Smart Miniaturized Personal Monitors For Black Carbon And Multiple Air Pollutants

Steven N. Chillrud

Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY

While personal monitoring is widely viewed as the gold standard for exposure assessment for airborne particulate matter (PM) and other pollutants, its use as an exposure tool in large-scale epidemiologic studies has been extremely limited to-date. Current methods of exposure assessment are too cumbersome, noisy and labor-intensive, and do not provide near-real time measurements of key analytes. Instead past studies have primarily been small, collecting integrated 24 to 48 hr samples from personal samplers weighing 1.5 – 3 kg. In preliminary studies, we have developed a prototype miniature personal monitor that has the ability to collect integrated samples of airborne PM in several pre-determined micro-environments for subsequent laboratory analysis, the first such device of which we are aware. Our current prototype is sufficiently small and light to be used by young children. However, it does not monitor pollutants in real-time, cannot monitor multiple pollutants, and needs additional validation work before being used in epidemiology studies. We are developing and testing a miniature (palm size), quiet, rechargeable personal sampler that will (1) record time- and space-resolved concentrations of black carbon (BC) in near-real-time, (2) collect and archive time- and space-resolved PM samples for later laboratory analysis, (3) be able to make one additional analysis in near real-time, i.e., a chemo-optical analysis of a relevant gas or vapor such as ozone), and (4) record location and activity data. Our design goals for size, power, cost and quietness will permit wide use on most individuals, including young children, without disruption of normal activities. Black carbon will be measured in near real-time via an internal subminiature optical adsorption analysis of deposited particles. Spatial information will be provided by a miniature global position sensor (GPS) for outdoor locations and small home-/work-/car- placed radio beacons for key indoor locations. The unit will archive multiple time- and space-resolved particulate samples, for lab analysis via optical, mass spectrometric and single particle techniques, to identify temporal-spatial patterns of exposure to particle sources and to a wide range of compounds. Samples can either be analysed upon arrival at the laboratory or be archived until health data are available thus allowing adiditional hypotheses to be tested. The programmable miniature “smart” personal monitoring system will have the flexibility to be used in a wide range of sampling designs to assess spatial and temporal patterns of exposure. Development milestones include designing, building and testing 3 progressively more advanced versions of the sampler. Version 1 will integrate a GPS sensor, shrink the size with newer electronics, but will lack real-time BC capabilities. Version 2 will incorporate a sampling wheel and optics to allow near real-time measurements of BC, and a "base unit" that will operate as a battery re-charger and permit continuous monitoring for up to a month without maintenance. To assess subject compliance, a button-size compliance/location sensor will also be built and tested at this stage. In Version 3 we will add and test the concept of incorporating ozone detection in near real-time. Solar powered and/or large-battery-powered base units will also be designed for use in settings where access to the power grid is limited, such as in developing countries or for use at fixed-site outdoor locations lacking power. Laboratory and field experiments will be carried out iteratively during development to generate sensor algorithms, find improvements as well as estimate precision and accuracy via comparison to traditional real-time and integrative sampling methods of PM. To further validate and test the monitor, a number of small pilot studies are planned in US urban centers and in the developing world. The final smart air pollution monitor will incorporate upgrades suggested by the latest field-testing.