BRA-2340, Development of Research and Environmental Pollution Control Programs for the State of São Paulo

FINAL REPORT OF THE CONSULTANTSHIP PROVIDED TO THE STATE OF SAO PAULO REGARDING THE DEVELOPMENT OF RESEARCH AND ENVIRONMENTAL POLLUTION CONTROL PROGRAMS FOR THE STATE OF SAO PAULO

From 3 November 1979 to 1 December 1979

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I. SUMMARY

A. Activities

Since the start of this assignment on 5 November 1979, numerous discussions have been held with members of CETESB staff, particularly with members of the air quality analytical and special projects laboratories, with engineers working on telemetry system, with meteorologists, data evaluation personnel and engineers from the motor vehicle testing laboratories (See Appendix I). All these technical personnel were most cooperative and supplied the technical information regarding the Sao Paulo area which have been utilized in this report.

A summary course on development in air pollution was given to selected CETESB staff members during the first two weeks. The discussions covered meteorology and contaminant emissions, and how they affect air quality; transport of air contaminants, source-receptor areas and photochemistry; air monitoring, including data collection, quality assurance and data interpretation; air quality trends, air quality standards and health effects; and the future program in the Sao Paulo area, particularly an assessment of the problem and suggested control measures.

Several days were spent visiting the chemistry laboratory, the automotive emissions laboratory, the air monitoring stations at Parque D. Pedro and São Caetano do Sul, and the telemetry center, and noting some of the major sources of contaminant emissions.

B. Findings

CETESB staff is well informed regarding the overall air pollution problem in the greater Sao Paulo area. Emission inventories have been compiled for the major contaminants from both mobile and stationary sources, and a brief survey of traffic has been attempted.

Air monitoring data show that air quality standards for particulate matter, sulfur dioxide, sulfates, carbon monoxide and oxidants (ozone) have been exceeded in the greater Sao Paulo area (Tables I, IV, V; Ref. 5). A potential exists for a continuous deterioration of air quality unless strict emission control measures are applied.

Air monitoring data, particularly for ozone and nitrogen dioxide, is very sparse; these deficiencies should be remedied when the telemetry system is implemented.

Further definition of the extents of sulfate and acid rain phenomena is needed; as are more detailed analyses of ambient aldehyde concentrations and the possible impact of increased aldehyde emissions in automotive exhaust from alcohol-fueled or gasoline-alcohol fuel mixtures upon ozone formation. Speciated hydrocarbon analyses from emission sources and from ambient air are needed to more thoroughly define the photochemical oxidant problem.

C. Recommendations

1. Encourage CETESB staff to maintain its technical awareness of air pollution progress in other areas and assist in the implementation of its proposed air pollution control program in the Greater Sao Paulo area.
2. Eliminate Gaps in Ambient Air Monitoring Data
   a) Implement Telemetry System
   b) Expedite Acquisition of Replacement Parts for Analytical Instruments
3. Increase Personnel Assigned to Special Projects Laboratory
4. Purchase Two Ultra-Violet Photometer Ozone Recorders (Dasibi, or equivalent)

With a very well informed but numerically limited technical staff presently assigned to chemical research and analysis, CETESB has already made considerable progress in definition

of the air pollution problem in the greater Sao Paulo area. Given the assistance needed in additional personnel and air monitoring equipment, even greater progress may be anticipated within the next two years.

II. OBJECTIVE OF THE CONSULTANTSHIP

The purpose of the consultantship is to provide technical advice regarding the study of photochemical reactions in the atmosphere in the Greater Sao Paulo area, and to suggest monitoring methods of sampling and analysis and air monitoring site locations for measurement of those pollutants.

III. FINDINGS

A. Background

CETESB staff is well informed regarding the overall air pollution problem in the Greater Sao Paulo area. Emission inventories have been compiled for carbon monoxide, hydrocarbons, oxides of nitrogen, oxides of sulfur and particulate matter for both automotive vehicles and stationary sources (Table II). Daily traffic data were gathered and presented as volume equivalents[a] for 15 major roadways in Sao Paulo during a 5 day period in October 1977. Volume equivalents (VE) ranged from 18.196 at Av. Santo Amaro, Av. São Gabriel to 46.814 at Radial Leste, Av. Alcantara Machado (1).

Preliminary reports (3,4) indicate that aldehyde concentrations in motor vehicle exhaust increase as the alcohol content of the fuel mixture increases from 0 - 20%, while carbon monoxide emissions appear to decrease. Aldehydes are believed to be an important source of the radicals OH, HO_2 and RO_2 which participate in the oxidation of NO to NO_2 and in most of the chemical reactions which consume hydrocarbons and aldehydes(2).

a) VE (volume equivalent = autos + 3X trucks + 4X buses.

Emphasis has correctly been placed on particulate matter and sulfur dioxide as ambient pollutants, and most of the air monitoring data available refers to these pollutants. The relative importance of specific industries in relation to particulate and sulfur dioxide emissions has also been pointed out by CETESB staff (Table III). During the years 1976, 1977 and 1978 the air quality standard for particulate matter of 240 $\mu g/m^3$/24 hour average was exceeded 189, 105 and 121 times, respectively, in the Sao Paulo rea (Table IV).

A special CETESB study at four stations during 1978 has indicated that sulfate levels at Embu-Guaçu, Pinheiros, Praça da República and São Caetano do Sul exceeded the California state air quality standard for this contaminant of 25 $\mu g/m^3$/ 24 hour average. At São Caetano do Sul that standard was exceeded on 62,5% of the sampling days. The highest value (78 $\mu g/m^3$/24 hour average) was measured at this station. This was not surprising since São Caetano do Sul is in a heavily industrialized area characterized by high SO_2 emissions. Meteorological conditions in the Greater Sao Paulo area seem to favor conversion of sulfur dioxide to sulfate, and therefore the control of sulfur dioxide emissions is extremely important.

Sufficient information has been gathered to identify carbon monoxide as a potential problem in terms of ambient concentrations (Table V) and as a potential health hazard(6). Carbon monoxide is also an excellent tracer for automotive exhaust, which, because of its optimal concentrations of hydrocarbons and oxides of nitrogen has been shown to be a major source of photochemical oxidant (2).

B. The Oxidant Problem

1. Sampling Stations

CETESB staff has already proposed a sampling network to provide the data necessary for quantitative definition of the photochemical oxidant problem in the Greater Sao Paulo area (1). It will comprise five permanent stations incorporated into a telemetering system currently being installed and tested for acceptance, and supplemented by an additional

five sites to be sampled with the two CETESB mobile laboratories.

The sites (Figure 1) were carefully selected after consideration of the distribution of moving and stationary sources of primary pollutants, topography of the Greater Sao Paulo region and the prevailing wind directions (1), and are listed below:

1. Telemetry, Parque D. Pedro
2. Telemetry, Mooca
3. Telemetry, Lapa
4. Telemetry, Congonhas
5. Telemetry, Juquitiba
6. Mobile Laboratory, Campo Grande
7. Mobile Laboratory, São Caetano do Sul
8. Mobile Laboratory, Casa Verde
9. Mobile Laboratory, Caieiras
10. Mobile Laboratory, Santana do Parnaíba

When implemented, these ten sites should provide minimal data required to define the photochemical oxidant problem in the Greater Sao Paulo area.

At the present time only one station, Juquitiba, is operating on the telemetry system. A second station, Parque D. Pedro, is undergoing tests prior to being placed on stream. One mobile laboratory is stationed at São Caetano do Sul; the second is at Parque D. Pedro, supplementing the telemetry data from that station.

2. Oxidant (Ozone)

Available oxidant data obtained during the 1976 - 1977 smog seasons, May through August, indicate 32 hours during which ozone values exceeded 0,08 ppm, the Sao Paulo state air quality standard. The maximum value of 0,157 ppm, 1 hour average, was measured at São Caetano do Sul on September 14, 1977. However, these values, while the highest measured to date, may not represent the true maximum oxidant values in the Greater Sao Paulo area. As indicated by CETESB staff (1), samples should be taken simultaneously at São Caetano do Sul, São Paulo, Casa Verde

and Caieiras in order to follow the development of photochemical oxidant during transport of the pollutants across the Greater Sao Paulo area.

No oxidant data were obtained during the smog seasons of 1978 - 1979 because of problems with instrumentation. Replacement parts for the three Bendix Ozone Analyzers were ordered, but were not received in time to permit sampling during the critical May through August periods when high oxidant values were to be expected.

3. Oxides of Nitrogen (NO, NO_2, NO_x)

Oxides of nitrogen (NO, NO_2 and the sum of NO + NO_2 (NO_x)) have not been routinely measured. Sampling at two stations, Central Zone, in 1976 and Praça da República in 1977, indicated that NO_2 concentrations, like O_3, peaked during the winter months May through September.

Examination of preliminary diurnal curves reveals a variation in nitric oxide which may be related to traffic emissions, and there are also indications of a negative interference of nitric oxide on ozone concentrations measured.

4. Aldehydes

Aldehydes are important precursors to ozone formation. As stated above, preliminary data indicate that aldehyde emissions in automobile exhaust increase as the percent of alcohol added to the gasoline increases. The effect of the alcohol fuel program an ambient concentrations of aldehyde and on the formation of photochemical oxidant should be determined by collection and analysis of ambient air samples and a careful evaluation of these data. At the present time such information is lacking.

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Encourage CETESB staff to maintain its technical awareness

of air pollution in the Greater Sao Paulo area and, assist the implementation of its proposed air pollution control program.

CETESB staff is well informed regarding the air pollution problem in the greater Sao Paulo area and is aware of the critical lack of data in some areas, particularly ambient concentrations of oxidant, nitrogen dioxide, speciated hydrocarbons, aldehydes and particulate sulfates, as well as emission data for oxides of nitrogen, speciated hydrocarbons and aldehydes.

The staff should be encouraged to continue its effort to apply the most recent and best available technology to the definition of the Greater Sao Paulo air pollution problem and to its eventual control through reduction of contaminant emissions from both stationary and mobile sources.

2. Eliminate Gaps in Ambient Air Monitoring Data

a) Implement Telemetry System

Deficiencies in acquisition of ambient contaminant data will be minimized when the telemetry system is fully implemented. This should occur within the next few months; certainly before the 1980 May-September smog season.

It is suggested that simultaneous measurement of ozone, nitrogen oxides, carbon monoxide, sulfur dioxide and hydrocarbons be made in 1980 according to the following schedule:

May-June	July-August	September
M São Caetano	T São Paulo	T São Paulo
T São Paulo (P.D.Pedro)	M Casa Verde	T Lapa
T Lapa	M Caieiras	M Santana do Parnaíba
M Santana do Parnaíba	T Lapa	M Caieiras
T Juquitiba	T Juquitiba	T Juquitiba
T Congonhas	T Congonhas	T Congonhas
T Mooca	T Mooca	T Mooca

b) Expedite Acquisition of Replacement Parts for Analytical Instruments

CETESB was unable to obtain ambient oxidant measurements during the smog seasons of 1978 - 1979 because of instrumentation problems associated, with the lack of replacement parts for the Bendix Ozone Analyzers. Parts were ordered, but did not arrive in time to perform the necessary analyses.
Perhaps PAHO could assist in obtaining the required replacement parts for three Bendix Ozone Analyzers and one Bendix NO_2 Analyzer currently used by the laboratory.

3. Increase Personnel Assigned to Special Projects Laboratory

Special projects have already demonstrated the potential carbon monoxide and sulfate problems in the Sao Paulo area. Oxides of nitrogen, particularily NO_2, will require special studies as soon as possible. Also, no time should be lost in defining the potential problem of "acid rains", related to SO_2 and NO_x emissions. Still another problem is that of the effect of the alcohol fuel program on ambient aldehyde and oxidant concentrations.

Finally, to determine the effect of hydrocarbon emission control programs, and of changes in ambient hydrocarbon concentrations with time, speciated hydrocarbon analyses should be made of emissions from stationary and mobile sources as well as of ambient samples throughout the area.

This group of projects should be undertaken now, and will require the services of at least two additional chemists assigned to the Special Projects Laboratory. The two chemists presently in that Section cannot possibly carry out the required projects without additional help. Supporting equipment may be required at some later date.

4. Purchase Two Ultra-Violet Photometer Ozone Recorders (Dasibi, or equivalent)

The Dasibi Ozone Recorder utilizes the principle of ultra-violet light absorption for ozone analysis, a physical method, rather than the chemical methods such as the chemiluminescent or potassium iodide methods.

The State of California has found the Dasibi to be an accurate, rugged instrument, and has tested it in the field and recommended its use as the official State method of ozone analysis. The EPA has designated the Dasibi as an equivalent method for field analysis and a reference calibration method.

A minimum of two such recorders is recommended: one to be maintained in the laboratory as a reference calibration unit; the second to be utilized in the field either to calibrate other ozone recorders or to provide supplemental oxidant data at locations other than the ten sites designated earlier.

REFERENCES

1. "Formação e Ocorrência de Oxidantes Fotoquímicos na Região da Grande São Paulo" PJ 5.3/79 - 1ª e 2ª Fase - 27.04.79 - GEE-AR/DMT/DAID/GQAR/DAV/DST, Superintendência de Tecnologia do Ar, Diretoria de Tecnologia de Saneamento do Ar e de Controle de Fontes de Poluição.

2. "Air Quality Criteria for Ozone and Other Photochemical Oxidants, Volume I" EPA-600/8-78-004. Office of Research and Development, U.S. Environmental Protection Agency. Washington D.C. 20460. Preprint. April 1978.

3. "Avaliação da Influência da Adição de Álcool na Gasolina em Diferentes Teores de Mistura nas Emissões de Aldeídos" GLA/DLTV. PJ 17.6, STAR/79.

4. "Avaliação da Influência da Adição de Álcool na Gasolinaem Diferentes Teores de Mistura nas Emissões de Monóxido de Carbono" CLA/DLTV. PJ 17.4, STAR/79.

5. "Relatório Anual, 1978" DAID/GEE-AR, Superintendência de Tecnologia do Ar, Diretoria de Tecnologia de Saneamento do Ar e de Controle de Fontes de Poluição. (Also 1976, 1977)

6. "Avaliação do Grau de Exposição de Amostras Populacionais de São Paulo (Brasil) ao Monóxido de Carbono" - Nilda A. Gallego Gandara de Fernícola e Ernesto Ronchini Lima. Rev. Saúde Pública, São Paulo 13: 151-8, 1979.

APPENDIX I

PERSONS WHO PROVIDED HELPFUL ASSISTANCE DURING THIS ASSIGNMENT

Organização Pan-Americana de Saúde

.Engº Carlos Hilburg - Assessor de Saneamento Ambiental

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TABLES AND FIGURES

TABLE I

INCIDENCE OF DAYS ON WHICH OZONE CONCENTRATIONS (DAILY MAXIMUM 1-HOUR AVERAGE) EXCEEDED 0,08 ppm

DATE	HOUR	O_3 (ppm) (1-Hr.Max.)	LOCATION
26/04/78	13 - 14	0,100	Tatuapé
26/04/78	14 - 15	0,114	Tatuapé
09/09/76	12 - 13	0,094	Tatuapé
04/09/76	15 - 16	0,082	Tatuapé
03/08/76	12 - 13	0,086	Tatuapé
31/07/76	12 - 13	0,100	Tatuapé
31/07/76	13 - 14	0,100	Tatuapé
15/09/77	14 - 15	0,083	São Caetano do Sul
15/09/77	15 - 16	0,082	São Caetano do Sul
14/09/77	15 - 16	0,157	São Caetano do Sul
13/09/77	12 - 13	0,098	São Caetano do Sul
12/09/77	14 - 15	0,084	São Caetano do Sul
09/09/77	14 - 15	0,087	São Caetano do Sul
09/09/77	15 - 16	0,098	São Caetano do Sul
03/09/77	15 - 16	0,085	São Caetano do Sul
22/08/77	13 - 14	0,092	São Caetano do Sul
22/08/77	14 - 15	0,098	São Caetano do Sul
16/08/77	13 - 14	0,100	São Caetano do Sul
10/06/77	13 - 14	0,095	São Caetano do Sul
14/06/76	9 - 10	0,110	São Caetano do Sul
13/06/76	12 - 13	0,082	São Caetano do Sul
03/06/76	10 - 11	0,098	São Caetano do Sul
03/06/76	11 - 12	0,111	São Caetano do Sul
03/06/76	14 - 15	0,082	São Caetano do Sul
09/10/77	13 - 14	0,090	Correio
30/06/77	4 - 5	0,100	Correio
29/06/77	22 - 23	0,100	Correio
22/05/77	10 - 11	0,090	Correio
22/05/77	11 - 12	0,100	Correio
22/05/77	12 - 13	0,093	Correio
31/07/76	12 - 13	0,086	Correio
31/07/76	13 - 14	0,092	Correio

TABLE II

ESTIMATION OF EMISSIONS FROM AUTOMOTIVE VEHICLES AND STATIONARY SOURCES IN THE GREATER SAO PAULO AREA[a]

Emission Source	Pollutant (Tons/Day)				
	CO	HC	NO_x	SO_x	MP
Automotive Vehicles					
Automobiles	2768	303	115	24	17
Utility and Commercial Vehicles	1339	146	56	11	8
Medium Weight Gasoline Trucks	163	33	6	1,3	0,7
Heavy Weight Gasoline Trucks	576	113	16	5,4	3
Diesel Trucks	137	22	100	52	9
Buses	58	11	58	30	4
TOTAL	5041	629	351	124	42
(Percent of Grand Total)	(95,7)	(75,7)	(83,6)	(18,1)	(7,6)
Stationary Sources					
Industrial Processes and Operations	86	127	-	18	399
Burning of Combustibles in Stationary Sources	19	9	62	541	28
Burning of Residual Solids	120	39	7	1	32
Others[b]	-	27	-	-	51
TOTAL	225	202	69	560	510
(Percent of Grand Total)	(4,3)	(24,3)	(16,4)	(81,9)	(92,4)
GRAND TOTAL	5266	831	420	684	552

a) "O1 Controle de Emissão de Fontes Móveis no Estado de São Paulo" Governo do Estado de São Paulo, Secretaria de Obras e do Meio Ambiente, Companhia de Tecnologia de Saneamento Ambiental. 10º Congresso Brasileiro de Engenharia Sanitária e Ambiental Manaus - 21 a 26 de janeiro de 1.979.

b) Other sources include commercial production and use of volatile materials, and sources of fugitive dust.

TABLE III

EMISSION OF PARTICULATE MATTER AND SULFUR DIOXIDE IN THE GREATER SÃO PAULO AREA FROM INDUSTRIAL OPERATIONS AND PROCESSING AND THE BURNING OF COMBUSTIBLE MATERIALS[a]

		GROUP			TOTAL
		A	B	C	
PARTICULATE MATTER	No. of Industries	69	193	1,813	2,075
	Percent	3,32	9,30	87,38	100
	Emissions (Tons/ Day)	384,44	31,80	10,56	426,80
	Percent	90,07	7,45	2,48	100
SULFUR DIOXIDE	No. of Industries	208	400	833	1441
	Percent	14,43	27,76	58,81	100
	Emissions (Tons/ Day)	443,01	81,42	25,75	550,18
	Percent	80,52	14,80	4,68	100

a) "Formação e Ocorrência de Oxidantes Fotoquímicos na Região da Grande São Paulo. PJ 5.3/79 - 1º e 2º Fase" 27/04/79. GEE-AR/DAID/DMT; GQAR/DAV/DST.

TABLE IV

NUMERO DE VEZES QUE A CONCENTRACAO ULTRAPASSOU PQAR E ATINGIU NIVEIS CRITICOS

MATERIAL PARTICULADO

ANO/QUADR.		PADRAO 24HS	NIVEIS		
			ATENCAO	ALERTA	EMERGENCIA
78					
	1	3	0	0	0
	2	110	6	0	0
	3	8	0	0	0
	ANUAL	121	6	0	0
77					
	1	7	0	0	0
	2	91	9	0	0
	3	7	0	0	0
	ANUAL	105	9	0	0
76					
	1	5	0	0	0
	2	171	37	2	0
	3	13	1	0	0
	ANUAL	189	38	2	0

OBSERVACOES -

	PQAR *	NIVEIS *		
		ATENCAO	ALERTA	EMERGENCIA
SO2 - MICROGR/M3,MEDIA DE 24HS	365	800	1600	2100
MP - MICROGR/M3,MEDIA DE 24HS	240	375	625	875
PRODUTO-(SO2.MP) - MICROGR/M3	----	65000	261000	393000

* DECRETO ESTADUAL NUMERO 8468 DE 08/09/1976

TABLE V

NÚMERO DE VEZES QUE A CONCENTRAÇÃO ULTRAPASSOU PQAR E ATINGIU NÍVEIS CRÍTICOS

MONÓXIDO DE CARBONO

ANO/QUADRIMESTRE		PADRÃO 1 h	PADRÃO 8 hs	NÍVEL		
				Atenção	Alerta	Emergência
78	1	1	84	20	0	0
	2	1	107	60	0	0
	3	3	108	41	0	0
	ANUAL	5	299	121	0	0
77	1	0	90	48	0	0
	2	1	112	64	0	0
	3	0	88	20	0	0
	ANUAL	1	290	132	0	0

OBSERVAÇÕES:

LOCAL: PRAÇA DO CORREIO

PQAR/CO/1H - 35 ppm

PQAR/CO/8H - 9 ppm

	NÍVEIS		
	Atenção	Alerta	Emergência
CO - 8 HS	15	30	40

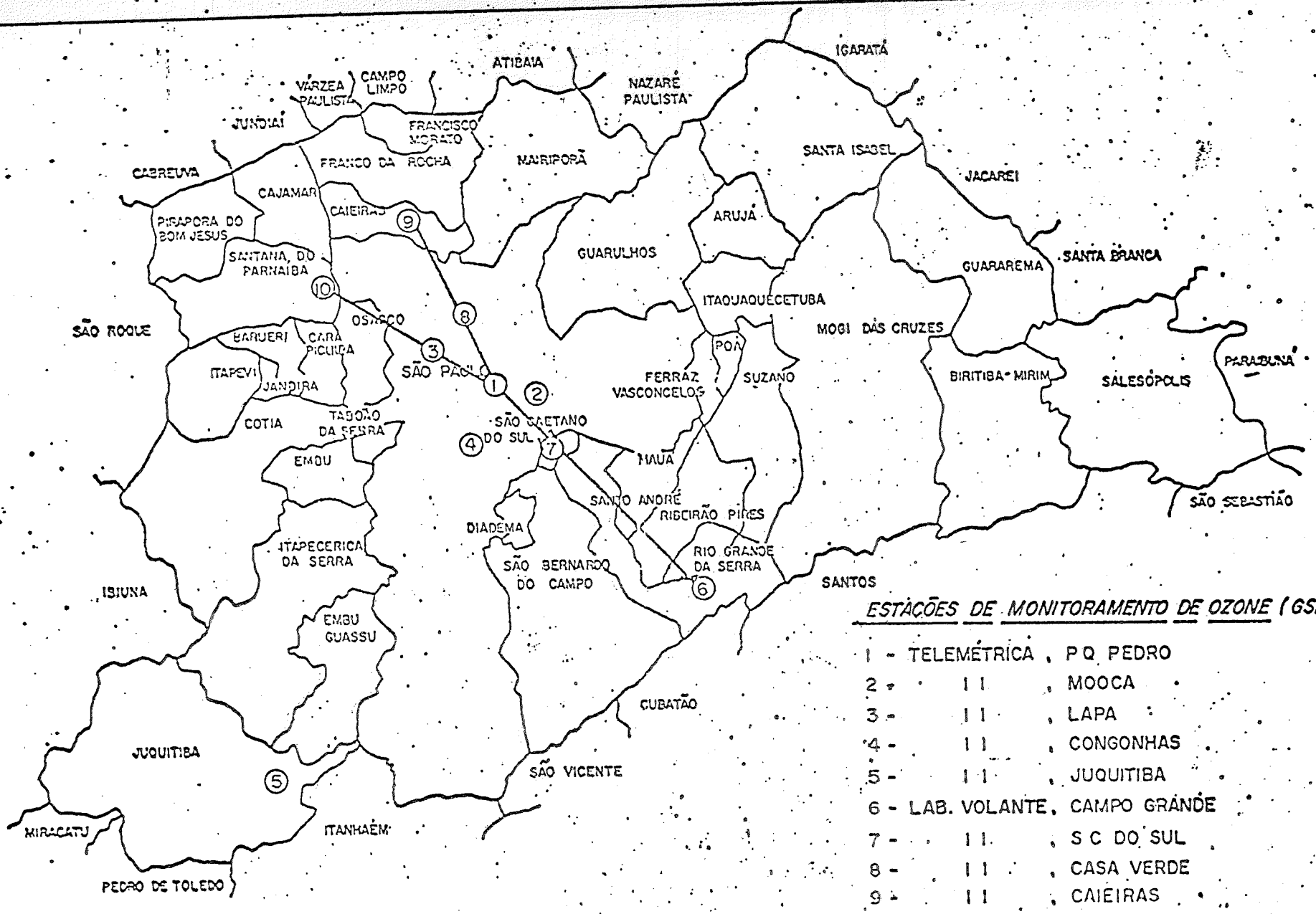
ESTAÇÕES DE MONITORAMENTO DE OZONE (GSP)
1 - TELEMÉTRICA , P Q PEDRO
2 - " , MOOCA
3 - " , LAPA
4 - " , CONGONHAS
5 - " , JUQUITIBA
6 - LAB. VOLANTE, CAMPO GRANDE
7 - " , S C DO SUL
8 - " , CASA VERDE
9 - " , CAIEIRAS
10 - " , SANTANA DO PARNAIBA
ATIBAIA
NAZARÉ PAULISTA
IGARATÁ
VARZEA PAULISTA
CAMPO LIMPO
JUNDIAÍ
FRANCISCO MORATO
FRANCO DA ROCHA
MAIRIPORÃ
CABREUVA
SANTA ISABEL
JACAREI
CAJAMAR
CAIEIRAS
ARUJÁ
PIRAPORA DO BOM JESUS
SANTANA DO PARNAÍBA
GUARULHOS
GUARAREMA
SANTA BRANCA
ITAQUAQUECETUBA
SÃO ROQUE
OSASCO
BARUERI
CARAPICUÍBA
MOGI DAS CRUZES
POÁ
ITAPEVI
JANDIRA
SÃO PAULO
FERRAZ VASCONCELOS
SUZANO
BIRITIBA-MIRIM
SALESÓPOLIS
PARAIBUNA
COTIA
TABOÃO DA SERRA
SÃO CAETANO DO SUL
EMBU
MAUÁ
SANTO ANDRÉ
RIBEIRÃO PIRES
SÃO SEBASTIÃO
DIADEMA
ITAPECERICA DA SERRA
SÃO BERNARDO DO CAMPO
RIO GRANDE DA SERRA
ISIUNA
SANTOS
EMBU GUASSU
CUBATÃO
JUQUITIBA
SÃO VICENTE
MIRACATU
ITANHAÉM
PEDRO DE TOLEDO
CETESB

FIGURE 1