Air Sampling For Source Identification And Feasibility Determination In The Machining Environment

This paper provides a strategy for evaluating sources of exposure and control measures necessary for exposure to machining fluids. The prescription for collecting air samples reflects a systems based approach for reducing the multiple sources of exposure to machining fluid particulate.

This approach applies regardless of the accepted exposure limit and method of analyzing the air sample. However, the rationale for the UAW's proposal of 0.5 mg/M^3 total particulate will help put the air sampling needs in perspective.

Rationale for Exposure Limit

The UAW petition to OSHA in 1993 proposed 0.5 mg/M^3 total particulate as a provisional exposure limit until a complete review of health effects and feasibility could be completed. This limit had been recommended by the UAW-GM Occupational Health Advisory Board based on early studies showing respiratory effects at exposures well below the current PEL for oil mist. Recent studies confirm the appearance of clinical respiratory illness such as occupational asthma and hypersensitivity pneumonitis arising in workers exposed to particulate below 0.5 mg/M^3 .

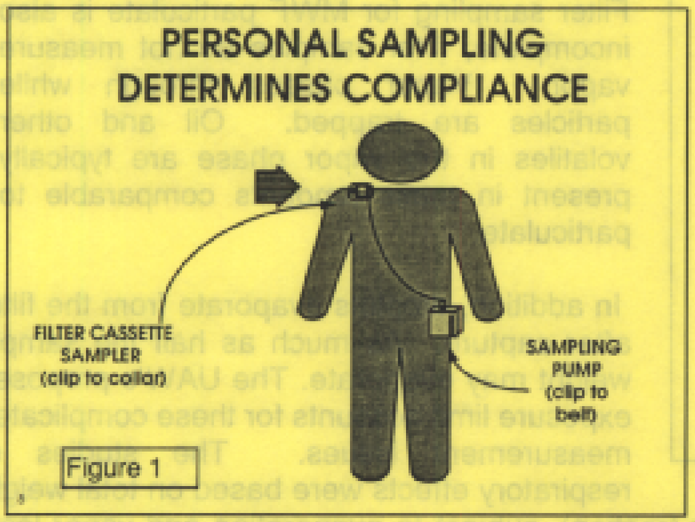
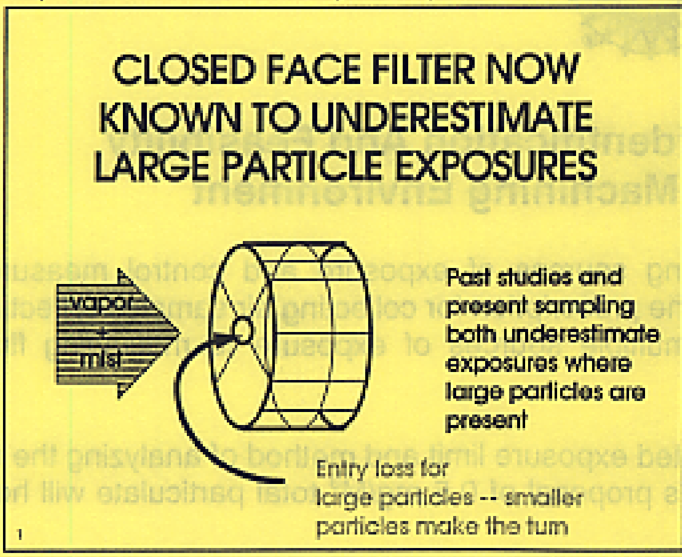


Figure 1

The UAW-proposed limit was approximately the median of the exposure distribution data available at the time, and so appeared immediately feasible. The limit was also a round number and a factor of ten below the existing limit for oil mist.

Weight of particulate was selected as the measure of exposure because the exposure-response data for respiratory and cancer effects were based on weight of particulate. Although those studies measured smaller particles (thoracic particulate), the UAW advocates total particulate measurement because sampling devices for thoracic particulate are not widely available. Analysis by weight is advocated because it simplifies analysis of samples by eliminating chemical testing or extraction. Requiring only a simple analysis would permit statistically valid sampling schemes requiring collection of many samples with either filters or real time aerosol monitors. Total particulate weight is the most appropriate single index for a complex and changing mixture of exposures where many components are toxic. There is no reason to emphasize oil alone, because the pure petroleum oil without contaminants is unlikely to be the most significant component of the mixture with regard to respiratory irritation.

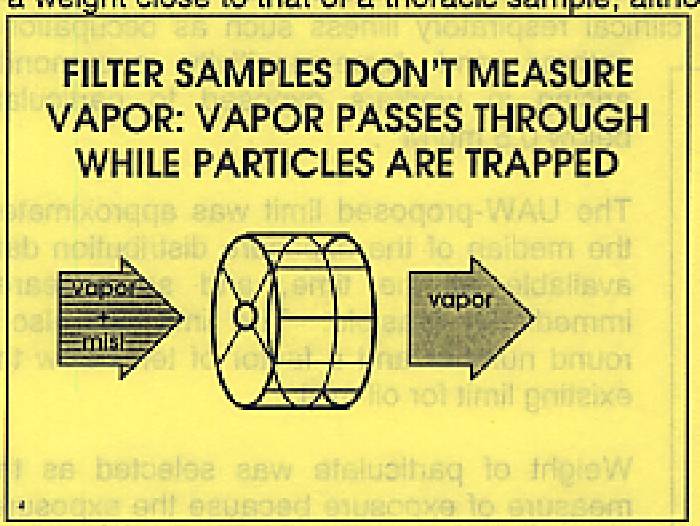


Personal breathing zone sampling is the appropriate method to determine a health based limit. While personal breathing zone samples are the appropriate measure of health risk, area and fixed position samples are needed to evaluate sources of exposure or effectiveness of engineering controls.

Sample Analysis Methods

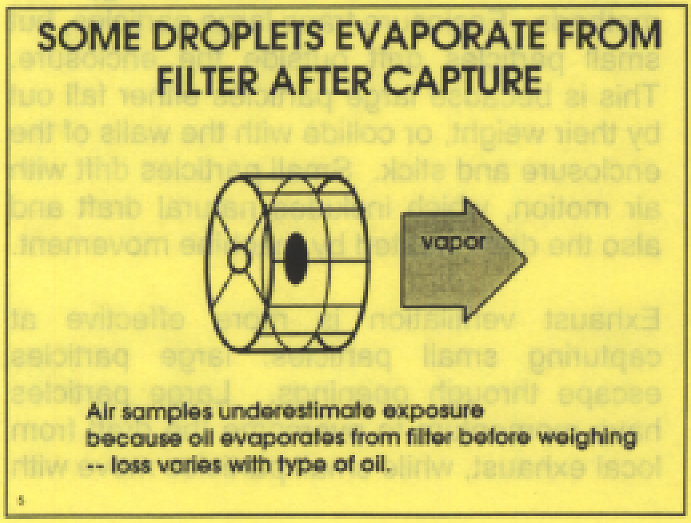
The current terminology of "total particulate" is incorrectly applied to samples collected with a closed face filter cassette. The closed face filter sample excludes a substantial amount of weight of larger particles which workers inhale or ingest, because large particles are excluded by the aerodynamics of the opening on the face.

A closed face filter total particulate measurement in a machining environment will generally yield a weight close to that of a thoracic sample, although particle size distribution may differ.



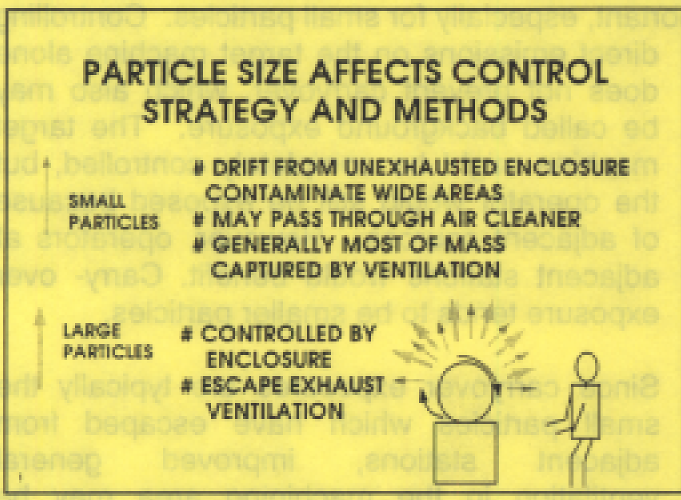
Filter sampling for MWF particulate is also incomplete, filter samples do not measure vapor. Vapor passes through while particles are trapped. Oil and other volatiles in the vapor phase are typically present in mass amounts comparable to particulate.

In addition, droplets evaporate from the filter after capture. As much as half the sample weight may evaporate. The UAW's proposed exposure limit accounts for these complicated measurement issues. The studies of respiratory effects were based on total weight of smaller particles from all sources (thoracic fraction), subject to evaporation and vapor loss. The 0.5 mg/m^3 value takes into account that total particulate weight would be higher than thoracic fraction weight alone.



Water is a major part of the aerosol for soluble oils and synthetics. Water flashes off the filter and is not part of the measured weight. Range finding studies indicate that oil mist -- the material which is extracted from filter by solvents is about 80% of total particulate. The small particles (thoracic fraction) are about 80% of total particulate measured by a closed face filter. The real-time aerosol monitor can be calibrated against filter samples. However, the RAM overestimates exposure unless it is directly calibrated against machining fluid total particulate.

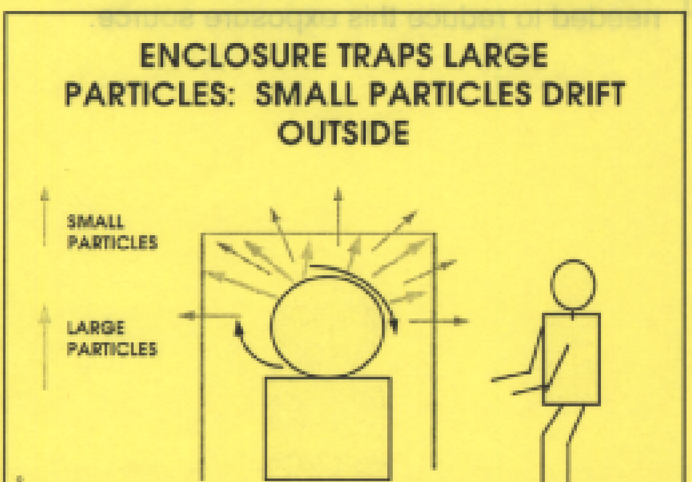
Among other sampling concerns, microbes and microbial products are difficult to measure in air. Studies show these are correlated with particulate levels and with concentration in bulk fluid. Formaldehyde is present at OSHA regulated levels in facilities which use triazine biocides.

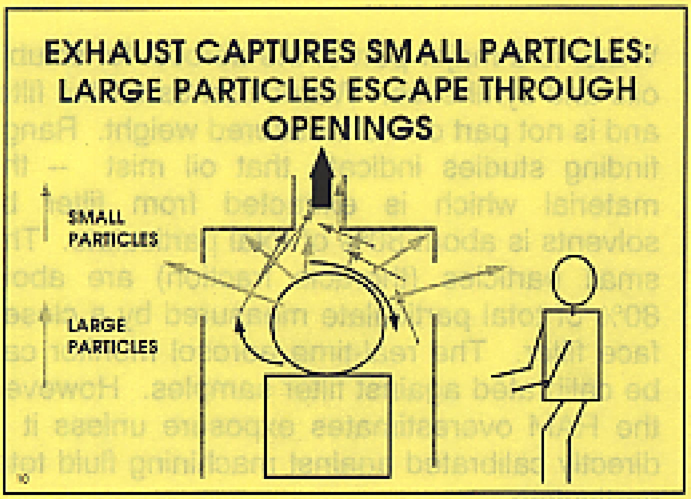


The actual amount of machining fluid particulate inhaled or ingested by people in machining environments is at least two to three times greater than indicated by the closed face filter total particulate method.

Control Technology Approaches

Direct exposure of a machine operator to machining fluids involves small and large particles. Large particles are those greater than 10 microns in diameter. Thoracic fraction particles are less than 10 microns. Respirable particles are those less than five (5) microns, and ultrafine particles are less than one (1) micron. Close to a machine, large particles dominate the weight of material inhaled. Farther from the machine, small particles are more important.



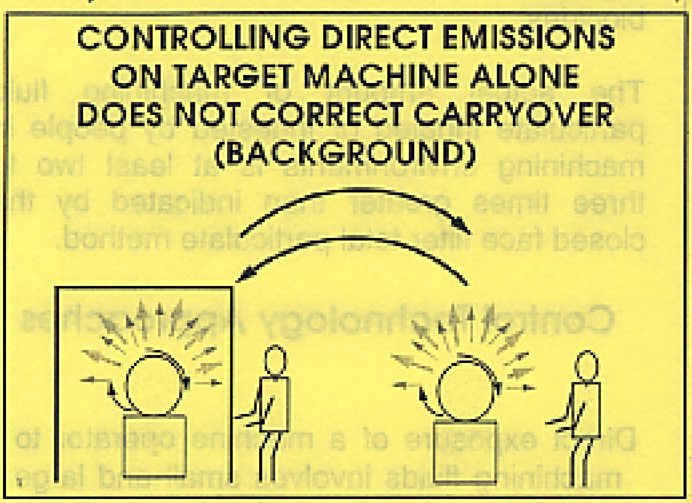


EXHAUST CAPTURES SMALL PARTICLES: LARGE PARTICLES ESCAPE THROUGH OPENINGS

Particle size affects control strategy and methods. Enclosure traps large particles, but small particles drift outside the enclosure. This is because large particles either fall out by their weight, or collide with the walls of the enclosure and stick. Small particles drift with air motion, which includes natural draft and also the draft created by machine movement.

Exhaust ventilation is more effective at capturing small particles: large particles escape through openings. Large particles have momentum to overcome the draft from local exhaust, while small particles move with the air.

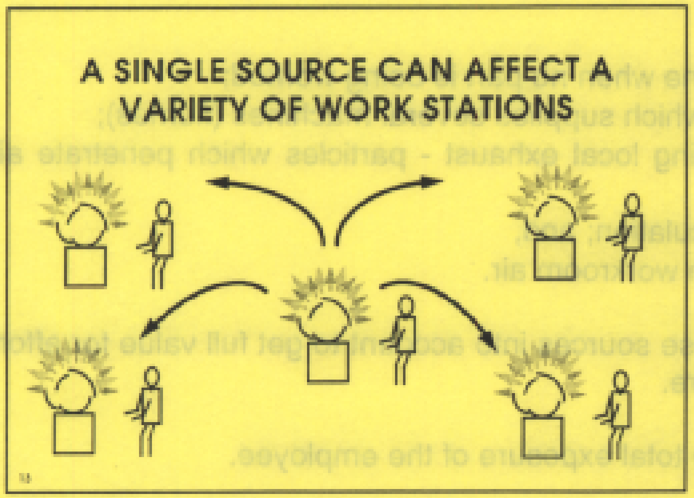
Carryover of mist between work stations is important, especially for small particles. Controlling direct emissions on the target machine alone does not prevent carryover, which also may be called background exposure. The target machine might be completely controlled, but the operator would still be exposed because of adjacent sources. However, operators at adjacent stations would benefit. Carry- over exposure tends to be smaller particles.

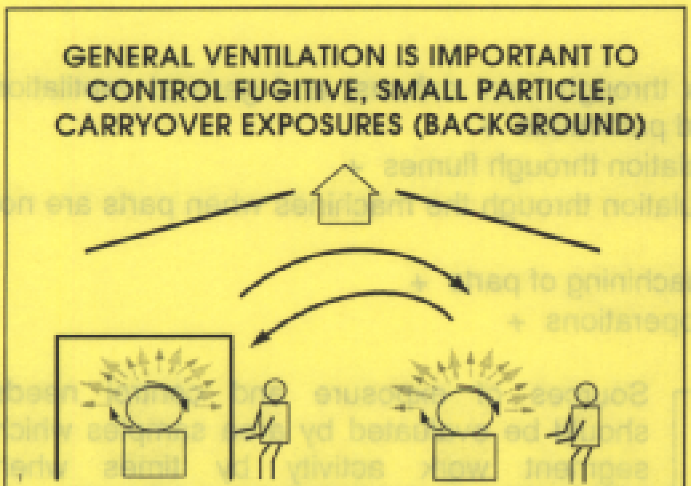


CONTROLLING DIRECT EMISSIONS ON TARGET MACHINE ALONE DOES NOT CORRECT CARRYOVER (BACKGROUND)

Since carryover exposures are typically the small particles which have escaped from adjacent stations, improved general ventilation in the machining area may be needed to reduce this exposure source.

A single exposure source can affect a variety of work stations. Often the heaviest source is the earliest operation in line with the heaviest cut. The important lesson for control strategy is that:





- a control measure on the target machine may appear less effective because of carryover or background from other sources.
- a control measure on the target machine will protect workers on adjacent machines as well.

Air sampling should start by measuring personal breathing zone exposures of employees in a machining area. The personal samples indicate whether additional control is needed, or the level of exposure associated with presence or absence of health complaints. Personal samples account for the time spent at various locations close to and far from sources of exposure during a routine work shift. Personal exposures to the same employee may vary considerably depending on specific activities on the day of sampling.

Fixed position samples reflect emissions, sources and control effectiveness. Experience shows that most stationary samples will be higher than most personal samples. This is because operators are not always in the area. However, a few of the personal samples will be substantially high compared to fixed position samples. This is because operators may get into special situations with very high exposure.

Metalworking Fluid Exposures Come From Several Sources Or Steps In The Production Process:

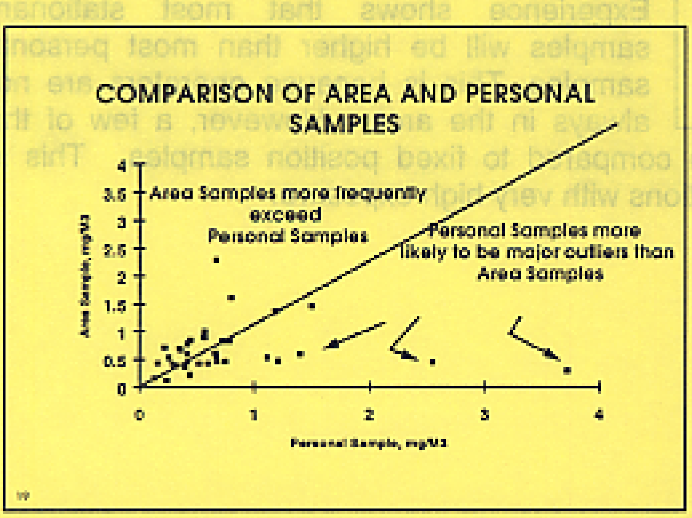
- Machining of part;
- Fluid flow through machine when no part is being worked;
- Fluid circulation system which supplies several machines (flumes);
- Air cleaner on recirculating local exhaust - particles which penetrate air cleaner;
- Air supply system - recirculation; and,
- Residual concentration in workroom air.

An air sampling strategy must take each of these sources into account to get full value for effort in identifying opportunities for reducing exposure.

The combination of all these sources yields the total exposure of the employee.

Total Exposure =

- Recirculation of particles through local exhaust and general ventilation plus persistent suspended particulate +
- Emissions from fluid circulation through flumes +
- Emissions from fluid circulation through the machines when parts are not being run +
- Generation from actual machining of parts +
- Carryover from adjacent operations +



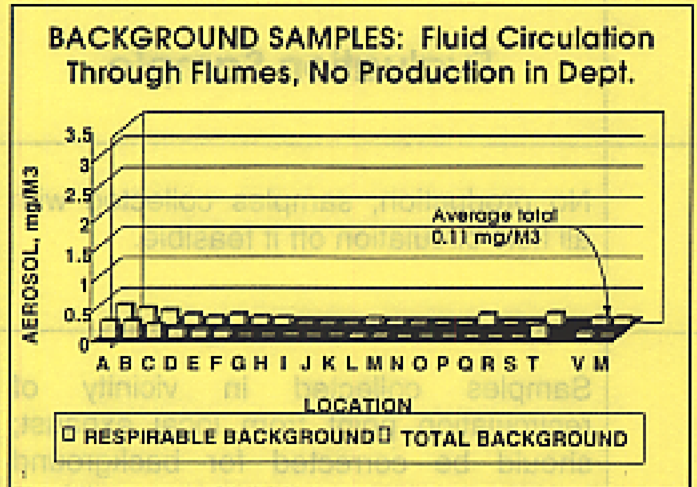
Sources of exposure and control needs should be evaluated by area samples which segment work activity by times when exposures are different, such as no production, start up, actual operation. Multiple personal breathing zone samples must be collected to determine exposure for standard compliance because exposures vary from worker to worker and day to day for a variety of reasons. Multiple area samples for work activity segments must be taken because particle levels vary with time even at a fixed location. Area sample points should be plotted on a floor plan of the work area. An area sample approximating an employee's work station should be selected for each target machine.

Air Sampling Arithmetic

Exposure Sources	Evaluation Sample
+ Air System recirculation plus persistent suspended particulate	No production; samples collected with all fluid circulation off if feasible.
+ Local exhaust ventilation recirculation	Samples collected in vicinity of recirculation point from local exhaust; should be corrected for background expected under production conditions sampled.
+ Flume circulation	No production or circulation through machines
+ Adjacent operation carryover	Production in areas adjacent to target, but no production circulation of fluid through target machine.
+ Circulation of fluid through target machine	Circulate fluid through target machine without production. Must be corrected for carryover from adjacent operations.
+ Mist generated by running production at target machine	Production; contribution to exposure from operation of target machine must be corrected by subtracting other sources.
= TOTAL EXPOSURE	

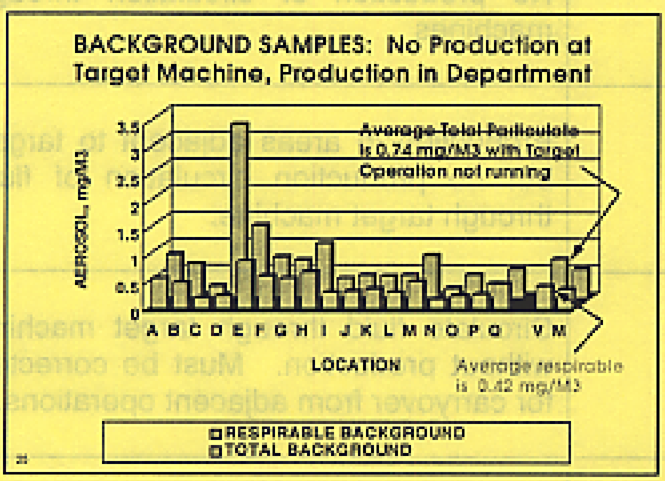
Application of Sampling Strategy to a Source Assessment Campaign

Results from a control technology evaluation study show the importance of a staged sampling campaign to identify sources. In this study, consultants measured both total particulate and the respirable fraction at various locations in several machining plants.



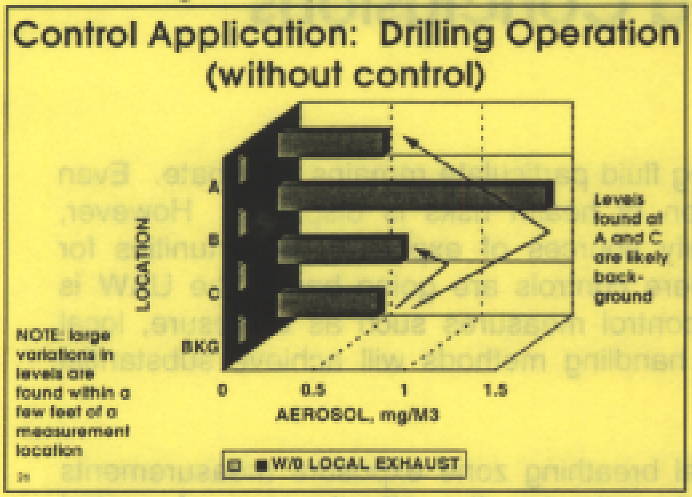
The first campaign measured both sizes of particles at 19 locations in a plant. These measurements were taken at a time when no production was running, no fluid was pumped through machines, but fluid was circulating through the flumes. Results varied at positions with an average total particulate level of 0.11 mg/M^3.

Another campaign was conducted in a different plant. This time, samples were collected around 17 machine work stations with fluid flowing but no production at the target station. The average exposure to total particulate was 0.74 mg/M^3, with a median about 0.5 mg/M^3. Total particulate samples were highly variable and highest close to the source. By contrast, respirable particulate samples averaged 0.42 mg/M^3 and were more consistent.

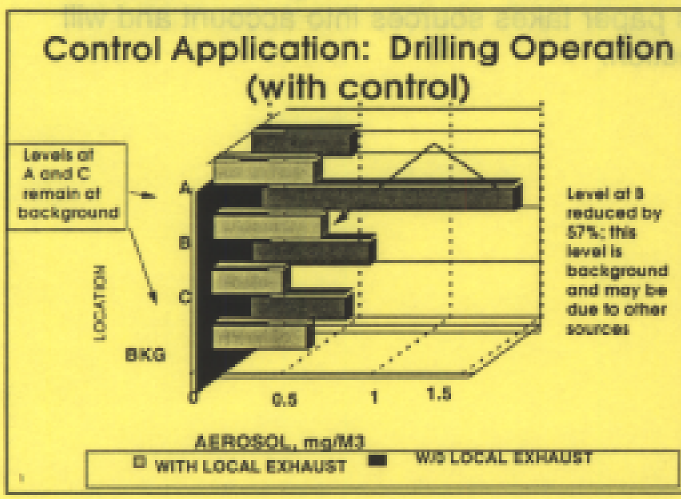


The importance of knowing the background -- contribution from sources other than the target machine, is seen from direct evaluation of control effectiveness at a drill. In this case, effectiveness of existing local exhaust was measured by turning the ventilation off to see how much exposure increased. Samples were taken at three locations within a few feet of the target machine, with ventilation off; (these are labeled A, B, and C in the figure). The value for BKG or background was the median of samples collected in the department. Note that exposures vary even within a few feet and by direction. The levels at A and C were essentially equal to background, and may reflect no direct contribution from the target machine.

Turning the ventilation on reduced exposure at location B by 57%, from nearly 1.2 mg/M^3 to about 0.5 mg/M^3. Exposures at points A and C were affected only slightly. Clearly the average of the three locations would be little changed, making it appear that ventilation was ineffective. However, the levels at A, B, and C after ventilation were essentially equal to background. Therefore, the ventilation may have been 100% effective in reducing the contribution of the target machine, but without appreciation of background it would have appeared ineffective.



Surprisingly, effectiveness of existing or planned controls can best be evaluated by first sampling ***away*** from the target work station to find other sources of exposure. Controlling one source reduces exposure at many other locations, especially for small particles which can drift. Complete control can be achieved only by controlling all sources with enclosure and exhaust, and then capturing the fugitive emissions by good, general ventilation.



Preparing For a Source Assessment Campaign

Before beginning an exposure and source assessment campaign, compile whatever information is already available:

- Past air sampling results;
- Floor plan for recording sampling locations;
- Documentation of ventilation system, such as blue prints;
- Copies of ventilation system test results; and,
- Fluid system documentation.

The present air system should be brought up to full design capacity:

- Restore all enclosures;
- Clean and repair ductwork;
- Check air cleaner filters;
- Measure exhaust airflow and compare to specification; and,
- Measure supply air flow and compare to specification.

Summary and Conclusions

The safe level of exposure to machining fluid particulate remains in debate. Even the proper measurement for evaluation of health risks is disputed. However, industrial hygiene sampling can identify sources of exposure, opportunities for exposure reduction, and situations where controls are going bad. The UAW is convinced that application of routine control measures such as enclosure, local exhaust, general ventilation and fluid handling methods will achieve substantial reductions from current exposure limits.

Typical air sampling limited to personal breathing zone exposure measurements overestimates the difficulties and underestimates the effectiveness of control measures at a target machine and work station. This is because typical sampling doesn't take cross contamination from sources other than the target into account. The sampling approach described in this paper takes sources into account and will reveal new opportunities for worker protection.

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