

## Quantification and correction of natural particulate matter in Gibraltar

2012



Report for Gibraltar Environmental Agency

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## Executive summary

This report describes the methodologies applied to determine the contribution of African dust and sea salt to the 2012 ambient airborne PM<sub>10</sub> mass concentration in Gibraltar. It summarises the impact of this quantification on Gibraltar's compliance with the 2012 24-hr and annual mean PM<sub>10</sub> Limit Value (LV) as specified in the European Commission's Air Quality Directive (AQD). The Directive allows natural contributions, where quantified, to be removed from the measured concentrations for compliance assessment. The PM<sub>10</sub> annual mean LV is 40 µg m<sup>-3</sup> and the PM<sub>10</sub> 24-hr LV is 50 µg m<sup>-3</sup>, not to be exceeded on more than 35 days in a calendar year.

The two natural sources of relevance to Gibraltar are (1) African dust, and (2) sea salt. The African dust component of the PM<sub>10</sub> mass concentration in Gibraltar has been quantified since 2006, however daily measurements to determine the contribution of sea salt to the PM<sub>10</sub> only commenced in Gibraltar in April 2011, allowing a quantification of both sources for the first time in 2011.

The PM<sub>10</sub> mass concentration is measured at Bleak House (classified under the Directive as an urban background station) and Rosia Road (classified under the Directive as an urban traffic station). In 2012, neither Rosia Road nor Bleak House exceeded the PM<sub>10</sub> 24-hr LV or the annual mean LV. Table E1 shows summary statistics for both monitoring stations. The table shows the original, uncorrected PM<sub>10</sub> mass concentrations from both air quality monitoring stations in Gibraltar, and the corrected mass concentration based on the quantification of African dust and then the correction for African dust and sea salt together.

**Table E1: 2012 summary of results of natural correction for compliance with AQD LVs.**

	Rosia Road (urban traffic)		Bleak House (urban background)	
	Annual mean (µg m <sup>-3</sup> )	Number of exceedances* of the PM <sub>10</sub> 24-hr LV	Annual mean (µg m <sup>-3</sup> )	Number of exceedances* PM <sub>10</sub> 24-hr LV
Uncorrected PM <sub>10</sub> mass concentration	34	18	26	3
Corrected PM <sub>10</sub> mass concentration after application of African dust correction factor	28	7	21	3
Corrected PM <sub>10</sub> mass concentration after application of African dust and sea salt correction factor	26	5	-----**	-----**

\* 35 permissible exceedances per annum.

\*\* Daily mean PM<sub>10</sub> sea salt mass fraction not measured at Bleak House.

Table E1 shows that Gibraltar was compliant with both the annual mean and 24-hr PM<sub>10</sub> LV in 2012 before the natural correction was applied. It also demonstrates that African dust remains a significant contributor to measured PM<sub>10</sub> concentrations in Gibraltar.

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# 1 Introduction

This report describes the methodologies applied to determine the contribution of African dust and sea salt to the 2012 ambient airborne PM<sub>10</sub> (hereafter simply referred to as PM<sub>10</sub>) mass concentration in Gibraltar. It summarises the impact of this quantification on Gibraltar's compliance with the 2012 PM<sub>10</sub> annual and 24-hr Limit Value (LV) as specified in the Air Quality Directive (AQD)<sup>1</sup>.

European Directive 1999/30/EC<sup>2</sup> specifies that Member States are obliged to implement action plans where the LVs for air pollutants, namely sulphur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>) and oxides of nitrogen (NO<sub>x</sub>), particulate matter (PM<sub>10</sub>) and lead in ambient air, are exceeded due to causes other than natural events. In July 2010 the AQD superseded the Framework Directive (96/62/EC) and the first three Daughter Directives (1999/30/EC, 2000/69/EC, and 2002/3/EC). As part of the AQD, the Commission issued further guidance for assessing and reporting of air pollutant concentrations where natural sources contribute to the exceedance of air pollutant LVs. Member States are required to inform the Commission in instances where natural events result in air pollutant concentrations that are significantly in excess of typical background concentrations. Member States are expected to provide justification to demonstrate that the measured exceedances were due to natural events. The mechanism for reporting concentrations to the Commission is the annual reporting questionnaire. The annual reporting questionnaire includes specific forms to allow the contribution from natural sources, and corrected PM<sub>10</sub> concentrations, adjusted for this natural component, to be reported. The two natural sources of relevance to Gibraltar are (1) African dust, and (2) sea salt.

The African dust component of the PM<sub>10</sub> mass concentration in Gibraltar has been quantified since 2006. A significant number of exceedances of the PM<sub>10</sub> 24-hr LV measured in Gibraltar arise due to African dust events which affect the Iberian Peninsula as a whole. There is considerable year-to-year variability in the number of African dust events. Typically African dust events arise due to a combination of drought in North Africa and synoptic-scale (e.g., over a horizontal scale of 1000 km) meteorology.

Gibraltar is a peninsula and therefore the impact of sea salt on the PM<sub>10</sub> mass concentration is likely to be significant under certain meteorological conditions. Synoptic scale meteorological events and sea state contribute to the generation of sea spray and therefore the contribution of sea salt to the PM<sub>10</sub> mass concentration in Gibraltar. Daily measurements to determine the contribution of sea salt to the PM<sub>10</sub> mass concentration commenced in Gibraltar on the 8<sup>th</sup> April 2011. The day-to-day variation in the contribution of sea salt to the PM<sub>10</sub> mass concentration can therefore be assessed.

In 2012 the Gibraltar Air Quality Monitoring Network recorded 18 exceedances (based on measurements taken at the Rosia Road air quality monitoring station<sup>3</sup>) of the PM<sub>10</sub> 24-hr LV (50 µg m<sup>-3</sup>). The AQD permits up to 35 exceedances of the LV per calendar year. This exercise is therefore an essential assessment to demonstrate compliance (or otherwise) after accounting for the contribution made by natural sources to the daily mean PM<sub>10</sub> mass concentration.

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<sup>1</sup> Directive 2008/50/EC (CAFE Directive), <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0050:EN:NOT>.

<sup>2</sup> Directive 1999/30/EC (the first Daughter Directive): Article 5, section 4.

<sup>3</sup> Station information can be found at [http://www.gibraltarairquality.gi/stats.php?t\\_action=info&t=3&station\\_id=GIB1&map=&q=7&s=&dy=](http://www.gibraltarairquality.gi/stats.php?t_action=info&t=3&station_id=GIB1&map=&q=7&s=&dy=)

The impact of both natural African dust and sea salt was assessed in 2012. In order to provide a complete PM<sub>10</sub> daily data set corrected for both natural sources it has been necessary to undertake the African dust quantification methodology prior to removing sea salt due to concerns that undertaking a sea salt correction first may affect the application of the prescribed African dust quantification methodology.

## 2 African dust

### 2.1 Method

This section presents the methodology used to determine the contribution of African dust events to the PM<sub>10</sub> mass concentration in Gibraltar. The term “African dust correction factor” refers to the mass concentration of PM<sub>10</sub> which was subtracted from the measured PM<sub>10</sub> mass concentration to account for the contribution of African dust events to elevated PM<sub>10</sub> mass concentrations in Gibraltar.

Overall, two forms of African dust correction are applied: the first to the measured daily mean PM<sub>10</sub> mass concentration, the second to the annual mean PM<sub>10</sub> mass concentration (determined from the daily mean measurements). The results of the 2012 African dust correction are presented here.

For the preparation of on-going mandatory reporting to the Commission, in-line with the Air Quality Directive (2008/50/EC), the Spanish authorities identified specific days in 2012 on which regional background PM<sub>10</sub> mass concentrations across the Iberian Peninsula were significantly enhanced by African dust events<sup>4</sup>. These events are referred to as “African dust days” and were assessed using a qualitative methodology developed by Querol et al.<sup>5</sup>.

The method for identifying African dust days was discussed at the workshop “Contribution of natural sources to PM levels in Europe” organised by the Joint Research Council, Ispra in October 2006 and was reviewed in the subsequent workshop report<sup>6</sup>. The methodology was incorporated into Commission staff working paper establishing guidelines for demonstration and subtraction of exceedances attributable to natural sources under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe<sup>7</sup>. For consistency, this approach has been adopted by Gibraltar for reporting exceedances of the PM<sub>10</sub> 24-hr and annual mean LV due to African dust events to the Commission.

2012 PM<sub>10</sub> mass concentrations from the regional background stations across the Iberian Peninsula, as shown in Figure 1, were used to determine the regional background PM<sub>10</sub> mass concentration using methodology developed by Escudero et al.<sup>8</sup>. This allowed the increase in the PM<sub>10</sub> mass concentration in Gibraltar due to African dust events to be derived.

Historically, the absence of a single regional background station to be paired with Gibraltar meant that the regional background PM<sub>10</sub> mass concentration was derived from several Spanish regional background stations (Figure 1). The methodology employed to calculate the regional background PM<sub>10</sub> mass concentration, and subsequently the increase in the

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<sup>4</sup> Pey, J., Querol, X., Gonz ales Ortiz, A., Jim enez, S., Moral, A. and Pallar es, M.: Episodios naturales de part culas 2011. CSIC, INM, CIEMAT, Ministerio de Medio Ambiente Direcci n General de Calidad y Evaluaci n Ambiental, 2011. [http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/Informe\\_episodios\\_naturales\\_Espa%C3%B1a%2BPortugal\\_tcm7-207635.pdf](http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/Informe_episodios_naturales_Espa%C3%B1a%2BPortugal_tcm7-207635.pdf)

<sup>5</sup> Querol, X., Alastuey, A., Escudero, M., Pey, J., Castillo, S., Perez, N., Ferreira, F., Franco, N., Marques, F., Cuevas, E., Alonso, S., Artinano, B., Salvador, P., de la Rosa, J., Jimenez, S., Cristobal, A., Pallares, M., and Gonzalez, A.: Methodology for the identification of natural African dust episodes in PM<sub>10</sub> and PM<sub>2.5</sub>, and justification with regards to the exceedances of the PM<sub>10</sub> daily limit value. For Ministerio de Medio Ambiente-Spain and Ministerio do Ambiente, Ordenamento do Territ rio e Desenvolvimento Regional – Portugal, 2007.

<sup>6</sup> Marelli, L.: Contribution of natural sources to air pollution levels in the EU – a technical basis for the development of guidance for the Member States. Post-workshop report from ‘Contribution of natural sources to PM levels in Europe’ workshop organised by JRC, Ispra, October 2006. EUR 22779 EN, 2007.

<sup>7</sup> Council of the European Union: Commission staff working paper establishing guidelines for demonstration and subtraction of exceedances attributable to natural sources under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe. SEC(2011) 208 final, 2011, [http://ec.europa.eu/environment/air/quality/legislation/pdf/sec\\_2011\\_0208.pdf](http://ec.europa.eu/environment/air/quality/legislation/pdf/sec_2011_0208.pdf).

<sup>8</sup> Escudero, M., Querol, X., Alastuey, A., Perez, N., Ferreira, F., Alonso, S., Rodriguez, S., and Cuevas, E.: A methodology for the quantification of the net African dust load in air quality monitoring networks. Atmospheric Environment, 41 (26), 5516-5524, doi:10.1016/j.atmosenv.2007.04.047, 2007.

PM<sub>10</sub> mass concentration due to African dust events from multiple stations, was discussed in previous studies<sup>9,10,11</sup>.

**Figure 1: Spanish regional background stations used in the determination of African dust days.**



Since 2009, the PM<sub>10</sub> mass concentration measurements from the regional background monitoring station at Alcornocales were made available by the Spanish Government for the purposes of quantifying the increase in the daily mean PM<sub>10</sub> mass concentration in Gibraltar due to African dust events. The regional background PM<sub>10</sub> monitoring station at Alcornocales is located significantly closer to Gibraltar than the other Spanish regional background monitoring stations shown in Figure 1. Given its proximity to Gibraltar, the African dust correction factor at the Alcornocales air quality monitoring station will be more representative of the situation in Gibraltar. For this reason Alcornocales continues to be used as the regional background monitoring station paired with the Gibraltar Air Quality Network stations in order to account for the impact of African dust.

The number of days allocated as “African dust days” refers to the total number of days for which the African dust correction factor was applied to the 2012 daily mean PM<sub>10</sub> mass concentration measured in Gibraltar. These do not necessarily correspond to the days of exceedance of the PM<sub>10</sub> 24-hr LV measured in Gibraltar. The aim of this exercise is not just to correct exceedance days, but to correct the daily mean PM<sub>10</sub> mass concentration on *any* day on which there was a significant contribution to the measured PM<sub>10</sub> mass concentration due to an African dust event. This approach allows for the calculation of a 2012 corrected annual mean PM<sub>10</sub> mass concentration for Gibraltar for comparison with the annual PM<sub>10</sub> LV stated in the Directive in addition to the 24-hr assessment.

The daily regional background measured PM<sub>10</sub> mass concentration for Alcornocales was calculated by initially removing the African dust days from the PM<sub>10</sub> mass concentration measurements. A moving 30<sup>th</sup> percentile across a 30 day period centred on the day for which the calculation was being made (i.e., the day of the calculation is day 15 of the 30 day

<sup>9</sup> Kent, A.J.: 2006 African dust quantification. [http://www.gibraltarairquality.gi/documents/Gib\\_natural\\_quantification\\_2006\\_v2.pdf](http://www.gibraltarairquality.gi/documents/Gib_natural_quantification_2006_v2.pdf)

<sup>10</sup> Kent, A.J.: 2007 African dust quantification. [http://www.gibraltarairquality.gi/documents/Gib\\_natural\\_quantification\\_2007\\_v1.pdf](http://www.gibraltarairquality.gi/documents/Gib_natural_quantification_2007_v1.pdf)

<sup>11</sup> Kent, A.J.: 2008 African dust quantification. [http://www.gibraltarairquality.gi/documents/Gib\\_natural\\_quantification\\_2008\\_v1.pdf](http://www.gibraltarairquality.gi/documents/Gib_natural_quantification_2008_v1.pdf)



period) was derived. This calculated value provides a measure of the regional background PM<sub>10</sub> mass concentration in the absence of African dust events.

The calculated regional background PM<sub>10</sub> mass concentration was subtracted from the daily mean PM<sub>10</sub> mass concentration measured at the regional background monitoring station (Alcornocales) to provide an African dust increment for that day. On occasions when negative increments were calculated these values were omitted from further calculations. The African dust increment on each day is subtracted from the daily mean PM<sub>10</sub> concentration measured at the station being corrected (Rosia Road). This results in series of “corrected” daily mean PM<sub>10</sub> concentrations from which the number of days of exceedance and annual mean can be re-calculated for assessment against the LV stated in the Directive.

The use of the measurements from the Alcornocales regional background PM<sub>10</sub> monitoring station made accounting for the contribution of African dust events to the PM<sub>10</sub> mass concentration in Gibraltar simpler and more robust. This approach avoids the need to establish a regional background PM<sub>10</sub> mass concentration based on a range of measurements taken across a wide spatial extent as used in 2006-08<sup>9,10,11</sup>. It is unclear whether the PM<sub>10</sub> mass concentration from the Alcornocales station will be available in future years. Therefore it may be necessary to revert to the previous approach in future.

## 2.2 African dust quantification results

The results of the application of the African dust correction factor to the 2012 daily mean PM<sub>10</sub> mass concentrations measured at the Rosia Road and Bleak House<sup>12</sup> monitoring stations are summarised below. Table 1 provides the number of exceedances of the PM<sub>10</sub> 24-hr LV before and after application of the correction. Table 2 summarises the annual mean PM<sub>10</sub> mass concentration at the two air quality monitoring stations in Gibraltar before and after application of the correction.

**Table 1: Number of exceedances of the PM<sub>10</sub> 24-hr LV of 50 µg m<sup>-3</sup> (35 permissible exceedances per year) in 2012.**

	Rosia Road (roadside)	Bleak House (background)
Number of exceedances based on the uncorrected PM <sub>10</sub> mass concentration	18	3
Number of exceedances based on the corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor	7	3

**Table 2: Summary of the 2012 annual mean PM<sub>10</sub> mass concentration (annual mean PM<sub>10</sub> LV = 40 µg m<sup>-3</sup>) (µg m<sup>-3</sup>).**

	Rosia Road (roadside)	Bleak House (background)
Uncorrected PM <sub>10</sub> mass concentration	34	26
Corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor	28	21

Table 1 and Table 2 demonstrate that the uncorrected measured concentrations complied with the Directive prior to the application of a correction for natural sources (African dust and sea salt). The number of exceedances of the PM<sub>10</sub> 24-hr LV was 18, compared to 35 permitted by the Directive. The 2012 annual mean PM<sub>10</sub> mass concentrations were 34 µg m<sup>-3</sup>

<sup>12</sup> Station information can be found at [http://www.gibraltairquality.gi/index.php?lg=&t\\_action=info&station\\_id=GIB2&t=3&map=](http://www.gibraltairquality.gi/index.php?lg=&t_action=info&station_id=GIB2&t=3&map=)

<sup>3</sup> and  $26 \mu\text{g m}^{-3}$  at Rosia Road and Bleak House, respectively. The annual mean  $\text{PM}_{10}$  LV is  $40 \mu\text{g m}^{-3}$ .

The application of African dust quantification and correction methodology in 2012 served to reduce the number of exceedances of the  $\text{PM}_{10}$  24-hr LV and the annual mean  $\text{PM}_{10}$  mass concentration as specified in the AQD. In order to account completely for natural sources, a further correction can be made to account for the contribution to measured concentrations from sea salt.

## 3 Sea salt

### 3.1 Overview

This section presents the methodology used to determine the contribution of sea salt in Gibraltar to the:

- Monthly mean total ambient airborne particulate matter (PM<sub>x</sub>), and
- Daily mean PM<sub>10</sub> mass concentration,

Prior to 2010 no formal quantification of the contribution of sea salt to the daily or annual mean PM<sub>10</sub> mass concentration was attempted in Gibraltar. Previous Spanish research<sup>13</sup> indicated that sea salt contributed ~10% of the PM<sub>10</sub> mass concentration (approximately 4 µg m<sup>-3</sup>) in the nearby Spanish town of La Línea de la Concepción, located just over the Gibraltar-Spain border.

The Commission staff working paper establishing guidelines for demonstration and subtraction of exceedances attributable to natural sources<sup>7</sup> states that due to the episodic nature of sea salt emissions, accurate daily quantification is required in order to apply a correction to the daily mean PM<sub>10</sub> mass concentration. Accounting for the sea salt contribution to the PM<sub>10</sub> mass concentration, termed the PM<sub>10</sub> sea salt mass fraction, reported in the Questionnaire also requires that the sea salt mass fraction be determined at each station reported.

The term “sea salt correction factor” refers to the daily PM<sub>10</sub> sea salt mass fraction which was subtracted from the measured daily mean PM<sub>10</sub> mass concentration. The sea salt mass fraction of PM<sub>10</sub> was determined on a daily basis from 8<sup>th</sup> April 2011 onwards at the Rosia Road monitoring station. This correction factor was applied after the daily mean PM<sub>10</sub> mass concentration was corrected for the influence of African dust. The results of the 2012 sea salt correction are presented here.

### 3.2 Sampling methodology

A comprehensive description of the methods used to quantify daily mean PM<sub>10</sub> sea salt mass fraction in Gibraltar are contained within the “Measurement of sea salt aerosol in Gibraltar” report<sup>14</sup>. The report summarises the operation of a dedicated Partisol sampler to determine the daily mean PM<sub>10</sub> sea salt mass fraction at the Rosia Road air quality monitoring station.

#### 3.2.1 Partisol sampler

Measurement of the daily mean PM<sub>10</sub> sea salt mass fraction was provided by a dedicated Thermo Scientific Partisol Plus 2025 Sequential Air Sampler installed at the Rosia Road monitoring station. Following exposure in the field, the exposed Partisol filters were returned to the laboratory. The water soluble components of the sampled particulate matter, including sea salt, were extracted from the sample filters by washing with deionised water. Ion

<sup>13</sup> Querol, X., Alastuey, A., Moreno, T., Viana, M.M, Castillo, S., Pey, J., Rodriguez, S., Artinano, B., Salvador, P., Sanchez, M., Garcia Dos Santos, S., Herce Garraleta, M.D., Fernandez-Patier, R., Moreno-Grau, S., Negral, L., Minguillon, M.C., Monfort, E., Sanz, M.J., Palomo-Marin, R., Pinilla-Gil, E., Cuevas, E., de la Rosa, J., and Sanchez de la Campa, A.: Spatial and temporal variations in airborne particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) across Spain 1999-2005, *Atmospheric Environment*, 42(17), 3964-3979, doi: 10.1016/j.atmosenv.2006.10.071, 2006.

<sup>14</sup> Lingard J. J. N. (2012). Measurement of sea salt aerosol in Gibraltar. [http://www.gibraltairquality.gi/documents/Quantification\\_of\\_the\\_contribution\\_of\\_sea\\_salt\\_final.pdf](http://www.gibraltairquality.gi/documents/Quantification_of_the_contribution_of_sea_salt_final.pdf)

chromatography was used to determine the chloride (Cl<sup>-</sup>) and sodium (Na<sup>+</sup>) concentrations of the extracts. The daily mean mass concentration ( $\mu\text{g m}^{-3}$ ) of the chloride and sodium ions in the sampled particulate matter were calculated using Equation (1).

### 3.3 Calculation of the PM<sub>10</sub> sea salt mass fraction

Three methods are proposed<sup>7</sup> for the calculation of the PM<sub>x</sub> and PM<sub>10</sub> sea salt mass fraction. These methods infer the PM<sub>10</sub> sea salt mass fraction from the measured chloride (Cl<sup>-</sup>) and/or sodium (Na<sup>+</sup>) concentrations. The proposed European method assumes that sea salt is composed only of NaCl and that all the chloride and sodium ions in the sampled PM<sub>10</sub> are associated with NaCl. Therefore, according to composition of sea salt, the PM<sub>x</sub> and PM<sub>10</sub> sea salt mass fraction can be calculated thus:

$$\text{Sea salt } (\mu\text{g m}^{-3}) = \frac{100}{55} \times \text{Cl}^- = 1.8 \times \text{Cl}^-, \text{ or} \quad \text{Equation (2)}$$

$$\text{Sea salt } (\mu\text{g m}^{-3}) = \frac{100}{30.6} \times \text{Na}^+ = 3.27 \times \text{Na}^+, \text{ or} \quad \text{Equation (3)}$$

$$\text{Sea salt } (\mu\text{g m}^{-3}) = (\text{Na}^+ + \text{Cl}^-) \times 1.168. \quad \text{Equation (3)}$$

Equation (2) was used to determine the PM<sub>x</sub> and PM<sub>10</sub> sea salt mass fraction. This is consistent with the UK approach<sup>15</sup> where a scaling factor of 1.648<sup>16</sup> is applied to infer the PM<sub>10</sub> sea salt mass fraction from chloride ion measurements, for pollutant mapping purposes. The use of chloride ion was potentially subject to positive and negative artefacts. The chloride concentration can be enhanced through the emission of hydrochloric acid (HCl) gas to the atmosphere from high-temperature combustion processes such as coal burning and incineration<sup>7</sup>. HCl emissions have decreased in recent years due to the reduction in the use of coal as a fuel in power generation and flue gas abatement measures.

This approach was adopted as PM<sub>10</sub> mass concentrations in Gibraltar were subject to enhancement due to African dust events: the horizontal transport of wind-blown dust from North Africa. One key component of wind-blown dust is sodium. Therefore the use of sodium to determine the PM<sub>x</sub> and PM<sub>10</sub> sea salt mass fraction may have been subject to enhancement due to the presence of sodium in the sampled PM<sub>x</sub> and PM<sub>10</sub> due to wind-blown dust.

Only the daily mean PM<sub>10</sub> sea salt mass fraction measurements from the Partisol sampler located at the Rosia Road monitoring station are used for the natural sources correction for compliance reporting, in accordance with the Guidance issued by the Commission<sup>7</sup>.

The contribution of natural sources (African dust and sea salt) to the PM<sub>10</sub> mass concentration measured at the Rosia Road monitoring station was achieved by firstly subtracting of the contribution to the daily mean PM<sub>10</sub> mass concentration from African dust. Secondly, the daily mean PM<sub>10</sub> sea salt mass fraction was subtracted to provide the daily and annual mean PM<sub>10</sub> mass concentration corrected for natural sources.

<sup>15</sup> Brookes, D.M., Stedman, J.R., Grice, S.E., Kent, A.J., Walker, H.L., Cooke, S.L., Vincent, K.J., Lingard, J.J.N., Bush, T.J., and Abbott, J. (2011). UK modelling under the Air Quality Directive (2008/50/EC) for 2010 covering the following air quality pollutants: SO<sub>2</sub>, NO<sub>x</sub>, NO<sub>2</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, lead, benzene, CO, and ozone. Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Government and the Department of the Environment for Northern Ireland, AEAT/ENV/R/3215 Issue 1. [http://uk-air.defra.gov.uk/reports/cat09/1204301513\\_AQD2010mapsrep\\_master\\_v0.pdf](http://uk-air.defra.gov.uk/reports/cat09/1204301513_AQD2010mapsrep_master_v0.pdf)

<sup>16</sup> The use of a scaling factor of 1.648 treats other alkali and alkaline metal components of sea salt (magnesium, calcium and potassium) as sodium.

### 3.4 Sea salt quantification results

The results of the application of the African dust and sea salt correction factor to the 2012 daily mean PM<sub>10</sub> mass concentrations measured at the Rosia Road and Bleak House<sup>17</sup> monitoring stations are summarised below. The correction for the contribution of sea salt to the daily mean PM<sub>10</sub> mass concentration was applied after the daily mean PM<sub>10</sub> mass concentration was corrected for the contribution from African dust.

For clarity and comparison the number of PM<sub>10</sub> 24-hr LV exceedances and annual mean PM<sub>10</sub> mass concentrations are presented below to demonstrate the contribution of African dust, then sea salt, to these PM<sub>10</sub> metrics. Table 3 provides the number of PM<sub>10</sub> 24-hr LV exceedances before and after application of the complete 2012 natural correction (African dust and sea salt). Table 4 summarises the annual mean PM<sub>10</sub> mass concentration at the two monitoring stations in Gibraltar before and after application of the complete 2012 natural correction (African dust and sea salt).

**Table 3: Number of exceedances of the PM<sub>10</sub> 24-hr LV of 50 µg m<sup>-3</sup> (35 permissible exceedances per year) in 2012.**

	Rosia Road (roadside)	Bleak House (background)
Number of exceedances based on the uncorrected PM <sub>10</sub> mass concentration	18	3
Number of exceedances based on the corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor	7	3
Number of exceedances based on the corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor <i>and</i> the sea salt correction factor	5	-----*

\* Daily mean PM<sub>10</sub> sea salt mass fraction not measured at Bleak House.

**Table 4: Summary of the 2012 annual mean PM<sub>10</sub> mass concentration (annual mean PM<sub>10</sub> LV = 40 µg m<sup>-3</sup>) (µg m<sup>-3</sup>).**

	Rosia Road (roadside)	Bleak House (background)
Uncorrected PM <sub>10</sub> mass concentration	34	26
Corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor	28	21
Corrected PM <sub>10</sub> mass concentration after application of the African dust correction factor <i>and</i> the sea salt correction factor	26	-----*

\* Daily mean PM<sub>10</sub> sea salt mass fraction not measured at Bleak House.

Table 3 shows that after African dust and sea salt were quantified and removed from measured concentrations at Rosia Road, the number of PM<sub>10</sub> 24-hr LV exceedances was 5, i.e., below the 35 permissible for compliance with the AQD. Measurements at Bleak House could not be corrected to account for the contribution of sea salt to the measured PM<sub>10</sub> mass concentration at this site because the daily mean PM<sub>10</sub> sea salt mass fraction was not measured at this station. The number of PM<sub>10</sub> 24-hr LV exceedances at Bleak House air quality monitoring station was 3 before and after natural corrections (African dust only) were applied.

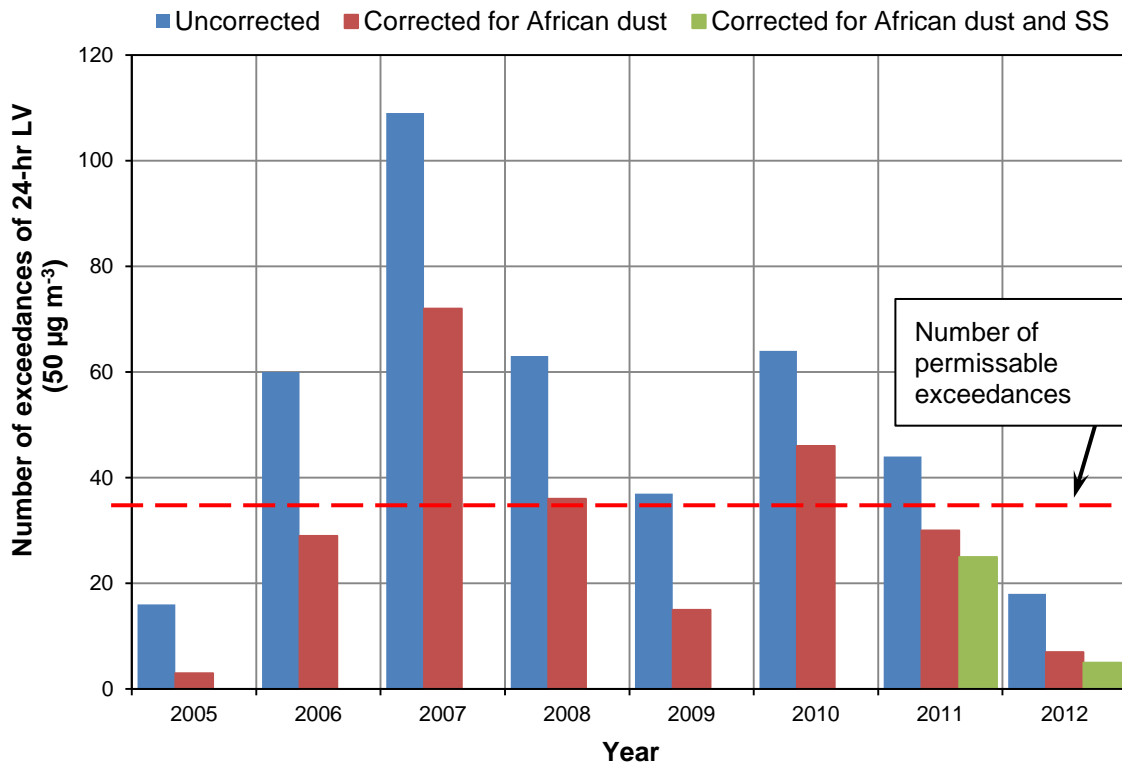
Table 4 shows that the annual mean PM<sub>10</sub> mass concentrations measured at the Rosia Road and Bleak House air quality monitoring stations were compliant with the annual mean LV

<sup>17</sup> Station information can be found at [http://www.gibraltairquality.gi/index.php?lg=&t\\_action=info&station\\_id=GIB2&t=3&map=](http://www.gibraltairquality.gi/index.php?lg=&t_action=info&station_id=GIB2&t=3&map=)

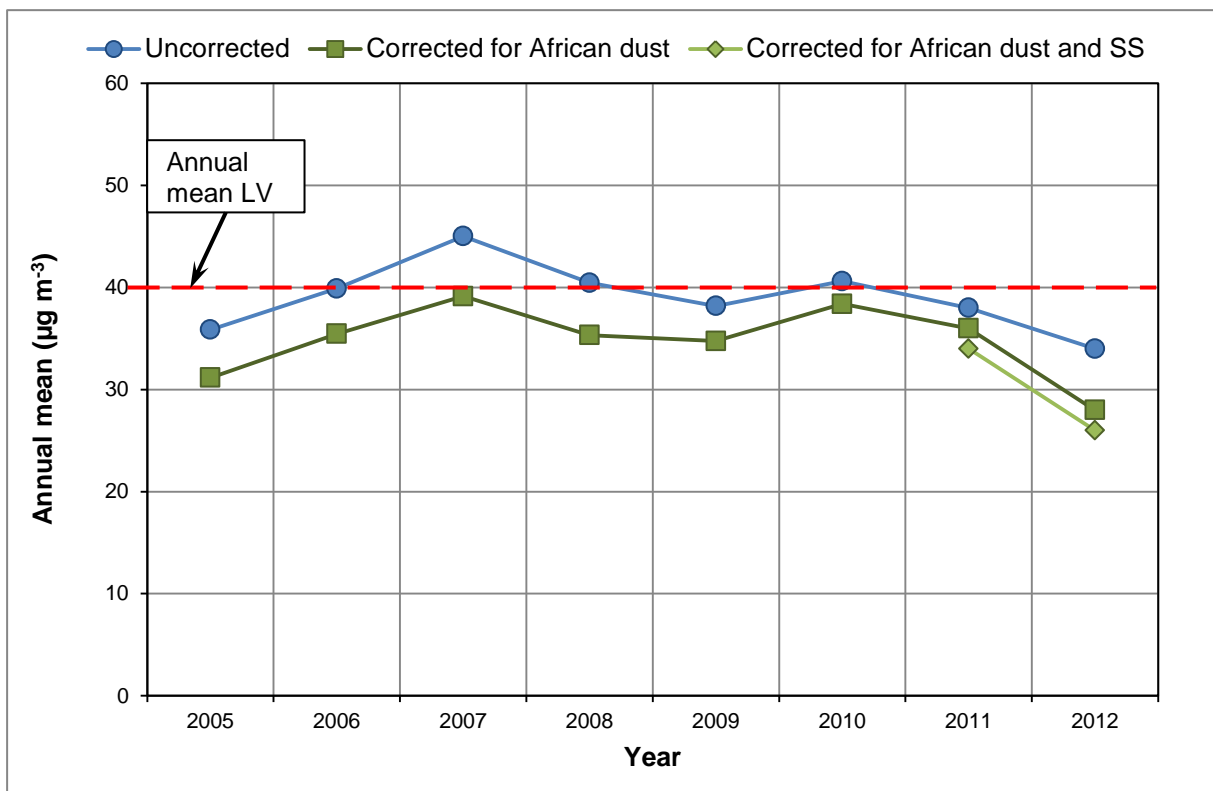
before accounting for the contribution of natural sources. The daily mean  $PM_{10}$  mass concentrations from Bleak House could not be corrected to account for sea salt, due to the absence of specific measurement equipment at the station as noted in the previous paragraph. The application of African dust quantification and correction methodology in 2012 served to reduce the number of exceedances of the  $PM_{10}$  24-hr LV and the annual mean  $PM_{10}$  mass concentration as specified in the AQD. In order to account completely for natural sources, a further correction can be made to account for the contribution to measured concentrations from sea salt. Figure 2 shows the variation in the number of exceedances of the  $PM_{10}$  24-hr LV in Gibraltar for the period 2005-2012. The figure shows the effect of the application of the African dust correction for the full period, and the sea salt correction for 2011 to the daily mean  $PM_{10}$  mass concentration measurements from the Rosia Road monitoring station. The red dashed line represents the number of permissible exceedances of the  $PM_{10}$  24-hr LV (35 per year) allowed by the AQD. Figure 2 allows the effect of application of the African dust correction factor to be seen in the context of compliance with the AQD over several years, as well as the application of the sea salt correction this year.

Figure 3 shows the annual mean  $PM_{10}$  mass concentration measured at the Rosia Road monitoring station including and excluding African dust correction from 2005-2012, and the sea salt correction this year. The red dashed line represents the annual mean  $PM_{10}$  LV. In Figure 3, the blue line shows the uncorrected annual mean  $PM_{10}$  mass concentration whilst the darker green line shows the annual mean  $PM_{10}$  mass concentration after accounting for African dust. The lighter green line shows the effect of the sea salt correction factor in further reducing the annual mean  $PM_{10}$  mass concentration from 2011 onwards.

**Figure 2:** Number of exceedances of the  $PM_{10}$  24-hr LV measured at the Rosia Road monitoring station, 2005-2012, before and after application of the African dust and sea salt (SS) correction.



**Figure 3:** Annual mean  $PM_{10}$  mass concentration measured at the Rosia Road monitoring station, 2005-2012, before and after application of the African dust and sea salt (SS) correction factor.



## 4 Summary

- Gibraltar was compliant in 2012 with the PM<sub>10</sub> 24-hr and annual mean LVs in the AQD before natural sources were quantified and removed from daily mean PM<sub>10</sub> mass concentrations at both Rosia Road and Bleak House monitoring stations.
- Application of African dust correction (only) to the daily mean PM<sub>10</sub> mass concentration measurements from the Rosia Road monitoring station reduced the number of exceedances of the PM<sub>10</sub> 24-hr LV from 18 to 7.
- Application of African dust correction (only) to the annual mean PM<sub>10</sub> mass concentration measurements from the Rosia Road air quality monitoring station reduced the annual mean concentration from 34 µg m<sup>-3</sup> to 28 µg m<sup>-3</sup>.
- The additional application of the sea salt correction (to African dust corrected PM<sub>10</sub> concentrations) resulted in 5 exceedances of the PM<sub>10</sub> 24-hr LV and resulted in an annual mean PM<sub>10</sub> concentration of 26 µg m<sup>-3</sup> at the Rosia Road air quality monitoring station.



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