AMERICAN UNIVERSITY – LIFE SCIENCES BUILDING

WASHINGTON, DC

BUILDING AIR QUALITY

RWDI #1502179

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SUBMITTED TO

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EXECUTIVE SUMMARY

Wind tunnel dispersion modeling was completed to assess air quality conditions and provide recommendations pertaining to the proposed Life Sciences Building located in Washington, DC. The primary conclusions and recommendations from the assessment are summarized below.

- The proposed manifolded fume hood exhausts met the recommended dilution criterion (which addresses both health and odor-based impacts) at all receptors assessed for both maximum flow and normal flow conditions. The recommended criterion was also met for a turndown scenario to a minimum of 50% of full flow conditions. The dilution level at the nearby residences were predicted to be at least nine time greater than the recommended target. No design modifications are recommended.

- The proposed vivarium and cage wash exhausts met the recommended odor-based dilution criterion at all the receptors assessed under all wind conditions. No design modifications are recommended.

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1 INTRODUCTION

Rowan Williams Davies & Irwin Inc. (RWDI) was retained to conduct an air quality assessment for the proposed Life Sciences Building at American University in Washington, DC. This final report presents the study objectives, approach, results and recommendations.

The purpose of the present assessment was to evaluate potential air quality impacts at on-site and off-site air sensitive receptors (i.e. air intakes and operable windows) from proposed exhausts on the Life Sciences building.

2 APPROACH

2.1 Dispersion Modeling

The assessment was accomplished by performing detailed tracer gas wind tunnel dispersion modeling on a 1:400 scale model of the proposed Life Sciences Building and surroundings including the residential buildings to the east of the campus. Wind tunnel modeling is considered to be the most accurate method of replicating airflow patterns around buildings and quantifying the effects these patterns have on exhaust dispersion. Photographs of the scale model in one of RWDI's boundary layer wind tunnels are presented below.

Testing was conducted by releasing a tracer gas of known concentration from each exhaust source and taking measurements at selected receptors under the influence of a full array of approaching winds. Mean concentrations of tracer gas at selected receptor locations were measured by drawing samples through flush-mounted tubes leading to a bank of infrared analyzers stationed outside the tunnel. Tests were completed for a range of wind directions and speeds in order to characterize dispersion of the exhaust in the context of the local aerodynamic conditions, including local topography, upwind terrain and building effects. Building effects were captured by constructing scale models of all buildings and structures with a 1,600-ft. radius of the proposed Life Sciences Building, while upwind terrain conditions were simulated by means of roughness elements and spires.

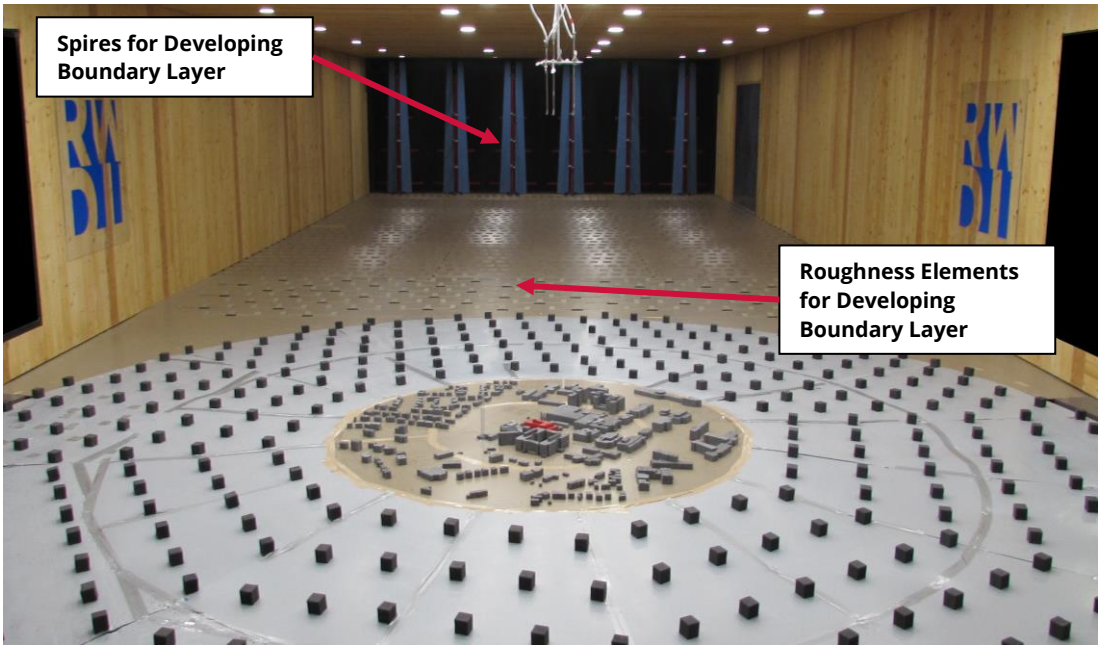


Image 1 - Photograph of Study Model in RWDI Boundary Layer Wind Tunnel

Image 2 - Close-Up Photograph of the of Study Model

2.2 Exhaust Sources and Receptors Assessed

Potential air quality impacts were evaluated from the exhaust sources summarized in Table 1, as per the detailed dispersion modeling methods outlined above. Air quality impacts are defined as adverse changes to the quality of air that reaches sensitive receptors such as building air intakes, openable windows, and sensitive outdoor spaces. This could take the form of high chemical emissions or odors. The specific impact of interest depends on the source, receptor, and goals of the assessment.

Table 1 - Summary of Exhaust Sources Modeled

Source Label	Source Description	Location	Emissions/Impacts of Interest
F1-F5	EF-1A to EF-1E: Proposed Laboratory Fume Hood Exhausts (5) (MK Plastics AXIJET-S 4025)	Life Sciences Building Roof	Chemical Emissions
F6-F7	EF-2A to EF-2B: Proposed Vivarium Exhausts (1+1) (MK Plastics AXIJET-S 2700)		Animal Odors
F8	EF-3: Cage Wash Exhaust (1) (COOK 120 CP)		Animal Odors

Specific details on the parameters modeled for each source listed in Table 1 are presented in Section 3.

Dispersion of the exhaust from sources listed in Table 1 was assessed at receptors representing outside air intakes serving occupied spaces, outdoor pedestrian areas, and passive air intakes such as operable windows[1]. These receptor locations are summarized in Table 2 with their locations illustrated in Figures 1 and 2.

Table 2 - Summary of Receptor Locations Modeled

Receptor Labels	Building	Approximate Elevation	Façade	Description
R1-R2	Life Science Building	Penthouse	South	Proposed OA Intake Louvers
R3	Centennial Hall	Level 7	Northeast	Representative Operable Windows
R4-R5	Anderson Hall		North	
R6	Leonard Hall	Level 8	East	
R7	Cassell Hall		South	
R8	School of International Service	Roof	n/a	Rooftop Air Intake
R9	Battelle-Tomkins Building			
R10	Constitution Hall			
R11	Bender Arena			
R12-R15	Residences	Level 2	n/a	Representative Air Sensitive Locations

[1] The representative receptors on the surrounding buildings was selected based on the communication with the design team.

Receptor Labels	Building	Approximate Elevation	Façade	Description
R16	Beeghly Building	Roof	n/a	Rooftop Air Intake

2.3 Criteria

For design purposes, RWDI applies dilution criteria to assess air quality impacts 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:

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

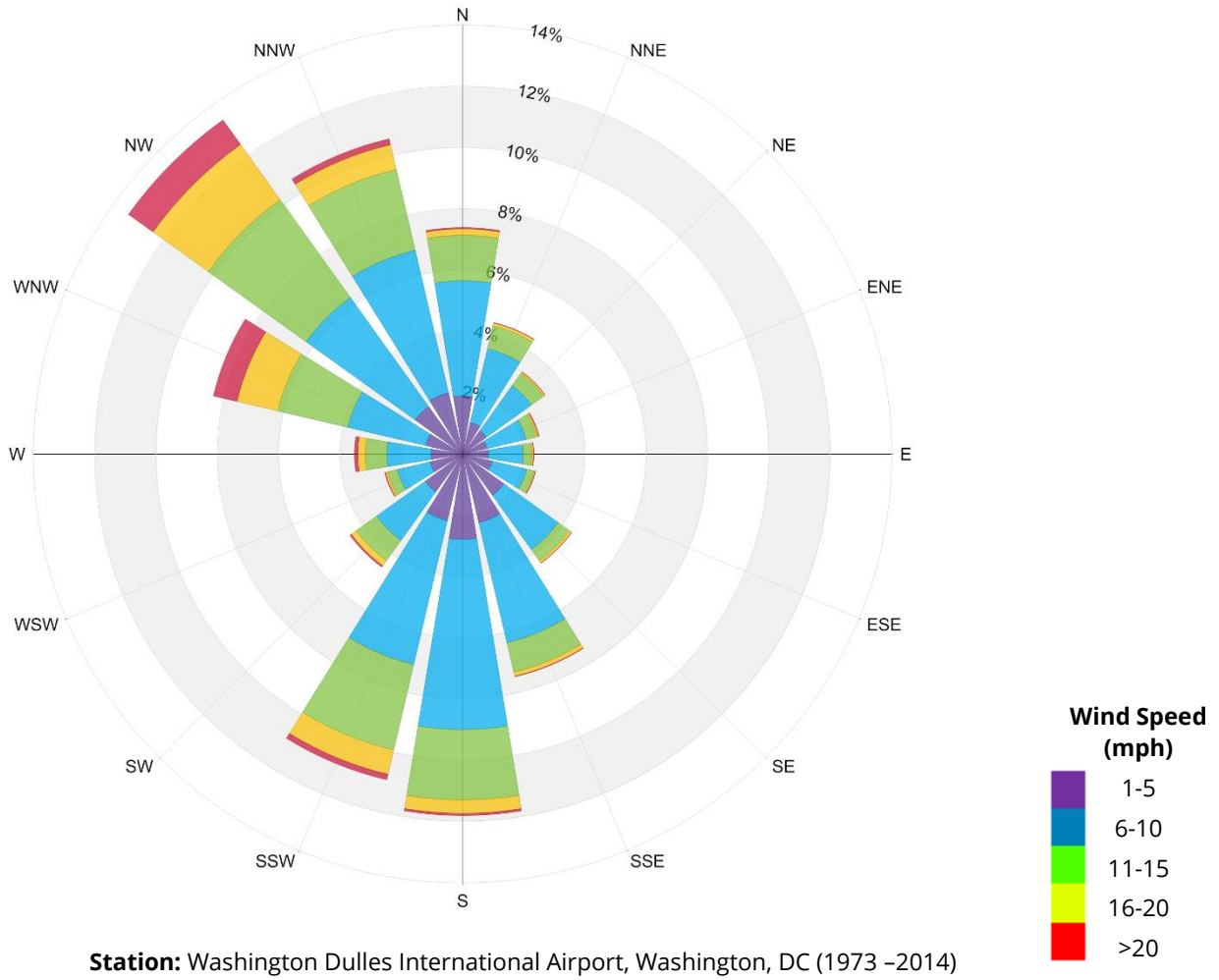
Dilution criteria for good design practice are developed for each exhaust source, and are based on specific odor emissions, air quality exposure limits, and/or odor thresholds. The design objective is for exhaust to be well diluted, at a level equal to or greater than the criteria, at all important receptors to achieve acceptable air quality. The dilution criteria applied for each of the exhaust sources evaluated are summarized in Table 3, and discussed in detail in Appendix A.

Table 3 - Summary of Dilution Criteria Applied

Source Label(s)	Exhaust Type	Recommended Dilution Criterion	Basis
F1-F5	Laboratory Fume Hoods	3,000:1 (Health & Odor)	• Based on a worst-case representative liquid chemical spill (or representative gaseous release) in a single fume hood. • Meets health and odor limits for the majority of substances on an extensive representative list of chemicals developed by RWDI.
F6-F8	Vivarium and Cage Wash	100:1 (Odor)	• Dilution required to meet a 50% odor detection threshold for vivarium spaces and associated activities.

2.4 Wind Climate

RWDI reviewed wind data from the Washington Dulles International Airport, the closest meteorological station with a substantial and recent data set used to estimate wind conditions at the site. A summary of the directional distribution of winds over a period from 1973 to 2014 is shown below. 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 center.



Station: Washington Dulles International Airport, Washington, DC (1973 –2014)

Image 3 - Directional Distribution (%) of Winds

Historical wind data can be used to estimate of the percent of time that wind conditions resulting in dilution levels less than the indicated dilution criteria are expected to occur, using a statistical analysis combined with wind tunnel results.

3 RESULTS AND RECOMMENDATIONS

Dispersion modeling results are presented and discussed in the following sections with worst-case predicted dilutions compared to recommended criteria.

3.1 Proposed Laboratory Fume Hood Exhausts (Sources F1-F5)

The proposed laboratory fume hood exhausts will be located on the east side of the penthouse with stacks discharging at a height that is flush with the top of the adjacent screen wall. During normal operations, all five fans will operate simultaneously at 80% capacity. In the event that one fan is not operational, four fans will operate at 100% capacity. The exhausts were also assessed at a lower flow rate of 50% of maximum capacity to investigate energy saving potential during low building occupancy periods. Exhaust parameters for each flow scenarios are summarized below, with results outlined in Table 4 for the minimum turndown scenario as the worst-case operating condition.

Exhaust parameters modelled:

Exhaust Sources:	F1-F5	F1-F5	F1-F5
Operation Scenario:	4 @ 100% capacity (Maximum Capacity)	5 @ 80% capacity (Normal Operation)	5 @ 50% capacity (Minimum Turndown)
Exhaust Flow Rate:	28,750 cfm	23,000 cfm	14,375 cfm
Stack Exit Velocity:	6,549 fpm	5,239 fpm	3,275 fpm
Stack Height:	Flush with Top of Screen Wall	Flush with Top of Screen Wall	Flush with Top of Screen Wall

Summary of Results:

Table 4 - Summary of Modeling Results for the Proposed Laboratory Fume Hood Exhausts (Sources F1-F5) – Normal and Turndown Flow Rate Operations

Receptor Label	Receptor Description	Dilution Criterion Applied	Worst-Case Dilution Level	
			80% capacity	50% capacity
R1-R2	Proposed OA Intake Louver	3000:1 (Health and Odor)	6,920:1	3,320:1
R3-R7	Representative Operable Windows		23,160:1	11,830:1
R8-R11, R16	Existing Rooftop Air Intake		14,830:1	10,130:1
R12-R15	Representative Air Sensitive Receptors on Residences		47,000:1	27,500:1

3.1.1 Discussion

The results are compared to a dilution criterion of 3,000:1, developed based on a chemical spill scenario covering the surface of a typical fume hood. This represents a typical worst-case emission scenario for fume hood exhausts.

The proposed manifolded fume hood exhausts met the recommended 3,000:1 criterion at all receptors assessed and for all wind conditions considered both for the maximum and normal operating scenarios. Results indicated that the fans can also be safely turned down to a minimum of 50% of maximum flow condition (i.e. 14,375 cfm and 3,275 fpm) during the low occupancy period for energy saving purposes. Resulting dilution levels at representative off-campus residences were predicted to be at least nine times greater than the recommended criterion. No design modifications are recommended.

3.2 Proposed Vivarium and Cage Wash Exhausts (Sources F6-F8)

The proposed vivarium and cage wash exhausts will be located on the east side the roof with the stacks discharging flush with the top of the adjacent screen wall. The fans were evaluated for simultaneous operation under full flow rate condition assuming 100% odorous air. Exhaust parameters for each stack are summarized below, followed by the worst-case dilution results presented in Table 5.

Exhaust parameters modelled:

Exhaust Source:	F6-F7	F8
Operation Scenario:	1 @ 100% capacity	1 @ 100% capacity
Exhaust Flow Rate:	12,000 cfm	2,000 cfm
Stack Exit Velocity:	6,101 fpm	3,031 fpm
Stack Height:	Flush with Top of Screen Wall	Flush with Top of Screen Wall

Summary of Results:

Table 5 - Summary of Modeling Results for the Proposed Vivarium and Cage Wash Exhausts (Sources F6-F8)

Receptor Label	Receptor Description	Dilution Criterion Applied	Worst-Case Dilution Level
R1-R2	Proposed OA Intake Louver	100:1 (Odor)	295:1
R3-R7	Representative Operable Windows		555:1
R8-R11, R16	Existing Rooftop Air Intake		835:1
R12-R15	Representative Air Sensitive Receptors on Residences		1,635:1

3.2.1 Discussion

RWDI recommends a dilution criterion of 100:1 to address odors pertaining to the animal holding spaces. As seen in Table 5, the vivarium and cage wash exhausts met the recommended at all receptors assessed for all wind conditions considered. No design changes are recommended.

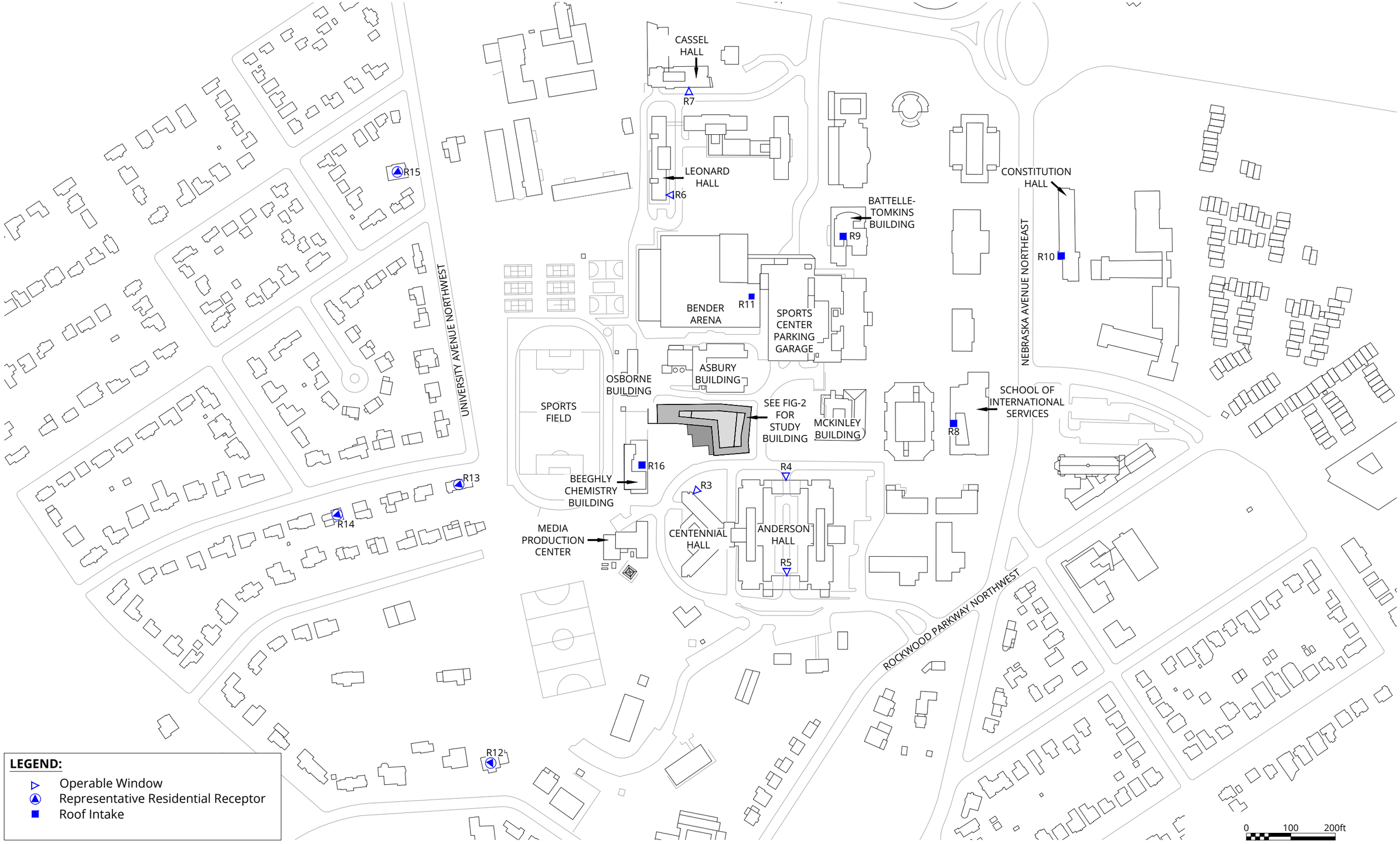
4 APPLICABILITY

The results and recommendations presented in this report pertain to the proposed Life Sciences Building as detailed in the architectural design drawings listed in Table 6, mechanical drawings and information received up to and including October 16, 2017, the exhaust parameters presented in Section 3, and the exhaust and receptor locations shown in Figures 1 and 3. Should there be any design changes that deviate from these parameters, the building and local air quality conditions may change. It is therefore recommended that RWDI be contacted and requested to review the potential effects of design changes. Also, note that the work described herein was conducted for the purposes of providing design guidance only. Modeling and/or other work in support of regulatory requirements was not conducted and may require separate study.

Table 6 - Drawing List

File Name	File Type	Date Received (dd/mm/yyyy)
A-15057.00-R17-CENTRAL.rvt	Revit	12-09-2017
AU LSB Schematic Design Revised Drawings.pdf	Adobe Portable Document Format	16-08-2017

FIGURES



LEGEND:

- Operable Window
- Representative Residential Receptor
- Roof Intake

Location of Existing Receptors Evaluated

American University Life Science Building - Washington, DC

True North

Project #1502179

Drawn by: DBB	Figure: 1
Approx. Scale:	1"=250'
Date Revised:	Sept. 26, 2017

SPORTS CENTER
PARKING GARAGE

OSBORNE
BUILDING

ASHBURY BUILDING

SPORTS
FIELD

R2

F1-F5

F8

F6-F7

R1

MCKINLEY
BUILDING

BEEGHLY
CHEMISTRY
BUILDING

ANDERSON
HALL

MEDIA
PRODUCTION
CENTER

LEGEND:

- Exhaust Stack
  - F1-F5: Manifolded Fume Hood Exhausts
  - F6-F7: Vivarium Exhausts
  - F8: Cage Wash Exhaust
- ▶ Air Intake Louver

0 30 60ft

Location of Proposed Exhaust Sources and Receptors Evaluated

American University Life Science Building - Washington, DC

True North

Project #1502179

Drawn by:	DBB	Figure:	2
Approx. Scale:	1"=60'		
Date Revised:	Sept. 26, 2017		

APPENDIX A

APPENDIX A: DISCUSSION OF DILUTION CRITERIA

Laboratory Exhausts

Laboratory Chemical Fume Hood Exhausts

For laboratory fume hood exhausts, RWDI suggests a minimum target dilution of 3,000:1, referenced to a 1,000 cfm exhaust flow rate. This dilution criterion is applied for design purposes and assumes that only one major spill (spill volume of several hundred milliliters) of any particular chemical would occur in any one fume hood at any one time. The one major spill can also represent the accumulated small, routine emissions from multiple fume hoods simultaneously if certain chemicals are used in many fume hoods at the same time.

RWDI analyzed more than 300 chemicals to predict the minimum required exhaust dilution to meet applicable exposure limits and/or odor thresholds given a major spill of one of the chemicals. The 300 chemicals are commonly used liquids and gases that have known short term health effects (8-hour or less) or that have strong odors. Solid compounds are not included due to their low rate of emissions to the atmosphere.

The above criterion value (3,000:1) addresses odor thresholds and occupational health limits for about 89% of chemicals in the list compiled by RWDI. While this level of dilution does not cover all chemicals on the list, it is RWDI's opinion that 3,000:1 is a reasonably protective target to apply for design purposes for laboratories. Further details on estimating emissions, developing a dilution criterion for fume hood exhausts, and RWDI's chemical list are provided in Appendices B and C. Note that the 3,000:1 target may not be sufficiently stringent for specialty laboratories using highly hazardous substances.

There is some benefit from internal dilution for the fume hood exhausts on this building. The design dilution target corresponds to a typical 1,000 cfm stack. For example, if the minimum exhaust flow rate of a manifolded fume hood exhaust fan was 10,000 cfm, an internal dilution of 10:1 would occur within the stack (assuming that only one spill of a given chemical occurs in one hood at a time). In this case the predicted stack-to-intake dilution from 10,000 cfm fans would be multiplied by 10 to account for internal dilution before comparison to the design criterion of 3,000:1. This internal dilution factor has been incorporated into the results of the exhaust dispersion analysis, where applicable.

It is important to note that a stack design meeting the above recommended dilution criterion for chemical fume hood exhausts would not guarantee that odors or health effects will not occur. Further, the design criterion does not exclude the possibility that emission rates may be larger than predicted from the spill scenario or that other chemicals not on the list provided to RWDI list will be used. Ultimately, it is the responsibility of the owners of the facility to determine if the suggested dilution criterion is suitable for the level of activities taking place within the facility.

Vivarium Exhaust

Vivarium and other associated animal holding and cage wash exhausts tend to emit strong and objectionable odors. Odor is highly subjective due to the varying degree of sensitivity within the human population. Consequently, it is often very difficult to eliminate odors entirely. The goal is therefore to design exhausts to meet a 50% detection threshold, which is recognized as an industry standard target for reducing odors to a generally acceptable level. A 50% detection threshold means that approximately 50% of an exposed population will be able to detect some odor at this level, but may not necessarily object to it, or be able to identify it. A smaller percentage of the population may find the odor objectionable. On average, 50% of the population will not detect any odor at this level.

For vivarium exhaust, RWDI recommends a dilution target of 100:1 to reduce vivarium and animal odors to generally acceptable levels. This dilution target is based on odor panel testing of a variety of vivarium exhausts conducted by RWDI in previous studies, and represents the units of clean air that are needed to dilute a unit of the exhaust effluent so that the odor is just detectable to 50% of an exposed population.

APPENDIX B

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

Exhausts from laboratory fume hoods have been known to cause odors 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 odor 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.

Image B1 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 odor 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 odor 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 Image B1 indicate the percentage of chemicals that will meet odor 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 odor 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 odor 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 Image B1. 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 215 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 Image B1.

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 Image B1 (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 odor 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 odors 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 Image B1 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 B1).

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.

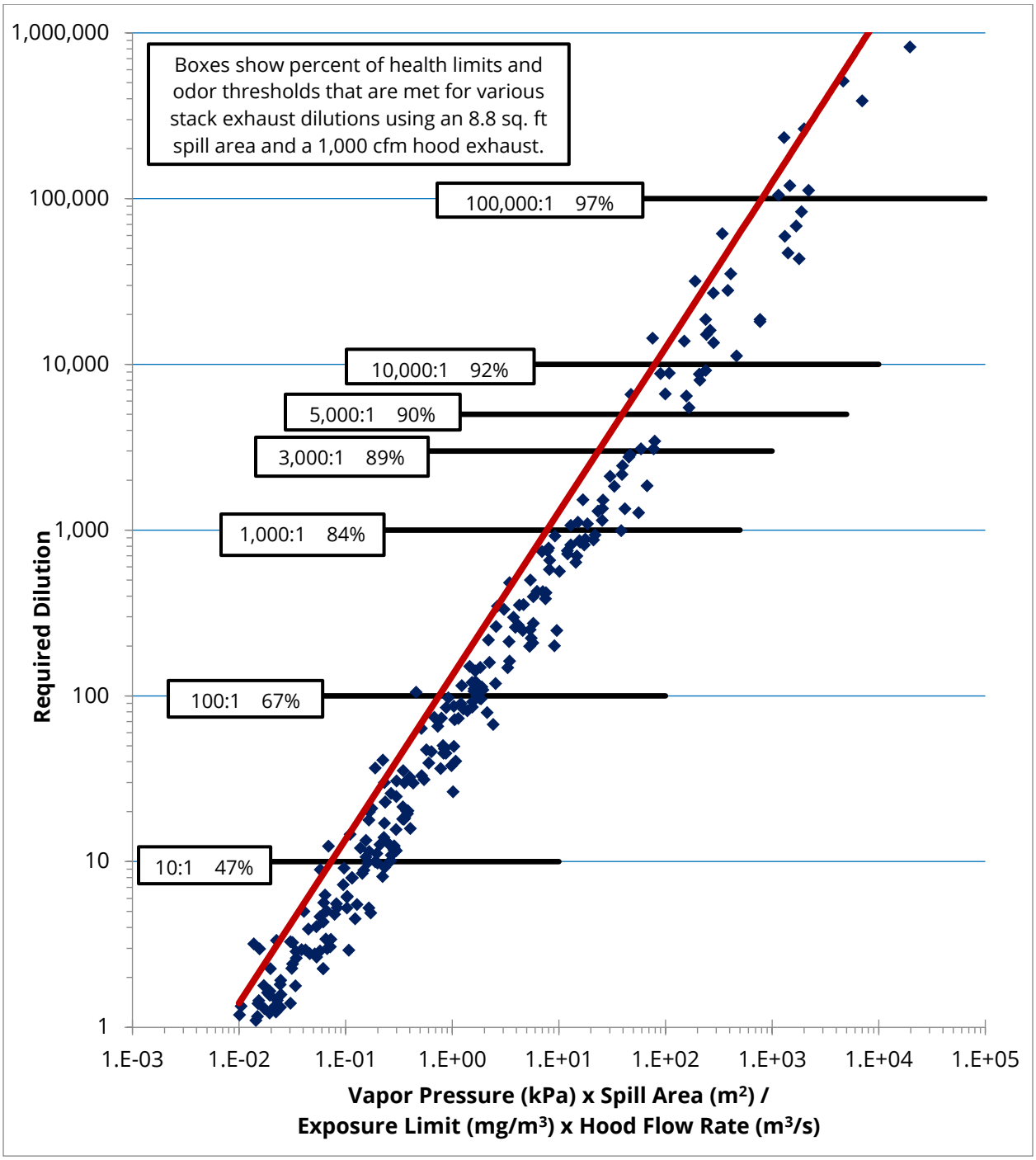


Image B1: Required Dilution Levels for 362 Chemicals to meet Health Limits and Odor Thresholds

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 B1: 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 C

APPENDIX C: 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 odor 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:

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

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]:

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

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:

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

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:

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

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. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.[6]

- Nagy, G.Z., 1991. The odor impact model. Journal of the Air Waste Management Association, p. 1360-1362.[7]
- Ruth, J.H., 1986. Odor 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. Odor thresholds are based on several references also described above. The last column indicates the worst case (highest) of either health or odor, 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. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.

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

Ruth, J.H., 1986. Odor 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.

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					ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density (kg/m^3)	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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/Odor
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

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					ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Density (kg/m^3)	Mass Emission Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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/Odor
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
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 odor standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

Odor Threshold Values taken from the following five sources (listed in priority):
1) American Industrial Hygiene Association. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, OH. 1989.
2) Nagy, George Z. The Odor 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. Odor 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) Odor threshold based on priority of resource used.
The minimum value out of the health and the odor values was used with the short term health limit taking precedence over the long-term health limit.

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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
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

LIQUIDS

Face Velocity	**100**	**fpm**	**0.51**	**m/s**
Total Spill Area	**8.8**	**ft²**	**0.813**	**m²**
Sing Fume Hood	**1000**	**cfm**	**0.472**	**m3/s**
Reynolds Number	**30480**		**0.0048**	**<===Chilton-Colburn j-Factor**

Chemical	CHEMICAL PROPERTIES								ODOR	HEALTH LIMITS		HEALTH / ODOR	DILUTION
	CAS No.	Molec. Weight (g/mol)	Vapor Pressure (kPa)	Vap Dens Interface (kg/m^3)	Diffusivity in Air (cm^2/s)	Mass Tr. Coeff. (m/s)	Evap Rate (mg/s)	Duct Conc. (mg/m^3)	Mean Odor 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 / Odor
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 odor standards
N/A indicates required dilution is not applicable.
"none" indicates criterion met at the source (i.e., no dilution required).

References for Odor Thresholds:
1) AIHA, 1989. Odor Thresholds for Chemicals with Established Occupational Health Standards. Akron, Ohio.
2) Nagy, G.Z., 1991. The odor impact model. Journal of the Air Waste Management Association, p. 1360-1362.
3) Ruth, J.H., 1986. Odor 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) Odor threshold based on priority of resource used.

The minimum value out of the health and the odor values was used with the short term health limit taking precedence over the long-term health limit.