



Gibraltar Monitoring Regime Assessment

2015-2019

Report for Gibraltar Environmental Agency

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Contact:

Andrew J Kent, Gemini Building, Fermi Avenue, Harwell, Didcot, OX11 0QR, UK

T: +44 (0) 1235 75 3629

E: andrew.kent@ricardo.com

Author:

Rebecca Morris

Approved by:

Andrew Kent

Signed



Date:

25/11/2020

Ref: ED 61636

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Executive summary

The Air Quality Directive and 4th Daughter Directive establish a coherent framework under which the limit values (LVs) or target values (TVs) regulating ambient air pollutants are set within Europe. Under Article 5 of the Air Quality Directive and Article 4 of the 4th Daughter Directive, a requirement is placed upon Member States to undertake an investigation of ambient air quality at least every five years in order to establish estimates for the overall distribution and levels of pollutants and to identify monitoring requirements in line with the guidance provided by the Directives. In accordance with Article 5 paragraph 2 of the Air Quality Directive, this document provides the third such review of pollutant levels and distribution since the original preliminary assessment was conducted in 2003. The review is based on the high quality monitoring data from the established network of fixed automatic monitoring stations as defined by the original assessment.

This review has utilised relevant measurements from Gibraltar's high quality, fixed monitoring network and these measurements have been compared with appropriate Upper and Lower Assessment Thresholds (UAT and LAT) and Long Term Objectives (LTO) presented in the relevant Directives. Exceedance of these values dictates the requirement for fixed monitoring. The results of the assessment are summarised in Table 1 below.

This review has also examined parts of the monitoring network that are not related to formal compliance reporting but which have evidential value. The merit of this monitoring has been reviewed and recommendations made.

Table 1 Summary of established monitoring requirements

Pollutant	Assessment Threshold Status	Formal requirement for fixed continuous monitoring	Recommendation for fixed continuous monitoring	Comments
NO ₂	>UAT	Yes	Yes	Current monitoring satisfies Directive requirements Recommend movement of Withams Road monitoring station.
PM ₁₀	>UAT	Yes	Yes	Current monitoring satisfies Directive requirements. Switch to FIDAS instruments.
PM _{2.5}	<LAT	No	Yes	PM _{2.5} considered to be most relevant size fraction from exposure/epidemiology perspective and for comparison against Limit Value (Stage 1 and 2). Add PM _{2.5} to Bleak House through FIDAS instrument. Need to achieve prescribed ratio of PM ₁₀ to PM _{2.5}
SO ₂	<LAT	No	Yes	Retain as useful indication of shipping emissions and to inform future monitoring regime assessments. Will demonstrate AQ impact of new power station at North Mole
CO	<LAT	No	Yes	Retain as useful indicator of traffic emissions (NO _x , NO ₂ and PM ₁₀ , PM _{2.5}) and to inform future monitoring regime assessments
Benzene	<LAT	No	Yes	Retain as useful indicator of traffic emissions (NO _x , NO ₂ and PM ₁₀ , PM _{2.5}) and to inform future monitoring regime assessments
O ₃	>LTO	Yes	Yes	Current monitoring satisfies Directive requirements
Arsenic	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
Cadmium	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
Nickel	LAT-UAT	Yes	Yes	Current monitoring satisfies Directive requirements
Lead	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
BaP	<LAT	No	Yes	Retain to inform future monitoring regime assessments

This assessment shows that the current network of ambient air pollution monitoring stations in Gibraltar is compliant with the criteria specified in the Air Quality Directive and 4th Daughter Directive going forward.

We recommend the continuation of fixed monitoring for pollutants currently in place for local Government policy support, abatement strategy assessment and for scientific justification and analysis. Although these are not required for formal compliance with the Directives in all cases, they provide information essential to comprehensive and robust action planning and reporting to the Commission.

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Glossary

Abbreviation	Definition
AADTF	Annual Average Daily Traffic Flow
AEI	Average Exposure Indicator
AOT40	Accumulated Ozone over Threshold of 40 ppb
AQD	Air Quality Directive
As	Arsenic
BaP	Benzo[a]Pyrene
BTEX	Benzene, toluene, ethyl-benzene and xylene
Cd	Cadmium
CO	Carbon Monoxide
ECO	Exposure Concentration Obligation
EU	European Union

Abbreviation	Definition
FDMS	Filter Dynamic Measurement System
GibTrAQ	Gibraltar Traffic Air Quality
HGV	Heavy goods vehicles
LAT	Lower Assessment Threshold
LGV	Light goods vehicles
LNG	Liquefied Natural Gas
LTO	Long Term Objectives
LV	Limit Value
NERT	National Exposure Reduction Target
Ni	Nickel
NO ₂	Nitrogen Dioxide
NO _x	Nitrogen Oxides
Pb	Lead
PM	Particulate Matter
RT	Road traffic
SO ₂	Sulphur Dioxide
TEOM	Tapered Element Oscillating Microbalance
TV	Target Value
UAT	Upper Assessment Threshold

1 Introduction

EU Council Directive 96/62/EC, (commonly known as The Framework Directive¹), and subsequent 'Daughter Directives'^{2,3,4} have established a coherent framework under which the limit values or target values regulating specified ambient air pollutants are set within Europe. More recently these Directives (excepting the fourth daughter Directive) have been revised and consolidated into a single Directive, known as the Air Quality Directive⁵.

Under Article 5 of Framework Directive, a requirement had been placed upon Member States to undertake a preliminary investigation of ambient air quality prior to the implementation of subsequent Daughter Directives setting limit values referred to in Article 4 of the Framework Directive. This was undertaken in 2003⁶ to inform upon the commissioning of the Gibraltar Air Quality Network by establishing estimates for the overall distribution and levels of pollutants and to identify monitoring requirements in line with the guidance provided by the daughter Directives.

In accordance with Article 5 paragraph 2 of the Air Quality Directive, this document provides the third review of pollutant levels and distribution since the original preliminary assessment was conducted in 2003 and second in 2014 and is based on the high quality monitoring data from the established network of fixed automatic monitoring stations as defined by the original assessment.

1.1 Scope of this report

The preliminary assessment undertaken prior to the establishment of the Gibraltar Air Quality Network shaped the network in terms of monitoring locations, numbers of monitors and the pollutants monitored.

In light of the measurements resulting from the Gibraltar Air Quality Network as it was originally defined, this document makes recommendations on the current and future composition of the monitoring network to ensure that the Gibraltar Environmental Agency and Government of Gibraltar can remain confident in the quality and compliance of the network. The review is focused on assessing the network relative to the requirements for minimum compliance with the Directives.

In some cases there may no longer be a formal requirement to maintain fixed monitoring based on recent measured concentrations from the existing network. However, there may still be valid scientific and policy support reasons to retain the measurements, for example to preserve a long-term data record, demonstrate continuing improvements in air quality (related to monitoring the success of implemented measures as part of an Air Quality Plan) or to provide defensible and robust support for policy decisions/ source apportionment analysis.

1.2 General approach

Our approach to the assessment of air quality regulated by the Air Quality and 4th daughter Directives has been to utilise relevant measurements from Gibraltar's high quality, fixed monitoring network that was not available to support the original preliminary assessment. An annual data capture threshold of

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

2 1st 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

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

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

5 Directive 2008/50/EC of the European Parliament and of the council of 21 May 2008 on ambient air quality and cleaner air for Europe

6 Bush, T. et al. (2003) Preliminary Assessment of air quality in Gibraltar (report: netcen/ED50212/Issue1 to the Gibraltar Environmental Agency)

75% has been applied in the calculation of most of relevant metrics to ensure that values have been used that are representative of the entire year. Due to the age of the instruments in the later parts of this five year period, the data capture has been lower. In order to utilise this data and in the absence of alternative data (other sites) to use, a lower data capture threshold has been applied. Care and expert judgement has been applied to ensure that data remains comparable and trustworthy relative to years with high data capture. This approach provides a representative annual mean whilst maximising the use of available data.

These measurements (i.e. the number of hours, number of days or annual mean exceeding) have been compared with appropriate Upper and Lower Assessment Thresholds (UAT and LAT) and Long-term Objectives (LTO) presented in the relevant Directives to determine an assessment threshold status for each pollutant. The LAT and UAT for pollutants covered by the Air Quality Directive are based on the LV for the respective pollutant with the exception of ozone, for which monitoring is assessed against the LTO. The LAT and UAT for pollutants covered by the 4th Daughter Directive are based on the Target Value (TV) for the respective pollutant. The pollutants assessed in this review are presented in Table 2, below.

Table 2 Pollutant assessment thresholds and criteria

Pollutant	Metric	LAT	UAT	Directive reference for assessment threshold/criteria
NO ₂	Hourly *	100 µg m ⁻³	140 µg m ⁻³	Air Quality Directive (Annex II)
	Annual	26 µg m ⁻³	32 µg m ⁻³	Air Quality Directive (Annex II)
PM ₁₀	Daily **	25 µg m ⁻³	35 µg m ⁻³	Air Quality Directive (Annex II)
	Annual	20 µg m ⁻³	28 µg m ⁻³	Air Quality Directive (Annex II)
PM _{2.5}	Annual	12 µg m ⁻³	17 µg m ⁻³	Air Quality Directive (Annex II)
SO ₂	Daily	50 µg m ⁻³	75 µg m ⁻³	Air Quality Directive (Annex II)
CO	Daily max 8-hr	5 µg m ⁻³	7 µg m ⁻³	Air Quality Directive (Annex II)
Benzene	Annual	2 µg m ⁻³	3.5 µg m ⁻³	Air Quality Directive (Annex II)
Ozone	Daily max 8-hr	LTO: 120 µg m ⁻³		Air Quality Directive (Annex VII, Section C)
Arsenic	Annual	2.4 ng m ⁻³	3.6 ng m ⁻³	4 th daughter Directive (Annex II)
Cadmium	Annual	2 ng m ⁻³	3 ng m ⁻³	4 th daughter Directive (Annex II)
Lead	Annual	0.25 µg m ⁻³	0.35 µg m ⁻³	Air Quality Directive (Annex II)
Nickel	Annual	10 ng m ⁻³	14 ng m ⁻³	4 th daughter Directive (Annex II)
BaP	Annual	0.4 ng m ⁻³	0.6 ng m ⁻³	4 th daughter Directive (Annex II)

* 18 exceedances permissible

** 35 exceedances permissible

1.2.1 Fixed continuous monitoring requirement

The need for fixed continuous monitoring is determined by the assessment threshold status for each pollutant (i.e. below LAT, above UAT or between LAT and UAT). Guidance on the number of fixed monitoring stations required for minimum compliance is provided in the relevant Directive(s) and incorporates reference to the population of the zones and agglomerations being assessed.

Pollutants classified as above the LAT for three or more of the five years⁷ of the assessment period require fixed continuous monitoring.

⁷ Air Quality Directive Annex II, part B

There is a minimum requirement for fixed continuous monitoring, but this can be supplemented with alternative information such as modelling in order to reduce the monitoring burden as long as the minimum monitoring requirements are met. Gibraltar's geographical scale and population (two significant criteria of the Directive) mean that even in cases where the zone is classified as above the UAT for a pollutant, the required monitoring is no more than the minimum. In effect, the implications for monitoring requirement of being classified as above the UAT and between the LAT and UAT are the same – i.e. the minimum monitoring specified by the Directive is required and so there is no advantage to being able to use supplementary forms of assessment such as modelling to reduce the monitoring requirement.

Where pollutants are classified as below the LAT for three or more years of the assessment period, there is no formal requirement according to the Directives to have fixed continuous monitoring, although there may be compelling reasons for this other than the legislative requirement (as discussed in Section 4).

1.3 Gibraltar Air Quality Monitoring Network

1.3.1 Fixed continuous monitoring

Three fixed automatic monitoring stations exist within the network and are illustrated in Figure 1. These are:

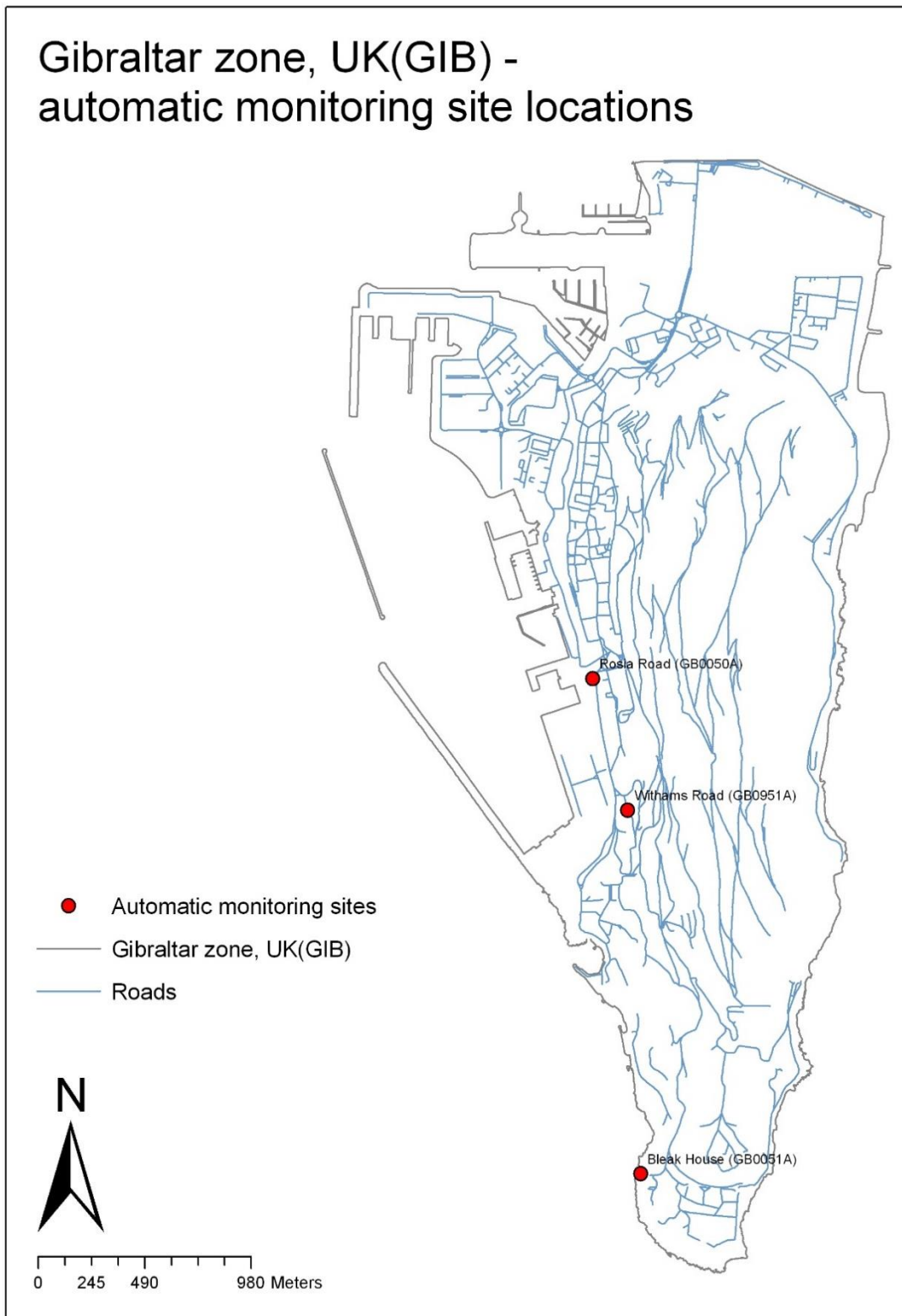
1. Rosia Road (GB0050A)
2. Bleak House (GB0051A)
3. Witham's Road (GB0951A)

Rosia Road is the principal monitoring station and is located in a roadside environment. Here a full suite of Air Quality and 4th Daughter Directive pollutants are measured - NO_x, NO₂, SO₂, PM₁₀, PM_{2.5}, CO, benzene, arsenic (As), cadmium (Cd), lead (Pb), nickel (Ni) and Benzo[a]Pyrene (BaP).

Bleak House is an urban background monitoring location and measures PM₁₀, ozone, NO_x and NO₂.

Witham's Road measures only NO_x and NO₂ and was established in 2008 following successively high indicative monitoring results (by diffusive sampler) and a modelling assessment that suggested this location was a pollution hotspot driven by emissions from the OESCO and MOD power stations. Though Witham's Road is officially classed as a roadside site under criteria specified in the Directives (i.e. it is within 5 metres of the kerb), the traffic count on this small road is exceptionally low and is not thought to contribute significantly to measured concentrations.

Figure 1 Map of fixed automatic monitoring locations in Gibraltar



2 Air Quality Directive Pollutants

2.1 Nitrogen Dioxide

The comparatively small spatial extent of Gibraltar (approximately 6.25 km²) and the presence of point sources means that there are no defined vegetation or ecosystem protection areas relevant to the Directives. This means that the NO_x annual mean metric is not relevant for the compliance of Gibraltar's monitoring network.

The hourly LAT for NO₂ is defined as 50% of the hourly Limit Value (LV) (i.e. 100 µg m⁻³). The hourly UAT for NO₂ is defined as 70% of the hourly LV (i.e. 140 µg m⁻³). The Directive states there are 18 permissible exceedances for these metrics per year. Calculated exceedances for LAT and UAT for NO₂ in Gibraltar are presented in Table 3.

Table 3 Calculated exceedances of hourly LAT and UAT for NO₂ in Gibraltar (2015-2019)

Year	Rosia Road			Bleak House			Witham's Road			Assessment Threshold status
	Data capture %	Hours above LAT	Hours above UAT	Data capture %	Hours above LAT	Hours above UAT	Data capture %	Hours above LAT	Hours above UAT	
2015	97	217	11	98	13	0	97	404	10	LAT-UAT
2016	98	67	0	81	8	0	99	241	13	LAT-UAT
2017	98	105	0	90	22	0	99	262	30	ABOVE UAT
2018	99	97	0	97	2	0	93	65	1	LAT-UAT
2019	90	45	1	94	3	0	88	48	0	LAT-UAT

The annual LAT for NO₂ is defined as 65% of the annual LV (i.e. 26 µg m⁻³). The annual UAT for NO₂ is defined as 80% of the annual LV (32 µg m⁻³). Calculated annual means for NO₂ in Gibraltar are presented in Table 4

Table 4 Calculated exceedances of annual LAT and UAT for NO₂ in Gibraltar (2015-2019)

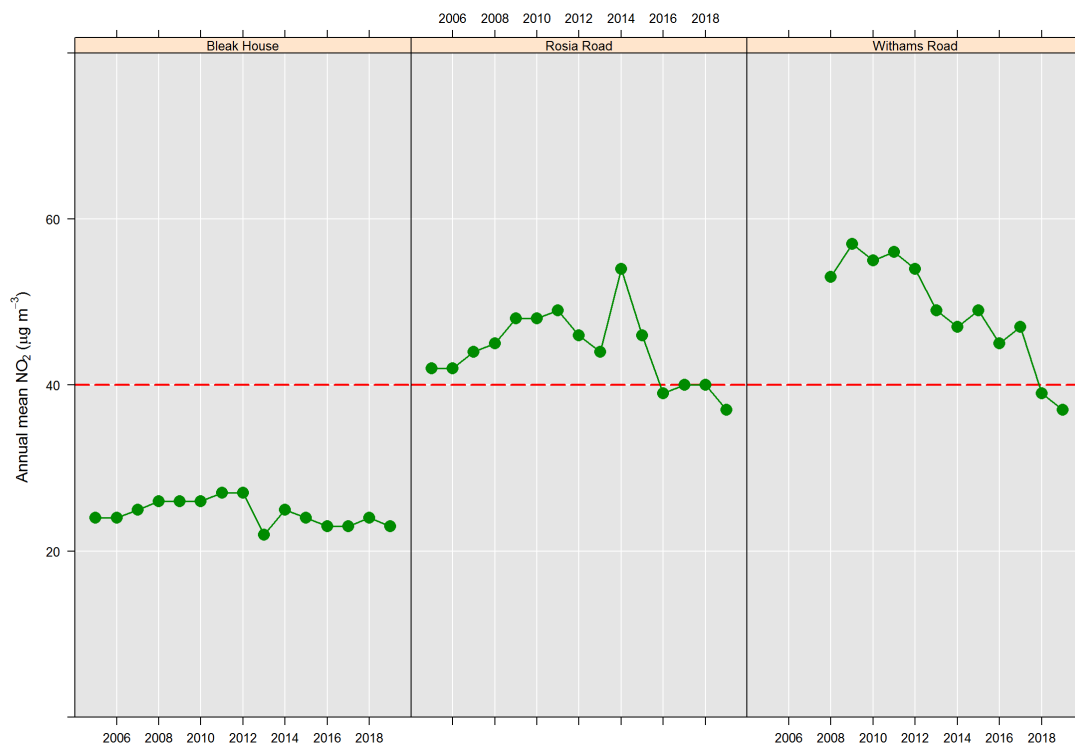
Year	Rosia Road		Bleak House		Witham's Road		Assessment Threshold status
	Data capture %	Annual mean (µg m ⁻³)	Data capture %	Annual mean (µg m ⁻³)	Data capture %	Annual mean (µg m ⁻³)	
2015	97	46.2	98	23.6	97	49.2	ABOVE UAT
2016	98	39.1	81	22.8	99	44.8	ABOVE UAT
2017	98	39.6	90	22.6	99	47.3	ABOVE UAT
2018	99	40.4	97	23.5	93	38.9	ABOVE UAT
2019	90	36.8	94	23.2	88	36.9	ABOVE UAT

All three monitoring sites have data captures in excess of the 75% threshold for each year. The hourly concentrations of NO₂ are only above the UAT in 2017, therefore not meeting the criteria for exceedance in Annex II part B of the AQD. The annual mean concentrations exceed the UAT in all five years. The Gibraltar zone has been classified as above the UAT for NO₂ and according to Annex V of the AQD this results in a requirement of at least one fixed continuous monitoring station. The current monitoring network therefore meets the Directive requirements and provides additional information on the complex sources of NO_x at different environment types (background, roadside, industrial).

2.1.1 Relocation of Withams Road

Withams Road monitoring station (measuring NO_x and NO₂ only) was established in 2008 with the specific intention of representing the highest concentrations at the time from the southern district power stations (principally OESCO). The Government's measure to commission a new LNG fired power station at Waterport allowing the southern district power stations to cease operation has been completed and a full year has passed. Monitoring evidence from the three stations is shown in Figure 2 and demonstrates that the concentrations at Withams Road have sharply declined to concentrations consistent with the nearby roadside site of Rosia Road and since 2018 has reported levels compliant with the annual mean NO₂ Limit Value. As a result, continued monitoring at this location no longer offers the best value evidence and it is recommended that a new site be established as an alternative which would better represent the new highest concentrations.

Figure 2 NO₂ compliance plot, Rosia Road, Bleak House, Withams Road, 2005-2019



The Air Quality Directive (2008/50/EC, Annex III, B)⁸ requires sampling to target areas of 'the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value' and 'levels in other areas within the zones and agglomerations which are representative of the exposure of the general population'. Identification of potential suitable locations has been undertaken using the Gibraltar Traffic Air Quality (GibTrAQ) model. The GibTrAQ model has been used to estimate NO_x and NO₂ concentrations in 2019. This dispersion model is not run routinely but is used as needed to guide decisions and offer insight into potential Government policies. The model estimates the road traffic contribution on road links around Gibraltar using road traffic counts, vehicle classifications, speeds and emissions data from the Gibraltar Air Pollution Emissions Inventory. A background concentration is also added to the road traffic contribution to account for non-road traffic sources.

The model has identified the top five roads across Gibraltar with the highest concentrations (see Table 5). Our recommendation is to establish fixed automatic monitoring at a new location on Devil's Tower

⁸ AQD, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en>

Road. Although this is ranked second place in Table 5, the justification for Devil's Tower Road over Governor's Lane is that it:

- has the joint highest road traffic contribution;
- has the highest traffic count;
- is the most relevant for future changes to road infrastructure (traffic diversion under eastern runway);
- is a pragmatically easier location to establish and maintain.

A recommendation has also been made to consider indicative measurements at Governor's Lane using sensors (AQMesh pod) as discussed in Section 3.3.2.

Table 5 Summary of estimated contributions at highest five modelled road links (2019)

Rank	Road name	2019 NO ₂ modelled estimate (annual mean)	2019 NO ₂ road traffic contribution (annual mean)	%RT contribution	Total cars (AADTF)	% petrol car	% diesel car	% cars	% mopeds	% HGV	% LGV	% Buses
1	Governor's Lane	46.6	21.3	46	15,429	13%	41%	54%	3%	30%	6%	7%
2	Devil's Tower Road	44.9	20.5	46	27,100	10.1%	32.4%	42.5%	1.8%	49.6%	4.2%	1.9%
3	Glacis Road	43.8	18.6	42	21,400	9%	30%	39%	1%	41%	4%	15%
4	Ragged Staff Road	43.7	18.5	42	10,000	6%	21%	27%	1%	65%	3%	4%
5	Town Range	42.9	16.9	39	7,000	15%	46%	61%	4%	28%	8%	0%

2.2 Particulate matter

The requirement to measure particulate matter prescribed by the AQD does not specifically discern between the different size fractions other than to prescribe

- a network-wide ratio between the size fractions of no more than 2:1 (of the required number of sampling points – sampling in excess of the requirement could deviate from this)
- additional criteria related to PM_{2.5} for exposure assessment (as described below).

Annex II of the AQD provides a specific LAT and UAT for annual mean PM₁₀, 24-hr PM₁₀ and annual mean PM_{2.5}. Therefore, the requirement for PM monitoring has been based on the most conservative ('worst case') outcome for any of these PM assessment thresholds.

2.2.1 PM₁₀

The 24-hr LAT for PM₁₀ is defined as 50% of the 24-hr LV (i.e. 25 µg m⁻³). The 24-hr UAT for PM₁₀ is defined as 70% of the 24-hr LV (i.e. 35 µg m⁻³). The Directive states there are 35 permissible exceedances for these metrics. Calculated exceedances for LAT and UAT for PM₁₀ in Gibraltar are presented in Table 6.

Table 6 Calculated exceedances of 24-hr mean LAT and UAT for PM₁₀ in Gibraltar (2015-2019)

Year	Data capture %	Rosia Road		Bleak House			Assessment Threshold status
		Days above LAT	Days above UAT	Data capture %	Days above LAT	Days above UAT	
2015	94	81	16	98	40	6	ABOVE UAT
2016	93	57	11	84	21	7	ABOVE UAT
2017	81	51	11	60	31	10	ABOVE UAT
2018	86	47	11	81	26	12	ABOVE UAT
2019	75	26	1	83	32	3	LAT-UAT

The annual LAT for PM₁₀ is defined as 50% of the annual LV (i.e. 20 µg m⁻³). The annual UAT for PM₁₀ is defined as 70% of the annual LV (28 µg m⁻³). Calculated annual means for PM₁₀ in Gibraltar are presented in Table 7.

Table 7 Calculated exceedances of annual mean LAT and UAT for PM₁₀ in Gibraltar (2015-2019)

Year	Rosia Road		Bleak House		Assessment Threshold status
	Data capture %	Annual mean (µg m ⁻³)	Data capture %	Annual mean (µg m ⁻³)	
2015	94	30.6	98	24.1	ABOVE UAT
2016	93	28.1	84	23.5	ABOVE UAT
2017	81	28.4	60	26.1	ABOVE UAT
2018	86	26.9	81	23.7	LAT-UAT
2019	75	26.2	83	24.5	LAT-UAT

PM₁₀ measurements at Rosia Road and Bleak House show exceedances of the annual mean UAT in four of the five years under assessment.

2.2.2 PM_{2.5}

The annual LAT for PM_{2.5} is defined as 50% of the annual LV (i.e. 12 µg m⁻³). The annual UAT for PM_{2.5} is defined as 70% of the annual LV (17 µg m⁻³). Calculated annual means for PM_{2.5} in Gibraltar are presented in Table 8.

Table 8 Calculated exceedances of annual mean LAT and UAT for PM_{2.5} in Gibraltar (2015-2019)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean (µg m ⁻³)	
2015	81	14	BELOW LAT
2016	85	12.6	BELOW LAT
2017	78	13	BELOW LAT
2018	83	12.5	BELOW LAT
2019	79	12	BELOW LAT

2.2.3 PM_{2.5} Average Exposure Indicator

Irrespective of the annual mean PM_{2.5} LAT and UAT, there are separate requirements set out by the AQD for monitoring PM_{2.5}. Article 15 and Annex XIV explain the application of an Average Exposure Indicator (AEI) to a National Exposure Reduction Target (NERT) and an Exposure Concentration Obligation (ECO). The AEI is required to be assessed at urban background locations according to Annex XIV section A. Annex V section B states that a single station is required per million population and additional urban areas in excess of 100,000 population. Gibraltar's population of approximately 30,000 does not meet this criterion. Therefore there is no requirement to monitor PM_{2.5} for the purposes of calculating the AEI for assessment against the NERT and ECO.

2.2.4 PM monitoring requirements

The most conservative assessment of PM₁₀ and PM_{2.5} across all metrics shows exceedances of the UAT and therefore the requirement to continue fixed monitoring in the zone. Annex V of the AQD shows the requirement for two fixed PM stations. PM₁₀ is measured by Partisol sampler at both Rosia Road and Bleak House. PM_{2.5} is measured by Partisol at Rosia Road only. An additional instrument (TEOM FDMS) located at Rosia Road measures PM₁₀ – this instrument provides near real time observations to support dissemination of public health information through the Gibraltar Air Quality website (<http://www.gibraltairquality.gi/>). The TEOM FDMS is not formally used for compliance

reporting. It is recommended that PM₁₀ and PM_{2.5} monitoring be continued at both Rosia Road and Bleak House (allowing essential background against roadside comparisons). It is also recommended that near-real time measurements continue at Rosia Road to inform the public of changing concentrations on an hourly basis to help them manage their exposure.

The Partisol samplers and the TEOM instrument are in need of replacement. Due to the development of new technology we recommend that the Partisol PM₁₀, the Partisol PM_{2.5} and the TEOM FDMS at Rosia Road are replaced with a single FIDAS⁹ instrument. The FIDAS is a relatively new instrument which measures PM at multiple size fractions in near real time, meets the quality criteria of the Air Quality Directive and has demonstrated equivalence with the reference standard. We recommend that the Partisol PM₁₀ instrument at Bleak House be replaced with a FIDAS instrument. The advantage of the change to a FIDAS is a significant consolidation of PM monitoring into a couple of instruments, reducing costs and increasing space at the monitoring huts. It also represents an improvement in data provision as PM_{2.5} will be available at Bleak House and all instruments (with both size fractions) will provide 1-hour data directly to the air quality website for public information. Hourly data is more useful for other analysis tasks because it can be better associated with meteorological variables throughout the day and source activity data (e.g. industrial processes, traffic flows) and so aids source identification and apportionment.

Because PM₁₀ and PM_{2.5} would be measured at both sites, the network-wide ratio of PM₁₀ to PM_{2.5} monitoring will continue to be met by the existing monitoring network.

2.3 Sulphur dioxide

As for NO_x, there is no requirement for Gibraltar to monitor SO₂ for protection of vegetation as there are no areas defined within Gibraltar according to the Directive criteria. This means that annual mean and annual and winter mean SO₂ metrics are not relevant for the compliance of Gibraltar's monitoring network.

The LAT for SO₂ is defined as 40% of the 24-hr LV (i.e. 50 µg m⁻³). The 24-hr UAT for SO₂ is defined as 60% of the 24-hr LV (i.e. 75 µg m⁻³). The Directive states three permissible exceedances for these metrics. Calculated exceedances for LAT and UAT for SO₂ in Gibraltar are presented in Table 9.

Table 9 Calculated exceedances of 24-hr mean LAT and UAT for SO₂ in Gibraltar (2015-2019)

Year	Data capture %	Rosia Road		Assessment Threshold status
		Days above LAT	Days above UAT	
2015	97	0	0	BELOW LAT
2016	98	0	0	BELOW LAT
2017	98	0	0	BELOW LAT
2018	98	0	0	BELOW LAT
2019	98	0	0	BELOW LAT

Rosia Road is the sole monitoring site for fixed automatic measurements of SO₂. Table 9 shows that the zone is below the LAT for all five years of the assessment.

⁹ <https://www.airmonitors.co.uk/download/palas-fidas-200/>

2.4 Carbon monoxide

The LAT and UAT for CO are based on a maximum daily running 8-hour mean concentration with the LAT being 50% of the LV (i.e. 5 mg m⁻³) and the UAT being 70% of the LV (i.e. 7 mg m⁻³). Calculated exceedances for LAT and UAT for CO in Gibraltar are presented in Table 10.

Table 10 Calculated exceedances of LAT and UAT for CO in Gibraltar (2015-2019)

Year	Data capture %	Rosia Road		Assessment Threshold status
		Days above LAT	Days above UAT	
2015	97	0	0	BELOW LAT
2016	99	0	0	BELOW LAT
2017	99	0	0	BELOW LAT
2018	99	0	0	BELOW LAT
2019	85	0	0	BELOW LAT

Rosia Road is the sole monitoring site for fixed automatic measurements of CO. The data in Table 10 show that the zone is below the LAT for all five years of the assessment.

2.5 Benzene

The LAT and UAT for benzene are based on the annual mean concentration with the LAT being 40% of the LV (i.e. 2 µg m⁻³) and the UAT being 70% of the LV (i.e. 3.5 µg m⁻³). Calculated exceedances for LAT and UAT for benzene in Gibraltar are presented in Table 11.

Table 11 Calculated exceedances of LAT and UAT for benzene in Gibraltar (2015-2019)

Year	Data capture %	Rosia Road	Assessment Threshold status
		Annual mean (µg m ⁻³)	
2015	93	1.5	BELOW LAT
2016	90	1.3	BELOW LAT
2017	73	1.3	BELOW LAT
2018	94	1.3	BELOW LAT
2019	90	1.1	BELOW LAT

Rosia Road is the sole monitoring site for fixed automatic measurements of benzene. Data in Table 11 shows that the zone is below the LAT for four of the five years of the assessment (one year omitted due to low data capture).

2.6 Ozone

Since its entry into force, ozone has been regulated by the Air Quality Directive. Unlike other pollutants there is no specific LAT or UAT for ozone. Instead the need for fixed monitoring is dictated by a single threshold (the Long Term Objective, LTO) for two metrics (one for health and one for vegetation protection), evaluated over 5 years, as stated in Article 9.1 of the Directive. The LTOs (defined in Annex VII, Section C of the Directive) are:

- for human health: 120 $\mu\text{g m}^{-3}$ as the maximum daily 8-hour mean ozone concentration
- for vegetation protection: AOT40 (May to July) of 6000 $\mu\text{g m}^{-3}\cdot\text{h}$

Historical exceedances of the LTOs are shown in Table 12 (the health-based LTO) and Table 13 (the vegetation-based LTO).

Table 12 Calculated exceedances of LTO (protection of health) for ozone in Gibraltar (2015-2019)

Year	Bleak House		Assessment Threshold status
	Data capture %	Maximum daily 8-hr mean ($\mu\text{g m}^{-3}$)	
2015	99	5	ABOVE LTO
2016	81	3	ABOVE LTO
2017	93	2	ABOVE LTO
2018	96	0	BELOW LTO
2019	81	28	ABOVE LTO

Table 13 Calculated exceedances of LTO (protection of vegetation) for ozone in Gibraltar (2015-2019)

Year	Bleak House		Assessment Threshold status
	Data capture %	AOT40 ($\mu\text{g m}^{-3}\cdot\text{h}$)	
2015	99	603	BELOW LTO
2016	99	359	BELOW LTO
2017	98	447	BELOW LTO
2018	100	425	BELOW LTO
2019	98	725	BELOW LTO

Bleak House is the sole monitoring station for ozone in Gibraltar. Four of the five years exceeded the LTO (protection of health) indicating a requirement to continue fixed monitoring in the zone.

2.7 Lead

The LAT and UAT for lead are based on an annual mean concentration, with the LAT being 50% of the LV (i.e. 0.25 $\mu\text{g m}^{-3}$) and the UAT being 70% of the LV (i.e. 0.35 $\mu\text{g m}^{-3}$). Calculated exceedances for LAT and UAT for lead in Gibraltar are presented in Table 14.

Table 14 Calculated exceedances of LAT and UAT for Pb in Gibraltar (2010-2014)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean ($\mu\text{g m}^{-3}$)	
2015	63	0.0099	BELOW LAT
2016	38	0.0048	BELOW LAT
2017	53	0.0085	BELOW LAT
2018	68	0.0069	BELOW LAT
2019	62	0.0056	BELOW LAT

Table 14 shows that measured concentrations are below the LAT for all five years of the assessment, meaning there is no specific requirement to assess lead by fixed continuous monitoring.

2.8 Arsenic

The LAT and UAT for arsenic (As) are based on an annual mean concentration with the LAT being 40% of the TV (i.e. 2.4 ng m⁻³) and the UAT being 60% of the TV (i.e. 3.6 ng m⁻³). Calculated exceedances for LAT and UAT for arsenic in Gibraltar are presented in Table 15.

Table 15 Calculated exceedances of LAT and UAT for As in Gibraltar (2015-2019)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean (ng m ⁻³)	
2015	63	1.6	BELOW LAT
2016	38	1.3	BELOW LAT
2017	53	1.4	BELOW LAT
2018	68	1.6	BELOW LAT
2019	62	1.2	BELOW LAT

Table 15 shows that measured concentrations are below the LAT for all five years of the assessment, meaning there is no specific requirement to assess arsenic by fixed continuous monitoring.

2.9 Cadmium

The LAT and UAT for cadmium (Cd) are based on an annual mean concentration with the LAT being 40% of the TV (i.e. 2 ng m⁻³) and the UAT being 60% of the TV (i.e. 3 ng m⁻³). Calculated exceedances for LAT and UAT for cadmium in Gibraltar are presented in Table 16.

Table 16 Calculated exceedances of LAT and UAT for Cd in Gibraltar (2015-2019)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean (ng m ⁻³)	
2015	63	2	BELOW LAT
2016	38	1.6	BELOW LAT
2017	53	1.6	BELOW LAT
2018	68	2	BELOW LAT
2019	62	1.6	BELOW LAT

Table 16 shows that measured concentrations are below the LAT for all five years of the assessment, meaning there is no specific requirement to assess cadmium by fixed continuous monitoring.

2.10 Nickel

The LAT and UAT for nickel (Ni) are based on an annual mean concentration with the LAT being 50% of the TV (i.e. 10 ng m⁻³) and the UAT being 70% of the TV (i.e. 14 ng m⁻³). Calculated exceedances for LAT and UAT for nickel in Gibraltar are presented in Table 17.

Table 17 Calculated exceedances of LAT and UAT for Ni in Gibraltar (2015-2019)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean (ng m ⁻³)	
2015	63	14	LAT-UAT
2016	38	11	BELOW LAT
2017	53	14	BELOW LAT
2018	68	12	LAT-UAT
2019	62	12	LAT-UAT

Table 17 shows that data capture fell below 75% for all five years. Three years with data capture above 60% show exceedance of the LAT. As a result there is a requirement for continued fixed measurements of nickel in Gibraltar. A continuation of measurements at Rosia Road is therefore recommended.

Previous modelling studies¹⁰ undertaken on behalf of the Gibraltar Environmental Agency have indicated that fuel-oil and gas-oil combustion by nearby shipping activities is likely to be a source of nickel in the area. Further modelling (unpublished) has shown that Spanish sources across the Bay of Gibraltar. (e.g. CEPSA refinery and Acerinox plant) are also likely to be contributors to Gibraltar's measured nickel concentrations. While concentrations of nickel since 2015 have been between 11 ng m⁻³ and 13 ng m⁻³ (well below the Target Value of 20 ng m⁻³), we recommend that monitoring is retained.

2.11 Benzo[a]Pyrene

The LAT and UAT for Benzo[a]Pyrene (BaP) are based on an annual mean concentration with the LAT being 40% of the TV (i.e. 0.4 ng m⁻³) and the UAT being 60% of the TV (i.e. 0.6 ng m⁻³). Calculated exceedances for LAT and UAT for BaP in Gibraltar are presented in Table 18.

Table 18 Calculated exceedances of LAT and UAT for BaP in Gibraltar (2015-2019)

Year	Rosia Road		Assessment Threshold status
	Data capture %	Annual mean (ng m ⁻³)	
2015	95	0.061	BELOW LAT
2016	97	0.065	BELOW LAT
2017	91	0.07	BELOW LAT
2018	79	0.065	BELOW LAT
2019	100	0.04	BELOW LAT

Table 18 shows that measured concentrations are below the LAT for all five years of the assessment, meaning there is no specific requirement to assess BaP by fixed continuous monitoring.

¹⁰ Abbott, J (2009) Contribution from shipping emissions to PM₁₀ and nickel contents on Gibraltar (AEA Report to Gibraltar Environmental Agency: AEA/ED43072/R2833 Issue 1)

3 Other network components

3.1 Sea salt measurements

The AQD specifies that contributions to measured PM concentrations from natural sources can be quantified and subtracted from measured concentrations prior to reporting. The justification for this approach is that Member States cannot be held accountable for non-anthropogenic sources. In Gibraltar this includes sea salt aerosol due to the proximity of the sea to all points in Gibraltar. This quantification is not mandatory, but it has been demonstrated to have a significant impact on the measured concentrations that must be reported to the Commission.

Given the expense of this monitoring and the change in measured concentrations across Gibraltar according to the last five years of measurements, it is recommended that these measurements cease at the end of 2020. Reported concentrations of particulate matter have been clearly below the Limit Values, as shown in Figure 3 and Figure 4 (for PM₁₀ and PM_{2.5}). These illustrate that Rosia Road no longer exceeds and is now consistent with concentrations measured at the background location (Bleak House), around 25-30 µg m⁻³.

In the event of a future year of unforeseen exceedance, it is unlikely that the sea salt concentration (typically 3-5 µg m⁻³) will make a significant impact and the requirement would be to identify the reason for the exceedance, quantify the source and then demonstrate to the Commission that action has been taken to ensure future compliance – continued sea salt measurements do not add value to these activities. The evidence base for sea salt is now long enough to offer a robust indication of likely levels in future even if a daily correction according to the official guidance weren't possible.

Figure 3 Annual mean PM₁₀ compliance plot, Bleak House and Rosia Road

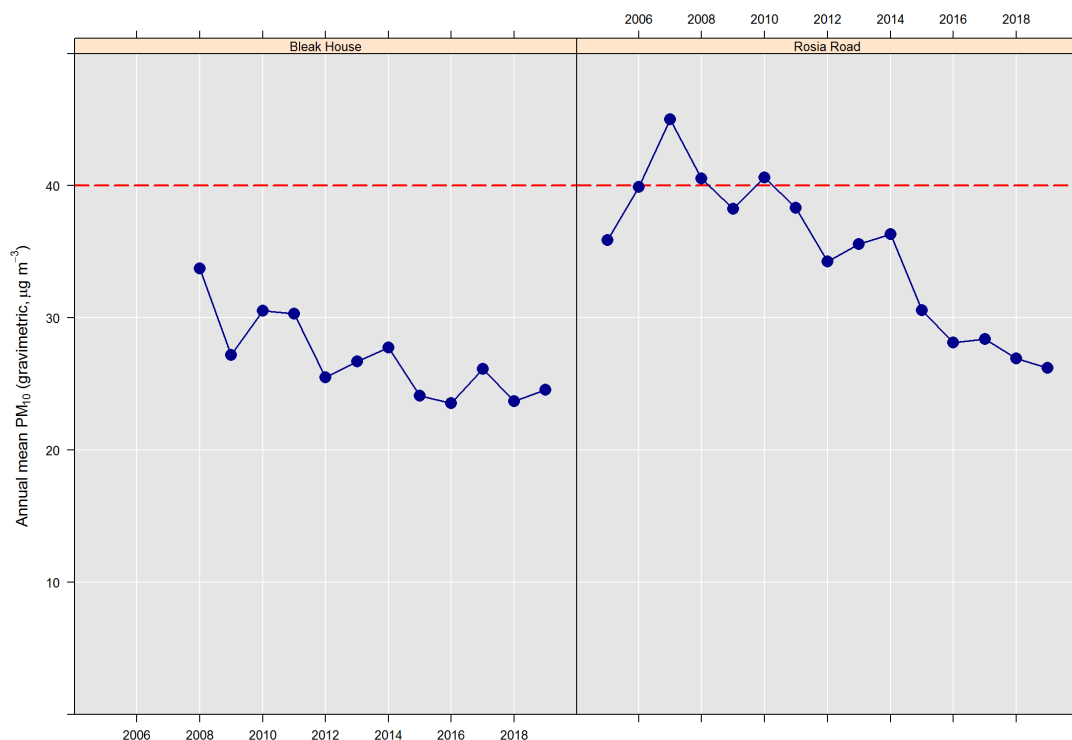
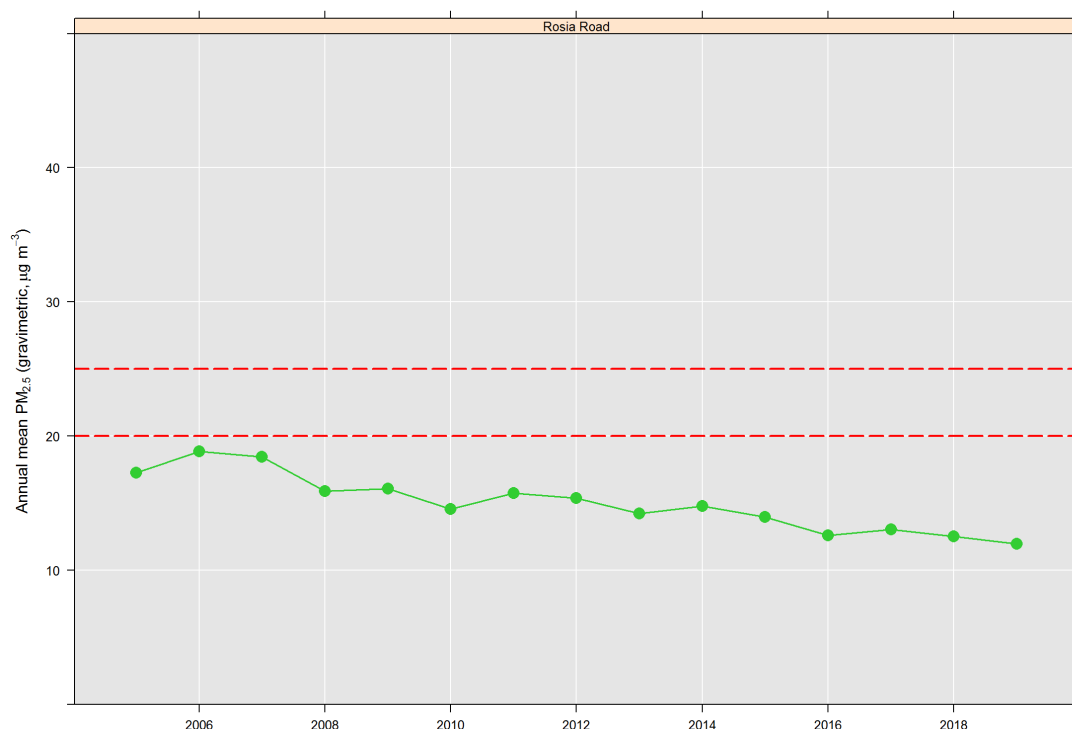


Figure 4 Annual mean PM_{2.5} compliance plot, Rosia Road



3.2 Replacement aethalometer

Black carbon concentrations are not required for formal compliance reporting, but this is a pollutant known to have climate forcing potential and it has been measured at Rosia Road at the Government's request since 2012. It is recommended that this monitoring continue with a replacement instrument from 2021.

3.3 Indicative sensor network (AQMesh)

3.3.1 Travelling standard

The data quality of indicative measurements from air quality sensor technologies remains a concern as the technology continues to mature. Like all sensors, the data is affected by environmental interferences such as temperature, relative humidity and other gases which require correction and careful consideration. In order to derive data of the highest possible quality from these devices it is critical that the sensor data is regularly characterised relative to an instrument of known high quality (e.g. one of the fixed automatic monitoring stations). This ensures that the data is as closely aligned to a reliable and traceable calibration chain as possible.

To facilitate this best-practice approach, it is recommended that an additional AQMesh¹¹ monitor is procured and operated solely as a travelling standard with which to service the data at other deployed AQMesh locations. This means that it would reside at Rosia Road and would not be available for deployment but it is critical to the robustness and defensibility of the AQMesh monitors deployed at locations of interest.

¹¹ <https://www.aqmesh.com/product/aqmesh/>

3.3.2 AQMesh sampling at Governor's Lane

Section 2.1.1 discussed the use of the GibTrAQ model and the recommendation for new monitoring at Devil's Tower Road. The model also identified Governor's Lane as one of the highest links in Gibraltar. This location was not as suitable for fixed automatic monitoring as Devil's Tower Road but remains an important location to consider. It would be harder to establish fixed automatic monitoring at this location but an AQMesh monitor would be more practical (though still challenging due to lack of space, access to power and potential shading of the solar panel by building façade of this narrow street canyon). It is recommended that further consideration be given to this location for monitoring using an AQMesh.

3.4 Non-automatic network

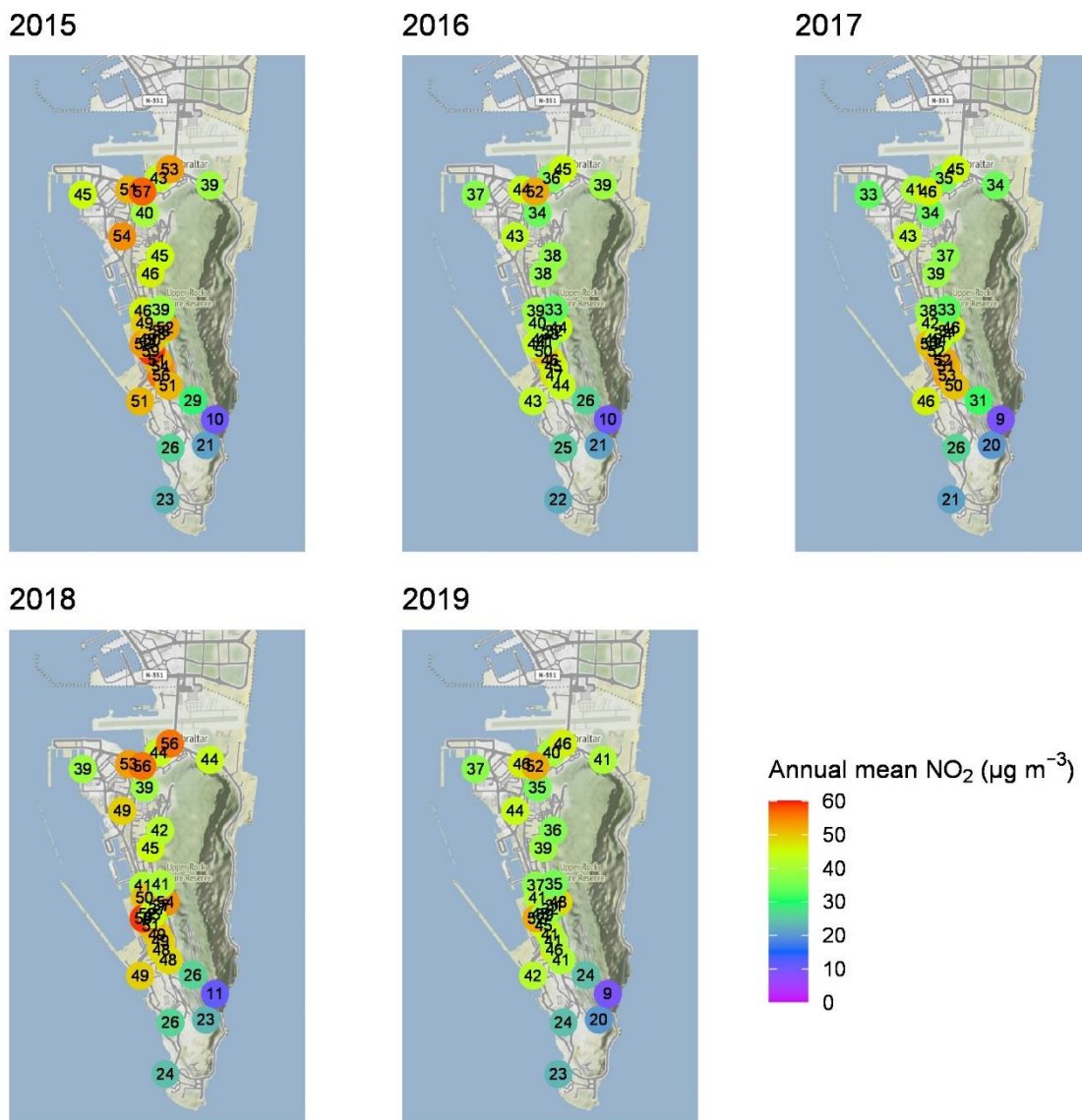
In addition to the fixed automatic monitoring sites in Gibraltar, an indicative passive sampler monitoring campaign to measure NO₂ and benzene, toluene, ethyl-benzene and xylene (BTEX) by Palmes diffusion tube has been established. Though less accurate than automatic monitoring (hence its indicative status), these samplers are distributed more widely across Gibraltar and provide better spatial representation of concentrations.

These diffusion tubes have been considered as part of the exercise to determine whether sources relevant to the outcome of the compliance assessment are being adequately represented with the existing fixed monitoring network. Diffusion tubes do not meet the strict measurement criteria specified by the Directive so these non-automatic concentrations cannot be directly compared with the defined assessment thresholds. However, they can be used to inform expert judgement on the presence of sources at distance from fixed monitoring within the compliance network.

The only pollutants that this passive sampler data could inform upon are NO₂ and benzene, both of which are independently (based on automatic measurements) recommended for continued fixed monitoring in the future.

The case for continued monitoring at all these locations has been reviewed, particularly noting areas where concentrations have declined. Figure 5 shows a spot map of indicative NO₂ monitoring across Gibraltar between 2015-2019. The southern district power stations are no longer operating, concentrations in this area have declined as a result and there is an abundance of diffusion tubes around the Jumpers area to represent this source. However, the tubes remain above the Limit Value and though the method is indicative, our recommendation is to retain them until concentrations are lower. It is recommended that monitoring continue in its current configuration for the foreseeable future.

Figure 5 Indicative NO₂ monitoring from non-automatic network, 2015-2019



Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.

4 Conclusions and recommendations

The status of Gibraltar zone for different pollutants relative to the assessment threshold criteria prescribed in the Directives is summarised in Table 19 along with the formal or recommended requirement for monitoring.

Table 19 Summary of monitoring requirements for compliance with Directives

Pollutant	Assessment Threshold Status	Formal requirement for fixed continuous monitoring	Recommendation for fixed continuous monitoring	Comments
NO ₂	>UAT	Yes	Yes	Current monitoring satisfies Directive requirements Recommend movement of Withams Road monitoring station.
PM ₁₀	>UAT	Yes	Yes	Current monitoring satisfies Directive requirements. Switch to FIDAS instruments.
PM _{2.5}	<LAT	No	Yes	PM _{2.5} considered to be most relevant size fraction from exposure/epidemiology perspective and for comparison against Limit Value (Stage 1 and 2). Add PM _{2.5} to Bleak House through FIDAS instrument. Need to achieve prescribed ratio of PM ₁₀ to PM _{2.5}
SO ₂	<LAT	No	Yes	Retain as useful indication of shipping emissions and to inform future monitoring regime assessments. Will demonstrate AQ impact of new power station at North Mole
CO	<LAT	No	Yes	Retain as useful indicator of traffic emissions (NO _x , NO ₂ and PM ₁₀ , PM _{2.5}) and to inform future monitoring regime assessments
Benzene	<LAT	No	Yes	Retain as useful indicator of traffic emissions (NO _x , NO ₂ and PM ₁₀ , PM _{2.5}) and to inform future monitoring regime assessments
O ₃	>LTO	Yes	Yes	Current monitoring satisfies Directive requirements.
Arsenic	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
Cadmium	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
Nickel	LAT-UAT	Yes	Yes	Current monitoring satisfies Directive requirements
Lead	<LAT	No	Yes	No formal requirement but available as bi-product of mandatory nickel monitoring.
BaP	<LAT	No	Yes	Retain to inform future monitoring regime assessments

The automatic measured data shows that several pollutants have exceeded the LAT (or LTO in case of ozone) for three or more years over the assessment period and therefore require fixed continuous monitoring. These are NO₂, PM₁₀, ozone and nickel.

The assessment indicates that concentrations of other pollutants over the assessment period are below the LAT for three or more years and therefore future fixed continuous monitoring is not strictly required for compliance. These pollutants are SO₂, CO, benzene, lead, arsenic, cadmium and BaP. Despite the lack of mandatory requirement to continue measuring these pollutants, there are compelling arguments to retain these instruments in the network:

- **Tracking progress of abatement measures and policy strategy**
Pollutants such as SO₂ and CO are vital components to the network in terms of source apportionment and characterization. For Gibraltar, the need to monitor and demonstrate the success of abatement measures put in place for PM₁₀ and NO₂ (e.g. for Air Quality Plans reporting), provides an argument to retain some pollutants. For example, measured SO₂ concentrations will demonstrate that a new power station is not causing limit value exceedances when it becomes operational. SO₂ is also associated with fuel combustion by shipping which is known to be a significant source of nickel in the Bay of Gibraltar. Maintaining monitoring for this pollutant in the network may provide useful proxy information for shipping contributions to measured concentrations in the future. CO is a useful proxy for road traffic exhaust emissions and this data can be used to provide context for other associated exhaust emissions (PM₁₀ and NO_x and NO₂) that will require mandatory fixed monitoring.
- **Metals analysis**
Continued fixed monitoring of lead, cadmium and arsenic is not formally required but the requirement for fixed monitoring of nickel concentrations remains. Due to the method of collection (by chemical speciation from a Partisol filter) all heavy metals are obtained in the same process. Therefore, by retaining monitoring for nickel, monitoring for these other heavy metals is effectively retained.
- **Evidence base for future assessment**
Despite the fact that recent historical data illustrates low concentrations of some pollutants, concentrations change continuously over time in relation to meteorology, local and transboundary sources. This is why the requirement to conduct regular Monitoring Regime Assessments exists in the Directives. Retaining fixed monitoring of non-essential pollutants in the network provides a strong evidence base to inform future assessments rather than relying on less reliable evidence from indicative monitoring campaigns (such as passive sampling) or emissions inventories (the detailed information for which Gibraltar may not easily be able to provide).

The Environmental Agency's long-term strategy for the monitoring network is determined in collaboration with the Government of Gibraltar. The strategy is continually reviewed in the context of compliance with the Directives, cost-efficiency relative to budgetary considerations and scientific value. Future monitoring, including newly established sites or site moves, are informed by all available information including automatic and non-automatic measurements, expert opinion and by model results where available.

The continuation of fixed monitoring for all pollutants, even those that are not formally required for compliance according to the assessment criteria specified in the Directives has important evidential value. Without these measurements there exists little alternative information about these pollutants to inform future requirements for monitoring and compliance (i.e. future Monitoring Regime Assessments). In other Member States there is often a large volume of proxy information related to emissions or a large number of monitoring stations. This information does not exist for Gibraltar, therefore the few monitoring sites that exist are the only source of information on levels of pollutants. Given the lack of alternatives, each site in the Gibraltar Air Quality Monitoring Network can be considered 'critical' in terms of information. There are other reasons to retain monitoring of all pollutants – they provide vital information for policy and abatement strategy assessment and for scientific justification and analysis that underpins other submissions and legislative requirements (such as the time extension applications and associated monitoring). Monitoring is often used to moderate dispersion model studies, either in calibrating the process or by testing the result in a

validation exercise, thereby grounding the result in reality (a key component of QA). Given Gibraltar's exceedance status there is a need for as much data as possible to help support policy design, implementation and review over the time extension period and years immediately afterwards.

Summary of recommendations

1. Consolidation PM instruments to FIDAS at Rosia Road and Bleak House.
2. Relocation of monitoring at Witham's Road to Devil's Tower Road.
3. Continuation of non-automatic monitoring.
4. Review of AQMesh monitoring locations and travelling standard.
5. Cessation of sea salt measurements at Rosia Road.
6. Replacement aethalometer at Rosia Road.



T: +44 (0) 1235 753000

E: enquiry@ricardo.com

W: ee.ricardo.com