18th International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 October 2017, Bologna, Italy

MODELLING AND EVALUATION OF EMISSION SCENARIOS DERIVING FROM WOOD BIOMASS BOILERS IN ALPINE VALLEY

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Abstract: In recent years there has been an increasing spread of wood biomass. The use of wood biomass as a fuel for domestic and industrial heating systems allows for a reduction of CO_2 emissions at a global scale, but it may also result in worse local air quality conditions, due to their emissions of particulate matter, in particular, and other pollutants. The aim of this study is to assess the trends of atmospheric pollution in a study area, assuming that all heating systems are replaced by small size biomass boilers linked to the buildings through district heating network. Ground level concentrations of PM, emitted by different heating systems, have been evaluated through numerical simulations performed by means of an atmospheric dispersion model. The impact of such a network have been analysed taking into account different emission scenarios, related to different boilers operating conditions. Results show that the environmental performances of a woodchip boilers network can be optimized by combining it with other renewable source of energy devoted to the supply of hot water. A sensitivity analysis has been done in order to observe how modification in some input data can influence the results and allow to improve the design hypothesis.

Key words: *Wood biomass, particulate matter, atmospheric emissions, pollutant dispersion modeling, environmental sustainability*

INTRODUCTION

In recent years there has been a growing spread of the use of renewable energy sources. Notably, a sharp increase of consumptions concerns the wood biomass, since its costs are highly competitive compared to other source of energy, especially for domestic heating (Stolarski et al., 2013).

An environmentally sustainable use of this energy source depends mainly on a correct exploitation of the forest resources and on the control of atmospheric pollutants emissions. Assuming that the timber consumption is suitably regulated by the forest management policies (Mendoza and Prabhu, 2014), the environmental impact of these systems is almost fully linked to pollutant emissions in the atmosphere. Replacing fossil fuels with wood biomass certainly reduce the total CO_2 emissions on a global scale, but may result in higher emissions of PM, PAHs and COVs, and therefore worse air quality conditions at the local scale. There are two main pollutant emissions related to the use of wood biomass as a fuel: release of combustion products from the heating systems and of pollutants from the vehicles transporting the wood. Therefore, large heating systems are not sustainable in regions where the timber availability is limited, such as alpine territories, since their adoption would require the transportation of huge amount of fuel for long distances, which would cause relevant vehicular pollutant emissions due to transport. In these conditions, smaller systems are best suited, as far as their need can be supplied by the timber present in the surrounding territory. Today, the use of reduced size systems is currently increasing in alpine regions (Paletto et al., 2013). In a perspective of a subvention of wood heating systems to replace traditional fuels, the environmental impact of these heating systems must be taken into account.

The most significant pollutants resulting from the installation of these plants are PM, NO_X and SO_2. In particular according the literature analysis, particulate matter emissions are particularly critical (Boman et

al., 2003). The impact of these systems in regions where atmospheric PM concentrations are significant must be carefully assessed. Critical air quality conditions can be further worsened if other pollutants sources are added (Pizzo and Clerico, 2012). Moreover, also if the limit values are not reached, disturbance and annoyance factors for the resident populations have to be considered (Bo et al., 2016).

The aim of the study is the assessment of the impacts on PM concentrations of a network of wood biomass heating systems located within an alpine valley in the north of Italy. The objective is the assessment of the hypothesis of the progressive replacement of traditional fossil fuel boilers with wood biomass boilers. In particular, the aim of the present research is, starting from already published results (Pognant et al., 2017), to observe how the results can be influenced changing some input data and how this modification can be considered in order to better understand the issue and improve the design hypothesis.

METHOD

The first phase of research has identified the emission scenarios that could best approximate the assumption of complete replacement of the current fossil fuel heating network. The scenario was constructed by considering some simplified hypotheses that would enable the modeling but which were, however, representative of the situation being analysed.

To estimate the air concentration of PM at ground level, simulations of atmospheric dispersion have been performed with the model SIRANE (Soulhac et al., 2012, 2011). SIRANE is a model conceived to simulate pollutant dispersion emitted from line sources (e.g. traffic emissions) and punctual sources (e.g. chimneys) at a local scale. The chosen sample area is located at the entrance of an alpine valley in the North West of Italy. The analysis is performed using the meteorological data for the year 2015.

In order to observe how the influence of varying operating conditions can affect air pollutant concentrations, different scenarios have been analysed assuming different hypothetical modes of operation. The key parameter is the emissions, which can be changed between full and partial load. The turnover between the two mode is assumed according to different hypothesis. The mode of functioning can be assumed a priori, with the same turnover regardless the external temperatures or keeping into account this factor.

The objective of the present work is to observe how modification of the input data can influence the results and how this parameters haves to be considered during the definition of the design hypothesis. In order to do so, first a sensitivity analysis has been done in order to observe how the results were influenced by the input data. After, some design hypothesis have been modified in order to determine their influence on the results.

RESULTS

Figure 1 shows by way of example the results obtained through the modeling of the emission scenario determined by the substitution of the whole traditional fuel heating network with wood biomass boilers. The period considered for the modeling is the month of January 2015. The emissions were considered to be influenced by the external temperature, namely the turnover is not constant but influenced by the temperatures. It can be observed how the concentration level are not very significant if compared with the limiting value (40 $\mu g/m^3$) indicated by the European legislation for PM_{10}. However, these emissions have to be considered as an additional factor comparing with the existing pollutants emissions in a territory. Hence, they cannot be considered as not important, also considering that traditional fuel emissions of PM are negligible.

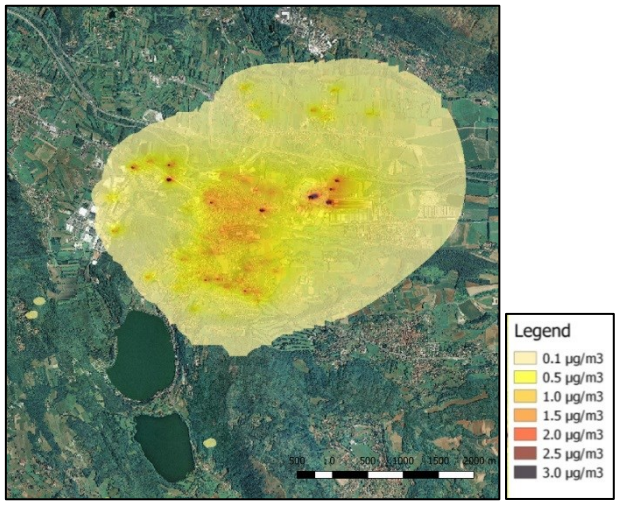

Figure 1. January concentration of PM due to the emissions of wood biomass boilers

Meteorological data that are considered most significant for the purpose of a sensitivity analysis are solar radiation and wind speed. Therefore, additional modeling have been done for the month of January. With regard to the solar radiation, in the modeling carried out, there are no significant changes both as regards the concentration maps that the trend of the concentration values in correspondence of the receptors.

The wind speed has been modified proportionally by 10% and 20%. Figure 2 shows that the influence of the wind speed values is directly proportional than the concentration values. Another significant parameter for the dispersion process is the height of the emission point. The input data have been modified by imposing a constant height of the boilers emission points corresponding respectively to 7 m, 8.5 m and 10 m. In the receptor concentration trends there are higher values in the hypothesis of higher emission points (Figure 3).

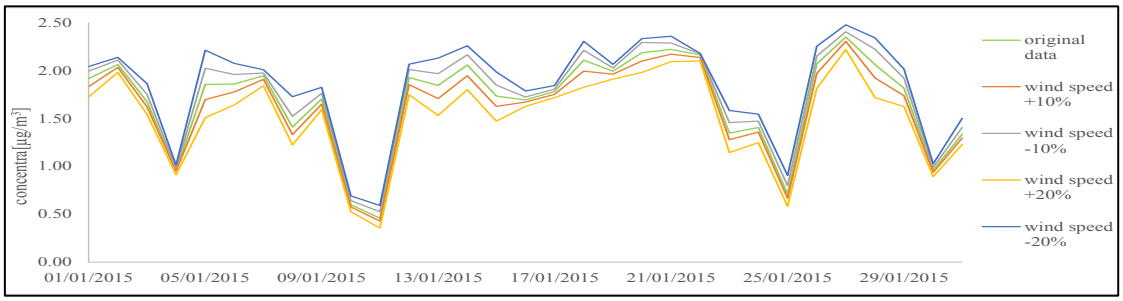

Figure 2. Average concentration trend at varying wind speeds in correspondence of a receptors

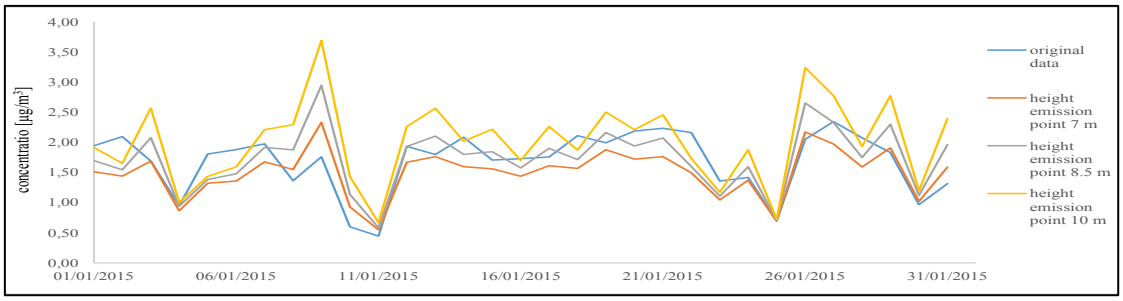

Figure 3. Average concentration trend at varying the height of emission point in correspondence of a receptors

To observe how the emissive scenario is influenced by variations of the outside temperature a sensitivity analysis was carried out. The temperature input has been therefore varied increasing and decreasing them

respectively of 2 °C. The modulation of the boiler, and consequently the emissions, has been varied according to these variations. Figure 4 shows respectively the concentration map with increased (Figure 4.a) and decreased temperature (Figure 4.b). Such results are compatible with a reduction and increase of the emissions caused by the higher and lower temperature. However, relating with Figure 1, there is a minimal alteration comparing to original data.

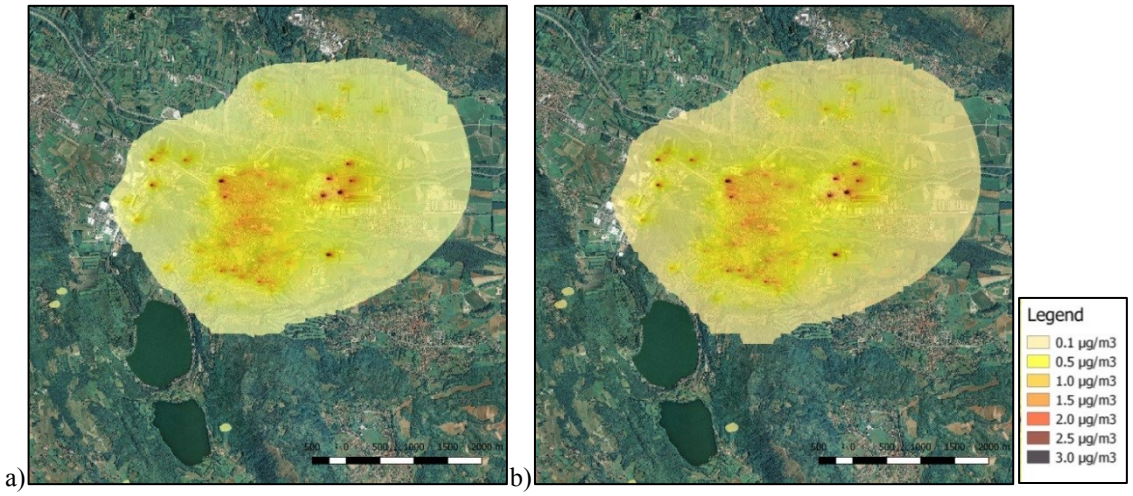

Figure 4. Concentration of PM from the emissions of biomass boilers with increased (a) and decreased (b) of 2°C temperature input data

In the starting hypothesis, a medium energy performance of the buildings was assumed in order to determine the size and the numbers of boilers needed to guarantee the energy demands. It can be assumed that greater sustainability would be reached in a perspective of improvement of buildings energy performance that would result in a significant reduction in emissions. This scenario is compatible with the bonus policies of such improvements currently present. Indeed, such a scenario is conceivable only if accompanied by the installation of solar panels. They are necessary to ensure the production of sanitary hot water for the summer period. Therefore, the input data have only been assumed for the colder months. In this scenario, the heat demand was calculated assuming an energy class of the buildings significantly better. Taking into account the presence of historic buildings an overall average energy class equal to B was deemed reachable. Based on this value the size of the installed boilers has been changed. The original location has been maintained but the hypnotized boilers have reduced power.

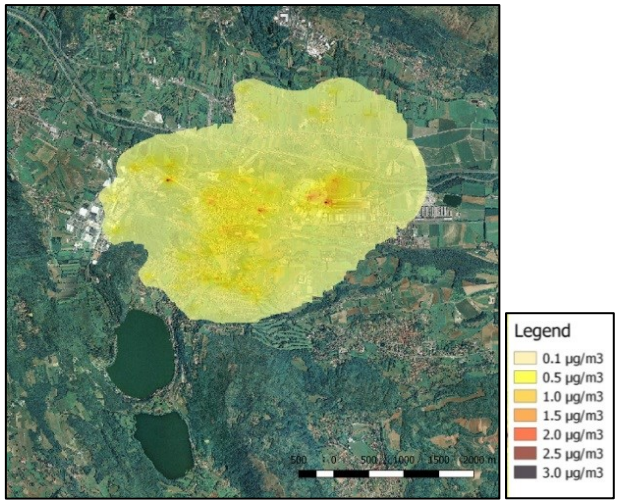

Figure 5. Concentration of PM from the emissions of biomass boilers in the hypothesis of improved buildings energy performance

Figure 5 shows the concentration maps obtained for the month of January in the hypothesis of improvement of building energy classification. Comparing to the original results, in addition to highlighting in general a lower diffusion of pollutants, there is a significant difference of about 20 $\mu g/m^3$ between the maximum value of the first and second case.

CONCLUSIONS

Woodchip boilers are new emerging heating system which are attractive for their reduction of CO_2 emissions, but whose use may worsen local air quality conditions compared to traditional heating systems. Aim of this paper was to assess the environmental impact of a network of small wood biomass boilers and observe how modification of the input data influence the results. To that purpose the dispersion of pollutants was simulated at the local scale in different emissions scenarios, taking into account both the pollutant directly emitted by the boilers and those emitted by vehicle transporting the woods needed to feed them. Simulations of pollutant dispersion were performed with SIRANE, a second generation Gaussian model.

The obtained results beyond allowing to observe how the modification of the input data influences the results, show how is not easy to determine the influence of one parameter on the results and how this has to be considered during the design hypothesis. In particular, the design of these systems have to consider different factors in order to obtain a solution really compatible with the environment and efficient regarding the energetic point of view.

The features of renewability and availability of wood biomass determine a growing interest in this source of energy. However, the results show how environmentally sustainable results can be achieved only coupling these systems with other renewable source of energy and moving towards an improvement of the energy performance of the buildings.

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