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Simultaneous Exceedances Of Short-Term Limit Values For Pm10, No_2 And O_3 In Italian Urban Areas

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PM10, NO_2 and O_3 are critical air pollutants whose limit values set up by legislation for the protection of human health are often exceeded in many Italian zones.
Since these pollutants are partially or totally secondary, the links between emissions and air concentrations are non-linear, which makes it troublesome to implement effective measures to reduce atmospheric concentrations.
Current legislation considers air quality standards for health protection separately for each one of these pollutants. However, recent studies stress the importance of the exposure to multi-pollutant mixtures (Various Authors, 2002)and association among the different air pollutants. Moreover, concurrent exceedances must be approached by an integrated set of measures that assures the reduction of concentration levels for all the exceeding pollutants.
This paper illustrates the concurrent short-term exceedances of PM10, NO_2 and O_3, and of couples of these pollutants (i.e. simultaneous exceedances of: PM10 and NO_2; PM10 and O_3, NO_2 and O_3), highlighting periods of the year and areas where such simultaneous exceedances occur. The data analysed are those used for the European exchange of information and are contained in APAT air quality data base; they refer to the major 24 urban agglomerations and span from 2002 to 2006.
The information presented can be useful for the analysis of determinants and sources of exposures to multi-pollutant mixtures (Hänninen et al., 2004) and may help in developing effective policies and control strategies for a healthier environment.

1. Introduction

The data presented in this paper are part of a broader work which is going on in APAT. This report will present total analyzed data in separated tables for each studied urban areas. It will show the time distribution of the exceedances of PM10, NO_2 and O_3 short-term standards, the total number of single or concurrent exceedances of PM10, NO_2 and O_3 for each month and their total number for every year considered from 2002 to 2006.
Table 1 shows limit values for PM10 and NO_2, and information threshold for O3 presently in force.

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Table 1: European air quality standards for PM10, NO_2, O_3

Pollutant	Air quality standard	Average period	Date by which standard has to be met	EU Legislation
PM10	Limit value 50 µg/m^3 not to be exceeded more than 35 times a calendar year	24 hours	1st January 2005	Directive 1999/30/EC
	Limit value 40 µg/m^3	Calendar year	1st January 2005	Directive 1999/30/EC
NO_2	Limit value 200 µg/m^3 not to be exceeded more than 18 times a calendar year	1 hour	1st January 2010	Directive 1999/30/EC
	Limit value 40 µg/m^3	Calendar year	1st January 2010	Directive 1999/30/EC
O_3	Information threshold 180 µg/m^3	1 hour	-	Directive 2002/3/EC

2. Methodology

2.1 Urban areas considered in the study

The analysis deals with the major 24 Italian urban areas with more than 150,000 inhabitants. The corresponding agglomerations (defined according to the current Framework directive on air quality assessment and management EC 96/62) have been considered, which were reported on 2004 air quality regional questionnaires sent by Italy to the European Commission in 2005. Some of these urban areas are part of the same agglomeration, generally constituted by continuous territorial areas (i.e. Livorno-Pisa, Firenze-Prato), others, constituted by not adjacent portions of territory, have been considered separately, as individual municipality . This is the case of Venezia, Padova, Verona in Veneto Region and Bari, Foggia,Taranto in Puglia Region.

2.2 Air quality monitoring network

The analysis is based on short-term air quality concentration data for PM10 (24-h average), NO_2 (1-h average) and O_3 (1-h average), measured at the monitoring stations selected by Italian Regions to assess and manage air quality for the year 2004. These monitoring sites are reported on the questionnaires sent to the European Commission in 2005. For each urban areas, only background and traffic monitoring station data have been analyzed, excluding those near industrial hotspots, being the formers considered as more representative of the human exposure to air pollution in urban areas.

2.3 Source and types of data

Air quality data are those collected for the European Exchange of Information and are contained in APAT air quality database (Bartoletti et al., 2007, Di Menno di Bucchianico et al., 2007, Gandolfo et al., 2007). They span from 2002 to 2006. Not all the years were covered by the selected stations at the time of database consultation. In

some cases, monitoring station selected by regions are not present in the database at all: this is the case of Foggia and Reggio Calabria.

Exceedences of PM10 daily limit value (50 μg/m^3), exceedances of the hourly limit value for NO_2 (200 μg/m^3) and exceedances of O_3 information threshold (180 μg/m^3) have been considered, in order to identify the concurrent short-term exceedances of PM10, NO_2 and O_3 and of couples of these pollutants (i.e. simultaneous exceedances of: PM10 and NO_2; PM10 and O_3; NO_2 and O_3), highlighting periods of the year and areas where such simultaneous exceedances occur.

3. Results

For the purpose of this paper the case of the agglomeration of Milano has been selected; in tables 2 and 3 data for 2006 have been reported.

Table 2 shows the time distribution of PM10, NO_2 and O_3 short-term exceedances; the days of the year in which these exceedances occurred are marked with a cross. Concerning the exceedances of NO_2 and O_3, for which legislation sets a hourly limit/target value, the cells are marked for those day when the hourly limit had been exceeded for at least one hour. 196 exceedances of the PM10 daily limit value occurred (Table 3), mainly concentrated on winter months (January, February, March, October, November, December). January was the worst month; PM10 limit value was exceeded in every day of this month, followed by December with 28 exceedances, November with 26, October with 25.

Comparing PM10 data with NO_2 and O_3 data in 2006, it is possible to see that the largest number of exceedances is related to PM10. A similar situation occurred for the other years in the period 2002-2006 with more than 140 daily PM10 exceedances for every year and a maximum in 2005 (212 exceedances). Again, most PM10 daily exceedances occurred in winter months.

Regarding NO_2, 41 days of exceedances occurred. The major number of exceedances of NO_2 limit value was measured in the winter time and the worst month was January. O_3 information threshold was exceeded in 28 days.

When simultaneous exceedances are considered, PM10/NO_2 couple was the most frequent. As shown on Table 3, 39 PM10/NO_2 simultaneous exceedances were detected in 2006. They mostly took place during winter months with a maximum in January with 15 simultaneous PM10/NO_2 exceedances. The situation is similar for the other years analyzed. With reference to simultaneous PM10/O_3 exceedances, 10 contemporaneous exceedances of short-term standard values were detected and they took place in June and September 2006. By analysing the data of the other years it is possible to see that exceedances for this couple were mostly experienced in the summer period (from May till September).

In 2006, simultaneous exceedances of the three pollutants (PM10, NO_2 and O_3), were measured on two days: 21 and 22 July. Concernig the other years, the simultaneous exceedances of PM10, NO_2 and O_3 in Milano mostly occurred in the summer period.

Table 4 shows the number of stations present in APAT database that have produced data for the considered year. The table indicates also those stations selected by Lombardia Region for air quality assessment for the considered year, that are not present in the database at the moment of consultation.

Figure 1 shows the number of the simultaneuos exceedances for $PM10/O_3$, $PM10/NO_2$, NO_2/O_3 , $PM10/NO_2/ O_3$ in Torino, Milano, Roma and Palermo agglomerations from 2002 till 2006. When for some station/year situation air quality data are missing, no number is reported. Simultaneous exceedances for $PM10/NO_2$ were the most frequent for all the considered years in Torino (excluding 2003), Milano, Roma and Palermo (excluding 2003); the maximum values occurred in 2006 for Torino with 44 simultaneous exceedances, Milano (39) and Roma (45), while in Palermo the maximum was detected in 2002 (16 $PM10/NO_2$ exceedances).
The analysis show that $PM10/O_3$ concurrent exceedances were generally second in order of frequency, after $PM10/NO_2$. An exception is 2003, when $PM10/O_3$ simultaneous exceedances were the most frequent in all the urban areas but Roma.
When comparing data for different years, it is important to note that the stations, and consequently their total number in a given area, may change.

Generally speaking, on the basis of the urban areas and on the years analysed, it is possible to say that the $PM10/NO_2$ simultaneous exceedances mostly occurred in winter time while the couple $PM10/O_3$ occurred in summer time.
Table 4 shows the total number of simultaneous exceedances measured in all the studied urban areas during 2006.

4. Conclusion

The analysis of simultaneous exceedances of PM10, NO_2 and O_3 concentration allows the analyses of the exposures to multi-pollutant mixtures and may help in developing effective policies and control strategies for a healthier environment.
This paper is a part of a work which is going on in APAT in order to create a specific reference for the modellers and scientist involved in multi-pollutant exposure for human health.

Table 2: Time monthly distribution of the PM10, NO_2 and O_3 exceedances occurred in Milan during 2006.

MILANO 2006																															
JANUARY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2		+	+	+						+	+	+	+	+	+				+	+	+	+								+	
PM10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
FEBRUARY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
O_3																															
NO_2	+	+	+	+			+	+	+				+																		
PM10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+		+				+	+			
MARCH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2																															
PM10	+	+	+	+				+	+	+			+	+	+	+	+	+	+	+	+	+	+		+	+	+	+		+	+
APRIL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
O_3																															
NO_2																															
PM10	+	+	+					+	+	+																					
MAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2																															
PM10								+								+		+								+		+	+		
JUNE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3													+	+	+						+	+	+	+		+	+	+		+	
NO_2																															
PM10													+	+					+	+	+	+	+	+	+	+	+	+	+		
JULY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3	+							+			+	+	+	+	+				+	+	+	+	+	+	+	+	+				
NO_2																				+	+										
PM10																				+	+										

Table 3: N. of exceedances of O_3, PM10 and NO_2 and of simultaneous exceedances of these pollutants.

2006			
exceedances JANUARY			
O_3	0	O_3 + PM10	0
NO_2	15	NO_2 +PM10	15
PM10	31	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances FEBRUARY			
O_3	0	O_3 + PM10	0
NO_2	8	NO_2 +PM10	8
PM10	22	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances MARCH			
O_3	0	O_3 + PM10	0
NO_2	0	NO_2 +PM10	0
PM10	24	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances APRIL			
O_3	0	O_3 + PM10	0
NO_2	0	NO_2 +PM10	0
PM10	6	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances MAY			
O_3	0	O_3 + PM10	0
NO_2	0	NO_2 +PM10	0
PM10	6	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances JUNE			
O_3	11	O_3 + PM10	9
NO_2	0	NO_2 +PM10	0
PM10	13	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances JULY			
O_3	16	O_3 + PM10	0
NO_2	2	NO_2 +PM10	0
PM10	2	O_3 + NO_2	0
		O_3 + PM10+NO_2	2

AUGUST	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2																															
PM10																															
SEPTEMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
O_3						+																									
NO_2																						+									
PM10					+	+	+	+					+	+	+					+	+	+	+					+	+		
OCTOBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2										+	+		+																		
PM10			+			+	+	+	+	+	+	+	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+
NOVEMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
O_3																															
NO_2							+	+					+	+									+							+	
PM10	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+		+	+		
DECEMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
O_3																															
NO_2							+						+	+	+						+				+						
PM10	+	+	+	+	+		+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

exceedances AUGUST			
O_3	0	O_3 + PM10	0
NO_2	0	NO_2 +PM10	0
PM10	0	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances SEPTEMBER			
O_3	1	O_3 + PM10	1
NO_2	1	NO_2 +PM10	1
PM10	13	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
N. exceedances OCTOBER			
O_3	0	O_3 + PM10	0
NO_2	3	NO_2 +PM10	3
PM10	25	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances NOVEMBER			
O_3	0	O_3 + PM10	0
NO_2	6	NO_2 +PM10	6
PM10	26	O_3 + NO_2	0
		O_3 + PM10+NO_2	0
exceedances DECEMBER			
O_3	0	O_3 + PM10	0
NO_2	6	NO_2 +PM10	6
PM10	28	O_3 + NO_2	0
		O_3 + PM10+NO_2	0

Table 4: N° of monitoring stations selected according to 2004 air quality questionnares and present in APAT database

2006	DM60 stations	APAT database stations
O_3	4	4
NO_2	16	15*
PM10	11	11

*MI_MONZA station missing

2006 total exceedances			
O_3	28	O_3 + PM10	10
NO_2	41	NO_2 +PM10	39
PM10	196	O_3 + NO_2	0
		O_3 + PM10+NO_2	2

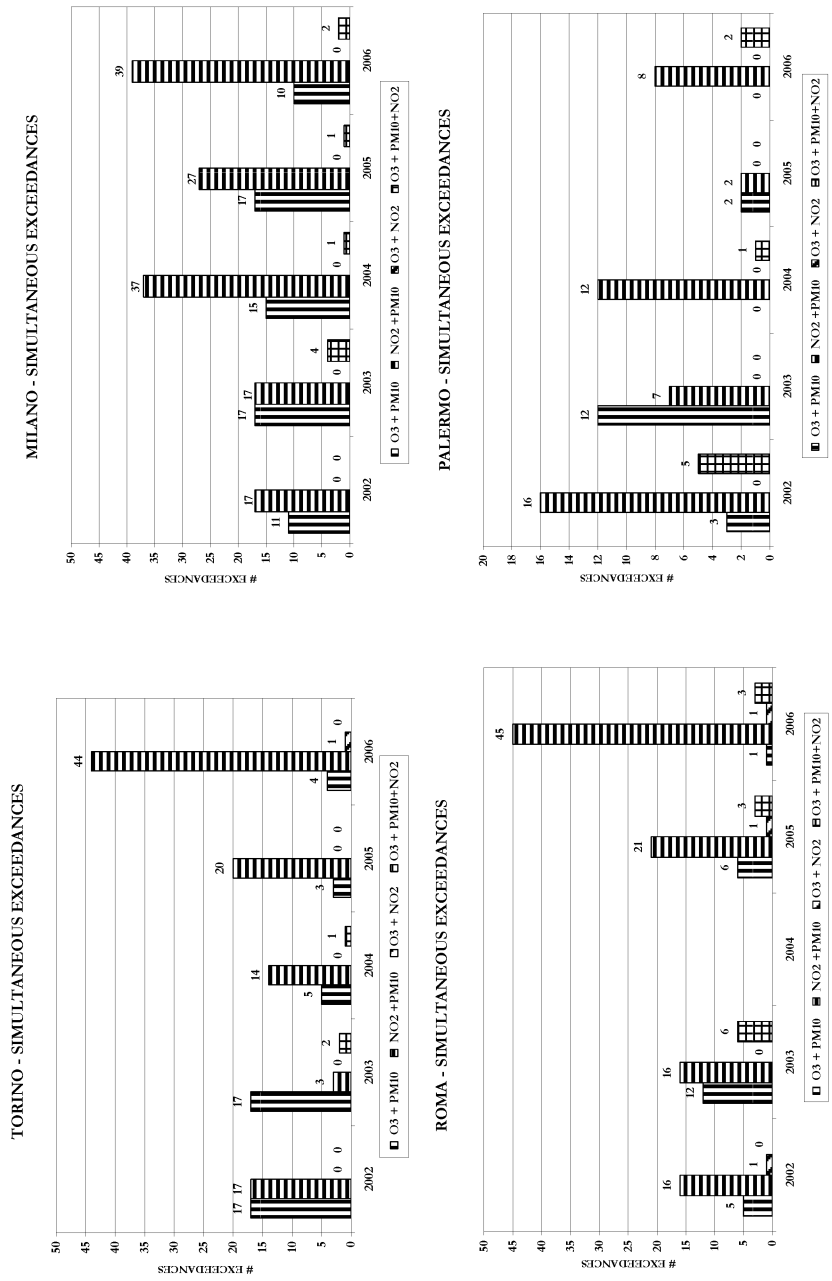

Figure 1: Simultaneous exceedances of O_3 and PM10, NO_2 and PM10, O_3 and NO_2, O_3 , PM10 and NO_2

Table 4: Total number of simultaneous exceedances of O_3 and PM10, NO_2 and PM10, O_3 and NO_2, O_3, PM10 and NO_2 in the studied urban areas for the 2006. (the symbol "*"means that in the 2004 air quality questionnares for the Sicily Region NO2 monitoring stations are not present. The empty cell means no monitoring stations in APAT database for at least one of the pollutant)

2006	TORINO	MILANO	BRESCIA	VERONA	VENEZIA	PADOVA	TRIESTE
O_3 + PM10	4	10	11	13	5	12	0
NO_2 +PM10	44	39	18	0	0	0	7
O_3 + NO_2	1	0	0	0	0	0	4
O_3 + PM10+NO_2	0	2	0	0	0	0	0

2006	GENOVA	PARMA	MODENA	BOLOGNA	FIRENZE	LIVORNO	ROMA
O_3 + PM10	1				10	0	1
NO_2 +PM10	0	0		2	1	0	45
O_3 + NO_2	0		0		0	0	1
O_3 + PM10+NO_2	0				0	0	3

2006	NAPOLI	BARI	TARANTO	PALERMO	MESSINA	CATANIA	CAGLIARI
O_3 + PM10	2			0	0	7	0
NO_2 +PM10	2			8	*	2	2
O_3 + NO_2	5	0		0	*	0	0
O_3 + PM10+NO_2	2			0	*	0	0

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