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Air pollution and air quality state in an Italian National Interest Priority Site. Part 2: the pollutant dispersion

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Abstract

In Campania region, southern Italy, a National Interest Priority Sites (NIPS) was identified: "Litorale Domitio-Agro Aversano" NIPS L.426/98, that includes a large part of the polluted agricultural land, belonging to more than 61 municipalities in the Naples and Caserta provinces. This second paper represents an analysis developed for a LIFE project (LIFE11/ENV/IT/275–ECOREMED): "Implementation of Eco-Compatible Protocols for Agricultural Soil Remediation in Litorale Domizio-Agro Aversano NIPS". The contribution of this second paper to the above-mentioned LIFE project consists in the appraisal of the air quality state in this NIPS area, estimating the pollutant concentrations of the main air pollutants (CO, VOC, NO_X and PM_{10}) in the area under investigation due to the principal industrial systems (namely punctual sources) and to the main diffused sources. All entropic activities which determine emissions in the atmosphere, in fact, depending on the distance from the areas under examination, could contribute to the soil qualification. The assessment of the air quality to local scale was carried by integrating the data of emission inventory in the NIPS area, that was estimated and reported in the first paper (Part 1), with elaborations of a Gaussian dispersion model.

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Keywords: air pollution; emission inventory; air quality state; gaussian dispersion model

1. Introduction

In Campania region, Southern Italy there were identified four National Interest Priority Sites (NIPSs), for a total surface of about 200.000 ha, with different levels and sources of pollution (Napoli Orientale, Litorale Domitio-Agro

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Aversano NIPS L. 426/98, Napoli bagnoli coroglio L. 388/2000, Litorale Vesuviano L. 179/2002, Bacino idrografico del Sarno L. 266/05; Aree di Pianura DM 445/2008).

Among these, the Litorale Domitio-Agro Aversano NIPS includes a large part of the polluted agricultural land, belonging to more than 61 municipalities in the Naples and Caserta provinces. In this area a high level spotted soil contamination is moreover due to the legal and outlaw industrial and municipal wastes dumping, with hazardous consequences also on the quality of the air and water table. Moreover there is a general perception of health risks due to the contamination of human food and air due to surface depositions of particles from waste combustion; recent studies carried by the International Society of Doctors for the Environment evidenced a 20% increase of human cancers in Naples and Caserta provinces.

The problem of contamination in Litorale Domitio-Agro Aversano NIPS, is linked to several European Environmental principles:

1. The food safety regulation
2. The polluter pays principle
3. The sustainable development strategy

As regarding the food safety, the Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 emphasizes the free movement of safe and wholesome food is a key principle in the smooth functioning of the internal market. Surveys, performed in 2002 confirmed the presences of PCDD/PCDF in milk, dairy products and food for animal consumption. The contamination of milk, crops and livestock in Litorale Domitio-Agro Aversano NIPS caused a strong economic damage for the local farmers but also a problem for the whole EU market, causing the retirement of several products from supermarkets.

The second point, the polluter pays principle that is endorsed to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment is not applicable to this case. In fact, in most cases, the farmers have their fields contaminated by criminal organizations and however they would be liable of remediate their own property.

The third point is the sustainable development strategy (Commission Communication of 13 December 2005 on the review of the Sustainable Development Strategy – A platform for action, COM (2005) 658), which represents a real turning point in the European Environmental policy, providing a coherent soil preservation framework for member states aimed to maintain soil chemical, physical and biological fertility, through the identification of contaminated sities and the definition of a national remediation strategy [1].

The sustainable development and the improvement of the environment are, then, main objective of the National and Europeans politics. The most recent European and Italian legislative decrees that have regulated the environmental matter, in fact, are oriented to planning and determination of the more opportune strategies for health safeguard and for ecosystem protection. It appears reasonable, therefore, that the environmental programming must use appropriate cognitive instruments to estimate the air quality state and the origins of air pollutions in order to support prevention and reorganization decisions. In this context, the inventory of emission sources and the environmental zoning of the territory are fundamental cognitive element for the planning activity and for air quality management [2].

This second paper fits exactly in this context, representing a synthesis of a study developed by the Department of Industrial Engineering (University of Naples Federico II) for a LIFE project (LIFE11/ENV/IT/275 – ECOREMED): "Implementation of Eco-Compatible Protocols for Agricultural Soil Remediation in Litorale Domizio-Agro Aversano NIPS". The contribution of the paper to this LIFE project consists in the appraisal of the air quality state in this NIPS, estimating the pollutant concentrations of the main air pollutants (CO, VOC, NO_X and PM_{10}), due to both the principal industrial systems (namely punctual sources) and to the main diffused sources in the area under investigation. Among the latter sources, the "road traffic" sector was taken into account in great detail [3, 4, 5]. In order to define the air quality state all over the territory of the NIPS area under well-specified conditions resulting from the available data of the emission inventory, that was shown in the first paper (Part 1), the analysis was carried out by using the Gaussian dispersion model ISC [6]; validation of these estimated concentrations was done by reference to real measurements [7].

All the results obtained in this study for the Litorale Domitio-Agro Aversano NIPS are important tools for studying air quality and to set up possible remediation plans in areas characterized by nonattainment of the limit values established by legislation. Besides, these dispersion models and emission projection scenarios are the only tools existing to forecast the agreement of future limit values established by laws.

2. Methods: the Gaussian Dispersion Model

The atmospheric emission inventory described in the first paper is a collection of data related to the emissions of pollutants into air in the NIPS area. These data include the chemical identity of the pollutants, a quantification of the human or natural activity responsible for the emission, the emission factors or the information needed for their calculation, the location and the temporal variation of the emissions for each activity. On the other hand, this emission inventory represents also an important cognitive element in order to organize the input data for atmospheric dispersion models which, according to the Directive, can be used to estimate air quality under well-specified conditions, that is the object of this second paper. As explained above, in fact, it seems understandable that in recent days the national and European programming must use suitable tools and instruments to characterize the sources of air pollutions and to estimate the air quality state in order to support prevention and reformation decisions. In this context, the dispersion models are very important instruments to analyze the physical phenomena regarding the gas atmospheric diffusion with a deterministic approach, also considering meteorological factors.

The dispersion models are therefore calculation tools that, through equations and algorithms, allow to describe in simplified way the phenomena (much complex) of the pollutant dispersion in atmosphere. The inputs of the dispersion models are the meteorological data (opportunely processed) acquired from the weather stations, and the polluting emission (from inventory); the output will be the concentration of the same pollutant in a specified point of the territory object of the simulation. The choice of the models to use for the simulation of the pollutant dispersion in atmosphere depends on various factors, the main ones are: the detail and the accuracy of the available database (emission inventory, meteorological factors, air quality data), the morphological complexity of the area under investigation, the characteristics of the emissive sources that are simulated, field of application (urban, rural or industrial area), the detail of the results that are desired to obtain [8].

The model proposed for the specific requirements of this analysis is the well-known Gaussian model ISC (Industrial Source Complex). Although the fundamental assumption of the Gaussian approach, that is the normal distribution of the concentrations, comes true in absolutely ideal conditions of atmosphere homogenous turbulence, the models that are based on this hypothesis are instruments of widest employment because they are characterized from a simple and practical use. The mathematical structure has an easy formulation and the results of the elaborations are in accordance with experimental data, above all for estimates in long term. On the other hand, the Gaussian method sure turns out not much suitable to deal situations characterized from not homogenous atmospheres, complex orography and unstable pollutants.

The ISC Short Term model provides options to model emissions from a wide range of sources that might be present at a typical industrial source complex. The basis of the model is the straight-line, steady-state Gaussian plume equation, which is used with some modifications to model simple point source emissions from stacks, emissions from stacks that experience the effects of aerodynamic downwash due to nearby buildings, isolated vents, multiple vents, storage piles, conveyor belts, and the like. The ISC Short Term model accepts hourly meteorological data records to define the conditions for plume rise, transport, diffusion, and deposition.

For the specific requirements of this analysis the ISC model was used in the long-term version. The ISC long-term model makes the same basic assumption as the short-term model, and uses input meteorological data that have been summarized into joint frequencies of occurrence for particular wind speed classes, wind direction sectors, and stability categories. In the long-term model, the area surrounding a continuous source of pollutants is divided into sectors of equal angular width corresponding to the sectors of the seasonal and annual frequency distributions of wind direction, wind speed, and stability.

3. Results and Discussion

The definition of the air quality state all over the territory of the NIPS area was performed by integration of the available data resulting from the emissions inventory, that was estimated and reported in the first paper (Part 1), with the Gaussian model ISC, in order to define the concentrations of the main air pollutants (CO, VOC, NO_X and PM_{10}), due to the principal industrial systems (namely punctual sources) and to the main diffused sources [9].

The gas atmospheric dispersion was analyzed on maps with meshes of 1 km x 1 km, characterized by receptors positioned at 2 m altitude. Under these conditions the application of the model determined the pollutant concentrations due to the principal industrial systems (namely punctual sources) and to the main diffused sources all over the territory.

The main results of the simulations provided by the model are shown in the maps of Figure 1, in which it's possible to gain the estimated concentrations of CO, NO_X, PM_{10} and VOC in every mesh of the reticulum in the central zone of the NIPS area. As already presented in the first paper (Part 1), in fact, the main punctual sources of atmospheric pollution and the maximum values of the emission density are located in the Naples-Caserta zone. The meteorological data needed to run these simulations are the values of the Naples airport weather station, properly processed.

Validation of these results was done by reference to real measurements. Initially a set of air monitoring stations were selected as significant in order to generalize the measures detected from these stations all over this territory [10,11]. Subsequently these stations were attributed to specific meshes 1 km x 1 km of the same reticulum used for the spatial dispersions of the pollutant emissions. For these meshes, the real measured concentrations were compared with predicted values of the models so calculating the percentage differences, that were always below 15 %, then acceptable [12]. In Table 1, besides, for the same investigated pollutants, the values of the minimum, average and maximum concentrations, obtained with the use of the Gaussian model ISC, are reported for each municipality of this examined zone.

Ultimately, by application of simulation model all over the NIPS area and for all pollutants, the territory environmental zoning will be obtained through the comparison between the air quality present background (that it's emerged by means of the estimate mathematical model) and the existing law standards, therefore individualizing the more critical zones of this area in which the value of the pollutants exceeds the limit fixed from the environmental legislation in force. Starting from these results it will be possible to formulate maintenance and remediation actions; in this way, the atmospheric emission inventories and the territory environmental zoning become a primary and essential cognitive element for the air quality management and they are also necessary to set up remediation programs in areas characterized by pollution problems [13].

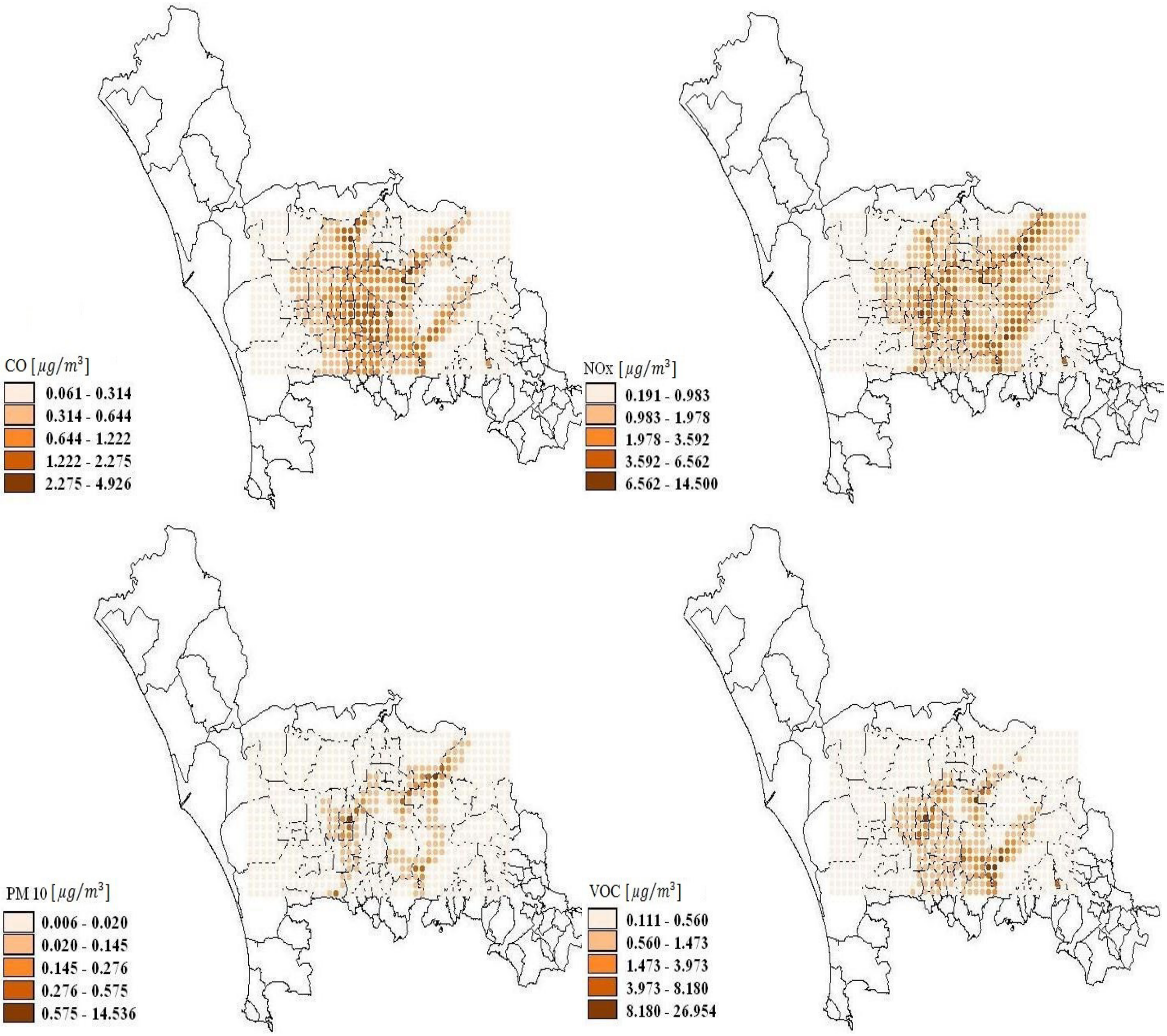

Fig. 1. CO, NO_X, VOC and PM_{10} concentrations [μg/m³] estimated through Gaussian model ISC in the central zone of the NIPS area

Table 1. CO, NO_X, VOC and PM_{10} concentrations for each municipality of the examined zone.

	CO [μg/m³]			NO_X [μg/m³]			VOC [μg/m³]			PM_{10} [μg/m³]		
Municipality	min.	av.	max.	min.	av.	max.	min.	av.	max.	min.	av.	max.
Arienzo	0,080	0,282	0,314	0,398	0,429	0,784	0,172	0,221	0,332	0,026	0,032	0,054
Aversa	0,084	0,278	0,295	0,418	0,455	0,840	0,182	0,233	0,352	0,027	0,034	0,058
Cancello ed Arnone	0,092	0,265	0,276	0,438	0,482	0,831	0,192	0,243	0,363	0,029	0,037	0,057
Capodrise	0,107	0,220	0,270	0,461	0,513	0,786	0,202	0,249	0,370	0,030	0,040	0,054
Capua	0,085	0,179	0,251	0,478	0,550	0,721	0,208	0,243	0,357	0,030	0,041	0,050
Casaluce	0,088	0,149	0,230	0,479	0,587	0,707	0,214	0,233	0,342	0,030	0,041	0,049
Casapulla	0,093	0,112	0,221	0,469	0,590	0,685	0,213	0,223	0,330	0,029	0,039	0,048
Caserta	0,128	0,210	1,456	0,452	0,582	0,934	0,203	0,216	0,420	0,028	0,037	0,079
Cervino	0,094	0,119	0,197	0,435	0,556	0,622	0,195	0,211	0,307	0,027	0,034	0,065
Curti	0,090	0,106	0,184	0,415	0,526	0,566	0,187	0,206	0,289	0,026	0,034	0,074
Grazzanise	0,088	0,091	0,168	0,397	0,497	0,513	0,181	0,200	0,267	0,025	0,034	0,039
Gricignano di Aversa	0,077	0,154	0,278	0,391	0,489	0,480	0,176	0,193	0,240	0,025	0,035	0,036
Maddaloni	0,064	0,141	0,266	0,384	0,479	0,446	0,171	0,185	0,225	0,024	0,035	0,032
Marcianise	0,061	0,174	0,251	0,376	0,468	0,420	0,166	0,174	0,211	0,025	0,033	0,030
Orta di Atella	0,196	0,081	0,237	0,366	0,455	0,503	0,160	0,169	0,200	0,024	0,031	0,035
Parete	0,177	0,076	0,236	0,354	0,438	0,531	0,154	0,163	0,243	0,024	0,029	0,037
Portico di Caserta	0,157	0,268	0,249	0,342	0,408	0,550	0,148	0,157	0,261	0,023	0,027	0,037
Recale	0,145	0,265	0,275	0,333	0,388	0,575	0,146	0,189	0,279	0,023	0,025	0,039
San Cipriano d'Aversa	0,130	0,263	0,295	0,320	0,369	0,636	0,142	0,201	0,299	0,021	0,029	0,042
San Felice a Cancello	0,113	0,263	0,282	0,307	0,351	0,710	0,137	0,215	0,321	0,020	0,031	0,048
San Marcellino	0,100	0,260	0,271	0,409	0,438	0,811	0,176	0,231	0,351	0,027	0,033	0,057
San Nicola la Strada	0,102	0,242	0,251	0,430	0,467	0,665	0,186	0,248	0,380	0,028	0,036	0,066
San Prisco	0,101	0,233	0,222	0,452	0,494	0,922	0,198	0,259	0,396	0,029	0,039	0,066
Santa Maria Capua Vetere	0,092	0,222	0,267	0,478	0,530	0,884	0,211	0,268	0,409	0,031	0,043	0,063
Santa Maria la Fossa	0,107	0,209	0,258	0,507	0,572	0,806	0,221	0,269	0,406	0,032	0,046	0,057
San Marco Evangelista	0,085	0,196	0,249	0,510	0,618	0,790	0,227	0,259	0,388	0,032	0,046	0,056
Acerra	0,088	0,177	0,243	0,507	0,638	0,764	0,230	0,248	0,371	0,031	0,044	0,055
Caivano	0,093	0,157	0,246	0,490	0,640	0,735	0,222	0,241	0,355	0,030	0,041	0,053
Giugliano in Campania	0,128	0,145	0,258	0,469	0,611	0,668	0,213	0,235	0,342	0,029	0,039	0,058
Nola	0,067	0,130	0,273	0,447	0,576	0,600	0,204	0,227	0,319	0,028	0,038	0,045
Pomigliano d'Arco	0,065	0,113	0,264	0,426	0,541	0,538	0,197	0,222	0,290	0,027	0,038	0,042

4. Conclusion

The aim of this paper was to provide the environmental characterization of the “Litorale Domitio-Agro Aversano” NIPS area for a LIFE project (LIFE11/ENV/IT/275–ECOREMED), estimating the air quality state to local scale through the use of a dispersion model. The pollutants covered by this analyses are: carbon monoxide (CO), nitrogen oxides (NO_X), particulate matter (PM_{10}) and volatile organic compounds (VOC).

The results obtained in this study supply a valid environmental programming instrument and an important tool for studying air quality and to set up possible remediation plans in the zones of the investigated area that are characterized by nonattainment of the limit values established by legislation; starting from these maps and these tools, it will be possible to formulate maintenance and remediation actions. In fact, the same procedures and simulation models can be used to examine strategies oriented to the air quality improvement; so new emissive background will be defined according to the adoption of new environmental laws and to the virtual implementation of low environmental impact technologies in the several analysed fields (transports, productive activities, energetic efficiency, etc.). However, future changes in pollutant emissions and in the air quality will be affected intensely by the evolution in anthropogenic emissions, that are always regulated by economic growth, environmental policy, and future application of emissions controls. Lastly, the emission inventory and this environmental characterization must be considered as a dynamic instrument since both the updating of many information and the data reliability and detail are in continuous evolution and improvement.

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