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LONG-TERM TRENDS OF SULFUR DIOXIDE IN THE SÃO PAULO
METROPOLITAN AREA 1973-1979

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A B S T R A C T

The present paper provides a qualitative information about the long-term trends of sulfur dioxide concentrations at the São Paulo Metropolitan Area.

The 24 hrs. average observations, gathered at ten sampling sites with different urban characteristics during the period July/73 to June/79, were reduced to monthly arithmetic means for each monitoring station. To these six years series of data it was applied the Kendall Correlation Coefficient Test to qualify the long-term behavior and the Whittaker-Henderson Type A smoothing formulas for achieving an acceptable graphical display.

The results showed a unique decreasing long-term trend, five stationary and four increasing trends. The same procedure used for all the ten monitoring stations as a composite site have showed a stationary trend.

1. SÃO PAULO METROPOLITAN AREA CHARACTERIZATION

São Paulo Metropolitan Area is composed of 37 municipalities occupying an area of about 8.000 km² (0.03% of the State of São Paulo) and having a population of about 13 million inhabitants (54% of the population of the State of São Paulo), located in the State of São Paulo, Brazil (Figure 1).

Annex 1 shows the 37 municipalities with their respective areas and population.

This region has an altitude varying from 820 meters to 720 meters and it is surrounded by mountains 1000 meters high. The area has a humid tropical climate with an average temperature of about 17.5°C. The minimum temperature is around 6°C and the maximum is near 33°C, reaching high humidity values. The pluviometric precipitation is about 1300 mm/year.

The surface winds are greatly affected by the topography mainly by the river valleys. The predominant wind directions in the region are as follows: SSE, E and NNW. The mean wind speed varies from 0,0 - 1,5 m/s during the winter to 2,6 - 5,5 m/s during the summer.

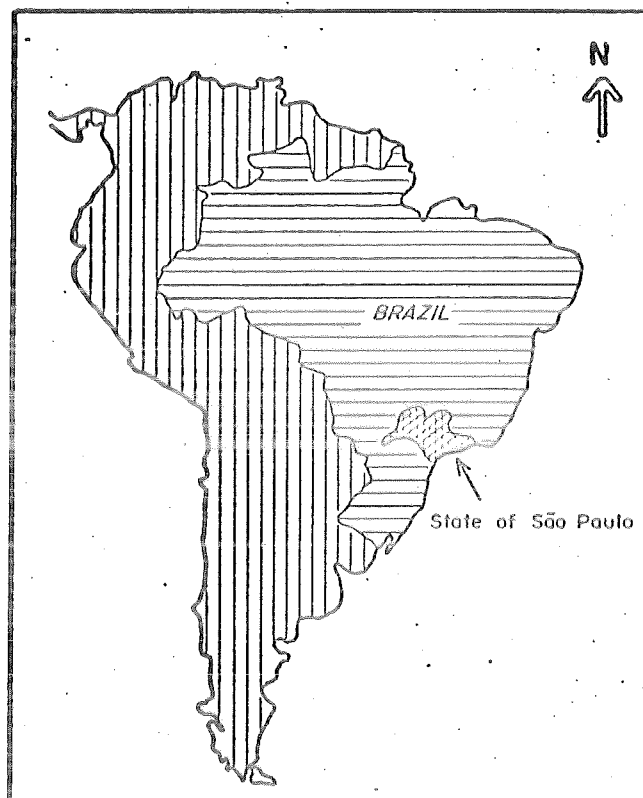
During the winter months, from May through July, low altitude temperature inversions and calm conditions cause very poor conditions for the dispersion of the air pollutants. During this period the highest air pollutant concentrations are recorded. However, during the summer months this region has a very good ventilation pattern.

São Paulo Metropolitan Area concentrates 47,000 industries (58.7%) of the 80,000 industries located in the State of São Paulo. The people working in this region (1.2 million) represents 66.6% of the total State industrial labor (1.8 million).

This remarkable concentration (46.2% of all industries installed in the State are at São Paulo City) is a fundamental characteristic of the State industrial distribution.

There are about 2 million motor vehicles in circulation in the region (about 100,000 are diesel powered).

THE STATE OF SÃO PAULO IN BRAZIL AND SOUTH AMERICA



SÃO PAULO METROPOLITAN AREA IN THE STATE OF SÃO PAULO

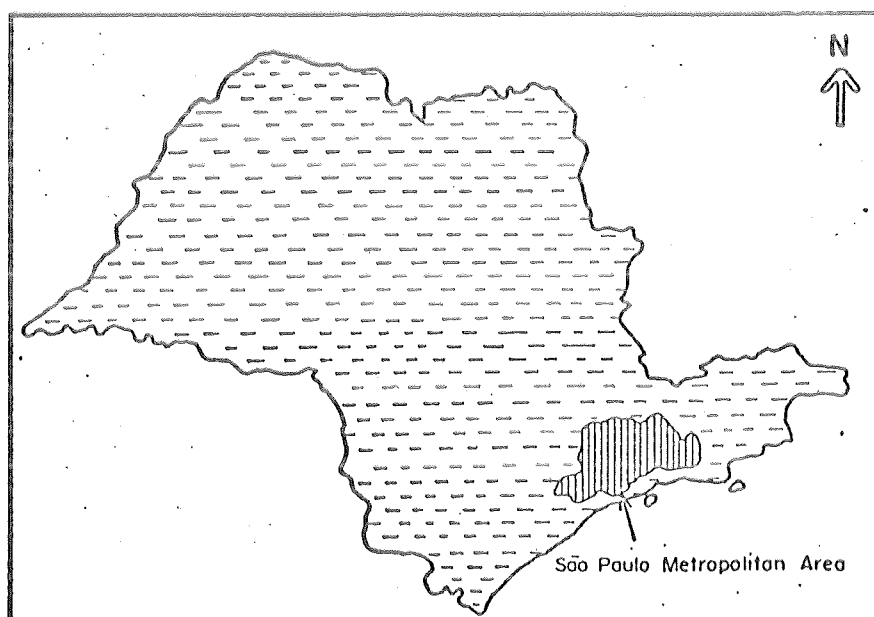


FIGURE 1

The development of this scenery occurred very rapidly during the last few decades conducted in a cahotic manner, without and adequate planning, leading consequently to an urban structure with serious social and environmental problems, including air pollution.

2. THE AIR POLLUTION PROBLEM

The state of São Paulo Environmental Protection Agency Companhia de Tecnologia de Saneamento Ambiental - CETESB has carried out, in 1976-1977, a survey of the air pollution sources in the São Paulo Metropolitan Area (SPMA), estimating that 7,753 MT/day of pollutants are emitted (Annex 2). The pollutant emitted in greater quantity is carbon monoxide with 5,266 MT/day, followed by hydrocarbon 831 MT/day, sulfur oxides with 684 MT/day, particulate matter with 552 MT/day and nitrogen oxides 420 MT/day.

The automotive traffic contributes with 79,80% of the total pollutant emissions in the area, and 16,63% are due to the industrial activities, including stationary combustion of fossil fuels with high sulfur content (about 5%), which are responsible for 79,1% of the sulfur oxides emissions. About 50% at the 14,200 industrial polluters in the area are composed by metallurgical, non-metallic minerals, chemical, textile, and food industries, which are estimated to be responsible for 80% of air pollutant emissions by industry.

However, in terms of sulfur oxides emissions, as shown in Annex 3, only 1,441 industries are involved, of which 208 account for 80,5% of emissions in the area.

CETESB has been operating a sampling network installed in the area since 1973, actually with 14 sampling stations (figure 2) measuring daily concentrations of SO₂ and particulate matter. The state of São Paulo adopted in 1976 air quality standards for the major pollutants as shown in Annex 4, however, most of these standards have been exceeded for long periods of time, mainly during the winter time. Annex 5 shows the number of times that the 24 hrs. average air quality standard for sulfur dioxide was exceeded for the stations under study.

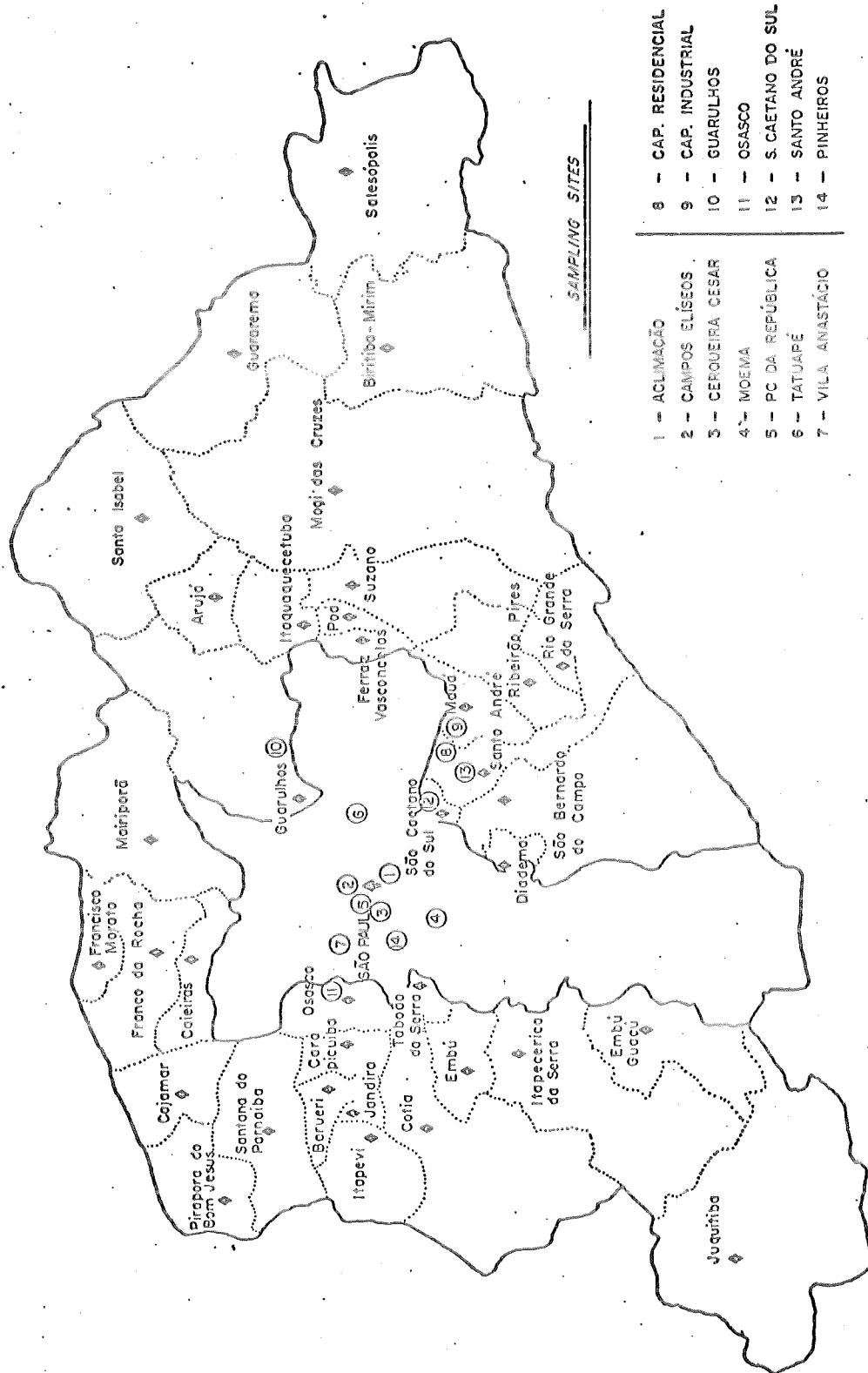


Figure 2 — SÃO PAULO METROPOLITAN AREA AND THE SAMPLING NETWORK

Capuava Industrial, the most industrialized area in SPMA surpassed the limit ($365 \mu\text{g}/\text{m}^3$) 151 times (76%) followed by Aclimação (8%) and São Caetano do Sul (5,5%).

3. METHODOLOGY

3.1 Sampling and Analysis (2)

The method is based on one recommended by the Ministry of Technology (now Department of Trade and Industry) in the United Kingdom for the routine determination of SO_2 (3). The principles of the method have been accepted by the British Standards Institution (4).

Sulfur dioxide in ambient air is oxidized to sulfuric acid (H_2SO_4) by absorption in a dilute solution of hydrogen peroxide (H_2O_2). The Acidity of this solution is determined by titration with standard alkali and calculated as SO_2 .

The method, however, is not specific, because after oxidation of SO_2 , net acidity is measured, and any acid or alkaline gas or vapor can interfere.

Hydrochloric acid (HCl), nitric acid (HNO_3), or acetic acid ($\text{C}_2\text{H}_4\text{O}_2$) of industrial origin could give rise to difficulties. Interference from carbon dioxide (CO_2) concentrations existing in urban air is prevented by adjustment of the absorbing reagent to pH 4.5, at which level equilibrium is attained with the normal concentration of CO_2 in air. Interference from ammonia can be assessed by separate determination of the ammonia present in the solution. It is not possible to detect less than $10 \mu\text{g}$ of SO_2 in 50 ml of absorbing solution by this technique. Tests have shown that the reproducibility of the method is good.

3.2 Data Analysis

The data was analysed by using the Kendall correlation coefficient test as described in reference (5), and the graphical behavior of the monthly means of SO_2 and their

trends were accomplished by using the Type A formulas of Whittaker-Henderson, as described in references (6, 7, 8 and 9).

The Kendall correlation coefficient is given by:

$$\tau = \frac{2S}{n(n-1)}$$

Where: S = total series score

n = number of terms in the series

If $\tau = \pm 1$ there is a perfect trend and for $\tau = 0$ the series is stationary. If $0 < |\tau| < 1$ there is no direct conclusion about the trend and the significance of the value has to be tested. For $n > 10$, the Kendall correlation coefficient may be assumed as normally distributed and the z-test at a chosen significance level (α) can test the null hypothesis ($\tau = 0$).

The Whittaker-Henderson Type A formula method is a difference - equation type of graduation of bulk data. Each ungraduated observation (U_x) may be considered as the sum of two parts, (V_x) the true value and (W_x) the error departure of (U_x) from (V_x), so that $U_x = V_x + W_x$ for all values of x .

The process of graduation may be described as the substitution of U_x by some function U'_x , derived from a limited number of values in the neighborhood of x , so that a regular function as (V_x) would be approximately reproduced and a random function like (W_x) and its differences would be greatly reduced.

The Whittaker-Henderson Type A formula used in this study was the same presented in the appendix of the paper of Spirtas and Levin (6), except by the estimates $\hat{U}_0$ and $\hat{U}_1$ assumed both equal to the arithmetic mean. The Weighting parameter a was, after some practical trials, taken equal to 30 for a clear representation of the long term trend.

4. DISCUSSION OF RESULTS

The actual SPMA air sampling network (figure 2) was implemented through the years. The six year period chosen in this study could only be satisfied in terms of continuity in data acquisition by ten stations and that was the only reason for their use.

Since July 1, 1978, the data have been corrected for ammonia interference, generating a pair of values for each sampling site, daily (10).

Table 1 shows the annual mean concentrations of SO_2 by sampling site including the SPMA annual averages and the sampling site means and figure 3 presents the annual mean values plotted for each sampling site and for the SPMA average, summarizing the trend patterns.

The trend patterns obtained were the following:

<u>Sampling Site</u>	<u>Trend Pattern</u>	
	<u>corrected</u>	<u>non corrected</u>
Moema	increasing	increasing
Campos Eliseos	increasing	increasing
Cerqueira Cesar	increasing	increasing
Guarulhos	increasing	increasing
Aclimação	increasing	stationary
Tatuapé	stationary	stationary
Osasco	stationary	stationary
São Caetano do Sul	stationary	stationary
Vila Anastácio	stationary	stationary
Capuava Industrial	decreasing	decreasing
SPMA Average	stationary	stationary

From figures 4 to 14 it can be seen the monthly mean values of SO_2 concentrations plotted for each sampling site and the long term trend pattern for data corrected and non corrected for ammonia interference.

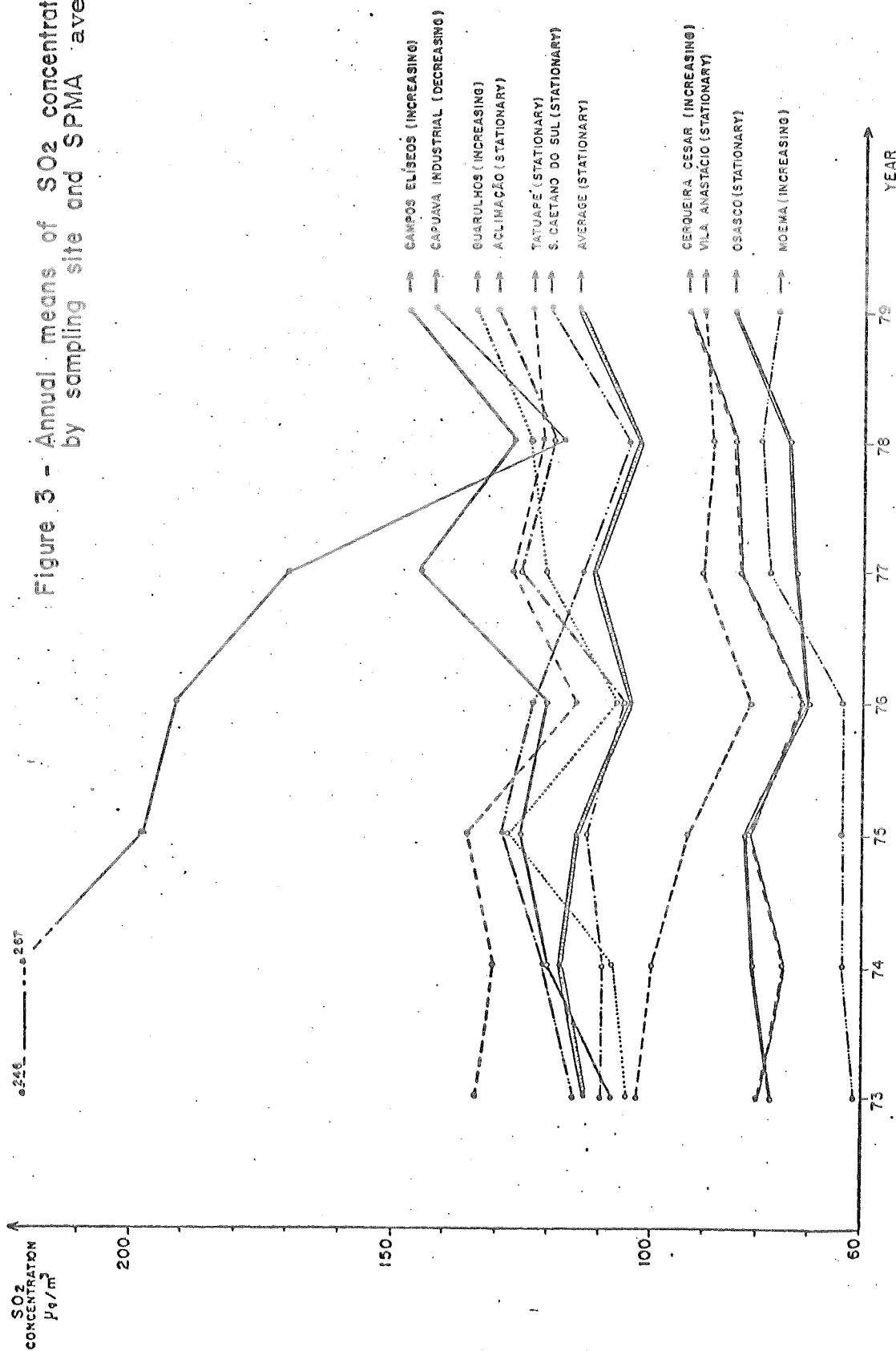
From Annex 6 to Annex 15 are presented the data used in this study including the data corrected for ammonia interference. Only Capuava Industrial presented a decreasing trend in both cases, using or not correction for ammonia interference, as

TABLE 1 - ANNUAL MEAN CONCENTRATION OF SO₂, FROM JANUARY, 1973 TO DECEMBER 1979

YEAR SAMPLING SITE	1973	1974	1975	1976	1977	1978	1979	SAMPLING SITE MEAN
ACLINAÇÃO	110	110	113	106	126	119 * 131	131 * 153	116 * 121
CAMPOS ELÍSEOS	107	120	126	121	146	128 * 143	148 * 169	128 * 133
CERQUEIRA CESAR	80	76	82	72	84	85 * 94	94 * 111	82 * 86
NOEMA	61	64	64	64	78	80 * 89	77 * 95	70 * 74
TATUAPÉ	134	131	136	115	127	122 * 134	124 * 145	127 * 132
V. ANASTÁCIO	104	101	94	82	91	89 * 98	91 * 106	93 * 97
CAPUAVA INDUSTRIAL	246	268	198	192	170	118 * 131	143 * 169	190 * 196
GUARULHOS	105	108	128	107	121	124 * 132	135 * 148	118 * 121
OSASCO	78	81	82	71	73	74 * 83	85 * 100	78 * 82
S. CAETANO DO SUL	115	121	129	123	114	105 * 113	121 * 135	118 * 121
ANNUAL MEAN	114	118	115	105	113	104 * 115	115 * 133	112 * 116

* CORRECTED FOR AMMONIA INTERFERENCE

Figure 3 - Annual means of SO₂ concentrations by sampling site and SPMA average



can be seen in figure 13.

In the sampling sites of Tatuapé, Osasco, São Caetano do Sul and Vila Anastacio stationary trends were obtained, as shown in figures 9, 10, 11 and 12 respectively.

On the other hand, figures 4, 5, 6 and 7 referred respectively to the sampling sites of Moema, Campos Eliseos, Cerqueira Cesar and Guarulhos are showing that the trend is increasing with or without the ammonia correction.

Only in the sampling site of Aclimação as presented in figure 8, there was a change in trend from stationary to increasing when the data were corrected for ammonia interference. Although Capuava Industrial was the only sampling site to present a decreasing trend, the São Paulo Metropolitan Area as an average composite site presented a stationary trend as shown in figure 14, for the period of 6 years considered in this study.

5. CONCLUSIONS

A pictorial view of the air quality deterioration by sulfur dioxide in the SPMA Region was presented. Despite all efforts that have been carried on by CETESB through its corrective and preventive actions, the overall situation remains far from the desirable aims. As it was seen from annex tables 5 to 16 both standards are being exceeded in almost all stations in the period, even at those presenting stationary trends.

As it was previously remarked about 200 industries are responsible for about 80% of SO_2 emissions and the use of high sulfur content oil is almost mandatory because of the small local stocks and the high prices of low sulfur petroleum in the international market. The absence of dessulfurization plants in the Brazilian oil refineries and the nowadays energy crisis tend to aggravate the situation.

Because the Capuava Region was a problematic area (see bulk series figure 3) mainly during the winter season and emphasized by the fact that this site is located upwind in relation to the city of São Paulo, under the main wind direction, CETESB has enforced the use of low sulfur oil to

4 big rank A industries of the region, allocating, since 1976, about 27,786 MT/month to these industries during the winter seasons. This action shifted the trend that it is now decreasing. The fact illustrates the effectiveness of a general control approach in the region.

Any strategy to be applied to reduce sulfur dioxide levels in the SPMA atmosphere should be focused over the rank A industries to be effective. Since the sulfur ratio content between high and low sulfur oil is about 4, the use of tall stacks is not practicable in terms of cost effectiveness; the unique way seems to be the enforcement of high efficiency SO₂ removal equipment for all rank A industries in a planned action to achieve a simultaneous control status. This type of action would be possible only with governmental financial facilities of credit. A better but not feasible solution would be the enforcement of low sulfur fuel oils to the rank A stationary sources.

It should be emphasized that in these difficult times of oil shortage situation that the SPMA region would not absorb the use of direct coal burning without serious health effects to its inhabitants, mainly due to the fact that the Brazilian coal has a large percent of ashes and a high sulfur content. It means that gasification or liquefaction of coal with severe environmental controls should be carefully planned in the case of future impossibility of fuel oil use in the area.

Figure 4 - Sampling Site: Momena

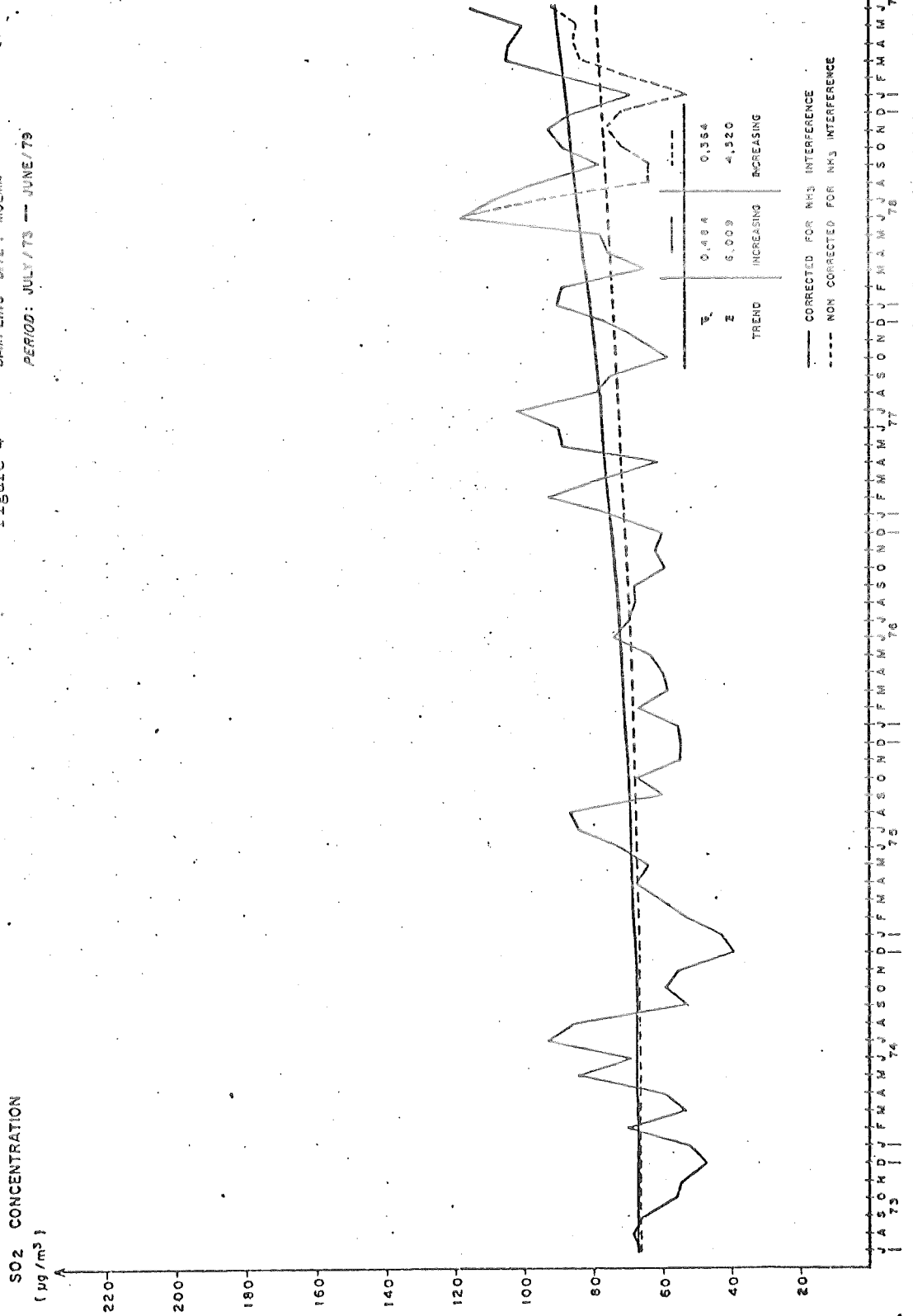


figure 5 - SAMPLING SITE: CAMPOS ELISEOS
PERIOD: JULY/73 - JUNE/79

SO₂ CONCENTRATION
($\mu\text{g}/\text{m}^3$)

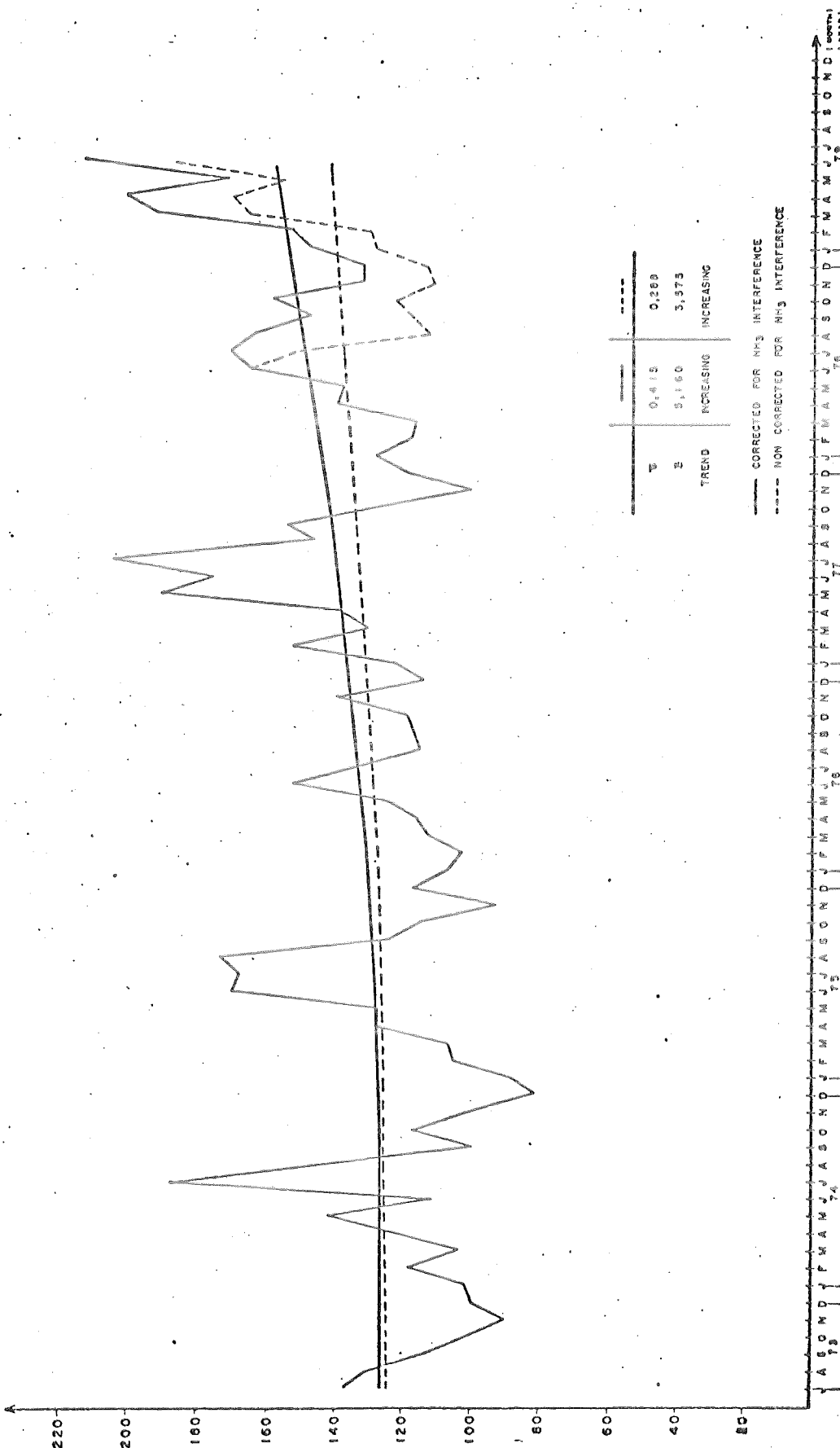


Figure 6 - SAMPLING SITE: CERQUEIRA CESAR
PERIOD: JULY 73 - JUNE 79

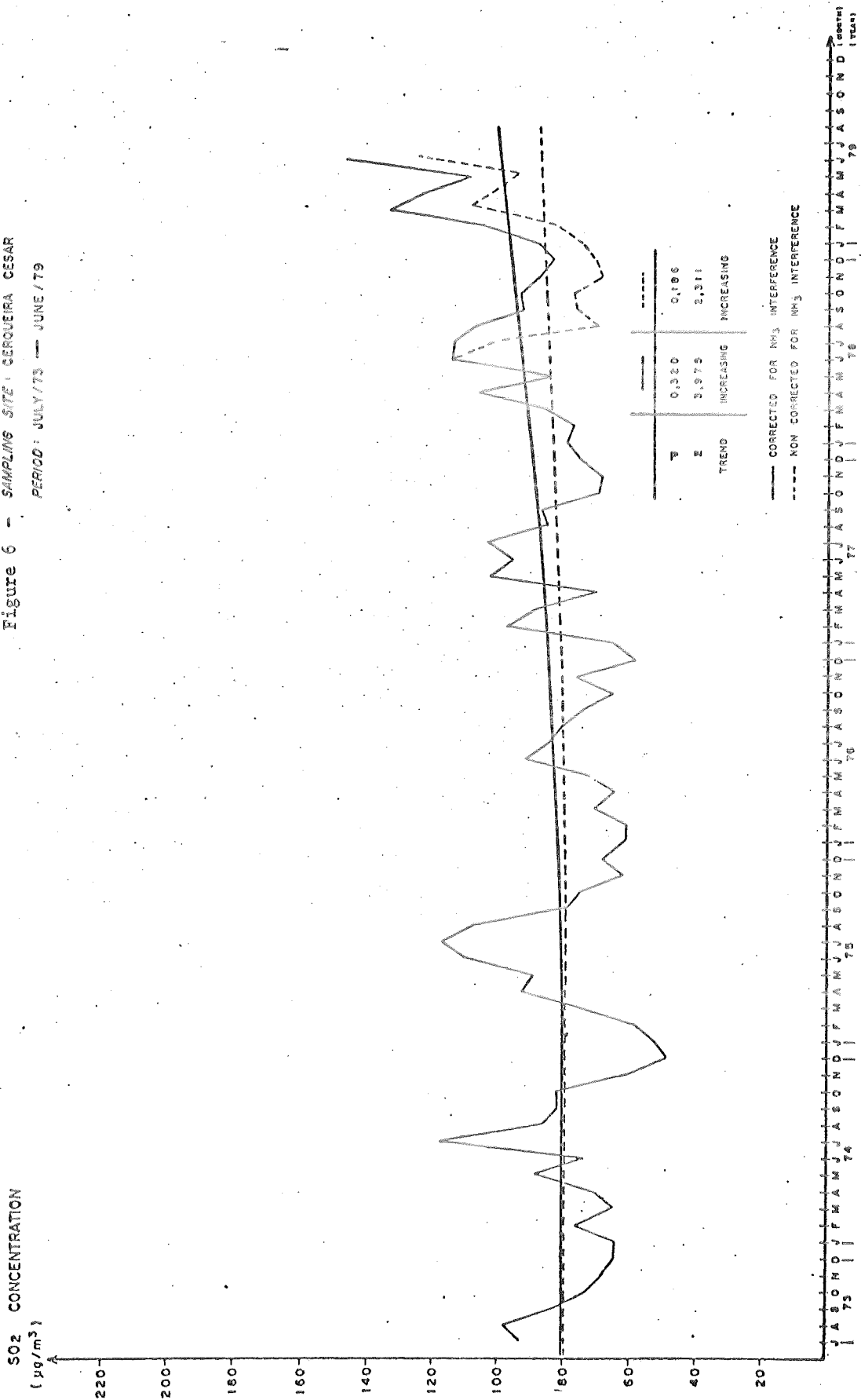


Figure 1 - Sampling Site: Quarulhos

PERIOD: JULY 173 - JUNE 179

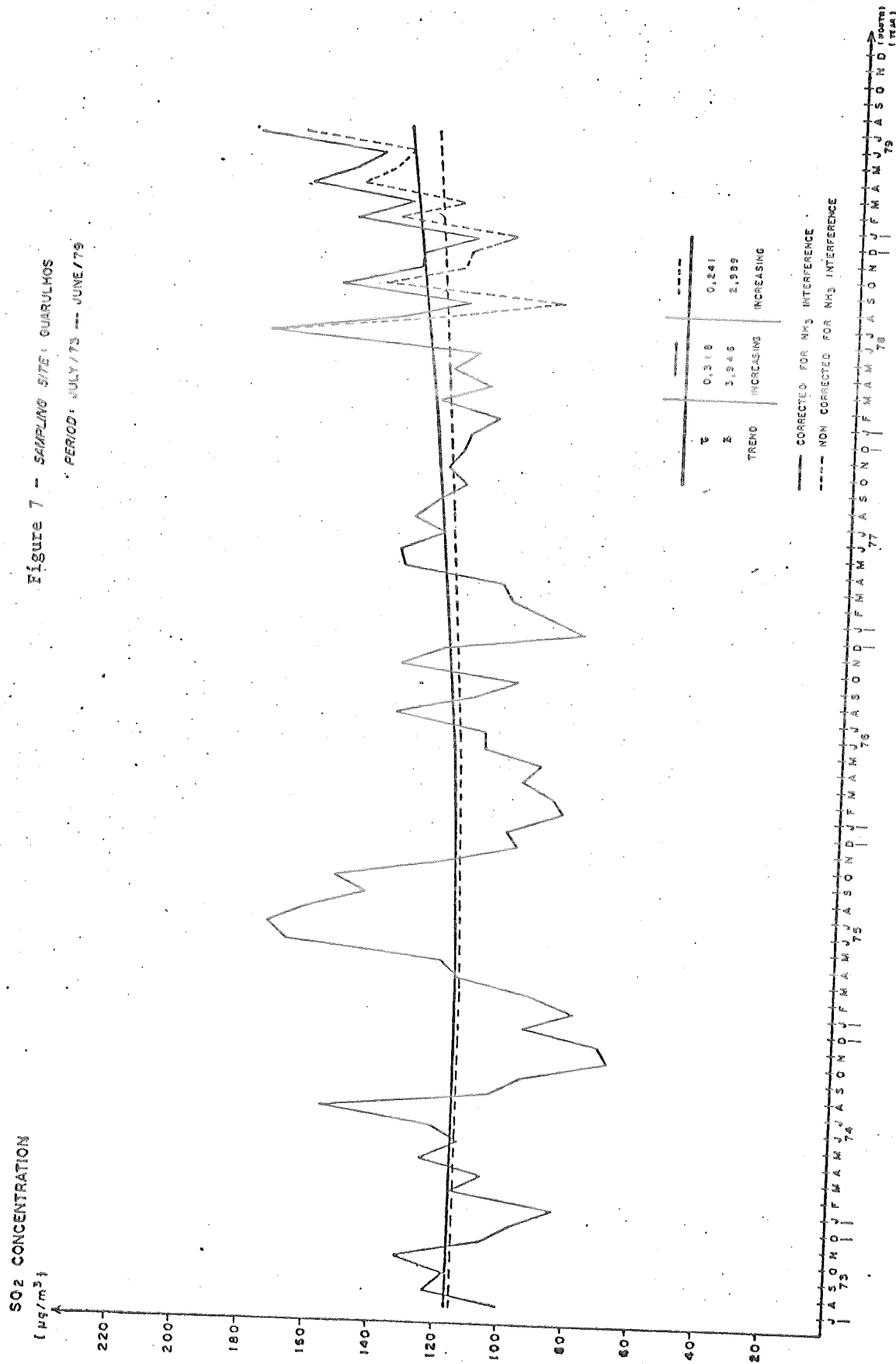


Figure 8 - SAMPLING SITE: ALCANTARÃO

PERIOD: JULY 73 - JUNE 79

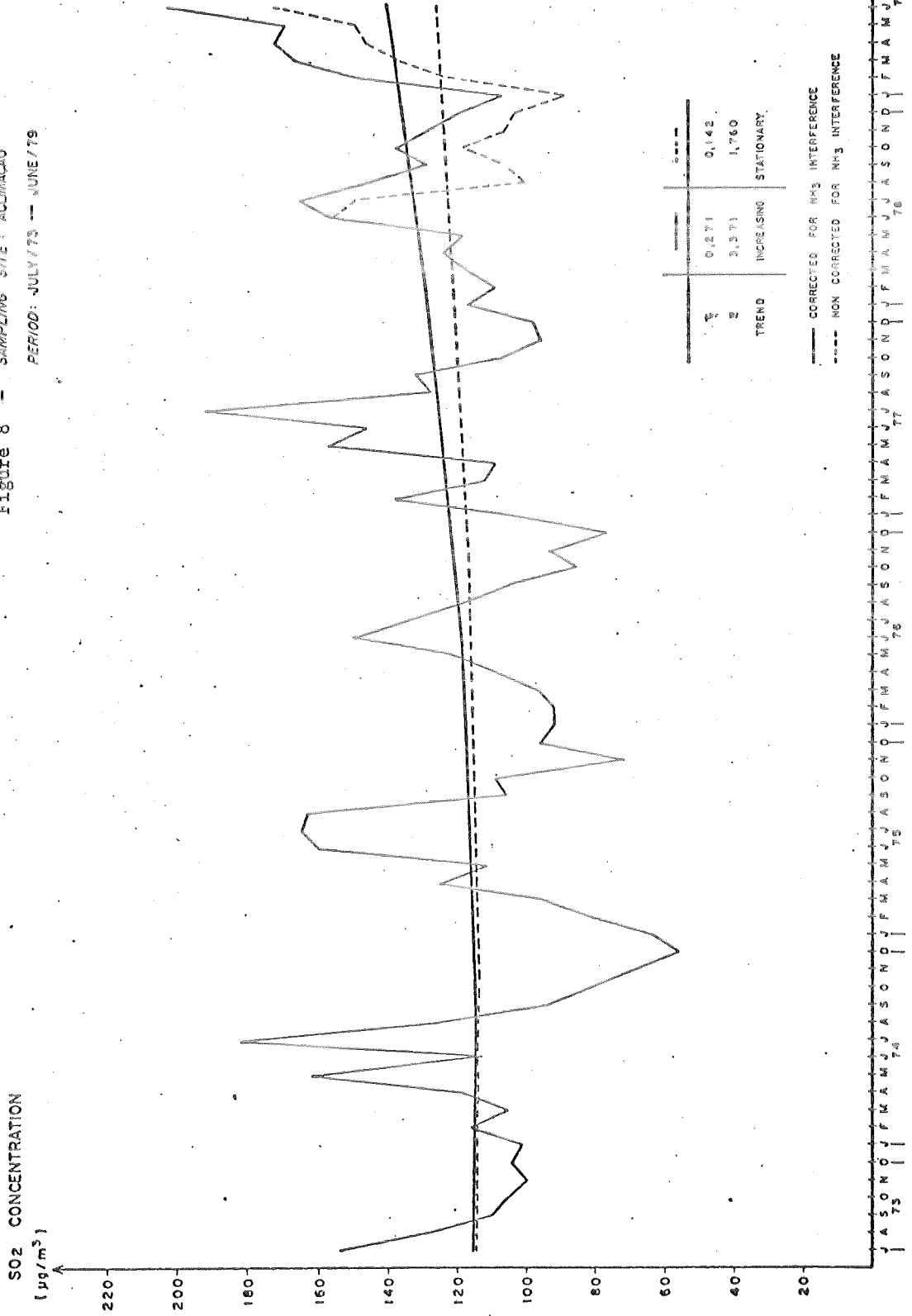


Figure 9 - SAMPLING SITE: TATUAPÉ
PERIOD: JULY/73 - JUNE/79

SO₂ CONCENTRATION
(µg/m³)

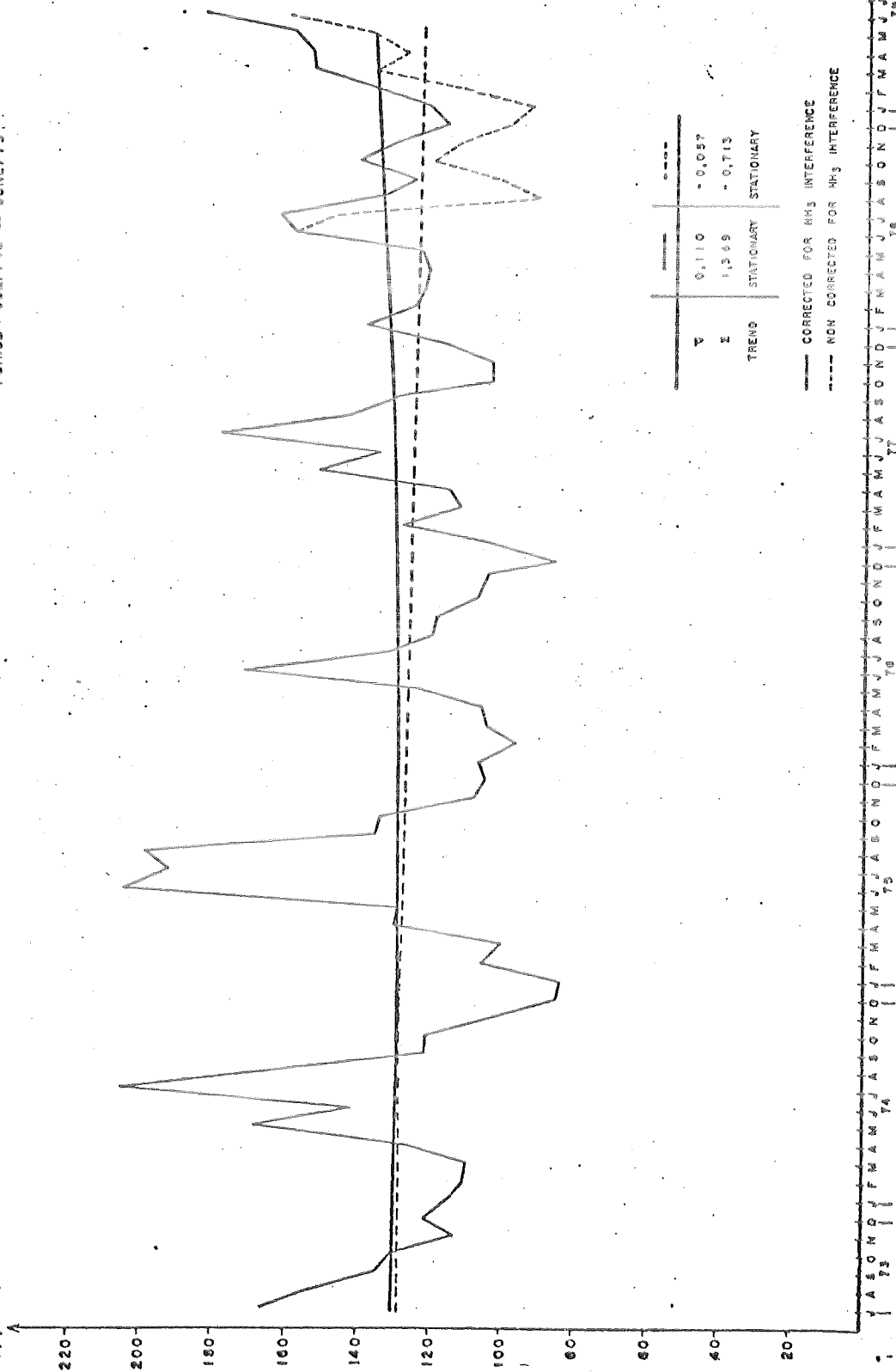
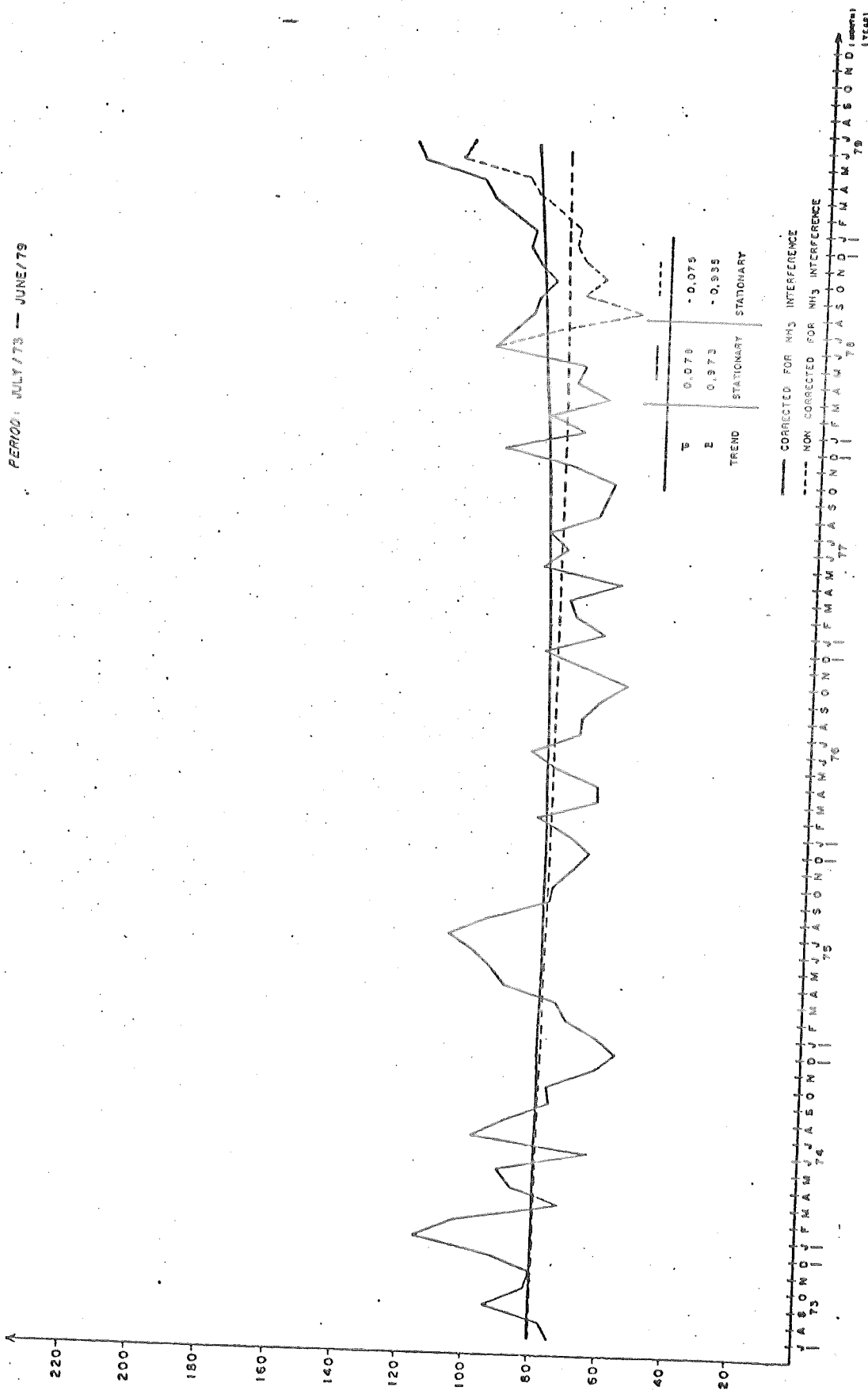


Figure 10 - SAMPLING SITE: OSASCO
PERIOD: JULY 1973 - JUNE 1979

SO₂ CONCENTRATION
($\mu\text{g}/\text{m}^3$)



SO₂ CONCENTRATION
(µg/m³)

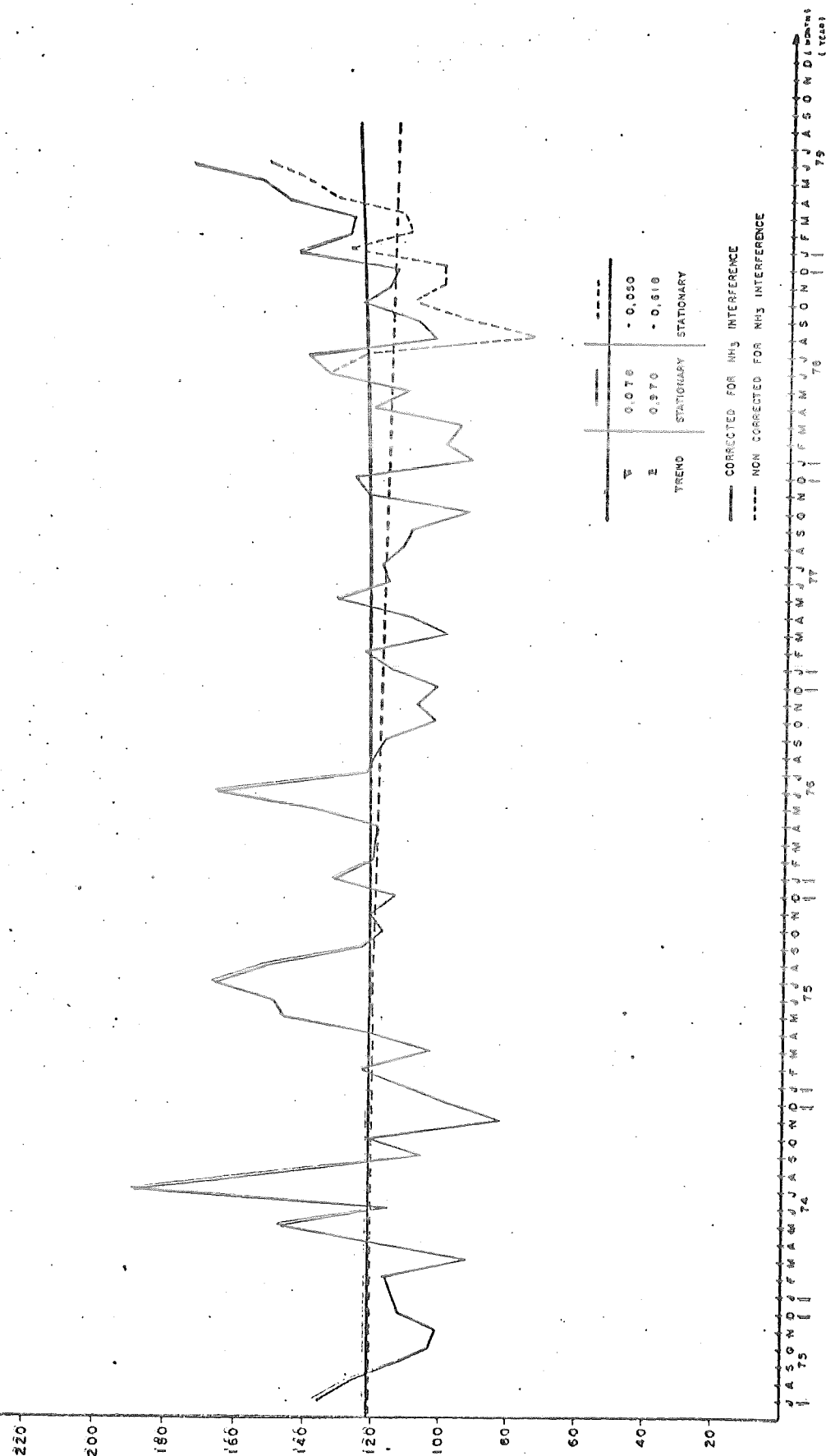


Figure 12 - SAMPLING SITE, VILA ANASTÁCIO
PERIOD: JULY 73 - JUNE 79

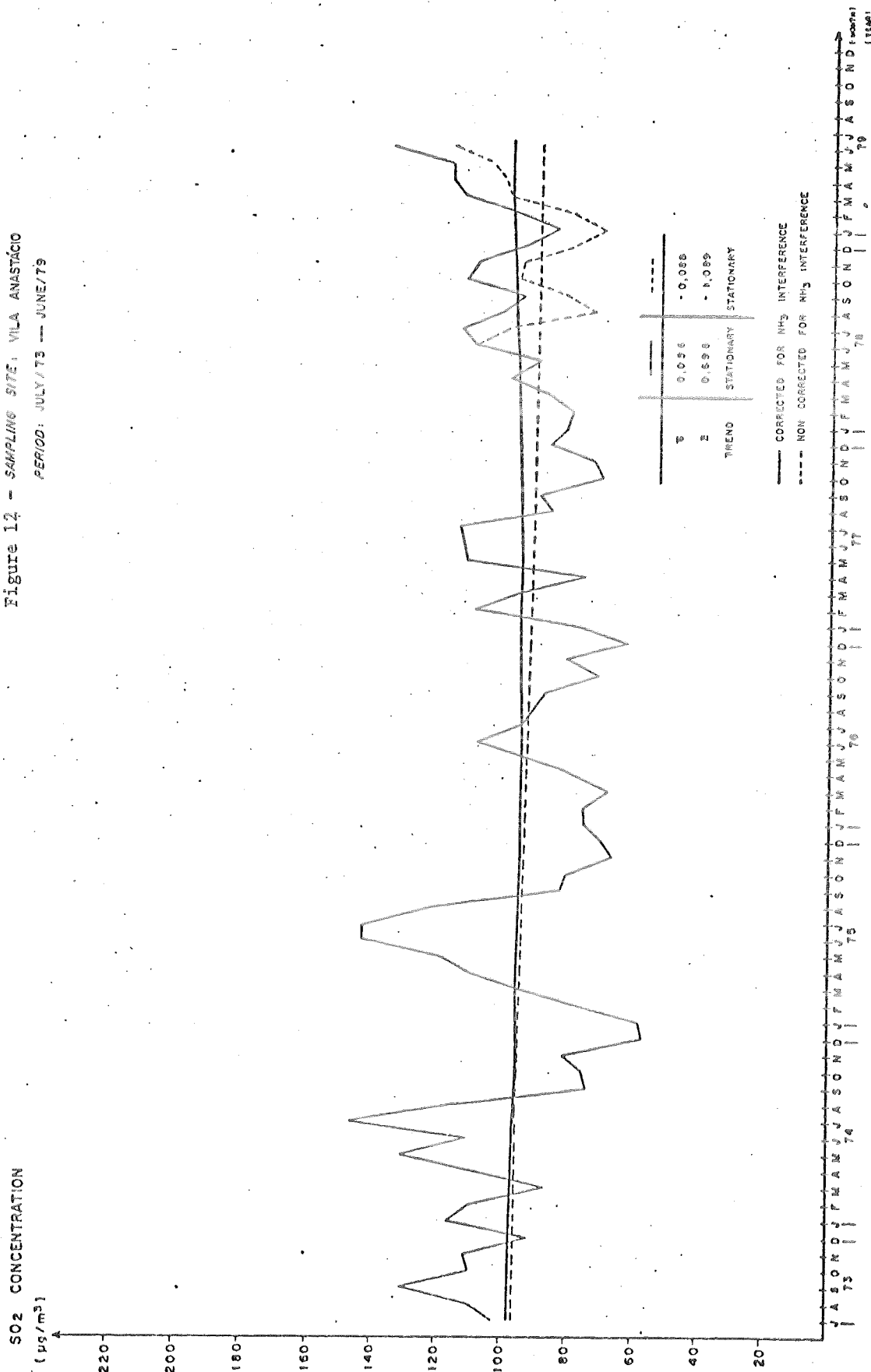


Figure 13.4 SAFELAND SITE: CAPUANA INDUSTRIAL
PERIOD : JULY/73 -- JUNE/79

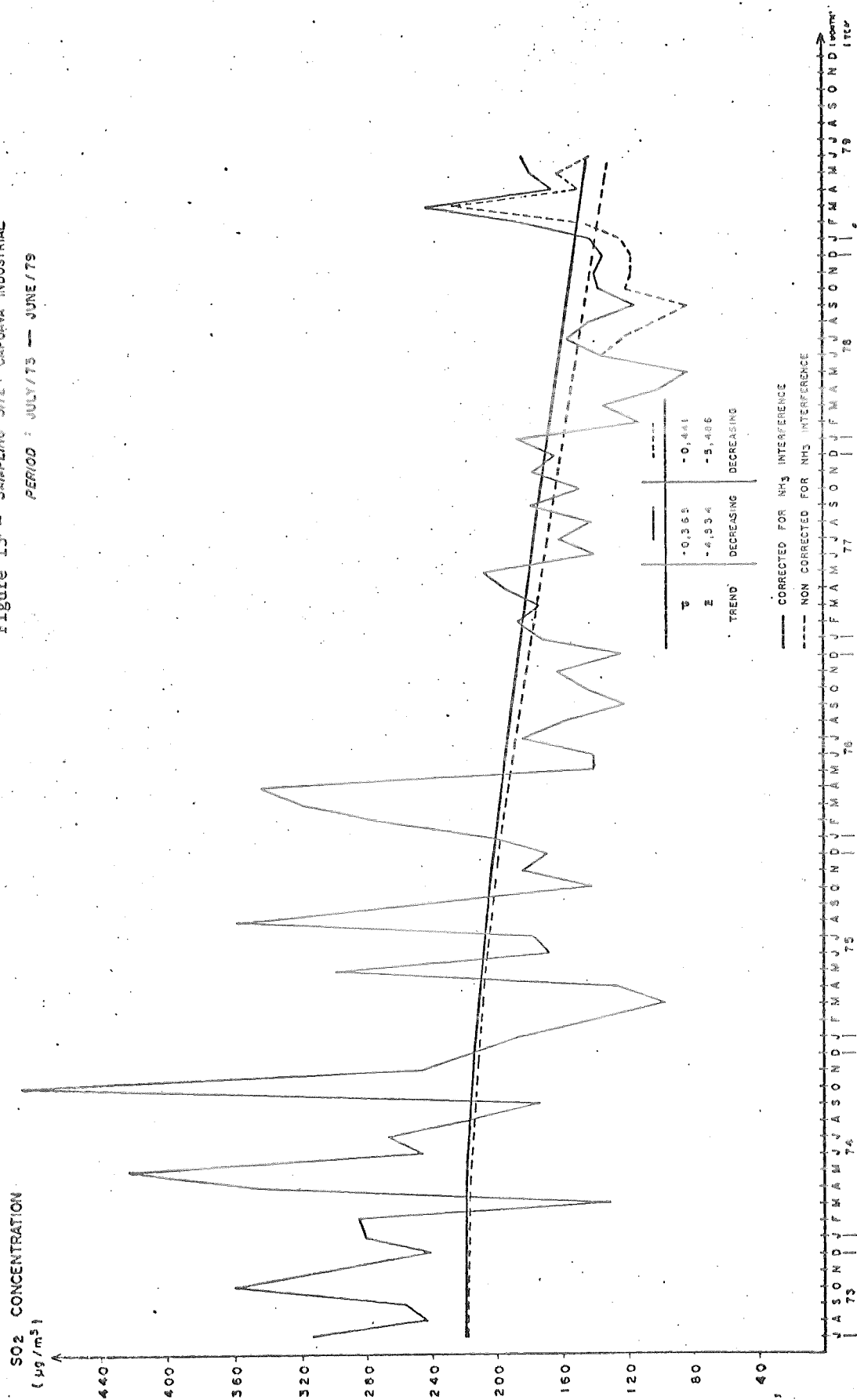
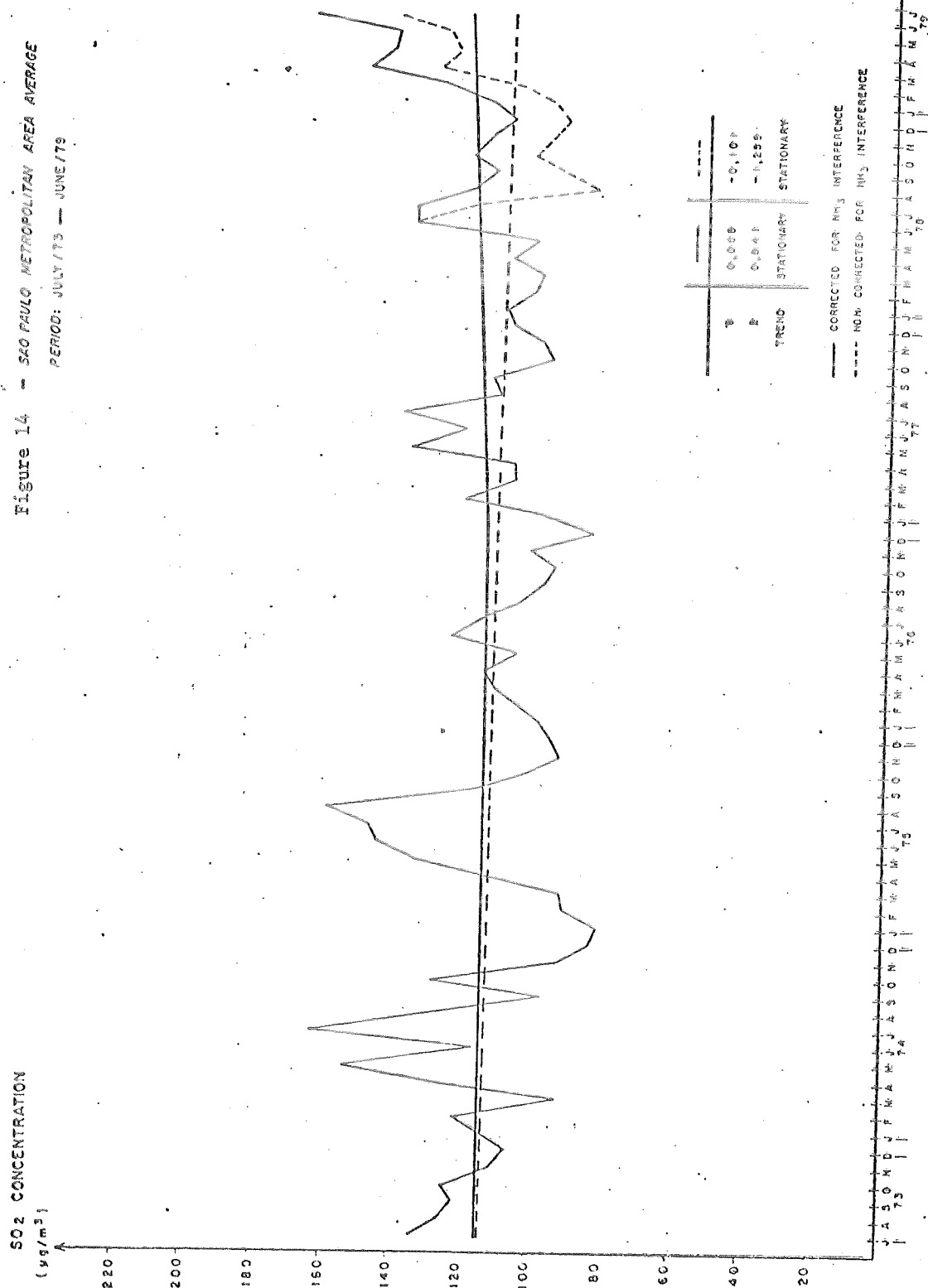


Figure 14 - SÃO PAULO METROPOLITAN AREA AVERAGE
PERIOD: JULY 1953 - JUNE 1979





CETESB

6. ANNEXES

Annex 1 - São Paulo Metropolitan Area - Area (Km²) and population (number of inhabitants) for each one of the 37 municipalities.

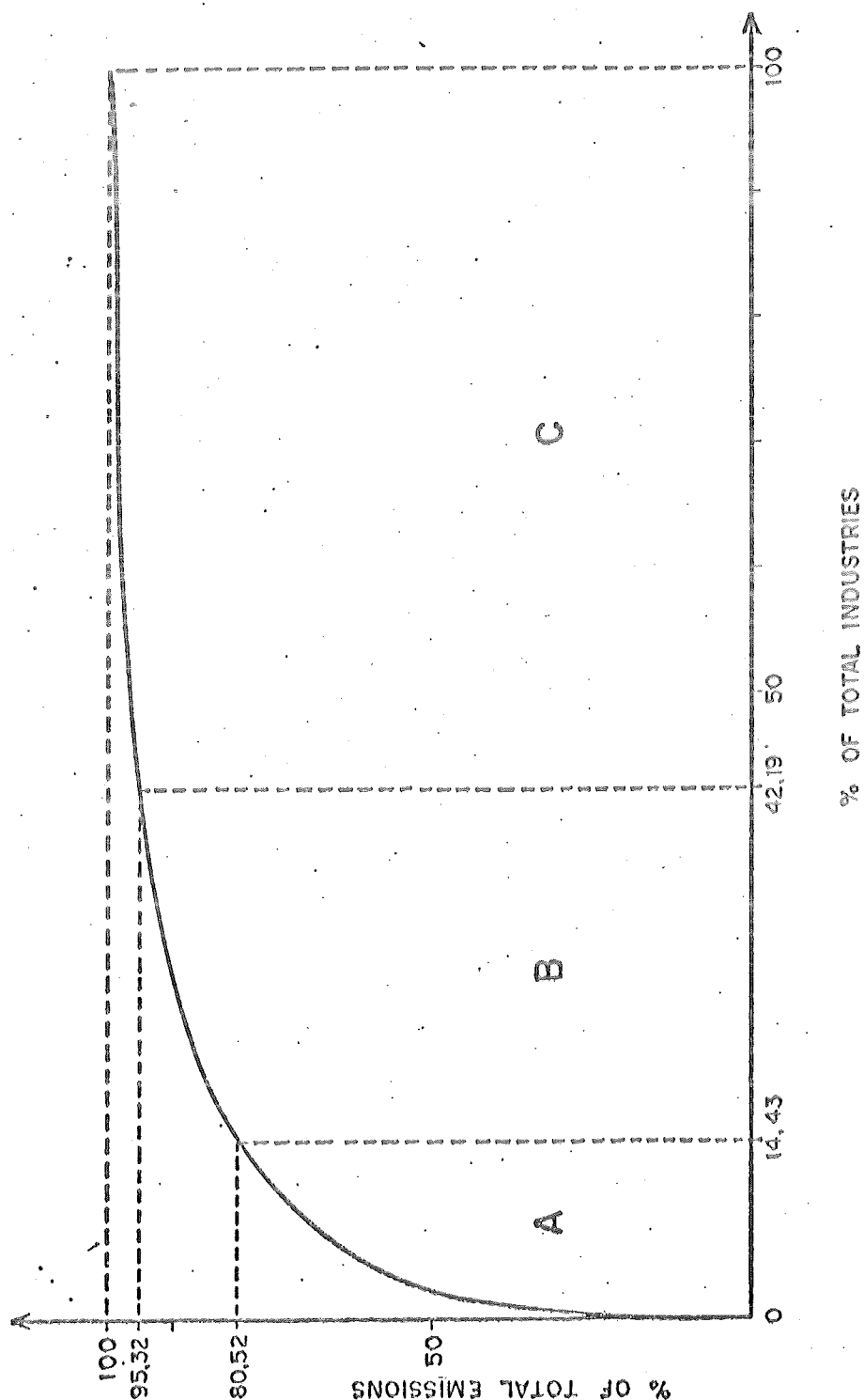
MUNICIPALITY	AREA (KM ²)	POPULATION 1980
Arujá	96	13.442
Barueri	61	83.865
Biritiba-Mirim	414	11.794
Caieiras	104	23.258
Cajamar	132	14.050
Carapicuíba	36	147.049
Cotia	354	55.478
Diadema	32	412.290
Embu	68	55.164
Embu-Guaçu	171	19.481
Ferraz de Vasconcelos	25	50.747
Francisco Morato	45	39.156
Franco da Rocha	143	46.269
Guararema	262	17.401
Guarulhos	334	500.176
Itapecerica da Serra	328	39.044
Itapeví	88	61.356
Itaquaquecetuba	83	62.571
Jandira	22	30.795
Juquitiba	550	8.242
Mairiporã	307	25.156
Mauá	67	292.051
Mogi das Cruzes	731	180.760
Osasco	68	575.287
Pirapora do Bom Jesus	99	4.666
Poa	17	52.020
Ribeirão Pires	107	45.231
Rio Grande da Serra	33	13.679
Salesópolis	418	9.275
Santa Izabel	361	21.913
Santana do Parnaíba	179	4.845
Santo André	179	610.124
São Bernardo do Campo	411	428.737
São Caetano do Sul	12	167.841
São Paulo	1.509	9.027.605
Suzano	185	99.319
Taboão da Serra	20	159.720
TOTAL	8.051	13.409.857

Annex 2 - AIR POLLUTION EMISSION INVENTORY - SAO PAULO METROPOLITAN AREA

POLLUTANT SOURCE	Particulates		SO _x		CO		NO _x		HC	
	MT/Day	%	MT/Day	%	MT/Day	%	MT/Day	%	MT/Day	%
Industrial Processes and Operations	399	72.28	18	2.63	86	1.63	-	-	127	15.28
Fuel combustion- Stationary sources	28	5.07	541	79.09	19	0.36	62	14.76	9	1.08
Motor Vehycles Diesel	13	2.36	82	11.99	195	3.70	158	37.62	33	3.97
Motor Vehycles Gasoline	29	5.25	42	6.14	4846	92.02	193	45.95	596	71.72
Solid Waste Burning	32	5.80	1	0.15	120	2.28	7	1.67	39	4.69
Other	51	9.24	-	-	-	-	-	-	27	3.25
TOTAL	552	100	684	100	5266	100	420	100	831	100

	A	B	C	TOTAL
Nº OF INDUSTRIES	208	400	833	1441
%	14,43	27,76	57,81	100
EMISSION (MT/DAY)	443,01	81,42	25,75	550,18
%	80,52	14,80	4,68	100

Annex 3 — SULFUR OXIDES EMISSION INVENTORY — CONTRIBUTION OF EACH GROUP OF INDUSTRIES (A, B, C)



Annex 4: Air Quality Standards for the State of São Paulo

POLUTANT	SAMPLING TIME (hrs)	STANDARD ($\mu\text{g}/\text{m}^3$)	REFERENCE METHOD
Total Suspended Particles	24 *	240	Hivol Sampler or equivalent
	AGM **	80	
Sulfur Dioxide	24 *	265	Pararosaniline or equivalent
	AAM ***	80	
Carbon Monoxide	1 *	40.000	NDIR or equivalent
	8 *	10.000	
Photochemical Oxidantes (as ozone)	1 *	160	Chemiluminescence or equivalent

* Not to be exceed more than once a year

** Annual geometric mean

*** Annual Arithmetic mean

Annex 5: Number of times air quality standard for SO₂ was exceeded*

YEAR SAMPLING SITE		1973	1974	1975	1976	1977	1978	1979	Absolute Frequency	Relative percent in relation to total nº of times
ACLIMAÇÃO		2	0	1	0	1	0	12	16	8
CAMPOS ELÍSEOS		0	1	0	0	0	0	5	6	3
CERQUEIRA CESAR		0	0	0	0	0	0	0	0	-
NOEMA		0	0	0	0	0	0	0	0	-
TATUAPÉ		0	1	4	0	1	2	0	8	4
V. ANASTÁCIO		0	0	0	0	0	0	0	0	-
CAPUAVA INDUSTRIAL		40	37	23	32	9	5	5	151	76
GUARULHOS		0	0	1	1	1	1	3	7	3.5
OSASCO		0	0	0	0	0	0	0	0	-
S. CAETANO DO SUL		2	2	4	0	0	0	3	11	5.5

* Only for the Stations studied

Annex 6 : MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Moema

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	52	43	56	74	90	53 * 69
FEBRUARY	-	70	53	67	93	89	70 * 88
MARCH	-	53	60	59	80	66	84 * 105
APRIL	-	60	67	60	62	76	86 * 104
MAY	-	84	64	63	89	78	85 * 101
JUNE	-	69	72	74	90	118	92 * 115
JULY	66	93	84	70	102	94 * 109	-
AUGUST	68	85	87	64	79	64 * 96	-
SEPTEMBER	65	53	60	68	75	64 * 78	-
OCTOBER	56	59	67	59	58	72 * 89	-
NOVEMBER	54	55	55	62	66	76 * 93	-
DECEMBER	47	39	55	60	76	72 * 86	-
ANNUAL MEAN	-	64	64	64	79	80	-

* WITH AMMONIA CORRECTION

Annex 7: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Campos Eliseos

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	102	88	107	123	128	128 * 148
FEBRUARY	-	118	105	103	153	118	130 * 153
MARCH	-	103	107	113	130	117	165 * 192
APRIL	-	121	128	116	139	140	170 * 201
MAY	-	142	127	125	191	138	155 * 171
JUNE	-	111	170	153	176	165	186 * 213
JULY	137	189	168	133	205	152 * 171	-
AUGUST	130	144	173	115	146	112 * 164	-
SEPTEMBER	113	99	124	117	155	117 * 147	-
OCTOBER	102	117	115	119	128	122 * 159	-
NOVEMBER	90	102	92	140	100	111 * 132	-
DECEMBER	100	81	117	114	119	113 * 132	-
ANNUAL MEAN	-	119	126	121	147	128	-

* WITH AMMONIA CORRECTION

Annex 8: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Cerqueira Cesar

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	64	52	61	65	80	75 * 89
FEBRUARY	-	76	58	61	98	78	83 * 105
MARCH	-	64	74	71	89	87	109 * 134
APRIL	-	70	93	65	70	107	101 * 123
MAY	-	88	89	73	103	85	95 * 109
JUNE	-	73	110	92	96	115	125 * 147
JULY	93	117	117	85	104	102 * 114	-
AUGUST	98	86	108	81	85	70 * 107	-
SEPTEMBER	82	82	79	74	87	77 * 93	-
OCTOBER	73	82	75	65	70	78 * 94	-
NOVEMBER	68	60	62	76	69	69 * 88	-
DECEMBER	64	49	68	59	76	71 * 84	-
ANNUAL MEAN	-	76	82	72	84	85	-

* WITH AMMONIA CORRECTION

Annex 9: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Guarulhos

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	—	84	80	85	93	110	143 * 156
FEBRUARY	—	116	94	89	104	128	123 * 138
MARCH	—	107	116	99	107	113	154 * 170
APRIL	—	125	121	93	137	125	144 * 157
MAY	—	114	169	111	139	117	139 * 148
JUNE	—	123	175	111	125	181	172 * 186
JULY	100	157	163	138	135	127 * 141	—
AUGUST	123	105	145	115	128	91 * 120	—
SEPTEMBER	117	96	155	101	119	146 * 160	—
OCTOBER	132	69	122	137	125	122 * 136	—
NOVEMBER	106	72	99	124	121	120 * 135	—
DECEMBER	97	96	103	81	119	107 * 119	—
ANNUAL MEAN	—	105	129	107	121	124	—

* WITH AMMONIA CORRECTION

Annex 10: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Aclimação

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	101	64	92	104	117	89 * 107
FEBRUARY	-	116	81	92	138	109	123 * 148
MARCH	-	105	95	97	112	117	137 * 166
APRIL	-	118	125	107	109	124	146 * 172
MAY	-	162	112	120	157	118	149 * 169
JUNE	-	113	160	150	146	156	172 * 202
JULY	154	182	165	134	192	149 * 166	-
AUGUST	129	126	163	118	127	100 * 146	-
SEPTEMBER	110	93	106	106	132	107 * 129	-
OCTOBER	106	81	109	85	107	118 * 138	-
NOVEMBER	100	68	72	93	96	106 * 129	-
DECEMBER	104	56	96	77	98	103 * 120	-
ANNUAL MEAN	-	110	112	106	126	119	-

* WITH AMMONIA CORRECTION

Annex 11: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Tatuapé .

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	114	84	107	104	139	93 * 121
FEBRUARY	-	110	106	96	129	126	112 * 138
MARCH	-	109	100	105	112	123	136 * 154
APRIL	-	126	130	106	116	122	128 * 154
MAY	-	168	129	124	152	124	137 * 159
JUNE	-	141	204	172	135	158	160 * 184
JULY	166	205	192	133	179	148 * 163	-
AUGUST	152	165	198	120	144	91 * 135	-
SEPTEMBER	134	121	135	119	131	102 * 126	-
OCTOBER	130	121	134	107	104	120 * 141	-
NOVEMBER	112	101	108	105	104	113 * 131	-
DECEMBER	121	85	105	86	118	99 * 117	-
ANNUAL MEAN	-	131	135	115	127	122	-

* WITH AMMONIA CORRECTION

Annex 12: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Osasco

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	115	63	72	64	72	75 * 89
FEBRUARY	-	103	72	82	73	83	81 * 96
MARCH	-	72	75	65	75	65	88 * 102
APRIL	-	87	91	65	60	75	91 * 105
MAY	-	91	95	77	83	73	111 * 123
JUNE	-	64	100	85	76	100	108 * 126
JULY	74	99	108	71	81	79 * 95	-
AUGUST	77	89	96	70	67	56 * 89	-
SEPTEMBER	94	76	78	65	65	73 * 87	-
OCTOBER	82	77	77	57	63	67 * 82	-
NOVEMBER	80	63	71	70	75	73 * 87	-
DECEMBER	93	57	67	82	96	76 * 90	-
ANNUAL MEAN	-	83	83	72	73	74	-

* WITH AMMONIA CORRECTION

Annex 13: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : São Caetano do Sul

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	114	111	131	115	92	129 * 143
FEBRUARY	-	116	123	120	123	100	111 * 128
MARCH	-	92	103	120	99	96	113 * 127
APRIL	-	119	120	119	110	121	133 * 146
MAY	-	147	146	138	131	111	141 * 153
JUNE	-	115	149	166	116	134	153 * 174
JULY	135	189	166	122	118	123 * 140	-
AUGUST	127	147	151	120	112	75 * 103	-
SEPTEMBER	114	105	123	117	110	96 * 108	-
OCTOBER	103	120	117	102	93	110 * 124	-
NOVEMBER	101	82	121	108	122	101 * 117	-
DECEMBER	112	98	114	102	126	101 * 114	-
ANNUAL MEAN	-	120	129	122	115	105	-

* WITH AMMONIA CORRECTION

Annex 14: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Vila Anastacio

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	116	58	75	77	82	70 * 85
FEBRUARY	-	109	76	76	109	80	80 * 97
MARCH	-	86	96	68	95	87	99 * 114
APRIL	-	109	109	78	76	99	101 * 117
MAY	-	130	118	92	112	90	105 * 117
JUNE	-	110	143	108	113	110	117 * 135
JULY	102	146	143	95	114	99 * 114	-
AUGUST	109	114	120	92	86	73 * 102	-
SEPTEMBER	130	74	83	87	90	82 * 95	-
OCTOBER	109	75	81	71	71	96 * 113	-
NOVEMBER	111	81	67	81	73	95 * 109	-
DECEMBER	91	57	70	62	87	80 * 95	-
ANNUAL MEAN	-	101	97	82	92	89	-

* WITH AMMONIA CORRECTION

Annex 15: MONTHLY MEANS OF SO₂ CONCENTRATIONS, FROM JULY, 1973 TO JUNE, 1979

SAMPLING SITE : Capuava Industrial

YEAR MONTH	1973	1974	1975	1976	1977	1978	1979
JANUARY	-	280	175	204	172	187	124 * 141
FEBRUARY	-	284	143	274	186	111	147 * 184
MARCH	-	130	96	318	173	134	227 * 242
APRIL	-	345	127	344	194	100	150 * 164
MAY	-	424	296	141	208	81	163 * 178
JUNE	-	244	167	141	139	135	143 * 183
JULY	313	266	176	183	162	124 * 157	-
AUGUST	242	216	358	158	141	105 * 143	-
SEPTEMBER	256	175	233	121	178	83 * 114	-
OCTOBER	359	485	140	145	148	121 * 137	-
NOVEMBER	297	245	184	163	177	118 * 139	-
DECEMBER	239	217	169	124	164	118 * 134	-
ANNUAL MEAN	-	276	189	193	170	118	-

* WITH AMMONIA CORRECTION.

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