EVALUATION OF PM10 CONCENTRATIONS IN AMBIENT AIR IN VELENJE AFTER THE FIRST YEAR OF MONITORING

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ABSTRACT

Since autumn 2011 PM10 concentrations in ambient air are being monitored in Velenje within the Slovenian state network. Year-round data are available only for 2012; compared with data from other Slovenian towns Velenje is the least polluted among them. The annual average concentrations in Velenje are comparable with both stations in Ljubljana, as well as with stations in Koper, Nova Gorica and Hrastnik. In all these towns except Hrastnik, there are almost twice as many days on which the acceptable daily limits are exceeded than in Velenje. Lower values than in Velenje were recorded only at the control station in the Kočevsko area (Iskrba). PM10 concentrations were also measured within the Environmental Information System of the Šoštanj Thermal Power Plant (ŠTPP) in Šoštanj, Škale, Pesje and the mobile station at the Unit 6 site by the EIMV Company. Allowable concentrations were not exceeded in 2012 on any of these locations and the average annual values were similar to those in Velenje. This favourable situation mainly results from district heating of households in the valley. If homes and other buildings, which are district heated, were to be individually heated, total PM10 emissions into the temperature inversion layer would be higher than emissions from the ŠTPP. Around 200 tons of particulate matter is released into the atmosphere annually from the ŠTTP and about 80% of this mass represents PM10. A third of the Slovenian electricity and heat for heating buildings, as well as heat for industrial processes in the Šalek valley are produced by the ŠTTP at the same time.

1. INTRODUCTION

Given the fact that the Šoštanj Thermal Power Plant (ŠTPP), the largest stationary sources of PM10 in Slovenia, in the Šalek Valley, is situated, one would expect the ambient concentrations of air pollutants to be increased. Both, non-governmental organizations [1] and the Slovenian Environmental Agency (ARSO) [2] assumed that the Values in the Municipality of Velenje exceed the permitted limit, but the results show otherwise. In Velenje the lowest concentrations were measured, as well as the minimum number of days, exceeding the limit concentration values from all measuring locations in Slovenia, with the exception of Iskrba in Kočevska Reka, (rural background). In this context, it should be stressed that data for Velenje were only available for 2012, so a comparison over a longer period is not possible. In addition, one should be aware that the locations of the monitoring stations in different areas are at different distances from major sources of PM10, so a completely reliable comparison is not possible. In Pesje and Škale under the Environmental Information System of the ŠTTP measurements of PM 10 have been ongoing since 2006, and since 2009 also in

Šoštanj. If these figures are compared with others in Slovenia that were available for this period, the relatively low burden of PM 10 in the Šalek Valley is noticeable.

2. DEFINITION AND CHARACTERISTICS OF PM10 AND LEGAL NORMS

Particles in ambient air appear as a mixture of solid and liquid particles. They are the result of emission of dust into the air and chemical reactions between pollutants such as ammonia, sulphur dioxide, nitrogen oxides and volatile organic substances.

More particularly, suspended particulate matter in air is classified according to the particle size [3]:

- total suspended particles (TSP) represent the majority of airborne suspended particles (size below 500 μm)
- PM10 particles whose size is smaller than 10 μm,
- PM2.5 are fine particles whose size is smaller than 2.5 μm. These particles can penetrate deep into the lungs and have a very detrimental effect on health.

Part of these particles are emitted into the atmosphere from sources on the surface (primary particles), while others are thew consequence of various conversions in the contaminated atmosphere (secondary particles). Particles may be of natural origin (pollen, dust, sea salt, smoke from forest fires, meteoritic powder, and volcanic ash) or anthropogenic origin (energy producers in the broadest sense, industry, transport, agriculture), such particles have a significant impact on human health, as well as on climate, visibility, etc. [3].
The results of measurements of air quality obviously vary from year to year and are dependent on the measurement location and the time of year. In recent years air particulates represent one of the major problems in the environment, not only in Slovenia, but also elsewhere in Europe and around the world.

Air quality in Slovenia is most affected by air emissions within the country and partly also due to cross-border long range transport of pollutants. The occurrence of elevated concentrations of pollutants in ambient air is a result of many factors, such as climatic characteristics, meteorological phenomena, physico-chemical processes of transformation of substances in the air and topography [3].

In accordance with Directive 2008/50/EC on ambient air quality and cleaner air for Europe (Ur. l. št. 152/2008 /Official gazette of the Republic of Slovenia), the Slovenian Regulation on ambient air quality (Ur. l. št 9/2011) defines ambient air quality standards, particularly the target, limit, warning, critical and alert thresholds for ambient air quality in order to avoid adverse effects on human health and the environment, and to prevent or reduce them. It also determines the method of informing the public of above threshold values for certain pollutants and the obligation to draw up plans to maintain and improve ambient air quality.

The Regulation on ambient air quality (Ur. l. št. 9/2011) lays down the thresholds and tolerances for PM10. The limit value for a time interval of 1 day of 50 $\mu g/m^3$, is not to be exceeded more than 35 times in a calendar year, and 40 $\mu g/m^3$ as the annual average. The daily tolerated excess is 25 μg/m^3 (75 μg/m^3 total) and 10 μg/m^3 (50 μg/m^3 total) per calendar year [4].

The National measurement network was established in 2001 and at that time consisted of 8 sampling points for PM10 in populated areas, and one background measuring point at Iskrba to assess the contribution to ambient air pollution with PM10 due to cross-border transport of pollutants [3].

Sources of PM10 in ambient air, which may cause the limit values for PM10 at the measuring points of the state network to be exceeded, are classified into the following groups according to the size of their contribution to overall air pollution by PM10:

- emission of particulate matter from road traffic, especially from motor vehicles powered by diesel engines;
- particulate emission from combustion plants using solid or liquid fuels, designed to heat residential and commercial premises;
- particulate emission from industrial sources of pollution;
- emission from diffuse sources of pollution, such as emission of secondary particles due to the re-suspension of road dust particles emission due to construction works, demolition works in construction, operation of devices in industry using of mineral raw materials, and dust emissions from agricultural land due to the implementation of agricultural activities.

3. PM 10 EMISSIONS IN SLOVENIA

According to an ARSO Report on emissions of particulate matter in 2010 19,685 t of PM 10 were released into the air. By far the largest share was accounted for by emissions from communal boilers and domestic heating (69.4 %). Road and non-road transport contributed 9.4 %, industrial sources 4.6 % and electricity and heat production 2.6 %.
According to the findings of ARSO, the distribution of PM 10 in the urban environment is different. The largest emitters in the winter period are industry and transport (Celje 31 %, Nova Gorica 20 %, Zagorje 43 %) on one hand, and wood burning (Celje 24 %, Nova Gorica 29 %, Trbovlje 26 %) on the other.

Companies that are obliged to carry out operational monitoring of the emission of substances into the air from stationary pollution sources and to report the results according to The Rules on initial measurements and operational monitoring of substances into the air from stationary pollution sources and about the conditions for its implementation (Ur. l. RS št. 105/2008) [9], and according to The Regulation of the emission of substances into the air from stationary pollution sources (Ur. l. RS, št. 31/2007, št. 70/2008, št. 61/2009)[10] are required to report their annual emissions. This data is published on the ARSO website (http://www.arso.gov.si/zrak/, marec 2013) but only emissions from definable releases are present on the list.

There were 15 companies in Slovenia in 2011 whose dust emissions exceeded 10 t. Burning of solid fuels contributes the largest share of PM 10 (ŠTPP, TTPP, TE-TOL), followed by the metal and wood processing industries. Among individual sources, the ŠTPP (200 t) and TTPP (100 t) lead the list of PM 10 emitters (Table 1)

Table 1: The largest dust emission sources (total dust) in Slovenia in 2011 (http://www.arso.gov.si/zrak/)

	Emission source	Amount (t)
1.	ŠOŠTANJ THERMAL POWER PLANT	213
2.	TRBOVLJE THERMAL POWER PLANT	98
3.	LJUBLJANA THERMAL POWER PLANT	44
4.	TALUM KIDRIČEVO (Al. production)	43,6
5.	LESONIT Ilirska Bistrica (Wood industry)	34
6.	ACRONI Jesenice (Steel Plant)	30
7.	CINKARNA Celje (Metal smelting)	29,5
8.	KNAUF INSULATION Škofja Loka	25,6
9.	METAL Ravne na Koroškem	23,8
10.	VLAKNIN Krško (Paper production)	22,4
11.	JAVOR Vezane plošče Pivka (Wood composites)	21
12.	TANIN SEVNICA	19,1
13.	SMART INDUSTRIES Godovič	14,4
14.	TREIBACHER SCHLEIFMITTEL, D.O.O. Ruše	11,6
15.	KOMUNALA Kočevje	10,2
	Together	614,6

A simple calculation shows that the ratio between electricity production on one hand and dust emissions on the other is much more favourable in the ŠTPP than in the TTPP. In year 2011 ŠTPP produced 3.779 GWh of electricity – therefore dust emission was 56 kg/GWh. In TTPP 669 GWh of electricity were produced, so the dust emission was 146 kg/ GWh.

4. NETWORKING PM 10 EMISSION MEASUREMENTS AND ITS RESULTS

Within the national network (ARSO), measurements of PM10 emissions are currently on-going in 15 Slovene cities, 12 of them located in predominantly urban environments. The measuring point in Koper is located in Hrvatini and it also records long-range transport from Italy. Measurements in the Murska Sobota region are carried out near the Rakičan, relatively close to transport routes in a so-called urban/ rural location. The Iskrba measuring point is quite distant from local emission sources. From these measurements information relevant to air pollution in the wider area of protection of nature, vegetation, animals and humans, as well as for the determination of long-range transport of pollutants is obtained [3].

When analysing the results (Tables 2 and 3) it is necessary to take into account that the measurement points might not be necessarily strictly comparable, because there are significant disparities in location, transport routes and microclimatic characteristics.

In addition to Iskrba, there are five other locations in the group of those with an average annual level less than 25 $\mu g/m^3$: Ljubljana-BF, Hrastnik, Nova Gorica, Velenje and Koper.

This value is exceeded by less than 1 μg/m^3 in Ljubljana Bežigrad and Kranj. Average annual concentrations of between 26-30 μg/m^3 were found in Novo Mesto and Murska Sobota, while in Maribor, Zagorje, Trbovlje, Žerjav and Celje they exceeded 30 μg/m^3.

The differences in the number of days exceeding the limits are much greather than the differences in annual average concentrations. The concentration of 50 μg/m^3 was exceeded just once in Iskrba and 65 times in Trbovlje, where the situation was the worst. Among other locations the best results were in Velenje with 11 excess days, followed by Hrastnik (17 x), Nova Gorica (20 x), Ljubljana (21 x) and Koper (23x). In addition to Trbovlje the daily concentrations were exceeded on more than 35 days in Zagorje, Novo Mesto, Murska Sobota and Žerjav. Elsewhere concentrations were within the prescribed limits.

Table 2: Average monthly and annual concentrations of PM10 in Slovenia in 2012 in μg/m^3 (Source of data: www.arso.si, www.okolje.info)

Place./ month	LJ-Bežigr	LJ-BF	MB cent.	Zagorje	Hrastnik	Trbovlje	Novo mesto	Kranj	MS	Iskrba	Žerjav	Celje	Nova. Gorica	Velenje	Koper	Šoštanj	Šoštanj mesto	Škale	Pesje
Jan	40	35	37	56	33	51	46	35	38	13	55	47	38	26	29	24	28	22	13
Feb	40	38	47	56	38	56	55	45	55	23	61	59	35	41	34	36	43	34	21
Mar	35	30	36	45	36	60	34	32	33	18	37	42	32	34	32	31	42	27	31
Apr	16	15	26	20	17	19	18	15	19	12	22	19	17	16	20	12	25	18	16
May	16	15	26	21	16	18	15	16	18	14	18	17	16	15	17	13	27	19	16
June	17	17	21	20	17	19	18	17	18	16	19	18	19	17	20	16	27	21	23
July	19	18	21	19	16	19	17	17	16	14	20	17	19	17	21	15	25	22	22
Aug	18	19	20	18	17	18	18	19	18	12	19	19	18	18	21	16	26	21	21
Sept	19	21	32	20	18	21	18	19	19	15	20	21	19	20	19	17	17	22	20
Oct	22	23	33	25	21	24	27	24	25	17	23	26	21	22	23	17	21	20	21
Nov	27	28	33	35	26	35	35	29	37	17	30	41	28	22	23	18	24	21	22
Dec	32	40	32	51	35	51	43	41	48	9	37	48	32	20	25	18	22	17	19
Year	25,1	24,9	30,3	32,2	24,2	32,6	28,7	25,8	28,7	15,0	30,1	31,2	24,5	22,3	23,7	19,4	27,3	22,0	20,4

Table 3: Number of days with an average concentration of PM 10 over 50 μg/m^3 in Slovenia in 2012 (Sources of data:www.arso.si, www.okolje.info)

Place./ month	LJ-Bežigr	LJ-BF	MB cent.	Zagorje	Hrastnik	Trbovlje	Novo mesto	Kranj	MS	Iskrba	Žerjav	Celje	Nova Gorica	Velenje	Koper	Šoštanj	Šoštanj mesto	Škale	Pesje
Jan	9	4	6	17	5	13	10	5	8	0	17	14	7	0	6	0	1	0	0
Feb	6	6	10	16	2	16	15	11	14	1	19	16	5	9	4	5	7	6	1
Mar	2	1	2	11	3	17	1	2	2	0	3	8	1	2	1	1	8	0	1
Apr	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	1	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Sept	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Oct	0	0	4	0	0	0	1	0	1	0	0	1	0	0	3	0	0	0	0
Nov	2	3	5	5	0	7	7	0	9	0	3	5	3	0	5	0	0	0	0
Dec	8	7	3	13	7	12	10	9	10	0	2	11	3	0	3	0	0	0	0
Year	27	21	34	62	17	65	44	27	44	1	44	55	20	11	23	7	21	9	2

5. SOURCES OF PM10 EMISSIONS IN THE ŠALEK VALLEY AND THE AMBIENT CONCENTRATIONS

The largest source of emissions of PM10 in the valley is the ŠTTP, though its chimneys are higher than the local inversion layer (approximately 100 m above the valley floor) Traffic is another source of PM10. As a result of the district heating network through which heat from the ŠTPP is distributed, there are almost no local emission sources on the floor of the valley.

Another source of dust is incorporation of so-called »stabilizat« (mixture of ash and gypsum resulting from flue gas desulphurisation at the ŠTPP) into the subsidence area. Mitigation measures are employed such as grassing those areas that are not affected by subsidence due to coalmining, and irrigation of active surfaces. Another source of PM10 emissions is the ventilation of the mine. Coal dust also enters the atmosphere from the coal depot. To control these impacts, the Environmental Information System of the ŠTPP (EIS) was supplemented by measurement points at Pesje and Škale. Additionally, the concentrations of PM10 in Šoštanj and at a mobile station on the site of Unit 6 are being monitored. The average annual value at Šoštanj, Pesje and Škale are comparable to those in Velenje and in 2012 they were even better, both in terms of average concentrations and days exceeding the limit daily concentration (Tables 4 and 5).

Table 4: The annual PM 10 concentration in μg/m^3 (Source www.okolje.info)

Year	2006	2007	2008	2009	2010	2011	2012
Pesje	28	21	20	22	22	22	20
Škale	26	24	22	24	23	23	22
Šoštanj					24	27	19

Table 5: Number of days with a concentration over 50 μg/m^3 PM10 (Source www.okolje.info)

Year	2006	2007	2008	2009	2010	2011	2012
Pesje	24	14	9	12	10	17	2
Škale	19	11	12	13	12	20	9
Šoštanj					18	30	7

The annual average concentrations of PM 10 in Pesje and Škale exceeded 25 μg/m^3 only in the first year of measurements. The number of days exceeding the concentration of 50 μg/m^3 was lower than in most other places in Slovenia.

The year 2011 is worth mentioning, when relatively high concentrations of PM10 were measured in the Šalek Valley, in particular an increase in the number of days exceeding of the daily concentration of 50μg/m^3. However, a similar increase was seen in other places too, with the exception of Koper and Nova Gorica. Even in Iskrba the limit daily concentration was exceeded on 4 days (3 days after correction). None of measuring points of the state network except Iskrba had annual average concentrations of PM 10 under 27μg/m^3 – the value at Šoštanj. In Pesje and Škale average annual values of 22 or 23 μg/m^3 were measured. These higher values of PM10 concentrations in 2011 were also the result of Saharan sand deposing, so the measured values for 2011 were corrected by ARSO [11].

There is no data available on the share of PM 10 from different sources, since measurements were began in September 2011 and year-round data measured only for 2012.

6. POTENTIAL AIR POLLUTION IN THE ŠALEK VALLEY DUE TO THE HEATING OF HOMES

There were 813,531 households in Slovenia at the end of 2010. According to the Slovenian Environmental Agency, 9,672 t of PM10 were emitted into the air from this source. The average emission calculated from this data is 11.9 kg per household. Since households that are connected to a district heating system and those that are heated in other ways are excluded, we stress that this amount is only an approximate estimate.

There are 13,600 households connected to the district heating system in the Šalek Valley. Heat for district heating is generated at the ŠTPP. If we consider the average potential emission from household heating in this way, 162 t of PM10 emissions are prevented annually by district heating alone.

The Public Utility Company also supplies heat to industrial companies, so they have no need for installing their own boilers. Thus, the emission of PM 10 in the valley is lower for another 83 t (if we take the same basis as for individual heating systems).

Therefore, if households, industrial companies and public buildings were not supplied with heat from the district heating system, around 245 t of PM10 would be emitted into the air. This compares with up to 172 t of PM10 emitted from the ŠTPP, which at the same time produces 1/3 of Slovenian electric energy.

The impact of transport cannot be assessed without measurements. The study “Biomonitoring of air quality along the corridors ...” [12] measured the concentrations of PM 10 at distances of 5 and 20 m from the edge of the road. The results showed that concentrations at the distance of 20 m were higher than those at the distance of 5 m. When this is compared with results of other studies, it could be concluded that the concentrations must be measured, and not just simply calculated from models.

Comparison of the results with selected industrial areas in Europe (Usti Region, Upper Silesia, Várpalota) showed that the air in the Šalek Valley is significantly less polluted than in those areas [13].

7. ENERGY-SAVING BUILDINGS, ENERGY USE AND EMISSIONS OF PM 10

Large amounts of energy could be saved in Slovenia by construction of energy-efficient buildings. This would directly reduce the emission of all pollutants resulting from the heating of residential and other buildings. Moreover, state investments and subsidies are better placed for improving the energy efficiency of buildings than those for electric vehicles [14]. Drašler [15] estimated that heating consumes more than 9,000 GWh of heat per year just for residential buildings in Slovenia. If already rehabilitated buildings are subtracted, the potential to reduce thermal energy consumption is still 4,723 GWh annually. The most appropriate method of heating low energy and energy-efficient buildings is by a heat pump. In this way, the total consumption of energy is considerably reduced, and consumption of electric energy increases [16]. Beside total energy savings this also means lower emissions of particulate matter PM 10 and, consequently, better living conditions in resudental areas.

8. CONCLUSION

Despite the siting of the largest stationary source of PM10 in Slovenia (the ŠTPP), fairly heavy traffic and concentration of population in the Šalek Valley, the concentrations of this pollutant are relatively low in comparison to other parts of Slovenia. Both the levels of PM10, as well as the number of days on which the limit concentrations are exceeded in Velenje were among the lowest for the urban settlements where this parameter is monitored, according to the results of the Slovenian Environmental Agency. The main reason for this is the absence of emissions from homes and other buildings. For practically all the buildings in the central area of the Šalek Valley heat is provided from the ŠTPP via the district heating system. In addition, at the northern outskirts of the valley a gas pipeline network was built. Nevertheless, data about PM10 concentrations should be treated with great caution because they were measured for only one year and, furthermore, the locations of the measurement sites in different settlements are not strictly comparable for many other reasons.

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