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The Assessment of the Interaction of Airborne Contamination with Building Ventilation Performance

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Introduction

Various stages in the manufacture of goods in rubber or other polymers give rise to airborne contamination in the factory workroom. Investigations have been carried out over the last three years in industrial buildings housing a variety of manufacturing processes. These investigations were to collect data prior to the designing of solutions to improve the control of airborne contamination. A study of the data reveals that the satisfactory control of airborne contamination in a workroom depends on many factors. It is necessary to take into account all relevant factors so that a satisfactory solution can be achieved. This paper outlines the type of data that is collected, how it is collected and interpreted and what conclusions can be drawn.

Data Collection

Contaminant Source and Behaviour

Air sampling, using normal occupational hygiene techniques, reveals where personal exposure to airborne contamination is above permitted levels. This leads to the need to review where the contamination is coming from, how it is produced and how it behaves once it is emitted into the workroom atmosphere.

The physico-chemical properties of the contaminant and action of the process can usually be determined by the engineer with the co-operation of the works chemist. However, the engineer also needs to know about the behaviour of the contaminant, local to the process and when it is entrained in the workroom atmosphere.

Behaviour local to the process can be studied using a dust lamp[1], Schlieren photography[2], or Infra-red techniques[3,4] as appropriate. The rate of release of contamination can be estimated from the shape and size of the emission combined with velocity of the contaminant.

An estimate of volume flow rate is required where this is generated by stack effect due to heat from the product or process causing emission of contamination. It may be relevant to measure temperature of the air current generated by stack effect and of the product or process. Both contact and remote sensing of temperatures are useful.

Behaviour of contamination when entrained in the workroom atmosphere is best assessed using arrays of static samplers or portable air sampling equipment with a direct read-out.

Exhaust Ventilation

Exhaust ventilation, both general and local, has its performance measured using conventional methods[5] such as Pitot-static tube traverses of ducted systems. Volume flow rates are thus obtained for all exhaust systems in a workroom.

Supply Air

A similar exercise is carried out to measure the volume flow rates of all supply air to the workroom.

Passive sources, such as louvres or vents are measured where possible, in addition to mechanically powered supply air systems.

Workroom Pressure Differentials

Pressure differences between the interior of a workroom and atmosphere or adjacent rooms, may exist as a result of wind pressure, stack effect or imbalance of exhaust over supply air. Measurements are made of these pressure differentials at convenient places around the workroom when all the workroom ventilating equipment is working normally. A sensitive manometer, reading to 1 Pa is required[6]. Mean wind velocity and direction at the time of the test are noted.

Air Currents in the Workroom

Air currents can be created by one or more of the following means: movement of people, transport or machinery; wind pressure; stack effect; building leakage; mechanically-supplied air; imbalances of exhaust and supply air. Smoke is used to visualise air currents and a velometer is used to estimate gross volume flow rates.

Discharges from Exhaust Ventilation Systems

It is important to assess the performance of the discharge arrangements and the behaviour of the contaminated air when it is discharged from an exhaust system to the atmosphere. Besides a physical check of the geometry of the discharge arrangements, the efflux velocity of the contaminated air is measured.

The behaviour of the contaminated air can often be assessed by direct viewing or taking 'dust lamp' photographs using the sun.

Staining of the surroundings of a discharge also reveals useful information as to the behaviour of the contaminated air. Smoke can be injected into the exhaust air so as to make air patterns visible.

Wind data are obtained from the nearest meteorological office. This is then turned into a wind rose which is drawn onto a site plan so that an assessment of the effect of prevailing wind can be made.

Typical Data

Once on-site data have been collected, calculations can be made, the results collated and conclusions drawn. Alterations to the equipment or the process can then be designed.

The results of some actual investigations are summarised in Table 1. This Table illustrates typical values that are obtained from studies of workroom ventilation performance.

Table 1. Some typical data

Item	Units	Factory			
		1	2	3	4
Product		Tyres	PU foam	Hose	Wheels
Airborne contamination type (see note 1)		RPF	TDI	RPF	Spray paint
Does process generating contamination occupy whole or part of workroom?		Part	Whole	Part	Part
Floor area of whole workroom	m^2	20290	1370	1890	8309
Volume of whole workroom	m^3	146090	8200	11800	50480
Floor area of workroom containing process	m^2	5072	1370	995	502
Volume of workroom containing process	m^3	36553	8200	5900	3050
Total exhaust from workroom	m^3/s	145	22	15	34
Total supply air to workroom	m^3/s	36	13	0	0
Pressure difference relative to atmosphere (note 2)	Pa	–20	–4	–5	–0.5
Pressure difference relative to adjacent workroom	Pa	–13	–2	–	–5
Exhaust efflux velocity (average) (note 3)	m/s	–	12	8	–
Exhaust discharge direction (note 3)		down	up	horizontal	down
Is exhaust discharge above or below highest point on building?		below	above	below	below
Is there contaminant entrainment from other parts of workroom?		no	yes	no	yes
Is there contaminant entrainment from adjacent workroom?		no	no	no	no
Is there re-entrainment from discharges?		yes	no	yes	yes

Notes:

1. RPF = rubber processing fumes. TDI = toluene diisocyanate.
2. Largest value.
3. Exhaust discharges via some designs of weather cowl deflect downwards and do not allow efflux velocity to be measured.

Interpretation of Data

Workroom Air Balance

Airflow in and out of a given volume of workroom must be in balance. This balance can be summarised as:

Σ mechanically powered exhaust air + Σ ex-filtration

= Σ mechanically powered supply air + Σ infiltration.

From measurements made on mechanically-powered supply and exhaust systems, and on volume flow rates through such workroom openings as vents, louvres and doorways, we can draw up an air balance. The degree of out of balance of mechanically-exhausted air with respect to mechanically-supplied air will be reflected in the measurements of pressure differential between the workroom and atmosphere or adjacent workrooms. Airflow will then result from these pressure differentials.

When contaminated air has escaped into a workroom atmosphere, it will be entrained in the workroom air currents. This contaminated air can then eventually pass the breathing zone of a person in the workroom. This mechanism is often the reason for higher than expected exposures to airborne contamination when a person works at an exhaust-ventilated work station.

Movement of contaminated air from one part of a workroom to another, or from one workroom to a neighbouring workroom, can be a source of background contamination in an otherwise unexpected location.

Re-entrainment of Contamination from Discharge

The combination of wind, stack height and location, efflux velocity, building shape, surrounding topography and climatic conditions[7] can militate against satisfactory dispersal of contaminated air from an exhaust system discharge stack.

As a minimum requirement, exhaust systems must discharge vertically[8], above the highest point[8] on the building and at an adequate efflux velocity[7]. If this is not done, there will be a downwash from the stack which will be entrained in air currents generated by the interaction of wind with the building[7,8].

With contaminated air being held close to the building, it can then re-enter the building either via supply air inlets or via building infiltration. The end result is the same as that discussed under workroom air balance. Contaminated air passes the breathing zone of people in the workroom.

Conclusions

It is necessary to make comprehensive measurements and observations of the behaviour of airborne contamination and how it interacts with building ventilation performance. Engineering designs for airborne contamination control to improve standards of occupational hygiene, can only be made on the basis of taking all the relevant factors into account.

References

1. Principles of local exhaust ventilation.
   Joint Standing Committee on Health, Safety and Welfare in Foundries.
   First Report of the Sub-committee on Dust and Fume, p7 and 69–73.

2. Clark, R.P. and Mullan, B.J.
   Airflows in and around linear downflow 'safety' cabinets.
   Journal of Applied Bacteriology 1978, 45, p131–135.

3. Carlsson, P., Lungquist, B. and Neikter, K.
   Thermocamera studies of gases and vapours.
   British Journal of Industrial Medicine 1982, 39 p300–305.

4. Davidge, R.O.C.
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5. BS 848: Part 1, 1980.
   Fans for general purposes, methods for testing performance.

6. Hama, G.M.
   When and where is make-up air necessary?
   Air Conditioning, Heating and Ventilating, November 1959, p60–62.

7. The dispersion of air pollution: Notes to accompany films on air pollution.
   Loughborough University of Technology.

8. Industrial ventilation: A manual of recommended practice: 15th Edition, p6–19 to 6–20 and 6–39 to 6–41.

Recent Acquisitions

The following papers have recently been acquired by the Air Infiltration Centre's library:

1. Ward, I.C., Sharples, S.
   An investigation of the infiltration characteristics of windows and doors in a tall building using pressurization techniques.
   Dept of Building Science Report BS68, University of Sheffield, August 1982.

   Sets out the design and construction of pressure test rigs for use in windows and doorways.

*2. Penman, J.M., Rashid, A.A.M.
   Experimental determination of air flow in a naturally ventilated room using metabolic carbon dioxide.
   Building and Environment, Vol. 17, No. 4, 1982, p253–256.

   Reports extension of the metabolic CO_2 method to a naturally ventilated room.

3. Sandberg, M., Blomqvist, C., Sjöberg, M.
   Warm air systems:
   Part 1. Temperatures and temperature efficiencies.
   Part 2. Tracer gas measurement and ventilation efficiencies.
   Swedish Building Research Institute, Bulletins M82:22 and M82:23, 1982.

   Reports results from more than 100 tests of 6 different warm air schemes.

Copies of the paper marked with an asterisk are available from the AIC to organisations in participating countries. The remainder are available on loan.