Optical characterization and deployment of a distributed low-cost wireless particle sensor network

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Compact low-cost sensors for measuring PM concentrations are becoming popular in recent times (Wang *et al*, 2015). In this work, we used a Sharp GP2Y1010AU0F (Sharp GP2Y), an Arduino Nano, and an XBee module, as shown Figure 1, to set up an efficient wireless system which potentially broadens its application in multipoint field measurements that provide local and real-time PM concentrations.

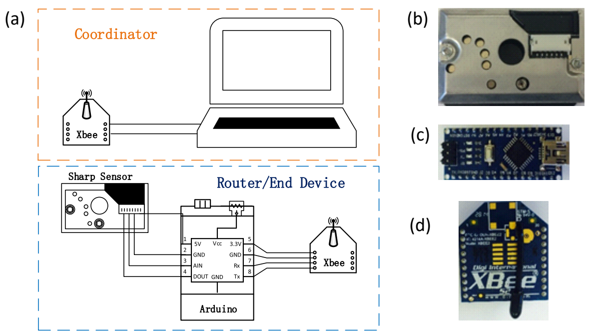

Figure 1. Major components of the wireless sensor system, (a) Assembled wireless sensor system, (b) Sharp GP2Y1010AU0F (Sharp GP2Y) sensor, (c) Arduino Nano ATmega328P Microcontroller, (d) XBee Series 2 wireless module.

One question that remains for the low-cost particle sensors is whether the signal is proportional to mass concentration or to other properties of the aerosol. We combined theoretical and experimental results to answer this question and then determined the reason for the system's dependence on material and size distribution. Theoretical calculations were based on the scattering calculation in the Mie regime. Experiments were based on aerosolized sodium chloride particles, produced by a TSI constant output atomizer 3076 and a Sonaer 2.4 MHz ultrasonic nebulizer. Reference instruments were a TSI scanning mobility particle sizer (SMPS) and a TSI aerodynamic particle sizer (APS). Figure 2 demonstrates good overall linearity between the calculated scattered light intensity and the signal output for particles in a wide size range. Hence the sensor output should indicate the calculated scattered light intensity rather than the particle mass concentration. With further analysis, we presented an equation to evaluate the linearity as a function of refractive index and size distribution parameters only. Further improvements of the sensor structure was expected to eventually eliminate the size distribution dependent disadvantage.

The characteristics of the low-cost wireless end devices described here, such as sampling interval, sampling node density, calibration parameters, and others, are conveniently adjusted according to the demand. Their portable size and self-contained power system make them applicable to mobile source sampling. It is also feasible to apply the wireless system in a confined space, such as in a reactor or chimney. In this work, we have deployed the sensor network for air quality monitoring in various indoor and outdoor locations, for example, garages, kitchens, construction sites, and so on. The personal exposure to particles in these scenarios is further calculated.

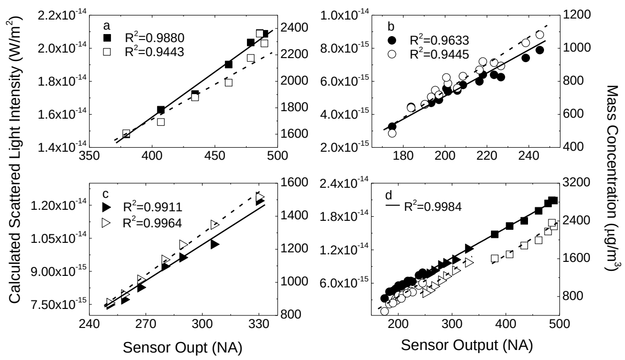

Figure 2. Relationship of the calculated scattered light intensity and the mass concentration as a function of the sensor output for small particles from 14.6 to 661.2 nm. Concentration in the atomizer: (a) 12 μg/cc NaCl (b) 18 μg/cc NaCl (c) 32 μg/cc NaCl (d) Combined results of three sets of tests. In each figure, solid and hollow symbols represent the calculated scattered light intensity and the mass concentration, respectively.

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Reference:

Wang, Y., Li, J., Jing, H., Zhang, Q., Jiang, J., & Biswas, P. (2015). *Aerosol Sci. Technol.*, 49(11), 1063-1077.