SMED Report No 177 2015

Swedish Environmental Emissions Data

New method of calculating emissions from tyre and brake wear and road abrasion

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Contract No. 2250-15-002

Commissioned by the Swedish Environmental Protection Agency

Published at: www.smed.se

Publisher: Swedish Meteorological and Hydrological Institute

Address: SE-601 76 Norrköping, Sweden

Start year: 2006

ISSN: 1653-8102

SMED is short for Swedish Environmental Emissions Data, which is a collaboration between IVL Swedish Environmental Research Institute, SCB Statistics Sweden, SLU Swedish University of Agricultural Sciences, and SMHI Swedish Meteorological and Hydrological Institute. The work co-operation within SMED commenced during 2001 with the long-term aim of acquiring and developing expertise within emission statistics. Through a long-term contract for the Swedish Environmental Protection Agency extending until 2014, SMED is heavily involved in all work related to Sweden's international reporting obligations on emissions to air and water, waste and hazardous substances. A central objective of the SMED collaboration is to develop and operate national emission databases and offer related services to clients such as national, regional and local governmental authorities, air and water quality management districts, as well as industry. For more information visit SMED's website www.smed.se.

SMED utgör en förkortning för Svenska MiljöEmissionsData, som är ett samarbete mellan IVL, SCB, SLU och SMHI. Samarbetet inom SMED inleddes 2001 med syftet att långsiktigt samla och utveckla den svenska kompetensen inom emissionsstatistik kopplat till åtgärdsarbete inom olika områden, bland annat som ett svar på Naturvårdsverkets behov av expertstöd för Sveriges internationella rapportering avseende utsläpp till luft och vatten, avfall samt farliga ämnen. Målsättningen med SMED-samarbetet är främst att utveckla och driva nationella emissionsdatabaser, och att tillhandahålla olika tjänster relaterade till dessa för nationella, regionala och lokala myndigheter, luft- och vattenvårdsförbund, näringsliv m fl. Mer information finns på SMEDs hemsida www.smed.se.

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Sammanfattning

Emissionsfaktorerna för partiklar från vägslitage utreddes under 2014 som en följd av Trafikverkets kommentarer angående emissionsfaktorn för $PM_{2.5}$ för dubbdäck. Utredningen resulterade i reviderade emissionsfaktorer för vägslitage, och det konstaterades också att Sverige borde basera sina utsläpp från däck- och bromsslitage samt vägslitage på en mer robust modell som även tar hänsyn till meteorologi.

I detta projekt användes modellsystemet SIMAIR till att utveckla en ny metod för beräkning av emissioner från vägtrafikens fordons- och vägslitage i Sverige. Den nya metoden tar hänsyn till flera faktorer som inte har tagits hänsyn till i tidigare utsläppsberäkningar, såsom meteorologi, regionala variationer och uppmätta PM_{10}-halter i trafiknära miljöer (gaturum) för verifiering av modellen.

För åren 2008-2014 erhölls årliga emissionsfaktorer för PM_{10} för åtta olika regioner som täcker hela landet. Medelvärdet av emissionsfaktorerna per region varierade mellan 120 mg km^{-1} i södra Sverige och 200 mg km^{-1} i region Öst. De resulterande emissionerna är generellt något högre jämfört med i tidigare beräkningar.

Den nya metoden bedöms förbättra kvaliteten i Sveriges utsläpps-beräkningar för fordons- och vägslitage avsevärt. För att ytterligare förbättra metoden föreslås jämförande beräkningar när NORTRIP-modellen har implementerats i SIMAIR, och att automatisera metoden så att det är möjligt att årligen uppdatera emissionsfaktorerna med fler väglänkar som grund.

Summary

In 2014, the Swedish emission factors used for particulate matter from road abrasion were reviewed as a consequence of remarks made by the Swedish Transport Administration (STA) regarding $PM_{2.5}$ emission factors for studded tyres. The review resulted in revised emission factors from road abrasion, and it also concluded that Sweden should base its estimates from tyre and brake wear and road abrasion on a more robust model that also takes meteorology into account.

In the current project, the SIMAIR model system was used to develop a new method to estimate non-exhaust PM emissions from road traffic in Sweden. The new methodology takes into account several factors that have not been considered in previous estimates, such as meteorology, regional variations and measured PM_{10} concentrations in urban street canyons for model verification.

Annual emission factors for PM_{10} were obtained for eight different regions covering all of Sweden for the years 2008-2014. The average emission factors per region vary between 120 mg km^{-1} in southern Sweden and 200 mg km^{-1} in region Öst (eastern Sweden). The resulting emissions are generally somewhat higher than previous estimates.

The new method is considered to substantially improve the quality of the Swedish non-exhaust PM emission estimates. The method can be further improved when the NORTRIP model has been implemented in SIMAIR, and by automatizing the method to enable annual updates of the emission factors that are representative for more road links.

Background

In the beginning of 2014, the Swedish Transport Administration observed that the emission factors that were used within SMED to calculate $PM_{2.5}$ from road abrasion due to use of studded tyres seemed unlikely high compared to the results from several recent scientific studies. This led to an investigation within SMED with the purpose of updating the emission factor (Jerksjö 2014). At the same time the emission factors for $PM_{2.5}$ from non-studded tyres and PM_{10} and TSP for both studded tyres and non-studded tyres were reviewed. The updated emission factors were used in the Swedish air emission inventory for submission 2015.

However, one conclusion from the review was that Sweden should develop a more robust model for estimates of particle emissions from tyre and brake wear and road abrasion, considering also the impact of meteorology on the emissions.

Two different models for non-exhaust particles have been discussed; NORTRIP and the model for non-exhaust particles in SIMAIR. NORTRIP is an emission model for road dust that recently has been developed within the framework of a Nordic research program. SIMAIR is a national model system for calculation of air quality in Sweden that includes e.g. annual updates of meteorology and use of studded tyres, which makes it possible to regularly update the emission factors in a rational way. The model system SIMAIR is also used within the research program SCAC (http://www.scac.se).

Compared to the resuspension model in SIMAIR, the NORTRIP model includes more physical processes, but requires more input data. NORTRIP is not yet implemented in an operative modelling system, which is why calculations only can be performed for a few separate streets and years. The advantage of choosing SIMAIR is that the model already exists in an operational production environment, which enables regular calculations for several traffic environments and for several years.

Project objective

The aim of the project is to develop a new method of calculating national emission factors of TSP, PM_{10} and $PM_{2.5}$ from tyre and brake wear and road abrasion, based on the model system SIMAIR.

Methodology

The model system SIMAIR

SIMAIR is a coupled model system with databases and dispersion models operating on different spatial scales, which enable the concentrations of air pollutants to be divided into local, urban and regional contributions. There are applications for road traffic (SIMAIR-road and SIMAIR-intersection) and for small-scale residential wood combustion (SIMAIR-rwc). An outline of the model is shown in Figure 1, and a summarizing description of the SIMAIR model is given below. Further details can be found in Omstedt et al. (2011) and Gidhagen et al. (2009).

Through a user-friendly web-based interface, all Swedish municipalities can use the system to assess whether concentration levels of particles (PM_{10}), nitrogen dioxide (NO_2), benzene, and carbon monoxide (CO) are in compliance with the limit values of the EU Air Quality Directive (2008/50/EC) and the environmental objectives in Sweden. The model is used in many different applications such as mapping of air quality, scenario studies and epidemiological studies. Yearly updates are made of road traffic, emissions, meteorology and background concentrations.

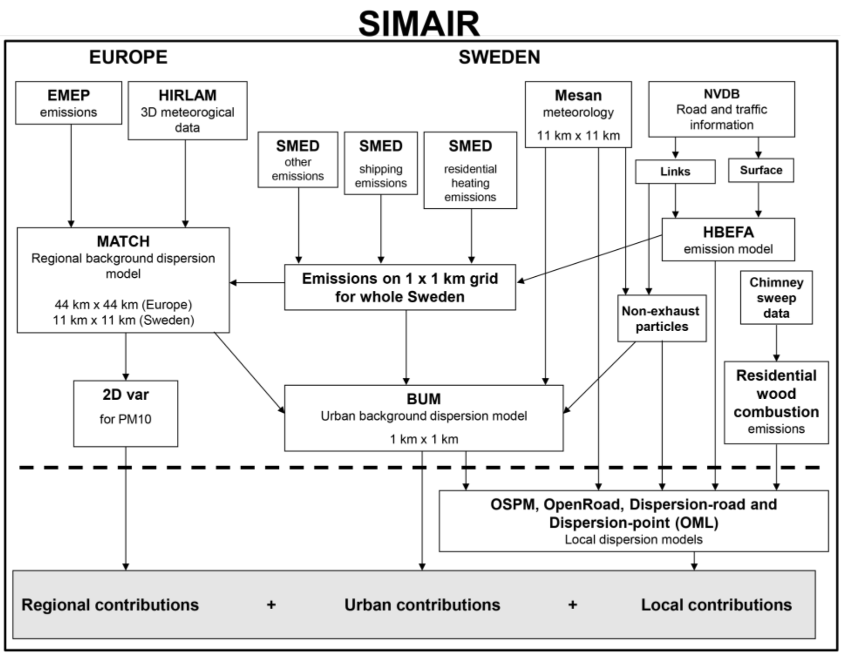

Figure 1. Outline of the databases and models in the SIMAIR system. The dashed line separates stored data and pre-calculated concentrations from larger-scale models (above the dashed line) and concentrations calculated from the web-based user interface (below the dashed line).

Regional background concentrations

Calculations of regional background concentrations are performed using the MATCH multi-scale atmospheric transport and chemistry model (Robertson et al., 1999; Andersson et al., 2007). MATCH is driven by meteorological data from the HIRLAM weather forecast model (44×44 km^2), and emission data from the EMEP inventory (50×50 km^2). Since the MATCH model does not yet include secondary inorganic aerosols, PM_{10} measurements from a few rural stations in Scandinavia are also included by using two-dimensional variational data assimilation.

Urban background concentrations

Urban background concentrations, on a 1×1 km^2 grid, are simulated with the urban model SWE-BUM (Andersson et al., 2011). The SWE-BUM model uses geographical distributed emissions provided by SMED (1×1 km^2) and meteorological data from the routine objective analysis Mesan system (Häggmark et al., 2000) with a spatial resolution of 11×11 km^2 and a time resolution of 1 hour.

Two model approaches are used for the dispersion. For ground-level sources, such as road traffic, a joint approach with a back-trajectory model in an upward influence area is used. A Gaussian point source model is used for tall stack emissions.

Local concentrations

On the local scale, traffic data from the Swedish National Road Database (NVDB) are used to obtain up-to-date information about road links such as coordinates, functional road class, speed limits and the number of lanes. A parallel database is used for traffic intensity; measured for state-owned roads and simulated for municipal roads (for further information see Gidhagen et al., 2009). Emission factors for exhaust emissions are derived from HBEFA[1] and non-exhaust PM-emissions are calculated from a road dust emission model described in more detail in the next section.

Different local dispersion models are applied depending on the environment. For street canyons (i.e. surrounded by buildings along one or both sides), the OSPM model is used (Berkowicz, 2000). If the traffic environment is not surrounded by buildings or obstacles (open road conditions), a simplified Gaussian model for infinite line sources is used. For more complex traffic situations, such as road crossings, a model for finite line sources is used.

[1] http://www.hbefa.net

SIMAIR has been validated against monitoring data with good results (Andersson and Omstedt, 2009; Andersson and Omstedt, 2013).

The model for non-exhaust particles in SIMAIR

In SIMAIR, a semi-empirical model is used for non-exhaust traffic emissions (Omstedt et al., 2005). Two time dependent equations are solved. The first equation describes the budget of the road dust layer due to road wear, sanding and vehicle-induced turbulence. The second equation describes the budget of the surface moisture due to precipitation, evaporation and runoff. The equations are connected by the surface moisture. During wet conditions, a road dust layer is built up from road wear which strongly depends on the use of studded tyres and road sanding. The dust layer is reduced during dry road conditions by suspension of particles due to vehicle-induced turbulence. The dust layer is also reduced by wash-off due to precipitation. Direct non-tailpipe vehicle emissions due to the wear and tear of the road surface, brakes and tyres are accounted for as constant emission factors.

The model is able to account for the main features in the PM_{10} variability, especially the peak in PM_{10} concentrations in late winter and early spring that is commonly experienced in the Nordic countries where studded tyres are used. A similar model is used in Finland (Kauhaniemi et al., 2011).

The emission factor is calculated for the total vehicle distribution for each street, i.e. not separately for different vehicle types such as passenger cars, heavy duty vehicles etc. Heavy duty vehicles are assumed to contribute less to the non-exhaust direct emissions due to a lower use of studded tyres.

Since $PM_{2.5}$ and TSP are not yet included in SIMAIR, it is only possible to obtain emission factors for PM_{10} from SIMAIR's output data. However, emission factors for $PM_{2.5}$ and TSP are calculated with relationships between PM_{10} and $PM_{2.5}$/TSP according to the literature (see section Calculation of emission factor for $PM_{2.5}$ and TSP).

Furthermore, emission factors include both direct and indirect emissions (resuspension is included).

Regions and streets

There are large gradients in the road abrasion emissions in Sweden, due to varying meteorological conditions and different use of studded tyres. In order to capture these different features, the country is divided into different regions. In each region, emission factors and vehicle-kilometers are calculated according to SIMAIR. This information, together with national vehicle-kilometers, is used to calculate non-exhaust emissions (see the Result section).

The different regions are given in Table 1. The share of studded tyre use is only available in SIMAIR according to the different National Transport Administration regions (TRV-regions), thus, the division of regions in this study follows the TRV-regions. However, Värmland is separated from region Väst, and Småland is separated from region Syd, due to large variation of meteorological conditions within these regions. In SIMAIR the use of studded tyres for each TRV-region is based on Däckbranschens Informationsråd[2] and is updated yearly.

Table 1. Regions studied for calculation of non-exhaust emissions within this study.

Region	Included counties (län)
Norr	Norrbotten, Västerbotten
Mitt	Jämtland, Västernorrland, Gävleborg, Dalarna
Stockholm	Stockholm, Gotland
Öst	Uppsala, Västmanland, Örebro, Södermanland, Östergötland
Värmand	Värmland
Väst	Västra Götaland, Halland
Småland	Jönköping, Kronoberg, Kalmar
Syd	Blekinge, Skåne

In each region, calculations of emission factors are made for a few well documented streets according to Table 2. Regarding the selection of streets, emissions from both inner-city streets as well as transit routes have been calculated in order to obtain representative weighted average of emission factors.

Input data, such as traffic data (traffic intensity, share of heavy duty vehicles, number of lanes etc.) and street canyon configuration, have been updated for all streets in the SIMAIR-calculations. The information has been obtained from measurements and assessments by the municipalities.

[2] http://www.dackinfo.se/wp-content/uploads/2012/04/Dackundersokning_PV_vinter_2015.pdf

More details are given in Andersson and Omstedt (2009), Omstedt et al., (2012) and Andersson and Omstedt (2013).

For almost all streets, SIMAIR has been validated against monitoring data of PM_{10} for one or more years. The calculated concentrations have been corrected based on comparisons with monitoring data (bias correction). In this study this correction is also made for the calculation of emission factors. Hence, an assumption is made that there is a linear relationship between emissions and total concentrations, and that the discrepancy between the modelling and measurements is mainly caused by the local traffic. However, even though this is a simplification, the bias correction is expected to improve the results in comparison with no use of correction.

Calculation of emission factors for $PM_{2.5}$ and TSP

In order to calculate emission factors for $PM_{2.5}$ and TSP, relationships between PM_{10} and $PM_{2.5}$ and TSP emission factors, respectively, according to the literature have been used. The emission factor for $PM_{2.5}$ is calculated as PM_{10} times a factor of 0.2. This factor is based on data from Hornsgatan in Sweden (Ketzel et al, 2007) and is also used in the on-going national research programme SCAC.

For TSP, the Tier 1 fractions of PM_{10}/TSP according to the EMEP/EEA Guidebook 2013 have been used (0.76 for tyre and brake wear and 0.50 for road abrasion).

The emission factor for vehicle component wear (tyre and brake wear) is estimated at approximately 10 mg vkm^{-1}, based on data discussed in Omstedt et al. (2005).

Table 2. Streets in each region that are used for calculating a weighted average of the non-exhaust emission factor.

Region	Municipality	Street
Norr	Luleå	Sandviksgatan
	Luleå	Smedjegatan
	Skellefteå	E4 Viktoriagatan
	Umeå	Västra Esplanaden
Mitt	Falun	Gruvgatan
	Gävle	Staketgatan
	Örnsköldsvik	Centralesplanaden
	Östersund	Färjemansgatan
	Sundsvall	Strandgatan
Stockholm	Sollentuna	E4 Häggvik
	Stockholm	E4 Lilla Essingen
	Stockholm	Hornsgatan indata
	Stockholm	Sveavägen
	Stockholm	Norrlandsgatan
Öst	Uppsala	Kungsgatan
	Västerås	Stora gatan
	Örebro	Rudbecksgatan
	Norrköping	Kungsgatan
	Enköping	E18 Testsite
Värmland	Karlstad	Hamngatan
	Sunne	Storgatan
Väst	Göteborg	E6 at Gårda
	Göteborg	Sprängkullsgatan
	Trollhättan	Drottninggatan
	Halmstad	Viktoriagatan
Småland	Växjö	Storgatan
	Jönköping	Barnarpsgatan
	Kalmar	Södra vägen
Syd	Malmö	Dalaplan
	Helsingsborg	Malmöleden

Calculation of national and regional vehicle-kilometers

Since the road network implemented in SIMAIR does not include all roads, the distribution of vehicle-kilometers in the different regions is based on national data of vehicle-kilometers from the Swedish Transport Administration, in order to account for the total number of national vehicle-kilometers. Regional and national vehicle-kilometers are included in Appendix B.

The national total number of vehicle-kilometers from the emission database in SIMAIR is lower (approximately 20 %) than the national total according to the Swedish Transport Administration. This is expected since all municipal roads as well as many smaller roads in rural areas are not included in SIMAIR.

Calculation of emissions 1990-2014

Emissions are calculated using the regional emission factors with corresponding vehicle-kilometers (adjusted with national vehicle kilometers as described above).

Since emission factors are calculated only from 2008 onwards, regional emission factors for 1990 – 2007 are estimated using the average regional emission factor for 2008-2014.

Results and discussion

Emission factors for tyre and brake wear and road abrasion

In Figures 2 through 9, the PM_{10} emission factors calculated by SIMAIR are shown for each region and street. The emission factor represents the total non-exhaust emission factor (tyre and brake wear and road abrasion), corrected based on a comparison with ambient air monitoring data according to the previous section (Regions and streets). Numerical values are given in Appendix A.

According to the plots it can be concluded that the weighted average of the PM_{10} emission factor has a maximum in region Öst (an average of 260 mg km^{-1} for the years 2008-2014). The reason is likely a combination of a large use of studded winter tyres and meteorological conditions with more occasions with dry road conditions. In northern Sweden the use of studded winter tyres is also large; however, more snow implies lower non-exhaust emissions (an average of 200 mg km^{-1} for the years 2008-2014). In southern Sweden (region Syd), the use of studded winter tyres is lower and thus the non-exhaust emission are lower (an average of 120 mg km^{-1} for the years 2008-2014).

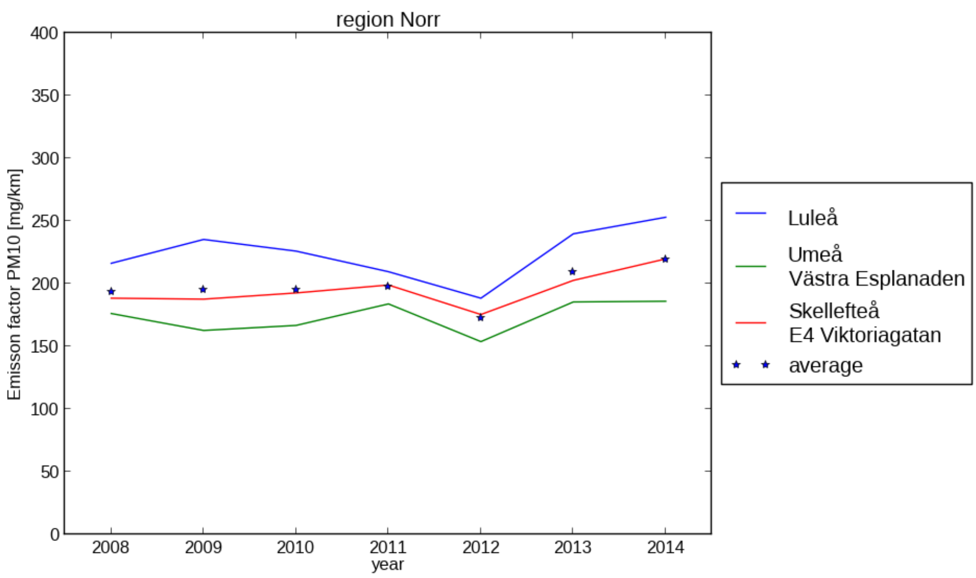

Figure 2. Calculated non-exhaust emission factor of PM_{10} by SIMAIR for the different streets in region Norr, corrected against monitoring data. In each region, a weighted average is calculated. The non-exhaust emission factor includes both emissions from tyre and brake wear and road abrasion.

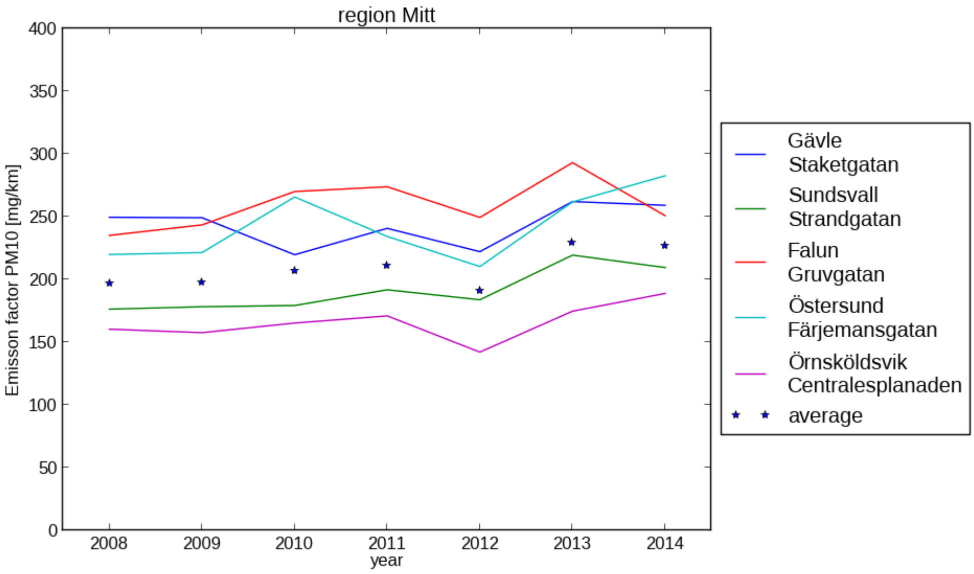

Figure 3. The same as Figure 2, but for region Mitt.

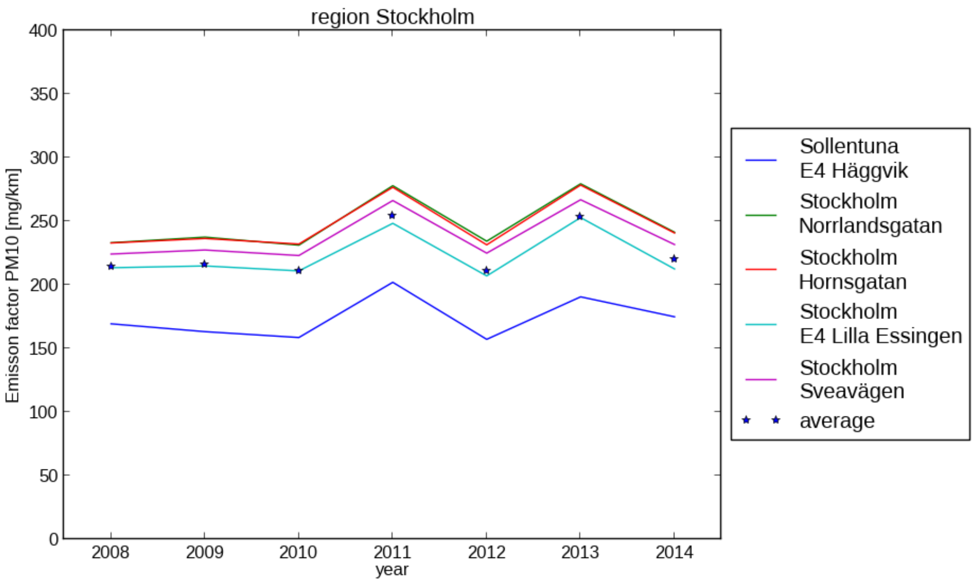

Figure 4. The same as Figure 2, but for region Stockholm.

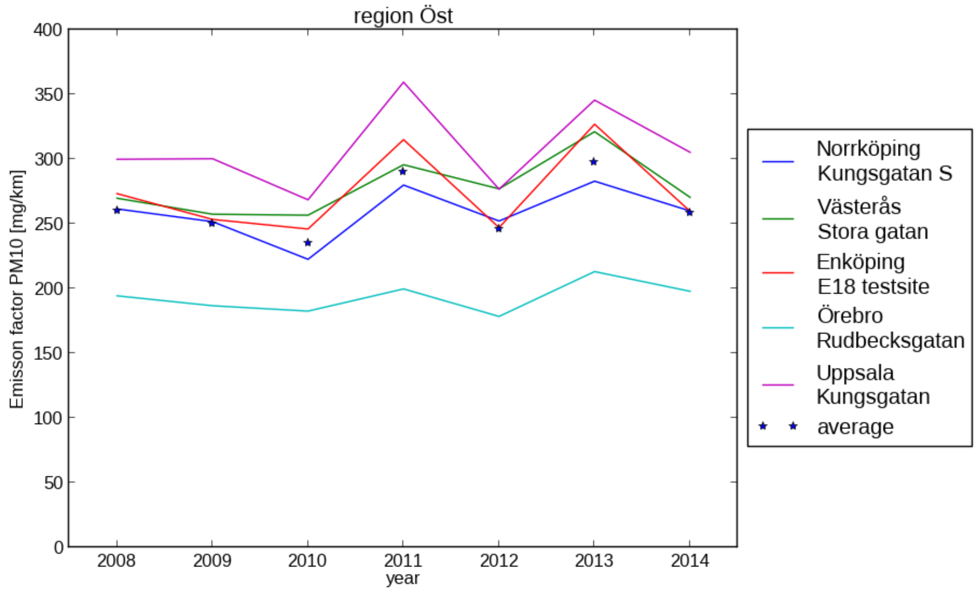

Figure 5. The same as Figure 2, but for region Öst.

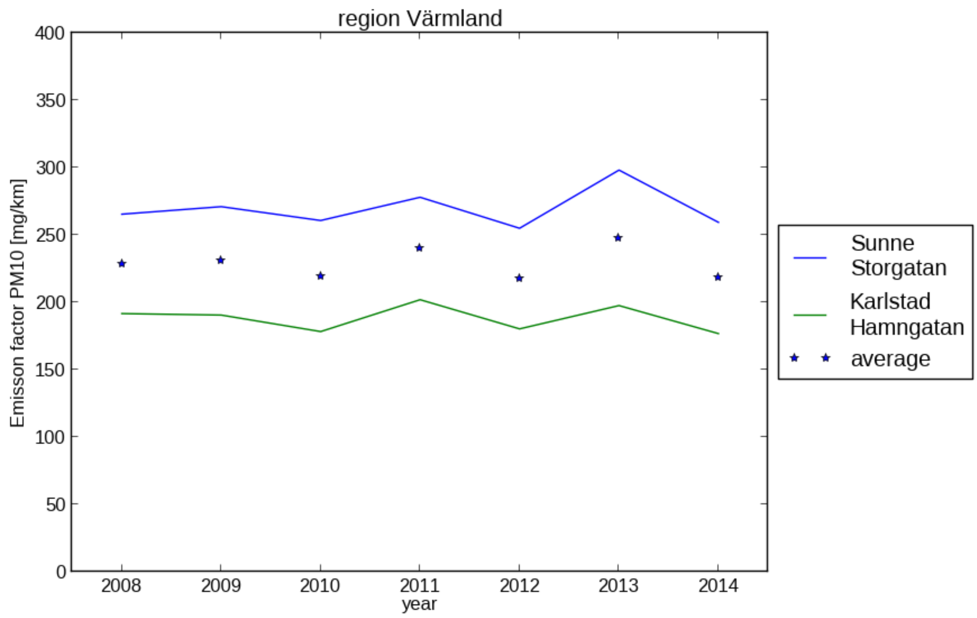

Figure 6. The same as Figure 2, but for region Värmland.

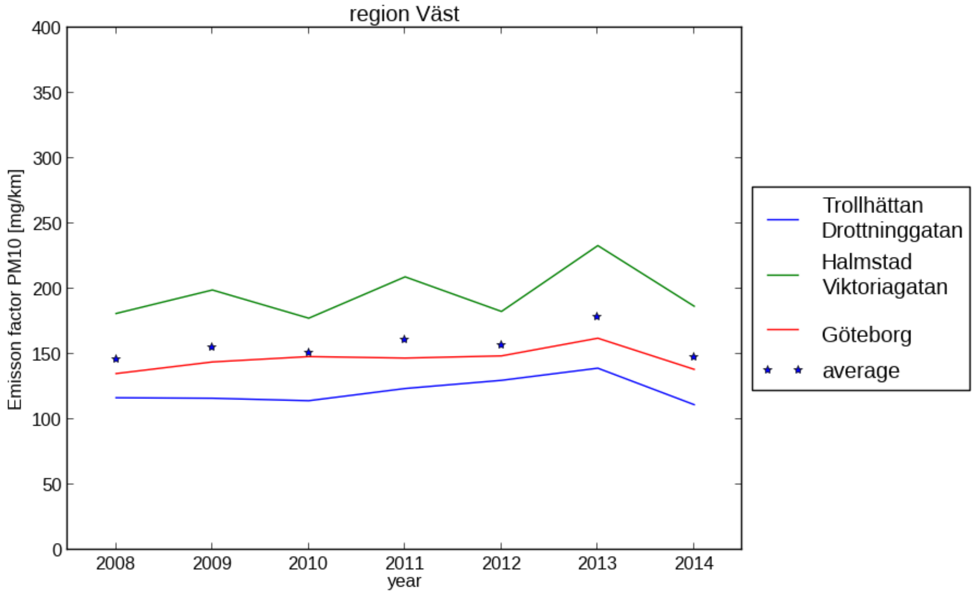

Figure 7. The same as Figure 2, but for region Väst.

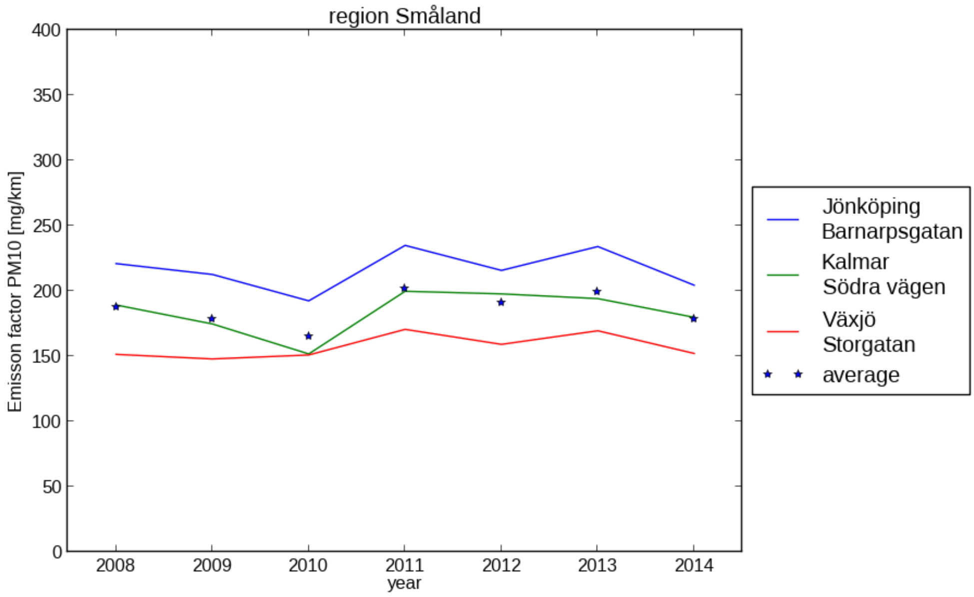

Figure 8. The same as Figure 2, but for region Småland.

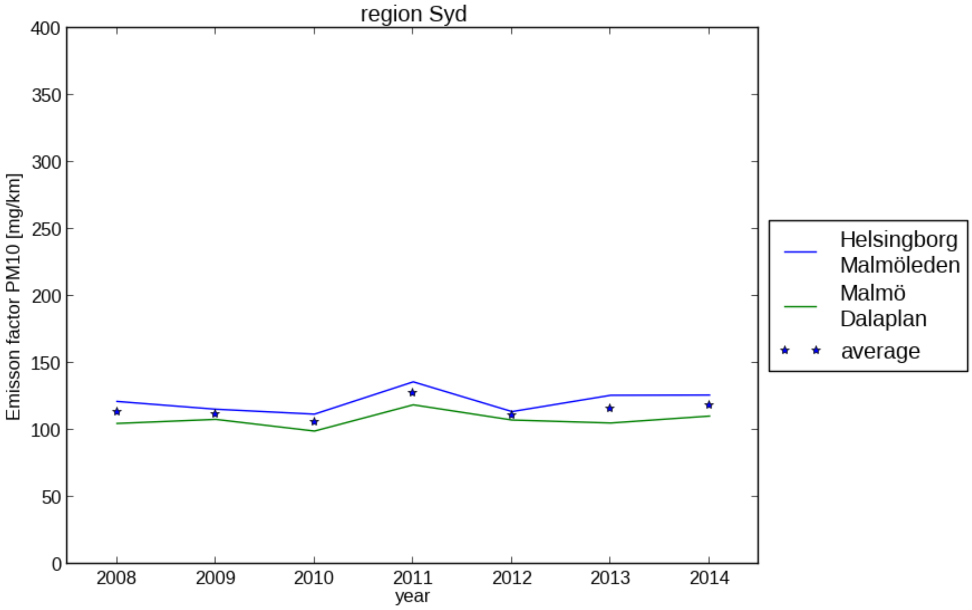

Figure 9. The same as Figure 2, but for region Syd.

National emissions of PM_{10}, $PM_{2.5}$ and TSP from tyre and brake wear and road abrasion

National PM emissions from tyre and brake wear and road abrasion (NFR 1A3bvi and 1A3bvii) calculated according to the new method, are shown in Figure 10. As described above, emission factors for PM_{10} are calculated directly by the model, whereas $PM_{2.5}$ and TSP emissions have been calculated by using fractions from the literature. Emissions in Figure 10 include resuspension.

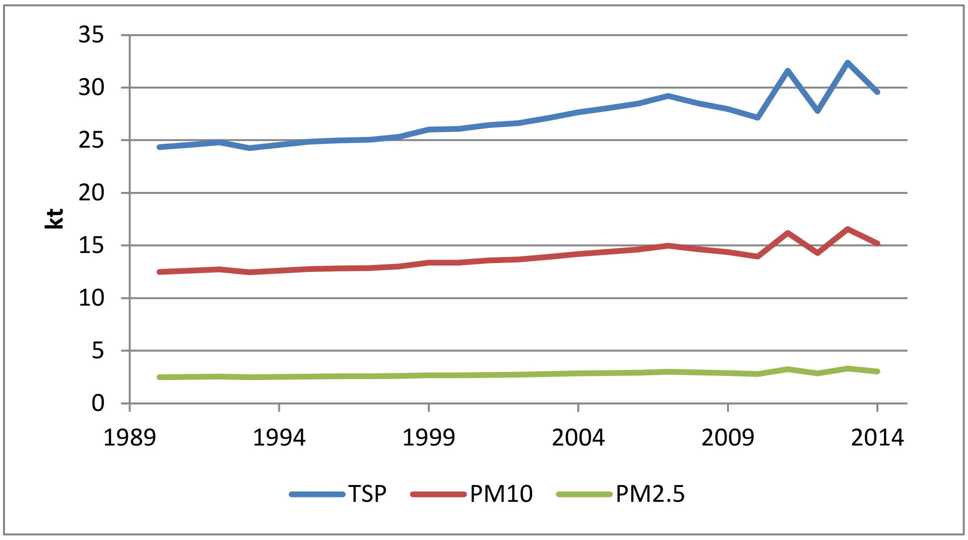

Figure 10. PM emissions from tyre and brake wear and road abrasion according to the new calculation method.

In order to compare the new method to previously reported emissions, emissions of PM_{10}, $PM_{2.5}$ and TSP from tyre and brake wear and road abrasion are shown in Figure 11 through Figure 13, respectively, together with emissions reported in submission 2016. Emissions as reported in submission 2014 are also included since there was a major revision of the emission factors for road abrasion between submission 2014 and 2015. Corresponding figures for tyre and brake wear and road abrasion are shown separately, see Appendix C.

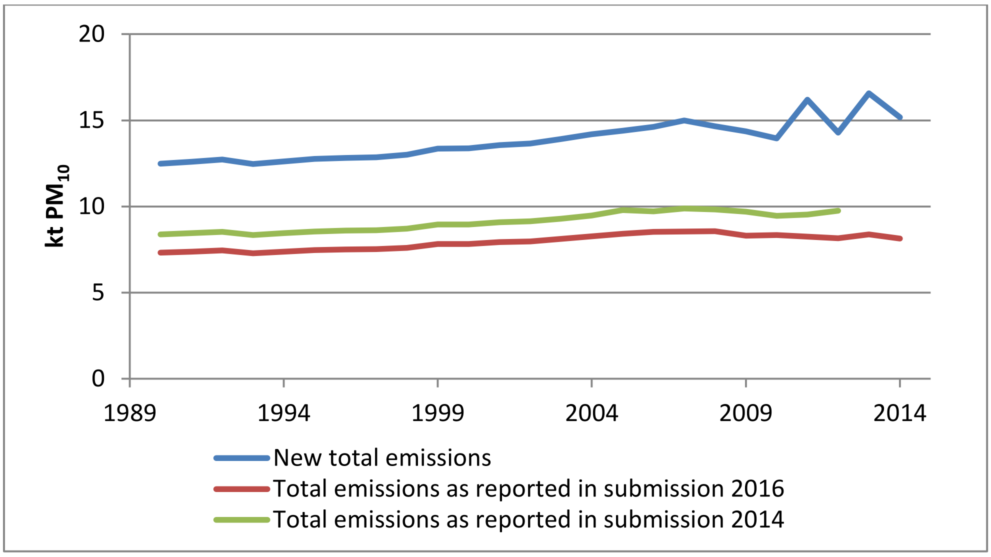

Figure 11. New total PM_{10} emission estimates together with corresponding emissions in submission 2016 and 2014.

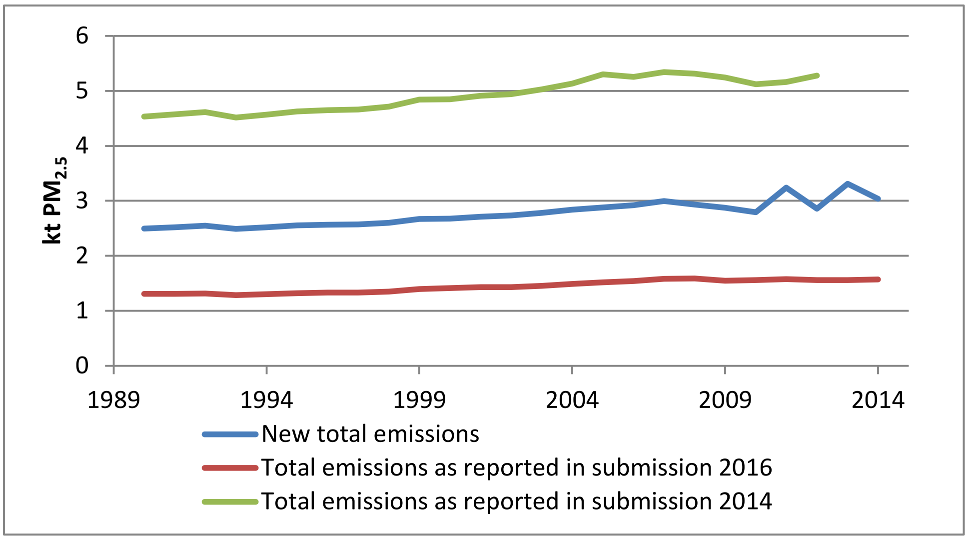

Figure 12. New total $PM_{2.5}$ emission estimates together with corresponding emissions in submission 2016 and 2014.

The new emission estimates for PM_{10} as well as TSP are higher than emissions reported in both submission 2016 and 2014 (Figure 11 and 13), whereas the new $PM_{2.5}$ emission estimates are in between submission 2014 and 2016 emission reportings (Figure 12).

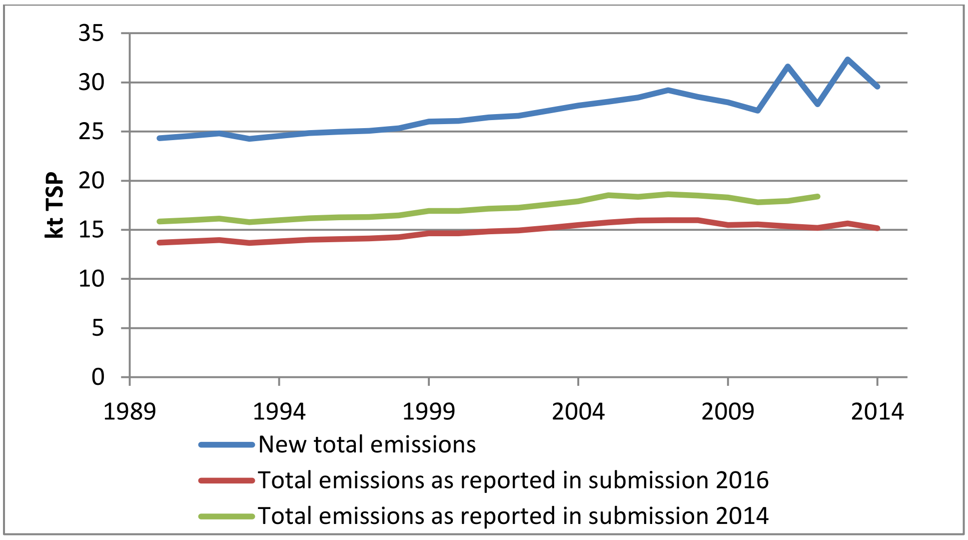

Figure 13. New total TSP emission estimates together with corresponding emissions in submission 2016 and 2014.

The new method has several advantages compared to the method used previously; it takes into account meteorological and regional variations, and is thus expected to have a higher accuracy than the previous national emission factors. All PM fractions show a large fluctuation for the latter years compared to previous years. This is due to the fact that variation in meteorology has been taken into account from 2008 onwards, whereas for earlier years, the emission factor is constant and the only varying parameter is the annual regional vehicle-kilometers. This also demonstrates that meteorology has a relatively large impact on annual emissions.

One reason for the higher emissions that result from the new method may be that resuspension is included in the new method. In previous submissions, default emission factors from the EMEP/EEA Guidebook has been used, and it is somewhat unclear whether resuspension is included in these emission factors. On one hand the Guidebook states that resuspension should not be included in the emissions; on the other hand it states that since it is not possible to distinguish between freshly emitted particles and resuspended particles, the emission factors provided in the Guidebook include some part of the resuspended particles (EMEP/EEA 2013). The proposed new methodology for estimating Swedish particle emissions from this source is transparent in that it is clear that resuspension is included in the estimates.

Conclusions, future possibilities and follow-up studies

In this project a new methodology for calculations of national non-exhaust emissions of particles has been developed. The new method has the advantage in that the emissions are calculated separately for eight regions in Sweden. Hence, the variability in both meteorological conditions and in the use of studded tyres is taken into account. In previous submissions the same emission factors have been applied for all of Sweden.

The limitations of the new method consist in that it is not possible to separate emissions from tyre and brake wear from those from road abrasion, which is why a constant emission factor for tyre and brake wear had to be used, in order to fit the results to the NFR reporting template. It is also not possible to separate emissions from different vehicle types, which affects BC emission estimates since BC emissions are calculated by default emission factors from the EMEP/EEA Guidebook that are specified by vehicle type.

Furthermore, only PM_{10} emission factors can be modelled, which means that $PM_{2.5}$ and TSP emissions have to be calculated using data on $PM_{2.5}/PM_{10}$ and PM_{10}/TSP fractions from the literature.

However, the advantages of the new method outweigh the limitations by large, and the new method is regarded to considerably improve the Swedish emission inventory for this sector.

Nevertheless, in follow-up studies it might be possible to improve the method further. In this project, calculations were made for two to five representative streets in each region. However, in the future a method for automatic SIMAIR calculations of emission factors for all streets in each region could be developed. Such a method would capture the variability of meteorology, vehicle composition and other conditions even better.

Another possible improvement of the calculation could be to use the new non-exhaust emission model NORTRIP (Denby et al., 2013a; Denby et al., 2013b), developed within the framework of a Nordic research program. In a validation study (Andersson and Omstedt, 2013), comparison of NORTRIP and SIMAIR's current non-exhaust emission model have been made against monitoring data of PM_{10} from Stockholm (Hornsgatan), Gothenburg (E6 at Gårda) and Umeå (Västra Esplanaden). The models showed comparable emissions, even though NORTRIP showed a slightly better agreement with the measurement data.

An advantage of NORTRIP is that the different processes that contribute to the emissions of particles are described separately, which means that it is possible to better separate different types of emissions, for example tyre and brake wear and road abrasion. This is beneficial from an emission inventory point of view, as these two sources are separated in the NFR reporting templates. With NORTRIP it would also be possible to separately calculate emission factors for different types of vehicles, for example passenger cars, heavy duty vehicles etc. The separation into different vehicle types would facilitate BC emission estimates, as BC fractions of $PM_{2.5}$ are provided by vehicle type in the EMEP/EEA Guidebook.

A project for implementation of NORTRIP in SIMAIR started in November 2015. The goal is to have NORTRIP operating in SIMAIR during autumn 2016. Thus, a follow-up project including both automatic calculations in SIMAIR and the use of the NORTRIP model could possibly be initiated in late 2016.

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Appendix A

Table A.1. SIMAIR's calculated non-exhaust emission factor of PM_{10} for the different streets, corrected against monitoring data. In each region, a weighted average is calculated. The non-exhaust emission factor includes both from tyre and brake wear and road abrasion.

			Non-exhaust PM10 emission factor [mg km^{-1}]						
Region	**Municipality**	**Street**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Norr	Luleå	Sandviksgatan	257.3	281.8	270.0	249.6	224.5	285.0	302.0
	Luleå	Smedjegatan	175.8	189.4	182.6	170.2	153.0	195.1	204.6
	Skellefteå	E4 Viktoriagatan	188.8	188.0	192.9	199.2	175.7	202.9	220.1
	Umeå	Västra Esplanaden indata 08	163.1	150.8	154.4	170.1	142.4	171.7	172.2
		Västra Esplanaden indata 09	176.4	162.8	166.8	184.1	153.9	185.6	186.1
		Västra Esplanaden indata 13	190.1	175.5	179.9	198.4	166.0	200.0	200.7
	weighted average		193.9	195.5	195.4	197.8	172.9	209.6	219.9
Mitt	Falun	Gruvgatan	235.4	243.8	270.4	274.2	249.7	293.4	251.1
	Gävle	Staketgatan	249.8	249.5	220.0	241.0	222.4	262.4	259.4
	Örnsköldsvik	Centralesplanaden	160.7	157.9	165.6	171.3	142.4	175.0	189.1
	Östersund	Färjemansgatan	220.2	221.7	266.0	234.5	210.6	262.1	282.9
	Sundsvall	Strandgatan	176.6	178.5	179.5	192.1	184.1	219.7	209.8
	weighted average		197.1	198.3	206.7	210.9	190.8	229.6	227.3
Stockholm	Sollentuna	E4 Häggvik	169.7	163.5	158.9	202.3	157.5	190.9	175.2
	Stockholm	E4 Lilla Essingen	213.7	215.1	211.2	248.6	207.3	253.2	212.8
	Stockholm	Hornsgatan indata 08	220.4	223.7	219.5	261.8	218.9	263.3	227.8
		Hornsgatan indata 09	246.0	249.7	245.3	292.2	244.6	294.1	254.4
	Stockholm	Sveavägen	224.5	227.7	223.3	266.6	225.2	267.2	232.0
	Stockholm	Norrlandsgatan	233.4	237.8	231.5	278.2	234.6	279.7	241.7
	weighted average		214.9	216.2	211.5	254.5	211.3	253.9	220.5
Öst	Uppsala	Kungsgatan	300.1	300.6	268.8	359.7	277.1	345.9	305.5
	Västerås	Stora gatan	270.1	257.7	256.9	295.9	277.3	321.5	270.7
	Örebro	Rudbecksgatan	194.7	187.0	182.8	200.0	178.7	213.4	198.1
	Norrköping	Kungsgatan	261.8	252.0	222.9	280.2	252.4	283.2	260.2
	Enköping	E18 Testsite	273.6	253.7	246.3	315.3	247.4	327.2	259.9
	weighted average		260.1	250.2	235.6	290.2	246.6	298.2	258.9
Värmland	Karlstad	Hamngatan	191.9	190.8	178.6	202.3	180.6	197.9	177.1
	Sunne	Storgatan indata 08	250.6	255.9	246.3	262.5	240.8	281.6	244.3
		Storgatan indata 13	280.8	286.6	275.8	294.1	269.7	315.3	275.0
	weighted average		228.8	231.1	219.8	240.3	217.9	248.2	218.4

Väst	Göteborg	E6 Gårda indata 08	130.5	139.3	143.6	142.2	144.1	157.2	133.6
		E6 Gårda indata 09	109.2	116.6	120.2	118.5	120.1	131.1	111.8
	Göteborg	Sprängkullsgatan	166.6	177.0	181.4	181.1	182.7	199.2	170.5
	Trollhättan	Drottninggatan	116.9	116.5	114.6	124.0	130.2	139.5	111.6
	Halmstad	Viktoriagatan	181.4	199.4	177.8	209.5	183.0	233.5	187.0
	weighted average		146.2	155.2	151.4	161.2	157.0	179.1	147.9
Småland	Växjö	Storgatan	151.7	148.2	151.2	170.9	159.4	169.8	152.4
	Jönköping	Barnarpsgatan	221.3	212.9	192.7	235.2	216.0	234.3	204.7
	Kalmar	Södra vägen	189.6	175.0	152.0	200.1	198.1	194.4	180.1
	weighted average		187.5	178.7	165.3	202.1	191.2	199.5	179.1
Syd	Malmö	Dalaplan	105.3	108.3	99.6	119.2	107.8	105.6	110.8
	Helsingsborg	Malmöleden	121.7	115.9	112.2	136.3	114.1	126.3	126.5
	weighted average		113.5	112.1	105.9	127.8	111.0	116.0	118.6

Appendix B

Table A.2 National vehicle-kilometers used in this study. Data from the Swedish Transport Administration.

Year	National Vehicle-kilometer
1990	6.44E+10
1991	6.5E+10
1992	6.57E+10
1993	6.42E+10
1994	6.5E+10
1995	6.58E+10
1996	6.61E+10
1997	6.63E+10
1998	6.71E+10
1999	6.89E+10
2000	6.9E+10
2001	7E+10
2002	7.04E+10
2003	7.18E+10
2004	7.32E+10
2005	7.43E+10
2006	7.54E+10
2007	7.73E+10
2008	7.81E+10
2009	7.67E+10
2010	7.68E+10
2011	7.79E+10
2012	7.73E+10
2013	7.72E+10
2014	7.85E+10

Table A.3. Regional vehicle-kilometers from the emission database in SIMAIR. These data are used to distribute the national vehicle-kilometers in the different regions.

Region	Country (län)	2008	2009	2010	2011	2012	2013
Norr	Norrbotten	1.91E+09	1.92E+09	1.92E+09	1.95E+09	1.93E+09	1.96E+09
Norr	Västerbotten	1.77E+09	1.77E+09	1.77E+09	1.8E+09	1.79E+09	1.81E+09
Norr total		3.68E+09	3.69E+09	3.69E+09	3.74E+09	3.73E+09	3.76E+09
Norr % of national total		6%	6%	6%	6%	6%	6%
Mitt	Jämtland	1.11E+09	1.11E+09	1.11E+09	1.12E+09	1.12E+09	1.13E+09
Mitt	Västernorrland	1.79E+09	1.8E+09	1.8E+09	1.83E+09	1.82E+09	1.84E+09
Mitt	Gävleborg	2.11E+09	2.12E+09	2.12E+09	2.15E+09	2.14E+09	2.16E+09
Mitt	Dalarna	2.13E+09	2.14E+09	2.14E+09	2.17E+09	2.15E+09	2.18E+09
Mitt total		7.14E+09	7.17E+09	7.17E+09	7.27E+09	7.23E+09	7.31E+09
Mitt % of national total		12%	12%	12%	12%	12%	12%
Stockholm	Stockholm	8.67E+09	8.67E+09	8.67E+09	8.79E+09	8.75E+09	8.86E+09
Stockholm	Gotland	3.54E+08	3.55E+08	3.55E+08	3.58E+08	3.56E+08	3.59E+08
Stockholm total		9.02E+09	9.02E+09	9.02E+09	9.15E+09	9.1E+09	9.22E+09
Stockholm % of national total		15%	15%	15%	15%	15%	15%
Öst	Uppsala	2.35E+09	2.35E+09	2.35E+09	2.39E+09	2.38E+09	2.41E+09
Öst	Västmanland	1.61E+09	1.61E+09	1.61E+09	1.64E+09	1.63E+09	1.65E+09
Öst	Örebro	2.01E+09	2.02E+09	2.02E+09	2.05E+09	2.04E+09	2.06E+09
Öst	Södermanland	2.07E+09	2.08E+09	2.08E+09	2.11E+09	2.1E+09	2.12E+09
Öst	Östergötland	2.89E+09	2.9E+09	2.9E+09	2.95E+09	2.93E+09	2.96E+09
Öst total		1.09E+10	1.1E+10	1.1E+10	1.11E+10	1.11E+10	1.12E+10
Öst % of national total		18%	18%	18%	18%	18%	18%
Värmland	Värmland	2.12E+09	2.13E+09	2.13E+09	2.16E+09	2.15E+09	2.17E+09
Värmland total		2.12E+09	2.13E+09	2.13E+09	2.16E+09	2.15E+09	2.17E+09
Värmland % of national total		3%	3%	3%	3%	3%	3%
Väst	V. Götaland	1.1E+10	1.1E+10	1.1E+10	1.11E+10	1.11E+10	1.12E+10
Väst	Halland	2.47E+09	2.48E+09	2.48E+09	2.52E+09	2.5E+09	2.53E+09
Väst total		1.34E+10	1.35E+10	1.35E+10	1.37E+10	1.36E+10	1.37E+10
Väst % of national total		22%	22%	22%	22%	22%	22%
Småland	Jönköping	2.67E+09	2.68E+09	2.68E+09	2.72E+09	2.7E+09	2.73E+09
Småland	Kronoberg	1.56E+09	1.57E+09	1.57E+09	1.59E+09	1.58E+09	1.6E+09
Småland	Kalmar	1.77E+09	1.78E+09	1.78E+09	1.8E+09	1.79E+09	1.81E+09
Småland total		6.01E+09	6.03E+09	6.03E+09	6.11E+09	6.08E+09	6.14E+09
Småland % of national total		10%	10%	10%	10%	10%	10%
Syd	Blekine	9.77E+08	9.79E+08	9.79E+08	9.94E+08	9.88E+08	9.99E+08
Syd	Skåne	7.81E+09	7.82E+09	7.82E+09	7.94E+09	7.9E+09	7.99E+09
Syd total		8.78E+09	8.8E+09	8.8E+09	8.94E+09	8.89E+09	8.99E+09
Syd % of national total		14%	14%	14%	14%	14%	14%
Nationell total SIMAIR		6.11E+10	6.13E+10	6.13E+10	6.22E+10	6.18E+10	6.25E+10

Appendix C

National PM emissions resulting from the new method.

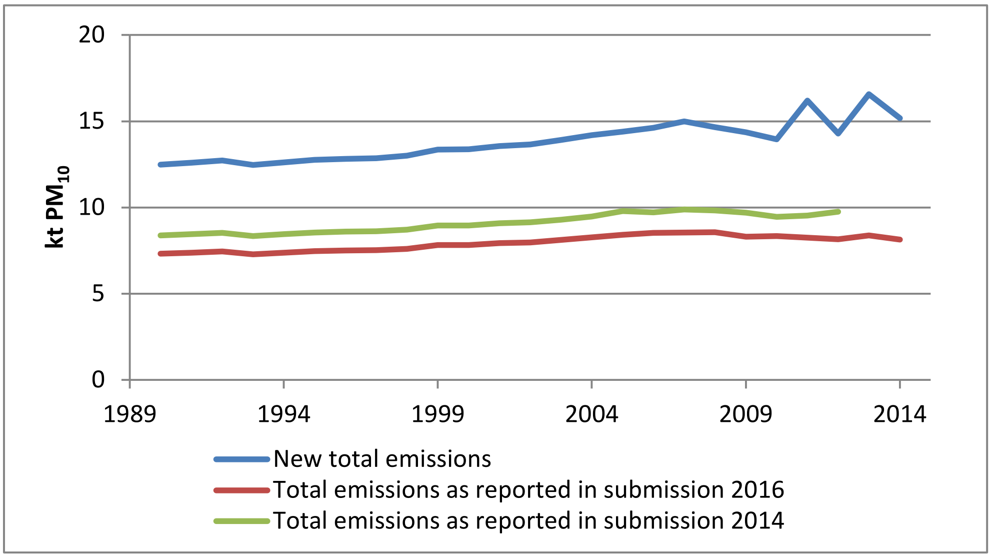

Figure 10. New total PM_{10} emission estimates together with corresponding emissions in submission 2016 and 2014.

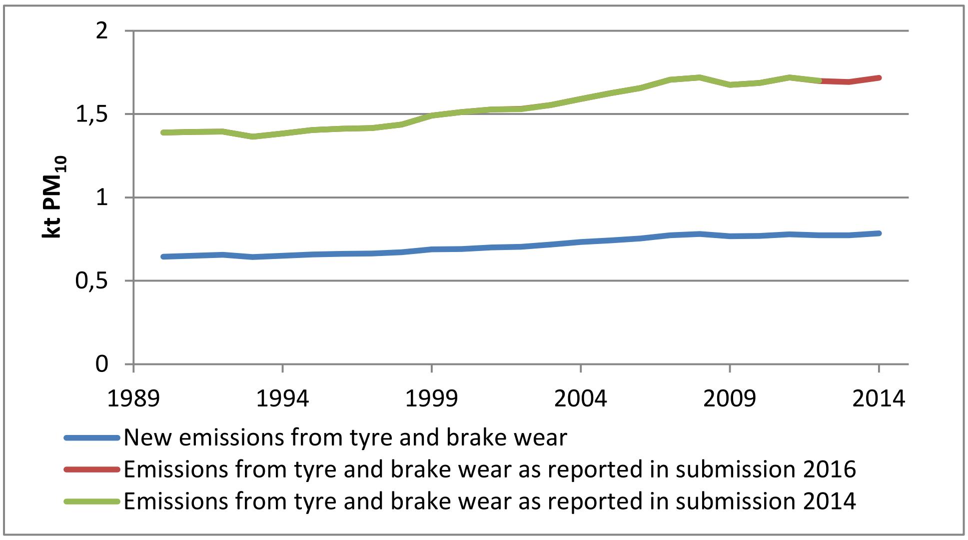

Figure 11. New PM_{10} emission estimates from tyre and brake wear together with corresponding emissions in submission 2016 and 2014.

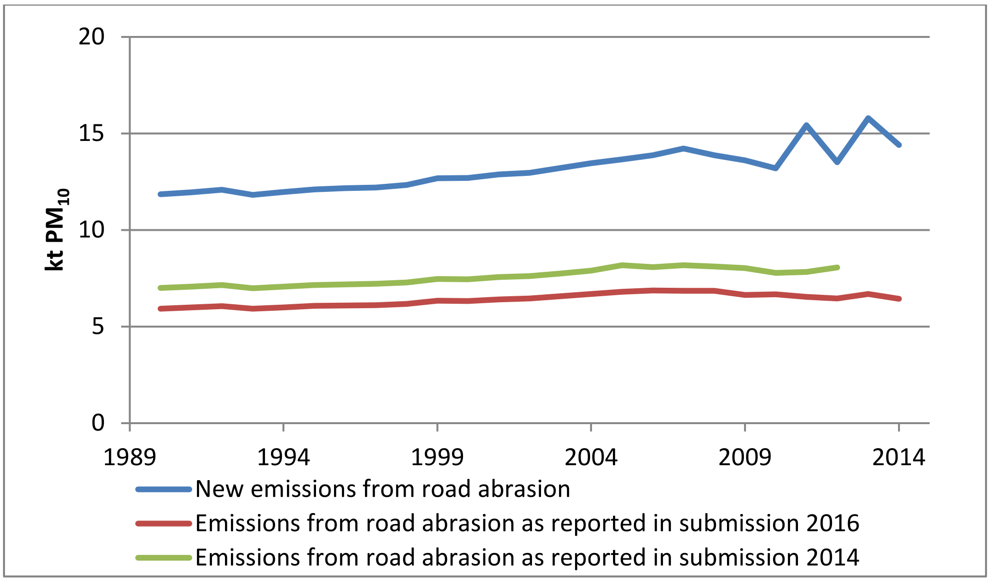

Figure 12. New PM_{10} emission estimates from road abrasion together with corresponding emissions in submission 2016 and 2014.

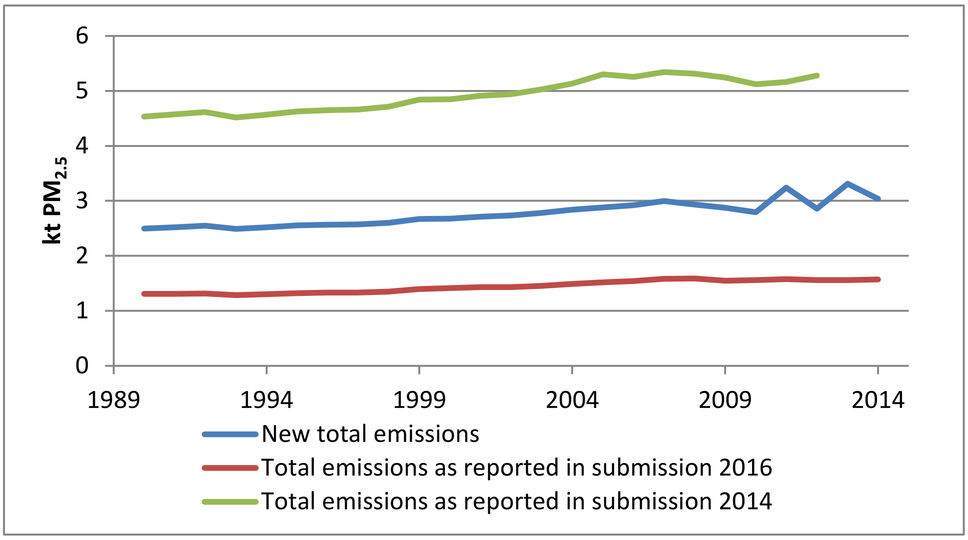

Figure 14. New total $PM_{2.5}$ emission estimates together with corresponding emissions in submission 2016 and 2014.

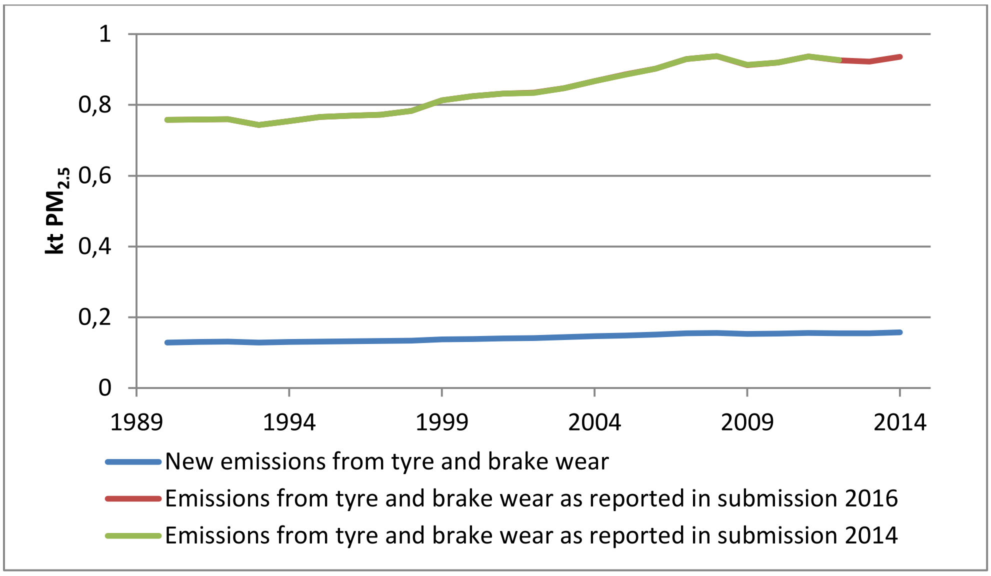

Figure 15. New $PM_{2.5}$ emission estimates from tyre and brake wear together with corresponding emissions in submission 2016 and 2014.

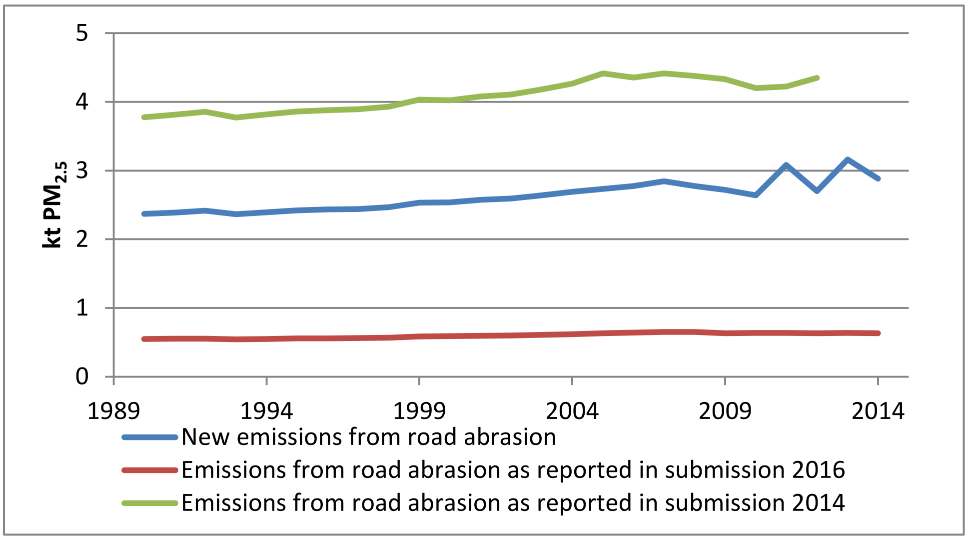

Figure 16. New $PM_{2.5}$ emission estimates from road abrasion together with corresponding emissions in submission 2016 and 2014.

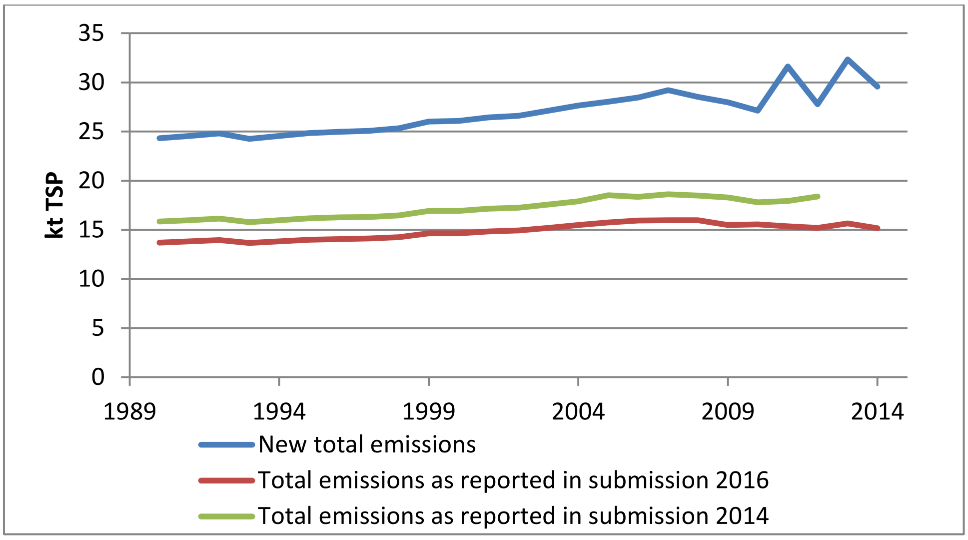

Figure 17. New total TSP emission estimates together with corresponding emissions in submission 2016 and 2014.

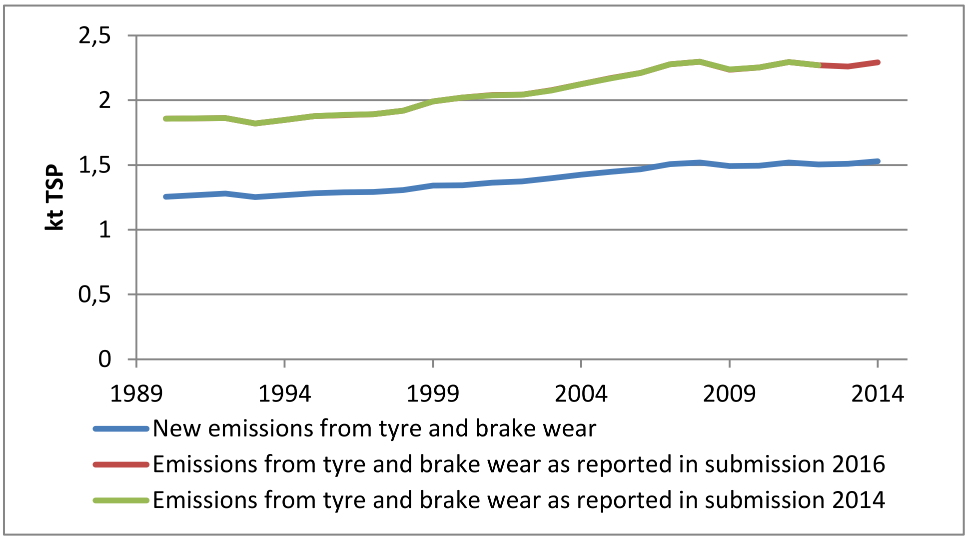

Figure 18. New TSP emission estimates from tyre and brake wear together with corresponding emissions in submission 2016 and 2014.

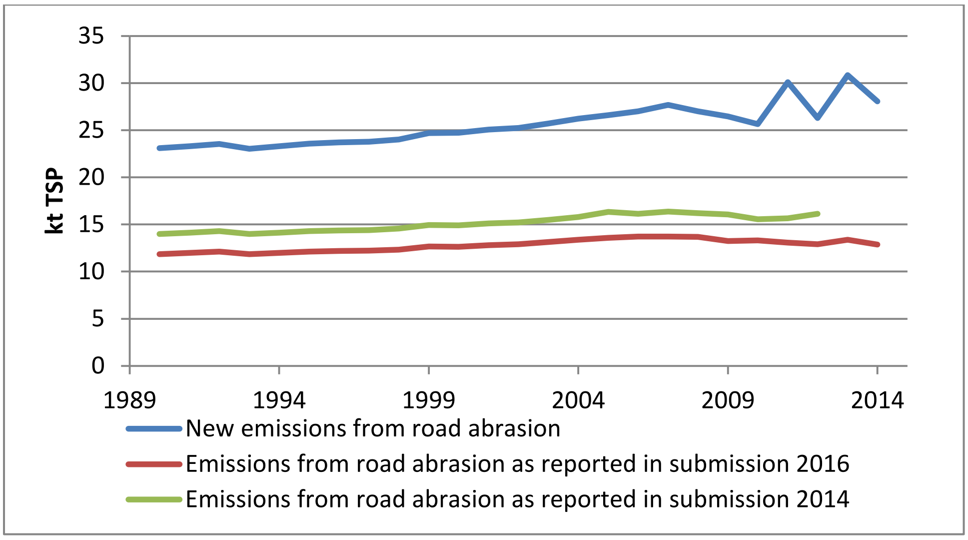

Figure 19. New TSP emission estimates from road abrasion together with corresponding emissions in submission 2016 and 2014.