Atmospheric emissions of one pulp and paper mill. Contribution to the air quality of Viana do Castelo

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Abstract: One of the most sensitive environmental impact of the pulp and paper mills is associated with the atmospheric pollution namely with sulphur compounds, particulate matter and nitrogen oxides. The study undertaken aimed to evaluate the influence of one pulp and paper mill to the air quality of a Portuguese city located in the vicinity. A range of numerical models were used to produce the concentration maps: the ADMS-Urban model for the pollutants dispersion; the Hills model to calculate air flow and turbulence over complex terrain, including the effects of variable surface roughness and EPER data (The European Pollutant Emission Register) to estimate the emissions factors.

Key-Words: Urban air pollution; Air pollution modelling; Kraft pulp and paper mill

1 Introduction

The Healthy Cities Project is, today, a worldwide movement, having on its basis the concept Health for All (HFA).

In 1986 the World Health Organization (WHO) selected eleven cities in order to demonstrate that the new approaches in public health defended by HFA worked in practice. This is how the concept Healthy Cities was born.

Viana do Castelo is a mid-sized city located in the northwest Portuguese seaside, which undertook the challenge of developing an environmental program leading to the integration in the Healthy Cities European Network. Within this program, the identification of urban air pollution levels and people exposure were considered a priority.

The work developed in Viana do Castelo used local emission inventories to model concentrations of the key pollutants in the city, and the outputs included time series of predicted concentrations which were compared with measured data at monitoring sites. Predicted concentration includes time series at locations coincident with monitors and contour maps over the total calculation area. The present work was performed to attain the following objectives:

- to quantify the atmospheric emissions from one pulp and paper mill located in the vicinity of Viana do Castelo
- to evaluate the influence of this pulp and paper mill to the air quality of the city of Viana do Castelo.

In line with most of the EU countries, Portuguese specific legislation requires local government authorities to manage air quality in their areas, with the aim of achieving the objectives laid out in Table 1.

Table 1 – Portuguese annual limit concentration for the protection of human health [1,2]

Pollutant	Average period	Value
Nitrogen dioxides (NO_2)	Calendar year	40 µg/m3
Particulate matter (PM_{10})	Calendar year	40 µg/m3
Ozone (O_3)	8 hours (rolling average)	110 µg/m3
Sulphure dioxide (SO_2)	24 hours	125 µg/m3

2 Atmospheric emissions from Kraft pulp mill

In Portugal paper manufacturing began in the end of the 14th century. However, the first mills appeared only in the beginning of the 18th century. It was the first country to manufacture chemical pulp form eucalyptus: using sulphite in 1923; and sulphate in 1957 [3]. Since that time production has been gradually increasing with the construction of newer plants to face the demands from external markets.

At present, Kraft pulp is one of Portugal largest exports due to the availability of pine and eucalyptus forests in the country. The Pulp and Paper Sector's activity contributes strongly to the Portuguese economy growth, as it is a net exporter sector. The sector has an imports coverage rate of about 40% [3], contributing positively to the country's economy.

One of the most sensitive environmental impacts of the Kraft (sulphate) pulp mills is associated with the atmospheric pollution which is mainly composed of solid particulate, carbon monoxide, sulphure dioxide, nitrogen oxides, hydrogen sulphide and mercaptans, such as methylmercaptan, dimethylmercaptan and dimethyldisulphide [4, 5].

The main stationary sources of emissions to the atmosphere occurring from the kraft process are associated to the production process: recovery boiler stacks, limestone kiln stacks and the stack from the smelt dissolving tank.

The particulate emissions are mainly composed of salts: from the recovery boiler and smelt tank stacks produces sodium salts and calcium salts from limestone kiln stack.

The sulphur dioxide is emitted from the recovery boiler as an oxidation product occurring in that unit. Carbon oxides are emitted as an oxidation product formed in the combustion units, such as recovery boiler, lime kiln and other auxiliary boilers.

The reduced sulphur compounds that contribute to the typical odour of these plants are mainly composed of mercaptans.

Urban air pollution became one of the main factors of degradation of the quality of life in the cities. This problem tends to worsen due to the unbalanced development of urban spaces and the incompatibilities of uses. The atmospheric pollutants are emitted from existent sources and, subsequently, transported, dispersed and several times transported in the atmosphere reaching several receivers through wet deposition (rainout and washout of the rain and snow) or dry deposition (adsorption of particles)[6, 7]. Due to the dispersion effect happened during the reaction, the concentration of the secondary pollutants doesn't usually reach maximum values close to the emission source. The impact can however extend to great areas not confined to the area of the source [6].

Numerous dispersion models are available, which constitute an important toolbox in the simulation of the air pollution situation. The model adopted for this research, was developed by CERC in the United Kingdom [8]. This model has been used in over half of the pollution pilot studies carried out in the UK [9, 10]. It uses a parameterization of the boundary layer physics in terms of boundary layer depth and Monin-Obukhov length and use a skewed-Gaussian concentration profile in convective meteorological conditions. In stable and neutral meteorological conditions the model assumes for the distribution of the concentration profile a Gaussian plume with reflection at ground and inversion layer [8].

The dispersion model has a methodological processor which uses the input variables, typically day of the year, time of the day, cloud cover, wind speed, wind direction and temperature, to calculate the parameters to be use in the model such as boundary layer depth and Monin-Obukhov length. The model does not take into account anthropogenic heat sources and the effect of the increased roughness in towns and cities.

An additional and important feature of the dispersion model, which makes suitable modelling in urban environment, is the inclusion of the chemistry scheme making possible the calculation of the chemical reaction between nitric oxide, nitrogen dioxide, ozone and volatile organic compounds in the atmosphere.

3 Contribution of one pulp and paper mill to the air quality of Viana do Castelo

The study undertaken aimed to evaluate the influence of one pulp and paper mill to the air quality of a Portuguese city – Viana do Castelo, located in the northwest seaside. This is a mid-sized city, which has a population of 36.544 inhabitants living in an overall area of 37,04 Km2. The most remarkable industrial source of air pollution is one pulp and paper mill located in the vicinity of the city (Fig. 1).

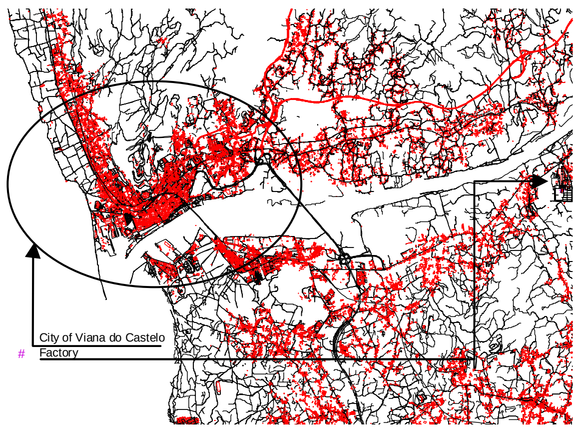


Fig.1 – Factory *vs.* Viana do Castelo location

The main products of this pulp and paper mill are unbleached sulphate eucalyptus and pine pulp, recovered paper pulp and kraftliner paper.

Based on emissions factors, and on physical characteristics of the area, horizontal maps of three main pollutants were created: NO_x, PM_{10} and SO_x. A range of numerical models were used to produce results. The ADMS-Urban model was used for the pollutants dispersion, the Hills model was used to calculate air flow and turbulence over complex terrain, including the effects of variable surface roughness [8] and the EPER register [11] was used to calculate the factors emissions for the factory. The dispersion model, is linked to a GIS (Geographical Information System) platform for input and output data. For the validation process the BOOT statistical approach was used [12].

3.1 Calculation of horizontal air pollution maps

The modelling of dispersion of air pollution in built-up urban areas must integrate all the parameters which influence the dispersion, among others, the topography, the site, and meteorological condition like the wind and the heterogeneousness of the atmosphere.

A full survey, including topographic characteristics, surface roughness and the specification of the emission source, was carried out for the whole city.

Taking the data gathered, the model was used to produce horizontal maps of three important industrial air pollutants (NO_x, PM_{10} and SO_2).

The calculation parameters adopted are laid out on Table 2.

Table 2 – Calculation parameters adopted

Meteorological conditions	Data supplied by the Portuguese Institute of Meteorology (hourly) for one year
Monin-Obukhov length	30 m
Surface roughness	0,5 m
Meteorological conditions	Data supplied by the Portuguese Institute of Meteorology (hourly)
Emissions inventory	industrial source
Height of the maps	1,2 m

3.2 Emissions Data

In order to evaluate the influence of the pulp and paper mill to the air quality of the city of Viana do Castelo the pulp and paper mill was the unique contribution. This factory is one PCIP mill (Prevention and Control Integrated of the Pollution), and for that reason is forced to make the register EPER (The European Pollutant Emission Register). The EPER is web available [11].

Table 3 shows the global emissions factors for the pulp and paper mill.

Table 3 – Global emissions for the pulp and paper mill

Pollutant	ton/year	kg/h
PM10	102,00	12,14
NOx	526,00	62,62
SOx	1030,00	122,62

For the hourly average calculation was considered 15 days for stop-maintenance and 334 days of work. Since this factory works 24h a day, that period represents 8400 hours of work.

Table 4 shows the global stack characteristics.

Table 4 – Stack characteristics

Stack height [m]	93,15
Stack diameter [m]	3,60
Vertical velocity of release at source exit [m/s]	10,0
Temperature of the release [ºC]	160,0
Stack location	48196,85; 225674,13

3.3 Meteorological Data

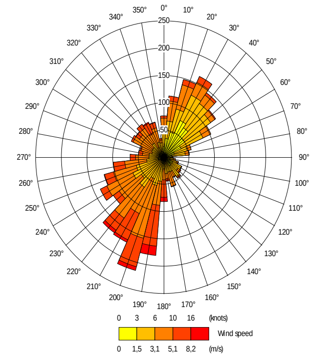
It was used an hourly sequential meteorological data supplied by the Portuguese Institute of Meteorology for the year of 2001.

The summer scenario includes June, July, August and September (Julian days 152 to 273) and the winter scenario comprehends the remaining period of the year 2001. The observed meteorological conditions show 20% of occurrences of clean sky and 13% of sky totally cloudy in the summer scenario. The winter scenario shows 10% of occurrences of sky completely clean and 28% of sky totally cloudy.

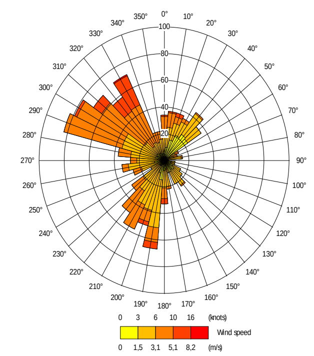
The average wind velocity oscillates between 0,8 and 8,9 m/s in the summer scenario and 0,8 and 12,8 m/s in the winter scenario.

The percentage of calm winds (veloc. <0.55m/s) during winter scenario was 19% and 20 % during summer scenario.

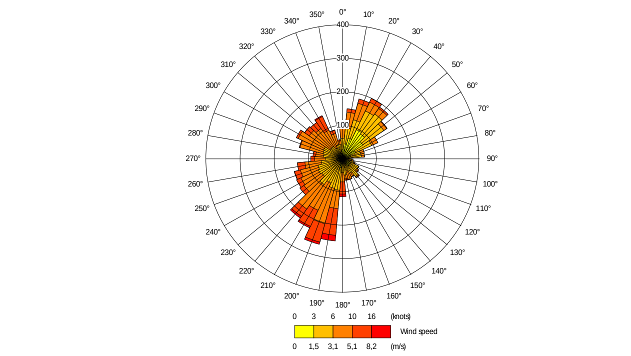
The Figure 2 shows the wind-rose for the meteorological data. The predominant wind direction in winter was North-Northeast/East and South-Southeast/South with a total of occurrences 22.2% and 17,4% respectively. The summer scenario reveals predominant wind direction from South/South-Southwest and from West-northwest/ Northeast, with 19% and 24% of the total of occurrences respectively.



a) winter scenario



b)summer scenario



c) Year long term average

Fig.2 – Wind-roses

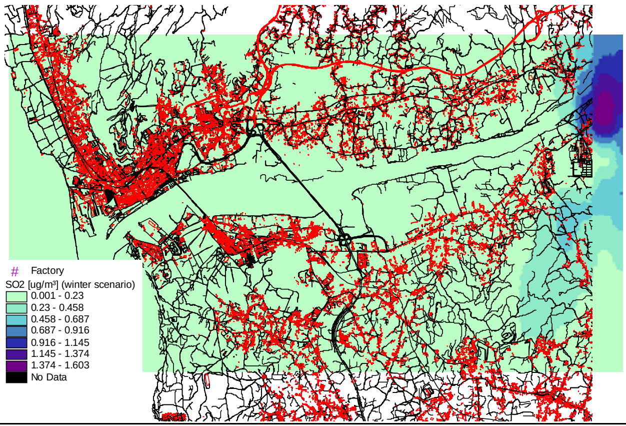
3.4 Calculation of horizontal air pollution maps

The maps of the concentration of the pollutants should be understood as the average situation of the atmospheric pollution i.e. long term maps.

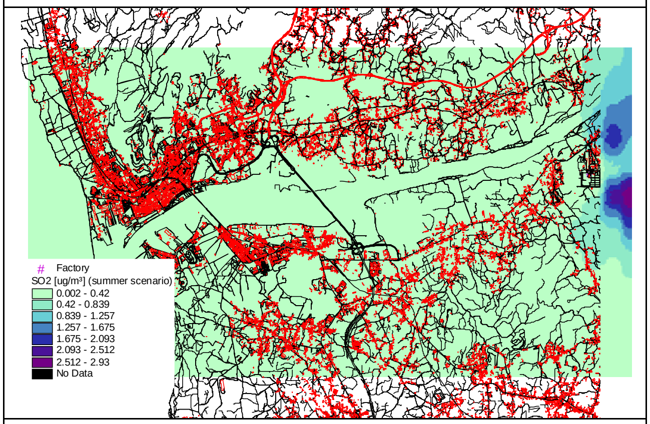
Due to the variable characteristics of wind (velocity and direction) that generate the wind fields along the year, it was created three scenarios:

- The "year long term average" scenario represents one year.
- The "summer scenario" represents the following period: Julian day from 152 to 273.
- The "winter scenario" comprehends the remaining period.

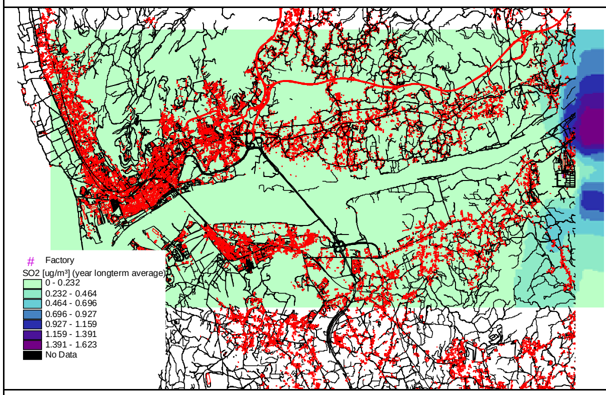
Figures 3, 4 and 5 shows the SO_2, NO_x, and PM_{10} concentrations maps, respectively, obtained from the "winter scenario", "summer scenario" and from the year 2001.



a) winter scenario

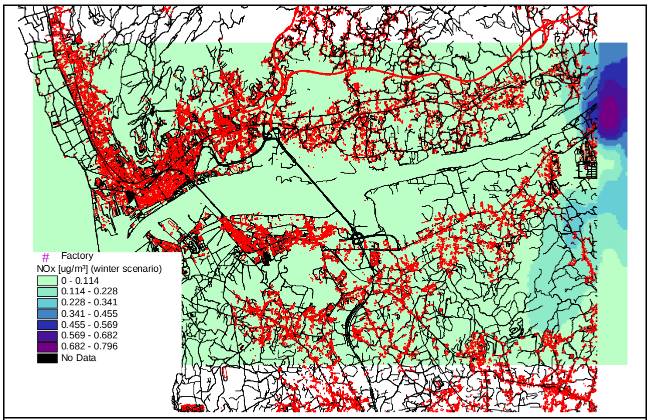


b) summer scenario

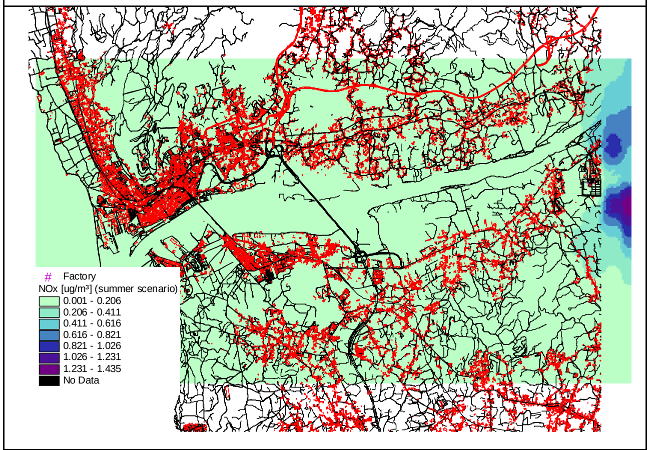


c) year long term average

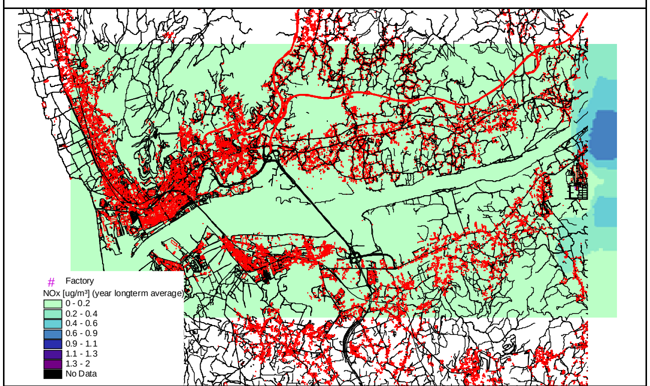
Fig.3 – SO_2 concentration maps



a) winter scenario

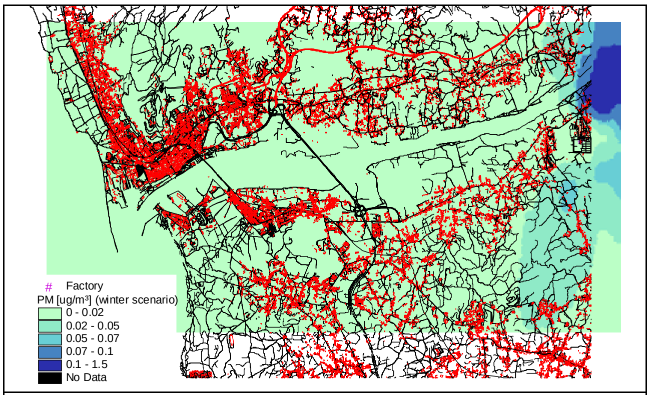


b) summer scenario

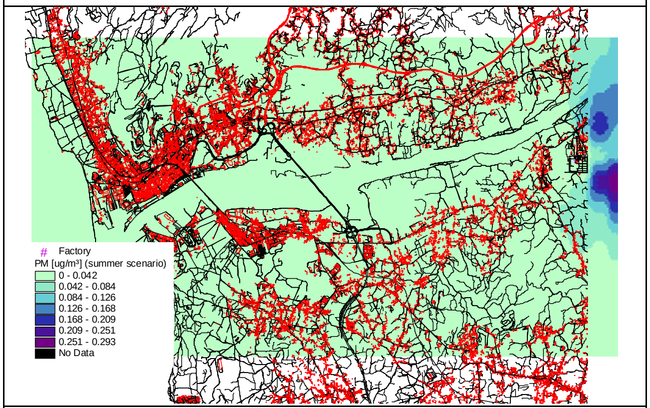


c) year long term average

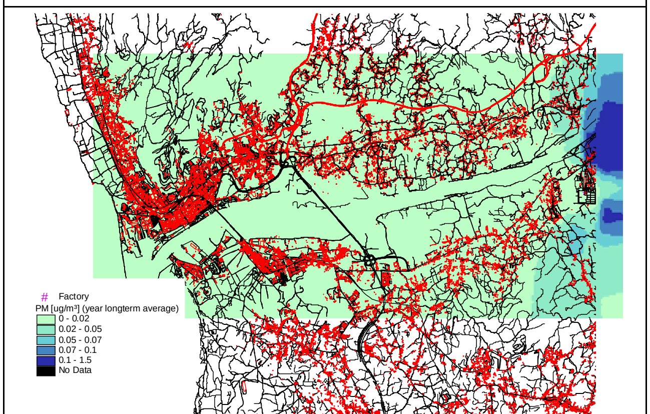
Fig.4 – NO_x concentration maps



a) winter scenario



b) summer scenario



c) year long term average

Fig.5 – PM_{10} concentration maps

6 Discussion and Conclusion

We have evaluated the atmospheric concentrations of particulate matter, sulphite dioxide and nitrogen dioxides in the city of Viana do Castelo, both under the influence of one emission point that represents a pulp and paper mill located in the vicinity of that city.

Due to the variable characteristics of winds (velocity and direction) that generate the wind fields throughout the year, it was created three scenarios:

The "year long term average" scenario, which represents the year 2001; the "summer scenario" representative of June, July, August and September (2001); and the "winter scenario" that comprehend the remaining period of the year 2001.

The first conclusion of this study shows that the pulp mill and paper do not affect air quality in the city of Viana do Castelo.

The Figures 3, 4 and 5 shows that the concentrations of SO_2, NO_x and PM_{10} are higher near the source, in downwind direction.

Depending on the meteorological condition the results show a clear influence on the near vicinity of the factory. As a consequence, the factory contributes with one additive concentration ranging from 0,02 to 1,5 $\mu g/m^3$ of PM_{10}; 0,23 to 1,6 $\mu g/m^3$ of SO_2 and 0,2 to 1,5 $\mu g/m^3$ of NO_x.

The spread of the plume of pollutants generated from the factory reveals a clear tendency to the southwest in the winter scenario and to the northeast in the summer scenario. In the long term concentrations maps the spread of the plume takes the east tendency.

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