	0	3	0.992	3.6	0.9998
11/0 7	Bolton	2871	3	3	0.996	3.1	0.9999
06/0 9	Bradford Centre		0	3	0.997	3.1	0.9999
31/0 7	Bristol Centre	m400- 95	14	3	0.092	3.1	1.0000
10/0 7	Bury Roadside	1453	2	3	1.000	3.1	0.9999
12/0 7	Coventry Memorial Park		0	3	1.002	3.1	0.9995
01/0 8	Exeter Roadside	9812- 94	20	3	1.22	3.5	0.9999

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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Date Year =200 1	Site	Analyser number	<sup>1</sup> Zero output	Uncerta inty (ppb)	<sup>2</sup> Calibrat ion Factor	Uncertai nty (%)	*R <sup>2</sup>
20/0 8	Hull Centre	m400- 219	0	3	0.103	3.1	0.9999
19/0 7	Leamington Spa	1469	20	3	1.055	3.2	0.9999
07/0 9	Leeds Centre	m400 056	-7	3	0.102	3.1	1.0000
17/0 8	Leicester Centre	M400 218	-10	3	0.098	3.1	1.0000
03/0 7	London Bexley	m400- 062	3	3	0.477	3.1	0.9999
04/0 7	London Bloomsbury	92371	8	3	0.123	3.2	0.9998
16/0 7	London Brent	9812-12	17	3	0.487	3.4	0.9998
02/0 7	London Hillingdon	427- 012	8	3	0.099	3.1	0.9994
08/0 8	London Westminster	400- 879	8	3	0.475	3.1	1.0000
01/0 8	Manchester Piccadilly	E42701 02	-10	3	0.194	3.5	0.9998
31/0 7	Manchester South	ETI9312 2	-8	3	0.095	3.2	0.9999
14/0 8	Middlesbrough	m400- 149	13	3	0.095	3.1	1.0000
14/0 8	Newcastle Centre	m400- 96	-3	3	0.1	3.1	1.0000
13/0 8	Norwich Centre	gra0427 -0	1	3	1.017	3.1	0.9996
21/0 8	Nottingham Centre	427-011	-1	3	0.111	3.1	0.9982
02/0 8	Plymouth Centre	35925- 251	13	3	0.049	3.1	1.0000

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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AEA Identification Number: 20568104

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Date Year =2001	Site	Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>
25/07	Preston		0	3	1.09	3.1	1.0000
03/07	Reading	h-ar-004	4	3	1.146	3.1	0.9997
13/08	Redcar	799	3	3	0.472	3.1	1.0000
05/09	Rotherham Centre	D4270106	1	3	1.009	3.1	0.9997
01/08	Salford Eccles	194	-8	6.8	0.887	4.5	0.9968
20/07	Sandwell West Bromwich	93083	0	3	0.493	3.1	0.9996
03/09	Sheffield Centre	427-010	-15	3	0.106	3.1	1.0000
05/07	Southampton Centre	m400-217	8	3	0.091	3.1	0.9999
07/08	Southend-on-Sea		0	3	0.978	3.1	0.9999
09/07	Stoke-on-Trent Centre	AR003	3	3	0.972	3.1	0.9996
07/08	Thurrock	400-1040	0	3	0.484	3.1	0.9999
24/07	Wirral Tranmere	10788	0	3	0.954	3.1	0.9999
30/07	Wolverhampton Centre	0427-009	0	3	0.074	3.2	0.9999

#### 4. Oxides of Nitrogen

Date Year =2001	Site		Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	*Converter efficiency (%)
<b>Scottish Sites</b>									
12/09	Aberdeen	NO	10268	4	5	0.253	5.0	0.9981	

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Date Year =2001	Site		Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	*Conversion efficiency (%)
		NOx		5	5.2	0.256	5.0	0.9982	92.2
10/09	Dumfries	NO	200-1494	5	5	0.426	5.0	0.9977	98.5
		NOx		2	5.4	0.43	5.0	0.9980	
23/07	Edinburgh Centre	NO	m200-092	-9	5	0.47	5.0	0.9981	99.3
		NOx		1	5.4	0.473	5.0	0.9981	
24/07	Glasgow Centre	NO	gra447-011	-6	5	0.443	5.0	0.9973	90.5
		NOx		3	5.5	0.455	5.0	0.9973	
24/07	Glasgow City Chambers	NO	m200-575	1	5	1.297	5.0	0.9984	95.2
		NOx		2	5.5	1.307	5.0	0.9982	
24/07	Glasgow Kerbside	NO	Ambirak H	10	6.8	2.511	5.0	0.9966	98.6
		NOx		9	8.4	2.551	5.0	0.9964	
23/07	Grangemouth	NO	700B-312	-1	5	1.036	5.0	0.9987	97.5
		NOx		-1	5.4	1.068	5.0	0.9988	
11/09	Inverness	NO	m200-1489	-2	5	0.394	5.0	0.9976	98.7
		NOx		-1	5.2	0.398	5.0	0.9977	
<b>Welsh Sites</b>									
22/08	Cardiff Centre	NO	m200-033	7	5	0.336	5.0	0.9999	99.1
		NOx		1	5.3	0.33	5.0	0.9999	
20/08	Cwmbran	NO	350e-4060	1	5	1.051	5.0	0.9992	

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Date Year =2001	Site		Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	*Conversion efficiency (%)
		NOx		4	5.5	1.142	5.0	0.9993	99
22/08	Port Talbot	NO	m200-320	-1	5	1.037	5.0	0.9995	100
		NOx		-2	5.4	1.03	5.0	0.9997	
21/07	Swansea	NO	api200-148	0	5	0.585	5.0	0.9998	95.2
		NOx		-3	6.2	0.583	5.0	0.9999	
<b>N.Irish Sites</b>									
17/07	Belfast Centre	NO	m200-038	2	5	0.33	5.0	0.9999	99
		NOx		-9	5.3	0.326	5.0	1.0000	
18/07	Derry	NO	j-ar-009	19	5.1	1.968	5.0	0.9977	97.2
		NOx		12	6.8	1.897	5.0	0.9912	
<b>English Sites</b>									
04/09	Barnsley	NO		34	11.3	3.179	5.0	0.9987	85.9
	Gawber	NOx		34	13.5	3.17	5.0	0.9987	
11/07	Bath	NO	eti11690	1	5	1.12	5.0	0.9972	95.1
	Roadside	NOx		1	5.3	1.122	5.0	0.9981	
14/08	Billingham	NO	574	5	5.3	2.185	5.0	0.9999	96.6
		NOx		5	7	2.169	5.0	1.0000	
23/07	Birmingham	NO	92377	-10	5	0.416	5.0	0.9999	

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	Centre	NOx		3	5.2	0.424	5.0	1.0000	99

26/07	Birmingham	NO	92457	-3	5	0.451	5.0	0.9997	
	East	NOx		-3	5.8	0.453	5.0	0.9997	98.8
31/07	Blackpool	NO	l-ar-010	41	10.4	2.896	5.0	0.9953	
		NOx		41	11.1	2.913	5.0	0.9946	96.1
11/07	Bolton	NO	2359	1	5	0.921	5.0	0.9981	
		NOx		2	5.6	1.261	5.0	0.9986	97.2
29/08	Bournemouth	NO	API-522	2	5	1.11	5.0	0.9978	
		NOx		1	5.6	1.112	5.0	0.9980	95.4
06/09	Bradford	NO		22	6.6	2.439	5.0	0.9980	
	Centre	NOx		23	8.7	2.487	5.0	0.9980	98.2
30/08	Brighton	NO	592B-263	99	6.9	2.461	5.0	0.9991	
	Roadside	NOx		100	9.4	2.706	5.0	0.9991	101.7
31/07	Bristol	NO	m200-105	-8	5	0.415	5.0	0.9999	
	Centre	NOx		-5	5.2	0.417	5.0	0.9999	98.6
30/07	Bristol Old	NO	m200-653	5	5.6	2.249	5.0	0.9999	
	Market	NOx		5	7.3	2.265	5.0	1.0000	99.5
10/07	Bury	NO	1710	-1	5	0.894	5.0	0.9987	

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Date Year = 2001	Site		Analyser number	<sup>1</sup> Zero output	Uncertainty (ppb)	<sup>2</sup> Calibration Factor	Uncertainty (%)	*R <sup>2</sup>	*Conversion efficiency (%)
	Roadside	NOx		2	5.7	0.915	5.0	0.9986	98.3
17/07	Cambridge	NO	42c-55355	0	5	1.059	5.0	0.9989	
	Roadside	NOx		0	5.3	1.065	5.0	0.9989	95.9
06/08	Canterbury	NO	200A-1147	2	5	1.197	5.0	0.9999	
		NOx		3	5.4	1.195	5.0	0.9999	98.9
12/07	Coventry	NO		5	8.6	2.883	5.0	0.9995	
	Memorial Park	NOx		5	9.8	2.873	5.0	0.9992	95.4
01/08	Exeter	NO	9841-85	21	8.6	2.748	5.0	0.9998	
	Roadside	NOx		21	9.7	2.817	5.0	0.9999	100
30/08	Hove	NO	6158-273	100	5	2.004	5.0	0.9989	
	Roadside	NOx		99	6.6	2.021	5.0	0.9989	101.2
20/08	Hull	NO	m200-186	-9	5	0.493	5.0	0.9981	
	Centre	NOx		-20	5.7	0.478	5.0	0.9981	99.6
19/07	Leamington	NO	53	24	5.1	2.066	5.0	0.9979	
	Spa	NOx		21	6.9	2.074	5.0	0.9967	104
07/09	Leeds	NO	106	-8	5	0.416	5.0	0.9999	
	Centre	NOx		-15	5.2	0.411	5.0	0.9999	97.4
17/08	Leicester	NO	M200191	-9	5	0.478	5.0	0.9998	

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	Centre	NOx		-21	5.7	0.488	5.0	0.9997	97.7
07/08	Liverpool Centre	NO NOx	93098	-17 -26	5 5.3	0.441 0.442	5.0 5.0	0.9996 0.9996	100.2
04/07	London A3 Roadside	NO NOx	Ambirak H	101 101	10.8 11.9	3.147 3.175	5.2 5.0	0.9916 0.9914	95.6
03/07	London Bexley	NO NOx	m200-059	1 0	5 6.9	2.013 2.02	5.0 5.0	0.9973 0.9973	97.5
16/07	London Brent	NO NOx	1852	23 28	6.8 8.4	2.395 2.394	5.0 5.0	0.9983 0.9983	102.9
29/08	London Cromwell Rd 2	NO NOx	10775	-1 -1	6.8 8.2	2.519 2.511	5.0 5.0	0.9999 1.0000	98.1
02/07	London Hillingdon	NO NOx	447-010	25 24	5 5.3	0.401 0.408	5.0 5.0	0.9929 0.9932	97.9
08/08	London Westminster	NO NOx	200a-573	2 -1	15.7 15.7	3.94 3.85	5.0 5.0	0.9999 0.9999	98.1
01/08	Manchester Piccadilly	NO NOx	447-006	-17 -15	5 5.2	0.386 0.408	5.0 5.0	0.9913 0.9917	96.5
31/07	Manchester	NO	GRA0447	90	5	0.624	5.0	0.9971	

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	South	NOx		90	5.8	0.637	5.0	0.9972	98.8
02/08	Manchester Town Hall	NO NOx	M200-846	0 1	6.0 8.0	2.359 2.358	5.0 5.0	0.9976 0.9977	99
14/08	Middlesbrough	NO NOx	M200-139	-13 -16	5 5.3	0.4 0.399	5.0 5.0	0.9999 0.9999	98.5
14/08	Newcastle Centre	NO NOx	37	-15 -29	5 6.2	0.518 0.503	5.0 5.0	1.0000 1.0000	99.2
09/07	Northampton	NO NOx	851318061	0 -4	5 5.3	0.985 0.986	5.0 5.0	0.9998 0.9998	101.6
13/08	Norwich Centre	NO NOx	Ambirak	-1 -3	6.7 7.7	2.497 2.373	5.0 5.0	0.9976 0.9970	100
14/08	Norwich Roadside	NO NOx	94604	-3 -4	5 5.4	1.176 1.175	5.0 5.0	0.9985 0.9979	85.1
21/08	Nottingham Centre	NO NOx	447-009	3 2	5 5.5	0.606 0.613	5.0 5.0	0.9986 0.9987	99.5
02/07	Oxford Centre	NO NOx	411B-179	100 105	5 6.6	1.139 1.181	5.0 5.0	0.9998 0.9999	95.1
02/08	Plymouth	NO	49c66639-	3	5	0.202	5.0	0.9998	

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	Centre	NOx	353	4	5.4	0.208	5.0	0.9999	99.5
10/07	Portsmouth	NO	903005	0	5	0.992	5.0	1.0000	99.3
		NOx		0	5.3	0.996	5.0	1.0000	
25/07	Preston	NO	Ambirak	36	12.5	3.415	5.0	0.9995	100
		NOx		36	13.4	3.422	5.0	0.9986	
03/07	Reading	NO	AR-004	-1	9.6	2.591	5.0	0.999	98.5
		NOx		0	8.7	2.65	5.0	0.9992	
13/08	Redcar	NO	497	1	5	1.053	5.0	1.0000	96.7
		NOx		3	5.7	1.054	5.0	1.0000	
05/09	Rotherham	NO	D4470108	2	5	0.714	5.0	0.9999	95.1
	Centre	NOx		3	5.2	0.733	5.0	1.0000	
01/08	Salford	NO	488	0	5	1.276	5.0	0.9985	101.1
	Eccles	NOx		1	5.9	1.325	5.0	0.9985	
20/07	Sandwell	NO	93081	13	5	1.584	5.0	0.9994	99.4
	W Bromwich	NOx		10	5.8	1.593	5.0	0.9993	
03/09	Sheffield	NO	447-008	5	5	0.473	5.0	1.0000	97.1
	Centre	NOx		5	5.2	0.475	5.0	1.0000	
03/09	Sheffield	NO	847	-2	6.6	2.478	5.0	0.9999	

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	Tinsley	NOx		-2	8	2.457	5.0	0.9999	99.1
05/07	Southampton Centre	NO	m200-187	-10	5	0.461	5.0	0.9999	100.6
		NOx		-12	5.6	0.457	5.0	0.9999	
07/08	Southend-on-Sea	NO	AR-011	66	5	1.108	5.0	0.9991	95.9
		NOx		66	6.4	1.128	5.0	0.9995	
12/07	Stockport	NO	1853	19	7.7	2.586	5.0	0.9976	103.4
		NOx		21	9.5	2.783	5.0	0.9967	
13/08	Stockton-on-Tees Yarm	NO	9841a-118	0	5	1.072	5.0	0.9996	95.7
		NOx		-1	5.5	1.114	5.0	1.0000	
09/07	Stoke-on-Trent Centre	NO	AR-003	36	7.7	2.472	5.0	0.9973	96.9
		NOx		35	9.2	2.528	5.0	0.9971	
07/08	Thurrock	NO	11004	-3	5	1.136	5.0	1.0000	97.7
		NOx		-1	5.4	1.141	5.0	1.0000	
05/09	Walsall Alumwell	NO	848	0	7	2.566	5.0	0.9999	98.4
		NOx		0	8.6	2.607	5.0	0.9999	
16/07	Walsall Willenhall	NO	1337	6	5	0.915	5.0	1.0000	97.3
		NOx		7	5.3	0.926	5.0	1.0000	
29/08	West	NO	10774	2	5	1.39	5.0	1.0000	

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	London	NOx		3	5.5	1.392	5.0	0.9999	96.1
08/08	Wigan	NO	Horiba - n	0	5	0.975	5.0	0.9990	
	Leigh	NOx		0	5.3	0.971	5.0	0.9989	99.3
24/07	Wirral	NO	Ambirak	24	6.6	2.439	5.0	0.9993	
	Tranmere	NOx		24	8.4	2.511	5.0	0.9992	99.4
30/07	Wolverhampton	NO	gra0447	37	5	0.49	5.0	0.9968	
	Centre	NOx	-007	30	5.3	0.493	5.0	0.9962	97

### 5. Particulate Analysers

Date Year =2001	Site	Analyser number	Calculated Spring Constant k <sub>0</sub>	Uncertainty (%)	<sup>4</sup> k <sub>0</sub> accuracy (%)	<sup>3</sup> Measured Main Flow	Uncertainty (%)	<sup>3</sup> Measured Total Flow	Uncertainty (%)
	<b>Scottish Sites</b>								
12/09	Aberdeen	21371	9938	1	-2.1	1.77	5	15.82	4
23/07	Edinburgh Centre	1200-1209	12472	1	-0.1	2.06	5	17.21	4
24/07	Glasgow Centre	20913	13089	1	-1.9	2.00	5	16.94	4
24/07	Glasgow Kerbside	21316	13556	1	-1.0	2.01	5	18.14	4
23/07	Grangemouth	1200c1522	12339	1	-2.5	2.97	5	16.81	4

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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## AEA Technology Environment

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Date Year = 2001	Site	Analyser number	Calculated Spring Constant $k_0$	Uncertainty (%)	$^4k_0$ accuracy (%)	$^3$ Measured Main Flow	Uncertainty (%)	$^3$ Measured Total Flow	Uncertainty (%)
	<b>Welsh Sites</b>								
22/08	Cardiff Centre	2165	11200	1	0.6	2.02	5	16.39	4
20/08	Cwmbran	21557	12489	1	-0.4	3.06	5	16.36	4
22/08	Port Talbot	1200-1868	10668	1	0.7	3.08	5	17.08	4
21/07	Swansea	1200-1260	14316	1	-1.7	1.99	5	17.02	4
	<b>N.Irish Sites</b>								
17/07	Belfast Centre	1818	13111	1	-3.2	2.58	5	17.12	4
17/07	Belfast Clara St					n/a	n/a	17.35	4
18/07	Derry	49608	10816	1	-0.7	2.05	5	16.88	4
	<b>English Sites</b>								
23/07	Birmingham Centre	2297	11852	1	-1.9	2.00	5	16.67	4
26/07	Birmingham East	92454	16760	1	-1.5	2.05	5	17.50	4
31/07	Blackpool	22980	12881	1	-2.0	2.00	5	16.71	4
11/07	Bolton	21197	14785	1	-2.5	2.92	5	16.51	4
06/09	Bradford Centre	21494	11185	1	-1.5	2.02	5	16.22	4
31/07	Bristol Centre	1200-1198	11925	1	0.2	Failed leak test			
10/07	Bury Roadside	658	11386	1	-1.8	1.96	5	16.52	4
06/08	Canterbury	1200-1260	13876	1	-1.1	3.04	5	16.75	4

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

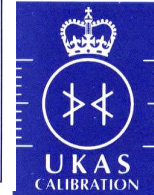
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Date Year =2001	Site	Analyser number	Calculated Spring Constant $k_0$	Uncertainty (%)	$^4k_0$ accuracy (%)	$^3$ Measured Main Flow	Uncertainty (%)	$^3$ Measured Total Flow	Uncertainty (%)
12/07	Coventry Memorial Park	21918	12776	1	-4.6	3.05	5	17.40	4
20/08	Hull Centre	2299	14007	1	-1.2	1.84	5	15.51	4
19/07	Leamington Spa	9408	10870	1	-0.7	Not tested		16.69	4
07/09	Leeds Centre	2032	12931	1	0.7	1.97	5	16.33	4
17/08	Leicester Centre	1817	11466	1	0.9	2.02	5	16.34	4
07/08	Liverpool Centre	2034	13828	1	-2.1	1.96	5	16.42	4
04/07	London A3 Roadside	21314	10262	1	-1.9	1.75	5	16.38	4
03/07	London Bexley	2000	10243	1	-2.2	2.09	5	17.23	4
04/07	London Bloomsbury	92373	9418	1	-0.1	Failed leak test			
16/07	London Brent	21145	17184	1	-1.9	2.93	5	16.57	4
02/07	London Hillingdon	209039506	8410	1	-1.9	2.04	5	16.61	4
01/08	Manchester Piccadilly	20914	11923	1	-1.1	Not tested			
14/08	Middlesbrough	2143	8110	1	0.2	2.00	5	16.68	4
14/08	Newcastle Centre	ETI92388	11891	1	-1.1	1.98	5	16.55	4
09/07	Northampton	21621	10852	1	-2.7	2.95	5	16.23	4

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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Date Year = 2001	Site	Analyser number	Calculated Spring Constant $k_0$	Uncertainty (%)	$^4k_0$ accuracy (%)	$^3$ Measured Main Flow	Uncertainty (%)	$^3$ Measured Total Flow	Uncertainty (%)
13/08	Norwich Centre	21495	11931	1	-2.3	1.93	5	16.45	4
21/08	Nottingham Centre	209159507	8585	1	-1.0	1.97	5	16.47	4
02/08	Plymouth Centre	1200b135169	12736	1	-0.7	2.01	5	16.37	4
10/07	Portsmouth	21578	10267	1	-2.9	2.94	5	16.27	4
25/07	Preston	22881	12742	1	-6.2	1.91	5	17.30	4
03/07	Reading	140ab2131	12907	1	-2.2	1.96	5	16.69	4
13/08	Redcar	21344	11666	1	-1.0	2.93	5	16.66	4
01/08	Salford Eccles	21168	14237	1	-1.2	1.94	5	16.44	4
20/08	Scunthorpe	2129	4919	1	-1.4	Not tested - unsafe access			
03/09	Sheffield Centre	20904	11059	1	-2.3	1.98	5	16.16	4
05/07	Southampton Centre	2298	13599	1	-1.7	1.94	5	16.17	4
07/08	Southend-on-Sea	1200c1548	13353	1	-0.3	Not tested		16.67	4
12/07	Stockport	659	10342	1	-0.7	2.92	5	16.45	4
13/08	Stockton-on-Tees Yarm	22885	13956	1	-2.4	3	5	14.88	4
09/07	Stoke-on-Trent Centre	21317	18014	1	-1.9	1.97	5	16.47	4
24/07	Wirral Tranmere	22883	12963	1	-2.5	1.88	5	17.4	4
30/07	Wolverhampton Centre	20917	13428	1	-2.3	2.09	5	17.23	4

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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The above factors have been calculated using certified standards. The analysers listed above have been tested for zero response, calibration factor, linearity, converter efficiency (NOx analysers), m-xylene interference (SO<sub>2</sub> analysers), k<sub>0</sub> / main flow rate (for TEOM analysers) and total flow rate (for particulate analysers), by documented methods. Note that the test results are valid on the day of test only, as analyser drift over time cannot be quantified.

The calibration results for NO<sub>x</sub>, NO, CO, SO<sub>2</sub>, O<sub>3</sub> and Particulates are those that fall within our scope of accreditation. Results marked with an asterisk (\*) on this certificate are not UKAS accredited, but have been included for completeness.

<sup>1</sup>The zero response is the zero reading on the logging system of the analyser when audit zero gas was introduced to the analysers under test.

<sup>2</sup>The calibration factor is the multiplying factor required to scale the reading on the data logging system into concentration units (ppb for NO, NO<sub>x</sub> and SO<sub>2</sub>, ppm for CO – 1ppm = 1000 ppb). It should be used in conjunction with the analyser output and the zero response, according to the following equation:

$$\text{Concentration} = (\text{output} - \text{zero response}) \times \text{Calibration factor}$$

<sup>3</sup>The calculated main flow rate (where this is applicable) is the flow rate through the sensor unit of a TEOM analyser. The calculated total flow rate is the flow rate through a particulate analyser.

<sup>4</sup>The k<sub>0</sub> accuracy value (specifically for TEOM analysers) indicates the closeness of the calculated result to the manufacturer's specified value of k<sub>0</sub>.

\*R<sup>2</sup> is the correlation coefficient of linearity

\*Converter is the measured efficiency of the NO<sub>2</sub> to NO converter in the Oxides of Nitrogen analyser

\*meta-xylene interference is the response of the SO<sub>2</sub> analyser when supplied with approx. 1ppm meta-xylene

This certificate is an electronic representation of a master copy, held at AEA Technology Environment. Hard copies of this document are available on request.

**The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.**

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