The Current State of PM_{10} Air Pollution in the Area of Influence of the Rovinari Thermal Power Plant

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This paper presents the current state of PM_{10} air pollution in the area of influence of Rovinari thermal power plant in Gorj county. In the Rovinari area the air quality monitoring network includes an automatic station on the Southeast part of Rovinari town. PM_{10} concentration was monitored by this automatic station (code GJ-2). The reference method for the sampling and measurement of PM_{10} fraction is described by EN12341/1998 European Norm. Exceeding of particulate emissions is admitted until 2013 under the condition of complying with the emission limits allocated to the ROVINARI thermal power plant. The highest concentrations of PM_{10} were recorded during the cold season (December – February) when the number of exceeded permitted limits by 42% of overtaking in 2012. During the year 2012 the lowest number of exceeding was recorded in period April – August. The Rovinari thermal power plant promoted and executed upgrading works of electro filters related to power units in order to reduce dust concentrations to fit the emission permitted limits of $50mg/m^3$.

Keywords: PM_{10} air pollution, particulate emissions, thermal power

Particles with aerodynamic diameter less than 10 µm (PM_{10}) are target pollutants of the European Union framework Directive on ambient AQ (air quality) assessment, and for the World Health Organization due to their negative effects on human health and environment [1]. PM can penetrate in the human organism where they are being deposited in the respiratory system. The size and shape of particles, and defense mechanism of the respiratory system are factors that influence the penetration and deposition of particles in human respiratory system. The airborne particle penetrate in the deepest part of the lungs due tho their size ($PM_{2.5}$ – respirable fraction, PM_{10} – thoracic fraction) [2].

The short- and long-term human exposure to high particulate matter concentrations increases also the risk of cardiovascular diseases [3, 4].

Thus, in recent decades most industrialized countries established more stringent allowable levels of particulate matter [5]. Romanian like other european countries took over these values into the national laws [6].

The main sources of PM emissions in urban areas are represented by road traffic related to exhaust emissions, tire/engine wear and re-suspension of road dust, and in industrialized areas the main sources are considered: thermal power plants, heavy duty vehicles traffic, incomplete combustion processses [7]. Coal dominated energy structure of energy sector from Gorj County is one of the major causes of air pollution with PM_{10}.

Situated in the Gorj county, on the right bank of the river Jiu, at about 20 km southwest of the city of Tg – Jiu, Rovinari Thermal Power Plant is one the largest electricity producers from Romania. Rovinari Thermal Power Station has an installed capacity of 1320 MW (4x330 MW) consisting of power units 3, 4, 5 and 6, set into operation during the period 1976-1979. Each power unit is equipped with a Benson type boiler of 1035t/h. Thermal Power Plant Rovinari uses coal (lignite) from the 5 mining areas grouped into three quarries: Rovinari (Rovinari East and Gârla areas) Tismana (Tismana I and Tismana II areas) and Pinoasa quarry. Ash is driven by the flue gas towards the stack in the coal combustion process. Its retention occurs in many areas along the gas path.

Thermal Power Plant of Rovinari is the main source of air pollution for the area surrounding Rovinari, and the most important polluter with powders, and particles resulting from the combustion of fossil fuels. This process also can result in particulate matter in the atmosphere by involving the superficial layer of ash and slag deposits in favourable weather conditions. Other sources of floated powders are excavation, heap dumping, loading and transport as well as intense road traffic [8].

The operators of the existing large combustion plants (IMA I and IMA II) issued program proposals for the progressive decreasing of annual emissions of sulphur dioxide, nitrogen oxides and dust in order to comply with the emission limit values.

These programs were negotiated and approved after verification and analysis performed by Technical Secretariats for IMA activity control constituted by the Environmental Protection Agencies. Progressive emission reduction programs are part of the compliance programs.

Progressive emission reduction programs should include information on: the means of operation of large combustion plants; establishing emission limit values and justifying any exemption applicable; technological measures proposed for the progressive reduction of sulphur dioxide, nitrogen oxides and powders emissions until reaching the emission limit values ; timetable for implementation of technological measures; measures for monitoring emissions; cost estimates for the implementation of technological measures to reduce emissions and monitoring foreseen; target emissions of each large combustion plant.

All proposals have been included in the National Program to Reduce Emissions of Sulphur Dioxide, Nitrogen Oxides

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and Powders from Large Combustion Plants, approved by MMGA Ministerial Order no. 833/2005 [9].

In order to achieve the objectives of the National Program and to achieve its goal of reducing emissions by taking steps to comply with the emission limit values, there were established three stages of compliance:

Stage 1: by 12.31.2006;

Stage 2: 1.01.2007 - 12.31.2013;

Stage 3: 01.01.2016 - 12.31.2017.

Both regarding the sulfur dioxide and powders, the Thermal Power Plant of Rovinari was included in stage 2, and regarding the oxides of nitrogen in stage 3.

Technological measures leading to emission reduction proposed in the National Programme are mainly: changing fuel type used with a less polluting one, changing combustion technology and equipment, using technologies to reduce emissions of sulphur dioxide, nitrogen oxides and powders.

In order to reduce powder concentrations to comply with the emission limit value of 50 mg/m^3, the Rovinari Thermal Power Plant promoted and executed modernization works on electrofilters related to power units.

Thus, works for upgrading electrofilters on boilers 5 and 6 (IMA2) ended in late 2011. For upgrading the electrofilters related to energy units IMA1 (heater 3 + heater 4) the deadline regarding settling within emission limits was established for the end of 2013, according to the National Programme for the Progressive Reduction of Emissions of Sulphur Dioxide, Nitrogen Oxides and Powders.

Impact assessment of pollutants discharged into the atmosphere by the Rovinari Thermal Power Plant is done in two ways:

- regarding emissions, quantities of pollutants from flue gases are compared with the limit values set out in the Government Decision No. 440/2010 [10];

- regarding the dispersion (emission) of pollutants in the pollution source surrounding area, the values obtained are relative to permissible limit values stated by applicable regulations.

Experimental part

Air quality monitoring network in the Rovinari area includes an automatic station for air quality monitoring (code GJ – 2), located in the southeast of Rovinari town. With this automated station there are monitored gaseous pollutants such as: sulphur dioxide, nitrogen oxides, carbon monoxide and tropospheric ozone, as well as floated powders, PM_{10} fraction (fig. 1).

Monitoring of floated powders from the Rovinari area is performed using a network of 16 sampling points (fig. 2).

The data collected by the automatic monitoring station are transmitted at hourly intervals as hourly averages, to the local centre server (Environmental Protection Agency). The data are sent to the national centre for certification for preparation of reports and informing the public after the verification and validation.

Air quality is represented by suggestive quality indices, derived from the concentration values of the main air pollutants measured.

The specific air quality index is a coding system of concentration levels registered for each of the monitored pollutant. A general index of air quality as the larger of the specific indices corresponding to monitored pollutants is established based on these specific indices.

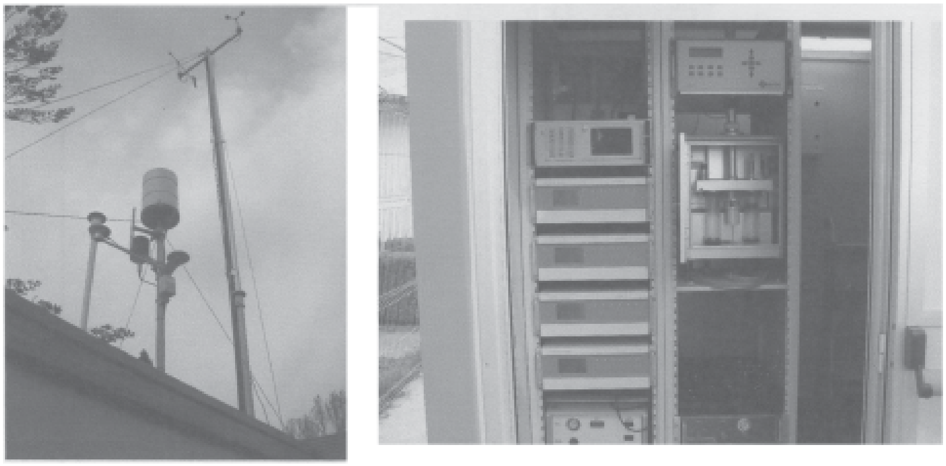

Fig.1. Automatic station for air quality monitoring

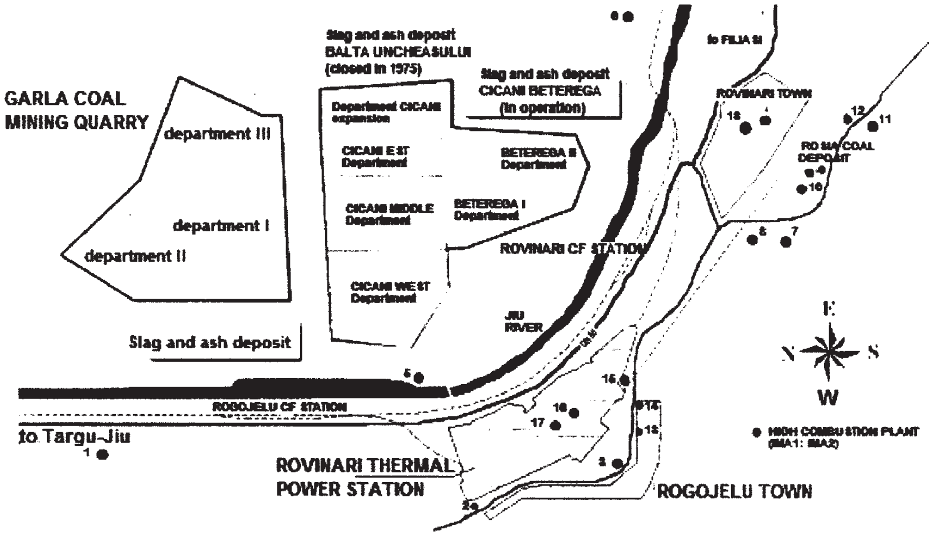

Fig. 2. Floated powders monitoring network from the Rovinari area

General index	Range of concentration ($\mu g/m^3$) for:				
	SO_2	NO_2	CO	O_3	PM_{10}
1(excellent)	0 – 49.9	0 – 49.9	0 – 2.9	0 – 39.9	0 – 9.9
2 (very good)	50 – 74.9	50 – 99.9	3 – 4.9	40 – 79.9	10 – 19.9
3 (good)	75 – 124.9	100 – 139.9	5 – 6.9	80 – 119.9	20 – 29.9
4 (moderate)	125 – 349.9	140 – 199.9	7 – 9.9	120 – 179.9	30 – 39.9
5 (poor)	350 – 499.9	200 – 399.9	10 – 14.9	180 – 239.9	40 – 49.9
6 (very poor)	>500	>400	>15	>240	>100

Table 1
CONCENTRATION RANGE FOR ESTABLISHING THE GENERAL INDEX

At least 3 specific indices corresponding to monitored pollutants must be available in order to calculate the quality general index.

The general air quality index may range from 1 (excellent) to 6 (very bad) (table 1).

There are also monitored various weather parameters such as: wind speed and direction, temperature, rain fall, relative humidity, atmospheric pressure, solar radiation to interpret air quality data.

Floated powders content (PM_{10} fraction)

The sampling and measurement of the PM_{10} fraction was carried out in accordance with the European Norm EN 12341/1999 [11]. This European Norm specifies the performances of the sampling instruments for the PM_{10} fraction in view of the harmonizing of measurements systems, according to the provisions of the Directives of the European Union Council 96/62/EC for the evaluation and management of the environmental air quality.

The measuring principle is based on the filter sampling of the PM_{10} fraction separated from the air-floated particles and their gravimetric determination. In this case it was used a Low Volume System of the LVS-PM_{10} type (fig. 3).

The reference measurement method uses an aspiration system of PM_{10} directly coupled to a filter substrate and a control device of the aspiration flow rate, followed by a gravimetric determination of the PM_{10} mass collected on the filter. The sampling flow rate was adjusted to $2m^3/h$ (fig. 4).

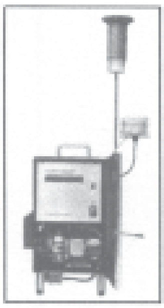

Fig.3. Sampling system for the LVS powders

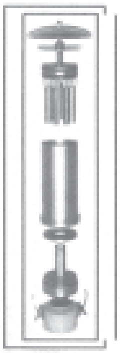

Fig. 4. Powders sampling head

The air flow is accelerated inside the aspiration compartment by an impactor with 8 impact nozzles and then is directed by a pipe towards the impact surface. After that, the air flow is led by a line towards the filter support. This support is adjusted for the insertion of a circular filter with the diameter of 47 mm.

Before sampling, the filters are conditioned for 24 h by drying in an desiccator with calcium chloride. It is weighed and exposed for sampling for another 24 h. After sampling, the filters are again weighed and used for determination of PM_{10} fraction.

Results and discussions

The mass concentration of particles in different areas have been monitored and studied. PM_{10} content is calculated using the following equation:

$$PM_{10} = \frac{m_1 - m_2}{V}\left(\mu g / m^3\right) \qquad (1)$$

where:

m_1 = filter mass after exposure;
m_2 = filter mass before exposure;
V = volume of air sampled.

Interpretation of results for PM_{10} was made according to the Order of the Minister of Waters and Environmental Protection No. 592/2002 laying down limit values, threshold values and criteria and methods for assessment of sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter (PM_{10} and $PM_{2.5}$), lead, benzene, carbon monoxide and ozone in ambient air [12]. Maximum admissible limit for PM_{10} to protect health is considered the daily limit value. In compliance with the provisions stipulated by this Order, the emissions of PM_{10} found within the inhibited areas during average period of 24 h shall not exceed the maximum admissible value of 50 $\mu g/m^3$ [10].

During 2011, due to faults in the climate chamber, the automatic station for air quality monitoring operated only during September – December.

In 2011 there were registered and validated 92 daily average values for PM_{10} (table 2.).

Of these measurements in 41 cases were recorded exceeding of the limit value allowed, which represents a 44.6% frequency of exceeding.

Most daily average concentrations above limit value allowed were registered in December (fig. 5).

Thus, out of 31 average daily values validated, 24 exceeded the limit value allowed, representing 77.42% of the total daily monthly average, and 26% of all measurements made during 2011.

Also, exceeding recorded in December accounted for almost 60% of all exceedings recorded during the operational period of the monitoring station in 2011.

The highest daily average concentration was recorded in early December (298.73 $\mu g/m^3$) being about 6 times above the admissible limit value, while the lowest was recorded on 16 December (21.35 $\mu g/m^3$) being about 2.3 times lower than the value limit.

The lowest average daily concentrations were recorded in October. Of the 28 valid values only 7 were above the permissible limit, which represented 25% of the monthly daily average, 7.6% of the total measurements and 17% of the total exceedings during 2011.

The highest daily average concentration was recorded on 31st October (97.07 $\mu g/m^3$), being 1.9 times above the permissible limit. The lowest daily average concentration was recorded on 9th October (6.18 $\mu g/m^3$) and was 8.1 times lower than the permissible limit value (fig. 5). During 2012, the number of average daily values registered and validated was of 304 (table 3).

Of these measurements, 122 daily average values exceeded the permissible limit, represented 40.1% from the total of values recorded in 2012. Most daily average concentrations that were above the permissible limit value were recorded during the cold season. Thus, the highest number of exceeds of this period was recorded in January

Month Day	September µg/m³	October µg/m³	November µg/m³	December µg/m³
1		40.15	157.98	254.36
2		38.56	43.88	223.93
3	43.25	42.78	80.21	298.73
4	47.05		49.33	246.28
5	49.26	48.75		225.74
6	42.15	75.41		90.75
7	39.47	78.12		138.99
8	35.68	33.71		78.67
9	29.58	6.18		138.72
10	34.06	30.19		205.21
11	38.42	40.23		182.50
12	49.46	46.52		100.29
13	41.78	41.70		115.73
14	45.35	38.57		286.25
15	62.78	36.89		46.06
16	43.92	21.71		21.35
17	49.26	48.32		33.43
18	44.18	75.46		45.15
19	39.21			43.51
20	41.39			48.56
21	44.58	72.45		72.13
22	48.15	60.22		97.84
23	88.13	35.43		112.46
24	91.25	19.26		60.59
25	41.23	23.62		119.28
26	68.41	20.17		127.09
27	73.48	47.60		49.41
28	95.36	47.54		167.61
29	47.81	49.12		134.72
30	90.06	69.59	255.90	113.64
31		97.07		90.84

Table 2
PM_{10} VALUES RECORDED IN THE SURROUNDING ROVINARI AREA IN 2011

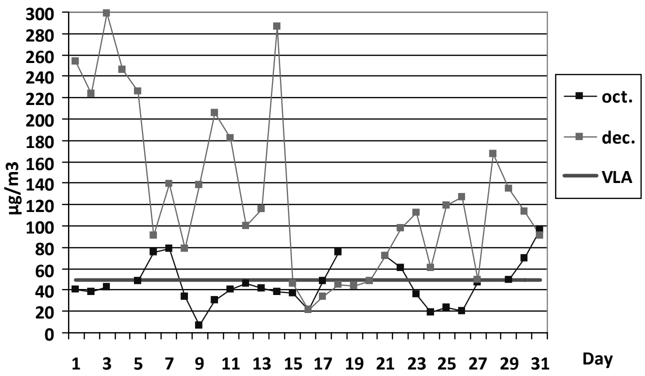

Fig.5. Changes in average daily concentrations of PM_{10} during October and December 2011 in the Rovinari area (VLA – daily limit value for protection human health, 50 µg/m³

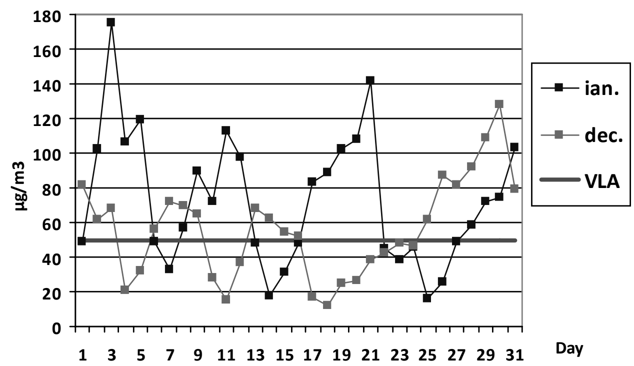

Fig 6. Changes in average daily concentrations of PM_{10} during January and December 2012 in the Rovinari area

and December, and represented 58% of all valid values in the month (fig. 6).

Moreover, the number of exceeding recorded in the three winter months (January, February and December) being 42% of exceeding in 2012.

The highest concentration of PM_{10} measured during this period was recorded in January (174.93 µg/m³) and was above the permissible limit value of approx. 3.5 times, while the lowest was recorded in December (11.65 µg/m³) being 4.3 times below the limit allowed.

If it is reported the number of exceedings registered in one month to the total daily average values validated during that month, the lowest average daily concentrations were registered in the month of May (fig7.). Thus, out of the total 26 daily averages validated in May, only 4 events exceeded the limit value of 50 µg/m³, which accounts for 15.4%.

This month there was also recorded the lowest monthly average (35.46µg/m³). The highest daily average concentration recorded this month was 1.7 times higher than the limit allowed. The lowest daily average concentration was 9.4 µg/m³; this value of concentration being about 5.3 times below the allowed limit.

The period during 2012 when there was registered the lowest exceeds number of the allowed limit value was April-August. Relating the number of exceeds during this period to the total number of exceeds registered in 2012, it appears that they represent 18.8% of them, and the number of validated measurements for the same period is 35.8% of all validated measurements (fig.8.).

Taking into account that the general air quality index is given by specific index with the highest value, it was found that out of a total of 169 general index calculated, 120 were due to the values of PM_{10} concentration, which represented 71%.

Table 3
FLOATED POWDERS (GRAVIMETRIC PM_{10}) – GJ – 2 STATION IN ROVINARI 2012

Day\Month	Concentrations of gravimetric PM_{10} ($\mu g/m^3$)											
	J	F	M	A	M	J	J	A	S	O	N	D
1	49.06	88.39	44,73	20.17			44.15		45.33	65.03	46.8	81.74
2	102.56	78.67	48,63	39.04			45.96		48.42	76.1	29.43	61.63
3	174.93	68.68	36,49	48.76	76.04		75.91		49.13	85.18	61.32	68.36
4	106.62	86.03	39,12	115.79	84.85		64.23	46.78	38.86	92.85	44.78	20.44
5	119.24	47.13	44,48	15.48	47.24		66.86	39.15	36.22	56.4	46.61	31.89
6	48.56	47.06	48,39	109.74	30.8		45.21	58.96	52.21	68.74	26.32	56.12
7	32.52	44.97	38,24	40.86	46.51		43.32		74.02	54.14	19.35	71.8
8	57.12	72.13	86,57	18.71	41.7	54.78	34.52		40.31	40.36	14.46	69.31
9	89.37	98.56	88,9	29.61	34.07	47.23	45.77		33.96	48.96	39.87	64.68
10	71.93	115.19	133,72	41.59	80.85	40.06	45.61		39.64	72.84	56.17	27.63
11	112.44	93.2	45,96	137.08	59.87	30.52	42.77		45.32	58.32	43.12	15.32
12	97.91	90.48	35,61	116.28	46.23	41.33	41.04		39.14	60.5	65.24	36.44
13	48.26	78.03	44,56	42.4	39.52	38.7	37.32		44.31	55.41	26.48	68.21
14	17.26	104.11	47,08	15.53	9.45	26.25	41.42		63.67	46.69	41.39	62.43
15	31,52		38,66	13.35	11.81	33.41	46.15		78.1	51.05	64.08	54.38
16	47.89		85,03	15.08	27.34	40.59	41.24		40.5	66.19	46.14	51.86
17	83.01		83,98	10.54	17.17	25.98	37.49		32.7	32.43	89.48	17.15
18	89.1		92,9	33.16	20.08	45.88	38.21		40.52	45.97	71.67	11.65
19	102.09		84,55	21.53	24.62	41.61	38.56		46.6	49.85	57.32	24.7
20	107.9		95,84	10.72	17.53	42.36	52.77		42.23		64.23	26.78
21	141.59	143.77	45,48	18.8	23.35	68.13	5.,6		41.42		16.07	38.67
22	44.55	115.55	138,46	19.44	32.7	76.22	44.79		39.3		42.8	42.79
23	38.24	99.11	161,97	38.7	22.62	69.22	26.8		48.39		66.24	48.09
24	45.69	72.09	104,74	42.24	39.61	25.07		82.12	54.14		41.25	46.68
25	16.35	46.4	86,89	46.14	40.79	46.33		93.93	49.85		57.60	61.68
26	25.8	47.12	47,37	43.88	14.63			84.3	48.13		51.77	87.48
27	48.96	37.67	47,66		22.53	36.59		31.98	71.44		19.23	81.64
28	58.32	42.3	40,04		9.99	41.13		15.26	74.2		41.64	92.34
29	72.4	46.02	126,84			59.86		39.13	70.94		56.24	108.7
30	74.49		42,51			46.06		37.22	79.56		72.14	127.62
31	103.47		47,97					42.48				79.56

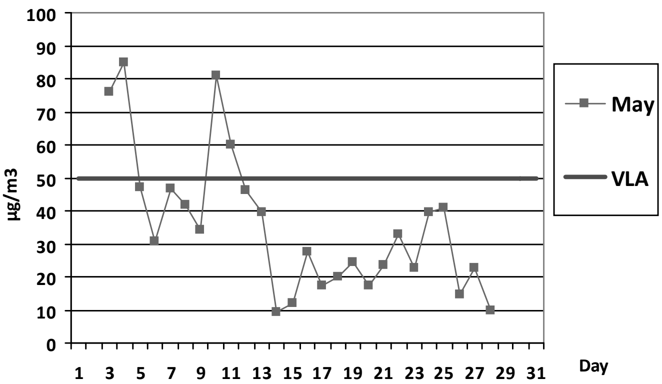

Fig.7. Changes in average daily concentrations of PM_{10} during May 2012 in the Rovinari area

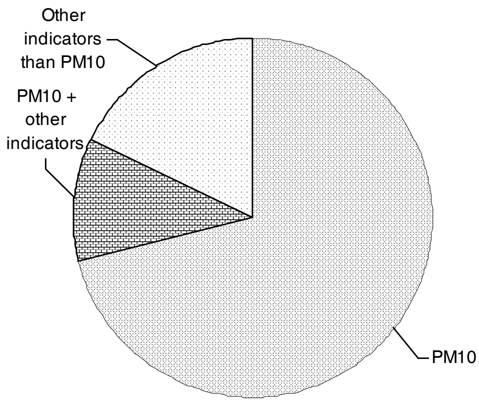

Fig. 9. PM_{10} contribution to establishing the general quality index

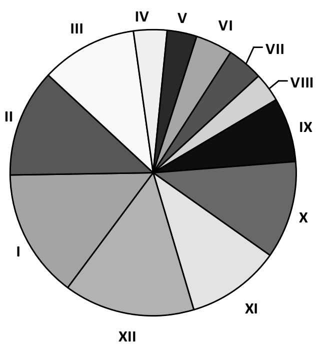

Fig. 8. Distribution of monthly exceedings in 2012

Fig. 10. Distribution of general air quality indices determined using PM_{10} concentration

In 19 cases, general air quality index was given by the values of two or three indices, each time PM_{10} being involved as well. In the other cases, the general air quality indices were determined by the concentrations of other indices monitored (fig 9).

Of the 120 general air quality indices established based only on the de PM_{10} concentrations values, 76 of them (63.3%) represented a moderate general air quality index, 27 of them meaning 22.5% represented a poor general air quality index, 12 of them that is 10% represented a good general air quality index and 5 of them a very good quality index (fig. 10).

The seasonal variations of the number of exceedances the proposed limit value of PM_{10} are dominated by changes in meteorological conditions. PM_{10} levels decrease during the months with high temperatures (from May to August), and with more frequent precipitation as rain.

Temperature inversions are generated during the winter months. This phenomenon occurs on clear nights when the soil loses the heat acquired by radiation and low-lying air layers are cooled faster than the upper layers of air. When PM_{10} are emitted under temperature inversion conditions, they accumulate in the layers of the troposphere close to the ground. This phenomenon causes transport through these layers to occur too slowly, producing an increased concentration of PM_{10}. This is why in the winter months (December – even March) were recorded high concentrations of PM_{10} in the area of influence of the Rovinari Thermal Power Plant.

The measurement results are of special interest for the Implementation of the European Commission Document "Integrated Pollution Control (IPPC) - Reference Document on Best Available Techniques for Large Combustion Plants - BREF", which was developed as a long-term strategic and integrated policy advice to protect against significant negative effect of air pollution on human health and the environment.

For this purpose, Rovinari Thermal Power Plant prepared a series of programs including technical and organizational measures. These programs aim primarily to reduce emissions of sulphur dioxide, nitrogen oxides and powders from large combustion plants.

These programs include objectives to be achieved, the proposed technological measures for the progressive reduction of emissions of SO_2, NO_x and powders to reach the emission limit values, deadlines for implementation of technological measures, cost estimates for the implementation of technological measures to reduce emissions, responsibilities and target emissions of each large combustion plant.

Regarding the total annual emission levels of SO_3, NO_x and powders, they were set according to the actual annual operating time of each plant, the type of fuel used and the thermal power of the plant.

The measures within these programs are primarily regarding the use of techniques to reduce emissions of SO_2, NO_x and powders.

Conclusions

Considering the transition periods negotiated with the European Union regarding the compliance with the limit values of emissions allowed, at present there were found exceedings of these values of powders.

Powder emissions measured in the air in the area of influence of Rovinari Thermal Power Plant had different values. The highest concentrations of PM_{10} were registered during the cold season (December-February) when the number of exceedings represented 42% out of the total exceedings in 2011.

The period during 2012 having the lowest number of exceeds was April-August.

Values of PM_{10} concentrations contributed to establishing the general air quality indices in 71% of the cases.

Out of the general air quality indices established based on the PM_{10} values, the predominant one was the good quality index (63.3%) and 4.16% represented a very good quality index.

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