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Case Report

Application of In-Field Outdoor Measurements in the Testing Phase of a Small Plant Prototype

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Abstract

Assessing the environmental impact at the design phase of a project is complex and time-consuming, therefore it is often neglected. This is doubly true in the designing of prototype plants. The aim of the present work is to show how expeditious measurements in the testing phase can be applied in order to quantify the emissions before placing the product on the market.

Keywords: Air pollution; Emissions; Environmental impact assessment; Noise; Outdoor; Particulate matter; Prototype design

Introduction

Any kind of project requires that a series of compromises need to be implemented in order to reach a final version that takes into account all the possible variables to its realization. Regarding the projects applied to territorial contexts, in the preliminary design phases, the assessments of potentially harmful environmental impacts are frequently marginally considered. Moreover, especially for prototype plants, there is not sufficient knowledge during the design phase for a real assessment of the pollutant emissions. Therefore, it may be necessary during prototype testing phases to put in place expeditious measurement campaigns to characterize the plant from the point of view of awaited emissions. The aim of the present study is to show how the emissions coming from this kind of sources could be characterized, in order to have a preliminary assessment of the environmental pressures which they can induce on territories, before their distribution on the market. The research, specifically, is applied to the prototype of a wood biomass micro generation plant and it is part of a larger research framework by the authors, analyzing the interaction and possible joint approaches between environmental and occupational safety in indoor and outdoor work and life environments considering both damage and annoyance/disturbance relapses to the involved workers, population and territories [1,2].

Description of the Prototype Plant

The case study is part of the "ENSESBID" project done in collaboration between the departments of Energy (DENERG) and Environment, Land and Infrastructure (DIATI) of the Politecnico di Torino and the Cooperative "La Foresta", a company that operates in the field of forest biomass (PEFC certificated) [3,4]. Within the project, a prototype plant of wood biomass micro generation and of energy-sufficient wood processing has been designed and developed. The prototype consists in an integrated system to dry timber planks and recover thermal energy of wood by-products. The final system is composed by a container "boiler" and a container "dryer". The whole prototype has been put in proximity of a wood fuel terminal place for the testing phase. In a following phase of the project, the plant has been moved near the end-user in order to recover part of heat, produced during drying timber planks operations, to warm a built up area.

Environmental Measurements

The plant's main pressures on the environment consist in particulate matter (PM) and noise emissions. Thus, dedicated measurement campaigns during the prototype testing phase have been carried out so as to quantify such potentially harmful emissions.

Monitoring of PM_{10} for airborne particulate assessment

In order to assess airborne pollutants emissions, the prototype plant has been considered as an emissive source relative to particulate matter. The chosen indicator (PM_{10}) is defined in the legislation [5] as follows: "PM_{10} shall means particulate matter which passes through a size-selective inlet as defined in the reference method for the sampling and measurement of PM_{10}, EN 12341, with a 50% efficiency cut-off at 10µm aerodynamic diameter". The European PM_{10} limit values for life environments need to be taken, for the case study, only as indicative since they represent concentration limits at the receptor of damage. In fact, as regards the present case study, the methodology described hereinafter is applied for measuring the concentration of particulate matter close to the emissive sources (near field). To assess how a source of emissions could influence a territory, long-term sampling monitoring should be designed in order to observe the modification in air quality at the receptors. The aim of the carried out measurements is to assess the pressures on the territory deriving by the sources. The measurement campaign goes from 13/03/2016 to the 04/07/2016 through an environmental airborne particulate mass concentration low-volume reference sampler [6]. The sampling point, for the best characterization of the source from the emissive point of view (i.e. precautionary principle), has been placed down-wind respect to the source (Figure 1). Along the monitoring, the plant was in operation from the 13/06/2016 to the 27/06/2016, a period overall characterized by favorable meteorological conditions, suitable with the purposes of the source characterization. The monitoring results are reported in the following Table 1.

Figure 1: Location of the PM_{10} sampling point.

Table 1: Synthesis of PM10 daily mean concentrations.

Measure Date	Dust Weight (µg)	PM10 Concentration (µg/m^3)	Measure Date	Dust Weight (µg)	PM_{10} Concentration (µg/m^3)
13/06/2016	935	54.19 (errors in the sampling)	24/06/2016	1755	34.79
14/06/2016	2045	39.59	25/06/2016	1890	37.48
15/06/2016	2770	54.63	26/06/2016	2630	52.04
16/06/2016	840	16.59	27/06/2016	1725	31.9
17/06/2016	350	n.d.	28/06/2016	3625	67.27
18/06/2016	770	15.4	29/06/2016	1915	35.41
19/06/2016	615	12.27	30/06/2016	955	17.93
20/06/2016	890	17.61	1/7/2016	885	16.64
21/06/2016	1340	26.51	2/7/2016	1210	22.57
22/06/2016	1635	32.45	3/7/2016	1100	20.23
23/06/2016	1630	32.45			

Monitoring for the noise impact assessment

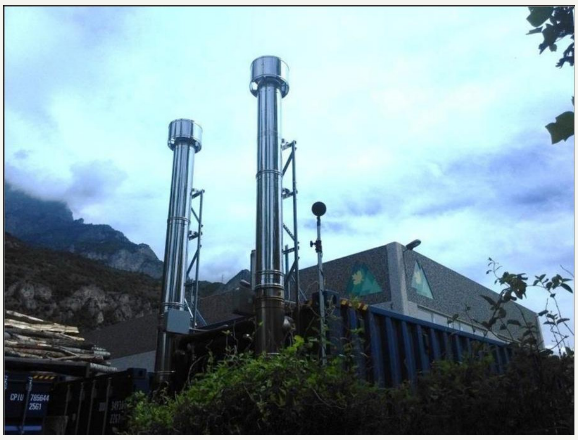

Figure 2: Positioning of the measuring point relatively to the emissive source.

The prototype plant has been considered also as a potentially impacting noise emissive source. The measurements were made at near field, in accordance with the procedures defined by legislation [7-10], by a class-1 integrating sound level meter equipped by a microphone extension mounted on a tripod 2m high. The measurements were performed at a fixed location in the vicinity of the dryer container of the prototype (Figure 2). The microphone was positioned, as precautionary measure, in a central position. The measurements have detected the trend over time of the signal, the weighted equivalent level, the frequency spectrum and other acoustic indicators, such as the maximum and minimum "A" weighted levels. The measurement campaign goes from 21/06/2016 to 13/07/2016. In the period in which the measures took place, the plant was in operation from the 13/06/2016 to the 27/06/2016. For the whole sampling time, the meteorological conditions have been verified to be in accordance with the provisions of legislation [7]. Therefore, the data collected in not suitable meteorological conditions have not been considered.

Table 2 shows the results of sound level measurements including the total duration of the measures and the considered noise indicators. For the best management of the high-resolution data collected in broadband during the monitoring, the sampling has been separated into two files. Therefore, with the partial "A" are summarized the averaged indicators for the period between 21/06/2016 and 29/06/2016 and with the partial B the period between 29/06/2016 and 13/07/2016. Raw data have been processed in order to obtain the levels, for the entire duration of monitoring, concerning day/night-time, as required by legislation

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(Table 3). The results include the data filtering related to unsuitable meteorological conditions, which have been detected during the measurement period. The second step in data processing has been focused to analyse the contributions of the background noise (prototype off) and of the environmental noise during system operation. Such approach makes possible to obtain an estimation of the actual contribution of the system in operation (F) excluding the noise generated from the particulate matter measuring instrument (P), located several dozen meters downstream of the plant, compared to the other widespread background sources (R). There were three characteristic time intervals:

Table 2: Results of the measurements (raw data).

Name	Starting Time	Time Passed	Overload (%)	LAeq (dB)	LAFmax (dB)	LAFmin (dB)
A	21/06/2016 12:11	190:24:42	0	56,3	98,7	36,6
B	29/06/2016 10:36	336:45:54	0	55	105,7	26,7
TOTAL	21/06/2016 12:11	527:10:36	0	55,5	105,7	26,7

Table 3: Results of the measurements (day/night filtered).

Name	Starting Time	Time Passed	Overload (%)	LAeq (dB)	LAFmax (dB)	LAFmin (dB)
Day	21/06/2016 12:11	351:10:36	0	55	99,8	31,8
Night	21/06/2016 22:00	174:00:00	0	50,7	105,7	26,7

a) 21/07/2016 - 27/07/2016: Environmental noise with plant and PM measuring instrument on (F+P+R);

b) 28/07/2016 - 04/07/2016: Environmental noise with plant off, background noise and on (F+P);

c) 04/07/2016 - 13/07/2016: Background noise, plant and PM measuring instrument off (R).

As a first approximation, the background noise (R) measured between 4 and 13 July 2016 was considered as representative value of the entire monitoring period. Therefore, to estimate the contribution of the sole source, the following procedure has been followed:

a) Collection and processing of input data;

b) Calculation of the contribution of (P_{calc});

c) Calculation of the environmental noise at plant on without the contribution of PM sampling instrument ($F+R_{calc}$)

d) Calculation of the plant contribution (F).

Table 4: Results of the measurements (source contribution during the night).

Data	L_{Aeq}	L_{95}	L_{90}	Calculation	L_{Aeq}	L_{95}	L_{90}
Period F-R-P	52,2	47,6	48	P calculated ((R-P)-R)	45,3	40,7	41,8
Period R-P	50,5	42	43,4	F+R calculated ((F+R+P)-(Pcalc))	51,2	46,6	46,8
Period R	48,9	36,3	38,1	F calculated ((F+R calc)-(R))	47,4	46,1	46,2

The used input data refer to the night period, representing the conditions of potentially highest risk of intense environmental noise caused by the introduction of the source. Moreover, this solution allows to reduce the incidence of the overall wind conditions, which have been significant mostly during daytime for the entire measurement. To further minimize the variability which can be induced by wind gusts, the previously described methodology was applied considering also the statistical levels L_{95} and L_{90} (Table 4).

In order to verify the results, the assessment has been repeated with the values collected in the daytime period (previously not considered) (Table 5).

Table 5: Results of the measurements (source contribution during the day).

Data	LA_{eq}	L_{95}	L_{90}	Calculation	LA_{eq}	L_{95}	L_{90}
Period F-R-P	55,6	48	49	P calculated ((R-P)-R)	43,8	36	35
Period R-P	54,6	44	46	F+R calculated ((F+R+P)-(P calc))	55,3	48	49
Period R	54,2	44	45	F calculated ((F+R calc)-(R))	48,9	46	47

Discussion

The measurement campaign for the assessment of airborne particulate describes a PM_{10} average value which is equal to 30.72±1.17μg/m^3 and a variation range that goes from 12.27 to 67.27μg/m^3. The atypical maximum daily value, recorded the 28/06/2016 while the system was not in operation and at calm wind conditions, cannot be correlated directly to the source. It is congruent that such value can be attributed at least partially to the persistence of the particulate coming from road traffic emissions from near the prototype plant. Besides this outlier, generally lower daily values can be observed for the day of prototype off rather than the days of operations. Overall, the magnitude of the determined values shows a clear influence of other sources of PM, such as the dirt road in front of the measuring point. In general under optimal conditions for the measurements, the values obtained are on

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average lower than the annual limit corresponding to 40μg/m^3 [5]. The occurring of disturbances events - in particular caused by the frequent presence of wind gusts between 12pm and 6pm - led to a slightly higher contribution of the source during daytime rather than in nighttime. The application of statistical levels, minimizing these effects but incomparable with any regulatory limit value, highlight a minor deviation of the results between nighttime and daytime. The analysis of the frequency spectra, does not evidence any impulsive episodes or pure tones or low frequency prevalence.

Conclusion

The monitoring results show an overall emissive framework compatible with the territory. With the exception of few values, considering also the previously described outlier and the limitations of the developed analysis at near field, the PM_{10} monitoring campaign has not evidenced a clear impact from the prototype plant at the testing location. Regarding noise, the source estimated emissive values are coherent with the acoustic territorial zoning class III, consisting in the most cautionary between the areas of possible installation for this type of plants. The results of the study are validated for the site-specific expeditious methodology applied at the testing area. Thus, the implementation of the prototype plant for sales requires the adoption of specific assessments in order to verify the compatibility with air quality standards and the acoustic classification of the territory. Indeed, the study should be intended as promoting the assessment of the state to be known, considering also background environmental quality determined by the other existing sources of the context, to assess the environmental impact also of prototypes and small plants over the normative requirements.

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