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Paul A. Baron

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Modern Real-time Aerosol Samplers

Paul A. Baron

National Institute for Occupational Safety and Health, Division of Physical Sciences and Engineering, 4676 Columbia Parkway, Cincinnati Ohio 45226

A number of direct reading aerosol instruments useful for industrial hygiene measurements and research have been developed in the last 15 years, many with government support. These instruments have attempted to address various industrial hygiene problem areas, including making real-time respirable dust measurements, making personal dust exposure measurements, and calibrating personal sampling devices.

This discussion covers a review of a selected number of instruments, ranging from simple photometers to a more sophisticated size distribution measurement system. Several laboratory and field applications of these and similar instruments are presented. Baron, P.A.: *Modern Real-time Aerosol Samplers*. *Appl. Ind. Hyg.* 3:97-103; 1988.

Introduction

Real-time aerosol monitoring instrument usage in the occupational health field has increased considerably in the last 15 years. Much of this increased usage is due to the availability of more sophisticated and well-characterized instruments. These instruments were perhaps not used as much as they might be for a variety of reasons. Some difficulties stem from the wide range of particle sizes that can be found in industrial settings. The particle diameter can range from 0.001 μm for condensation nuclei to 200 μm and up for dust particles emitted into the air. If one is interested in the mass of these particles, the range covers 15 orders of magnitude. It is rare to find instruments that can operate effectively over more than two orders of magnitude in particle size. In addition, particles in the workplace can have a wide range of chemical properties. To measure workplace aerosols effectively, it is necessary to determine the appropriate aspect of an aerosol that is to be measured. For industrial hygiene purposes, this typically means relating the aerosol measurement to the aerosol toxicity.

Quite often, more than one instrument is needed to provide measurements over a wide size range. On the other hand, in spite of all the potentially confounding variables, it is often possible to use relatively simple and limited instruments to provide very useful information. The real-time and spatial information is often more important than highly accurate measurements. The single most common aerosol measurement in workplaces is respirable dust mass. An instrument that has a usable response in

the 0.5–10 μm size range can be adequately tailored for these types of measurements.

Apart from the physical aspects of aerosols, there are a number of other reasons why the instruments are often not used. There are very few aerosols present in today's industrial environment that pose an immediate danger to health; most of the health risks are produced by chronic exposure. This means that the immediacy of information is not as critical as it is for some gases. While compliance measurements typically dictate that personal time-weighted average (TWA) results be obtained, direct reading instruments may, in some cases, be substituted for these measurements. Quite often a toxic aerosol is a component or small part of the aerosol present, and a species specific method of detection is required. There are not many direct reading aerosol instruments meeting this requirement.

Some physical aspects of the instrumentation also prevent widespread use. There is no simple, rapid aerosol detector equivalent to detector tubes for gases; many industrial hygienists are not as familiar with making short-term, real-time measurements for aerosols as they are for gases. Much of the instrumentation is expensive. The logistics of using several instruments can also be cumbersome when a wide range of contaminants must be monitored. There have been a number of instruments that have suffered reliability problems in field use and thus created a negative attitude among users. Finally, the complexity of aerosol properties and behavior combined with the necessity to interpret the dynamics of the workplace air have prevented some from attempting to make real-time measurements.

The following discussion will present first some of the progress made in recent years addressing some of these problems with direct reading aerosol instruments and then some evaluations and applications of these instruments. The instruments discussed will primarily be ones that have been developed with National Institute for Occupational Safety and Health (NIOSH) support or involvement.

Review of Instrument Development

The last 15 years must be considered revolutionary in terms of direct reading instrument development. The following discussion presents an overview of some of the developments that have taken place since the early 1970s.

The first direct reading dust monitor to be developed with

NIOSH support was the Respirable Dust Monitor (RDM-101) from GCA/Technology. The RDM used beta radiation attenuation to detect aerosol deposited by impaction on a greased disk. This instrument gave a result after sampling for a period of one minute or longer. The lower cutoff of particle size due to the impaction collector was about one μm . The beta radiation counting precision produced a lower detection limit of about 0.2 mg/m^3 . Lower levels could be detected with longer sampling periods. It was accurate for a wide range of materials.^(1,2) This instrument is no longer commercially available.

The largest single dust monitoring program is the coal mine dust monitoring program enforced by the Mine Safety and Health Administration (MSHA). The Bureau of Mines (BOM) supported continued efforts through the mid 1970s to develop light scattering instruments (also called photometers or nephelometers) that would measure respirable coal mine dust. In 1977, a contract with GCA/Technology [recently renamed Monitoring Instruments for the Environment (MIE), Inc.] resulted in the production of the Real-Time Aerosol Monitor (RAM).⁽³⁾ This instrument allowed the direct measurement of respirable dust concentrations in the rugged environment and potentially explosive atmosphere of coal mines. It gave a continuous readout (allowing the operator to follow rapid changes in concentration) with a nominal measurement range of 0.001 to 200 mg/m^3 , an internal calibration and zero check, a clean air sheath to keep the optics clean, a light emitting diode to illuminate the aerosol, and an output for data logging or stripchart recording. It also had an optional drier in the sheath air system to prevent condensation on the optics under high humidity. Many of these features combined to give the instrument good long-term stability and reliability.

This instrument, as well as other photometers, are generally used as supplements to, rather than replacements for, respirable dust filter sampling. Laboratory studies have shown good correlation of instrument response with generated dust,^(2,4) though good correlation in a specific study does not necessarily mean good accuracy. Photometers, as well as other direct reading dust instruments, are sensitive to size distribution changes, humidity, and composition of the measured aerosol.

The RAM development had several offshoots. The RAM-S, a stripped down version using an external pump, with no zero and range check, was intended for use as a control system monitor. Also, the machine-mounted respirable dust monitor (MMRDM) was supported by BOM at the request of MSHA to provide a system that would monitor the mining machine, one of the primary sources of dust in the coal mine. The MMRDM was intended for use in an alternative, less labor intensive, strategy for determining compliance with coal mine dust standards. It would have shut the mining machine off when dust concentrations reached unacceptable levels. The MMRDM was built and demonstrated but never implemented for compliance purposes.⁽⁵⁾ Reliability problems, calibration changes with type of coal, and interference from water droplets and high humidity were some of the reasons its use was resisted by the mining operators.⁽⁶⁾

A third offshoot of the RAM was the development of the mini-RAM, supported jointly by BOM, NIOSH, and the Environmental Protection Agency (EPA). This instrument was a miniaturized version of the RAM that had no integral sampling pump, but did have data logging and signal averaging capability. For the first time, it allowed the user to wear the instrument as a personal monitor, an important factor since personal exposure measurements have often shown higher and more variable concentrations than area monitoring. The passive sampling approach depended on local convection to push the aerosol through the detection

region. This approach also negated some of the advantages of the RAM, namely the clean air sheath for the optics and the zero and range check. However, when combined with a personal sampling pump and cyclone, the mini-RAM was found to give fairly reliable respirable dust readings.^(7,8) Two other miniaturized photometers were introduced [designated the Personal Dust Monitor (PDM), MDA Scientific, and the Hand-held Aerosol Monitor (HAM), ppm, Inc.] subsequent to the development of the mini-RAM.

In 1980, BOM and NIOSH supported the development of a personal, end of shift readout monitor based on the Tapered Element Oscillating Microbalance (TEOM).⁽⁹⁾ The TEOM is a device that can be used to measure the mass collected on its vibrating tubular glass sensor. The sensor replaced the filter cassette in a standard coal mine dust personal sampler, and a small filter on the sensor collected dust for an entire work shift. At the end of the shift, the sensor was placed in a readout system that recorded and logged the collected mass. Although this system has been found to work well, the advantage of rapid and automated analysis has to be weighed against the simplicity and low cost of the current coal mine dust personal sampler. It shows some promise as an accurate, rapid readout mass sensor.⁽¹⁰⁾

One of the drawbacks of aerosol monitoring instruments is that they are typically not specific for the toxic component of an aerosol. An attempt to alleviate this drawback resulted in the development (supported by the Department of Energy, NIOSH, and EPA) of a portable X-ray fluorescence (XRF) analyzer at Columbia Scientific Industries between 1977 and 1981.⁽¹¹⁾ The detection system used radioactive sources to irradiate a filter sample with X-rays, and the fluorescent X-rays of each element were selectively detected through the use of X-ray filters. While the portable XRF analyzer was not strictly a direct reading instrument, it did give the health professional field analytical capability. The instrument was capable of analyzing any one of 20 elements (between sulfur and uranium on the periodic table) in a filter sample in a period of two minutes. The sensitivity was sufficient to analyze most of these elements at their TLV on an eight-hour TWA sample. There were a number of reliability problems with the instrument, mainly related to the computer components.⁽¹²⁾ The instrument was never commercialized by the developer because of the availability of similar instruments (for ores and metals) and the commercialization cost of an additional product. More recently, a continuous monitor for lead using a paper tape filter has been developed using the X-ray fluorescence principle.⁽¹³⁾

Another instrument developed for a specific contaminant was the Fibrous Aerosol Monitor (FAM). This was developed at GCA/Technology with support from NIOSH, BOM, and EPA in 1977.⁽¹⁴⁾ The FAM was to detect asbestos fibers in real-time at the concentration of the then-current standard of 2 fibers/ml^3 . The FAM detected all fibers by using a combined electrostatic alignment and light scattering system. As an asbestos monitor, it was prone to interference from some common dusts such as cotton and other organic fibers, fibrous glass, and particle chains of metal fumes. In the absence of other aerosols, laboratory tests indicated fairly good correlation with the standard method of phase contrast light microscopy.⁽¹⁵⁻¹⁷⁾ Field test results were mixed, with some types of operations providing good results and others poor correlation with the reference method.^(16,17) The FAM may respond differently to straight fibers, such as amphiboles, than to curly fibers, such as chrysotile. The early FAM instruments also had reliability problems, mostly related to alignment of the laser beam. Many of these problems have apparently been solved.⁽¹⁸⁾

Although some theoretical work has been done,⁽¹⁹⁾ there is still some question as to how the instrument responds to real fibers with non-regular shapes. The FAM has been recently modified by placing a polarizing filter in front of the detector.⁽¹⁸⁾ Preliminary tests at NIOSH indicate that this has improved the discrimination against non-fibrous dusts.

The Aerodynamic Particle Sizer (APS) was developed by TSI, Inc., in 1981 with NIOSH support to fill a need for direct aerodynamic sizing of aerosol particles in the respirable dust size range.⁽²⁰⁾ This instrument sizes individual particles by accelerating them through a nozzle and measuring the particle velocity with light scattering. The aerodynamic size distribution is then calculated through a calibration with unit density spheres. Although the measured size is a function of density as well as aerodynamic size, the rapid measurement and data handling capability of the APS make it a useful laboratory and field instrument.⁽²¹⁾ Some other problems with APS measurements have also been noted, principally with sizing droplets with low surface tension and coincidence at higher particle concentrations. A modified version of the APS (Model 3310) is now in use at NIOSH. It features improved anti-coincidence circuitry and particle size measurement up to 30 μm .

A very recent development is a miniaturized condensation nucleus counter (CNC) called a PORTACOUNT used as a field quantitative fit tester for respirators. This device was developed at TSI, Inc., with U.S. Army support and based on earlier work using CNC's for fit testing.⁽²²⁾ The PORTACOUNT can detect all particles in the size range 0.02–1 μm and concentration range $0.1\text{--}5 \times 10^5$ particle/ml, allowing it to measure fit factors up to 10^5 . It is small, self-contained and has automatic, direct readout of fit factor as well as some self-diagnostic capability.

While the above discussion does not present a comprehensive list of all the direct reading dust instruments that are available today, it does indicate the broad spectrum of new capability that has arisen in the last decade and a half. Table I gives an indication of some useful parameters to consider in the application of these instruments.

Direct Reading Aerosol Instrument Applications Laboratory Studies

Many evaluations of direct reading aerosol instruments indicate that the instruments provide reasonably good correlation with reference methods under laboratory conditions and that this correlation degrades in field situations. There are a number of reasons for this, including that field situations are less controllable for doing accurate comparisons. In addition, the instruments themselves respond in ways not directly comparable to the reference methods. For instance, photometers respond to size distribution changes and refractive index changes in the aerosol. Thus, except for well mixed and stable field aerosols, these instruments may not correlate well in the field with reference methods which are typically based on gravimetric analysis of TWA filter samples. Therefore, the best applications of direct reading instruments are those taking advantage of the availability of immediate results and the rapid response to changes in concentration. Some instruments (e.g., the APS, optical particle counters, the quartz crystal microbalance [QCM] cascade impactor [California Measurements], and the PCAM, a combined photometer/optical particle counter [ppm, Inc.]) give size distribution information as well, but in most field instruments, this information is not available.

Various photometers have been used in our laboratories and in the NIOSH toxicology laboratories to monitor dust chambers on a routine basis. Penetration measurements of cyclones and impactors have been carried out using the APS.^(23,24) The use of the APS allowed the investigation of a number of variables in a short period of time. In an analytical method evaluation system, an optical particle counter was calibrated using several impactors so that size distribution data could be taken more rapidly.⁽²⁵⁾

The ability of particle size measuring instruments to give an accurate size distribution for workplace aerosols is often a major question. These aerosols can have a number of different components and cover a wide size range. An evaluation of several size distribution measurement instruments was carried out to assess their accuracy in determining the emissions from a large stand grinder.^(26,27) The grinding process studied, removing surface blemishes from gray iron castings, produced an aerosol that was a combination of several materials including metal and metal oxide, hydrocarbons from the grinding wheel binder, and barium sulfate, a grinding wheel lubricant. The elemental data were provided by scanning electron microscope (SEM)/energy dispersive X-ray analyses of filter samples. Some of the larger particles were excluded by the choice of sampling location near front of the grinder. The instrument comparison included the QCM cascade impactor, a Climet optical particle counter (OPC), a Particle Measurement Systems active scattering laser spectrometer (laser OPC), and an APS. Figure 1 shows a comparison of the number-weighted aerodynamic size distributions obtained with the various instruments as well as the size distribution obtained from filter samples analyzed with the SEM and an automated image analysis system (LeMont, Inc.). It can be seen that there are significant discrepancies between the various instruments. A most probable distribution was estimated by evaluating the deficiencies and strengths of each instrument and creating a composite distribution.

The QCM cascade impactor seemed to give the correct slope of the distribution but gave concentration values that were apparently too small, perhaps because of internal losses in the instrument. Its relatively low resolution also smoothed out some details of the size distribution. The laser OPC also seemed to give the correct slope of the distribution, but, because of uncertainties in estimating particle densities and refractive index, the calculated aerodynamic size distribution was also low. The laser OPC also gave spurious counts at the very small particle sizes

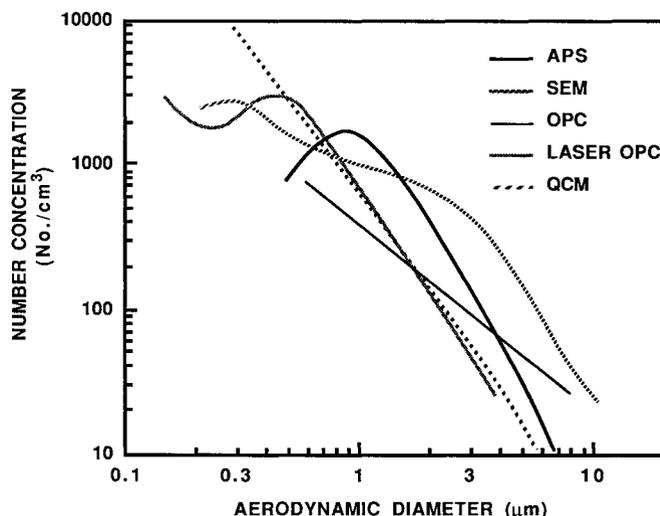


FIGURE 1. Size distributions of a grinding aerosol as measured by several instruments.⁽²⁶⁾

TABLE I. Typical Parameters For Some Direct Reading Aerosol Instruments

Instrument ^(a) Type	Cost ^(a,b) (in \$1000)	Time Response ^(a,c) of Readout	Measured ^(d) Parameter	Important Aerosol ^(e) Properties	Particle Size ^(f) Range (μm)	Main Advantages	Main Disadvantages
Photometer	2-6	continuous	Total light scattering	Density, Size distribution, Refractive index	0.3-15	Continuous readout	Calibration changes with dust type
β-attenuation Monitor	(g)	1-30 min	Absorption of β-radiation	Atomic number	1-15	≈ Direct measure of mass	Low sensitivity ^(h)
Optical Particle Counter	3-20	0.1-10 min	Light scattering size and count	Density, Refractive index	0.3-15	Indication of size distribution, High sensitivity	Low resolution and accuracy in sizing
Piezo-balance	4	0.5-2 min	Mass	Particle size	0.02-10	≈ Direct measure of mass, Measures fumes	Sensor cleaning ^(h)
Piezo-balance Cascade Impactor	20	1-60 min	Mass	Particle size	0.05-25	≈ Direct measure of mass, Size distribution	Sensor (h) cleaning internal losses
Condensation Nucleus Counter	6-20	0.5-30 sec	Particle count	Particle count	0.01-1	Small particle sensitivity	Alcohol emission
Fibrous Aerosol Monitor	14	1-1000 min	Light scattering "size" of fibers and count	Fiber length, Fiber diameter	Optically visible fibers	≈ Specific for fibers	Non-asbestos interferences
Aerodynamic Particle Sizer	35	2-10 min	≈ Aerodynamic size	Density	0.8-15	≈ Direct measure of aerodynamic diameter	Coincidence and density effects
Tapered Element Oscillating Microbalance	20	0.01-30 min	Mass	Adsorbed water	0.002-15	Direct measure of mass	Frequent filter replacement ^(h)

(a) Except for FAM and APS these comments may apply to a range of instruments from hand portable to stand-alone systems with data loggers or computers.

(b) Approximate price range including hand portable instruments to stand-alone systems.

(c) Some instruments display a continuous indication of detected signal, but actual concentration is determined after the time period indicated in table.

(d) Physical property of aerosol that produces instrument signal.

(e) Parameters that significantly affect accuracy of measurement.

(f) Upper size limit of 15 μm is due primarily to sampling limitations. Some instruments may correct for these inlet losses.

(g) Hand portable version no longer commercially available. Ambient particulate monitor (for PM-10 standard) available for \$15000.

(h) May exhibit transient response to liquid aerosols or to high humidity.

due to noise generated by the larger particles. The APS response dropped off significantly below about one μm. It also dropped off somewhat in the 6-10 μm range due to anti-coincidence circuitry. The density correction was not factored into the aerodynamic size calculation in this figure. If an average particle density of about two is assumed, then the size distribution measured by the APS comes somewhat closer to the laser OPC and QCM cascade impactor curves.

Although not a direct reading instrument, the SEM provides some interesting results for comparison. The SEM or the transmission electron microscope are often used as reference methods for many studies, especially in toxicology. Note that the shape of the SEM size distribution is different from the other distributions. This is apparently due to several measurement problems. The limited resolution of the image analysis system may cause problems in precise sizing of the smaller particles. Estimates of particle densities may cause a shift in the calculated aerodynamic sizes, although knowing the chemical composition of individual particles can help in this regard. Finally, the fact that particles are measured resting on a flat surface means that asymmetric

particles may present their largest cross section for measurement. This apparently causes the size overestimation of the larger particles. This error becomes especially important when trying to estimate the mass of these particles. Since aerosol mass is often the relevant parameter for health related measurements, errors in the large particle size range become quite important. There is almost a sixfold difference between the lowest and highest total mass estimates from these various instruments.

This study concluded that the APS, even with some limitations, gave the most useful estimate of aerodynamic size. Some recent developments may improve this instrument further. Predictive equations have been developed to correct errors in APS size determination due to non-unit particle density.⁽²⁸⁾ Note that the correlation for this density effect was not carried out in the above study and would result in about a 10 percent decrease in the total mass estimated by the APS.

The APS has been used to investigate the properties of both passive sampling devices as well as other direct reading instruments. The APS was used to measure penetration curves of cyclones and impactors.^(22,23) However, some of these studies did

not take into account the effect of density on the aerodynamic size reported by the APS. For instance, a nebulized suspension of dust was used as the challenge aerosol in several tests. This aerosol consisted of agglomerated particles, making it difficult to estimate the density of the particles. While the bulk density of the particles was high (3.5 g/cm^3), the agglomerated particles probably had a density less than 2 g/cm^3 . This would decrease the corrected sizes less than 10 percent.

The APS was used to determine the relative particle size dependent response of several photometers to a volcanic ash aerosol.⁽²⁹⁾ Photometer response to other aerosol materials can also be evaluated by this technique. Aerosol was generated in a test chamber, sampled through an impactor, and measured by both the APS and the instrument being tested. The impactor cut point was decreased in small increments, and the differential response of the photometer could be directly compared to the APS calculated mass. Figure 2 shows the size-dependent response curve for the RAM compared to the definition for respirable dust.

Field Studies

The APS is not only useful as a laboratory instrument but is sufficiently rugged to be used in the field. The items most vulnerable to workplace dust are the computer disk drive and the keyboard so these have been placed in a glove box arrangement supplied with filtered air. The APS and a sampling system were used at a limestone powder grinding operation. A Hi-Vol sampler drew air through 4-inch plastic flexible hose to the APS inlet where it was sampled isokinetically. The flexible ducting allowed sampling from various locations as much as fifteen feet from the APS cart.

The APS was used to measure water droplet distributions near a health club whirlpool where an outbreak of Legionnaire's disease occurred.⁽³⁰⁾ The APS was suspended with scaffolding over the whirlpool surface at several locations and the water droplet size distributions measured. To prevent water vapor condensation on the internal parts of the instrument, the instrument's cooling fan was connected to 2-inch diameter tubing that brought outside room air into the instrument. Similar measurements can be made at aeration ponds in water treatment plants and at cooling towers where bacterial generation in water droplet aerosols may cause disease.

Direct reading instruments can augment personal measurements with TWA filter samples by targeting those areas in which personal samples need to be taken and by allowing optimization of sampling volumes for the filter sample analytical method. In

addition, where aerosol size distribution and concentration do not change much with time, the direct reading instrument can be calibrated to provide a direct replacement for the filter sampling.⁽³¹⁾

Direct reading dust instruments can be used to implement a number of human feedback mechanisms for improving workplace conditions. The documentation of the effects of work practices can aid the health professional in convincing workers to modify those practices and reduce exposure. This documentation can also be supported by direct reading instruments which provide confidence in the operation of control systems both to the worker, to management and to others that are potentially exposed in nearby locations. These feedback mechanisms are especially useful in asbestos removal or abatement operations. Asbestos abatement operations require the use of a containment system to prevent the release of asbestos into nearby locations and into the environment. The FAM has been used to check the effectiveness of these containment systems by locating leaks as well as to monitor work practices within the removal operation to minimize dust release.⁽¹⁶⁾

The recirculation of workplace air is often desirable for economic and energy conservation reasons. A direct reading control monitor measuring the performance of filtration system in the recirculation loop is an essential component if optimum use of recirculation is to be achieved safely. The monitors themselves must be highly reliable and easily maintained. Operational parameters such as flow rate and sensor performance need to be self-monitored by these instruments.⁽²⁹⁾ The utility of these monitors was demonstrated in a foundry recirculation system. The final filter in the recirculation system was found to be torn, a fault not indicated with the simple pressure drop indicator in use. In addition, the primary cleaning system, a pulse jet air cleaner/cartridge filter, was not working correctly. The dust monitor allowed rapid repair and evaluation of the entire air cleaning system.^(29,32)

The evaluation and improvement of workplace dust control measures are often difficult, if not impossible, to carry out with traditional filter sampling methods.^(33,34) Various projects at NIOSH have evaluated workplace situations for optimum placement and implementation of controls. An early evaluation involved a bag opening operation at an asbestos product manufacturing plant.⁽³⁵⁾ The FAM was situated at the bag opening site, the instrument readout was manually recorded, and detailed notes were taken of the operation and the surroundings. The principle source of asbestos dust was found to be the forklift that moved pallets of bags around and brought the bags to the bag opening site. Because of the short-term activities involved, this correlation of high levels with an alternate activity would not have been brought out by traditional sampling methods. Other operations in the same plant were monitored using RAM's and the data recorded with strip chart recorders.

Based on experiences collecting information during a number of site surveys, integration of a variety of technologies allowed a much more complete assessment of the dynamics of various operations. In an evaluation of a manual weighout and transfer operation, the time-resolved concentrations at several points around the operation were measured with photometers and recorded with a data logging computer. One of the photometers was worn by the worker. This allowed a number of different statistical analyses to be carried out.⁽³⁶⁾ Synchronizing a video recording with the data logging allowed considerable detail to be extracted from the data. Since the operation was repetitive, a time series

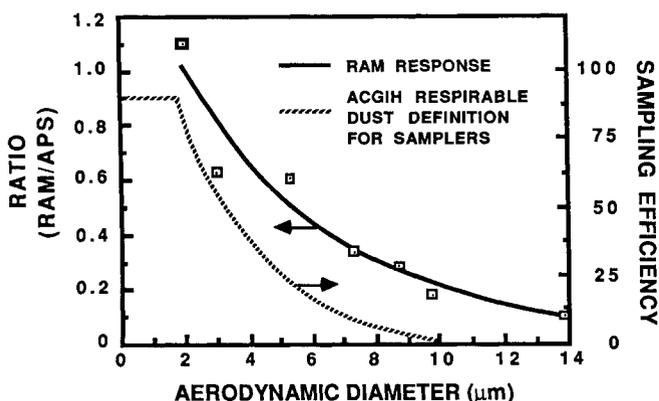


FIGURE 2. Size dependent response of the RAM for a volcanic ash aerosol⁽²⁹⁾ compared with the respirable dust curve.

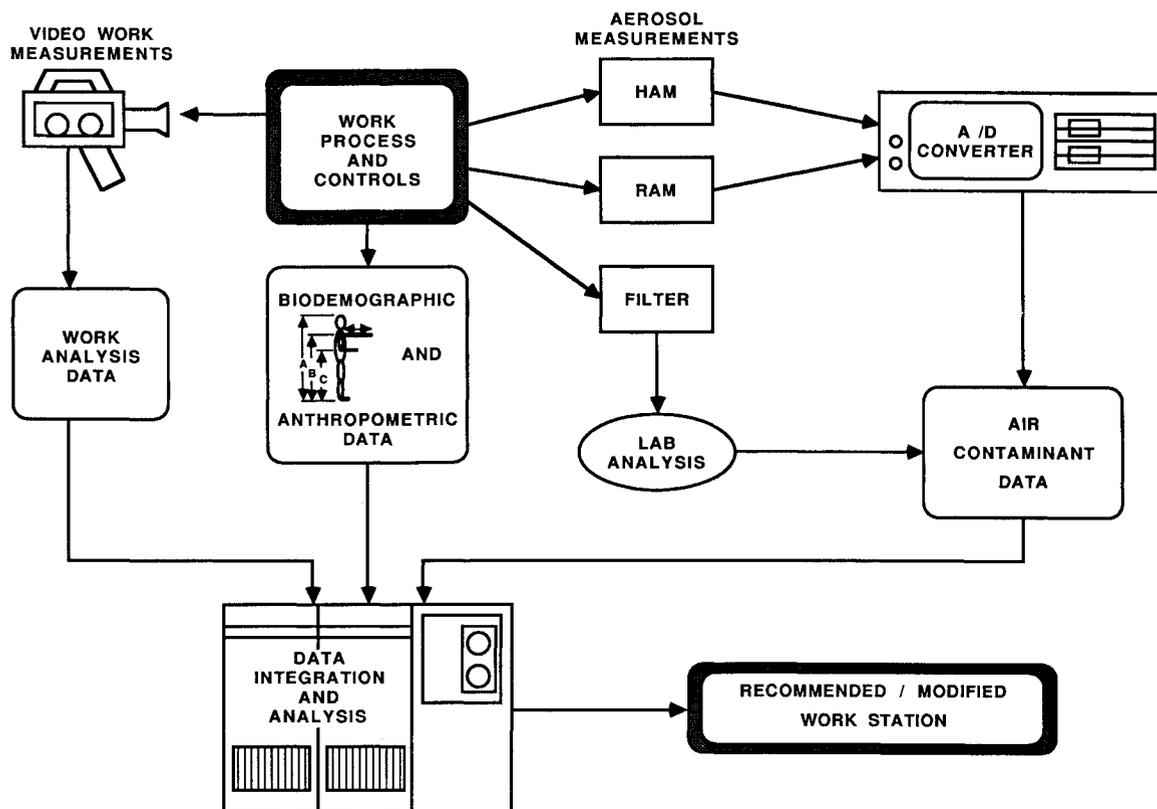


FIGURE 3. Overall data acquisition and analysis scheme for evaluating work processes and controls to develop recommendations for improvements.⁽³⁸⁾

analysis was carried out and the work components of the operation producing the dust were detailed. This analysis indicated that the scooping of material from a drum gave the largest contribution to the personal dust exposure.⁽³⁷⁾

In addition to these measurements, anthropometric and biodemographic data were also obtained to provide a more complete, quantitative picture of the operation. Figure 3 shows all of these items combined through data integration and analysis on a mainframe computer, resulting in recommendations for modified work practices and condition.⁽³⁸⁾

Conclusions and Recommendations

Over the last 15 years, a number of new instruments have been developed. New instrument development has slowed considerably in the last several years, though work has continued in evaluating various instruments and integrating the instruments with other types of measurements. Current trends in instrument development seem to point largely in an evolutionary direction, with aerosol sensors being miniaturized and integrated with other technologies, such as computer and video systems. These trends will produce instruments which are more reliable, self-diagnostic, and "user friendly." With these instruments, the health professional will have increased capability to directly measure aerosols on a routine basis and solve workplace health problems.

A number of instruments have been shown to be useful in evaluating sources of exposure and providing immediate quantitative feedback unavailable from more traditional measurement methods. However, in deciding to measure aerosols with these instruments, the industrial hygienist must weigh the alternatives in terms of cost, reliability, and accuracy. Table I has been included to help select an instrument suited for specific types of measurements.

Disclaimer

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

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Hazard Control Management Certification Board Examination Schedule for the Following Certifications:

Certified Hazard Control Management (CHCM)
Certified Product Safety Management (CPSM)
Certified Healthcare Safety Professional (CHSP)

Detroit, Michigan — May 7, 1988
Atlanta, Georgia — May 18, 1988
Washington, DC — May 25, 1988

Applications, study guides and additional information may be obtained by contacting: Hazard Control Certification Board, 8009 Carita Court, Bethesda, MD 20817; telephone (301) 984-8969.

Special note to Military Installations: Arrangements can be made to offer the examination on a continuous basis at military installations that have a training and testing activity.