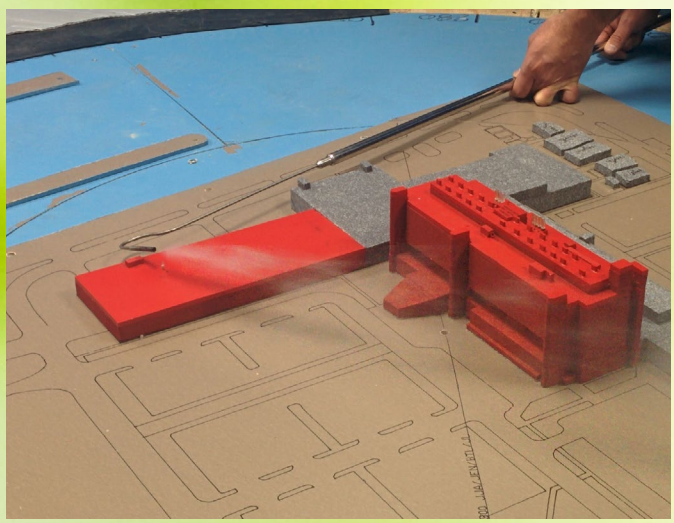
DIALOG®



Canada Centre for Inland Waters Administration and Laboratory Building Laboratory Modernization Plan (LMP)

2015-08-08

PWGSC Project R.072688.001

Environment Canada

Burlington, Ontario

RS 2.1.2

Design Concept - Appendix D
RWDI Exhaust Dispersion &
Re-Entrainment Study

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Canadian Center for Inland Waters (CCIW)
Laboratory Exhaust System Upgrade
Burlington, ON

Final Report

Exhaust Dispersion & Re-entrainment Study
RWDI # 1501726
June 19, 2015

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1. EXECUTIVE SUMMARY

A wind tunnel exhaust dispersion study was performed for the proposed Canadian Centre for Inland Waters (CCIW) Laboratory Exhaust System Upgrade in Burlington, ON. Testing was completed on a 1:300 scale model of the site and surroundings in one of RWDI's boundary layer wind tunnels. Exhaust sources evaluated included the proposed north and south centralized manifolded laboratory fume hood exhausts on the Administration and Laboratory (A&L) Building. These are illustrated as Sources F1-F4 and F5-F7 in Figure 1, respectively. The proposed Hydraulics laboratory exhaust (Source F8 in Figure 1) was also evaluated. Key results and recommendations are listed below:

- **A&L North Centralized Laboratory Exhausts:** The minimum recommended stack height for the desired turndown flow rate conditions (30% flow of the total fan flow) is 5 ft above the main penthouse roof.

- **A&L South Centralized Laboratory Exhausts**: The minimum recommended stack height for the desired turndown conditions of 30% flow is 6 ft above the main penthouse roof.

- **Hydraulics Laboratory Fume Hood Exhaust:** The minimum height recommended for the Hydraulics fume hood exhaust is found to be 10 ft above the main roof.

2. INTRODUCTION

Rowan Williams Davies & Irwin Inc. (RWDI) was retained by DIALOG to conduct an exhaust re-entrainment assessment for the proposed Canadian Centre for Inland Waters (CCIW) Laboratory Exhaust System Upgrade in Burlington, ON. The project includes, but is not limited to, the construction of two new centralized laboratory fume hood exhausts severing the north and south side of the A&L Building, and the replacement of the existing Hydraulics laboratory exhaust fan.

This final report presents the background, objectives, results and recommendations from RWDI's wind tunnel assessment. A summary of the overall recommendations from the study are presented in last section, entitled, "5. SUMMARY OF RECOMMENDATIONS".

3. BACKGROUND AND APPROACH

The objective of the assessment was to assist in the design of the new laboratory exhausts systems to ensure that the effluent is properly dispersed to minimize the potential for re-entrainment of the proposed A&L centralized laboratory fume hood exhausts and the Hydraulics laboratory fume hood exhaust fan replacement back into the CCIW and minimize impingement on the surrounding environment. The assessment also evaluated the potential for exhaust turndown of the A&L centralized exhausts to achieve energy savings for the building.

RWDI conducted a preliminary design review on the Laboratory Modernization Plan (LMP) project for the A&L and Hydraulics buildings dated May 22, 2015. The exhaust sources and receptors selected for wind

tunnel testing were based on the potential re-entrainment concerns identified in our initial design review and communications with the design team. Details on the exhaust parameters and receptor locations included in the wind tunnel testing phase were outlined RWDI's wind tunnel test plan document issued for comment on May 29, 2015 prior to testing.

The potential for exhaust re-entrainment from the selected sources was evaluated by performing detailed tracer gas wind tunnel dispersion modelling on a 1:300 scale model of the CCIW buildings and immediate surroundings (see Images 1 and 2). Wind tunnel modelling is considered to be the most accurate method of replicating airflow patterns around buildings and of quantifying the effects these patterns have on levels of exhaust dispersion and re-entrainment.

A summary of the methodology used for evaluating exhaust dispersion within one of RWDI's boundary-layer wind tunnels, including a discussion of the local wind climate, can be found in Appendix A. A list of the drawings used for construction of the physical model is presented in Appendix B. Photographs of the scale model in one of RWDI's boundary-layer wind tunnel are presented below.

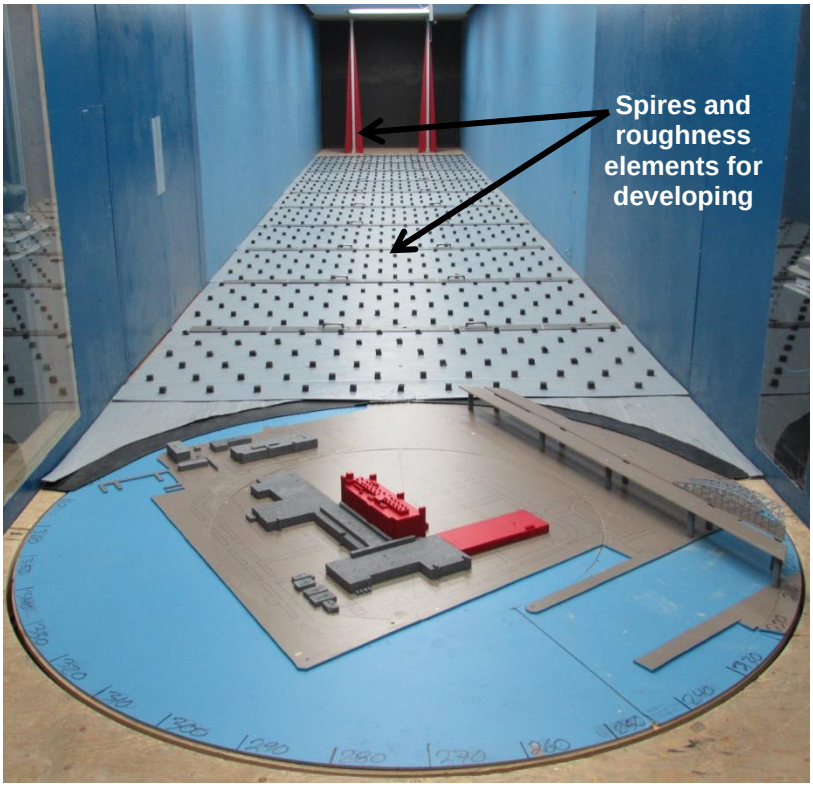


Image 1 - Photograph of Study Model in RWDI's Boundary-Layer Wind Tunnel

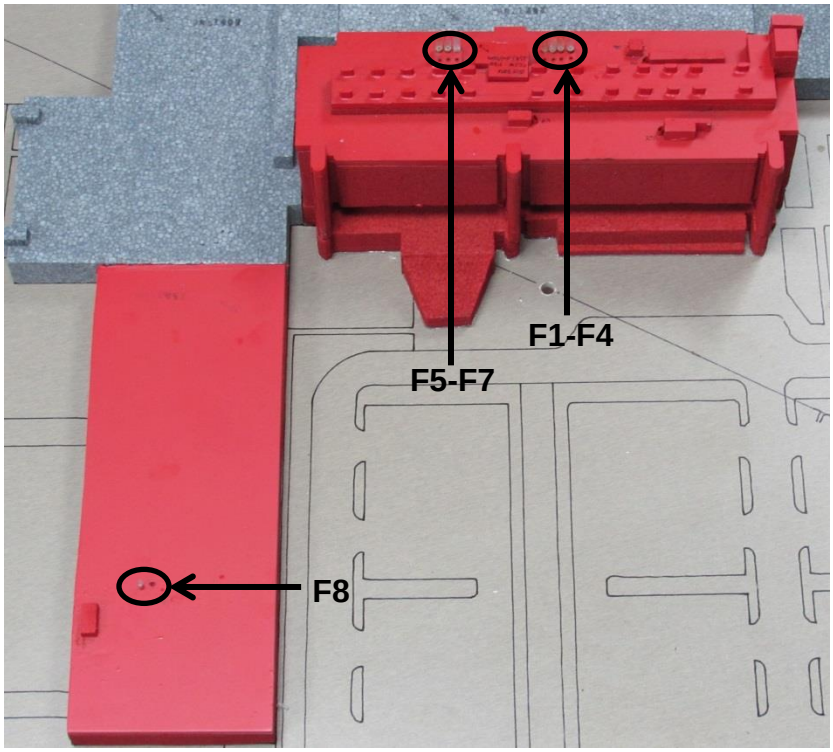


Image 2 - Close-Up Photograph of the of Study Model showing the Exhausts Sources that were Tested

3.1 Exhaust Sources and Receptors Modelled

The potential for exhaust re-entrainment from the following exhaust sources was evaluated at 8 proposed and existing air-sensitive receptors at the CCIW site:

- A&L Building Proposed North Centralized Laboratory Fume Hood Exhausts (Sources F1 – F4 in Image 2)
- A&L Building Proposed South Centralized Laboratory Fume Hood Exhausts (Sources F5 – F7), and
- Hydraulics Laboratory Fume Hood Exhaust Replacement (Source F8).

The locations of the exhaust sources and receptors evaluated are illustrated in Figure 1, and shown in Image 2. Details regarding exhaust source parameters and the receptors modelled are presented in Appendix C.

3.2 Dilution Criteria

For design purposes, RWDI applies dilution criteria to assess re-entrainment levels from various types of exhaust sources. Exhaust dilution (*D*), is defined as the ratio of source concentration (C_o) to the concentration predicted at a receptor (*C*). In other words:

$$D = \frac{C_o}{C}$$

A dilution criterion specifies the factor by which the exhaust must be diluted to meet suggested air quality criteria, standards, and/or odour thresholds. If the predicted exhaust dilution is greater than or equal to the minimum suggested level of dilution, then recommended air quality limits and odour thresholds would be met. The dilution criterion applied for the laboratory fume hood exhaust sources evaluated is summarized in Table 1 and discussed further in Appendices D and E.

Table 1: Summary of Dilution Criteria

Source Description	Dilution Criterion	Basis
Sources F1-F4 A&L Proposed North Centralized Laboratory Fume Hood Exhaust	3,000:1 (Health and Odour)	• Based on a chemical spill in a typical fume hood (surrogate for a high emission scenario). • Target to meet health limits and odour thresholds for approximately 90% of chemicals on RWDI's compiled list of more than 340 commonly used chemicals in laboratory research.
Sources F5-F7 A&L Proposed South Centralized Laboratory Fume Hood Exhaust		
Source F8 Hydraulics Laboratory Fume Hood Exhaust Replacement		

4. MODELLING RESULTS

Wind tunnel dispersion modelling results are presented and discussed for the proposed laboratory fume hood exhausts on a source-by-source basis in Tables 2 to 4. The tables present source specific dilution criteria, and worst-case measured dilution levels. A discussion of results and recommendations follows each table.

4.1 A&L North Centralized Manifolded Fume Hood Exhausts (Sources F1-F4)

4.1.1 Description

The proposed north centralized laboratory fume hood exhausts are to be located on the main roof of A&L building on the west side of the existing penthouse as indicated in Image 2 and Figure 1. The exhausts will discharge from four individual vertically oriented stacks aligned north/south with a maximum flow rate of 15,000 cfm per stack. The initial test configuration of the stacks was flush with the main penthouse roof at full flow. A desired 30% turndown fan flow rate was also evaluated to determine the potential for fan energy savings while still achieving the desired level of dilution at the air intakes. The wind tunnel modelling results for these exhaust sources are presented in Table 2.

Table 2: Summary of Results for A&L Building Proposed North Centralized Laboratory Fume Hood Exhaust

Source Label & Description	Recommended Dilution Criterion	Operating Scenario	Stack Height (ft)	Worst-Case Predicted Dilution[1] (receptor)	Criterion Met?
Source F1-F4 Proposed A&L North Centralized Laboratory Fume Hood Exhausts	**3,000:1** (Laboratory Fume Hood Exhaust)	*Full Flow:* 15,000 cfm per stack	Flush with main penthouse roof	4,650:1 (R6)	Yes
		30% Flow: 4,500 cfm per stack	Flush with main penthouse roof	1,170:1 (R6)	No
			5 ft above main penthouse roof	3,115:1 (R6)	Yes

Note: **[1]** Worst-case dilution levels are reported in the table. Dilution levels will be higher (better) at all other receptors. Shaded cells indicate that the recommended dilution criterion was not met.

4.1.2 Discussion and Recommendations

The recommended dilution criterion was met at all receptors assessed in the case of the full fan flow rate configuration with stacks flush with the top of the main penthouse (see Table 2). Reducing exhaust flow rate to 30% of full flow did not meet the recommended dilution criterion under the same stack height configuration with a worst-case dilution level of 1,170:1.

Increasing the stack height above the main penthouse roof improved the worst-case dilution level and, with a stack height of 5 ft above the main penthouse roof, the worst-case dilution met the recommended criterion under all wind conditions. The worst-case dilution level occurred at the same receptor (i.e. R6) for all the operating scenarios and stack heights evaluated.

The recommended stack height for the north centralized laboratory exhausts (Sources F1-F4), to meet the criterion for both the full flow and 30% flow turndown conditions is 5 ft above the main penthouse roof. This stack height will allow for turndown of the fans as the building demand is reduced, regardless of the ambient wind conditions.

4.2 A&L South Centralized Manifolded Fume Hood Exhausts (Sources F5-F7)

4.2.1 Description

The proposed south centralized laboratory fume hood exhausts are to be located on the main roof of A&L building on the west side of the existing penthouse as indicated in Image 2 and Figure 1. The exhausts will discharge from three individual vertically oriented stacks aligned north/south with maximum flow rate of 16,667 cfm per stack. The initial test configuration of the stacks was flush with the main penthouse roof. A turndown scenario of 30% fan flow rate was also evaluated to determine the potential for fan energy savings while still achieving the desired level of dilution at the air intakes. The wind tunnel modelling results are presented in Table 3.

Table 3: Summary of Results for A&L Building Proposed South Centralized Laboratory Fume Hood Exhaust

Source Label & Description	Recommended Dilution Criterion	Operating Scenario	Stack Height (ft)	Worst-Case Predicted Dilution[1] (receptor)	Criterion Met?
Source F5-F7 South Centralized Laboratory Fume Hood Exhausts	**3,000:1** (Laboratory Fume Hood Exhaust)	*Full Flow:* 16,667 cfm per stack	Flush with main penthouse roof	4,150:1 (R7)	Yes
		30% Flow: 5000 cfm per stack	Flush with main penthouse roof	2,490:1 (R6)	No
			6 ft above main penthouse roof	3,045:1 (R6)	Yes

Note: **[1]** Worst-case dilution levels are reported in the table. Dilution levels will be higher (better) at all other receptors. Shaded cells indicate that the recommended dilution criterion was not met.

4.2.2 Discussion and Recommendations

The recommended dilution criterion was met at all receptors assessed in the case of the full flow configuration with stacks terminating flush with the top of the main penthouse (see Table 3). The desired turndown of 30% of full flow did not meet the recommended dilution criterion under the same stack height configuration. The worst-case dilution level shifted from R7 in the case of the full flow to R6 for the exhaust fan turndown scenario.

Increasing the stack height to 6 ft above the penthouse roof enhanced the dilution at the worst-case receptor (R6) and the 3,000:1 dilution criterion was met under all wind conditions.

The recommended stack height for the south centralized laboratory exhausts (Sources F5-F7) to meet the criterion for both the full flow and 30% flow is 6 ft above the main penthouse roof. This stack height will allow for turndown of the fans as the building demand is reduced, regardless of the ambient wind conditions.

4.3 Hydraulic Laboratory Exhausts (Source F8)

4.3.1 Description

The existing laboratory fume hood exhaust located at the east end of Hydraulics building will be replaced as part of the system upgrade project. The exhaust location is as indicated as Source F8 in Image 2 and Figure 1. Exhausts will discharge from two vertically oriented stacks each with a constant volume flow rate of 3,000 cfm and will operate in an N+1 arrangement. Tests were completed for a single stack extending 10 ft above the main roof. The wind tunnel modelling results for this exhaust source are shown in Table 4.

Table 4: Summary of Results for Hydraulics Laboratory Fume Hood Exhaust

Source Label & Description	Recommended Dilution Criterion	Operating Scenario	Stack Height (ft)	Worst-Case Predicted Dilution (receptor)	Criterion Met?
Source F8 Hydraulics Laboratory Fume Hood Exhaust	**3,000:1** (Laboratory Fume Hood Exhaust)	One Fan at Full Flow: 3,000 cfm	10 ft above main roof	4,210:1 (R5)	Yes

4.3.2 Discussion and Recommendations

Table 4 shows that the recommended dilution criterion was met at all receptors assessed with the proposed flow rate and stack height of 10 ft above the Hydraulics Building roof. No design changes are recommended.

5. SUMMARY OF RECOMMENDATIONS

Wind tunnel testing was completed to assess the potential for exhaust re-entrainment of the proposed laboratory fume hood exhausts as part of the Canadian Centre for Inland Waters System Upgrade Project in Burlington, ON. The recommendations from the assessment are summarized below.

A&L laboratory Fume Hood Exhausts

- To meet the recommended criterion for minimum 30% flow rate conditions under all wind conditions for the purpose of energy savings the following stack heights are recommended:
    - Extend the north centralized laboratory exhaust stacks (Sources F1-F4) to a minimum height of 5 ft above the main penthouse roof; and
    - Extend the south centralized laboratory exhaust stacks (Sources F5-F6) to a minimum height of 6 ft above the main penthouse roof.

Hydraulics Laboratory Fume Hood Exhausts

- The recommended height for the proposed Hydraulics building laboratory fume hood exhausts is 10 ft above the main roof.

FIGURES

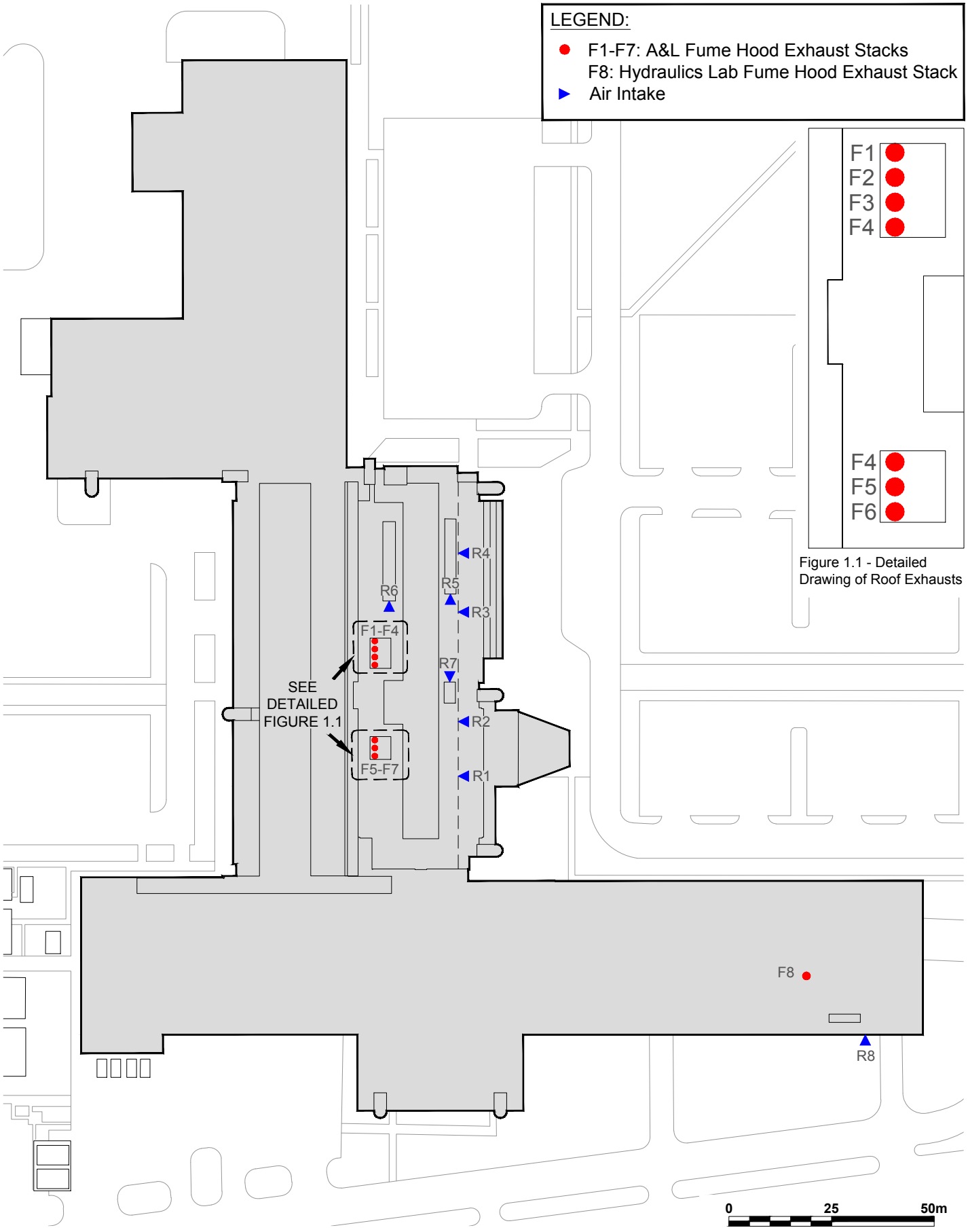


Figure 1.1 - Detailed Drawing of Roof Exhausts

Location of Exhaust Sources and Receptors

Canadian Centre for Inland Waters (CCIW) - Burlington, Ontario

True North

Project #1501726

Drawn by: ARM	Figure:	1
Approx. Scale:		1:1250
Date Revised:		June 12, 2015

RWDI

APPENDIX A

APPENDIX A: METHODOLOGY

Methodology

Exhaust dispersion was evaluated by testing a 1:300 scale model of the Canadian Centre for Inland Waters (CCIW) - Laboratory Exhaust System Upgrade in one of RWDI's boundary-layer wind tunnels. Wind tunnel modelling is considered to be the most accurate method of predicting impacts from building exhausts because it simulates air flow patterns around complex building configurations and can account for local topography. The surrounding terrain was considered to be suburban (mostly winds from north) and open for the rest of directions, and was simulated by means of roughness elements and spires.

Testing was conducted by releasing a tracer gas of known concentration from each source and taking measurements at selected receptors under the influence of approaching wind. Tests were completed for a broad range of wind directions and speeds (i.e., up to 24 wind directions in 15 degree increments and up to five wind speeds). The wind directions and wind speeds were chosen to capture worst-case impacts from each exhaust source at each receptor.

Mean concentrations of tracer gas at selected receptors locations were measured by drawing samples through flush-mounted tubes leading to a bank of infrared analysers stationed outside the tunnel. The measured concentration at a receptor (C) was then compared to the tracer gas concentration at the source (C_o) to determine the exhaust dilution (D). Dilution represents the factor by which pollutant concentrations and odours are reduced between the tip of the exhaust and the receptor location.

$$D = \frac{C_o}{C} \qquad [1]$$

The model scale exhaust dilutions are translated into full-scale values using established scaling procedures. The dilutions presented in this report correspond to full-scale values averaged over a one-hour time period.

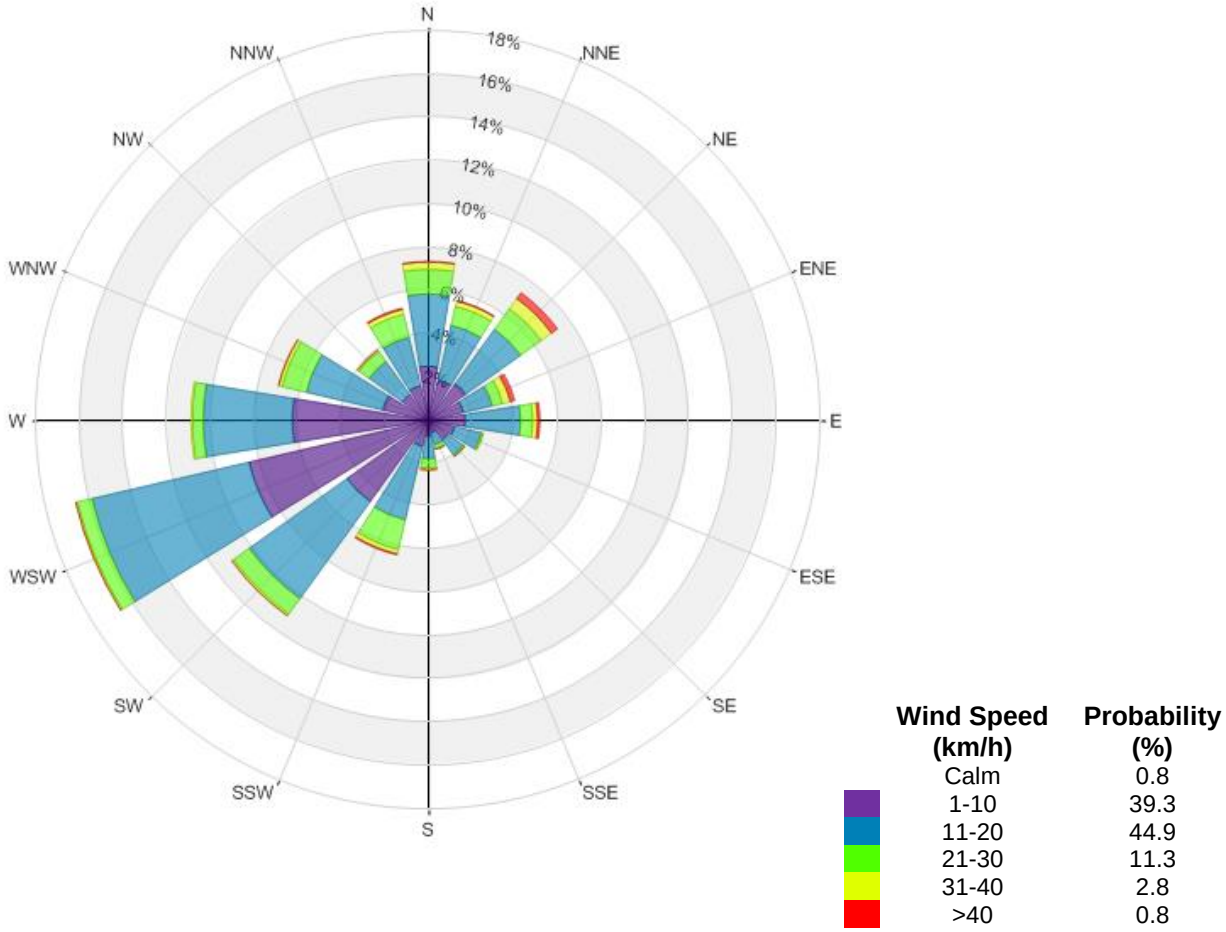
The full-scale dilution levels were compared to recommended source-specific dilution criteria. In situations where measured dilution levels were found to be below (i.e., did not meet) the suggested design dilution criterion, mitigation recommendations were developed for the proposed exhausts. Detailed discussion of the criteria applied is provided in Appendices D and E.

Wind Climate

RWDI reviewed wind data from nearby meteorological stations to understand the predominant wind conditions at the site. Wind statistics recorded at the Burlington Piers Meteorological Station between 2008 and 2014 were reviewed. In the determination of local wind climate, the long-term wind data measured at the Hamilton International Airport and the design wind speeds listed in the National Building

Code of Canada were also considered, together with the local topography such as Lake Ontario, Niagara Escarpment, the Skyway Bridge, surrounding buildings and other elements.

A summary of the directional distribution of winds over a period from 2008 to 2014 from the Burlington Piers Station is shown below. This wind rose can be used to understand the predominant wind directions at the site. The wind directions in the figure refer to the direction from which the wind blows, while the annual frequency of a given wind direction is shown as a distance radially from the centre. The most frequent winds originate from the west and south-west directions. Winds from the south and south-east are less frequent.



Directional Distribution (%) of Winds (Blowing From)
Station: Burlington Piers, Burlington, ON (2008 – 2014)

APPENDIX B

APPENDIX B: DRAWING LIST

Table B1 presents a summary of drawings and information used to construct the physical model of the Canadian Centre for Inland Water Redevelopment.

Table B1: List of Drawings and Information Used for Model Construction

Description	File Name	File Type	Date Received (dd/mm/yyyy)
3D Model	CCIW Copy - 3D View - {3D - msx64}	.dwg	N/A
3D Model	CCIW Central-2014	.rvt	07/05/2015

APPENDIX C

APPENDIX C: SUMMARY OF EXHAUST SOURCES AND RECEPTORS

Table 1: Summary of Exhaust Source Parameters

Source Label	Description	Stack Height (ft)	Flow Rate (cfm)	Stack Diameter (in)	Exit Velocity (fpm)
F1-F4	A&L Building Proposed North Centralized Laboratory Fume Hood Exhausts (4)	Flush with Main Penthouse Roof	Full Flow 15,000 (per stack)	30	3,050
			30% Flow 4500 (per stack)		920
F5-F7	A&L Building Proposed South Centralized Laboratory Fume Hood Exhausts (3)	Flush with Main Penthouse Roof	Full Flow 16,667 (per stack)	31.4	3,110
			30% Flow 5000 (per stack)		930
F8	Hydraulics Laboratory Fume Hood Exhaust Replacement (1+1)	10 (above Roof)	3,000	14	2,810

Table 2: Summary of Receptor Locations

Receptor Labels	Building	Elevation	Façade	Description
R1-R4	A&L building	Level 3	East	Existing Air Intake Louvres
R5-R7		Roof	n/a	Rooftop AHUs
R8	Hydraulics Lab	Roof	South	Serving Rooftop AHU-44

APPENDIX D

CONSULTING ENGINEERS & SCIENTISTS

APPENDIX D: DILUTION CRITERIA AND CHEMICAL HANDLING PROTOCOLS FOR LABORATORY FUME HOOD EXHAUST STACKS

Exhausts from laboratory fume hoods have been known to cause odours and adverse health effects if the exhausts are re-ingested back into a building with insufficient dilution. RWDI can predict the dilutions of exhausts with wind tunnel and numerical modelling. However, the modelling results must be compared to dilution criteria to determine whether an exhaust stack is well designed. This technical note discusses possible dilution criteria, makes suggestions on how to select the criteria and suggests a method of chemical assessment to demonstrate compliance with the chosen criteria.

RWDI has looked at the problem of dilution criteria from several perspectives: 1) exhaust stack dilution needed for various liquid chemical spills in the fume hood, 2) analogous dilution criteria for fume hood leakage tests, 3) the available literature, and 4) achievable dilutions for reasonable stack designs. Each of these perspectives is discussed below, along with a suggested procedure.

Examination of Liquid Spills

The best possible method of determining dilution requirements is to know exactly what chemicals are emitted and at what emission rates. Back-calculating a design dilution is then straightforward. For almost all laboratory situations, this emission information is not known in detail. To help determine representative emission information, RWDI has examined more than 300 commonly used liquid chemicals with known health limits and/or odour thresholds to determine what dilutions are necessary for various accidental spill sizes. Accidental spills are used since they would represent the upper end of possible emission rates from the many processes that may be performed, such as boiling liquids, acid digestion, and pouring and mixing of liquids.

Figure 1 below presents the calculations of required dilution for spill scenarios of 362 liquid chemicals. This figure can be used by laboratory designers and operators to estimate required dilution for a chemical release scenario without detailed evaporation calculations. (Estimated evaporation rates for chemical spills in fume hoods are described in detail in another RWDI Technical Note). First, the value on the x-axis is determined for the scenario. The horizontal x-axis is a combination of parameters relating to the spill: namely vapor pressure of the liquid in kPa (1 mm Hg = 0.133 kPa), spill area in m^2 (1 m^2 = 10.77 ft^2), chemical exposure limit (mg/m^3), and fume hood volume flow rate in m^3/s (1 m^3/s = 2,119 cfm). The exposure limit can be an odour threshold or a health limit. For health limits, RWDI typically uses occupational health limits from the American Conference of Governmental Industrial Hygienists (ACGIH), specifically their 8-hour Time Weighted Averaged - Threshold Limit Values (TWA-TLV). After the point on the x-axis is determined, the corresponding required dilution is read from the y-axis where the x-axis value intersects the data points. The spread in the data points is due to variations in chemical properties, such as molecular weight and diffusivity.

For example, consider a spill of nitric acid (90%), with an odour threshold of 0.7 mg/m^3 (more restrictive than the ACGIH TWA - TLV of 5.2 mg/m^3) and a vapor pressure of 6.39 kPa (48 mmHg at 20°C). If the

spill area is 0.81 m^2 (8.8 ft^2) corresponding roughly to a typical five-foot fume hood and the volume flow rate of the hood is 0.47 m^3/s (1,000 cfm), then the spill parameter on the horizontal x-axis is

$$\frac{6.39 \times 0.81}{0.7 \times 0.47} = 15.7$$

For nitric acid (90%), the corresponding required dilution on the vertical y-axis axis range from 500:1 to 2,000:1. A red trend line has been placed near the upper bounds of the data points to estimate a dilution target for a given chemical. For this example a dilution target of approximately 1,900:1 would be selected based on the trend line. This methodology can be used to provide an approximation of the dilution criterion for chemicals not on RWDI's list of commonly used laboratory chemicals. Alternatively, an approximate dilution target can be estimated based on the following equation for the red trend line:

$$y = 125x$$

Where:

y = Approximate dilution target

x = Value of x-axis equation

For this example, given an x-axis value of 15.7, the dilution target estimate using the equation would be:

$$y = 125(15.7) \cong 1{,}900{:}\,1$$

Note that the trend line and equation are intended to provide a conservative estimate of a dilution target for a chemical that is not on RWDI's list of commonly used laboratory chemicals and should not be used to determine specific dilution targets for a chemical.

The boxed values inside Figure 1 indicate the percentage of chemicals that will meet odour and health criteria for a given dilution value, assuming a 1,000 cfm fume hood flow rate, a spill area of 8.8 ft^2, health limits from ACGIH (TWA-TLV), and published odour thresholds. For example, dilutions between 3,000:1 and 5,000:1 are adequate for about 89 percent of the chemicals. If a 3,000:1 dilution criterion is specified for a stack, the other 11 percent of the chemicals on the list would require special handling procedures to reduce the risk of large spills and releases. In practice, many of these chemicals are already well known to need special handling, and large quantities are not typically used. If the list of chemicals analysed is considered representative of all chemicals used in fume hoods, then we can expect the 11 percent of the chemicals in any facility may require handling protocols.

Chemical Handling Protocols

If a chemical dilution target is greater than the minimum dilution level estimated for a given exhaust, the corresponding health limits and/or odour thresholds would not be met in all wind conditions. In order to meet these limits without stack modifications, handling protocols can be put in place for the chemicals that require dilution levels greater than that being achieved. This can be performed in one of two ways; limiting the volume of chemical in the fume hood or limiting the area that could be covered in the event of

a chemical spill (typically done through the use of a spill tray). The maximum volumetric usage rate or spill area can be determined based on a ratio of the achieved dilution to the required dilution criterion.

From the above example for a spill of nitric acid (90%), the required dilution criterion of approximately 1,900:1 was determined based on the red trend line provided in Figure 1. If, for example, your stack to receptor dilution is determined to be 1,000:1, then the ratio of the achieved dilution to required dilution level is:

$$\frac{1{,}000:1}{1{,}900:1} = 0.53$$

Restricting the spill area via a spill tray will reduce the surface area that is available for evaporation, thereby reducing the concentration of the chemical in the exhaust stack. Assuming a constant spill depth of 0.5 mm (0.02 in) a reduction in spill volume correlates directly into a reduction in evaporative area. Therefore, in order to achieve a 53% reduction in evaporative area, the spill area must be reduced by 53%.

$$8.8\ ft^2 \times 0.53 = 4.7\ ft^2$$

RWDI's spill scenario assumes a spill volume of 406 mL (a spill that covers the entire fume hood area of 8.8 ft^2 (0.8 m^2) and which is 0.5 mm (0.02 in) deep). In order to determine the maximum allowable volumetric usage rate, the original volume of 406 mL must be multiplied by the above calculated factor of 0.53.

$$406\ mL\ \times 0.53\ = 215\ mL$$

Therefore, if a chemical with a dilution target of 1,900:1 were to be used in a fume hood that was determined to be achieving a 1,000:1 stack to receptor dilution level then the chemical would need to be used either with a maximum of 271 mL at a time, or be used in a spill tray that is 4.7 ft^2 or smaller.

Adjustment of Dilution Criteria for Various Exhaust Flow Rates

Problems with fume hood exhausts typically arise from large or accidental releases from one fume hood at a time. Exhausts from other fume hoods can be considered relatively clean and will provide added dilution internal to the building before reaching the stack. This internal dilution should be taken into account. As internal dilution increases, less outdoor stack exhaust dilution is needed, and the dilution criterion can be adjusted accordingly. Therefore, several exhaust stacks with differing flow rates can have varying dilution criteria, which can create confusion during the design phase of a project.

To account for varying flow rates of several stacks, RWDI usually references the dilution criterion to a 1,000 cfm flow rate. Then if the actual flow rate for a particular stack differs from 1,000 cfm, the criterion can be adjusted for that stack as needed. For example, a 3,000:1 dilution criterion referenced to a 1,000 cfm exhaust may be specified for a project. A particular stack with a 10,000 cfm exhaust, ten times the 1,000 cfm reference exhaust flow rate, would have a factor of 10 internal dilution since the fumes from the accidental spill from one fume hood would be internally diluted by exhausts from other fume hoods.

The 10,000 cfm stack would have its criterion reduced from 3,000:1 to 300:1 to account for the internal dilution within that particular stack.

Fume Hood Performance

Fume hood manufacturers routinely test hoods using the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 110-1995 tracer gas test (ASHRAE, 1995). In the ASHRAE 110 test, a tracer gas is released in the fume hood at 4 litres per minute (0.14 cfm), and tracer gas concentration is measured at the breathing zone of a mannequin standing in front of the hood. A common acceptance criterion used by hood manufacturers for the ASHRAE 110 test is to have breathing zone concentrations less than 0.05 ppm (see for example the 2012 American Industrial Hygiene Association (AIHA) Z9.5 Standard on Laboratory Ventilation). A more lenient 0.10 ppm concentration is usually considered acceptable under field conditions. For the reference 1,000 cfm fume hood, the 0.05 ppm value corresponds to a 2,800:1 dilution between the fume hood and the mannequin, and the 0.10 ppm field criterion corresponds to 1,400:1. These dilutions at the face of the hood are analogous to the dilution provided by the stack since the release occurs in the fume hood for both dilutions. The only difference is the location of the exposed person, the mannequin at the hood versus the persons exposed to contaminated outside air.

In RWDI's opinion, the stack dilution should be at least as large as that provided by the fume hood since the stack and fume hood are both safety devices dealing with the same emissions. The 2,800:1 dilution value from the ASHRAE 110 tests compares well with the 3,000:1 dilution that satisfies the requirements of approximately 90 percent of the chemicals in Figure 1.

Literature Review

The only known published dilution criterion for design of laboratory fume hood exhausts is that of Halitsky (1988 annual meeting of the Air Pollution Control Association) that has been incorporated in the 2011 ASHRAE HVAC Applications Handbook. For an accidental release, Halitsky specifies that a 15 cfm vapor release should not have an outside air intake concentration exceeding 3 ppm. With a reference 1,000 cfm exhaust, this criterion corresponds to a 5,000:1 dilution, reasonably close to the analogous fume hood criteria (2,800:1) and the value at which 89 percent of chemicals are controlled in Figure 1 (between 3,000:1 and 5,000:1).

Achievable Dilutions for Reasonable Stack Designs

It is difficult to quantify achievable dilutions since there are varying aesthetic values, building geometries, and budgets possible. However, RWDI can make some general comments. In our experience, achieving dilutions of 10,000:1 or greater (referenced to 1,000 cfm) is difficult and requires an aggressive stack design. For a stack exhausting a single fume hood, dilutions of 1,000:1 and greater are difficult. On the lower end of the dilution scale, dilutions of 10:1 or 100:1 will probably cause frequent odour complaints based on our experience with laboratory exhaust problem cases. RWDI has in the past used dilution criteria in the vicinity of 1,000:1 for numerous projects with very few problems reported.

Conclusion: A Suggested Dilution Procedure

RWDI does not specify firm dilution criteria for fume hood exhausts without review of emissions and consultation with the client. Based on the above discussion, RWDI suggests as a starting point a dilution criterion of 3,000:1 referenced to a 1,000 cfm fume hood exhaust stack. For stack exhaust flow rates differing from the reference 1,000 cfm flow rate, the required dilution can be adjusted as discussed above. The 3,000:1 dilution level avoids odours and occupational health effects for about 89 percent of spills on RWDI's chemical list, is consistent with ASHRAE 110 fume hood test criteria, is consistent with other published data, and has been found to be reasonably achievable. A more lenient criterion may be used if chemical usage is relatively mild. On the other hand, a more stringent criterion may be desirable if chemical usage is intense or if potentially exposed people are sensitive, such as at hospitals or schools. It is recommended that Figure 1 be used by the client to evaluate required dilutions for chemicals to be used and that protocols be placed on chemical usage amounts or spill areas as described above. If the 3,000:1 dilution target is applied, consideration should also be given to applying handling protocols to chemicals requiring dilution levels above 3,000:1 (refer to Table 1).

References

ACGIH (American Conference of Governmental Industrial Hygienists). 1998 TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, Cincinnati, Ohio, 1998.

ANSI/AIHA (American National Standards Institute / American Industrial Hygiene Association). American National Standard for Laboratory Ventilation, Standard Z9.5-1992. Fairfax, Virginia, 2012.

ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers). Method of Testing Performance of Laboratory Fume Hoods. ASHRAE Standard 110-1995. Atlanta, GA. 1995.

ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers). Handbook -- HVAC Applications, Chapter 16. Atlanta, GA. 2011.

Halitsky, J. "Dispersion of laboratory exhaust gas by large jets." 81st Annual Meeting of the Air Pollution Control Association. Paper 88-75.1, Dallas, TX, 1988.

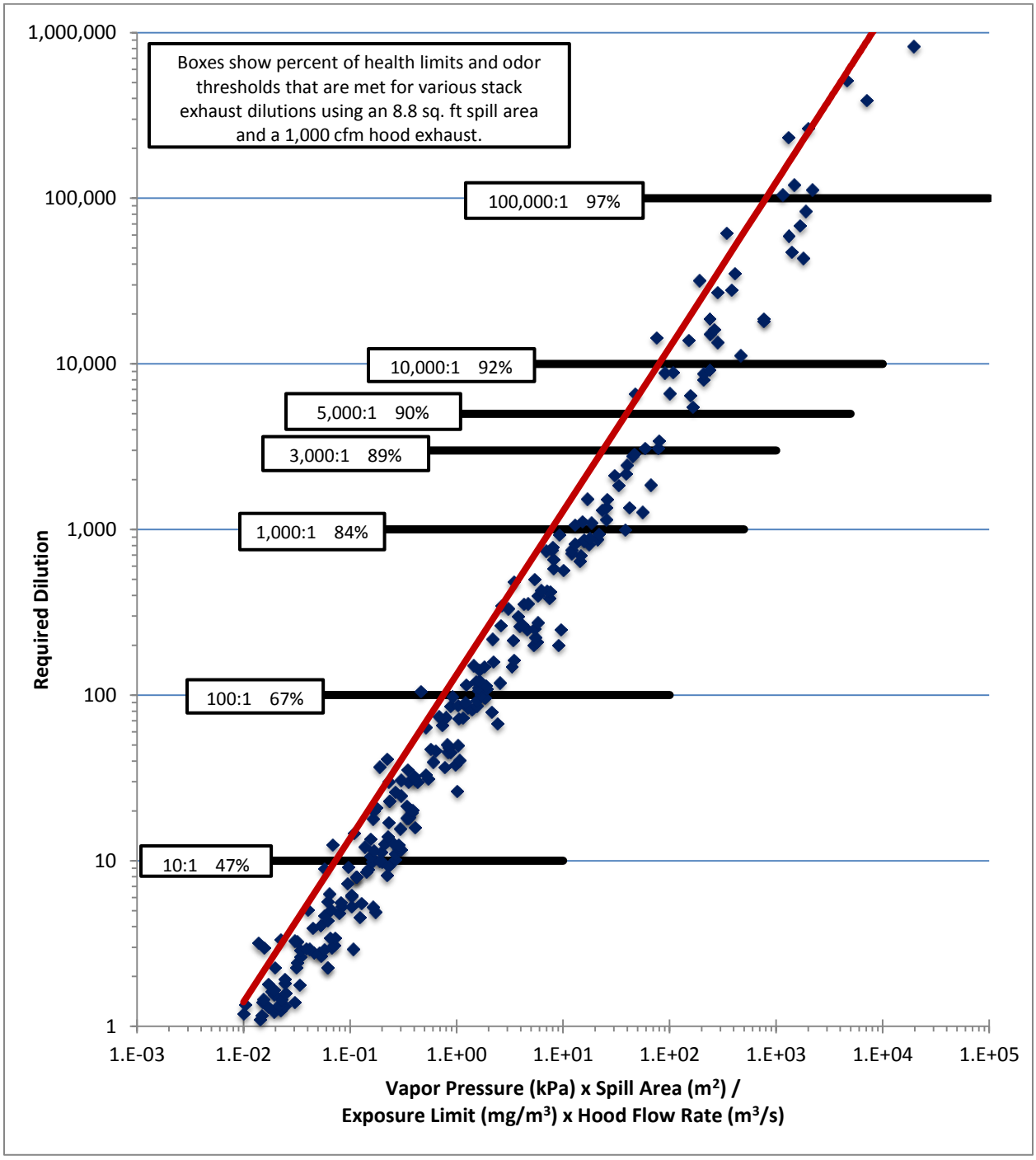


Figure 1: Required Dilution Levels for 362 Chemicals to meet Health Limits and Odour Thresholds

Notes:

i) Required dilution less than 1:1 not shown – indicates that a chemical meets its exposure limit within the exhaust stack.
ii) Face velocity of 100 fpm assured.

Table 1 – Handling Limits for Liquid Chemicals on RWDI List for a Dilution Level of 3,000:1

Chemical Name	CAS Number	Volume Use Limit [mL]	Spill Area Limit [ft^2]
Propargyl alcohol	107-19-7	395	8.50
Ethyl ether	60-29-7	394	8.48
n-Butylamine	109-73-9	355	7.64
Ethylamine	75-04-7	223	4.79
1,1-Dimethylhydrazine	57-14-7	189	4.07
Tetranitromethane	509-14-8	185	3.98
Dimethyl disulfide	624-92-0	184	3.96
Acrolein	107-02-8	152	3.27
Isopropylamine	75-31-0	140	3.01
Bromine	7726-95-6	138	2.98
Bromine pentafluoride	7789-30-2	138	2.97
Propionaldehyde	123-38-6	133	2.85
Dimethylamine (25 %)	124-40-3	108	2.33
Diethylamine	109-89-7	90	1.94
sec-Amyl acetate	626-38-0	88	1.90
Tetramethyl lead	75-74-1	85	1.83
Methyl tert-butyl ether	1634-04-4	81	1.74
Methyl acrylate	96-33-3	76	1.64
Hydrofluoric acid (46 to 53%)	7664-39-3	67	1.45
Dimethylamine (40 %)	124-40-3	65	1.41
Benzenethiol (phenyl mercaptan)	108-98-5	65	1.41
Sulfur monochloride	10025-67-9	45	0.98
Isopropyl ether	108-20-3	44	0.94
1-2-Dibromo-3-chloropropane	96-12-8	38	0.83
Xylidine	1300-73-8	35	0.75
Dimethylamine (60 %)	124-40-3	28	0.61
Acetaldehyde	75-07-0	26	0.56
Pentaborane	19624-22-7	21	0.44
Osmium tetroxide	20816-12-0	20	0.43
Methyl isocyanate	624-83-9	18	0.38
Dimethyl sulfide	75-18-3	15	0.32
Arsenic trichloride	7784-34-1	12	0.25
n-Butyl mercaptan	109-79-5	11	0.23
bis-Chloromethyl ether	542-88-1	10	0.22
Sulfur pentafluoride	5714-22-7	5 [1]	0.11 [1]
Perchloromethyl mercaptan	594-42-3	5 [1]	0.10 [1]
Ethyl acrylate	140-88-5	3 [1]	0.07 [1]
Chromyl chloride	14977-61-8	2 [1]	0.05 [1]
Trimethylamine (40 %)	75-50-3	1 [1]	0.03 [1]
Nickel carbonyl	13463-39-3	1 [1]	0.02 [1]
Ethyl mercaptan	75-08-1	0.25 [1]	0.01 [1]

Note: [1] Handling limits may not be feasible. Store/use chemical in the smallest quantity possible and handle with extreme caution.

APPENDIX E

APPENDIX E: ESTIMATING CHEMICAL EMISSIONS FROM FUME HOODS

The proper design of chemical fume hood exhaust stacks requires an estimate of the concentrations of chemical vapors in the stack. The level of chemical vapors in the stack is dependent on many variables including the type of process being undertaken in the fume hood, the face velocity through the hood and the flow rate of the hood exhaust plus the physical state and the volatility of the chemical in question. The evaluation of acceptable levels of chemical fumes is also dependent on the toxicity or odour potential of the particular substance.

This document outlines the method used to estimate chemical emissions from both liquid and gaseous chemicals within a fume hood. The calculated emission rates are estimates only and are intended to provide a guideline for good engineering design of fume hood exhaust stacks. It is left to the owner or operator of the facility to determine whether the calculations are appropriate for their facility, or whether the list of chemicals presented herein is sufficiently comprehensive for a given application.

Determination of Evaporation Rate for Liquid Chemicals

The method described herein is a conservative estimate of liquid chemical emissions based on the principle of mass transfer from a flat plate. This method assumes a hypothetical worst-case spill of a chemical over the entire surface of a typical bench-top fume hood. This method ignores the effect of cooling on evaporation rates. For highly volatile liquids, the high initial evaporation rate cools the liquid, which lowers vapor pressure and evaporation rate.

Emissions of liquid chemicals and solutions from fume hoods are calculated by estimating the mass transfer rates (evaporation rates) of these substances. The mass transfer is driven by the chemical vapor density gradient and is expressed as follows:

$$q_B = h_m(\rho_{Bi} - \rho_\infty)A \quad \textbf{(1)}$$

where q_B = the evaporation rate of the chemical (kg/s);

h_m = the mass transfer coefficient (m/s);

ρ_{Bi} = the chemical vapor density at the interface (kg/m^3);

ρ_∞ = the chemical vapor density at infinity or background (kg/m^3); and,

A = the exposed area of the chemical (m^2).

Note that ρ_{Bi} is taken to be zero. The chemical vapor density at the film interface is calculated using the ideal gas law, assuming that the air is saturated with the chemical at this point. The relationship is given by[1]:

$$\rho_{Bi} = \frac{M_B p_{Bi}}{R_g T_i} \quad \textbf{(2)}$$

where M_B = the molecular weight of the chemical (kg/mol);
ρ_{Bi} = the partial pressure of the vapor (i.e. vapor pressure) at 20°C (kPa);
R_g = the molar gas constant (kPa·m^3/mol·K); and,
T_i = the temperature of the air in the fume hood (K).

The mass transfer coefficient h_m from Equation (1) is calculated assuming the area of the chemical (e.g., area of a spill) is exposed to airflow over a flat plate. In such cases, the mass transfer coefficient is determined empirically using the Chilton-Colburn analogy[1], given as follows:

$$h_m = \frac{j_D u / P_{AM}}{(\mu/\rho D_{AB})^{2/3}} \quad \textbf{(3)}$$

where j_D = the Chilton-Colburn j factor (dimensionless);
u = the mean free-stream velocity of air flow across the plate (m/s);
P_{AM} = the logarithmic mean density factor (dimensionless);
μ = the viscosity of air at 20°C (kg/m·s);
ρ = the density of air at 20°C (kg/m^3); and,
D_{AB} = the diffusivity of chemical vapor in the air (m^2/s).

The mean density factor is approximately equal to unity. For this application, we have assumed a mean free-stream velocity of 0.5 m/s (100 fpm). The Chilton-Colburn j factor is a function of the Reynolds number. For the assumed velocity of 0.5 m/s, the resulting value for the j factor is 0.0048.

Estimating the diffusivity of the chemical vapor in air is accomplished using the Fuller/Schettler/Giddings method[2] for binary mixtures at moderately low pressures (< 10 atm). This relationship is defined as follows:

$$D_{AB} = \frac{10^{-3} T^{1.75} [(M_A + M_B)/M_A M_B]^{1/2}}{P\left[(\Sigma v)_A^{1/3} + (\Sigma v)_B^{1/3}\right]^2} \quad \textbf{(4)}$$

where T = the temperature of the mixture (K);
P = the pressure of the mixture (atm);
M_A = the molecular weight of the air (kg/mol);
M_B = the molecular weight of chemical (kg/mol);

Σv_A = the atomic diffusion volume of the air (dimensionless); and,

Σv_B = the atomic diffusion volume of chemical vapor (dimensionless).

Atomic diffusion volumes have been determined empirically from linear regression of experimental data[2] for various binary mixtures.

In many cases, the diffusivity for a chemical compound in air has been published. In these instances, the published value has been used in lieu of Equation (4).

Determination of Concentration in Exhaust Duct from Liquid Chemicals

Having determined the emission rate, the concentration of chemical vapors in the fume hood duct is calculated as follows:

$$C_{duct} = \frac{q}{Q} \quad \textbf{(5)}$$

where C_{duct} = the concentration of vapor in the exhaust duct (kg/m^3);

q = the evaporation rate of the chemical (kg/s); and,

Q = the flow rate of air through the duct (m^3/s).

Determination of Emission Rate for Compressed Gases

The method described herein is a conservative estimate of chemical emissions from compressed gas bottles based on the ideal gas law. This method assumes a reasonable maximum volumetric gas flow rate of 4 liters per minute (0.000067 m^3/s) out of the cylinder.

The ideal gas law is used to calculate the gas density, in kg/m^3, as follows:

$$\rho = \frac{P_{atm}}{RT} \times MW \quad \textbf{(6)}$$

where ρ = the gas density in (g/m^3);

P_{atm} = the atmospheric pressure (Pa);

R = the gas constant (8.314 J/mol K);

T = the gas temperature (K); and,

MW = the molecular weight (g/mol).

The mass emission rate is calculated from the gas density and the assumed gas flow rate through the following equation:

$$\dot{m} = \rho \times Q_{gas} \quad \textbf{(7)}$$

where $\dot{m}$ = the mass emission rate (g/s); and,

Q_{gas} = the gas flow rate out of the cylinder (m^3/s).

Alternatively, the cylinder characteristics can be applied to estimate the mass emission rate. When the valve of a pressurized gas bottle is left wide open, the peak-gas emission rate is dependent on physical properties of the gas, the size of the valve throat, and the gas pressure. This emission rate can be calculated through the following fluid mechanics relationship:

$$\dot{m} = k\sqrt{\frac{M_B d^4 P^2}{RT}} \quad \textbf{(8)}$$

where k = a gas specific constant (dimensionless);
P = the bottled gas pressure (kPa gauge);
M_B = the molecular weight of chemical (kg/mole);
R = the universal gas constant (J/mole/K);
T = the gas temperature (K); and,
d = the diameter of the gas bottle valve throat (m).

The above method of calculation results in a worst-case estimate of an emission rate. The results for many typical bottled gases indicate that with practical stack designs, an accidental release of this type will lead to excessive concentrations at nearby fresh air intakes. Therefore, special handling procedures should be adopted for bottled gases, including low risk ones, to guard against accidental releases. Most suppliers of bottled gases have documentation on the handling of bottled gases.

Determination of Concentration in Exhaust Duct from Gaseous Chemicals

Having used either of the above methods to determine the emission rate, the concentration of chemical vapors in the fume hood duct, resulting from gaseous chemicals, is calculated as follows:

$$C_{duct} = \frac{\dot{m}}{Q_{hood}} \quad \textbf{(9)}$$

where C_{duct} = the duct concentration (g/m^3);and,
Q_{hood} = the fume hood flow rate (m^3/s).

Determination of Dilution Requirement

The required dilution is determined as the ratio of the concentration of chemical vapors at the stack to the maximum desired concentration at the air intake (or other sensitive area). This is represented as follows:

$$D_{required} = \frac{C_{duct}}{C_{desired}} \quad \textbf{(10)}$$

where $D_{required}$ = the required dilution; and,
$C_{desired}$ = the desired concentration (e.g., exposure limit).

The desired concentration varies from one chemical to another. A variety of exposure limits may be used. In our calculations shown in the attached tables, we have used the following exposure limits as the desired concentrations:

- American Conference of Governmental Industrial Hygienists (ACGIH) Time-Weighted Average (TWA) and Short-Term Exposure (STEL) limits or Ceiling values[3].
- National Institute of Occupational Safety and Health (NIOSH), TWA, STEL, or Ceiling values[4]
- Occupational Safety and Health Administration (OSHA) TWA, STEL, or Ceiling values[5]
- AIHA 1989. Odour Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.[6]
- Nagy, G.Z., 1991. The odour impact model. Journal of the Air Waste Management Association, p. 1360-1362.[7]
- Ruth, J.H., 1986. Odour thresholds and irritation levels of several chemicals: a review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.[8]
- 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.[9]

RWDI has estimated emission rates and dilution requirements for more than 350 chemicals, based on the above methods. Emissions for liquid chemical spills were calculated using a typical 5-ft bench-top fume hood with an exhaust flow rate of 1,000 cfm and a spill area of 8.8ft^2. For gaseous chemicals, the assumed 4 liters per minute outlet flow rate was applied.

Attached Summary Tables

The two tables attached at the end of this technical note show predicted emission rates and dilution requirements for liquids and compressed gases. Health limits are based on occupational limits of ACGIH, NIOSH, or OSHA as described above. The table shows the most stringent 8-hour TWA and the most stringent STEL/Ceiling value from the three sources. Odour thresholds are based on several references also described above. The last column indicates the worst case (highest) of either health or odour, which is used for design purposes. If both the 8-hour TWA and STEL/Ceiling values exist for a chemical, the short term STEL/Ceiling health limit is used because the emission duration is assumed to be an hour or less.

References

American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Handbook, 1993 Fundamentals, Chapter 5, "Mass Transfer", Atlanta, 1993.

Perry, R.H. and D. Green, Perry's Chemical Engineers' Handbook, 6th Edition, 1984.

American Conference of Government Industrial Hygienists, 2001 Guide to Occupational Exposure Values, Cincinnati, Ohio, 2001.

National Institute of Occupational Safety and Health (NIOSH), TWA, STEL, or Ceiling values.

Occupational Safety and Health Administration (OSHA) TWA, STEL, or Ceiling values.

AIHA 1989. Odour Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.

Nagy, G.Z., 1991. The Odour Impact Model. Journal of the Air Waste Management Association, p. 1360-1362.

Ruth, J.H., 1986. Odour Thresholds and Irritation Levels of Several Chemicals: A Review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.

3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

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GASES

Pressure	**101325.00**	**Pa**
Temperature	**293.00**	**K**
Gas Constant	**8.31**	**J/mol*K**
Gas Flow Rate	**4.00**	**l/min**
Hood Flow Rate	**1000.00**	**cfm**

Chemical	CHEMICAL PROPERTIES					ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odour Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health/Odour
Acetylene	74-86-2	26.04	1.08	72.20	152.87	510.00	2662.000	NV	510.000	none
Ammonia	7664-41-7	17.03	0.71	47.23	99.99	11.84	24.000	17.000	11.841	8
Arsine	7784-42-1	77.93	3.24	216.10	457.54	3.19	0.002	0.160	0.002	228768
Boron Trichloride	10294-34-5	117.17	4.87	324.91	687.91	NV	NV	NV	NV	N/A
2-Butene (beta-butylene)	107-01-7	56.11	2.33	155.58	329.41	NV	NV	NV	NV	N/A
Carbon Monoxide	630-08-0	28.01	1.17	77.67	164.45	114561.96	229.000	29.000	229.000	none
Chlorine	7782-50-5	70.91	2.95	196.62	416.30	0.23	1.450	1.500	0.232	1794
Chlorine Dioxide	10049-04-4	67.45	2.81	187.04	396.01	41.38	0.830	0.280	0.830	477
Chlorodifluoromethane (Freon 22)	75-45-6	86.47	3.60	239.78	507.68	NV	4375.000	3500.000	4375.000	none
Carbon Tetrafluoride	75-73-0	88.01	3.66	244.05	516.72	NV	NV	NV	NV	N/A
Cyanogen Chloride	506-77-4	61.48	2.56	170.48	360.96	2.00	0.060	NV	0.060	6016
Diborane	19287-45-7	27.67	1.15	76.72	162.44	2.84	NV	0.100	0.100	1624
Dichlorosilane	4109-96-0	101.01	4.20	280.09	593.03	NV	NV	NV	NV	N/A
Dichloro-1,1,2,2,-tetrafluoroethane, 1,2 (Freon 114)	76-14-2	170.92	7.11	473.96	1003.49	NV	NV	6990.000	6990.000	none
Difluorodichloromethane (Freon 12)	75-71-8	120.92	5.03	335.31	709.94	NV	NV	4950.000	4950.000	none
Ethylene (ethene)	74-85-1	28.05	1.17	77.79	164.71	309.79	NV	NV	309.794	none
Ethylene Oxide	75-21-8	44.05	1.83	122.15	258.62	756.69	9.000	0.180	9.000	29
Fluoroform (Carbon Trifluoride, trifluoromethane)	75-46-7	70.01	2.91	194.15	411.06	NV	NV	NV	NV	N/A
Fluorine	7782-41-4	37.99	1.58	105.35	223.04	6.00	3.100	0.200	3.100	72
Hexafluoropropane (hydrofluorocarbon)	690-39-1	152.00	6.32	421.49	892.41	NV	NV	NV	NV	N/A
Hydrogen Bromide	10035-10-6	80.91	3.37	224.37	475.04	6.67	9.900	10.000	6.667	71
Hydrogen Chloride	7647-01-0	36.46	1.52	101.11	214.07	2.39	7.000	NV	2.388	90
Hydrogen Fluoride	7664-39-3	20.01	0.83	55.48	117.46	0.03	2.300	2.455	0.033	3589
Hydrogen Sulfide	7783-06-4	34.08	1.42	94.49	200.06	0.01	15.000	7.000	0.013	15271
Methyl Bromide (Bromomethane)	74-83-9	94.94	3.95	263.26	557.40	565.69	80.000	3.900	80.000	7
Methyl Chloride	74-87-3	50.49	2.10	140.00	296.42	20.65	207.000	103.000	20.649	14
Methyl Mercaptan	74-93-1	48.11	2.00	133.41	282.46	0.00	1.000	0.980	0.001	265831
Methane	74-82-8	16.04	0.67	44.49	94.19	NV	NV	NV	NV	N/A
Nitrogen Trifluoride	7783-54-2	71.00	2.95	196.89	416.86	NV	NV	29.000	29.000	14
Nitric Oxide	10102-43-9	30.01	1.25	83.21	176.17	0.66	NV	30.000	0.657	268
Nitrogen Dioxide	10102-44-0	46.01	1.91	127.59	270.13	4.47	1.800	5.600	1.800	150
Nitrous Oxide	10024-97-2	44.01	1.83	122.05	258.40	NV	NV	46.000	46.000	6
Ozone	10028-15-6	48.00	2.00	133.10	281.81	0.03	0.200	0.100	0.032	8824

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Pressure	**101325.00**	**Pa**
Temperature	**293.00**	**K**
Gas Constant	**8.31**	**J/mol*K**
Gas Flow Rate	**4.00**	**l/min**
Hood Flow Rate	**1000.00**	**cfm**

Chemical	CHEMICAL PROPERTIES					ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odour Threshold (mg/m^3)	Short-Term Health Limit (mg/m^3)	Long-Term Health Limit (mg/m^3)	Limiting Value (mg/m^3)	Maximum Required Dilution Health/Odour
Phosgene (carbonyl chloride)	75-44-5	98.92	4.11	274.29	580.75	3.35	0.800	0.400	0.800	726
Phosphine (hydrogen phosphide)	7803-51-2	34.00	1.41	94.27	199.60	0.19	1.000	0.400	0.195	1025
Sulfur Dioxide	7446-09-5	64.06	2.66	177.63	376.10	7.07	13.000	5.000	7.074	53
Sulfur hexafluoride	2551-62-4	146.05	6.07	404.99	857.48	NV	NV	5970.000	5970.000	none
Silane	7803-62-5	32.12	1.34	89.06	188.57	NV	NV	6.600	6.600	29
Silicon Tetrafluoride	7783-61-1	104.08	4.33	288.61	611.06	4.25	NV	NV	4.250	144
Trifluoroacetyl Chloride	354-32-5	132.47	5.51	367.34	777.74	NV	NV	NV	NV	N/A
Vinyl Chloride	75-01-4	62.50	2.60	173.31	366.94	36.15	12.900	2.600	12.900	28

Chemical Properties can be referenced to www.chemfinder.com

ACGIH, OSHA, NIOSH Health Limits taken from 2001 Guide to Occupational Exposure Values, compiled by ACGIH
NV indicates no value for air quality or odour standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

Odour Threshold Values taken from the following five sources (listed in priority):
1) American Industrial Hygiene Association. Odour Thresholds for Chemicals with Established Occupational Health Standards. Akron, OH. 1989.
2) Nagy, George Z. The Odour Impact Model. J. Air Waste Manage. Assoc., October 1991. Volume 41, No. 10, pp 1360-1362.
3) Same as source 1)
4) Ruth, Jon H. Odour Thresholds and Irritation Levels of Several Chemicals: A Review. American Industrial Hygiene Association (47). March, 1986. pp A142-A151.
5) 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

Maximum Required Dilution based on:
1) Minimum of STEL or C of ACGIH, OSHA, and NIOSH limits(short-term health);
2) Minimum of TWA of ACGIH, OSHA, and NIOSH limits(long-term health);
3) Odour threshold based on priority of resource used.
The minimum value out of the health and the odour values was used with the short term health limit taking precedence over the long-term health limit.

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LIQUIDS

100	fpm	0.51	m/s
8.8	ft²	0.813	m²
1000	cfm	0.472	m³/s
30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Acetaldehyde	75-07-0	44.05	99.00	1.79E+00	0.11	1.84E-03	2683.46	5685.94	0.12	45.00	360.00	0.12	47104
Acetic acid	64-19-7	60.05	1.52	3.75E-02	0.11	1.80E-03	54.88	116.28	0.18	37.00	25.00	0.18	640
Acetic anhydride	108-24-7	102.10	0.47	1.97E-02	0.07	1.40E-03	22.45	47.58	0.58	20.00	20.00	0.58	81
Acetone	67-64-1	58.08	24.40	5.82E-01	0.11	1.83E-03	865.85	1834.64	147.28	1782.00	590.00	147.28	12
Acetone cyanohydrin	75-86-5	85.10	0.11	3.74E-03	0.10	1.73E-03	5.25	11.13	10.44	4.00	NV	4.00	3
Acetonitrile	75-05-8	41.05	9.70	1.63E-01	0.11	1.88E-03	250.06	529.86	1947.57	101.00	34.00	101.00	5
Acetophenone	98-86-2	120.15	0.13	6.41E-03	0.06	1.21E-03	6.29	13.32	1.57	NV	49.00	1.57	8
Acetyl acetone	123-54-6	100.12	0.93	3.82E-02	0.07	1.35E-03	41.86	88.70	0.04	NV	NV	0.04	2169
Acetyl chloride	75-36-5	78.50	33.20	1.07E+00	0.07	1.37E-03	1195.27	2532.63	NV	NV	NV	NV	N/A
Acetylene tetrabromide	79-27-6	346.00	0.02	2.84E-03	0.05	1.12E-03	2.58	5.46	NV	NV	14.00	14.00	none
Acrolein	107-02-8	56.06	28.10	6.47E-01	0.09	1.65E-03	869.84	1843.08	4.13	0.23	0.25	0.23	8013
Acrylamide	79-06-1	71.00	0.001	2.9E-05	0.10	1.73E-03	0.04	0.09	NV	NV	0.03	0.03	3
Acrylic acid	79-10-7	72.06	0.40	1.18E-02	0.09	1.58E-03	15.16	32.13	0.27	NV	5.90	0.27	118
Acrylonitrile	107-13-1	53.06	11.50	2.50E-01	0.10	1.68E-03	341.65	723.91	3.47	22.00	2.20	3.47	208
Allyl alcohol	107-18-6	58.08	2.30	5.48E-02	0.09	1.62E-03	72.29	153.18	4.04	10.00	1.19	4.04	38
Allyl chloride	107-05-1	76.53	45.00	1.41E+00	0.08	1.51E-03	1734.62	3675.46	5.27	6.00	3.00	5.27	698
Allyl glycidyl ether	106-92-3	114.00	0.27	1.26E-02	0.06	1.27E-03	13.05	27.66	44.00	44.00	4.70	44.00	none
Amitrole	61-82-5	84.00	1.00E-06	3.45E-08	0.09	1.58E-03	4.44E-05	9.41E-05	NV	NV	0.20	0.20	none
Ammonium chloride	12125-02-9	53.00	0.13	2.89E-03	0.10	1.73E-03	4.07	8.62	NV	20.00	10.00	20.00	none
Ammonium hydroxide sol'n (10%), as NH4	1336-21-6	35.00	15.00	2.16E-01	0.19	2.61E-03	457.20	968.74	24.34	24.00	17.00	24.00	40
Ammonium hydroxide sol'n (20%), as NH4	1336-21-6	35.00	29.50	4.24E-01	0.19	2.61E-03	897.60	1901.90	24.34	24.00	17.00	24.00	79
Ammonium hydroxide sol'n (30%), as NH4	1336-21-6	35.00	74.20	1.07E+00	0.19	2.61E-03	2257.68	4783.76	24.34	24.00	17.00	24.00	199
n-Amyl acetate	628-63-7	130.18	0.67	3.58E-02	0.06	1.20E-03	34.88	73.90	0.28	532.00	266.00	0.28	267
sec-Amyl acetate	626-38-0	130.18	0.93	4.97E-02	0.10	1.73E-03	69.84	147.98	0.01	532.00	266.00	0.01	13830

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n-Amyl alcohol	71-41-0	88.15	0.22	7.89E-03	0.06	1.23E-03	7.89	16.71	5.59	NV	NV	5.59	3
t-Amyl alcohol	75-85-4	88.15	1.60	5.79E-02	0.06	1.23E-03	57.88	122.64	0.83	NV	NV	0.83	148
Aniline	62-53-3	93.12	0.04	1.53E-03	0.06	1.24E-03	1.55	3.27	9.14	NV	7.60	7.60	none
2-Anisidine	90-04-0	123.15	0.01	6.57E-04	0.10	1.73E-03	0.92	1.96	NV	NV	0.50	0.50	4
Anisole	100-66-3	108.14	1.30	5.77E-02	0.06	1.26E-03	58.93	124.86	0.22	NV	NV	0.22	565
Arsenic trichloride	7784-34-1	181.00	1.33	9.90E-02	0.06	1.23E-03	98.93	209.61	NV	0.002	0.01	0.002	104806
Azinphos methyl	86-50-0	317.00	8.00E-08	1.04E-08	0.04	9.89E-04	8.37E-06	1.77E-05	NV	NV	0.20	0.20	none
Benzaldehyde	100-52-7	106.13	0.13	5.66E-03	0.07	1.35E-03	6.23	13.20	0.01	NV	NV	0.01	1093
Benzene	71-43-2	78.11	10.00	3.21E-01	0.08	1.45E-03	378.54	802.08	194.88	3.20	0.32	3.20	251
Benzenethiol (phenyl mercaptan)	108-98-5	110.18	0.19	8.46E-03	0.10	1.73E-03	11.89	25.18	0.00	0.50	2.30	0.001	18629
Benzoic Acid	65-85-0	122.00	0.13	6.66E-03	0.10	1.73E-03	9.36	19.83	NV	NV	NV	NV	N/A
Benzothiazole	95-16-9	135.00	4.50	2.49E-01	0.10	1.73E-03	350.45	742.56	0.99	NV	NV	0.99	751
Benzoyl chloride	98-88-4	140.60	0.05	2.94E-03	0.10	1.73E-03	4.14	8.76	0.04	2.80	NV	0.04	218
Benzyl Alcohol	100-51-6	108.13	0.02	8.88E-04	0.10	1.73E-03	1.25	2.64	24.54	NV	NV	24.54	none
Benzyl chloride	100-44-7	126.58	0.13	6.75E-03	0.07	1.31E-03	7.20	15.25	0.21	5.00	5.00	0.21	72
Benzylamine	100-46-9	107.16	13.30	5.85E-01	0.07	1.31E-03	622.63	1319.29	NV	NV	NV	NV	N/A
Biphenyl	92-52-4	154.00	0.001	8.22E-05	0.10	1.73E-03	0.12	0.24	0.00	NV	1.00	0.003	74
Boron tribromide	10294-33-4	251.00	5.33	5.49E-01	0.05	1.03E-03	459.89	974.45	NV	10.00	NV	10.00	97
Bromine	7726-95-6	159.83	23.00	1.51E+00	0.08	1.50E-03	1834.75	3887.61	0.44	1.30	0.66	0.44	8813
Bromine pentafluoride	7789-30-2	175.00	44.00	3.16E+00	0.05	1.14E-03	2923.32	6194.17	NV	NV	0.70	0.70	8849
Bromobenzene	108-86-1	157.02	0.54	3.48E-02	0.06	1.27E-03	35.88	76.02	NV	NV	NV	NV	N/A
1-Bromobutane	109-65-9	137.03	5.35	3.01E-01	0.06	1.30E-03	317.08	671.86	NV	NV	NV	NV	N/A
2-Bromobutane	78-76-2	137.03	9.33	5.25E-01	0.06	1.30E-03	552.96	1171.67	NV	NV	NV	NV	N/A
1-Bromopropane	106-94-5	122.90	16.00	8.07E-01	0.07	1.38E-03	902.72	1912.75	NV	NV	NV	NV	N/A

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Bromoform	75-25-2	252.77	0.67	6.95E-02	0.06	1.25E-03	70.74	149.90	17.45	NV	5.00	5.00	30
1-Butoxy-2-propanol	5131-66-8	132.00	0.19	1.01E-02	0.10	1.73E-03	14.24	30.17	NV	NV	NV	NV	N/A
n-Butyl acetate	123-86-4	116.16	1.33	6.34E-02	0.06	1.24E-03	64.10	135.82	1.47	950.00	710.00	1.47	92
sec-Butyl acetate	105-46-4	116.16	1.30	6.20E-02	0.06	1.24E-03	62.66	132.76	21.76	NV	950.00	21.76	6
n-Butyl acrylate	141-32-2	128.00	0.50	2.63E-02	0.10	1.73E-03	36.92	78.23	0.05	NV	11.00	0.05	1525
Isobutyl alcohol	78-83-1	74.00	1.20	3.65E-02	0.10	1.73E-03	51.23	108.54	10.90	NV	150.00	10.90	10
n-Butyl alcohol	71-36-3	74.00	0.60	1.82E-02	0.07	1.40E-03	20.77	44.00	3.63	150.00	61.00	3.63	12
tert-Butyl alcohol	75-65-0	74.00	4.10	1.25E-01	0.07	1.36E-03	137.98	292.37	2905.52	450.00	300.00	450.00	none
sec-Butyl alcohol	78-92-2	74.00	1.60	4.86E-02	0.07	1.36E-03	53.85	114.10	9.69	455.00	300.00	9.69	12
n-Butylamine	109-73-9	73.00	11.00	3.30E-01	0.08	1.45E-03	387.43	820.92	0.24	15.00	NV	0.24	3437
Butyl Cellosolve (2-butoxyethanol)	111-76-2	118.17	0.10	4.85E-03	0.10	1.73E-03	6.82	14.44	0.48	NV	24.00	0.48	30
n-Butyl ether	142-96-1	130.23	0.64	3.42E-02	0.06	1.20E-03	33.32	70.61	0.97	NV	NV	0.97	73
n-Butyl glycidyl ether (BGE)	2426-08-6	130.00	0.43	2.29E-02	0.06	1.20E-03	22.35	47.36	NV	30.00	133.00	30.00	2
n-Butyl lactate	138-22-7	146.20	0.05	3.00E-03	0.06	1.21E-03	2.95	6.25	35.00	NV	25.00	25.00	none
n-Butyl mercaptan	109-79-5	90.00	4.70	1.74E-01	0.07	1.38E-03	195.11	413.41	0.00	1.80	1.80	0.004	112310
o-sec-Butylphenol	89-72-5	150.00	0.004	2.46E-04	0.06	1.19E-03	0.24	0.50	NV	NV	30.00	30.00	none
p-tert-Butyl toluene	98-51-1	148.00	0.10	6.08E-03	0.05	1.08E-03	5.33	11.30	30.00	120.00	6.10	30.00	none
n-Butyric acid	107-92-6	88.11	0.06	2.06E-03	0.07	1.32E-03	2.22	4.70	0.09	NV	NV	0.09	50
n-Butyronitrile	109-74-0	69.10	2.55	7.23E-02	0.10	1.73E-03	101.65	215.38	NV	NV	22.00	22.00	10
Carbon disulfide	75-15-0	76.00	40.00	1.25E+00	0.09	1.60E-03	1625.02	3443.23	3.90	30.00	3.00	3.90	883
Carbon tetrachloride	56-23-5	154.00	12.00	7.59E-01	0.07	1.37E-03	842.18	1784.49	1587.24	12.60	31.00	12.60	142
Chloroacetaldehyde	107-20-0	79.00	13.00	4.22E-01	0.09	1.59E-03	545.33	1155.48	3.00	3.00	NV	3.00	385
Chloroacetone	78-95-5	92.50	2.80	1.06E-01	0.10	1.73E-03	149.41	316.58	NV	3.80	NV	3.80	83
Chloroacetyl chloride	79-04-9	112.94	2.50	1.16E-01	0.08	1.48E-03	139.20	294.95	NV	0.69	0.20	0.69	427

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Chlorobenzene	108-90-7	112.60	1.20	5.55E-02	0.07	1.34E-03	60.41	128.01	5.99	NV	46.00	5.99	21
Chlorobromomethane	74-97-5	129.00	15.00	7.94E-01	0.08	1.48E-03	954.04	2021.50	2100.00	NV	1050.00	1050.00	2
1-Chlorobutane	109-69-3	92.57	10.80	4.10E-01	0.07	1.38E-03	459.47	973.55	NV	NV	NV	NV	N/A
2-Chlorobenzaldehyde	89-98-5	140.60	0.13	7.50E-03	0.06	1.21E-03	7.41	15.70	NV	NV	NV	NV	N/A
Chlorodiphenyl (42% free chlorine)	53469-21-9	258.00	1.30E-04	1.38E-05	0.10	1.73E-03	0.02	0.04	NV	NV	0.001	0.001	41
Chlorodiphenyl (54% free chlorine)	11097-69-1	326.00	8.00E-06	1.07E-06	0.10	1.73E-03	0.002	0.003	NV	NV	0.001	0.001	3
Chloroform	67-66-3	119.38	21.30	1.04E+00	0.09	1.62E-03	1377.47	2918.69	937.46	9.78	49.00	9.78	298
bis-Chloromethyl ether	542-88-1	115.00	4.01	1.89E-01	0.10	1.73E-03	266.02	563.67	NV	NV	0.00	0.005	119930
1-Chloro-1-nitropropane	600-25-9	123.60	0.80	4.06E-02	0.10	1.73E-03	57.04	120.86	NV	NV	10.00	10.00	12
Chloropicrin	76-06-2	164.00	2.70	1.82E-01	0.09	1.59E-03	234.57	497.03	6.48	NV	0.67	0.67	742
beta-Chloroprene	126-99-8	88.54	27.10	9.85E-01	0.10	1.73E-03	1384.16	2932.86	14.11	3.60	36.00	3.60	815
Chlorosulfonic acid	7790-94-5	116.53	0.13	6.22E-03	0.09	1.61E-03	8.12	17.20	NV	NV	NV	NV	N/A
Ortho-Chlorotoluene	95-49-8	126.58	0.48	2.49E-02	0.10	1.73E-03	35.05	74.27	1.13	375.00	250.00	1.13	66
Chromic acid	1333-82-0	100.00	0.13	5.34E-03	0.10	1.73E-03	7.50	15.89	NV	0.10	0.001	0.10	159
Chromyl chloride	14977-61-8	154.90	2.70	1.72E-01	0.10	1.73E-03	241.26	511.21	NV	NV	0.001	0.001	511209
Cresol (o, m, & p-isomers)	1319-77-3	108.15	0.04	1.78E-03	0.07	1.32E-03	1.90	4.02	0.003	NV	10.00	0.003	1516
Crotonaldehyde	4170-30-3	70.00	4.00	1.15E-01	0.08	1.49E-03	139.09	294.73	0.31	0.86	6.00	0.31	936
Cumene (isopropyl benzene)	98-82-8	120.00	1.10	5.42E-02	0.06	1.21E-03	53.27	112.87	0.16	NV	245.00	0.16	719
Cyanogen bromide	506-68-3	105.90	12.30	5.35E-01	0.07	1.37E-03	594.69	1260.08	NV	NV	NV	NV	N/A
Cyclohexane	110-82-7	84.00	10.27	3.54E-01	0.09	1.56E-03	450.05	953.60	2679.75	NV	344.00	344.00	3
Cyclohexanol	108-93-0	100.00	0.13	5.34E-03	0.06	1.29E-03	5.58	11.83	0.65	NV	200.00	0.65	18
Cyclohexanone	108-94-1	98.00	0.53	2.13E-02	0.07	1.30E-03	22.55	47.77	14.03	NV	100.00	14.03	3
Cyclohexene	110-83-8	82.15	8.93	3.01E-01	0.07	1.34E-03	327.27	693.44	0.60	NV	1010.00	0.60	1147
Cyclohexylamine	108-91-8	99.00	1.43	5.81E-02	0.10	1.73E-03	81.67	173.04	217.92	NV	40.00	40.00	4

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Cyclopentadiene	542-92-7	66.10	49.00	1.33E+00	0.10	1.73E-03	1868.42	3958.95	4.87	NV	200.00	4.87	814
Cyclopentane	287-92-3	70.10	53.33	1.53E+00	0.10	1.73E-03	2156.58	4569.54	NV	NV	1720.00	1720.00	3
Cyclopentanone	120-92-3	84.12	1.52	5.25E-02	0.08	1.47E-03	62.81	133.09	NV	NV	NV	NV	N/A
Decaborane	17702-41-9	122.00	0.03	1.35E-03	0.10	1.73E-03	1.90	4.03	0.30	0.75	0.25	0.30	13
1-Decene	872-05-9	140.00	0.23	1.30E-02	0.10	1.73E-03	18.33	38.85	NV	NV	NV	NV	N/A
n-Decyl alcohol	112-30-1	158.28	0.13	8.45E-03	0.05	1.07E-03	7.37	15.62	NV	NV	NV	NV	N/A
Diacetone alcohol	123-42-2	116.00	0.11	5.24E-03	0.06	1.26E-03	5.36	11.35	1.28	NV	238.00	1.28	9
Diazinon	333-41-5	304.00	1.90E-05	2.37E-06	0.10	1.73E-03	0.003	0.01	NV	NV	0.10	0.10	none
1-2-Dibromo-3-chloropropane	96-12-8	236.40	0.11	1.07E-02	0.10	1.73E-03	15.00	31.79	0.17	NV	0.001	0.001	31785
Dibutyl phosphate	107-66-4	210.20	0.13	1.12E-02	0.10	1.73E-03	15.76	33.40	NV	10.00	5.00	10.00	3
Dibutyl phthalate	84-74-2	278.40	1.30E-07	1.49E-08	0.04	9.17E-04	1.11E-05	2.35E-05	NV	NV	5.00	5.00	none
o-Dichlorobenzene	95-50-1	147.00	0.13	7.84E-03	0.06	1.26E-03	8.05	17.06	4.21	300.00	150.00	4.21	4
p-Dichlorobenzene	106-46-7	147.00	0.17	1.03E-02	0.06	1.26E-03	10.53	22.31	0.72	NV	60.00	0.72	31
1,1-Dichloroethylene	75-35-4	96.94	67.00	2.67E+00	0.10	1.73E-03	3746.74	7938.91	NV	NV	20.00	20.00	397
1,2-Dichloroethylene (sym)	540-59-0	96.94	24.00	9.55E-01	0.10	1.73E-03	1342.12	2843.79	25.75	NV	790.00	25.75	110
trans-1,2-Dichloroethylene	156-60-5	97.00	71.00	2.83E+00	0.10	1.73E-03	3972.89	8418.08	NV	NV	790.00	790.00	11
Dichloroethyl ether	111-44-4	143.00	0.09	5.46E-03	0.06	1.26E-03	5.60	11.88	440.91	58.00	29.00	58.00	none
1,2-Dichloroethane	107-06-2	99.00	8.80	3.58E-01	0.08	1.47E-03	427.64	906.12	105.28	8.00	4.00	8.00	113
1,1-Dichloro-1-nitroethane	594-72-9	144.00	2.00	1.18E-01	0.07	1.37E-03	131.69	279.04	NV	60.00	10.00	60.00	5
1,1-Dichloroethane	75-34-3	99.00	24.00	9.75E-01	0.08	1.47E-03	1166.30	2471.24	1044.87	NV	400.00	400.00	6
1,3-Dichloropropene	542-75-6	111.00	4.00	1.82E-01	0.10	1.73E-03	256.13	542.71	NV	NV	4.50	4.50	121
1,2-Dichloropropane	78-87-5	113.00	5.73	2.66E-01	0.10	1.73E-03	373.52	791.44	NV	508.00	347.00	508.00	2
Dichlorvos	62-73-7	221.00	0.001	1.18E-04	0.10	1.73E-03	0.17	0.35	NV	NV	0.90	0.90	none
Dicrotophos	141-66-2	237.00	1.00E-05	9.73E-07	0.10	1.73E-03	0.001	0.00	NV	NV	0.25	0.25	none

RWDI
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LIQUIDS

100	fpm	0.51	m/s
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1000	cfm	0.472	m³/s
30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Dicyclopentadiene	77-73-6	132.21	0.19	1.01E-02	0.10	1.70E-03	14.03	29.73	0.06	NV	27.00	0.06	500
Diethylamine	109-89-7	73.00	26.00	7.79E-01	0.09	1.59E-03	1008.50	2136.88	0.16	45.00	15.00	0.16	13504
2-Diethylaminoethanol	100-37-8	117.00	0.13	6.24E-03	0.10	1.73E-03	8.77	18.59	0.05	NV	9.60	0.05	353
Diethylene glycol	111-46-6	106.12	0.001	5.66E-05	0.07	1.37E-03	0.06	0.13	NV	NV	NV	NV	N/A
Diethylene glycol monoethyl ether	111-90-0	134.00	0.02	1.03E-03	0.10	1.73E-03	1.45	3.06	3.88	NV	NV	3.88	none
Diethylene glycol monomethyl ether	111-77-3	120.00	0.02	1.18E-03	0.10	1.73E-03	1.66	3.52	NV	NV	NV	NV	N/A
Diethyl ketone	96-22-0	86.10	4.70	1.66E-01	0.10	1.73E-03	233.44	494.63	9.86	1057.00	705.00	9.86	50
Diethyl phthalate	84-66-2	222.00	2.20E-04	2.00E-05	0.10	1.73E-03	0.03	0.06	NV	NV	5.00	5.00	none
Diglycidyl ether (DGE)	2238-07-5	130.20	0.01	5.34E-04	0.10	1.73E-03	0.75	1.59	25.00	2.80	0.50	2.80	none
Diisobutyl ketone	108-83-8	142.00	0.23	1.32E-02	0.06	1.20E-03	12.85	27.23	9.30	NV	145.00	9.30	3
Diisopropylamine	108-18-9	101.19	8.00	3.32E-01	0.06	1.27E-03	342.84	726.44	0.54	NV	20.00	0.54	1350
N,N-Dimethyl acetamide	127-19-5	87.00	0.20	7.14E-03	0.07	1.42E-03	8.23	17.43	162.39	NV	35.00	35.00	none
N,N-Dimethylaniline	121-69-7	121.20	0.07	3.43E-03	0.06	1.19E-03	3.33	7.05	0.07	50.00	25.00	0.07	101
Dimethylamine (25 %)	124-40-3	45.10	17.33	3.21E-01	0.07	1.31E-03	341.42	723.42	0.06	27.60	9.20	0.06	11247
Dimethylamine (40 %)	124-40-3	45.00	28.67	5.30E-01	0.07	1.31E-03	564.17	1195.42	0.06	27.60	9.20	0.06	18626
Dimethylamine (60 %)	124-40-3	45.00	66.67	1.23E+00	0.07	1.31E-03	1311.94	2779.85	0.06	27.60	9.20	0.06	43313
n,n-Dimethyl-1,3-diaminopropane	109-55-7	102.00	0.80	3.35E-02	0.10	1.73E-03	47.07	99.74	NV	NV	NV	NV	N/A
Dimethyl disulfide	624-92-0	94.00	3.81	1.47E-01	0.10	1.73E-03	206.60	437.76	0.07	NV	NV	0.07	6633
Dimethylformamide	68-12-2	73.00	0.36	1.08E-02	0.08	1.54E-03	13.49	28.59	20.47	NV	30.00	20.47	1
1,1-Dimethylhydrazine	57-14-7	60.00	13.70	3.37E-01	0.09	1.66E-03	456.45	967.16	22.58	0.15	0.03	0.15	6448
Dimethylphthalate	131-11-3	194.00	0.001	1.04E-04	0.10	1.73E-03	0.15	0.31	NV	NV	5.00	5.00	none
Dimethylsulfate	77-78-1	126.00	0.07	3.47E-03	0.08	1.43E-03	4.02	8.52	NV	NV	0.50	0.50	17
Dimethyl sulfide	75-18-3	62.00	56.00	1.43E+00	0.10	1.73E-03	2002.88	4243.88	0.05	NV	NV	0.05	83213
Dimethyl sulfoxide	67-68-5	78.00	0.06	1.92E-03	0.10	1.73E-03	2.70	5.72	NV	NV	NV	NV	N/A

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LIQUIDS

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
1,4-Dioxane	123-91-1	88.00	3.90	1.41E-01	0.07	1.42E-03	163.19	345.79	43.19	3.60	72.00	3.60	96
1,3-Dioxolane	646-06-0	74.00	10.53	3.20E-01	0.10	1.73E-03	449.51	952.45	122.22	NV	61.00	61.00	16
Dipropylene glycol methyl ether	34590-94-8	148.20	0.05	3.04E-03	0.10	1.73E-03	4.27	9.06	1122.50	900.00	600.00	900.00	none
Dipropyl ketone	123-19-3	114.00	0.16	7.49E-03	0.10	1.73E-03	10.52	22.30	NV	NV	233.00	233.00	none
Di-sec-octyl phthalate	117-81-7	391.00	0.00	2.09E-04	0.10	1.73E-03	0.29	0.62	NV	10.00	5.00	10.00	none
Epichlorohydrin	106-89-8	93.00	1.70	6.49E-02	0.08	1.46E-03	76.83	162.80	3.73	NV	1.90	1.90	86
Ethanolamine	141-43-5	61.00	0.05	1.33E-03	0.10	1.67E-03	1.81	3.83	7.54	15.00	6.00	7.54	none
Enflurane	13838-16-9	184.00	23.30	1.76E+00	0.10	1.73E-03	2473.15	5240.31	NV	15.10	566.00	15.10	347
2-Ethoxyethanol (EGEE)	110-80-5	90.12	0.54	2.00E-02	0.10	1.73E-03	28.07	59.48	9.95	NV	1.80	1.80	33
2-Ethoxyethylacetate	111-15-9	132.00	0.30	1.63E-02	0.06	1.23E-03	16.30	34.54	0.32	NV	2.70	0.32	107
Ethyl acetate	141-78-6	88.00	9.60	3.47E-01	0.07	1.38E-03	389.67	825.67	64.79	NV	1400.00	64.79	13
Ethyl acrylate	140-88-5	100.00	4.00	1.64E-01	0.07	1.35E-03	179.85	381.08	0.00	61.00	20.00	0.001	388223
Ethyl alcohol	64-17-5	46.00	5.90	1.11E-01	0.01	3.77E-04	34.18	72.42	338.65	NV	1880.00	338.65	none
Ethyl benzene	100-41-4	106.00	0.93	4.05E-02	0.07	1.31E-03	43.02	91.16	1.90	543.00	434.00	1.90	48
Ethyl bromide	74-96-4	109.00	50.00	2.24E+00	0.08	1.48E-03	2688.30	5696.20	890.00	NV	22.00	22.00	259
Ethyl butyl ketone	106-35-4	114.00	0.53	2.48E-02	0.06	1.22E-03	24.63	52.18	4.66	350.00	230.00	4.66	11
Ethyl ether	60-29-7	74.14	59.00	1.80E+00	0.10	1.72E-03	2515.91	5330.91	1.72	1520.00	1200.00	1.72	3093
Ethyl-3-ethoxy propionate	763-69-9	146.00	0.09	5.57E-03	0.10	1.73E-03	7.83	16.60	0.11	NV	NV	0.11	151
Ethyl formate	109-94-4	74.00	26.00	7.90E-01	0.08	1.54E-03	988.10	2093.67	57.43	NV	300.00	57.43	36
2-Ethyl hexanol	104-76-7	130.00	0.01	3.74E-04	0.10	1.73E-03	0.52	1.11	0.80	NV	NV	0.80	1
Ethyl iodide	75-03-6	155.97	18.30	1.17E+00	0.07	1.41E-03	1347.30	2854.77	NV	NV	NV	NV	N/A
Ethyl mercaptan	75-08-1	62.13	59.00	1.50E+00	0.09	1.64E-03	2010.22	4259.41	0.00	1.30	1.30	0.001	4789159
Ethyl silicate	78-10-4	208.00	0.13	1.14E-02	0.05	1.07E-03	9.87	20.91	30.63	NV	85.00	30.63	none
Ethylamine	75-04-7	45.00	48.00	8.87E-01	0.10	1.78E-03	1285.09	2722.96	0.50	27.60	9.20	0.50	5480

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Ethylene chlorohydrin	107-07-3	80.50	0.67	2.21E-02	0.09	1.56E-03	28.12	59.59	1.32	3.00	16.00	1.32	45
Ethylene dibromide	106-93-4	188.00	1.50	1.16E-01	0.07	1.32E-03	123.85	262.43	76.80	1.00	0.35	1.00	263
Ethylene glycol	107-21-1	62.00	0.01	1.69E-04	0.10	1.73E-03	0.24	0.50	13.00	100.00	NV	13.00	none
Ethylene glycol dinitrate	628-96-6	152.10	0.01	5.99E-04	0.10	1.73E-03	0.84	1.78	NV	0.10	0.31	0.10	18
Ethylene glycol monobutyl ether acetate	112-07-2	160.00	0.04	2.63E-03	0.10	1.73E-03	3.69	7.82	NV	NV	33.00	33.00	none
Ethylenediamine	107-15-3	60.00	1.30	3.20E-02	0.09	1.66E-03	43.23	91.61	8.37	NV	25.00	8.37	11
Ethyleneimine	151-56-4	43.00	21.30	3.76E-01	0.11	1.83E-03	559.00	1184.46	2.05	NV	0.88	0.88	1346
Formaldehyde solution (37 %)	50-00-0	30.03	0.173	2.1E-03	0.15	2.25E-03	3.89	8.25	2.20	0.12	0.02	0.12	67
Formamide	75-12-7	45.04	0.01	2.40E-04	0.10	1.73E-03	0.34	0.72	150.00	NV	15.00	15.00	none
Formic acid	64-18-6	46.00	4.47	8.44E-02	0.13	2.07E-03	141.87	300.60	43.88	19.00	9.00	19.00	16
Furan	110-00-9	68.08	65.96	1.84E+00	0.09	1.65E-03	2477.23	5248.96	NV	NV	NV	NV	N/A
Furfural	98-01-1	96.08	0.13	5.25E-03	0.10	1.73E-03	7.37	15.62	2.80	NV	7.90	2.80	6
Furfuryl alcohol	98-00-0	98.00	0.13	5.23E-03	0.07	1.36E-03	5.80	12.28	32.07	60.00	40.00	32.07	none
Glutaraldehyde (100 %)	111-30-8	100.00	2.10	8.62E-02	0.07	1.36E-03	95.51	202.36	0.16	0.20	NV	0.16	1302
Glutaraldehyde (50 %)	111-30-8	100.00	0.002	8.21E-05	0.07	1.36E-03	0.09	0.19	0.16	0.20	NV	0.16	1
Glycerin	56-81-5	92.00	3.30E-04	1.25E-05	0.10	1.73E-03	0.02	0.04	NV	NV	5.00	5.00	none
Glycidol	556-52-5	74.00	0.12	3.65E-03	0.10	1.73E-03	5.12	10.85	NV	NV	6.10	6.10	2
Halothane	151-67-7	197.00	32.40	2.62E+00	0.10	1.73E-03	3682.03	7801.79	265.89	16.20	404.00	16.20	482
n-Heptane	142-82-5	100.00	5.30	2.18E-01	0.10	1.73E-03	305.74	647.83	940.70	1800.00	350.00	940.70	none
Hexachlorocyclopentadiene	77-47-4	273.00	0.01	1.23E-03	0.10	1.73E-03	1.73	3.67	2.22	NV	0.10	0.10	37
Hexamethyldisilazane	999-97-3	161.00	2.67	1.76E-01	0.10	1.73E-03	247.61	524.65	NV	NV	NV	NV	N/A
Hexamethylene diisocyanate	822-06-0	168.00	0.01	4.83E-04	0.10	1.73E-03	0.68	1.44	0.07	0.14	0.03	0.07	21
Hexamethylene diisocyanate biuret	4035-89-6	479.00	1.00E-05	1.97E-06	0.10	1.73E-03	0.00	0.01	NV	NV	NV	NV	N/A
1,6-Hexane diamine	124-09-4	116.00	0.40	1.90E-02	0.10	1.73E-03	26.77	56.72	NV	NV	2.30	2.30	25

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
n-Hexane	110-54-3	86.00	16.53	5.84E-01	0.10	1.73E-03	820.06	1737.62	446.58	NV	176.00	176.00	10
Hexanoic acid	142-62-1	116.16	0.03	1.29E-03	0.07	1.36E-03	1.43	3.03	NV	NV	NV	NV	N/A
2-Hexanone	591-78-6	100.00	1.47	6.03E-02	0.10	1.73E-03	84.80	179.68	0.31	40.00	4.00	0.31	578
sec-Hexyl acetate	108-84-9	144.00	0.40	2.36E-02	0.10	1.73E-03	33.23	70.41	2.30	NV	295.00	2.30	31
Hexylene glycol	107-41-5	118.00	0.01	3.20E-04	0.10	1.73E-03	0.45	0.95	19.00	121.00	NV	19.00	none
Hydrazine	302-01-2	32.00	1.30	1.71E-02	0.10	1.73E-03	24.00	50.85	4.84	0.04	0.01	0.04	1271
Hydrobromic acid	10035-10-6	80.91	2.10	6.97E-02	0.10	1.73E-03	98.02	207.69	6.66	9.90	10.00	6.66	31
Hydrochloric acid (10 %)	7647-01-0	36.47	0.001	7.89E-06	0.15	2.28E-03	0.01	0.03	2.39	7.00	NV	2.39	none
Hydrochloric acid (20 %)	7647-01-0	36.47	0.03	4.09E-04	0.10	1.73E-03	0.57	1.22	2.39	7.00	NV	2.39	none
Hydrochloric acid (30 %)	7647-01-0	36.47	1.41	2.12E-02	0.10	1.73E-03	29.73	63.00	2.39	7.00	NV	2.39	26
Hydrochloric acid (35 %)	7647-01-0	36.47	13.30	1.99E-01	0.10	1.73E-03	279.81	592.88	2.39	7.00	NV	2.39	248
Hydrochloric acid (40 %)	7647-01-0	36.47	53.20	7.96E-01	0.10	1.73E-03	1119.15	2371.34	2.39	7.00	NV	2.39	993
Hydrofluoric acid (46 to 53%)	7664-39-3	20.00	14.67	1.20E-01	0.21	2.86E-03	279.80	592.87	0.03	2.30	2.46	0.03	18120
Hydrogen Cyanide (liquid at <26C)	74-90-8	27.00	82.70	9.17E-01	0.17	2.49E-03	1856.28	3933.23	2.12	5.00	11.00	2.12	1854
Hydrogen peroxide (35 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (50 %)	7722-84-1	34.00	0.05	6.98E-04	0.19	2.63E-03	1.49	3.17	NV	NV	1.40	1.40	2
Hydrogen peroxide (70 %)	7722-84-1	34.00	0.10	1.40E-03	0.19	2.63E-03	2.99	6.33	NV	NV	1.40	1.40	5
Hydrogen peroxide (90 %)	7722-84-1	34.00	0.18	2.51E-03	0.19	2.63E-03	5.38	11.39	NV	NV	1.40	1.40	8
Indene	95-13-6	116.15	0.15	7.15E-03	0.10	1.73E-03	10.05	21.30	0.02	NV	45.00	0.02	1067
Isoamyl acetate	123-92-2	130.20	0.54	2.89E-02	0.10	1.73E-03	40.56	85.94	1.17	532.00	266.00	1.17	73
Isoamyl alcohol	123-51-3	88.20	0.32	1.16E-02	0.10	1.73E-03	16.28	34.50	0.16	450.00	360.00	0.16	213
Isobutyl acetate	110-19-0	116.20	1.74	8.30E-02	0.10	1.73E-03	116.64	247.14	5.23	NV	700.00	5.23	47
Isophorone	78-59-1	138.00	0.04	2.27E-03	0.10	1.73E-03	3.18	6.75	1.07	28.00	23.00	1.07	6
Isopropyl acetate	108-21-4	102.20	6.33	2.66E-01	0.10	1.73E-03	373.19	790.75	17.14	836.00	418.00	17.14	46

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LIQUIDS

100	fpm	0.51	m/s
8.8	ft²	0.813	m²
1000	cfm	0.472	m³/s
30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Isopropyl alcohol	67-63-0	60.00	4.41	1.09E-01	0.10	1.73E-03	152.64	323.42	105.52	984.00	491.00	105.52	3
Isopropyl ether	108-20-3	102.20	15.90	6.67E-01	0.10	1.73E-03	937.40	1986.24	0.07	1300.00	1040.00	0.07	27952
Isopropyl glycidyl ether	4016-14-2	116.20	1.26	6.01E-02	0.10	1.73E-03	84.46	178.96	1440.00	240.00	238.00	240.00	none
Isopropylamine	75-31-0	59.10	61.30	1.49E+00	0.10	1.73E-03	2089.89	4428.24	0.51	24.00	12.00	0.51	8724
Iodine	7553-56-2	253.80	0.04	4.17E-03	0.10	1.73E-03	5.86	12.41	9.00	1.00	NV	1.00	12
Kerosene	8008-20-6	175.00	1.40	1.01E-01	0.10	1.73E-03	141.33	299.47	4.70	NV	100.00	4.70	64
Malathion	121-75-5	330.00	5.40E-06	7.32E-07	0.10	1.73E-03	0.001	0.002	13.50	NV	10.00	10.00	none
2-Mercaptoethanol	60-24-2	78.13	8.00	2.57E-01	0.10	1.73E-03	360.57	764.00	0.88	NV	NV	0.88	864
Mercury	7439-97-6	201.00	2.70E-05	2.23E-06	0.11	1.86E-03	0.003	0.01	NV	0.10	0.03	0.10	none
Mesityl oxide	141-79-7	98.20	1.20	4.84E-02	0.10	1.73E-03	67.98	144.04	0.07	100.00	40.00	0.07	2110
Methacrylic acid	79-41-4	86.00	0.09	3.07E-03	0.10	1.73E-03	4.32	9.15	1.90	NV	70.00	1.90	5
Methyl acetate	79-20-9	74.00	23.00	6.99E-01	0.08	1.54E-03	874.09	1852.09	544.79	757.00	606.00	544.79	3
Methyl acrylate	96-33-3	86.00	9.30	3.28E-01	0.10	1.73E-03	461.38	977.61	0.06	NV	7.00	0.06	16026
Methyl alcohol	67-56-1	32.00	13.00	1.71E-01	0.13	2.08E-03	288.77	611.87	209.41	325.00	260.00	209.41	3
Methyl n-amyl ketone	110-43-0	114.00	0.20	9.36E-03	0.10	1.73E-03	13.15	27.87	0.86	NV	233.00	0.86	32
Methyl tert-butyl ether	1634-04-4	88.00	26.80	9.68E-01	0.10	1.73E-03	1360.48	2882.71	0.19	NV	180.00	0.19	15112
Methyl cellosolve	109-86-4	76.09	0.80	2.50E-02	0.10	1.73E-03	35.12	74.40	7.47	NV	0.30	0.30	248
Methyl cellosolve acetate	110-49-6	118.13	0.30	1.45E-02	0.10	1.73E-03	20.44	43.32	1.59	NV	0.50	0.50	87
Methyl ethyl ketone	78-93-3	72.00	10.40	3.07E-01	0.10	1.73E-03	431.96	915.27	47.12	885.00	590.00	47.12	19
N-Methyl aniline	100-61-8	107.15	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	7.84	NV	2.00	2.00	3
Methyl formate	107-31-3	60.00	64.00	1.58E+00	0.09	1.58E-03	2021.86	4284.09	4907.98	368.00	246.00	368.00	12
5-Methyl-2-hexanone (methy isoamyl ketone)	110-12-3	114.00	0.67	3.14E-02	0.10	1.73E-03	44.06	93.36	0.63	NV	234.00	0.63	148
Methyl iodide	74-88-4	142.00	53.20	3.10E+00	0.10	1.73E-03	4357.89	9233.85	NV	NV	10.00	10.00	923
Methyl isobutyl carbinol	108-11-2	102.18	0.37	1.55E-02	0.10	1.73E-03	21.81	46.21	20.40	165.00	100.00	20.40	2

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Methyl isobutyl ketone (MIBK)	108-10-1	100.00	0.80	3.28E-02	0.06	1.29E-03	34.37	72.82	3.60	300.00	205.00	3.60	20
Methyl isocyanate	624-83-9	57.05	46.00	1.08E+00	0.10	1.73E-03	1513.87	3207.72	4.90	NV	0.05	0.05	68249
Methyl methacrylate	80-62-6	100.13	3.87	1.59E-01	0.07	1.35E-03	174.21	369.14	0.20	410.00	205.00	0.20	1840
Methyl propyl ketone	107-87-9	86.17	3.60	1.27E-01	0.10	1.73E-03	178.95	379.18	27.14	881.00	530.00	27.14	14
n-Methyl-2-pyrrolidinone	872-50-4	99.15	0.04	1.59E-03	0.10	1.73E-03	2.23	4.73	41.00	NV	NV	41.00	none
Methyl salicylate	119-36-8	152.00	0.01	8.11E-04	0.10	1.73E-03	1.14	2.42	0.74	NV	NV	0.74	3
Methylcyclohexane	108-87-2	98.00	4.90	1.97E-01	0.10	1.73E-03	277.01	586.96	2000.00	NV	NV	2000.00	none
Methylcyclohexanol	25639-42-3	114.20	0.27	1.27E-02	0.10	1.73E-03	17.79	37.69	2350.00	NV	NV	2350.00	none
o-Methylcyclohexanone	583-60-8	112.20	0.13	5.99E-03	0.10	1.73E-03	8.41	17.83	NV	NV	NV	NV	N/A
Methylcyclopentadienyl manganese tricarbonyl	12108-13-3	218.00	0.01	6.00E-04	0.10	1.73E-03	0.84	1.79	NV	NV	0.20	0.20	9
Methylacrylonitrile	126-98-7	67.09	9.00	2.48E-01	0.10	1.73E-03	348.32	738.05	15.87	NV	2.70	2.70	273
Methylal	109-87-5	76.10	44.10	1.38E+00	0.10	1.73E-03	1935.97	4102.10	NV	NV	3100.00	3100.00	1
Methylene bisphenyl isocyanate	101-68-8	250.00	1.86E-05	1.91E-06	0.10	1.73E-03	0.003	0.01	3.99	0.20	0.05	0.20	none
Methylene chloride	75-09-2	85.00	53.00	1.85E+00	0.10	1.73E-03	2598.79	5506.53	556.24	435.00	87.00	435.00	13
Methylene iodide	75-11-6	268.00	0.09	9.98E-03	0.10	1.73E-03	14.02	29.71	NV	NV	10.00	10.00	3
N-Methylimidazole	616-47-7	82.11	0.05	1.80E-03	0.10	1.73E-03	2.52	5.35	NV	NV	NV	NV	N/A
N-Methylmorpholine	109-02-4	101.00	0.67	2.76E-02	0.10	1.73E-03	38.84	82.29	NV	NV	NV	NV	N/A
alpha-Methyl styrene	98-83-9	118.20	0.31	1.49E-02	0.10	1.73E-03	20.93	44.35	15.48	480.00	240.00	15.48	3
Methylamine (40 %)	74-89-5	31.00	31.50	4.01E-01	0.10	1.73E-03	563.31	1193.59	5.96	19.00	6.40	5.96	200
Morpholine	110-91-8	87.12	0.90	3.22E-02	0.10	1.73E-03	45.23	95.84	0.04	105.00	70.00	0.04	2445
Naphtha (coal tar)	8030-30-6	110.00	3.47	1.57E-01	0.10	1.73E-03	219.94	466.02	420.00	NV	400.00	400.00	1
Naphthalene	91-20-3	128.00	0.01	3.78E-04	0.10	1.73E-03	0.53	1.13	0.20	75.00	50.00	0.20	6
1-Naphthol	90-15-3	144.00	0.13	7.86E-03	0.10	1.73E-03	11.05	23.41	NV	NV	NV	NV	N/A

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LIQUIDS

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Nickel carbonyl	13463-39-3	171.00	43.00	3.02E+00	0.10	1.73E-03	4241.71	8987.68	8.57	NV	0.01	0.01	1283954
Nicotine	54-11-5	162.00	0.01	3.79E-04	0.10	1.73E-03	0.53	1.13	NV	NV	0.50	0.50	2
Nitric acid (70 %)	7697-37-2	63.02	0.73	1.89E-02	0.13	2.07E-03	31.77	67.31	0.70	10.00	5.00	0.70	97
Nitric acid (90 %)	7697-37-2	63.02	6.39	1.65E-01	0.13	2.07E-03	278.06	589.17	0.70	10.00	5.00	0.70	847
Nitrobenzene	98-95-3	123.11	0.02	1.01E-03	0.10	1.73E-03	1.42	3.01	1.86	NV	5.00	1.86	2
Nitroethane	79-24-3	75.00	2.08	6.40E-02	0.10	1.73E-03	89.99	190.68	620.00	NV	307.00	307.00	none
Nitroglycerin	55-63-0	227.00	3.46E-05	3.22E-06	0.10	1.73E-03	0.00	0.01	NV	0.10	0.46	0.10	none
Nitromethane	75-52-5	61.00	3.70	9.26E-02	0.10	1.73E-03	130.20	275.88	124.00	NV	50.00	50.00	6
1-Nitropropane	108-03-2	89.09	1.01	3.69E-02	0.10	1.73E-03	51.91	109.98	510.13	NV	90.00	90.00	1
2-Nitropropane	79-46-9	89.09	1.74	6.36E-02	0.10	1.73E-03	89.42	189.48	556.53	NV	36.00	36.00	5
Nitrotoluene (m isomers)	99-08-1	137.10	0.01	7.32E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
Nitrotoluene (o isomers)	88-72-2	137.00	0.01	8.27E-04	0.10	1.73E-03	1.16	2.46	0.10	NV	11.00	0.10	26
Nitrotoluene (p isomers)	99-99-0	137.00	0.01	7.31E-04	0.10	1.73E-03	1.03	2.18	0.10	NV	11.00	0.10	23
Octane	111-65-9	114.22	1.39	6.52E-02	0.05	1.10E-03	58.46	123.88	700.74	1800.00	350.00	700.74	none
1-Octanol	111-87-5	130.20	0.01	4.65E-04	0.05	1.16E-03	0.44	0.93	0.69	NV	NV	0.69	1
2-Octanol	123-96-6	130.20	0.13	7.12E-03	0.05	1.16E-03	6.71	14.21	NV	NV	NV	NV	N/A
Oleic Acid	112-80-1	282.47	7.28E-08	8.44E-09	0.07	1.34E-03	0.00	0.00	44.00	NV	NV	44.00	none
Osmium tetroxide	20816-12-0	254.00	0.93	9.70E-02	0.10	1.73E-03	136.27	288.74	0.02	0.005	0.002	0.005	61433
Oxalic acid	144-62-7	126.00	1.30E-04	6.72E-06	0.10	1.73E-03	0.01	0.02	NV	2.00	1.00	2.00	none
Oxo-heptyl acetate	90438-79-2	158.00	0.11	6.92E-03	0.10	1.73E-03	9.73	20.61	NV	NV	NV	NV	N/A
Oxo-hexyl acetate	88230-35-7	144.00	0.19	1.10E-02	0.10	1.73E-03	15.51	32.86	0.93	NV	NV	0.93	35
Pentaborane	19624-22-7	63.17	23.00	5.96E-01	0.10	1.73E-03	838.14	1775.91	2.51	0.03	0.01	0.03	59197
Pentachlorophenol	87-86-5	266.00	1.50E-05	1.64E-06	0.10	1.73E-03	0.002	0.005	NV	NV	0.50	0.50	none
Pentane	109-66-0	72.00	65.00	1.92E+00	0.10	1.73E-03	2699.74	5720.43	1087.95	1800.00	350.00	1087.95	5

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
2-Pentanol	6032-29-7	88.20	1.33	4.82E-02	0.07	1.35E-03	52.94	112.17	NV	NV	NV	NV	N/A
3-Pentanol	584-02-1	88.20	0.27	9.67E-03	0.07	1.35E-03	10.63	22.52	NV	NV	NV	NV	N/A
Pentyl mercaptan	110-66-7	104.20	18.40	7.87E-01	0.10	1.73E-03	1106.02	2343.52	NV	2.10	NV	2.10	1116
Perchloromethyl mercaptan	594-42-3	186.00	8.70	6.64E-01	0.10	1.73E-03	933.49	1977.95	0.01	NV	0.76	0.01	263727
Phenol	108-95-2	94.00	0.05	1.93E-03	0.07	1.40E-03	2.20	4.66	0.23	60.00	19.00	0.23	20
Phenyl ether	101-84-8	170.20	0.003	1.89E-04	0.05	1.09E-03	0.17	0.35	0.07	14.00	7.00	0.07	5
Phenyl glycidyl ether	122-60-1	150.00	0.001	6.16E-05	0.10	1.73E-03	0.09	0.18	NV	6.00	0.60	6.00	none
Phenyl isocyanate	103-71-9	119.12	0.20	9.78E-03	0.08	1.44E-03	11.41	24.18	NV	NV	NV	NV	N/A
Phenylhydrazine	100-63-0	108.00	0.01	2.22E-04	0.10	1.73E-03	0.31	0.66	NV	0.60	0.44	0.60	1
Phosphoric acid (75 %)	7664-38-2	98.00	0.75	3.02E-02	0.10	1.72E-03	42.12	89.24	NV	3.00	1.00	3.00	30
Phosphoric acid (85 %)	7664-38-2	98.00	0.29	1.17E-02	0.10	1.72E-03	16.32	34.59	NV	3.00	1.00	3.00	12
Phosphorus oxychloride	10025-87-3	153.30	5.32	3.35E-01	0.10	1.73E-03	470.47	996.87	NV	3.00	0.60	3.00	332
Phosphorus trichloride	7719-12-2	137.00	13.00	7.31E-01	0.10	1.73E-03	1027.40	2176.94	NV	2.80	1.10	2.80	777
Phthalic acid	88-99-3	166.14	0.13	8.87E-03	0.06	1.18E-03	8.49	17.99	NV	NV	NV	NV	N/A
Piperidine	110-89-4	85.00	5.30	1.85E-01	0.10	1.73E-03	259.88	550.65	1.29	NV	NV	1.29	426
Potassium Hydroxide	1310-58-3	56.00	0.27	6.21E-03	0.10	1.73E-03	8.72	18.48	NV	2.00	2.00	2.00	9
Propargyl alcohol	107-19-7	56.00	1.55	3.56E-02	0.10	1.73E-03	50.07	106.10	0.03	NV	2.00	0.03	3088
Propionaldehyde	123-38-6	58.08	29.00	6.91E-01	0.09	1.62E-03	911.22	1930.78	0.21	NV	48.00	0.21	9194
beta-Propiolacetone	57-57-8	72.10	0.31	9.09E-03	0.10	1.73E-03	12.77	27.06	NV	NV	1.50	1.50	18
Propionic acid	79-09-4	74.10	0.40	1.22E-02	0.08	1.55E-03	15.32	32.46	0.20	45.00	30.00	0.20	162
n-Propyl acetate	109-60-4	102.13	3.30	1.38E-01	0.07	1.32E-03	148.87	315.43	0.75	1040.00	835.00	0.75	420
n-Propyl alcohol	71-23-8	60.09	2.00	4.93E-02	0.09	1.55E-03	62.21	131.81	13.03	614.00	492.00	13.03	10
n-Propyl nitrate	627-13-4	105.00	2.40	1.03E-01	0.10	1.73E-03	145.37	308.02	210.00	170.00	105.00	170.00	2
Propylene Dichloride	78-87-5	113.00	5.73	2.66E-01	0.10	1.73E-03	373.52	791.44	1.20	508.00	347.00	1.20	659

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Propylene glycol	57-55-6	76.10	0.13	4.17E-03	0.08	1.52E-03	5.16	10.92	16.00	NV	NV	16.00	none
Propylene glycol 1-methyl ether	107-98-2	90.00	1.60	5.91E-02	0.10	1.73E-03	83.07	176.01	121.00	540.00	360.00	121.00	1
Propylene glycol-1-methyl ether-2-acetate	108-65-6	132.00	0.50	2.71E-02	0.10	1.73E-03	38.07	80.67	0.70	NV	NV	0.70	115
Propylene imine	75-55-8	57.10	15.00	3.52E-01	0.10	1.73E-03	494.09	1046.91	NV	NV	4.70	4.70	223
Propylene oxide	75-56-9	58.00	59.00	1.40E+00	0.10	1.73E-03	1974.04	4182.76	106.75	NV	4.80	4.80	871
Pyridine	110-86-1	79.10	2.40	7.79E-02	0.10	1.73E-03	109.51	232.04	2.14	NV	15.00	2.14	109
Quinone	106-51-4	108.00	0.02	9.75E-04	0.10	1.73E-03	1.37	2.90	0.40	NV	0.40	0.40	7
Sodium Hydroxide (50%)	1310-73-2	40.01	0.20	3.28E-03	0.10	1.73E-03	4.62	9.78	NV	NV	2.00	2.00	5
Stoddard solvent (Mineral spirits)	8052-41-3	144.00	0.53	3.13E-02	0.10	1.73E-03	44.03	93.29	28.76	1800.00	350.00	28.76	3
Styrene, monomer	100-42-5	104.00	0.57	2.43E-02	0.10	1.73E-03	34.20	72.46	0.60	170.00	85.00	0.60	122
Sulfamic acid	5329-14-6	97.10	0.01	5.18E-04	0.09	1.57E-03	0.66	1.40	NV	NV	NV	NV	N/A
Sulfur monochloride	10025-67-9	135.00	0.90	4.99E-02	0.10	1.73E-03	70.09	148.51	0.01	5.50	6.00	0.01	26897
Sulfur pentafluoride	5714-22-7	254.10	75.10	7.83E+00	0.10	1.73E-03	11008.31	23325.31	NV	0.10	0.25	0.10	233253
Sulfuric acid (100 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (98 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (93 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
Sulfuric acid (78 %)	7664-93-9	98.00	0.04	1.61E-03	0.10	1.73E-03	2.26	4.79	0.60	3.00	1.00	0.60	8
1,1,2,2-Tetrachloroethane	79-34-5	167.90	0.67	4.62E-02	0.10	1.73E-03	64.89	137.50	50.13	NV	6.90	6.90	20
Tetrachloroethylene	127-18-4	166.00	1.87	1.27E-01	0.10	1.73E-03	179.07	379.43	319.10	685.00	170.00	319.10	1
Tetraethyl lead	78-00-2	323.00	0.02	2.65E-03	0.10	1.73E-03	3.73	7.90	NV	NV	0.08	0.08	105
Tetrahydrofuran	109-99-9	72.10	19.00	5.62E-01	0.10	1.73E-03	790.25	1674.45	91.42	735.00	590.00	91.42	18
Tetramethyl lead	75-74-1	267.30	3.30	3.62E-01	0.10	1.73E-03	508.85	1078.19	NV	NV	0.08	0.08	14376
Tetranitromethane	509-14-8	196.00	1.10	8.85E-02	0.10	1.73E-03	124.37	263.53	NV	NV	0.04	0.04	6588
Thioglycolic acid	68-11-1	92.10	1.33	5.03E-02	0.10	1.73E-03	70.66	149.72	NV	NV	3.80	3.80	39

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LIQUIDS

100	fpm	0.51	m/s
8.8	ft²	0.813	m²
1000	cfm	0.472	m³/s
30480		0.0048	<===Chilton-Colburn j-Factor

Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Thionyl chloride	7719-09-7	118.90	13.30	6.49E-01	0.09	1.56E-03	822.00	1741.73	NV	4.90	NV	4.90	355
Toluene	108-88-3	92.00	2.90	1.10E-01	0.08	1.44E-03	128.18	271.59	6.02	560.00	188.00	6.02	45
Toluene-2,4-diisocyanate	584-84-9	174.00	0.003	2.36E-04	0.10	1.73E-03	0.33	0.70	7.40	0.14	0.04	0.14	5
m-Toluidine	108-44-1	107.20	0.13	5.85E-03	0.10	1.73E-03	8.22	17.43	7.22	NV	8.80	7.22	2
o-Toluidine	95-53-4	107.20	0.04	1.76E-03	0.10	1.73E-03	2.47	5.24	1.78	NV	8.80	1.78	3
Tributyl phosphate	126-73-8	266.30	0.001	5.79E-05	0.10	1.73E-03	0.08	0.17	NV	NV	2.20	2.20	none
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	187.40	37.80	2.91E+00	0.10	1.73E-03	4086.37	8658.53	592.36	9500.00	7600.00	592.36	15
1,2,4-Trichlorobenzene	120-82-1	181.46	0.13	9.91E-03	0.10	1.73E-03	13.92	29.50	21.97	37.00	NV	21.97	1
1,1,1-Trichloroethane	71-55-6	133.42	17.00	9.31E-01	0.10	1.73E-03	1308.42	2772.38	2128.17	1910.00	1900.00	1910.00	1
1,1,2-Trichloroethane	79-00-5	133.00	2.53	1.38E-01	0.10	1.73E-03	194.11	411.30	NV	NV	45.00	45.00	9
Trichloroethylene	79-01-6	131.40	7.70	4.15E-01	0.07	1.38E-03	466.65	988.78	440.69	11.00	134.00	11.00	90
Trichlorofluoromethane	75-69-4	137.00	92.00	5.17E+00	0.10	1.73E-03	7270.84	15406.05	181.03	5600.00	5600.00	181.03	85
1,2,3-Trichloropropane	96-18-4	147.40	0.40	2.42E-02	0.10	1.73E-03	34.01	72.07	40.31	NV	60.00	40.31	2
Triethanolamine	102-71-6	149.00	0.005	2.87E-04	0.10	1.73E-03	0.40	0.86	61.00	NV	5.00	5.00	none
Triethylamine	121-44-8	101.00	7.20	2.99E-01	0.08	1.51E-03	365.54	774.54	1.03	12.40	4.10	1.03	750
Triethylene glycol	112-27-6	150.20	0.0001	8.02E-06	0.08	1.47E-03	0.01	0.02	NV	NV	NV	NV	N/A
Trifluoroacetic acid	76-05-1	114.00	14.30	6.69E-01	0.08	1.49E-03	812.45	1721.48	NV	NV	NV	NV	N/A
Trimethylamine (40 %)	75-50-3	59.00	67.30	1.63E+00	0.10	1.73E-03	2290.57	4853.44	0.01	36.00	12.00	0.01	822618
1,2,4-Trimethylbenzene (as mixed isomers)	95-63-6	120.00	0.13	6.55E-03	0.10	1.73E-03	9.21	19.51	11.78	NV	123.00	11.78	2
2,2,4-Trimethylpentane	540-84-1	114.30	5.50	2.58E-01	0.08	1.49E-03	313.25	663.73	NV	1800.00	350.00	1800.00	none
2,4,6-Trimethylpyridine	108-75-8	121.20	0.27	1.33E-02	0.08	1.49E-03	16.06	34.03	NV	NV	NV	NV	N/A
Turpentine	8006-64-2	136.00	0.70	3.91E-02	0.10	1.73E-03	54.92	116.36	791.96	NV	556.00	556.00	none
n-Valeraldehyde	110-62-3	86.00	6.70	2.37E-01	0.10	1.73E-03	332.39	704.30	0.25	NV	175.00	0.25	2855
Vinyl acetate	108-05-4	86.00	11.10	3.92E-01	0.10	1.73E-03	550.68	1166.82	0.42	15.00	35.00	0.42	2764

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LIQUIDS

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Chemical	CHEMICAL PROPERTIES								ODOUR	HEALTH LIMITS		HEALTH / ODOUR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m³)	Diffusivity in Air (cm²/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m³)	Mean Odour Threshold (mg/m³)	Short-Term Health Limit (mg/m³)	Long-Term Health Limit (mg/m³)	Limiting Value (mg/m³)	Maximum Required Dilution Health / Odour
Vinyl toluene	25013-15-4	118.00	0.15	7.12E-03	0.10	1.73E-03	10.01	21.20	240.00	483.00	242.00	240.00	none
Xylene (o,m, p-isomers)	1330-20-7	106.16	0.87	3.79E-02	0.10	1.73E-03	53.28	112.89	86.84	651.00	434.00	86.84	1
Xylidine	1300-73-8	121.20	20.00	9.95E-01	0.10	1.73E-03	1398.33	2962.89	0.08	NV	2.50	0.08	35160

All chemical properties can be referenced to Canadian Centre for Occupational Health and Safety
www.ccohs.ca

TWA is typically for an 8-hour averaging period.
STEL is typically for a 15-minute averaging period.
Ceiling limit (C) was used if there was no STEL.
NV indicates no value for air quality or odour standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

References for Odour Thresholds:
1) AIHA, 1989. Odour Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.
2) Nagy, G.Z., 1991. The odour impact model. Journal of the Air Waste Management Association, p. 1360-1362.
3) Ruth, J.H., 1986. Odour thresholds and irritation levels of several chemicals: a review. Journal of the American Industrial Hygienists Association, 47:A-142-A-151.
4) 3M - Occupational Health and Environmental Safety Division. 2000 Respirator Selection Guide. November 1999. www.3M.com/occsafety.

Maximum Required Dilution is based on:
1) Minimum of STEL or C of ACGIH, OSHA, and NIOSH limits(short-term health);
2) Minimum of TWA of ACGIH, OSHA, and NIOSH limits(long-term health);
3) Odour threshold based on priority of resource used.
The minimum value out of the health and the odour values was used with the short term health limit taking precedence over the long-term health limit.