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Particulate Matter in the Excavation Work Sites in Urban Areas

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Abstract: Problem statement: Excavation work sites in urban areas for infrastructures and buildings cause a great deal of disturbance and damage due to the emission of particulate matter, in particular in the area involved in urban renovation work. Under Italian legislation limits currently exist for PM_{10} and PM2, 5 but, in the case of excavation work sites, it would be also necessary to consider limits for Total Suspended Particulate Matter (TSP), but these no longer exist. **Approach:** A 20-month monitoring period near the exposed population was carried out measuring and analyzing the concentration of TSP, PM_{10} and PM2, 5. This monitoring was done in order to determine statistically significant results, to find out what the pollutant sources are and the microclimate conditions and the particle-size values to take into account as a critical condition to be managed and controlled inside excavation work sites in an urban area. **Results:** The data obtained shows that excavation work sites increase particulate matter concentration, which may already be high. PM_{10} measured near the excavation work site and urban traffic, represented about 70% of TSP. In the city measurement of PM_{10} were usually around 10% higher. TSP concentration values depended on the type of work activity and, although they were similar to TSP concentration values in the city, sometimes they were 60% higher. **Conclusion:** The high levels of particulate matter due to the excavation work sites in urban areas can significantly increase the health risk effect. In the roads near the excavation work sites, even when there is no excavation work activity, the resurgence of dust from the ground by vehicles results in high levels of TSP. The results of this study are of interest for local government as a basis for prevention, monitoring and control of environmental impacts due to the dispersion of dust into the atmosphere, generated by excavation work sites.

Key words: Total Suspended Particulate Matter (TSP), local government, excavation work sites, environmental impacts, imposing limit, quality standards

INTRODUCTION

The interest on health problem concerning the exposure to particulate matter, has focalized, in the last decades (APHEIS, 2005), the attention on specific particle size (EPA, 2005) and on the improvement of sampling (Tsai and Huang, 1995) methods EPA, 2006.

Since 1980 the EU has been approving several directives on air quality, in particular to manage and control great industrial plants (EEA, 2007), by imposing limit values for pollutants.

Directive 96/62/CE on the Evaluation and management of air quality in the environment is aimed at protecting human health and the environment with harmonized European procedures.

Directive 99/30/CE establishes air quality limit values for different pollutants. PM_{10} is limited to 50 μg m^{-3} on 24 h and to 20 μg m^{-3} averages per year.

The Sixth Environment Action Programme entitled "Environment 2010: Our Future, Our Choice", which covers the period from 22 July 2002 to 21 July 2012, introduces limit values for PM_{10} and PM2, 5, ensuring the application of air quality standards (WHO, 2005; AQEG, 2005; EEA, 1999) and defining a strategy on air pollution.

In Italy the evolution of monitoring, according to UE Directives, starts from TSP sampling (1994-2002) to PM_{10} (from 2002) (Paoletti *et al*., 2002) and PM2, 5 (from 2010).

In the excavation work sites, due to particular particle size of the work activity of crushing, demolition,

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excavation and grading land, it would be necessary to consider, besides PM_{10} and PM2, 5, also TSP.

Since in Italy the legislation does no longer take into account TSP, the 150 μm m^{-3} attention limit value and the 300 μm m^{-3} warning value of the repealed law, could be used to safeguard the human health.

This study is aimed, through a 20-month monitoring period of TSP, PM_{10} and PM2, 5 in an important excavation work site, at understanding the real contribute to the particulate matter of the work activity, in order to know which the parameter to consider safeguarding the exposed population are.

Several literature studies (ATS, 2000; Dockery *et al.*, 1993; 1996; Hester and Harrison, 1998) on the effects of particular matter show the correlation between dust concentration and the manifestation of chronic respiratory diseases (asthma, bronchitis, emphysema) and cardiovascular diseases. Larger particle size induce irritation, dryness and inflammation of larynx and pharynx, while smaller particle size (less than 5-6 μm) can cause and aggravate chronic respiratory diseases (asthma, bronchitis, emphysema), induce bronchial inflammation, fibrosis, ischemia, tumor and in general reduce the immune system versus infections and other pollutants (WHO, 2003).

This study wants to evaluate the criticity of the excavation work sites, through the correlation between TSP, PM_{10} and PM2, 5 considering the meteorological, traffic and type of sources effects.

MATERIALS AND METHODS

The measurement method used for the sampling of TSP, PM_{10} and PM2, 5 is gravimetric, using the filter weight difference before and after sampling.

The filter used is fiber quartz, diameter 47 mm, sampling efficiency>99.5%, according to standard EN 12341:2001.

The analytical balance has a sensitivity of 0.01 mg.

The instruments used for sampling are Fig. 1:

- Sequential Sampler EXPLORER PLUS CONTROLLER 16 (16 filters)
- Sequential Solenoid Sampler EXPLORER EV8 (8 filters)

Using the pickup heads according to UNI EN 12341 (2.3 m^{-3} h), the sequential system complies with the requirements of current legislation.

Fig. 1: Sequential Sampler EXPLORER PLUS CONTROLLER 16 (16 filters) and Sequential Solenoid Sampler EXPLORER EV8 (8 filters)

The instrument is equipped with sensors for the detection of micro-climatic conditions (temperature, pressure, humidity).

Using the appropriate sampling head, it was possible to sample TSP, PM_{10} and PM2, 5.

Case study: The case study is about the analysis of the airborne dust generated by a large excavation work site in urban area, which belongs to an important project to transform the city.

The site occupies an area of about 135,000 m^{-2}. The area involves a large residential area and the construction of shopping malls and expansion of green areas, in order to make this new urban order a new pole of attraction of the city.

The interventions provided within the site, which represent a source of dust, are divided into the following activities:

- Demolition of the buried artifacts structures and foundations of existing industrial sites
- Crushing and screening of debris from demolition in mobile plant for the recovery of non-hazardous waste, installed within the site area. This material is deposited in specific areas waiting for the re-use within the site or marketed outside
- Excavations for infrastructure works and private construction. The material is loaded onto trucks and delivered to the screening plant located within the area. The undersize fraction is deposited in the appropriate areas in heaps of 1000 m^3. This material is dampened (by watering) or covered with protective HDPE sheeting to prevent dispersion of dust into the atmosphere
- Backfill material from undersize, by grab excavators, loaders and graders

The typical sources of dust emission in the excavation work sites are:

- Tracks yard and storage areas
- Areas of material handling
- The resurgence by wind

Another important emission, unless properly controlled, is the transportation of materials on public roads; because of the dispersion of the load and the release of the means of transport not enough cleaned (tires, boxes).

It is also important to assess the contribution of road traffic emissions. The dispersion of dust into the air also depends on weather conditions.

Monitoring of particulate matter: The first Point (P1) of monitoring Fig. 2 is located near a residential building with 160 families in the entire complex and about 70 families in the side directly exposed to the site. This building, considered as a critical point, is located a few meters away from the site, near an urban traffic road.

During most of the measurement period, the site area, next to the monitoring point, was characterized by the presence of high mounds of variable size material, located a few meter from the building complex, which have affected the data collected.

The second monitoring Point (P2) is located near a residential complex Fig. 3 in which 150 families live, half of them directly exposed to the site. The site is 15-30 m from the facade of the buildings and P2 is about 200 m far from the urban traffic road.

The working cycle runs from Monday to Friday from 9 a.m. to 18 p.m. and on Saturdays from 9 a.m. to 13 p.m.

Fig. 2: First monitoring Point (P1)

Fig. 3: Second monitoring Point (P2)

The monitoring took place over 24 h for a total duration of 20 m.

The obtained values were compared with the values of the law, in particular:

- TSP-Level of attention: 150 μg m^{-3}; Alert level: 300 μg m^{-3}
- PM_{10}-24 h limit value: 50 μg m^{-3} not to be exceeded more than 35 times per year
- PM2, 5: 25μg m^{-3}

The monitoring results were compared with the values of the measuring stations located throughout the city, in order to better understand the contribution of the excavation work site and the traffic pollution.

RESULTS

The TSP results of January measurement in P1, reported in Table 1, have been related to the meteorological condition and to the activity of the excavation work site.

The TSP results of January measurement in P1 are reported as example in Table 2.

Table 3 and Fig. 4 show the concentration in the two monitoring point P1 and P2 in comparison with measurements from a monitoring station in the city, not so far from the site, referring to the same period of analysis. This is aimed at evaluating the origin and composition of the TSP.

Table 1: Correlation results–meteo condition–type of work activities in January

	Monitoring data:TSP-Month; January- Location: P1		
	Meteo	type of	conc. TSP
Day/month	condition	work activity (*)	(μg m^{-3})
01/01	Cloud	NO ACTIVITY	162, 2
02/01	Cloud	CM	130, 1
03/01	Rain	CM	37, 2
04/01	Rain	CM	30, 8
05/01	Cloud	CM	38, 4
06/01	Rain	CM	33, 9
07/01	Sun	CM	90, 8
08/01	Cloud	D	81, 1
09/01	Cloud	D	82, 3
10/01	Sun	S D CM	165, 8
11/01	Sun	NO ACTIVITY	108, 6
14/01	Cloud	S	n.a.
15/01	Cloud	S	20, 7
16/01	Rain	S	19, 6
18/01	Sun	SFD	124, 1
21/01	Fog/ Cloud	CM	155, 5
22/01	Sun	CM	172, 9
28/01	Sun	SFD	137, 9
29/01	Sun	SCM	n.a.
30/01	Cloud	SCM	137, 2
31/01	Cloud	CM	179, 8

Table 2: TSP results in P1 in January

Day/month	Average (°C)	Monitoring data: TSP - Month; January - Location: P1 Average p (hPa)	Average humidity (%)	Duration (min)	Volume (Litres)	TSP wheight (µg)	Conc. TSP (µg m^{-3})
01/01	5, 3	1045, 9	49, 71	1440	50618, 8	8210	162, 2
02/01	5, 1	1045, 1	62, 47	1440	51352, 6	6680	130, 1
03/01	4, 5	1043, 6	74, 01	1440	51103, 9	1900	37, 20
04/01	6, 3	1046, 6	79, 45	1440	51301, 6	1580	30, 80
05/01	8, 0	1041	81, 58	1440	51327, 2	1970	38, 40
06/01	8, 2	1039, 2	77, 45	1440	51870, 1	1760	33, 90
07/01	6, 9	1043, 4	77, 98	1440	33596, 1	3050	90, 80
08/01	6, 4	1049, 9	79, 62	1440	51673, 5	4190	81, 10
09/01	7, 5	1048, 4	74, 61	1440	51381, 6	4230	82, 30
10/01	7, 6	1048, 9	68, 33	1440	51199, 1	8490	165, 8
11/01	7, 5	1044, 1	74, 26	1440	50842, 1	5520	108, 6
14/01	9, 4	1041, 6	75, 52	1440	50427, 6	n.a.	n.a.
15/01	9, 1	1040, 1	79, 73	1440	51165, 6	1060	20, 70
16/01	8, 8	1032, 7	81, 57	1440	51499, 4	1010	19, 60
18/01	9, 8	1041, 7	63, 1	1440	50376, 2	6250	124, 1
21/01	7, 4	1043, 6	80, 35	1440	49139, 1	7640	155, 5
22/01	11, 3	1033, 9	52, 6	1440	49162, 9	8500	172, 9
28/01	14, 8	1044, 9	41, 84	1440	50094, 1	6910	137, 9
29/01	11, 1	1048, 1	64, 88	1440	49441, 3	n.a.	n.a.
30/01	10, 4	1042, 9	72, 57	1440	49764, 7	6830	137, 2
31/01	9, 9	1040, 1	70, 7	1440	48997, 7	8810	179, 8

Table 3: TSP concentration in P1, P2 and comparison with a monitoring station in the city

Day/month	Conc. TSP in P1 (µg m^{-3})	Conc. TSP in P2 (µg m^{-3})	Conc. TSP in the city (µg m^{-3})
1-Jan	162, 2	99, 6	109
1-Feb	130, 1	41, 3	91
1-Mar	37, 2	20, 3	62
1-Apr	30, 8	16, 3	40
1-May	38, 4	20, 7	42
1-Jun	33, 9	15, 9	48
1-Jul	90, 8	n.a.	83
1-Aug	81, 1	26, 1	94
1-Sep	82, 3	28, 4	82
1-Oct	165, 8	55, 2	104
1-Nov	108, 6	38, 3	110
14/01	n.a.	31, 6	85
15/01	20, 7	12, 2	56
16/01	19, 6	9,1	35
18/01	124, 1	n.a.	87
21/01	155, 5	108	135
22/01	172, 9	50, 2	105
28/01	137, 9	59	139
29/01	n.a.	41, 9	127
30/01	137, 2	40, 3	145
31/01	179, 8	51, 5	n.a.

DISCUSSION

Data in Table 1 shows that the most critical operations for the formation of airborne materials are in particular excavation, demolition and loading/unloading. With regard to the crushing and screening, the company that operates in the site uses machines that allow minimization of dust generation through nozzles that humidify the material to be treated.

The results of monitoring show that, in general, particulate matter concentrations are lower when:

- The humidity is high
- There is moderate or strong wind and the atmosphere is unstable in the lower layers
- There is weak or no wind and a sunny day

Table 3 and Fig. 4 show that the TSP concentrations in the city are generally higher than the concentrations obtained in P1 (located near the road) and are, in most cases, significantly higher than the measurements made in P2 (site area).

The days in which there is no activity, as well as Saturdays and Sundays, should be considered as moments of persistence of particles in the air due to the continuous presence of deposited mounds and the traffic on the roads next to the measuring points. The contribution of traffic to the airborne concentration in the air, during periods of inactivity, is shown by the high values observed, even after the removal of mounds.

It has been necessary to evaluate the values of PM_{10} and PM2, 5, in order to better characterize the contribution of the excavation work site from external anthropogenic sources, particularly from urban traffic.

This assessment was achieved by further monitoring campaign next to the receivers and a comparison with the city stations for the measurement of airborne particulates (TSP, PM_{10} and PM2, 5).

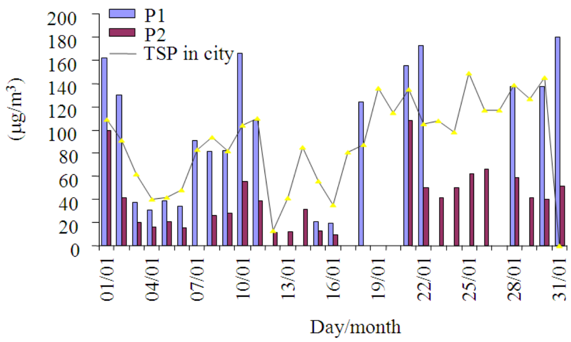

Fig. 4: TSP concentration in P1, P2 and comparison with a monitoring station in the city

The most interesting comparison has been done with data from point P1, located near the city roads, while the control unit in point P2 shows very low PM_{10} concentration, as well as TSP, due to the absence of road in the immediate vicinity of the measuring unit.

The measured values of PM_{10} in the urban context are strongly influenced by air pollution due to vehicular traffic. In particular, the percentage of PM_{10} on TSP varies from a low value in August (52.8%) to a maximum in January (76.1%). It is possible to read these values as a function of weather and climate and of the external anthropogenic pressures (emissions from vehicular traffic and domestic heating, which varies depending on the season).

PM_{10} measured in P1 represented about 70% of TSP. In the city measurement of PM_{10} was usually around 10% higher, confirming the contribution of the excavation work to the particle size greater than 10 microns.

PM2, 5 represent instead 45% of TSP in point P1, with a lower variability over time than PM_{10} concentration.

The days of exceedance of TSP concentration of 150 µg m^{-3}, often correspond to exceedances of PM_{10} and PM2, 5 limit values.

It is important to say that the examined excavation work site involved a wide area, respect to the power machine. That means low values of fine particle size, in particular PM2, 5. This is typical of buildings excavation works, respect to infrastructure work, like urban underground excavation works, which present a higher power machine in a reduced area.

It is possible to conclude that excavation work sites in urban areas contribute to increase yet significant particular matter concentration values.

CONCLUSION

The long-term monitoring next to the receivers showed that the concentration of airborne dust is strongly influenced by:

- The weather and climate (temperature, pressure, relative humidity, wind)
- Type of work activities in the excavation work site (excavation, crushing, screening, demolition, mitigation works)
- Anthropogenic pressures existing in the area near to the site (urban traffic, resurgence of dust caused by transit of working and private vehicles)

It is possible to say that the concentration of TSP is strongly influenced by high values of PM_{10} and PM2, 5, due in particular to vehicular traffic. The high concentration of total suspended particulate matter, therefore, is not only due to the working activities or to the material deposited for long periods in front of the monitoring unit inside the working site, but also to the existing traffic flow in the near urban area. The significant difference between the particulate matter concentration measured near the road and the values inside the site, but far from roads, are justified by the important contribution of urban traffic flow to the raising of particulate matter concentration. This increase occurs in areas near the urban road network, both on the concentration of PM_{10} and PM2, 5, both on TSP, due to the rising of dust deposited on the streets next to the site.

High PM_{10} and PM2, 5 concentration values involve important health effect on the exposed population, but even when such values are under limit values, an excavation work in urban area can often contribute to increase the disturbance and damage risk.

It can be concluded that an excavation work site located in an urban area contributes to increasing values of the concentration of airborne, which are already high in the air, especially near roads. In order to determine this contribution, to avoid incorrect assessments, it is necessary to monitor TSP values and compare them with the concentration of PM_{10} and PM2, 5.

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