

CONTROL STRATEGIES FOR LIQUID PROCESS PHOTOCOPIER EMISSIONS

G. Kerr and P. Sauer¹
Public Works Canada
Ottawa, Ontario
Canada K1A 0G2

Although emissions from liquid process photocopiers have been implicated in sick building syndrome a number of times, few studies have attempted to quantify the emissions and develop appropriate strategies for controlling concentrations. This report describes tests performed on a typical copier at different air change rates and with different control mechanisms. The data were successfully fitted to a mass balance model and the results allowed some conclusions to be drawn about the strategies.

INTRODUCTION

Since energy conservation became widespread, there has been increasing concern over the buildup of volatile organic compounds (VOC) in interior spaces, and their effects on human health and comfort. One very common source of VOC in office buildings is the liquid process photocopier (1).

Liquid process photocopiers (LPP) use a solvent whose principal constituents are isodecanes (formula $C_{10}H_{22}$). A small amount of the solvent is released into the air each time a copy is made. The company who hold the patent on the LPP process have provided data on the emission, and one of the aims of this project was to assess their findings.

Strategies that might be appropriate for controlling concentrations of solvent in the air include increasing the outdoor air rate, using a charcoal filter as an air cleaner, and using local ventilation from the machine direct to outdoors. Each of these was examined.

METHOD

The tests were performed on weekends in a room used solely for photocopying. A plan of the room is shown in Figure 1. Air is supplied to the room by the induction unit labelled I, and exhausted through the ceiling. Infiltration or exfiltration can occur through the room and elevator doors, and through the closed damper of the window fan F. The oscillating fan (also labelled F) beside the photocopier was used to enhance air mixing. The local ventilation fan LV was installed for only one test. At all other times this window was closed.

To obtain quantitative data on the emission rate the tests were set up as follows:

- a fixed number of copies (16 or 32) were made every 5 minutes. The same

¹died December 1989

original was used for all the tests.

- the total VOC (TVOC) concentration was measured every 5 minutes at the test points (T1-T4 on the floor plan) using a photoionization detector, HNU Systems model PI101. The instrument was calibrated (in mg/m³) with n-decane.
- a tracer gas test was run simultaneously with the emission test, and samples were collected at points T1 and T3. Sulphur hexafluoride was used as the tracer, and samples were collected using evacuated containers and disposable syringes as described by Tamura and Evans (2). The samples were analyzed using a Thermo Electron Instruments model 511A gas chromatograph equipped with an electron capture detector. The air change rate was determined from a least-squares fit of the logarithm of the tracer concentration versus time.
- Measurements were normally taken at a height of 1 m. To assess air mixing, TVOC concentrations were also measured periodically in the room corners and at heights from 0-2 m.

The copy rate of 16 every 5 minutes was chosen because it is very similar to the average usage of that copier (about 1500 copies per day), and fairly typical for that building.

The filter system tested was a Racal Breathe Easy safety mask equipped with 3 AP3 filters each containing 120 g charcoal. The air flow through the filters is stated by the manufacturer to be approximately 8 cfm (4 L/sec). The flow rate was not measured during the tests. The mask was placed next to the copy tray of the copier, since TVOC concentrations measured there were usually larger than those found near the exhaust ports at the back of the machine. The filters were weighed before and after the test to determine TVOC uptake.

The local ventilation unit consisted of a window fan connected to a twelve-foot length of vent drier hose. The other end of the hose was secured close to the copy tray.

A mass balance model incorporating emission, air exchange and removal of VOC by the filter was used to fit the TVOC concentrations. The calculation was performed iteratively using the equation below and a period of 5 minutes.

$$C_{\text{new}} = C + [Q_e dt + (Q_e dt C_a / 10^6) - (Q_e dt C / 10^6) - (Q_e dt C / 10^6)] / V$$

C_{new} = TVOC concentration at end of period - mg/M³
 C = Initial TVOC concentration in the space - mg/M³
 Q_e = Rate of emission of TVOC - mg/s
 dt = time period - seconds
 Q_a = Fresh air flow rate - M³/s
 C_a = TVOC concentration in fresh air - mg/M³
 Q_f = Flow rate through filter - M³/s
 V = Room volume - M³

This equation will give a valid description of concentrations provided that:

- the air in the space is perfectly mixed
- the ideal gas laws that relate weight of liquid and volume of gas are valid for photocopier fluid
- adsorption and desorption effects on furnishings and finishes can be ignored
- if a filter is used, the TVOC concentration is in the range where nearly complete adsorption occurs in the filter, and the filter is not overloaded

As an alternative, the effect of the filter was determined by calculating the 10% breakthrough time from equation (10) of reference (3), and assuming constant adsorption rate up to that time. The two approaches are discussed below.

Early in the data analysis it became apparent that, with photoionization detection, n-decane is not a suitable calibration material for photocopier solvent. Concentrations found using the PI101 were compared to those determined by flame ionization detection (FID) using the method of reference

(1). This enabled a correction factor to be applied to the PI101 data.

RESULTS AND DISCUSSION

The FID:PI101 concentration ratios found were 3.86, 4.24, 3.74 and 3.27. The average of these, 3.78, was used to correct the PI101 TVOC concentrations.

Air mixing was judged to be efficient during the tests. In general, TVOC measurements taken anywhere in the room during a one minute period agreed within 10%. Concentrations of the two sets of tracer gas samples were also close.

The TVOC data were predicted well by the mass balance model, though it was found necessary to allow the emission of VOC per photocopy to vary over a small range. The tests are not accurate enough to detect any deviation from the ideal gas laws, or any adsorption/desorption effects.

The results of the four tests are listed in Table 1. The fitted and experimental data used to determine air change rate and TVOC emission rate for the first test are shown in Figure 2.

The photocopier manufacturer has indicated that 0.241 g (0.322 ml) of solvent is released for each copy made. The emission rates shown in Table 1 are close to the manufacturer's value. Since the potential errors are probably greater than 10%, it is not known whether the difference between the first two emission rates and the last two is real. The last two both applied suction to the copier near the copy tray.

Using the model with the manufacturer's emission rate and a room volume of 67 M³, daily average TVOC concentrations were calculated for different copy rates and air change rates. The copy rates were 500, 1500 and 2500 copies in an 8-hour day, and the air change rates 0.5, 1, 2, and 4 air changes per hour (covering approximately 10% to approximately 100% outdoor air). The daily averages were all below the manufacturer's recommended exposure limit of 1800 mg/M³, but all above 25 mg/M³, a level at which Molhave (4) has found that people suffer mild discomfort and respiratory irritation. Thus dilution ventilation will satisfy occupational health requirements, but may not provide a comfortable and productive environment, for people working all day in a moderate-sized room containing a liquid process photocopier.

For the third test, assuming the filter system adsorbed all the VOC from the air stream passing through it gave good agreement between measured and calculated TVOC uptake. High filter efficiency is also indicated by the low (but unstable) TVOC concentrations measured in the filter exhaust. When the calculation method involving breakthrough time was used, a filter efficiency of 0.4 was needed to give agreement between the calculated and measured uptake by the charcoal. The discrepancy is probably due to the charcoal being of a different type from that evaluated by Nelson and Correia (3), as there are at least three types available, each with different adsorbency. The filter removed only 4% of the emitted VOC. This is not surprising, since the air flow rate through the filter was only 5% of the air change rate. A filter of this size is, therefore, inadequate for removing VOC at the air change rates used during these tests. Larger units with higher flow rates are available. However, with a copy rate of 1500 per day, maintaining room concentration about 25 mg/M³ would require filter replacement every 1-2 weeks. Since the filters cost \$100 or more each, this is not thought to be a cost effective solution.

Based on the test performed, local ventilation did not appear to be effective. This is probably due to a combination of factors: inadequate fan speed (the air change rate was almost the same with and without the LV fan); poor capture of the photocopier vapour (a hood was not used, and the vapour was probably dispersed by the fan F); and lack of supply air to assist capture. In retrospect, this was an inadequate test of local ventilation capability, and should be repeated using more appropriate conditions and equipment. Since

local ventilation depends on incomplete mixing, the mass balance model will predict concentrations poorly. A more sophisticated model incorporating the effects of air flow should be used to fit data.

CONCLUSIONS AND RECOMMENDATIONS

The emission rates per copy found during the tests were close to the value supplied by the manufacturer.

Concentrations of photocopier fluid in air can be calculated with a simple mass balance model, provided that the copy rate, the volume of the space and the air exchange rate are known, and provided that the air in the space is well mixed.

On the basis of these measurements and calculations, filtration using charcoal does not appear to be a useful control strategy for LPP emissions. Dilution ventilation is likely to satisfy occupational health requirements under most conditions, though it may not always adequately provide for occupant comfort.

Local ventilation was incompletely evaluated by the test described here, and further tests of this strategy should be conducted.

ACKNOWLEDGMENTS

We are grateful to L. Jutras for help in carrying out the tests, and to Dr. Y. Tsuchiya for assistance with the FID analysis.

REFERENCES

1. Tsuchiya Y, Clermont MJ, Walkinshaw DS (1988) Wet process copying machines: a source of volatile organic compound emissions in buildings Environmental Toxicology and Chemistry 7:15-18.
2. Tamura GT, Evans RG (1983) Evaluation of evacuated glass tubes for sampling of SF₆/air mixture for air exchange measurement ASHRAE J October 1983:40-43.
3. Nelson GO, Correia AN (1976) Respirator cartridge efficiency studies: VIII. summary and conclusions American Industrial Hygiene Association J 37:514-525.
4. Molhave L (1986) Indoor air quality in relation to sensory irritation due to volatile organic compounds ASHRAE Transactions 92:306-316

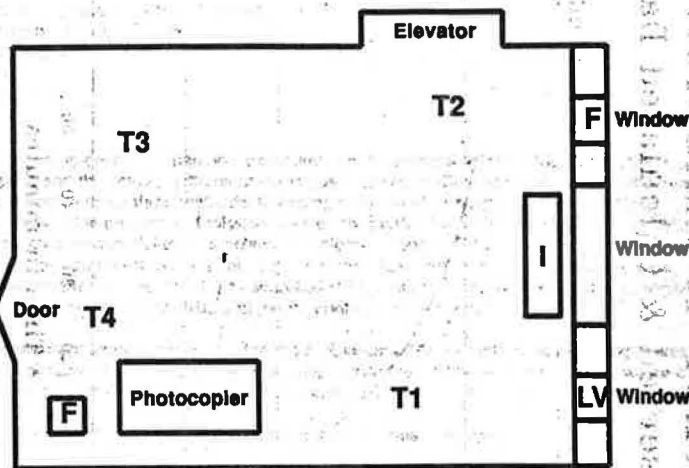
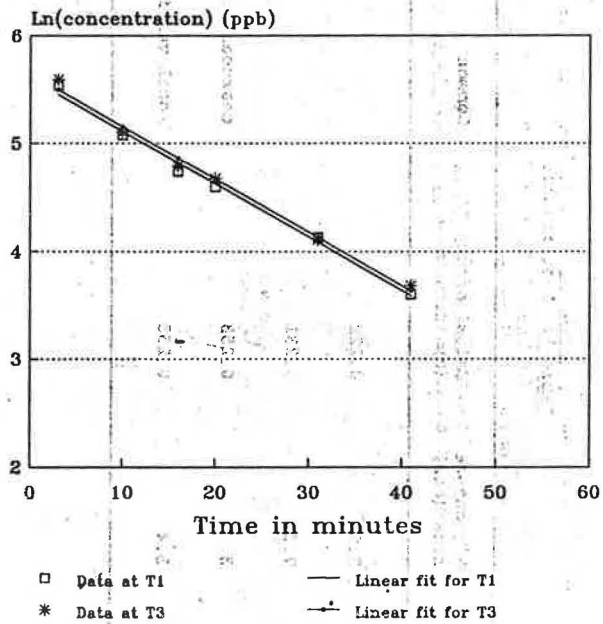


Figure 1: Floor plan of the test room

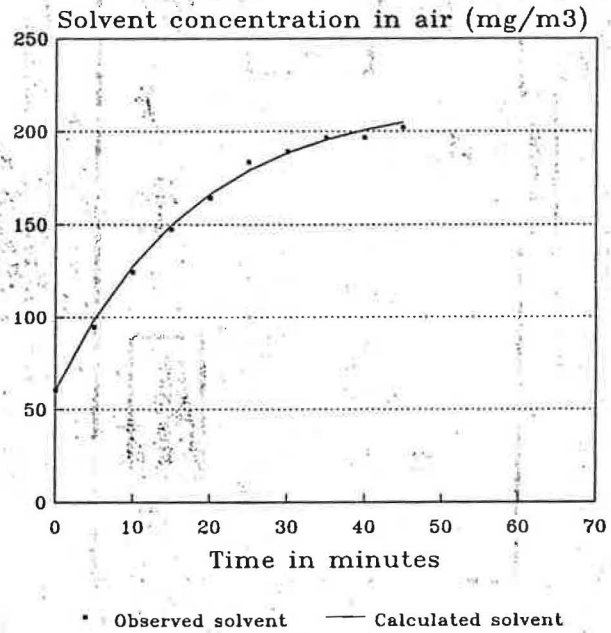
Table 1: Test results

Copies/ 5 minutes	Air change rate (ach)	Emission/copy (g) (fitted)	Comment
16	2.9	0.222	
16	7.8	0.231	
32	3.8	0.258	charcoal filter used
16	3.4	0.253	local ventilation used

TEST 1: TRACER GAS
Nofilter, door shut, 16 copies



TEST 1: EMISSION
Observed & Calculated Data



2.9 ach; 0.222 g/copy

Figure 2: Experimental and calculated data