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An Atmospheric Dispersion Model for the Environmental Impact Assessment of Thermal Power Plant in Valley Region.

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ABSTRACT

This paper addresses the implementation of a co-generation thermal power plant, the Central de Cogeração da Baixada Santista (CCBS), designed to generate 950 MW of power and 400 t/h of steam from either natural gas or refinery gas. The plant will be installed in the municipality of Cubatão, São Paulo, Brazil, in the south area of PETROBRÁS Presidente Bernardes Refinery (RPBC), which is located 70 km from São Paulo and 15 km from Santos Port. All steam produced by the plant will be delivered to RPBC plant. The refinery presently consumes a significant amount of power supplied by the Interconnected System, as well as a large amount of steam generated by oil-fired boilers that have been operating for approximately 40 years. The implementation of the CCBS plant will result in the deactivation of those boilers. The new power plant will deliver the entire production of steam, 400 t/h, and 40 MW of power to RPBC. The surplus power, approximately 900 MW, will be delivered to the regional electric system, which is located at one of the ends of the national interconnected grid. The most important environmental impacts associated with the plants operation should be related to air emissions, although federal and state environmental standards on this matter are anticipated to be met. The region where CCBS will be installed has already an industrial complex located on the entrenched valleys of Mogi and Cubatão rivers, next to Serra do Mar ridge, whose complex topography hampers the dispersion of pollutants. An atmospheric dispersion study was performed, based on ISCST3 modeling and aimed at assessing future concentrations of pollutants to be emitted by CCBS, namely PM, NO_x, SO_2, CO and NMHC. The study comprehended the area of influence defined by critical meteorological conditions and comprised two different scenarios: existing emissions from five stacks of operating boilers at RPBC; and future emissions from four stacks of the combined cycle (four gas turbines, four recovery boilers and two steam turbines), after the substitution of RPBC sources by CCBS ones. The simulation outputs revealed that the implementation of CCBS will result in a decrease in the concentration of the targeted pollutants, as well as a large reduction in the consumption of fuel oil, which will be used no longer. Therefore, although the capacity of the CCBS will be higher than the existing plant, the results indicated a noticeable improvement in the air quality in the area of influence. These results are supported by the substitution of fuel oil by natural gas, by the application of a high-efficiency, co-generation combined cycle and by the utilization of next-generation combustion techniques and higher exhaust velocities. These aspects will result in lower specific consumption of fuel and lower pollutant emissions.

INTRODUCTION

This study is a part of the environmental permitting process addressed to the installation of the Central de Cogeração da Baixada Santista - CCBS, a thermal power plant to be located in the site of Presidente Bernardes Refinery (RPBC), in the municipality of Cubatão, São Paulo, Brazil. The power generation process will be integrated to the refinery process in order to allow the compatibility of current industrial uses, including water supply, industrial effluent treatment and construction site. The proposed project will optimize the current water consumption of the Refinery, whose water intake will drop from 11,500 m^3/h to approximately 7,800 m^3/h. The unit will generate 950 MW (± 5%, depending upon the gas turbine manufacturer), firing natural gas and delivering both power and steam to RPBC and surplus power to third parties. The steam supplied to RPBC will replace the steam presently generated by six oil-fired boilers that will be permanently deactivated right after the commercial start-up of CCBS. The utilization of natural gas as the thermal power plant fuel will bring environmental benefits, namely in terms of air quality, by drastically decreasing the emission of particulate matter and SO_2. Likewise, next-generation combustion techniques will reduce the specific emission of NOx. The start-up of CCBS will allow the optimization of the material/energy balance of the gas fuel system of RPBC, so all gas excess that is presently flared will be routed to the recovery boilers (HRSG) of the new thermal power plant. This study aims at assessing the concentrations of pollutants emitted by both the refinery and the proposed plant in the influence area of the project, by using the model ISCST3 and based on critical meteorological conditions, considering two different target scenarios: the current emissions of five stacks of the operating boiler system of RPBC and the future emissions of four stacks of the combined cycle (two gas turbines, four recovery boilers and two steam turbines), after replacing the refinery sources by CCBS ones. Although the dispersion study of the corresponding environmental impact assessment study comprised the emissions of PM, NO_x, SO_2, CO and Non-methane Hydrocarbons (NMHC), this paper will address only emissions and concentrations of NO_X, whether due to length restrictions of this work or considering the extremely low concentrations calculated for the remaining pollutants[1].

Background

The Central de Cogeração da Baixada Santista (CCBS) will be held by a consortium composed of the following companies: Marubeni Corporation, Sithe do Brasil Ltda. and Petróleo Brasileiro S.A. – Refinaria Presidente Bernardes (RPBC). Sithe do Brasil Ltda. is a subsidiary of Sithe Energies, Inc. Both Marubeni Corporation are Sithe Energies, Inc. have a wide experience in developing projects as Independent Energy Producers worldwide. PETROBRAS has a wide experience in producing, transporting and commercializing oil products and natural gas. Sithe Energies, Inc. was founded in 1984, when the independent generation market was opened in the US. Marubeni Corporation, founded in 1858, is a global company with approximately 9,000 employees and assets over US$ 55 billion. The company is seated in Japan and possesses over 700 affiliated companies in 83 countries worldwide. RPBC is a high-complexity refining company that also operates oil and gas pipelines, port facilities, storage parks and natural gas production facilities. The refinery plays an important role in the project since the co-generation unit will be installed within its site. The CCBS project will be linked to RPBC, delivering steam and power and receiving raw, clarified and demineralized water from de refinery. The project is essential to PETROBRAS in order to ensure the operational continuity of RPBC while comprising another step in the environmental impact reduction policy of Cubatão industrial park.

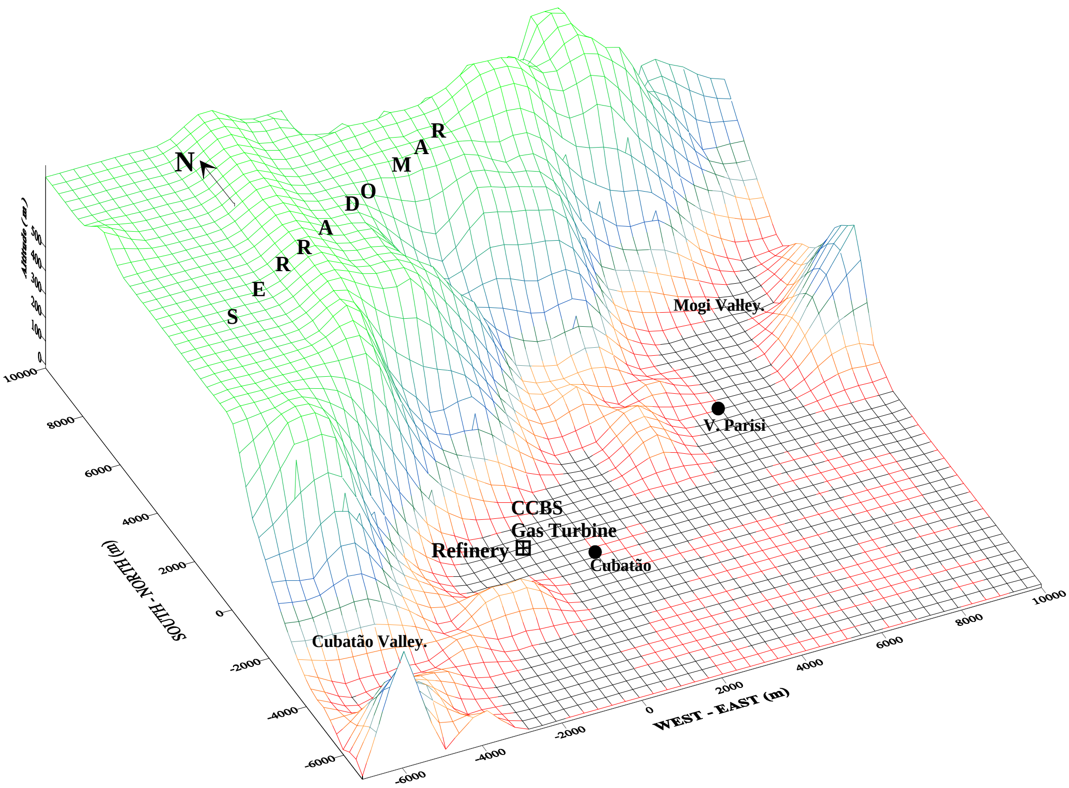
Characterization of the project area

The CCBS facilities will be installed in a 7.2 ha area located in the south portion of Presidente Bernardes Refinery (RPBC), in the municipality of Cubatão. The site is located approximately 70 km from São Paulo and 15 km from the Port of Santos, at Piaçaguera – Guarujá road (SP-55) and Imigrantes Highway (SP-160). The municipality occupies an area of 148km^2, with a total population of 108,309 inhabitants. The city is located along the FEPASA railroad that interconnects the Port of Santos to the inland areas of the state. An exclusive railroad branch serves RPBC.

Topographically, the municipality of Cubatão is located in São Paulo state, between the ocean and Serra do Mar ridge, which is aligned toward SW-NE and reaches up to 1,000 meters in the municipality. Both the urban and industrial areas of Cubatão are located in a plain area composed by small hills with average heights of 200 m. The local topography can be generally described as complex, composed by two basins: one surrounding downtown Cubatão (southwest) and one composed by Mogi river valley (north-northeast) and Quilombo river valley (Northeast). These topographic features originated a semi-closed system, restricting air circulation, so the region becomes critical in terms of pollutant dispersion in certain periods of the year, namely during the winter, see Figure 2.

Figure 1 – Location of the site in Cubatão.

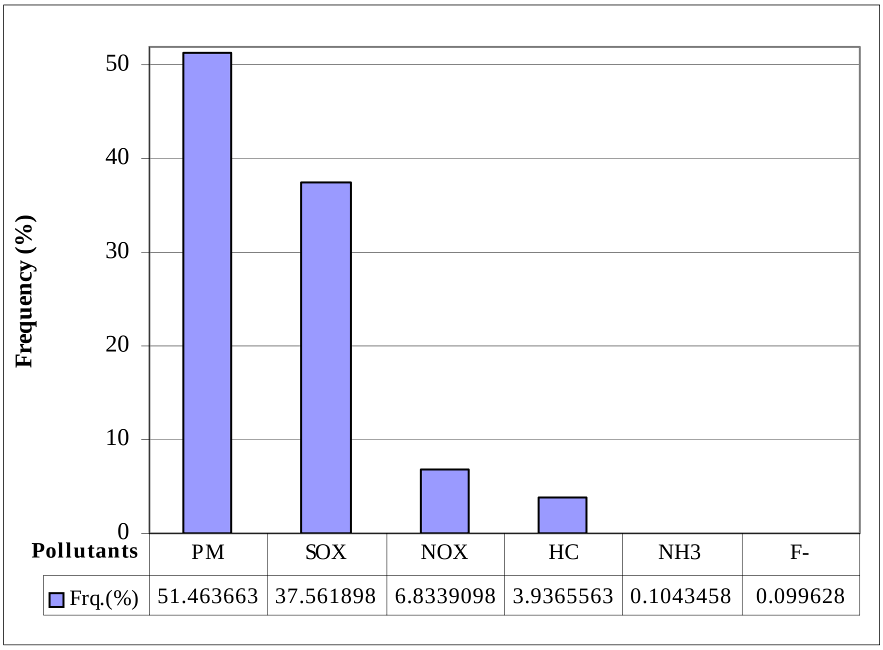
Figure 2 – Topography of Cubatão.



Climate and Air Quality Characterization

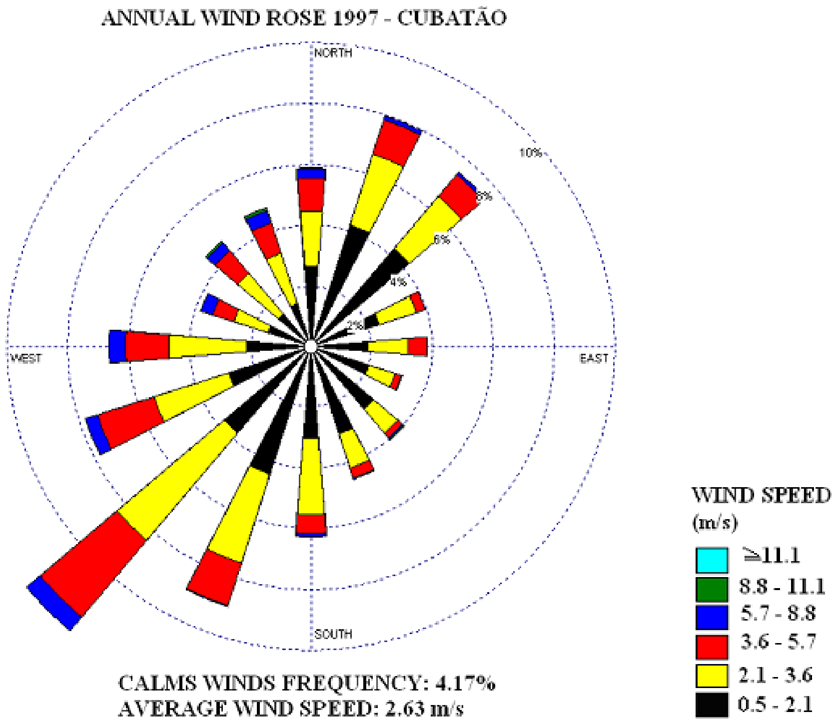
The air quality in the municipality of Cubatão is monitored by the CETESB, the state environmental agency, which has operated a network of automatic stations since 1983, measuring eight pollutants and four meteorological parameters. A large industrial park is installed in the region, including chemical and petrochemical plants, fertilizer plants, steel industries, cement, paper and non-metallic mineral plants, representing over 260 air pollution sources emitting approximately 100,000 tons of pollutants per year. Particulate matter represents the largest emission of these plants, followed by SO_2 and, with a small contribution percentage, NO_X. The emission of the remaining pollutants is very low, as displayed at Figure 3.

Figure 3 – Inventory of the relative emission of pollutants in the region of Cubatão [2].



The climate of Baixada Santista, the region where Cubatão is located, is classified as wet sub-tropical, with a moderately dry winter and a warm, wet summer (*Köppen* classification, see Trewartha, 1954)[3]. According to the values of the climatologic Normal of DNMET (1992)[4], provided by Santos meteorological station, the temperatures range from 12 ^{o}C in the coldest month to 31 ^{o}C in the warmest one. The annual mean temperature is 19 ^{o}C and the annual rainfall indexes may be as high as 3,000 mm, depending on the dominant meteorological factors during the year. The annual mean atmospheric pressure is 968.6 hPa while the annual mean relative humidity ranges from 76 through 98%. Therefore, although the climate of the region is not fully favorable to industrial activities, the high rainfall indexes help in preventing air quality from worsening by naturally washing the atmosphere. As a result of the regional relief, the winds are predominantly due Southwest during the day, with a lower frequency of northeast winds during the night as shown in Figure 3. Although the wind rose is based on data from 1997, the simulation was also carried out based on hourly wind data from 1994. The 1997 wind rose displays the most critical conditions in terms of pollutant dispersion.

Figure 3 - Annual wind rose (1997), Cubatão region.



METHODOLOGY

The Modeling System

The dispersion analysis was carried out using the Industrial Source Complex Model (ISCST3) provided by the United States Environmental Protection Agency (EPA) [5]. The ISCST3 model is the most widely used commercially available numerical model in the United States for air dispersion analyses. The current version of the ISCST3 is noted for its ease of use, good internal documentation, and its acceptance by the EPA as a regulatory model. It is generally applicable to point and area sources. Many states and provinces also recognize the ISC dispersion model for regulatory applications. The Lakes Environmental Software has put in a lot of effort to create the easier to use and most stable interface on the market. It is a user-friendly interface EPA's ISCST3 model. This interface was developed specially for Microsoft Windows and runs under Windows 95.

The ISCST3 was used to estimate the maximum concentrations ground level impacts of NO_X due to the emissions from the thermal power plant plumes sources. Maximum 1hour and annual average NO_X concentrations were calculated. Cartesian receptor grids were adopted to correctly determine the location and magnitude of the maximum concentrations.

Discrete Receptor

Table 1 displays the location of the closest discrete receptors to the site. These receptors were selected based on their location related to RPBC-CCBS, considering the prevailing direction of the winds. Five most vulnerable places were identified: Downtown Cubatão, Vila Parisi, Cubatão river valley, Mogi river valley and a part of the Refinery site that affects the Serra do Mar ridge. These receptors could be occasionally reached by air pollutants, depending on the directions of the winds. The concentration outputs calculated by the model will be plotted on iso-concentration maps.

Table 1 – Location of discrete receptors

Receptor	**Receptor Coordinates, (m)**		
	East (X)	North (Y)	Altitude (m)
Downtown Cubatão	1800	-2200	3
Vila Parisi	6100	+2400	3
Serra do mar ridge, close to CCBS	-1500	2000	3
Cubatão valley	-4000	-4000	6
Mogi valley	9000	6000	4

Emission Parameters

Emission data and exhaust parameters were surveyed for both the proposed plant and the existing boilers of RPBC in order to support impact assessment of air emissions in Cubatão. The expected changes in air quality will be a consequence of the difference between the contribution of the current emissions of the refinery boilers and the contribution of the new sources related to the operation of CCBS. In order to assess this difference, the following different scenarios have been evaluated:

- Present conditions – RPBC boiler system;
- Phase 1 – Future emissions of the Module #1 of CCBS + RPBC boilers;
- Phase 2 – Future emissions of four stacks, after replacing RPBC sources by CCBS turbines.
- Phase 3 – Modules 3 and 4 firing natural gas.

The emission data input into ISCST3 for each scenario are listed at Tables 2 through 5:

Table 2 – Existing system – Emission and exhaust parameters of RPBC boilers

RPBC Boilers	**Coordinates**		**Emission Rates (g/s)**						**Source Parameters**				
	X (m)	Y(m)	PM	SOx	NOx	CO	[2] HC	[3] HCNM	V(m^3/s)	H(m)	D(m)	V(m/s)	T(K)
GV01	0.0	0.0	0.91	11.3	4.6	0.4	0.1	2.0x10^{-2}	14.56	40.0	3.20	1.81	478
[1]GV03/04	0.0	-21.0	2.3	28.6	11.5	1.0	0.2	6.0 x10^{-2}	39.13	40.O	3.20	4.87	473
GV05	0.0	-43.8	2.1	26.3	20.4	1.6	0.2	8.0 x10^{-2}	39.13	40.0	3.20	5.07	449
GV06	0.0	-63.0	2.0	25.4	19.2	1.5	0.2	8.0 x10^{-2}	40.78	40.0	3.20	4.79	445
GV07	87.5	66.5	0.6	8.5	8.7	0.6	0.1	3.0 x10^{-2}	122.8	70.1	3.65	11.73	558

[1] - GV03 and GV04 share a single stack.
[2] – HC – Total organic carbon (TOC).
[3] – HCNM – Volatile organic compounds (VOC).

Table 3 – Phases 1, 2 and 3 - Emission and exhaust parameters of CCBS plant.

Scenarios	CCBS Turbines	Coordinates		Emission Rates (g/s)						Source Parameters				
		X (m)	Y(m)	PM	SO_2	NO_X	CO	[2]HC	[3]HCM	Vm^3/s	H (m)	D (m)	Vs (m/s)	T (K)
Phase 1	[1] Module(1)	70	-570	1.95	2.85	15.28	15.00	2.5	1.00	496.13	47.50	5.62	20.0	375.2
	2GV05-RPBC	0.0	-43.8	2.1	26.3	20.4	1.6	0.2	0.08	40.77	40.0	3.20	5.07	449
Phase 2	Module(1)	70	-570	1.95	2.85	15.28	15.00	2.50	1.00	496.13	47.50	5.62	20.0	375.2
	Module(2)	110	-570	1.95	2.85	15.28	15.00	2.50	1.00	496.13	47.50	5.62	20.0	375.2
Phase 3	Module(1)	70	-570	1.95	2.85	15.28	15.00	2.50	1.00	496.13	47.50	5.62	20.0	375.2
	Module(2)	110	-570	1.95	2.85	15.28	15.00	2.50	1.00	496.13	47.50	5.62	20.0	375.2
	Module (3)	170	570	1.25	2.85	4	6	1.95	0.4	496.13	47.50	5.62	20.0	375.2
	Module (4)	220	570	1.25	2.85	4	6	1.95	0.4	496.13	47.50	5.62	20.0	375.2

[1] – Module (1) comprises a Gas Turbine, a Recovery Boiler and a Steam Turbine.
[2] – HC – HC – Total organic carbon (TOC).
[3] – HCNM – Volatile organic compounds (VOC).

These figures consider that the surplus refinery gas produced by RPBC is fully burned in the recovery boilers of CCBS through the so-called supplemental firing, improving the thermal efficiency of RPBC and reducing the flaring of this product. This gas will be burned in the recovery boilers during both Phases 1 and 2. Since modules 3 and 4 will fire only natural gas, a reduction in the emission of pollutants is expected for phase 3. The reduction in NO_X emissions will be also related to better burning systems. If the existing combustors were kept, the NO_X emissions indexes associated to modules 3 and 4 would be hardly achieved. However, a significant improvement can be observed in the reduction of the emission of that pollutant in the combustors. It can be expected that the emission rates of the gas turbines that will be utilized in modules 3 and 4 (in 2004) will be equivalent to those presently achieved by using additional emission control/abatement equipment.

It is also necessary to consider here that this study assumed that all NO_X emitted by both the refinery and the thermal power plant is fully converted into nitrogen dioxide, NO_2. Although this assumption does not correspond to reality, it is highly conservative, since only a small percentage of NO_X yields NO_2. Several studies and methods available in the associated literature[6] confirm this difference, indicating that the actual maximum concentrations of NO_2 are significantly lower than the total NO_X ones.

Grid System Used in the Simulation

The next step of the study comprised defining a system grid, centered in the main stack of the plant. The grid covered a 36 x 29 km area, or 1,044 km^2. The simulation models interpolate and generate 1,140 receptors within this grid, thus providing a better overview of the dispersion calculation results. The grid was designed to cover an area 7 times larger than Cubatão (148 km^2), covering discrete receptors related to both the thermal plant and the refinery, in order to allow plotting iso-concentration lines and identifying maximum concentration points.

Model Results and Discussion

Analysis of Pollutants

As already mentioned, the first simulation addressed the sources corresponding to the existing boilers of RPBC (GV01, GV03/04, GV05, GV06 and GV07) and the following pollutants: SO_X, PM, NO_X, CO, HC and HCNM.

The emissions of the targeted pollutants were considered continuous and the simulations were applied to determine their concentrations at ground level. The maximum concentration of the set of stacks that corresponded to each source was then identified in the model outputs and compared to the respective federal air quality standards of each pollutant. The ISCST3 simulation was based on two sets of meteorological data: 1994 and 1997. Series from 1995 and 1996 were not used due to failures. The results displayed in Tables 6 through 9 indicate low-magnitude concentrations of PM, CO, HC and HCNM, namely after RPBC boilers are replaced by CCBS turbines. Is it important to mention that the pollutant concentrations are minimum during Phase 3, regardless the considered meteorological condition.

Table 6 - Results of the simulations for Particulate Matter emissions, PM, in µg/m^3, 24-h mean, for 1994 and 1997, compared to the national air quality standard.

Pollutant / Source	Particulate Matter, (MP) 1994		Particulate Matter, (MP) 1997		PM_{10} Standard	
	Maximum mean concentration, µg/m^3		Maximum mean concentration, µg/m^3		Concentration, µg/m^3	
	1st Maximum (24h)	Annual	1st Maximum (24h)	Annual	(24 h)	Annual
RPBC- 5 boiler stacks, integrated	14.7	5.3	20.4	5.0	**150**	**50**
Phase 1 – 2 stacks, integrated	3.3	1.2	6.4	0.8		
Phase 2 - 2 stacks, integrated.	3.1	0.7	4.0	0.5		
Phase 3 - 4 stacks, integrated.	5.0	1.2	6.0	0.8		

Table 7 - Results of the simulations for Carbon Monoxide, CO, in µg/m^3, 1h and 8h means, for 1994 and 1997, compared to the national air quality standard.

Pollutant / Source	Carbon Monoxide, (CO) 1994		Carbon Monoxide, (CO) 1997		CO Standard	
	Maximum mean concentration, µg/m^3		Maximum mean concentration, µg/m^3		Concentration, µg/m^3	
	1st Maximum (1h)	(8 h)	1st Maximum (1h)	(8 h)	(1 h)	(8 h)
RPBC- 5 boiler stacks, integrated	38.2	15.4	40.0	24.9	**40.000.0**	**10.000.0**
Phase 1 – 2 stacks, integrated	16.3	8.3	16.0	8.0		
Phase 2 - 2 stacks, integrated.	23.04	11.6	23.7	14.3		
Phase 3 - 4 stacks, integrated.	33.0	18.6	32.3	19.5		

Table 8 - Results of the simulations for Total Hydrocarbon emissions, HC, in µg/m^3, 3-h mean, for 1994 and 1997, compared to the national air quality standard.

Pollutant / Source	Total Hydrocarbons, (HC) 1994		Total Hydrocarbons, (HC) 1997	
	Maximum mean concentration, µg/m^3		Maximum mean concentration, µg/m^3	
	1st Maximum (3 h)	annual	1st Maximum (3 h)	annual
RPBC- 5 boiler stacks, integrated	6.0	0.6	6.7	0.1
Phase 1 – 2 stacks, integrated	9.2	0.6	10.4	0.4
Phase 2 - 2 stacks, integrated.	10.9	0.5	16.4	0.6
Phase 3 - 4 stacks, integrated.	20.4	1.0	25.6	1.1

Table 9 - Results of the simulations for Non-Methane Hydrocarbon emissions, HCNM, in µg/m^3, 3-h mean, for 1994 and 1997, compared to the national air quality standard

Pollutant / Source	Non-methane Hydrocarbons, (HCNM) 1994		Non-methane Hydrocarbons, (HCNM) 1997	
	Maximum mean concentration, µg/m^3		Maximum mean concentration, µg/m^3	
	1st Maximum (3 h)	annual	1st Maximum (3 h)	annual
RPBC- 5 boiler stacks, integrated	6.0	0.6	6.7	0.1
Phase 1 – 2 stacks, integrated	9.2	0.6	10.4	0.4
Phase 2 - 2 stacks, integrated.	10.9	0.5	16.4	0.6
Phase 3 - 4 stacks, integrated.	20.4	1.0	25.6	1.1

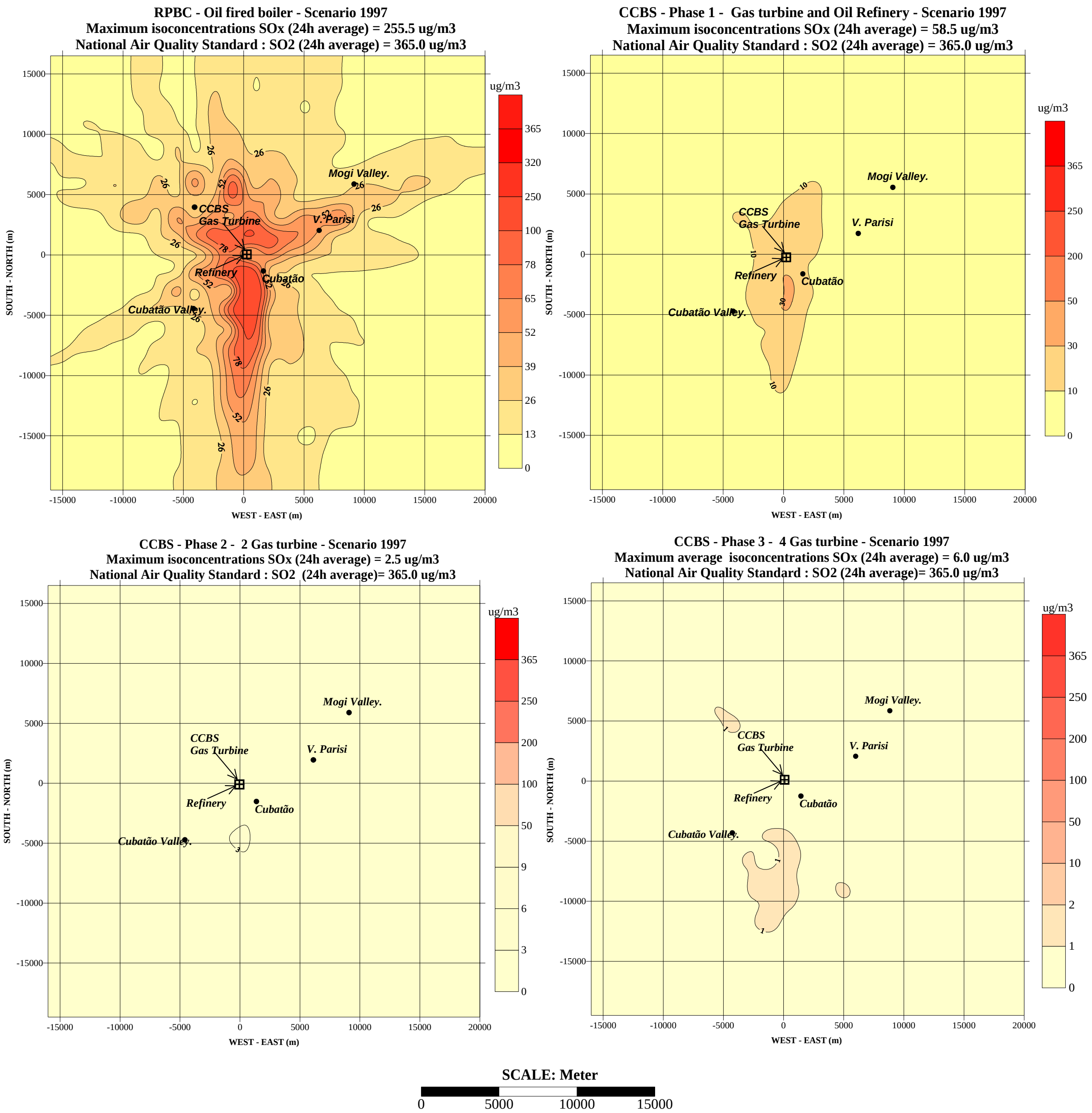
Analysis of SO_X

Table 10 displays the simulation results for sulfur oxides, SO_X, indicating both 24-h and annual means for the emissions of the existing five boilers of the refinery. The maximum concentration was observed for 1997, 255.5 μg/m^3. The concentrations decrease as the process changes move from Phase 1 to Phase 3, when they reach a minimum value of 6.0 μg/m^3, which is 42.6 times lower than the initial concentration (255.5 μg/m$^{3)}$ observed for the boiler system. In a way or another, all results are lower than the 24-h standard for SO_2, 365.0 μg/m^3. Therefore, a very significant improvement in the local air quality can be expected in terms of SO_X after the power plant startup with natural gas. This improvement can be viewed in the SO_X isoconcentration maps displayed in Figure 4. The maps are sequentially displayed according to the four assessed scenarios (Present conditions – RPBC and CCBS, Phases 1,2 and 3), using the same color keys, indicting a considerable reduction in SO_X concentrations as the existing boilers are deactivated and CCBS gas turbines start running with natural gas. The environmental improvement is already clear in Phase 1, when SO_X concentrations decrease to values significantly below the corresponding air quality standards.

Table 10 - Results of the simulations for Sulfur Oxide emissions, SO_x, in μg/m^3, 24-h and annual means, for 1994 and 1997, compared to the national air quality standard.

Pollutant / Source	**Sulfur Oxides, (SO_x)1994**		**Sulfur Oxides, (SO_x) 1997**		**SO_2 standard**	
	Maximum mean concentration, μg/m^3		Maximum mean concentration, μg/m^3		Concentration, μg/m^3	
	1st Maximum (24h)	Annual	1st Maximum (24h)	Annual	(24 h)	Annual
RPBC- 5 boiler stacks, integrated	184.5	66.1	255.5	62.1	**365.0**	**80.0**
Phase 1 – 2 stacks, integrated	41.3	15.0	58.3	8.6		
Phase 2 - 2 stacks, integrated.	2.6	0.6	2.5	0.3		
Phase 3 - 4 stacks, integrated.	6.9	1.3	6.0	0.6		

Figure 4 – Comparison between SO_x isoconcentrations for 4 scenarios: present conditions (RPBC) and CCBS Phases 1, 2 and 3.



Analysis of NO_X

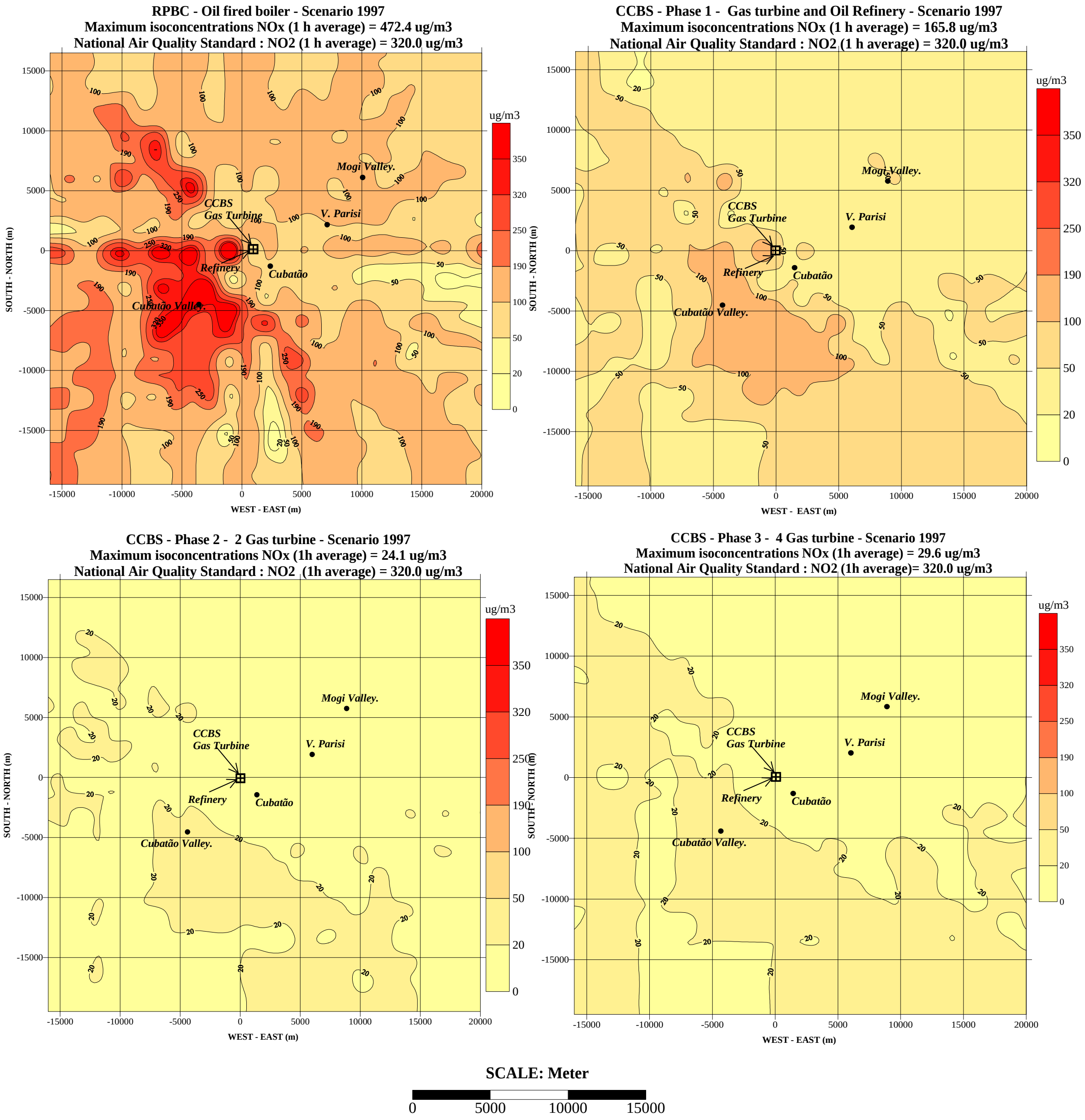
Table 11 displays the simulation results for NO_X. It was observed that the maximum 1h mean concentration obtained for the present conditions, i.e., the operation of the refinery boilers, was 472.4 µg/m^3 (for the meteorological conditions of 1997). Assuming that all NO_X is converted to NO_2, the maximum concentration would be 40.7% higher than the 1h standard for NO_2 (320.0 µg/m^3). However, this concentration decreases when Phase 1 conditions are simulated (one oil-fired boiler and one gas turbine), reaching a maximum 1h concentration of 165.8 µg/m^3 for NO_X, which is 64.9 % lower than the maximum result obtained for the existing boiler system. As for Phase 2 (2 turbines running on natural gas) the maximum NO_X concentration drops to 24.5 µg/m^3 (meteorological conditions for 1994), i.e., 85.2 % lower than the value observed for Phase 1. Finally, for Phase 3 (4 turbines running on natural gas, full load) the maximum concentration of NO_X calculated by the model increases to 30.4 µg/m^3, (meteorological conditions for 1994), when compared to Phase 2. Nevertheless, assuming that all NO_X is converted to NO_2 in the atmosphere, this value is still 10.5 lower than the corresponding hourly standard for NO_2, 320.0 µg/m^3. Therefore, a very significant improvement in the local air quality can be expected in terms of NO_X after the power plant start-up with natural gas, replacing the existing oil-fired boilers. This improvement can be viewed in the NO_X iso-concentration maps displayed in Figure 5. The maps are sequentially displayed according to the four assessed scenarios (Present conditions – RPBC and CCBS, Phases 1,2 and 3), using the same color keys, indicating a reduction in NO_X plumes as the project moves from one scenario to another, characterizing a progressive environmental improvement in Cubatão region until the full deactivation of RPBC boilers.

In terms of annual means, Table 11 indicates that the maximum concentrations associated to the integrated boiler system are 21.5 µg/m^3 and 23.3 µg/m^3 for 1994 and 1997, respectively. Once again, assuming a complete conversion of NO_X into NO_2, it was observed that the final results are four times lower than the corresponding annual standard, 100 µg/m^3. When the replacement of the existing boilers is considered, the annual mean concentrations also decrease, remarkably from Phase 1 to Phase 3, when the maximum concentration of NO_X reaches 2.0 µg/m^3.

Table 11 - Results of the simulations for Nitrogen Oxide emissions, NO_x, in µg/m^3, 1h and annual means, for 1994 and 1997, compared to the national air quality standard

Pollutant / Source	**Nitrogen Oxides, (NO_x) 1994**		**Nitrogen Oxides, (NO_x) 1997**		**NO_2 standard**	
	Maximum mean concentration, µg/m^3		Maximum mean concentration, µg/m^3		Concentration, µg/m^3	
	1st Maximum (1 h)	Annual	1st Maximum (1 h)	Annual	(1 h)	Annual
RPBC- 5 boiler stacks, integrated	450.2	21.5	472.4	23.3	**320**	**100**
Phase 1 – 2 stacks, integrated	138.4	11.3	165.8	4.4		
Phase 2 - 2 stacks, integrated.	24.5	1.6	24.1	0.6		
Phase 3 - 4 stacks, integrated.	30.4	2.0	29.6	0.74		

Figure 5 – Comparison between NO_x iso-concentrations for 4 scenarios: present conditions (RPBC) and CCBS Phases 1, 2 and 3.



CONCLUSION

This study aimed at assessing the environmental impacts of a co-generation plant on air quality as part of the environmental permitting process of Central de Cogeração da Baixada Santista – CCBS, a thermal power plant to be implemented in the site of Presidente Bernardes Refinery, RPBC, in the municipality of Cubatão, São Paulo, Brazil. The plant will generate approximately 950 MW, firing natural gas and delivering both power and steam to RPBC and surplus power to third parties. The steam supplied to the refinery will replace the steam presently generated by six oil-fired boilers that will be permanently deactivated right after the commercial start-up of the thermal power plant.

The study indicated that the maximum mean concentrations associated to the future emissions of the plant represent an environmental improvement as a result of the deactivation of the refinery boilers and the start-up of Phases 1, 2 and 3 of CCBS project. The iso-concentration curves for SOx, displayed in Figure 4, indicate a pattern similar to that observed for NOx, but with a more accentuated decrease as the boilers are replaced. This result was quite expected, since the fuel oil presently fired in the boilers will be replaced by natural gas. It must be highlighted that the simulation was based in the highest emission index of sulfur compounds allowed by the local natural gas supplier, 110 µg/m3. Likewise, it is important to consider that, in terms of energy, the natural gas flow rate of Phase 3 is higher than the fuel oil flow rates in the boilers. The concentration of sulfur compounds found in the natural gas is usually lower than 10 ppm before the odorization performed by COMGAS. The reduction in the mean concentrations of SO_X to values significantly below the air quality standard for this compound can be already observed in Phase 1 of CCBS project, indicating a significant environmental improvement in the project influence area. This improvement trend was also observed in terms of NO_X, as shown in the iso-concentrations maps displayed in Figure 5.

The HCNM is another group of pollutants that deserved a special attention in the study for its importance in terms of photochemical reactions. Although the emission rates of HCNM from the thermal power plant are higher than those observed for the existing boilers of the refinery, the maximum 3-h mean concentrations of this pollutant did not exceeded 4% of the standard recommended by USEPA (160µg/m3) for both assessed years. The maximum concentrations of HCNM calculated for Phase 1 of CCBS project are close to the values observed for RPBC boilers and approximately 1% of the standard. In terms of annual means, the calculated concentrations for all three configurations of the thermal power plant lay below 0.5 $\mu g/m^3$.

As for the maximum 1h and 8h mean concentrations of CO, the values calculated for CCBS plant lay around 1% of the corresponding air quality standard.

Although the project of CCBS thermal power plant considers the utilization of the best available combustion technology, such as Dry Low NO_X burners, the final total emission of nitrogen oxides may be higher than the values presently emitted by the boilers, as a result of the higher capacity of the new plant. However, the simulation results indicated that the utilization of taller stacks and higher exhaust velocities will reduce the maximum concentrations of pollutants to values significantly lower than those generated by the existing emission system. The aforementioned aspects improve the air dispersion capacity in the plume, resulting in a wider dispersion area and, consequently, in lower concentration peaks of pollutants both in the center of the plume and at ground level. Therefore, despite the higher capacity of CCBS when compared to the existing boiler system, the results calculated by ISCST3 indicate that, after the start-up of the thermal power plant, a significant environmental improvement will be observed in the air quality of the project area of influence. This result is mainly achieved by the replacement of fuel oil by natural gas, by the application of a combined cycle with high-efficiency co-generation process, the utilization of modern combustion techniques, taller stacks and higher exhaust velocities, a set of aspects that reduce the specific consumption of fuel and the specific emission of pollutants.

Therefore, the study concludes that after the start-up of CCBS thermal power plant, the maximum concentration of the targeted pollutants will represent a significant environmental improvement to Cubatão region.

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Key Words

Oil-fired boilers, NO_X, *Dry Low* NO_X, refinery, natural gas, gas turbines, fuel oil, co-generation combined cycle, pollutants.