A MODEL APPROACH IN RISK ASSESSMENT
A case study in the indutrial area of Porto Marghera, Venice (I)

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1 Introduction

This work is part of the 1998 Environmental Budget worked out by the Regional Environmental Agency (ARPAV), for the industrial area of Porto Marghera, Venice (I).
Using the PSR scheme (OECD, 1994), Pressure (energy and raw materials consumption, air and water emissions, garbage production, ecc.) and State indicators (air, water and soil monitoring, dispersion models, ecc.) have been characterized:

- to better know how the amount of pollution and the consumption of resources are balanced in this industrial site;
- to enable decision-makers, public administrations and industries to set priorities in environmental policies;
- to present the State of the environment in a way that it is understandable for the public;
- to compare the current State of local environment with quality targets.

Porto Marghera industrial site is located 5 km NW the historical center of Venice, between the urban inland (Mestre, Marghera and Malcontenta) and the coastal lagoon.
It spans on an area of 2000 hectares: 1400 ha for industries, 340 ha of water channels; 120 ha for the commercial harbour; 80 ha for roads and railways; 40 ha for State lands.
The main activities are: coke-derived products, refineries, aluminium and semi-finished material production, shipyards, chemistry, fertilizer production. The area counts 295 firms, with 13.740 employees.
In order to achieve a better sustainability in Porto Marghera industrial site, in 1998 national and regional public authorities, in accordance with local industries, signed a program to decrease pollutant emissions. At first, Regional Environmental Agency (ARPAV) evaluated mass and energy balances, collecting production and environmental data, supplied by local industrial plants. Using these data, air toxic emissions from point and area sources were characterized. To define new air emission targets for the various industrial activities (waste treatment, coastal oil storage, fluoride production, energy production, refineries and chemical production) a modeling approach has been followed.

2 Meteorological characterization

The selection of meteorological critical events by listing SO_2 acute concentration episodes in the residential nearby was used for the *Short Term* worst-case simulation, with Mestre and Marghera urban sites leeward the industrial area.

The predominant critical conditions are listed below:

- neutral conditions (“D”stability class);
- mixing height: 50/350 m (winter time); 50/250 (summer time);
- wind direction: from South to North;
- wind speed: 3-4,5 m/s (winter time);. 2-4 m/s (summer time).

For *Long Term* simulation, a Joint Frequency Function was built, considering one year meteorological data (1998). RASS data allowed to compute mixing height and stability classes, while ground meteorological measures allowed to obtain the other model input parameters.

3 Tracers and their emissions

Each production cycle was identified through one or more emitted substances, named “tracers”. A “rough” preliminary health risk assessment, based on emission amount and toxic/carcinogenic effects, allowed this “tracers” selection, from a list of about thirty pollutants investigated.
The choice was made on the basis of an *Impact Index*, computed for each pollutant:

- as product of its total annual emission and its *Unit Risk* ([1]);
- as ratio between its total annual emission (chronic effects) or hour emission (acute effects) and its *Reference Exposure Level* (μg/m^3) ([2]).

The following Tables (1, 2, 3) show the hierarchy, in terms of carcinogenic and toxic (acute and chronic) sanitary potential risk, for all the substances emitted in the industrial area. Selected tracers are pointed out in yellow color.

Table 1 Impact index due to potential carcinogenic effects.

Pollutant	Total Annual Emission (ton/y)	Unit Risk (μg/m^3)$^{-1}$	Normalized Impact Index
Acrilonytrile	4,26	2,90E-04	1
Vinyl chloride	6,6	7,80E-05	4,16E-01
Gasolina	126,56	1,60E-06	1,64E-01
Ethylene chloride	5,9	2,00E-05	9,55E-02
Diesel fuel	24,07	1,60E-06	3,12E-02
Butadiene		1,70E-04	2,44E-02
Lead and its compounds	0,267	8,00E-05	1,73E-02
Benzene	0,419	2,90E-05	9,83E-03
PCDD+PCDF	0,000000073	3,80E+01	2,24E-03
Styrene	2,45	5,70E-07	1,13E-03
IPA	0,00058	1,70E-03	8,02E-04
Acetaldehyde	0,182	2,70E-06	3,97E-04
PCB	0,000077	1,40E-03	8,72E-05
Isocyanate	0,0038	1,10E-05	3,4E-05

Table 2 Impact index due to acute toxic effects.

Pollutant	Total Annual Emission (kg/h)	REL (μg/m^3)	Normalized Impact Index
NO_X	1647,55	4,70E+02	1
SO_X	2211,72	6,60E+02	9,56E-01
Sulfuric acid	2,56	2,50E+01	2,93E-02
Chlorine	0,13	2,30E+01	1,65E-03
Ammonia	3,41	2,10E+03	4,64E-04
Hydrochloric acid	0,97	3,00E+03	9,22E-05
Hydrogen sulfide	0,00477	4,20E+01	3,24E-05
Xylene	0,0766	4,40E+03	4,97E-06
Hydrocyanic acid	0,0209	3,30E+03	1,18E-06
Mercury and its compounds	1,82E-06	3,00E+01	1,73E-08

([1]) The Unit Risk factor is defined as the estimated probability of a person contracting cancer as a result of constant exposure to an ambient concentration of 1 μg/m^3 over a 70 year lifetime.

([2]) The concentration level at or below which no adverse health effects are anticipated for a specified exposure duration is termed the Reference Exposure Level (REL).

Table 3 Impact index due to chronic toxic effects.

Pollutant	Total Annual Emission (ton/y)	REL ($\mu g/m^3$)	Normalized Impact Index
NO_X	14432,54	4,70E+02	1
SO_X	19374,69	6,60E+02	9,56E-01
Acrilonytrile	4,26	2,00E+00	6,94E-02
Hydrochloric acid	8,49	7,00E+00	3,95E-02
Sulfates	22,47	2,50E+01	2,93E-02
Ammonia	29,91	1,00E+02	9,74E-03
Vinyl chloride	6,6	2,60E+01	8,26E-03
Lead and its compounds	0,267	1,50E+00	5,80E-03
Chlorine	1,17	7,10E+00	5,36E-03
Ethylene chloride	5,9	9,50E+01	2,02E-03
Gasoline	126,56	2,10E+03	1,96E-03
Isocyanate	0,0038	9,50E-02	1,32E-03
Toluene	6,33	2,00E+02	1,03E-03
Methyl Alcohol	14,36	6,20E+02	7,54E-04
PCDD+PCDF	0,000000073	3,50E-06	6,79E-04
Halogenated Organic Substances	14,46	7,00E+02	6,73E-04
Acetaldehyde	0,182	9,00E+00	6,58E-04
Diesel fuel	24,07	2,10E+03	3,73E-04
Benzene	0,419	7,10E+01	1,92E-04
Dimethylamine	0,0084	2,00E+00	1,36E-04
Styrene	2,45	7,00E+02	1,14E-04
Hydrocyanic acid	0,183	7,00E+01	8,52E-05
Xylene	0,671	3,00E+02	7,28E-05
Hydrogen sulfide	0,0418	4,20E+01	3,24E-05
Phtalate	0,005	7,00E+01	2,33E-06
PCB	0,000077	1,20E+00	2,09E-06
Mercury and its compounds	0,000016	3,00E-01	1,73E-06

Sulphur Dioxide, Chlorine, Acrylonitrile and Vinyl Chloride are emitted respectively by 43, 6, 28 and 6 stacks or point sources. Total annual emission for the selected substances are: Sulphur Dioxide: 19375 ton/y; Chlorine: 1,17 ton/y; Acrylonitrile: 4,26 ton/y; Vinyl Chloride: 6,60 ton/y.

4 Model approach and computational results

The modelling approach objective was to assess short and long term impact on environment and health due to air emissions (Pressure), and to evaluate the sustainability of emission reduction policies in the industrial area of Porto Marghera.

Short and long term scenarios have been performed to evaluate acute and chronic sanitary impact. According to EPA Risk Assessment Guidelines (CAPCOA, 1993), ISC3 (Industrial Source Complex) model was used to compute air pollutant concentrations.

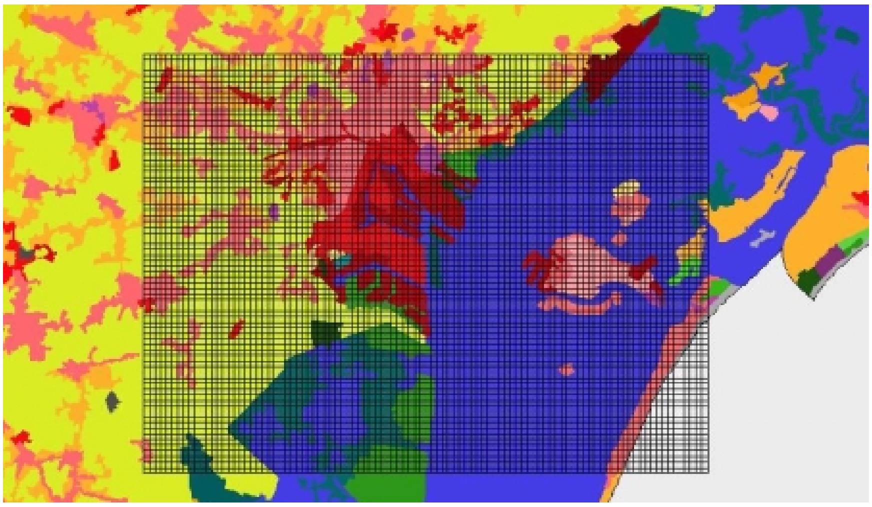

Figure 1 Computational domain (this and next figures have been produced with Nebula-LTK).

This gaussian model, developed by EPA and AMS, is based on stability classes approach. Since a single wind speed and direction is used in the whole domain, tThe used domain, a rectangle 20x15 km^2 wide (100x75 cells) centered on the industrial area of Porto Marghera (Figure 1), partially satisfies these hypothesis.
In Tables 4 and 5 short term results are reported, for winter and summer simulations. In Table 4 two more simulations are reported, considering a mixing height of 275 m, so that all the emissions are included in the mixing layer. In Table 6, 1998 long term simulations are reported.

Table 4 Short term simulation for Sulphur Dioxide (winter and summer time).

Sulphur Dioxide	Winter ($\mu g/m^3$)	Summer ($\mu g/m^3$)	Winter (Hmix=275 m) ($\mu g/m^3$)	Summer (Hmix=275 m) ($\mu g/m^3$)
Mean	43,6	12,4	33,8	43,8
Max	466,4	414,5	556,9	499,1
98° perc.	292,8	100,3	295,4	318,6
95° perc.	221,6	71,6	220,2	241,4
90° perc.	159,9	51,6	147,0	162,0

Table 5 Short term simulation for Chlorine (winter and summer time).

Chlorine	Winter ($\mu g/m^3$)	Summer ($\mu g/m^3$)
Mean	0,0028	0,0045
Max	0,1506	0,1814
98° perc.	0,0311	0,0512
95° perc.	0,0219	0,0364

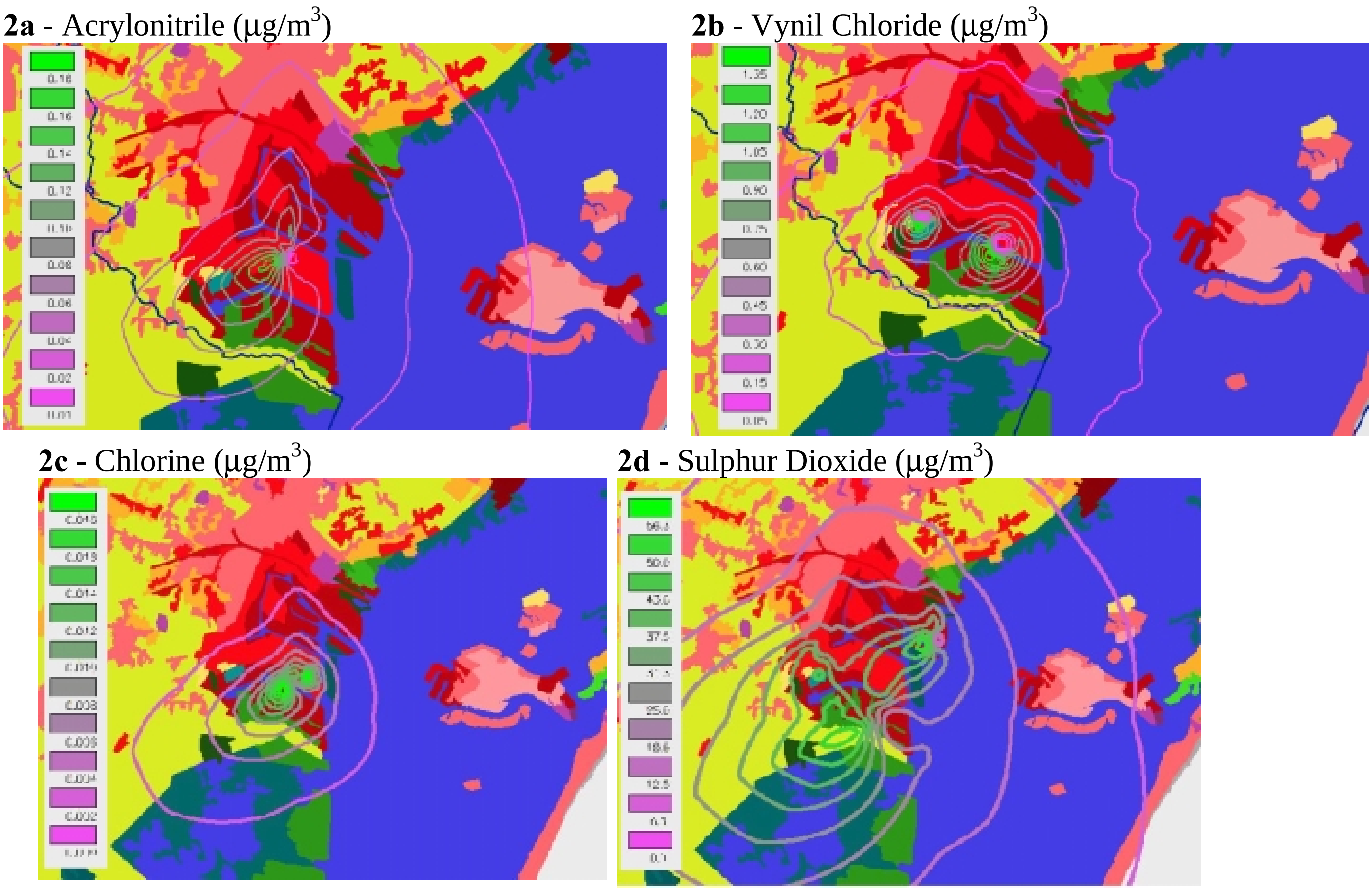

Figure 2 Long Term simulations.

Table 6 Long term simulation for Sulphur Dioxide, Chlorine, Acrylonitrile (1998).

	Sulphur Dioxide (µg/m^3)	Chlorine (µg/m^3)	Acrylonitrile (µg/m^3)	Vinyl Chloride (µg/m^3)
Mean	15	0,0013	0,0179	0,0635
Max	72	0,0329	0,1704	1,5251
98° perc.	44	0,0058	0,0679	0,4099
95° perc.	37	0,0036	0,0462	0,2155

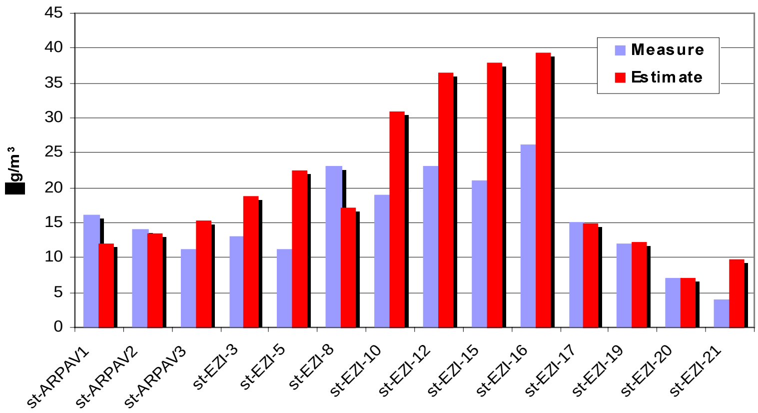

Figure 3 Comparison between SO_2 measures (µg/m^3, annual mean) and estimates (µg/m^3, annual mean).

Long term SO_2 simulation results were compared with data collected by 14 stations of the local air monitoring networks (see Figure 3). Correlation is good, as shown by the following parameters:

- correlation coefficient: 0,78;
- bias: 8,9 µg/m^3;
- root mean square error: 6,7 µg/m^3.

5 Conclusions and developments

Application of short term ISC3 gaussian model, to Sulphur Dioxide and Chlorine, pointed out the lack of acute health risk referable to these substances, in fact:

- SO_2 maximum value (466 µg/m^3) is lower then its acute REL (660 µg/m^3);
- Cl maximum value (0,1814 µg/m^3) is lower then its acute REL (23 µg/m^3).

This was conformed by the long term form:

- SO_2 maximum value (72 µg/m^3) is lower then its chronic REL (660 µg/m^3);
- Cl maximum value (0,0329 µg/m^3) is lower then its chronic REL (7,1 µg/m^3).

The evaluation of carcinogenic risk referred to Acrylonitrile and Vinyl Chloride concentration computed with the model (Figures 2a, 2b), the implementation of emission data bases, increasing the number of firms and pollutants, the analysis of incidental scenarios and the performance of more advanced dispersion models (e.g. the eulerian Calpuff and Spray) are the future steps of this work.

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