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Investigation of relationship between saturated vapour concentration and real exposure to vapour

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Investigation of relationship between saturated vapour concentration and real exposure to vapour

Ian Pengelly & Paul Johnson
Health and Safety Laboratory
Harpur Hill
Buxton
Derbyshire
SK17 9JN

Quantitative risk assessment is a key component of chemical approval schemes. This study was designed to provide information to better assess levels of risk and the potential for human exposure to low volatility chemical substances. The approach taken was to investigate the relationship between the fundamental physiochemical property of saturated vapour concentration (SVC) and measured airborne concentrations of such substances and to carry out baseline testing under different experimental and simulated work conditions. The results of these tests indicate that, whilst SVC may provide a reasonable estimate of the maximum possible concentration of any given compound and/or the relative ratios of different compounds, for chemical compounds of low volatility real airborne concentrations are considerably lower (generally less than 1% of SVC). Consequently, SVC significantly over-estimates airborne concentrations of these low volatility substances in the workplace and hence we conclude that it is not an accurate indicator of the likely risk of airborne exposure. Although the scope of the tests carried out in this project was very limited, it is apparent that the airborne concentration, and hence the potential for exposure by inhalation, is probably more dependent on the nature of the task being undertaken or usage of the compound than on the SVC.

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KEY MESSAGES

The aim of this project was to investigate the extent of the relationship between saturated vapour concentration (SVC) and real airborne concentrations in low volatility chemical substances. The work was undertaken because HSE, and others, are often asked to apply professional judgement in assessing risk from exposure to chemicals and, whilst SVC values are readily available for most chemical compounds, there is relatively little information on whether this provides a useful, or accurate, indicator of likely airborne concentrations or exposure, particularly for low volatility compounds. Consequently, the use of SVC data to make such judgements curently carries with it much uncertainty and the potential for significant error or challenge.

Based on results obtained from a very small number of candidate compounds, we found that whilst SVC may provide a reasonable estimate of the maximum possible concentration of any given compound and/or the relative ratios of different compounds, for low volatility compounds (with vapour pressures in the range 1 to 10 Pa at 20°C) real airborne concentrations were considerably lower (generally less than 1% of SVC). Consequently, we conclude that SVC does not provide an accurate indication of real indoor airborne exposures for low volatility chemical substances as it significantly over-estimates likely airborne concentrations, and hence the risk of airborne exposure.

Although the scope of the tests carried out in this project was very limited, the results indicate real exposures to be more dependent on how the material is being used than on SVC. For example, in our tests the potential for inhalation exposure to cinnamaldehyde in a flip-top bin was much lower than to phenoxyethanol in a simulated painting exercise, despite cinnamaldehyde having the higher SVC.

As previously stated, most of the simulations of real exposure with the test compounds showed airborne concentrations of less than 1% of the SVC (usually considerably less). Consequently, any workplace monitoring of low volatility substances is likely to require a technique capable of measurement of at least sub-ppm, and probably low ppb, concentrations.

One of the semi-volatile compounds tested was found to undergo chemical decomposition, thus generating airborne concentrations of a second, more volatile, substance as well as the parent compound. This clearly illustrates the need, when assessing risk and the potential for airborne exposure, to consider the possibility of chemical decomposition and for suppliers to provide relevant information. Decomposition products are also likely to be more volatile than their parent compound and thus have the potential to generate higher airborne concentrations.

The tests carried out in this project have only involved measurement of airborne concentrations in the vapour phase. However, real exposure to low volatility compounds is likely to involve both vapour and particulate, with total airborne concentrations, which, once again, may be much more dependent on the precise nature of the task or process being undertaken than on SVC.

Development of an accurate model for predicting real exposure to low volatility chemical substances, based on the very limited data generated in this project, will be very difficult.

EXECUTIVE SUMMARY

Aims and Objectives

HSE is the Competent Authority for a range of chemical approval schemes where quantitative risk assessment is a key component. This study was designed to provide information to allow HSE, and others, addressing exposure to low volatility chemical substances to better assess levels of risk and the potential for human exposure.

The approach of the study was:-

- To investigate the relationship between the fundamental physiochemical property of saturated vapour concentration (SVC) and measured airborne concentrations in low volatility chemical substances by use of appropriate candidate compounds.

- To carry out baseline testing; firstly in a number of small-scale experiment under controlled environmental conditions, and secondly, in a series of larger scale experiments mimicking more realistic scenarios in a test room.

Main Findings

In the baseline tests, carried out in 2-litre and 20-litre silanised glass chambers, the three candidate compounds, namely cinnamaldehyde, phenoxyethanol and 1-methylnaphthalene, generated airborne concentrations of between 6% and 33% of SVC over a 6-hour time period under ambient conditions. In tests extended to 24 hours, airborne concentrations up to 42% of SVC were observed.

Not unexpectedly, increasing air temperature also increases the measured airborne concentration of the three candidate compounds. A comparison of results from the two test chambers showed longer equilibration times in the larger chamber, but after 24 hours, relatively little effect on the final airborne concentration.

One of the three candidate compounds, cinnamaldehyde, showed evidence of chemical decomposition, generating benzaldehyde. Initially, the levels of benzaldehyde are much lower than those of cinnamaldehyde, but after 6 hours the concentrations of the two substances are fairly similar and after 24 hours levels of benzaldehyde are around 2 – 3 times higher. These trends are accelerated at higher temperature. This finding illustrates the potential for airborne exposure, not only from the source compound, but also from more volatile breakdown products.

In the larger scale experiments, with a small open container of cinnamaldehyde, airborne concentrations, at head height directly above the source material, were less than 0.01% of SVC (or 1 - 2 ppb). This is around 1000 times lower, under ambient conditions, than those measured in the baseline tests. Increasing the temperature of the source material was found to increase the airborne concentration. However, at 55°C the airborne concentrations of cinnamaldehyde in the test room were only around 0.2% of SVC (or 50 ppb), which is nearly 100 times less than those in the baseline tests, even using neat cinnamaldehyde as the source material.

Tests carried out with the cinnamaldehyde source material in a flip-top plastic bin, mimicking the use of this material in sanitary bins, showed that, when the lid of the bin was opened, even for prolonged periods, airborne concentrations of cinnamaldehyde at waist and head height were again less than 0.01% of SVC (or 1 - 2 ppb). Concentrations of up to 40 ppb were measured adjacent to the bin when the lid was open (with up to 170 ppb inside). However, these results are both less than 1% of SVC, even using neat cinnamaldehyde as the source material and a

poorly ventilated room. It is therefore concluded that the potential for exposure, by inhalation, from a bin containing a source of cinnamaldehyde is very low.

Larger scale experiments with a small open container of phenoxyethanol also generated much lower concentrations than the baseline tests. Once again, increasing the temperature of the source material increased airborne concentration, however even when increased to 75°C, airborne concentrations were still only around 0.2% of SVC (or 2% of those measured at room temperature in the baseline tests). A test using an aqueous solution of phenoxyethanol (in place of neat material) also produced extremely low airborne concentrations.

Higher airborne concentrations were obtained from simulated painting tests, onto a cardboard substrate, with phenoxyethanol. The highest concentrations, up to 2% of SVC (250 ppb) under ambient conditions, were obtained when air was blown across the surface of the "painted" substrate. These concentrations are around 10 times greater than from a small open container at 75°C, although still around 6 times less than those measured in the baseline tests. The combination of a thin film of material, giving a greater surface area, and air movement over the "painted" surface, appears to have significantly increased the rate of evaporation of phenoxyethanol and, if combined with an increase in temperature, the results suggest that the airborne concentration could be increased to 1 ppm or more. It should be noted however, that the highest airborne concentration observed in the "painting" experiments was still only a small percentage of the SVC, and that this was achieved using neat phenoxyethanol in a poorly ventilated room. In "real life" it is much more likely that the source material would be a dilute formulation, and the work area would be better ventilated, both of which would almost certainly result in a significant reduction of the airborne concentrations.

Conclusions and Implications

The results of these tests (with compounds with vapour pressures in the range 1 to 10 Pa at 20°C) indicate that, whilst SVC may provide a reasonable estimate of the maximum possible concentration of any given compound and/or the relative ratios of different compounds, for chemical compounds of low volatility real airborne concentrations are considerably lower (generally less than 1% of SVC). Consequently, SVC significantly over-estimates airborne concentrations of these low volatility substances in the workplace and hence we conclude that it is not an accurate indicator of the likely risk of airborne exposure.

It was noted that the main finding of this investigation, that SVC greatly exceeds real airborne concentrations for low volatility chemical substances, shows good agreement with the results of previous work, in which airborne concentrations of two semi-volatile pesticides, prallethrin and bioallethrin, generated using heated plug-in devices inside a typical room were also found to be less than 1% of their respective SVC values.

Although the scope of the tests carried out in this project was very limited, particularly in terms of the number of compounds and range of "workplace" variables tested, it is apparent that the airborne concentration, and hence the potential for exposure by inhalation, is probably more dependent on the nature of the task being undertaken or usage of the compound than on SVC. For example, the potential for airborne exposure to neat cinnamaldehyde contained in a flip-top bin was much lower than to neat phenoxyethanol in a simulated painting exercise, despite cinnamaldehyde having the higher SVC.

Most of the larger scale tests showed concentrations of 1% of SVC or less (often considerably less). Consequently, for workplace monitoring, a method capable of measurement of at least sub-ppm, and probably low ppb, concentrations will be required.

Despite only three compounds being tested, one of these, cinnamaldehyde, was found to undergo chemical decomposition, generating airborne concentrations of benzaldehyde as well as cinnamaldehyde. This clearly illustrates the need, when assessing risk and the potential for airborne exposure, to consider the possibility of chemical decomposition and for suppliers to provide relevant information. Decomposition products are also likely to be more volatile than their parent compound, with a higher SVC, and so have the potential to generate higher airborne concentrations.

The tests carried out in this project have only involved measurement of airborne concentrations in the vapour phase. However, in "real" workplaces, it is likely that low volatility compounds will exist as a mixed phase (i.e. vapour and droplets/particulate), with total airborne concentrations, which, once again, may be much more dependent on the precise nature of the task or process being undertaken than on SVC.

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1. INTRODUCTION

HSE is the Competent Authority for a range of chemical approval schemes, such as REACh (**R**egistration, **E**valuation, **A**uthorisation & restriction of **Ch**emicals), where quantitative risk assessment is a key component. As part of this work HSE is required to conduct in depth evaluation of substances and prepare draft decisions regarding registration. HSE therefore needs to maintain its position as a highly respected leader in this field that moves to improve exposure and risk assessment processes to ensure safety and provide better accuracy and precision in judgement. As such HSE staff are routinely asked to apply professional judgement to exposure situations where much uncertainty exists.

As part of exposure assessment, the saturated vapour concentration (SVC) of a pure substance is often used as an indicator of the potential for exposure in a range of situations (AIHA, 2000a). This presents a worst case scenario, i.e. a worker breathing air saturated with the substance of interest. There is evidence (AIHA, 2000b) that for low volatility substances may be a significantly poor indicator of airborne concentrations. Such calculations depend on several assumptions such as zero ventilation and sufficient time to reach equilibrium. This being the case, there is a significant likelihood of erroneous estimates of risk, potentially opening HSE up to challenge.

Previous work carried out by HSL, on behalf of HSE, investigating potential exposure to airborne pesticides generated from electric plug-in devices (Wheeler, 2003), showed evidence of such errors. These plug-in devices, on heating, release synthetic pyrethroids such as prallethrin and bioallethrin, and are effective for up to eight hours. Heating increases the rate at which the pesticide is released into the atmosphere when compared to an unheated formulation and, as part of this study, airborne concentrations were measured over a period of eight hours in rooms with low ventilation rates (ca. 0.05 air changes per hour (ACH)). Whilst the quantity of pesticide released was sufficient to exceed the saturated vapour concentration, air samples taken in the room showed that airborne concentrations of the pesticides were only around 0.6% of the calculated SVC. At more realistic ventilation rates, or if no heating was involved, it is likely that the airborne concentrations would have been significantly lower, meaning that the calculated SVC value would have over-estimated the likely airborne concentration by an even greater amount. Other work with pesticides such as dichlorvos, methacrifos, ethoprophos, pirimicarb, chlorpyriphos-methyl, demeton-S-methyl and bioallethrin also detected airborne concentrations much lower than the calculated SVC (Pengelly, 2003).

Although information on SVC is readily available, there appears to be little intelligence available that allows those involved in risk characterisation to use this data to make sound judgements based on prevailing conditions and using generic evidence. Consequently, HSE's Chemicals Regulation Directorate (CRD) decided that there was a need to investigate the relationship between SVC and likely "real world" exposures and also how these airborne concentrations may be affected by a range of "workplace" and environmental variables. As previously stated, past experience with pesticides indicates that SVC is likely to significantly over-estimate "real world" concentrations of low volatility substances. Consequently, the scope of the project will incorporate a series of experiments, using three selected candidate compounds (see Table 1), under controlled conditions, to compare measured concentrations with SVC. The findings from this work will have direct application to HSE enabling better informed judgements with regard to potential airborne exposures from a wide range of chemical substances of low volatility, particularly pesticides or biocides where low levels of exposure may not tolerated or which may produce local effects.

Table 1: Candidate Compounds for Baseline Study & Test Chamber Experiments

Substance (CAS Number)	1-Methylnaphthalene (90-12-0)	Cinnamaldehyde (104-55-2)	Phenoxyethanol (122-99-6)
Solubility	Water: 25.8 mg/l at 25°C (poor); (+ ether, alcohol, benzene)	Water: 1.1 g/l at 20°C (slight); (+ alcohols, aldehydes, ketones, esters, mineral oil, chlorinated solvents, terpenes)	Water: 24 – 27 g/l at 20°C (moderate); (+ alcohols, ether, NaOH)
Melting & Boiling Points	MPt: -22°C BPt: 243°C (at 101.3 kPa)	MPt: -8°C BPt: 248°C (at 101.3 kPa)	MPt: 12°C BPt: 247°C (at 101.3 kPa)
Vapour Pressure	0.009 kPa at 25°C	0.003 kPa at 20°C 0.004 kPa at 20°C	0.0013 kPa at 25°C 0.0013 kPa at 25°C
Saturated Vapour Concentration	92.1 ppm at 25°C	32.9 ppm at 20°C	13.2 ppm at 25°C 12.8 ppm at 25°C
References	ATSDR, 2005	Clark, 1991; Windholm, 1976	Windholm, 1976; IPCS, 2003

The three selected candidate compounds were chosen, following discussions with the customer, to match the following criteria:

- Readily available;
- Standard analytical methodology;
- Remains liquid for range of experiments;
- Low volatility, with an SVP of between 0.01 and 0.001 kPa;
- Low toxicity;
- Non-reactive;
- Found in biocidal product formulations.

It was proposed that the airborne concentrations of the test compounds be first investigated, and compared with calculated SVCs, in a small-scale baseline study carried out under closely controlled environmental conditions. The original proposal envisaged a factorial design to determine the effects of a number of "workplace" variables, including temperature, application, ventilation and radiant heat. However, this approach would have required a large number of experiments to be carried and, after discussions with the HSE customer, it was decided that this could be significantly reduced to around 10 – 15 tests.

In addition to the baseline study, a small number of larger scale tests were carried out using two of the candidate compounds, cinnamaldehyde and phenoxyethanol, in a room sized exposure chamber. These tests measured airborne concentrations inside the chamber under a variety of environmental conditions and, in addition, simulated exposure scenarios identified following discussions with the customer. Variables such as temperature, ventilation and air movement were investigated to determine the effect on airborne concentration of the two compounds, in

particular those which increase airborne concentrations, and to compare these values with both calculated SVCs and those obtained in the baseline study. In the case of cinnamaldehyde, several tests were carried out with the material contained in a plastic bin, to mimic use of this substance in sanitary bins, whilst in the case of phenoxyethanol, tests were carried out which mimicked painting operations.

The findings from this work, based on investigation of low toxicity materials, will have direct application to making better informed judgements when dealing with exposures from a wide range of chemical substances where low levels of exposure are not tolerated or produce local effects.

2. IMPLICATIONS

The results of this project indicate that, whilst SVC may provide a reasonable estimate of the maximum possible concentration of any given compound and/or the relative ratios of different compounds, for chemical compounds of low volatility real airborne concentrations are considerably lower (generally less than 1% of SVC). Consequently, SVC significantly over-estimates airborne concentrations of these low volatility substances in the workplace and hence we conclude that it does not provide an accurate indicator of the likely risk of airborne exposure.

Although the scope of the tests carried out in this project was very limited, particularly in terms of the number of compounds and range of "workplace" variables tested, it is apparent that the airborne concentration, and hence the potential for exposure by inhalation, is probably more dependent on the nature of the task being undertaken or usage of the compound than on SVC. For example, the potential for airborne exposure to neat cinnamaldehyde contained in a flip-top bin was much lower than to neat phenoxyethanol in a simulated painting exercise, despite cinnamaldehyde having the higher SVC.

Most of the larger scale tests showed concentrations of less than 1% of SVC (often considerably less). Consequently, for workplace monitoring of these substances, a method capable of measurement of at least sub-ppm, and probably low ppb, concentrations will be required.

Despite only three compounds being tested, one of these, cinnamaldehyde, was found to undergo chemical decomposition, generating airborne concentrations of benzaldehyde as well as cinnamaldehyde. This clearly illustrates the need, when assessing risk and the potential for airborne exposure, to consider the possibility of chemical decomposition and for suppliers to provide relevant information. Decomposition products are also likely to be more volatile than their parent compound, with a higher SVC, and so have the potential to generate higher airborne concentrations.

The tests carried out in this project have only involved measurement of airborne concentrations in the vapour phase. However, in "real" workplaces, it is likely that low volatility compounds will exist as a mixed phase (i.e. vapour and droplets/particulate), with total airborne concentrations, which, once again, may be much more dependent on the precise nature of the task or process being undertaken than on SVC.

3. EXPERIMENTAL

The experimental work carried out was split into two phases; firstly, a baseline study comprising a number of small-scale experiments carried out under controlled environmental conditions; secondly, a series of larger scale experiments carried out in a room-sized test chamber. In both cases the vapour concentrations of the substances under tests were determined by collection onto Tenax TA sorbent tubes and analysis by thermal desorption (TD) and gas chromatography-mass spectrometry (GC-MS).

3.1 BASELINE STUDY

Initially, a baseline study based on a factorial design was envisaged. However, this would have involved a considerable number of experiments and so, after discussion, an alternative approach was agreed. This was to carry out a small number of laboratory experiments using three candidate compounds cinnamaldehyde, phenoxyethanol and 1-methylnaphthalene. These tests, summarised in Table 2, were intended to establish baseline vapour concentrations generated by the three substances under a variety of different conditions. At periodic intervals during each test a number of 50 ml air samples were collected onto Tenax TA sorbent tubes for subsequent analysis by TD and GC-MS. The vapour concentrations generated by each experiment could then be compared with the SVCs of the three compounds.

Table 2: Baseline Study – Summary of Test Conditions

Test	Analyte(s)	Test Conditions
A	Cinnamaldehyde; 1-Methylnaphthalene	Sealed 2-litre glass chamber; 20°C; 24-hours duration; 50 µl of each analyte spiked onto glass fibre filters
B	Phenoxyethanol; 1-Methylnaphthalene	Sealed 2-litre glass chamber; 20°C; 24-hours duration; 50 µl of each analyte spiked onto glass fibre filters
C	Phenoxyethanol; 1-Methylnaphthalene	Sealed 20-litre glass chamber; 20°C; 24-hours duration; 50 µl of each analyte spiked onto glass fibre filters
D	Cinnamaldehyde; 1-Methylnaphthalene	Sealed 20-litre glass chamber; 20°C; 24-hours duration; 50 µl of each analyte spiked onto glass fibre filters
E	Phenoxyethanol (5% aqueous soln)	20-litre glass chamber; 20°C; 6-hours duration; 1 ml of solution spiked onto cellulose filter paper
F	Phenoxyethanol (5% aqueous soln)	20-litre glass chamber ventilated at 2 litres/min; 20°C; 6-hours duration; 1 ml of solution spiked onto cellulose filter paper
G	Cinnamaldehyde; 1-Methylnaphthalene	Sealed 2-litre glass chamber; 35°C; 6-hours duration; 50 µl of each analyte spiked onto glass fibre filters
H	Phenoxyethanol; 1-Methylnaphthalene	Sealed 2-litre glass chamber; 35°C; 6-hours duration; 50 µl of each analyte spiked onto glass fibre filters
I	Phenoxyethanol; Cinnamaldehyde; 1-Methylnaphthalene	Sealed 4-litre glass chamber; 20°C air temperature; 55°C surface temperature; 6-hours duration; 50 µl of each analyte spiked onto glass fibre filters

Aside from the three different analytes, the main variables examined in these experiments were; container size (2-litre or 20-litre); air temperature (20°C or 35°C); neat material or aqueous solution (phenoxyethanol); effect of increasing surface temperature (55°C). The experiments were all of at least 6-hours duration, with the initial four experiments extended to 24-hours, providing information on equilibration times for each of the analytes. In order to minimise losses due to adsorption, the inner surfaces of all the glass chambers used in the baseline study experiments were silanised before commencement of the work and then cleaned with soapy water and thoroughly dried prior to each test. The tests were not intended to provide a comprehensive analysis of the effects of the main variables, which would have required a large number of experiments, but to provide baseline data for comparison with both the SVC and with the subsequent experiments in the larger scale test chamber.

3.2 TEST CHAMBER EXPERIMENTS

Two sets of experiments were carried out, using cinnamaldehyde and phenoxyethanol as the test analytes, in a test room measuring approximately 4 m × 4 m × 3 m. The tests were carried out at ambient (air) temperature and relative humidity. The test room could be ventilated if required. These experiments were intended to investigate airborne concentration, which might be expected in a small indoor working environment. These data could then be compared with the SVC and with the results obtained from the baseline study. With both analytes, the tests comprised a small number of initial experiments with the test analyte in a small dish, followed by additional experiments mimicking a work operation or possible source of exposure. In the case of cinnamaldehyde, this is from use of the analyte in sanitary bins and, in the case of phenoxyethanol, use of the analyte in coatings applied by brush.

3.2.1 Cinnamaldehyde Tests

A total of 13 tests were carried out in the test chamber using cinnamaldehyde as the test analyte. The test conditions for each of the experiments are summarised in Table 3.

The initial 7 tests were carried out with the cinnamaldehyde (either neat or as an aqueous solution) contained in a shallow glass dish (approximately 5.5 cm in diameter) intended to allow easy evaporation of the test analyte. All seven tests were of 2 hours duration. The dish was placed approximately 50 cm above floor levels and 6 pumped air samples taken at a fixed point directly above the dish at a height of approximately 1.5 m (i.e. roughly in the breathing zone of a person standing directly over the source material). The six air samples were taken over time periods of 0 to 10 minutes, 10 to 20 minutes, 20 to 40 minutes, 40 to 60 minutes, 60 to 90 minutes and 90 to 120 minutes from the beginning of each test. Five of the tests were carried out with the room unventilated, the remaining two with the room ventilated at a rate of approximately 5 air changes per hour.

The remaining 6 tests were carried out with the cinnamaldehyde placed in a 50 ml glass beaker in the bottom of a plastic flip-top bin (approximately 50 cm high and with a base area of approximately 600 cm^2) lined with a polythene bag. These latter tests were intended to mimic scenarios possible exposures to cinnamaldehyde where the chemical is used in sanitary bins. During these tests the bin was left closed for varying periods of time, then opened. In most of the tests the "open" time was 10 minutes, but the final test was carried out with a much longer "open" time of 2 hours. Air sampling was carried out during the "open" time. In the case of the 10-minute tests, five air samples were taken at fixed points, one inside the bin (about half way up), one by the open lid, one about 50 cm above the open lid and the final two about 1 m above the open lid. In the 2-hour test, four air samples were taken at a point roughly 1 m above the open lid, over time periods of 0 to 30 minutes, 30 to 60 minutes, 60 to 90 minutes and 90 to 120

minutes from the beginning of the test. In addition, one air sample was taken next to the open lid over the whole 2-hour "open" time. All six of the bin tests were carried out with the room unventilated.

In all 13 tests the air samples were collected onto Tenax TA sorbent tubes at a flow rate of around 50 ml/min and analysed for the presence of cinnamaldehyde and benzaldehyde by TD and GC-MS.

Table 3: Cinnamaldehyde Tests - Summary of Test Conditions

Test	Test Conditions
CT-01	Open glass dish containing 20 ml of a 5% aqueous solution of cinnamaldehyde No room ventilation; Room Temperature (RT) = 21°C; Relative Humidity (RH) = 75%
CT-02	Open glass dish containing 1 ml of neat cinnamaldehyde No room ventilation; RT = 19°C; RH = 75%
CT-03	Open glass dish containing 1 ml of neat cinnamaldehyde placed on a hot plate at 35°C; No room ventilation; RT = 19°C; RH = 45%
CT-04	Open glass dish containing 1 ml of neat cinnamaldehyde placed on a surface at 55°C; No room ventilation; RT = 18°C; RH = 48%
CT-05	Open glass dish containing 1 ml of neat cinnamaldehyde placed on a hot plate at 55°C; Room ventilated at 5 AC/hr; RT = 19°C; RH = 42%
CT-06	Open glass dish containing 3 ml of neat cinnamaldehyde placed on a hot plate surface at 55°C; No room ventilation; RT = 18°C; RH = 48%
CT-07	Open glass dish containing 3 ml of neat cinnamaldehyde placed on a hot plate at 55°C; Room ventilated at 5 AC/hr; RT = 19°C; RH = 43%
CT-08	50 ml glass beaker containing 1 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed for 15 minutes; opened for 10 minutes; No room ventilation; RT = 18°C; RH = 55%
CT-09	50 ml glass beaker containing 1 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed for 1 hour; opened for 10 minutes; No room ventilation; RT = 18°C; RH = 55%
CT-10	50 ml glass beaker containing 3 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed overnight; opened for 10 minutes; No room ventilation; RT = 17°C; RH = 59%
CT-11	50 ml glass beaker containing 3 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed for 1 hour; opened for 10 minutes; No room ventilation; RT = 17°C; RH = 57%
CT-12	50 ml glass beaker containing 3 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed for 3 hours; opened for 10 minutes; No room ventilation; RT = 18°C; RH = 55%
CT-13	50 ml glass beaker containing 3 ml of neat cinnamaldehyde placed in a plastic flip-top bin lined with polyethylene; Bin left with lid closed overnight; opened for 2 hours; No room ventilation; RT = 17°C; RH = 51%

3.2.2 Phenoxyethanol Tests

A total of 12 tests were carried out in the test room using phenoxyethanol as the test analyte. The test conditions for each of the experiments are summarised in Table 4.

Table 4: Phenoxyethanol Tests - Summary of Test Conditions

Test	Test Conditions
PT-01	Open glass dish containing 4 ml of neat phenoxyethanol No room ventilation; RT = 17°C; RH = 51%
PT-02	Open glass dish containing 4 ml of neat phenoxyethanol placed on a hot plate surface at 35°C; No room ventilation; RT = 19°C; RH = 65%
PT-03	Open glass dish containing 4 ml of neat phenoxyethanol placed on a hot plate surface at 55°C; No room ventilation; RT = 20°C; RH = 59%
PT-04	Open glass dish containing 4 ml of neat phenoxyethanol placed on a hot plate surface at 75°C; No room ventilation; RT = 20°C; RH = 59%
PT-05	Open plastic tray containing 50 ml of a 20% aqueous solution of phenoxyethanol; No room ventilation; RT = 20°C; RH = 46%
PT-06	12 ml of neat phenoxyethanol spread over 4 × 150 mm GF/A filters; No room ventilation; RT = 20°C; RH = 59%
PT-07	20 ml of neat phenoxyethanol brushed onto a piece of cardboard; No room ventilation; RT = 20°C; RH = 59%
PT-08	50 ml of a 10% aqueous solution of phenoxyethanol brushed onto a piece of cardboard; No room ventilation; RT = 20°C; RH = 44%
PT-09	20 ml of neat phenoxyethanol brushed onto a piece of cardboard; 1.6 – 2.0 m/s air movement over surface; No room ventilation; RT = 20°C; RH = 45%
PT-10	20 ml of neat phenoxyethanol brushed onto a piece of cardboard; 0.4 – 0.7 m/s air movement over surface; No room ventilation; RT = 20°C; RH = 45%
PT-11	50 ml of a 10% aqueous solution of phenoxyethanol brushed onto a piece of cardboard; 1.6 – 2.0 m/s air movement over surface; No room ventilation; RT = 20°C; RH = 45%
PT-12	20 ml of neat phenoxyethanol brushed onto a piece of cardboard; 6 hour test duration; No room ventilation; RT = 20°C; RH = 41%

The first 5 tests were carried out with the phenoxyethanol (either neat or as an aqueous solution) contained in either a shallow glass dish (approximately 5.5 cm in diameter) or plastic tray (approximately 16 cm × 10 cm in size). As with the previous tests with cinnamaldehyde, this was intended to allow easy evaporation of the test analyte. These tests were of 2 or 3 hours duration. The dish was placed approximately 50 cm above floor levels and 6 pumped air samples taken at a fixed point directly above the dish at a height of approximately 1.5 m (i.e. roughly in the breathing zone of a person standing directly over the source material). The six air samples were taken over time periods of 0 to 15 minutes, 15 to 30 minutes, 30 to 60 minutes, 60

to 90 minutes, 90 to 120 minutes and 120 to 180 minutes from the beginning of each test. All of the tests were carried out with the room unventilated.

The remaining 7 tests were carried out with the phenoxyethanol (again either neat or as an aqueous solution) being thinly spread over an adsorbent surface. In the first test a quantity of neat phenoxyethanol was placed onto four 15 cm diameter GF/A filter papers and spread using a glass rod. In the remaining six tests, quantities of phenoxyethanol (neat or as an aqueous solution) were spread over pieces of cardboard (approximately 30 cm × 30 cm in size) using a 1" paint brush (over a period of a minute or so at the start of the test). These latter tests were intended to both mimic painting scenarios and increase the surface area (and the potential for evaporation) of the test material. In addition, and again to increase the potential for evaporation, the final four tests utilised a desk fan to blow air over the surface of the "painted" cardboard. The fan was run at either full speed, placed 50 cm away from the test piece, to give an air velocity over the "painted" surface, measured using a TSI anemometer, of 1.6 - 2.0 m/s, or at two-thirds speed, placed 1 m away from the test piece, to give an air velocity over the "painted" surface of 0.4 - 0.7 m/s. These tests were all of 3 hours duration, with the exception of the final tests, which was of 6 hours duration. During each test six air samples were taken over time periods of 0 to 15 minutes, 15 to 30 minutes, 30 to 60 minutes, 60 to 90 minutes, 90 to 120 minutes and 120 to 180 minutes from the beginning of each test. In the final test, six consecutive 1-hour air samples were taken over the period of the test. Once again, all the tests were carried out with the room unventilated.

In all 12 tests the air samples were collected onto Tenax TA sorbent tubes at a flow rate of around 50 ml/min and analysed for the presence of phenoxyethanol by TD and GC-MS.

4. TEST RESULTS

4.1 BASELINE STUDY

The results obtained from the baseline tests are summarised in Table 5. Further details may be found in Annex 1.

Table 5: Baseline Study Tests – Summary of Results

Test	Analyte	Airborne Concentration (ppm)								
		1	2	3	4	5	6	7	8	9
A	C	0.0	0.0	0.4	0.6	1.3	1.3	2.1	2.2	2.0
	B	0.0	0.0	0.1	0.1	0.3	0.3	1.2	2.1	6.8
	M	0.1	0.8	4.6	6.7	10.6	10.2	17.7	20.3	24.6
B	P	0.0	0.3	0.7	1.1	1.2	1.5	1.5	1.7	3.7
	M	4.3	14.0	19.7	24.6	26.2	27.4	29.9	26.8	39.3
C	P	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.3	3.7
	M	0.0	0.1	0.4	0.9	1.6	2.4	7.6	16.6	31.6
D	C	0.0	0.0	0.0	0.1	0.2	0.4	1.3	2.2	3.8
	B	0.0	0.0	0.0	0.0	0.0	0.1	0.5	1.4	8.5
	M	0.3	0.4	0.7	1.3	2.3	3.3	9.7	14.5	28.7
E	P	0.0	0.1	0.6	1.1	1.8	2.2	5.0	5.2	-
F	P	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	-
G	C	1.1	5.9	10.2	11.2	10.7	10.2	9.6	7.7	-
	B	0.1	0.7	1.5	3.2	4.8	6.0	16.2	21.8	-
	M	5.5	24.6	39.8	50.5	54.1	55.3	63.2	59.6	-
H	P	0.1	0.7	2.2	4.0	434	4.8	5.3	5.3	-
	M	5.1	22.7	41.1	58.5	59.2	61.2	66.5	66.1	-
I	C	4.6	6.3	5.3	4.7	4.4	4.2	4.0	5.5	-
	B	0.5	1.2	3.0	5.0	6.3	7.6	15.0	14.4	-
	P	1.8	3.2	3.2	3.4	3.7	3.9	4.1	5.9	-
	M	28.4	44.8	53.1	56.1	57.8	59.4	48.8	26.9	

C = Cinnamaldehyde; B = Benzaldehyde; M = 1-Methylnaphthalene; P = Phenoxyethanol

Test 1 = 2 mins; Test 2 = 7 mins; Test 3 = 15 mins; Test 4 = 30 mins; Test 5 = 45 mins; Test 6 = 1 hr; Test 7 = 3 hrs; Test 8 = 6 hrs; Test 9 = 24 hrs

In Test A the concentration of methylnaphthalene shows a fairly rapid increase over the first three hours, reaching around 18 ppm (or about 20% of SVC). The rate of increase then slows, reaching around 25 ppm (or about 28% of SVC) after 24 hours. Cinnamaldehyde also shows an initial rapid rise in concentration, reaching around 2 ppm (or about 6% of SVC) after 3 hours. After this initial rise, the concentration of cinnamaldehyde remains virtually constant, at around 2 ppm, for the remaining 21 hours of the test. In addition to methylnaphthalene and cinnamaldehyde, benzaldehyde was also detected in the air samples. The concentration of benzaldehyde increases in an almost linear manner, reaching around 7 ppm (or about 0.5% of SVC) after 24 hours (based on a vapour pressure of 0.13 kPa at 25°C (IPCS, 2006)).

The methylnaphthalene results in Test B show a similar pattern to those observed in Test A, but reaching slightly higher overall concentrations, of around 39 ppm (or about 42% of SVC). These differences are probably due to experimental error as the analytical methodology being

used has not been fully evaluated and will therefore be subject to a greater degree of overall uncertainty than is usually the case. Phenoxyethanol also behaves in a similar manner, reaching around 1.5 ppm (or about 12% of SVC) after 3 hours and around 3 ppm (or about 25% of SVC) after 24 hours. No significant other components were observed in the air samples taken in Test B.

The data for Test C show the initial concentration of methylnaphthalene increasing more gradually than was the case in the 2-litre chamber used in Test B. However, the concentration after 24 hours is fairly similar, reaching around 32 ppm (or about 34% of SVC). Phenoxyethanol also behaves in a similar manner, reaching around 1.5 ppm (or about 12% of SVC) after 3 hours and around 3 ppm (or about 25% of SVC) after 24 hours. No significant additional components were observed in the air samples taken in Test C.

The results for Test D are very similar to those obtained from Test A, using the 2-litre chamber, with the exception that the initial rise in concentration was slightly slower. Concentrations of cinnamaldehyde and methylnaphthalene were very similar and benzaldehyde was also present, again at concentrations very similar to those observed in Test A.

The results for Test E show a rapid rise in the concentration of phenoxyethanol over the first two hours of the test, reaching around 5 ppm (or about 35% of SVC), before levelling out. These concentrations are slightly higher than those observed in Tests B and C.

In Test F, with ventilation of the chamber (~0.1 air changes per minute), the concentration of phenoxyethanol reached around 0.8 ppm (or about 0.6% of SVC) after 30 minutes. Thereafter, the concentration reached around 2 ppm (or 1.8% of SVC) after 6 hours. These values are significantly less than those observed in Test E (an equivalent test, but using an unventilated chamber).

The concentration of methylnaphthalene in Test G rose rapidly in the first hour, reaching around 55 ppm (or about 60% of SVC), before levelling out. Cinnamaldehyde also shows an initial rapid rise in concentration, reaching around 11 ppm (or about 35% of SVC) after an hour, before gradually dropping to around 8 ppm (or about 25% of SVC) after 6 hours. Benzaldehyde was also detected in the air samples, with concentration once again increasing in an almost linear manner, reaching around 22 ppm (or about 1.4% of SVC) after 6 hours. The concentrations of all three substances are significantly greater than those observed in Test A, carried out in the same chamber, but at a lower air temperature of 20°C.

As with Test G, the concentration of methylnaphthalene in Test H rose rapidly in the first hour, this time reaching around 65 ppm (or about 70% of SVC), before levelling out. Phenoxyethanol also shows an initial rapid rise in concentration, reaching around 5.3 ppm (or about 40% of SVC) after a 2 hours, before it too levelled out. The concentrations of both substances are significantly higher than those detected in Test B.

Test I produced quite different concentration plots for the three test compounds (and benzaldehyde). Cinnamaldehyde showed a very rapid increase in concentration, reaching around 6 ppm (or almost 20% of SVC) after just 10 minutes. The concentration then slowly dropped over the next 2 hours, to around 3.5 ppm, before gradually rising again, reaching around 5.5 ppm at the end of the test. Benzaldehyde showed a gradual increase in concentration over the first three hours, reaching around 15 ppm (or about 1% of SVC) before levelling out. Methylnaphthalene showed a rapid initial increase in concentration, reaching around 60 ppm (or about 65% of SVC), before levelling out. Then, after around 2 hours, the concentration began to decrease, dropping back to around 27 ppm (or about 30% of SVC) after 6 hours. Finally, phenoxyethanol also showed an initial rapid rise in concentration, reaching just over 3 ppm (or about 25% of SVC) after only 10 minutes. After that, the concentration continued to increase,

but at a much slower rate, reaching around 6 ppm (or about 45% of SVC) after 6 hours. Visually, it was noted during Test I, that the walls of the glass chamber began to show evidence of clouding, which, it is assumed, is due to condensation of one, or more, or the test analytes.

4.2 CHAMBER TESTS

4.2.1 Cinnamaldehyde

The results obtained from the initial chamber tests with cinnamaldehyde are summarised in Table 6. Further details may be found in Annex 2.

Table 6: Chamber Tests Using Cinnamaldehyde – Summary of Results

Test	Analyte	Airborne Concentration (ppb)					
		1	2	3	4	5	6
CT-01	C	*< 4*	*< 3*	*< 2*	*< 2*	*< 1*	*< 1*
	B	*< 11*	*< 9*	*< 6*	*< 5*	*< 3*	*< 3*
CT-02	C	*< 4*	*< 3*	2	4	2	< 1
	B	*< 11*	*< 9*	*< 5*	*< 5*	*< 3*	3
CT-03	C	5	3	4	11	12	16
	B	*< 10*	*< 9*	*< 4*	*< 4*	*< 3*	3
CT-04	C	12	11	41	50	37	47
	B	*< 11*	*< 9*	11	6	5	6
CT-05	C	42	34	9	S/F	31	11
	B	*< 9*	*< 9*	*< 5*	S/F	3.5	*< 3*
CT-06	C	21	14	39	54	49	50
	B	*< 8*	*< 7*	4	7	5	7
CT-07	C	22	39	34	15	29	24
	B	*< 9*	*< 7*	3	*< 3*	3	2

C = Cinnamaldehyde; B = Benzaldehyde; Results in italic, and preceded by "<", are below the limit of detection; S/F = Sample failed
Test 1 = 0 - 10 mins; Test 2 = 10 - 20 min; Test 3 = 20 - 40 mins; Test 4 = 40 - 60 mins; Test 5 = 60 - 90 mins; Test 6 = 90 - 120 mins

Test CT-01 showed airborne concentrations of cinnamaldehyde below the limit of detection (typically around 1 ppb) over the entire duration of the test. Airborne concentrations of cinnamaldehyde in this test are therefore more than 1000 times lower than those observed in the baseline study tests. Concentrations of benzaldehyde were also below the limit of detection (typically around 5 ppb) in all six samples. In this, and all subsequent tests, the limit of detection was determined from analysis of at least two blank TD tubes, using the following equation:-

Limit of Detection (LOD) = 3 × Standard Deviation of results from at least 2 blank tubes

For information, the figures in Annex 2 show all values, including those below the calculated limits of detection for each experiment.

Test CT-02 changed the source material from a 20% aqueous solution to a volume of neat material containing a similar total quantity of cinnamaldehyde. This increased airborne concentrations of cinnamaldehyde in the chamber to between 1 and 4 ppb (less than 0.01% of SVC), with a slight downward trend over the duration of the test. Concentrations of benzaldehyde remained below the limit of detection in all six samples.

Test CT-03 increased the temperature of the dish containing the cinnamaldehyde from around 20°C to 35°C. This produced airborne concentrations of cinnamaldehyde in the test chamber of around 3 - 5 ppb (0.2% of SVC) in the first 30 minutes, gradually increasing to around 15 ppb (0.05% of SVC) by end the 2-hour test. Increasing the temperature of the surface on which the cinnamaldehyde is sitting, to around 15°C above ambient, has therefore resulted in an approximate 4-fold increase in the measured airborne concentration (although levels are still around 100 times less than those observed in the baseline tests). Measured concentrations of benzaldehyde were still generally below the limit of detection.

Test CT-04 raised the temperature of the dish containing the cinnamaldehyde still further, to 55°C. This produced airborne concentrations of cinnamaldehyde in the test chamber of around 11 ppb (0.03% of SVC) in the first 15 minutes, rising to around 40 - 50 ppb (0.15% of SVC) after 30 minutes, before remaining at this level for the remainder of the test. Increasing the temperature of the surface on which the cinnamaldehyde is sitting, to around 30°C above ambient, has therefore resulted in an approximate 10-fold increase in the measured airborne concentration (although levels are still only around 1 - 2% of those observed in the baseline tests). Concentrations of benzaldehyde were still generally below the limit of detection.

Test CT-05, was a repeat of Test CT-04, but with the room ventilation turned on. Airborne concentrations of cinnamaldehyde in the test chamber rose rapidly to around 40 ppb (0.12% of SVC) before showing a gradual fall to around 10 ppb (0.03% of SVC) after 2 hours. Initial airborne concentrations are therefore slightly higher than in the unventilated room, possibly due to air movement, but then tend to reduce, rather than increase, with time. Once again, measured concentrations of benzaldehyde were barely above the limit of detection in all six samples.

Test CT-06 was a repeat of Test CT-04, but with the volume of neat cinnamaldehyde increased from 1 ml to 3 ml. Airborne concentrations of cinnamaldehyde in the test chamber very similar to those of Test CT-04, with levels of around 15 - 20 ppb (0.06% of SVC) in the first 15 minutes, rising to around 50 ppb (0.15% of SVC) by the end of the test. Increasing the volume of cinnamaldehyde present, from 1 ml to 3 ml, therefore appears to have very little effect on the airborne concentration. Measured concentrations of benzaldehyde were still close to the limit of detection.

Test CT-07 was a repeat of Test CT-06, but with the room ventilation turned on. Airborne concentrations of cinnamaldehyde in the test chamber were similar to those of Test CT-05, with levels rising to around 40 ppb (0.12% of SVC) in the first 15 minutes, before gradually decreasing to around 20 ppb (0.06% of SVC) by the end of the test. So, once again, increasing the volume of cinnamaldehyde present, from 1 ml to 3 ml, therefore appears to have very little effect on the airborne concentration. Measured concentrations of benzaldehyde were still close to the limit of detection.

The results obtained from the chamber tests with the cinnamaldehyde source placed inside the plastic bin are summarised in Table 7. Further details may be found in the Annex Report.

Test CT-08 showed that, after an equilibration time of 15 minutes, the mean cinnamaldehyde concentration inside the bin was around 22 ppb (0.07% of SVC). Outside the bin, even right next to the open lid, the cinnamaldehyde concentration was below the limit of detection (typically around 2 ppb). The concentration of benzaldehyde inside the bin was around 16 ppb, with levels outside the bin just above the limit of detection (of around 1 ppb).

Table 7: Bin Tests Using Cinnamaldehyde – Summary of Results

Test	Analyte	Airborne Concentration (ppb)			
		1	2	3	4
CT-08	C	22	*< 2*	*< 2*	*< 2*
	B	16	2	1	1
CT-09	C	8	*< 2*	*< 2*	*< 2*
	B	10	3	2	1
CT-10	C	77	24	*< 2*	*< 2*
	B	122	41	4	*< 1*
CT-11	C	70	19	*< 2*	*< 2*
	B	76	20	2	2
CT-12	C	70	25	*< 2*	*< 2*
	B	86	28	2	*< 1*
CT-13	C	166	3	*2*	2
	B	147	2	2	2

C = Cinnamaldehyde; B = Benzaldehyde; Results in italic, and preceded by "<", are below the limit of detection
Test 1 = Inside Bin; Test 2 = By bin lid; Test 3 = 50 cm above bin; Test 4 = 100 cm above bin lid (For CT-13:- Test 1 = Inside Bin (0 – 120 mins); Test 2 = 100 cm above bin (0 – 30 mins); Test 3 = 100 cm above bin (30 – 60 mins); Test 4 = 100 cm above bin lid (60 – 120 mins))

Test CT-09 showed that, with a longer equilibration time of 1 hour, the mean cinnamaldehyde concentration inside the bin was around 8 ppb (0.02% of SVC). Outside the bin, even right next to the open lid, the airborne concentration of cinnamaldehyde was still below the limit of detection. The concentrations of benzaldehyde inside the bin was around 10 ppb, with levels outside the bin again just above the limit of detection (of around 1 ppb).

Test CT-10 used a larger volume of cinnamaldehyde (3 ml) and a longer overnight (ca. 16 hour) equilibration time. This gave a cinnamaldehyde concentration inside the bin of around 77 ppb (0.23% of SVC). Outside the bin, the cinnamaldehyde concentration immediately next to the open lid was around 24 ppb (0.07% of SVC), but 50 cm and 1 m above the open lid the air borne concentrations were still below the limit of detection. The concentration of benzaldehyde inside the bin was around 122 ppb, which, like the baseline study tests, indicates that benzaldehyde is generated when cinnamaldehyde is left to evaporate for a more prolonged period. The concentration of benzaldehyde by the open lid was around 40 ppb. The sampler located 50 cm above the bin gave a concentration of 4 ppb, but the one located 1 m above the bin was below the limit of detection. These results show that if the bin is left to equilibrate for a longer period of time, the airborne concentration inside increases significantly (although levels are still less than observed in the baseline tests). However, when opened, airborne concentrations outside the bin, other than right by the open lid remain extremely low. Consequently, the potential for exposure by inhalation, as determined by the concentration at roughly head height, would appear to be extremely low.

Tests CT-11 and CT-12 were carried out on the same day as Test CT-10, with the bin left for an additional 1 hour and 3 hours respectively (after having been left open for 10 minutes). The two test produced similar results to Test CT-10, for both cinnamaldehyde and benzaldehyde, with the only significant concentrations being inside the bin and immediately adjacent to the open lid. The concentration inside the bin remains fairly constant, even when the bin is open and closed, and, once again, the potential for exposure by inhalation, appears to be extremely low.

In Test CT-13, the bin was left open for a much longer (2-hour) period. The mean concentration inside the bin over the test period was 166 ppb for cinnamaldehyde (0.5% of SVC) and 147 ppb for benzaldehyde. However, at head height, the concentration of the two analytes was only around 2 - 3 ppb, even with the bin left open for this prolonged period of time. The concentrations of both analytes in these samples were only slightly above the limits of detection and remained almost unchanged over the whole 2-hour test period. Once again these results tend to indicate that, for this particular scenario, the potential for exposure by inhalation is very low.

4.2.2 Phenoxyethanol

The results obtained from the chamber tests with phenoxyethanol are summarised in Table 8. Further details may be found in Annex 3.

Table 8: Chamber Tests Using Phenoxyethanol – Summary of Results

Test	Airborne Concentration (ppb)					
	1	2	3	4	5	6
PT-01	*< 3*	*< 3*	*< 2*	*< 2*	*< 2*	-
PT-02	*< 3*	*< 3*	*< 2*	2	3	-
PT-03	*< 3*	6	5	11	13	-
PT-04	12	22	25	28	32	-
PT-05	*< 3*	*< 3*	*< 2*	*< 2*	*< 2*	*< 1*
PT-06	2	3	4	4	5	6
PT-07	15	20	11	11	11	11
PT-08	2	4	4	5	6	6
PT-09	41	71	99	123	144	181
PT-10	24	46	72	90	107	131
PT-11	21	34	66	89	104	113
PT-12	76	150	184	209	235	247

Results in italic, and preceded by "<", are below the limit of detection

Test 1 = 0 - 15 mins; Test 2 = 15 - 30 min; Test 3 = 30 - 60 mins; Test 4 = 60 - 90 mins; Test 5 = 90 - 120 mins; Test 6 = 120 - 180 mins

Test PT-01 showed airborne concentrations of phenoxyethanol below the limit of detection (typically around 2 - 3 ppb) over the entire duration of the test. The airborne concentrations of phenoxyethanol in this test are therefore more than 1000 times lower than those observed in the baseline study tests.

Test PT-02 increased the temperature of the dish containing the phenoxyethanol from around 20°C to 35°C. This slightly increased concentrations of phenoxyethanol, but levels only exceeded the limit of detection after around 60 minutes of the test and are still extremely low.

Test PT-03 raised the temperature of the dish containing the phenoxyethanol to 55°C. This produced a more noticeable increase in the airborne concentrations of phenoxyethanol, with levels in the test chamber about 10 times greater than those at room temperature. Concentrations exceeded the limit of detection in all but the initial 15 minutes, showing a gradual, and roughly linear, increase over time, reaching around 12 ppb (0.09% of SVC) at the end of test.

Test PT-04 raised the temperature of the dish containing the phenoxyethanol still further, to 75°C. This produced a further 4-fold increase in concentration, with levels now about 40 – 50 times those at room temperature. Once again the results showed a gradual, and roughly linear increase of concentration with time, reaching around 54 ppb (0.4% of SVC) at the end of test. However, this final concentration is still around 30 times less than those observed at room temperature in the baseline study tests.

Test PT-05 was a repeat of Test PT-01, but with the 4 ml of neat phenoxyethanol replaced with 50 ml of a 20% v/v aqueous solution. Despite the greater analyte content of the source material, the results were fairly similar, with only one sample exceeding the limit of detection, and a concentration, at the end of the test, of only just over 1 ppb.

Test PT-06 was also carried out at room temperature, but in an attempt to increase the airborne concentration, used three times more phenoxyethanol (12 ml) than was used in Test PT-01. In addition, rather than just placing the source material in a glass dish, it was spread over four 150 mm glass fibre filter papers giving a bigger potential surface area for evaporation. Compared with Test PT-01, this produced an initial concentration of around 2 ppb, rising gradually to around 6 ppb after 3 hours (or around 3 - 4 times higher than those in Test PT-01). It is not clear whether this increase in airborne concentration is due to the increase in the amount of phenoxyethanol used or to the increase in surface area (or a combination of both). However, as most of the phenoxyethanol used in Tests PT-01 to PT-04 remained unevaporated at the end of the 2-hour test period, increased surface area would seem the more likely explanation.

In Test PT-07, 20 ml of neat phenoxyethanol was applied, using a paintbrush, onto a piece of plain cardboard (ca. 850 cm^2) at room temperature. This test was intended to both mimic painting scenarios and increase the surface area (and the potential for evaporation) of the test material. The test results show an initial concentration of around 15 ppb (0.11% of SVC), rising to around 20 ppb (0.15% of SVC) after 30 minutes, before dropping to around 10 ppb (0.08% of SVC) for the remainder of the test. These levels are around 10 times greater than those observed in Test PT-01.

Test PT-08 was a repeat of Test PT-07, but with the 20 ml of neat phenoxyethanol replaced by 50 ml of a 10% aqueous solution. Compared with Test PT-07, this produced a significantly lower initial concentration, of around 2 ppb (0.02% of SVC), followed by a very gradual, and roughly linear increase, reaching around 6 ppb (0.05% of SVC) after 3 hours. These levels are around 3 - 4 times greater than those observed in Test PT-05 (generated from an aqueous solution placed in a glass dish).

Test PT-09 was also a repeat of Test PT-07, but in an attempt to increase the rate of evaporation, a flow of air, generated using a desk fan, was passed over the surface of the "painted" cardboard with a face velocity of around 1.6 - 2.0 m/s. Compared with Tests CT-07 this produced an initial concentration of around 40 ppb (0.30% of SVC), which then increased steadily with time, reaching around 180 ppb (or 1.4% of SVC) after 3 hours. This concentration is almost 20 times greater than that observed at the same stage in Test CT-07 (and over 100 times more than that in Test CT-01), but is still only around 10% of that observed in the baseline tests. Nevertheless, the results of Test PT-09 clearly show that passing a flow of air across the surface of the

phenoxyethanol leads to a significant increase in the rate of evaporation (greater even than raising temperature).

Test PT-10 was a repeat of Test PT-09, but with the face velocity of the air flow reduced to around 0.4 – 0.7 m/s. This produced an initial concentration of around 20 ppb (0.15% of SVC), which then increased steadily with time, reaching around 130 ppb (1.0% of SVC) after 3 hours. So, compared with Test PT-09, the lower air flow does result in lower airborne concentrations, but the airborne concentration of phenoxyethanol after 3 hours is still over 10 times greater than that observed in Test PT-07 (with zero air flow).

Test PT-11 was also a repeat of Test PT-09, but with the 20 ml of neat phenoxyethanol replaced by 50 ml of a 10% aqueous solution. This produced an initial concentration of around 20 ppb (0.15% of SVC), which then increased steadily with time, reaching just over 110 ppb (0.84% of SVC) after 3 hours. These values are around 50 – 60% of those observed in Test PT-09, but around 10 - 20 times greater than those in Test PT-08 (an equivalent test carried out with zero air flow).

Test PT-12 was a further repeat of Test PT-09, but with the test period extended to 6 hours. This produced a mean concentration of around 76 ppb (0.58% of SVC) in the first hour, increasing to just over 180 ppb (1.4% of SVC) after 3-hours (i.e. very similar to the 3-hour concentration in Test PT-09) and to around 250 ppb (1.9% of SVC) at the end of the test. The airborne concentration of phenoxyethanol therefore continues to increase between 3 and 6 hours, but the rate of increase appears to be slowing and, under these conditions at least, it appears unlikely that concentrations such as those observed in the baseline tests (i.e. 2 – 3 ppm) would occur.

4.3 DISCUSSION

In the baseline tests, the three test compounds were found to generate airborne concentrations, after 6 hours at room temperature, of around 2 ppm (about 6% of calculated SVC) of cinnamaldehyde, 1.5 ppm (about 12% of calculated SVC) of phenoxyethanol and 20 - 25 ppm of methylnaphthalene (again about 25% of calculated SVC). Increasing the size of the chamber appears to slow equilibration time, but to have relatively little effect on final concentration. The 24-hour experiments showed airborne concentrations of the test compounds continuing to increase (with levels up to 90% greater than those after 6 hours). However, the rate of increase suggests that it is unlikely that the airborne concentrations of any of these particular compounds would reach the SVC within a reasonable time-scale.

The results of the baseline tests suggest that, as well as evaporation, cinnamaldehyde undergoes chemical decomposition to form benzaldehyde. Such a loss by chemical decomposition may be a reason for the comparative shortfall of cinnamaldehyde, relative to its calculated SVC. The test results indicate that the rate of formation of benzaldehyde increases with both time and temperature. At room temperature, the airborne concentration of cinnamaldehyde is greater than that of benzaldehyde for the first 6 hours, after which time benzaldehyde is more prevalent. At 35°C, this "cross-over" time is reduced to around 2 - 3 hours and, when heated to 55°C, to less than an hour. Also, because benzaldehyde is more volatile than cinnamaldehyde, it can evaporate more easily, and the highest concentrations of benzaldehyde observed in the baseline tests were 3 - 4 times greater than the highest concentrations of cinnamaldehyde. This is a potentially important observation as other semi-volatile components may also undergo both decomposition and evaporation, and it is very likely that most decomposition products will be more volatile than their parent composition, and hence have the potential to generate higher vapour concentrations.

Not unexpectedly, increasing air temperature led to increased airborne concentrations of the three test compounds (and, as previously mentioned, increased chemical decomposition of cinnamaldehyde). Raising the surface temperature on which the test samples were sitting had a similar effect, at least initially, but then the airborne concentrations of the three test compounds behaved somewhat differently. The reasons for these differences are unclear, but may, in part, be due to condensation on the (cooler) chamber walls.

The experiments carried out in the test chamber using a small container of cinnamaldehyde showed airborne concentrations substantially less than those observed in the baseline tests. At room temperature, airborne concentrations at head height were less 1 - 2 ppb (less than 0.01% of SVC), or around 1000 times lower than the baseline tests. Increasing the temperature of the cinnamaldehyde source material, but not the surrounding air, did increase the airborne concentration, but only by 3 - 4 times when raised to 35°C or by 10 times when raised to 55°C. Consequently, even at a surface temperature of 55°C the airborne concentrations are still 50 - 100 times less than those observed at room temperature in the baseline tests. A test carried out using an aqueous solution of cinnamaldehyde as the source material, in place of the neat cinnamaldehyde used in the other tests, generated even lower airborne concentrations. Measured concentrations of benzaldehyde were extremely low in all seven tests, with most close to, or below, the limit of detection.

The main outcome of the tests with the cinnamaldehyde source kept in a plastic flip-top bin were that, when the lid was opened, even for prolonged periods, the airborne concentration of cinnamaldehyde measured at waist and head height in all six experiments was extremely low (less than 2 ppb). Airborne concentrations of benzaldehyde at these locations were also negligible. Much higher concentrations of cinnamaldehyde (up to 166 ppm) were measured inside the bin, although this is still less than 10% of those measured in the baseline tests. This may be because the walls of the bin, being plastic, are not as inert as the silanised glass of the chamber used in the baseline tests and airborne material may therefore be being lost by adsorption. Airborne concentrations of up to 40 ppb were measured adjacent to the open bin lid. Overall however, the results indicate that the potential for exposure, by inhalation, from a bin containing a source of cinnamaldehyde is very low.

The chamber tests with phenoxyethanol also generated much lower concentrations than the baseline tests. Once again, airborne concentrations could be increased by raising the temperature of the source material, with a 3 - 4 fold increase at 35°C, a 10-fold increase at 55°C and an increase of around 40 - 50 times at 75°C. However, even at 75°C, airborne concentrations were still only around 2% of those measured at room temperature in the baseline tests. A test using an aqueous solution of phenoxyethanol (in place of neat material) also produced extremely low airborne concentrations. Higher concentrations were obtained from the simulated painting tests, particularly when air was blown across the surface of the "painted" material. These experiments produced airborne concentrations, at room temperature of up to 250 ppb, which is around 10 times greater than the test with the neat phenoxyethanol at 75°C and only 6 times less than the levels measured in the baseline tests. The combination of a thin film of material, giving a greater surface area, and air movement, to aid evaporation, has therefore shown the greatest potential for increasing airborne concentration of this analyte and, if combined with an increase in temperature, the results of the previous tests suggest that the airborne concentration could be increased to 1 ppm or more. It should be noted however, that the highest airborne concentration observed in the "painting" experiments are still only around 2% of the calculated SVC for phenoxyethanol, and that this was achieved using neat phenoxyethanol in a poorly ventilated room. In "real life" it is much more likely that the source material would be a dilute solution, and the work area would be better ventilated, both of which would almost certainly result in a significant reduction of the airborne concentrations.

Finally, it was noted that the main finding of this investigation, that SVC greatly exceeds real airborne concentrations for low volatility chemical substances (with vapour pressures in the range 1 to 10 Pa at 20°C), shows good agreement with the results of previous work (Wheeler, 2003), in which airborne concentrations of two semi-volatile pesticides, prallethrin and bioallethrin, generated using heated plug-in devices inside a typical room were also found to be less than 1% of their respective SVC values.

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6. ANNEX 1: BASELINE STUDY - RESULTS

Table 9: Airborne Concentrations - Baseline Test A

Test	Time		Cinnamaldehyde		Benzaldehyde		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.00	< 0.01%	0.0	< 0.01%
2	1	0.0	0.00	< 0.01%	0.00	< 0.01%	0.1	0.1%
3	7	0.1	0.03	0.1%	0.01	< 0.01%	0.8	0.9%
4	16	0.3	0.36	1.1%	0.07	0.01%	4.6	5.0%
5	30	0.5	0.64	1.9%	0.12	0.01%	6.7	7.2%
6	45	0.8	1.32	4.0%	0.31	0.02%	10.6	11.5%
7	60	1.0	1.32	4.0%	0.30	0.02%	10.2	11.1%
8	90	1.5	1.65	5.0%	0.50	0.04%	11.8	12.8%
9	130	2.2	1.73	5.3%	0.77	0.06%	12.9	14.0%
10	180	3.0	2.09	6.3%	1.20	0.09%	17.7	19.3%
11	240	4.0	1.96	5.9%	1.46	0.11%	17.5	19.0%
12	300	5.0	1.98	6.0%	1.55	0.12%	17.6	19.1%
13	360	6.0	2.15	6.5%	2.07	0.16%	20.3	22.0%
14	1320	22.0	2.02	6.2%	6.93	0.53%	24.0	26.1%
15	1380	23.0	2.24	6.8%	7.57	0.57%	26.3	28.5%
16	1440	24.0	1.99	6.0%	6.80	0.52%	24.6	26.7%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

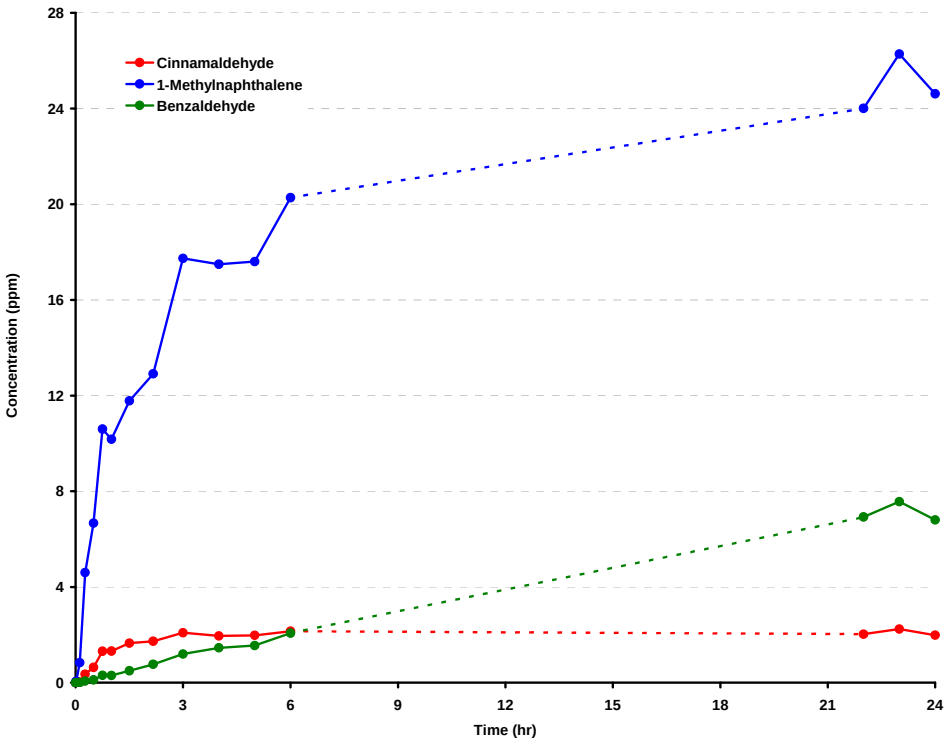

Figure 1: Airborne Concentrations - Baseline Test A

Table 10: Airborne Concentrations - Baseline Test B

Test	Time		Phenoxyethanol		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.0	< 0.01%
2	1	0.0	0.02	0.2%	4.3	4.7%
3	7	0.1	0.33	2.5%	14.0	15.2%
4	16	0.3	0.72	5.5%	19.7	21.4%
5	30	0.5	1.09	8.3%	24.6	26.7%
6	45	0.8	1.24	9.4%	26.2	28.4%
7	60	1.0	1.49	11.4%	27.4	29.7%
8	90	1.5	1.37	10.4%	27.0	29.4%
9	130	2.2	1.33	10.1%	26.1	28.3%
10	180	3.0	1.54	11.7%	29.9	32.4%
11	240	4.0	1.54	11.7%	28.6	31.0%
12	300	5.0	1.85	14.1%	30.0	32.6%
13	360	6.0	1.73	13.1%	26.8	29.1%
14	1370	22.9	2.97	22.6%	36.4	39.5%
15	1400	23.4	3.07	23.4%	36.4	39.5%
16	1440	24.0	3.67	27.9%	39.3	42.7%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

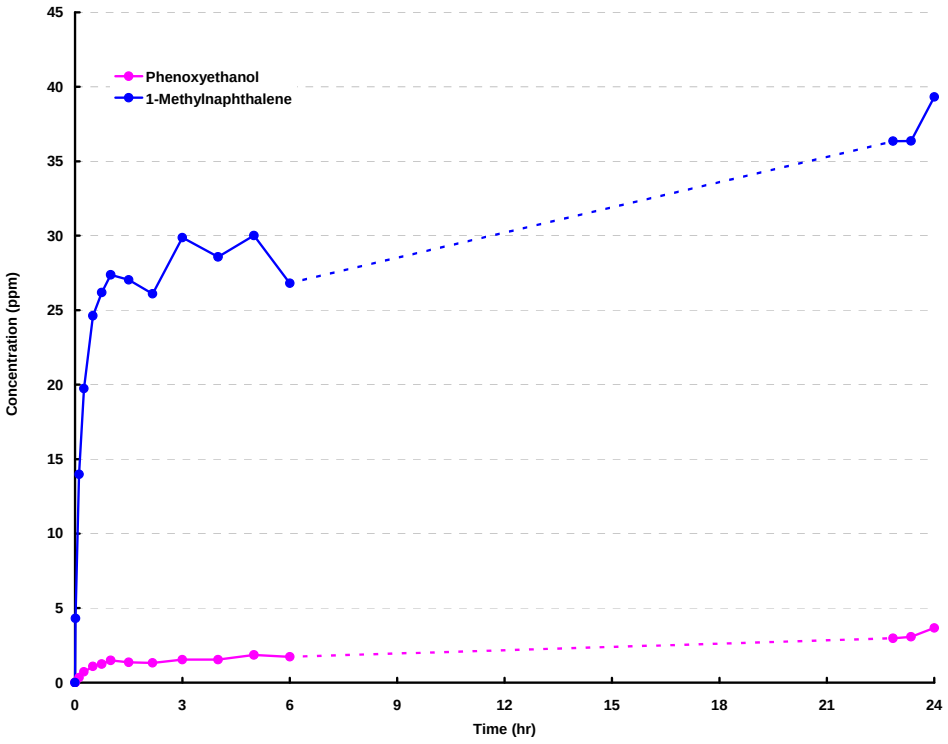

Figure 2: Airborne Concentrations - Baseline Test B

Table 11: Airborne Concentrations - Baseline Test C

Test	Time		Phenoxyethanol		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.0	< 0.01%
2	1	0.0	0.00	< 0.01%	0.0	< 0.01%
3	7	0.1	0.00	< 0.01%	0.1	0.1%
4	15	0.3	0.00	< 0.01%	0.4	0.4%
5	30	0.5	0.00	< 0.01%	0.9	0.9%
6	45	0.8	0.01	0.1%	1.6	1.7%
7	60	1.0	0.02	0.1%	2.4	4.7%
8	90	1.5	0.06	0.5%	4.3	5.5%
9	120	2.0	0.11	0.9%	5.1	8.3%
10	180	3.0	0.29	2.2%	7.6	11.0%
11	240	4.0	0.56	4.3%	10.1	13.3%
12	300	5.0	0.69	5.2%	12.2	18.0%
13	360	6.0	1.33	10.1%	16.6	29.1%
14	1320	22.0	3.07	23.3%	29.3	31.9%
15	1380	23.0	3.82	29.0%	30.8	33.5%
16	1440	24.0	3.72	28.3%	31.6	34.3%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

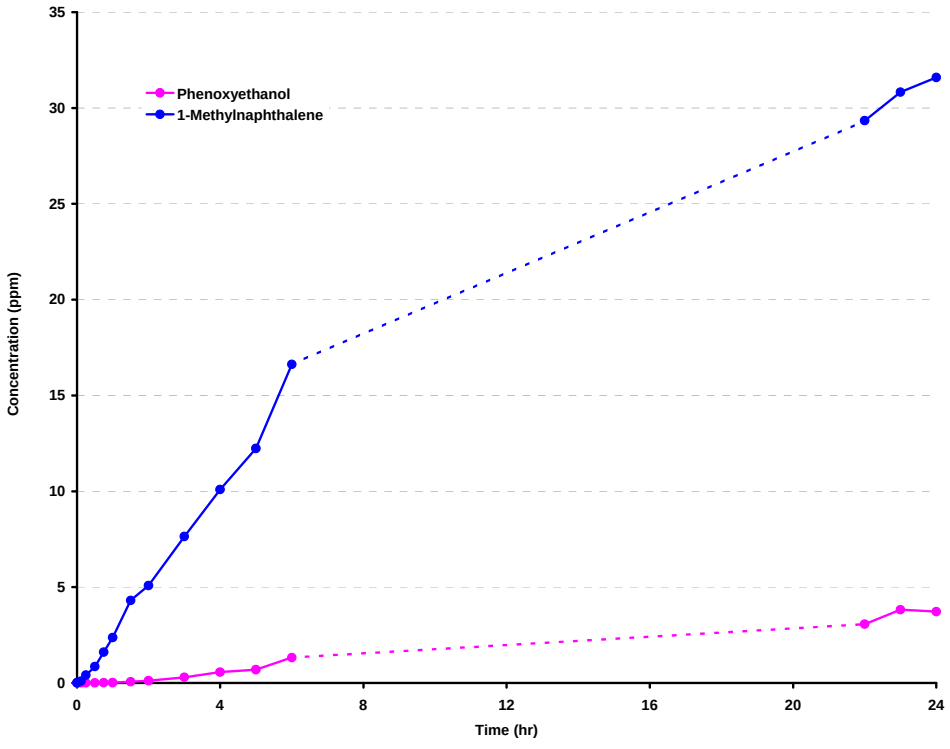

Figure 3: Airborne Concentrations - Baseline Test C

Table 12: Airborne Concentrations - Baseline Test D

Test	Time		Cinnamaldehyde		Benzaldehyde		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.00	< 0.01%	0.0	< 0.01%
2	1	0.1	0.00	< 0.01%	0.00	< 0.01%	0.3	0.3%
3	7	0.2	0.01	< 0.01%	0.00	< 0.01%	0.4	0.5%
4	16	0.3	0.03	0.1%	0.00	< 0.01%	0.7	0.7%
5	30	0.5	0.07	0.2%	0.00	< 0.01%	1.3	1.4%
6	45	0.8	0.19	0.6%	0.01	< 0.01%	2.3	2.5%
7	60	1.0	0.39	1.2%	0.05	< 0.01%	3.3	3.6%
8	90	1.5	0.73	2.2%	0.15	0.01%	5.1	5.6%
9	130	2.2	1.21	3.7%	0.35	0.03%	7.9	8.5%
10	180	3.0	1.32	4.0%	0.51	0.04%	9.7	10.5%
11	240	4.0	1.70	5.2%	0.76	0.06%	11.7	12.7%
12	300	5.0	1.88	5.7%	1.05	0.08%	12.9	14.0%
13	360	6.0	2.17	6.6%	1.43	0.11%	14.5	15.7%
14	1320	22.8	3.50	10.6%	7.57	0.58%	27.1	29.4%
15	1380	23.5	3.76	11.4%	8.68	0.66%	29.2	31.7%
16	1440	24.0	3.78	11.5%	8.49	0.65%	28.7	31.1%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

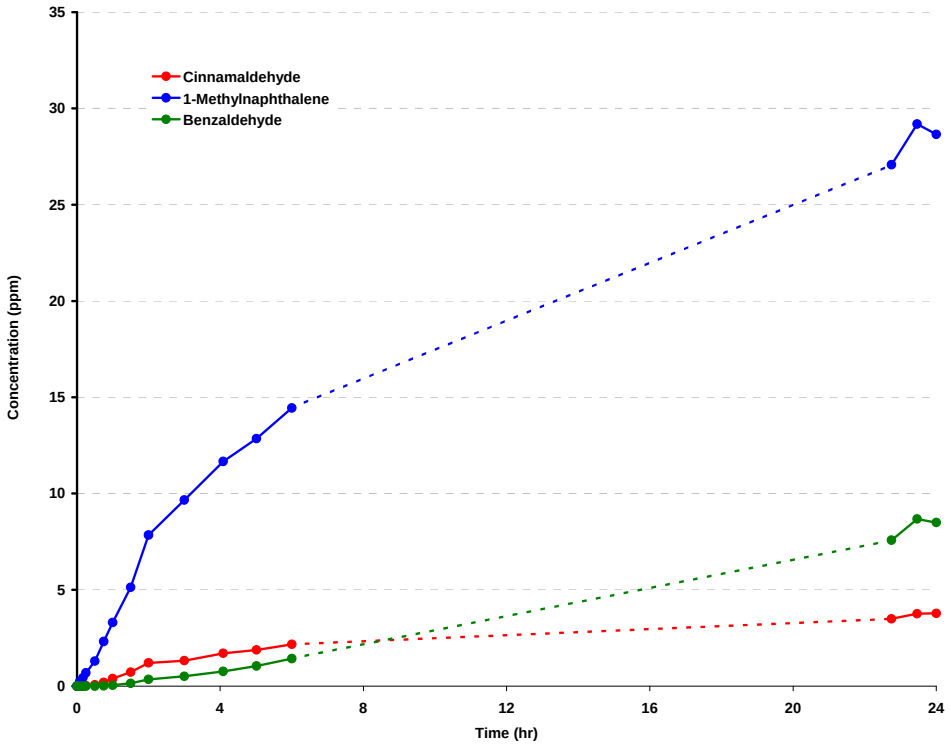

Figure 4: Airborne Concentrations - Baseline Test D

Table 13: Airborne Concentrations - Baseline Test E

Test	Time		Phenoxyethanol	
No.	min	hr	ppm	% SVC†
1	0	0.0	0.00	< 0.01%
2	1	0.0	0.00	< 0.01%
3	7	0.1	0.14	1.1%
4	15	0.3	0.61	4.6%
5	30	0.5	1.07	8.2%
6	45	0.8	1.77	13.4%
7	60	1.0	2.22	16.9%
8	90	1.5	2.78	21.1%
9	120	2.0	4.95	37.6%
10	255	4.3	4.62	35.1%
11	300	5.0	4.14	31.5%
12	345	5.8	5.16	39.2%
13	395	6.6	2.93	22.2%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

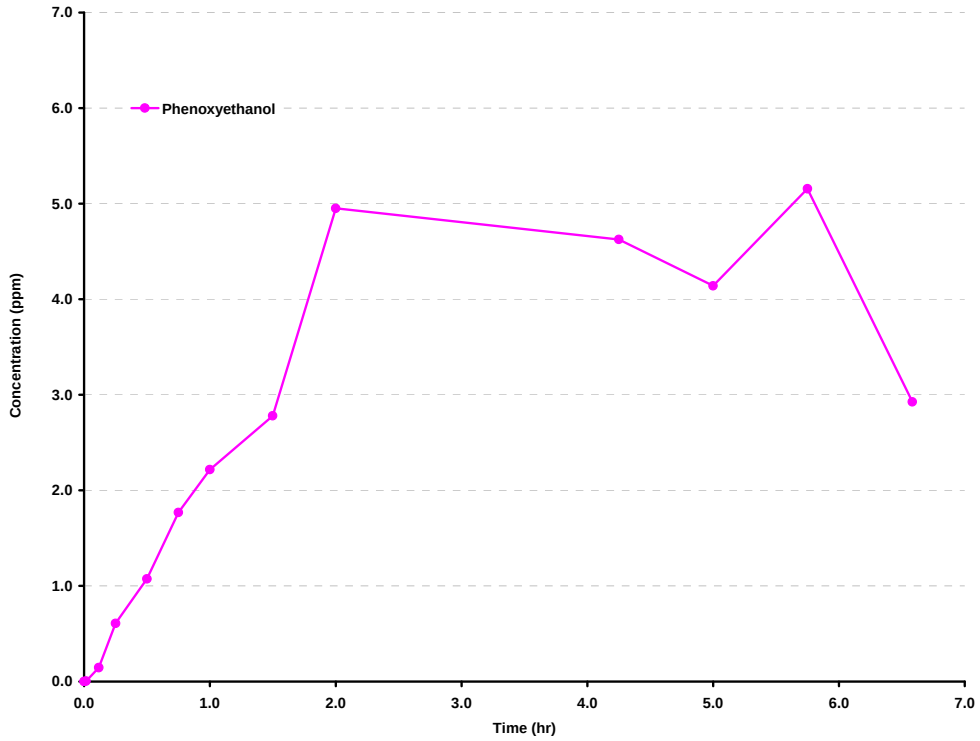

Figure 5: Airborne Concentrations - Baseline Test E

Table 14: Airborne Concentrations - Baseline Test F

Test	Time		Phenoxyethanol	
No.	min	hr	ppm	% SVC†
1	0	0.0	0.00	< 0.01%
2	1	0.0	0.01	< 0.01%
3	7	0.1	0.04	0.3%
4	15	0.3	0.06	0.5%
5	30	0.5	0.08	0.6%
6	45	0.8	0.06	0.5%
7	60	1.0	0.06	0.5%
8	92	1.5	0.08	0.6%
9	120	2.0	0.05	0.4%
10	180	3.0	0.08	0.6%
11	240	4.0	0.08	0.6%
12	300	5.0	0.26	2.0%
13	360	6.0	0.17	1.3%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

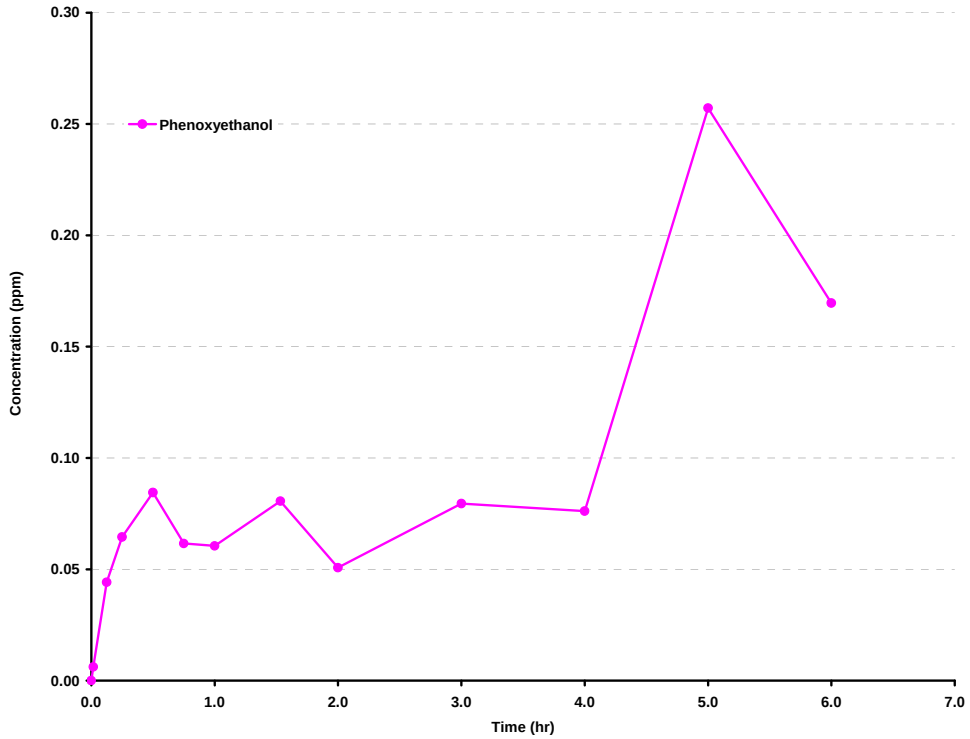

Figure 6: Airborne Concentrations - Baseline Test F

Table 15: Airborne Concentrations - Baseline Test G

Test	Time		Cinnamaldehyde		Benzaldehyde		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.00	< 0.01%	0.0	< 0.01%
2	1	0.0	1.05	3.2%	0.14	0.01%	5.5	6.0%
3	7	0.1	5.94	18.1%	0.65	0.05%	24.6	26.7%
4	15	0.3	10.21	31.1%	1.54	0.12%	39.8	43.2%
5	30	0.5	11.23	34.1%	3.23	0.25%	50.5	54.8%
6	45	0.8	10.65	32.4%	4.77	0.36%	54.1	58.7%
7	60	1.0	10.23	31.1%	6.01	0.46%	55.3	60.0%
8	90	1.5	9.54	29.0%	7.64	0.58%	56.0	60.8%
9	120	2.0	9.21	28.0%	9.12	0.69%	57.5	62.4%
10	200	3.3	9.55	29.0%	16.24	1.23%	63.2	68.6%
11	240	4.0	8.49	25.8%	16.96	1.29%	60.6	65.8%
12	300	5.0	8.11	24.6%	19.29	1.47%	60.5	65.7%
13	370	6.2	7.66	23.3%	21.81	1.66%	59.6	64.7%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

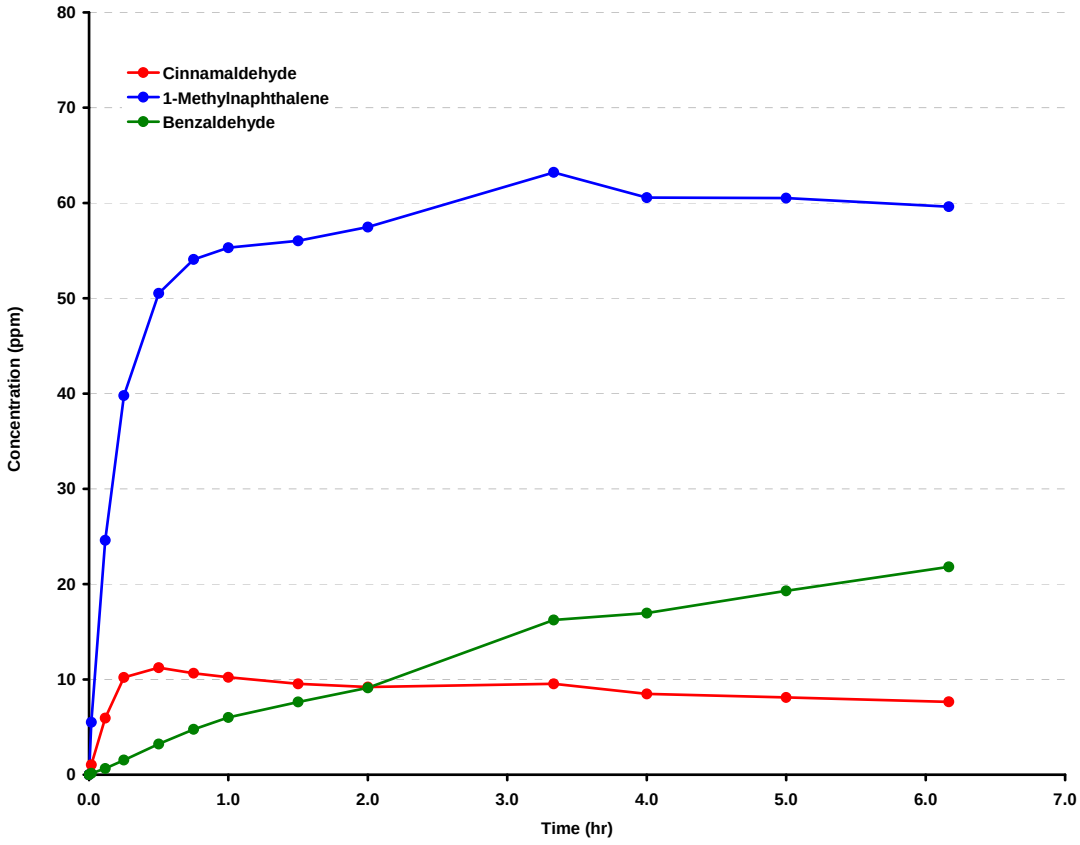

Figure 7: Airborne Concentrations - Baseline Test G

Table 16: Airborne Concentrations - Baseline Test H

Test	Time		Phenoxyethanol		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.00	< 0.01%	0.0	< 0.01%
2	1	0.0	0.05	0.4%	5.1	5.5%
3	7	0.1	0.74	5.6%	22.7	24.6%
4	15	0.3	2.18	16.6%	41.1	44.6%
5	30	0.5	4.04	30.7%	58.5	63.5%
6	45	0.8	4.39	33%	59.2	64.3%
7	60	1.0	4.83	36.7%	61.2	66.4%
8	90	1.5	4.83	36.7%	63.4	68.8%
9	120	2.0	5.25	39.9%	65.3	70.9%
10	180	3.0	5.29	40.2%	66.5	72.2%
11	240	4.0	5.24	39.8%	66.2	71.8%
12	300	5.0	5.44	41.3%	66.4	72.0%
13	360	6.0	5.28	40.1%	66.1	71.7%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

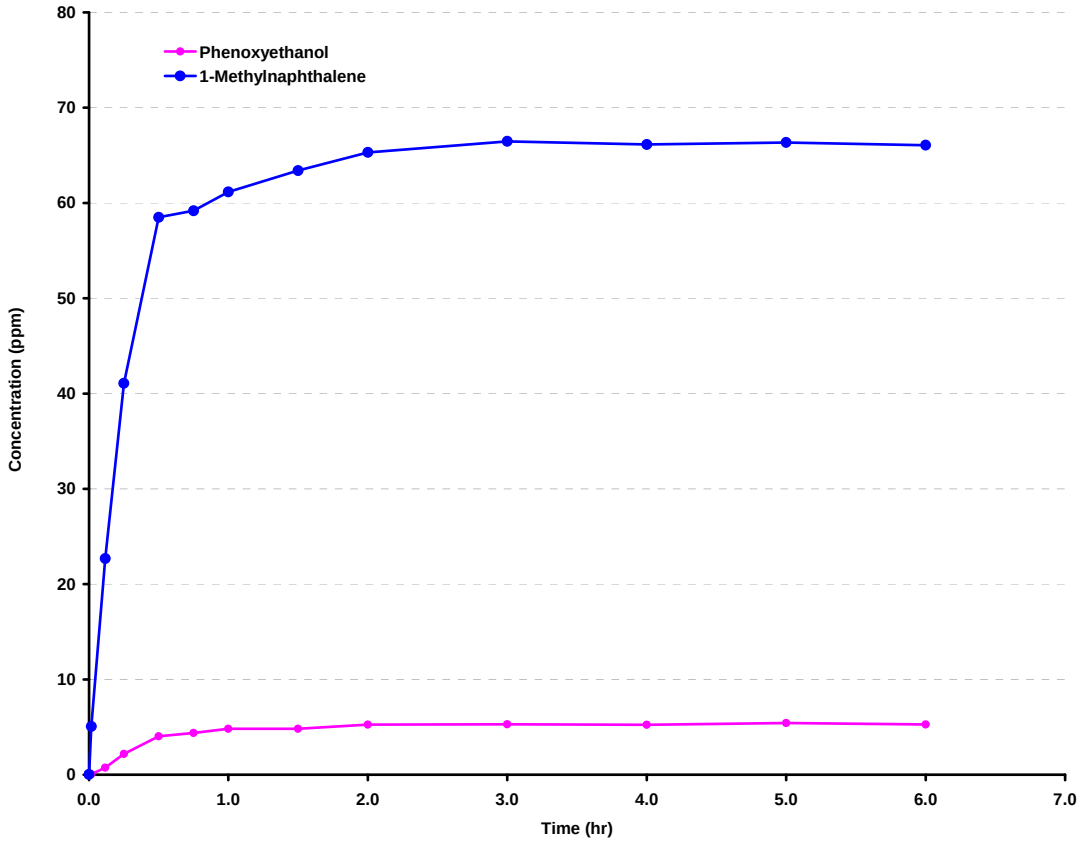

Figure 8: Airborne Concentrations - Baseline Test H

Table 17: Airborne Concentrations - Baseline Test I

Test	Time		Cinnamaldehyde		Benzaldehyde		Phenoxyethanol		Methylnaphthalene	
No.	min	hr	ppm	% SVC†	ppm	% SVC†	ppm	% SVC†	ppm	% SVC†
1	0	0.0	0.30	0.9%	0.03	< 0.01%	0.25	1.9%	0.1	0.1%
2	2	0.0	4.60	14.0%	0.48	0.04%	1.81	13.8%	28.4	30.9%
3	7	0.1	6.30	19.1%	1.23	0.09%	3.17	24.1%	44.8	48.6%
4	15	0.3	5.26	16.0%	2.96	0.22%	3.24	24.7%	53.1	57.6%
5	30	0.5	4.65	14.1%	5.03	0.38%	3.41	25.9%	56.1	60.9%
6	45	0.8	4.40	13.4%	6.30	0.48%	3.68	27.9%	57.8	62.7%
7	60	1.0	4.22	12.8%	7.58	0.58%	3.92	29.8%	59.4	64.5%
8	90	1.5	3.61	11.0%	10.05	0.76%	3.62	27.5%	58.7	63.8%
9	120	2.0	3.54	10.8%	11.87	0.76%	3.81	29.0%	60.7	65.9%
10	180	3.0	3.96	12.0%	15.00	1.14%	4.14	31.4%	48.8	53.0%
11	240	4.0	4.64	14.1%	16.02	1.22%	4.75	36.1%	40.9	44.4%
12	300	5.0	4.83	14.7%	15.07	1.15%	4.77	36.2%	32.5	35.3%
13	360	6.0	5.45	16.6%	14.43	1.10%	5.94	45.2%	26.9	29.2%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

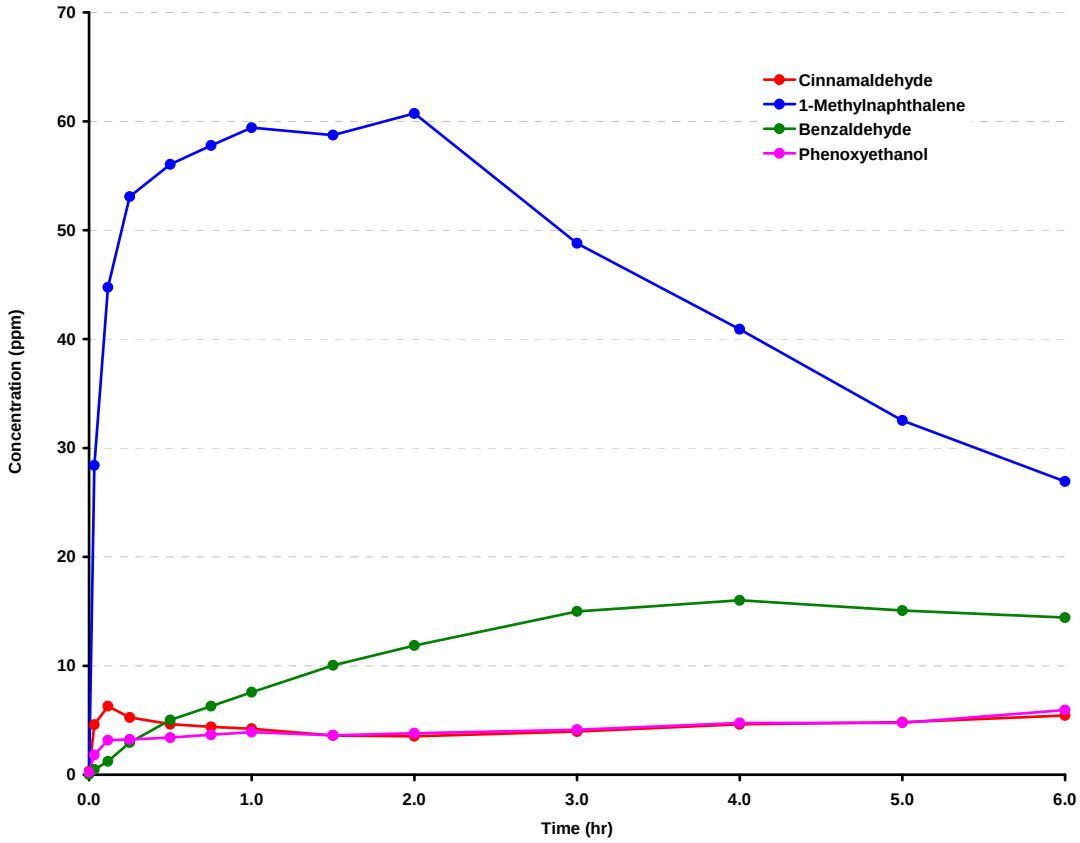

Figure 9: Airborne Concentrations - Baseline Test I

7. ANNEX 2: CINNAMALDEHYDE TESTS - RESULTS

Table 18: Airborne Concentrations - Cinnamaldehyde Test CT-01

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	< 0.004	< 0.008%	< 0.011	< 0.0008%
2	10	20	< 0.003	< 0.007%	< 0.009	< 0.0007%
3	20	40	< 0.002	< 0.004%	< 0.006	< 0.0004%
4	40	60	< 0.002	< 0.003%	< 0.005	< 0.0003%
5	60	90	< 0.001	< 0.002%	< 0.003	< 0.0002%
6	90	120	< 0.001	< 0.002%	< 0.003	< 0.0002%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

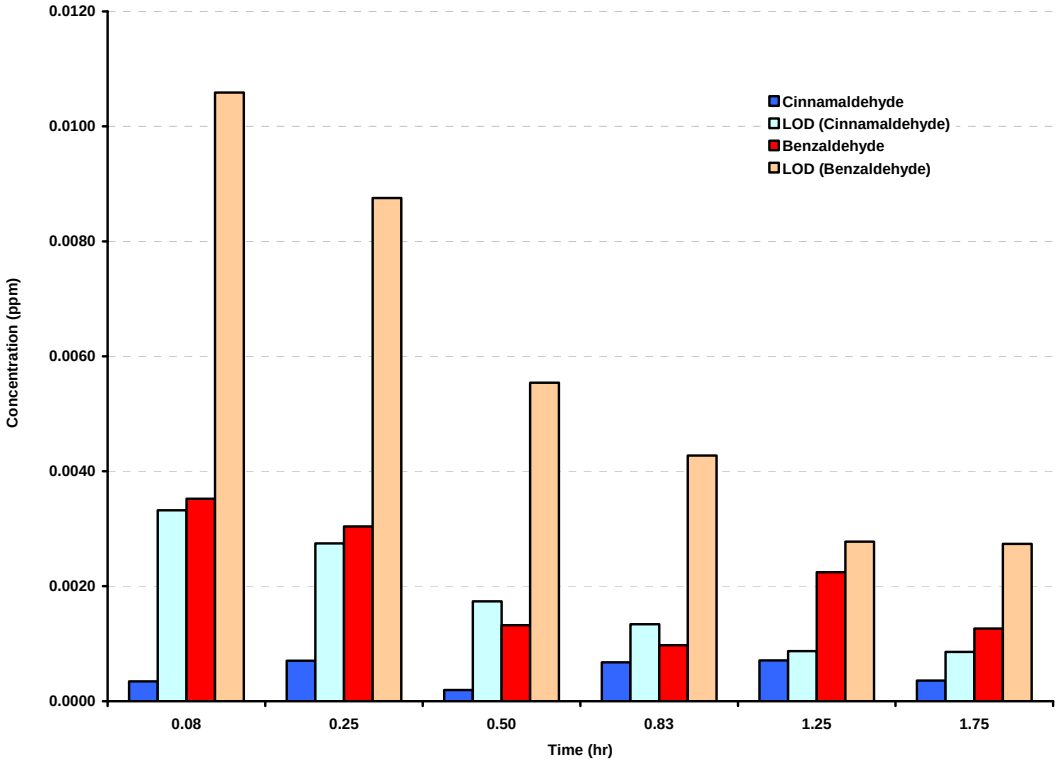

Figure 10: Airborne Concentrations - Cinnamaldehyde Test CT-01

Table 19: Airborne Concentrations - Cinnamaldehyde Test CT-02

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	< 0.004	< 0.009%	< 0.011	< 0.0008%
2	10	20	< 0.003	< 0.008%	< 0.009	< 0.0007%
3	20	40	0.002	0.007%	< 0.005	< 0.0004%
4	40	60	0.004	0.012%	< 0.005	< 0.0004%
5	60	90	0.002	0.005%	< 0.003	< 0.0002%
6	90	120	< 0.001	< 0.002%	< 0.003	0.0002%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

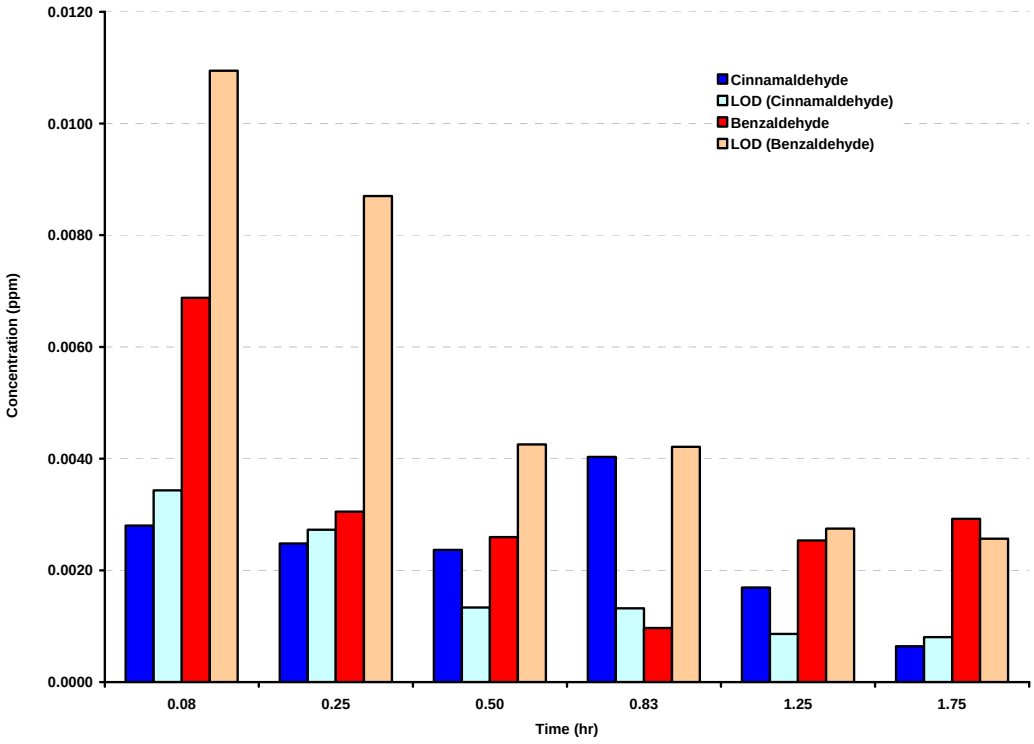

Figure 11: Airborne Concentrations - Cinnamaldehyde Test CT-02

Table 20: Airborne Concentrations - Cinnamaldehyde Test CT-03

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	0.005	0.015%	< 0.010	< 0.0008%
2	10	20	0.003	0.009%	< 0.009	< 0.0007%
3	20	40	0.004	0.013%	< 0.004	< 0.0003%
4	40	60	0.011	0.033%	< 0.004	< 0.0003%
5	60	90	0.012	0.036%	< 0.003	< 0.0002%
6	90	120	0.016	0.047%	0.003	0.0002%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

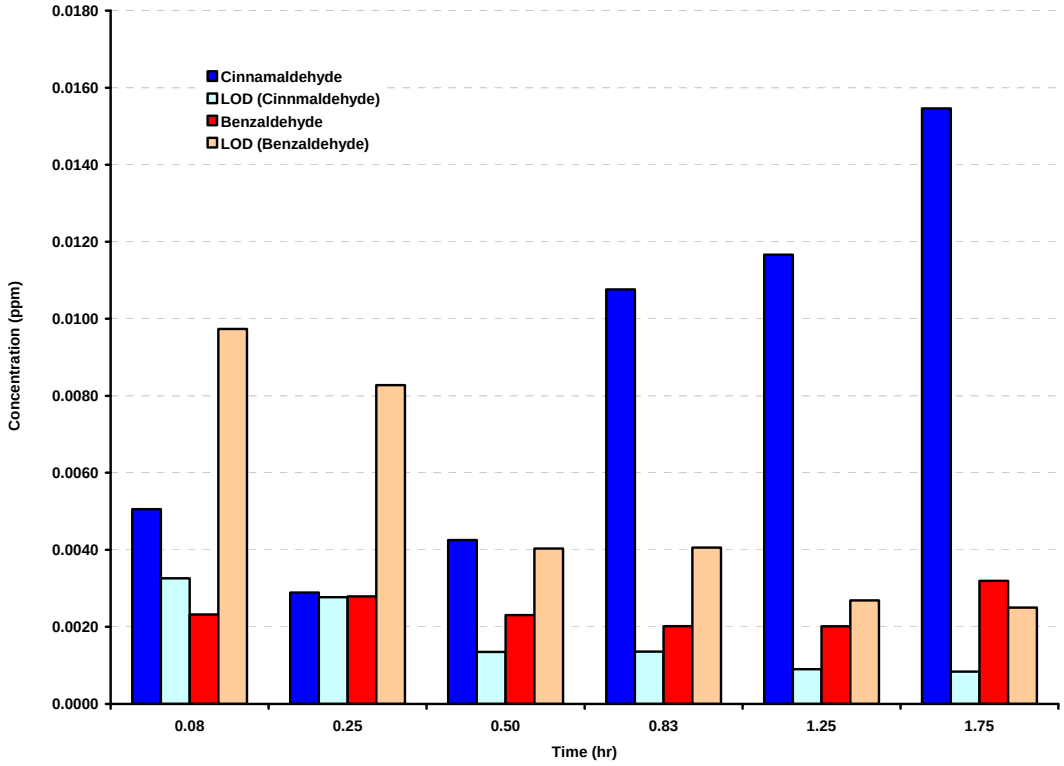

Figure 12: Airborne Concentrations - Cinnamaldehyde Test CT-03

Table 21: Airborne Concentrations - Cinnamaldehyde Test CT-04

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	0.012	0.04%	< 0.011	< 0.0009%
2	10	20	0.011	0.03%	< 0.009	< 0.0007%
3	20	40	0.041	0.13%	0.011	0.0008%
4	40	60	0.050	0.15%	0.006	0.0004%
5	60	90	0.037	0.11%	0.005	0.0004%
6	90	120	0.047	0.14%	0.006	0.0005%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

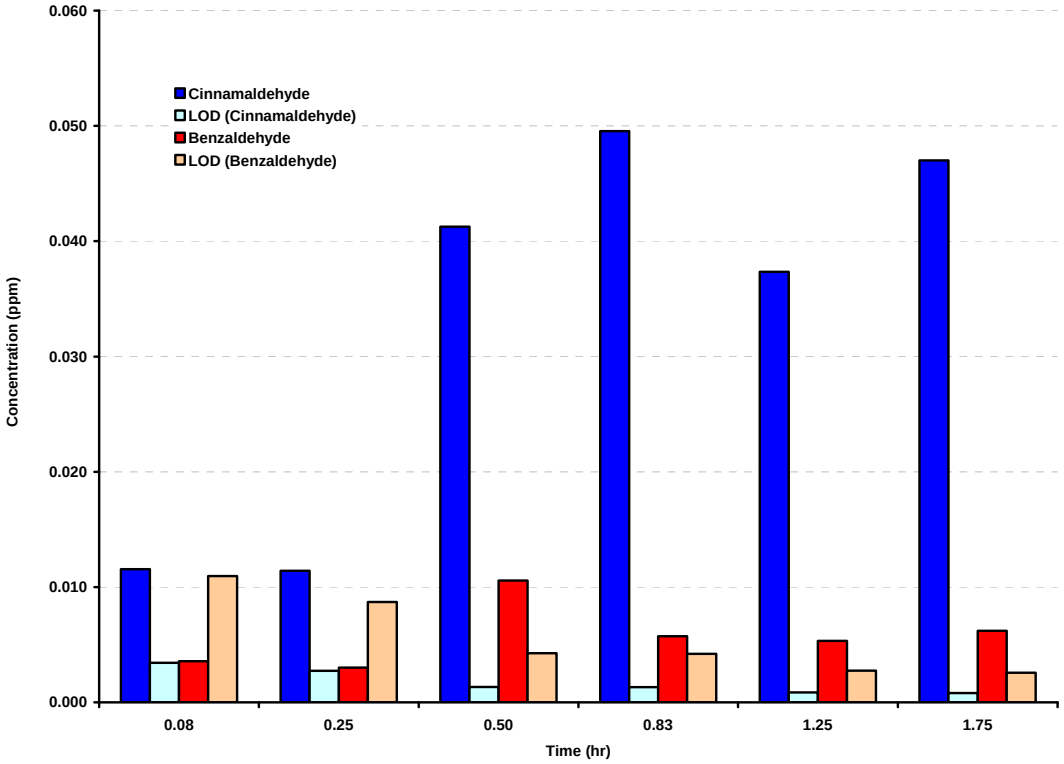

Figure 13: Airborne Concentrations - Cinnamaldehyde Test CT-04

Table 22: Airborne Concentrations - Cinnamaldehyde Test CT-05

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	0.042	0.13%	< 0.011	< 0.0007%
2	10	20	0.034	0.10%	< 0.009	< 0.0007%
3	20	40	0.009	0.03%	0.011	< 0.0004%
4	40	60	Failed	Failed	Failed	Failed
5	60	90	0.031	0.09%	0.003	0.0002%
6	90	120	0.011	0.03%	0.001	0.0002%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

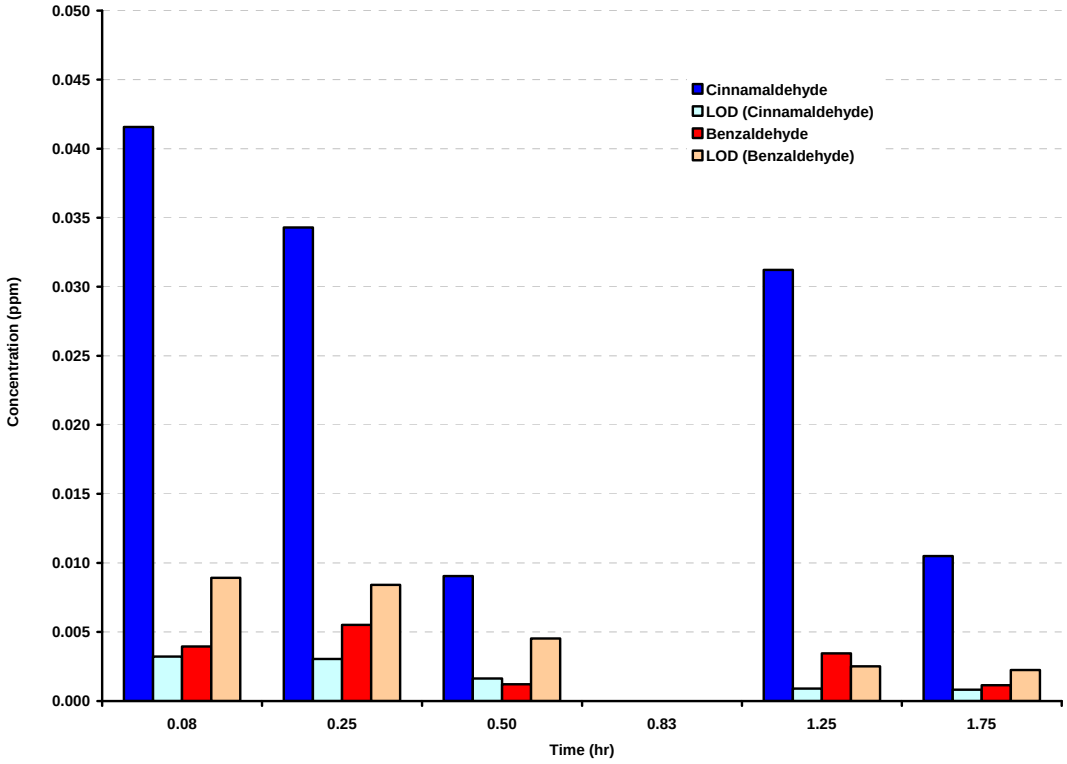

Figure 14: Airborne Concentrations - Cinnamaldehyde Test CT-05

Table 23: Airborne Concentrations - Cinnamaldehyde Test CT-06

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	0.021	0.06%	< 0.008	< 0.0006%
2	10	20	0.014	0.04%	< 0.007	< 0.0005%
3	20	40	0.039	0.12%	0.004	0.0003%
4	40	60	0.054	0.17%	0.007	0.0005%
5	60	90	0.049	0.15%	0.005	0.0004%
6	90	120	0.050	0.15%	0.007	0.0005%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

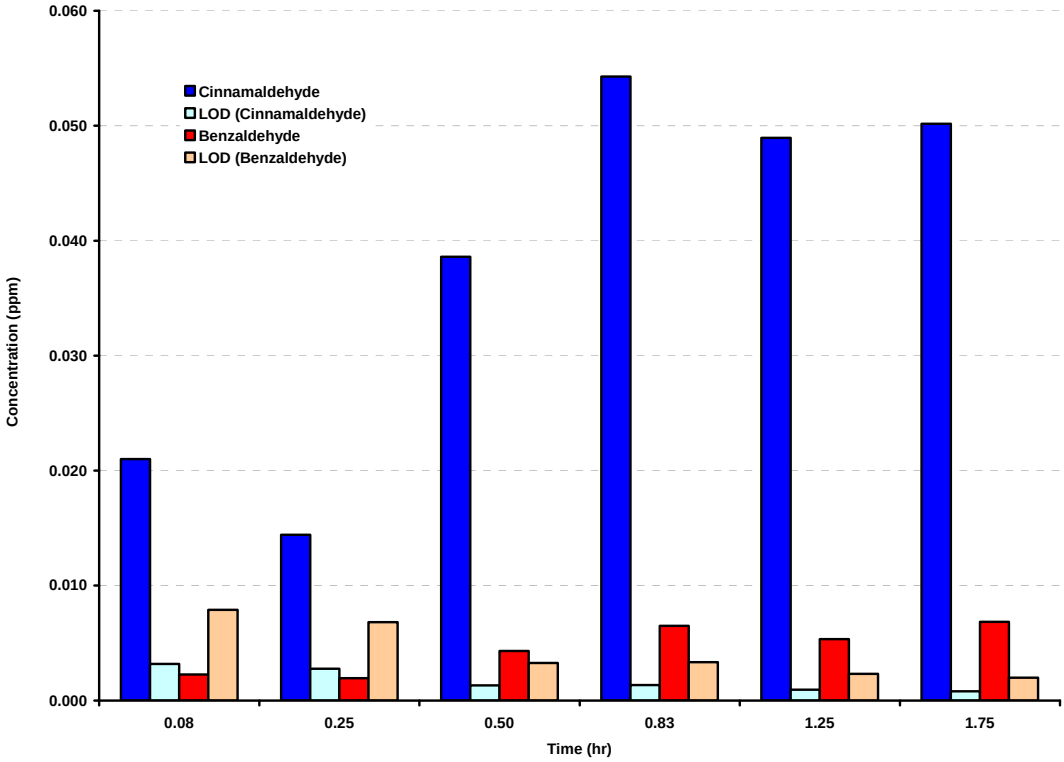

Figure 15: Airborne Concentrations - Cinnamaldehyde Test CT-06

Table 24: Airborne Concentrations - Cinnamaldehyde Test CT-07

Test	Time		Cinnamaldehyde		Benzaldehyde	
No.	Start	End	ppm	% SVC†	ppm	% SVC†
1	0	10	0.022	0.07%	< 0.009	< 0.0007%
2	10	20	0.039	0.12%	< 0.007	< 0.0005%
3	20	40	0.034	0.10%	0.003	0.0003%
4	40	60	0.015	0.05%	<0.003	< 0.0003%
5	60	90	0.029	0.09%	0.003	0.0002%
6	90	120	0.024	0.07%	0.002	0.0002%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

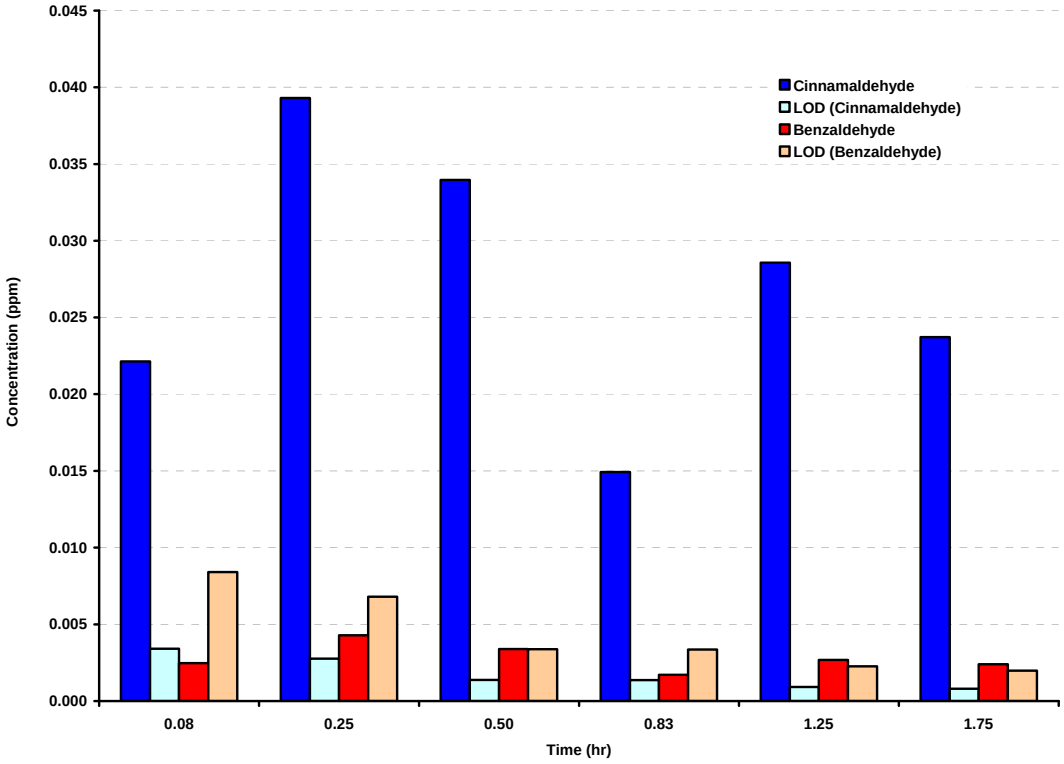

Figure 16: Airborne Concentrations - Cinnamaldehyde Test CT-07

Table 25: Airborne Concentrations - Cinnamaldehyde Test CT-08

Test No.	Sample Location	Sampling Time	Cinnamaldehyde ppm	Cinnamaldehyde % SVC†	Benzaldehyde ppm	Benzaldehyde % SVC†
1	Inside bin	10	0.022	0.07%	0.016	0.0012%
2	Next to open lid	10	< 0.002	< 0.01%	0.002	0.0002%
3	0.5 m above lid	10	< 0.002	< 0.01%	0.001	0.0001%
4	1.0 m above lid	10	< 0.002	< 0.01%	0.001	0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

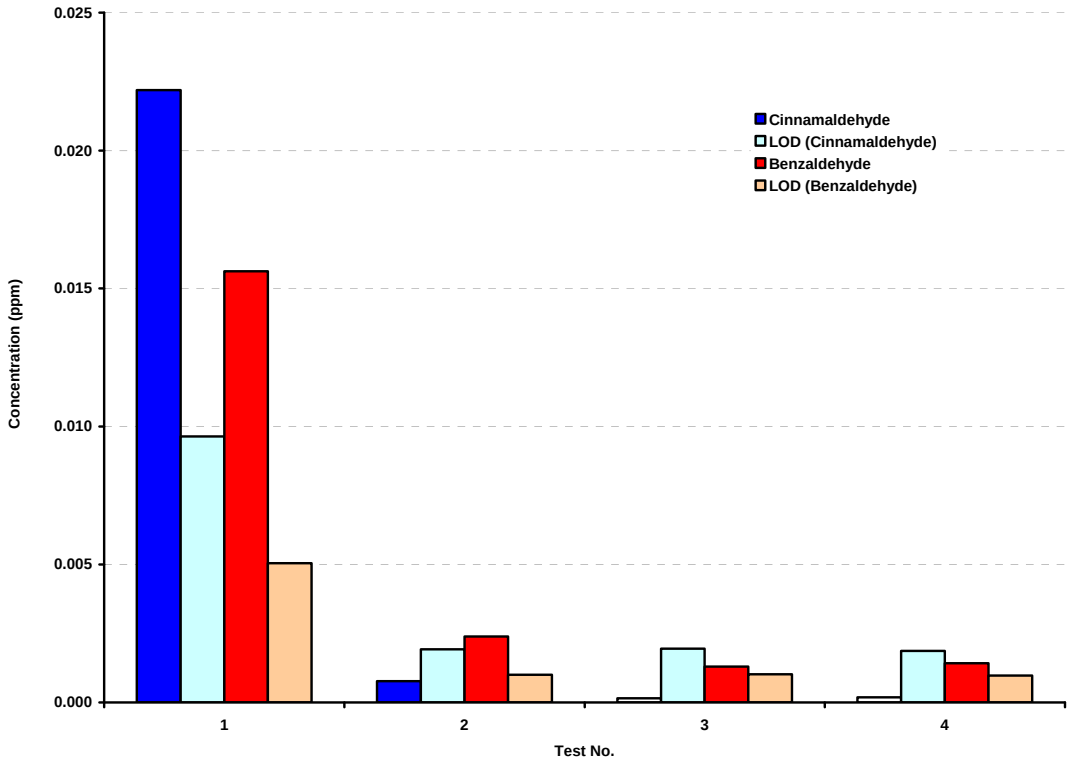

Figure 17: Airborne Concentrations - Cinnamaldehyde Test CT-08

Table 26: Airborne Concentrations - Cinnamaldehyde Test CT-09

Test No.	Sample Location	Sampling Time	Cinnamaldehyde ppm	Cinnamaldehyde % SVC†	Benzaldehyde ppm	Benzaldehyde % SVC†
1	Inside bin	10	0.008	0.07%	0.010	0.0008%
2	Next to open lid	10	< 0.002	< 0.01%	0.003	0.0002%
3	0.5 m above lid	10	< 0.002	< 0.01%	0.002	0.0002%
4	1.0 m above lid	10	< 0.002	< 0.01%	0.001	0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

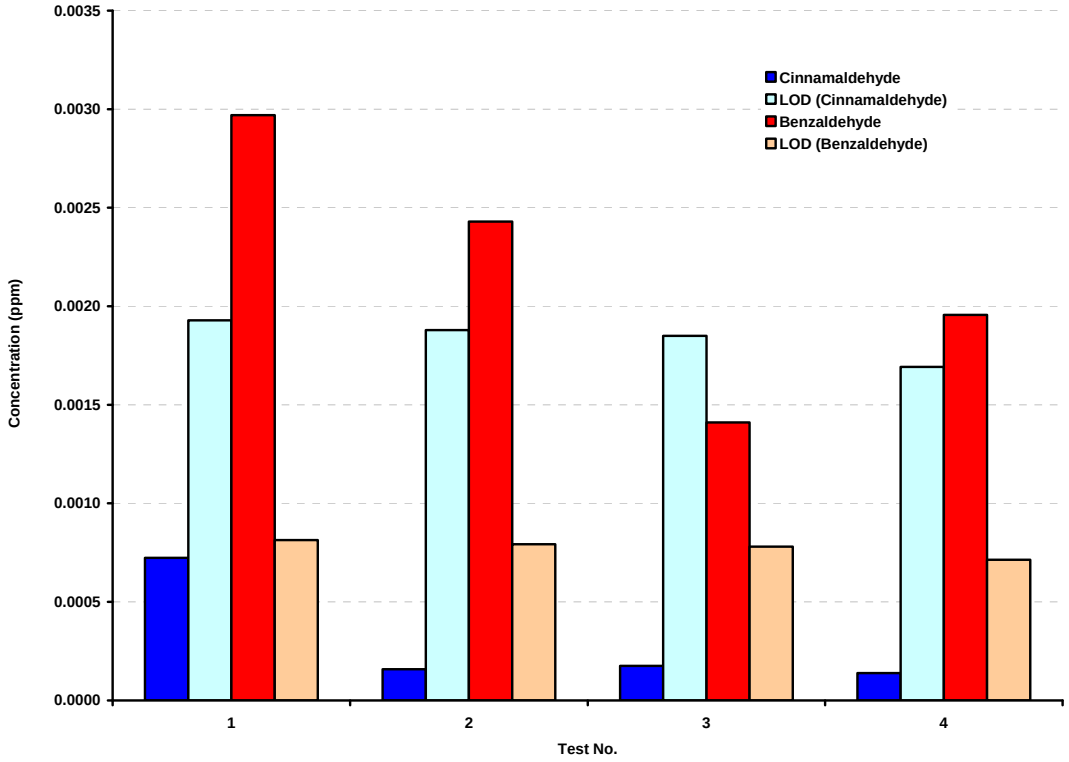

Figure 18: Airborne Concentrations - Cinnamaldehyde Test CT-09

Table 27: Airborne Concentrations - Cinnamaldehyde Test CT-10

Test	Sample	Sampling	Cinnamaldehyde		Benzaldehyde	
No.	Location	Time	ppm	% SVC†	ppm	% SVC†
1	Inside bin	10	0.077	0.23%	0.122	0.0093%
2	Next to open lid	10	0.024	0.07%	0.041	0.0031%
3	0.5 m above lid	10	< 0.002	< 0.01%	0.004	0.0003%
4	1.0 m above lid	10	< 0.002	< 0.01%	< 0.001	< 0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

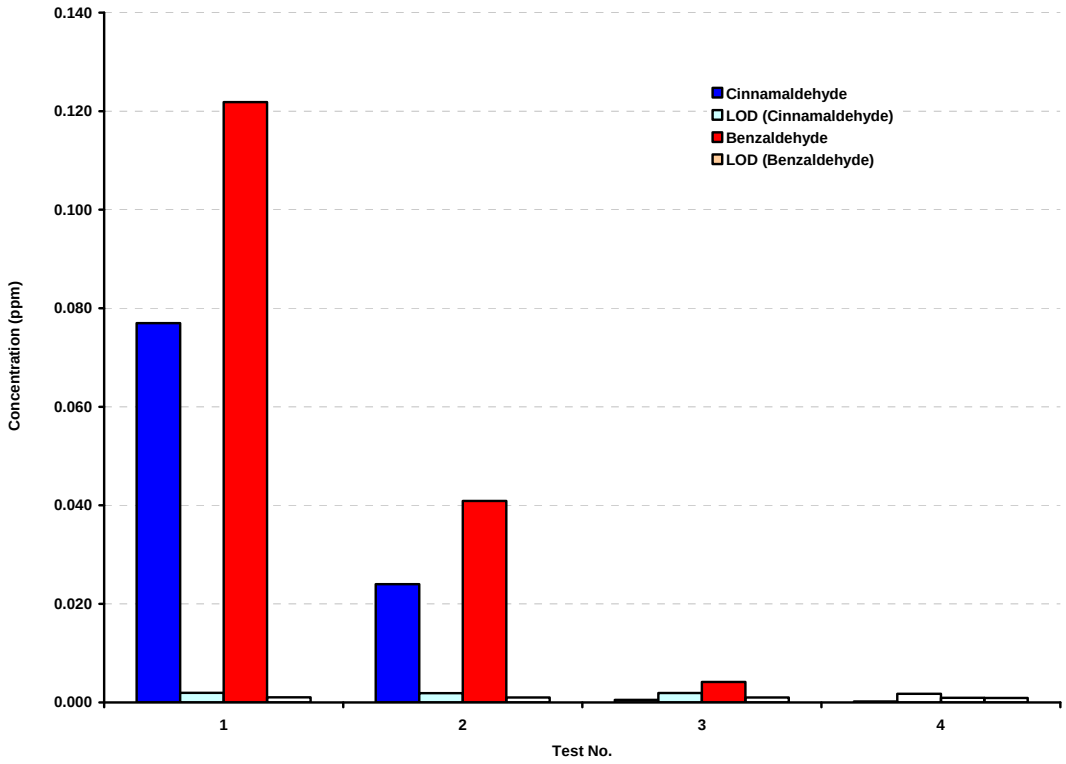

Figure 19: Airborne Concentrations - Cinnamaldehyde Test CT-10

Table 28: Airborne Concentrations - Cinnamaldehyde Test CT-11

Test	Sample	Sampling	Cinnamaldehyde		Benzaldehyde	
No.	Location	Time	ppm	% SVC†	ppm	% SVC†
1	Inside bin	10	0.070	0.21%	0.076	0.0058%
2	Next to open lid	10	0.019	0.06%	0.020	0.0016%
3	0.5 m above lid	10	< 0.002	< 0.01%	0.002	0.0001%
4	1.0 m above lid	10	< 0.002	< 0.01%	0.002	0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

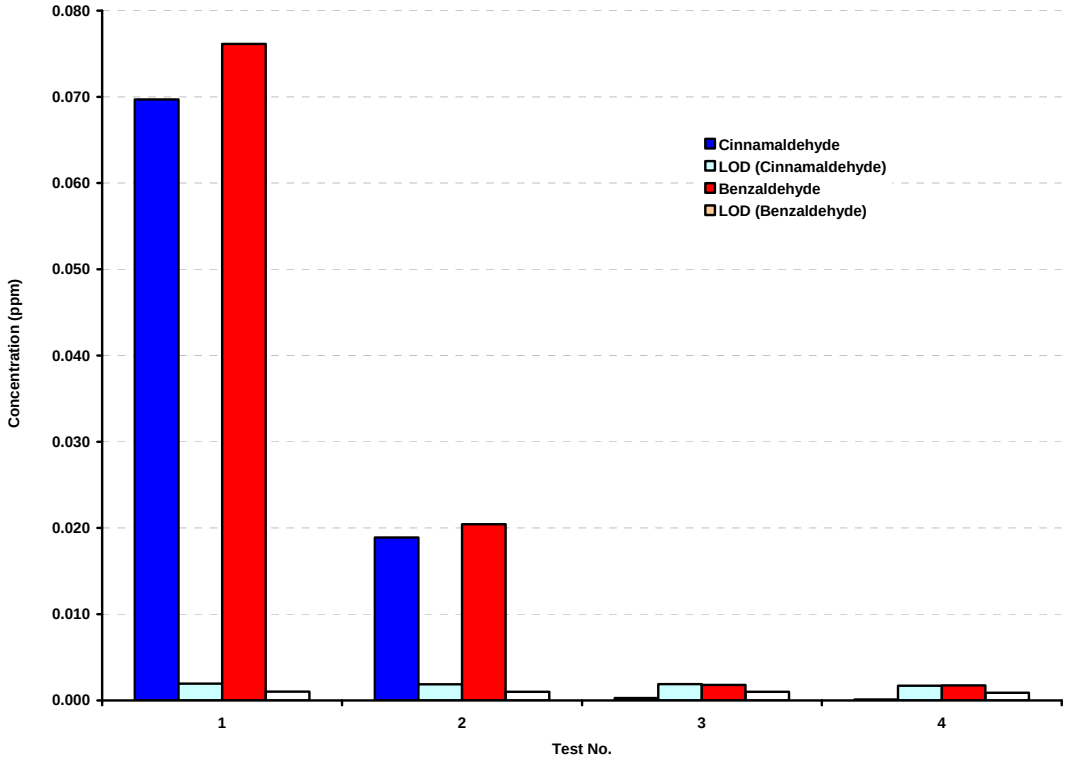

Figure 20: Airborne Concentrations - Cinnamaldehyde Test CT-11

Table 29: Airborne Concentrations - Cinnamaldehyde Test CT-12

Test	Sample	Sampling	Cinnamaldehyde		Benzaldehyde	
No.	Location	Time	ppm	% SVC†	ppm	% SVC†
1	Inside bin	10	0.070	0.21%	0.086	0.0065%
2	Next to open lid	10	0.025	0.07%	0.029	0.0022%
3	0.5 m above lid	10	< 0.002	< 0.01%	0.002	0.0001%
4	1.0 m above lid	10	< 0.002	< 0.01%	< 0.001	< 0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

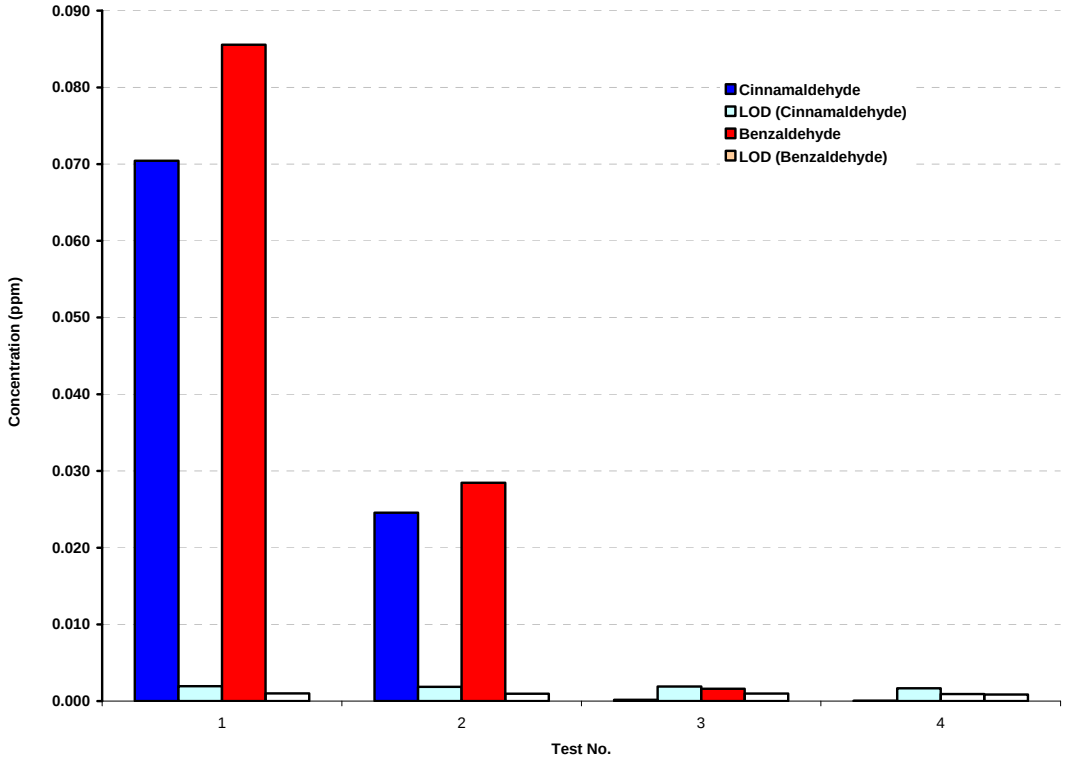

Figure 21: Airborne Concentrations - Cinnamaldehyde Test CT-12

Table 30: Airborne Concentrations - Cinnamaldehyde Test CT-13

Test	Sample	Sampling	Cinnamaldehyde		Benzaldehyde	
No.	Location	Time	ppm	% SVC†	ppm	% SVC†
1	Inside bin	0 - 120	0.166	0.504%	0.147	0.0112%
2	1 m above lid	0 - 30	0.003	0.010%	0.002	0.0001%
3	1 m above lid	30 - 60	0.002	0.006%	0.002	0.0001%
4	1 m above lid	60 – 90	0.003	0.008%	0.002	0.0001%
5	1 m above lid	90 - 120	0.003	0.009%	0.002	0.0001%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

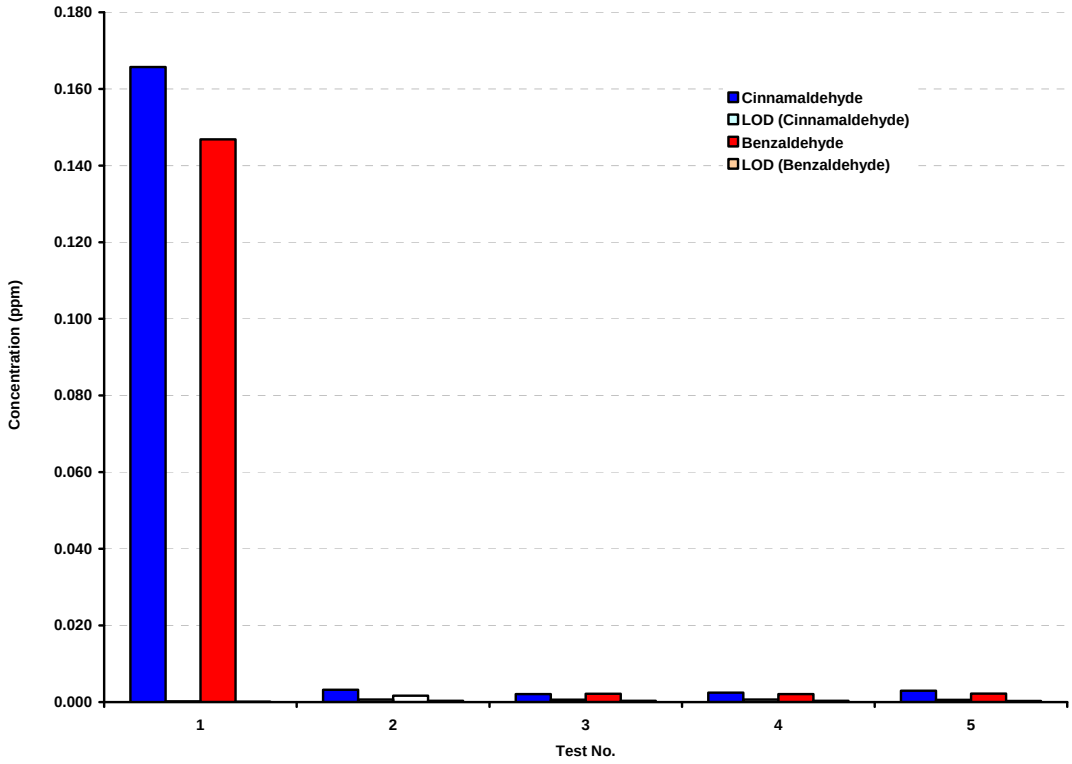

Figure 22: Airborne Concentrations - Cinnamaldehyde Test CT-13

8. ANNEX 3: PHENOXYETHANOL TESTS - RESULTS

Table 31: Airborne Concentrations – Phenoxyethanol Test PT-01

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	< 0.003	< 0.02%
2	15	30	< 0.003	< 0.02%
3	30	60	< 0.002	< 0.01%
4	60	90	< 0.002	< 0.01%
5	90	120	< 0.002	< 0.01%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

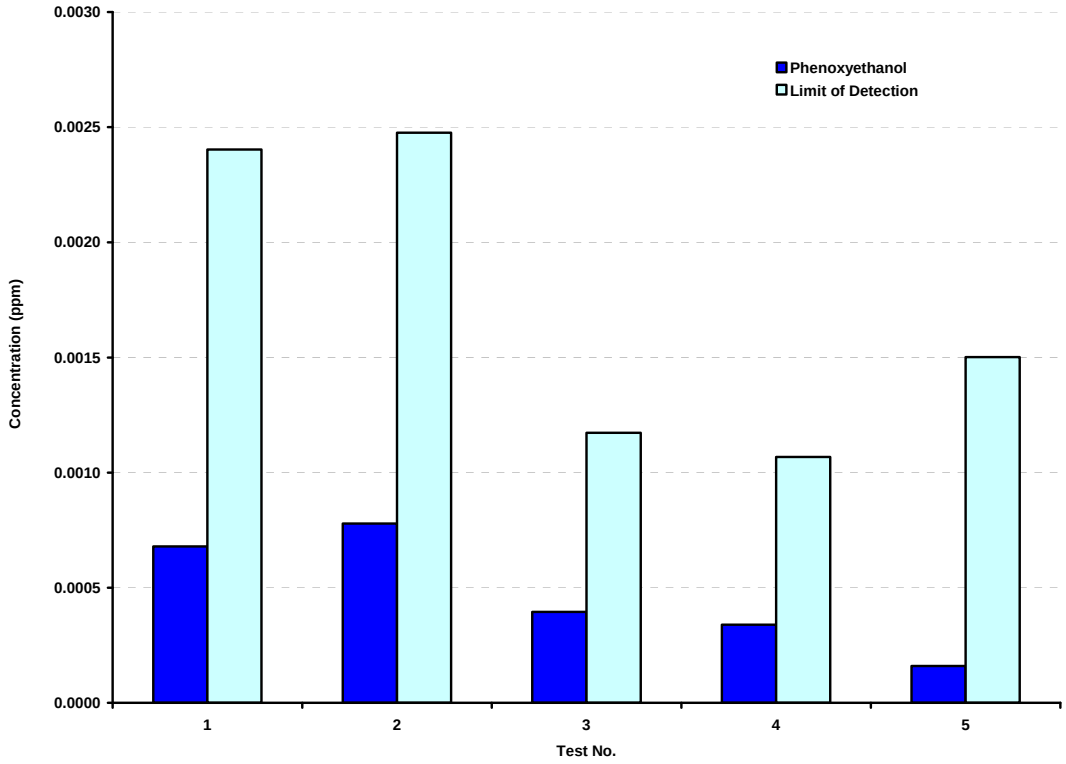

Figure 23: Airborne Concentrations - Phenoxyethanol Test PT-01

Table 32: Airborne Concentrations – Phenoxyethanol Test PT-02

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	< 0.003	< 0.02%
2	15	30	< 0.003	< 0.02%
3	30	60	< 0.002	< 0.01%
4	60	90	0.002	0.01%
5	90	120	0.003	0.01%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

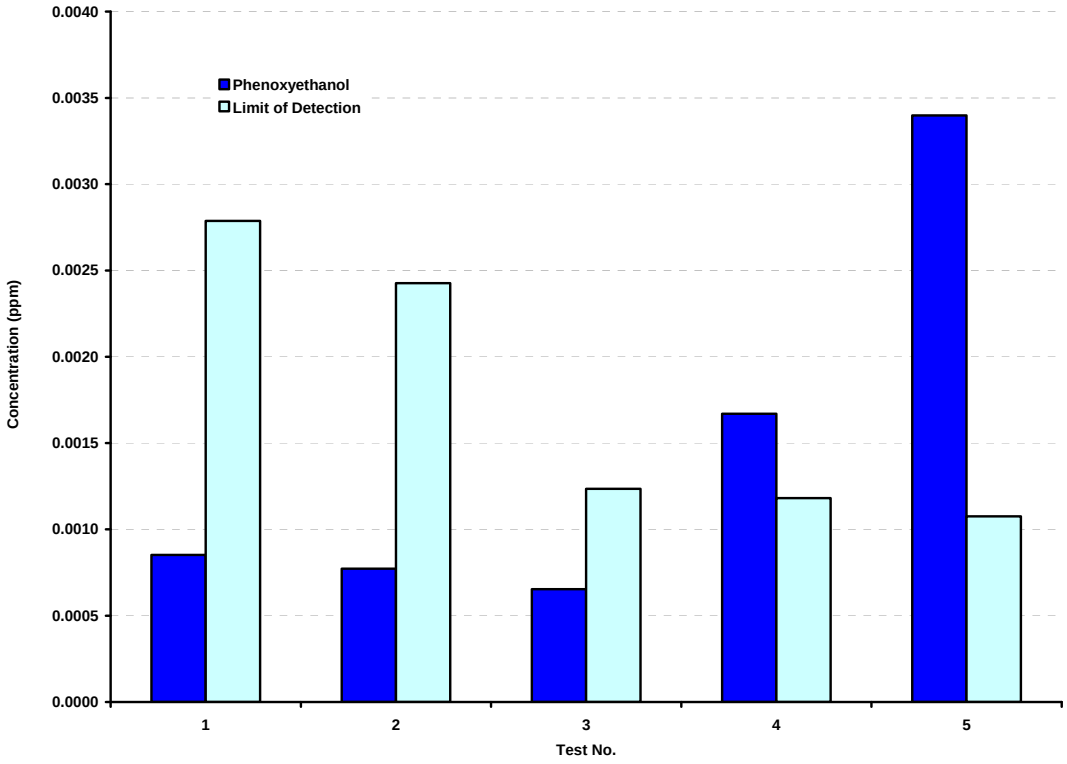

Figure 24: Airborne Concentrations - Phenoxyethanol Test PT-02

Table 33: Airborne Concentrations – Phenoxyethanol Test PT-03

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	< 0.003	< 0.02%
2	15	30	0.006	0.04%
3	30	60	0.005	0.04%
4	60	90	0.011	0.08%
5	90	120	0.013	0.10%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

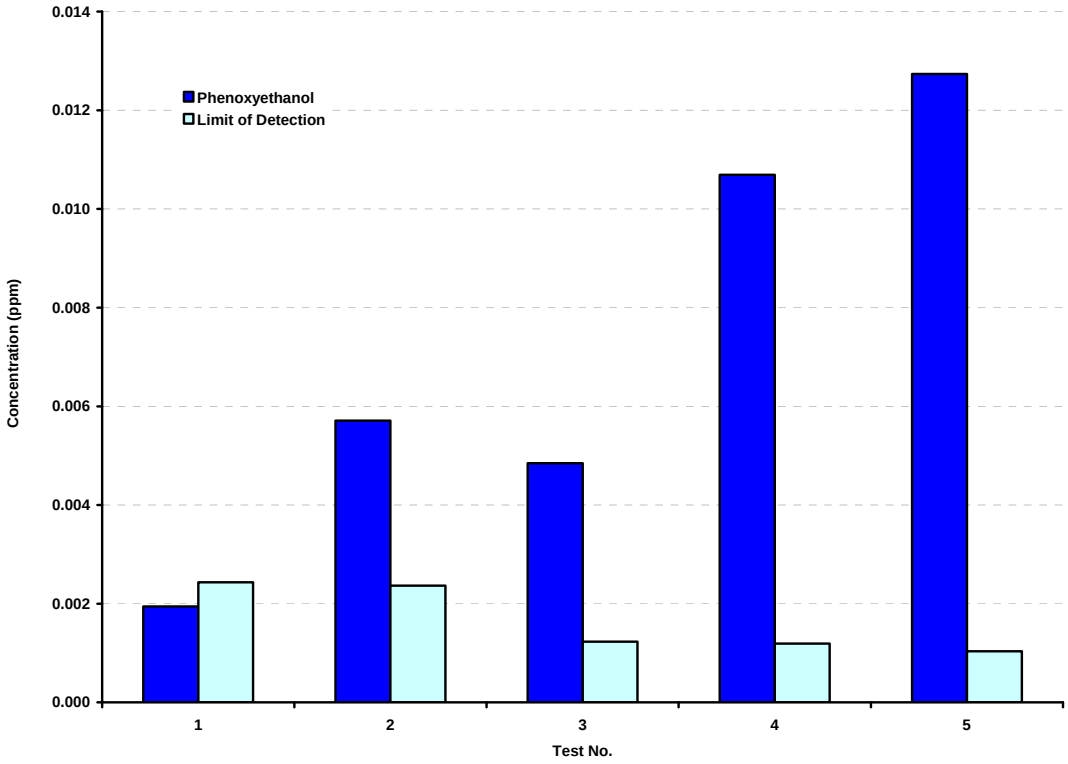

Figure 25: Airborne Concentrations - Phenoxyethanol Test PT-03

Table 34: Airborne Concentrations – Phenoxyethanol Test PT-04

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.012	0.09%
2	15	30	0.022	0.17%
3	30	60	0.025	0.19%
4	60	90	0.028	0.21%
5	90	120	0.032	0.25%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

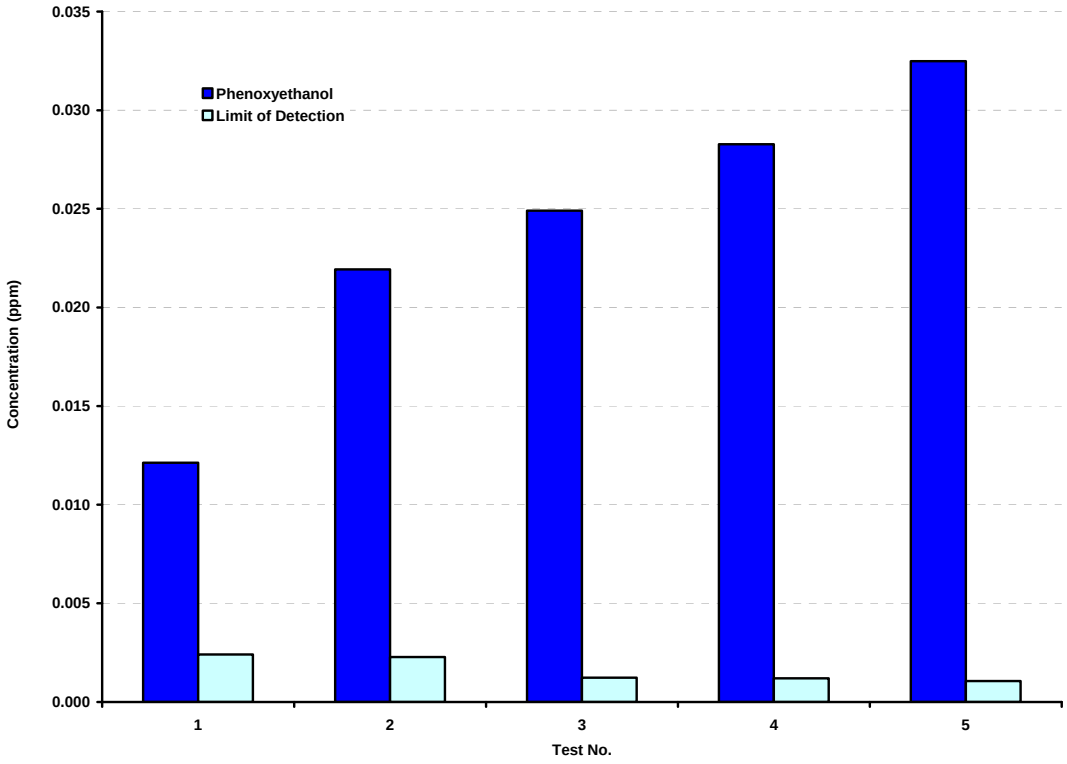

Figure 26: Airborne Concentrations - Phenoxyethanol Test PT-04

Table 35: Airborne Concentrations – Phenoxyethanol Test PT-05

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	< 0.003	< 0.02%
2	15	30	< 0.003	< 0.02%
3	30	60	< 0.002	< 0.01%
4	60	90	< 0.002	< 0.01%
5	90	120	< 0.002	< 0.01%
6	120	180	< 0.001	< 0.01%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

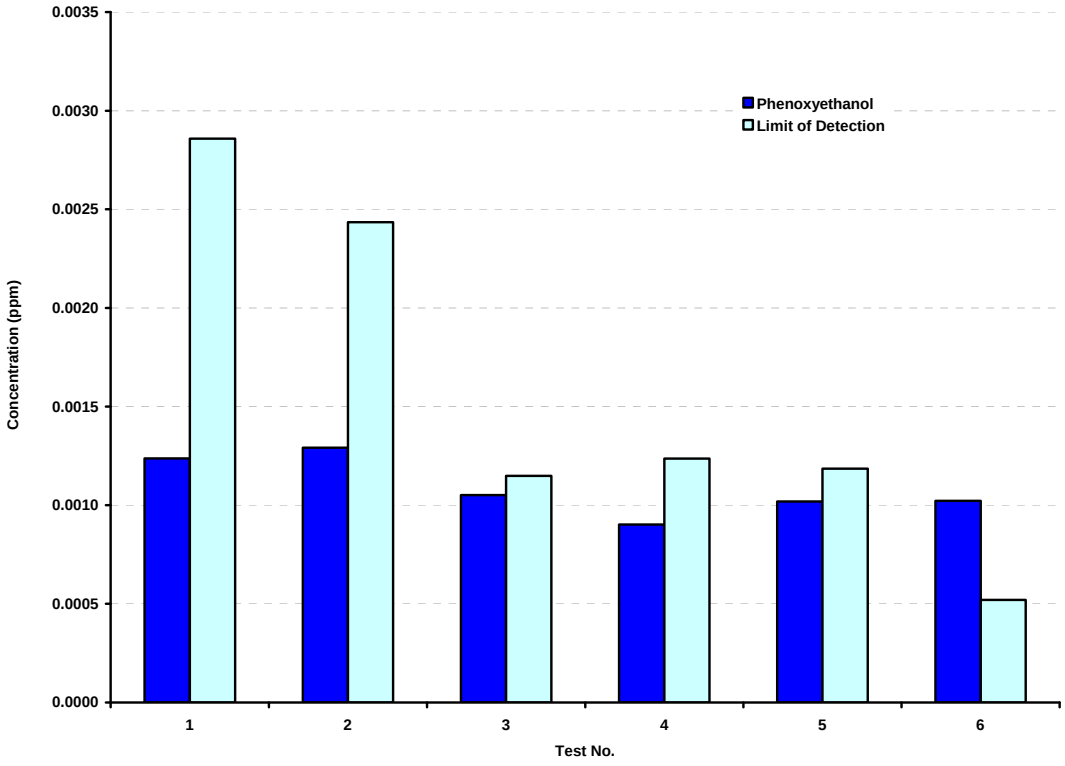

Figure 27: Airborne Concentrations - Phenoxyethanol Test PT-05

Table 36: Airborne Concentrations – Phenoxyethanol Test PT-06

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.002	0.01%
2	15	30	0.003	0.02%
3	30	60	0.004	0.03%
4	60	90	0.004	0.03%
5	90	120	0.005	0.03%
6	120	180	0.006	0.04%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

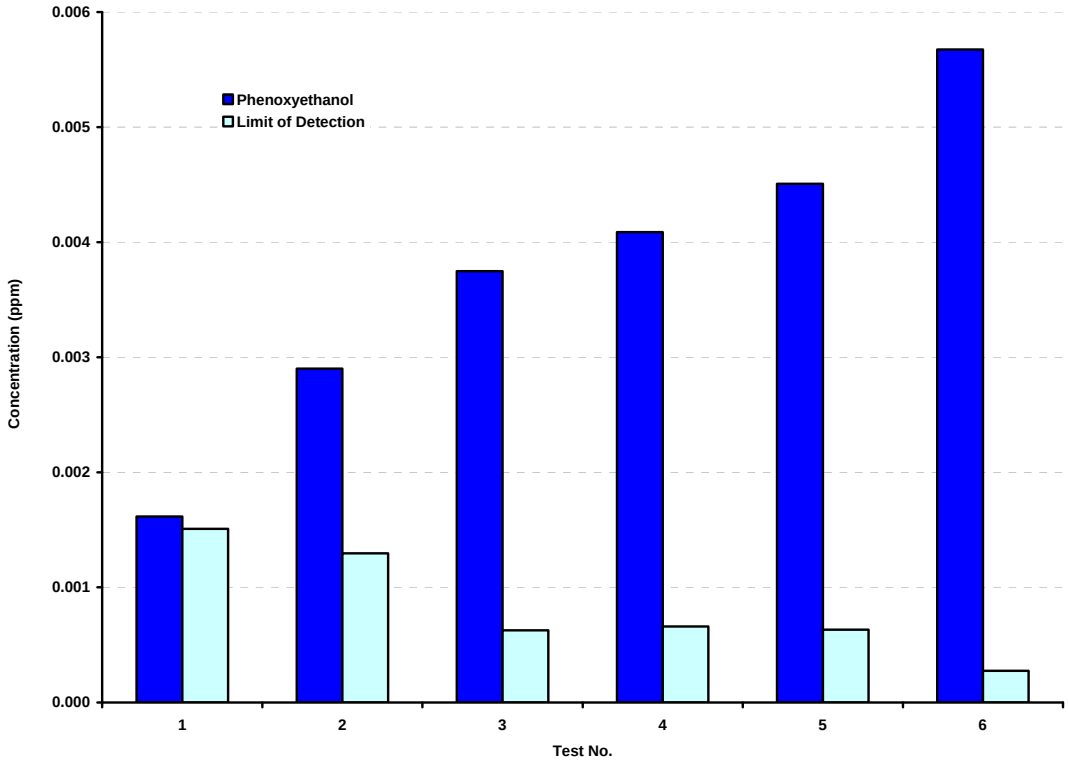

Figure 28: Airborne Concentrations - Phenoxyethanol Test PT-06

Table 37: Airborne Concentrations – Phenoxyethanol Test PT-07

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.015	0.11%
2	15	30	0.020	0.15%
3	30	60	0.011	0.09%
4	60	90	0.011	0.08%
5	90	120	0.011	0.08%
6	120	180	0.011	0.08%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

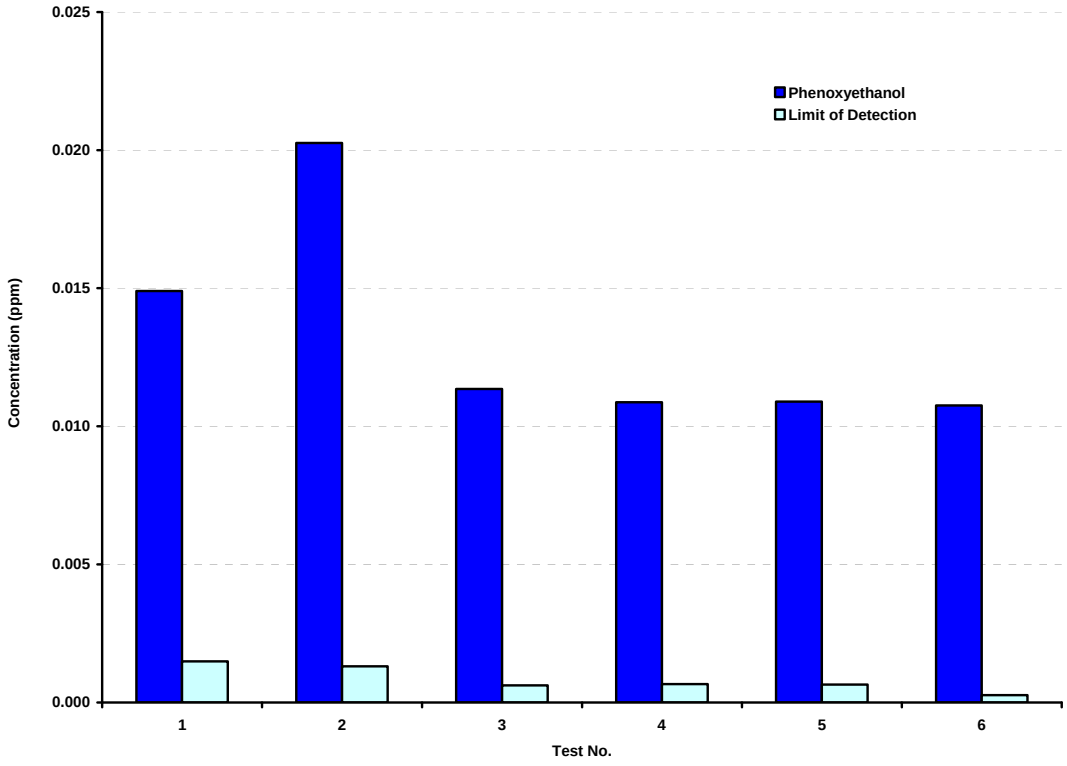

Figure 29: Airborne Concentrations - Phenoxyethanol Test PT-07

Table 38: Airborne Concentrations – Phenoxyethanol Test PT-08

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.002	0.02%
2	15	30	0.004	0.03%
3	30	60	0.004	0.03%
4	60	90	0.005	0.04%
5	90	120	0.006	0.04%
6	120	180	0.006	0.05%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

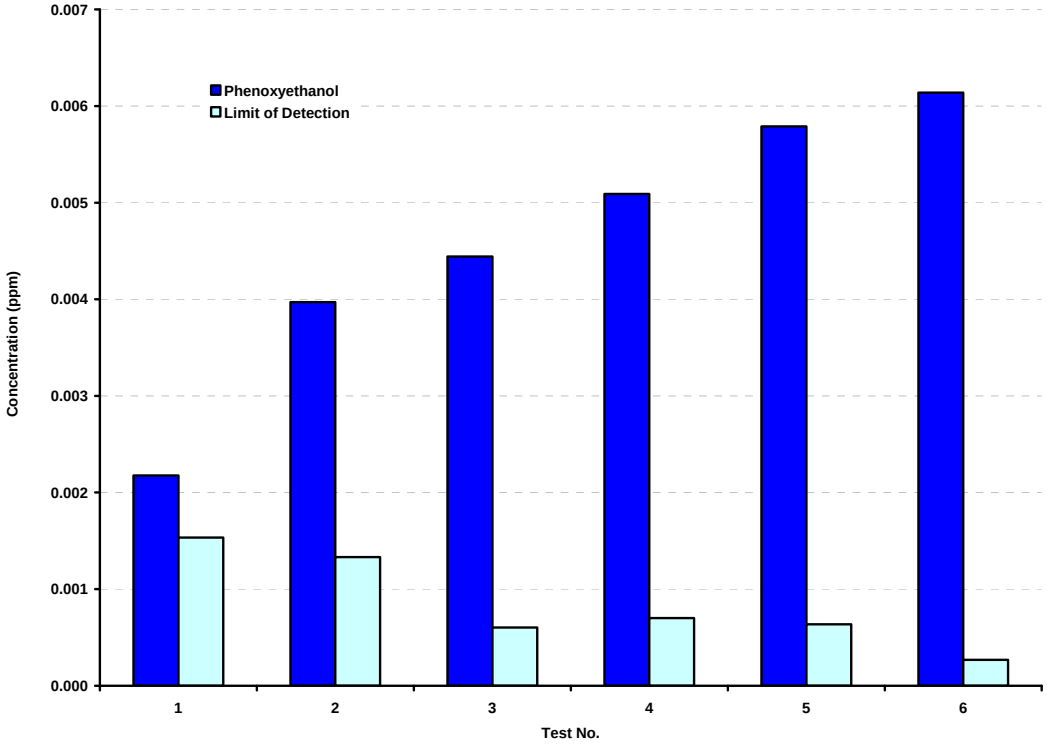

Figure 30: Airborne Concentrations - Phenoxyethanol Test PT-08

Table 39: Airborne Concentrations – Phenoxyethanol Test PT-09

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.041	0.31%
2	15	30	0.071	0.54%
3	30	60	0.099	0.75%
4	60	90	0.123	0.93%
5	90	120	0.144	1.10%
6	120	180	0.181	1.37%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

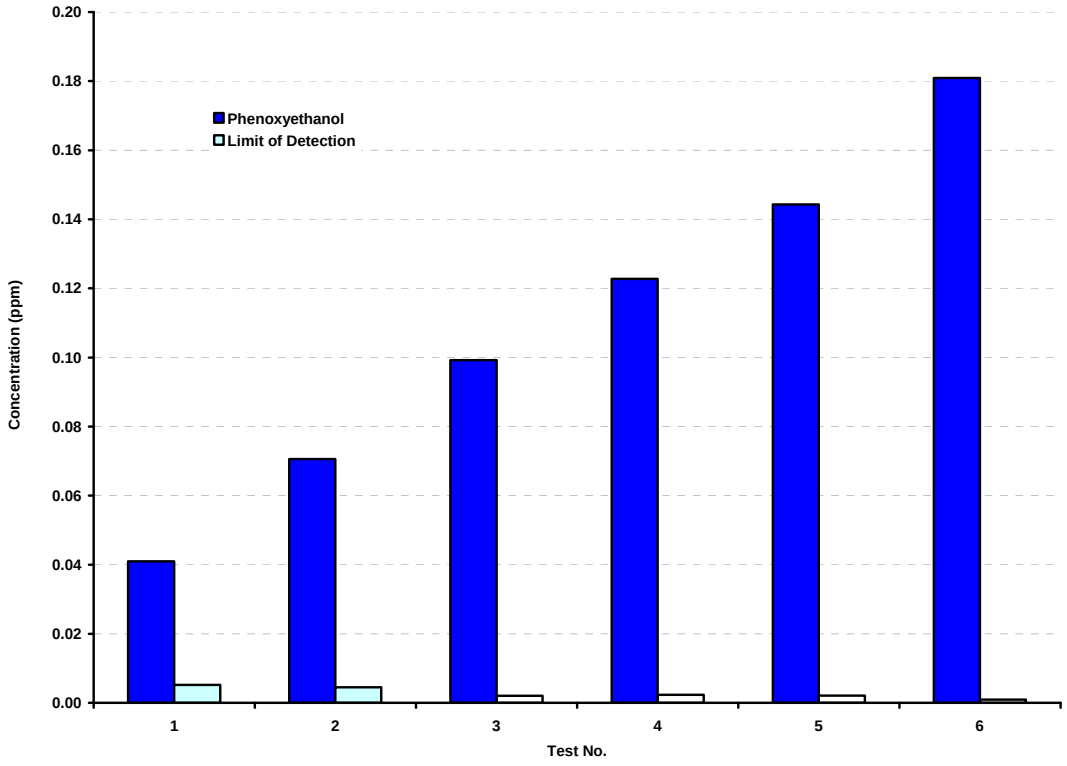

Figure 31: Airborne Concentrations - Phenoxyethanol Test PT-09

Table 40: Airborne Concentrations – Phenoxyethanol Test PT-10

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.024	0.18%
2	15	30	0.046	0.35%
3	30	60	0.072	0.54%
4	60	90	0.090	0.68%
5	90	120	0.107	0.81%
6	120	180	0.131	1.00%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

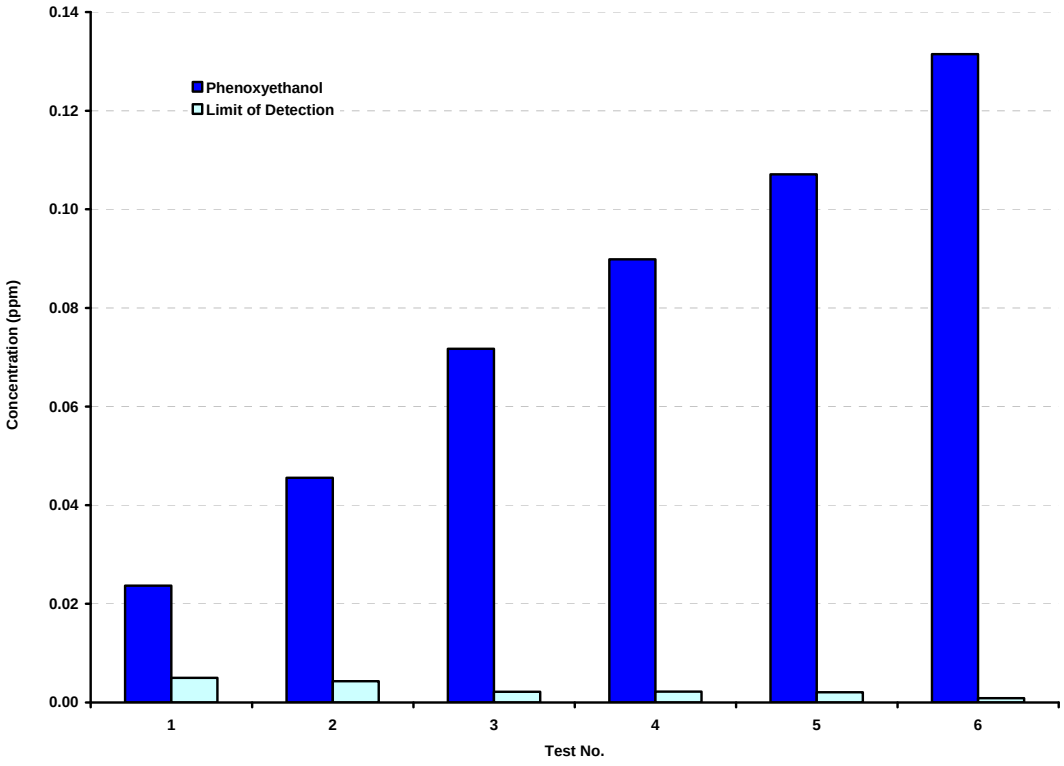

Figure 32: Airborne Concentrations - Phenoxyethanol Test PT-10

Table 41: Airborne Concentrations – Phenoxyethanol Test PT-11

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	15	0.021	0.16%
2	15	30	0.034	0.26%
3	30	60	0.066	0.50%
4	60	90	0.089	0.68%
5	90	120	0.104	0.79%
6	120	180	0.113	0.86%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

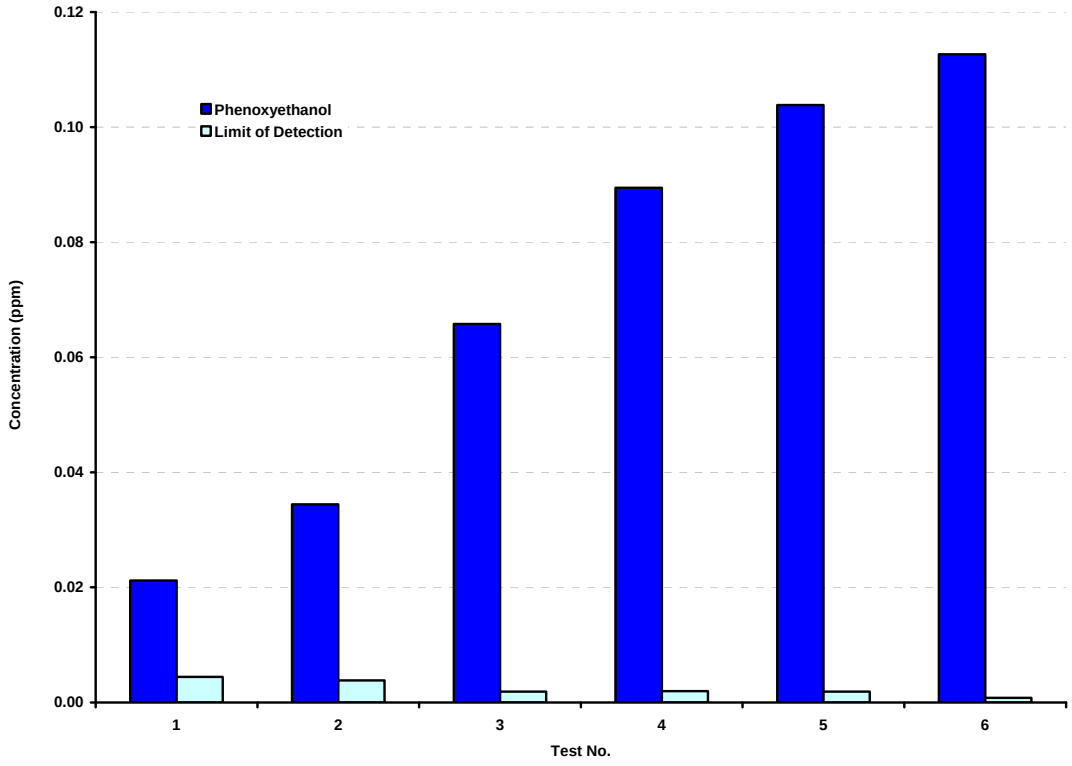

Figure 33: Airborne Concentrations - Phenoxyethanol Test PT-11

Table 42: Airborne Concentrations – Phenoxyethanol Test PT-12

Test	Time (min)		Phenoxyethanol	
No.	Start	End	ppm	% SVC†
1	0	60	0.076	0.58%
2	60	120	0.151	1.14%
3	120	180	0.184	1.40%
4	180	240	0.209	1.58%
5	240	300	0.235	1.79%
6	300	360	0.247	1.87%

† = Concentration as a proportion of calculated Saturated Vapour Concentration (SVC) at 20°C

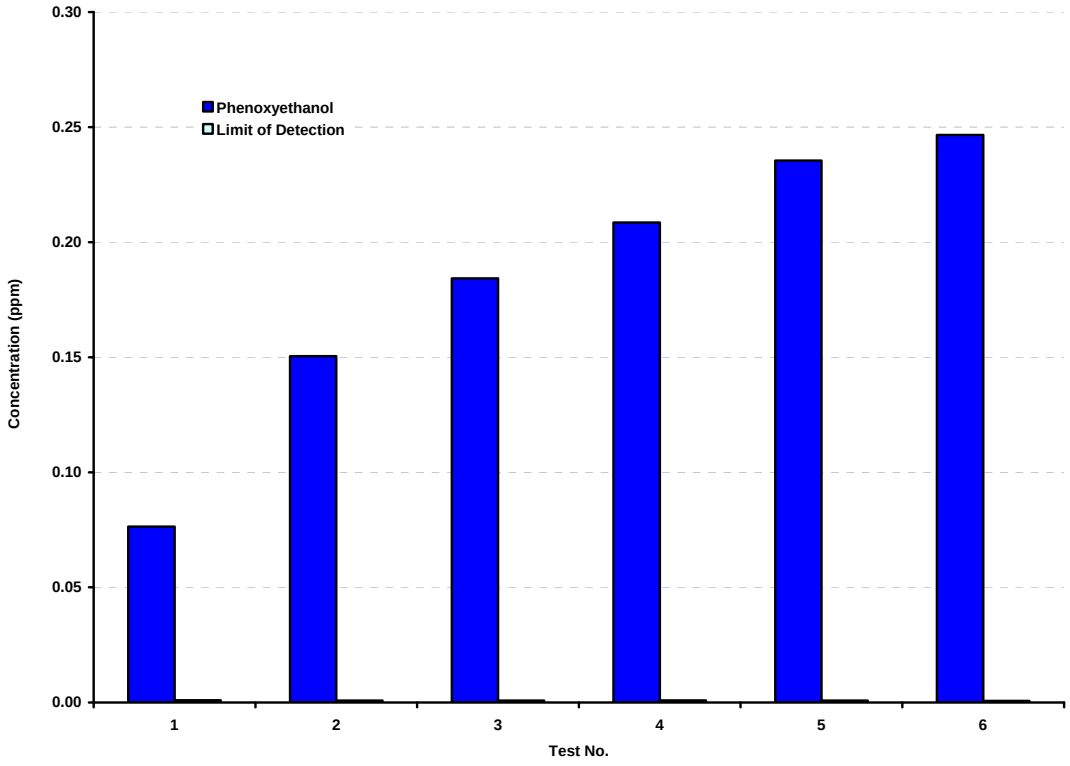

Figure 34: Airborne Concentrations - Phenoxyethanol Test PT-12

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Investigation of relationship between saturated vapour concentration and real exposure to vapour

Quantitative risk assessment is a key component of chemical approval schemes. This study was designed to provide information to better assess levels of risk and the potential for human exposure to low volatility chemical substances. The approach taken was to investigate the relationship between the fundamental physiochemical property of saturated vapour concentration (SVC) and measured airborne concentrations of such substances and to carry out baseline testing under different experimental and simulated work conditions. The results of these tests indicate that, whilst SVC may provide a reasonable estimate of the maximum possible concentration of any given compound and/or the relative ratios of different compounds, for chemical compounds of low volatility real airborne concentrations are considerably lower (generally less than 1% of SVC). Consequently, SVC significantly over-estimates airborne concentrations of these low volatility substances in the workplace and hence we conclude that it is not an accurate indicator of the likely risk of airborne exposure. Although the scope of the tests carried out in this project was very limited, it is apparent that the airborne concentration, and hence the potential for exposure by inhalation, is probably more dependent on the nature of the task being undertaken or usage of the compound than on the SVC.

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