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EVALUATION OF AIR QUALITY IN A REGION OF COAL PROCESSING AND SIDERURGIC ACTIVITIES IN THE STATE OF RIO GRANDE DO SUL, BRAZIL

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ABSTRACT

The present work involved the determination of total suspended particles, SO_2 e NO_2 in the municipalities of Charqueadas and São Jerônimo, Rio Grande do Sul, Brasil. The area is marked by the presence of coal-fired power stations and siderurgic activities. The gases SO_2 and NO_2 do not affect air quality, but the results revealed contamination of air in Charqueadas due to total suspended particles. The presence of Fe, Mn, Cu, Cr and Ni, is probably due to the steel industry. On the other hand, Pb and part of Cu and Ni can be attributed to the coal- fired power station.

RESUMO

O presente trabalho envolveu a detreminação de particulas totais em suspensão, SO_2 e NO_2 nos municípios Charqueadas e São Jerônimo, Rio Grande do Sul, Brasil. Na área está inserida duas termolétricas e uma siderúrgica. Os gases SO_2 e NO_2 não afetam a qualidade do ar, mas os resultados revelaram contaminação do ar em Charqueadas devido a partículas totais em suspensão. A presença de Fe,Mn, Cu, Cr e Ni são, provavelmente, originários da indústria siderurgia. Por outro lado, podem ser atribuído a presença de Pb e, também em parte de Cu e Ni pode ser atribuído a termoelétrica.

KEYWORDS: Air Quality, Sulfur Dioxide, Nitrogen Dioxide, Suspended Particles, Heavy Metals.

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INTRODUCTION

The purpose of the present work is to contribute to the understanding of air quality in the State of Rio Grande do Sul, Brazil, evaluating the environmental impact caused by coal processing and steel production activities and determine the parameters that are indicatives of air pollution: SO_2, NO_2, total suspended particles and associated metals. The region, chosen for this study was the Baixo Jacuí(Lower Jacuí River) including the municipalities of Charqueadas and São Jerônimo.

The use of fossil fuels for energy generation, including coal, is a major source of emission of particulate pollutants, SO_2 and NO_2. The concentration these pollutants depend on the characteristics of the coal (ash and sulfur contents) and on the combustion process employed.

Problems related to the emission of pollutants are not always solved by a modification of the combustion process or by the use of controlling devices used to attend standards required by specific legislation of each country.

This legislation varies significantly from country to country and tends to be more restrictive as far as air quality standards are concerned. Atmospheric pollutants are a major challenge for Brazilian and world wide agencies of environmental protection since they still surpass legal limit values of air quality standards and the satisfactory reduction of their concentration in metropolitan areas has still to be achieved.

In Southern Brazil, particulate matter and SO_2 are the object of particular concern, since their emission levels are usually high, when compared to standards of other countries. This is mainly due to the lack of controlling devices for SO_2 and the low efficiency of the systems used for fine particles, which are generally metal enriched and pose a great risk to human heath.[1-5]

The large scale use of coal in electric energy generation has caused serious alterations in the atmospheric environmental quality in various areas of the state of Rio Grande do Sul, Brazil. One of them is the Baixo Jacuí River Basin, marked by the presence of coal-fired power stations, siderurgic industries and deposit of coal and ash wastes. The implantation of a new coal-fired power station (Jacuí I) will increase even more the coal combustion and in all probability will also aggravate the atmospheric contamination.

EXPERIMENTAL

Air samples were collected during the period of May 1994 to November 1995 on every sixth day using a procedure proposed by the United States Environmental Protection Agency (USEPA)[6]. Sulfur dioxide, nitrogen dioxide were collected using high volume gas (Tri-Gas) and total suspend particles (Hi-Vol) samplers. Samplings were done at three different sites: two in the municipality Charqueadas and one in the municipality São Jerônimo (see Figure 1). The selection of these sites followed various criteria and included the distance from the sources of pollution, the proximity to the center of the two towns and the preferential direction of the winds.

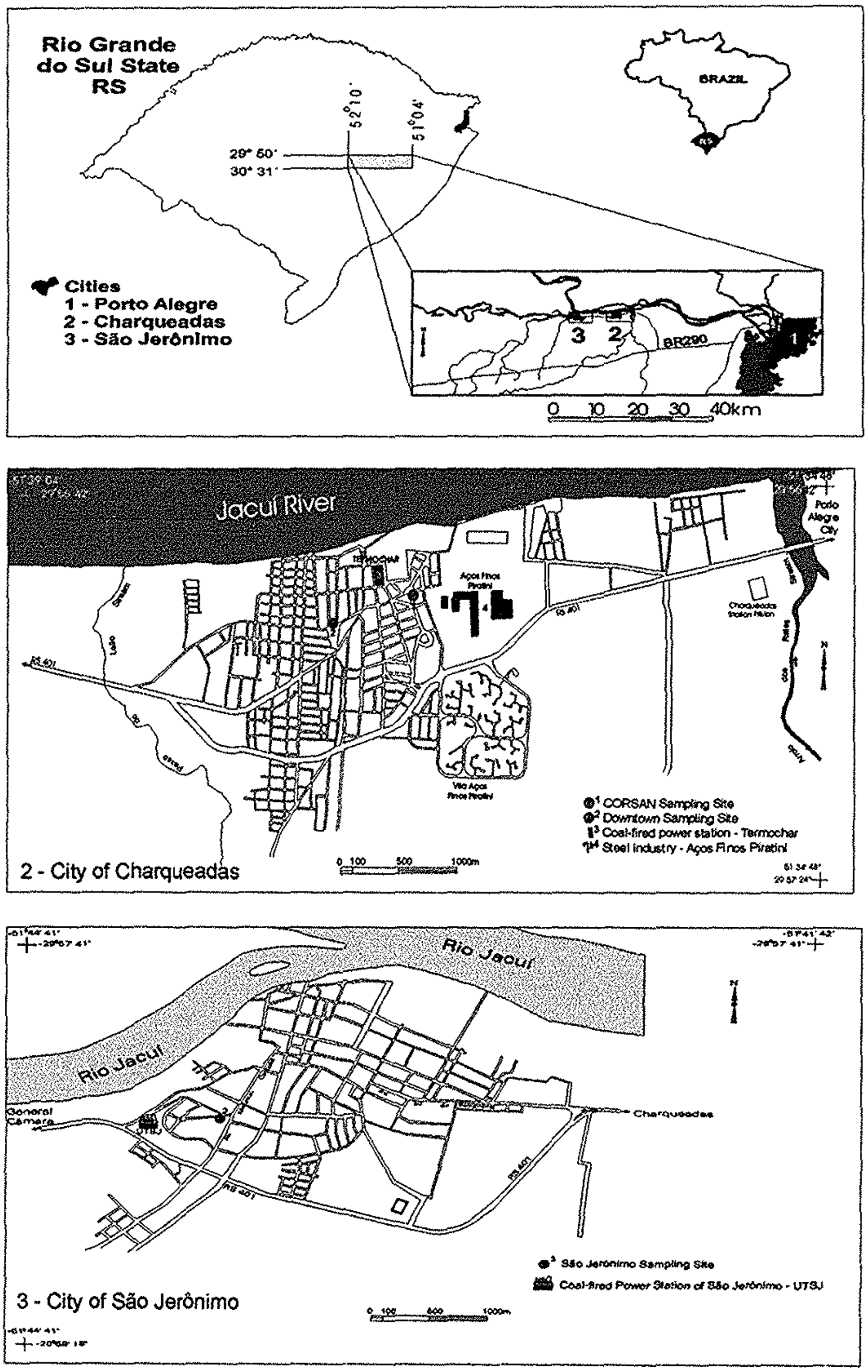

Figure 1. Location of Air Sampling Sites - Charqueadas and São Jerônimo Municipalities, State of Rio Grande do Sul, Brazil.

Sulfur and nitrogen dioxide were determined, respectively, by the pararosaniline method[6] and by a colorimetric method based on sodium arsenite, recommended by the United States Environmental Protection Agency[7]. The concentration of total suspended particles was determined according to a procedure given by the same agency[8].The study of the metals associated to particulate matter, collected with July 1994, started with the preparation of samples that consisted of dividing the filter in to four equal parts and analyzing only one of them. The extraction of the metals was done according to a procedure described by Sanchez and collaborators[9] and consisted of extracting the metals from the filter paper, adding 20 ml of concentrated HNO_3 and 20 ml of 30% H_2O_2 into a flask provided with a reflux condenser and heating in a steam bath. Subsequently, aliquots of 30 ml of concentrated HCl and 10 ml of concentrated HNO_3 were added in diferent steps until the complete elimination of organic matter. The determination of metals (Fe, Mn, Cu, Pb, Cr, Ni, Co e Cd) present in the extracts was performed by atomic absorption spectrometry.

RESULTS AND DISCUSSION

Gases: SO_2 and NO_2. Sulfur dioxide concentrations measured over a period from May 1994 to November 1995 are shown in Figure 2. These results are compared to air quality standards established by Brazilian Legislation[10]. As an be seen, the SO_2 concentrations at the three sites were generally low and surpassed the secondary standards value(100 $\mu g\ m^{-3}$) only at the CORSAN (Water Company Treatment Plant), sampling site in Charqueadas, localized close to anthropogenic sources - the steel plant and coal-fired power station. The anomaly was verified only on three specific dates (September 30, 1994; October 24,1994 and April 1, 1995) when maximum values reached 118 $\mu g\ m^{-3}$, 212.2 $\mu g\ m^{-3}$e 174.2 $\mu g\ m^{-3}$, respectively. The experimental annual mean value for SO_2 concentration was inferior to the primary annual standard (80 $\mu g\ m^{-3}$) for all sampling sites.

On the other hand, the mean measurement to at the CORSAN sampling site in Charqueadas (64.4 $\mu g\ m^{-3}$) surpassed the annual mean secondary standards(40$\mu g\ m^{-3}$), indicating a slight alteration of air quality, which is likely to worsen with the installation of the new coal-fired power station (Jacuí I) at a nearly location. Data of the present study are in good agreement with those obtained by the JICA/ELETROSUL/CEEE (Japan International Cooperation Agency/ Centrais Elétricas do Sul do Brasil/ Companhia Estadual de Energia Elétrica - RS)[11] monitoring that reveals that the air quality in the Charqueadas Municipal has not altered by SO_2.

Figure 3 illustrates the concentrations determined for NO_2 during the period of May 21,1994 to November 11,1995 at the three sampling stations. The results are compared to the German Standards[12], since Brazilian Legislation[10] does not establish concentration limits for NO_2 for a 24 hour sampling period. In general, the concentrations obtained for NO_2 were low, fluctuated during the period under considerations and the annual average was inferior to the German Standard (100μgm^{-3})[12]. These results agree with those obtained by the

JICA/ELETROSUL/CEEE[11] monitoring study performed in Charqueadas and suggest that there is no alteration of the air quality due to NO_2 from local sources.

Total Suspended Particles. Figure 4 illustrates the results obtained for the concentration of total suspended particles for same period described above and for the three sampling locations. These results are compared to air quality standards specified by Brazilian Legislation[10]. Results obtained for the CORSAN sampling station in Charqueadas contained values that surpassed nine times the primary standard (240 $\mu g\ m^{-3}$) set by Brazilian Legislation and twenty four times the secondary standard *(150 $\mu g\ m^{-3}$) during the period under consideration. For the Downtown sampling site in* Charqueadas, elevated values of total suspended particles were also obtained although they are less significant than those of the CORSAN location. At the Downtown sampling site, the concentration of particulates surpassed the primary standard only one occasion (September,24 1994) and the secondary standard on the different opportunities.

Mean geometrical annual averages for the CORSAN and Downtown stations in Charqueadas were superior to both annual primary and secondary standards, 80 $\mu g\ m^{-3}$ and 60 $\mu g\ m^{-3}$, respectively. These results show the air quality contamination by total suspended particles, suggesting a strong contribution of emission of local sources such as the coal-fired power stations (TERMOCHAR) and particularly the steel plant (Aços Finos Piratini). This siderurgic has no control for emission[13] and the atmospheric pollution can be verified visually by the reddish color of the smoke, the city of São Jerônimo dues not yet present serious problems of atmospheric contamination by particulate material. However, on certain dates (April 24, 1995 and May 28,1995) we measured concentration of particulate above the secondary standards (150 $\mu g\ m^{-3}$)[10]. This was probably due to anthropogenic factor located in Charqueadas (coal-fired power station and steel industry) and the direction of the winds on those days.

Metals associated with suspended particles. Table 1 summarizes geometrical means, maximum and minimum values for metals associated with total suspended particles at the three sites studied for the periods of June 21,1994 to November 17,1995. Of all the metals studied, Fe presented the highest concentration at all sites, the most elevated values being those detected at the Charqueadas CORSAN station. The emission of iron oxide associated with particulate material could be visually detected by the reddish color in the smoke of the steel industry.

The concentration of the other elements studied was also more elevated at the CORSAN station, except for Cr and Ni that presented higher values at the Downtown Charqueadas sampling site on certain days. This difference can be explained by horizontal movement of air masses containing these elements in association with finer suspended particles, that remain in suspension in air for move prolonged periods of time.

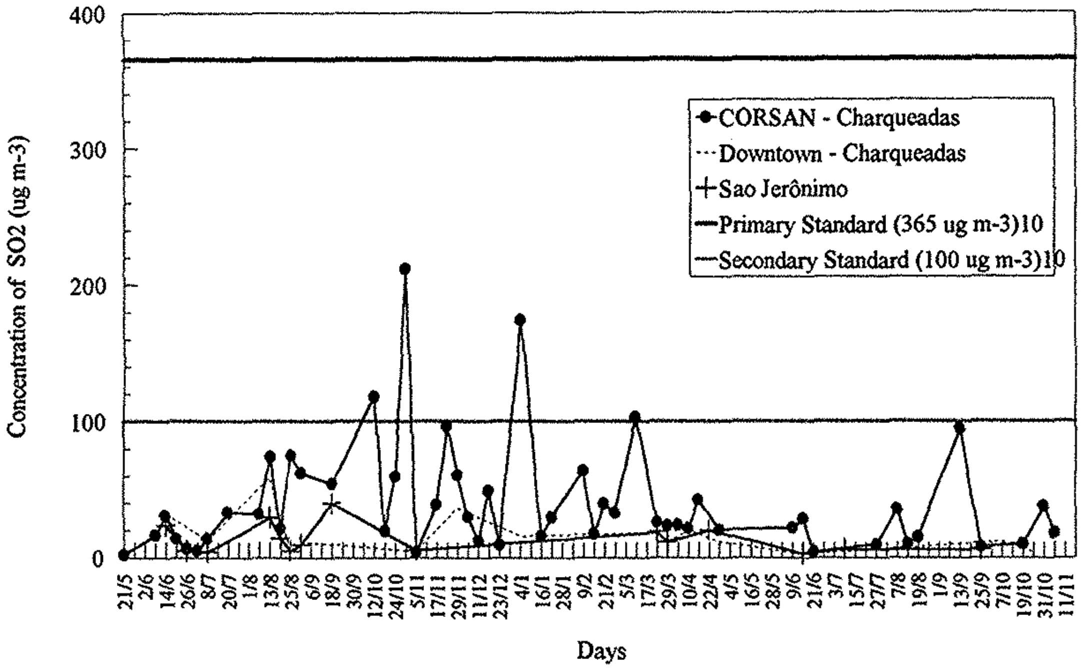

Figure 2. Concentrations of SO_2 ($\mu g\ m^{-3}$) determined during the period of May 1994 to November 1995 for the three sites studied in of Charqueadas and São Jerônimo.

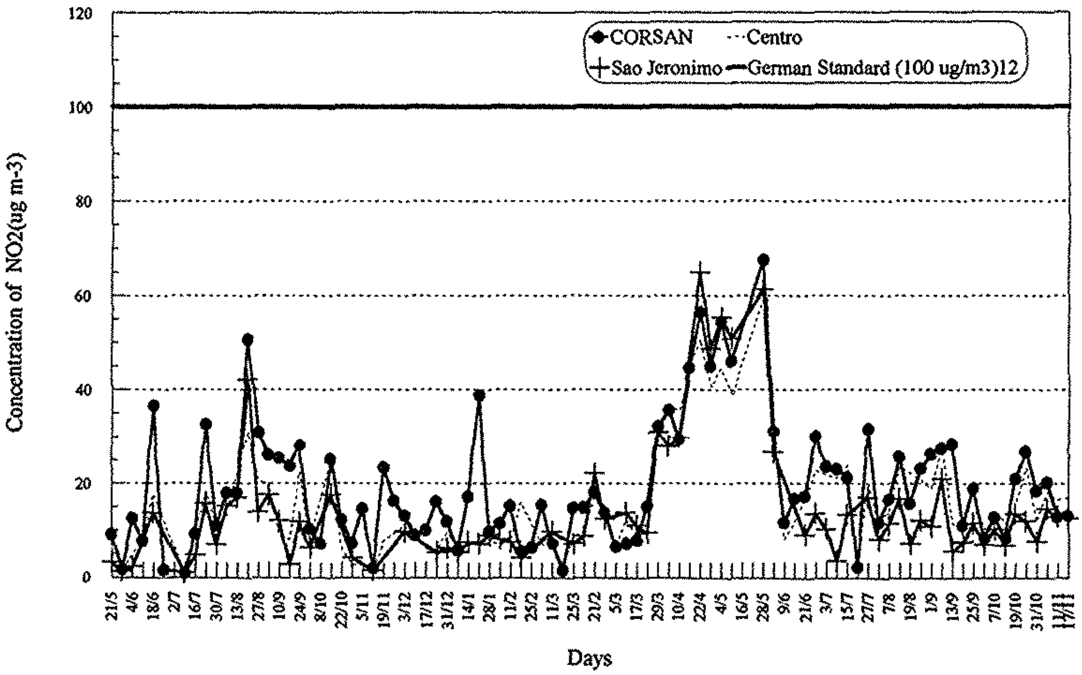

Figure 3. Concentration of NO_2 ($\mu g\ m^{-3}$) determined during the period of May 1994 to November 1995 for the three sampling stations in of Charqueadas and São Jerônimo.

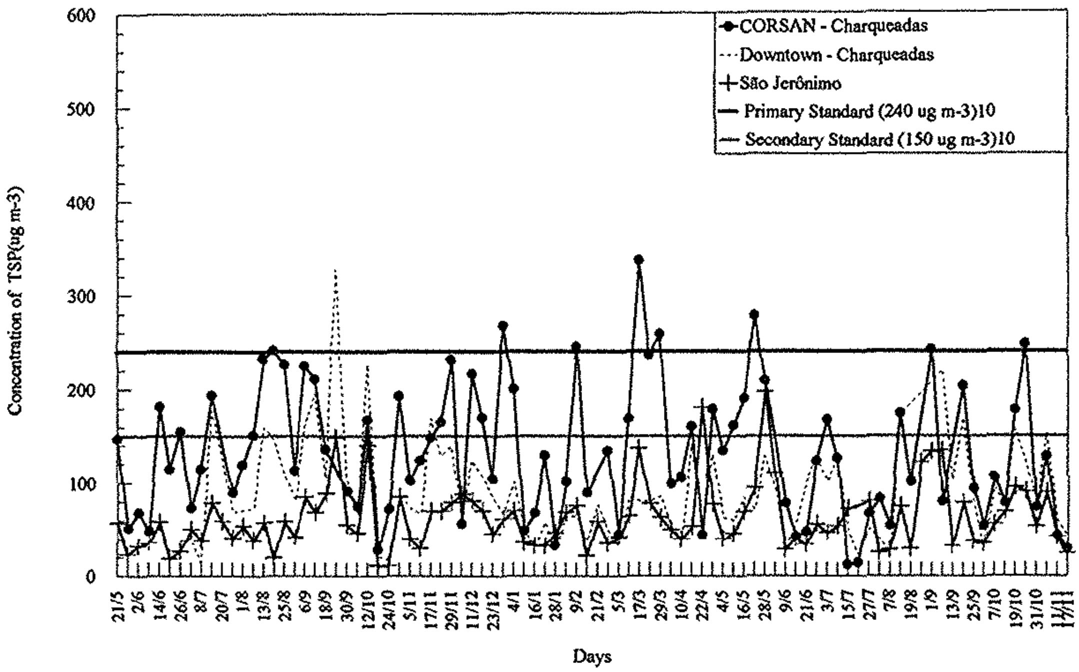

Figure 4. Concentration of total suspended particles –TSP (µg m^{-3}) determined during the period of May 1994 to November 1995 for the three sampling stations in of Charqueadas and São Jerônimo.

Table 1 also shows a comparison of our experimental results and those of another urban center, Rio de Janeiro, Brazil. As can be seen, Fe and Mn are present in higher concentrations in Charqueadas and São Jerônimo, indicating atmospheric contamination due to the siderurgic industry. On the other hand, the concentrations of Pb were lower, also when compared to standards recommended by several countries (0,3-2,0 µg m^{-3})[12].

Table 1. Environmental concentrations of metals associated with total suspended particles in Charqueadas and São Jerônimo Municipalities compared to Rio de Janeiro.

	Charqueadas						São Jerônimo			Rio de Janeiro
	CORSAN(µg m^{-3})			Downtown(µg m^{-3})			São Jerônimo(µg m^{-3})			Average concentration in urban center * (ng/ m^3)
	Mean	Max	Min.	Mean	Max.	Min	Mean	Max	Min.	Mean *
Fe	15,0	64,4	1,51	6,05	33,3	0,78	2,0	6,26	0,30	1231/2467 **
Mn	0,32	1,4	0,025	0,16	0,80	0,015	0,036	0,22	0,002	92
Cu	0,18	0,44	0,065	0,104	0,27	0,048	0,098	0,18	0,48	155
Pb	0,14	1,2	0,019	0,095	0,87	0,0016	0,052	0,119	0,004	715
Cr	0,14	1,02	0,015	0,063	1,14	0,005	0,022	0,086	0,002	60
Ni	0,08	0,85	0,003	0,027	1,36	0,0015	0,018	0,134	0,003	52
Co	0,0084	0,04	0,0009	0,007	0,13	0,0008	0,006	0,043	0,0010	39
Cd	0,0065	0,15	0,0011	0,005	0,013	0,0009	0,004	0,008	0,0007	5,2
PTS	162	499	29,4	98,97	328	32,24	61,01	197,0	19,2	--

Sources : * Mean environmental concentration in urban locations [14]

** Mean environmental concentration in an urban center, Rio de Janeiro, Brazil [15]

This was to be expected, since lead has not been used as a gasoline additive (as tetraethyl lead) since 1988, and was the principal source of pollution in urban atmosphere.

Table 2 presents Pearson's correlation coefficient for the concentrations of metals, total suspended particles and weather conditions for the three station. Most elements studied showed a higher correlation coefficient for the two station in the town of Charqueadas. For Fe/Mn and Mn/Cr correlation coefficients were also high for the sampling station in São Jerônimo.

Table 2. Pearson's correlation coefficient for the concentration of metals, total suspended particles and weather data for the three stations.

	Fe	Mn	Cu	Pb	Cr	Ni	Co	Cd	PTS
CORSAN - Charqueadas									
Fe	1,000	0,7372***	0,7583***	0,7349***	0,7356***	0,4449*	-0,2820	-0,1284	0,1737
Mn		1,000	0,6851***	0,7628***	0,7397***	0,5919**	-0,1193	-0,0762	0,0975
Cu			1,000	0,6519**	0,7149***	0,4359*	-0,3118	-0,0504	0,0239
Pb				1,000	0,8507***	0,4918*	-0,1534	-0,0939	0,0487
Cr					1,000	0,7574***	-0,1021	-0,0580	0,1609
Ni						1,000	0,1642	-0,0215	0,0551
Co							1,000	-0,1108	0,1019
Cd								1,000	-0,1748
PTS									1,000
Downtown - Charqueadas									
Fe	1,000	0,7470***	0,7086***	0,8158***	0,5416*	0,2938*	-0,1134	0,5014*	0,4866*
Mn		1,000	0,5762**	0,6961***	0,6571**	0,4773*	-0,1462	0,2863	0,3744
Cu			1,000	0,5169*	0,7776***	0,5942**	-0,1796	0,5200*	0,4304*
Pb				1,000	0,4133*	0,1059	-0,1007	0,5876**	0,2112
Cr					1,000	**0,9094***	-0,0213	0,5280*	0,3221*
Ni						1,000	-0,0712	0,3251	0,2613
Co							1,000	-0,1458	-0,1281
Cd								1,000	0,0775
PTS									1,000
São Jerônimo									
Fe	1,000	**0,6828*****	0,2959*	0,2490	0,4998*	0,2228	-0,1796	-0,0297	0,2911*
Mn		1,000	0,5274*	0,3201*	**0,8571*****	-0,0270	-0,2496	0,2367	0,2164
Cu			1,000	0,2948	0,5341*	-0,1942	-0,2904	0,1668	-0,0989
Pb				1,000	0,3281*	0,0698	-0,059	0,2719	-0,0994
Cr					1,000	0,0420	-0,2980	0,1776	0,1523
Ni						1,000	-0,1768	-0,3038	-0,0589
Co							1,000	**0,7349*****	-0,2118
Cd								1,000	0,2350
PTS									1,000

** Significance factor at 0,1 % ** Significance factor at 1 % * Significance factor at 5 %

These results, associated with the preferential wind direction (E-SE) suggest that the steel plant is responsible for the emission of these elements. Its already mentioned, this plant dues not have any control system for particulate matter[13].On the other hand, Pb is, probably due to the coal-fired power station located nearby. This power station is also partially responsible for emissions of Cu and Ni. These elements together with Pb are concentrated at the surface of finer ash particles and are hard to retain by the electrostatic precipitator.

The differences determined for metals from one sampling site to another may be attributed to their association to different types of particles (probably finer ones) that reach more distant sites from the emitting sources.

Figures 5 to 13 illustrate the annual geometric means for metals for the period from May 1994 to November 1995. A difference in the spacial distribution of Fe, Mn, Cr and Ni, whose concentrations were higher at the Corsan station was verified. The other elements did not show any significant difference, presenting practically the same behavior at the three sites studied.

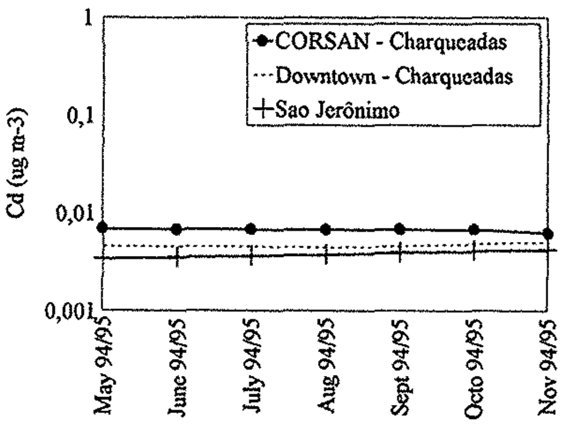

Figure 5. Annual geometric mean for Cd ($\mu g\ m^{-3}$)

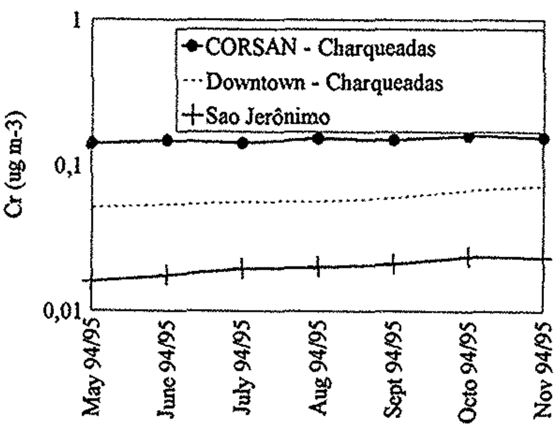

Figure 6. Annual geometric mean for Cr ($\mu g\ m^{-3}$)

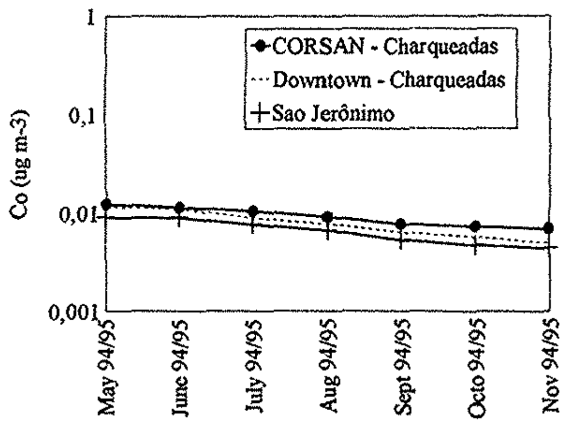

Figure 7. Annual geometric mean for Co ($\mu g\ m^{-3}$)

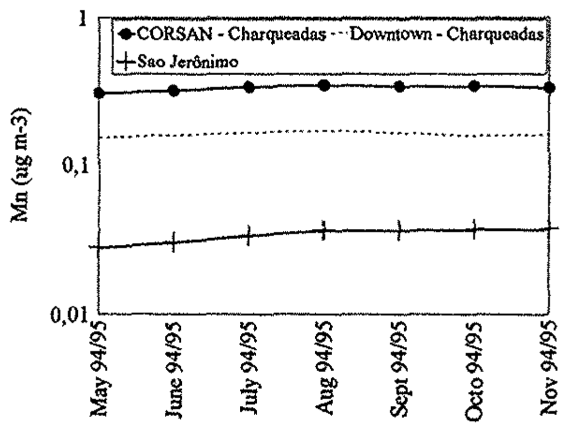

Figure 8. Annual geometric mean for Mn ($\mu g\ m^{-3}$)

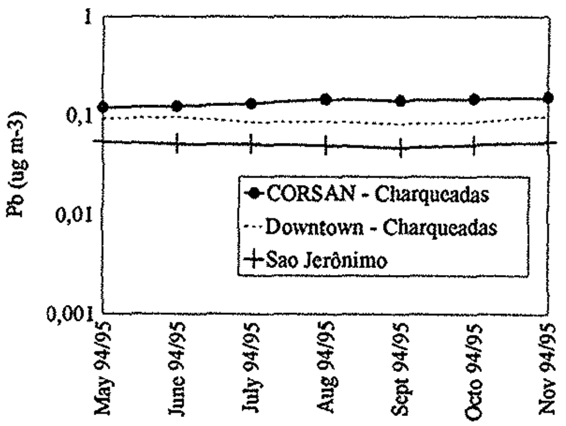

Figure 9. Annual geometric mean for Pb ($\mu g\ m^{-3}$)

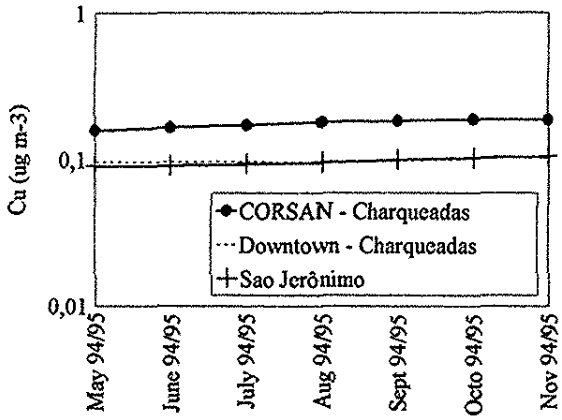

Figure 10. Annual geometric mean for Cu ($\mu g\ m^{-3}$)

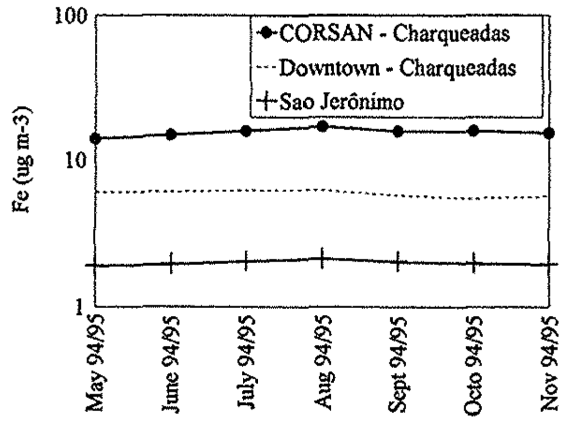

Figure 11. Annual geometric mean for Fe ($\mu g\ m^{-3}$)

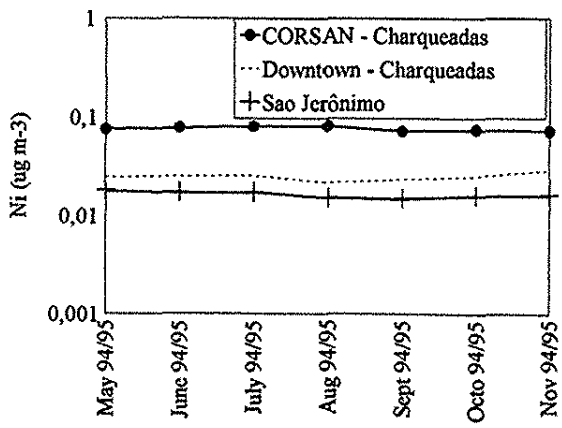

Figure 12. Annual geometric mean for Ni ($\mu g\ m^{-3}$)

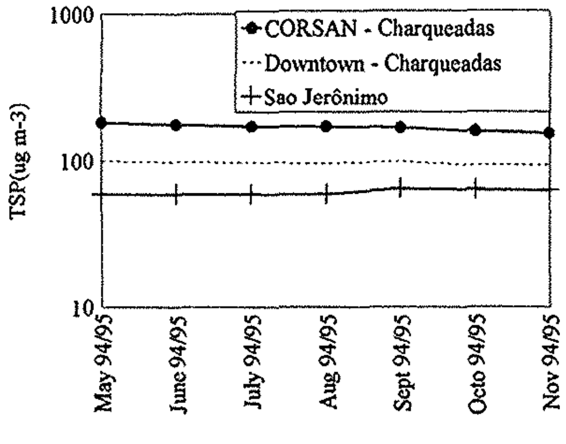

Figure 13. Annual geometric mean for TSP($\mu g\ m^{-3}$)

CONCLUSIONS

The experimental results obtained for the period of May 1994 to November 1995 for the three stations studied (Corsan and Downtown Charqueadas and São Jerônimo) showed that according to Brazilian and German standards, the air quality is not affected by SO_2 and NO_2. On the other hand, the municipality of Charqueadas showed contamination by total suspended particles, both primary (240 $\mu g\ m^{-3}$) and secondary (150 $\mu g\ m^{-3}$) Brazilian standards being surpassed by several orders. Metals associated to total suspended particles indicated elevated environmental concentrations of Fe due to local anthropogenic sources. Fe along with Mn, Cu, Cr and Ni are probably originate from of the local siderurgic industry that does not use any controlling systems for particulates. The presence of Pb and part of Cu and Ni can be attributed to the coal-fired power station, located near the siderurgic industry. Apparently, the efficiency of the particle retaining systems employed decreases for finer particle size (< 10 µm). The best correlation for the elements was obtained for the CORSAN station for Mn/Fe, Cu/Fe, Pb/Mn, Cr/Ni, Cr/Cu, Cr/Mn and Cr/Fe. For the Downtown Charqueadas sampling site the best correlation was obtained for Cr/Ni, Cr/Cu and Pb/Fe. These results suggest, that there exist associations of these elements to particles of different types and sizes, for the case of total suspended matter.

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