Triethylamine
Trimethylamine

Method number:	PV2060
Matrix:	Air
Target concentration:	Triethylamine: 10 ppm (41 mg/m^3)(ACGIH TWA TLV) Trimethylamine: 10 ppm (24 mg/m^3)
Procedure:	Samples are collected by drawing a known volume of air through a 10% phosphoric acid coated XAD-7 tube. Samples are desorbed with 1 mL of 1:1 methanol: deionized water for ½ hour with shaking, then 0.5 mL of the sample is removed and added to 0.5 mL of a 1:4 solution of 1.0 N NaOH:methanol and analyzed by gas chromatography using a flame ionization detector.
Recommended air volume and sampling rate:	10 L at 0.1 L/min (maximum 20 liters at a flow rate of 0.2 L/min)
Reliable quantitation limit:	Triethylamine: 0.04 ppm (0.2 mg/m^3) Trimethylamine: 0.08 ppm (0.2 mg/m^3)
Status of method:	Partially Evaluated Method. This method has been subjected to established evaluation procedures, and is presented for information and trial use.

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1. General Discussion

1.1 Background

1.1.1 History

There are stop-gap methods for triethylamine (TEA) and trimethylamine (TMA) collected on Alumina tubes, but there was great variability in the collection capacity between the various lots of tubes studied, with the more recent lots having much lower collection capacity. A better means of collection was desired. The 10% phosphoric acid coated XAD-7 tubes were then tried and found to have desorption, retention, and storage recoveries above 95%. Desorption with a 1:4 solution of 1.0 N NaOH:water was initially tried and found to give recoveries above 95%, but something on the XAD-7 resin, or the resin itself, appeared to react with the NaOH causing a sticky residue to build up in the syringe on the autosampler, despite using a solvent wash. To avoid this problem, resorption with 1:1 water:methanol was used (30 minutes of shaking was necessary), then 0.5 mL was removed from the vial containing resin, making sure all the resin was left behind, and neutralized with 0.5 mL of a 1:4 solution of 1.0 N NaOH:methanol before analysis.

1.1.2 Toxic effects (This section is for information only and should not be taken as the basis of OSHA policy.) (References. 5.2, 5.3, and 5.4)

TEA and TMA are skin, eye, and mucous membrane irritants. Exposure to high concentrations, or over extended periods of time, can lead to corneal damage. High doses of TEA result in central nervous system stimulation associated with the inhibitory action of TEA on monoamine oxidase activity. Rats exposed to 1000 ppm TEA died in four hours. Rabbits exposed to 50 ppm TEA showed skin and lung irritation. An intravenous injection of 90 mg/kg TMA killed half the mice tested. The OSHA TWA PEL for triethylamine is 25 ppm (100 mg/m^3), the ACGIH TWA TLV is 10 ppm (41 mg/m^3), and the ACGIH STEL TLV is 15 ppm (62 mg/m^3). The ACGIH TWA TLV for trimethylamine is 5 ppm (12 mg/m^3) and ACGIH STEL TLV is 15 ppm (36 mg/m^3).

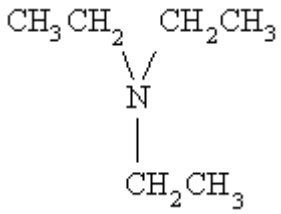
1.1.3 Workplace exposure (Reference 5.5)

Triethylamine is used as a catalytic solvent in chemical synthesis; accelerator activator for rubber; in wetting, penetrating, and waterproofing; as an agent of quaternary ammonium types; in the curing and hardening of polymers; as a corrosion inhibitor, and as a propellant. Trimethylamine is used as an insect attractant; as a warning agent in natural gas; in organic synthesis; in disinfectants; in plastics; as a flotation agent; and in the manufacture of quaternary ammonium compounds. TMA is a natural degradation product of plant and animal residues, and is the major odor produced from rotting marine animals.

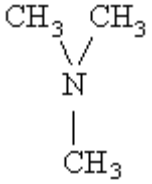
1.1.4 Physical properties and other descriptive information (References 5.5 and 5.6)

Triethylamine

Synonyms:	N,N-Diethylethanamine; (Diethylamino)ethane
CAS number:	121-44-8
IMIS:	2480
RTECS:	YE0175000; 84562
DOT:	UN 1296 (flammable liquid)

Molecular weight:	101.19
Flash point:	-7°C (20°F)(cc)
Boiling point:	89.7°C
Melting point:	-115°C
Odor:	strong fishy or amine odor
Color:	clear to light yellow liquid
Autoignition temperature:	249°C (480°F)
Density:	0.7255
Molecular formula:	$C_6H_{15}N$
Structural formula:	

Trimethylamine

Synonyms:	N,N-Dimethylmethanamine
CAS number:	75-50-3
IMIS:	T127
RTECS:	PA0350000; 47804
DOT:	UN 1083 (flammable gas); UN 1297 (aqueous solution) (flammable liquid)
Molecular weight:	59.13
Flash point:	12.2°C (10°F) (cc); 25% aqueous solution 3.3°C (38°F)(oc)
Boiling point:	-4°C
Melting point:	-117°C
Odor:	strong fishy or amine odor
Color:	gas; aqueous solutions are clear to light yellow
Autoignition temperature:	190°C (374°F)
Molecular formula:	C_3H_9N
Structural formula:	

The analyte air concentrations throughout this method are based on the recommended sampling and analytical parameters of 10 liters and a desorption volume of 1 mL. Air concentrations listed in ppm are referenced to 25°C and 101.3 kPa (760 mmHg).

1.2 Limit defining parameters

1.2.1 Detection limit of the overall procedure (DLOP)

The detection limit of the overall procedure is 1 μg per sample (0.01 ppm or 0.05 mg/m^3). This is the amount of analyte spiked on the sampler that will give a response that is significantly different from the background response of a sampler blank.

The DLOP is defined as the concentration of analyte that gives a response (Y_{DLOP}) that is significantly different (three standard deviations (SD_{BR})) from the background response (Y_{BR}). $Y_{DLOP} - Y_{BR} = 3(SD_{BR})$

The direct measurement of Y_{BR} and SD_{BR} in chromatographic methods is typically inconvenient, and difficult because Y_{BR} is usually extremely low. Estimates of these parameters can be made with data obtained from the analysis of a series of samples whose responses are in the vicinity of the background response. The regression curve obtained for a plot of instrument response versus concentration of analyte will usually be linear. Assuming SD_{BR} and the precision of data about the curve are similar, the standard error of estimate (SEE) for the regression curve can be substituted for SD_{BR} in the above equation. The following calculations derive a formula for the DLOP:

$$SEE = \sqrt{\frac{\sum (Y_{obs} - Y_{est})^2}{n - k}}$$

Y_{obs} = observed response
Y_{est} = estimated response from regression curve
n = total no. of data points
k = 2 for a linear regression curve

At point Y_{DLOP} on the regression curve $Y_{DLOP} = A(DLOP) + Y_{BR}$

A = analytical sensitivity (slope)

therefore

$$DLOP = \frac{(Y_{DLOP} - Y_{BR})}{A}$$

substituting $3(SEE) + Y_{BR}$ for Y_{DLOP} gives

$$DLOP = \frac{3(SEE)}{A}$$

Table 1.2.1
Detection Limit of the Overall Procedure

mass per sample (μg)	area counts (μV-s)
1.03	1130
2.06	2311
3.09	3396
4.12	4288
5.15	5140
6.18	6295
7.21	7416
8.24	8384
9.27	9573
10.3	10615

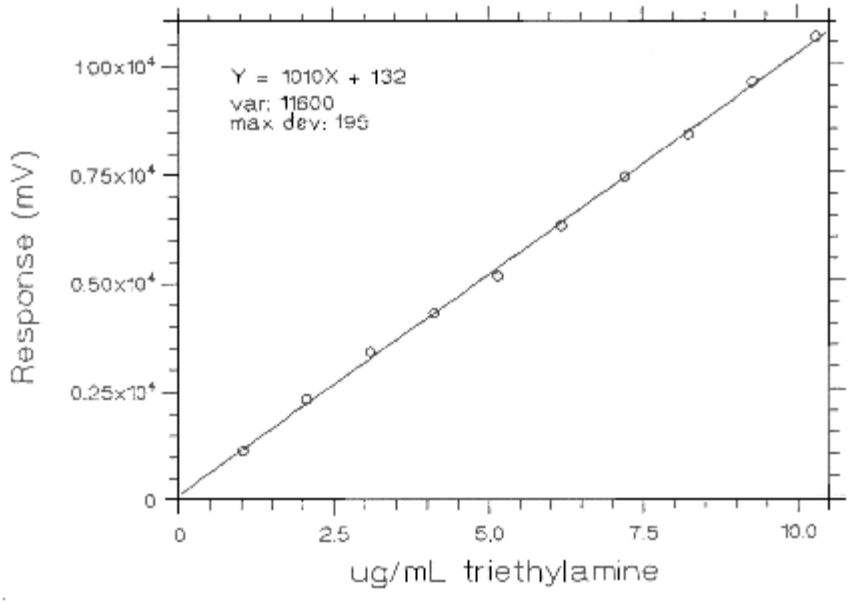


Figure 1.2.1.
Plot of TEA data to determine the DLOP/RQL.

1.2.2 The reliable quantitation limit is 2.0 μg per sample (0.04 ppm TEA or 0.08 ppm TMA). This is the amount of analyte spiked on a sampler that will give a signal that is considered the lower limit for precise quantitative measurements.

The RQL is considered the lower limit for precise quantitative measurements. It is determined from the regression line data obtained for the calculation of the DLOP (Section 1.2.1), providing at least 75% of the analyte is recovered. The RQL is defined as the concentration of analyte that gives a response (Y_{RQL}) such that $Y_{RQL} - Y_{BR} = 10(SD_{BR})$

therefore

$$RQL = \frac{10(SEE)}{A}$$

Table 1.2.2
Detection Limit of the Overall Procedure

mass per sample (μg)	area counts (μV-s)
1.01	210
2.01	468
3.02	630
4.03	889
5.03	1129
6.04	1525
7.05	1851
8.05	2162
9.06	2396
10.1	2807

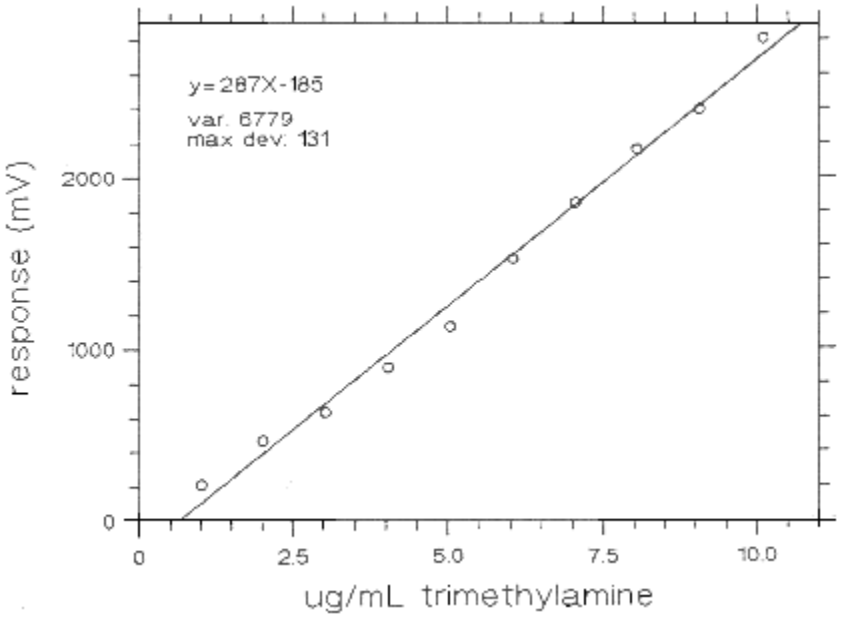


Figure 1.2.2
Plot of TMA data to determine the DLOP/RQL.

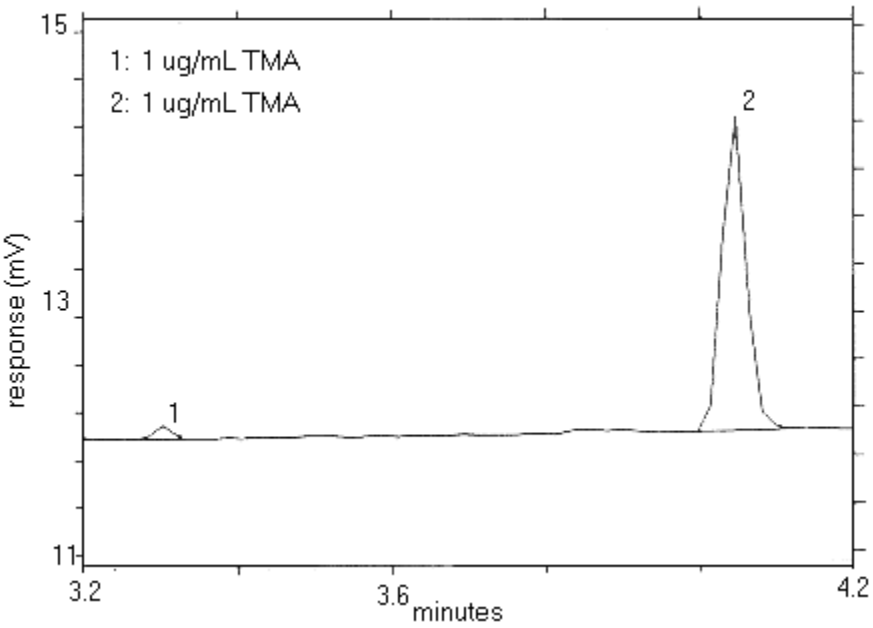


Figure 1.2.3.
Chromatogram of the RQL.

2. Sampling Procedure

2.1 Apparatus

2.1.1 Samples are collected using a personal sampling pump calibrated, with the sampling device attached, to within ±5% of the recommended flow rate.

2.1.2 Samples are collected on 10% phosphoric acid coated XAD-7 tubes. For this evaluation, lot 540 tubes were used. These contain 80 mg adsorbing section with a 40 mg backup section separated by a 2 mm portion of urethane foam, with a Silanized glass wool plug before the adsorbing section and a 3 mm plug of urethane foam at the back of the backup section. The ends are flame sealed and the glass tube containing the adsorbent is 7 cm long, with a 6 mm O.D., SKC tubes or equivalent.

2.2 Technique

2.2.1 Immediately before sampling, break off the ends of the sampling tube. All tubes should be from the same lot.

2.2.2 Attach the sampling tube to the pump with flexible tubing. It is desirable to utilize sampling tube holders which have a protective cover to shield the employee from the sharp, jagged end of the sampling tube. Position the tube so that sampled air passes through the reference, larger, section of the tube first.

2.2.3 Air being sampled should not pass through any hose or tubing before entering the sampling tube.

2.2.4 Attach the sampler vertically with the reference, larger, section pointing downward, in the worker's breathing zone, and positioned so it does not impede work performance or safety.

2.2.5 After sampling for the appropriate time, remove the sample and seal the tube with plastic end caps. Wrap each sample end-to-end with a Form OSHA-21 seal.

2.2.6 submit at least one blank sample with each set of samples. Handle the blank sampler in the same manner as the other samples except draw no air through it.

2.2.7 Record sample volumes (in liters of air) for each sample, along with any potential interferences.

2.2.8 Ship any bulk samples separate from the air samples.

2.2.9 submit the samples to the laboratory for analysis as soon as possible after sampling. If delay is unavoidable, store the samples in a refrigerator.

2.3 Desorption efficiency

2.3.1 The desorption efficiencies (DE) of triethylamine were determined by liquid-spiking 10% phosphoric acid coated XAD-7 tubes with 41.4 (1.00), 207 (5.00), 414 (10.0), and 828 μg (20.0 ppm) triethylamine. These samples were stored overnight at ambient temperature and then desorbed with 1 mL of 1:1 solution of deionized water (pH 7):methanol for 30 minutes on the shaker. A 0.5 mL aliquot of each sample was removed and added to 0.5 mL of a 1:4 solution of 1.0 N NaOH:methanol and analyzed by GC-FID. The average desorption efficiency over the studied range was 99.9%.

Table 2.3.1
Desorption Efficiency of Triethylamine

	41.4 μg	207 μg	414 μg	828 μg
DE (%)	99.2	97.6	101	98.3
	102	102	101	98.5
	97.2	97.4	99.2	99.6
	102	99.0	100	102
	99.6	101	100	102
	99.5	98.8	99.0	101
mean	99.9	99.3	100	100
overall average	99.9			
standard deviation	±1.54			

2.3.2 The desorption efficiencies (DE) of trimethylamine were determined by liquid-spiking 10% phosphoric acid coated XAD-7 tubes with 24.4 (1.01), 122 (5.05), 244 (10.1), and 489 μg (20.2 ppm). These samples were stored overnight at ambient temperature and then desorbed with 1 mL of a 1:1 solution of deionized water:methanol for 30 minutes on the shaker. A 0.5 mL aliquot of each sample was removed and added to 0.5 mL of a 1:4 solution of 1.0 N NaOH:methanol and analyzed by GC-FID. The average desorption efficiency over the studied range was 98.9%.

Table 2.3.2
Desorption Efficiency of Trimethylamine

	24.4 μg	122 μg	244 μg	489 μg
DE (%)	101	98.8	99.1	101
	97.7	101	96.1	97.2
	98.8	99.3	94.9	101
	98.5	100	102	102
	94.0	99.4	100	97.4
	95.4	97.7	102	100
mean	97.6	99.4	99.0	99.8
overall average	98.9			
standard deviation	±2.27			

2.4 Retention efficiency

2.4.1 The sampling tubes were spiked with 828 μg (20.0 ppm) triethylamine, allowed to equilibrate overnight at room temperature, and then had 20 liters humid air (86% RH at 23°C) pulled through them at 0.2 Lpm. They were opened desorbed, and analyzed by GC-FID. The results were corrected for desorption efficiency. The retention efficiency averaged 101%. There was no triethylamine found on the backup portions of the tubes.

Table 2.4.1
Retention Efficiency of Triethylamine

Tube #	A section recovery (%)	B section recovery (%)	total recovery (%)
1	98.9	0.0	98.9
2	102	0.0	102
3	99.7	0.0	99.7
4	102	0.0	102
5	103	0.0	103
6	99.8	0.0	99.8
		mean	101

2.4.2 The sampling tubes were spiked with 489 μg (20.2 ppm) trimethylamine, allowed to equilibrate overnight at room temperature, and then had 20 L humid air (83% RH at 21°C) pulled through them at 0.2 Lpm. They were opened, desorbed, and analyzed by GC-FID. The results were corrected for desorption efficiency. The retention efficiency averaged 99.1%. There was no trimethylamine found on the backup portions of the tubes.

Table 2.4.2
Retention Efficiency of Trimethylamine

Tube #	A section recovery (%)	B section recovery (%)	total recovery (%)
1	101	0.0	101
2	100	0.0	100
3	98.3	0.0	98.3
4	99.5	0.0	99.5
5	97.1	0.0	97.1
6	98.5	0.0	98.5
		mean	99.1

2.4.3 A collection study was performed by using a sampling train consisting of a glass fiber filter in series with a 10% phosphoric acid coated XAD-7 tube. The glass fiber filter was spiked with 828 μg (20.0 ppm) TEA and 489 μg (20.2 ppm) TMA. Immediately, 20 liters of humid air (81% RH at 21°C) was drawn through the sampling train. Samples were desorbed and analyzed that same day. The back-up portions of the tubes had little or no TEA or TMA found on them.

Table 2.4.3
Collection Efficiency of TEA and TMA

Sample #	TEA GFF	TEA 'A'	TEA 'B'	TEA Total	TMA GFF	TMA 'A'	TMA 'B'	TMA Total
1	1.0	100	0.0	101	2.0	96.6	2.0	101
2	0.0	102	0.0	102	0.0	102	0.0	102
3	1.0	98.0	0.0	99.0	3.2	96.4	0.0	99.7
4	1.0	100	0.0	101	4.2	96.9	0.0	101
mean				101				101

2.5 Sample

2.5.1 The front sections of six sampling tubes were each spiked with 414 μg (10.0 ppm) of TEA. Six more tubes had 10 liters of humid air (82% RH at 21°C) drawn through them before they were spiked with 414 μg (10.0 ppm) of TEA. They were sealed and stored

at room temperature. Three dry samples and three humid air samples were analyzed after 7 days and the remaining three samples of each after 14 days. The amounts recovered, corrected for desorption efficiency, indicate good storage stability for the time period studied.

Table 2.5.1
Storage Test for Triethylamine

Dry Samples		Humid Air Samples	
time (days)	recovery (%)	time (days)	recovery (%)
7	101	7	100
7	99.2	7	101
7	99.5	7	99.9
14	99.5	14	99.6
14	98.8	14	99.3
14	99.2	14	98.1
mean	99.5	mean	99.7

2.5.2 The front sections of six sampling tubes were each spiked with 244 μg (10.1 ppm) of TMA. Six more tubes had 10 liters of humid air (81% RH at 21°C) drawn through them before they were spiked with 244 μg (10.1 ppm) of TMA. They were sealed and stored at room temperature. Three dry samples and three humid air samples were analyzed after 7 days and the remaining three samples of each after 14 days. The amounts recovered, corrected for desorption efficiency, indicate good storage stability for the time period studied..

Table 2.5.2
Storage Test for Trimethylamine

Dry Samples		Humid Air Samples	
time (days)	recovery (%)	time (days)	recovery (%)
7	101	7	103
7	99.3	7	101
7	103	7	99.4
14	99.6	14	99.9
14	99.8	14	99.4
14	97.1	14	97.8
mean	100	mean	100

2.6 Precision

2.6.1 The precision was calculated using the area counts from six injections of each standard at concentrations of 20.7, 104, 207, and 414 µg/mL triethylamine in the desorbing solution.

Table 2.6.1
Triethylamine Precision Study

injection #	20.7 µg/mL	104 µg/mL	207 µg/mL	414 µg/mL
1	22408	115255	242174	518445
2	22424	111279	241752	516027
3	21931	113935	243488	523164
4	22242	113361	240352	520050
5	22245	112715	236823	516514
6	21903	112091	236531	516575
mean	22192	113106	240187	518463
standard deviation	±227	1407	2898	2754

2.6.2 The precision was calculated using the area counts from six injections of each standard at concentrations of 12.2, 61.0, 122, and 244 µg/mL trimethylamine in the desorbing solution.

Table 2.6.2
Triethylamine Precision Study

injection #	12.2 µg/mL	61.0 µg/mL	122 µg/mL	244 µg/mL
1	3892	17895	36866	73132
2	3790	18178	36869	74586
3	3786	18556	36112	73943
4	3742	18051	35411	73407
5	3847	18650	35520	73706
6	3791	18533	35019	73315
mean	3808	18311	35966	73682
standard deviation	±53.0	311	781	529

2.7 Recommended air volume and sampling rate.

Based on the data collected in this evaluation, 10 L air samples should be collected at a sampling rate of 0.1 L/min.

2.8 Interferences

2.8.1 It is not known if any compounds will severely interfere with the collection of TEA and TMA on 10% phosphoric acid coated XAD-7 tubes. In general, the presence of other contaminant vapors in the air will reduce the capacity of the adsorbent tubes to collect TEA and TMA.

2.8.2 Suspected interferences should be reported to the laboratory with submitted samples.

2.9 Safety precautions (sampling)

2.9.1 The sampling equipment should be attached to the worker in such a manner that it will not interfere with work performance or safety.

2.9.2 All safety practices that apply to the work area being sampled should be followed.

2.9.3 Protective eye wear should be worn when breaking the ends of the glass sampling tubes.

3. Analytical Procedure

3.1 Apparatus

3.1.1 The instrument used in this study was a gas chromatograph equipped with a flame ionization detector, specifically a Hewlett Packard model 5890.

3.1.2 A GC column capable of separating the analyte from any interferences. The column used in this study was a 60 meter Stabilwax DB, 1.0 μ film thickness, 0.32 mm i.d..

3.1.3 An electronic integrator or some suitable method of measuring peak areas.

3.1.4 Two milliliter vials with Teflon^{TM}-lined caps.

3.1.5 A 10 μL syringe or other convenient size for sample injection.

3.1.6 Pipets for dispensing the desorbing solution.

3.1.7 Volumetric flasks - 10 mL and other convenient sizes for preparing standards.

3.2 Reagents

3.2.1 GC grade nitrogen, hydrogen, and air.

3.2.2 Triethylamine, Reagent grade

3.2.3 Trimethylamine, Reagent grade

3.2.4 Methanol, HPLC grade

3.2.5 Sodium hydroxide, reagent grade

3.2.6 Deionized water, pH adjusted to 7

3.2.7 1.0 N NaOH was prepared by adding 4 grams of NaOH to 100 mL deionized water. This solution should be prepared fresh with each analysis as the concentration of sodium hydroxide solutions change with exposure to air.

3.2.8 The desorbing solution was prepared by mixing 50 mL methanol with 50 mL deionized water that had been pH adjusted to 7.

3.2.9 The neutralizing solution was prepared by mixing 20 mL 1.0 N NaOH with 80 mL methanol.

3.3 Standard preparation

3.3.1 At least two separate stock standards are prepared by diluting a known quantity of TEA and TMA with 1:4 water:methanol pH adjusted to 7 or slightly more basic.

3.3.2 Dilutions of the stock standards should be prepared to bracket the range of the samples. The standards used in this study ranged from 1 to 414 μg/mL.

3.4 Sample preparation

3.4.1 Sample tubes are opened and the front and back section of each tube are placed in separate 2 mL vials.

3.4.2 Each section is desorbed with 1 mL of 1:1 water:methanol.

3.4.3 The vials are sealed immediately and allowed to desorb for 30 minutes with constant shaking..

3.4.4 A 0.5 mL aliquot of each sample is removed, being careful to leave the media behind, placed into a 2 mL vial, and 0.5 mL of a 1:4 solution of 1.0 N NaOH:methanol is added to neutralize the sample. The vial is sealed and shaken briefly to mix well, and then analyzed. The liquid in the vial may appear to be cloudy; this will settle out upon sitting. If the solution of 1:4 1.0 N NaOH:methanol is not freshly prepared, check its ability to neutralize the samples by desorbing a blank tube. If the resulting solution of adding 0.5 mL of the sample to 0.5 mL of the 1:4 1.0 N NaOH:methanol is pH 7 or more basic, the 1:4 solution may be used.

3.5 Analysis

3.5.1 Gas chromatograph conditions.

Injection size:	1 μL
Flow rates (mL/min)	
Nitrogen (make-up):	30
Hydrogen(carrier):	2

Hydrogen(detector):	60
Air:	450

Retention times (min)

Trimethylamine:	3.28
Triethylamine:	4.03
Methanol:	6.10

Temperatures (°C)

Injector:	180
Detector:	220
Column:	80° for 2 min then 10°/min to 130° for 3 min

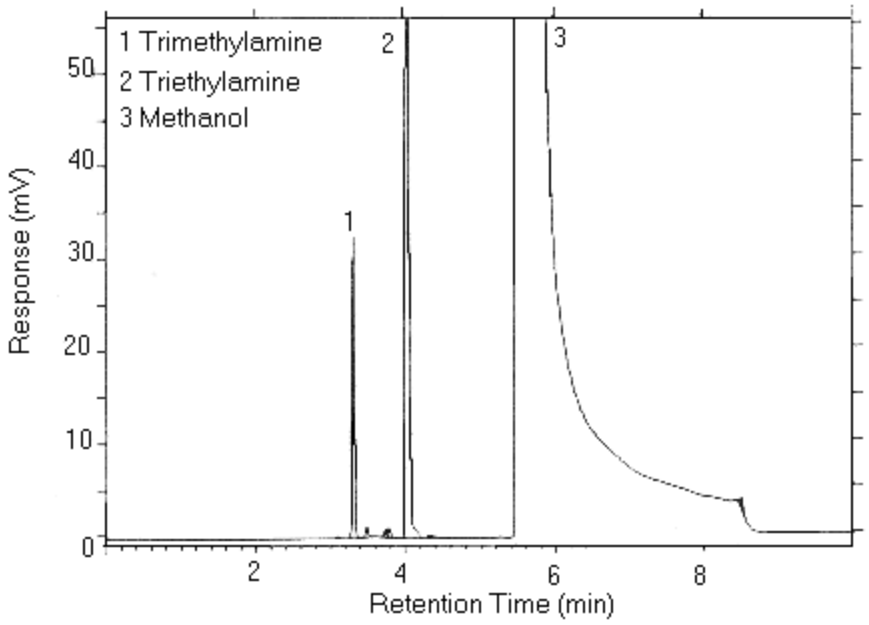


Figure 3.5.1
Chromatogram of the target concentration.

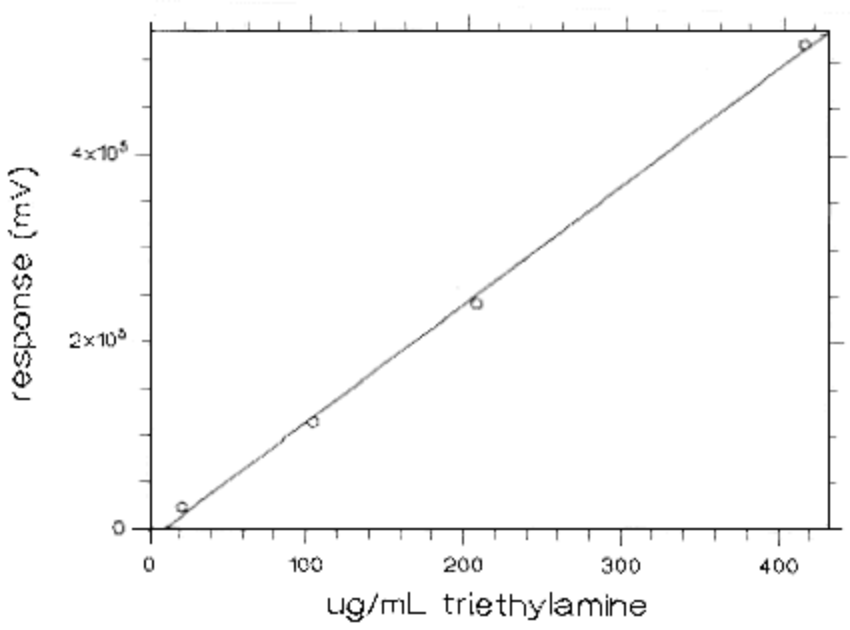


Figure 3.5.2
Calibration curve for TEA based on standards presented in 2.6.1.

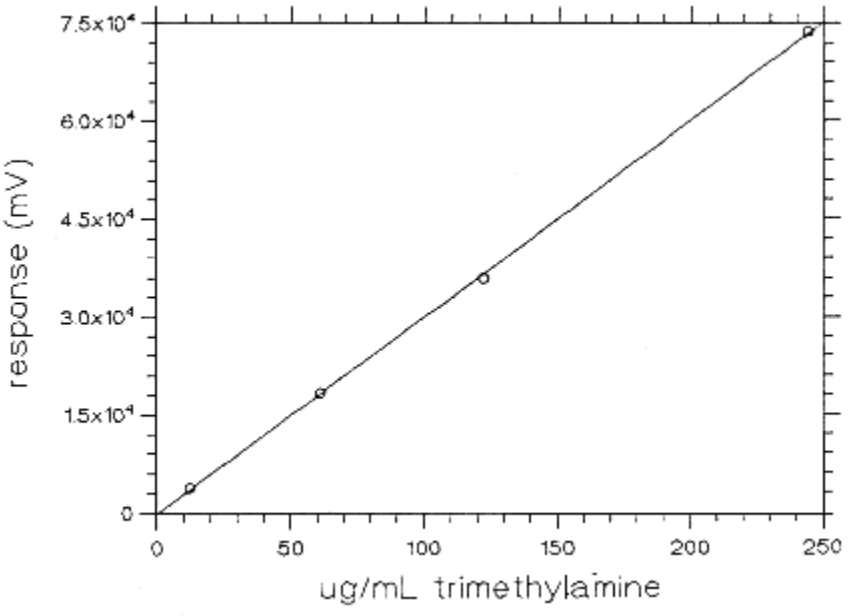


Figure 3.5.3
Calibration curve for TMA based on standards presented in 2.6.2.

3.5.2 Peak area are measured by an integrator or other suitable means.

3.6 Interferences (analytical)

3.6.1 Any compound that produces a response and has a similar retention time as the analyte is a potential interference. If any potential interferences were reported, they should be considered before samples are desorbed. Generally, chromatographic conditions can be altered to separate an interference from the analyte.

3.6.2 When necessary, the identity or purity of an analyte peak may be confirmed by GC-Mass spec or by another analytical procedure.

3.7 Calculations

3.7.1 The instrument was calibrated with a standard of 207 μg/mL TEA and 122 μg/mL TMA in the desorbing solution. The linearity of the calibration was checked with standards over the range of 1 to 414 μg/mL.

3.7.2 If the calibration is non-linear, two or more standards at different concentrations must be analyzed, bracketing the samples, so a calibration curve can be plotted and sample values obtained.

3.7.3 To calculate the concentration of analyte in the air sample the following formulas are used:

$$\frac{(\mu g/m)\ (\text{desorption volume})}{(\text{desorption efficiency})} = \text{mass of analyte in sample}$$

$$\frac{(\text{mass of analyte in sample})}{\text{molecular weight}} = \text{number of moles of analyte}$$

$$(\text{number of moles of analyte}) \quad (\text{molar volume at } 25°C \text{ \& } 760mm) = \text{volume the analyte will occupy at } 25°C \text{ \& } 760mm$$

$$\frac{(\text{volume analyte occupies})\ (10^6)^*}{(\text{air volume})} = ppm$$

* All units must cancel.

3.7.4 The above equations can be consolidated to the following formula.

$$\frac{(\mu g/mL)(DV)(24.45)(10^6)}{(10\ L)(DE)(MW)} \times \frac{(g)}{(1000\ mg)} \times \frac{(mg)}{(1000\ \mu g)} = ppm$$

μg/mL = concentration of analyte in sample or standard
24.45 = Molar volume (liters/mole) at 25°C and 760 mm
MW = Molecular weight (g/mole)
DV = Desorption volume
10 L = 10 liter air sample
DE = Desorption efficiency

note: the desorption volume should include the dilution factor from the neutralization, i.e., *1 mL desorption* × [1 mL analyzed/0.5 mL of sample] = *2*

3.7.5 This calculation is done for each section of the sampling tube and the results added together.

3.8 Safety precautions

3.8.1 Avoid skin contact and inhalation of all chemicals.

3.8.2 Wear safety glasses, gloves and a lab coat at all times while in the laboratory areas.

4. Recommendations for Further Study

Collection studies using known vapor concentrations of TEA and TMA need to be performed, along with reproducibility studies.

5. References

5.1 *"NIOSH Manual of Analytical Methods"*, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Second Edition, Vol. 1, Method 221.

5.2 *"Documentation of the Threshold Limit Values and Biological Exposure Indices"*, Fifth Edition, American Conference of Governmental Industrial Hygienists Inc., Cincinnati, OH, 1986, p. 604 and 607.

5.3 "1993-1994 Threshold Limit Values for Chemical substances and Physical Agents and Biological Exposure Indices", American Conference of Governmental Industrial Hygienists Inc., Cincinnati, OH, 1993, p. 34.

5.4 "Federal Register", 1993, 29 CFR, OSHA 1910 (Wed., June 30), Table Z-1, p. 35341.

5.5 Lewis, R., *"Hawley's Condensed Chemical Dictionary"*, Twelfth Edition, Van Nostrand Reinhold Co., New York, 1993, p. 1174 and 1181.

5.6 Windholz, M., *"The Merck Index"*, Eleventh Edition, Merck & Co., Rahway N.J., 1989, p. 1521 and 1528