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EEA´s revision of the European air quality index bands

Authors:
Alberto González Ortiz (EEA), Joana Soares (NILU), Jaume Targa (4sfera), Maria Colina (4sfera), Laia Azcón (4sfera), Lorena Banyuls (4sfera), Myriam Tobollik (UBA), Silvia Monge (EEA), Ragnhildur Finnbjornsdottir (EEA)

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Executive summary

The updated European Air Quality Index (EAQI) uses an updated methodology to define the bands for the different categories, which ensures consistency across pollutants. The updated bands reflect alignment with both the World Health Organization (WHO) 2021 Air Quality Guidelines and some of the air quality standards defined in the revised Ambient Air Quality Directive (Directive (EU) 2024/2881). The index will be refreshed hourly, based on hourly concentrations for all pollutants, including PM. This ensures an improvement of its sensitivity to temporal changes. The updated index will still be presented at station level (although a map layer with modelled concentrations can also be shown, as is the case in the current index app).

The updated bands are defined according to the long- and short-term air quality guideline levels and the interim targets defined by the WHO, and the concept of equal relative risks of all-cause mortality due to short-term exposure for the different pollutants in the different bands. The long- and short-term air quality guideline levels for each pollutant mark the first two categories for that pollutant. From there, $PM_{2.5}$ is used as the reference pollutant for which the initial bands are fixed according to its WHO interim targets. For the rest of the pollutants, the bands are defined by calculating the concentrations that would result in the same risk of mortality as for the corresponding $PM_{2.5}$ concentration. The resulting bands are further refined to make them coincide with some of the information and alert thresholds defined in the revised EU Ambient Air Quality Directive.

The updated index results in a tool with solid scientific grounds and communication consistency, that also fulfils the needs of information to the public in the EEA member countries.

Pollutant	Reference time	Good	Fair	Moderate	Poor	Very poor	Extremely poor
$PM_{2.5}$	1h	0-5	6-15	16-50	51-90	91-140	>140
PM_{10}	1h	0-15	16-45	46-120	121-195	196-270	>270
O_3	1h	0-60	61-100	101-120	121-160	161-180	>180
NO_2	1h	0-10	11-25	26-60	61-100	101-150	>150
SO_2	1h	0-20	21-40	41-125	126-190	191-275	>275

Health messages

	Good	Fair	Moderate	Poor	Very poor	Extremely poor
General population	The air quality is good. Enjoy your usual outdoor activities.	Enjoy your usual outdoor activities	Enjoy your usual outdoor activities	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat	Reduce physical activities outdoors.
Sensitive populations	The air quality is good. Enjoy your usual outdoor activities.	Enjoy your usual outdoor activities	Consider reducing intense outdoor activities, if you experience symptoms.	Consider reducing physical activities, particularly outdoors, especially if you experience symptoms.	Reduce physical activities, particularly outdoors, especially if you experience symptoms.	Avoid physical activities outdoors.

1 Introduction

The European Air Quality Index([1]) (EAQI) was launched in 2017 in the context of the 1st Clean Air Forum([2]). An air quality index AQI is a communication tool that helps users to understand more about air pollution and its impact on their health. The EAQI is refreshed hourly based on concentrations of key pollutants: particulate matter smaller than 10 and 2.5 µm in diameter (PM_{10} and $PM_{2.5}$, respectively), nitrogen dioxide (NO_2), ozone (O_3) and sulphur dioxide (SO_2). The concentrations from more than 3,500 air quality monitoring stations across Europe, as reported by the European Environment Agency (EEA) member countries, cooperating countries and other voluntary reporting countries, are used to categorise the EAQI. The categorization is complemented where necessary (i.e., missing values and predicted index) using forecasted air quality levels as provided by the Copernicus Atmospheric Monitoring Service (CAMS([3])). The index depicts the air quality situation from the preceding 48 hours and into the next 24 hours (only using the forecasted levels by CAMS for the next 24 hours).

In the current index, the bands used to define the different index categories are based on the relative risks (RR) for all-cause mortality associated with short-term exposure to $PM_{2.5}$, O_3 and NO_2, as provided by the World Health Organization (WHO) in its report on the Health Risks of Air Pollution in Europe project (HRAPIE; UNKNOWN AUTHOR, 2013). The relative risk of exposure to $PM_{2.5}$ is taken as a basis for defining the index bands, specifically the increase in the risk of mortality per 10 µg/m^3 increase in the daily mean concentration of $PM_{2.5}$. To define the bands of the other pollutants, the relative risks' functions for $PM_{2.5}$, O_3 and NO_2 are assumed to be linear. Then, the concentrations of O_3 and NO_2 that pose an equivalent relative risk to a 10 µg/m^3 increase in the daily mean of $PM_{2.5}$ are calculated. For PM_{10} concentrations, a constant ratio between PM_{10} and $PM_{2.5}$ of 2:1 is assumed, which is in line with the recommendations of the World Health Organization (UNKNOWN AUTHOR, 2013). For SO_2, the bands reflect the limit values set under the EU Ambient Air Quality Directive (AAQD) 2008/50/EC (EU, 2008). Table 1.1 describes the bands of the current EEA's EAQI.

Hourly concentrations for NO_2, O_3 and SO_2 and the 24-hour running means for the past 24 hours for PM_{10} and $PM_{2.5}$ are used every hour to assign a category to every pollutant (following Table 1.1) and then the worst of them categorises the overall index in that hour.

The current EEA's EAQI needs to be updated to adapt the bands to the new scientific evidence provided by the WHO Air Quality Guidelines (AQG) published by the WHO in 2021 (WHO, 2021). Table 1.2 shows the WHO AQG levels and interim targets (IT) for regulated pollutants. In addition, the revised AAQD (EU) 2024/2881 (EU, 2024) also requests that Member States provide and maintain an AQI "covering hourly updates on at least SO_2, NO_2, PM_{10}, $PM_{2.5}$ and O_3". Furthermore, that index "shall build on the air quality indices at European scale provided by the EEA and include information regarding impacts on health, including information tailored to sensitive population and vulnerable groups" or Member States "may use the AQ index defined by the EEA".

([1]) https://www.eea.europa.eu/themes/air/air-quality-index
([2]) https://environment.ec.europa.eu/topics/air/clean-air-forum_en
([3]) https://atmosphere.copernicus.eu/

Table 1.1 Current EEA's EAQI bands (category and its lower and upper limits)

Pollutant	Averaging time	Index category (based on pollutant concentrations in µg/m^3)					
		Good	Fair	Moderate	Poor	Very poor	Extremely poor
$PM_{2.5}$	24h	0-10	11-20	21-25	26-50	51-75	76-800
PM_{10}	24h	0-20	21-40	41-50	51-100	101-150	151-1200
NO_2	1h	0-40	41-90	91-120	121-230	231-340	341-1000
O_3	1h	0-50	51-100	101-130	131-240	241-380	381-800
SO_2	1h	0-100	101-200	201-350	351-500	501-750	751-1250

Table 1.2 WHO AQG levels and interim targets (from WHO, 2021)

Pollutant	Averaging time	Interim target (µg/m^3, CO mg/m^3)				AQG level (µg/m^3, CO mg/m^3)
		1	2	3	4	
$PM_{2.5}$	Annual	35	25	15	10	5
	24-hour ([a])	75	50	37.5	25	15
PM_{10}	Annual	70	50	30	20	15
	24-hour ([a])	150	100	75	50	45
O_3	Peak season ([b])	100	70	-	-	60
	8-hour ([a])	160	120	-	-	100
NO_2	Annual	40	30	20	-	10
	24-hour ([a])	120	50	-	-	25
SO_2	24-hour ([a])	125	50	-	-	40
CO	24-hour ([a])	7	-	-	-	4

[a] 99th percentile (i. e., 3-4 exceedance days per year).

[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

In June 2023, the EEA contacted the Eionet thematic group on air, asking the national experts to show their interest in participating in a working group (WG) on the EAQI bands update. With this co-creation activity, the EEA intended to take stock of the ongoing national activities and work collaboratively among the EEA, the European Topic Centre on Health and the Environment (ETC HE) and the interested Eionet countries to define new bands for the EAQI, considering also the latest recommendations on indexes by the WHO (Cromar and Lazrak, 2023).

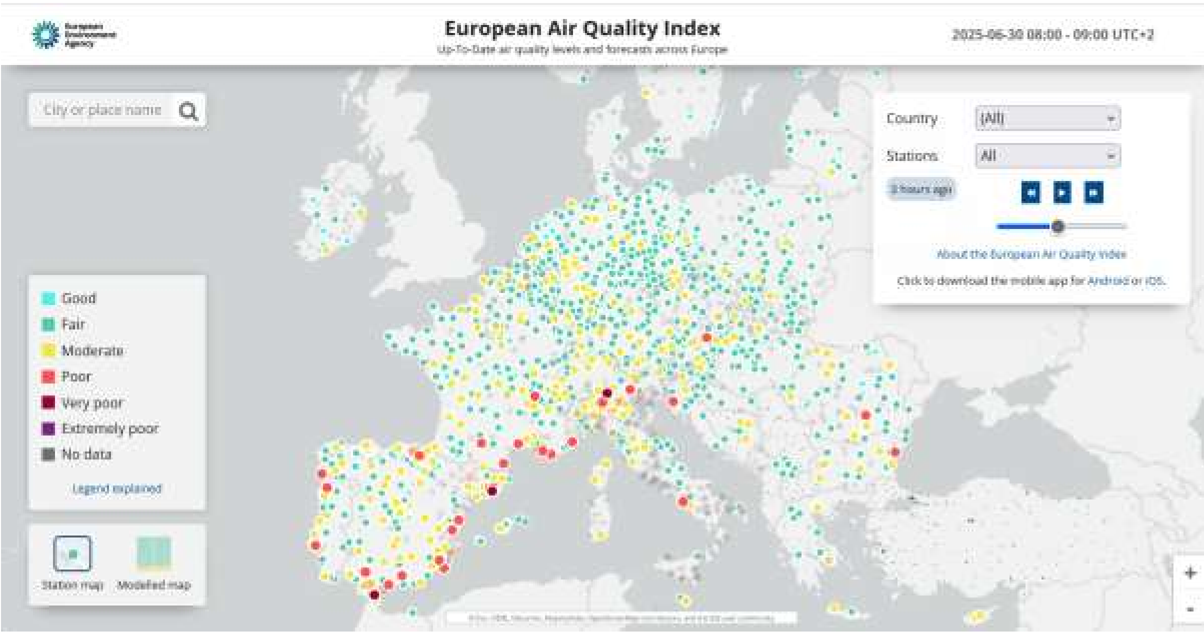
This report reflects on the proposals considered for the updated EAQI bands and the way to derive them in the context of collaboration with the above mentioned WG. Chapter 2 summarizes the updated EAQI. Chapter 3 describes the steps that led to different proposals for updating the bands, which are then compared in Chapter 4. Chapter 5 analyses further improvements to the proposals and concludes with the final band proposal. Chapter 6 presents the associated health messages and finally Chapter 7 offers some final considerations.

2 General remarks on the updated European Air Quality Index

As already specified, the update of the EAQI will only affect the current bands that define the different index categories. The index will still be divided into six bands, with the same colour coding and wording of classes (good, fair, moderate, poor, very poor, extremely poor) as it is now, and the categorization process will not be changed (apart of using hourly values to categorize the pollutant sub-indexes also for PM). The index is presented at station level based on the pollutant with the highest subindex observed at the station([4]), see Figure 2.1. Depending on the availability, the observations for NO_2, PM_{10}, $PM_{2.5}$, O_3, and/or SO_2 for individual stations reported via e-reporting (E2a) are used for the categorisation. For a station to be assigned an index value and be depicted in full colour, the number of its measured pollutants must be in line with the following:

- For traffic stations: Either $PM_{2.5}$ or PM_{10} needs to be measured as well as NO_2.
- For background and industrial stations: Either $PM_{2.5}$ or PM_{10} needs to be measured as well as NO_2 and O_3.

Figure 2.1 Screenshot of the dashboard displaying the new EAQI



Those stations that do not fulfil the minimum number of pollutants for their station type are depicted as semi-transparent circles, indicating that the index is not calculated with the minimum number of required pollutants. Furthermore, the semi-transparent circle is grey if the index (calculated with the available pollutants) is good, fair or moderate; and if it is poor, very poor or extremely poor, it is depicted with the corresponding category colour.

The main considerations to define the updated bands are the following:

- Hourly values are considered for all pollutants, also for PM instead of the daily mean concentrations.
- The first two bands of the index for all pollutants are defined by the corresponding WHO guideline levels for long- and short-term exposure (for SO_2, that does not have a long-term AQ

([4]) Nevertheless, a layer showing an index based on modelled maps will be shown, as it is the case for the current index app.

guideline level defined, the updated annual limit value (ALV) in the revised AAQD (EU) 2024/2881 was considered instead).

- The remaining bands for $PM_{2.5}$ are defined based on the WHO short-term interim targets 4, 2 and 1.
- Mortality is the health outcome considered.
- The remaining bands for PM_{10}, NO_2, O_3 and SO_2 are defined by a mortality risk approach, i.e., assuming linearity and estimating the concentrations of those pollutants which would imply an equivalent risk increase as for $PM_{2.5}$ (the reference pollutant).
- The resulting concentrations for these remaining bands are converted into hourly values.
- Further small refinements of the bands were done to round the band values or to make them coincident with the information or alert values defined in the revised AAQD.
- The health messages, remain as they are in the current EAQI.

The table with the final bands and health messages is available at Table 5.2 and Table 6.1, respectively.

3 Methodology for the first proposal for the updated bands of the EAQI

3.1 Feedback from the Working Group

The WG created to improve the EAQI included entities from eight different countries. They presented their current indexes and/or shared their ideas for updating bands in their AQI. Participants included: the Belgian Interregional Environment Agency (IRCEL – CELINE([5]), Belgium), L'observatoire de la qualité de l'air en Région Sud Provence-Alpes-Côte d'Azur (AtmoSud([6]), France), the German Environmental Agency (UBA([7]), Germany), the Portuguese Environmental Agency (APA, Portugal), the Serbian Environmental Protection Agency (SEPA([8]), Serbia), the National Institute for Public Health and the Environment (RIVM([9]), Netherlands), the Environment Agency from Luxembourg (AEV([10])) and the Finnish Meteorological Institute (FMI([11])).

Generally, the indexes presented were based either on setting band limits using WHO guideline levels and/or EU legal standards (limit and target values and information and alert thresholds), the so-called pragmatic approach; or a risk-based approach where mortality and/or morbidity equivalent risks are used for the same band of each pollutant, similarly to the current EEA European AQ index. Most entities qualify the index defining sub-indexes for every pollutant and using the worst specific pollutant sub-index. Furthermore, AtmoSud (France) presented a cumulative index([12]), which uses high-density mapping instead of stations. In this cumulative index, the sub-indexes of four pollutants are added at a spatial resolution of 25 m, instead of considering the maximum index specific for each pollutant. This allows for highlighting areas of multiple exposure.

It was also suggested to explore synergies when more than one pollutant is exceeded and incorporate that event into the methodology of the index, as is already the case for the Netherlands, where the index([13]) is increased to the next worst band when all four pollutants are in the same band.

The different indexes presented were considered in the process of updating the EAQI bands.

3.2 Considerations for revising the EAQI

3.2.1 Risk-based and pragmatic approaches for individual pollutants at station level

First, it was considered to move from the current approach of using the pollutant with the worst sub-index category into a cumulative approach, as proposed by AtmoSud. In this case, several pollutants and their health impacts can be assessed together. Nevertheless, if the index is based on observations and not all pollutants are being measured in all the stations, those stations measuring all pollutants will be "penalised", as the possible risk of all pollutants will be counted, while for stations missing pollutants their corresponding risks will also be missing. This could be overcome by using concentration maps (for instance, those produced by the ETC HE (e.g., ETC HE, 2023)). However, not all the EEA territory is covered by the ETC HE maps (Türkiye is missing for $PM_{2.5}$ and the French, Portuguese and Spanish overseas territories fall out of the maps domain). And the maps shown in the index app have a resolution of 1x1 km^2, far from the 25 m in the French case. Lastly, there is limited

([5]) https://www.irceline.be/en
([6]) https://www.atmosud.org/
([7]) https://www.umweltbundesamt.de/en/topics/air
([8]) https://sepa.gov.rs/vazduh/
([9]) https://www.rivm.nl/en/climate-change-and-health/air-quality
([10]) https://aev.gouvernement.lu/fr/dossiers/2021/air-quality.html
([11]) https://en.ilmatieteenlaitos.fi/air-quality-group
([12]) https://www.atmosud.org/article/icair-cumulative-air-index
([13]) https://www.luchtmeetnet.nl/meetpunten

evidence that the effect is cumulative, due to possible double-counting of the effects (UNKNOWN AUTHOR, 2013) or to other kinds of interactive effects (for instance, synergistic instead of cumulative).

It was decided that the updated bands will be defined as in the current EAQI: using the risk-based approach, the concentrations measured at monitoring stations and, as originally planned (since the idea was only to change the bands), calculate subindexes for (max) 5 specific pollutants and, finally, take the worst subindex to categorize the index.

The advantages of an index based on risks are the possibility of linking it to health effects and the possibility of using the WHO AQG to set the limits of the bands. Furthermore, the use of a pragmatic approach, at least for defining the upper limits of the first bands, could be useful, implying that not exceeding the annual WHO AQG levels (or the summer or peak season O_3 level) would mean a "good" index and that not exceeding the WHO daily AQG levels would mean a "fair" index. This is the approach used in the updated Belgian index([14]), but the definition of the rest of the bands in the Belgian index looses the principle that for the same categories of the different pollutants, their impact on premature mortality is not equal.

3.2.2 Hourly based index

Most of the participating countries expressed the need for an index that is as responsive to pollution changes as possible. This implies using hourly data for all pollutants, including PM for which running 24-hour averages are used in the current EAQI. But, since the relative risks for short-term exposure are mostly defined for 24 hours for PM, NO_2 and SO_2 and 8 hours for O_3, it would imply the need to find a relationship for the European stations between the 24-hour concentrations and the 1-hour concentrations for $PM_{2.5}$, PM_{10}, SO_2 and NO_2 as well as the 8-hour concentrations and the 1-hour concentrations of O_3, as shown by the Belgian, Dutch and German approaches.

3.2.3 RR for non-accidental mortality (only)

Using only the risk for mortality due to short-term exposure may overestimate the impact of O_3 (as faced by the update of the Belgian index) and NO_2 (see in Table 3.1 WHO relative risks (RR) for mortality due to short-term exposure to selected air pollutants per 10µg/m^3 increment (from WHO, 2021) the RRs for short-term mortality, WHO, 2021, which are higher for 10µg/m^3 NO_2 than for 10µg/m^3 $PM_{2.5}$). To avoid this, morbidity impacts could be considered, as the German approach does. Following an analysis of possible RRs done by experts of the Heinrich Heine University Düsseldorf, RRs for several morbidity outcomes were identified from meta-analyses (see Table 3.2). Nevertheless, combining these different mortality and morbidity outcomes can be challenging from an epidemiological and health-related perspective. For instance, the RRs of the different health outcomes are not available for all the pollutants as in the undertaken analysis only those exposure-outcome pairs for which evidence of a causal relationship was available were chosen. A further look into the ongoing WHO project *Estimating the morbidity from air pollution and its economic costs* (EMAPEC) (Forastiere et al., 2024), did not find either RRs for the same outcomes and pollutants. Finally, the pollutants have different effects on the human body and, most importantly, the outcomes represent different physiological processes. Therefore, EEA decided to use only the risk for all non-accidental mortality for this EAQI band update.

([14]) https://www.irceline.be/en/air-quality/measurements/air-quality-index-november-2022

Table 3.1 WHO relative risks (RR) for mortality due to short-term exposure to selected air pollutants per 10µg/m³ increment (from WHO, 2021)

Pollutant	Reference time	RR for non-accidental mortality, %	95% confidence interval
$PM_{2.5}$	24 hours	0.65	(0.44-0.86)
PM_{10}	24 hours	0.41	(0.34-0.49)
O_3	8 hours	0.43	(0.34-0.52)
NO_2	24 hours	0.72	(0.59-0.85)
SO_2	24 hours	0.59	(0.46-0.71)

Table 3.2 Relative risks (RR) for several morbidity outcomes identified in an analysis of publications (increase per 10µg/m³ increment)

Pollutant	Reference time	RR for CVD admissions, % (95% CI)	RR for respiratory admissions, % (95% CI)	RR for emergency department visits or hospital admissions due to asthma, % (95% CI)
$PM_{2.5}$	24 hours	1 (0.17-1.66)	1.4 (-0.18-4)	2.9 (1.1-3.1)
PM_{10}	24 hours	0.7 (0.19-1.12)	1.6 (0.04-3.14)	0.8 (0.5-1)
O_3	8 hours		0.2 (-1.1-1.5)	0.3 (-0.7-1.5)
NO_2	24 hours		1.8 (1.15-2.45)	1.4 (0.8-2)
SO_2	24 hours			1 (0.1-2)

Source: UBA- technical document on the AQI (to be published).

3.2.4 $PM_{2.5}$ as a reference pollutant

$PM_{2.5}$ is the pollutant with the highest number of studies for human health in terms of mortality and morbidity and is the pollutant for which the epidemiological research is most robust. This is also reflected in the availability of studies on short-term exposure and morbidity outcomes for the other pollutants. For this reason, it was decided to keep $PM_{2.5}$ as the anchor or reference pollutant from which to build the definition of the new bands for this EAQI update.

3.2.5 A pragmatic and risk-based approach chosen

Following the above-mentioned rationale, the EEA and the ETC HE decided that the bands should be defined using both the pragmatic and the risk approach. On the one hand, the latest long- and short-term AQG levels recommended by the WHO are considered when defining the first two bands for all pollutants. In this way, protection against long-term (or chronical, linked to annual means and therefore to the long-term WHO AQG level) and short-term (linked to daily means and therefore to the 24-hour AQG levels) effects is assured, respectively. On the other hand, the Interim targets (IT) defined in the WHO Guidelines for $PM_{2.5}$ are used to set the band limits for the remaining $PM_{2.5}$ bands. IT are associated with a specific decrease in health risk and are recommended by WHO as incremental steps in the progressive reduction of air pollution towards the AQG levels.

The remaining bands for the other pollutants will then be assessed by finding the concentrations that entail equivalent risks to those concentrations of $PM_{2.5}$ for the same band, assuming linearity ([15]) in

([15]) A linear relationship between the RR of death and the concentration, for all pollutants and over all concentration ranges, is assumed. This assumption is generally accepted, in particular for $PM_{2.5}$, PM_{10} and, to a lesser extent, for NO_2, for which some studies have observed a non-linear relationship (on a 24-hour average). For O_3, several studies observed a non-linear relationship (Orellano et al. 2020).

the form of the RR functions for all concentration ranges. Finally, all bands need to be translated into health recommendations that consider air pollution effects.

3.3 Methodology steps of the first proposed updated index

3.3.1 Definition of the bands "good" and "fair"

As explained above, it was decided that the pragmatic approach should be used for defining the first two bands for all pollutants, i.e., the values for long (1-year, or peak season for O_3) and short-term (daily) exposure defined by the WHO AQG should be considered as the upper limit bands for good and fair levels, respectively (for SO_2, that does not have a long-term AQ guideline level defined, the updated ALV in the revised AAQD (EU) 2024/2881 was considered instead). Therefore, the long-term guideline level marks the change between "good" and "fair", and the short-term guideline level marks the change between "fair" and "moderate", see Table 3.3.

Table 3.3 Proposed upper concentrations (in µg/m^3) for the "good" and "fair" bands of the updated EAQI

Pollutant	Good	Fair
$PM_{2.5}$	5	15
PM_{10}	15	45
O_3	60	100
NO_2	10	25
SO_2	20	40

3.3.2 Definition of the "moderate", "poor", and "very poor" bands

$PM_{2.5}$

Using the WHO Global update of the AQG as was done for the first two bands, the WHO ITs for short-term exposure to $PM_{2.5}$ were chosen to define the remaining $PM_{2.5}$ bands. The 24-hour IT 4, 2, and 1 mark the upper concentrations for "moderate", for "poor", and for "very poor", respectively (see Table 3.4).

In this way,

- Further values recommended by the WHO (in this case associated with a specific decrease in health risk) are used.
- The last bands have an even width.
- And, most importantly, consistency with the 24-hours bands defined in the current index is assured. This implies that, in relation to the current index, only the first two bands are modified for the 24-hours $PM_{2.5}$ concentrations, making them more homogeneous in terms of width.

Table 3.4 Proposed upper concentrations (in µg/m^3) for the "good" to "very poor" bands for 24h $PM_{2.5}$ of the updated EAQI

Pollutant	Good	Fair	Moderate	Poor	Very poor
$PM_{2.5}$	5	15	25	50	75

PM_{10}, NO_2, O_3 and SO_2

The values for the remaining pollutants are obtained by a risk-based approach, estimating a $PM_{2.5}$-equivalent mortality risk increase for the upper concentrations of one band in relation to the previous one. The first step is to calculate the excess mortality for these pollutants related to the $PM_{2.5}$ concentrations in the bands. Since $PM_{2.5}$ is chosen as the reference pollutant, its excess mortality is set to a relative value of 1. The equivalent excess mortality for remaining pollutants is calculated based on the equation below:

$$CF_{PM2.5\_i} = \frac{RR_{PM2.5}}{RR_i} \quad (3.1)$$

Where $CF_{PM2.5\_i}$ is the conversion factor to obtain a concentration of pollutant *i* with the same excess mortality as a given concentration of $PM_{2.5}$, $RR_{PM2.5}$ is the excess mortality for 10µg/m^3 of $PM_{2.5}$, and RR_i is the excess mortality for the 10µg/m^3 of pollutant *i*. The estimated values of the conversion factors for the individual pollutants are described in Table 3.5.

Table 3.5 RR for non-accidental mortality per 10µg/m^3 based on the WHO Guidelines (WHO, 2021) and the conversion factor ($CF_{PM2.5i}$) to obtain a concentration of pollutant i with the same excess mortality as a given concentration of $PM_{2.5}$

Pollutant (i)	Reference time (h)	RR for non-accidental mortality (%) per 10µg/m^3 (WHO, 2021)	$CF_{PM2.5i}$
$PM_{2.5}$	24	0.65	1.00
PM_{10}	24	0.41	1.59
O_3	8	0.43	1.51
NO_2	24	0.72	0.90
SO_2	24	0.59	1.10

The second step is to calculate the upper limits of the bands in relation to the increase of $PM_{2.5}$ concentrations according to the equation below:

$$Ci_{j+1} = \Delta PM2.5_{j,j+1} * CF_{PM2.5_i} + Ci_j \quad (3.2)$$

Where Ci_j and Ci_{j+1} are the upper limit concentrations of two consecutive bands j and j+1 for pollutant *i*, where *j* is defined from 2 (fair) to 5 (very poor), $\Delta PM2.5_{j,j+1}$ is the increment between the maximum value of the bands *j* and *j+1* for $PM_{2.5}$, e.g., moderate (j+1=3) and fair (j=2) and $CF_{PM2.5_i}$ is obtained from Table 3.5Table 3.5 RR for non-accidental mortality per 10µg/m^3 based on the WHO Guidelines (WHO, 2021) and the conversion factor ($CF_{PM2.5i}$) to obtain a concentration of pollutant i with the same excess mortality as a given concentration of $PM_{2.5}$. For example, if the value for moderate level for PM_{10} is estimated using Eq. 3.2, the values for $PM_{2.5}$ bands in Table 3.4 , and the upper value of the "fair" band for PM_{10} from Table 3.3 it will look like:

$$\mathrm{PM10}_{\mathrm{moderate}} = (25 - 15) * 1.59 + 45 = 61 \quad (3.3)$$

Table 3.6 shows the outcome of estimating the upper limits for moderate, poor, and very poor bands.

Table 3.6 Upper limit concentrations (in µg/m³) for moderate, poor and very poor bands of the proposed EAQI

Pollutant	Reference time (h)	Moderate	Poor	Very poor
$PM_{2.5}$	24	25	50	75
PM_{10}	24	61	100	140
O_3	8	115	153	191
NO_2	24	34	57	79
SO_2	24	51	79	106

3.3.3 From daily to hourly values

Analysis to find a European relationship between the short-term WHO AQG levels (defined as daily mean values for all pollutants except ozone, daily maximum 8-hour average) and daily maximum hourly values by applying regression analysis using pollutant measurements between 2018 and 2022, similarly to what was done by Stieb et al. (2008) are show in Annexes 1 and 2. Annex 1 provides an analysis of the possible relationships between 24h concentrations (8h for O3) and hourly concentrations, concluding a linear regression is the best and simplest approximation. Annex 2 provides an analysis of the linear relationship between the daily mean (the mean of hourly values in one day) and the daily hourly maximum values for PM_{10}, $PM_{2.5}$, NO_2, and SO_2, as well as the linear relationship between daily maximum 8-hour values and daily hourly maximum values for O_3.

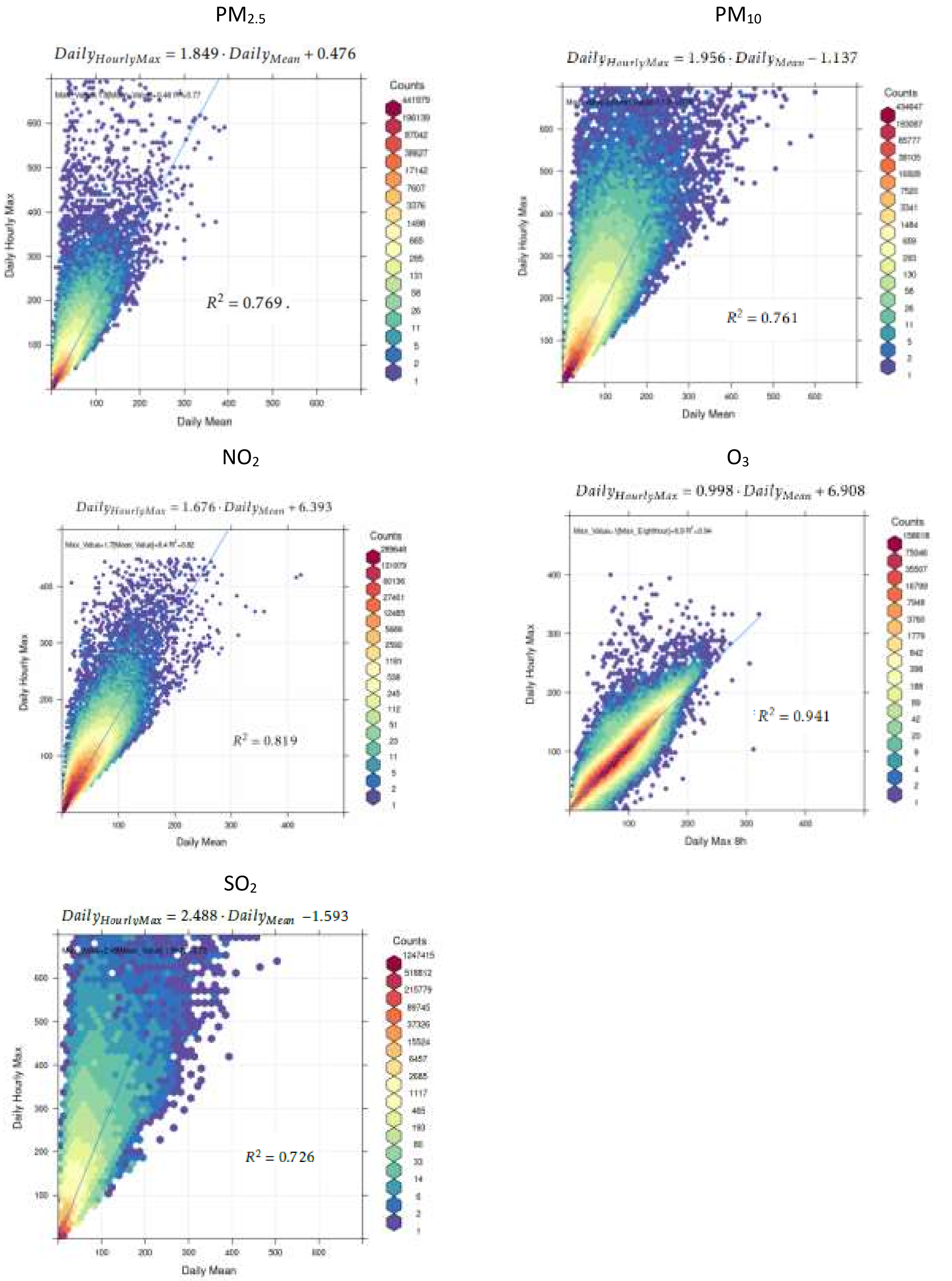
The regression equations for the individual pollutants can then be used to convert the upper limit concentrations of the bands in the updated EAQI in Table 3.6 into hourly values. The equations were obtained using all available values for individual pollutants. The scatter plots, coefficient of determination (R2), and the regression function are presented in Figure 3.1 and Table 3.7 presents the transformation factors to convert 24-hour (PM2.5, PM10, NO2, SO2) and 8-hour running mean (O3) values to hourly values.

The analysis was also done per country, and it is available in Annex 2 in case countries wanted to apply it in their national indexes. Nevertheless, both the EEA and the ETC HE recommend using the relationship for all countries in view of keeping consistency among the different national indexes and the European one.

Table 3.7 Transformation functions to convert 24-hour ($PM_{2.5}$, PM_{10}, NO_2, SO_2) and 8-hour running mean (O_3) values into hourly values based on the data shown in Figure 3.1

Pollutant	Reference time	Transformation function
$PM_{2.5}$	1h	1.849 * dailyMean + 0.476
PM_{10}	1h	1.956 * dailyMean – 1.137
O_3	1h	0.998 * 8hMean + 6.908
NO_2	1h	1.676 * dailyMean + 6.393
SO_2	1h	2.488 * dailyMean – 1.593

Figure 3.1 Relationship between the daily hourly maximum and the daily mean for PM2.5, PM10, NO2 and SO2, and the 8-hour daily maximum for O3, European stations, 2018-2022



The upper limits for the three bands in Table 3.6 are then converted to reflect hourly exposure using the transformation functions in Table 3.7. The final values are available in Table 3.8, which includes the values for both daily (or 8h for O_3) and hourly reference times.

Table 3.8 Maximum concentration for moderate, poor and very poor bands (in µg/m³) of the EAQI

	Reference time (24h, 8h O_3)			Reference time (1h)		
Pollutant	moderate	poor	very poor	moderate	poor	very poor
$PM_{2.5}$	25	50	75	47	93	139
PM_{10}	61	100	140	118	195	273
O_3	115	153	191	122	160	198
NO_2	34	57	79	63	101	139
SO_2	51	79	106	125	194	262

3.3.4 Definition of extremely poor

The last band (extremely poor) for all the pollutants included in the index is defined by any value above the upper limit of the very poor band, for 1-hour reference time, as shown in Table 3.8
The resulting proposed index bands are shown in Table 3.9.

Table 3.9 Proposed updated EAQI (in µg/m³), without refinement.

Pollutant	Reference time	Good	Fair	Moderate	Poor	Very poor	Extremely poor
$PM_{2.5}$	1h	0-5	6-15	16-47	48-93	94-139	>139
PM_{10}	1h	0-15	16-45	46-118	119-195	196-273	>273
O_3	1h	0-60	61-100	101-122	123-160	161-198	>198
NO_2	1h	0-10	11-25	26-63	64-101	102-139	>139
SO_2	1h	0-20	21-40	41-125	126-194	195-262	>262

3.3.5 Refinement of the first proposed updated index

The bands presented in Table 3.9 need to be refined to round values and, where possible, make them coincident with the information and alert thresholds in the revised AAQD (EU, 2024).

The values in the original table are modified as follows:

- The upper limits of the moderate band are converted:
  - For $PM_{2.5}$, from 47 to 50, to be coincident with the 1-hour information threshold and the 24-hour alert threshold.
  - For PM_{10}, O_3 and NO_2, the values are rounded to the nearest ten, changing from 118, 122 and 63 to, respectively, 120, 120 and 60.
- The upper limit of the $PM_{2.5}$ poor band is rounded to the nearest ten, changing from 93 to 90; and for SO_2 from 194 to 190.
- The upper limits of the very poor band
  - Are rounded to the nearest ten for $PM_{2.5}$, PM_{10} and O_3, changing from 139, 273 and 198 to, respectively, 140, 270 and 200.
  - Are converted for NO_2 and SO_2 from 139 and 262 to, respectively, 150 and 275, to make them coincident with the 1-hour information threshold.

The resulting values are shown in Table 3.10

Table 3.10 Refined first proposal for the bands of the updated EAQI (in µg/m³)

Pollutant	Reference time	Good	Fair	Moderate	Poor	Very poor	Extremely poor
$PM_{2.5}$	1h	0-5	6-15	16-50	51-90	91-140	>140
PM_{10}	1h	0-15	16-45	46-120	121-195	196-270	>270
O_3	1h	0-60	61-100	101-120	121-160	161-200	>200
NO_2	1h	0-10	11-25	26-60	61-100	101-150	>150
SO_2	1h	0-20	21-40	41-125	126-190	191-275	>275

3.4 Other suggested changes to the methodology

Following the consultation with health experts, DG ENV and national experts to the first proposal of the updated methodology, two additional changes were suggested.

The first modification consists of the upper limit of “fair” (in the hourly bands, see Table 3.10) to make that band equally wide as the “moderate” band. This would result in the values shown in Table 3.11 and will be referred to as “index_5”.

Table 3.11 Refined first proposal for the upper limits (in µg/m³) of the bands of the EAQI once the upper limit of the “fair” band is modified (index_5)

Pollutant	Reference time	good	fair	moderate	poor	very poor	extremely poor
$PM_{2.5}$	1h	5	**25**	50	90	140	> 140
PM_{10}	1h	15	**65**	120	195	270	> 270
O_3	1h	60	**90**	120	160	200	> 200
NO_2	1h	10	**35**	60	100	150	> 150
SO_2	1h	20	**70**	125	200	275	> 275

The second modification is to have a new set of bands starting from equally-wide 24h bands for $PM_{2.5}$, so, instead of the values in Table 3.4, the ones in Table 3.12.

Table 3.12 Proposed upper concentrations (in µg/m³) for the "good” to “very poor” 24h bands for $PM_{2.5}$, considering equal width

Pollutant	Good	Fair	Moderate	Poor	Very poor
$PM_{2.5}$	5	15	25	35	45

This would result in the 24h/8h bands shown in Table 3.13.

Table 3.13 Proposed 24h and 8h bands (in µg/m³) starting from 24h $PM_{2.5}$ bands with equal width

Pollutant	Reference time	good	fair	moderate	poor	very poor	extremely poor
$PM_{2.5}$	24h	5	15	25	35	45	> 45
PM_{10}	24h	15	45	61	77	93	> 93
O_3	8h	60	100	115	130	145	> 145
NO_2	24h	10	25	34	43	52	> 52
SO_2	24h	20	40	51	62	73	> 73

Once converted into hourly bands and further refined by modifying the upper limit of "fair" to make that band equally wide as "moderate" (in line with index_5), the final hourly bands would be those shown in Table 3.14 and will be referred to as "index_6".

Table 3.14 Proposed final bands (in µg/m³) starting from 24h $PM_{2.5}$ bands with equal width and modifying the "fair" band (index_6)

Pollutant	Reference time	good	fair	moderate	poor	very poor	extremely poor
$PM_{2.5}$	1h	5	25	50	65	85	> 85
PM_{10}	1h	15	65	120	150	180	> 180
O_3	1h	60	90	120	140	*180*	*> 180*
NO_2	1h	10	35	60	80	*100*	*> 100*
SO_2	1h	20	70	125	150	180	> 180

4 Comparison of the different options for the update of the European AQ index

For the preparation of the comparison, a total of 1,190 stations were analysed, equivalent to 4,320 Sampling Points (SPOs), for which several options, as presented above, have been implemented.

The selection of the stations followed these steps:

- All statistics for the year 2022 were downloaded, calculated from air quality values originating both from AirBase and AQ e-Reporting (data flow E1a). Data tables are available on the European Air Quality Portal (European Air Quality Portal – The Data and Information Gateway on Air Quality in Europe([16])).
- Only those statistics with a data coverage greater than 75% were retained.
- For PM_{10}, only the aggregation "P1Y-P1D-per90.4" (corresponding to the percentile 90.4 of PM_{10} daily concentrations) was considered, while for the other pollutants (SO_2, NO_2, O_3, PM_{10}, and $PM_{2.5}$), the aggregation "P1Y-hr-max" (corresponding to the maximum hourly value in a year) was used.
- Each station was ordered based on the value of the obtained aggregation for each pollutant.
- 5% of the stations with the lowest and highest values were removed to get rid of possible outliers and keep values closer to the most common ones.
- From the remaining stations, the 100 stations with the highest values, the 100 with the lowest measured values, and the 100 with intermediate values were selected.

4.1 Comparison of the resulting indexes

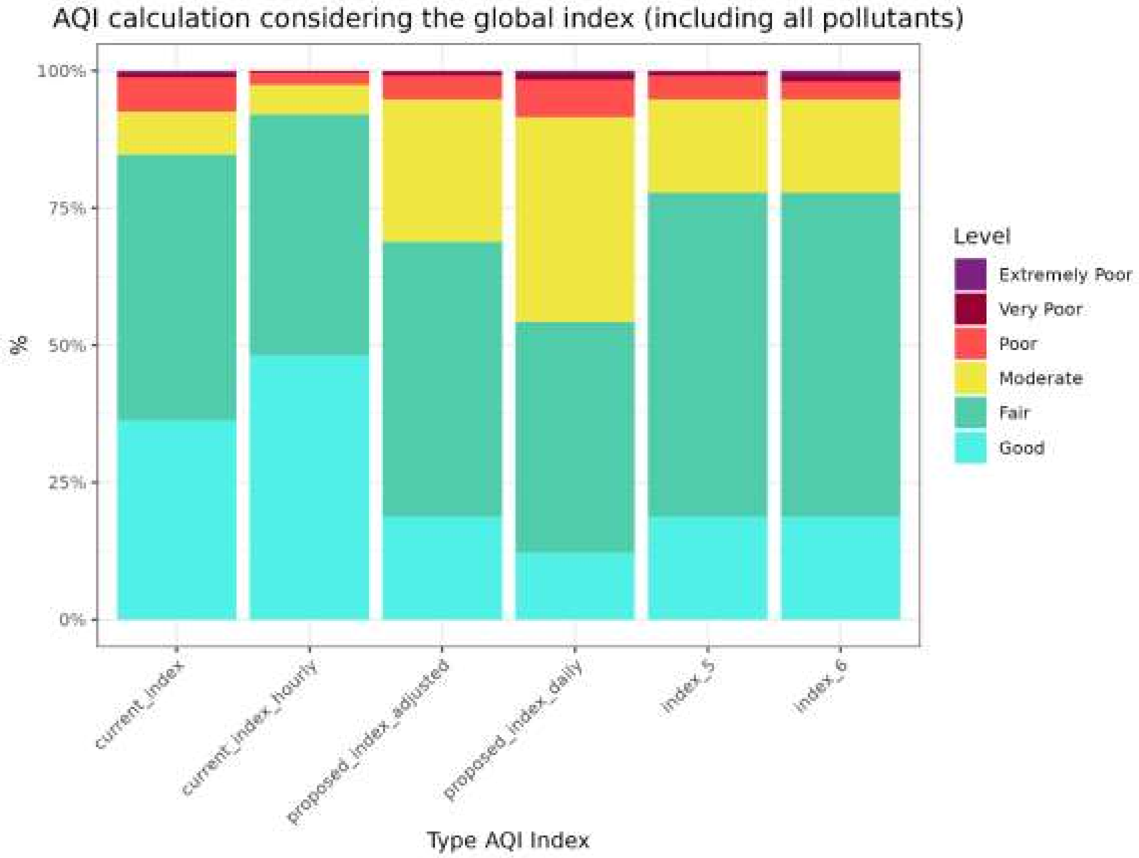
For the selected stations, different AQI and pollutant subindexes have been calculated using different limit bands according to the proposed options above:

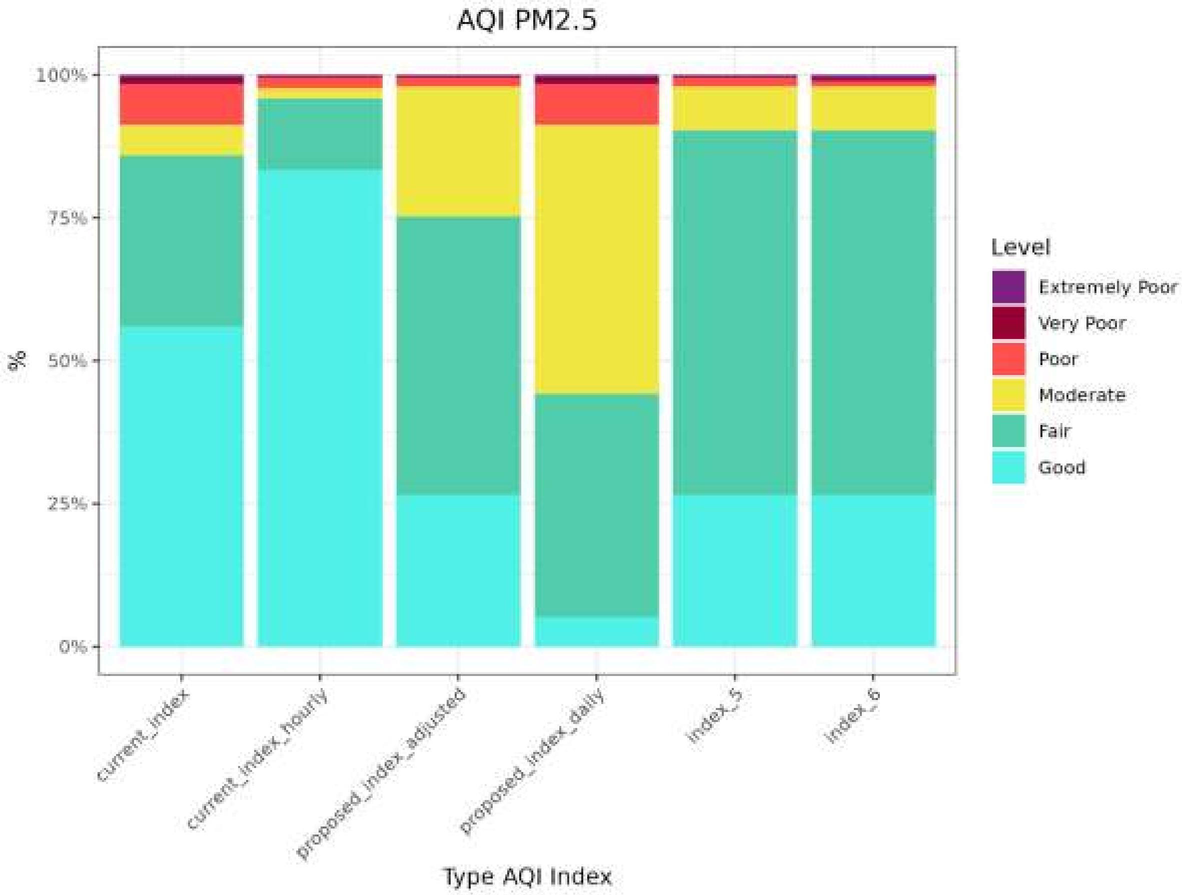
- The current methodology applied by the EEA ("current_index", see Table 1.1)
- The current methodology where the 24-hour values of PM_{10} and $PM_{2.5}$ have been converted into hourly values ("current_index_hourly")
- The first proposed methodology with the hourly values refined ("proposed_index_adjusted", Table 3.10)
- The first proposed methodology with the hourly bands for PM converted into 24-hour values ("proposed_index_daily")
- The "proposed_index_adjusted" with the hourly "fair" bands modified to make the "fair" and "moderate" bands equally wide ("index_5", Table 3.11).
- An index calculated starting from equally wide $PM_{2.5}$ bands (5, 15, 25, 35 and 45) and with the hourly "fair" bands modified to make the "fair" and "moderate" bands equally wide ("index_6", Table 3.14)

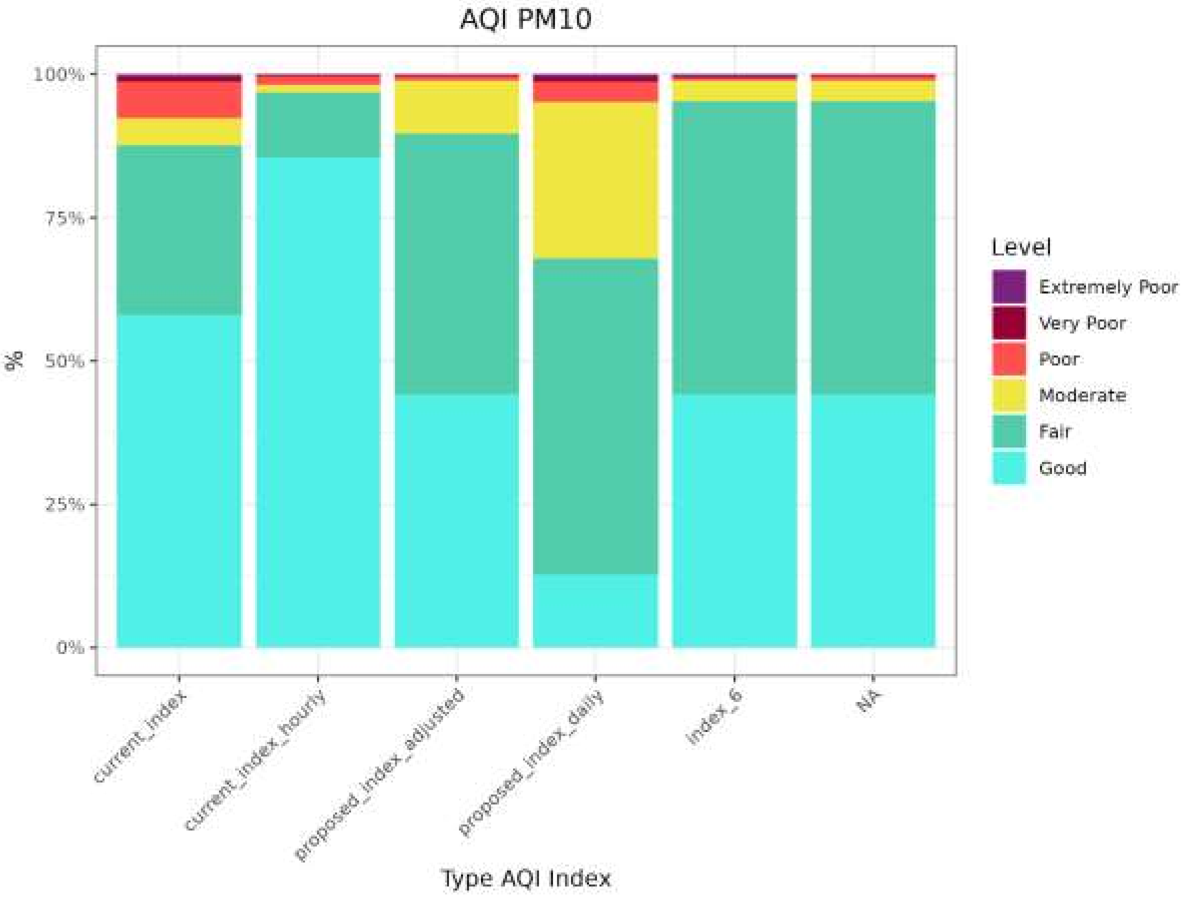
Figure 4.1 shows the different index and subindexes values obtained with the six different options.

([16]) https://aqportal.discomap.eea.europa.eu/

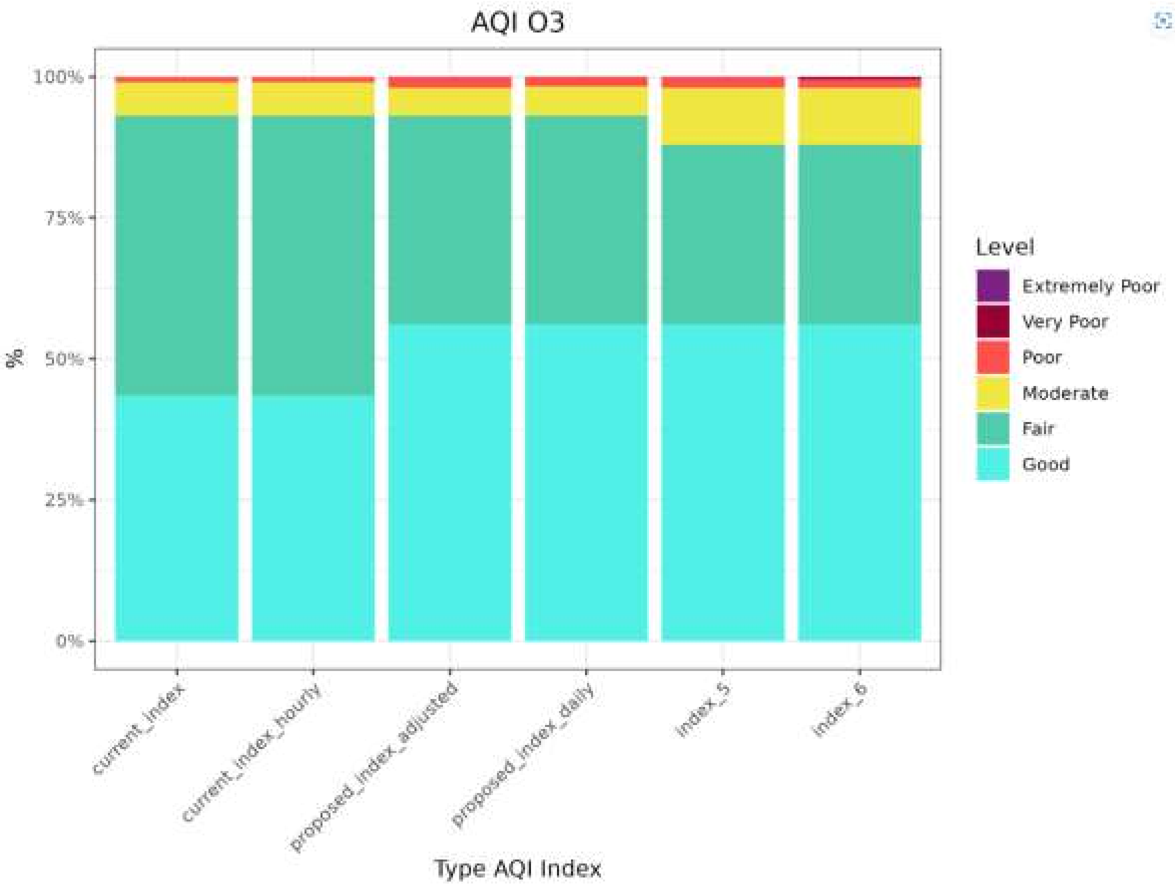
Figure 4.1 Values of the indexes and subindexes obtained according to different options to categorize the updated limit bands



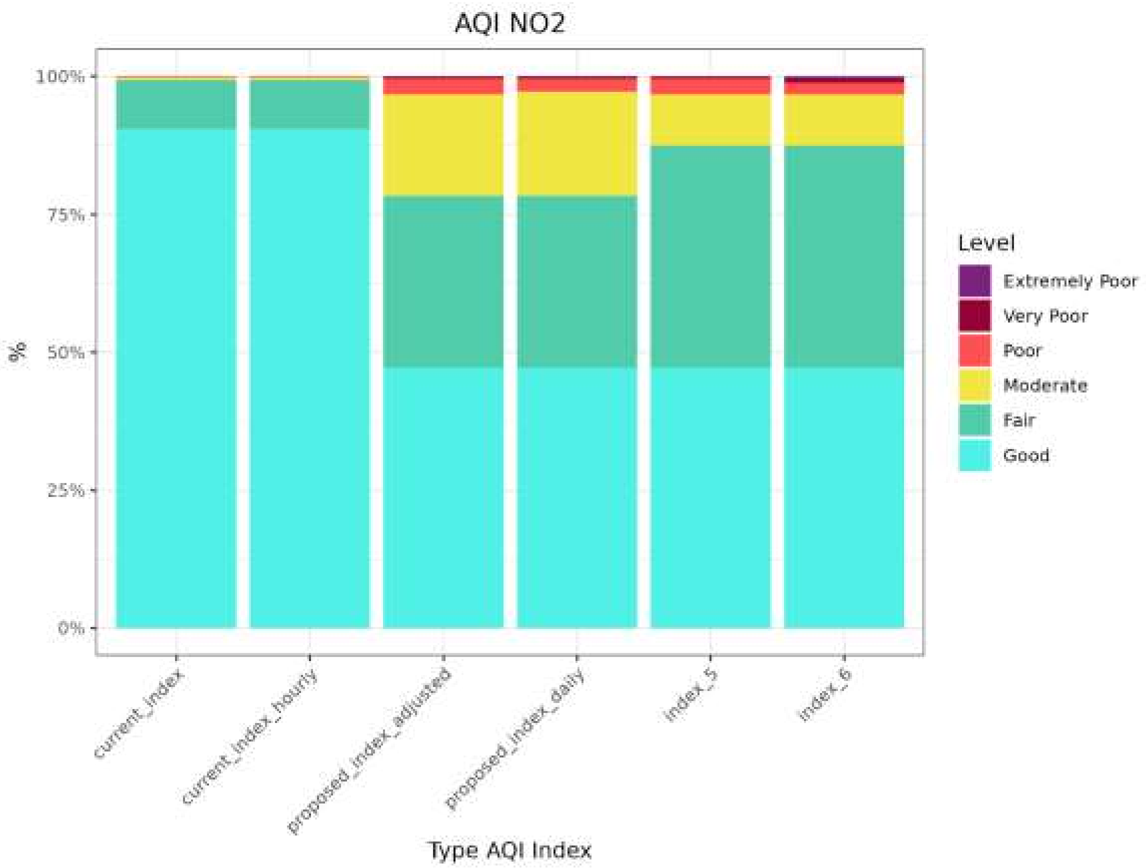


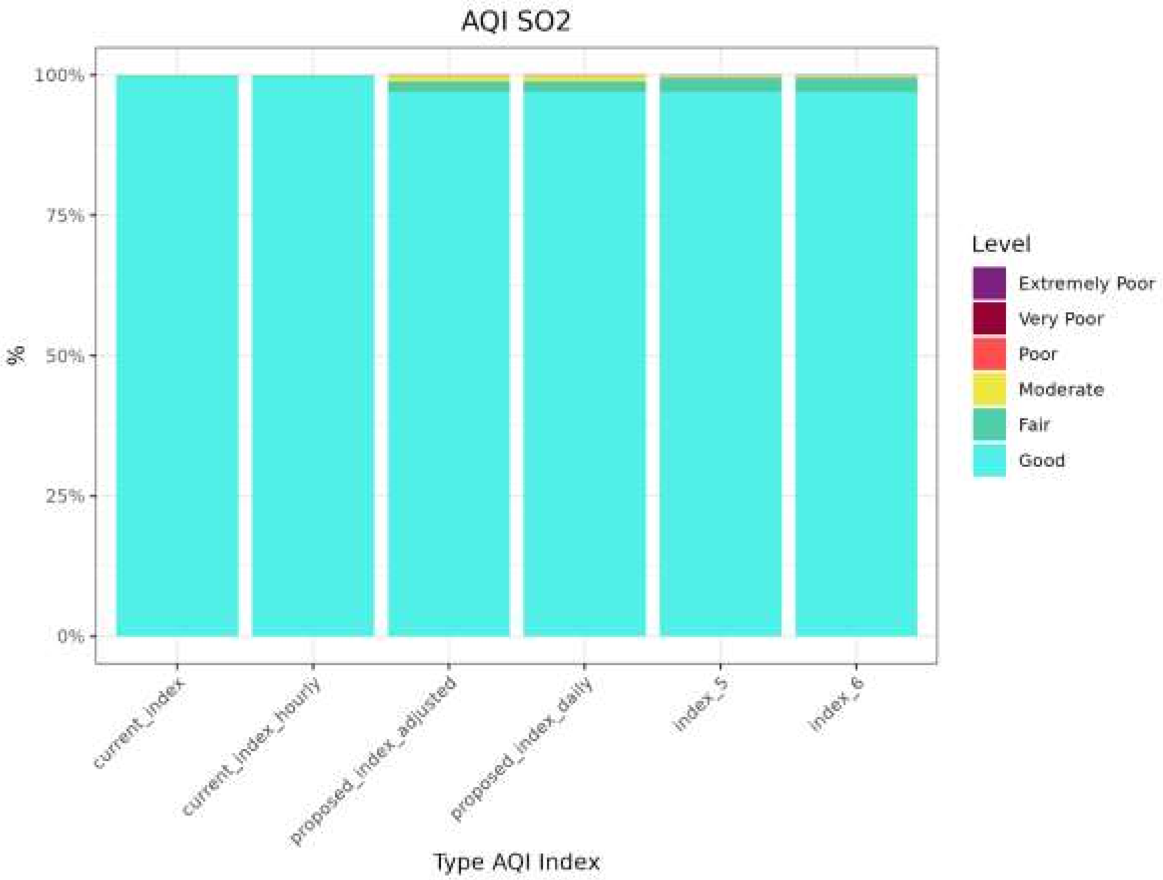


AQI PM10
100%
75%
50%
25%
0%
%
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_6
NA
Type AQI Index
Level
Extremely Poor
Very Poor
Poor
Moderate
Fair
Good



AQI O3
100%
75%
50%
25%
0%
%
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index
Level
Extremely Poor
Very Poor
Poor
Moderate
Fair
Good

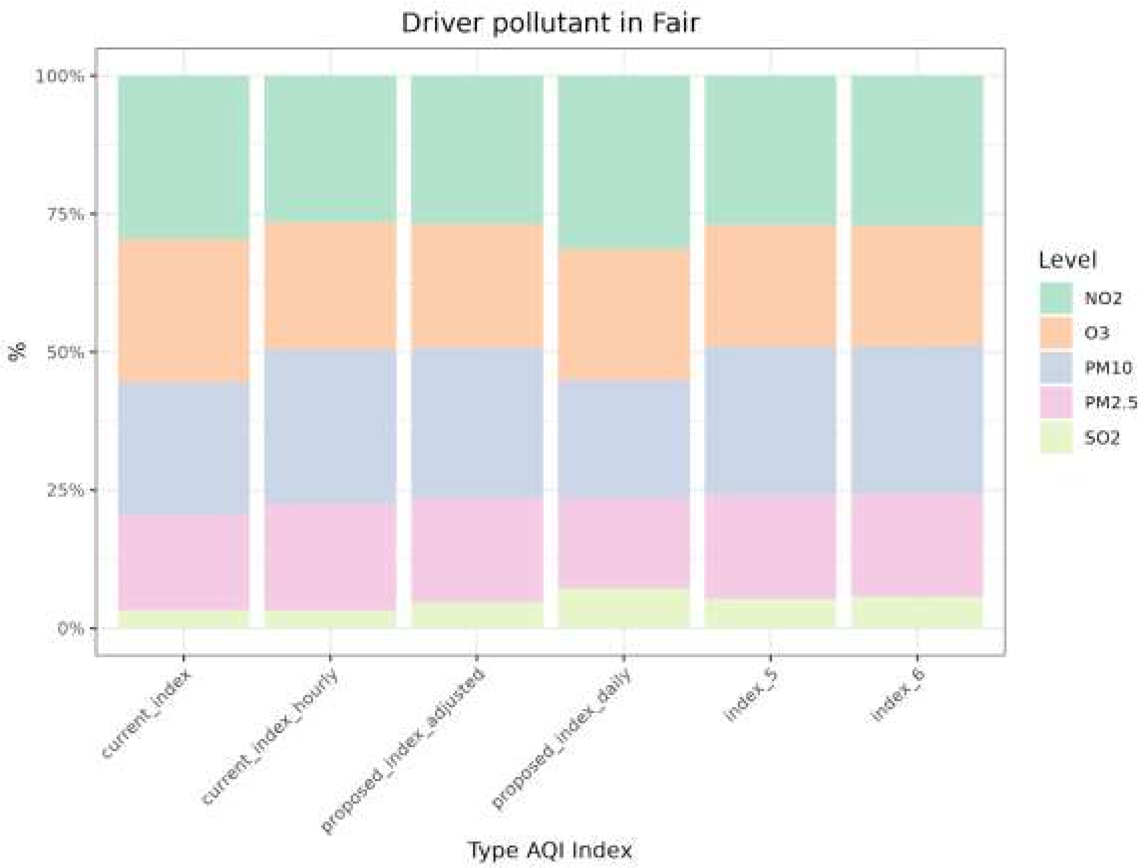

AQI NO2
100%
75%
50%
25%
0%
%
Level
Extremely Poor
Very Poor
Poor
Moderate
Fair
Good
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index

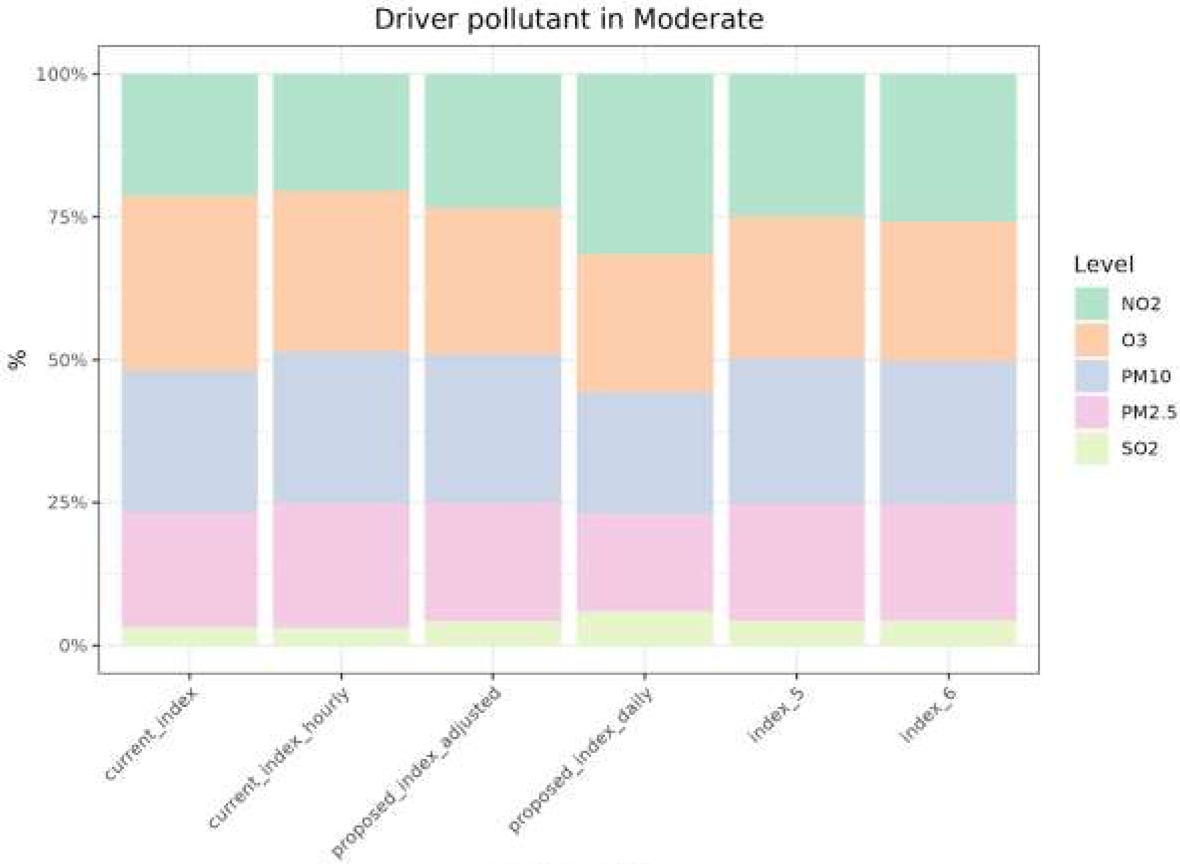

AQI SO2
100%
75%
50%
25%
0%
%
Level
Extremely Poor
Very Poor
Poor
Moderate
Fair
Good
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index

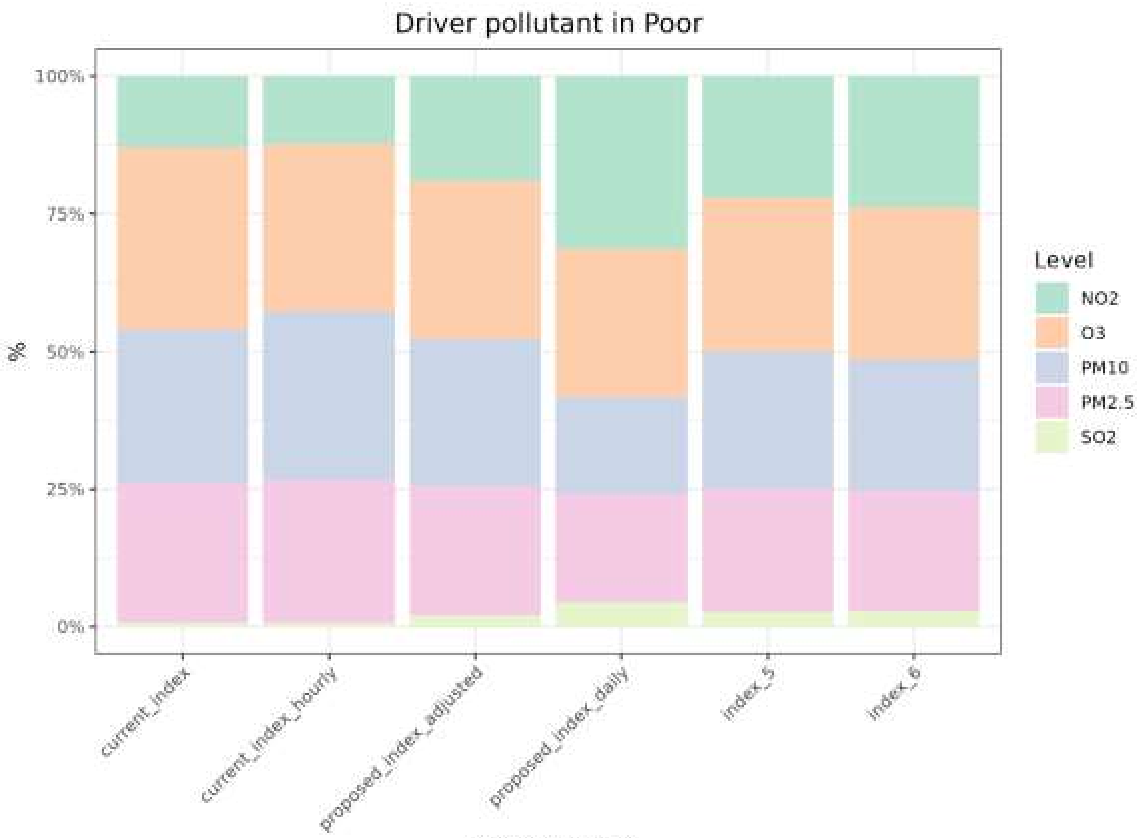
4.2 Comparison of the driving pollutant

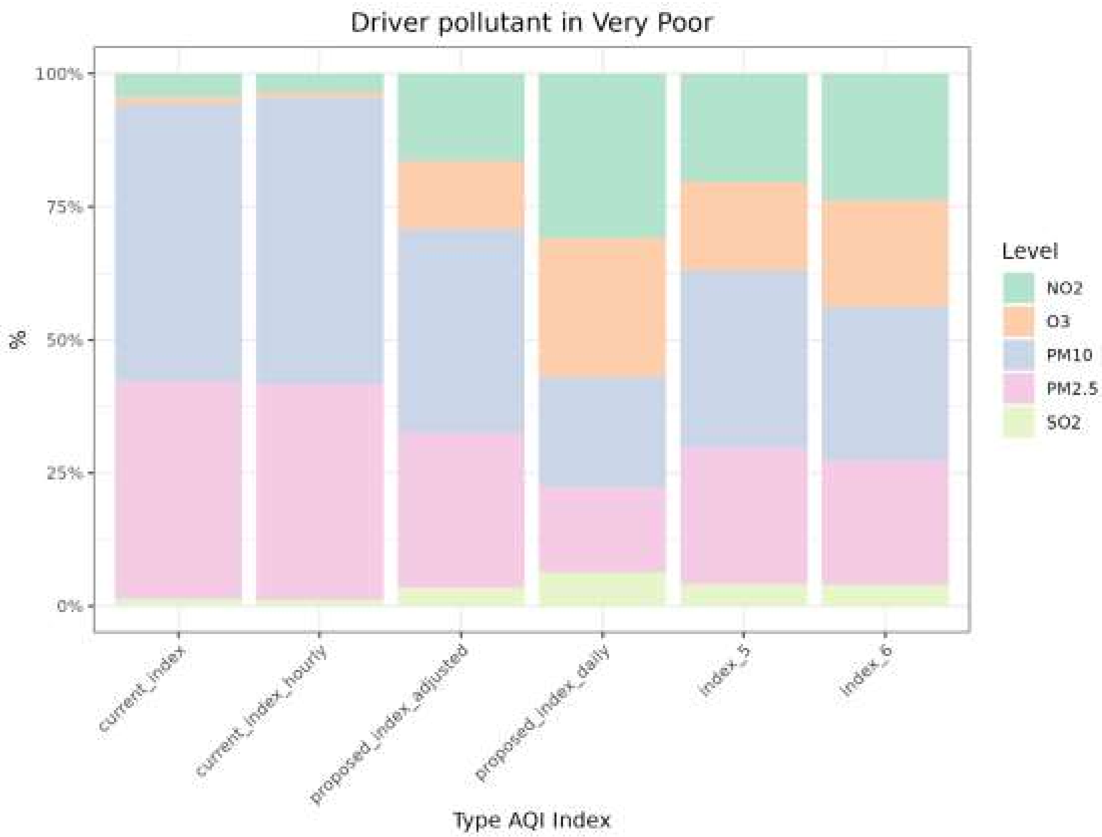
To understand which pollutant is driving the index for each band in each proposed option, graphs in Figure 4.2 show the percentage of hours for which each pollutant is responsible for each index category (except for “good”, when all the pollutants subindexes are “good”).

Figure 4.2 Driver pollutant of the different index categories for the different options (Type AQI index)

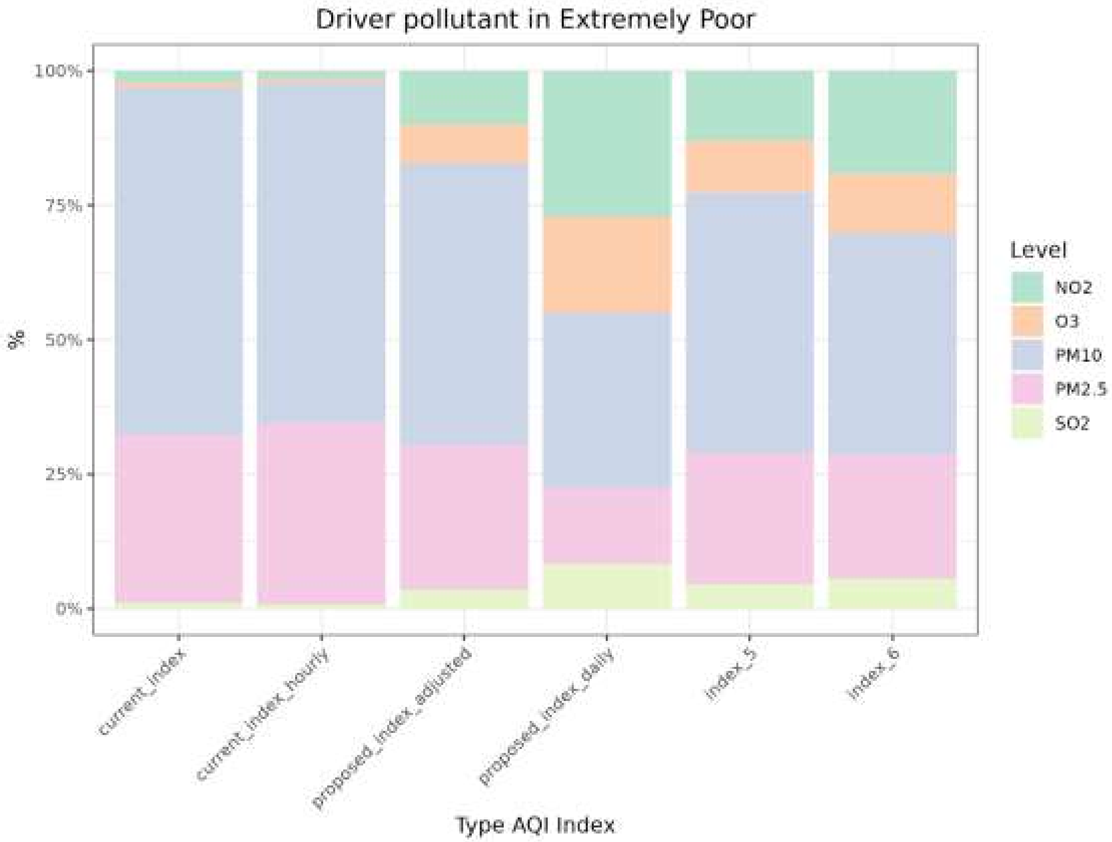



Driver pollutant in Moderate
100%
75%
50%
25%
0%
%
Level
NO2
O3
PM10
PM2.5
SO2
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index


Driver pollutant in Poor
100%
75%
50%
25%
0%
%
Level
NO2
O3
PM10
PM2.5
SO2
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index



Driver pollutant in Very Poor
100%
75%
50%
25%
0%
%
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index
Level
NO2
O3
PM10
PM2.5
SO2



Driver pollutant in Extremely Poor
100%
75%
50%
25%
0%
%
current_index
current_index_hourly
proposed_index_adjusted
proposed_index_daily
index_5
index_6
Type AQI Index
Level
NO2
O3
PM10
PM2.5
SO2

4.3 Comparison of the linearity and the RR in every band

Finally, to compare the linearity of the bands' upper limits, Figures 4 to 8 present three plots:

1. the upper concentrations of each band;
2. the upper bands concentrations converted back into 24h (or 8h in the case of O_3); and
3. the RR of these converted bands compared to the short-term WHO AQG level.

for five considered proposed options:

a) The current index (Table 1.1)
b) The first proposed updated index with the refined bands (Table 3.10)
c) The first proposed updated index with the refined bands and forcing O_3 "poor" and "very poor" bands to be coincident with the information and alert thresholds (new proposal not included in 4.1, see Table 4.1)
d) The suggested index_5 (Table 3.11)
e) The suggested index_6 (Table 3.14)
Table 1.1Table 3.10Table 3.13Table 3.14

Table 4.1 Proposed upper limits of the 1h bands (in µg/m^3) as in Table 3.10 but forcing the "poor" and "very poor" O_3 bands to meet the information and alert thresholds, respectively

Pollutant	Reference time	good	fair	moderate	poor	very poor	extremely poor
$PM_{2.5}$	1h	5	15	50	90	140	> 140
PM_{10}	1h	15	45	120	195	270	> 270
O_3	1h	60	100	120	**180**	**240**	**> 240**
NO_2	1h	10	25	60	100	150	> 150
SO_2	1h	20	40	125	190	275	> 275

In the plots, Y-axes of the first two plots show the upper concentrations of the bands in µg/m^3; while the Y-axis of the third plot shows the percentage increase of mortality from one band to the following one. X-axes indicate the different bands: 1: good; 2: fair; 3: moderate; 4: poor; and 5: very poor.
The solid lines are drawn to make easier the visualization of the linearities (or lack of them) of the different sets of upper limit bands.

Forcing the O_3 bands to make them coincident with the information and alert thresholds implies losing linearity in the increase of mortality. Forcing the "fair" bands, on the contrary, improves the linearity, but at the cost of the communication coherence obtained when keeping the upper "fair" at the short-term AQG level. Therefore, it was concluded to keep the first proposal for the updated bands (Table 3.10).

Figure 4.3 Upper limits of the bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m³), and RR of the converted bands, current AQ index

Figure 4.4 Upper limits of the hourly bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m³), and RR of the converted bands, first proposed updated AQ index

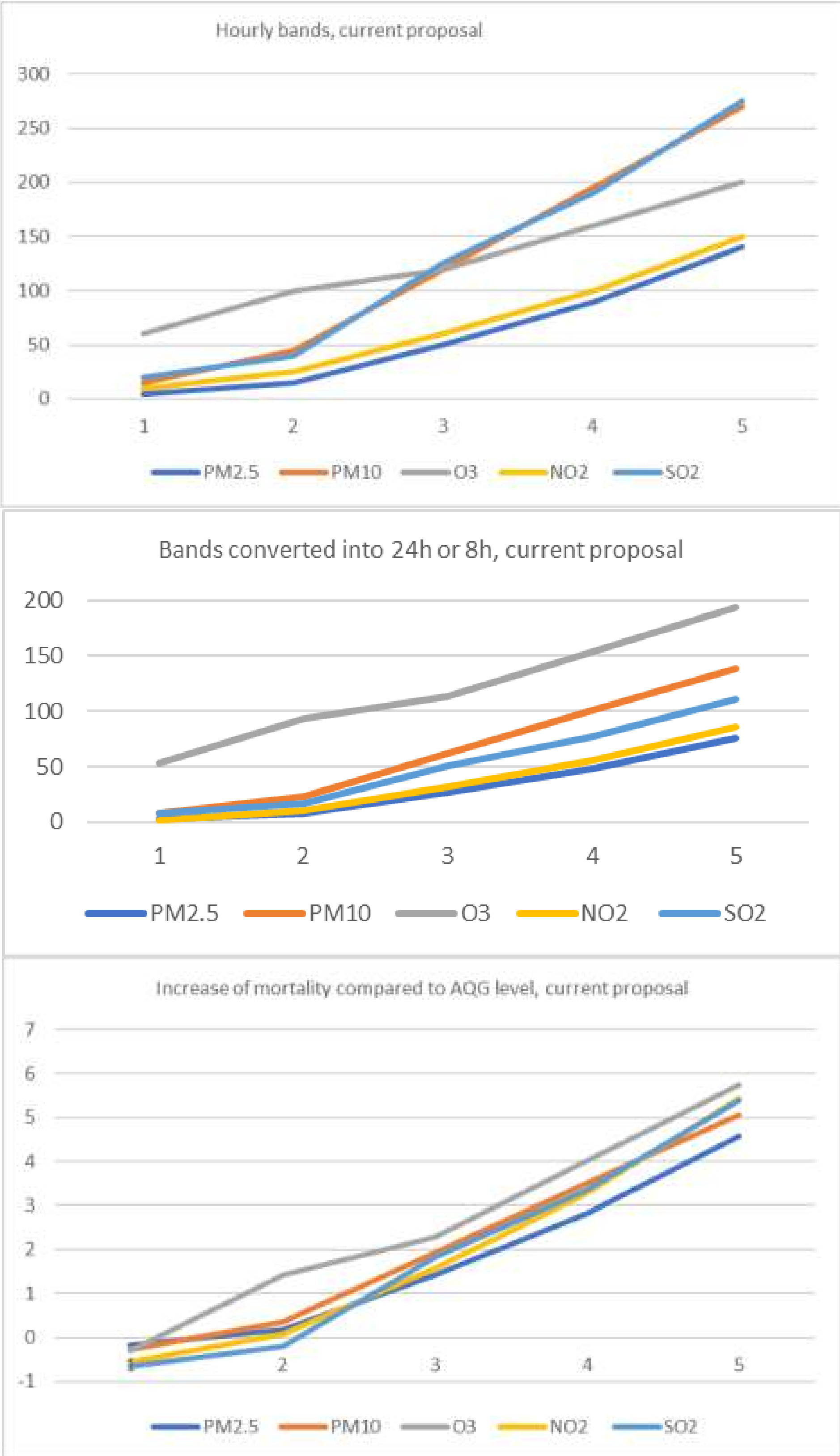


Figure 4.5 Upper limits of the hourly bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m^3) and RR of the converted bands, first proposed updated AQ index forcing O_3 bands

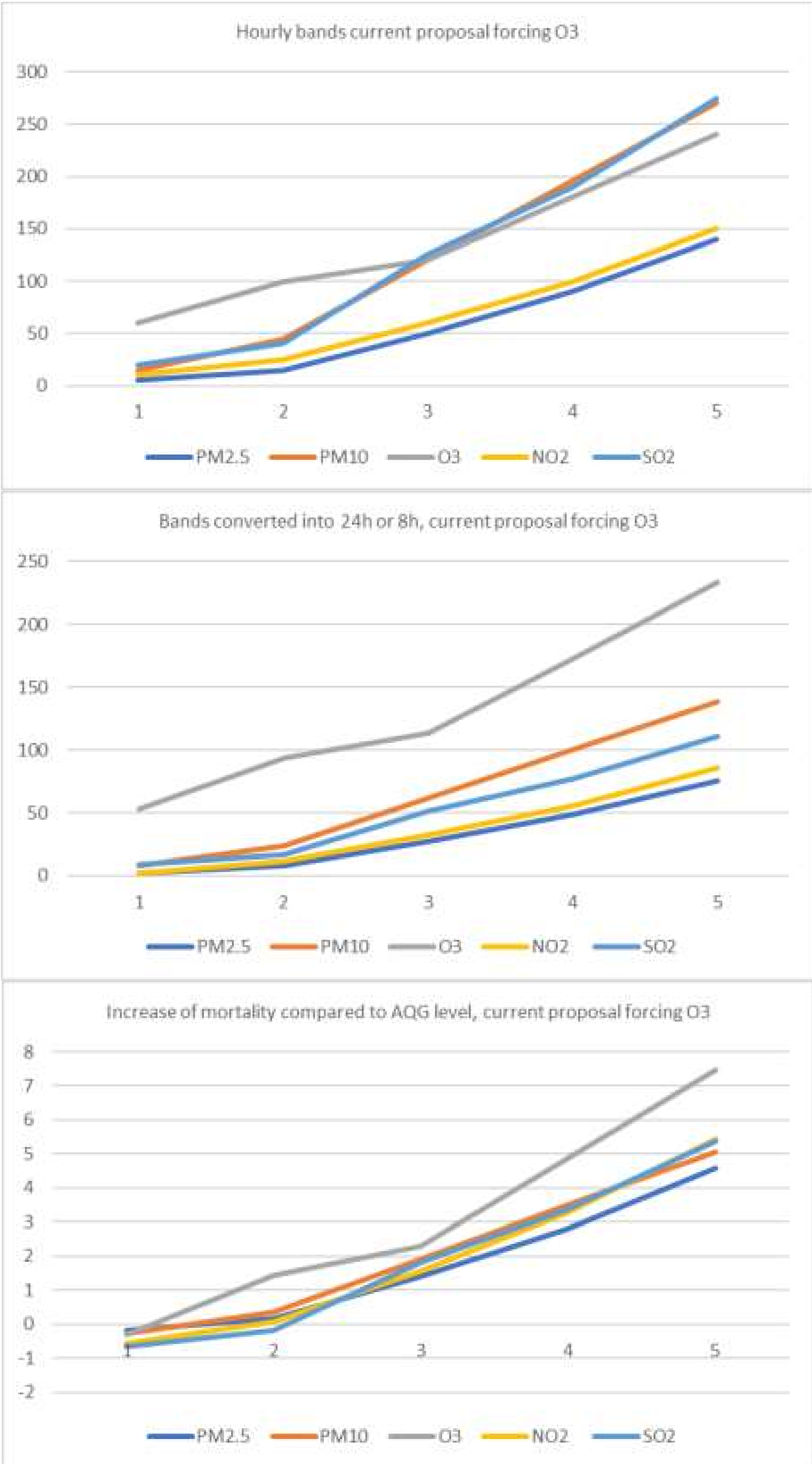


Figure 4.6 Upper limits of the hourly bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m^3) and RR of the converted bands, first proposed updated AQ index forcing fair bands

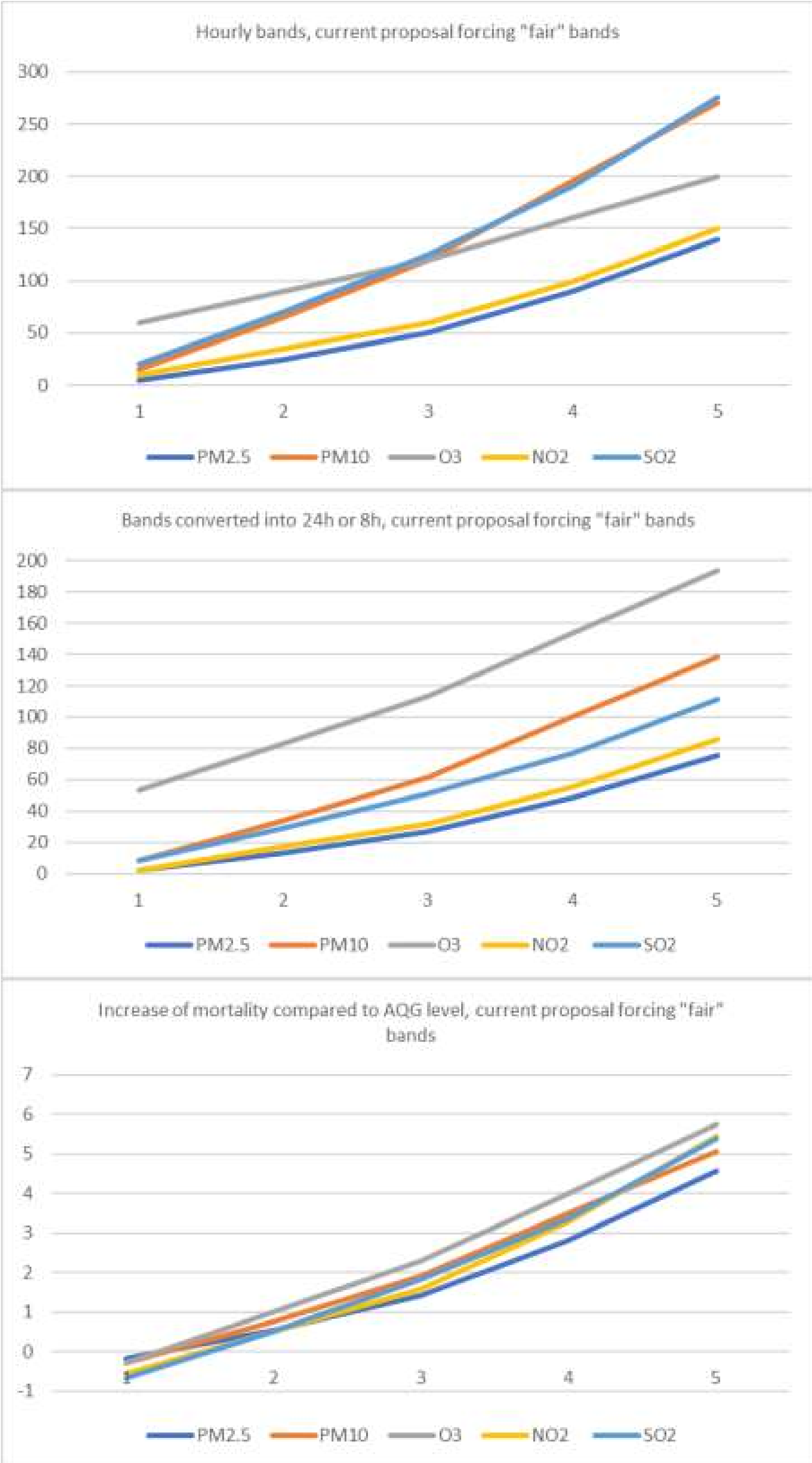
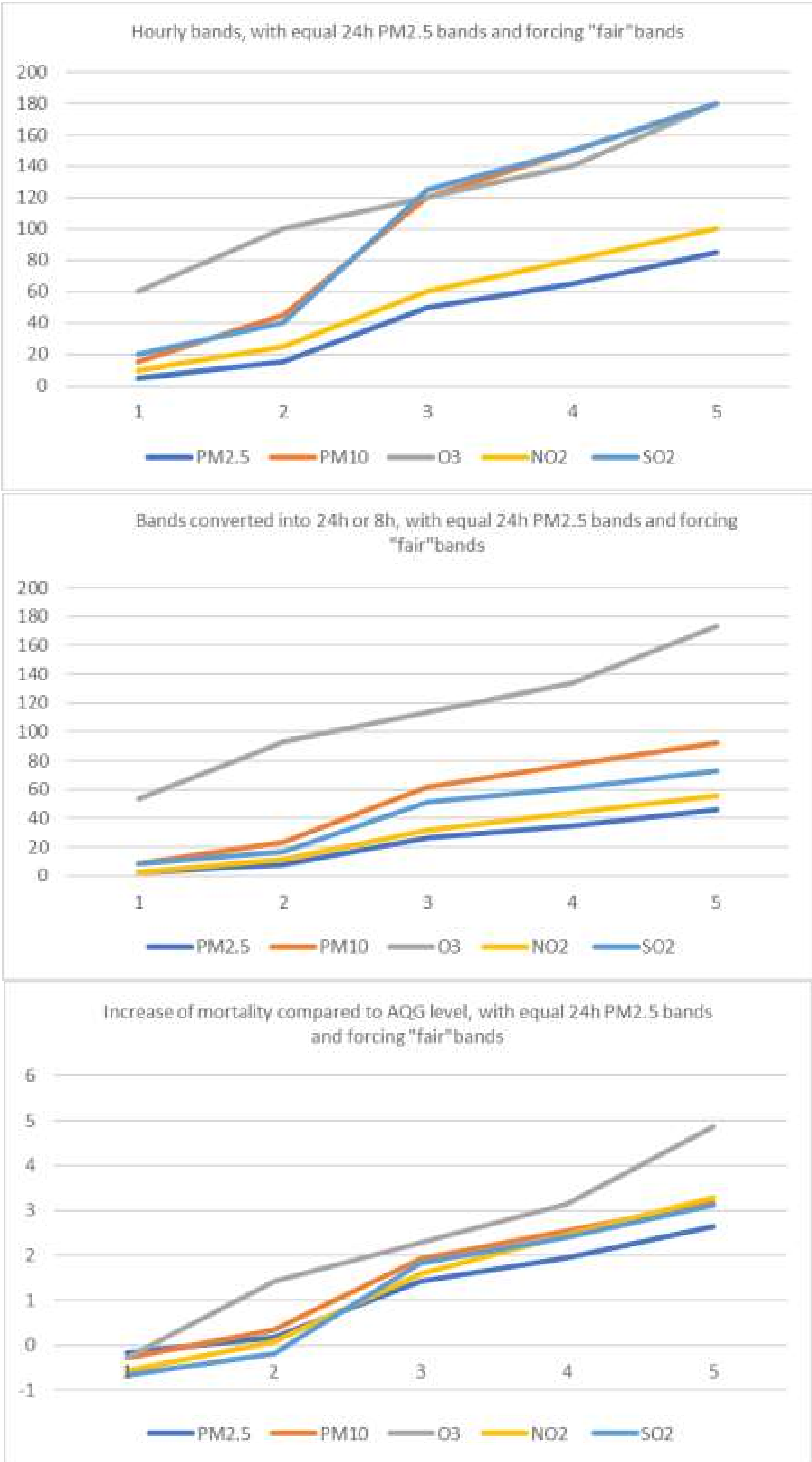


Figure 4.7 Upper limits of the hourly bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m³) and RR of the converted bands, proposal of AQ index with equally wide PM2.5 bands and forcing fair bands



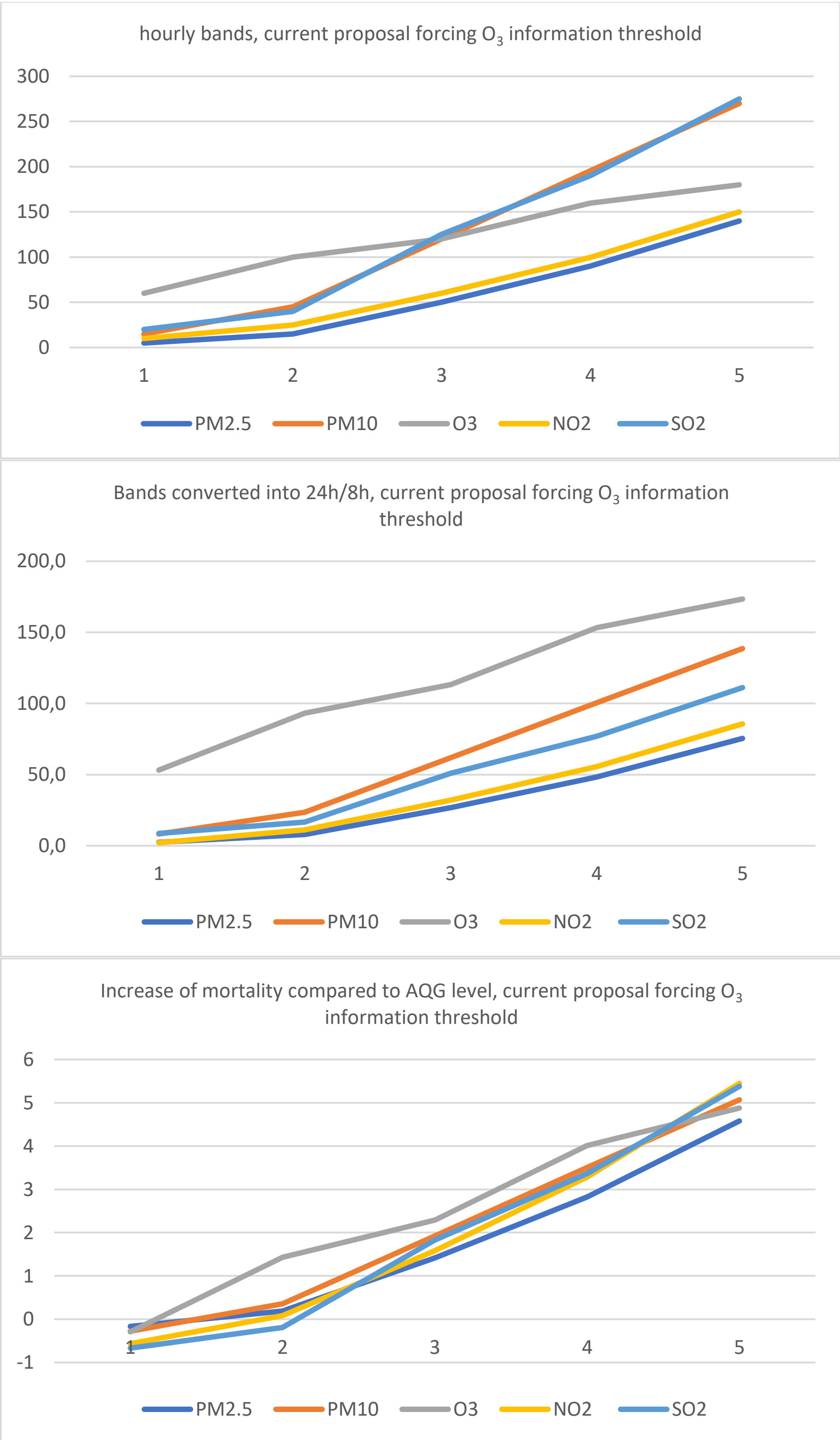
5 Further improvements to the first proposal and final proposal

The first proposal was presented to the WG at the 3rd meeting as the definitive EEA/ETC HE proposal, together with the results for the other options. Most of the countries in the meeting showed an interest in including as band limits both the O_3 information and alert thresholds, as defined by the Ambient Air Quality Directives (EU, 2008, 2024) for coherence and communication purposes. Since this could further impact the differences in the relative risks among bands, as shown above, it was agreed to perform an additional test forcing the O_3 bands to include only the information threshold (Table 5.1). The test outcomes are presented in Figure 5.1.

Table 5.1 Proposed 1h bands (in µg/m^3) forcing the very poor O_3 band to meet the information threshold

Pollutant	Reference time	good	fair	moderate	poor	very poor	extremely poor
$PM_{2.5}$	1h	5	15	50	90	140	> 140
PM_{10}	1h	15	45	120	195	270	> 270
O_3	1h	60	100	120	160	**180**	**> 180**
NO_2	1h	10	25	60	100	150	> 150
SO_2	1h	20	40	125	190	275	> 275

Figure 5.1 Upper limits of the bands, upper limits of the hourly bands converted into 24h (8h) (both in µg/m³), and RR of the converted bands, first proposed updated index forcing the very poor O_3 band to meet the information threshold



This results in an acceptable increase of the very poor risk, compared to the other pollutants. Furthermore, making the information threshold coincident with the very poor upper limit keeps consistency with the information thresholds for NO_2 and SO_2.

Therefore, considering all the results and trying to find a compromise among communication, linearity and equivalent risks, it was agreed to accept Table 5.1 as the final proposal for the updated index, which will result as presented in Table 5.2.

Table 5.2 Final agreed updated EEA European air quality index

Pollutant	Reference time	Good	Fair	Moderate	Poor	Very poor	Extremely poor
$PM_{2.5}$	1h	0-5	6-15	16-50	51-90	91-140	>140
PM_{10}	1h	0-15	16-45	46-120	121-195	196-270	>270
O_3	1h	0-60	61-100	101-120	121-160	161-180	>180
NO_2	1h	0-10	11-25	26-60	61-100	101-150	>150
SO_2	1h	0-20	21-40	41-125	126-190	191-275	>275

6 Health messages

Since only the initial 24h $PM_{2.5}$ bands have been changed in relation to the current index, and the current health messages are quite generic, it is proposed to keep the health messages as they are in the current EAQI. The health messages are described in Table 6.1.

Table 6.1 Health messages related to the EAQI bands

AQ index	General population	Sensitive populations
Good	The air quality is good. Enjoy your usual outdoor activities.	The air quality is good. Enjoy your usual outdoor activities.
Fair	Enjoy your usual outdoor activities	Enjoy your usual outdoor activities
Moderate	Enjoy your usual outdoor activities	Consider reducing intense outdoor activities, if you experience symptoms.
Poor	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat	Consider reducing physical activities, particularly outdoors, especially if you experience symptoms.
Very poor	Consider reducing intense activities outdoors, if you experience symptoms such as sore eyes, a cough or sore throat	Reduce physical activities, particularly outdoors, especially if you experience symptoms.
Extremely poor	Reduce physical activities outdoors.	Avoid physical activities outdoors.

7 Final considerations

The combination of the pragmatic and risk-based approaches assures a tool with solid scientific grounds and communication consistency, that also fulfils the needs of information to the public in the member countries.

When it comes to the pragmatic approach, the definition of the first two bands in line with the WHO long- and short-term guidance levels assures alignment with the WHO recommendations and protection against the effects linked to exposure to those levels. Forcing the O_3 very poor upper limit band to meet the information thresholds makes easier to fulfil the obligation of informing the public and assures consistency also with the NO_2 and SO_2 very poor bands. Forcing other bands was rejected because either increased the risk in comparison with other pollutants or lost the communication coherence with the WHO guidance levels.

Furthermore, tests performed during the process by some participants in the WG proved that:

- The agreed bands seem to reflect better than the current index the differences in air quality at the different station types.
- The agreed bands seem to reflect better also the main pollutant in each station type.
- Partially due to the change from 24h values to hourly values for PM, the hourly variability seems better reflected with the agreed bands.
- The agreed bands reflect well the different air quality situations in the countries, especially those related with specific episodes of high concentrations; and they result in a more coherent occurrence of the different EAQI categories between summer and winter.
- The frequency of occurrence of the different EAQI categories with the agreed bands seem coherent with the occurrence of some current national indexes.
- The national relationships between 24h/8h concentrations and the daily maximum hourly concentrations may differ from the European ones depending on the type of station and pollutant but the results so far show that with the agreed EAQI bands the risk calculations are sound.

EEA and ETC HE are convinced that the reached agreement makes the updated European air quality index a suitable tool for communication purposes at European level.

List of abbreviations

Abbreviation	Name	Reference
AQI	Air quality index	
EAQI	European air quality index	
EEA	European Environment Agency	www.eea.europa.eu
ETC HE	European Topic Centre on Human health and the environment	www.eionet.europa.eu/etcs/etc-he
NO_2	Nitrogen dioxide	
O_3	Ozone	
$PM_{2.5}$	Particulate matter with a diameter equal or smaller than 2.5µm	
PM_{10}	Particulate matter with a diameter equal or smaller than 10µm	
SO_2	Sulfur dioxide	

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Annex 1. Study of possible relationships between 24h concentrations (8h for O_3) and hourly concentrations

In order to find the best relationship between 24-hour (or eight-hour) values and the hourly value, the following types of relationships have been analysed:

- **Linear Relationship**

The relationship between the variables is a straight line. The equation is:

$$y=a+bx$$

- **Logarithmic Relationship**

Here, the relationship is modelled as logarithmic in the x variable. The equation is:

$$y=a+b\cdot\log(x)$$

- **Exponential Relationship**

In this case, the relationship is exponential:

$$y=a\cdot e^{bx}$$

- **Polynomial (Quadratic) Relationship**

A quadratic relationship extends the linear model by including a squared term. The equation is:

$$y=a+b\cdot x+c\cdot x^{2}$$

- **Inverse Relationship**

An inverse relationship between x and y is described by:

$$y=a+b/x$$

- **Power (Potential) Relationship**

The power relationship is:

$$y=a\cdot x^{b}$$

For each of these models, the coefficient of determination (R^2) has been calculated to determine which one best fits the data, see Table A.1.

Table A.1 Coefficient of determination (R^2)

Pollutant	R^2linear	R^2log	R^2exp	R^2poly2	R^2inverse	R^2power
PM_{10}	**0.76**	0.51	0.64	**0.76**	0.00	0.73
$PM_{2.5}$	**0.77**	0.48	0.61	**0.77**	0.00	0.72
NO_2	**0.82**	0.69	0.63	**0.83**	0.00	**0.82**
SO_2	**0.73**	0.21	0.33	**0.74**	0.00	0.55
O_3	**0.94**	0.78	0.80	**0.94**	0.01	**0.94**

As can be seen, the values obtained in the linear, polynomial (and in the case of NO_2 and O_3, the potential model) are very similar.

Additionally, an analysis of the residuals distribution is performed for all models, as a good fit not only has a high R^2 but should also have residuals without a clear pattern.

- **Root Mean Squared Error (RMSE)**
  The RMSE is a standard measure that takes the square root of the average of the squared residuals. It is more intuitive because it returns the residuals in the same units as the original data, making interpretation easier.

Table A.2 Root Mean Squared Error (RMSE)

pollutant	RMSElinear	RMSElog	RMSEexp	RMSEpoly2	RMSEinverse	RMSEpower
PM_{10}	**20.10**	28.75	0.43	**20.10**	41.17	21.29
$PM_{2.5}$	**11.25**	16.90	0.47	**11.24**	23.48	12.34
NO_2	**10.59**	13.77	0.51	**10.34**	24.86	10.52
SO_2	**14.66**	25.09	1.06	**14.39**	28.15	18.93
O_3	**7.15**	13.71	0.21	**7.09**	29.30	7.43

As with the R^2, the results obtained between the linear, polynomial, and potential models for NO_2 are very similar.

For this reason, given the similar results when applying the linear or polynomial models, the linear model has ultimately been chosen over other models, as it greatly simplifies the calculations and the understanding of the data.

Annex 2. Linear relationship between the daily mean and the daily hourly maximum values for PM_{10}, $PM_{2.5}$, NO_2, and SO_2 and between the daily 8-hourly mean and the daily hourly maximum values for O_3

Executive summary

This annex provides an overview and analysis of the relationship between Daily Mean values (the mean of hourly values in one day) and the Daily Hourly Maximum values for PM_{10}, $PM_{2.5}$, NO_2 and SO_2 as well as the relationship between Daily 8-hour Mean values and Daily Hourly Maximum values for O_3. The objective of this analysis is to find a European relationship between the short-term WHO AQ guideline levels (defined as daily mean values for all pollutants except O_3, daily mean 8-hour average) and daily maximum hourly values, in order to base the European air quality index in hourly values.

Methodology

The method used for this analysis involved examining validated data for these five pollutants from 2018 to 2022. A regression analysis was conducted between Daily Mean values and Daily Maximum Hourly values (mean 8-hour average for O_3), filtered by different categories (country, year, season station classification, and country classification according to CAMS), resulting in an equation for each category. Additionally, an equation covering all values across Europe was derived.

These equations were then applied to the following levels, depending on each pollutant:

- 40 µg/m³ for PM_{10} (daily mean)
- 15 µg/m³ for $PM_{2.5}$ (daily mean)
- 25 µg/m³ for NO_2 (daily mean)
- 125 µg/m³ for SO_2 (daily mean)
- 100 µg/m³ for O_3 (daily mean 8-hour average)

The CAMS country classification used for the regional analysis is based on the following table:

Table A2.1. CAMS country classification

CountryCode	CAMSclass	CountryCode	CAMSclass
AL	Sourthern Europe	LT	Eastern Europe
AD	Western Europe	LU	Western Europe
AT	Central Europe	MK	Sourthern Europe
BE	Western Europe	MT	Sourthern Europe
BA	Sourthern Europe	ME	Sourthern Europe
BG	Sourthern Europe	NL	Central Europe
HR	Sourthern Europe	NO	Northern Europe
CY	Sourthern Europe	PL	Central Europe
CZ	Central Europe	PT	Western Europe
DK	Northern Europe	RO	Eastern Europe
EE	Eastern Europe	RS	Sourthern Europe
FI	Northern Europe	SK	Central Europe
FR	Western Europe	SI	Sourthern Europe
GE	Eastern Europe	ES	Western Europe
DE	Central Europe	SE	Northern Europe
GR	Sourthern Europe	CH	Central Europe
HU	Central Europe	UA	Eastern Europe
IS	Western Europe	GB	Western Europe
IE	Western Europe	TR	Sourthern Europe
IT	Sourthern Europe	XK	Sourthern Europe
LV	Eastern Europe		

Results

Linear regression results for each pollutant

To begin with, a regression analysis has been carried out using all the available valid data for each pollutant using data from 2018 to 2022 (all countries, stations types...).

For each pollutant, a regression equation has been obtained linking Daily (or mean 8-h) with Max Daily Hourly values.

PM_{10}

As shown in the plot, the equation obtained for PM_{10} is:

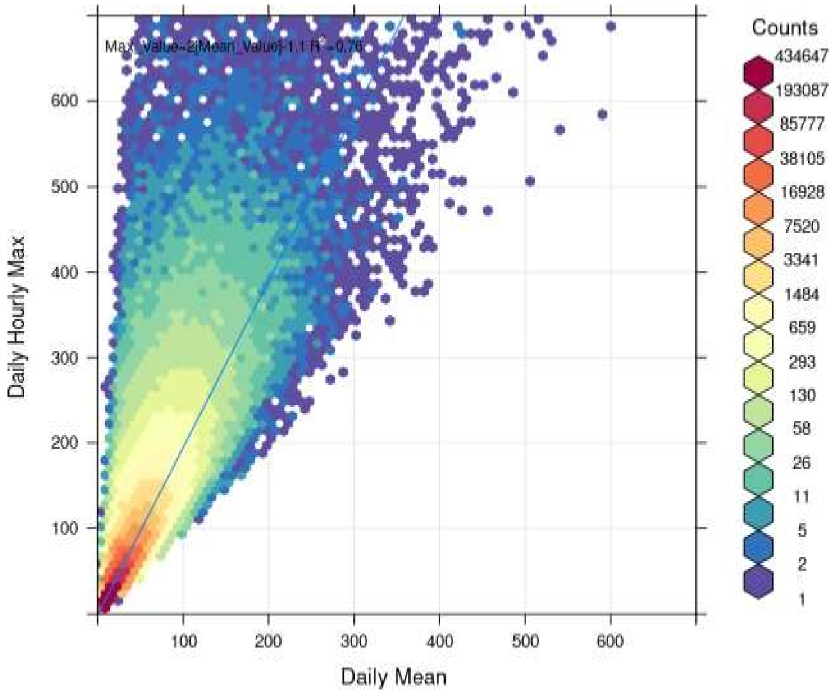
$$Daily_{HourlyMax} = 1.956 \cdot Daily_{Mean} - 1.137$$

and a coefficient of determination $R^2 = 0.761$.

Applied for $Daily_{Mean} = 40\mu g/m^3$

$$\mathbf{Daily_{HourlyMax} = 77.103\mu g/m^3}$$

Figure A2.1: xy scatter plot including linear regression for PM_{10}



$PM_{2.5}$

The equation obtained for $PM_{2.5}$ is:

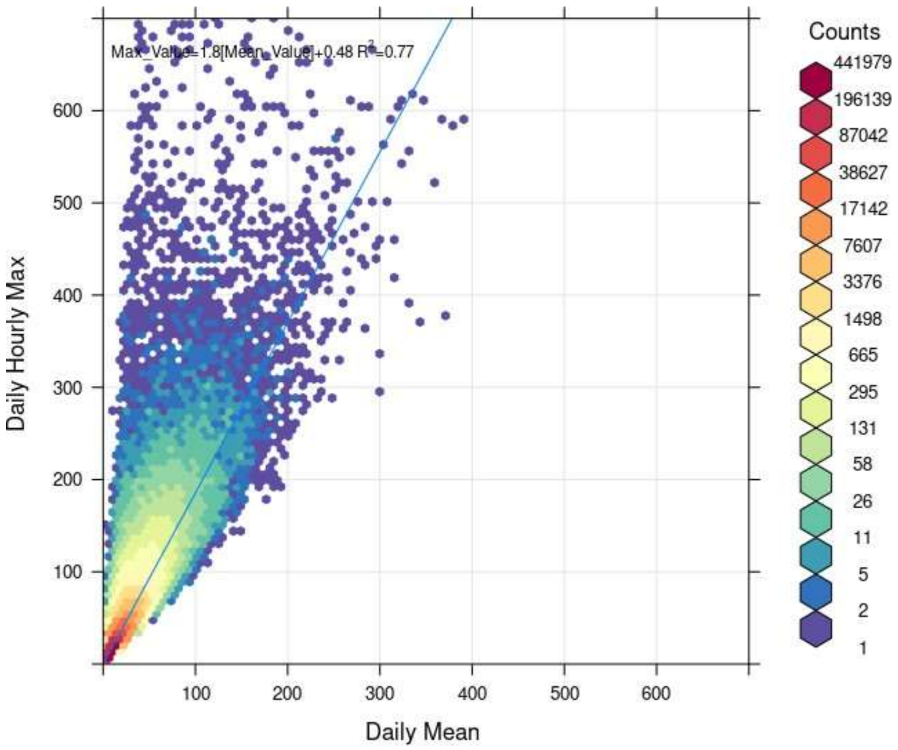
$$Daily_{HourlyMax} = 1.849 \cdot Daily_{Mean} + 0.476$$

and a coefficient of determination $R^2 = 0.769$

Applied for $Daily_{Mean} = 15\mu g/m^3$

$$\mathbf{Daily_{HourlyMax} = 28.211\mu g/m^3}$$

Figure A.2.2: xy scatter plot including linear regression for $PM_{2.5}$



NO_2

The equation obtained for NO_2 is:

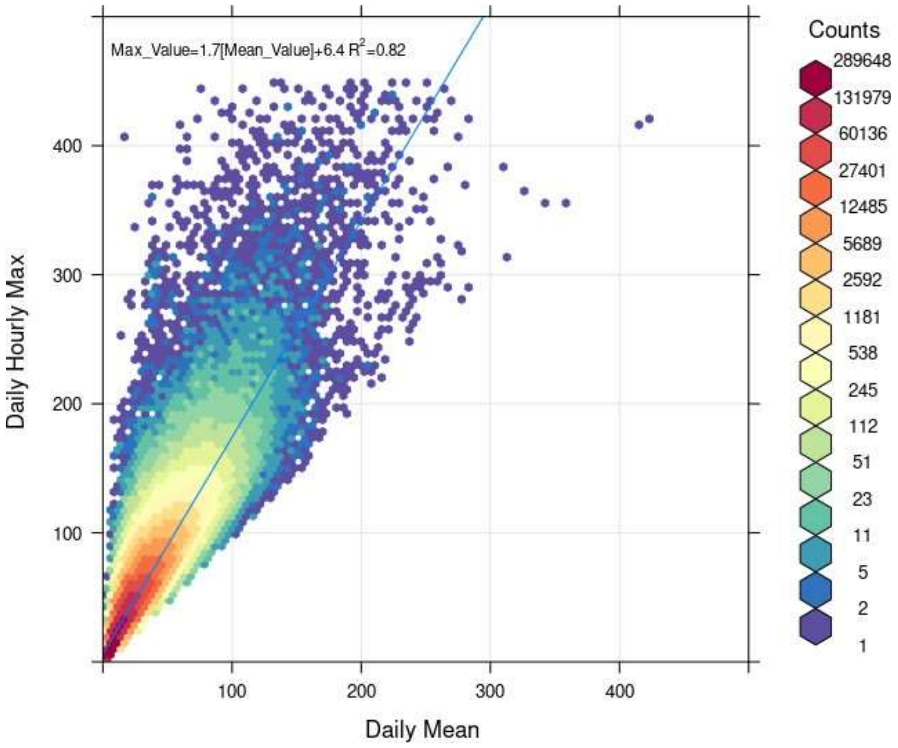
$$Daily_{HourlyMax} = 1.676 \cdot Daily_{Mean} + 6.393$$

and a coefficient of determination $R^2 = 0.819$

Applied for $Daily_{Mean} = 25 \mu g/m^3$

$$\mathbf{Daily_{HourlyMax} = 48.293 \mu g/m^3}$$

Figure A2.3: xy scatter plot including linear regression for NO_2



SO2

The equation obtained for SO_2 is:

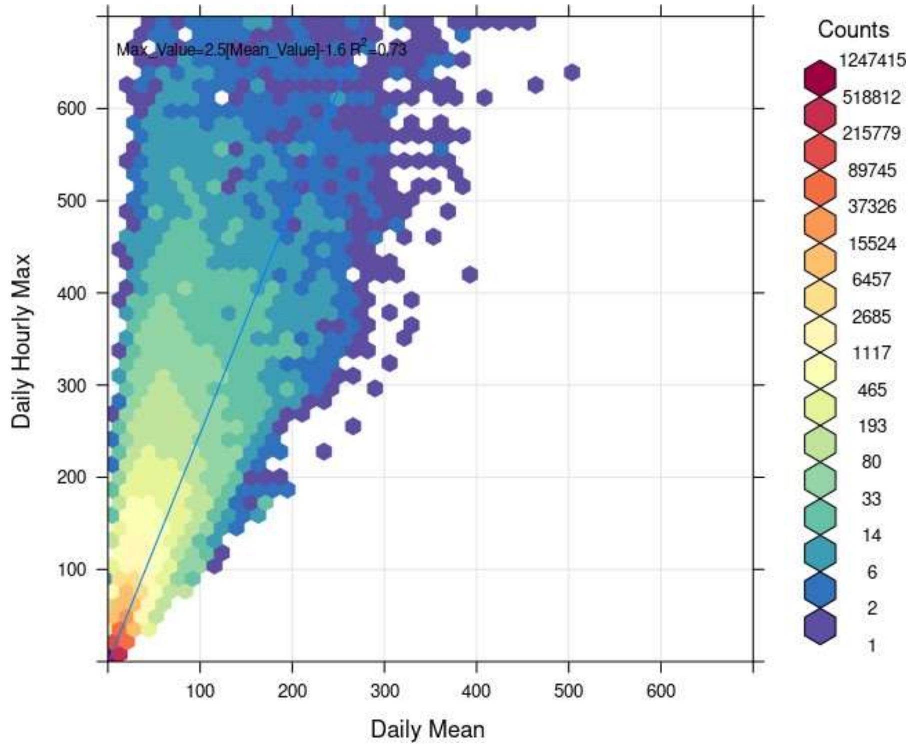
$$Daily_{HourlyMax} = 2.488 \cdot Daily_{Mean} + -1.593$$

and a coefficient of determination $R^2 = 0.726$.

Applied for $Daily_{Mean} = 125\mu g/m^3$

$$\mathbf{Daily_{HourlyMax} = 309.407\mu g/m^3}$$

Figure A2.4: xy scatter plot including linear regression for SO_2



O_3

The equation obtained for O_3 is:

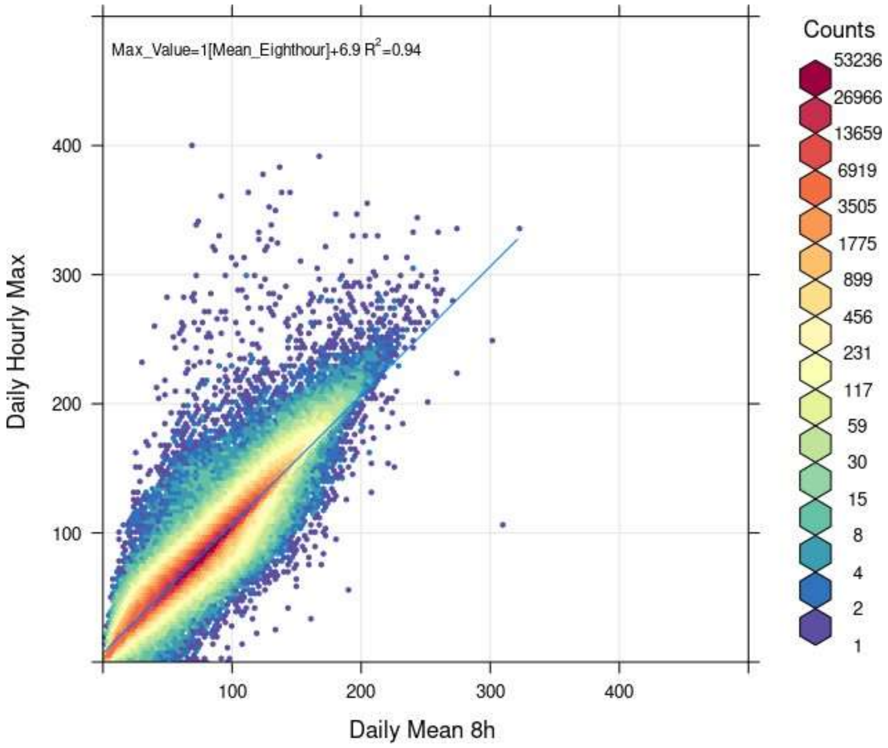
$$Daily_{HourlyMax} = 0.998 \cdot Daily_{Mean8h} + 6.908$$

and a coefficient of determination $R^2 = 0.941$.

Applied for $Daily_{Mean8h} = 100\mu g/m^3$

$$\mathbf{Daily_{HourlyMax} = 106.708\mu g/m^3}$$

Figure A2.5: xy scatter plot including linear regression for O_3



Analysis of regression results by variable type

For each variable within each type (category), the data has been filtered, a regression equation has been obtained, and applied to the values used in the previous section.

For each pollutant, a box plot has been generated with all the values obtained within each type to visualize the variation and dispersion of each one.

Figure A2.6: Box Plot Analysis of PM_{10} across types

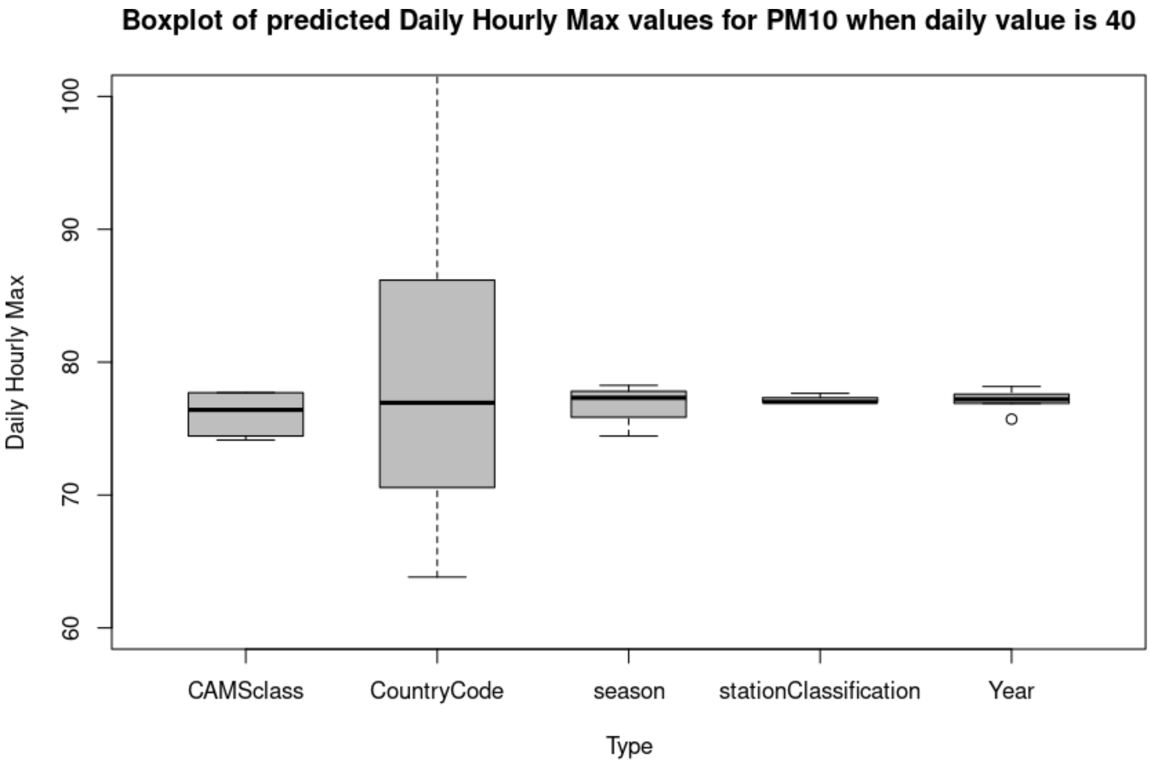


Figure A2.7: Box Plot Analysis of $PM_{2.5}$ across types

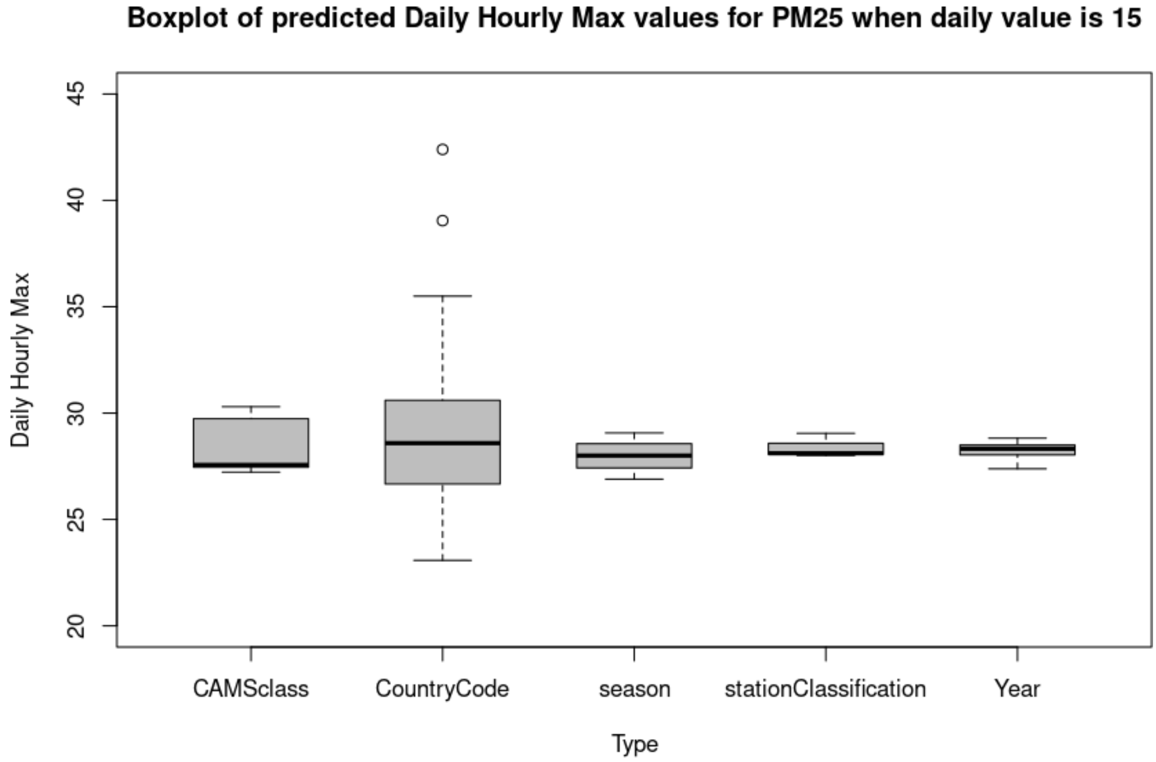


Figure A2.8: Box Plot Analysis of NO2 across types

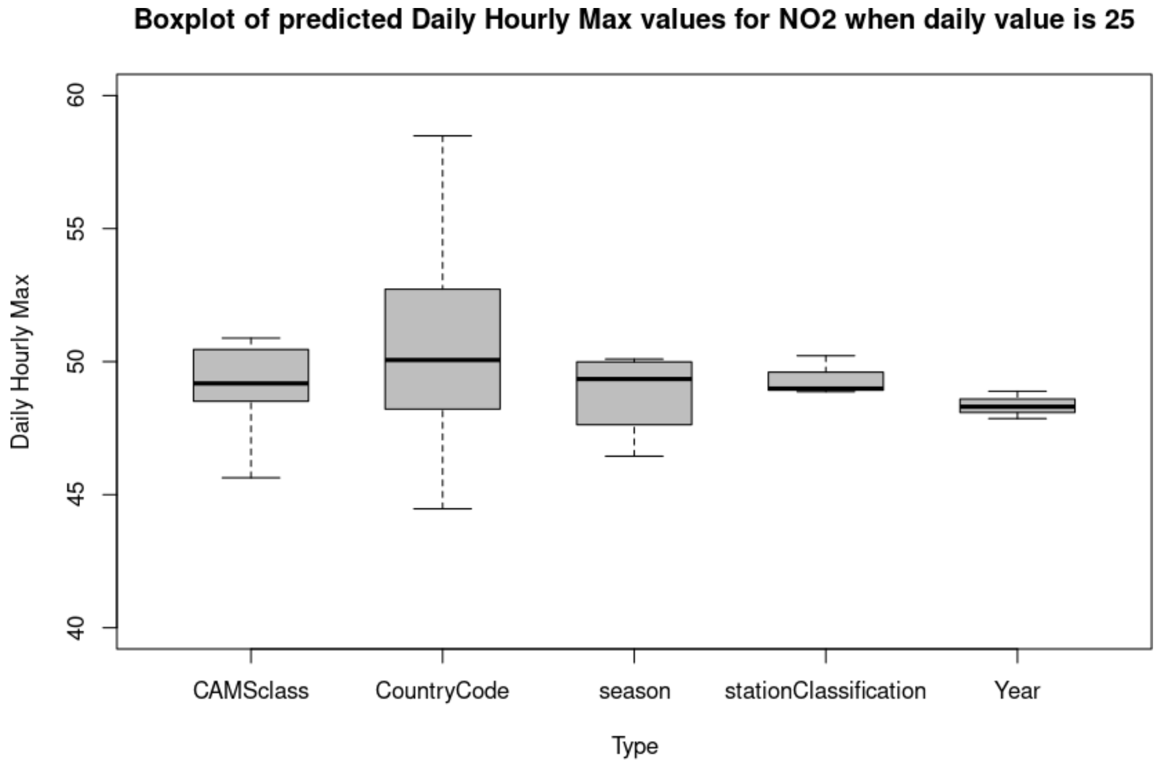


Figure A2.9: Box Plot Analysis of SO_2 across types

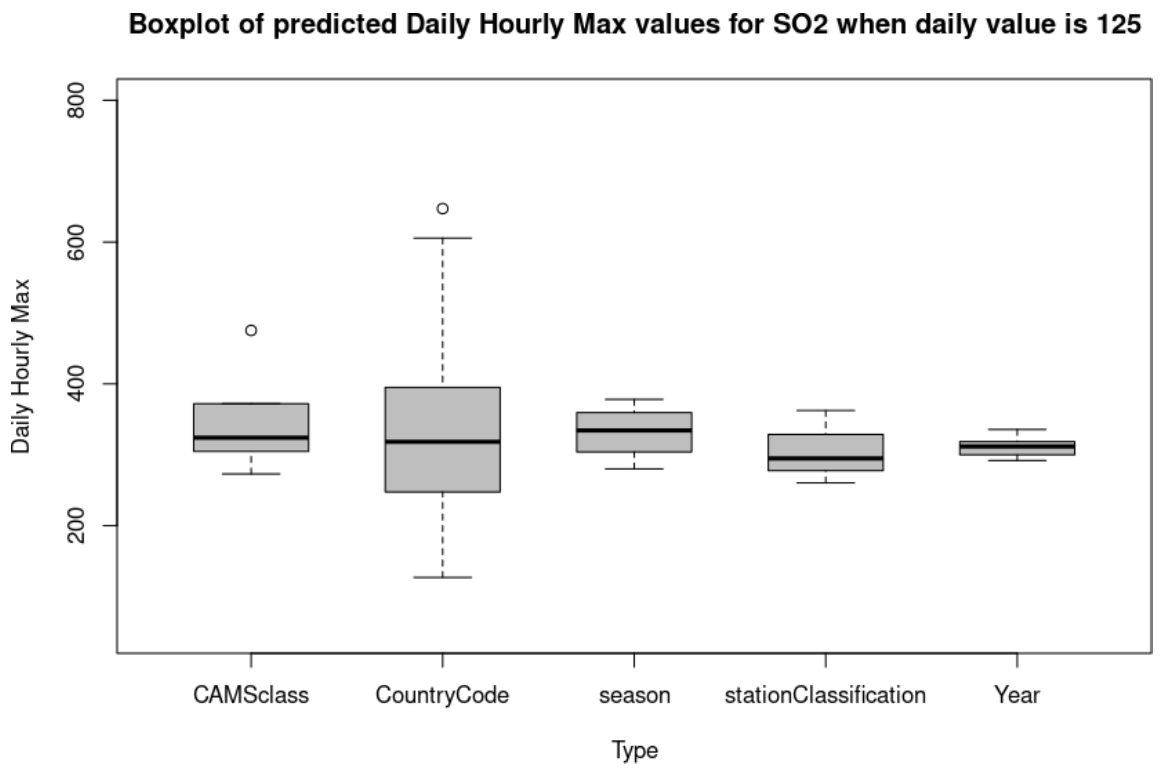
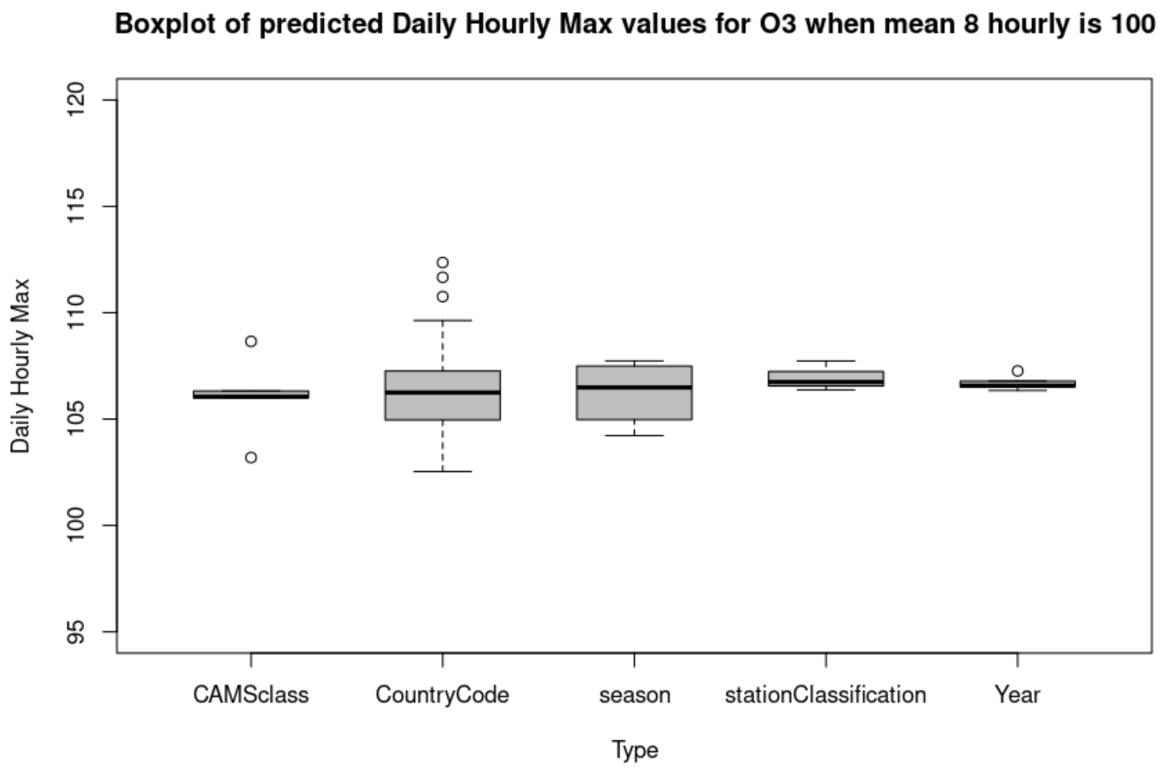


Figure A2.10: Box Plot Analysis of O_3 across types



Result tables

Here the results of all the regressions and values obtained in the previous section for the different variable types are shown.

Table A2.2: Regression analysis results by variable type for PM_{10}

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	AD	5.975	2.063	22.048	88.495	0.634
CountryCode	AL	-4.264	2.261	21.484	86.176	0.786
CountryCode	AT	2.346	1.633	12.739	67.666	0.618
CountryCode	BA	9.159	1.723	29.949	78.079	0.839
CountryCode	BE	-1.905	1.909	18.133	74.455	0.613
CountryCode	CZ	6.785	1.584	14.216	70.145	0.721
CountryCode	DE	0.643	1.748	14.727	70.563	0.556
CountryCode	DK	-10.640	2.629	23.853	94.520	0.575
CountryCode	ES	1.093	1.901	18.901	77.133	0.711
CountryCode	FI	-5.562	2.788	18.368	105.958	0.731
CountryCode	FR	1.674	1.708	12.633	69.994	0.655
CountryCode	GR	-3.056	2.055	23.891	79.144	0.663
CountryCode	HR	-1.129	1.947	19.380	76.751	0.628
CountryCode	IS	-2.836	2.992	23.706	116.844	0.630
CountryCode	IT	2.468	1.687	19.467	69.948	0.588
CountryCode	LT	-1.439	1.948	16.392	76.481	0.718
CountryCode	LU	-1.276	1.774	9.796	69.684	0.666
CountryCode	LV	-0.979	2.175	15.251	86.021	0.688
CountryCode	MK	-0.704	2.156	28.126	85.536	0.842
CountryCode	NL	3.999	1.752	17.880	74.079	0.459
CountryCode	NO	-5.678	2.808	20.695	106.642	0.759
CountryCode	PL	-1.634	2.030	22.616	79.566	0.737
CountryCode	PT	0.184	1.591	10.651	63.824	0.777
CountryCode	RO	-0.431	1.823	15.355	72.489	0.699
CountryCode	RS	4.559	1.781	23.901	75.799	0.782

Table A2.2: Regression analysis results by variable type for PM_{10} (continued)

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	SE	-7.458	2.746	21.707	102.382	0.792
CountryCode	SI	0.936	1.808	13.858	73.256	0.781
CountryCode	SK	1.649	1.692	14.072	69.329	0.718
CountryCode	TR	-3.354	2.024	35.586	77.606	0.765
CountryCode	XK	0.838	2.154	25.728	86.998	0.757
Year	2018	-0.931	1.916	20.661	75.709	0.753
Year	2019	-1.073	1.957	19.802	77.207	0.757
Year	2020	-1.072	1.981	20.156	78.168	0.766
Year	2021	-1.209	1.970	19.488	77.591	0.771
Year	2022	-1.384	1.957	20.416	76.896	0.759
stationClassification	Background	-1.451	1.960	19.704	76.949	0.783
stationClassification	Traffic	-0.717	1.943	20.307	77.003	0.722
stationClassification	Industrial	-0.386	1.951	21.473	77.654	0.721
CAMSclass	Western Europe	0.376	1.844	16.193	74.136	0.686
CAMSclass	Sourthern Europe	-1.940	1.991	31.529	77.700	0.779
CAMSclass	Central Europe	-0.039	1.862	16.547	74.441	0.688
CAMSclass	Northern Europe	-6.135	2.770	20.498	104.665	0.766
CAMSclass	Eastern Europe	-0.987	1.935	16.268	76.413	0.711
season	winter	0.211	1.951	23.431	78.251	0.792
season	spring	-1.134	1.960	20.476	77.266	0.740
season	summer	-1.202	1.891	16.653	74.438	0.665
season	autumn	-1.470	1.971	19.270	77.370	0.774
All	All	-1.137	1.956	20.113	77.103	0.761

Table A2.3: Regression analysis results by variable type for $PM_{2.5}$

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	AD	2.760	1.776	8.542	29.400	0.604
CountryCode	AL	-2.138	2.321	13.626	32.677	0.770
CountryCode	AT	3.201	1.325	5.405	23.076	0.779
CountryCode	BA	9.919	1.942	30.757	39.049	0.814
CountryCode	BE	3.253	1.504	6.901	25.813	0.781
CountryCode	CZ	6.124	1.536	10.046	29.164	0.792
CountryCode	DE	2.087	1.550	8.943	25.337	0.599
CountryCode	DK	-11.181	3.112	16.864	35.499	0.315
CountryCode	ES	-0.633	2.054	10.658	30.177	0.679
CountryCode	FI	1.048	1.682	4.728	26.278	0.620
CountryCode	FR	1.992	1.618	6.589	26.262	0.735
CountryCode	GR	-5.670	2.366	13.906	29.820	0.745
CountryCode	HR	1.885	1.711	11.852	27.550	0.745
CountryCode	IS	-0.490	2.859	9.290	42.395	0.531
CountryCode	IT	0.849	1.884	15.783	29.109	0.595
CountryCode	LT	2.489	1.638	8.616	27.059	0.715
CountryCode	LU	2.920	1.417	3.825	24.175	0.798
CountryCode	LV	1.757	1.923	8.174	30.602	0.656
CountryCode	MK	0.155	2.179	24.448	32.840	0.824
CountryCode	NL	2.658	1.692	12.289	28.038	0.532
CountryCode	NO	0.390	2.109	8.170	32.025	0.671
CountryCode	PL	-0.153	1.957	16.568	29.202	0.754
CountryCode	PT	1.072	1.539	4.962	24.157	0.751
CountryCode	RO	0.816	1.766	9.648	27.306	0.719
CountryCode	RS	4.202	1.591	11.458	28.067	0.823
CountryCode	SE	0.587	1.767	6.899	27.092	0.609
CountryCode	SI	1.327	1.775	10.633	27.952	0.812
CountryCode	SK	2.500	1.611	9.812	26.665	0.758
CountryCode	TR	0.481	1.915	16.827	29.206	0.802
CountryCode	XK	2.402	1.897	13.900	30.857	0.837
Year	2021	0.288	1.869	10.498	28.323	0.798
Year	2022	-0.467	1.931	11.472	28.498	0.767
Year	2018	1.581	1.720	11.689	27.381	0.754
Year	2019	1.335	1.780	11.001	28.035	0.754

Table A2.3: Regression analysis results by variable type for $PM_{2.5}$ (continued)

type	variable	intercept	slope	rmse	predictedy	rsquared
Year	2020	0.335	1.899	11.707	28.820	0.764
stationClassification	Background	0.691	1.828	10.869	28.111	0.774
stationClassification	Traffic	0.706	1.820	10.798	28.006	0.770
stationClassification	Industrial	-0.621	1.978	13.767	29.049	0.754
CAMSclass	Western Europe	1.116	1.763	8.600	27.561	0.696
CAMSclass	Sourthern Europe	0.277	1.964	17.465	29.737	0.798
CAMSclass	Central Europe	1.363	1.724	11.006	27.223	0.727
CAMSclass	Northern Europe	0.224	2.005	7.494	30.299	0.648
CAMSclass	Eastern Europe	2.448	1.667	8.724	27.453	0.710
season	winter	0.971	1.873	15.969	29.066	0.775
season	spring	0.781	1.811	9.994	27.946	0.755
season	summer	0.673	1.748	7.292	26.893	0.630
season	autumn	0.971	1.806	10.129	28.061	0.767
All	All	0.476	1.849	11.287	28.211	0.769

Table A2.4: Regression analysis results by variable type for NO_2

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	AD	12.394	1.461	9.903	48.919	0.806
CountryCode	AL	5.628	1.808	9.256	50.828	0.794
CountryCode	AT	5.382	1.624	9.074	45.982	0.824
CountryCode	BA	9.161	1.665	10.938	50.786	0.805
CountryCode	BE	6.601	1.556	9.491	45.501	0.818
CountryCode	BG	3.798	1.927	13.298	51.973	0.807
CountryCode	CH	6.533	1.570	9.634	45.783	0.826
CountryCode	CY	4.912	2.143	12.198	58.487	0.853
CountryCode	CZ	4.323	1.684	8.755	46.423	0.813
CountryCode	DE	4.244	1.609	8.958	44.469	0.852
CountryCode	DK	2.586	1.850	7.385	48.836	0.858
CountryCode	EE	1.662	2.244	6.998	57.762	0.833
CountryCode	ES	5.436	1.924	11.306	53.536	0.818
CountryCode	FI	2.902	1.968	8.285	52.102	0.822
CountryCode	FR	6.936	1.699	10.264	49.411	0.836
CountryCode	GR	14.936	1.360	11.651	48.936	0.847
CountryCode	HR	8.337	1.821	12.731	53.862	0.767
CountryCode	HU	6.024	1.731	11.515	49.299	0.789
CountryCode	IE	6.903	1.766	10.990	51.053	0.809
CountryCode	IS	4.419	2.098	9.547	56.869	0.838
CountryCode	IT	7.992	1.590	11.449	47.742	0.800
CountryCode	LT	0.558	2.098	10.867	53.008	0.818
CountryCode	LU	3.786	1.679	8.507	45.761	0.896
CountryCode	LV	3.301	2.070	11.185	55.051	0.774
CountryCode	ME	8.984	1.789	10.539	53.709	0.740
CountryCode	MK	4.300	1.906	10.026	51.950	0.820
CountryCode	MT	6.240	2.011	11.927	56.515	0.818
CountryCode	NL	6.475	1.571	10.320	45.750	0.755
CountryCode	NO	9.138	1.680	10.783	51.138	0.832
CountryCode	PL	5.291	1.717	10.456	48.216	0.783
CountryCode	PT	4.232	1.931	11.425	52.507	0.868
CountryCode	RO	4.629	1.762	13.205	48.679	0.799

Table A2.4: Regression analysis results by variable type for NO_2 (continued)

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	RS	6.562	1.740	13.200	50.062	0.769
CountryCode	SI	6.031	1.710	9.763	48.781	0.796
CountryCode	SK	3.970	1.711	8.263	46.745	0.853
CountryCode	TR	8.793	1.633	19.562	49.618	0.811
CountryCode	XK	4.447	1.931	12.622	52.722	0.788
Year	2018	7.356	1.638	12.133	48.306	0.821
Year	2019	7.271	1.653	12.243	48.596	0.821
Year	2020	6.135	1.669	11.033	47.860	0.817
Year	2021	5.963	1.685	10.946	48.088	0.814
Year	2022	5.512	1.735	11.320	48.887	0.815
stationClassification	Background	4.869	1.760	10.710	48.869	0.801
stationClassification	Traffic	10.562	1.537	13.157	48.987	0.794
stationClassification	Industrial	5.247	1.799	10.798	50.222	0.781
CAMSclass	Western Europe	6.159	1.789	11.013	50.884	0.821
CAMSclass	Sourthern Europe	7.936	1.623	13.380	48.511	0.815
CAMSclass	Central Europe	4.984	1.626	9.431	45.634	0.825
CAMSclass	Northern Europe	5.457	1.800	9.680	50.457	0.849
CAMSclass	Eastern Europe	4.106	1.803	12.439	49.181	0.818
season	winter	7.319	1.565	12.432	46.444	0.817
season	spring	6.371	1.749	11.300	50.096	0.822
season	summer	4.757	1.805	10.193	49.882	0.810
season	autumn	5.690	1.725	11.589	48.815	0.818
All	All	6.393	1.676	11.529	48.293	0.819

Table A2.5: Regression analysis results by variable type for SO_2

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	AD	0.563	1.976	1.494	247.563	0.581
CountryCode	AL	9.811	-0.004	5.647	9.311	0.002
CountryCode	AT	-1.344	2.953	5.022	367.781	0.659
CountryCode	BA	15.432	2.177	70.110	287.557	0.679
CountryCode	BE	-2.792	4.515	9.215	561.583	0.768
CountryCode	BG	-12.050	3.094	24.648	374.700	0.582
CountryCode	CH	-0.411	2.590	2.139	323.339	0.467
CountryCode	CY	0.748	1.778	1.723	222.998	0.633
CountryCode	CZ	-3.171	3.086	10.115	382.579	0.639
CountryCode	DE	-1.780	3.796	5.976	472.720	0.745
CountryCode	DK	0.436	2.024	1.972	253.436	0.415
CountryCode	EE	0.002	3.851	3.475	481.377	0.780
CountryCode	ES	-3.071	2.701	7.476	334.554	0.620
CountryCode	FI	-0.748	4.851	7.563	605.627	0.743
CountryCode	FR	-0.337	4.257	12.598	531.788	0.708
CountryCode	GR	-2.150	2.090	8.263	259.100	0.523
CountryCode	HR	-2.577	3.296	10.639	409.423	0.574
CountryCode	HU	-1.141	1.853	3.720	230.484	0.662
CountryCode	IE	-2.148	2.758	8.961	342.602	0.660
CountryCode	IS	2.064	3.144	13.030	395.064	0.725
CountryCode	IT	-0.642	1.994	6.018	248.608	0.534
CountryCode	LT	-0.325	1.289	4.078	160.800	0.578
CountryCode	LU	0.552	1.185	1.795	148.677	0.580
CountryCode	LV	0.718	1.010	0.834	126.968	0.943
CountryCode	ME	-0.086	2.520	37.079	314.914	0.613
CountryCode	MK	-0.521	2.670	12.175	333.229	0.938
CountryCode	MT	-0.331	2.503	0.968	312.544	0.673
CountryCode	NL	0.072	3.145	6.262	393.197	0.745
CountryCode	NO	7.274	3.568	34.070	453.274	0.731
CountryCode	PL	-1.738	2.420	8.713	300.762	0.663
CountryCode	PT	0.672	1.617	3.876	202.797	0.493
CountryCode	RO	-8.372	2.630	9.846	320.378	0.521
CountryCode	RS	-24.903	4.677	40.264	559.722	0.695

Table A2.5: Regression analysis results by variable type for SO_2 (continued)

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	SE	-3.372	5.205	6.844	647.253	0.817
CountryCode	SI	-0.913	2.344	2.653	292.087	0.590
CountryCode	SK	-1.736	1.779	8.923	220.639	0.409
CountryCode	TR	-3.037	2.554	19.935	316.213	0.775
CountryCode	XK	6.691	1.212	15.782	158.191	0.499
Year	2018	-1.101	2.503	14.736	311.774	0.711
Year	2019	-2.044	2.702	14.600	335.706	0.728
Year	2020	-1.385	2.411	15.679	299.990	0.734
Year	2021	-2.276	2.567	13.989	318.599	0.729
Year	2022	-1.404	2.347	14.011	291.971	0.732
stationClassification	Background	-1.531	2.371	12.956	294.844	0.763
stationClassification	Traffic	-1.305	2.093	11.099	260.320	0.709
stationClassification	Industrial	-1.760	2.914	18.356	362.490	0.700
CAMSclass	Western Europe	-2.854	2.999	9.262	372.021	0.610
CAMSclass	Sourthern Europe	-1.766	2.452	21.425	304.734	0.748
CAMSclass	Central Europe	-1.314	2.603	7.835	324.061	0.642
CAMSclass	Northern Europe	1.028	3.795	17.591	475.403	0.754
CAMSclass	Eastern Europe	-4.758	2.222	9.248	272.992	0.510
season	winter	-0.715	2.247	14.913	280.160	0.815
season	spring	-2.444	2.747	14.091	340.931	0.713
season	summer	-3.628	3.054	13.963	378.122	0.623
season	autumn	-2.326	2.641	14.541	327.799	0.699
All	All	-1.593	2.488	14.629	309.407	0.726

Table A2.6: Regression analysis results by variable type for O_3

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	AD	12.708	0.921	14.445	104.808	0.941
CountryCode	AL	14.311	0.928	16.464	107.111	0.933
CountryCode	AT	8.691	0.972	33.784	105.891	0.947
CountryCode	BA	7.066	1.046	31.006	111.666	0.939
CountryCode	BE	5.671	1.005	30.267	106.171	0.938
CountryCode	BG	6.169	1.008	18.966	106.969	0.950
CountryCode	CH	8.253	0.985	31.316	106.753	0.957
CountryCode	CY	12.908	0.961	16.774	109.008	0.896
CountryCode	CZ	6.056	0.993	28.805	105.356	0.953
CountryCode	DE	6.448	0.995	43.239	105.948	0.950
CountryCode	DK	5.601	0.983	17.972	103.901	0.928
CountryCode	EE	4.935	0.991	17.109	104.035	0.938
CountryCode	ES	8.732	0.974	29.903	106.132	0.919
CountryCode	FI	4.198	0.987	16.981	102.898	0.940
CountryCode	FR	6.490	0.993	37.193	105.790	0.944
CountryCode	GR	8.032	1.016	23.328	109.632	0.937
CountryCode	HR	9.186	0.977	22.253	106.886	0.944
CountryCode	HU	6.941	1.005	22.639	107.441	0.956
CountryCode	IE	7.168	0.956	18.397	102.768	0.917
CountryCode	IT	8.431	0.999	45.687	108.331	0.952
CountryCode	LT	5.479	0.992	19.011	104.679	0.928
CountryCode	LU	6.720	0.985	21.871	105.220	0.952
CountryCode	LV	5.541	0.985	15.484	104.041	0.924
CountryCode	ME	6.516	0.990	13.335	105.516	0.948
CountryCode	MK	8.510	0.995	20.447	108.010	0.953
CountryCode	MT	5.759	0.992	12.603	104.959	0.933
CountryCode	NL	6.014	1.003	29.661	106.314	0.935
CountryCode	NO	5.632	0.969	17.035	102.532	0.932
CountryCode	PL	5.740	1.007	32.751	106.440	0.953
CountryCode	PT	6.247	1.000	23.838	106.247	0.906
CountryCode	RO	7.720	0.995	24.089	107.220	0.940
CountryCode	RS	8.403	0.995	21.835	107.903	0.949

Table A2.6: Regression analysis results by variable type for O_3 (continued)

type	variable	intercept	slope	rmse	predictedy	rsquared
CountryCode	SE	4.684	0.986	18.519	103.284	0.940
CountryCode	SI	10.662	0.966	22.636	107.262	0.951
CountryCode	SK	7.458	0.989	22.627	106.358	0.951
CountryCode	TR	4.959	1.058	36.448	110.759	0.927
CountryCode	XK	11.058	1.013	25.885	112.358	0.780
Year	2018	6.865	1.004	42.283	107.265	0.941
Year	2019	7.385	0.994	33.989	106.785	0.936
Year	2020	6.842	0.995	28.285	106.342	0.942
Year	2021	6.716	0.998	30.935	106.516	0.941
Year	2022	6.970	0.996	25.877	106.570	0.944
stationClassification	Background	6.741	1.000	40.757	106.741	0.943
stationClassification	Traffic	8.232	0.995	33.783	107.732	0.935
stationClassification	Industrial	6.872	0.995	33.486	106.372	0.926
CAMSclass	Western Europe	7.305	0.987	33.229	106.005	0.932
CAMSclass	Sourthern Europe	7.552	1.011	46.034	108.652	0.944
CAMSclass	Central Europe	6.752	0.993	40.709	106.052	0.950
CAMSclass	Northern Europe	4.691	0.985	20.639	103.191	0.938
CAMSclass	Eastern Europe	7.021	0.993	27.426	106.321	0.935
season	winter	9.522	0.947	27.957	104.222	0.908
season	spring	5.720	1.000	24.067	105.720	0.919
season	summer	1.553	1.057	30.526	107.253	0.923
season	autumn	7.835	0.999	31.367	107.735	0.923
All	All	6.908	0.998	39.800	106.708	0.941

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