CARBON DIOXIDE FOOD AND BEVERAGES GRADE, SOURCE QUALIFICATION, QUALITY STANDARDS AND VERIFICATION

EIGA Doc 70/17

Revision of Doc 70/08

EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL

AVENUE DES ARTS 3-5 • B – 1210 BRUSSELS
Tel: +32 2 217 70 98 • Fax: +32 2 219 85 14
E-mail: info@eiga.eu • Internet: www.eiga.eu

CARBON DIOXIDE FOOD AND BEVERAGES GRADE, SOURCE QUALIFICATION, QUALITY STANDARDS AND VERIFICATION

Prepared by EIGA WG-8 Food Gases and Carbon Dioxide

EUROPEAN INDUSTRIAL GASES ASSOCIATION AISBL
Avenue des Arts 3-5 B 1210 Brussels Tel +32 2 217 70 98 Fax +32 2 219 85 14
E-mail: info@eiga.eu Internet: www.eiga.eu

Table of Contents

Amendments from 70/08

Section	Change
	Editorial to align style with EIGA Style Manual
	Title amended to clarify application is food and beverage
1	Introduction rewrite
3.1	Addition of definitions
4.1	New references
5.1.3	Fermentation sources
5.1.3.1	Additional requirements
5.1.3.2	New section
5.1.3.3	New section
5.3	Additional requirements
Appendix A	Change of title

Appendix B	Additional fermentation processes and vinyl acetate source
Appendix C	Control frequency changes

Note: Technical changes from the previous edition are underlined

1

1 Introduction

This publication describes the specification requirements for liquid carbon dioxide in bulk production tanks or intermediate storage tanks at the gas supplier's depots for use in foods and beverages.

2 Scope and purpose

2.1 Scope

This publication is applicable to carbon dioxide used in beverage or in food when carbon dioxide is in direct contact with food or with beverage such as an ingredient or additive.

2.2 Purpose

To provide recommendations for good practice in order to provide guidance on the key characteristics for the quality and purity of carbon dioxide for use in foods and beverages and the quality assurance and quality control procedures necessary to ensure compliance. Individual needs however, may dictate the application of additional requirements negotiated between carbon dioxide suppliers and carbon dioxide users.

The publication also provides recommendations for the qualification of plants used to produce carbon dioxide for use in foods and beverages. These recommendations are also intended to assist carbon dioxide suppliers to achieve compliance with applicable regulatory standards such as EC Directive 2000/63/EC *amending Directive 96/77/EC laying down specific purity criteria on food additives other than colours and sweeteners*, EC Council Directive 98/83/EC *of 3 November 1998 on the quality of water intended for human consumption*, INS No. 290, JECFA – *Joint FAO/WHO Expert Committee on Food Additives*, US Good Manufacturing Practice (21CFR10) and local governmental requirements[1] [1,2,3,4].

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication Terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Used only to indicate the future, not a degree of requirement.

3.1.6 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Carbon dioxide

Colourless, odourless, non-combustible gas.

NOTE Carbon dioxide above the triple point temperature of -56.6°C and below the critical point temperature of 31.1°C can exist in both a gaseous and a liquid state. Bulk liquid carbon dioxide is commonly maintained as a refrigerated liquid and vapour at pressures between 1230 kPa (approx. 12 bar) and 2557 kPa. (Approx. 25 bar). Carbon dioxide can also exist as a white opaque solid with a temperature of -78.5°C at atmospheric pressure. For information on properties, handling and safety of carbon dioxide see EIGA SI 24, *Carbon dioxide physiological hazards, "Not just an asphyxiant"* [5].

3.2.2 Carbon dioxide plant

Any installed facility that is capable of producing liquid carbon dioxide meeting industry product specifications.

3.2.3 Raw gas

Carbon dioxide feed gas before the carbon dioxide purification system.

3.2.4 Source plant

Any plant with one or more processes generating gaseous carbon dioxide usually as a by-product or from natural sources.

4 Limiting Characteristics

Appendix A shows the maximum concentration of the listed components in ppm v/v (unless otherwise specified) for liquid carbon dioxide to be suitable for use in foods and beverages in compliance with applicable regulatory requirements and without adverse effect on sensory characteristics. In this publication ideal gas behaviour is assumed when expressing composition in terms of ppm by volume.

Carbon dioxide is a by-product of many different natural and chemical processing mechanisms making it unique in the industrial gas market. This capability of multiple source types makes it unique in the industrial gas market. The variation of sources results in a variety of specific impurities that can be anticipated to be present in the raw carbon dioxide. Typical sources and their respective anticipated components are listed in Appendix B. The levels of these trace impurities in addition to the limiting characteristics given in Appendix A shall be assessed.

4.1 Levels of the unlisted components

There may be other compounds as yet unknown or undetected in some carbon dioxide sources. The supplier and customer may assign acceptable levels for these potential compounds. Additionally, established and published regulations may be used to define reasonable and prudent levels for example EN 936 *Chemicals used for treatment of water intended for human consumption. Carbon dioxide* regarding drinking water [6].

4.2 Method of calculating the level of a component in carbon dioxide for beverage applications

This publication provides a method for calculating a component's level of contribution to the beverage product from its concentration level in the carbon dioxide.

a) It is recognised that trace impurities are present in the final product carbon dioxide and are assumed, for the purposes of this calculation, that they are consumed with the beverage product.

   The following assumptions are made:

   - All of the impurities in the liquid carbon dioxide are assumed to be present in the vaporised carbon dioxide.

   - When carbon dioxide is added to a liquid beverage, all of the impurities are assumed to remain in solution and are consumed.

b) To determine the contribution of a component in carbon dioxide used for these applications, the following assumption is made:

   - For beverages, the carbon dioxide concentration absorbed in the beverage is based on the known volumes bubbled through the liquid.

4.3 General formula

To calculate the concentration of impurity in the beverage due to a contaminant in carbon dioxide the following assumptions are made:

- Full carbonation of water needs 8g of carbon dioxide per litre of water. This concentration is used to determine the worst case scenario;
- A contamination of Cμl/l (Cppm v/v) in gaseous CO_2 = C*M/44 μg/g (ppm w/w) where M is the molecular weight of the contaminant, 44 is the molecular weight of carbon dioxide and ideal gas behaviour is assumed; and
- The contamination in the carbonated beverage due to this contaminant is therefore 8*C*M/44 μg/litre of beverage.

5 Plant and process qualification

It is the responsibility of the company selling liquid carbon dioxide to the food and beverage industry, to ensure that qualified sources of carbon dioxide are used.

To be qualified for supply of liquid carbon dioxide to the food and beverage segment, the source operator shall fulfil all legal requirements as described in the current European and national food and beverage legislation, see EIGA Doc 125, *Guide to the supply of gases for use in foods* [7].

In addition, the liquid carbon dioxide produced by the source operator shall consistently meet the purity criteria listed in Appendix A <u>if intended to be used in beverages</u>.

In accordance with legal requirements each supplier should implement a HACCP system according to Article 5 of Regulation (EC) No 852/2004 *of the European Parliament and of The Council of 29 April 2004 on the hygiene of foodstuffs* [8]. The qualification process should include the following steps.

5.1 Source Evaluation

The supplier should perform an analysis of the source raw gas stream before design of the purification plant. During design the process controls required to ensure that carbon dioxide is produced according to the specification shall be determined. The initial assessment of the raw gas source will give an indication of the normal variations in the composition of the raw gas. This can be used to select the components to be analysed and the frequency of regular analysis. Such an assessment should include a broad screening by chemical analysis, of components that could possibly be present as impurities for the type of source or introduced as contaminants in the process. The specific impurities listed in Appendix B for <u>manufacturing carbon dioxide intended from</u> the generic sources shall be assessed on a periodic basis or in case of process change to ensure that the impurity concentrations in the raw gas are in accordance with the plant design assumptions. The detection level should be the same as that used for analysis of the final product. <u>Consideration should be given to seasonal variations in the composition of the raw gas stream and any variability in the feedstock</u>.

5.1.1 Chemical process plants as carbon dioxide sources

The carbon dioxide raw gas is taken from different sources, in accordance with Appendix B.

In selection of a source as a possible raw gas stream for a carbon dioxide plant, it is necessary to assess the raw gas production process and the process feed stock.

The results of the raw gas analyses should be discussed with the process plant /source operator, to check if the raw gas composition could change under normal operation. The process operator should also inform the carbon dioxide plant, if there are changes in the process or its feed stock, which could affect the carbon dioxide quality.

5.1.2 Natural wells / Geothermal sources

The carbon dioxide raw gas of natural wells shall be assessed in detail. The geological source and possible changes of components that can be found in the raw gas, particularly in case of variation of extraction, shall be taken into consideration. The raw gas composition from a natural well will vary with time and this shall be taken into account.

5.1.3 Fermentation sources

Fermentation processes are those that operate without oxygen. In the context of carbon dioxide production there are two main types of process. The first process uses yeast which is a fungus for the production of carbon dioxide and alcohol and the second type of process uses mesophilic or thermophilic anaerobic bacteria and archaea for the production of carbon dioxide and methane.

NOTE There could be national requirements that restrict the application and use of carbon dioxide depending on how it is generated.

5.1.3.1 Ethanol based carbon dioxide

Carbon dioxide raw gas from yeast based fermentation processes require a detailed assessment to account for potentially larger variability than chemical process sources.

The composition of the raw gas can vary due to apparently minor changes in the feedstock caused by factors such as soil type, type of vegetable matter, storage of feedstock, water supply, growing conditions fertilisers or pesticides.

5.1.3.2 Biogas (methane) carbon dioxide sources (Anaerobic digestion)

Anaerobic digestion is the bacterial digestion of organic matter in the absence of air, primarily into carbon dioxide and methane.

This type of source is acceptable but requires particular care in evaluation as a potential source of carbon dioxide for use in foods and beverages. Anaerobic digestion (AD) biogas plants can run on a variety of feedstock types that can be divided into purpose-grown vegetable matter referred to as energy crops, and organic waste matter. Carbon dioxide feedgas from AD plant running purely on energy crops should be subjected to the same evaluation criteria as carbon dioxide feedgas from yeast based fermentation sources (5.1.3.1). Carbon dioxide feedgas from a biogas plant that uses waste, or a mixture of waste and energy crops, requires greater care than for energy crops in evaluation as a potential source of carbon dioxide for use in food and beverages.

For all types of feedstock (including energy crops and waste) to the AD plant a detailed and extensive risk assessment is essential to account for any chemical and biological risks to ensure the product complies with Appendix A and is safe to use for foods and beverages. Any change of feedstock will require approval and revision of the risk assessment.

AD plant and feedstock shall be compliant with EU regulations EC 1069/2009 Regulation (EC) No 1069/2009 of the European Parliament and of the Council *of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)* and EC 142/2011." Commission Regulation (EU) No 142/2011 of 25 February 2011 *implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive* [9,10]

The following points shall be considered within the risk assessment process for AD plants to supply liquid carbon dioxide for use in foods and beverages:

- The food safety risk analysis includes the digester biogas process;
- Final product carbon dioxide is always compliant with the Appendix A;
- Before supply to the food and beverage customer there is either complete on-line analysis of the carbon dioxide production or a complete batch analysis.

Additionally, it is strongly recommended that a food safety management system, for example ISO 22000 *Food safety management,* [11] is in place for the carbon dioxide plant.

5.1.3.3 Municipal landfill-sourced carbon dioxide

Municipal landfill is a source type where waste is buried and capped. Subsequent degradation produces carbon dioxide and methane.

Municipal landfill sources have a very variable feedstock because an unlimited number of waste types could be fed to the landfill Therefore an extensive assessment of risk to determine appropriate purification processes and ongoing analysis is required if this feedstock is to be acceptable.

5.2 Production qualification tests and design validation

All carbon dioxide production facilities supplying carbon dioxide to beverage customers shall be proven by analysis of all the key characteristics in Appendix A, plus appropriate components identified from Appendix B, to be capable of meeting the specification. This analysis may be a single analysis of a new facility or a series of analyses at a frequency determined by the supplier or by agreement with the customer.

A risk assessment, see EIGA Doc 125 [7] should be used to identify key process controls required to ensure compliance with the specification. This assessment may be conducted by various methods[2]. The effectiveness of these process controls may be assessed directly by chemical analysis, by the use of process tracers or by the use of process control instrumentation, for example flow switches to verify operation of water scrubbers, temperature controls on catalytic oxidation systems, pressure and flow controls on stripping columns. The operation of the plant should be reviewed on a regular basis and be subject to periodic maintenance to ensure that the plant is still operating to the design conditions.

5.3 Quality control/ Quality assurance

Each facility producing carbon dioxide for the food and beverage industry should have a documented system for quality management following the model in the ISO 9000, *Quality management*, [12] or ISO 22000 (HACCP) series of standards [11]. Whilst preferable, it is not essential that the quality system is certified. A formal food safety management system in accordance with the ISO 22000 [11] series of standards is regarded as best practice but a formal assessment of food safety risk, including the raw gas process and feedstock, using the HACCP methodology is a legal requirement and shall be implemented at all plants producing carbon dioxide for use in foods.

The quality control and quality assurance procedures described by this publication only apply to the carbon dioxide production sources.

The supplier should assure that carbon dioxide supplied to the beverage industry meets the specification given in Appendix A and the appropriate components identified from Appendix B. The frequency of analysis required to prove compliance shall be determined by the supplier although Appendix C may be used as a guide.

6 Quality control in carbon dioxide production

The carbon dioxide raw gas composition shall determine the design of the plant, especially the purification steps and procedures and also the analytical controls during the process. Raw gas shall be analysed at least once per year.

The purification process shall need analytical controls for the process, if no other relevant parameters can be used, to assure that the purification step is working as intended.

Analytical controls during the purification process may be continuous using on-line instruments or based on spot checks. This choice and the selection of the frequency for checks will depend on:

[2] Acceptable methods could include Failure Mode Effect Analysis FMEA or Hazard Analysis by Critical Control Points (HACCP)

- Component to be measured;
- Likely concentration of the component;
- Importance of the component to the perceived quality of the carbon dioxide:
- Ease of measurement;
- Risk assessment of the purification process designed to remove the component to acceptable levels;
- Regulatory mandates and/or individual guide; and
- Source type.

The frequency of checks will vary depending on consideration of these factors and can typically be from one per hour to two per year for components not analysed by continuous monitoring instruments.

7 Finished product analysis and release for sale

7.1 Carbon dioxide storage tank at the plant

The carbon dioxide is liquefied and pumped into one or more storage tanks. At some carbon dioxide plants, it is possible to use each tank (or a cluster of tanks) as a batch, see EIGA Doc 125, [7]. This gives the possibility to release product based on analysis of the storage before the storage is used for filling of the tankers. The analysis of a batch should normally refer to the compounds found relevant from the raw gas assessment, and user requirements. The batch analysis can reduce the online-analysis in the plant to a minimum.

However, many plant storage tanks are operated in a continuous manner and batch analysis is not practical. Conformity of the storage is assured by analysis of the incoming product to the tank and/or regular analysis of the stored carbon dioxide. Release of product may in this case be based on process control data showing consistent compliance, together with daily checks of key parameters

Suggested frequency of sampling and analysis against EIGA guideline specification is given in Appendix C.

In case of non-conformity, appropriate quality assurance routines shall be implemented in order to stop tanker filling and delivery and to take corrective and preventive actions including consideration of product recall.

7.2 Carbon dioxide intermediate storage tanks (depots)

The conformity of the storage is assured by importing into the tank only product which complies with this specification. Compliance check and release of product according to this specification may be accomplished by total control of the release quality of incoming product, but also by performing analysis directly on product at intermediate storage, and release the product based on these tests.

8 Third party laboratory checks

Where possible final product carbon dioxide should be sampled and analysed by a test-laboratory independent from the production plant. This gives the possibility to cross-check the results of the production plant.

9 Frequencies

Appendix C is a guide to the analytical frequencies but individual application is dependent on the risk assessment.

10 Analytical methods

The analytical methods used to prove compliance with the specification are attached as Appendix D.

Alternative methods may be used if these are validated as being at least equivalent to those in Appendix D.

The sample shall be taken from the liquid phase of the bulk storage tank or from the liquid carbon dioxide product stream from the production plant. Where the sample is taken in a cylinder then the cylinder shall be at room temperature prior to analysis and the phase of the sample cylinder to be analysed for various components is given in Appendix D.

11 References

Unless otherwise stated the latest edition shall apply.

[1] EC Directive 2000/63/EC amending Directive 96/77/EC *laying down specific purity criteria on food additives other than colours and sweeteners*, 98/83/ www.ec.europa.eu

[2] EC Council Directive 98/83/EC of 3 November 1998 *on the quality of water intended for human consumption*, www.ec.europa.eu

[3] INS No. 290, JECFA – Joint FAO/WHO Expert Committee on Food Additives, www.fao.org/ag/agn/**jecfa**-additives/specs/Monograph1/Additive-107.pdf

[4] United States Good Manufacturing Practice (21CFR10) www.accessdata.fda.gov

[5] EIGA SI 24, *Carbon dioxide physiological hazards, “Not just an asphyxiant”* www.eiga.eu

[6] EN 936 *Chemicals used for treatment of water intended for human consumption. Carbon dioxide* www.cen.eu

[7] EIGA Doc 125, *Guide to the supply of gases for use in foods* www.eiga.eu

[8] Regulation (EC) No 852/2004 *of the European Parliament and of The Council of 29 April 2004 on the hygiene of foodstuffs* www.ec.europa.eu

[9] EC 1069/2009 Regulation (EC) No 1069/2009 *of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)* www.ec.europa.eu

[10] EC 142/2011." Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council *laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive*. www.ec.europa.eu

[11] ISO 22000, *Food safety management,* www.iso.org

[12] ISO 9000, *Quality management* www.iso.org

[13] EC 231/2012 *Commission Regulation (EU) No 231/2012 of 9 March 2012 laying down specifications for food additives listed in Annexes II and III to Regulation (EC) No 1333/2008 of the European Parliament and of the Council* www.eur-lex.europa.eu/

APPENDIX A:

EIGA LIMITING CHARACTERISTICS

FOR CARBON DIOXIDE TO BE USED IN BEVERAGES FOR SOURCE SPECIFICATION[3]

Component	Concentration
Assay	99.9% v/v min.
Moisture	20 ppm v/v max
Ammonia	2.5 ppm v/v max.
Oxygen	30 ppm v/v max.
Oxides of nitrogen (NO/NO2)	2.5 ppm v/v max. each
Non-volatile residue(particulates)	10 ppm w/w max.
Non-volatile organic residue (oil and grease)	5 ppm w/w max.
Phosphine ***	0.3 ppm v/v max
Total volatile hydrocarbons (calculated as methane)	50 ppm v/v max. of which 20 ppm v/v max non-methane hydrocarbons.
Acetaldehyde	0.2 ppm v/v max.
Aromatic hydrocarbon	0.02 ppm v/v max.
Carbon monoxide	10 ppm v/v max.
Methanol	10 ppm v/v max.
Hydrogen cyanide*	0.5 ppm v/v max
Total sulfur (as S) **	0.1 ppm v/v max.
Taste and odour in water	No foreign taste or odour
Appearance in water	No colour or turbidity
Odour and appearance of solid CO2 (snow)	No foreign odour or appearance

* Analysis necessary only for carbon dioxide from coal gasification sources

** If the total sulphur content exceeds 0.1 ppm v/v as sulphur then the species must be determined separately and the following limits apply:

Carbonyl Sulphide	0.1 ppm v/v max.
Hydrogen Sulphide	0.1 ppm v/v max.
Sulphur Dioxide	1.0 ppm v/v max.

*** Analysis necessary only for carbon dioxide from phosphate rock sources

Where carbon dioxide complies with the specification then by definition the requirements for acidity and reducing substances as required by European Law are met.

[3] Where carbon dioxide is to be used in food applications, the appropriate European legislation should be consulted EC 231/2012 *Commission Regulation (EU) No 231/2012 of 9 March 2012 laying down specifications for food additives listed in Annexes II and III to Regulation (EC) No 1333/2008 of the European Parliament and of the Council*, [13]

APPENDIX B:

Possible trace impurities by source type (Excluding air gases and water)

The source types are generic sources and there are variations in individual processes. Therefore, the supplier should assess whether or not all of the components listed are applicable to the actual plant.

Component	Combustion	Wells/ Geothermal	Fermentation /bioethanol AD (purely energy crops)	Anaerobic digestion (waste)	Hydrogen or Ammonia	Phosphate Rock	Coal Gasification	Ethylene Oxide	Acid Neutralisation	Vinyl acetate
Aldehydes	√	√	√	√	√		√	√		√
Amines	√				√					
Benzene	√	√	√	√	√		√	√	√	√
Carbon monoxide	√	√	√	√	√	√	√	√	√	√
Carbonyl sulphide	√	√	√	√	√	√	√		√	
Cyclic aliphatic hydrocarbons	√	√		√	√		√	√		√
Dimethyl sulphide		√	√	√		√	√		√	
Ethanol	√	√	√	√	√		√	√		√
Ethers		√	√	√	√		√	√		√
Ethyl acetate		√	√	√			√	√		√
Ethyl benzene		√		√	√		√	√		√
Ethylene oxide							√	√		
Halocarbons	√			√			√	√		√
Hydrogen cyanide	√						√			
Hydrogen sulphide	√	√	√	√	√	√	√	√	√	√
Ketones	√	√	√	√	√		√	√		√
Mercaptans	√	√	√	√	√	√	√	√		√
Mercury	√	√					√			
Methanol	√	√	√	√	√		√	√		√
Nitrogen oxides	√		√	√	√		√	√	√	□
Phosphine						√				
Radon		√				√			√	
Sulphur dioxide	√	√	√	√	√	√	√		√	
Toluene		√	√	√	√		√	√		√
Vinyl chloride	√						√	√		√
Volatile hydrocarbons	√	√	√	√	√		√	√		√
Xylene		√	√	√	√		√	√		√

APPENDIX C:

Control Frequencies

Frequencies / Components	Online or Daily or Batchwise	Yearly **	When changes at the source	Notes
Raw gas Source		1	1	
Purity	1	1		On carbon dioxide plants, the purity is: 100% of carbon dioxide less total of all impurities = 99,9%, (ISBT)
Dew point (moisture)	1	1		
Ammonia	2	1		
Oxygen	2	1		
Oxides of nitrogen	2	1		
Non-volatile residue (particulates)	2	1		
Non-volatile organic residue	2	1		
Phosphine	2	1		Only if raw gas is from phosphate rock
Total volatile hydrocarbon	1	1		
Acetaldehyde	2	1		
Benzene	2	1		
Carbon monoxide	2	1		
Methanol	2	1		
Hydrogen cyanide	2	1		Only if found in raw gas
Total sulfur	2	1		
Taste and odour in water	1	1		
Others*	2	1		

1 Recommended minimum frequency.

2 Analysis is not required at this frequency if a formal risk assessment has been undertaken which has concluded that the specified maximum level for each component in the carbon dioxide product cannot be exceeded in normal operation or in a failure mode.

* See Appendix B

** The yearly control is done as a general check by a test-laboratory, independent from the production plant.

APPENDIX D:

Analysis methods

Component	Phase *	Method
Assay	Liquid	Absorption in potassium hydroxide, for example: Ors/ Zahm Nagel, IR spectroscopy
Moisture	Liquid	Hygrometry – capacitance, electrolytic, piezo-electric, cooled mirror, IR spectroscopy, colorimetric tube, quartz crystal
Oxygen	Vapour	Gas chromatography or dedicated analyser
Oxides of nitrogen	Liquid	Chemiluminescence, colorimetric, colorimetric tube, mass spectrometry, infra-red spectroscopy
Non-volatile residue	Liquid	Gravimetric
NVOR	Liquid	Gravimetric, infra-red spectroscopy
Acetaldehyde	Liquid	Gas chromatography, infra-red spectroscopy, colorimetric tube, infra-red spectroscopy
Benzene	Liquid	Gas chromatography, mass spectrometry, UV spectroscopy,
Carbon monoxide	Vapour	Gas chromatography, colorimetric tube, infra-red
Methanol	Liquid	Gas chromatography, mass spectrometry, colorimetric tube, UV spectroscopy, infra-red spectroscopy
Ethanol	Liquid	Gas chromatography, mass spectrometry, colorimetric tube, infra-red spectroscopy
Ketones	Liquid	Gas chromatography, mass spectrometry, infra-red spectroscopy
Toluene	Liquid	Gas chromatography, mass spectrometry, infra-red spectroscopy, UV spectroscopy
Xylene	Liquid	Gas chromatography, mass spectrometry, infra-red spectroscopy, UV spectroscopy
Hydrogen cyanide	Vapour	Gas chromatography, mass spectrometry, calorimetric tube, infra-red spectroscopy
Ethylene oxide	Vapour	Gas chromatography, mass spectrometry, colorimetric tube, infra-red spectroscopy
Total sulfur	Liquid	UV fluorescence/ oxidiser, dedicated analysers, sulfur chemi-luminescence
Carbonyl sulphide	Liquid	Gas chromatography, mass spectrometry, infra-red spectroscopy
Sulphur dioxide	Liquid	Gas chromatography, colorimetric tube, mass spectrometry, infra-red spectroscopy
Hydrogen sulphide	Liquid	Gas chromatography, UV fluorescence, colorimetric tube, mass spectrometry, infra-red spectroscopy
Heavy metals	Liquid	Atomic absorption or inductively coupled plasma, colorimetric tube (for some metals)
Amines	Liquid	Gas chromatography, colorimetric tubes, infra-red spectroscopy
Radon	Liquid	Mass spectrometry
Total hydrocarbons	Vapour	Gas chromatography or THC analyser

* When analysed in a sample cylinder