16th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
8-11 September 2014, Varna, Bulgaria

MODELLING THE IMPACT OF A COAL-FIRED POWER PLANT, LOCATED IN SOUTHERN ITALY, FOR RISK ASSESSMENT PURPOSES

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Abstract: Dispersion models, including information on meteorology, emissions and topography can be a useful tool to predict ground level mean concentrations around pollutant sources. Thus it is possible to identify, on average, areas of maximum and minimum population exposure as well as to assess contaminants which are not measured at ground. This study allowed to evaluate for primary pollutants (NOx, SO2, PM10 and heavy metals) the contribution of different emitting sources, related to the coal-fired power plant activities located in the Brindisi area, in the southern Italy. In particular the primary PM10 and heavy metals assessment represented a preliminary activity to the evaluation of the environmental exposure for the population living in Brindisi area. This evaluation will allow to carry out the first risk assessment for environmental health related to power plant activities.
The simulation was conducted for one year. Different emissions belonging to the power plant were modelled including hourly stack emissions, emissions produced by the storage and handling of primary materials in the stockyards (i.e. coal), emissions related to transportation of materials by heavy duty trucks, emissions related to the hotelling of ships in the port area. The modelling system included the SWIFT meteorological model, the SURFPRO turbulence pre-processor and the SPRAY Lagrangian particles dispersion model. SPRAY is a 3D model particularly suited to provide an accurate local distribution of the primary pollutants in the atmosphere in non-homogeneus and non-stationary conditions.
A comparison between measured and modelled SO2 concentrations, at managed ARPA monitoring stations, was also performed, since this pollutant represents a good proxy for the industrial sector. Results showed a satisfactory accordance for the annual mean.

Key words: *coal-fired power plant, Lagrangian model, environmental exposure level.*

INTRODUCTION

Risk assessment and management approaches to environmental issues are increasingly being used at all levels of policy and regulation.

Dispersion models are an appropriate tool to carry out a risk assessment for environmental health in a complex meteorological area, where industrial emissions are particularly relevant. The use of modeling techniques also allows to separate and evaluate quantitatively the contribution of different emission sources on ambient air quality, enabling to interpret the monitoring stations data and to evaluate the best mitigation and remediation air quality control strategies.

In this study the contribution of different emitting sources, related to the coal fired power plant activities, located in the Brindisi area, in the southern Italy, have been investigated with a modelling system including the SWIFT meteorological model, the SURFPRO turbulence pre-processor and the SPRAY Lagrangian particles dispersion model has been applied to provide an accurate local distribution of the primary pollutants in the atmosphere in non-homogeneous and non-stationary conditions. Due to the combination of synoptic circulation regime and local features, meteorology of the area is quite complex: in fact, the wind field is characterized by a great temporal variability and all the area is subject to complex land-sea-land circulation system.

THE INVESTIGATED AREA AND EMISSION DATA

Brindisi is one of the most industrialized cities of Apulia Region, located in the Mediterranean sea in south-eastern corner of Italy (Figure 1(a) and (b)), with several polluting emission activities including two power plants, a petrochemical plant and several pharmaceutical, metallurgical, manufacturing and cement industries. Among these, the big coal power plant located 12 km away to the SE from the city and belonging to the Italian ENEL Power Corporation can affect air quality and have significative impact on local emissions as reported on Regional atmospheric emission inventory (INEMAR, ARPA Puglia, 2011). In order to evaluate the environmental impact, different emissions belonging to the power plant activities were modelled including: hourly stack emissions, storage and handling of primary materials in the stockyards (i.e. coal), transportation of materials by heavy duty trucks, hotelling of ships (power plant related) in the port area. Table 1 shows the total emissions derived from the 2010 regional atmospheric emission inventory, built up on the basis of INEMAR (INventario di EMissioni in Aria). The hourly emission values by the stacks were obtained from the Emission Monitoring System (SME), relative to 2010 year. Such data consist of hourly values of macro-pollutants NOx, SO2, CO and TSP issued by each fireplace; these data also consist of a series of thermodynamic parameters describing the state of the gas output, the flow rates of the fuels used and the power produced.

Table 1. Total yearly emissions for industrial sources, traffic, residential heating and the harbour.

Emission sources	NOx (Mg/year)	SO2 (Mg/year)	PM10 (Mg/year)	PM2.5 (Mg/year)	AS (kg/year)	Cd (kg/year)	Ni (kg/year)	Pb (kg/year)
Stacks	7812	7596	546	546	72.2	12.5	742	792
Mineral Stockyards	-	-	34.1	11.3	0.02	0.03	1.1	0.3
Storage and handling of primary materials	-	-	0.79	0.12	0.0005	0.0008	0.024	0.008
Transportation of materials by heavy duty trucks	0.34	0.001	0.49	0.16	-	0.0009	0.007	0.02
Harbour	216	188	23.9	22.3	0.0006	0.0002	0.02	0.002

The climatological wind roses (Figure 1(b)) based on statistics compiled over three decades meteorological data measured by the Air Force meteorological synoptic station of Brindisi shows a prevailing NNW component (14%). So, to evaluate the impact of the coal-fired power plant, the choice of the simulation domain has taken into account both the climatological data and the height of the source. Within this area eleven air quality monitoring stations defined by conventional classification established by the Italian regulation as rural (i.e. R#) and suburban (i.e. S#) has been considered. The monitoring stations, which location and characteristics are summarised in Table 2, are daily managed and reported by Regional Environmental Protection Agency ARPA in the institutional air quality monitoring system.

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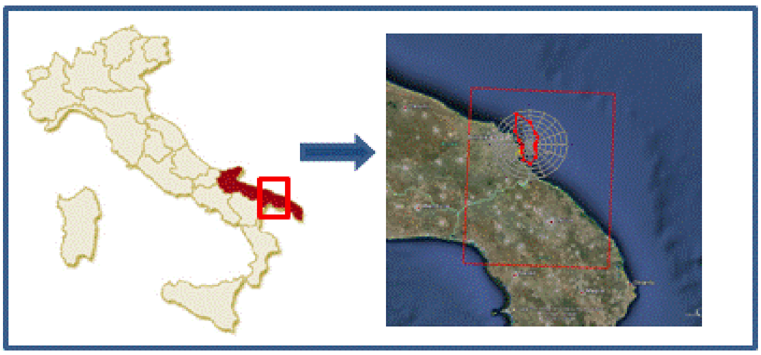

Figure 1 (a) and (b). Investigated area and simulation domain

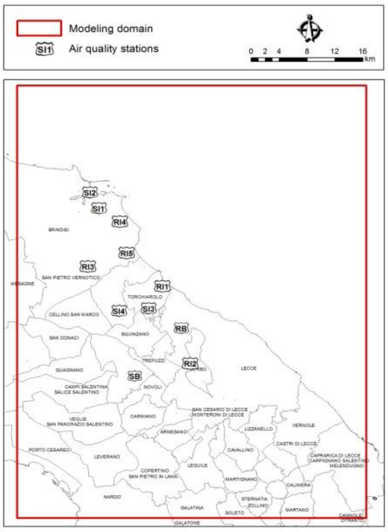

Figure 2. Distribution of air quality monitoring stations

Table 2. Location and characteristics of the monitoring stations

Stations	X-UTM (km)	Y-UTM (km)	Type	Monitored parameters
SI1 – Sisri	751.700	4501.449	Suburban-Industrial	CO,C6H6,PM10,NO2,SO2
SI2 – Terminal Passeggeri	750.422	4503.838	Suburban-Industrial	CO,C6H6,O3,PM10,NO2,SO2
SI3 – Torchiarolo	758.842	4486.404	Suburban-Industrial	CO,O3, PM10,NO2,SO2
SI4 – S.P. Vernotico	754.781	4486.042	Suburban-Industrial	PM10,NO2,SO2
SB – Campi salentin	756.857	4476.277	Suburban-Background	CO,C6H6,PM10,NO2
RB – S.M. Cerrate	764.242	4483.446	Rural-Background	PM10,NO2,SO2
RI1 – Lindinuso (Enel)	760.838	4489.753	Rural-Industrial	PM10,NO2,SO2
RI2 – Surbo (Enel)	764.807	4478.158	Rural-Industrial	PM10,NO2,SO2
RI3 – Tuturano (Enel)	750.135	4492.721	Rural-Industrial	PM10,NO2,SO2
RI4 – Cerano (Enel)	754.878	4499.453	Rural-Industrial	PM10,NO2,SO2
RI5 – Parco Carbonile Sud (Enel)	756.577	4494.756	Rural-Industrial	PM10

MODELLING SETUP

The modelling system used for this study included the SWIFT meteorological model, the SURFPRO turbulence pre-processor and the SPRAY Lagrangian dispersion model (Tinarelli et al., 2000; Gariazzo et al., 2007). SPRAY simulates the transport, dispersion and deposition of pollutants emitted from sources of different kind over complex terrain, by following the path of marked fictitious particles in the atmospheric turbulent flow. The model is able to easily take into account complex situations, such as the presence of breeze cycles, strong meteorological inhomogeneities and non-stationary, low wind calm conditions and recirculations.

The studied area has been subdivided according to a 101x131 cells horizontal grid system, while 15 layers of variable thickness have been used to vertically split the domain from ground level up to the top, fixed at 5000 m above ground level. Meteorology fields were reconstructed by SWIFT and SURFPRO codes on hourly basis, using as input the tridimensional meteorological products supplied, for the year 2007, by the MINNI project (Zanini, 2009, www.minni.org). The Batchvarova-Gryning algorithm (Batchavarova et al., 1991) was used to estimate the height of the boundary layer. This algorithm allows to reconstruct in a realistic way the phenomenology of internal growth of the boundary layer, which characterizes the coastal sites.

RESULTS AND DISCUSSIONS

To better understand the influence of different emission sources on pollutant concentrations, in different parts of the studied area, a quantitative source apportionment for primary and regulatory pollutants has been performed. Table 3 shows the simulated concentration for SO2, NOx, PM10 and source contributions in percent at the monitoring stations for macro-pollutants and for As, Pb, Cd and Ni.

Table 3. Total annual concentrations (bold) in μgm^{-3} of macro-pollutants and source contributions in percent at the monitoring stations predicted by SPRAY model.

	SI1	SI2	SI3	SI4	SB	RB	RI1	RI2	RI3	RI4	RI5
SO2 (μgm^{-3})	**1.56**	**1.55**	**2.19**	**1.22**	**0.96**	**1.16**	**1.45**	**1.09**	**0.79**	**0.95**	**1.25**
Stacks (%)	34	26	96	95	96	96	95	97	89	64	86
Mineral Stockyard (%)	0	0	0	0	0	0	0	0	0	0	0
Transport by trucks (%)	0	0	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0	0	0	0	0	0	0	0	0	0	0
Harbour (%)	66	74	4	5	4	4	5	3	11	36	14
NOx (μgm^{-3})	**1.78**	**1.78**	**2.27**	**1.18**	**1.01**	**1.18**	**1.42**	**1.12**	**0.8**	**1.05**	**1.31**
Stacks (%)	33	26	96	94	96	96	95	97	87	63	84
Mineral Stockyard (%)	0	0	0	0	0	0	0	0	0	0	0
Transport by trucks (%)	0	0	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0	0	0	0	0	0	0	0	0	0	0
Harbour (%)	66	74	4	6	4	4	5	3	13	37	16
PM10 (μgm^{-3})	**0.21**	**0.22**	**0.22**	**0.11**	**0.08**	**0.09**	**0.14**	**0.09**	**0.08**	**0.16**	**7.05**
Stacks (%)	20	14	71	74	83	77	63	79	60	31	1
Mineral Stockyard (%)	11	4	24	18	11	17	31	16	24	39	98
Transport by trucks (%)	3	1	0	0	0	0	0	0	1	2	0
Storage and handling (%)	2	15	0	0	0	0	0	0	1	1	1
Harbour (%)	63	65	5	8	6	6	6	5	14	27	0
As											
Stacks (%)	100	99	100	100	100	100	100	100	100	99	72
Mineral Stockyard (%)	0	0	0	0	0	0	0	0	0	0	28
Transport by trucks (%)	0	0	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0	0	0	0	0	0	0	0	0	0	0
Harbour (%)	0	0	0	0	0	0	0	0	0	0	0
Cd											
Stacks (%)	96	93	99	99	99	99	98	99	98	94	18
Mineral Stockyard (%)	2	1	1	1	0	1	2	1	1	5	81
Transport by trucks (%)	1	1	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0	5	0	0	0	0	0	0	0	0	1
Harbour (%)	0	0	0	0	0	0	0	0	0	0	0
Ni											
Stacks (%)	98	96	99	99	100	100	99	100	99	97	29
Mineral Stockyard (%)	1.2	1	1	1	0	0	1	0	1	3	70
Transport by trucks (%)	0.2	0	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0.3	3	0	0	0	0	0	0	0	0	1
Harbour (%)	0.2	0	0	0	0	0	0	0	0	0	0
Pb											
Stacks (%)	99	99	100	100	100	100	100	100	100	99	59
Mineral Stockyard (%)	0	0	0	0	0	0	0	0	0	1	41
Transport by trucks (%)	1	0	0	0	0	0	0	0	0	0	0
Storage and handling (%)	0	1	0	0	0	0	0	0	0	0	0
Harbour (%)	0	0	0	0	0	0	0	0	0	0	0

It is evident that the stacks emissions are the principal contributor to the total concentrations for all the micro-pollutants considered (As, Cd, Ni, Pb). As regard macro-pollutants (SO2, NOx and PM10) the harbour activities represent the principal contributor for the SI1 and SI2 stations closest to the harbour area. The mineral stockyard activities show a relevant contribution only for PM10 specie and the effects are evident at station RI5, located in proximity of the mineral deposits.

In order to evaluate the accuracy of the system used in this study, the model predictions of SO2 were compared with measurements taken from the air quality stations. Figure 3 (a) and (b) shows respectively the distribution of mean concentration level and the scatter plot of measured versus predicted yearly mean concentrations of SO2. Results show a satisfactory accordance for the annual mean values, more evident for stations that are located along the plume dispersion axis, while the worst results were obtained at stations located at greater distance (RI2) or to the north of the industrial area (SI2, RI4). It should be noted that the comparison should be considered indicative because the modeling, although considered emissions to 2010, was performed on the meteorological database of 2007 and also because the measured data takes into account the contributions from other sources in the area.

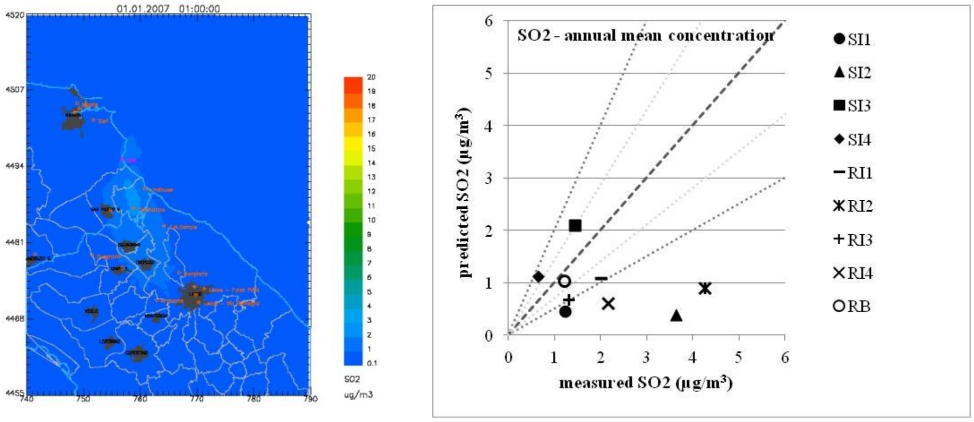

Figure 3. Annual average concentration map and scatter plot of measured versus predicted yearly mean concentrations of SO2

CONCLUSIONS

This study has allowed to evaluate the contribution of different emitting sources, related to a coal-fire power plant located in the Brindisi area, in the southern Italy, to the impact of primary pollutants (NOx, SO2, PM10, PM2.5). This is a preliminary activity for the evaluation of the environmental exposure of the population living in Brindisi area to dangerous micropollutants (POP's and heavy metals). The simulation was conducted by using the SWIFT meteorological model, the SURFPRO turbulence pre-processor and the SPRAY Lagrangian particles dispersion model for one base year. Different emissions belonging to the power plant were modelled including hourly stack emissions, emissions produced by the storage and handling of primary materials in the stockyards (i.e. coal), emissions related to transportation of materials by heavy duty trucks, emissions related to the hotelling of ships in the port area. A quantitative source apportionment has been performed, showing the major contribution due to stack emissions in all monitoring stations, followed by harbour activities and mineral stockyards. An analysis of simulation results versus local network monitoring data has revealed a good agreement between predicted and observed annual mean SO2 concentration.

AKNOLEWGEMENTS

The authors acknowledge Dr. Vito La Ghezza for its technical support and ENEA for providing data produced within the MINNI Project over the south Italy domain and for the year 2007

REFERENCES

Apulia Atmospheric Emission Inventory 2011. [online] Available at: http://www.inemar.arpa.puglia.it/

Batchvarova, E., and S. E. Gryning, 1991: Applied model for the growth of the daytime mixed layer. Bound. Layer Meteor., 56, 261-274

Gariazzo C., Papaleo V., Pelliccioni A., Calori G., Radice P., Tinarelli G. (2007) 'Application of a Lagrangian particle model to assess the impact of harbour, industrial and urban activities on air quality in the Taranto area, Italy', *Atmospheric Environment*, Vol.41, pp. 6432-6444

Tinarelli G., Anfossi D., Bider M., Ferrero E., Trini Castelli S. (1999) 'A new high performance version of the Lagrangian particle dispersion model SPRAY, some case studies', Air Pollution Modelling and its Applications XIII.

Zanini G. (2009) 'Il sistema MINNI, modello integrato nazionale per la valutazione degli effetti dell'inquinamento atmosferico e dell'efficacia delle politiche di riduzione delle emissioni di inquinanti atmosferici.' Epidemiologia e prevenzione, anno 33 (6), novembre-dicembre 2009, supplemento 1 PMID 20418584.