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Workplace air quality — Determination of total isocyanate groups in air using 2-(1-methoxyphenyl) piperazine and liquid chromatography

Qualité de l'air des lieux de travail — Dosage des groupes isocyanate totaux dans l'air à l'aide de (méthoxy-1 phényle)-2 pipérazine et de la chromatographie en phase liquide

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 16702 was prepared by Technical Committee ISO/TC146, *Air quality*, Subcommittee SC 2, *Workplace atmospheres*.

Annex A of this International Standard is for information only.

Workplace air quality — Determination of total isocyanate groups in air using 2-(1-methoxyphenyl)piperazine and liquid chromatography

1 Scope

This International Standard gives general guidance for the sampling and analysis of airborne organic isocyanates in workplace air, using the 2-(1-methoxyphenyl) piperazine reagent and liquid chromatography.

This International Standard is applicable to the measurement of a wide range of organic compounds containing isocyanate functional groups (NCO), including isocyanate monomers and prepolymers.

This International Standard is applicable to the measurement of any product containing free isocyanate groups.

This International Standard is applicable to the measurement of time-weighted-average concentrations of organic isocyanates in workplace atmospheres, and for sampling over periods in the range 10 min to 8 h. It is designed for personal monitoring, but may also be used for fixed-location monitoring by suitable modification.

This International Standard is applicable to the measurement of airborne organic isocyanates in the concentration range approximately 0,1 µg NCO·m^{-3} to 140 µg NCO·m^{-3} for a 15 l sample volume.

The qualitative and quantitative detection limits for isocyanate, defined as three times and ten times the standard deviation of six blank determinations, have been found to be typically around 0,001 µg NCO and 0,004 µg NCO per sample respectively (electrochemical detection). For a 15 l air sample, these values correspond to qualitative and quantitative detection limits of 0,07 µg·m^{-3} and 0,3 µg·m^{-3} respectively.

EXAMPLES Aromatic monomers include toluene diisocyanate (TDI) and methylene bis(4-phenyl isocyanate) (4,4-diisocyanatodiphenylmethane, MDI). Aliphatic monomers include isophorone diisocyanate (IPDI) and 1,6-hexamethylene diisocyanate (HDI). Isocyanate oligomers or prepolymers are derived from these monomers by self-condensation or reaction with polyols.

NOTE 1 Organic isocyanates can also arise from thermal decomposition of polyurethanes. If both isocyanates and amines are believed to be present, use of a standard which enables the simultaneous determination of both amines and isocyanates may be more appropriate (ISO method in draft). An alternative procedure using the MAP [1-(9-anthracenylmethyl)piperazine] reagent is also available (ISO method in draft).

NOTE 2 The objective of air monitoring is usually to determine worker exposure and, therefore, the procedures described in this International Standard are for personal sampling in the breathing zone. The procedures may be used for background or fixed location sampling. However, it should be recognized that, due to aerodynamic effects, samplers designed for personal sampling do not necessarily exhibit the same collection characteristics when used for other purposes.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6141:2000, *Gas analysis — Requirements for certificates for calibration gases and gas mixtures*.

ISO 6145 (all parts), *Gas analysis — Preparation of calibration gas mixtures — Dynamic volumetric methods*.

ISO 6349, *Gas analysis — Preparation of calibration gas mixtures — Permeation method*.

BS 7653-3:1993, *Piston and/or plunger operated volumetric apparatus (POVA) — Methods of test*.

EN 482, *Workplace atmospheres — General requirements for the performance of procedures for the measurement of chemical agents*.

EN 1076, *Workplace atmospheres — Pumped sorbent tubes for the determination of gases and vapours — Requirements and test methods.*

EN 1232, *Workplace atmospheres — Pumps for personal sampling of chemical agents — Requirements and test methods*.

3 Principle

A measured volume of air is drawn through a glass impinger containing 1-(2-methoxyphenyl)piperazine (1-2MP) solution and/or a filter impregnated with (1-2MP) reagent. Any organic isocyanates present will react to form non-volatile urea derivatives. The resultant solution is concentrated and analysed by high performance liquid chromatography (HPLC) with ultraviolet (UV) and electrochemical (EC) detection. Isocyanate-derived peaks are identified on the basis of their EC and UV responses and also by diode-array detection (DAD) and comparison with derivatized bulk (where available). Quantification is carried out by comparison with the relevant isocyanate monomer standard. The total isocyanate-in-air concentration is calculated from the sum of all the isocyanate-derived peaks.

4 Reagents and materials

During the analysis, use only reagents of recognized analytical reagent grade.

4.1 1-2MP reagent, 1-(2-methoxyphenyl)piperazine, commercially available in appropriate (> 98%) purity.

4.2 Reagent solvent, commonly toluene.

It should be of chromatographic quality, and shall be free from compounds co-eluting with the substances of interest. Before use for the preparation of impregnated filters or for preparation of monomer standards, it is advisable to dry the solvent with anhydrous calcium chloride or magnesium sulfate. This step may be omitted for preparation of the absorbing solution, as it will pick up atmospheric moisture during sampling.

4.3 Reagent solutions.

4.3.1 Absorbing solution

Accurately weigh approximately 50 mg of 1-2MP and transfer to a dry 100 ml volumetric flask. Dissolve and make up to the mark with reagent solvent, and mix thoroughly. Dilute 10 ml of this stock solution to 100 ml with reagent solvent in a second volumetric flask to give a 260 µM absorbing solution.

4.3.2 Preparation of solution for impregnating filters (Solution A)

Accurately weigh out approximately 0,25 g of 1-2MP and transfer to a 25 ml volumetric flask. Make up to the mark with dried reagent solvent and shake to mix.

4.3.3 Stability of reagent solutions

Prepare fresh solutions weekly.

4.4 Calibration standards.

4.4.1 Monomer derivatives

Add the appropriate isocyanate (0,1 g) to 0,6 g of 1-2MP dissolved in dry toluene (10 ml) and leave to stand for 1 h. A white crystalline urea will precipitate. Collect this on a filter paper and wash several times with dry toluene to remove excess reagent.

Recrystallize the urea from toluene, by warming to about 60 ^{o}C and slowly add methanol to dissolve the urea. Allow to cool and filter the resulting crystals, washing with cold, dry toluene. Dry the solid in air. The urea derivatives are only slightly soluble in toluene but readily soluble in methanol or acetonitrile.

MDI and HMDI (dicyclohexylmethane-4,4'-diisocyanate) are rather insoluble in toluene. The alternative method of preparation given below may be more suitable for these compounds.

Slowly add a solution of the appropriate isocyanate (0,5 g) in dichloromethane (25 ml) to a solution of 1-(2-methoxyphenyl)piperazine (1,0 g) in dichloromethane (50 ml). A white suspension will form. Add this dropwise to a beaker of hexane (500 ml) with stirring. Filter the resultant precipitate and redissolve it in a minimum volume of dichloromethane. Add hexane to re-precipitate the solid, filter this and wash with hexane. Dry the urea derivative in air.

NOTE This second method may also be used for isocyanate prepolymers.

4.4.2 Preparation of standard solutions of recrystallized isocyanate monomer derivatives

Weigh out a known mass of the urea derivative, place in a 100 ml volumetric flask and make up to the mark with acetonitrile or methanol. Take aliquots of this solution and dilute volumetrically in acetonitrile to create a series of standard solutions over the concentration range 0,01 µg NCO·ml^{-1} to 1,0 µg NCO·ml^{-1}. Prepare further standard solutions if the concentration range of the samples exceeds that of the standards.

Then:

$$c_s = (c_u \cdot M_n \cdot n)/M_u$$

where

c_s is the concentration of isocyanate in the standard (µg NCO·ml^{-1});

c_u is the concentration of urea derivative in the standard (µg·ml^{-1});

M_n is the relative molecular mass of NCO;

n is the number of isocyanate groups/molecule;

M_u is the relative molecular mass of the urea derivative.

4.4.3 Stability of isocyanate ureas and their solutions

Stock solutions of isocyanate monomer derivatives have been found to be stable for over six months if kept in a freezer. Isocyanate monomers (TDI) on filters and toluene solution have been found to be stable up to 90 days (73 % and 81 % recoveries respectively) [1].

4.5 HPLC mobile phase.

Dissolve 5 g of anhydrous sodium acetate in 1 l distilled water. Adjust the pH of this solution to 6,0 with glacial acetic acid. Add 550 ml of this solution to acetonitrile (450 ml) and degas this solution by filtering under vacuum or by bubbling a stream of helium through it to give a 45 % acetonitrile/55 % sodium acetate buffer.

5 Apparatus

Ordinary laboratory apparatus and the following.

5.1 Sampler.

The choice of sampler used depends on the form in which the isocyanate is present.

For vapour-phase isocyanates, sampling shall be carried out using an impregnated filter only. If no particles of diameter less than 2 µm are expected, then sampling may be carried out with an impinger only. In all other cases, or where the isocyanate form is not known, the use of an impinger backed by an impregnated filter is suggested. Details of alternative sampling procedures are given below.

5.2 Filters, of 25 mm diameter suitable for use in the selected sampler.

The chosen filter type should have a capture efficiency of not less than 95 % and be suitable for collection of stable samples of isocyanate. 1-2MP-impregnated GF/A filters have been found to be suitable.

5.3 Filter holder.

Details of suitable sampling heads are given in [2]. A 25 mm IOM head fitted with a stainless steel cassette is recommended for filter samples.

Where the impinger/filter combination is used (6.8), it has been found to be more convenient to use a 25 mm filter holder.

5.4 Midget impinger.

A number of designs of bubblers and impingers are available [3]. A midget impinger [4] consists of a graduated receiver and a tapered inlet tube.

NOTE “Non-spill” impingers are commercially available.

5.5 Sampling pump, in accordance with EN 1232 or equivalent.

NOTE The sampling pump should also be in accordance with local safety regulations.

5.6 Tubing.

Plastic, rubber or other suitable tubing, about 90 cm long, of appropriate diameter to ensure a leak-proof fit to both pump and sampler. Fluran[1)] tubing has been found to have fewer problems due to extraction of contaminants associated with it. Clips shall be provided to hold the sampler and connecting tubing to the wearer's lapel area.

It is not recommended to use any tubing upstream of the first collection element (filter or impinger), as sample losses may occur.

5.7 Flowmeter, portable, capable of measuring the appropriate flowrate to within ± 5%, and calibrated against a primary standard [2].

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1) Fluran is an example of a suitable product available commercially. This information is given for the convenience of users of this International Standard, and does not constitute an endorsement by ISO of this product.

Flowmeters incorporated in sampling pumps are not suitable for accurate measurement of the flowrate. However, they can be useful for monitoring the performance of samplers, provided they have adequate sensitivity.

5.8 Filtration equipment.

A solvent-resistant filter unit of < 0,5 µm pore size for filtration of LC solvents. Syringeless filters or < 0,5 µm syringe filters for filtration of the desorbed samples prior to LC analysis.

5.9 Ancillary equipment, including belts or harnesses to which the sampling pump can be conveniently fixed (unless the pump is sufficiently small to fit into a worker's pocket), flat-tipped tweezers for handling the filters, containers to transport the filters and/or impinger solutions, protective holder for impinger.

5.10 Liquid chromatograph (HPLC) linked to ultraviolet (UV) and electrochemical (EC) detectors.

The EC detector should be used in the oxidation mode. A diode-array detector is also advisable for confirmation of identification.

Temperature fluctuations shall be avoided in order to obtain the sensitivity required in this method. This can be achieved by thermostatting the HPLC column and EC detector. EC performance can be improved by recirculating the mobile phase in a closed loop and by use of a guard cell (set to ~ + 50 mV above analytical cell potential) before the injector. A pulse dampener will also decrease the LC system noise (pulse ripple) and so increase signal to noise (S/N) ratio.

5.11 Autosampler.

These are commercially available.

6 Sampling

6.1 Calibration of pump

Calibrate the pump with a representative impinger and/or filter assembly in line, using an appropriate external calibrated meter. If an impinger is used, it shall contain absorbing solution (or toluene).

6.2 General

For long-term sampling, select a sampling period of an appropriate duration, such that the filter does not become overloaded with particulate material.

NOTE An 8-h time-weighted average concentration may be derived from the results of two or more consecutive samples.

6.3 Preparation of sampling equipment — General

Clean the samplers (filter cassette and/or impingers) before use. Disassemble the samplers, soak in laboratory detergent solution, rinse thoroughly with water, wipe with absorptive tissue and allow to dry thoroughly before reassembly. Alternatively, use a laboratory washing machine.

6.4 Preparation of sampling equipment — Filters

6.4.1 Preparation of impregnated filters

Accurately weigh out approximately 0,25 g of 1-(2-methoxyphenyl)piperazine and transfer to a 25 ml volumetric flask. Make up to the mark with dried toluene and shake to mix. This is solution A (see 4.3.2)

In an area free from dust and isocyanates and using blunt tweezers, place a number of 25 mm glass-fibre filters on a clean glass plate so that no filters are touching. Using a suitable microlitre syringe, dispense 200 µl of solution A

onto the surface of each filter, ensuring that the reagent impregnates the whole filter. Allow the filters to dry in air for several hours. When completely dry, transfer the filters from the glass plate to a screw-cap brown bottle using blunt tweezers. Label the bottle with the preparation and 'use before' date. Store until required in a dark cupboard or refrigerator for up to six months from preparation.

6.4.2 Preparation of sampling devices with filters

In an area free from isocyanates, load the filters into clean, dry samplers using clean flat-tipped tweezers. Connect each loaded sampling head to a sampling pump using plastic tubing, ensuring that no leaks can occur. Switch on the pump, attach the calibrated flowmeter to the sampling head so that it measures the flow through the sampler inlet orifice, and set the appropriate flowrate with an accuracy of ± 5 %. Switch off the pump and seal the sampler with a protective cover to prevent contamination during transport to the sampling position.

6.5 Preparation of sampling equipment — Impingers

In an area free from isocyanates and immediately before sampling, transfer 10 ml of the absorbing solution into an impinger and assemble it. Place the impinger in a protective holder and connect to the sampling pump with suitable tubing. Ensure that all connections are free from leaks.

6.6 Collection of filter samples — Vapour phase samples

In an area free from isocyanates, affix the sampler to the worker, on his/her lapel and as close to the mouth and nose as possible. Place the sampling pump in a convenient pocket or attach it to the worker in a manner that causes the minimum inconvenience, e.g. to a belt around the waist. When ready to begin sampling, remove the protective cover from the sampler and switch on the pump. Record the time at the start of the sampling period, and if the pump is equipped with an elapsed time indicator, ensure that this is set to zero. Draw a measured volume of air through the sampler at a rate of 2,0 l·min^{-1}. The recommended air volume is within the range 20 l to 900 l.

Since it is possible for a filter to become clogged, monitor the performance of the sample periodically, a minimum of every 2 h (or more frequently if heavy filter loadings are suspected). Measure the flowrate with the calibrated flowmeter and record the measured value. Terminate sampling and consider the sample to be invalid if the flowrate is not maintained to within ± 5 % of the nominal value throughout the sampling period.

Regular observation of the flow fault indicator is an acceptable means of ensuring that the flowrate of flow-stabilized pumps is maintained satisfactorily, provided that the flow fault indicator indicates malfunction when the flowrate is outside ± 5 % of the nominal value.

At the end of the sampling period, measure the flowrate with an accuracy of ± 5 % using the calibrated flowmeter, switch off the sampling pump, and record the flow time and the time. Also observe the reading on the elapsed time indicator, where fitted. Consider the sample to be invalid if the reading on the elapsed time indicator and the timed interval between switching on and switching off the sampling pump do not agree to within ± 5%, since this may suggest that the sampling pump has not been operating throughout the sampling period. Reseal the sampler with its protective cover and disconnect it from the sampling pump.

Carefully record the sample identity and all relevant sampling data. Calculate the mean flowrate by averaging the flowrate measurements throughout the sampling period, and calculate the volume of air sampled, in litres, by multiplying the flowrate in litres per minute by the sampling time in minutes.

6.7 Collection of impinger samples — Vapour, or particulate phase samples with particles > 2 μm

The comments made above regarding monitoring flowrate and recording of sample identity also apply to impingers. When used for personal sampling, the impinger should be mounted in the worker's breathing zone, e.g. on the lapel. The impinger should be maintained in an approximately vertical position. Also check the impinger periodically to ensure that the absorbing solution has not evaporated.

Draw a measured volume of air through the impinger. The recommended sample volume is at least 15 l, and the recommended flowrate $1\ l\cdot min^{-1}$. If an 8-h sample is required, several shorter samples should be taken at $1\ l\cdot min^{-1}$ and summed. In practice, sampling is carried out over the period the worker is in contact with the isocyanate, which is usually less than 8 h. It may be necessary to top up the impinger with dry reagent solvent during the sampling period because of solvent loss due to evaporation.

6.8 Collection of impinger backed by filter samples — Other cases

In situations other than those covered by 6.6. and 6.7, a combination of an impinger and filter shall be used, as an impinger or filter used alone is not always effective for collecting isocyanates [5, 6]. The problems lie with the particles: particles less than 1 µm to 2 µm are collected poorly by impingers, and particles containing both isocyanate and polyol (generally somewhat larger) may not be derivatized efficiently with filter collection. An impinger followed by a filter will catch any small particles that pass through the impinger on the filter and efficiently derivatize the larger particles in the impinger.

For the combination of impinger backed by filter, a sampling rate of $1\ l\cdot min^{-1}$ is suggested.

6.9 Transportation

For transport to the laboratory, remove each filter from the sampler, place in a 50 mm × 35 mm glass vial containing 2 ml 1-2MP absorbing solution and cap the vial. If deposition from particulates is suspected, rinse the inlet of the sampler head with a little dilute 1-2MP solution.

For impinger samples, transfer the contents to a glass vial and seal with a PTFE-lined screw-cap. Rinse the impinger and its inlet tube with a small volume of reagent solvent and add the washings to the vial. It is not necessary to note the final volume of the solution or to make it up to its original volume.

6.10 Blanks

Field blanks should be prepared by using samplers identical to those used for test sampling and subjecting them to the same handling procedure as the test samples, except for the actual period of sampling. Label these as blanks.

7 Procedure

7.1 Safety precautions

WARNING — This International Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this International Standard to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

Wear disposable gloves during analysis to reduce the possibility of contamination and to protect the hands from harmful solvents/reagents.

7.2 Cleaning of glassware

Before use, clean all glassware to remove any residual grease or chemicals. First soak overnight in laboratory detergent solution and then rinse thoroughly with water.

7.3 Pre-reaction of impinger samples before HPLC analysis

Acetylation of unreacted 1-2MP reagent improves the chromatographic separation of isocyanate derivatives. After sampling, transfer the contents of the impinger to a screw-cap vial as described above. Allow at least 24 h to elapse from the time of sampling to ensure complete reaction of the isocyanate prepolymers. Pipette 100 µl acetic anhydride into the vial and mix well. Evaporate to dryness, redissolve the residue in 2 ml acetonitrile and transfer to a glass vial. Analyse using a liquid chromatograph (LC) as described below.