NIGHT OUTDOOR AIR AS A MAJOR SOURCE OF INDOOR AIR PARTICLE CONCENTRATION IN AN OFFICE

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1. INTRODUCTION

People spend a larger part of their time indoor than outdoor and are most exposed to the indoor air pollution. One of the major contaminants of indoor environment is airborne particulate matter. In fact, the airborne particles with an aerodynamic size smaller than 10 µm are inhalable and penetrate more or less deeply into the human respiratory system (Gerrity 1995). The finest particles can also penetrate into the blood during gaseous exchanges and reach other organs (liver and bladder) by the bloodstream (Nemmar et al 2002). Particulate pollution constitutes a potential health hazard contributing to the development of respiratory diseases and cardiovascular diseases. Numerous types of particle like plant and animal biological aerosols, mineral, exhaust soot from motors combustion, found inside, may originate from outdoor air background. They penetrate through building ventilation. In fact, the outdoor air plays an important role in the indoor air pollution.

Our experiment consisted to measure the airborne particle number concentrations in the High Court (HC) building located in Pointe-à-Pitre, a town of Guadeloupe (French West Indies). Some employers working in this environment equipped with an air conditioning system sourcing outdoor air became sick. They presented some symptoms of pollution exposure like headache, dizziness, fatigue and upper airway irritation of the nose, throat and eyes.

2. SAMPLING SITE AND METHOD

The experiment carried out from Friday, January 29th 2010 to Wednesday, February 10th 2010. The sampling site was an office of the High Court building is located in a shopping area of Pointe-à-Pitre, an urban town of Guadeloupe (French West Indies).(Figure 1)

An optical particle counter Lighthouse 3016 IAQ (Lighthouse Worldwide Solutions, Fremon, CA, USA) was used to measure the indoor number concentration in the HC building. The data were collected as particle number per volume in 6 following size ranges: [0.3µm - 0.5 µm[, [0.5µm - 1µm[, [1µm - 3µm [, [3µm - 5µm [, [5µm - 10µm [, ≥ 10 µm. Two concentrations have been calculated from those data. The first called $Optical_{PM3}$ composed of number concentrations of particles with diameter lower than 3 µm and the second called $Optical_{PM10}$ is the total number concentrations of particles with diameter lower than 10 µm. The sampling time was twenty minutes with a delay of ten minutes, so we obtained two measures per hour.

Two TEOMs (Tapered Element Oscillating Microbalance) (Rupprecht & Patashnick Co., Inc (R&P), Albany, NY, USA), were used to perform outdoor PM2.5 (particulate matter with a diameter lower than 2.5 µm) and PM10 (particulate matter with a diameter lower than 10 µm) mass concentrations. The first one is situated 6 km from HC building in the suburban town of Baie-Mahault and the second one is located 600 meters from the HC building in the city of Pointe-à-Pitre and their data called $TEOM_{PM2.5}$ and $TEOM_{PM10}$, respectively.The sampling time was fifteen minutes and we did an average to obtain two measures per hour. Figure 1 presents the location of different measurement sites.

3. OUTDOOR PARTICLES

From Friday, January 29th 2010 to Wednesday, February 10th 2010, the averaged $TEOM_{PM2.5}$ and averaged $TEOM_{PM10}$ for daytime (4:30 AM to 6:00 PM) and for nighttime (6:30 PM to 4:00 AM) are presented in Figure 2. For most days, we can observe that the daytime and nighttime $TEOM_{PM10}$ averages are close. In fifty percent of the cases, the nighttime $TEOM_{PM10}$ averages are higher than the daytime averages. Vecchi et al (2007) found the same behaviors in the urban area of Milan (Italy). They observed night averaged PM10 concentrations close to and slighty higher than the daytime averages. During the nighttime, $TEOM_{PM2.5}$ averages observed in Figure 2, are very close to and mostly higher than the daytime averages. The nighttime particulate pollution emissions are generally less important than the daytime emissions. But in our case, the outdoor particle concentrations can depend on the Trade winds. In fact, during daytime, the wind speed is two time faster than during nighttime and increase the dispersion of the pollutants. This could explain the nearness between the daytime and nighttime concentrations.

4. INDOOR PARTICLES

The average $Optical_{PM3}$ and $Optical_{PM10}$ for the daytime and the nighttime are presented in Figure 3 The nighttime $Optical_{PM3}$ and $Optical_{PM10}$ number concentration averages are higher than the daytime averages except for two days, the 2Sd and 6Th days of February month, when they are close. The $Optical_{PM3}$ and $Optical_{PM10}$ are close for the same slot, daytime or nighttime and suggest that

$Optical_{PM10}$ are essentially composed of $Optical_{PM3}$. Figure 4 presents the variations of the indoor particle number concentration for $Optical_{PM3}$ and $Optical_{PM10}$ during the measure period. The largest peaks occurred during the night between 6:40 PM and 10:07 PM. On this figure you can see also that $Optical_{PM3}$ and $Optical_{PM10}$ have the same behavior and which present values close to one another.

In the further part of the study, only the night data take into account. The larger indoor concentrations during the night are astonishing; because during the night there is no human activity inside the building.

5. NIGHT OUTDOOR AND INDOOR INTERACTION

The relationship between indoor and outdoor particles concentrations is determined more easily during the night because of the human activity absence in the building. Furthermore, during the daytime other parameters influence more or less the indoor particulate matter behavior such as, particles generation by occupants themselves or generation and re-suspension by occupant's activities (Gomes et al 2007; Géhin et al 2008; Hersen et al 2008). The larger indoor particle concentration peaks have been observed during the nighttime. We have not identified indoor source which explain this behavior. This result could be attributed to an outdoor particulate contamination.

Figure 5 presents the six nights with the most similar concentration variations between $Optical_{PM10}$ and $TEOM_{PM2.5}$ or $TEOM_{PM10}$. For each night, you can observe a good linear correlation coefficient that suggests indoor concentrations were related to the outdoor ones. Thus, the outdoor origin of the indoor night concentration increases could be promoted. From a definite threshold you can see a smoothing effect on the outdoor particle concentrations penetrate indoor probably due to the losses in the mechanical ventilation and its ducts. On the Figure 5, you can observe a gap close to or higher than 30 minutes between outdoor and indoor higher peaks. This delay could be attributed to the supply time of the mechanical ventilation and can be related to particle size.

6. SUMMARY

The night outdoor concentrations are close to or higher than those of the daytime probably due to Trade winds impact. The indoor $Optical_{PM10}$ are essentially composed of $Optical_{PM3}$ with concentrations greater during the night. On the entire sample period of 12 days, 6 days present very good linear correlation coefficients between indoor and outdoor concentration variations. This involves that the major part of the indoor particulate pollution came from outdoor and reveal a good concordance between number particle concentrations and mass concentrations. During the simultaneous indoor outdoor observations, we observed that the air conditioning has a smoothing effect on the outdoor particle concentrations from a definite threshold probably. This behavior could due to the loss by turbulence, impaction, sedimentation, centrifugation or filtration inside the air conditioning system. A delay of 30 minutes and more between indoor and outdoor data peaks could be defined by the supply time of the mechanical ventilation. Indoor PM_{10} concentration increase during the nighttime implies there is a mass loading of particles on the surfaces likely to be resuspended and can involve an impact on health. In fact, in the entire sample period, the second largest peaks occurred in the beginning of the daytime with values include between maximum night concentrations and the background concentration. These particles resuspended from the cleaning operation early in the morning and the beginning activity of the offices, in addition with the outside morning maximum particulate pollution of the downtown of Pointe-à-Pitre could be the plausible cause of the symptoms of the employers and transform the office into a toxic environment.

Thereafter, this study could be in depth by:

- Working on the delay according to meteorological conditions (wind speed, wind direction and rainfall data).
- Repeating the experiment by synchronizing the two TEOMs and the optical particle counter with the same sampling time.
- Recalculating the mass concentrations from the optical number concentrations to determine an Indoor/Outdoor ratio.

7. ACKNOWLEDGEMENTS

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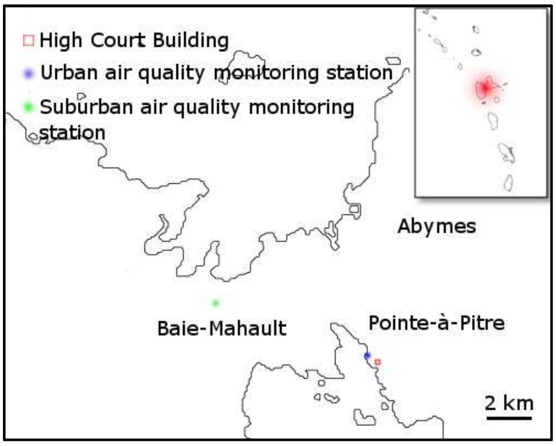

Figure 1: Sampling location

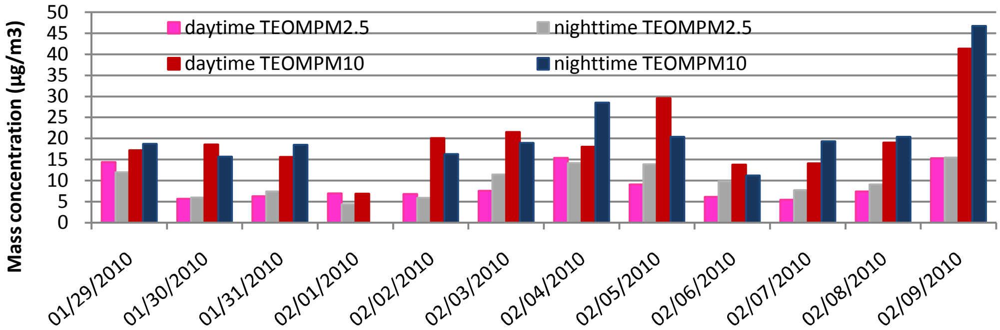

Figure 2: Daytime and nighttime averaged $TEOM_{PM2.5}$ and $TEOM_{PM10}$ for the sample period

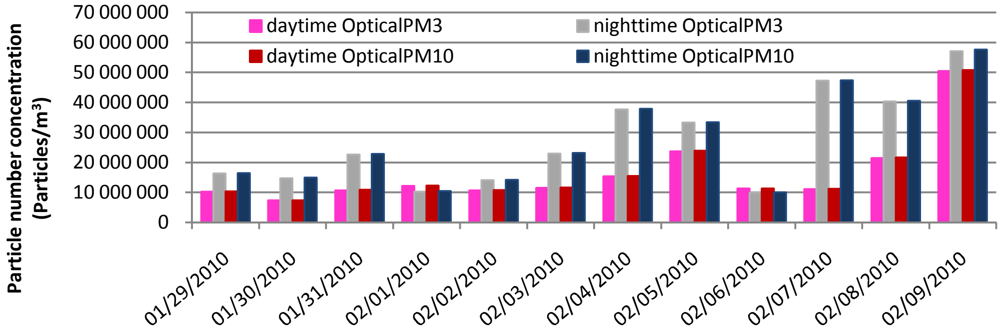

Figure 3: Daytime and nighttime averaged $Optical_{PM3}$ and $Optical_{PM10}$ during the sample period

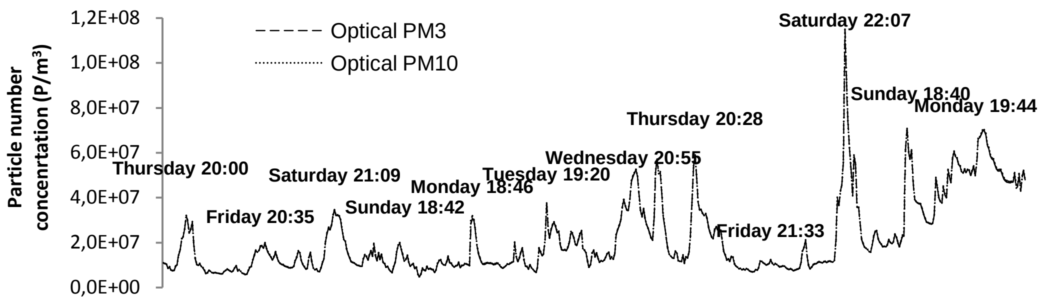

Figure 4: $Optical_{PM3}$ and $Optical_{PM10}$ concentrations during the sample period.

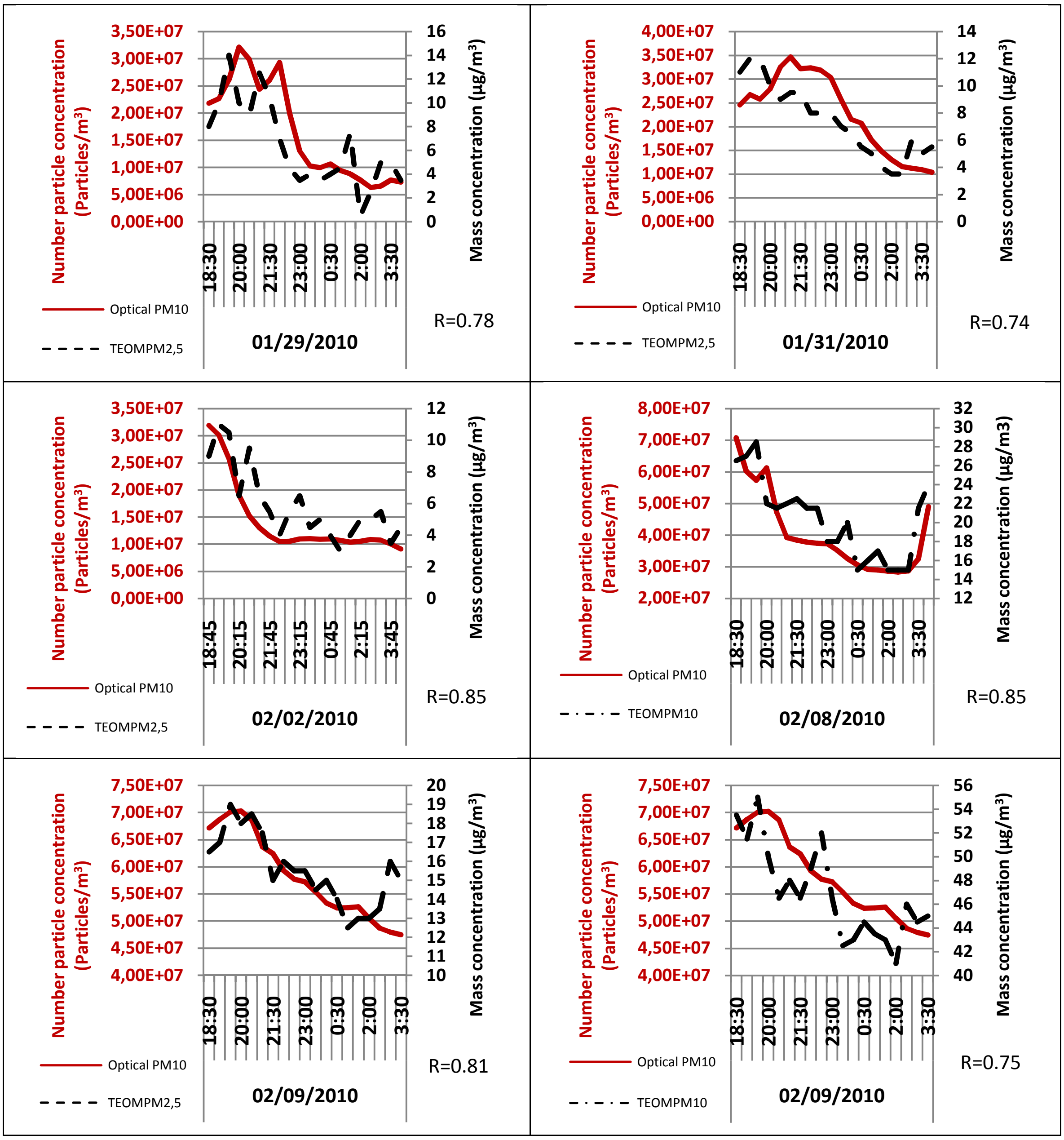

Figure 5: 6 days with close concentration variations between Optical$_{PM10}$ and TEOM$_{PM2.5}$ or TEOM$_{PM10}$, during the nighttime (6:30 PM and 4:00 AM)