Method number:	PV2094
Target concentration:	2 mg/m^3 OSHA TWA PEL
Procedure:	Samples are collected by drawing a known volume of air through an XAD-7 tube coated with 10% phosphoric acid. Samples are desorbed with methanol and analyzed by gas chromatography with a flame ionization detector (GC-FID) using capillary column. Better sensitivity can be obtained using liquid chromatography with an ultraviolet detector (LC-UV).
Air volume and sampling rate studied:	100 minutes at 0.2 L/min (20 L)
Status of method:	Partially validated method. This method has been only partially evaluated and is presented for information and trial use.

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1 General Discussion

1.1 Background

1.1.1 History of procedure

OSHA has an exposure standard for hydroquinone at a level of 2 mg/m^3 TWA. NIOSH method 5004 collects hydroquinone on a mixed cellulose ester filter and field extraction within one hour of collection with a 1% acetic acid solution (Ref. 5.1). The acetic acid is to prevent hydroquinone from isomerizing to benzoquinone. Retention studies performed at the OSHA lab with humid air (91% RH) showed vaporization of the hydroquinone off of the filters, with only 81% recovery on filters analyzed immediately after the air was drawn. OSHA Method 39 recommends collection of pentachlorophenol on OVS-7 tubes and desorption with methanol (Ref. 5.2), since hydroquinone is similar to pentachlorophenol, this means of collection and analysis were attempted. The hydroquinone sublimed off the glass fiber filter, and collected on the XAD-7 resin. There it isomerized to benzoquinone in the presence of water vapor, and the benzoquinone reacted with the XAD-7 resin. This isomerization continued with storage, with more benzoquinone being formed each day stored. To prevent the isomerization of hydroquinone to benzoquinone, a phosphoric acid coated XAD-7 resin was used for a retention study. No loss of the hydroquinone was observed. This media was further evaluated and found to have good retention, desorption, and storage.

1.1.2 Potential workplace exposure (Ref. 5.3)

Hydroquinone is used as a depigmentor, a photographic reducer and developer, a reagent in determination of small quantities of phosphates, and an antioxidant in oils and greases. It is used as an intermediate in the manufacture of dyes. In human medicine, it is an ingredient in topical creams for blemishes, and in bleaching creams.

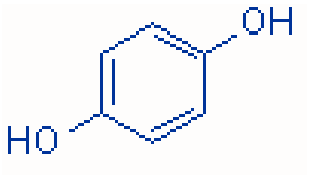
1.1.3 Toxic Effects (This section is for information purposes only and should not be taken as the basis for OSHA policy.) (Ref. 5.4)

Hydroquinone is a skin, eye, mucous membrane, and gastrointestinal irritant. In humans, ingestion of 1 gram of hydroquinone has caused tinnitus, nausea, vomiting, and shortness of breath, cyanosis, convulsions, delirium, and collapse. Death has occurred in some individuals after ingestion of 5 grams of hydroquinone. Workplace exposure for greater than 5 years, to levels that had no systemic effects, caused staining, and opacification of the cornea.

1.1.4 Physical properties (Ref. 5.3):

CAS:	123-31-9
IMIS:	1490
RTECS:	MX3500000; 41010
DOT:	UN 2662 (Poison)
Synonyms:	1,4-Benzenediol; Quenelle; p-dihydroxybenzene; Hydroquinol; Aids; Black and White Bleaching cream; Eldoquin; Eldopaque; Quinine; Tecquinol
Molecular weight:	110.11
Melting point:	170-171 ºC
Boiling point:	285-287 ºC
Flash point:	165 ºC (329 ºF) (closed cup)
Odor:	phenolic
Color:	white to light yellow crystals which turn brown with exposure to light and air
Molecular formula:	$C_6H_6O_2$

Structure:



1.2 Limit defining parameters

1.2.1 The detection limit of the analytical procedure is 1 µg hydroquinone. This is the smallest amount that could be detected under normal operating conditions.

1.2.2 The overall detection limit is 0.05 mg/m^3. (All mg/m^3 amounts in this study are based on a 20-liter air volume and 1 mL desorption.)

1.3 Advantages

1.3.1 The sampling procedure is convenient.

1.3.2 The analytical method is reproducible and sensitive.

1.3.3 Reanalysis of samples is possible.

1.3.4 It may be possible to analyze other compounds at the same time.

1.3.5 Interferences may be avoided by proper selection of column and GC parameters, or LC parameters if liquid chromatography is used.

1.4 Disadvantages

None known.

2 Sampling procedure

2.1 Apparatus

2.1.1 A calibrated personal sampling pump, the flow of which can be determined within ±5% at the recommended flow.

2.1.2 XAD-7 tubes containing 20/60 mesh XAD-7 coated with 10% phosphoric acid, with an 80 mg adsorbing section and a 40 mg backup section, separated by a silane treated glass wool plug before, after, and between the adsorbing sections. The ends are flame sealed and the glass tube containing the adsorbent is 7-cm x 6-mm o.d. and 4-mm i.d., SKC tubes or equivalent.

2.1.3 Tubes are available through SKC, catalog number 226-98, or can be prepared from phosphoric acid coated XAD-7 resin, which is prepared in the following manner.

Approximately 100 grams of Amberlite XAD-7 20/60 mesh, a porous polyacrylate adsorbent manufactured by Rolm and Haas, was washed several times with 100 mL deionized water to remove the fine particles. The resin was washed three times with 100 mL methanol, then three times with acetonitrile, and the excess acetonitrile was removed by vacuum filtration. The resin was placed in a round bottom flask and treated with a solution of 14 mL reagent grade phosphoric acid in 200 mL acetonitrile. It was allowed to stand for 10 minutes, then the resin was dried using a rotary evaporator. The acid-coated

XAD-7 resin, with the odor of acetonitrile present, was then stored in a tightly sealed container or packed into tubes.

2.2 Sampling technique

2.2.1 Open the ends of the coated XAD-7 tubes immediately before sampling.

2.2.2 Connect the coated XAD-7 tubes to the sampling pump with flexible tubing.

2.2.3 Place the tubes in a vertical position to minimize channeling, with the smaller section towards the pump.

2.2.4 Air being sampled should not pass through any hose or tubing before entering the coated XAD-7 tubes.

2.2.5 Seal the coated XAD-7 tubes with plastic caps immediately after sampling. Seal each sample lengthwise with a Form OSHA-21 seal.

2.2.6 With each batch of samples, submit at least one blank tube from the same lot used for samples. This tube should be subjected to exactly the same handling as the samples (break ends, seal, & transport) except that no air is drawn through it.

2.2.7 Transport the samples (and corresponding paperwork) to the lab for analysis.

2.2.8 Bulks submitted for analysis must be shipped in a separate mailing container from other samples.

2.3 Desorption efficiency

Six tubes were spiked with loadings of 4.0 µg (0.2 mg/m^3), 20 µg (1 mg/m^3), 40 µg (2 mg/m^3), and 80 µg (4 mg/m^3) hydroquinone. They were allowed to equilibrate overnight at room temperature. They were then opened, each section placed into a separate 2 mL vial, desorbed with 1 mL of methanol, with 0.25 µL/mL dimethyl formamide internal standard, for 30 minutes with shaking, and analyzed by GC-FID. The overall average was 100 %.(Table 2.3)

Table 2.3
Desorption Efficiency

tube #	% recovered			
	4.0 µg	20 µg	40 µg	80 µg
1	100	101	103	103
2	103	101	103	101
3	102	99.4	98.0	98.6
4	102	97.3	103	98.1
5	100	98.7	98.2	103
6	100	100	95.8	97.6
average	101	99.6	100	100

overall average = 100%
standard deviation = ±2.19

2.4 Retention efficiency

The six-coated XAD-7 tubes were spiked with 40 µg (2.0 mg/m^3) hydroquinone, allowed to equilibrate overnight, and then had 20 liters humid air (91% RH) pulled through them. They were

then opened, desorbed, and analyzed by GC-FID. The retention efficiency averaged 99.7%. There was no hydroquinone found on the backup portions of the tubes. (Table 2.4)

Table 2.4
Retention Efficiency

tube #	% recovered		total
	'A'	'B'	
1	101	0.0	101
2	100	0.0	100
3	98.7	0.0	98.7
4	101	0.0	101
5	97.5	0.0	97.5
6	99.8	0.0	99.8

average = 99.7%

2.5 Storage

Coated XAD-7 tubes were spiked with 40 µg (2.0 mg/m^3) hydroquinone and stored at room temperature, in room light, until opened and analyzed. The recoveries averaged 97.4% for the 14 days stored. (Table 2.5)

Table 2.5
Storage Study

day	% recovered
7	97.6
7	96.6
7	95.7
14	100
14	98.3
14	96.0
overall average -	97.4

2.6 Precision

The precision was calculated using the area counts from six injections of each standard at concentrations of 4.0, 20, 40, and 80 µg/mL hydroquinone in the desorbing solution. The pooled coefficient of variation was 0.0388. (Table 2.6)

Table 2.6
Precision Study

injection number	4.0 µg/mL	20 µg/mL	40 µg/mL	80 µg/mL
1	1186	5715	11525	22647
2	1187	5636	11428	22860
3	1149	5650	11525	22782
4	1169	5777	11391	22745
5	1162	5750	11587	22853
6	1136	5814	11612	23155
average	1165	5724	11511	22840
standard deviation – CV	±88.4 0.0759	±70.5 0.0123	±86.8 0.00754	±173 0.00757

pooled CV = 0.0388

Where:

$$CV\ \left(Coefficient\ of\ Variation\right) = \frac{\left(standard\ deviation\right)}{\left(average\right)}$$

$$Pooled\ CV = \sqrt{\frac{A1\left(CV1\right)^2 + A2\left(CV2\right)^2 + A3\left(CV3\right)^2 + A4\left(CV4\right)^2}{A1 + A2 + A3 + A4}}$$

A1, A2, A3, A4 = number of injections at each level
CV1, CV2, CV3, CV4 = Coefficient of variation at each level

2.7 Air volume and sampling rate studied

2.7.1 The air volume studied is 20 liters.

2.7.2 The sampling rate studied is 0.2 liters per minute.

2.8 Interferences

Suspected interferences should be listed on sample data sheets.

2.9 Safety precautions

2.9.1 Sampling equipment should be placed on an employee in a manner that does not interfere with work performance or safety.

2.9.2 Safety glasses should be worn at all times.

2.9.3 Follow all safety practices that apply to the workplace being sampled.

3 Analytical method

3.1 Apparatus

3.1.1 Gas chromatograph equipped with a flame ionization detector. A HP 5890 gas chromatograph was used in this study.

3.1.2 GC column capable of separating the analyte and an internal standard from any interference. The column used in this study was a 15-m x 0.32-mm i.d (0.25 µm d_f DB-WAX) capillary column.

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

3.1.4 Two milliliter vials with PTFE-lined caps.

3.1.5 A 1-µL, 10-µL syringes for sample injection.

3.1.6 Pipettes for dispensing the desorbing solution. The Glenco 1-mL dispenser was used in this method.

3.1.7 Volumetric flasks, 5-mL, and other convenient sizes for preparing standards.

3.1.8 An analytical balance capable of weighing to the nearest 0.01 mg.

3.1.9 If a liquid chromatography is used for analysis, the instrumentation should be a liquid chromatograph equipped with an autosampler and an ultraviolet detector, and a C18 column. A Waters 510 pump, 710 B WISP, 440 detector with extended wavelength module was used. The column was a 25-cm × 6-mm, (5µm Supelco LC-18-DB).

3.2 Reagents

3.2.1 Purified GC grade nitrogen, hydrogen, and air. (for GC analysis only)

3.2.2 Hydroquinone, Reagent grade

3.2.3 Methanol, HPLC grade

3.2.4 Dimethyl formamide, Reagent grade

3.2.5 For GC analysis the desorbing solution is 0.25 µL/mL dimethyl formamide internal standard in methanol. If analysis is performed by liquid chromatography, it may be better to not use an internal standard, as on many C18 columns it is difficult to separate the dimethyl formamide from the hydroquinone.

3.2.6 Deionized water (mobile phase for LC analysis only)

3.2.7 Phosphoric acid (mobile phase for LC analysis only)

3.3 Sample preparation

3.3.1 The sample tube is opened and each section is placed in separate 2-mL vials, along with the separating glass wool.

3.3.2 Each section is desorbed with 1 mL of the desorbing solution.

3.3.3 The vials are sealed immediately and allowed to desorb for 30 minutes on a shaker, (a roto-rack, or a sample rocker table).

3.4 Standard preparation

3.4.1 Standards are prepared by diluting a known quantity of hydroquinone with the desorbing solution. The LC stock solutions also had 0.1 mL/L of H_3PO_4 added to them.

3.4.2 At least two separate stock standards should be made. Dilutions of the stock standards are prepared to bracket the samples. For this study, standards ranged from 1 to 80 µg/mL.

3.5 Analysis

3.5.1 Gas chromatograph conditions.

Column: 15-m x 0.32-mm i.d., (0.25 µm d_f DB-WAX) capillary column

Flow rates	**(mL/min)**	**Temperature**	**(ºC)**
Nitrogen (makeup):	30	Injector:	240
Hydrogen (carrier):	1.5	Detector:	240
Air:	450	Column:	80 ºC for 2 min then
Hydrogen (detector):	30		heat 10 ºC/min to 200 ºC

Injection size: 1 µL
Elution time: 15.69 min

Chromatogram:

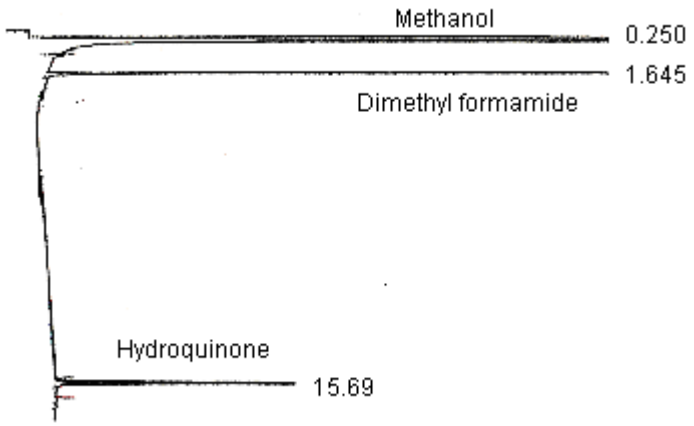


Figure 1. An analytical standard of 40 µg/mL hydroquinone in methanol with 0.25 µL/mL dimethyl formamide internal standard, and analyzed by gas chromatography.

3.5.2 Liquid chromatograph conditions.

Column:	25-cm x 6-mm, 5 µm Supelco LC-18-DB
Mobile Phase:	1 mL of 0.1:5:95 phosphoric acid:methanol:water (if using methanol with the dimethyl formamide internal standard)
Mobile Phase:	1 mL/min of 0.1:25:75 phosphoric acid:methanol:water (if using methanol only as desorbing solvent)
Injection size:	10 µL
Detector:	UV at 219 nm (UV max is 223 nm, secondary max is 200 nm, tertiary max is 291 nm) (Note: if the analysis is performed at 219 the DMF can be used as an internal standard, but if 291 nm is used the DMF does not have a response at that wavelength)

Chromatograms:

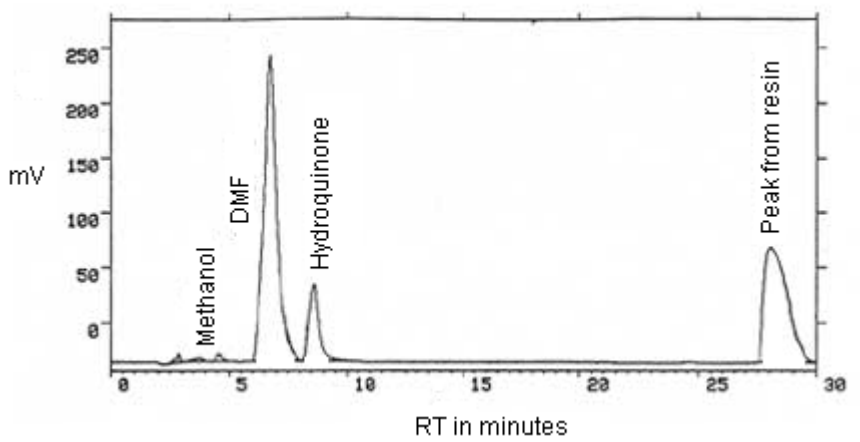


Figure 2. An analytical standard of 40 µg/mL hydroquinone in methanol with 0.25 µL/mL dimethyl formamide (DMF) internal standard, analyzed by liquid chromatography with an UV detector at 219 nm, and using a mobile phase of 0.1:5:95 H_3PO_4:methanol:water.

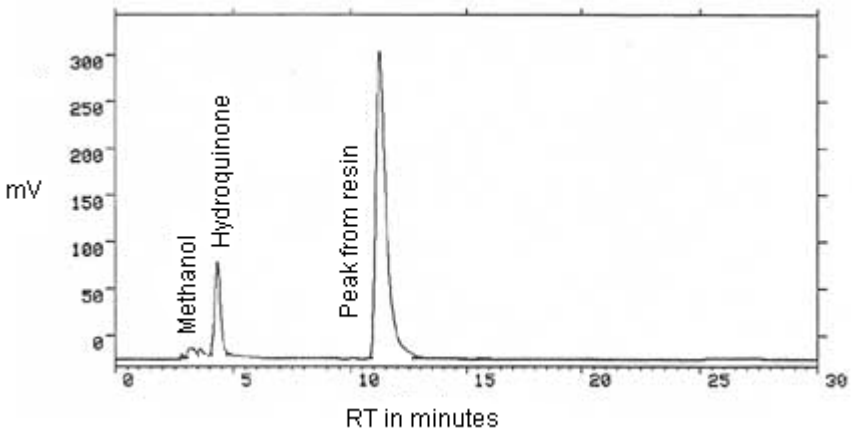


Figure 3. An analytical standard of 40 µg/mL hydroquinone in methanol with 0.25 µL/mL dimethyl formamide internal standard, analyzed by liquid chromatography with an UV detector at 219-nm, and using a mobile phase of 0.1:25:75 H_3PO_4:methanol:water.

3.5.3 The following chromatogram was analyzed on an HP5890 Series II gas chromatogram with a flame ionization detector.

Column: 60-m x 0.32-mm i.d. (0.25 µm d_f DB-1) capillary column

Flow rates	**(mL/min)**	**Temperature**	**(ºC)**
Nitrogen (makeup):	30	Injector:	200
Hydrogen (carrier):	1.5	Detector:	250
Air:	450	Column:	80 ºC for 4 min then
Hydrogen (detector):	30		heat 10 ºC/min to 160 ºC, hold 5 min

Injection size: 1 µL
Elution time: 11.115 min

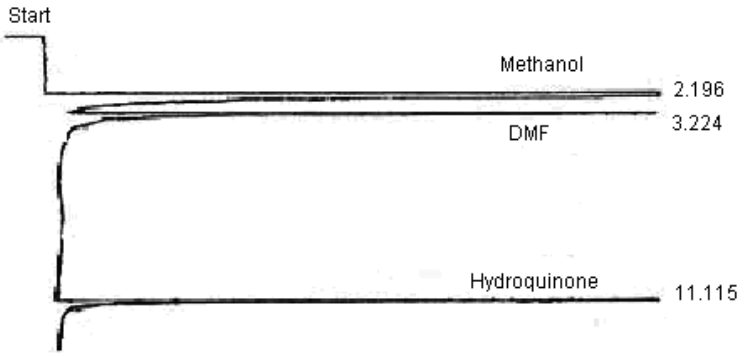


Figure 4. A gas chromatogram of 75 µg/mL hydroquinone in methanol with DMF as internal standard.

3.5.3 Peak areas are measured by an integrator or other suitable means.

3.6 Interferences (analytical)

3.6.1 Any compound having the general retention time of the analyte or the internal standard used is interference. Possible interferences should be listed on the sample data sheet. GC parameters should be adjusted if necessary so these interferences will pose no problems.

3.6.2 Retention time data on a single column is not considered proof of chemical identity. Samples over the target concentration should be confirmed by GC/Mass Spec or other suitable means.

3.6.3 There is a reaction between the excess phosphoric acid and the methanol to form trimethyl phosphate. On the column used in this study, trimethyl phosphate eluted at 10 minutes. The amount formed is approximately 50 µg. If another column is used for this analysis, the trimethyl phosphate should be separated from the other peaks.

3.7 Calculations

3.7.1 A curve with area counts versus concentration is constructed from the calibration standards.

3.7.2 The area counts for the samples are plotted on the calibration curve to obtain the concentration of hydroquinone in solution.

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

$$\text{mass of analyte, } \mu g = \frac{(\mu g / mL)(\text{desorption volume, } mL)}{(\text{desorption efficiency, decimal})}$$

$$\text{moles of analyte} = \frac{(\text{mass of analyte, } \mu g)(1\,g)}{(\text{molecular weight})(10^6\,\mu g)}$$

$$\text{volume of analyte} = (\text{moles of analyte})(\text{molar volume})$$

$$ppm = \frac{(volume\ of\ analyte)(10^6)^*}{(air\ volume,\ L)}$$

* All units must cancel.

3.7.4 The above equations can be consolidated to form the following formula. To calculate the mg/m³ of analyte in the sample based on a 20-liter air sample:

$$ppm = \frac{(\mu g / mL)(DV)(24.46)}{(L)(DE)(MW)}$$

Where:

μg/mL = concentration of analyte in sample
24.46 = Molar volume (liters/mole) at 25 °C and 760 mmHg
MW = Molecular weight (g/mole)
DV = Desorption volume, mL
20 L = Air volume, L
DE = Desorption efficiency, decimal

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 All handling of solvents should be done in a hood.

3.8.2 Avoid skin contact with all chemicals.

3.8.3 Wear safety glasses, gloves and a lab coat at all times in laboratory area.

4 Recommendations for further study

Collection study should be performed. Finish validating method.

5 References

5.1 "NIOSH Manual of Analytical Methods," U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Third Edition, Method 5004.

5.2 Cummins, K., Method 39, "Phenol and Cresol," Organic Method's Evaluation Branch, OSHA Salt Lake Technical Center, 1982.

5.3 Windholz, M., "The Merck Index," Eleventh Edition, Merck Co., Rahway N.J., 1989, p. 762.

5.4 "Documentation of the Threshold Limit Values and Biological Exposure Indices," Fifth Edition, American Conference of Governmental Industrial Hygienists Inc., Cincinnati, OH, 1986, p. 319.