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Method for the determination of hydrazine in workplace air using gas chromatography-mass spectrometry (GC-MS)

Air Monitoring Method

W. Krämer[1], T.H. Brock[2,*], R. Hebisch[3,*], A. Hartwig[4,*], MAK Commission[5,*]

[1] *Method development, BASF SE, ESE/MA - Z 570, Carl-Bosch-Straße 38, 67056 Ludwigshafen, Germany*

[2] *Head of the working group "Analytics", German Social Accident Insurance, Institution for the raw materials and chemical industry, Prevention - Department of Hazardous Substances, Biological Agents and Analytical Chemistry, Kurfürsten-Anlage 62, 69115 Heidelberg, Germany*

[3] *Head of the working group "Air Analyses" of the Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Federal Institute for Occupational Safety and Health (BAuA), Friedrich-Henkel-Weg 1–25, 44149 Dortmund, Germany*

[4] *Chair of the Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Institute of Applied Biosciences, Department of Food Chemistry and Toxicology, Karlsruhe Institute of Technology (KIT), Adenauerring 20a, Geb. 50.41, 76131 Karlsruhe, Germany*

[5] *Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Kennedyallee 40, 53175 Bonn, Germany*

* *email: T.H. Brock (analytik@bgrci.de), R. Hebisch (luftanalysen-dfg@baua.bund.de), A. Hartwig (andrea.hartwig@kit.edu), MAK Commission (arbeitsstoffkommission@dfg.de)*

Please direct correspondence to Berufsgenossenschaft RCI, Fachbereich Gefahrstoffe und biologische Arbeitsstoffe, P.O. Box 101480, 69004 Heidelberg, Germany; analytik@bgrci.de

Keywords: hydrazine; air analyses; analytical method; workplace measurement; hazardous substance; gas chromatography; mass spectrometry; GC-MS; XAD-2, impregnated with 2,4-pentanedione; liquid desorption

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W. Krämer[1], T.H. Brock[2,*], R. Hebisch[3,*], A. Hartwig[4,*], MAK Commission[5,*]

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Abstract

This analytical method is a validated measurement procedure for the determination of hydrazine in workplace air for risk assessment at work. Sampling is performed by drawing a defined volume of air through an adsorption tube filled with XAD-2 impregnated with 2,4-pentanedione using a flow-regulated pump. The flow rate is set to 200 mL/min with a recommended air sample volume of approx. 48 litres at a sampling period of 4 hours. After sampling the formed 3,5-dimethylpyrazole is extracted with methanol and analysed by means of gas chromatography-mass spectrometry (GC-MS). The absolute limit of quantification (LOQ) is 0.05 ng and the relative LOQ is 0.002 mg/m^3 based on an air sample volume of approx. 48 litres. The mean recovery was 82% and the expanded uncertainty for the overall measurement method 18%.

Joint Publication of the Analytical Subcommittee of the Chemistry Board of Experts of the Expert Committee Raw Materials and Chemical Industry of the German Social Accident Insurance and the Working Group “Air Analyses” of the Permanent Senate Commission of the DFG for the Investigation of Health Hazards of Chemical Compounds in the Work Area.

Keywords

hydrazine; air analysis; analytical method; workplace measurement; air sampling; hazardous substances; measurement method; measuring procedure; XAD-2; 2,4-pentanedione; 3,5-dimethylpyrazoles; gas chromatography-mass spectrometry; GC-MS

Author Information

[1] BASF SE, ESE/MA – Z 570, 67056 Ludwigshafen, Germany
[2] German Social Accident Insurance Institution for the raw materials and chemical industry, Prevention – Department of Hazardous Substances, Biological Agents and Analytical Chemistry, Kurfürsten-Anlage 62, 69115 Heidelberg, Germany
[3] Head of the working group “Air Analyses” of the Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Federal Institute for Occupational Safety and Health (BAuA), Friedrich-Henkel-Weg 1-25, 44149 Dortmund, Germany
[4] Chair of the Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Department of Food Chemistry and Toxicology, Institute for Applied Biosciences, Karlsruhe Institute of Technology (KIT), Adenauerring 20a, Geb. 50.41, 76131 Karlsruhe, Germany
[5] Permanent Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, Deutsche Forschungsgemeinschaft, Kennedyallee 40, 53175 Bonn, Germany

[*] Email: T.H. Brock (analytik@bgrci.de), R. Hebisch (luftanalysen-dfg@baua.bund.de), A. Hartwig (andrea.hartwig@kit.edu), MAK Commission (arbeitsstoffkommission@dfg.de)

Method for the determination of hydrazine in workplace air using gas chromatography-mass spectrometry (GC-MS)

German Social Accident Insurance
Expert Committee Raw Materials and Chemical Industry
Subcommittee Hazardous Substances

Analytical Subcommittee of the Chemistry Board of Experts[1]

Recognised analytical procedures for the determination of carcinogens, mutagens or substances toxic to reproduction

Order number: DGUV Information 213-520 Method 04 Issued: May 2014

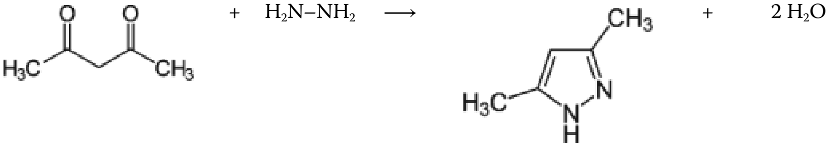
This method has been tested and recommended for the determination of hydrazine in the air at workplaces by the German Social Accident Insurance.

Both personal and stationary sampling can be performed for risk assessment at work.

Sampling is carried out with a pump and collected onto XAD-2 impregnated with 2,4-pentanedione. Analysis is performed by gas chromatography-mass spectrometry (GC-MS) after solvent desorption.

Name	CAS number	Molar mass
Hydrazine	302-01-2	32.05

Reaction equation:



2,4-Pentanedione Hydrazine 3,5-Dimethylpyrazole

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[1] Please direct correspondence to Berufsgenossenschaft Rohstoffe und chemische Industrie, Prävention, P. O. Box 101480, 69004 Heidelberg, Germany; analytik@bgrci.de

Summary

The analytical method describes the determination of the mean concentration of hydrazine in workplace air averaged over the sampling period after personal or stationary sampling.

Principle: A defined air volume is drawn through a tube filled with XAD-2 impregnated with 2,4-pentanedione using a suitable flow-regulated sampling pump. After sampling the formed 3,5-dimethylpyrazole is desorbed with methanol and analysed by means of gas chromatography-mass spectrometry (GC-MS).

Limit of quantification: Absolute: 0.05 ng of hydrazine
Relative: 0,002 mg/m^3 of hydrazine for an air sample volume of 48 L, 2 mL desorption solution and an injection volume of 1 µL.

Selectivity: The method is selective due to the combination of gas chromatography (GC) and mass spectrometry (MS).

Advantages: Personal and selective measurements are possible.

Disadvantages: No indication of peak concentrations.

Apparatus: Pump, flow meter, adsorption tube filled with XAD-2 impregnated with 2,4-pentanedione, gas chromatograph with mass selective detector (GC-MS).

Detailed description of the method

Contents

1 Equipment, chemicals and solutions

1.1 Equipment

For sampling:

- Adsorption tubes filled with XAD-2 impregnated with 2,4-pentanedione (acetylacetone) (5 percent per weight), filling quantity 200 mg;
  Own production of the sample tubes: glass tubes (one-sided closed by melting), lengh approx. 6 cm, ID approx. 4 mm, and XAD-2 (20/60 mesh), e.g. Sigma-Aldrich, 82024 Taufkirchen, Germany (see Section 1.4)
- Tube holder
- Flow meter, e.g. Gilibrator, from Gilian, supplied by Haan & Wittner, 71296 Heimsheim, Germany
- Sampling pump, suitable for a flow rate of 200 mL/min, e.g. PP5, from Gilian

For sample preparation and analytical determination:

- Gas chromatograph with mass selective detector (e.g. Agilent 6890 gas chromatograph with MSD 5973 A mass selective detector)
- Capillary column: 30 m, ∅0.25 mm, 1.0 µm film thickness (e.g. J&W DB-WAX)
- Microlitre syringe, 10 µL
- Screw-capped vials, 5 mL with caps and septa
- Autosampler vials, 1.5 mL with PP screw caps and PTFE-coated butyl rubber septa
- Drying cabinet, evacuable
- Ultrasonic bath
- Analytical balance
- Variable piston pipette
- Volumetric flasks, 10, 25 and 250 mL

Gases for operation of the gas chromatograph:

- Helium 5.0, purity 99.999% (carrier gas)
- Nitrogen 5.0, purity 99.999% (make-up gas)

1.2 Chemicals

- Methanol, purity 99,9%, e.g. Merck, 64293 Darmstadt, Germany
- 2,4-Pentanedione, purity 97%, e.g. Sigma-Aldrich
- Hydrazine, purity 98,5%, e.g. Sigma-Aldrich
- 3,5-Dimethylpyrazole, purity 99%, e.g. Sigma-Aldrich
- Pyrazole, purity 99% (internal Standard (ISTD)), e.g. Sigma-Aldrich

1.3 Solutions

Pyrazole stock solution (ISTD):	Solution of approx. 3.5 mg pyrazole (ISTD) per mL methanol Approx. 35.5 mg of pyrazole are weighed exactly to the nearest 0.1 mg into a 10 mL volumetric flask. Then the flask is filled to the mark with methanol and shaken.
Desorption solution:	Solution of 14.2 µg pyrazole (ISTD) per mL methanol 1 mL of the pyrazole stock solution is pipetted into a 250 mL volumetric flask, into which several millilitres of methanol have already been placed. Then the flask is filled to the mark with methanol and shaken.
3,5-Dimethylpyrazole stock solution:	Solution of approx. 0.73 mg of 3,5-dimethylpyrazole per mL desorption solution Approx. 7.4 mg of 3,5-dimethylpyrazole (purity of 99%) are weighed exactly to the nearest 0.1 mg into a 10 mL volumetric flask. Then the flask is filled to the mark with desorption solution and shaken.
3,5-Dimethylpyrazole calibration solutions:	Solutions of approx. 0.2 to 9 µg of 3,5-dimethylpyrazole per mL desorption solution Pipettes are used to add 3, 27, 51, 75, 99 and 123 µL of the respective 3,5-dimethylpyrazole stock solution each into a 10 mL volumetric flask into which several millilitres of the desorption solution have already been placed. Then the flasks are filled to the mark with desorption solution and shaken.

Based on an air sample volume of 48 L, a concentration range of approx. 3 to 126 µg/m^3 of hydrazine is covered by these solutions (the conversion factor from 3,5-dimethylpyrazole to hydrazine is 0,3334; see Table 1).

The prepared calibration solutions are stable for at least three months when stored at room temperature.

For the purpose of checking the calibration a solution is to be used, which has been prepared independently from the calibration solutions described above.

Table 1 Concentrations of the hydrazine calibration solutions in mg/L and in µg/m³

Addition of stock solution [µL]	3,5-Dimethylpyrazole [mg/L]	Hydrazine [mg/L]	Hydrazine [µg/m³]*
3	0.22	0.07	3.1
27	1.98	0.67	27.7
51	3.73	1.26	52.4
75	5.49	1.82	77.0
99	7.24	2.44	101.6
123	9.00	3.03	126.3

*concerning of an air sample volume of 48 L.

1.4 Preparation of the adsorption tubes

The adsorbent XAD-2 is purified by thermal treatment in an evacuable drying cabinet at a temperature of 120 °C under a slight vacuum of approx. 650 mbar over a period of 48 hours. Then the XAD-2 can be impregnated with 2,4-pentanedione as the derivatisation reagent.

For impregnation of the XAD-2 with 2,4-pentanedione, 10 g of the purified XAD-2 is to suspend with 100 mL of methanol to which 500 µL of 2,4-pentanedione have been added. Then the mixture is leave to stand for approx. one hour. Afterwards, the solvent is removed using a rotary evaporator. The impregnated XAD-2 can be stored in a dark bottle for at least six month.

For preparing the sample tubes first a plug of quartz wool is placed into the tubes which are one-sided closed by melting. Then approx. 200 mg of the impregnated XAD-2 are filled into each tube and fixed with another plug of quartz wool. Finally the tubes are sealed with plastic caps and the date of preparing is noted on the tubes. The prepared sample tubes are stable for at least six month when stored at room temperature in a dark bottle.

2 Sampling

Sampling can be carried out as stationary or personal sampling. Immediately prior to sampling a sample tube is opened and connected to a flow-regulated pump. A flow rate of 200 mL/min is then set. With a sampling time of four hours, this is equivalent to an air sample volume of approx. 48 litres. After sampling, the flow rate must be checked for constancy. If the deviation from the adjusted flow rate is greater than ± 5%, it is advisable to discard the measurement (see DGUV-Information 213-500 “Allgemeiner Teil”, Section 3 [3]). Subsequently, the loaded sample tube is sealed with the caps provided. The important parameters for the determination of the concentration in air (sample volume, temperature, air pressure, relative humidity) are documented in the sampling record.

The method was checked with a flow rate of 200 mL/min up to an air sample volume of 48 L.

3 Analytical determination

3.1 Sample preparation

The content of the loaded sample tube is transferred into a 5 mL sample vial. After addition of 2 mL of the desorption solution, the vial is sealed and treated for 15 minutes in the ultrasonic bath. Then the supernatant solution with the formed 3,5-dimethylpyrazole is separated and transferred into an autosampler vial and analysed by means of gas chromatography-mass spectrometry.

In order to ensure that the desorption solution and the sample tubes used do not contain any interfering impurities, the content of a prepared sample tube per sample series (with the same date of preparing as described above) is extracted with 2 mL of the desorption solution (blank solution).

1 µL each of the sample solution and the blank solution are injected into the gas chromatograph and a chromatogram is recorded as described in Section 3.2. The quantitative evaluation is carried out according to the internal standard method using the peak areas of the 3,5-dimethylpyrazole and the peak area of the pyrazole as the internal standard.

3.2 Operating conditions for gas chromatography

The characteristics of the method stated in Section 5 were obtained under the following operating conditions:

Apparatus:	Agilent 6890 gas chromatograph with MSD 5973 A mass selective detector and autosampler
Separation column:	J&W DB-WAX fused silica capillary (polyethylene glycol), ID 0.25 mm, film thickness 1.0 µm, length 30 m
Temperatures:	Injector: 220 °C Detector: 280 °C Oven with temperature programme: Initial temperature 40 °C, isothermal for 1 min Heating rate 25 °C/min up to the final temperature of 220 °C; 4 min isothermal
Injection:	Split injection; Split ratio 1 : 5
Injection volume:	1 µL
Carrier gas:	Helium 5.0; 1.5 mL/min (constant flow)
Ionisation modus:	Electron Impact Ionisation (EI) (70 eV)
Measuring modus:	SIM (Selected Ion Monitoring) Recorded masses (m/z in amu)

	Quantification	Qualification
3,5-Dimethylpyrazole:	96	95
Pyrazole (ISTD):	68	41

Dwelltime: 50 ms

4 Evaluation

4.1 Calibration

1 µL of the calibration solutions described in Section 1.3 is injected into the gas chromatograph in each case. The calibration function is obtained by plotting the ratio of the peak areas of 3,5-dimethylpyrazole to the peak areas of pyrazole as the internal standard (ISTD) versus the corresponding concentration ratios of hydrazine (converted from 3,5-dimethylpyrazole with the conversion factor of 0,3334) and pyrazole in the individual calibration solutions.

4.2 Calculation of the analytical result

From the received chromatograms the peak areas of the hydrazine derivative (3,5-dimethylpyrazole) and the peak areas of pyrazole are determined. Then the quotient is formed and from the respective calibration function the corresponding value for the mass of hydrazine in the sample solution in µg is calculated. The concentration by weight *(c)* in mg/m³ of the hydrazine in the air sample is calculated according to the following Equation (1):

$$c = \frac{m}{V \cdot \eta} \tag{1}$$

where:

c is the mass concentration of hydrazine in mg/m³
m is the mass of hydrazine in the analytical sample in µg
V is the air sample volume in litres
η is the recovery

If the calculated concentration of the hydrazine is outside the calibration range, then the sample solution must be appropriately diluted with desorption solution and the quantification must be repeated using the diluted sample solution.

5 Reliability of the method

The characteristics of the method were calculated as stipulated in DIN EN 482 [1]. For this purpose the following two validation solution were prepared:

Validation solution 1:	Solution of 1.21 mg hydrazine per mL methanol Several millilitres of methanol are placed into a 10 mL volume flask and the flask is then weighed. A microlitre pipette was used to add 12 µL of hydrazine into the volume flask and the flask is weighed again. Afterwards, the flask is filled to the mark with methanol and shaken.

Validation solution 2:	Solution of 0.12 mg hydrazine per mL methanol 1 mL of the validation solution 1 is pipetted into a 10 mL volumetric flask, into which several millilitres of methanol have already been placed. Then the flask is filled to the mark with methanol and shaken.

5.1 Precision and recovery

In order to assess the measurement procedure according to DIN EN 482 [1], six adsorption tubes were each spiked with the two validation solutions described in Section 5. The tubes were connected via a sixfold tube holder with the pump whereby the volume flow for each tube can be adjusted separately. Using a positive-displacement pipette 5 µL of the validation solution 2 (lowest concentration) and 5 or 10 µL of the validation solution 1 (higher concentration) are spiked onto the impregnated XAD-2 tubes. Then laboratory air was drawn through the tubes at a flow rate of 200 mL/min over a time period of two hours at a temperature of 23 °C and a relative humidity of approx. 65%. The loaded masses of hydrazine corresponded to an air volume of 48 litres the concentrations listed in Table 2.

The samples were prepared and analysed as described in Section 3. The calculated relative standard deviations and recoveries are shown in Table 2. The mean relative standard deviation was 2.1% and the mean recovery 82%.

Table 2 Characteristics of the analytical procedure for hydrazine

Concentration [µg/m^3]	Standard deviation (rel.) [%]	Recovery [%]
12.9	3.2	84
126	1.5	79
251	1.6	82

5.2 Limit of quantification

The limit of quantification (LOQ) was calculated using the method of the "blank-value" according to DIN 32645 [2]. For that a solution of approx. 0.05 mg per litre of 3,5-dimethylpyrazole were prepared and analysed by GC-MS (sixfold determination). The LOQ were calculated from the results of the scattering.

The absolute LOQ for hydrazine (after conversion) is 0.05 ng. This is equivalent to a relative LOQ of 0.002 mg/m^3 for an air sample volume of 48 litres, 2 mL of desorption solution and an injection volume of 1 µL.

5.3 Uncertainty

The expanded uncertainty was estimated taking all relevant influencing factors into consideration as stipulated in DIN EN 482 [1]. The uncertainty of the entire method and thus also of the analytical result consists principally of the uncertainty contributions of the air sampling (e.g. air sample volume, deviation from the sampling convention) and the analytical preparation (extraction agent volume, scatter of the calibration function, fluctuations in the recovery and the reproducibility). The expanded uncertainty for the here described overall measurement method is 18%.

5.4 Storage stability

The loaded adsorption tubes can be stored at room temperature without losses for at least 14 days.

6 References

1 DIN EN 482 (2012) Workplace atmospheres – General requirements for the performance of procedures for the measurement of chemical agents. Beuth Verlag, Berlin, Germany

2 DIN 32645 (2008) Chemical analysis – Decision limit, detection limit and determination limit under repeatability conditions – Terms, methods, evaluation. Beuth Verlag, Berlin, Germany

3 DGUV Information 213-500 (2015) Allgemeiner Teil. Von den Unfallversicherungsträgern anerkannte Analysenverfahren zur Feststellung der Konzentration krebserzeugender, erbgutverändernder oder fortpflanzungsgefährdender Stoffe in der Luft in Arbeitsbereichen. Deutsche Gesetzliche Unfallversicherung (DGUV), Berlin, Germany, http://publikationen.dguv.de/dguv/pdf/10002/213-500.pdf

Author: W. Krämer for the Analytical Subcommittee of the Chemistry Board of Experts of the Expert Committee Raw Materials and Chemical Industry of the German Social Accident Insurance