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IMPACT ASSESSMENT OF POLLUTANT EMISSIONS IN THE ATMOSPHERE FROM A POWER PLANT OVER A COMPLEX TERRAIN

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ABSTRACT

The development of a natural gas-fired tri-generation power plant (520 MW Combined Cycle Gas Turbines (CCGT) + 58 MW) in the Republic of San Marino (RSM), a small independent country in Northern Italy, is under assessment. The power plant has the aim to meet completely the energy requirements of RSM and export part of its production to Italy. The present work investigates the impact assessment of pollutants emitted in the atmosphere from the power plant stacks, subjected to the regulatory limits defined by the Italian law (DL 152/2006 and DL 46/2014, implementation of 2010/75/EU). The impact assessment was performed via lagrangian simulation of the atmospheric dispersion of the emitted plume by the means of the Aria Industry package (Aria Technologies, France, and Arianet, Italy). The dispersion was simulated for NO_x and CO pollutants. The simulated concentrations were compared with the air quality limits of the Italian law (DL 155/2010 implementation of 169 2008/50/EC). Since the simulated concentration of CO were widely lower than the regulatory limits, the simulation focused only on NO_x.

DOMAINS AND METHODS

Spatial domain

40 x 40 km², 200 m square cells, 10 layers on vertical grid, 1500 m top level → diagnostic wind, temperature and concentration fields

20 x 20 km², 100 m square cells → only concentration fields

Simulation periods

10-days periods representative of low, moderate and large atmospheric dispersion conditions of 2014:

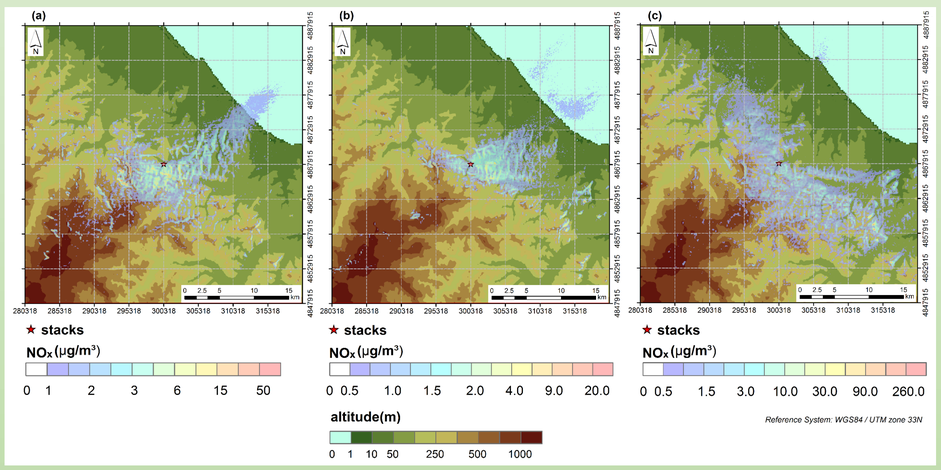
- ✓ March 11th and 20th (worst-case meteorological condition)
- ✓ June 6th to 15th
- ✓ June 19th to 28th
- ✓ November 8th to 17th.

RESULT

The simulation results for the most critical period, from March 11th to 20th, is shown at right as maps (a and b) of average hourly NO_x concentrations from the plume emitted by the power plant, in the first atmospheric layer (10 m) of the spatial domain (20 x 20 km² (a), and 40 x 40 km² (b)).

The simulated plume appears stretched approximately from West to East. The average hourly NO_x concentration maximum value in the investigated period is 65 µg/m³, at about 5 km West from the power plant, close to the Mount Titano relief, that represents a physical barrier to the plume dispersion. The plume concentration at ground over the domain is lower than 2 µg/m³. On the larger domain (b) isolated concentration peacks with maximum values of about 90 µg/m³ occur against natural obstacles (as hills), about 25 km South - East of the plant.
The maximum average hourly NO_x ground concentration for March 14th (representative day for local sea-breeze effect evaluation), was 110 µg/m³ and occurred close to the Mount Titano, due to the local sea-breeze combination with the prevailing atmospheric circulation at mesoscale. The average plume value for the domain is equal to 2.2 µg/m³.

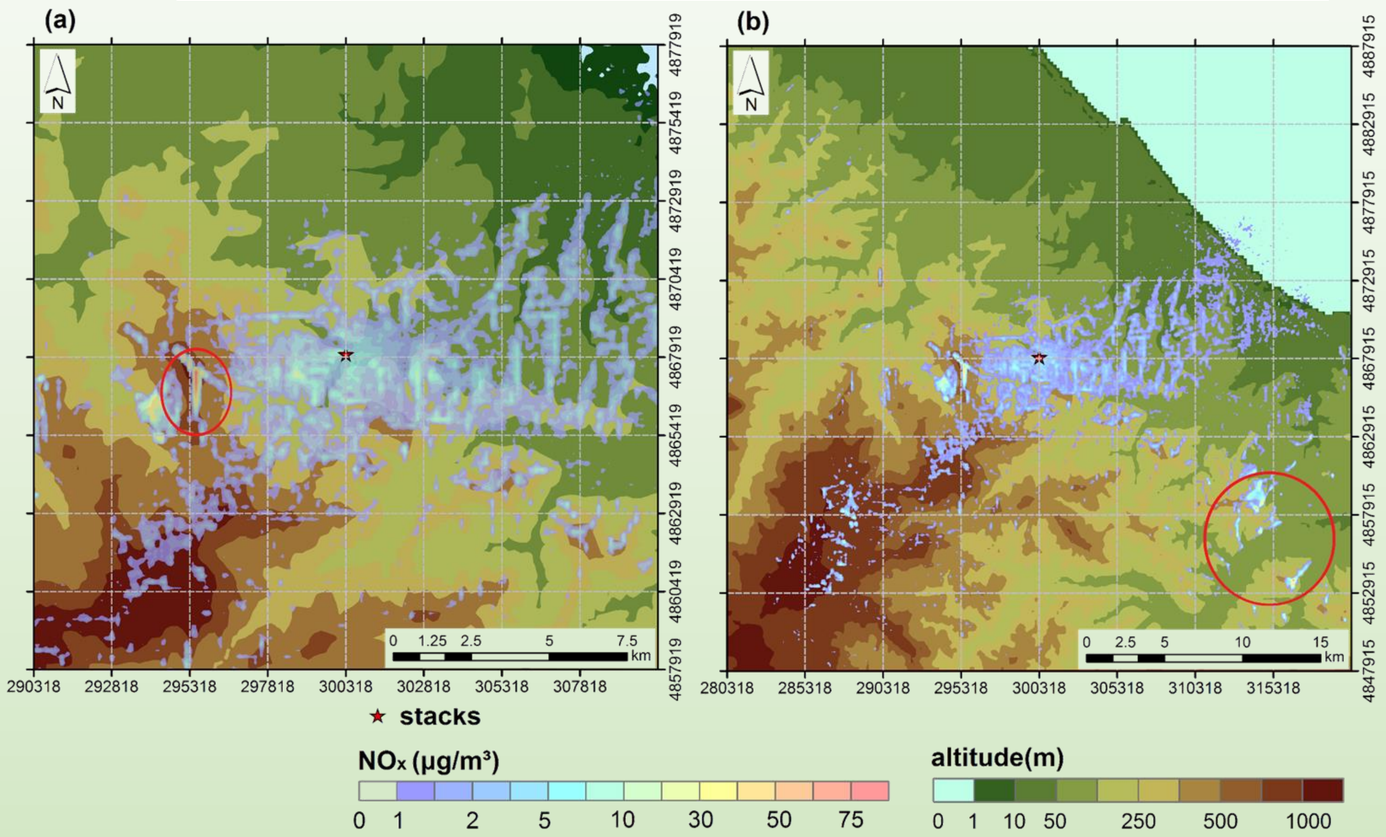
In the other analyzed periods the average hourly NO_x concentration maxima result 77 µg/m³ ((a) June 6th to 15th), 30 µg/m³ ((b) June 19th to 28th) and 390 µg/m³ ((c)November 8th to 17th) respectively (maps below).

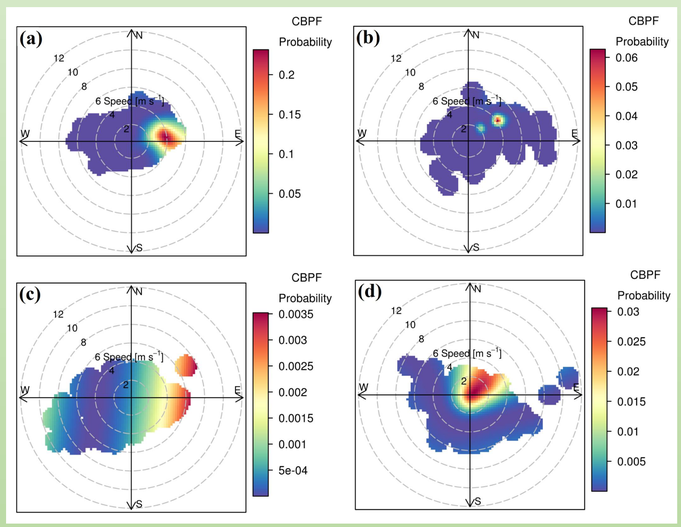


COGENERATION PLANT

The cogeneration plant is the Mitsubishi MHPS GT Model M701F5 and H-25(42) Combined Cycle Gas Turbines (CCGT, 520MW and 58MW thermal power) powered by methane gas. For the plant, whose efficiency η = 61% (as assured by the Manufacturer), the NO_x emission limit results in 52 mg/Nm³ and 100 mg/Nm³ for CO in dry exhaust gas (DL 46/2014). The emitted NO_x concentration was set to 50 mg/Nm³ , as provided by the Manufacturer, and slightly below the emission limit of 52 mg/Nm³ .

Source unit	Stack height	Stack inner diameter	Exhaust gas flow	Exhaust gas temperature	Gas exit velocity	NO_x
	(m)	(m)	($Nm^3\ h^{-1}$)	(°C)	($m\ s^{-1}$)	($mg\ Nm^{-3}$)
M701F5 CCGT	70	6.2	1 885 000	85	25	50
H-25(42) CCGT	70	2.7	290 000	85	20	50





The NO_x pollutant roses for the four simulation periods performed using SWIFT wind data for the source point at the plant stack elevation and the hourly NO_x ground simulated concentrations in a 100 m x 700 m area over the Eastern slope of Mount Titano were used to obtain conditional bivariate probability functions (CBPF) (figure at left).
The concentration range used to compute CBPF considered levels larger than the regulatory limit of 200 µg/m³ .
The outcome of CBPF were compared to the 2014 wind rose at the meteorological ground station closest to the plant, that shows the percentage of wind conditions (winds from Northeast - East and calms) that may be responsible of concentration peaks around the Mount Titano area: the frequency of the wind events blowing from Northeast – East is of about 11% while the calms correspond to 7.0% in the year.

CONCLUSIONS

In spite of the very high pollutant emission rate from the plant stacks, the simulation showed a limited environmental impact: average hourly concentration at ground level were very low, with only isolated peaks where the emitted plume hits the mountain reliefs.
The investigation shows that the regulatory limit for average hourly NO_x concentration is already exceeded more than 18 times during the investigated periods, but limited to a wide, steep slope area along the cliff of Mount Titano. Due to its location respect to the source, this area may be considered the most exposed to a local accumulation of pollutants emitted from the power plant.
Single peaks (in scattered domain cells) mainly occur in different areas of the domain for each simulated period, without the evidence of recurring accumulation points. CO ground concentrations resulted always largely lower than the regulatory limits.
The paper highlighted the SPRAY ability in reliably simulating the dispersion of a pollution plume through a complex terrain and under unsteady wind conditions.

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