EVALUATION OF FUGITIVE DUST FROM CONSTRUCTION SITES IN THE CITY OF SHANGHAI

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Abstract: China's cities are growing faster, more than in other countries. The presence of conspicuous number of construction yards can affect seriously the air quality of the cities, moreover the PM_{10} emissions from these sources are still underestimate. A monitoring campaign and model simulation results are presented in this paper. The aim of the project, conduct in the city of Shanghai, was to evaluate a dust emission factor from the constructions sites. A first assessment activity was developed from October to November 2006, in the Peng Xin Mansion construction site, where 8 PM_{10} sequential samplers and 2 meteorological towers, were deployed. The data collected were used to improve a new simplify methodology, also a Gaussian plume model AERMOD was rund. Results from the air dispersion model comes by different emission factors calculated from two procedures, one from the AP-42 Environmental Protection Agency (EPA-USA) and the second from an empirical areal emission factor. The first procedure assigns different sources depending on construction activities and in this case no good results were achieved. The reason was identify in the lack of a knowledge regarding the source locations depending on schedule time, the specific employed machinery and the detailed construction operations. The second procedure, based on the determination, from the measured data, of an areal emission factor, gave, for 6 selected days, good results regarding the trends and the values obtained comparing with the measured data. Considering the results obtained, we found for the construction site, one seasonal emission factor: the value is 1.8 g/(m2*sec) of PM10 emitted. At the end to better understand the role of the construction yards in the air quality budget in a city of Shanghai we use the estimated emission factor as input in the AERMOD model.

Key words: *Shanghai city, emission factor, construction site, air modelling.*

1. INTRODUCTION

This work is related to the APEM project (Air Pollution Emission Monitoring) developed in Shanghai, China, between the CNR (Italian Institute for Atmospheric Pollution) and the SEMC (Shanghai Emission Monitoring Center). Main goal of the project is to identify the emission factors from specific polluted activities in China.

Sanghai is China's biggest city with about 18 million of habitants in the year 2005. The city is located at the mouth of the Yangtze river in Jiangsu province and is one of the world's largest seaport. It has a strong commercial and industrial base with China's largest petrochemical complex, its largest steel output, and other major industries. Years of rapid economic growth with a great amount of energy usage and urban development have burdened its air quality, resulting in visibility reduction and public health concerns (Boming et al.2003). The recent environmental survey shows that the concentration of PM10 is high in the atmosphere of Shanghai City, the annual average of which is larger than 100 μgm^{-3} (Zang, 1999, 2002). Some studies link these high values of a dust generation to the widespread construction activities in this rapidly developing city (Li et al, 2003; Shu et al, 2000).

The evaluation of fugitive emissions of particulate matters from construction activities (excavation, drilling, blasting, handling material etc.) and other diffuse emission sources (traffic re-suspension, handling of dry bulk goods, windblown dust from stock piles etc.) is very important, especially when standards for particulate matter are exceeded and control plans are needed. In dry weather periods, handling of bulk goods, heavy transportation and open works contribute significantly to direct emissions of dust and fine particles, also the finely dispersed materials are re-suspended by vehicles in the urban atmospheric environment. In wet periods, mud and clay materials have to be transported from construction sites to the near dump, causing pollution from loosing materials and traffic emissions.

Such processes are very significant for the impact on air pollution and contribute significantly to the degradation of air quality. If additional sources, such as traffic and industries are involved in atmospheric emissions, it is necessary to discriminate the different sources in order to plan effective abatement strategies. Unfortunately it's not so simple to measure the contribution of the dust emissions from construction sites where the emissions (mainly of fine and coarse particles) are depending upon several parameters. These are the type of works, the terrain and its geological texture and composition, the relationship between on site and off site pollution, the type of heavy transportation of demolition material and, finally, upon the meteorological conditions.

According to this, estimations of particulate emissions from model scenarios are easily leading to highly incorrect results, while measurements provide data, which are very difficult to interpret and to translate in terms of specific emissions. Since both measurements and models do not provide a solid answer to the problem, it is expected that a combination of both may give the added value needed for fully understand and quantitatively evaluate the contribution of different sources to atmospheric pollution in a given area. A method based on the evaluation of the fugitive dust emission from the construction site, matching dust samplers and dispersion model, has been developed to understand the real impact of the construction activities in the city of Shanghai.

2. EXPERIMENTAL SETUP, ASSESMENT AND EQUIPMENT IN USE

For the study was selected a construction site named Peng Xin Mansion, located in the Yangpu District in Shanghai. The dimension of the area is 18670 m^2, the activities are related to the construction of a big building. Four weeks of measurements were developed in the months October and November 2006.

For the evaluation of the emission factor from the construction site several equipments have been deployed. For the measure of the 24 hour concentrations the sampler named Microdust was used (developed by an Italian enterprise in co-operation with the Italian Atmospheric Pollution Institute-National Research Council). It is composed by cyclones for PM_{10} particle-size cutting in low flow condition (20 litres minute); inside the sampler is placed a plate which contain 8 filter holders with a 37 mm diameter, and it allows keeping the particulate for 8 consecutive days and over 24 hours. To measure the atmospheric conditions two wind towers were deployed on site, these were equipped with sonic anemometers (DNB046 (LSI Lastem), Thermohygrometers DMA580 (LSI Lastem), n.1 Barometer CX115P (Atmospheric pressure sensor); n.1 Global Radiation sensor Pyranometers C101R. A video recorder system to control continually the work phases in the area of study was installed.

A wind field analysis of the area, to identify a mean wind direction (North East-South West), was done before to install the equipment. Six microdusts were placed in the downwind side (SW side = **B** side), three at the ground level and three at 6m above the ground and two microdusts were placed in the upwind side (NE side = **A** side) at 0 m and 6 m above the ground. One wind station was placed in the B side; another one, due to the impossibility to use the A side, was place inside the construction site to collect further information regarding the wind conditions.

For the measure of the PM_{10} concentrations 37 mm Teflon and plastic filters were used, all the filters were weighted in Italy, in the CNR IIA laboratories before and after the assessment. The filters were put at least 24 hours, before the weighting procedure, in a filter conditioning cabinet (Activa Climatic) that ensures constant conditions of temperature (20°C±1°C°) and relative humidity (50±5%). The balance used was a Cahn balance mod. Micro C-34.

Samplers of the soil were taken from the construction site to characterise the ground. Road dust (silt) loading for the paved roads inside the construction site was collected. The method for the laboratory analysis was similar to that reported in the AP-42 document (EPA AP42, 1995). The results of this test provided also the particle size distribution in percent of sand (20÷2000 μm), silt (2÷50 μm) and clay (<2 μm).

Dispersion models are the most widely used techniques for estimating the impact of non-reactive pollutant (Petersen et al. 1987, Scire et al. 1980). It is proposed to use a Gaussian model AERMOD to predict the dispersion of particulate matter (PM_{10}) (Ghenai, 2006) over a construction site. AERMOD is a steady-state Gaussian plume model useful for the computation of pollutant dispersion applicable to rural and urban; flat and complex terrain; surface and elevated release; and multiple sources (point, area and volume) of emissions (Cimorelli et al., 2004; EPA 2004). AERMOD requires hourly surface meteorological observations for simulating the pollutant dispersion. The meteorological data used in the model were taken from the on-site tower.

3. METHODOLOGY

Construction consists of a series of different operations, each with its own duration and potential for dust generation. Emissions from any single construction site can be expected to have a definable beginning and to vary substantially over different phases of the construction process (US EPA, 1995).

Due to the complexity of the activities in the construction sites, two approaches were tested: one coming from the EPA AP-42 manual and the other from a simplified procedure. Using the first approach the construction activities are shared in the main sources of pollution, one by one described by equation determined by test field. This approach for the construction site activities requires a delved knowledge of the phases in the building sites and of the works. The second approach use a methodology in which the emission factor from a construction site is defined as the net flux emitted from a downwind site, this methodology is applicable when the wind conditions are similar to the main direction defined by the upwind and downwind direction.

The aim of two procedures is to obtain the emission factors input values of the AERMOD dispersion model. If it is supposed that the background concentration is the same in the all site, the difference of the concentrations from the A side to the B side is just due to the contribution of the construction activity. To verify the reliability of the two procedures we have analysed the differences between the A and B side concentration of the PM_{10} obtained from the measures compared with the same differences obtained from the Gaussian model.

AP-42 emission factors

Empirical correlations for estimating PM_{10} emissions are summarized in the AP-42 (US EPA 1995). Emission factors from AP-42 are derived from experiments on specific sources that are reported on EPA web site. To predict PM_{10} concentration, using these formulas, are necessary site specific information regarding road surface silt content, mean vehicle speed, weight, number of wheels and the moisture in the ground.

The construction works have been divided in the recognisable types of activity observed from the videos registered. The following equations were used for the present work:

1) Paved Road:

$$E = k\left(\frac{sL}{2}\right)^{0.65}\left(\frac{W}{3}\right)^{1.5} - C \quad (1)$$

where E is particulate emission factor (having units matching the units of k), k is particle size multiplier for particle size range and units of interest, C is emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear (US EPA, 1995), sL is road surface silt loading (gm^{-2}) and W is average weight (tons) of the vehicles travelling the road.
2) Emission factor from engines by Corinair Inventory Emission (European Environmental Agency, 2006:

$$E = N * HRS * HP * LF * EF_i \quad (2)$$

where E is mass of emissions of pollutant i during inventory period, N is source population (units), HRS is annual hours of use, HP is average rated horsepower, LF is typical load factor and Ef_i is average emissions of pollutant i per unit of use ($gk^{-1}Wh^{-1}$).

Further emission factors, such as truck loading and bulldozing, were obtained using the equations from the Western Surface Coal Mines (US EPA, 1995).

3) Truck loading:

$$E = 0.58 * \frac{K}{M^{1.2}} \quad (3)$$

4) Bulldozing:

$$E = 35.6 * \frac{s^{1.2}}{M^{1.4}} \quad (4)$$

where E is mass of emissions of pollutant i during inventory period, M material moisture content (%), K scaling factor for PM10 and s material silt content (%).

Videos were recorded during the campaign to identify the yard activities and generate a time sequence of the different emission factors considering real works, namely "hourly emission factor" input of AERMOD software.

Upwind downwind approach
Fugitive dust emission factors are most commonly determined by measuring the horizontal flux from an emitting area such as a road or vacant lot. This is accomplished by locating sampling systems with the desired size-selective inlet at various elevations downwind of the dust-emitting area. Monitors located upwind are used to determine the flux into the emitting domain. Each of the downwind samplers is used to represent the amount of dust carried by the wind component perpendicular to a plane parallel to the source. Both the wind speed and concentration vary with height above ground level, so the horizontal flux is calculated through an area that extends above and below each sampler. These fluxes are added to obtain the aggregate emission rate from the source, after the flux of particles into the emitting area has been subtracted (Watson et al. 1996, Chuen-Jinn et al. 2002). The mass of particles emitted from the area of exam will be calculated by summing the different flux planes through which particles might pass. The PM_{10} in each flux planes is represented by the valued measured in each sampler. The PM_{10} emission factor can be expressed as:

$$E = \frac{1}{A}\sum_{1}^{n}(C_i - C_b)u_i(z)(\cos \vartheta)\Delta h_i L_i \quad (5)$$

where E is the emission factor (μgm^{-2}), A area of the construction site (m^2), L_i flux plane length (m), Δh_i height increment of flux plane i (m), C_i average concentration (μgm^{-3}), C_b background concentration (upwind concentration) (μgm^{-3}) and $u_i(z)(\cos\theta)$ wind speed perpendicular to the flux plane (ms^{-1}).

Using the data measured on site, for each day we found one areal emission factor, this value was used as input value of the AERMOD dispersion model.

4. DATA ANALYSIS

Metereology of the fiel campaign
Meteorology data were analyzed from October 9th to November 6th. The wind speeds were weak at that period with a mean value of 1.3 ms^{-1} and there were not a preferential direction of the wind. Only for one day (October 22nd) was raining. To evaluate the emission factors of the construction site from the empirical methodology, we used some days of the all campaign. In the specific case the days for which was observed a 24 hours wind was from NE or SW. The days were: October 12th, 13th, 18th, 21st and November 4th and 5th.

PM10 from the field campaign and surrounding stations
In the last years, from 2001, the daily PM_{10} average has reached the value of 100 g/m^3 data reported from Shanghai Environmental Monitoring Center. In our experiment the measured concentration was higher in the most of the days of 100 μgm^{-3}.

To compare the measured data with the background concentration were used three monitoring stations, the Sipiao, the EPB Yangpu and the HongKou station. Sipiao is the closest to the construction site located on the south. Sipiao is a background station.

The Shanghai city has many activities that could increase the dust concentration in the atmosphere: building construction sites, cement factories, vehicle exhaust, coal boilers and steel mills (Li et al., 2003; Shu et al., 2000).

When the wind blow from north the PM_{10} are related to particles emitted from the northern Baoshan industrial and power station complex (Shu et al., 2000), in these case all station shown the highest PM_{10} values.

5. RESULTS

AP-42 Emission factors

Using the emission factors from the US EPA as input of the AERMOD dispersion model, it is possible to compare the differences between the A and B side from the model output and the same data collected.

As reported in the Figure 1, (where are presented the differences between the two methods, the AP-42 versus the empirical, and the measured data), not good correlation for the AP-42 was detected. Indeed if for the first two days it seems that the AP-42 output data give results bigger, (in terms of difference from the upwind and down wind concentration) than the measured, in the following days is different. The divergence is probably due to incomplete information regarding the works running in the construction site and to the applications of the equations AP-42 in different country contest.

More field tests, and more information, regarding the type of works running in the construction site are necessary to find better correlation with the measured data. The application of AP-42 methodology in a construction site it should still improved.

Upwind downwind approach

The net flux emitted from the area, gave good correlation with the data assessed in the construction site, in the days selected, in terms of similar differences between the line A and B.

For the month of October the data got from the areal emission factor were 35% bigger than the measured, in November the data were 10% bigger than the measured. From the results obtained, applying to each daily emission factor a correction (resulting from the comparison with the measured data), we found one average emission factor for the Yangpu construction site, valid for the month of October and November 2006 (seasonal emission factor), this value is 1.8 $\mu g/(m^2*second)$ of PM_{10} emitted.

In Figure 1 are showed the model simulations. Comparing the AP-42 with daily emission factor results, it was adopted a daily factor that better approximates the real emissions. After that it was calculated a weekly and a seasonal emission factor from the daily factor. Using a seasonal factor of 1.8 $\mu gm^{-2}s^{-1}$, the gap respect the real measure was around 40%, instead using the weekly emission factor it was estimated around 36%.

At the end it was adopted the seasonal emission factor to model the impact of several construction sites recognized from the satellite images of the city. In some cases the model confirm the theory that the presence of several construction sites in the same district could be the main cause of the dust pollution.

6. CONCLUSION

PM_{10} related with construction activities for a city of Shanghai is becoming a node of concern in term of air quality degrading. This study focused on a new empirical methodology to evaluate the impact of construction yards, supported by an air dispersion model AERMOD. At the end of the study it was obtained an areal emission factor from a specific construction sites useful for further studies.

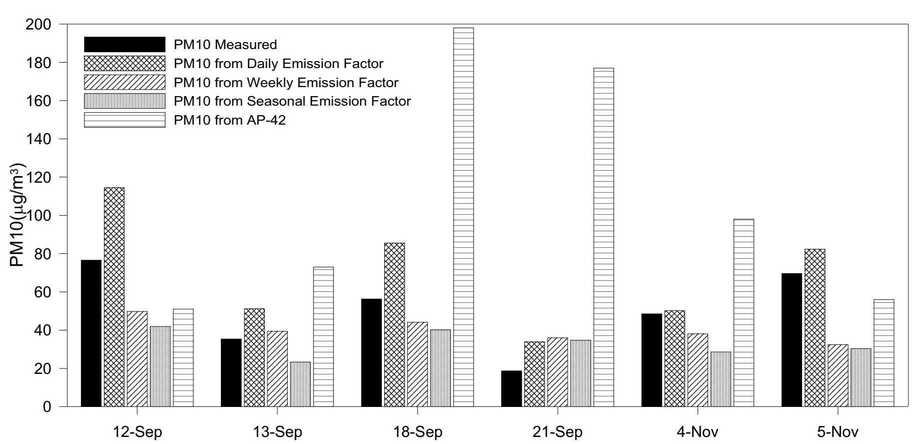

Figure 1. Absolute delta values reported for a selected days of the field campaign. The best delta approximation comes from PM10 from daily emission factor.

To identify a proper emission factor two methodologies, the empirical and the AP-42, have been compared each other. At the moment the results obtained using the emission factor form the AP-4 by EPA didn't allow to find good

results; the mistakes are related to the lack of information regarding the works running in the construction site and to the applications of the equations AP-42 in different contests.
The empirical new methodology based on a measured net flux emitted from the area, gave good correlation with the data assessed in the construction site, in the days selected, in terms of similar differences between the line A and B. One emission factor for the Yangpu construction site, valid for the month of October and November 2006, this value is 1.8 $\mu gm^{-2}s^{-1}$ of PM_{10} emitted.

This first study is referred to a single construction site for a limited period of the year and also too few days with a good wind direction. In any case the idea to get one yearly or seasonal emission factor for different construction activities with different characteristics could be a right way to evaluate the contribution on the dust generation in the city of Shanghai.

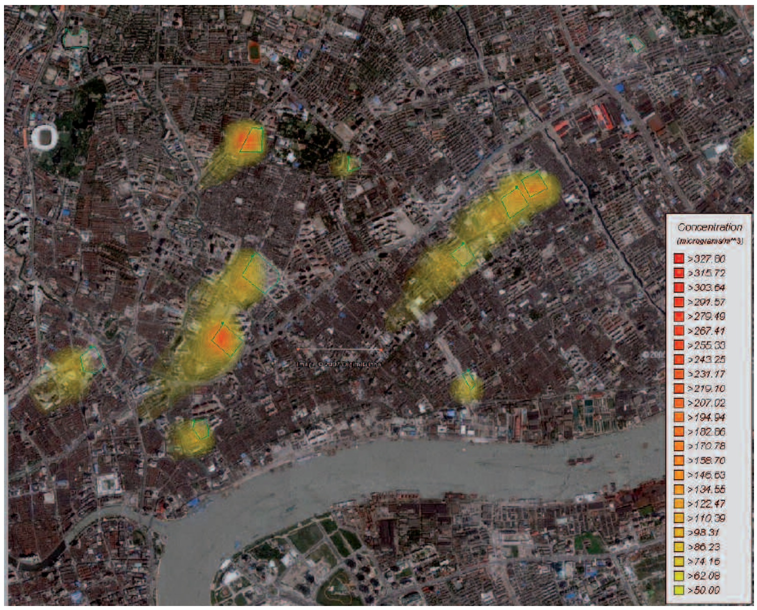

Figure 2. AERMOD Modeling Output PM10 (μgm^{-3}) from several construction sites (green line): is possible to see, the sum effect, in terms of dust pollution from different emission sources.

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