

ESCAPE: European Study of Cohorts for Air Pollution Effects

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MEASUREMENT OF NO₂ and NO_x IN OUTDOOR AIR WITH THE OGAWA BADGE

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MEASUREMENT OF NO₂ and NO_x IN AMBIENT AIR USING THE OGAWA BADGE

1. Purpose and applicability

This SOP contains the protocol for performing measurements of NO_x and NO₂ in outdoor air for the EU-multicenter study ESCAPE.

The Ogawa badge is a passive sampler, implying that no pump is used in sampling. The sampler consists of a collection filter that is coated with a reactive chemical. Separate filters are available for NO_x and NO₂. NO is calculated by subtracting NO₂ from the NO_x measurement. The precision of NO measurements is typically less than the precision for NO₂. The coated filter absorbs NO₂ with high efficiency, resulting in a very low concentration near the filter. Molecular diffusion results in a flow from the air surrounding the sampler to the reaction filter.

Sampling is started (ended) by removing (placing) the badge from (in) a resealable plastic bag. The sampled amount of NO₂ (NO_x) on the filter is determined after extraction using the spectrophotometric Saltzman reaction. With the recorded sampling time and sampling rates of the badge it is possible to calculate the average concentration of NO₂ and NO_x. Sampling rates are dependent on temperature and humidity. Single measurements will be conducted as various projects have documented that the precision is adequate for sampling durations of 1-7 days (e.g. van Roosbroeck et al. 2007; Madsen et al. 2007; Aguilera et al. 2008).

2. Definitions

SOP : Standard Operating Procedure

UHQ : Ultra clean water of 18 Megohm-cm resistivity at 25 °C.

3. References

- Aguilera I, Sunyer J, Fernandez-Patier R, G. H, A. A, Meliefste K, Bomboi_Mingarro MT, Nieuwenhuijsen MJ, Hoek G, Brunekreef B, group Is. et al., 2008. Estimation of outdoor NO_x, NO₂ and BTEX exposure in a cohort of pregnant women using land use regression modeling. *Environmental Science and Technology*, 42: 815-821.
- Madsen C, Lodrup-Carlsen KC, Hoek G, Oftedal B, Nafstad P, Meliefste K, Jacobsen R, Nystad W, Carlsen KH, Brunekreef B, 2007. Modeling the intra-urban variability of outdoor traffic pollution in Oslo, Norway-a GA2LEN project. *Atmospheric Environment*, 41:7500-7511.
- Van Roosbroeck S, Jacobs J, Janssen N, Oldenwening M, Hoek G, Brunekreef B, 2007. Long-term personal exposure to PM_{2.5}, soot and NO_x in children attending schools located near busy roads, a validation study. *Atmos Environ*, 41: 3381-3394.

4. Discussion

The protocol is based upon and is consistent with the manufacturers (Ogawa) protocol, available at <http://www.ogawausa.com/index.html>. It adds especially field instructions and quality control. Additions are based upon experiences in, among others, the EU Sixth framework program GALEN study.

5. Responsibilities

- 1 The Co-ordinator is responsible for the final review and approval of this SOP.
- 2 The Local Principal Investigator is responsible that new versions of this SOP are available for every member of the project team and that older SOP versions are collected and destroyed.
- 3 Members of the project team are responsible for working according to this SOP and reporting of local and temporal deviations and local changes of this SOP.
- 4 Kees Meliefste is responsible for the preparation of the text of this SOP.

6. Equipment and materials

6.1 Equipment

The Ogawa badges have been ordered from the manufacturer. All badges will be prepared by IRAS and transported to the partners responsible for the fieldwork. Each Ogawa badge contains a NO₂ and a NO_x filter. The Ogawa Sampler is reusable multiple times. Only the pre-coated collection filters are used once.

6.2 Materials

Items 1/4 needed for all centres (supplied by IRAS). Other items needed at IRAS only.

1. Ogawa badges
2. Sampling frame to install the tubes in the field (a plate to hold the Ogawa badges)
3. Container, clip, elastics and zip-lock bag to transport / connect badges to sampling frame
4. field forms and pens (Appendix 3)
5. cartridges to produce "zero-air" (NO₂, SO₂ and particle free air)
6. glove box with "zero-air"
7. laboratory gloves
8. pair of tweezers
9. analytical balance
10. desiccator with dried blue silica gel
11. drying stove
12. spectrophotometer VIS
13. laboratory test tubes plus caps
14. test tube rack
15. pipettes
16. general glassware
17. chemicals for Saltzman method, if used. Use only chemicals of recognized analytical grade (p.a.) and only double-distilled or de-ionised and distilled water.

Because sampling rates are used in the calculations, temperature and relative humidity data are needed. These can be measured at the site or taken from routine meteorological measurements sites. Depending on the study area, data can be taken from one or multiple sites. Collect hourly data as meteorological data will have multiple purpose within ESCAPE (see study manual).

6.3 Paper materials

18. Field forms to record data in the field (Appendix 3)
19. Laboratory forms to record calibration lines, calibration factor, check samples

6.4 Chemicals

- | | |
|---|--|
| - C ₃ H ₆ O | acetone |
| - C ₆ H ₈ N ₂ O ₂ S | sulfanil amide |
| - C ₁₀ H ₁₆ N ₂ O ₈ | E.D.T.A. (ethylene diamine tetra acetate) |
| - C ₁₂ H ₁₄ N ₂ .2HCl | N.E.D.A. (N-(1naphthyl)ethylenediammoniumdichloride) |
| - NaNO ₂ | sodium nitrite (for standard solution) |
| - NaOH | sodium hydroxide |
| - H ₃ PO ₄ | phosphoric acid |

7. Procedures

Each center conducts the procedures listed in 7.2 and 7.3.1. The other sections specify the IRAS tasks.

7.1 Preparations in the laboratory

For final cleaning and preparing solutions, good quality water needs to be used. If available, ultrapure water (UHQ) should be used. Alternatively, double distilled or de-ionized and then distilled water could be used, provided that the quality is sufficient to achieve low blanks (7.1.2). We will use the term UHQ water in this text.

7.1.1. Cleaning:

Cleaning of new badges:

New badges are rinsed 3 times with UHQ water, once with industrial ethanol (purity of 95%) and dried at room temperature on sheets of tissue paper. The clean badges do not react with NO₂, so this procedure can be conducted outside the glove box in a generally clean laboratory.

Cleaning of used badges:

Unless, the badge is visibly dirty they do need to be cleaned extensively. Grids (used in the analysis) and the outer diffuser end caps are cleaned as described above for new badges. Wipe the other parts of the badge –that have not been exposed- with tissue paper wetted with ethanol.

All preparations from here on should be conducted in the glove box with “zero-air”.

7.1.2 Preparing

The glove box should be connected to a 'zero air' system. "Zero air" should be free of NO₂ and nitrate aerosol as a minimum. "Zero air" can be produced by leading pressurized air through successively,

- a cartridge filled with a mixture of active carbon and Purafill (Manganese oxide) to remove SO₂ and NO₂ respectively
- a cartridge filled with dry blue silica gel, to dry the air.

Coated filters

Coated filters are ordered from the manufacturer. Filters come in boxes of 40. We have observed that the blank levels differ between different boxes. Hence we keep four badges (number 10, 20, 30, 40) in the laboratory to characterize the blank level of the batch (the average lab blank is subtracted). The laboratory needs to keep track of the batch to which exposed filters belong.

Assembling the Ogawa Sampler

The sampler is comprised of 2 chambers. Each chamber contains an Ogawa sampling assembly as shown in Figure 1. Start at the innermost position with the pad and progress outwards to the diffuser end cap to set-up a sampler assembly. Insert a NO₂ and a NO_x filter into the sampler.

After assembly, seal the loaded sampler into the zip-lock plastic bag. Make sure no air remains in the bag and close the bag carefully. We have ordered stronger bags than the original Ogawa bags, hence we do not use the orange Ogawa containers that are specified in the Ogawa protocol.

Storage of prepared badges

Keep the badges out of sunlight as much as possible. The badges have to be stored at 4 ± 3 °C. A prepared badge can be used for sampling up until 3 months after storage in the refrigerator.

Transport from IRAS to partners

New Ogawa badges are transported to you by aircraft express mail and are sealed in zip-lock bags in a Perspex box. After reception, the badges have to be stored at 4 ± 3 °C directly. For transport via Aircraft transport, secure the top of the Perspex box with elastic or tape in order to avoid leaks in the package due to air pressure differences.

7.1.3. Transport to the field

Transport to the field occurs in the zip-lock plastic bag as you received them from IRAS and next in the Perspex box with cold packs.

Sample coding

Filter codes will be provided by IRAS such that the preparation batch can be identified. The centre adds a unique sample code that identifies the sample. Do not write the code on the Ogawa badge itself but include the code and the badge nr on the plastic zip-lock bag. The coding procedure is described in Attachment 1.

7.2 Field procedures

The following items should be provided by the laboratory for a visit to any particular site to change samples:

- 1 Ogawa badge plus sampling frame
- Field forms with instruction for sampling date (Appendix 3)
- watch to record time

Installing equipment

The technical criteria for the measurement sites are listed in the ESCAPE study manual. As specified in the ESCAPE study manual, sampling duration is 14 days. Because of differences between weekdays and weekends, every effort should be made to obtain a 14-day sample. Sampling occurs simultaneously with the PM monitoring in those areas where PM₁₀ is measured

Start of sampling

1. Remove the Ogawa badges from the Perspex box and open the zip-lock bag. Connect the badge to the sampling frame such that rain cannot affect the sampler:
 - a. Connect frame to a surface (rain pipe, telegraph pole etc.) using tie-raps and tape such that the frame is well-connected and does not damage the (painted) surfaces
 - b. Place the Ogawa badge in the badge holder
 - c. Clip the badge to the sampling frame
 - d. Put the cup above the badge to prevent rain impact on the badge
2. Sampling starts when the badge is removed from the plastic bag. Take the bag back to the laboratory.
3. Record time of start of sampling on the field form to the nearest 1 minute.

End of sampling

1. Inspect the equipment and record irregularities on the field form (such as badge fallen, disappeared, construction activities)
2. Sampling is ended by placing the badge in the zip-lock bag and next in the Perspex box with cold packs. Carefully squeeze air from plastic bag before closing
3. Record time of ending of sampling on the field form (to the nearest 1 minute)

Make sure the badge is stored in the refrigerator as soon as possible.

7.3 Treatment of samples in the laboratory after sampling

7.3.1 Storage and transport

After exposure the badges will be stored in the refrigerator at 4 ± 3 °C in the dark. After all 40 sites have been measured once, samples will be transported to IRAS using express mail in the Perspex box with cold packs.

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7.3.2. Extraction

After exposure, the stainless steel screens (3 and 5, figure 1) and the coated filter are added to a 50 ml plastic test tube containing 16 ml of UHQ water. Use separate test tubes for NO₂ and NO_x. The analysis is then conducted immediately.

7.4 Analysis

The analysis is done by spectrophotometric determination of nitrite, using the Saltzman method. The analysis is described in detail in the Ogawa protocol.

7.4.1 Solutions

All chemicals are of p.a. quality and are dissolved in UHQ water.

7.4.1.1 Sulphanilamide solution

The sulphanilamide solution is prepared by dissolving 80g of p.a. grade sulphanilamide in a mixture of 200 ml concentrated phosphoric acid and 700 ml UHQ. This solution is then diluted with UHQ to a total of 1000ml. Stored at 4 ± 3 °C the solution is stable for 3 months.

7.4.1.2 NEDA solution

The NEDA solution is prepared by dissolving 0.56 g N-(1-Naphthyl)-ethylenediamine dihydrochloride into 100 ml of UHQ. Stored in the dark at 4 ± 3 °C the solution is stable for 3 months.

7.4.1.3 Color Producing Reagent

Prepare color-producing reagent immediately before use. Mix the sulphanilamide solution and the NEDA solution in a ratio 10:1 (10 parts sulphanilamide solution to 1 part NEDA solution). Discard any left over of the reagent

7.4.1.4 Stock STANDARD solution of nitrite

First dry a few grams of sodium nitrite (NaNO₂) by leaving it for four hours in an oven at 105 °C. Cool in a desiccator with dry blue silica gel to prevent uptake of water vapour. Dissolve 1.500 g of sodium nitrite p.a. (MERCK 6549) and also 0.2 g of sodium hydroxide p.a. (MERCK 6498) in UHQ water and fill up to 1 litre. When stored in a refrigerator at 4 ± 3 °C, the solution is stable for 3 months. A 1 ml sample of this solution contains 1000 µg of Nitrite.

7.4.1.5 Stock CONTROL solution of nitrite

First dry a few grams of sodium nitrite (NaNO₂) by leaving it for four hours in an oven at 105 °C. Cool in a desiccator with dry blue silica gel to prevent uptake of water vapour. Dissolve 1.500 g of sodium nitrite p.a. (MERCK 6549) and also 0.2 g of sodium hydroxide p.a. (MERCK 6498) in UHQ water and made up to 1 litre. When stored in a refrigerator at 4 ± 3 °C, the solution is stable for 3 months. A 1 ml sample of this solution contains 1000 µg of Nitrite.

7.4.1.6 Nitrite working standard solution

Dilute the nitrite stock standard solution by 100 times with UHQ. This solution must be prepared freshly every day.

7.4.1.7 Nitrite working control solution

Dilute the nitrite stock control solution by 100 times with UHQ. This solution must be prepared freshly every day.

7.4.1.8 Calibration series

Then 0, 0.16, 0.32, 0.48, 0.64 and 0.8 ml samples are each diluted with UHQ to make 8 ml solutions. This produces working standard solutions of 0 – 1.0 µg nitrite/ml. These solutions must be prepared daily on each analysis day.

The first step of the measurement procedure for NO₂ is to obtain a satisfying calibration line. A new calibration line is produced on each analyses run in triplicate.

The spectrophotometer is turned on at least 30 minutes before use for warming up. The standard solution of nitrite is pipetted into polystyrene tubes. Polystyrene is preferred instead of glass, because glass is reactive which is especially problematic at low concentrations of nitrite. 4 ml of color producing reagent are added. The tubes are closed, shaken and stored in the refrigerator. After 30 minutes the tubes are shaken again and left on the table to allow the solutions to warm up to room temperature for 30 minutes. Then the absorbance is measured at 545 nm.

7.4.1.8 Check samples

After each 10 samples of an analysis run, one check sample is analyzed. These samples are necessary to detect potential problems with either reagents or spectrophotometer or 30 minutes time cycles. Use the standard solution of 0.80 $\mu\text{g}/\text{ml}$ (used for the calibration curve) as the check samples. This standard solution was chosen such that the expected concentration range of the samples is covered. All checked samples should deviate less than 10 % from the amount of nitrite of the matching calibration standards.

7.4.1.9 Analysis of the samples

The spectrophotometer is turned on at least 30 minutes before use for warming up (dependent on specific equipment). Add 4 ml of colour producing reagent to each tube. Place the tubes with the grids and the reaction filter in the refrigerator for 30 minutes to allow the colour to develop. After 30 minutes the tubes are shaken again and left on the table to allow the solutions to warm up to room temperature for 30 minutes. Then the absorbance is measured at 545 nm.

Because there is not sufficient sample to re-analyse a tube, there may be a problem with concentrations that are higher than the highest calibration standard. The analyst should judge subjectively the colour of the samples and dilute very high concentrations with UHQ. Next, the absorbance is measured directly at 545 nm.

7.4.1.10 Procedure to calculate the calibration factor

By linear regression forced through zero a regression slope is calculated. In this regression the dependent variable -the Y-variable- should be the measured absorbance (minus the absorbance of the blank of the calibration line). Do not include (0,0) as a point in this calculation. The concentration (mg/l) in the standard solution is the independent variable. The calibration factor (f) is calculated as the reciprocal of the regression slope. In all cases a plot of the calibration line is made to check for linearity and outliers.

7.5 Quality control procedures

7.5.1 Internal quality control procedures

1. Four laboratory blanks are taken (by IRAS) from each lot of 40 coated filters that are analysed simultaneously with the samples. The average of these blanks will be used in the final calculations of the NO_2 and NO_x concentration. Record the values in a control chart.
2. Before each analysis run, a full calibration is conducted in triplicate. The calculated calibration factor by using a spectrophotometer should be within 10% of 1.04 mg/l. absorbance (for a 10 mm cuvet)
3. Each analysis run will contain in addition to the samples:
 - three calibration standards prior to the analysis of the samples
 - one control sample per rack of 10 samples
 - three calibration standards at the end of the analysis run

A control sample is a solution of nitrite prepared independently of the calibration standards, using different glassware and preferably another batch of chemicals. It should be prepared in the same matrix as the samples and in the concentration range to be expected. The results of the latter two control standards should not deviate more than 10% from the corresponding calibration standards at the start of the analysis run. The control sample should not deviate more than 10% from the target level. Record the value of the control sample and the calculated calibration factor in a control chart.

4. During each sampling session for the PM/ NO_x areas, one **field blank** should be collected at the continuous monitoring site, such that in total twelve field blanks will be available spread over the

study period. For the NO_x only areas, in each of the three sampling sessions, four blanks should be taken such that twelve field blanks will be available spread over the study period. A field blank is a badge that is prepared and transported to the field in the same way as the samples. At the site take the badge from the box and open the plastic bag. Then close the bag again and take the blank back to the lab. In previous projects (that included transport of samples), field blanks were found to be comparable to lab blanks. Field blanks are used to calculate the limit of detection: three times the standard deviation of the field blanks, using standard sampling rates (section 7.6) and sampling times (14 days) to calculate a concentration.

5. During each sampling session for the PM/ NO_x areas, one **field duplicate** should be collected, such that in total twelve field duplicates will be available spread over the study period. For the NO_x only areas, in each of the three sampling sessions, four duplicates should be taken such that twelve field duplicates will be available spread over the study period. The measurements should occur at the same sampling height as the regular sample. Duplicates (and blanks) will be made at the continuous monitoring site. In this way the duplicate also serves as a backup for the primary measurement. Duplicates are used for quality control purposes (precision of the measurement) only. They will not be used to calculate an average for those few samples for which two samples are available.
6. Effects of transport procedures on blank and exposed badges will be evaluated. We will expose 10 badges to the same concentration. Five badges will be stored in IRAS laboratory and five badges will be transported to and from one of the participating centres. Five blank badges will be transported as well. Then in one analysis batch, these badges will be analyzed for transport effects

7.5.2 External quality control procedures

In each study area, collocation with a continuous chemiluminescence monitor should be performed to evaluate the validity of the Ogawa badge measurement. In each study period, a comparison should be made. The comparison should be made at a background and a traffic location, as differences between passive samplers and monitors may depend on NO / NO₂ ratios and the ozone concentration.

Comparisons with other passive samplers will be performed at selected locations, e.g. the Ruhr area by IUTA. This is of interest since the Ogawa sampler is not a standard sampler considered in the European Harmonization efforts for passive sampling.

A control program will be developed by IRAS to document the impact of storage time on new and exposed badges.

7.6 Calculations

The NO₂ concentration in ambient air is calculated as:

$$C = (Q_{\text{NO}_2} * \alpha_{\text{NO}_2}) / t$$

with:

C	=	concentration NO ₂ (ppb)
Q _{NO2}	=	collected mass of NO ₂ (ng)
α _{NO2}	=	sampling rate (at 20 C and 70% RH: α = 56)
t	=	sampling time (minute)

The NO concentration in ambient air is calculated as:

$$C = ((Q_{\text{NO}_x} - Q_{\text{NO}_2}) * \alpha_{\text{NO}}) / t$$

with:

C	=	concentration NO (ppb)
Q _{NO2}	=	collected mass of NO ₂ (ng)
Q _{NOx}	=	collected mass of NO _x (ng)
α _{NO}	=	sampling rate (at 20 C and 70% RH: α = 60)
t	=	sampling time (minute)

Finally, the NO_x concentration in ambient air is calculated as the sum of the concentration of NO and NO₂.

The collected mass (Q) of NO₂ and NO_x from the badge is calculated from measured absorbance. This will be provided to you by IRAS.

$$Q = (A - A_b) / f * V * 1000 * d$$

with:

Q	=	collected mass (ng).
A	=	absorbance analysis sample.
A _b	=	mean absorbance of the four lab blank badges for each preparation batch *
f	=	calibration factor ((absorbance / μg/ml)
V	=	volume analysis sample (8 ml).
d	=	dilution factor (1.0, unless the sample had to be diluted)

NOTE: The absorbances of samples should not be corrected for the absorbance of the blank reagent (A₀). The absorbance of blank reagent is taken into account by the subtraction of the mean absorbance of the four lab blank NO₂ badges

Sampling rates can be calculated according to the formulas taken from the Ogawa protocol:

$$\alpha_{\text{NO}} = 10000 / ((-0.78 * P * \text{RH}) + 220)$$

with:

α_{NO} = sampling rate

$$P = (2P_{\text{N}} / (P_{\text{T}} + P_{\text{N}}))^{2/3}$$

P_{N} = water vapour pressure in mm Hg at 20 C (17.535)

P_{T} = water vapour pressure in mm Hg at ambient temperature (Appendix 4)

RH = relative humidity (in %)

$$\alpha_{\text{NO}_2} = 10000 / ((0.677 * P * \text{RH}) + 2.009 * T + 89.8)$$

with:

α_{NO} = sampling rate

$$P = (2P_{\text{N}} / (P_{\text{T}} + P_{\text{N}}))^{2/3}$$

P_{N} = water vapour pressure in mm Hg at 20 C (17.535)

P_{T} = water vapour pressure in mm Hg at ambient temperature (Appendix 4)

RH = ambient relative humidity (in %)

T = ambient temperature in degrees centigrade.

The impact on sampling rates is quite substantial, e.g. NO₂ sampling rates vary from 84 (-10 C and 50% RH) to 52 at 30C and 80% RH. We will enter the average temperature and RH of the sampling week from nearby weather stations in the formulas. In most projects concentrations calculated in this way agreed well with chemiluminescence data. Errors may be introduced since temperature and concentration vary during the sampling week. Because the impact on sampling rate is non-linear, calculation of hourly sampling rates and next averaging of the sampling rate will result in a different average rate. If in addition, hourly concentrations and temperature are correlated (e.g. because of diurnal variations) an additional error may be introduced. Temperature and RH at the site may differ from those recorded at an e.g airport. In addition, T and RH may be different from ambient in the sampling cup. We will consider these potential errors as limitations of the sampling method. IRAS will experimentally determine the impact of deviations of T and RH in the sampling cup. Helmholtz will perform tests at one site in Augsburg.

Calculations have been programmed in Excel files that will be distributed to you by IRAS. Please do not change the formulas in the file as this will complicate the final check performed by IRAS.

8. Data records

- control charts calibration line
- control charts calibration factor
- control charts control samples
- control charts preparation blanks
- control charts check sample
- field forms containing sampling characteristics (Appendix 3)
- spreadsheet containing all information for a specific sample

9. Sample archiving

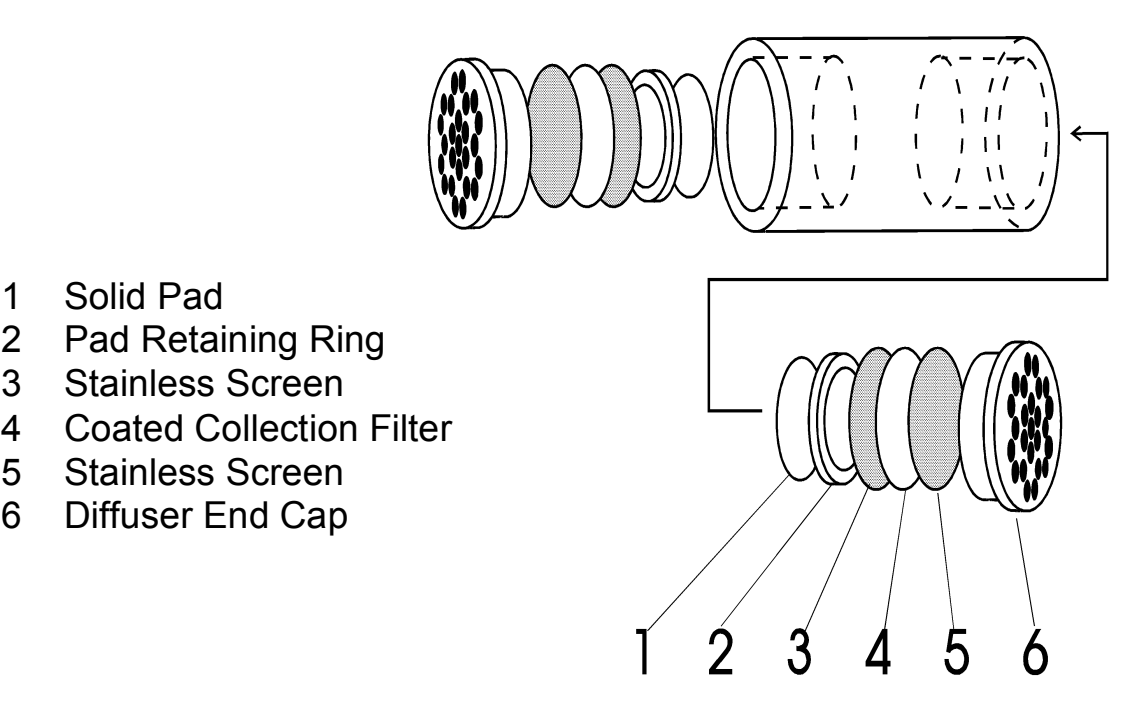
n.a.

10. Implementation and application

n.a.

Attachments

Figure 1 Ogawa Sampler Assembly



Appendix 1: Sample coding “E S C A P E” project

Coding samples :	CCGLCCddmmyyA	
Country + group		3 digits (3 letters) (see coding list study manual, Appendix 2) ^a
Location nr	01 - 40	2 digits (2 numbers) ^a
Component	P1 ór P2 ór NO ór OX ór PH	2 digits (2 letters ór 1 letter + 1 number)
Date	ddmmyy	6 digits (6 numbers) start date
Additional	S or B or D	1 digit (1 letter) S=sample, B=blank, D=duplicate

a) Also used as location coding on site characterization form

Appendix 2: Coding list Study areas

Study Area	Code	Epidemiologic study acronym	Measurements
Győr, Hungary	HUG	APREG	PM+NO _x
Florence, Italy	IFL	EPIC	NO _x
Turin, Italy	ITU	EPIC, SIDRIA, ECRHS	PM+NO _x
Varese, Italy	IVA	EPIC	NO _x
Verona, Italy	IVE	ECRHS	NO _x
Pavia, Italy	IPA	ECRHS	NO _x
Rome, Italy	IRO	GASPII, SIDRIA	PM+NO _x
Barcelona, Spain	SPB	ECRHS, INMA	PM+NO _x
San Sebastian, Galdakao, Spain	SPS	EPIC, INMA, ECRHS	NO _x
Huelva, Spain	SPH	ECRHS	NO _x
Oviedo, Spain	SPO	ECRHS, INMA	NO _x
Girona, Spain	SPG	REGICOR	PM+NO _x
Athens, Greece	GRA	EPIC	PM+NO _x
Heraklion, Greece	GRH	RHEA	PM+NO _x
Oxford, Norfolk, Norwich, Ipswich, UK	UKO	EPIC, ECRHS, UK 1946 cohort	PM+NO _x
Bradford, UK	UKB	BIB	NO _x
Manchester, UK	UKM	MAAS, UK 1946 cohort	PM+NO _x
Utrecht, Netherlands	NLU	EPIC	PM+NO _x
Amsterdam, Netherlands	NLA	EPIC, ABCD	
Doetinchem, Netherlands	NLD	EPIC	
Maastricht, Netherlands	NLM	EPIC	PM+NO _x
Rotterdam, Netherlands	NLR	PIAMA	
Antwerp, Belgium	BAN	ECRHS	
Heidelberg, Germany	GHE	EPIC	NO _x
Erfurt, Germany	GER	ECRHS	NO _x
Ruhr Area, Germany	GRU	SALIA, RECALL	PM+NO _x
Munich, Germany	GMU	LISA + GINI	PM+NO _x
Augsburg, Germany	GAU	KORA	
Lugano, Switzerland	SWL	SAPALDIA	PM+NO _x
Basel, Switzerland	SWB	SAPALDIA, ECRHS	NO _x
Geneva, Switzerland	SWG	SAPALDIA	NO _x
Vorarlberg, Austria	AUV	VHM&PP	NO _x
Copenhagen, Denmark	DCO	DCH, National Birth Cohort	PM+NO _x
Oslo, Norway	NOS	HUBRO, MOBA	PM+NO _x
Stockholm, Sweden	SST	BAMSE, TWINGENE, 60 YEAR OLDS	PM+NO _x
Umea, Sweden	SUM	ECRHS, EPIC	NO _x
Paris, France	FPA	ECRHS, EPIC, GAZEL, EGEA	PM+NO _x
Grenoble, France	FGR	ECRHS, EGEA, GAZEL	NO _x
Marseille, France	FMA	EPIC, EGEA, GAZEL	NO _x
Lyon, France	FLY	EPIC, EGEA, GAZEL	NO _x
Nancy, Poitiers, France	FNA	EDEN	NO _x *
Helsinki, Turku, Finland	FIH	FINRISK	PM+NO _x
Cracow, Poland	POC	HAPIEE	PM+NO _x
Kaunas, Lithuania	LIK	KANC	PM+NO _x

Appendix 3: Field form NO₂ and NO_x measurements with Ogawa Badge

FIELDFORM " E S C A P E " PROJECT			
<i>European Study of Cohorts for Air Pollution Effects</i>			
country :			
city :			
location nr :			
GPS Coord.:			
site type:	<input type="checkbox"/> regional background	<input type="checkbox"/> street	
	<input type="checkbox"/> urban background	<input type="checkbox"/> reference	
	name person installation :		
	name person collection :		
		OGAWA NO _x / NO ₂	OGAWA <input type="checkbox"/> blank <input type="checkbox"/> duplicate
	lab number :		
	I.D. sample code :		
	start date :		
	start time :		
	end date :		
	end time :		
irregularities :			

Appendix 4: Table with water vapour coefficients as a function of temperature

Temperature [T] degC	Water Vapor Pressure [Pr] mmHg	Vapor Pressure Coefficient [P] dimensionless
-10	2.149	1.4697
-9	2.326	1.4609
-8	2.514	1.4518
-7	2.715	1.4421
-6	2.931	1.4320
-5	3.163	1.4213
-4	3.410	1.4101
-3	3.673	1.3984
-2	3.956	1.3861
-1	4.258	1.3732
0	4.579	1.3599
1	4.926	1.3459
2	5.294	1.3314
3	5.685	1.3164
4	6.101	1.3009
5	6.543	1.2849
6	7.013	1.2685
7	7.513	1.2515
8	8.045	1.2341
9	8.609	1.2163
10	9.209	1.1980
11	9.844	1.1794
12	10.518	1.1605
13	11.231	1.1412
14	11.987	1.1217
15	12.788	1.1018
16	13.634	1.0818
17	14.530	1.0615
18	15.477	1.0411
19	16.477	1.0206
20	17.535	1.0000
21	18.650	0.9794
22	19.827	0.9587
23	21.068	0.9380
24	22.377	0.9174
25	23.756	0.8969
26	25.209	0.8764
27	26.739	0.8561
28	28.349	0.8360
29	30.043	0.8160
30	31.824	0.7962
31	33.695	0.7767
32	35.663	0.7575
33	37.729	0.7385
34	39.898	0.7198
35	42.175	0.7013
36	44.563	0.6832
37	47.067	0.6655
38	49.692	0.6480
39	52.442	0.6309
40	55.324	0.6142