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Colophon

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Abstract

Particulate matter has become an important issue as a result of the health effects associated with the spreading of dust, microorganisms and endotoxins from different sources. In order to validate the efficiency of some aerosol reduction techniques, it is important to be able to perform reliable and accurate measurements. This report describes a protocol for using one of the different types of aerosol samplers, the RespiCon Particle Sampler, for field studies.

Keywords: particulate matter, aerosol, dust, RespiCon, sampler, protocol, particle size distribution

Inhoud

1 Introduction

Continuous exposure to small dust particles (particulate matter) during a large period, or a short exposure to high (daily averaged) dust concentrations, has been associated with adverse health effects both in humans and animals (Donham *et al.*, 1984; Preller, 1995; Dosman *et al.*, 1997; Hoek *et al.*, 1997; Bloemen *et al.*, 1998; Vonk and Schouten, 1998). Bloemen *et al.* (1998) estimated that in the Netherlands, on average, a number of 4000 deaths per year could be associated with health problems due to exposure to small dust particles. However, this estimate is based on American studies, usually giving higher estimates than European studies (Rombout *et al.*, 2000). When using information from Dutch studies Rombout *et al.* (2000) arrived to an estimate of approximately 1000 deaths per year. More recently, Milieucompendium (2001) estimated this number to be 2500 deaths per year.

An extra complication when relating particulate matter and health effects is that there does not seem to be a threshold for those effects. Even at concentrations below the current regulations, health problems have been observed (Hoek *et al.*, 1997; Vonk and Schouten, 1998; WHO, 2000; US-EPA, 2001). Besides, not all dust particles have the same negative effect: the size and composition of the particles is of great importance. With respect to their sizes, a separation is made between inhalable dust (50% cut-point of 100 μm (PM_{100}), and includes big and small particles), thoracic dust (50% cut-point of 10 μm (PM_{10}), and respirable dust (50% cut-point of 4 μm (PM_4)). Chemically, a differentiation is made between primary dust (dust particles directly emitted to the atmosphere) and secondary dust (product of the transformation/reaction of primary emitted components (SO_2, CO_2, NH_3)). Keuken *et al.* (1999) suggested three mechanisms by which particulate matter could cause health effects:

1. A direct mechanical effect in the respiratory track
2. A direct (systematic) toxic effect
3. An indirect effect as carrier for toxic particles

Due to these associated health effects, particulate matter has become an important issue. This has been the reason for WHO in providing guidelines for particulate matter (WHO, 2000) and for the EU to provide standards for PM_{10} in a daughter directive (1999/20/EC) of the EU Air Quality Directive (96/62/EC). Table 1 summarizes these standards (annual and daily means), and the limitations for exceeding the daily standards.

Table 1 EU standards for PM_{10}

Year	Averaging time	Maximum permitted	Exceedances allowed
2005	Daily	50 $\mu g.m^{-3}$	35 permitted exceedances per year
	Annual	40 $\mu g.m^{-3}$	
2010	Daily	50 $\mu g.m^{-3}$	7 permitted exceedances per year
	Annual	20 $\mu g.m^{-3}$	

Although the industry and transport sectors are the most important sources of dust particles, the contribution from agricultural sources, which have increased in the last few years (Buringh and Opperhuizen, 2002; table 2) cannot be neglected.

Table 2 Emissions of PM_{10} in ktonnes per year by different economic sectors in the Netherlands (Buringh and Opperhuizen, 2002)

	1980	1995
Transport	32.6	21.2
Industry	52.8	21.3
Consumers	4.5	3.9
Agriculture	7.9	9.7
Storage and handling	2.0	2.8
Waste incineration	4.3	0.1
Energy sector	11.0	0.7
Other	0.8	1.1
TOTAL	**115.9**	**60.9**

Within the agricultural sector, animal houses (dried faeces, feed, hair/feathers and skin particles of the animals, and bedding materials) are the most important sources of dust emissions (Donham and Gustafsson, 1982; CIGR, 1994; Aarnink *et al.*, 1997). The national government aims to a reduction of dust emissions in 2030 of 85-95% with respect to the emissions in 1990 (NMP4, 2001). Biofilters and air scrubbers have been suggested as a possibility to reduce dust, microorganisms and endotoxins from animal houses (Seedorf *et al.*, 1999; Martens *et al.*, 2001; Aarnink *et al.*, 2003). However, their efficiency for this task has not been proven yet.

The purpose of this report is to describe a protocol that can be used to measure the dust emission from animal houses, and to prove the efficiency of emission reduction techniques (biofilters, air scrubbers, …) to reduce dust emissions. In chapter 2, the measurement method and strategy where this protocol is based on, are presented. Chapter 3 describes the different steps to follow to measure dust concentrations for field studies, and the maintenance activities to be performed. Finally, chapter 4 shows the calculation method used to determine dust concentrations or emissions.

2 Measurement method and strategy

2.1 Measurement method

The dust sampling system used for this kind of measurements is the RespiCon Particle Sampler from Hund Wetzlar. In this sampler the dust concentration and the size distribution of the measured in- and outgoing air are determined by using a gravimetric method. The RespiCon Particle Sampler is a multi-stage, virtual impactor that collects airborne particles onto three individual filters. The three sampling filters and the impactor are assembled in a concentric unit with cylindrical symmetry (see figure 1). The air is drawn into the system through a ring-gap sampling inlet via a constant-flow personal sampling pump (Buck-geni vss-5). Coarse particles pass straight through to the lower collector while other particles are aerodynamically separated onto the appropriate filter. The first filter (separation stage 1) collects the particles with an aerodynamic diameter smaller than 4 μm. The second filter (separation stage 2) collects the particles below 10 μm, while the third filter (stage 3) collects the remaining particles. Inside the instrument the total flow (3.11 $l.min^{-1}$) is divided into three individual streams with flow rates Q_1=2.66, Q_2=0.33, and Q_3=0.11 $l.min^{-1}$. The airflow through the Respicon is checked prior to every measurement with a flowmeter.

The mass of collected particles is determined by comparing the filter weights before and after sampling. By measuring the amount of dust collected on the filters it is possible to determine:

1. Inhalable dust (diameter < 100 μm)
2. Thoracic dust or small particles (diameter < 10 μm)
3. Respirable dust (diameter < 4 μm). It is possible, by changing the inlet head of the sampler, to measure particles with a diameter smaller dan 2.5 μm.

The different components of the RespiCon sampler are shown in figure 1.

2.2 Measurement strategy

To measure the efficiency of biofilters or similar systems, one RespiCon unit should be placed before and another one after the system. For monitoring in animal houses, they should be placed in places where a representative sample is obtained. In order to avoid systematic errors associated, it is advised to exchange the units/filters that are used at the inlets and outlets.

Another important point is that the inlet head provided with the RespiCon units makes the use of the sampler only appropriate when the air velocity is lower than 2 $m.s^{-1}$, but it is also available for measurements at wind speeds up to 4 $m.s^{-1}$, although other inlet heads are then necessary. Therefore, we should take care that the location selected to put the sampler complies with this requirement. It is suggested to locate the sampler outside the ventilation shaft, but close enough to have a representative sample of the outgoing air.

The measurement period depends on the estimated concentration, but in general a standard sampling period of 1 day is used. When it is suspected that dust concentrations are low, the measurement period should be increased in order to get enough amount of dust on the filters (at least 10 mg) and decrease the measurement error. The measurement period should be based on whole-day measurements, in order to take into account the daily variation in emission associated with, for example, climate in the animal house and activity of the animals.

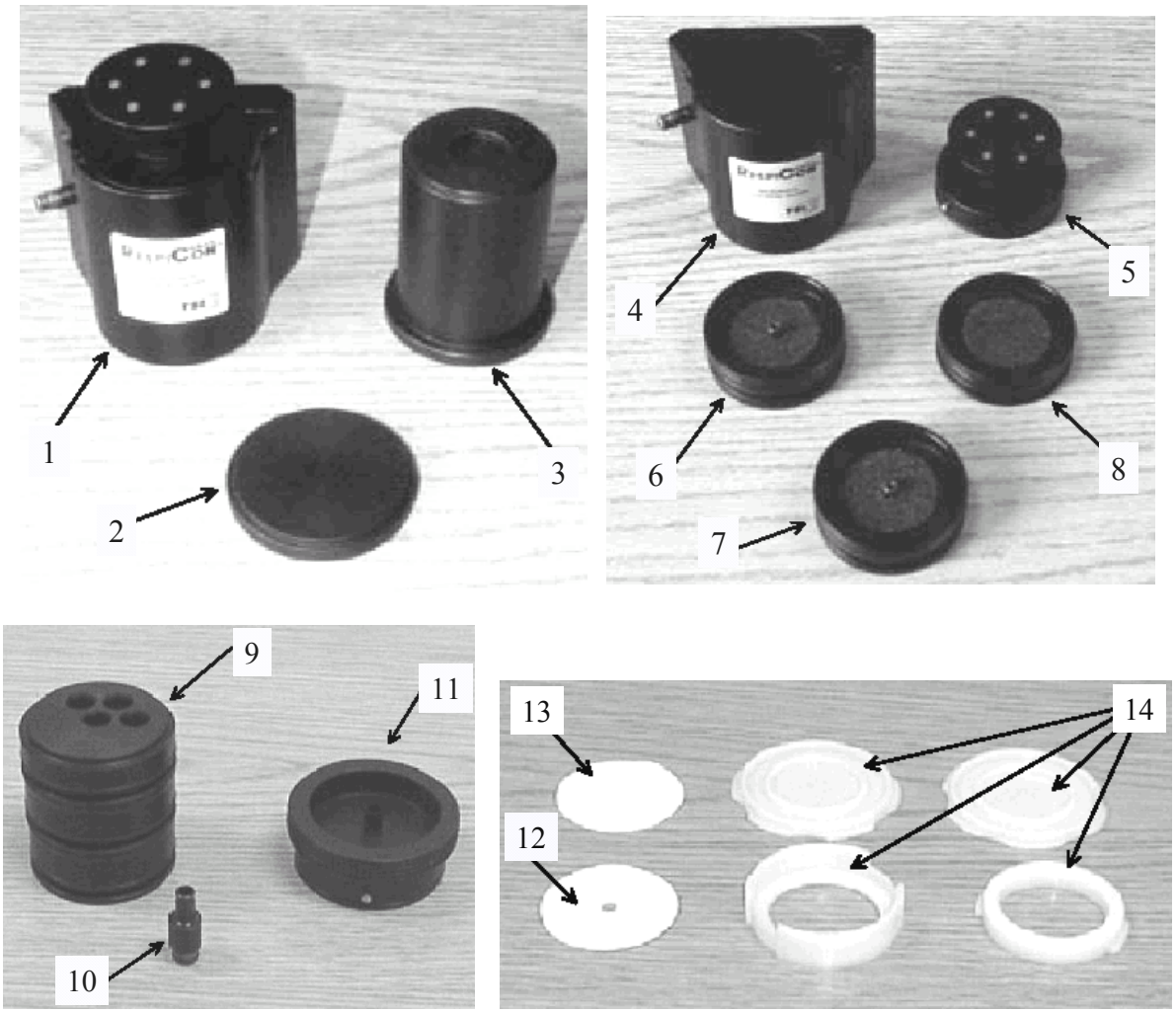

Figure 1 RespiCon sampler. 1: RespiCon sampler; 2: Removal lid; 3: Removal cylinder; 4: RespiCon body unit; 5: Inlet head; 6-8: filter stages; 9: Stage flow checker; 10: Stage flow checker inlet; 11: Total flow checker; 12: 37-mm filter with hole; 13: 37-mm filter without hole; 14: Filter cassette (shown disassembled) with top and bottom lid

3 Measurement protocol

3.1 Preparation of the samplers in the lab

3.1.1 Materials

- Gloves
- Pen/Marker
- Weighing Form
- Pair of tweezers (forceps)
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes for the zero measurements
- Set of three 37-mm filters (2 with hole, 1 without hole)+ cassettes + petri dishes (per RespiCon unit) for the measurements
- Oven to dry the petri dishes
- Exicator
- Balance with a precision of at least 0.1 mg

When necessary (first measurement period):

- Alcohol
- Pressurized air (clean and dry)
- Flow Check Form
- Flow checking equipment (stage flow checker, stage flow checker inlet, total flow checker, sample pump, flowmeter)
- Removal cylinder and removal disk (from the RespiCon unit)

3.1.2 Procedure

The following procedure should be performed in the lab, in a clean environment, to prepare each of the 2 RespiCon samplers, and for the zero (background) measurements:

1. Always wear latex gloves while working with dust.
2. Mark three petri dishes (corresponding to one RespiCon unit) as shown in appendix A.
3. Put a 37-mm filter with hole in two of the petri dishes, and a 37-mm filter without hole in the third petri dish.
4. Dry the petri dishes (with filter) during 4 hours in the oven at a temperature of 70 °C. Make sure that the inside of the oven is clean and free of other potential dust contaminants.
5. Let the petri dishes (with filter) cool down to ambient temperature for 1 hour in the exicator. Make sure that the inside of the exicator is clean and free of other potential dust contaminants.
6. Determine the weight of the filters and/or the combination filter-petri dish, with a precision of at least 0.1 mg (appendix B) and write the values in the Weighing Form (appendix D).
7. Store the petri dishes (with filter) in the exicator, to avoid water absorption.

8. Take a clean and dry cassette (the drying process for the cassettes is the same as for the petri dishes, and is usually performed as a post-treatment after the measurements) and take all the pieces apart.
9. Insert the bottom ring in the bottom lid of the filter cassette and put the filter support in. Then use a pair of tweezers (forceps) to take one of the weighed 37-mm filter with hole from the petri dish (check that the code from the cassette and the filter (petri dish) correspond to each other) and insert it into the filter support.
10. Align the top ring and gently press it into place, using both hands. Close the cassette with the top lid and put it back into the petri dish.
11. Store the petri dish (with the cassette) in the exicator
12. Repeat steps 7-10 for the second 37-mm filter with hole and for the 37-mm filter without hole.

The following steps will be performed in the lab before starting a new measurement series (measurement period 1). Otherwise, the sampler will be already at the measurement location, and the steps will be performed at the location (see also section 3.2).

13. Clean and dry the RespiCon following the procedure shown in appendix C1 (at the start of a new series clean surfaces with alcohol).
14. Install the three filters and filter stages to be used for the zero (background) measurements in the body unit and close it with the inlet head.
15. Perform total flow check and stage flow check (internal flows) following the procedures described in appendix C2 and C3, respectively.

3.2 Procedure for dust sampling at the measurement location

3.2.1 Materials

- Gloves
- Sampling Form
- Flow Check Form
- Pen/Marker
- Alcohol
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes for the zero measurements
- Set of three 37-mm filters (2 with hole, 1 without hole)+ cassettes + petri dishes (per RespiCon unit) for the measurements
- Set of three cassettes + petri dishes (per RespiCon unit) to store the used filters
- Exicator or dry and dark box
- Pump for the measurements
- Flow checking equipment (stage flow checker, stage flow checker inlet, total flow checker, sample pump, flowmeter)
- Removal cylinder and removal disk (from the RespiCon unit)

3.2.2 Procedure

If you are starting a new measurement series, i.e. you are in the first measurement period, start the procedure at step 6, otherwise start immediately at step 1.

1. Write the date and time when you stop the measurements, and the code of the cassettes of that particular sampler, in your Sampling Form (appendix D).
2. Disassemble the RespiCon Particle Sampler as shown in appendix E1.
3. Clean and dry the RespiCon following the procedure shown in appendix C1 (at the start of a new series clean surfaces with alcohol).
4. Install the three filters and filter stages to be used for the zero (background) measurements in the body unit and close it with the inlet head.
5. Perform total flow check and stage flow check (internal flows) following the procedures described in appendix C2 and C3, respectively.
6. Put the three (new) filters from the filter cassettes into the filter stages with the code corresponding to every specific sampler in the body unit and close it with the inlet head as shown in appendix E2.
7. Put the RespiCon unit on place at the selected measurement point.
8. Keep the empty and marked petri dishes and cassettes in an exicator or in a clean, dry and dark box. Turn on the pump and write the date and time when you start the measurements, and the code of the cassettes of that particular sampler, in your Sampling Form (appendix D).

3.3 Handling of collected samples at the lab

3.3.1 Materials

- Gloves
- Pen/Marker
- Weighing Form
- Pair of tweezers (forceps)
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes with the zero measurements
- Set of three 37-mm filters (2 with hole, 1 without hole)+ cassettes + petri dishes (per RespiCon unit) with the sample
- Oven to dry the petri dishes and cassettes
- Exicator
- Balance with a precision of 0.1 mg
- Alcohol
- Pressurized air (clean, dry)

3.3.2 Procedure

Once the collected dust samples have been transported into the lab, the following procedure should be performed (in a clean environment):

1. Dry the cassettes (with the filters) during 4 hours in the oven at a temperature of 70 °C. Make sure that the inside of the oven is clean and there is no other material in there.
2. Let the cassettes (with the filters) cool down to ambient temperature for 1 hour in the exicator. Make sure that the inside of the exicator is clean and there is no other material in there.
3. Use a pair of tweezers (forceps) to take (carefully) the filters out of the cassettes, and put the filters in different petri dishes.
4. Determine the weight of the filters and/or the combination filter-petri dish, with a precision of 0.1 mg (see appendix B) and write the values in the Weighing Form (appendix D).
5. Wash the empty cassettes with alcohol and dry with pressurized air.
6. Put the washed cassettes in a petri dish, let them dry and store them for further use.

3.4 Maintenance activities

The following procedures should be performed before each use of the RespiCon Particle Sampler at the measurement location or in the lab (see also appendix C):

1. Always wear latex gloves while working with dust.
2. Clean RespiCon Particle Sampler (impactor nozzles, body unit and inlet head).
3. Perform total flow check and stage flow check.
4. Check O-rings.

The following procedures should be performed only if needed:

1. Always wear latex gloves while working with dust.
2. Clean orifices (if unable to obtain correct flow on each stage)
3. Replace O-rings (only if damaged).
4. Replace orifices (only if damaged).

4 Data analysis

The mass loadings of the three filters are not completely independent from each other. This is due to the way the virtual impactor works. When m_1 is the mass loading of the first filter, the second and third filter should at least have loadings corresponding to:

$$m_2 = 0.124 \cdot m_1$$
$$m_3 = 0.04 \cdot m_1 + 0.33 \cdot (m_2 - 0.124 \cdot m_1)$$

You should use these values in the evaluation spread sheet when m_1 can be safely determined but the mass loadings of filter 2 and filter 3 are below the detection limit.

The mass concentration of the aerosol size fractions can be calculated from the aerosol masses deposited on the filters, the sampling time and the volume flow rates, according to the following algorithm:

- Respirable fraction: $C_{resp} = \frac{m_1 \cdot 1000}{t_s}$
- Thoracic fraction: $C_{thor} = \frac{(m_1 + m_2) \cdot 1000}{(Q_1 + Q_2) \cdot t_s}$
- Inhalable fraction: $C_{inh} = \frac{(m_1 + m_2 + m_3) \cdot 1000}{(Q_1 + Q_2 + Q_3) \cdot t_s}$

Where:

C_{resp}	=	Respirable fraction [mg.m^{-3}]
C_{thor}	=	Thoracic fraction [mg.m^{-3}]
C_{inh}	=	Inhalable fraction [mg.m^{-3}]
m_1	=	Mass deposited on filter #1 [mg]
m_2	=	Mass deposited on filter #2 [mg]
m_3	=	Mass deposited on filter #3 [mg]
Q_1	=	Flow rate through filter #1 [l.min^{-1}; default=2.66]
Q_2	=	Flow rate through filter #2 [l.min^{-1}; default=0.33]
Q_3	=	Flow rate through filter #3 [l.min^{-1}; default=0.11]
t_s	=	Sample time [min]

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Appendix A Marking the petri dishes and the cassettes

A.1 Materials

- Gloves
- Marker
- Set of three cassettes + petri dishes for the zero measurements
- Set of three cassettes + petri dishes (per RespiCon unit) for the measurements

A.2 Procedure

1. Always mark the cassettes before drying.
2. Always wear latex gloves while working with dust.
3. Be consistent when selecting a code to label both the petri dish and the cassette where the filter will be weighed and transported. The following code is suggested for the two (at this moment) available RespiCon units:
   - U1.S1.P1: RespiCon unit 1, stage 1, period 1 (37-mm filter with hole)
   - U1.S2.P1: RespiCon unit 1, stage 2, period 1 (37-mm filter with hole)
   - U1.S3.P1: RespiCon unit 1, stage 3, period 1 (37-mm filter without hole)

   - U2.S1.P1: RespiCon unit 2, stage 1, period 1 (37-mm filter with hole)
   - U2.S2.P1: RespiCon unit 2, stage 2, period 1 (37-mm filter with hole)
   - U2.S3.P1: RespiCon unit 2, stage 3, period 1 (37-mm filter without hole)

If it is measured during more than one measurement period, the same code will be used with the only change of the period where it is measured. For example:

- U2.S2.P1: RespiCon unit 2, stage 2, period 2 (37-mm filter with hole)

For zero (background) measurements, use the code U0 for the RespiCon unit. For example:

- U0.S2.P1: Zero (background) measurements, stage 2, period 2 (37-mm filter with hole)

Appendix B Procedure to weigh the filters

B.1 Materials

- Gloves
- Pen/Marker
- Data Evaluation Form
- Pair of tweezers (forceps)
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes for the zero measurements
- Set of three 37-mm filters (2 with hole, 1 without hole)+ cassettes + petri dishes (per RespiCon unit) for the measurements
- Balance with a precision of 0.01 mg

B.2 Procedure

This procedure will be used before and after the sampling:

1. Be sure that the filters are stored in a room under controlled environmental conditions (20 °C, 50% relative humidity) at least one day before the measurements are taken place. Perform the weighing procedure also in this room.
2. Always wear latex gloves while working with dust.
3. Set the counter on the desired sequential number.
4. Print date en time.
5. Check zero reading (press print with empty balance).
6. Put the dried and cooled petri dish (with the filter) on the balance.
7. Press print.
8. Note the sequence number and the code of the petri dish in the weighing-form (see appendix A).
9. Close the weighing series with a zero reading.
10. Print date and time.
11. Repeat steps 4-8 for all filters
12. Press end and add the print out with the weights to the weighing-form (see appendix D).

Appendix C Maintenance

C.1 Cleaning RespiCon Particle Sampler

C.1.1 Materials

- Gloves
- Pipe cleaner
- Pressurized air (clean, dry)

C.1.2 Procedure

Always wear latex gloves while working with dust.

Aerosol flow through the virtual impactor nozzles is critical to the proper functioning of the RespiCon Particle Sampler. These nozzles should be cleaned before each sample using the supplied pipe cleaners (eventually with water, soap or alcohol) and dried with pressurized air. The nozzles are located at:

a. The underside of the inlet head
b. The centre of the first filter stage
c. The centre of the second filter stage.

Although most of the particles entering the RespiCon Particle Sampler will be captured on the filters, some build-up may occur within the body unit and on the filter stages. These areas, together with the inlet head, will be cleaned with pressurized air.

C.2 Procedure for total flow check

C.2.1 Materials

- Gloves
- Flow checking equipment (stage flow checker, stage flow checker inlet, total flow checker, sample pump, flowmeter)
- Removal cylinder and removal disk (from the RespiCon unit)

C.2.2 Procedure

The total flow through the RespiCon Particle Sampler must be maintained at 3.11 $l.min^{-1}$±2% (3.04-3.17 $l.min^{-1}$). A check of the total flow is a good way to verify the system integrity of the unit. This quick test helps to verify that:

- All O-rings are in place and intact.
- Filters are correctly installed.
- The pump flow is correctly set.

To perform a total flow check, use the following procedure:

1. Always wear latex gloves while working with dust.
2. Remove the inlet head and install the total flow checker by placing it onto the body unit and turning clock-wise.
3. Attach a tube from the total flow checker to a flow-measuring instrument with a capacity of at least 3.2 $l.min^{-1}$ (Gilian flowmeter), and the sample tube from the RespiCon unit outlet to the sample pump (figure 2).
4. Turn on the pump. Measure and register flows and adjust until they meet the specified range (3.04-3.17 $l.min^{-1}$).

Figure 2 Attach flowmeter and sampling pump to RespiCon total flow checker

C.3 Procedure for stage flow check

C.3.1 Materials

- Gloves
- Flow checking equipment (stage flow checker, stage flow checker inlet, total flow checker, sample pump, flowmeter)
- Removal cylinder and removal disk (from the RespiCon unit)

C.3.2 Procedure

While the total flow through the RespiCon unit is a good test of system integrity, it is possible for the total flow to be correct while the three internal flows are out of balance. These flows regulate the functioning of the two virtual impactors and maintain the correct particle size separation. To perform a check of the individual stage flows, use the following procedure:

1. Always wear latex gloves while working with dust.
2. Remove the filters and filter stages (if they are installed in the body unit).
3. Install the stage flow checker into the body unit (make sure it is seated against the bottom of the body unit).
4. Install the total flow checker onto the top of the body unit (make sure it is seated correctly, and the O-ring makes a good seal).
5. Attach the pump to the RespiCon unit outlet and a suitable flowmeter (Gilian flowmeter) to the total flow checker inlet (figure 2).

6. Turn on the pump. Measure and register flows and adjust until they meet the specified range (3.04-3.17 l.min^{-1}).
7. Remove the total flow checker.
8. Install the stage flow checker inlet into the hole marked "Q1". For ease of insertion, slightly moisten the inlet fitting)-rings with water, and insert the fitting with a twisting motion.
9. Attach a tub from the stage flow checker inlet to the flow measuring instrument (figure 3).
10. With the pump still running, check the flowmeter reading. Table 3 contains the desired flow rate for each stage.
11. Install the stage flow checker inlet into the hole marked "Q2" and repeat steps 9-10.
12. Install the stage flow checker inlet into the hole marked "Q3" and repeat steps 9-10.

Figure 3 Attach flowmeter and sampling pump to RespiCon stage flow checker

Table 3 Flow rate for the three stages

Stage	Nominal	Accuracy	Range
Q_{total}	3.11 l.min^{-1}	± 2%	3.04-3.17 l.min^{-1}
Q_1	2.66 l.min^{-1}	± 3%	2.59-2.75 l.min^{-1}
Q_2	0.333 l.min^{-1}	± 5%	0.31-0.35 l.min^{-1}
Q_3	0.111 l.min^{-1}	± 5%	0.105-0.116 l.min^{-1}

C.4 Check O-rings

The RespiCon Particle Sampler contains 13 O-rings (see table 4). Each of them is important for maintaining good seals and correct flow rates within the instrument. You should become familiar with the location of each O-ring and should routinely inspect them prior to assembly of the instrument. Always wear latex gloves while working with dust.

Table 4 Flow rate for the three stages

Location	Diameter
Perimeter of inlet head	42 mm
Underside of inlet head and 1st and 2nd filter stage (x3)	32 mm
Top of each filter stage (x3)	32 mm
Perimeter of each filter stage (x6)	42 mm

C.5 Clean orifices

C.5.1 Materials

- Gloves
- Screwdriver
- Pressurized air (clean, dry)

C.5.2 Procedure

The three orifices, located near the RespiCon Particle Sampler outlet, control the internal flows within the instrument. After prolonged use, the orifices may need to be cleaned. If you are not able to obtain the correct flows within the RespiCon (when the total flow is correct) it is also a possible indication that the orifices need to be cleaned. To clean the orifices use the following procedure:

1. Using a small, slotted screwdriver, remove the three orifices located next to the RespiCon Particle Sampler outlet (figure 4).
2. Blow out any accumulated particles using pressurized air.
3. Install the red, colour-coded orifice at the top (2.66 $l.min^{-1}$), the yellow orifice in the middle and the green orifice at the bottom

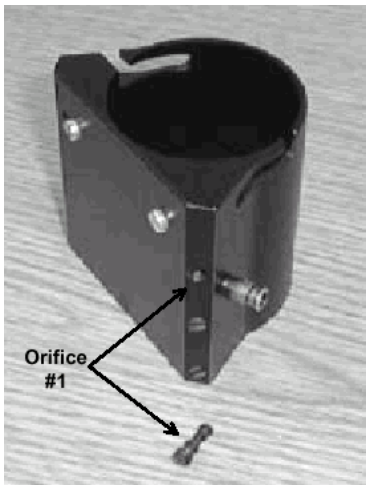

Figure 4 Orifice location, orifice #1 shown removed

Appendix D Forms

D.1 Weighing Form

RESPICON PARTICLE SAMPLER #1 Weighing Form					
Date	Filter stage		Mass (mg)		Date
Start	#	Code	Start	End	End
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				
	1 2 3				

D.2 Sampling Form

RESPICON PARTICLE SAMPLER #1 Sampling Form								
	Start measurement period		End measurement period		Code Filter stage #			
Sampling Location	Date	Time	Date	Time	1	2	3	Measurements performed by

RESPICON PARTICLE SAMPLER #2 Sampling Form								
	Start measurement period		End measurement period		Code Filter stage #			
Sampling Location	Date	Time	Date	Time	1	2	3	Measurements performed by

D.3 Flow Check Form

RESPICON PARTICLE SAMPLER #1 Flow Check Form							
Sampling Location	Date	Meas. #	Q1	Q2	Q3	Qg	Measurements performed by
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					

RESPICON PARTICLE SAMPLER #2 Flow Check Form							
Sampling Location	Date	Meas. #	Q1	Q2	Q3	Qg	Measurements performed by
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					
		1 2 3 4 5					

Appendix E Assembling and disassembling the RespiCon Particle Sampler

E.1 Disassembling the RespiCon Particle Sampler

E.1.1 Materials

- Gloves
- Set of three cassettes + petri dishes for the zero measurements
- Set of three cassettes + petri dishes (per RespiCon unit) for the samples
- Exicator
- Removal cylinder and removal disk (from the RespiCon unit)

E.1.2 Procedure

1. To disassemble the RespiCon Particle Sampler first remove the inlet head by pressing down slightly and turning it counter-clockwise. Place the body unit on top of the removal cylinder and cover with the removal disk (figure 5A).
2. Press down with the palm (figure 5B) of your hand on the removal disk. The filter stages will come loose and the body can be pushed down.
3. Remove the three filter stages from the body unit and remove the filter cassettes from each stage. Close the cassettes with the top and bottom lid, mark them and put them in the marked petri dishes. Check that the code from the cassettes and the petri dishes correspond to each other
4. Keep the marked petri dishes and cassettes in an exicator or in a dry and dark box.

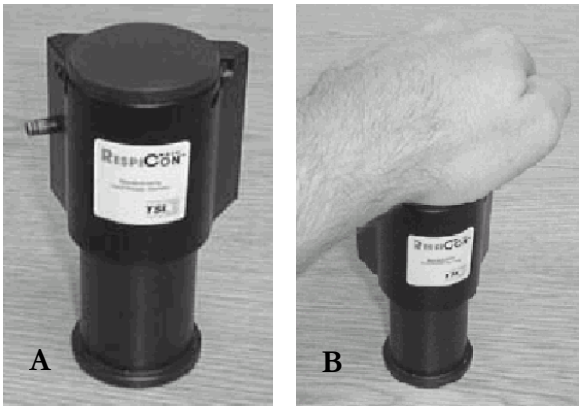

Figure 5 Disassembling the RespiCon Particle Sampler

E.2 Assembling the RespiCon Particle Sampler

E.2.1 Materials

- Gloves
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes for the zero measurements
- Set of three 37-mm filters (2 with hole, 1 without hole) + cassettes + petri dishes (per RespiCon unit) for the samples
- Removal cylinder and removal disk (from the RespiCon unit)

E.2.2 Procedure

The filter stages are identified by ring(s) inscribed around the perimeter. Filter stage #1 has one ring, filter stage #2 has two rings, and filter stage #3 has three rings. The filter stages must be assembled in order, with #1 on the top and #3 on the bottom. If the stages are assembled in the incorrect order, they will not physically fit into the body unit. Do not force the units if you experience excessive resistance, but check the order from the filter stages instead. Examine the exterior of the filter stages to ensure that the two O-rings on each stage are intact. The following procedure should be used:

1. Take out the top and bottom lid of the marked cassettes (with the filter inside), and place the cassettes on the filter stages that correspond to that specific code. Check that the filters are carefully centred in relation to the filter cassettes and filter stages.
2. Assemble the filter stages loaded with the cassettes as follows: put filter stage 2 on top of filter stage 3, and filter stage 1 on top of filter stage 2. The ring labels of the filter stages must be at the top.
3. Place the body unit over the removal cylinder. Place the staked filter stages onto the removal cylinder (figure 6A) and lift the body unit (figure 6B).
4. Invert the removal cylinder. Using the removal cylinder, press firmly down on the top filter stage stack until the three stages are seated tightly at the bottom of the body unit (figure 6C). This step requires a fair amount of force to overcome the friction caused by the O-rings. Do not press filter stages into body unit using fingers. Doing so may disrupt or damage the filters.
5. Place the inlet head on top of the sampler.

Figure 6 Assembling the RespiCon Particle Sampler