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Air Quality Monitoring and Its Implication on the Environmental Licensing Process in Brazil

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ABSTRACT

In the state of Sao Paulo, Brazil, public policies regarding the air quality aimed at the welfare of the population are strongly dependent on monitoring conducted by the Sao Paulo State Environmental Company (CETESB), which can be influenced by faulty monitors and equipment support and cuts in power supply, among others. A research conducted from 1998 to 2008 indicated that a significant portion of the air quality automatic stations in the state of Sao Paulo did not meet the criterion of representativeness of measurements of PM_{10}, NO_2, O_3, CO and SO_2 concentrations which resulted in the classification of some municipalities as the nonattainment area, a situation evidenced for PM_{10} and O_3 parameters. The network unavailability for each parameter was estimated and compared with the monitoring networks operated in Canada and the UK. This paper discusses the implications of the lack of representativeness of measurements in the environmental licensing process of pollution sources from 2008, when by the effect of state law, municipalities have been qualified according to their air quality nonattainment level.

KEYWORDS

Air Quality Monitoring; Public Policies; Environmental Licensing

1. Introduction

The air quality improvement in industrialized regions can be achieved by knowing environmental pollutant concentrations, which are measured through monitoring the quantity emitted by each source, and imposing emission restrictions for new industries and the expansion of existing ones. In many countries, this search is consolidated through the environmental license of industrial activities and by establishing targets and timetables for the pollutant reduction.

Brazil has experienced the intense industrialization since 1960s. However, the first pollutant measurements carried out were restricted to monthly rates of sulfation, settleable dust and corrosiveness [1], which are characteristics of industrial activity. Subsequently, the systematic monitoring of air quality that began in Rio de Janeiro in 1967 [2] and in Sao Paulo in 1972 [1] broadened the spectrum encompassing vehicular pollutants.

In 1976, the Sao Paulo State Environmental Company (CETESB) has started the pollution source licensing process, which currently considers the nonattainment level concept by specific pollutant as part of the strategy to accept new pollution sources as well as the expansion of existing ones [3].

The determination of nonattainment areas depends on CETESB monitoring, which is performed by manual and automatic networks. Its distinctive role in the establishment and maintenance of public policies aimed at population welfare is strongly dependent on the quality of these measurements. They are routinely checked and the inconsistent ones are disregarded for the purposes of the value expression of a pollutant concentration. It also depends on the amount of measurements that can be influenced by equipment failures or supplementary services failures such as power and telephone networks, among others [4].

This paper discusses the implications of measurement amount reduction of an air quality automatic monitoring network on the environmental licensing process of pollution sources in the state of Sao Paulo, Brazil.

2. Air Quality Monitoring in Sao Paulo, Brazil

The air quality measurement and its result interpretation, both considered as a synonym for monitoring, have been carried out since 1973 by CETESB, through manual and automatic networks which regularly follow the concentrations of air pollutants in urban areas of cities either well industrialized or with more than 500,000 inhabitants.

The dissemination of these monitoring results is made by reporting them in the communication international network (internet) in real time and daily bulletins. They are also sent to the media, with a summary of atmospheric pollution results in the previous 24 hours. It is also issued an annual report reflecting the air quality in the state.

The air quality monitoring by the CETESB's automatic network also subsidizes the licensing of new emission sources by classifying regions in relation to the nonattainment level associated with certain pollutants.

3. Availability of Automatic Network: Data Failures and Representativeness

The correct information of the air quality depends on the proper operation of the automatic network composed of stations with pollutant monitors and infrastructure, such as computers and air conditioners. Proper operation means: 1) functioning when necessary; 2) working properly and, finally; 3) functioning for the time desired or sufficient to maintain the data (or measurement) generated accordingly to the representativeness criterion adopted.

For the measurements performed by the automatic network, the following representativeness criterion is adopted [4]:

1) Hourly average valid when 75% of the measurements are considered valid at the hour;

2) Daily average valid when 66.7% of the hourly average is considered valid on the day;

3) Monthly average valid when 66.7% of the daily average is considered valid in the month;

4) Annual average valid when 50% of the daily average is considered valid for the four-month period January to April, May to August and September to December.

The intermittent operation of a station and, particularly, of a measuring device, may disqualify its measurements, based on previous criterion. As a result, decision processes as the environmental licensing of a new plant or control actions of pollutant sources may be jeopardized because of this lack of data, a situation illustrated and discussed below.

Table 1 was made based on the research conducted by [5] using annual reports and daily bulletins of air quality issued by CETESB for the period from 1998 to 2008. The figures represent per parameter and per year the fraction of stations which were in operation and that did not meet the representativeness criterion due to monitors and infrastructure failures, being these data of effective interest for the purpose of assessing the automatic network availability.

Monitors and infrastructure failures should be seen in different perspectives concerning their causes. For monitors, CETESB carries out a preventative maintenance program since long time. Maintenance tasks are performed by a monitoring network dedicated team with periodic visits to the stations for the program application, besides testing the proper operation of the monitors. It can be inferred that there is, therefore, a reasonable control over the failure causes, which are generally associated with component degradation leading to a relative regularity in the disqualification of the measured data over the period of observation. Yet, infrastructure failures have different origins, some of them are external to CETESB, such as telephony failures which prevent the transmission of the measured data to the central, or even different areas of the company itself, such as maintenance (ground of stations, air conditioning equipments) and hardware and software support (central server and data acquisition system). Failure increasing since 2002 may be related to infrastructure aging, at least, internal to CETESB and with the absence of a preventive mainten-

Table 1. Percentage of stations in operation that did not meet the representativeness criterion.

Year	PM_{10}	NO_2	O_3	CO	SO_2
2008	0.205	0.174	0.161	0.067	0.333
2007	0.366	0.333	0.217	0.176	0.666
2006	0.241	0.400	0.316	0	0.455
2005	0.266	0.500	0.056	0.333	0.166
2004	0.233	0.428	0.158	0.154	0.462
2003	0.142	0.417	0.187	0.154	0.091
2002	0.153	0.182	0.062	0	0.231
2001	0.115	0.231	0	0	0
2000	0.310	0.417	0	0	0.077
1999	0.200	0.181	0.077	0	0.100
1998	0.208	0.100	0	0.100	0.444

ance program [5].

Until now, it was shown that a significant portion of the annual environmental monitoring is jeopardized by non-compliance to the measurement representativeness criterion, and the main causes are monitors and infrastructure failures. The average, minimum and maximum percentages of unavailability at the time of observation, per parameter, can be seen in **Table 2**.

Comparison with other Air Quality Monitoring Networks

It is interesting to see if the situation presented and summarized in **Tables 1** and **2** is similar to other air quality monitoring automatic networks. A search in the scientific and technical literature and institutional information led to reports issued by Environment Canada, Canada's environmental agency, and the environmental agencies[1] of the United Kingdom (UK) about the behavior of their national monitoring networks.

The environmental agency of Canada [6-13] presents extensive diagnosis of air quality in Canada. The report covering the years 2005 and 2006 informed the presence of 319 automatic stations, being 236 in urban areas and the rest in rural areas. There are 145 SO_2 monitors, 79 CO, 152 NO_2, 219 O_3, 59 PM_{10}, and 196 $PM_{2.5}$ monitors. **Table 3** shows the fraction of stations that did not meet the representativeness criterion from1998 to 2006. These reports show by season, year and parameter, the monthly and annual averages of measured concentrations and the signal (-) when measurements did not meet the aforementioned criterion.

References [14-19] presented a detailed diagnosis of the air quality in the UK. The 2008 report informs the presence of 127 automatic stations, being 102 in urban areas (18 in London) and 25 in rural areas. There are 45 SO_2 monitors, 27 CO, 111 NO_2, 80 O_3, 77 PM_{10} and 53 $PM_{2,5}$ monitors. The fraction of stations that did not meet the representativeness criterion between 2003 and 2008 can be seen in **Table 4**.

Despite the significant difference in the number of stations and monitors, it is reasonable to compare the lack of data representativeness (or unavailability) of monitoring performed by the Canada and UK networks against CETESB's network in Brazil.

A simple comparison of the mean values in **Table 2** with the ones in **Table 5** (Environment Canada and the UK environmental agencies) leads to the conclusion that the mean unavailability of the CETESB's automatic network is greater than these environmental agencies as well as the maximum values achieved especially for NO_2 and SO_2.

[1]Department for Environment, Food and Rural Affairs (DEFRA); The Welsh Assembly Government; The Scottish Government; The Department of Environment in Northern Ireland.

Table 2. Average, minimum, and maximum values of CETESB's automatic network unavailability, by parameter.

Parameter	Unavailability		
	Minimum	Average	Maximum
PM_{10}	0.115	0.222	0.366
NO_2	0.100	0.306	0.500
O_3	0	0.112	0.360
CO	0	0.089	0.333
SO_2	0	0.275	0.666

Table 3. Unavailability of the Environment Canada automatic network.

Year	Unavailability				
	PM_{10}	NO_2	O_3	CO	SO_2
2006	0.083	0.135	0.070	0.056	0.090
2005	0.076	0.156	0.154	0.123	0.165
2004	0.035	0.072	0.119	0.105	0.097
2003	0.086	0.182	0.083	0.097	0.062
2002	0.121	0.155	0.095	0.095	0.091
2001	0.221	0.189	0.120	0.122	0.116
2000	0.162	0.182	0.140	0.176	0.095
1999	0.131	0.252	0.178	0.154	0.094
1998	0.196	0.204	0.133	0.160	0.123

Source: adapted from references [6-13].

Table 4. Unavailability of the United Kingdom automatic network.

Year	Unavailability				
	PM_{10}	NO_2	O_3	CO	SO_2
2008	0.169	0.081	0.051	0.074	0.044
2007	0.026	0.044	0	0.026	0.064
2006	0.031	0.045	0.059	0.063	0.039
2005	0.014	0.045	0.011	0.051	0.039
2004	0.123	0.045	0.057	0.025	0.051
2003	0.069	0.123	0.071	0.088	0.064

The figures presented in **Tables 1**, **3** and **4** reflect the measurement representativeness criteria adopted by the institutions. **Table 6** presents these criteria, making it clear that CETESB and Environment Canada ones are similar, especially in the annual average, which is reported in the quality report of the institutions, by parameter and station.

Reports from Environment Canada and the Environmental Agencies in the UK do not have the causes for the

Table 5. Minimum, average and maximum values of unavailability of automatic network of Environment Canada and the United Kingdom environmental agencies, as a parameter.

Parameter	Unavailability					
	Minimum		Average		Maximum	
	Canada	UK	Canada	UK	Canada	UK
PM_{10}	0.035	0.014	0.123	0.072	0.221	0.169
NO_2	0.072	0.044	0.170	0.064	0.252	0.123
O_3	0.070	0	0.121	0.042	0.178	0.071
CO	0.056	0.025	0.121	0.055	0.176	0.088
SO_2	0.062	0.039	0.104	0.050	0.165	0.064

Table 6. Criteria of measurement representativeness.

	CETESB	Environment Canada	United Kingdom
Hourly average	Valid when 3/4 of measurements are considered valid	Not mentioned	Requires that at least 3 measured averages of 15 min are considered valid
Daily average	Valid when 2/3 of the hourly average are considered valid	Calculated if 3/4 of hourly measurements are available	Valid when 3/4 of the hourly average are considered valid
Monthly average	Valid when 2/3 of the daily average are considered valid	Calculated from 50% das of the hourly measurements available in the period	Monthly average valid when 3/4 of daily average are considered valid
Annual average	Valid when 1/2 of the daily average are considered valid for January-April, May-August and September-December	Calculated from 50% of hurly measurements available in the period and the monthly average in two months of each quarter	The criterion is not clear. However, it was observed that an average with 58,6% of the valid measurements was reported; another average was not reported with 48% of the valid measurements

Sources: reference [20]; adapted from reference [13]; adapted from reference [19].

measurements invalidation; it is not possible, based on these reports, a further comparison between these institutions and CETESB.

4. Classification of Municipalities regarding the Air Quality Nonattainment Level

Environmental licensing of pollution sources in the state of Sao Paulo is governed by law n˚ 997/76 and its rules, approved by decree n˚ 8468/76 and its amendments. For sources that emit air pollutants, licensing procedures in force in 2009 [21-23] established 1) the criterion for determining the air quality nonattainment level of the municipalities covered by the monitoring network of CETESB, 2) the qualification of this level in terms of severity and 3) restrictions on the establishment of these sources in cities classified as nonattainment area or close to the nonattainment area.

Applying the criterion, the city can be classified as attainment area (ATA), close to the nonattainment area (CNAA) or nonattainment area (NAA). The goal is to establish a rule for environmental licensing of pollution sources [24]. In general, one can say that for a new source to be established in the NAA or CNAA zone, it is necessary to prove that the industry will promote the reduction of emissions to the minimal amount equal to that emitted by the new source [24].

The criterion [21-23] requires measurements of the environmental monitoring of the three years previous to the year of the ranking, which is approved by the Environment Secretariat [20]. It is therefore, heavily dependent on the availability of the data generated by the manual and automatic monitoring stations, requiring measurement periods for three consecutive years to establish the nonattainment level. If data are available for shorter periods, the criterion provides more restrictive values for establishing the nonattainment level. Table 7 shows the application of the criterion for pollutants, considering the existence of measurements valid for 3, 2 and 1 year.

Cities considered NAA or CNAA by one or more regulated pollutants, which are: particulate matter (which includes PM_{10}, black smoke and total suspended particulate matter), NO_2, SO_2, CO and O_3, are presented in a report by CETESB. There are 214 municipalities classified based on the monitoring results for the years 2006, 2007 and 2008.

4.1. Monitoring and Nonattainment Level of PM_{10} Parameter

The same report shows the list of stations that measure PM_{10}, especially those classified as nonattainment level

Table 7. Municipality classification criterion for pollutants with automatic monitoring.

	NR	nonattainment level (NAA)	Close to nonattainment level (CNAA)	attainment level (ATA)
PM_{10} long term	3	AA > 50 μg·m^{-3}	AA > 45 μg·m^{-3}	AA ≤ 45 μg·m^{-3}
	2	AA > 45 μg·m^{-3}	AA > 40 μg·m^{-3}	AA ≤ 40 μg·m^{-3}
	1	AA > 45 μg·m^{-3}	AA > 40 μg·m^{-3}	AA ≤ 40 μg·m^{-3}
	0	UN	UN	UN
SO_2 long term	3	AA > 80 μg·m^{-3}	AA > 72 μg·m^{-3}	AA ≤ 72 μg·m^{-3}
	2	AA > 72 μg·m^{-3}	AA > 64 μg·m^{-3}	AA ≤ 64 μg·m^{-3}
	1	AA > 72 μg·m^{-3}	AA > 64 μg·m^{-3}	AA ≤ 64 μg·m^{-3}
	0	UN	UN	UN
O_3 short term	3	4˚ DV > 160 μg·m^{-3}	3˚ DV > 144 μg·m^{-3}	3˚ DV ≤144 μg·m^{-3}
	2	3˚ DV > 160 μg·m^{-3}	2˚ DV > 144 μg·m^{-3}	2˚ DV ≤ 144 μg·m^{-3}
	1	2˚ DV > 160 μg·m^{-3}	1˚ DV > 144 μg·m^{-3}	1˚ DV ≤ 144 μg·m^{-3}
	0	2˚ DV > 160 μg·m^{-3}	1˚ DV > 144 μg·m^{-3}	UN
CO short term	3	4˚ DV > 9 ppm	3˚ DV > 8.1 ppm	3˚ DV ≤ 8.1 ppm
	2	3˚ DV > 9 ppm	2˚ DV > 8.1 ppm	2˚ DV ≤ 8.1 ppm
	1	2˚ DV > 9 ppm	1˚ DV > 8.1 ppm	1˚ DV ≤ 8.1 ppm
	0	2˚ DV > 9 ppm	1˚ DV > 8.1 ppm	UN
NO_2 long term	3	AA > 100 μg·m^{-3}	AA > 90 μg·m^{-3}	AA ≤ 90 μg·m^{-3}
	2	AA > 90 μg·m^{-3}	AA > 80 μg·m^{-3}	AA ≤ 80 μg·m^{-3}
	1	AA > 90 μg·m^{-3}	AA > 80 μg·m^{-3}	AA ≤ 80 μg·m^{-3}
	0	UN	UN	UN

NR—number of representative years, UN—unrated, DV—daily value, AA—arithmetic average of the annual averages; Source: Adapted from reference [20].

or close to the nonattainment level, based on the criteria of short and long terms. For this parameter 28 cities are monitored, including Sao Paulo, with several automatic stations. **Table 8** contains the stations and consequently, municipalities where the arithmetic average (AA) of the valid years indicated the NAA classification when the air quality standard was exceeded or CNAA when the average was approximated to the standard.

Out of the 49 stations, only 11 showed representative average for three years.

In **Table 8**, the city of Osasco was classified as NAA based on PM_{10} arithmetic average (AA) of 46 μg·m^{-3}. If AA was originated from three years of valid measurements, the municipality would be classified as CNAA. In the case of particulate matter, only the municipality in which there is a station measuring the parameter is classified. For the same reason, we can verify that the municipality of Sao Paulo has been classified as CNAA as a result of the classification validated for two years or less of Cambuci, Centro, Congonhas, Parque D. Pedro II and Parelheiros stations.

4.2. Monitoring and Nonattainment Level of O_3 Parameter

For ozone, the report [20] presents the list of stations that measure the pollutant, mostly classified as nonattainment level or close to the nonattainment level, based on the short term criterion. There are 34 stations located in 20 municipalities, including the Metropolitan Region of Sao Paulo with 15, being 11 of them in Sao Paulo. Twenty-seven stations showed nonattainment level to the pollutant, and only six with representative average for three years.

Table 9 listed just some of the stations previously mentioned, more specifically those in which the classification brings aspects of interest for this work. In the case of ozone, the measurements are short-term, indicated as the one with the highest daily value (DV). For classification, the four DV obtained during three years of measurement are of interest, even if one or more of these years have not been considered valid according to the criterion.

If the values in **Table 9** were taken from two years of

Table 8. Classification of sub-region by PM_{10} (long-term) nonattainment level.

Station	Yearly arithmetic avarage ($\mu g \cdot m^{-3}$)			AA ($\mu g \cdot m^{-3}$)	NR	Classification
	2006	2007	2008			
Osasco	45	-	47	46	2	NAA
Cubatão—Vila Parisi	99	108	99	102	3	NAA
Cambuci	39	46	-	43	2	CNAA
Centro	-	45	45	45	2	CNAA
Congonhas	-	46	44	45	2	CNAA
Parelheiros	-	-	42	42	1	CNAA
Parque D. Pedro II	40	41	-	41	2	CNAA

NR—number of representative years, AA—arithmetic average of the annual averages. Source: Adapted from reference [20].

Table 9. Classification of the sub-region by O_3 (short term) nonattainment level.

Station	Maximum in the past three years ($\mu g \cdot m^{-3}$)				NR	Classification
	1° DV	2° DV	3° DV	4° DV		
Ribeirão Preto	175	169	162	160	1	NAA
Cubatão—Centro	221	220	204	203	3	NAA
Cubatão—Vale do Mogi	163	161	158	149	0	NAA
Cubatão—Vila Parisi	177	176	167	145	0	NAA
Araraquara	151	132	132	126	0	CNAA
Bauru	181	128	126	126	0	CNAA
Jaú	149	143	141	140	0	CNAA
Sao Jose do R.Preto	154	145	143	141	0	CNAA
Araçatuba	146	144	142	139	0	CNAA

NR—number of representative years; DV—daily value. Source: Adapted from reference [20].

valid measurements, Cubatão—Vale do Mogi would be classified as CNAA instead of NAA; Cubatão—Vila Parisi and Ribeirão Preto would be CNAA within three years. The municipalities of Araraquara, Bauru, Jau and Araçatuba, within two years, and Sao Jose do Rio Preto, three years would be classified as attainment area (ATA) instead of CNAA. It should be noted that these last five stations went into operation in the second quarter of 2008, therefore they show NR = 0. More specifically, it seems that the city of Ribeirão Preto was classified as NAA for O_3 based on one year of valid data. If the monitoring values for this city (**Table 9**) were based on three years of valid measurements, its classification would be CNAA, instead of NAA.

For SO_2 and NO_2 parameters, the air quality standard has not been exceeded and for measurements of CO, the classification was based on data of three years.

5. Implications of the Measurement Number Reduction in Environmental Licensing

The above mentioned legislation [21-23] states that the installation of new pollution sources or expansion of existing sub-zones classified as nonattainment area (NAA) or close to the nonattainment area (CNAA) are subject to the emissions offset, under the following conditions: 1) the total of added emission is ≥ 100 t·year^{-1} for particulate matter (PM); 2) ≥ 40 t·year^{-1} for nitrogen oxides (NO_x); 3) ≥ 40 t·year^{-1} for non-volatile organic compounds other than methane (VOCs, non-CH_4); 4) ≥ 250 t·year^{-1} for sulfur oxides (SO_x); and 5) ≥ 100 t·year^{-1} for carbon monoxide (CO). The offset will be in 110% of the total pollutant emissions added to the sub-region classified as NAA and at 100% for the ones classified as CNAA.

From the above, it is concluded that the industry that request environmental licensing in a sub-zone classified as NAA or CNAA will have to promote environmental offsetting if the total of new emissions added by pollutant is greater than the values mentioned above. In case the zone is classified within the upper range, for example, NAA rather than CNAA due the absence of one or more years of valid measurements, the industry is subject to more severe compensation, that is 110% to classification NAA or 100% for the classification CNAA. For example:

a new industry that may be installed in a nonattainment area for particulate matter and that has a predicted emission of particulate material of 200 t·year^{-1}, is required to reduce 220 t·year^{-1} of that pollutant in the nonattainment area by compensation.

6. Conclusions

The absence of three year valid measurements from 2006 to 2008 has resulted in the classification of some municipalities in 2009 as the nonattainment area when the proper classification would possibly be close to the nonattainment area. Also, some cities classified as close to the nonattainment area would be considered the attainment area, a situation evidenced for parameters PM_{10} and O_3.

Effects in the environmental licensing of air pollutant emission sources result from this classification, with the need for the environmental compensation in municipalities classified as the nonattainment area or close to the nonattainment area based on two or less years of valid measurements.

The absence of valid measurements, which arises predominantly from monitors and infrastructure failures, shows the need to improve the automatic network maintenance program in an attempt to increase the reliability of the monitors and to reduce the stoppage due to their component failures, increasing the ability to recover the measurement function in a shorter time. It is advisable to establish progressive targets to reduce the network average unavailability, once the initial objective to be reached may be linked to the values of Environment Canada, **Table 5**, since they result from a measurement representativeness criterion similar to the one adopted by CETESB (see **Table 6**).

If on one hand, we can advocate the precautionary principle which is used to adopt more restrictive values to establish the air quality nonattainment level. Reducing the automatic monitoring network availability has contributed to the reduction of the atmospheric monitoring effectiveness in its most important element: the immediate awareness of the air quality status of monitored zones.

REFERENCES

[1] Companhia Ambiental do Estado de São Paulo, "Web Page," 2013. http://www.cetesb.sp.gov.br/ar/informacoes-basicas/20-historico

[2] Instituto Estadual do Ambiente, "Relatório Anual da Qualidade do Ar do Estado do Rio de Janeiro 2009," 2013. http://www.inea.rj.gov.br/downloads/relatorios/qualidade_ar_2009.pdf

[3] SÃO PAULO (Estado), "Decreto nº 59.113, de 23 de abril de 2013," Diário Oficial do Estado de São Paulo, Sao Paulo, v.123, n.76, 24 abr. 2013.

[4] Companhia Ambiental do Estado de São Paulo, "Qualidade do ar no estado de São Paulo 2010," Sao Paulo, 2011. http://www.cetesb.sp.gov.br/ar/qualidade-do-ar/31-publicacoes-e-relatorios

[5] J. C. de M. XAVIER, "Análise da Disponibilidade da Rede Automática de Monitoramento da Qualidade do ar e seus Reflexos no Licenciamento Ambiental Realizado em São Paulo," Master Dissertation, Instituto Tecnológico de Aeronáutica, Sao Jose dos Campos, 2011. http://www.bd.bibl.ita.br

[6] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Summary for 1998," Environmental Protection Series Report 7/AP/31, Ontário, 2000. http://www.publications.gc.ca/site/eng/89526/publication.html

[7] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Summary for 1999," Environmental Protection Series Report 7/AP/32, Ontario, 2001. http://www.publications.gc.ca/site/eng/102399/publication.html

[8] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Summary for 2000," Environmental Protection Series Report 7/AP/33, Ontario, 2001. http://www.publications.gc.ca/site/eng/106036/publication.html

[9] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Summary for 2001," Environmental Protection Series Report 7/AP/34, Ontario, 2002. http://publications.gc.ca/collections/Collection/En49-2-7-34.pdf

[10] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Data Summary for 2002," Environmental Protection Series Report 7/AP/35, Ontario, 2003. http://publications.gc.ca/collections/Collection/En49-5-7-35.pdf

[11] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Data Summary for 2003," Environmental Protection Series Report 7/AP/37, Ontario, 2005. http://publications.gc.ca/collections/Collection/En49-2-7-37.pdf

[12] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Data Summary for 2004," Environmental Protection Series Report 7/AP/38, Ontario, 2007. http://publications.gc.ca/collections/collection_2007/ec/En49-2-7-38.pdf

[13] ENVIRONMENT CANADA, "National Air Pollution Surveillance (NAPS) Network: Annual Data Summary for 2005-2006," Environmental Protection Series Report 7/AP/39, Ontario, 2008.

http://publications.gc.ca/collections/collection_2008/ec/En49-2-7-39.pdf

[14] J. Bower, J. Lampert and G. Broughton, "Air pollution in the UK: 2003," Netcen/ED45098/Issue1, Didcot: Netcen, 2004. http://uk-air.defra.gov.uk/reports/cat05/0502251134_Report_Air_Pollution_in_the_UK_Part_1_text.pdf

[15] J. Bower, J. Lampert and G. Broughton, "Air pollution in the UK: 2004," Netcen/ED48692008/Issue 1, Didcot: Netcen, 2005. http://uk-air.defra.gov.uk/reports/cat05/0601311638_Air_Pollution_in_the_UK_2004_-_intro_and_contents.pdf

[16] J. Bower, *et al*., "Air pollution in the UK: 2005," Netcen/ED48692008/Issue 1, Didcot: Netcen, 2006. http://uk-air.defra.gov.uk/reports/cat05/0612111534-421_AirPollutionUK2005text.pdf

[17] J. Bower, *et al*., "Air Pollution in the UK: 2006," AEA/ENV/R/2544, Didcot: Netcen, 2007. http://uk-air.defra.gov.uk/library/annualreport/air_pollution_uk_2006.pdf

[18] J. Bower, *et al*., "Air Pollution in the UK: 2007," AEA/ENV/R/2544, Didcot: AEA, 2008. http://uk-air.defra.gov.uk/library/annualreport/air_pollution_uk_2007.pdf

[19] J. Bower, *et al*., "Air Pollution in the UK: 2008," AEAT/ENV/R/2823/Issue1, Didcot: AEA, 2009. http://uk-air.defra.gov.uk/library/annualreport/air_pollution_uk_2008.pdf

[20] Companhia Ambiental do Estado de São Paulo, "Relatório de Qualidade do ar no Estado de São Paulo 2008," Sao Paulo, 2009. http://www.cetesb.sp.gov.br/ar/qualidade-do-ar/31-publicacoes-e-relatorios

[21] SÃO PAULO (Estado), "Decreto n^o 48.523, de 02 de Março de 2004," Diário Oficial do Estado de São Paulo, Poder Executivo, Sao Paulo, v.114, n.41, 03 mar. 2004. Seção I, p. 1.

[22] SÃO PAULO (Estado), "Decreto n^o 50.753, de 28 de abril de 2006," Diário Oficial do Estado de São Paulo, Poder Executivo, Sao Paulo, v.116, n.80, 29 abr. 2006. Seção I, p. 1 e 3.

[23] SÃO PAULO (Estado), "Decreto n^o 52.469, de 12 de Dezembro de 2007," Diário Oficial do Estado de São Paulo, Sao Paulo, v.117, n.234, 13 dez. 2007.

[24] Companhia Ambiental do Estado de São Paulo, "Relatório de Qualidade do ar no Estado de São Paulo 2007 [Eletronic Resource]," Sao Paulo, 2008. http://www.cetesb.sp.gov.br/ar/qualidade-do-ar/31-publicacoes-e-relatorios