PERSPECTIVES OF LOW-COST SENSORS ADOPTION FOR AIR QUALITY MONITORING

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Low cost sensors open to a new vision of the air quality control. Their performances allow for a new strategy closer to the population and its health. Critical situations that cannot be seen with conventional approaches can be managed quickly through an original network of sensors. In the present paper the preliminary steps of an integrated sensor based research are presented. In particular, criteria for sensor selection referred to significant case-studies are discussed.

Keywords: air quality, low cost sensors, peak values, sentinel.

1. Introduction

The environment has always been on the first step in the attention of advanced countries from many decades. In recent years the European Union regulation for air quality management has reached important results in term of exposure and health implications of macro and micro-pollutants and in terms of protection of the environment. However, many actions remain to be developed mainly in urban areas, but the general trend is towards an average improvement of air quality with positive consequence on the health of the population.

Generally, the adopted regulations for air quality management are based on the concept of protecting the environment without facing with micro-scale critical situations, where human exposure to atmospheric pollutants can be inacceptable.

The monitoring and environmental warning systems today allow having some environmental information that is not sufficient or adequate for planning

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detailed corrective actions, or to quickly highlight critical situations potentially harmful to public health.

Air quality monitoring is a complex problem that requires the integration of multiple environmental information. Usually these data are coming from different environmental networks and often they are managed by different institutions. Therefore, sensor network, GIS models that indentify critical locations and Sensor Observation Service (SOS) that collect data and meta-data are used.

In the literature, three methods for interpolating air pollution data are available. The results from these can be combined with information from bioindicators [1-2].

- *The Kriging interpolation* method [3-4];
- *Land Use Regression* (LUR) method [4-5];
- *Diffusion/ dispersion modeling* of pollutants [6-7] and *GIS technology* [8-9].

In this frame, the Wireless Sensor Networks are effective means for monitoring in details environment pollution and life hazards, for example air quality in the cities and around storage and processing facilities such as ports, plants and dumps, fire warning through specific combustion gas detection, water pollution, dangerous or lethal gas warning in mining and oil industry [10-11].

Anyway, protocols and sensors are extremely new, and much research remains to be done to integrates these technologies and to improve the Environmental Information Systems (EIS). A key factor to improve the air quality monitoring is to share environmental data coming from different bodies (public and private companies) in a near real-time system, in order to take advantage of data from different sensor networks.

In this context, the present paper analyses some perspectives of low-cost (high density) monitoring network for a more direct control of the human health risk from atmospheric macro-pollutants.

2. Materials and methods

The work has been carried out in different steps, described in detaisl below.

As a ***first step***, in the present paper a few micro-scale critical situations were selected pointing out the peak values of O_3 and NO_2, CO, that could be reached and the potential effects on health, in order to develop strategies and policies to improve the status of air quality and to comply with the National and European legislations.

Critical situations could be found generally:

- in the yard of kindergartens and schools (when an important road is present in the proximity);

- in street canyons (when the flux of traffic can be critical);
- in residential areas close to highways;
- in residential areas close to tunnels;
- in residential areas above trenched roads;
- in the proximity of large industrial plants;
- in summer in residential areas.

For these situations a selection of parameters to be investigated by wireless sensors has been made.

As a ***second step***, low-cost sensors have been selected in order to check their viability to act as sentinels where the conventional approach of air quality monitoring cannot guarantee a high detail (that is in the cases analyzed in the first step).

As a ***third step***, preliminary experiments were developed in the Torino city, near the central zone for five days in the summer period. The measurements were made outdoor, with the sensors put at 10 meters above the street level and then in an office.

As a ***fourth step***, based also on this preliminary experience, an overall strategy has been developed for selected case studies. This step is sponsored by the Autonomous Province of Trento.

3. Results and discussion

In Table 1 the results of the analysis of the critical situations in terms of parameter selection are presented. The parameters have been filtered taking into account the availability of specific sensors in the sector. In particular, PM_{10} and similar parameters have been discarded as not yet suitable for a wireless sensor network.

Table 1

Selected parameters for potentially critical cases

Critical case	*Selected parameters*	*Notes*
Kindergartens	NO_2	CO could be added
Street canyon	NO_2	CO could be added
Highways proximity	NO_2	-
Tunnel proximity	NO_2	-
Trenched road proximity	NO_2	-
Industrial plants	CO, NO_2	Depending on process
Summertime	O_3	-

The parameter CO has not been considered in case of medium-high speed roads. The parameter NO has not been taken into account as not toxic. Large industrial plants could emit significantly either one of the two selected parameters, or both, or none of them: a preliminary analysis of the process is compulsory and the way of release into the atmosphere must be analyzed in details as well designed stacks could decrease the local impact to very low levels.

Then, the electrochemical low-cost sensors have been selected in order to act as sentinels in case of peak values of the parameters listed in Table 1.

The above listed sensors have been chosen taking into account their resolutions compared to the lowest peak value to be detected. For each parameter a group of low cost sensors will be adopted in order to generated data on an area.

For each low cost mini-network a high resolution sensor has been selected to be used as “mother” for a better interpretation of the generated data. The chosen NO_2, CO and O_3 sensors are thick low sensors.

The sensors will be calibrated in the WSN Calibration Laboratory of Polytechnic University of Turin, DISMIC department. One of the low-cost sensors is presented in Figure 1.

Fig. 1. The low-cost O_3 sensor

Critical values of O_3 can be found in summer in residential areas. To this concern, a preliminary experience has been developed in Torino during summer 2011.

In Figure 2 the preliminary O_3 measurements made outdoor and indoor during the five days are presented, showing also the deep details. In Figure 3, instead, the O_3 measurements are presented taking into account the sensor position, respectively:

- in the laboratory with closed windows;
- in the laboratory with opened windows;
- in balcony at 10 meters above the street level (the highest peaks).

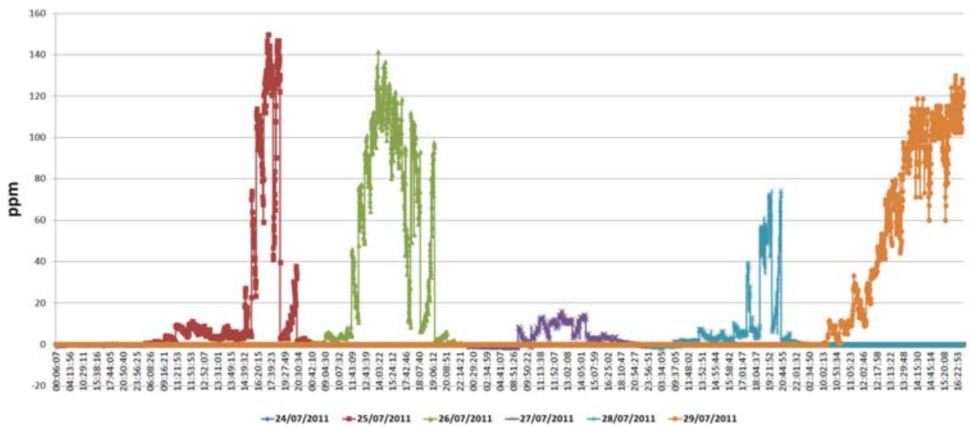

Fig. 2. The overall preliminary low-cost O_3 sensor measurements

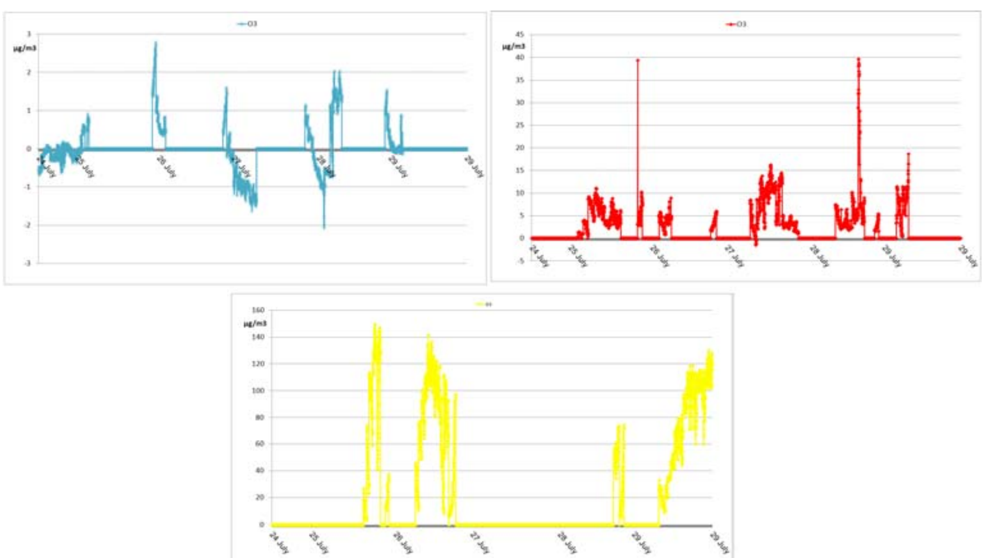

Fig. 3. The preliminary low-cost O_3 sensor measurements

As a preliminary qualitative check of the sensor performance, the generated data have been compared with the ones of the closest fixed station of the local Environmental Protection Agency. In Figure 4 the data from an average day in summer detected by a fixed station of air quality of the ARPA Piemonte are reported. Afternoon peaks are detected in both cases. Of course a “cheek to cheek” calibration/validation have been planned in order to avoid distance effects.

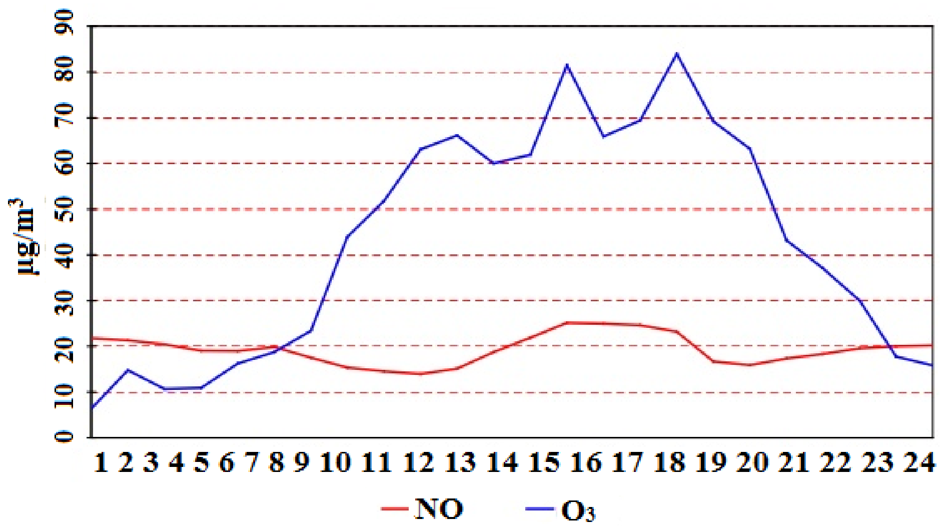

Fig. 4. O_3 (and NO) measurements

Taking into account the preliminary results of the experimentation, the characteristics of the region where the field measurements have been planned (Trentino), the timing of the overall research proposed to the Autonomous Province of Trento (one year), the overall strategy presented in Table 2 has been planned.

Table 2

Selected case studies in Trentino

Case study	Mini-network parameters
Cement work where a different strategy of co-combustion is planned	NO_2 in winter in selected a residential area close to the plant
Paper mill plant a different strategy of co-generation is planned	NO_2 in winter in a selected residential area close to the plant
Sintering plant where a different limit of CO emissions could be set	CO in a selected residential area close to the plant
One residential area	O_3 in summer in a selected residential area
One tourist area	O_3 in summer in a selected tourist area

The paper mill plant case study could be substituted by a test period along a highway. Additional modification of the strategy could be decided depending on optimization of timing and targets.

4. Conclusions

As regards to the use of low-cost sensors the sector seems to be ready for switching the air quality control strategy towards a direct health control. Low cost sensors for PM_{10} are not yet available but peaks of NO_2, CO and O_3 can be measured or detected.

The accurate detection of these peaks and the testing of the low cost sensor network in local conditions are essential to design proper sensor networks.

The future strategy, presented in Figure 5, of mixing different technologies like: low cost sensor networks with traditional sensor networks and other protocols promise to reach several advantages compared to traditional air quality monitoring systems:

- allows reaching higher spatial accuracy;
- reduces the redundancy of measures by different network systems;
- improves the localization of critical pollutants concentrations;
- reduces the costs improving data spatial resolution and quality;
- allows the creation of a real time alert system for dangerous pollutants.

The work in progress will be a significant reference experience. A progressive extension of the network is expected locally with private and public contributions. The same experience could be replicated easily thanks to the generation of guidelines for a correct approach wireless sensor based.

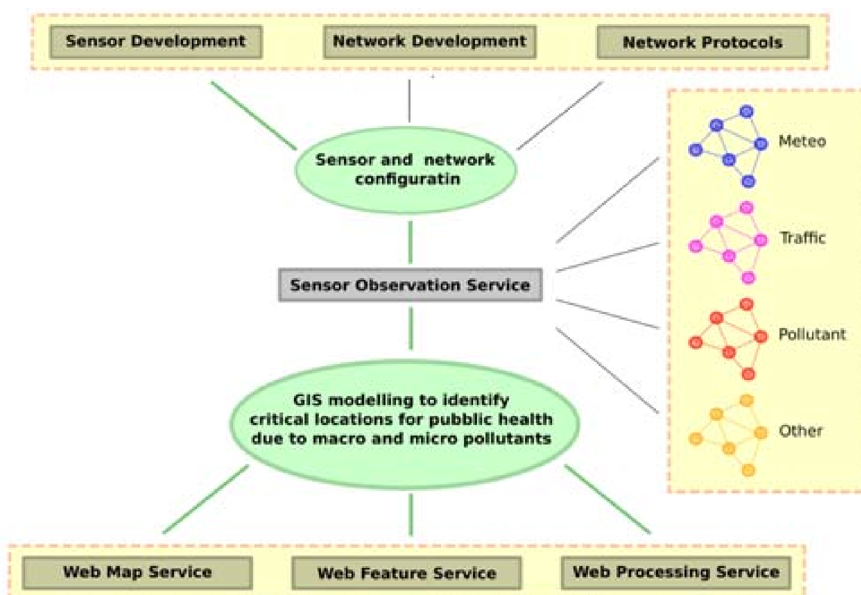

Fig. 5. Overall view of the approach

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