National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

EC concentrations *in the Netherlands*

National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Elemental Carbon (EC) concentrations in the Netherlands

RIVM report 2014-0128
J.P. Wesseling et al.

Colophon

Joost Wesseling,
Eric van der Swaluw,
Ronald Hoogerbrugge,
Guus Velders,
Wilco de Vries,
Sef van den Elshout, DCMR,
Michael Ameling, DCMR

Contact:

Joost.Wesseling@rivm.nl

This investigation was performed by order of and for the account of the Ministry of Infrastructure and the Environment, within the framework of the project "Urban Air Quality"

This is a publication of:

National Institute for Public Health and the Environment
P.O. Box 1 | 3720 BA Bilthoven
The Netherlands

www.rivm.nl/en

Publiekssamenvatting

Roetconcentraties in Nederland

Roet kan worden gebruikt als een indicator voor gezondheidseffecten van luchtverontreiniging als gevolg van verkeer. Tot nu toe worden daar meestal de twee maten voor fijnstof (PM_{10} en $PM_{2,5}$) voor gebruikt. Dit geeft echter een onvolledig beeld. Daarom zijn (voor het eerst) de roetconcentraties op alle adressen in heel Nederland in kaart gebracht. Informatie over roetconcentraties kan helpen keuzes te maken voor (verkeers)maatregelen die de luchtkwaliteit lokaal verbeteren.

Verkeer stoot relatief veel roet uit. De hoeveelheid roet nabij drukke verkeerswegen is dan ook relatief hoog. Voor roet is er geen grenswaarde, zoals voor fijnstof en stikstofdioxide.

Door uitbreiding van de roetmonitoring in Nederland zal naar verwachting in 2015 een nog meer gedetailleerde roetkaart opgesteld kunnen worden.

Het RIVM heeft, in samenwerking met de Milieudienst Rijnmond DCMR, de roetkaart in opdracht van het ministerie van Infrastructuur en Milieu (IenM) gemaakt.

Kernwoorden: luchtkwaliteit, roet, blootstelling

Abstract

EC concentrations in the Netherlands

Elemental Carbon (EC, soot) can be used as an indicator of health effects resulting from to traffic emissions. So far, the particulate matter concentrations (PM10 and PM2.5) are being used which results in an incomplete picture of the situation. Therefore, soot concentrations at all addresses in the Netherlands haven been determined. Information on these concentrations may help when selecting (traffic) measures to improve air quality.

If the results of policies are only based on the total amount of particulate matter in the air, the health effects of traffic pollution will be underestimated. If air quality is assessed using the soot concentrations, the negative effects of the emissions will be more evident. Long-term exposure to soot will lead to a shorter life expectancy, the more so with increasing concentrations.

Traffic is a relatively large source of soot. Near busy roads, soot concentrations are fairly high. Presently, these high soot concentrations cannot be observed in air quality maps. No legal limits have been set for soot, as opposed to particulate matter and nitrogen dioxide, where limits have been set. As a result, air quality assessments only focus on these two substances when assessing health effects. As soot only makes up a small part of particulate matter, differences in soot concentrations only have a very limited influence on particulate matter concentrations. Furthermore, negative health effects also occur when particulate matter and nitrogen dioxide concentrations are below their legal limit values.

On request of the Ministry of Infrastructure and the Environment, the National Institute for Public Health and the Environment (RIVM) and the environmental protection agency of the province of South Holland (DCMR) have developed a national soot-map for the Netherlands.

Keywords: air quality, elemental carbon, exposure

Contents

Introduction

Annual averaged concentration maps of particulate matter (PM) in the Netherlands are produced by the RIVM once every year at a 1km x 1km resolution (GCN). The GCN maps of PM are based on a combination of model calculations and measurements. The PM_{10} maps of GCN are used in the national air quality collaboration programme (NSL), which annually assess whether the Netherlands has reached the limit values for PM_{10} as set by EU legislation. This is done by calculating human exposure to outdoor concentrations of PM_{10} over the whole of the Netherlands on a local scale.

Elemental carbon (EC), one of the components of PM_{10}, has recently been associated with negative health effects (see e.g. Janssen et al., 2011). EC is especially associated with traffic-related sources. EC can therefore be used to assess the impact of local traffic measures. For this reason, EC has been included in the yearly production of GCN maps in 2012 (Velders et al, 2012.).

EC concentrations have been measured (using different methodologies) at a number of sites over the past few years in the Netherlands. Presently, there is enough information available from both measurements and calculations in order to present a detailed map of the EC concentrations in the Netherlands. Based on this map, it is possible to calculate the exposure levels to EC in the Netherlands in detail, for the first time.

1 Measurements of Elemental Carbon in the Netherlands

In this report we use the Elemental Carbon (EC) measurements calculated for the period 2010-2012 in the Netherlands. Figure 1 shows the 23 monitoring stations in the Netherlands where EC has been measured: 5 rural, 6 urban and 12 traffic stations. All measurements of EC used in this report have been performed by the RIVM, DCMR or GGD Amsterdam.

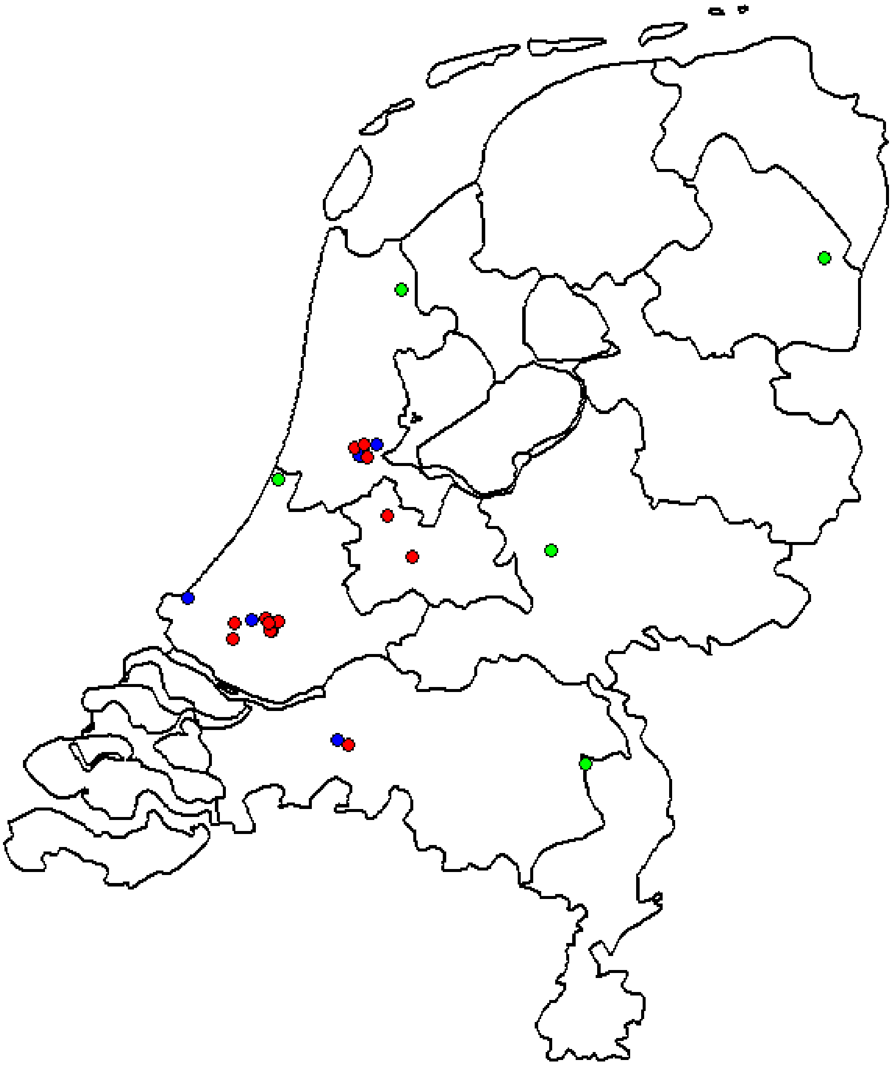


Figure 1 Monitoring stations in the Netherlands where elemental carbon was measured over the period 2010-2012. The colour of the dots indicates the station type (green=rural; blue=urban and red=traffic).

Most of the EC measurements were performed indirectly, using black smoke (BS) measurements obtained with the SX-200 method. Black smoke is not a component of PM like EC, but a measure for the absorption of light by the material which is collected on a PM_{10} filter. However, an empirical relation between EC and BS concentration was determined by Schaap & Denier van de Gon (2007). The EC measurements used in these empirical relations were from filters analysed by Sunset Laboratories. The relation between BS and EC makes a distinction between regional and urban monitoring stations:

$$EC = \begin{cases} 0.056 * BS + 0.16 & \text{(regional)} \\ 0.088 * BS + 0.32 & \text{(urban)} \end{cases} \quad (1)$$

These relations have been used in the present work to transform BS numbers from the period 2010-2012 to values for EC. The BS concentrations from traffic stations were converted in the same way as for the urban stations.

In addition to the BS measurements, the MAAP method has also been recently introduced in the Netherlands as a method to measure EC more directly, i.e. by measuring Black Carbon (BC). These types of measurements are currently performed by GGD-A and DCMR. The following formula for the conversion from BC to EC concentrations is used:[1]

$$EC = 0.7 * BC + 0.1 \quad (2)$$

All available data from 2010-2012 in the Netherlands have been used for the calibration of the calculations performed for EC in the next section. An overview of the data is presented in Appendix 1.

[1] This is the relation presented in Keuken et al (2011); Keuken et al (2013) use a slightly different relation stressing the need for more side by side measurements of EC and BC.

2 Calculations and calibration

2.1 EC calculations

The objective of this study was to produce an EC concentration map for the Netherlands for the year 2012. In order to develop this map, a comparison has to be made between the measurements and the calculations. To compare the measured concentrations, EC concentrations were calculated at all measuring locations using the Dutch standard calculation methods for local air quality[2]. These methods are also used for all official air quality assessments and for reporting exceedances to the EU. The national background concentrations were calculated first, and the contributions of highways and local roads were added afterwards. The EC contributions of all sources for which emissions are available are part of the national background, which are calculated on a 1x1 km grid as 1 of the GCN maps. Contributions from traffic, which show a strong gradient, are calculated separately using the local dispersion models. All necessary input for the local calculations is derived from the 'National Collaboration on Air Quality' (Dutch: NSL). This contains all the information on roads, traffic intensities, speed and stagnation.

The standard national background concentrations for 2012 are shown in Figure 2.

[2] See the Dutch website http://wetten.overheid.nl/BWBR0022817/ for a description.

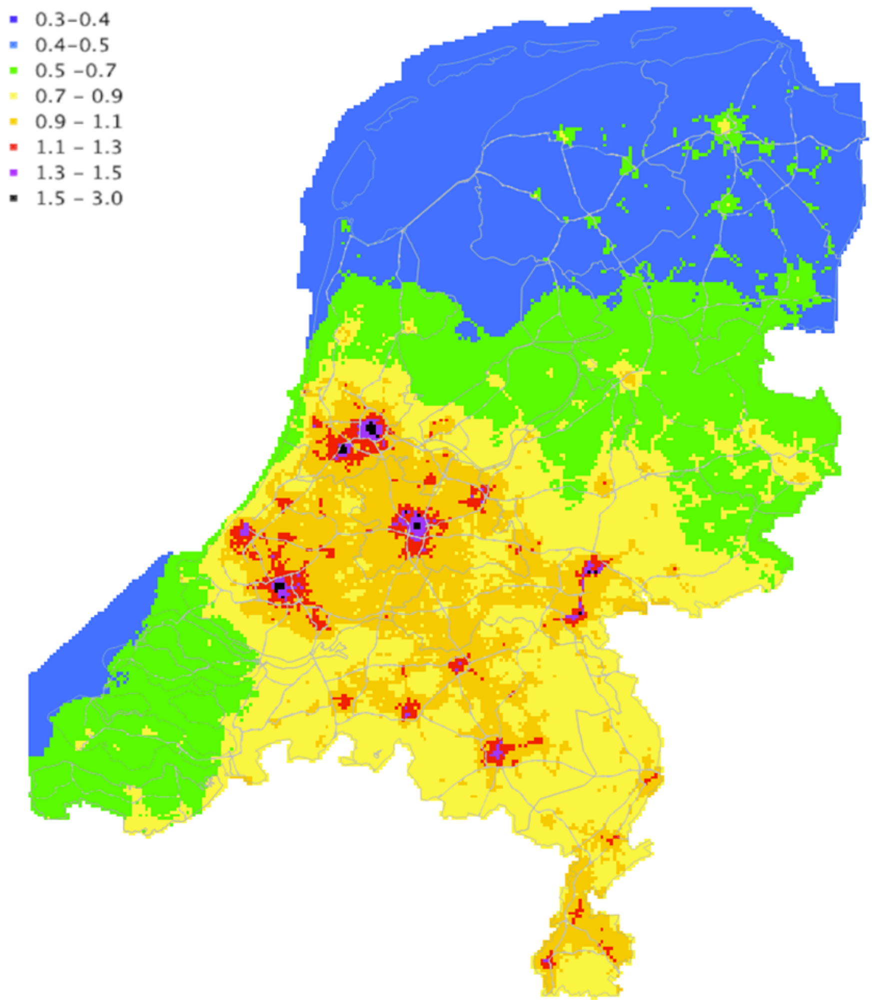


Figure 2 Uncalibrated calculated EC background concentrations for 2012. The scale, in ug/m3, is shown on the left of the figure.

2.2 Calibration

Figure 3 shows a comparison between measured and calculated EC concentrations over the period 2010-2012.

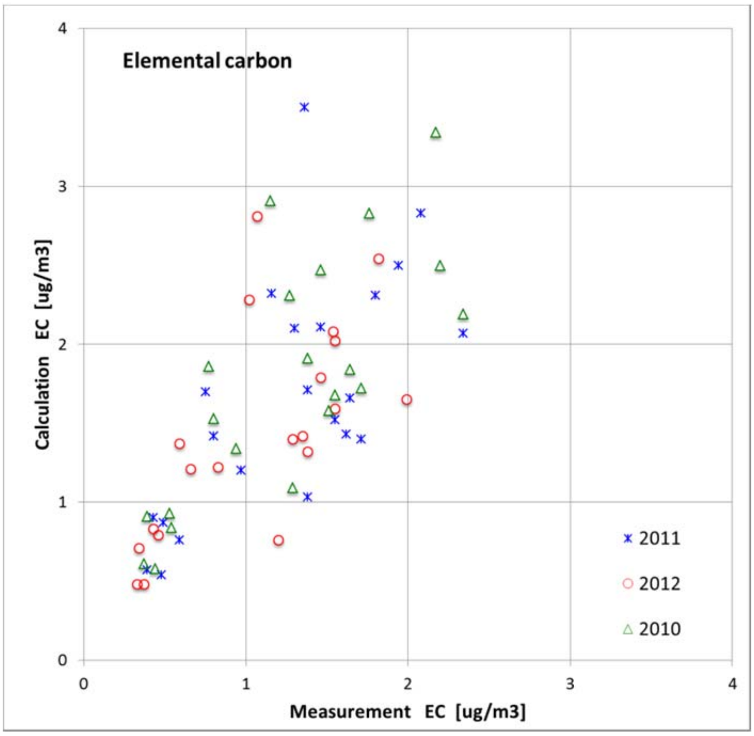


Figure 3 Comparison of uncalibrated calculated and measured EC concentrations.

Figure 3 shows that the calculated concentrations for most points are higher than the measured ones. This overestimation is observed for all three types of monitoring stations, i.e. rural background, urban background as well as traffic stations. Calibration of the calculated values is performed in the steps explained below.

First, it was decided to correct the national background concentrations with a constant amount, independent of the level of the originally calculated concentration: Rural background concentrations with concentrations in the order of 0.7 μg/m3, were corrected with -0.3 μg/m3, and city background levels of roughly 1.5 μg/m3 were adjusted by -0.5 μg/m3.

Additionally, for the year 2012, the measured background concentrations at the available five rural locations were interpolated. The interpolation shows a small gradient (see Figure 4)[3].

[3] Once more robust conversion factors for BS, BC, etc. to EC are available data from stations in neighboring countries may be added to the calibration in order to avoid interpolation artifacts at the Dutch borders.

Figure 4 Interpolation of EC concentrations measured at rural locations for the whole area of the Netherlands.

The interpolated levels were used as minimum values to ensure that the adjusted background levels in the EC map of 2012 could never become too low due to the adjustments themselves.

Next, after applying these corrections for the backgrounds, the EC concentrations measured at street locations were separately compared to the calculations. Based on this comparison, it was decided to scale the traffic contributions by 89%. The value of this adjustment factor depends on the adjustment of the background concentrations. Several combinations of background adjustments and scaling of the traffic contributions can yield roughly similar agreement between measurements and calculations. The combination chosen in this study may change once more data becomes available. This will not affect the absolute concentration levels, but it might change the split over the different concentration contributions (regional, urban, and street increment).

To summarizie, for the present calibration, the following steps were taken:

National background concentrations:
- low concentrations (roughly 0.7 μg/m3) → subtract 0.3 μg/m3;
- higher concentrations (roughly 1.5 μg/m3) → subtract 0.5 μg/m3;
- the above corresponds to the following correction for the full range of EC concentrations: EC_new = 0.75 * EC_original - 0.125;
- the correction for double-counting of highway contributions (needed in the calculations) is scaled by a factor 0.75;
- the minimum value for the EC concentration is limited by the interpolated measurements at rural locations.

Traffic contributions:
- all traffic contributions are scaled by a factor 0.89.

The old and calibrated background concentrations for 2012 for all cells (square kilometers) are compared in Figure 5, below.

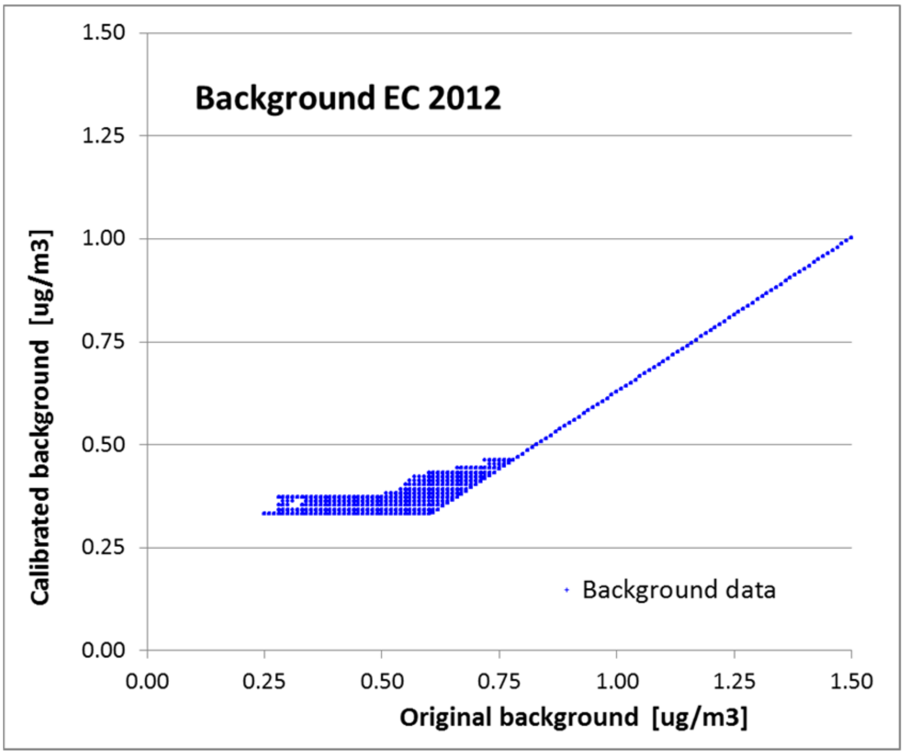


Figure 5 Comparison of calibrated and uncalibrated EC background concentrations.

Almost all the calibrated background concentrations are lower than the original values. For original concentrations below roughly 0.8 µg/m3, the new calibrated value depends on the value of the interpolated measurements at that location.

Using both the calibrated backgrounds and the scaled traffic contributions, new calculations were performed. Figure 6 shows the results of these new calculations for the period 2010-2012.

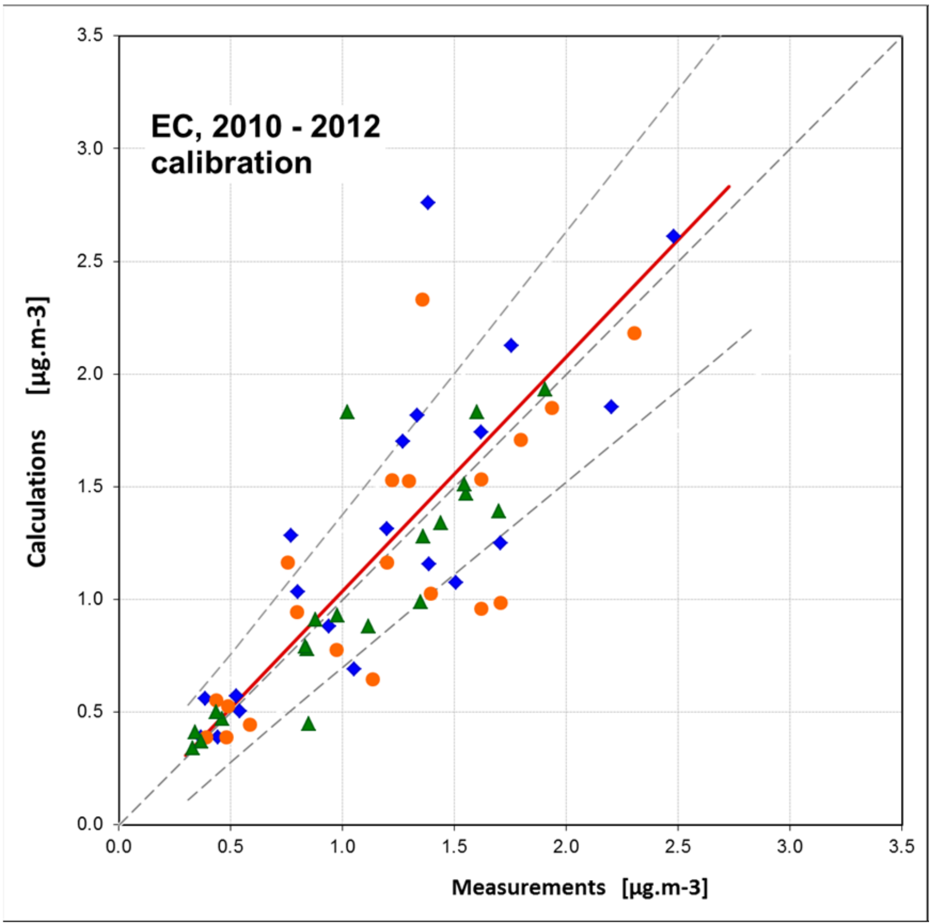


Figure 6 Comparison of calibrated calculated and measured EC concentrations.

With the new calculations, using the calibration as described above, we obtained a satisfactory agreement between measured and calculated EC concentrations. The differences between measured and calibrated concentrations seem to follow a Normal distribution, with a mean of 0.0 µg/m3 and a standard deviation of 0.3 µg/m3. There is a small positive bias in the fit. Excluding the large outlier in the data set results in an equally small negative bias in the fit.

More data is needed to obtain a significantly better fit. In addition, more reference EC measurements are needed to obtain more robust conversion factors for the various optical instruments, and more measurements in different locations are needed to obtain more insights into the various exposure situations.

2.3 EC concentration maps for 2012

As part of the National Collaboration on Air Quality, The RIVM prepare a number of concentration maps for NO2 and PM10. The official air quality maps used for regulatory purposes are created by calculating the concentrations firstly on all 350,000 locations where the air quality has to be assessed due to EU regulations. For exposure maps, the concentrations are calculated at all officially registered addresses. There are almost 8,000,000 addresses in the so-called “Basisregistraties Adressen en Gebouwen (BAG)” in the Netherlands. With the present calibration of the EC concentration background and traffic contributions,

it is also possible to calculate the EC concentrations at the locations of all addresses.
The calculated (calibrated) total background concentrations for the year 2012 are presented in Figure 7.

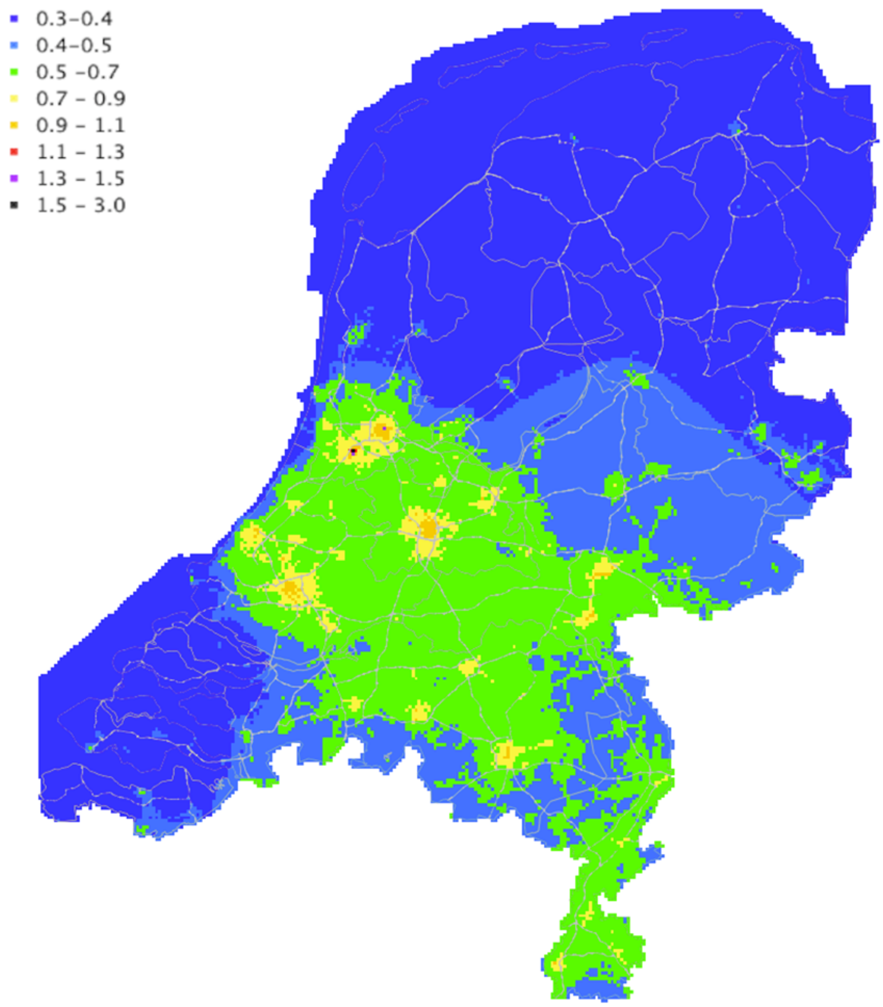


Figure 7 Calculated (calibrated) total background concentrations for the year 2012.

The background levels are lowest in the south-west and north-east of the country. In between there is a (roughly diagonal) band across the country showing higher concentration levels. In the major cities the calculated background concentrations increase significantly. The city centers show levels of up to one microgram per cubic meter.

Subsequently, the EC concentrations were calculated for all 350,000 locations used in the National Collaboration on Air Quality. For this, the contributions from traffic on the national highways and many smaller roads were added to the backgrounds. The results are presented below.

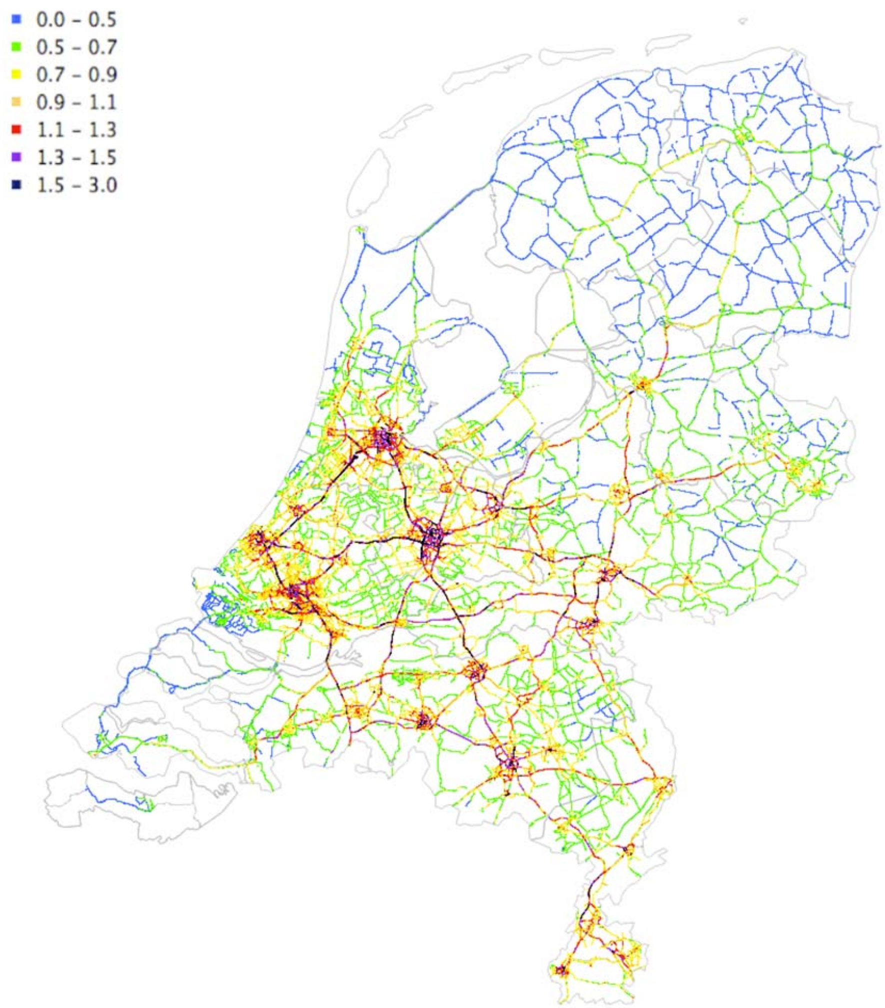


Figure 8 Calculated (calibrated) total concentrations for the year 2012.

Most remaining air quality problems in the Netherlands are in the densely populated western part of the country, around the four largest cities. We therefore show the concentrations for this region (the "Randstad" region) separately in Figure 9.

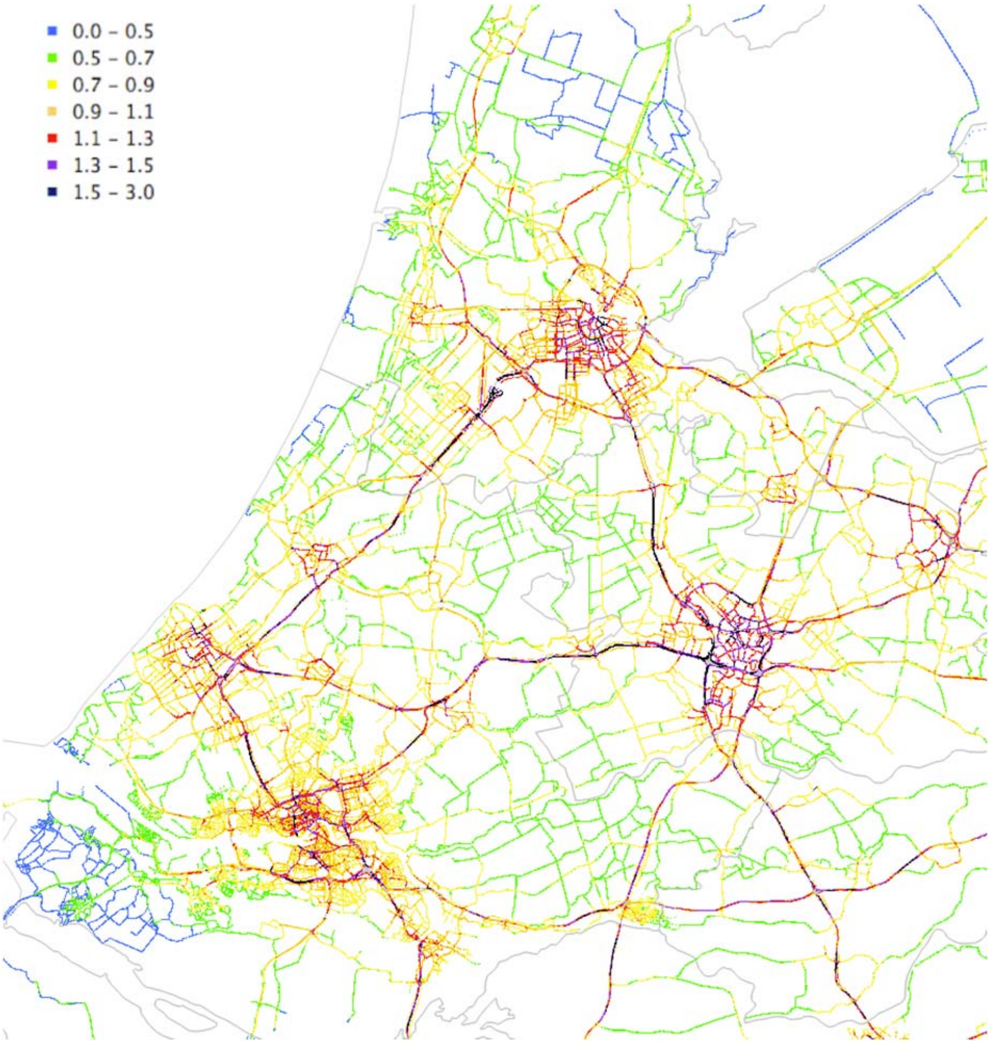


Figure 9 Calculated (calibrated) total concentrations for the year 2012 at the locations of the National Collaboration on Air Quality.

In order to determine the national EC exposure, the concentrations were calculated for all addresses in the Netherlands. The results are presented in Figure 10. Data is not shown for all individual 8,000,000 locations, only for approximately 4% of the locations. Showing all data points would result in too many overlapping data points.

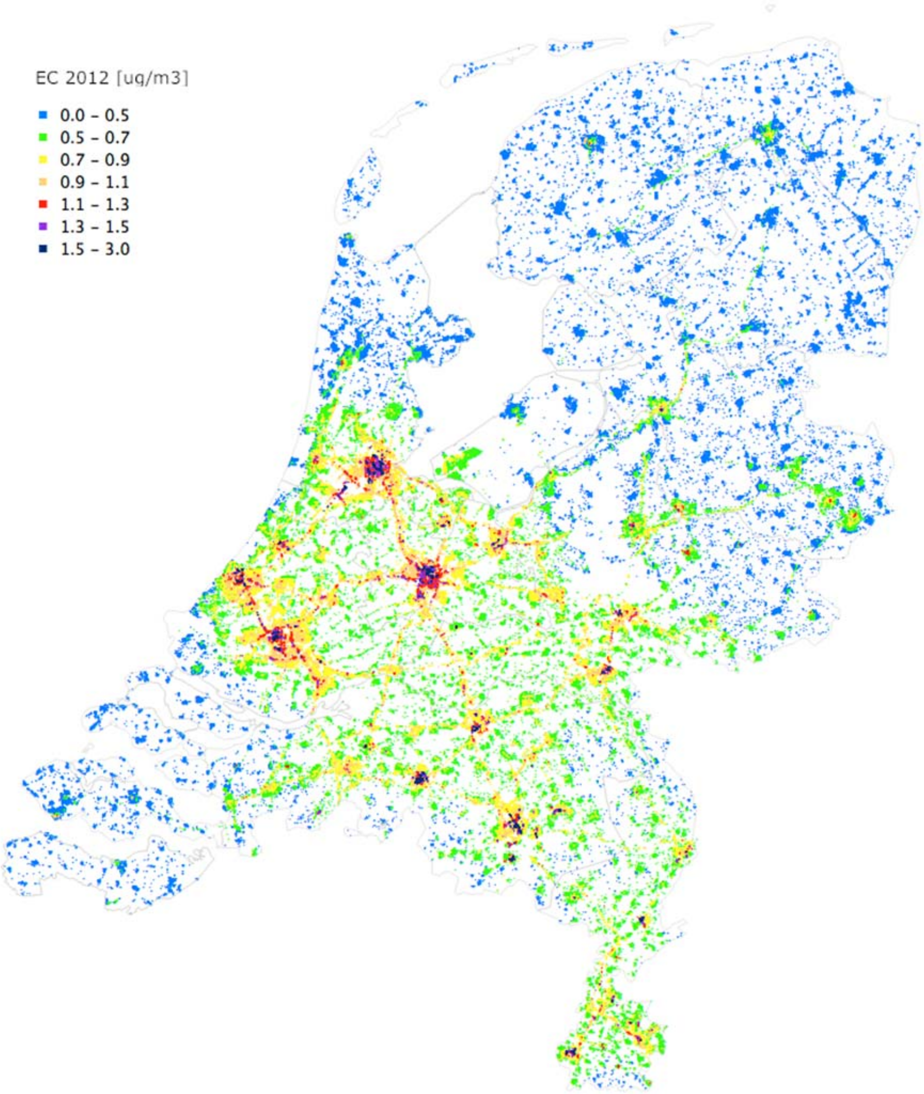


Figure 10 Calculated (calibrated) total concentrations for the year 2012 at address locations. Only 4% of the locations are shown.

The map shows several small regions that are almost white. In these regions the population density is very low. Figure 11 shows the distribution of concentrations, total, background, traffic contributions. Along the highways there are an estimated 1600 addresses where the EC contribution of the traffic is at least 0.5 μg/m3. The contribution is below 1.5 μg/m3 almost everywhere.

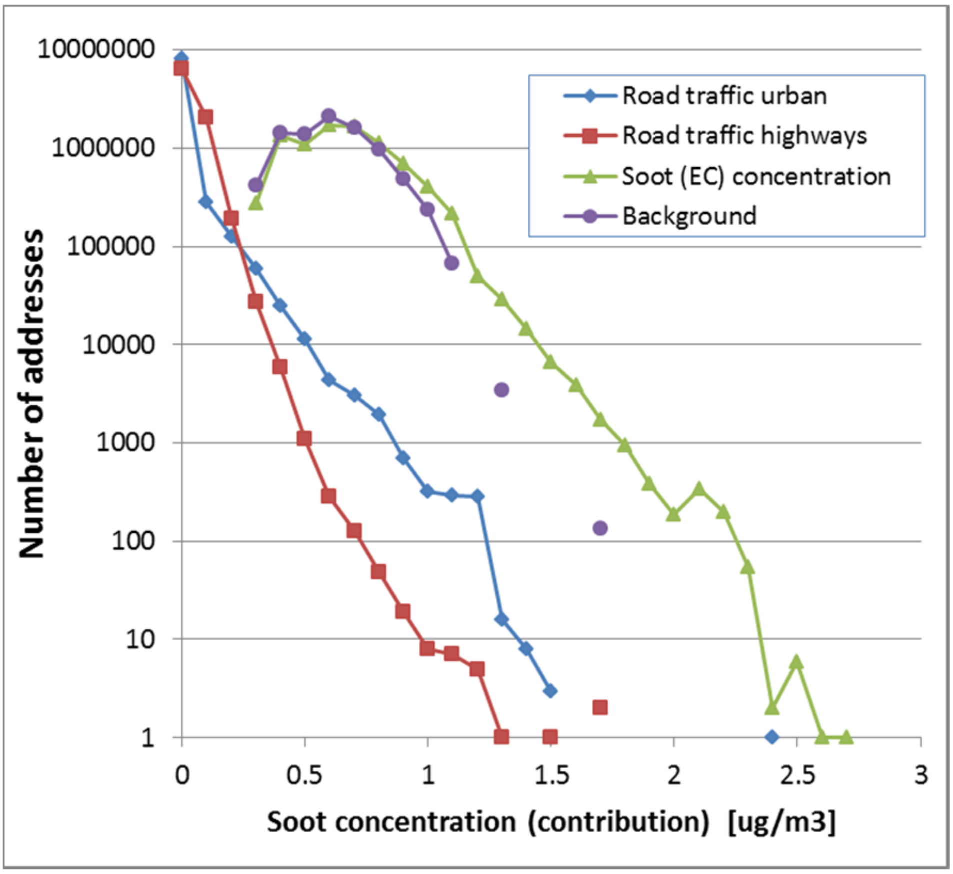


Figure 11 Calculated (calibrated) total EC concentrations for the year 2012, background concentrations and traffic contributions.

In the cities there are an estimated 22,000 addresses where the EC contribution of the local traffic in the streets is at least 0.5 µg/m3. An example of the detailed EC concentrations are shown for a busy city in the Netherlands in Figure 12.

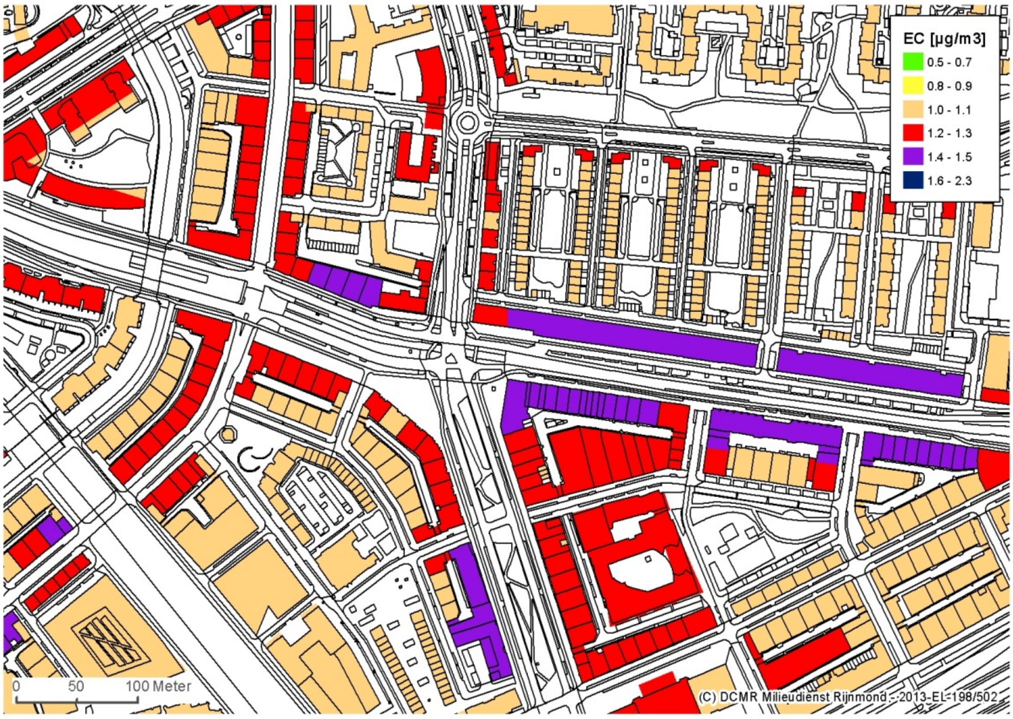


Figure 12 Calculated (calibrated) total EC concentrations for the year 2012 in a busy city.

2.4 Uncertainties

The uncertainties in the available measurements are substantial. Both the black smoke measurements and the black carbon measurements need to be scaled to yield elemental carbon. Furthermore, the bulk of the measurements are located in the western part of the country. There are only a limited number of measurements available in the eastern, northern and southern parts of the country. This results in additional uncertainties in the calibration.

The calculations are also subject to significant uncertainties. As discussed, the available background concentrations significantly overestimate the urban contributions. With the present calibration it is difficult to distinguish deficiencies in the urban background from those in local traffic contributions. More information, both on emission factors and measurements in streets, is needed. As a result the currently calculated distribution of traffic concentration contributions at address locations also has a large level of uncertainty.

2.5 New insights for 2013

In 2014, it became clear that the total EC emissions in the cities, as used in the national calculations, were too high. This contributed to urban concentrations that were found to be too high in our calibration. The new estimate for the emissions resulted in a national background map for 2013 with significantly lower urban concentrations. The new national EC background map for 2013 is shown in Figure 13.

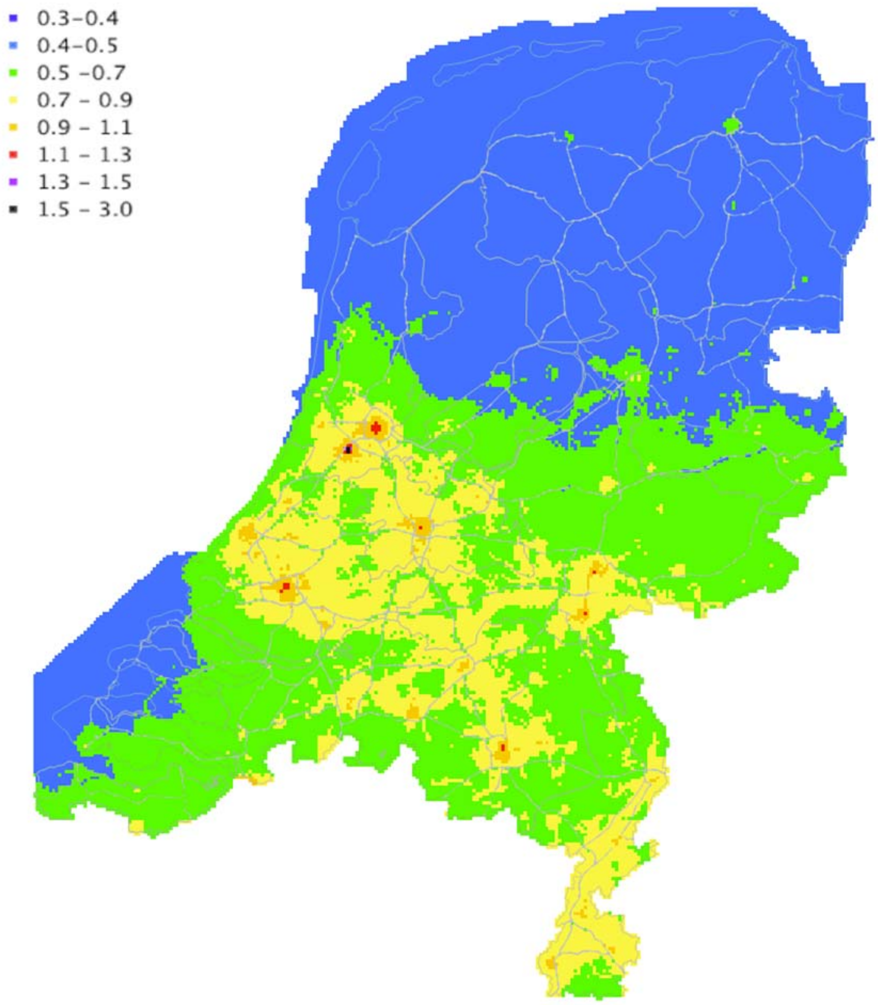


Figure 13 Calculated (calibrated) total background concentrations for the year 2012.

In the spring of 2014, after enough measurements during 2013 became available, a new calibration for 2013 was performed using the new national back ground map. The measured EC concentrations are listed in the appendix.

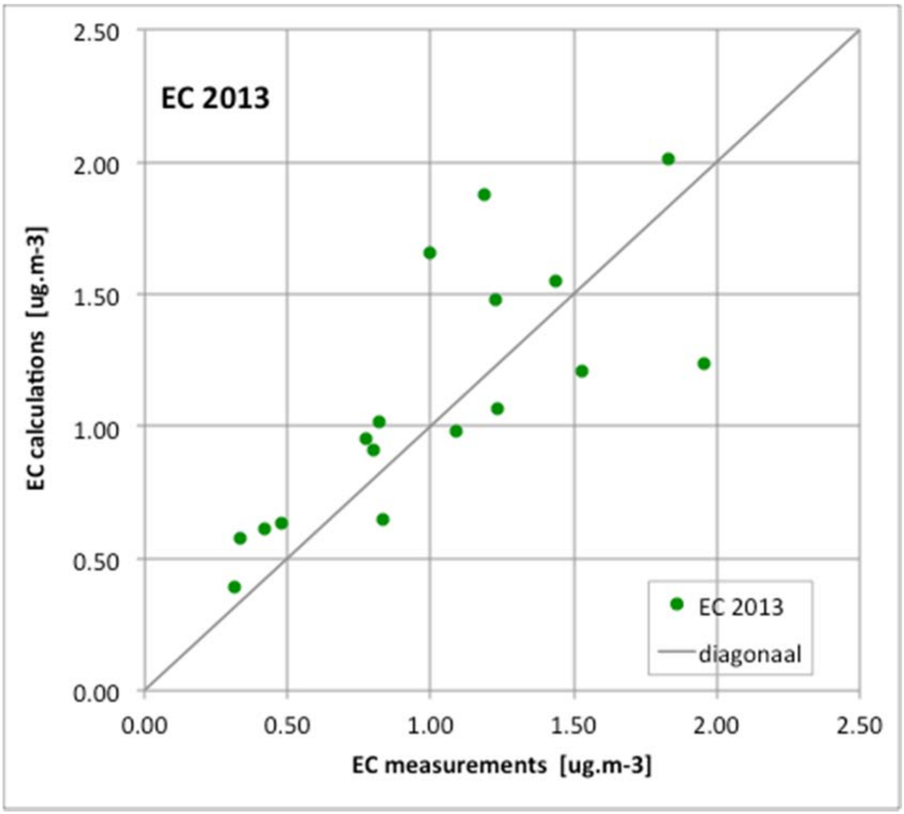
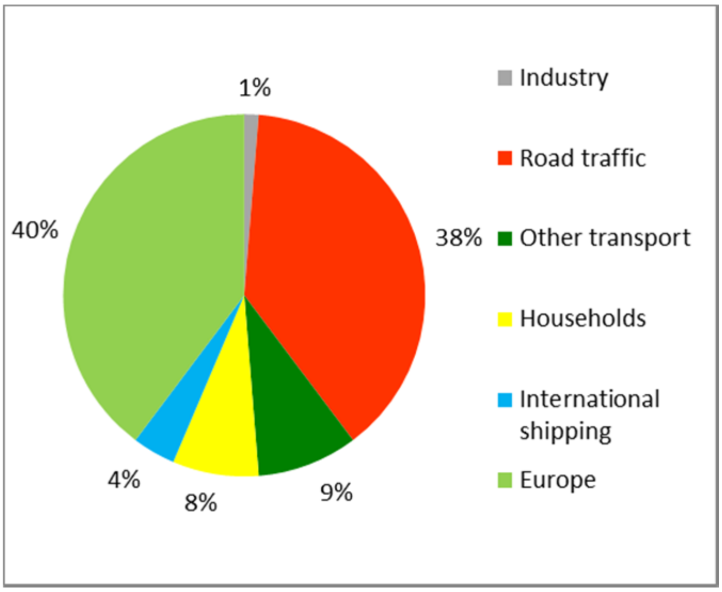


Figure 14 Comparison of calculated and measured EC concentrations for 2013.

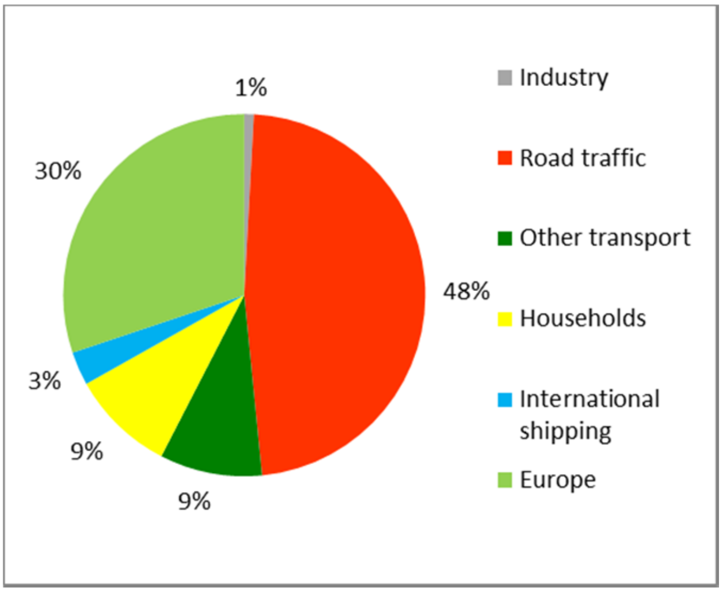
From the comparison, it is clear that calculations based on the recent national EC background concentrations for 2013, combined with the emission factor provided by the ministry in March 2014, show a good agreement with measurements for 2013. In the course of 2014, when new input becomes available from the 'National Collaboration on Air Quality', a new detailed exposure map for 2013 will be developed.

3 Detailed EC emissions and concentrations in the "Rijnmond"

Traffic is an important source of EC in the Netherlands. Even the EC fraction imported from abroad has a substantial traffic part, see Figures 15a and 15b. After European contributions and traffic, household emissions (the combustion of wood) are the largest source of EC in the Netherlands. Figure 15b highlights that traffic is an even more important source in urban agglomerations.



Figuur 15a. EC-concentration contributions (before calibration) in the 2012 1x1 km background map. (Based on Velders et al, 2012).The average values for the whole of the Netherlands are shown.

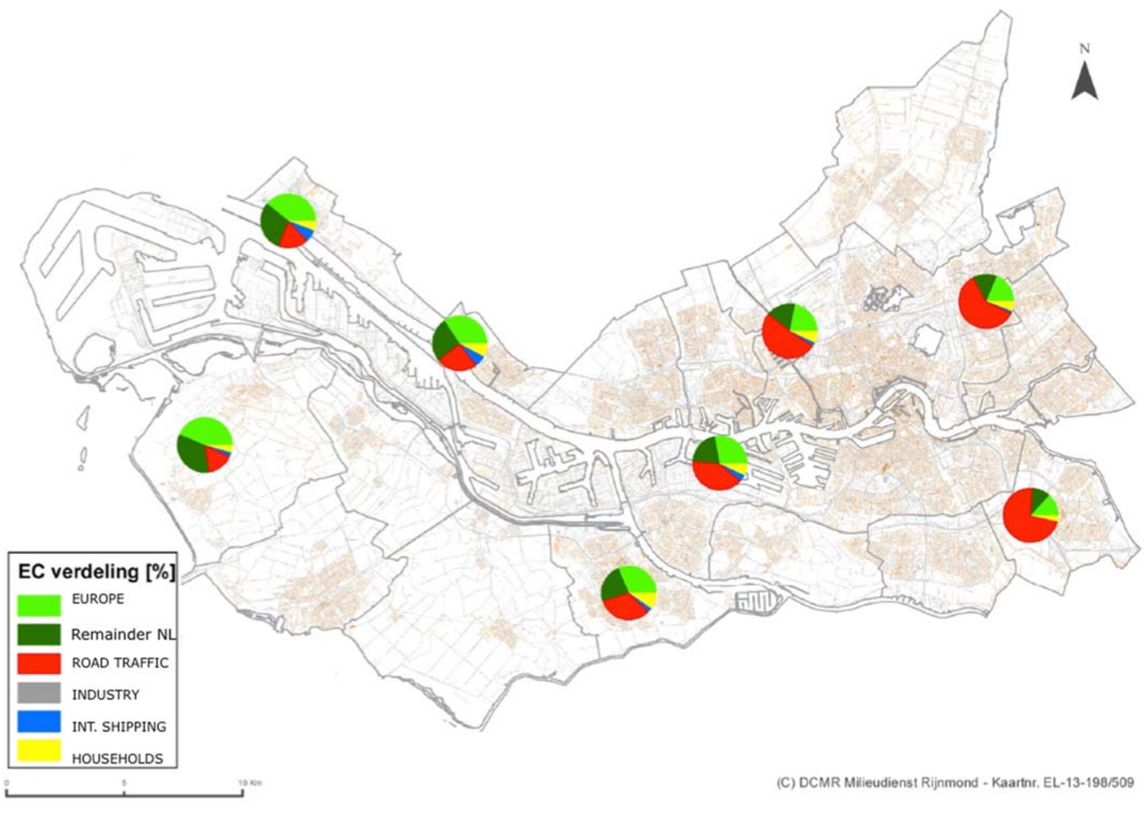


Figuur 15b. EC-concentration contributions (before calibration) in the 1x1 km background map for 2012. (Based on Velders et al, 2012). The average values for urban agglomerations are shown.

Traditional large emitters (e.g. of NOx) like the industry and energy sector are (almost) absent in these charts. This is due to comparatively modest EC emissions of these sources combined with a large emission height, resulting in minor contributions to the ambient concentrations. This even applies to the industrial area of the Rotterdam port (the 'Rijnmond' area). Figure 16 shows the concentration contribution in various parts of the Rijnmond area resulting from a high resolution (100x100m) model calculation.

On the western side of the area at the port entrance, the concentrations are relatively low and hence the contributions from abroad and from outside the study area are relatively high. Towards the east and the Rotterdam city centre, the concentrations increase and the traffic contribution also increases. At the motorway junction 'Ridderster', traffic makes up approximately 75% of the total EC concentration.

Shipping – a typical source in this area - is visible as a small source. Even in this area, residential combustion (mostly from wood) shows up as a considerable concentration contribution.



Figuur 16. Calibrated EC concentration contributions (2012) at different locations in the 'Rijnmond' area (detailed modelling of regional emissions combined with large scale backgrounds).

4 Discussion and recommendations

The comparison of modelled and measured concentrations shows a serious 'gap' between modelled and measured data. This was already observed byKeuken et al in 2013. The calibration of the modelled concentrations as presented in this report is therefore a necessary step to improve the agreement.

The calibration chosen in this study may change once more data becomes available. This will not affect the absolute concentration levels but it might change the split over the different concentration contributions (regional, urban, and street increment). More data is needed to obtain a significantly better fit. Also more reference EC measurements are needed to obtain more robust conversion factors for the various optical instruments, and secondly more measurements in different locations are needed to obtain more insights into the various exposure situations.

Additional research, including measurements, is needed to increase our understanding of the EC concentrations in the Netherlands and to further improve the exposure calculations. Whilst the current approach produces acceptable results for the absolute concentration levels, determining the relative importance of regional and urban background concentrations and the road increment needs further work.

Some items warrant specific attention:

- Low measured rural background concentrations versus higher modelled concentrations, European emissions may be overestimated or the calculated long-range dispersion may be too low.
- The build-up of EC concentrations in a city and the split between urban background and traffic contributions are quite uncertain. The modelling of the urban background should be investigated; more measurements (urban background versus street canyon) are needed.
- Measurements abroad, close to the Dutch border, may be used for additional calibration.
- A more robust conversion of optical measurements into EC is needed.
- In general, more EC measurements in the eastern part of the country are needed.
- More reference EC measurements are needed for an absolute calibration.

5 Literature

Janssen, N.A.H., Hoek, G., Lawson-Simic, M., Fischer, P., Bree van, L., Brink ten, H., Keuken, M., Atkinson, R., Anderson, H.R., Brunekreef, B., Cassee, F., 2011. Black carbon as an additional indicator of the adverse health effects of airborne particles compared to PM10 and PM2.5. Environmental Health Perspectives 119, 1691-1699.

Keuken MP, de Lange R, Hensema A, Denier van der Gon H, Jonkers S, Voogt M, et al. 2011. Verantwoording operationalisering roetindicator. TNO; TNO-rapport December 2011: TNO-060-UT-2011-02161.

Keuken, M.P., P. Zandveld, S. Jonkers, M. Moerman, A.D. Jedynska, R. Verbeek, A. Visschedijk, S. van den Elshout, P. Panteliadis and G.J.M. Velders. 2013. Modelling elemental carbon at regional, urban and traffic locations in The Netherlands.http://dx.doi.org/10.1016/j.atmosenv.2013.03.010

Velders, G.J.M., Aben, J.M.M., Jimmink, B.A., Geilenkirchen, G.P., van der Swaluw, E., de Vries, W.J., Wesseling, J., van Zanten, M.C., 2012. Large-scale Air Quality Concentration and Deposition Maps of the Netherlands. RIVM, Bilthoven, The Netherlands. Report 680362002. www.rivm.nl (in Dutch).

Appendix Station details and concentrations

Station number	Location	Type	Owner	Method
131	Vredeweg, Vredepeel	Regional	RIVM	SX-200
444	Vogelaarsdreef, De Zilk	Regional	RIVM	SX-200
538	Medemblikkerweg, Wieringerwerf	Regional	RIVM	SX-200
738	Riemterdijk, Wekerom	Regional	RIVM	SX-200
929	Noorderdiep, Valthermond	Regional	RIVM	SX-200
003	Nieuwendammerdijk, Amsterdam	Urban	GGD-A	SX-200
014	Overtoom, Amsterdam	Urban	GGD-A	SX-200
241	Bastenakenstraat, Breda	Urban	RIVM	SX-200
488	Zwartewaalstraat, Rotterdam	Urban	DCMR	MAAP
494	Schiedam	Urban	DCMR	MAAP
496	Berghaven, Hoek van Holland	Urban	DCMR	MAAP
007	Einsteinweg, Amsterdam	Traffic	GGD-A	SX-200
012	Van Diemenstraat, Amsterdam	Traffic	GGD-A	SX-200
017	Stadhouderskade, Amsterdam	Traffic	GGD-A	SX-200
240	Tilburgseweg, Breda	Traffic	RIVM	SX-200
433	Floreslaan, Vlaardingen	Traffic	RIVM	SX-200
448	Bentinckplein, Rotterdam	Traffic	RIVM	SX-200
483	A15 Botlek, Botlek	Traffic	DCMR	MAAP
487	Pleinweg, Rotterdam	Traffic	DCMR	MAAP
490	Maasboulevard, Rotterdam	Traffic	DCMR	MAAP
491	Overschie, Rotterdam	Traffic	DCMR	MAAP
492	Vasteland, Rotterdam	Traffic	DCMR	MAAP
638	Vleutenseweg, Utrecht	Traffic	RIVM	SX-200
641	A2 Breukelen, Breukelen	Traffic	RIVM	SX-200

Station number	EC 2010	EC 2011	EC 2012	EC 2013
Rural				
131	0.54	0.59	0.46	0.48
444	0.39	0.43	0.34	0.33
538	0.37	0.39	0.33	0.31
738	0.53	0.49	0.43	0.42
929	0.44	0.48	0.37	-
Urban				
003	0.80	0.80	0.66 (0.84)	0.80
014	0.77	0.75	0.59 (0.88)	0.82
241	0.94	0.97	0.83	0.78
488	1.20	1.20	0.98	-
494	1.39	1.40	1.12	1.09
496	1.05	1.14	0.85	0.83
Traffic				
007	2.00	1.97	1.77 (2.02*)	1.76
012	1.27	1.30	(1.42*)	1.23
017	1.38	1.36	1.07 (1.60*)	1.19
240	1.71	1.71	1.35	1.23
433	1.51	1.62	-	-
448	1.76	1.94	1.55	1.44
483	2.74	2.63	2.12	1.96
487	2.48	2.31	1.91	1.83
490	1.33	1.22	1.36	-
491	-	-	-	1.53
492	1.62	1.62	1.44	-
638	2.20	1.80	1.54	-
641	1.15	1.16	1.02	0.99

J.P. Wesseling et al.

RIVM report 2014-0128

Dit is een uitgave van:

Rijksinstituut voor Volksgezondheid en Milieu
Postbus 1 | 3720 BA Bilthoven
www.rivm.nl

December 2014

De zorg voor morgen begint vandaag

007595