Czech Hydrometeorological Institute

NFR 2A5a

PM2.5 analysis

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Subtitle

Analysis of a significant discrepancy in PM2.5 implied emission factor in NFR 2A5a

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During the testing of data to be submitted for IIR Report, a method of implied emission factors was used. This method had been applied to all viable NFR categories, checking for discrepancies in the timeline. Errors/differences larger than two sigma were part of the method's search.

One of these errors had been found within the NFR category 2A5a, Quarrying and mining of minerals other than coal. In case of this category, the measured emissions are PM2.5, PM10 and TSP. Of these, the large difference appeared only in the PM2.5 category, in year 2009. (See Table 1).

It was curious that the two sigma error appeared in only one emission category, when all three are tied together through the way the emissions are reported. Were this difference a result of a significant change during the year 2009 that happened to the sources – quarries – the dip in implied emission factor would be seen across all three of the measured emissions. Instead, it appears only in PM2.5. The goal of this analysis was then to find the cause of this difference.

In the year 2009 a new system of reporting (ISPOP) was being established, to be fully implemented in year 2010. This meant that during 2009, two methods of reporting from individual sources was possible, through the old channels and the new online ISPOP. At the same time, in 2010, new calculation factors were to be applied to the measurements done by source operators. This meant that several factors intersected in the time period between 2008 and 2010, with focus on the central year of 2009.

Table 1 Implied emission factors in NFR 2A5a between years 1990 – 2023; the two sigma data point in 2009 is shown in red

	PM2,5	PM10	TSP
1990	9,64E-06	3,19E-05	6,2188E-05
1991	9,64E-06	3,19E-05	6,2188E-05
1992	9,64E-06	3,19E-05	6,2188E-05
1993	9,88E-06	3,27E-05	6,3758E-05
1994	9,61E-06	3,18E-05	6,1976E-05
1995	9,64E-06	3,19E-05	6,2188E-05
1996	8,8E-06	2,92E-05	5,6821E-05
1997	7,3E-06	2,48E-05	4,8584E-05
1998	7,92E-06	2,68E-05	5,2435E-05
1999	7,42E-06	2,51E-05	4,9122E-05
2000	8,29E-06	2,75E-05	5,3615E-05
2001	8,31E-06	2,66E-05	5,1202E-05
2002	8,8E-06	2,12E-05	3,5951E-05
2003	8,45E-06	2,03E-05	3,4683E-05
2004	5,35E-06	1,79E-05	3,4906E-05
2005	5,44E-06	1,85E-05	3,6193E-05

2006	6,32E-06	2,15E-05	4,2153E-05
2007	6,61E-06	2,17E-05	4,2036E-05
2008	7,89E-06	2,44E-05	4,6856E-05
2009	4,23E-06	1,41E-05	2,7531E-05
2010	8,14E-06	1,51E-05	2,2007E-05
2011	6,65E-06	1,3E-05	1,9739E-05
2012	7,29E-06	1,47E-05	2,2799E-05
2013	8,99E-06	1,67E-05	2,4066E-05
2014	8,2E-06	1,53E-05	2,2195E-05
2015	7,8E-06	1,47E-05	2,1625E-05
2016	7,79E-06	1,49E-05	2,2864E-05
2017	8,64E-06	1,56E-05	2,2239E-05
2018	6,94E-06	1,22E-05	2,0129E-05
2019	6,93E-06	1,26E-05	2,1781E-05
2020	6,58E-06	1,19E-05	2,0671E-05
2021	6,67E-06	1,22E-05	2,1418E-05
2022	6,54E-06	1,2E-05	2,0989E-05
2023	5,29E-06	1,2E-05	2,0142E-05

The implied emission factor is also shown on Figure 1, and Figure 2, showing only the implied emission factor of PM2.5, since the values for both PM10 and TSP are necessarily higher and the changes in timeline for the PM2.5 are barely visible.

On Figure 2, the dip in year 2009 is easily visible, bracketed by two increases for years 2008 and 2010, which are conspicuously very similar in height. This similarity seems at first glance as data for 2009 simply having wrong values – except, as it turns out, after deeper analysis they are similar by happenstance, not because of the same methodology.

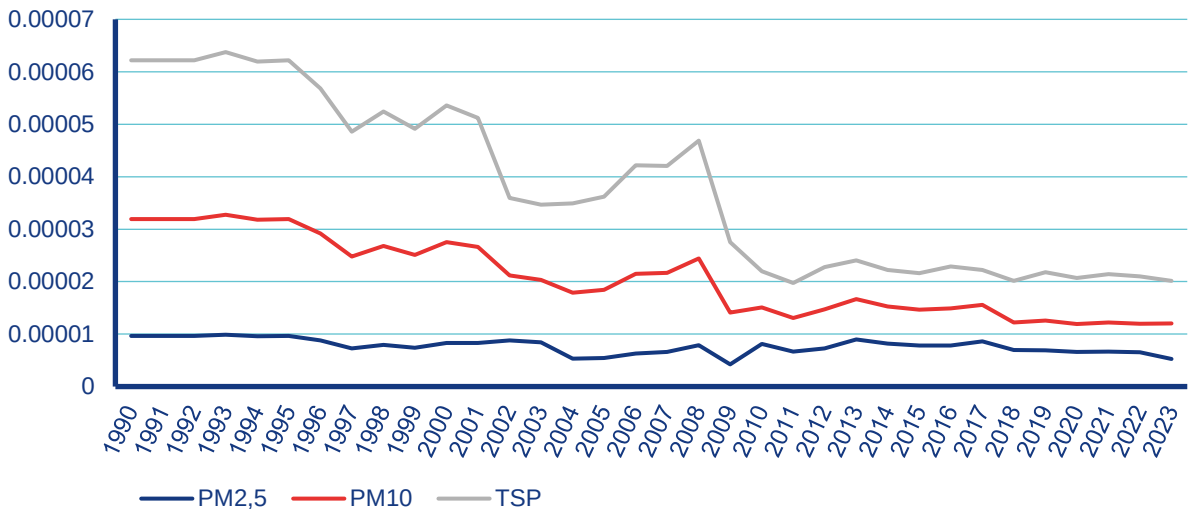

Figure 1 Implied emission factor for NFR 2A5a for years 1990 – 2023

Figure 2 Implied emission factor for PM2.5; a large dip visible in year 2009

The measured emissions, alongside the activity data is seen in Table 2. The same data is shown in Figure 3 and Figure 4. There is a visible jump between 2008 and 2009 (2010). This change is in fact almost exactly a cut in half from 2008, as seen in Table 4, showing the percentage change between the years. Emission values 2009/2008 sit in all three cases at around 50%, while activity data remains more or less the same (a decrease of circa 10%). In the following year, value 2010/2009 remains almost the same for PM10, decreases by 25% for TSP, but grows by 75% for PM2.5. It is this 'inexplicable' increase that forms part of the reason for the extreme value of implied emission factor. For completeness, activity data once again decreases by approximately 10%.

This discrepancy between emission data and activity data is easily seen in comparison of Figure 3 and Figure 4, one showing the activity data, the second the three emissions. There is a bump between years 2004 and 2010, but for activity data, the decrease from 2008 is less steep,

whereas the slope for emission data lowers drastically to significantly lower values compared even to 2004.

The change in calculation factors is shown in Table 3 and Figure 5 and Figure 6. The change happened between years 2009 and 2010, but otherwise remained more or less constant in the two parts of the timeline. (The changes are somewhat exaggerated in the graphs due to small decimal values being a relatively large fraction of the calculation factor.)

These calculation factors are used by source operators when calculating the emissions of PM10 and PM2.5 – the measured emission is TSP, and the other two are calculated as a fraction of the measured value based on the calculation factor. A change in both of these fractions/factors had resulted in an increase of PM10 and PM2.5 emissions compared to TSP emissions. This can be seen on the Figure 4, where the distance between the lines gets smaller in year 2010. But, in case of PM2.5 it did lead to a large increase of emissions – there is a visible dip and return in the graph, whereas for PM10, the value remains quite similar between 2009 and 2010. This difference once again hints at the causes of the extreme two sigma value of implied emission factor.

The change that happened was from 0.15 to 0.37 for PM2.5 and 0.51 to 0.67 for PM10. (These numbers are of course slightly differing across the years, as the values presented are retroactively calculated from the emission data, instead of the theoretical values.)

Table 2 Emission and activity data for years 1990 – 2023

	PM2,5	PM10	TSP	Activity data
1990	1,08	3,58	6,97	112070
1991	0,70	2,31	4,50	72419
1992	0,66	2,17	4,23	68018
1993	0,63	2,09	4,07	63815
1994	0,62	2,04	3,97	64033
1995	0,62	2,05	4,00	64250
1996	0,62	2,05	3,99	70300
1997	0,52	1,77	3,47	71331
1998	0,51	1,73	3,39	64639
1999	0,55	1,87	3,67	74658
2000	0,62	2,05	4,00	74602
2001	0,61	1,94	3,74	73067
2002	0,62	1,50	2,54	70701
2003	0,66	1,59	2,72	78449
2004	0,44	1,47	2,87	82259
2005	0,46	1,56	3,06	84501
2006	0,57	1,92	3,77	89396

2007	0,62	2,04	3,94	93772
2008	0,74	2,28	4,38	93413
2009	0,35	1,17	2,28	82750
2010	0,61	1,13	1,65	74792
2011	0,52	1,02	1,54	77975
2012	0,51	1,03	1,60	70010
2013	0,62	1,15	1,65	68685
2014	0,60	1,11	1,61	72665
2015	0,62	1,17	1,72	79577
2016	0,60	1,14	1,75	76505
2017	0,67	1,21	1,72	77409
2018	0,57	1,01	1,66	82662
2019	0,57	1,04	1,80	82417
2020	0,54	0,98	1,70	82194
2021	0,58	1,06	1,85	86435
2022	0,56	1,02	1,79	85342
2023	0,40	0,91	1,53	75932

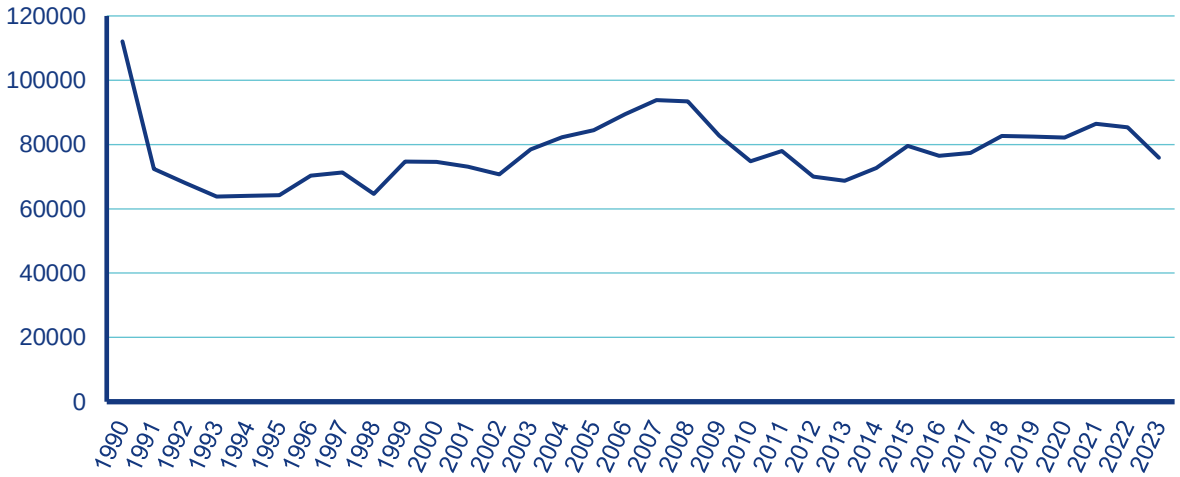

Figure 3 Activity data for NFR 2A5a between years 1990 – 2023

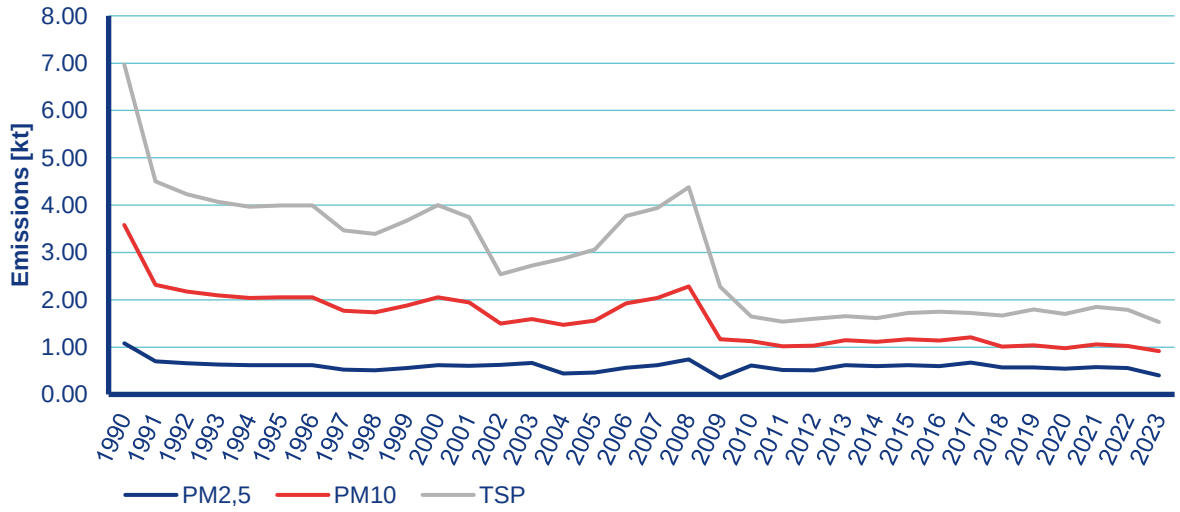

Figure 4 Emission data for NFR 2A5a between years 1990 – 2023

Table 3 Calculation factor for PM10 and PM2.5, as calculated from reported emission data

	PM2,5/TSP	PM10/TSP
1990	0,15500634	0,5136252
1991	0,15500634	0,5136252
1992	0,15500634	0,5136252
1993	0,15500634	0,5136252
1994	0,15500634	0,5136252
1995	0,15500634	0,5136252
1996	0,15486361	0,5135089
1997	0,15020294	0,5101533
1998	0,15106095	0,5108016
1999	0,15109843	0,5108299
2000	0,15471345	0,5133675
2001	0,1622676	0,5197749
2002	0,24469639	0,5898208
2003	0,24363603	0,5858956
2004	0,15321882	0,5120657
2005	0,15027936	0,5102088
2006	0,15	0,51
2007	0,15727681	0,5162919
2008	0,16844064	0,5208649
2009	0,15373074	0,5131761
2010	0,36986042	0,6840699

2011	0,33680544	0,6609247
2012	0,3197161	0,6462657
2013	0,37365693	0,6937186
2014	0,36964131	0,6890351
2015	0,36064538	0,6789512
2016	0,3408164	0,6528539
2017	0,38839335	0,7012255
2018	0,34484279	0,6071032
2019	0,31811203	0,5768146
2020	0,31810585	0,5766017
2021	0,31161389	0,570718
2022	0,31161389	0,570718
2023	0,26251277	0,5980117

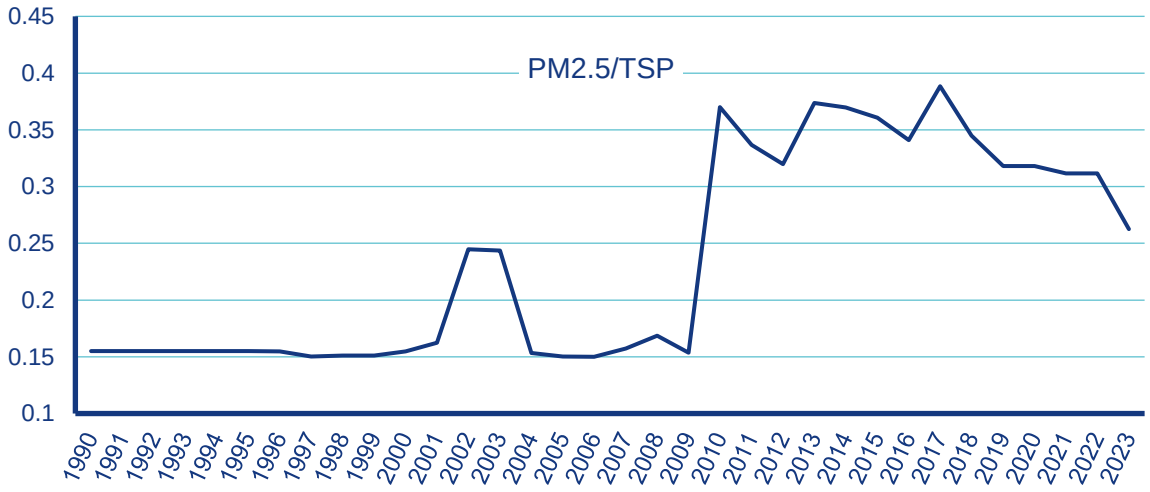

Figure 5 Calculation factor for NFR 2A5a for PM2.5 calculated from TSP measurements

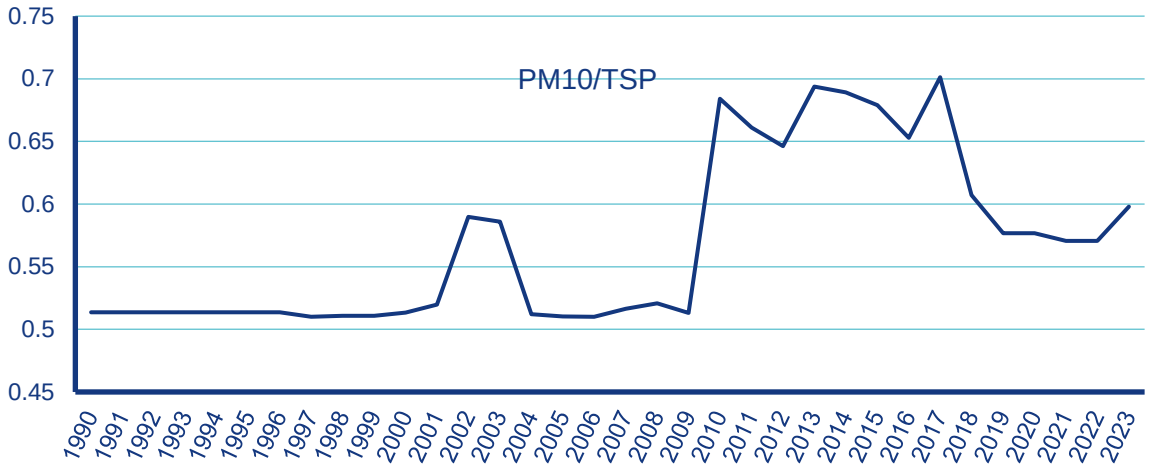

Figure 6 Calculation factor for NFR 2A5a for PM10 calculated from TSP measurements

Table 4 Comparison of emission and activity data in neighbouring years, the key year comparisons are signified in bold

	PM2,5	PM10	TSP	Activity data
07/06	1,097	1,059	1,046	1,049
08/07	1,189	1,120	1,110	0,996
09/08	0,475	0,513	0,521	0,886
10/09	1,738	0,963	0,722	0,904
10/08	0,826	0,494	0,376	0,801

There is a third factor to be considered. As was already mentioned, the collecting of data in the year 2009 was done in two separate ways, which were not compatible with each other. This could have led to discrepancies, or even some reports missing from the collected total. At the same time, newly reported facts were added to the new ISPOP system, which had led to differently applied calculation factors than previously. All of this could have thus led to incomplete and uncertain values of emission data for the year 2009.

An analysis was performed on reports from individual sources between years 2008 and 2010. There is a significant decrease of significant emission sources between years 2008 and 2009 – for sources above 5t in 2008, only a quarter of them had retained a similar level of pollution (this includes all increases as well). At the same time, only two sources increased above the 5t, which is a negligible addition. Most sources, as far as reported data is concerned, lowered their emissions by tens of percent, if not to just a fraction – a hundredth – of the 2008 value.

Due to the fact that these sources still report some emissions, it seems improbable their reports went missing. Whether the sharp decrease is a result of a change in methodology of reporting, or truly a decrease in emissions is sadly not visible through the reported data.

In the following year, 2010, most stayed at similar level of emissions as in 2009, though this time the number of more prominent sources increased almost three times.

As for the emission numbers themselves, there is a decrease of the fraction of larger sources between 2008 and 2010, from three quarters to a half. But it is the year 2009 where the fraction stands out – sources over 5t were only 15% of the total. This had led to halving the emissions, but it seems the large sources are disproportionately responsible for this decrease – or the lack of them.

Together, the effects led to the following: In 2008, the emission data was fully reported, using old calculation factors. In 2009, the reported emission data fell by 50% across all three emission types, using the old calculation factors. In 2010, new calculation factors were implemented, while TSP emission data decreased by approximately a quarter. That meant for PM10 that, by chance, the emission data value decreased marginally. For PM2.5, the new calculation factor led to an increase by almost 75% compared to 2009. At the same time, activity data fell by 10% each year, for a total decrease by 20% in 2008 – 2010 interval.

Together, in years 2008 – 2010, TSP emission continually fell to about 37.5%, PM10 fell by 50%, but PM2.5 only decreased to 83%, with a dip in 2009 to 50%.

This dip was thus formed by the effects acting upon the three years – compared to 2008, 2009 has half the emission data value, while compared to 2010, it uses a calculation factor that is approximately half of the new one. Together, this means 2008 data is twice as large, while 2010 data is once again twice as large, but none of the effects extend to 2009, leading to a dip in value, as seen in Figure 2 or Figure 1. (Twice as large in regards to implied emission factor – in 2010, the actual emission data value for PM2.5 is at circa 83% – but that is very close to the decrease in activity data to 80%, and so implied emission factor for PM2.5 in 2008 and 2010 is virtually the same.)

Removing this discrepancy seen as a two sigma error in implied emission factors could *theoretically* be done by either using the calculation factor from 2010, or using emission data similar to 2008 instead.

The second method would either lead to destruction of the calculation factor for PM2.5, or, if PM10 and TSP were changed to 2008-esque data as well, there would be an even larger discrepancy between emissions and activity data – with activity data already decreasing in 2009, while emission would be remaining the same.

The first method would lead to a mirroring of the implied emission factor for PM2.5 around the 2008 and 2010 axis – in other words, creating a peak, that, while not two sigma extreme, is visibly larger than any other value around it, and would thus seem suspect as well.

Due to the fact that ISPOP data cannot be extended back in time, there is no easy way to reconstruct the emission data for 2009. At the same time, the use of the new calculation factors relies on information reported in ISPOP, so it is once again not viable to recalculate the years before 2010 with the new calculation factors – instead, the old ones do in fact better represent the emission therein.

This error in PM2.5 will thus probably remain, as a relic of two changes in methodology, that bracket exactly this year, and so it stands out as incongruent with the others.

As can be seen in the other two analysed emission types – PM10 and TSP, these changes in methodology did not significantly change the time series, and it remained consistent in them. It is only the overlapping of several unfortunate factors that lead to the PM2.5 discrepancy.

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