Method no:	PV2320
Control number:	T-PV2320-01-0909-OAS
Target concentration:	5 ppm (23 mg/m^3)
OSHA PEL: ACGIH TLV:	none none
Procedure:	Samples are collected by drawing workplace air through glass sampling tubes containing XAD-7 with personal sampling pumps. Samples are extracted with 95:5 methylene chloride:*N,N*-dimethylformamide and analyzed by GC using a flame ionization detector (GC/FID).
Recommended sampling time and sampling rate:	240 min at 0.1 L/min (24 L)
Reliable quantitation limit:	17.7 ppb (82 µg/m^3)
Status of method:	Partially validated method. This method has been subjected to established evaluation procedures of the Methods Development Team and is presented for information and trial use.

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1. General Discussion

For assistance with accessibility problems in using figures and illustrations presented in this method, please contact OSHA Salt Lake Technical Center (OSHA SLTC) at (801) 233-4900.

1.1 Background

1.1.1 History

Air samples collected using XAD-7 tubes were received at OSHA SLTC with requested analysis for 2-chlorpyridine. XAD-7 resin is often extracted with methyl alcohol, therefore, this solvent was tried but the concentration of 2-chloropyridine decreased with time indicating a reaction with the solvent. Methylene chloride was tried as an extraction solvent and gave an extraction efficiency of 94.4%. The extraction solvent was modified with the addition of 5% *N,N*-dimethylformamide (DMF) which improved the recovery to 98.9%. Storage recoveries were good at ambient temperature for at least 14 days. Several internal standards were tried including tetrachloroethylene, trichloroethylene and *p*-cymene, but these chemicals decreased in concentration in solution with time, and are not recommended.

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

2-Chloropyridine is a poison by ingestion, inhalation, skin contact, or by intraperitoneal routes.[1] "May be fatal if absorbed through the skin. Causes digestive and respiratory tract irritation. Causes severe skin irritation."[2] 2-Chloropyridine is rapidly absorbed through the skin and causes liver damage. Repeated low-level exposures can cause cirrhosis of the liver.[3]

1.1.3 Workplace exposure[4]

2-Chloropyridine is used in the production of pesticides, antihistamines, germicides, and agricultural chemicals.

1.1.4 Physical properties and other descriptive information[5]

synonyms:	alpha-chloropyridine; *o*-chloropyridine		
CAS number:	109-09-1	vapor pressure:	1 mmHg @ 13.3 °C
IMIS number:[6]	C740	density:	1.209 (g/mL) @ 20 °C
boiling point:	168-170 °C (334-338 °F)	melting point:	-46 °C (-51 °F)
appearance:	clear oily liquid	flash point:	64 °C (146 °F)
molecular weight:	113.55	solubility:	alcohols, ether
autoignition temperature:	585 °C (1085 °F)	molecular formula:	C_5H_4ClN

[1] Lewis, R., ed., *Sax's Dangerous Properties of Industrial Materials*, 10th ed., Vol. 2, John Wiley & Sons Inc., New York, 2000, p 897.

[2] 2-Chloropyridine, 99% Material Safety Data Sheet, ACC# 01951, Acros Organics N.V., Fair Lawn, NJ, https://fscimage.fishersci.com/msds/01951.html (accessed April 2009).

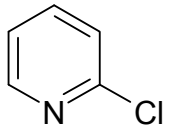
[3] Executive Summary 2-Chloropyridine. 2009. National Toxicology Program website. http://ntp.niehs.nih.gov/ntpweb/index.cfm?objectid=035E59DB-9F74-15FD-A78F03168BB16576 (accessed April 2009).

[4] Lewis, R., Ed., *Hawley's Condensed Chemical Dictionary,* 14th ed., John Wiley & Sons Inc., New York, 2001, p 289.

[5] Lewis, R., Ed., *Hazardous Chemicals Desk Reference,* 4th ed., Van Nostrand Reinhold, New York, 1997, p 281.

[6] 2-Chloropyridine (Chemical Sampling Information), 2009, U.S. Department of Labor, Occupational Safety and Health Administation website: http://www.osha.gov/dts/chemicalsampling/data/CH_228050.html (accessed April 2009).

structure:



This method was evaluated according to the OSHA SLTC "Evaluation Guidelines for Air Sampling Methods Utilizing Chromatographic Analysis"[7]. The Guidelines define analytical parameters, specify required laboratory tests, statistical calculations and acceptance criteria. The analyte air concentrations throughout this method are based on the recommended sampling and analytical parameters. Air concentrations in ppm are referenced to 25 °C and 101.3 kPa (760 mmHg).

1.2 Detection limit of the overall procedure (DLOP) and reliable quantitation limit (RQL)

The DLOP is measured as mass per sample and expressed as equivalent air concentration, based on the recommended sampling parameters. Ten samplers were spiked with equally descending increments of analyte, such that the highest sampler loading was 10.88 µg of 2-chloropyridine. This is the amount spiked on a sampler that would produce a peak about 10 times the response for a sample blank. These spiked samplers were analyzed with the recommended analytical parameters, and the data obtained used to calculate the required parameters [standard error of estimate (SEE) and slope] for the calculation of the DLOP. The slope was 387 and the SEE was 75.96. The RQL is considered the lower limit for precise quantitative measurements. It is determined from the regression line parameters obtained for the calculation of the DLOP, providing 75% to 125% of the analyte is recovered. The DLOP and RQL were 0.59 µg (5.3 ppb or 25 µg/m^3) and 1.96 µg (17.7 ppb or 82 µg/m^3), respectively. Recovery at this concentration was 96.9%.

Table 1.2.1
Detection Limit of the Overall Procedure for 2-Chloropyridine

mass per sample (µg)	area counts (µV·s)
0.00	0
1.09	364
2.18	707
3.26	1145
4.35	1745
5.44	2015
6.53	2328
7.62	2847
8.70	3300
9.77	3757
10.88	4199

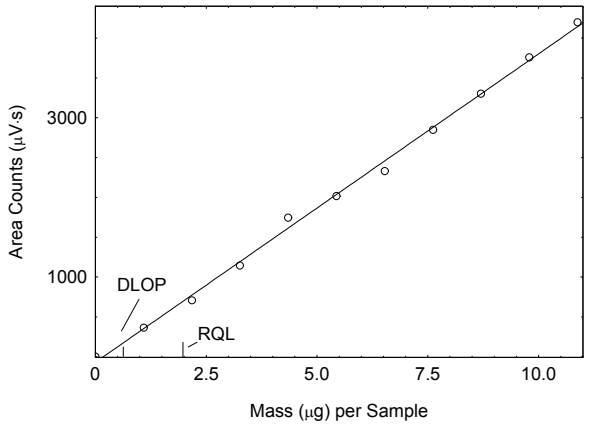


Figure 1.2.1. Plot of data to determine the DLOP/RQL of 2-chloropyridine. (y = 387x – 69.4)

[7] Burright, D.; Chan, Y.; Eide, M.; Elskamp, C.; Hendricks, W.; Rose, M. C. Evaluation Guidelines For Air Sampling Methods Utilizing Chromatographic Analysis, 1999. U.S. Department of Labor, Occupational Safety and Health Administration website. https://www.osha.gov/dts/sltc/methods/chromguide/chromguide.pdf (accessed April 2009).

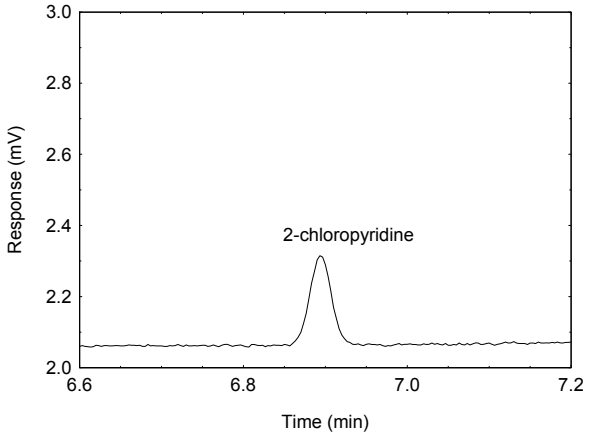


Figure 1.2.2. Chromatogram of the RQL.

2. Sampling Procedure

All safety practices that apply to the work area being sampled should be followed. The sampling equipment should be attached to the worker in such a manner that it will not interfere with work performance or safety.

2.1 Apparatus

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

Samples are collected with 11-cm × 4-mm i.d. × 6-mm o.d. glass sampling tubes packed with two sections (100/50 mg) of XAD-7. The sections are held in place with glass wool including a glass wool plug at the front. For this evaluation, commercially prepared sampling tubes were purchased from SKC, Inc. (Catalog no. 226-95, lot 5393).

2.2 Reagents

None required

2.3 Technique

Immediately before sampling, break off the ends of the flame-sealed tube to provide an opening approximately half the internal diameter of the tube. Wear eye protection when breaking the tube. Use tube holders when sampling to minimize the hazard of broken glass to the employee. All tubes should be from the same lot.

Connect the tube to the sampling pump with flexible tubing. The smaller section of each adsorbent tube is used as a back-up and is positioned nearest the sampling pump. Attach the tube holder to the sampling pump so that the adsorbent tube is in an approximately vertical position with the inlet facing down during sampling. Position the sampling pump, tube holder and tubing so they do not impede work performance or safety.

Draw the air to be sampled directly into the inlet of the tube holder. The air being sampled is not to be passed through any hose or tubing before entering the sampling tube.

After sampling for the appropriate time, remove the adsorbent tubes and cap each tube with plastic end caps. Seal each sample end-to-end with a Form OSHA-21 as soon as possible.

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

Record sample air volumes (liters), sampling time (minutes), and sampling rate (L/min) for each sample, along with any potential interferences on the Form OSHA 91A.

Submit the samples to the laboratory for analysis as soon as possible after sampling. If delay is unavoidable, store the samples at refrigerator temperature. Ship any bulk samples separate from the air samples.

2.4 Extraction efficiency

The extraction efficiency was determined by liquid-spiking the front section of XAD-7 tubes with 2-chloropyridine at 0.1 to 2 times the target concentration. These samples were stored overnight at ambient temperature, then extracted for 30 minutes using a lab shaker, and analyzed. The mean extraction efficiency over the studied range was 98.9%. An additional test was performed with wet sampling medium by drawing 24 L of humid air (80% relative humidity at 23 °C) through sampling tubes before spiking the front sections at 1.0 times the target concentration. These samples were also stored overnight at ambient temperature before analysis. The mean recovery from wet sampling medium was 97.5%. Wet extraction efficiency was not included in the mean extraction efficiency, as it may bias the results.

Table 2.4.1
Extraction Efficiency (%) of 2-Cholorpyridine

level		sample number				mean
× target concn	µg per sample	1	2	3	4	
0.1	60.4	97.1	97.6	98.6	98.8	98.0
0.5	302	99.6	101.0	98.9	99.2	99.7
1.0	604	98.6	97.9	99.7	98.9	98.8
2.0	1209	98.2	99.1	99.2	99.8	99.1
1.0 (wet)	604	96.6	97.4	97.9	98.1	97.5

2.5 Retention efficiency

A sampling train of two XAD-7 tubes in series was used to determine the retention efficiency. The front glass wool of the front XAD-7 tube was spiked with 1209 µg (10.9 ppm) 2-chloropyridine. Six spiked sampling trains immediately had 30 L of 80% RH air at 23 °C pulled through them at 0.1 L/min. The samples were extracted and analyzed. The mean recovery was 97.6%. For each sampling train there was no 2-chloropyridine found on the back-up section of the front tube or on either section of the second tube. The recommended air volume is 24 L (30 L x 0.8 = 24 L).

Table 2.5
Retention Efficiency (%) of 2-Chloropyridine

sampler	sample number						mean
	1	2	3	4	5	6	
front glass wool	0.0	0.0	0.0	0.0	0.0	0.0	0.0
front section of front tube	96.3	96.7	99.1	98.3	98.0	97.1	97.6
back section of front tube	0.0	0.0	0.0	0.0	0.0	0.0	0
total back tube	0.0	0.0	0.0	0.0	0.0	0.0	0
total both tubes	96.3	96.7	99.1	98.3	98.0	97.1	97.6

2.6 Sample storage

Fifteen samplers were each spiked with 604 µg (5.4 ppm) of 2-chloropyridine, then they had 24 L at 0.1 L/min of humid air (80% relative humidity at 23°C) drawn through them. Three samples were analyzed immediately, and the rest were stored. Six were stored at room temperature (23°C), while the other six were stored at refrigerated temperature (4°C). Three samples stored at room temperature and three samples stored at refrigerated temperature were analyzed after 8 days and the remaining six after 15 days. The amounts recovered, which were not corrected for extraction efficiency, indicate good storage stability for the time period studied.

Table 2.6
Storage Test for 2-Chloropyridine

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	99.1	97.6	98.9			
8	98.0	97.1	99.4	100.4	99.3	100.5
15	95.1	94.2	97.9	97.5	96.6	98.0

2.7 Recommended air volume and sampling rate

Based on the data collected in this evaluation, 24-L air samples should be collected at a sampling rate of 0.1 L/min for 240 minutes.

3. Analytical Procedure

Adhere to the rules set down in your Chemical Hygiene Plan[8]. Avoid skin contact and inhalation of all chemicals and review all appropriate MSDSs.

3.1 Apparatus

A gas chromatograph equipped with an FID detector. For this evaluation, an Agilent 6890 GC was used.

A GC column capable of separating 2-chloropyridine from the extraction solvent and any potential interferences. A 60-m × 0.32-mm i.d. capillary column, DB-1 1.0-µm df (J&W Scientific, Folsom, CA) was used in this evaluation.

An electronic integrator or some other suitable means of measuring peak areas. A Waters Empower 2 Data System was used in this evaluation.

[8] Occupational Exposure to Hazardous Chemicals in Laboratories. *Code of Federal Regulations*, Part 1910.1450, Title 29, 2003.

Glass vials with poly(tetrafluoroethylene)-lined caps. For this evaluation 2-mL vials were used.

A dispenser capable of delivering 1.0 mL of extraction solvent to prepare standards and samples. If a dispenser is not available, a 1.0-mL volumetric pipette may be used.

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

Calibrated 10-µL or 25-µL syringe for preparing standards. An SGE 25-µL syringe was used for this evaluation.

A shaker to agitate samples during extraction. An Eberbach mechanical shaker was used in this evaluation.

3.2 Reagents

2-Chloropyridine, [CAS no. 109-09-1], reagent grade. The 2-chlorpyridine (99% lot 07114BJ) used in this evaluation was purchased from Sigma Aldrich (Milwaukee, WI).

Dichloromethane (methylene chloride), anhydrous. [CAS no. 75-09-2], reagent grade. The methylene chloride (99.8+% lot 56396MJ) used in this evaluation was purchased from Sigma Aldrich (Milwaukee, WI).

N,N-Dimethylformamide (DMF)[CAS no. 68-12-2], Chromsolv Plus grade. The DMF (≥99.9% (lot 00541LD) used in this evaluation was purchased from Sigma Aldrich (Milwaukee, WI).

The extraction solvent solution was 95:5 v/v methylene chloride:DMF.

3.3 Standard preparation

Prepare standards by spiking microliter quantities of 2-chloropyridine. For example, 100 µL of 2-chloropyridine in 1-mL volumetric flask is equivalent to 119.6 mg/mL, and 10 µL of this dilution in 1-mL of solvent is equivalent to 1196 µg/mL of 2-chloropyridine. Standards at lower concentrations were prepared using microliter injections into volumetric flasks containing the extraction solvent, or pipette dilutions of analytical standards using volumetric flasks and the extraction solvent. For this evaluation, standards in the range of 0.001 to 1.196 mg/mL of 2-chloropyridine were used. An additional standard from a second source should be prepared to check the calibration.

Bracket sample concentrations with standard concentrations. If, upon analysis, sample concentrations fall outside the range of prepared standards, prepare and analyze additional standards to confirm instrument response, or dilute high samples with extraction solvent and reanalyze the diluted samples.

3.4 Sample preparation

Remove the plastic end caps from the sample tubes and carefully transfer each adsorbent section to separate 2-mL vials. Discard the glass tube and glass wool plug.

Add 1.0 mL of extraction solvent to each vial using the same dispenser as used for preparation of standards.

Immediately seal the vials with poly(tetrafluoroethylene)-lined caps, and shake the vials on a shaker for 30 minutes.

3.5 Analysis

Gas chromatographic conditions

GC conditions

Temperatures:

column:	initial 100 °C, hold 4 min, ramp at 10 °C/min to 160 °C, hold 0 min
injector:	250°C
detector:	260°C

run time:	10 min
column gas flow:	3.0 mL/min (hydrogen)
velocity:	50 cm/s
column mode:	constant pressure @ 14.7 psi

injection size:	1.0 µL (10:1 split)
inlet liner:	Agilent 5183-4647 or equivalent
column:	60-m × 0.32-mm i.d. capillary DB-1 (df = 1.0 µm)

FID conditions

hydrogen flow:	30 mL/min
air flow:	400 mL/min
nitrogen makeup flow:	25 mL/min

retention times: 2.57 min (methylene chloride); 4.10 min (DMF); and 6.90 min (2-chloropyridine)

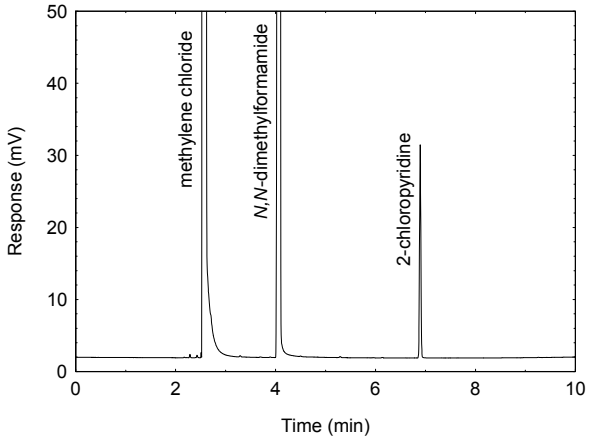


Figure 3.5.1. A chromatogram of 604 µg/mL 2-chloropyridine in 95:5 methylene chloride: DMF.

Peak areas are measured with an integrator or other suitable means.

An external standard calibration method is used. A calibration curve can be constructed by plotting response of standard injections versus micrograms of analyte per sample. Bracket the samples with freshly prepared analytical standards over the range of concentrations.

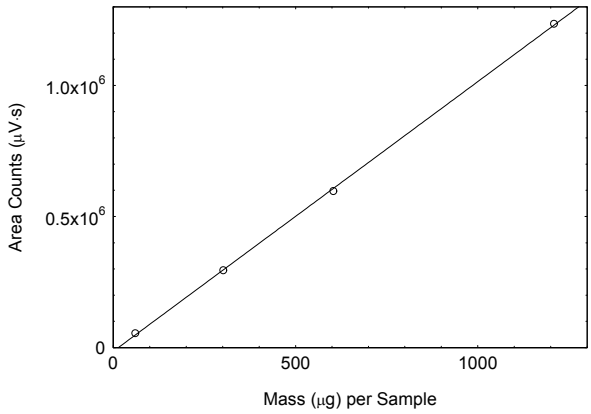


Figure 3.5.2. Calibration curve for 2-chloropyridine.
(y = 1029x-1.42E-4)

3.6 Interferences (analytical)

Any compound that produces a GC 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 extracted. Generally, chromatographic conditions can be altered to separate an interference from the analyte.

When necessary, the identity or purity of an analyte peak may be confirmed by additional analytical data. The mass spectrum in Figure 3.6 was obtained from the Wiley spectral library.

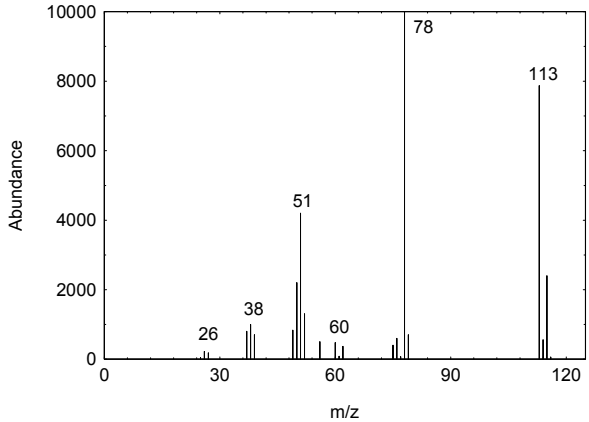


Figure 3.6. Mass spectrum of 2-chloropyridine.

3.7 Calculations

The amount of analyte per sampler is obtained from the appropriate calibration curve in terms of micrograms per sample, uncorrected for extraction efficiency. The back section is analyzed primarily to determine the extent of sampler saturation. If any analyte is found on the back section, it is added to the amount on the front section. This total amount is then corrected by subtracting the total amount (if any) found on the blank. The air concentration is calculated by using the following formulas.

$$C_M = \frac{M}{VE_E}$$

where C_M is concentration by weight (mg/m^3)
M is micrograms per sample
V is liters of air sampled
E_E is extraction efficiency, in decimal form

$$C_V = \frac{V_M C_M}{M_r}$$

where C_V is concentration by volume (ppm)
V_M is 24.46 (molar volume at NTP)
C_M is concentration by weight (mg/m^3)
M_r is molecular weight = 113.55

4. Recommendations for Further Study

Collection, reproducibility, and other detection limit studies need to be performed to make this a fully validated method. An internal standard should also be found and tested.