Monitoring of Particulate Emissions to Assess the Outcomes of Retrofitting Measures at an Ironmaking Plant

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This paper, deriving from a joint effort of its authors, reports the results of a wide-ranging survey on particulate matter (PM) emissions from the operation of ironmaking plants, where this type of emissions is especially problematic and, if not properly addressed, may lead to environmental deterioration conditions that are totally incompatible with the protection standards set at the European Union level. With reference to the Lucchini Severstal plant in Servola (Trieste – Italy), the description of its operating cycle and the relevant flows of materials is followed by an estimation of PM emissions from each of its main activities. Technical and economic efforts were focused on the most critical ones. These efforts led to the implementation of plant retrofitting measures, presently completed, which are illustrated in the paper together with the environmental performances shown by the monitoring activity performed on its systems within the framework of the Integrated Environmental Authorisation required by the regional authority. The analysis of air quality in the areas surrounding the manufacturing plant performed through the monitoring of PM10 concentrations for a significant period of time, before and after the actions taken, shows a positive trend that confirms, on the one hand, the absolute relevance of this source of emissions and, on the other hand, the effectiveness of the aforementioned measures.

KEY WORDS: ironmaking; particulate matter; environmental compatibility; best available technologies.

1. The Plant and Its Manufacturing Process

The ironmaking plant under examination1,2) covers an area of 600 000 m² (Fig. 1). It is located close to the sea, from which it receives its main raw materials to be processed (pit coal, iron ore, pellets), delivered by 60 000-ton vessels. The manufacturing plant was established at the end of the 19th century. Over the time it has undergone various changes in ownership and innumerable transformations resulting from both the progress of manufacturing techniques and changes in the manufacturing strategy adopted by its various owners. Traditionally based on an integrated cycle, the plant closed its iron shop in 2002. Therefore, today it simply manufactures pig iron (both slabs and molten pig iron) and metallurgical coke. Moreover, it should be stressed that in 2000 a 160 MW gas-turbine power plant was installed, which is fed by coke oven gas. With reference to the surveyed plant, it should also be recalled the pending litigation between the plant and the adjacent residential area, which has progressively extended along the line of setback of the plant.

The manufacturing process and the relevant flows of materials are summarised in the diagram of Fig. 2. The raw materials are iron ore and pit coal from various sources, which are delivered to the plant by vessels and stored in piles on yards. They are then collected from yards and preliminarily processed (coking for coal and sintering for iron ore) before being fed to the blast furnace for the production of molten iron. The molten iron is tapped from the furnace and flows into runners that lead to a transfer car (torpedo...
car) that feeds the casting machine, for the production of pig iron, or an adjacent plant that manufactures centrifuged cast iron tubes.

2. Estimation of Particulate Matter Emissions

Particulate matter (PM) emissions were estimated with reference to both stacked and fugitive emissions. The former were obtained from the results of regular stack monitoring activities (Table 1) performed with standardised methodology, whereas the latter were estimated according to consolidated methodologies as suggested by EPA (Environmental Protection Agency) and the IPPC Bureau (Integrated Pollution Prevention and Control Bureau), and based on the use of emission factors. Below the methodologies are fully detailed according to each of the five functional areas into which the plant can be divided.

2.1. Emissions from the Coking Plant

The Lucchini plant in Servola includes (see Table 2) 66 ovens for coal distillation divided into two batteries installed in the 90ies (old bank) and in 2001 (new bank), respectively. The two structures, which are physically adjacent, share the same auxiliary services such as oven charging (gravity), offtake piping (ascension pipe and collecting main), byproduct recovery, pushing (with the relevant PM offtake system), quenching (wet quenching in tower) and coking time system. The pre-heating system for the ovens, which was originally shared by the two batteries, has been recently split (2008) so that combustion parameters can be adjusted independently.

The emission figures reported in Table 2 are referred to a yearly average coke production of 449 000 t, corresponding to an equivalent molten iron production of 1 252 793 t, having assumed the emission factors for “old plants” as a basis for calculation.

With reference to the quenching tower, it should be stressed that the emission values declared by the owner (2.7 t/y), when referred to the yearly average production of cast iron (449 000 t), give emission factors of about 6 g per ton, which was regarded as a too optimistic value taking account of the plant obsolescence. Therefore, in this case, instead of

| Table 1. | Amount of particulate emissions at the stack over the years 2004–2006. |
|---|---|---|---|---|
|   | 2004 | 2005 | 2006 | Average |
| E1 | Heating of coke oven battery | 7.1 | 8.2 | 7.1 | 7.5 |
| E2 | Quenching tower | 2.3 | 3.5 | 2.3 | 2.7 |
| E3 | Coke screening | 3.6 | 2.3 | 6.9 | 2.7 |
| E4 | Ammonia distillation plant | 2.7 | 2.5 | 2.2 | 2.4 |
| E5 | Sinter plant | 17.9 | 10.7 | 7.3 | 11.9 |
| E7 | Sinter cooling | 13.3 | 13.5 | 7.6 | 11.5 |
| E9 | Cowper heating AFO2 | 0.7 | 3.2 | 2.7 | 2.2 |
| E31 | CCT boiler | 0.5 | – | 6.3 | 3.4 |
| E32 | Cowper heating 1 AFO3 | 3.0 | – | – | – |
| E33 | Cowper heating 2 AFO3 | 3.0 | – | – | – |
| E34 | Cowper heating 3 AFO3 | 3.0 | – | – | – |
| E35 | Bag house serving the cast house | 5.8 | 4.6 | 9.5 | 6.6 |
| E36 | Bag house serving the sinter plant | 5.9 | 7.4 | 8.8 | 7.4 |
| E38 | Pig iron casting machine | – | 12.4 | 8.4 | 10.4 |

| Table 2. | Figures of the coke oven battery in Servola. |
| “Old” battery | “New” battery |
| Number of ovens | 37 | 29 |
| Length of ovens | 13.22 m | 13.22 m |
| Width of ovens | 0.40 m | 0.40 m |
| Height of ovens | 4.40 m | 4.40 m |
| Charge of coal | 16.5 t | 16.5 t |
| Capacity of ovens | 21.7 m³ | 21.7 m³ |
| Pushings/day | 55 | 44 |
| Distillation time | 14 hours | 16 hours |
the reported emission values, it was decided to use those determined according to the emission factors provided by BATs (Best Available Techniques, see6) for the so-called “old plants” and comprised between 20 and 40 g/tLS (grams per ton of liquid steel), which correspond to 58±118 g/t of coke with an average value of 88 g/t of coke. Hence, considering a yearly average production of 449 000 t of coke, yearly emissions are comprised between 26.0 t and 52.9 t.

2.2. Fugitive Emissions from the Casting House in the Previous Situation

Emissions from the casting house are the first source of emissions of this shop and one of the major sources of emissions of the plant as a whole.3) This phenomenon is more serious in the initial (drilling the tap hole) and final (plugging the tap hole) stages. According to BATs, the emission factor at source varies between 400 and 1 500 g/t of cast iron produced with an average value of 950 g/t of cast iron. Even regarding this value as too pessimistic and assuming the value recommended by the US regulations (650 g/t of cast iron), it should not be disregarded the fact that the capture hood serving the tap hole in Servola was completely inappropriate to collect its emissions; hence, the only barrier between emissions and the external environment was a partial casting house containment.

The effectiveness of this containment was estimated by comparing the emission values proposed by the EPA regulations5) (Series AP 42, Table 12.5-1 on page 12.5-9) for emissions measured at roof monitors in the event of uncontrolled casting and emissions conveyed to the stack in case of optimal offtake system protecting both the tap hole and the runners as a whole. In the two scenarios mentioned above, the emission factors are 300 g/t and 650 g/t, respectively, with EPA emission factor rating equal to B, which gives their specific reliability. Therefore, out of the overall amount of PM emissions from the casting house, 300/650 × 100 = 46% is dispersed into the external air, whereas the remaining portion is deposited in the casting house itself. The figures reported in Table 5 are referred to a yearly production of cast iron of 387 000 t.

2.3. Fugitive Emissions from the Pig Iron Casting Machine

The typical emissions from the pig iron casting machine are similar to those from the casting house. Hence, it was deemed advisable to assume the same emission factor at source as that proposed for the casting house, i.e. 650 g/t of processed cast iron.

Similarly, it was deemed reasonable to extend to the plant under examination the remarks made about the function of the partial tap hole containment and the relevant inappropriateness of the capture hood to collect its PM emissions. As a matter of fact, although it was served by an offtake duct that nominally could control the phenomenon (200 000 m3/h), the effectiveness of the capture system was undermined by the excessive distance from the point of discharge and further aggravated by an unreliable containment, which prevented from keeping the whole environment under vacuum compared to the external environment.

Given a yearly average cast iron production of 321 000 t and following the same reasoning as that described above, values of particulate emissions comprised between 54.9 and 205.9 t per year were obtained.

2.4. Emissions from Handling and Storage Operations on Materials

The handling of materials required for plant operation inevitably produces diffused open source PM emissions.3) Since the complex calculation procedure that led to the results reported in Table 5 cannot be fully detailed in this paper, it should only be stressed that it was performed by taking account of the emissions from the various operations reported in Table 3 together with the standardised calculation methodologies used for estimation purposes.

Vehicle traffic figures used for analytical purposes are summarised in Table 4.

2.5. Definition of the Emission Framework

The results of the survey are summarised in Table 5 and the diagram of Fig. 3. Five main sources of emissions were identified, which account for 73% of the overall PM emissions from the plant. Below the measures taken into account, the containment objectives set and the costs to be incurred into are detailed.

3. Retrofitting Measures

3.1. Summary of Measures

Through the survey performed on the existing systems,

Table 3. Calculation methodologies for the assessment of the various sources of emissions.

| Source                                | Methodology |
|---------------------------------------|-------------|
| Handling and storage operations       | EPA Series AP-42, par. 13.2.4 |
| Wind erosion of piles                 | EPA Series AP-42, par. 13.2.2 |
| Vehicle traffic on unpaved roads      | Unpaved Roads, ed. 11/2006     |
| Vehicle traffic on paved roads        | EPA AP 42 – 13.2.1 Paved Roads   |

Table 4. Vehicle traffic figures within the plant.

| Source          | Coke | Iron ore and slag (internal) | Pig iron and slag (external) | Other vehicles |
|-----------------|------|------------------------------|-----------------------------|----------------|
| Number of trips per year | [–]  | 30 000                      | 26 000                      | 16 000         | 2 500          |
| Average trip length | km   | 1.2                         | 0.8                         | 2              | 1              |
| Percentage on unpaved roads | [–]  | 20%                         | 40%                         | 0%             | 0%             |
| Percentage on paved roads | [–]  | 80%                         | 60%                         | 100%           | 100%           |
| Average weight of vehicles | [–]  | 20                          | 40                          | 40             | 40             |
| Number of wheels of vehicles | [–]  | 4                           | 8                           | 8              | 8              |
the main areas to be improved were identified:
- offtake system serving the casting house;
- offtake system serving the pig iron casting machine;
- management of storage piles;
- quenching tower.

The action taken for the first system was aimed at capturing 90% of PM emissions by improving the offtake system. The drawbacks of the existing system were carefully analysed when designing the new solution to be implemented, whose main characteristics can be summarised as follows:

1. Installation of a completely new extraction hood, which is closed both at the rear and on its sides and has a

### Table 5. Particulate emissions from the ironworks in Servola before the implementation of retrofitting measures (t).

| Source                                      | Fugitive emission | At stack | Total particulate |
|---------------------------------------------|-------------------|----------|-------------------|
|                                            | min    | med    | max    | min    | med    | max    | min    | med    | max    |
| Coke oven battery                          |        |        |        |        |        |        |        |        |        |
| Coal handling                              |        |        |        |        |        |        |        |        |        |
| Charging                                   | 1.3    | 1.6    | 1.9    | 1.3    | 1.6    | 1.9    |
| Doors                                      | 5.0    | 5.0    | 5.0    | 5.0    | 5.0    | 5.0    |
| Leeds                                      | 0.1    | 0.2    | 0.4    | 0.1    | 0.2    | 0.4    |
| Ascension pipes                            | –      | 0.0    | 0.1    | –      | 0.0    | 0.1    |
| Pushing                                    | 4.5    | 7.8    | 11.2   | 3.4    | 6.0    | 8.5    | 7.9    | 13.8   | 19.7   |
| Quenching (as is)                          | 26.0   | 39.5   | 52.9   | 26.0   | 39.5   | 52.9   |
| Heating                                    | 7.1    | 7.5    | 8.2    | 7.1    | 7.5    | 8.2    |
| Sinter plant                               |        |        |        |        |        |        |        |        |        |
| E5 (electrostatic precipitator)            |        |        |        | 7.3    | 11.9   | 17.9   | 7.3    | 11.9   | 17.9   |
| E7 (sinter cooling)                        |        |        |        | 7.6    | 11.5   | 13.5   | 7.6    | 11.5   | 13.5   |
| E36 (baghouse)                             |        |        |        | 5.9    | 7.4    | 8.8    | 5.9    | 7.4    | 8.8    |
| Blast furnace                              |        |        |        |        |        |        |        |        |        |
| Top                                        | 0.8    | 5.8    | 11.5   | 0.8    | 5.8    | 11.5   |
| Coke screening                             | 2.3    | 3.6    | 6.9    | 2.3    | 3.6    | 6.9    |
| Casting house (as is)                      | 66.1   | 107.4  | 247.9  | 0.3    | 0.5    | 1.2    | 66.4   | 107.9  | 249.0  |
| Bleeders opening                           | 8.0    | 12.0   | 16.0   | 8.0    | 12.0   | 16.0   |
| Cowpers                                    | 0.7    | 2.2    | 3.2    | 0.7    | 2.2    | 3.2    |
| Pig iron casting machine                   |        |        |        |        |        |        |        |        |        |
| Casting                                    | 54.9   | 89.2   | 205.9  | 0.3    | 0.4    | 1.0    | 55.2   | 89.6   | 206.9  |
| Other sources                              | 8.4    | 10.0   | 12.0   | 8.4    | 10.2   | 12.0   |
| Vehicle traffic                            |        |        |        |        |        |        |        |        |        |
| Emission from traffic                      | 23.1   | 34.6   | 46.1   | 23.1   | 34.6   | 46.1   |
| Stockyards                                 |        |        |        |        |        |        |        |        |        |
| Emission from stock                        | 7.3    | 11.0   | 14.7   | 7.3    | 11.0   | 14.7   |
| Ammonia distillation plant                 |        |        |        |        |        |        |        |        |        |
| Stack E4                                   | 2.2    | 2.4    | 2.7    | 2.2    | 2.4    | 2.7    |
| Stack E31                                  | 0.5    | 3.4    | 6.3    | 0.5    | 3.4    | 6.3    |
| Total                                      | 165.4  | 266.3  | 551.6  | 77.8   | 114.8  | 152.1  | 243.1  | 381.1  | 703.7  |

**Fig. 3.** Incidence of each source on overall emissions.
size of 5 000 × 3 000 mm, i.e., five times larger than the previous one and equipped with a moving end so that the crane above it can easily operate;

2. Splitting of the offtake duct serving the hood and subsequent identification of a new path to convey an overall air flow of about 330,000 m³/h at speeds not exceeding 28 m/s.

The adaptation of the extraction system serving the pig iron casting machine was aimed at capturing PM emissions during molten iron tapping from torpedo car to moulds. Since lowering the hood was hardly conceivable owing to the need to ensure both an easy ladle tilting operation and the full freedom of movement of operators in safe conditions and with the maximum visibility, the discharge area was contained by extending the building structure so as to include the torpedo car and, at the same time, to obtain vacuum conditions through the adoption of gates and the extension of curtain walling surfaces.

Fugitive emissions resulting from the presence of outdoor stocks of bulk materials are highly influenced by the overall degree of moisture in the various handled materials. With reference to handling and storage operations, it should be noticed that an increase by 60% in moisture content halves PM emissions, whereas with reference to vehicle traffic, if roads are constantly kept wet for at least 80% of the year, then emissions are significantly mitigated with a mitigation factor corresponding to 0.20 for unpaved roads and 0.04 for paved roads (EPA figures), which in turn correspond to overall emissions from vehicle traffic comprised between 7.3 t and 14.7 t, respectively. The objectives described above were pursued through a network of fixed irrigators to ensure completely wet stocks and roads.

Lastly, with reference to the quenching tower, the analysis performed on this system showed that very low emissions (on the average lower than 25 g/t of coke and in some cases lower than 10 g/t of coke) could be achieved through very fast quenching, the so-called swamp quenching. Moreover, it was noticed that a vertical tower development was very important inasmuch as it could make the steam plume stay longer in the tower, thus improving its cleaning. This would have inevitably entailed the complete overhaul of the quenching tower based on its structural characteristics and, in particular, on its height.

3.2. Definition of the Plan of Measures
The analytical assessment of the average figures for emissions from the plant before and after the measures envisaged to improve the plant resulted in the determination of the relative impact of each investment in terms of emission containment, as detailed in the diagrams of Figs. 3 and 4.

For each retrofitting measure, Table 6 reports the overall costs that can be assumed and the relevant decrease in the amount of PM emissions from the plant both in terms of percentage and in absolute terms.

The economic relevance of the measure aimed at the overall review of the quenching tower is self-evident. However, its impact on the decrease in emissions would have been quite low when compared to the whole picture. It should be added that the feasibility of this measure was doubtful, especially owing to the lack of locations other than those currently in use for the new tower. If the old tower could not have been kept operating, then coke would have to be quenched in the area in front of the coking plant, which is normally devoted to emergency operations and is not equipped with any kind of environmental protection system. Given that 18 months would have been required to build the new tower, the environmental impact of this measure, although temporary, would have been significant, whereas the advantage in terms of percentage, although permanent, would have been modest. On the basis of these considerations, the idea of a new quenching tower was discarded.

3.3. Analysis of the Environmental Impact of the Plan on the Surrounding Urban Area
The figures on emissions stated above, which are relevant per se, become even more important where compared to the overall emissions in the urban area of Trieste, for which according to the most recent available data® (2005) the amount of overall particulate pollutant emissions on a yearly basis is 820 t. The same source estimates that the iron plant in Servola produces yearly average emissions amounting to

![Fig. 4. Predictable decreases in dust emissions following the implementation of all potential measures.](Image 359x230 to 501x384)

| Measure                                      | Amount [€] | Percentage impact [%] | Absolute impact [t] |
|----------------------------------------------|------------|-----------------------|---------------------|
| New extraction hood in the casting house     | 850 000    | –23                   | –87.6               |
| Curtain walling in order to obtain vacuum conditions at the casting machine | 450 000    | –16                   | –59.9               |
| New quenching tower                          | 12 000 000 | –8                    | –31.2               |
| Network for the irrigation of stocks          | 900 000    | –7                    | –26.4               |
| **Total**                                    | **14 200 000** | **–54**                | **–205.1**          |
| **Total (quenching tower omitted)**          | **2 200 000** | **–46**                | **–173.9**          |

*This figure corresponds to the expectable decrease in the percentage of dust emissions from the plant as a whole.*
214 t, being a value quite similar to that calculated by the authors of this paper (243 t) in the most optimistic scenarios (see Table 5). In any case, this source of emissions is absolutely relevant inasmuch as, before the implementation of the measures, this source virtually contributed for one fourth to the TSP (Total Suspended Particulate) emissions of Trieste as a whole. At the same time, it can be easily understood that the actions taken in the plant can significantly affect urban air quality inasmuch as they can decrease the PM amount contributed to the town on a yearly basis by 129 t, i.e. 15%.

3.4. Monitoring of Emissions

Following the implementation of the measures above, the renewed systems were systematically monitored in order to check their performances through PM measurements both upstream and downstream of the filters. With reference to the casting house and casting machine, Tables 7 and 8 report the results of these surveys and the calculation of the amounts of captured PM on a yearly basis.

With reference to the casting house, the yearly PM amount globally captured is about 190 t, which corresponds

| No. of sample | 1 | 2 | 3 | 4 |
|---------------|---|---|---|---|
| Starting time of sampling | 11.45 | 14.00 | 18.30 | 8.30 |
| Duct diameter (mm) | 2500 | 3800 |  |
| Air pressure (kPa) | 101.60 | 101.60 | 101.60 | 101.32 |
| Effluent temperature (°C) | 23 | 24 | 24 | 35 |
| Aeriform density (kg/Nm³) | 1.189 | 1.185 | 1.185 | 1.146 |
| Effluent speed (m/s) | 23.2 | 23.8 | 23.0 | 12.1 |
| Effective capacity (m³/h) | 410.429 | 420.361 | 406.423 | 493.861 |
| Standardised capacity (Nm³/h) | 377.541 | 385.376 | 372.598 | 437.741 |
| Operating stage of the plant | Castings | Castings | Castings | Castings |
| Length of sampling (min) | 60 | 50 | 45 | 60 |
| Average concentration (mg/Nm³) | 159.30 | 164.08 | 177.82 | 167.00 |
| Mass flow (kg/h) | 60.1 | 63.2 | 66.3 | 63.2 |
| Total particulate per operation (kg) | 60.1 | 52.7 | 49.7 | 54.2 |
| Castings/day | 10 |
| Days of production | 350 |
| Yearly particulate (t) | 189.7 |
| Yearly production (molten iron) (t/y) | 410,000 |
| Emission factor (g/t) | 463 |

| No. of sample | 1 | 2 | 3 | 4 |
|---------------|---|---|---|---|
| Starting time of sampling | 9.10 | 10.35 | 15.15 | 14.30 |
| Duct diameter (mm) | 1970 | 1970 | 1970 | 2400 |
| Air pressure (kPa) | 101.32 | 101.32 | 101.32 | 101.19 |
| Effluent temperature (°C) | 33 | 34 | 36 | 29 |
| Aeriform density (kg/Nm³) | 1189 | 1185 | 1185 | 1169 |
| Effluent speed (m/s) | 19.30 | 19.60 | 19.90 | 13.54 |
| Effective capacity (m³/h) | 211.294 | 215.216 | 218.276 | 220.540 |
| Standardised capacity (Nm³/h) | 188.507 | 191.381 | 192.846 | 199.430 |
| Operating stage of the plant | Castings | Castings | Castings | Castings |
| Length of sampling (min) | 55 | 70 | 50 | 58 |
| Average concentration (mg/Nm³) | 230.70 | 244.30 | 298.06 | 257.69 |
| Mass flow (kg/h) | 43.5 | 46.8 | 57.5 | 49.2 |
| Total particulate per operation (kg) | 39.9 | 54.5 | 47.9 | 47.4 |
| Castings/day | 4 |
| Days of production | 350 |
| Yearly particulate (t) | 69 |
| Yearly cast iron production (t/y) | 321,000 |
| Emission factor (g/t) | 215 |
to an emission factor of 462 g/t of cast iron. This figure falls within the range recommended by BATs (400–1500 g/t), which would confirm the validity of design assumptions.

With reference to the pig iron casting machine, the emission factor of 215 g/t is referred to captured PM. This figure should be added to the PM that owing the considerable hood installation height are deposited within the building.

3.5. Impact of Measures on Air Quality in the Areas Surrounding the Plant

Trieste is equipped with an air quality monitoring network based on fixed stations. Figure 5 reports the distribution of fixed stations around the plant for which historical data (from 2004 until today) are available on PM10 and, with reference to the sites of Muggia, Via Pitacco and Via Svevo, on TSP. All these stations are located within 1 km from the blast furnace, except for the station in Muggia, which is located 2 km away from the plant.

3.5.1. Temporal Evolution of PM10 Concentrations Over the Period 2005–2009

Table 9 reports the yearly average concentrations of PM10 and the yearly total days on which the threshold of 50 μg/Nm3 was exceeded. As an additional contribution to this discussion, Fig. 6 reports the moving averages at 30 days of PM10 concentrations for the year 2009 and for all stations under examination.

With reference to the yearly average concentrations of PM10, all monitoring stations under consideration confirm in absolute terms the compliance with the threshold provided for by the legislation in force (40 μg/Nm3). In relative terms, in 2006 and in 2007 emission values were substantially maintained. These values tended to decrease in 2008 and 2009. The same remarks can be made on the number of occurrences in which the daily reference value was exceeded (50 μg/Nm3): whereas the situation was quite critical in 2006 and in 2007, in 2008 and in 2009 there was a significant gradual improvement.

With reference to the monthly moving averages of PM10 (Fig. 7), all stations under consideration confirm a substantially overlapping trend with a concentration peak at the end of the winter period affecting the area of Trieste as a whole, which can be assumed to result from special weather conditions.

For a more in-depth discussion of the issues dealt with in this paper, the air quality data obtained from the monitoring station in Via S. Lorenzo in Selva should be examined because this station is located against the external perimeter

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Table 9. Average PM10 concentrations (μg/Nm³) and yearly number of days in which thresholds were exceeded.

| Station          | Yearly average concentrations | Yearly average concentrations | Number of days in which thresholds were exceeded |
|------------------|-------------------------------|-------------------------------|-----------------------------------------------|
|                  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Muggia           | 28.3  | 24.0  | 28.7  | 30.5  | 21.5  | 18.6  | 15   | 19   | 22   | 41   | 19   | 4    |
| Via Tor Bandena  | 48.6  | 21.4  | 23.3  | 25.4  | 21.2  | 19.2  | 84   | 10   | 5    | 27   | 14   | 12   |
| Via Pitacco      | 21.0  | 21.2  | 28.4  | 28.5  | 25.7  | 22.4  | 19   | 11   | 28   | 27   | 14   | 2    |
| Via Svevo        | 22.9  | 25.1  | 32.6  | 33.6  | 29.2  | 28.0  | 22   | 21   | 40   | 53   | 29   | 16   |
| Via Carpineto    | 26.6  | 26.2  | 30.6  | 31.3  | 27.5  | 24.5  | 35   | 24   | 50   | 46   | 29   | 15   |
| Piazza Libertà   | 27.8  | 23.9  | 26.4  | 27.7  | 24.8  | 19.6  | 33   | 15   | 19   | 32   | 19   | 11   |
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of the plant and at no more than 70 m from its casting house and, therefore, can be regarded as a significant source of information about the emissions from the plant. The diagram of Fig. 7 reports the monthly moving averages of PM10 concentrations from the summer of 2007 (when the monitoring station was set up) throughout the year 2009.

The situation, which was clearly critical in the summer of 2007, tended to a significantly improved scenario in 2008, with a further improvement in 2009, which however should be considered with prudence. It cannot be disregarded the fact that the casting activity in the blast furnace area stopped for 40 days in the second quarter of 2009 owing to a planned relining. However, this favourable situation for emissions did not affect the first quarter of 2009, when the improvement compared to the previous year was significant.

Figures 6 and 7 show that the moving average of PM10 concentrations sampled at S. Lorenzo in Selva and those related to the others sampling sites have opposite tendencies. Such phenomenon probably depends on the fact that the station of S. Lorenzo in Selva is located in the proximity of the main emission source; it is therefore not only subject to wind speed variability, like the other stations, but it is also more sensitive to wind directions than the sites that are farer from the plant. As a result, concentrations sampled at S. Lorenzo in Selva show a clear seasonal pattern with peaks in correspondence of months in which winds blowing from south prevail and the sampling station is downwind with respect to the emission source.

3.5.2. Temporal Evolution of Total PM Concentrations

For the situation of emissions in Trieste to be better understood, it is useful to mention the total PM concentrations for the area available from 2005 onwards as recorded by the monitoring stations in Via Pitacco and Via Svevo as well as for Muggia (see diagrams of Fig. 8). For each monitoring station under examination, there is a substantial decrease in the maximum values, which from the second quarter of 2008 are steadily below 60 μg/Nm3 against peaks of 100 μg/Nm3 in 2007 and values above 120 μg/Nm3 in 2006. In 2009 there was a further improvement in the situation, although again this improvement should be considered with prudence owing to a stop of the blast furnace for 40 days. However, it should be stressed that emission levels were constantly low throughout the year and that the stop was limited in time.

3.6. Conclusions

The methodological approach illustrated in this paper makes it possible to differentiate the retrofitting measures envisaged for the various systems in order to minimise the environmental impact of the manufacturing activity and to identify their relative impact on the emissions globally resulting from the plant.

The PM amounts that can be suppressed following the actions taken, which are about 170 t/y, i.e. approximately 46% of the total PM emissions from the old plant, are substantially confirmed by the experimental measurement surveys performed both on PM concentrations upstream and downstream of pollutant emission control systems and on the total amounts separated from them and extrapolated on a yearly basis.

Air quality data should be further examined. However, they show an improved environmental situation with a sensible decrease in the number of days on which the thresholds for PM concentrations were exceeded and apparently confirm the assumptions made about the relative incidence of the plant on emissions in the surrounding urban area.

Lastly, the relevance of fugitive emissions from the iron-making plant both in absolute and relative terms is self-evident. Out of about 380 t/y of overall emissions from the plant, as a whole as many as 270 t/y can be attributed to them.

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