Bristol-Myers Squibb

Operation, Maintenance, and Monitoring Plan – Building 3 Indoor Air Treatment System

Syracuse North Campus Restoration Area
(Site #C734138)
East Syracuse, New York

May 2022

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I, Christopher Davern, certify that I am currently a New York State registered Professional Engineer and that this *Operation, Maintenance, and Monitoring Plan – Building 3 Indoor Air Treatment System* was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER Technical Guidance for Site Investigation and Remediation (DER-10).

William McCune
Principal Geologist / Project Manager

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Acronyms and Abbreviations

ACH	air changes per hour
ATS	air treatment system
BMS	Bristol Myers Squibb
cfm	cubic feet per minute
COC	constituent of concern
DCE	dichloroethene
DER-10	DER-10 Technical Guidance for Site Investigation and Remediation
EHS	environment, health, and safety
ELAP	Environmental Laboratory Approval Program
FSAP	Field Sampling and Analysis Plan
HEPA	high-efficiency particulate air
HVAC	heating, ventilation, and air conditioning
LED	light-emitting diode
MERV	minimum efficiency reporting value
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBG	O’Brien & Gere
OMM	operation, maintenance, and monitoring
QAPP	Quality Assurance Project Plan
SVI	soil vapor intrusion
TCE	trichloroethene
$\mu g/m^3$	micrograms per cubic meter
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound(s)

1 Introduction

This plan is submitted on behalf of Bristol Myers Squibb (BMS) to outline the operation, maintenance, and monitoring (OMM) procedures to be conducted relating to the indoor air treatment system (ATS) installed for the Boiler Control Room located in the Building 3 basement of the BMS facility at 3551 Burnet Avenue in East Syracuse, New York (**Figure 1**).

2 Background

Dissolved-phase volatile organic compounds (VOC) have been reported in shallow groundwater in the vicinity of Building 3 (**Figure 2**), requiring soil vapor intrusion (SVI) investigation activities to be conducted in the Building 3 basement (i.e., the Boiler Control Room). The Boiler Control Room is typically occupied by two persons in shifts of 8 to 12 hours per day, seven days a week. The results of SVI activities in the Boiler Control Room were reported in a Building 3 Vapor Intrusion (VI) Assessment Report (Arcadis, 2019). Indoor air samples in the Boiler Control Room and ambient air samples outside of Building 3 were collected for laboratory analysis of VOC in accordance with United States Environmental Protection Agency (USEPA) Method TO-15 in March 2016, December 2016, January 2018, January 2019, and January 2021. An elevated water table in proximity to the Building 3 slab elevation precluded the collection of sub-slab vapor or near building soil vapor samples.

The primary constituent of concern (COC) in indoor air is trichloroethene (TCE), with concentrations ranging from 0.52 micrograms per cubic meter (µg/m^3) (January 2021 [duplicate sample]) to 1.6 µg/m^3 (December 2016) over these monitoring events. Mitigation measures to reduce TCE concentrations in indoor air have been implemented, including:

- In June 2018, the building's new heating, ventilation, and air conditioning (HVAC) system began operation with pleated air filters impregnated with activated carbon.
- In August 2018, several floor drains and cleanouts in the basement level of Building 3 were closed off using permanent one-way drain valves or removable sealed drain plugs. The condensate floor sump located outside of the eastern doorway in Building 2 was cleaned out and filled with flowable cement. The wall conduits that penetrated the Building 3 basement exterior walls were permanently sealed with hydraulic cement. A replacement flexible elbow was installed in a vertical drain to replace a broken Y-fitting to mitigate potential migration of soil vapor into Building 3.
- In Spring of 2020 the HVAC system's pleated air filters impregnated with activated carbon were replaced with filters having a minimum efficiency reporting value rating of 8 (MERV-8) to aid in the potential mitigation of airborne COVID-19 transmission within Building 3.
- In January 2021, weather stripping was installed on the Boiler Control Room doorways and the HVAC system was balanced to provide a more positive pressure environment.
- In April 2021, differential pressure monitors were installed in Building 3 to confirm the Boiler Control Room remains in a positive environment relative to ambient conditions at the connected buildings.

While a downward trend in indoor air TCE concentrations was demonstrated based on sampling conducted following mitigation measures, detected TCE concentrations remained above the New York State Department of Health (NYSDOH) guidance value for monitoring of 0.2 µg/m^3 for indoor air (NYSDOH, 2006). As a result of these data, BMS opted to install an indoor ATS in the Boiler Control Room as a supplemental mitigation measure to further reduce TCE concentrations in indoor air. The ATS, and its initial set up, sampling and reporting were described in letters submitted to the New York State Department of Environmental Conservation (NYSDEC) dated 19 March and 14 April 2021. In a 2 April 2021 letter, NYSDEC requested that a OMM Plan be submitted for the system, in addition to the summary report.

3 System Description

One Amaircare AirWash® MultiPRO (part number 2Y-A-1KPG-00) ATS was installed in the Boiler Control Room on 22 April 2021 (**Figure 3**). The ATS is equipped with a variable speed 235-Watt motor, is rated for a flow rate from 250 cubic feet per minute (cfm) to 800 cfm with a standard high-efficiency particulate air (HEPA) filter and has a 12-inch inner diameter inlet and outlet. The ATS has been fitted with an activated carbon canister (part number 94-A-1402-UL) consisting of approximately 22 pounds of media to provide for adsorption of VOC. Additional filter elements located upstream from the carbon canister include:

- A 13-inch tall by 13-inch wide by 1-inch thick media pad pre-filter (part number AFC1000726).
- A 13-inch tall by 13-inch wide by 2-inch thick pleated pre-filter (part number AFC1057554). The pleated pre-filter has a MERV rating of 8.
- A washable foam pre-filter (part number 91-A-1407-ET) that fits over the outside of the carbon canister.

The ATS with the above listed filter media installed has a reduced flow rate of 130 cfm to 300 cfm. In addition, the ATS has a small control panel that includes a knob for manual speed adjustment, a power-indicating light-emitting diode (LED), a change-filter LED, and a reset button. The change-filter LED illuminates when the pressure differential through the unit's filter elements exceeds 2 inches of water column. The ATS plugs into a conventional 120-volt electrical receptacle. Signage posted on the ATS instructs on-site personnel to notify the BMS Environment, Health and Safety (EHS) department if the unit is unplugged or if the change-filter LED is lit. A manufacturer's cut sheet and manual are included in **Appendix A**. A photograph of the installed ATS is included in **Appendix B**.

4 OMM Procedures

The following sections discuss the OMM procedures for the Boiler Control Room ATS. The results of OMM activities should be promptly reviewed so that adjustments to the system or OMM procedures may be made as needed to optimize performance.

4.1 Operation and Maintenance

The ATS is designed to operate continuously. The variable speed controller should be adjusted to the desired position for a flow rate of approximately 150 cfm (which is the second mark on the control knob in the clockwise position). This allows for 1.5 air changes per hour (ACH) based on dimensions of the Boiler Control Room. The optimum variable speed setting may be modified in the future based on system performance. BMS will maintain the ATS in a location where the air flow and/or noise from the unit avoids disruption to facility operations, the ATS will be centrally located and placed on or near the floor, away from corners of the room, and away from exit doorways.

Inspections of the ATS will be conducted weekly to confirm the following:

- The unit is plugged in and running.

- The placement of the unit meets the criteria described above.
- The power-indicating LED is on, and the change-filter LED is off.
- The variable speed control knob is set to the desired position for a flow rate of approximately 130 cfm (which is the first green mark on the control knob in the clockwise position).
- Signage is posted indicating that the system is not to be unplugged or shut off.
- The filter access panel is securely attached to the main housing.
- The filter changeout log was reviewed and scheduled changeouts performed.
- The doorway weather stripping and door closures are functioning as designed.

On a monthly basis, inspections will also include the following:

- Confirm the floor drains are clear of debris to maintain 1-way valve functionality.
- Request Building 3 differential pressure data from facility personnel.

Inspections will be documented on the checklist included in **Appendix C** or in a BMS electronic system.

Filter element replacements will be conducted on a routine basis per the attached field inspection form, or sooner if indicated by the change-filter LED. If the change-filter LED illuminates, the pre-filter elements should be replaced after turning off the ATS and pressing the reset button. If after turning the ATS back on, the change-filter LED is still on, then a carbon canister replacement should be performed. The ATS pre-filter elements are recommended for replacement at least quarterly. The optimum carbon canister replacement frequency will be dependent upon several factors (e.g., HVAC settings, potential VI/indoor air sources, facility fresh air change rate, temperature/humidity). For the first year of operation, each of the ATS filter elements (pre-filters and carbon) will be replaced on a quarterly basis (or sooner if the change-filter LED illuminates). Following the first year of operation, the carbon filter element replacement schedule will be reevaluated based on system performance and indoor air laboratory analytical results. Instructions for performing filter element replacements are included in the manufacturer’s manual included as **Appendix A**. Replacement of filter elements should be documented in the filter changeout log included in **Appendix C**.

In the event the ATS has an unscheduled shutdown, Building 3 maintenance staff will notify BMS EHS to note shut down time and estimated time for a restart. In the event of a scheduled shutdown, BMS EHS and Building 3 maintenance staff will coordinate in parallel the estimated time for shut down and start-up. In either case, BMS EHS will document shutdowns and report to NYSDEC and NYSDOH any shutdowns greater than 7 days within 24 hours (hrs) via electronic correspondence.

Waste carbon canisters generated during the operation of the ATS will be managed in accordance with the site waste classification, management, and disposal process.

4.2 Monitoring and Sampling

For the first year of operation, indoor air sampling will be conducted on a monthly basis to support assessing the future filter changeout schedule. Following the first year of operation, the indoor air sampling schedule will be reevaluated but is anticipated to change to a biennial indoor air test sample during the heating season for 4 years followed by every 4 years pending no increase in TCE levels have been identified and the ATS is meeting mitigation metrics.

Upon implementation of this Plan, each ATS sampling event will consist of collecting one indoor air, one duplicate and one ambient air sample collected using a passive sampler (e.g., Radiello 130/145 or similar). The use of an EPA-approved sorbent-diffusive passive sampler is appropriate for this location due to the continuous air movement within the room and the long duration worker occupancy. The samplers provide a longer sample collection period (>24 hrs) which in turn will provide a better dataset for assessing long term system functionality and the potential for human health exposures (USEPA, 2014). The samplers will be placed approximately three to five feet above the floor or ground surface (i.e., at approximate breathing zone height) and collected over a 7-day period. Samples will be analyzed for TCE, cis-1,2-dichloroethene (DCE) and trans-1,2 DCE. If two consecutive sampling events indicate cis-1,2 DCE and/or trans-1,2 DCE concentrations greater than the historical maximum detection of 0.30 µg/m^3 and 0.23 µg/m^3 respectively, BMS will collect a supplemental 12-hour TO-15 sample to assess the presence of vinyl chloride. Sample locations are shown on **Figure 3**. The ATS will be operating in the Boiler Control Room with entry doors kept closed to the extent feasible for the duration of the sampling period. BMS will provide 7-days notice to NYSDEC and NYSDOH in advance of indoor air sampling events.

Samples will be provided to an Environmental Laboratory Approval Program (ELAP)-certified laboratory for analysis in accordance with USEPA Method TO-17. One duplicate indoor air sample will be collected during each indoor air sampling event. As applicable, all scheduled samples will be collected in accordance with **Appendix D** and **E** addendums to the previously NYSDEC-approved FSAP (O'Brien & Gere [OBG] 2013a) and *Quality Assurance Project Plan* (QAPP; OBG 2013b) and the NYSDEC Division of Environmental Remediation *DER-10 Technical Guidance for Site Investigation and Remediation* (DER-10; NYSDEC 2010).

5 System Evaluation

The effectiveness of the system will be evaluated based on indoor air sample results. TCE concentrations in indoor air will be compared to the NYSDOH guidance values of 0.2 µg/m^3 for monitoring and 1.0 µg/m^3 for mitigation (NYSDOH, 2006).

If over time indoor air concentrations fall below the TCE guidance value for monitoring (0.2 µg/m^3), modifications to the system will be considered and may include:

- Reducing indoor air sampling frequency.
- Reducing carbon canister changeout frequency.

BMS will notify NYSDEC and NYSDOH in advance of implementing system optimization measures or modifications.

6 Reporting

For the first year, a brief letter report will be provided to NYSDEC and NYSDOH following each Boiler Control Room indoor air sampling event. The report will be submitted within 45 days of data validation and will include a summary of indoor air analytical data, completed OMM activities, and planned future OMM activities. Following the completion of the 1 year ATS assessment period, BMS will indicate in the final monthly letter report if any modifications to the system and this OMM Plan are warranted. In following years, BMS will submit an annual OMM report that include the weekly and monthly checks of the system as well and the dates of completed maintenance performed. If sampling occurs during the year, a summary of the analytical data will also be submitted in the annual report as applicable.

7 References

Arcadis. 2019. *Building 3 Vapor Intrusion (VI) Assessment Report.*

OBG. 2013a. *Field Sampling and Analysis Plan*.

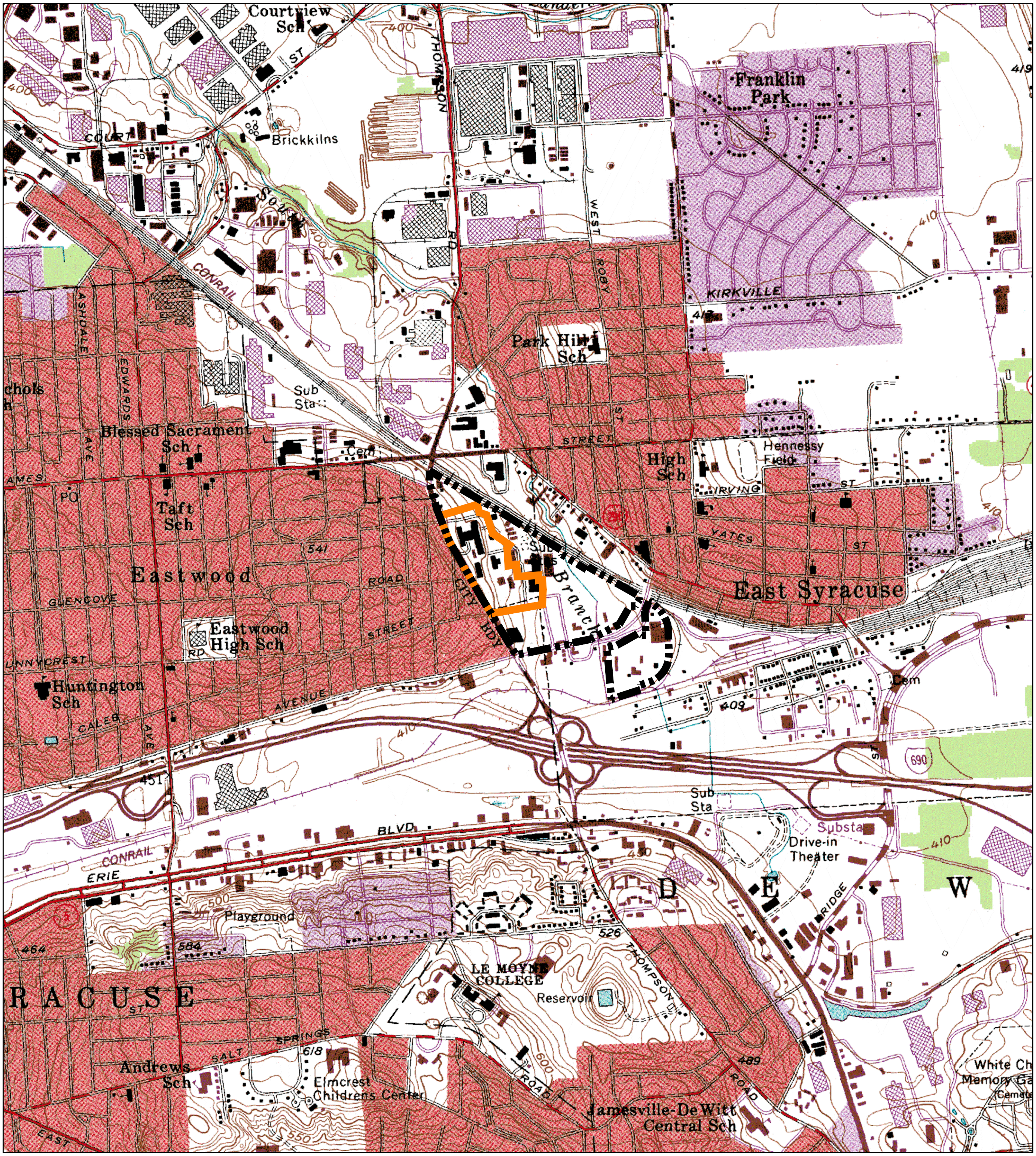
OBG. 2013b. *Quality Assurance Project Plan*.

NYSDOH. 2006. NYSDOH Guidance for Evaluating Soil Vapor Intrusion in the State of New York (With Applicable Updates).

NYSDEC. 2010. Division of Environmental Remediation *DER-10 Technical Guidance for Site Investigation and Remediation*. May. Available at: DER-10 Technical Guidance for Site Investigation and Remediation (ny.gov).

USEPA. 2014. Passive Samplers for Investigations of Air Quality: Method Description, Implementation, and Comparison to Alternative Sampling Methods. December. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100MK4Z.PDF?Dockey=P100MK4Z.PDF.

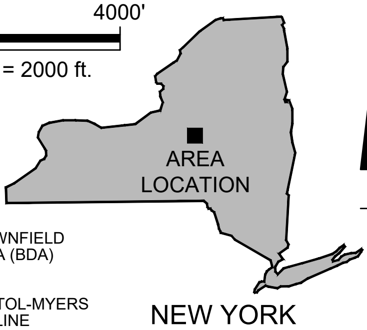
Figures



REFERENCE: BASE MAP USGS 7.5. MIN. TOPO. QUAD., SYRACUSE EAST, NEW YORK, 1957, PHOTOREVISED 1978.

0 2000' 4000'

Approximate Scale: 1 in. = 2000 ft.



LEGEND:

🟧	APPROXIMATE BROWNFIELD DEVELOPMENT AREA (BDA) BOUNDARY
▬ ▪ ▬	APPROXIMATE BRISTOL-MYERS SQUIBB PROPERTY LINE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
BUILDING 3 INDOOR AIR TREATMENT SYSTEM
OPERATION, MAINTENANCE, AND MONITORING PLAN

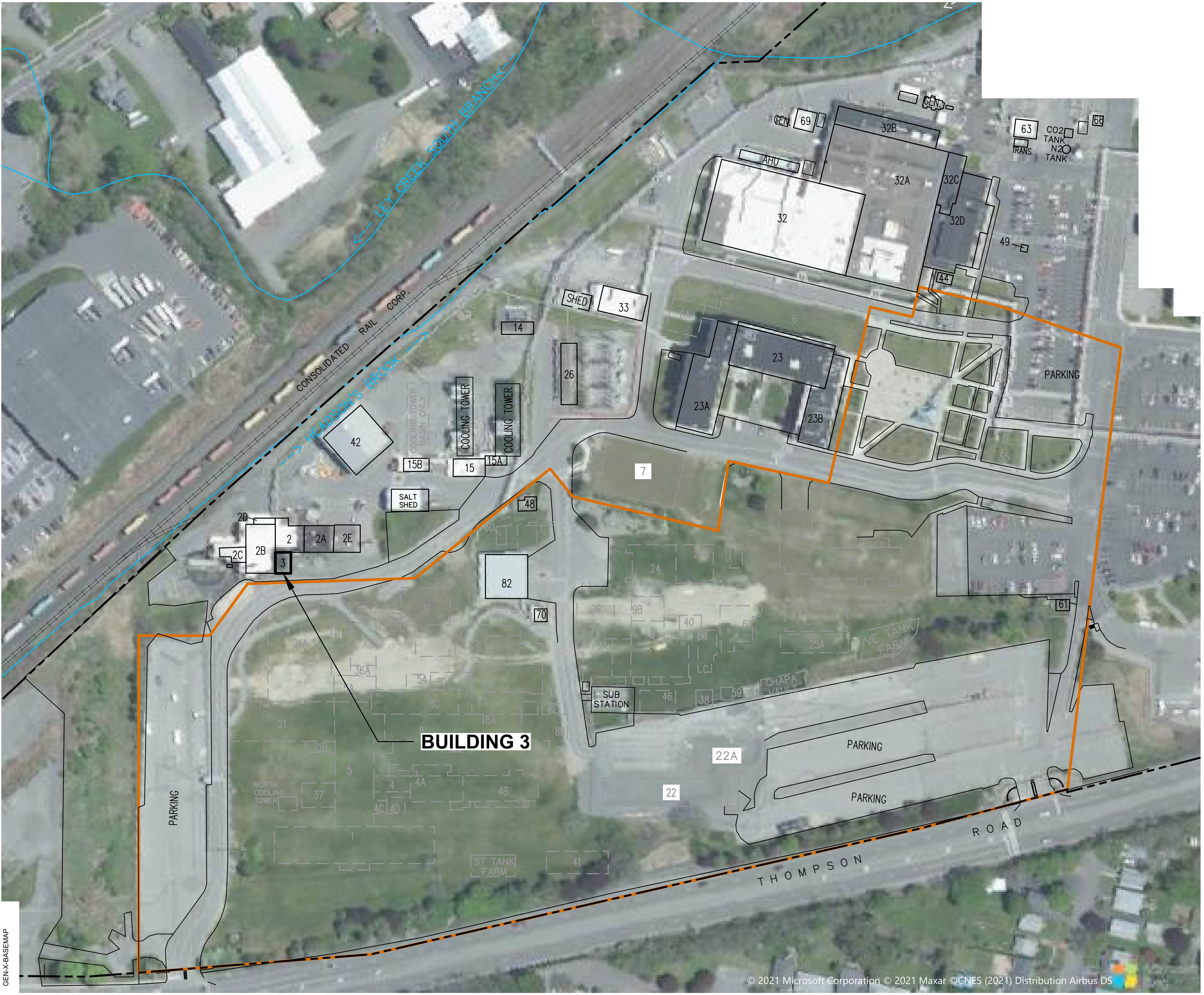
SITE LOCATION MAP

ARCADIS

FIGURE
1

C:\Users\posenauer\BIM 360\Arcadis\ANA - BRISTOL-MYERS COMPANY\Project Files\BDA Hydraulic Testing Program\2021\01-DWG\B3OMM_F01_SLM.dwg LAYOUT: 1 SAVED: 5/13/2021 5:03 PM ACADVER: 24.0S (LMS TECH) PAGESETUP: C-PA-PDF PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 5/13/2021 5:48 PM BY: POSENAUER, LISA

IMAGES: NY_Syracuse East.tif



LEGEND:

🟧	APPROXIMATE BROWNFIELD DEVELOPMENT AREA (BDA) BOUNDARY
— — —	APPROXIMATE BRISTOL-MYERS SQUIBB PROPERTY LINE
⬚ ⬚ ⬚	DEMOLISHED BUILDINGS
++++++++	EXISTING RAILROAD

NOTES:

1. BASEMAP SOURCE: MAP TITLED "BRISTOL-MYERS SQUIBB PART OF LOT 41 - TOWN OF DEWITT AND PART OF THE VILLAGE OF EAST SYRACUSE ONONDAGA COUNTY NEW YORK", DATED MARCH 25, 2010 PREPARED BY COTTRELL LAND SURVEYORS, P.C.. UPDATED BASED ON SUBSEQUENT AERIAL IMAGERY AND SITE VISITS AND SURVEY WITHIN THE BDA BY CT MALE ASSOCIATES, SYRACUSE, NY.
2. ABBREVIATIONS:
BMS = BRISTOL-MYERS SQUIBB COMPANY

0 160' 320'
GRAPHIC SCALE

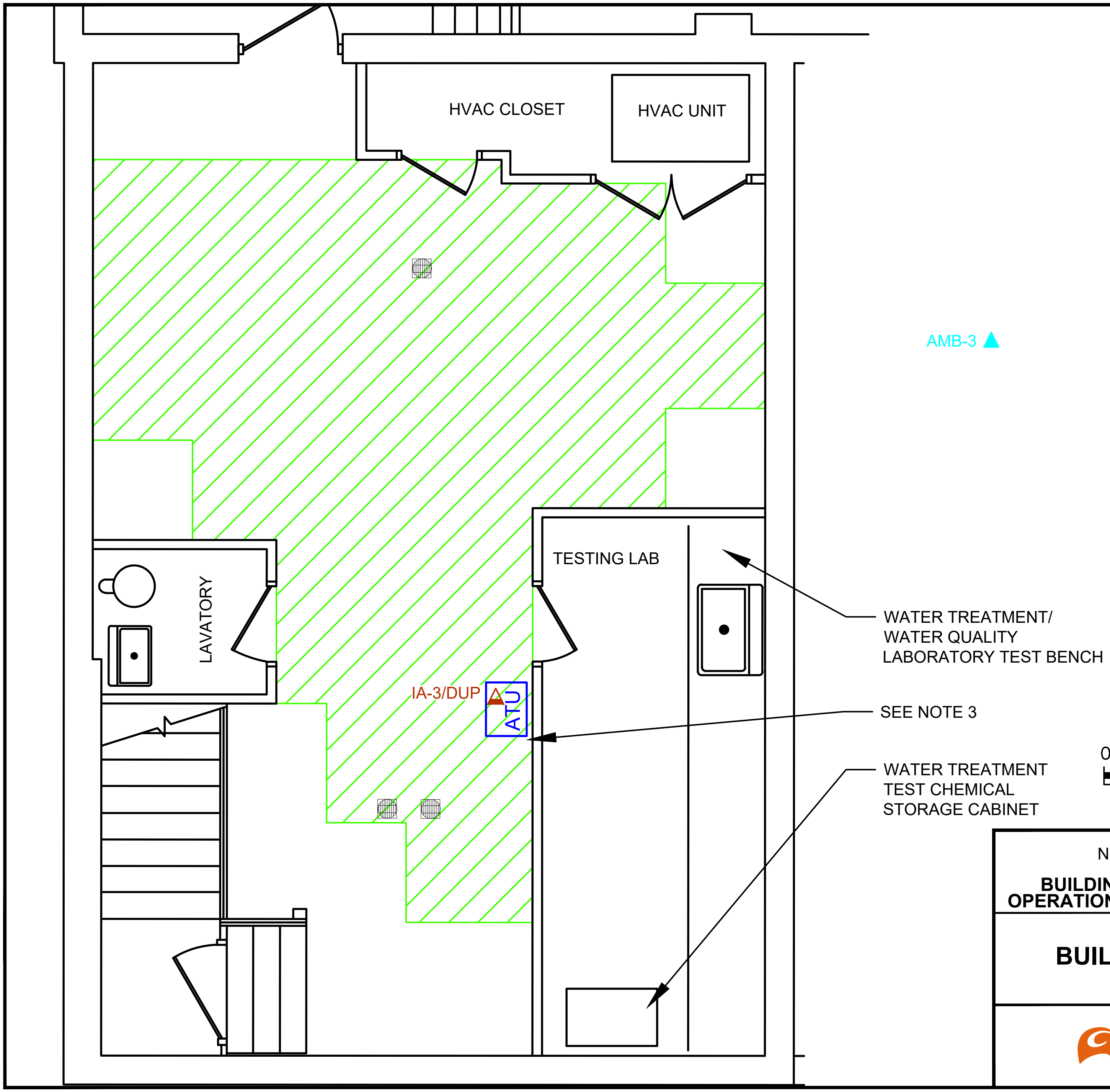
SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
BUILDING 3 INDOOR AIR TREATMENT SYSTEM
OPERATION, MAINTENANCE, AND MONITORING PLAN

SITE LAYOUT

ARCADIS

FIGURE
2

PLOTTED: 5/13/2021 5:50 PM BY: POSENAUER, LISA
XREFS:
GEN-X-BASEMAP



LEGEND:

▲	AMBIENT AIR SAMPLE LOCATION (SEE NOTE 2)
△	INDOOR AIR SAMPLING LOCATION
▦	FLOOR DRAIN
▭	EXISTING BUILDING
▨	ACCEPTABLE ATU PLACEMENT AREA (SEE NOTE 3)
ATU	AIR TREATMENT UNIT (SEE NOTE 3)

NOTES:

1. BUILDING 3 FLOOR PLAN PROVIDED BY BRISTOL-MYERS SQUIBB.
2. ACTUAL AMBIENT AIR SAMPLING LOCATION SHOULD BE LOCATED IN UPWIND ZONE.
3. INDOOR AIR TREATMENT UNIT (ATU) SHOULD NOT BE PLACED INSIDE ROOM CORNERS OR NEAR EXTERIOR DOORWAYS.

0 5' 10'
GRAPHIC SCALE

SITE #C734138: BMS SYRACUSE
NORTH CAMPUS RESTORATION AREA
EAST SYRACUSE, NY
BUILDING 3 INDOOR AIR TREATMENT SYSTEM
OPERATION, MAINTENANCE, AND MONITORING PLAN

BUILDING 3 BASEMENT LAYOUT

ARCADIS

FIGURE
3

Appendix A

Manufacturer’s Cut Sheet and Manual

airwash® MULTIPRO Air Scrubber

Interlocking cabinet profile
Provides stability when stacking during transport or when daisy-chaining multiple units

Contoured flex handle
Ample clearance for comfort and mobility, flexes downward for secure stacking

Air flow indicator
Indicates reduced airflow, alerting user filter change may be necessary

Durable housing
Rugged UL 94 compliant flame retardant polyethylene housing for tough environments

12" inlets/outlets
*Accomodates up to **800** cfm*

Quick release latches
Toolless filter changes and access for cleaning

Variable speed control
*Customize the airflow levels you need from **250** to **800** cfm*

User-friendly control panel
GFI protected receptacle outlets, allowing daisy chaining up to three units

Application Options

Perfect Seal® HEPA

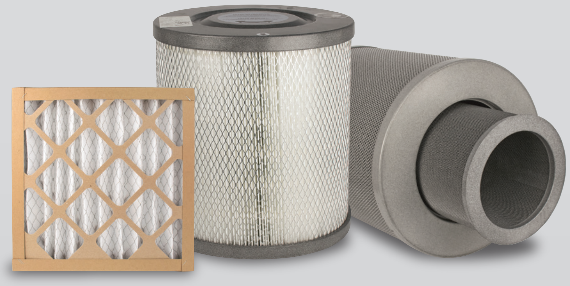
Toolless cylindrical Perfect Seal® HEPA filter media for dedicated fine particulate filtration down to 0.3 microns, option to add up to 3 pre-filters for extended service life

Perfect Seal® HEPA/VOC Combo

Toolless cylindrical Perfect Seal® HEPA & 5 lb. inner canister of dedicated activated carbon for air borne chemical and odour absorption, option to add up to 3 pre-filters for extended service life

Ultra VOC

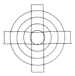
25 lb. activated carbon canister for extreme air borne chemical and odour absorption, option to add up to 3 pre-filters for extended service life



1-800-268-7732
www.amaircare.com

airwash® MULTIPRO Air Scrubber

Ordering Information

	2Y-A-1KPG-00	AirWash® MULTIPRO Negative Air Scrubber, includes installed Perfect Seal® HEPA cylinder and silicone O-ring
	AFC1000726	Media pad pre-filter, 13” x 13” x 1”
	AFC1057554	Pleated pre-filter, MERV 8, 13” x 13” x 2”
	91-A-1407-ET	Washable foam pre-filter, compatible with HEPA and exterior carbon cylinder
	90-A-14ME-ET	Toolless Perfect Seal® HEPA cylinder
	94-A-1402-UL	Ultra VOC Carbon cylinder, exterior 25 lb (gross weight) activated carbon canister
	89-A-00F-00D8-RS	Replacement silicone O-ring for HEPA and exterior carbon cylinder
	94-A-1402-ET	VOC Carbon cylinder, interior 5 lb. (gross weight) activated carbon canister
	92-A-1401-ET	VOC Carbon blanket, interior
	89-A-P0S-16-NA	Replacement wire pre-filter holder

AirWash® *MULTIPRO* Specifications

Weight:	36 lbs (without filters); 42 lbs (with HEPA filter)
Dimensions:	19” W x 20” H x 32” L 9 (482.6 W x 508 H x 812.8 L)
Airflow:	250 to 800 CFM
Variable Speed Control:	3050 RPM max
Power Supply:	115 vac/1 ph./60 Hz.
Operating current:	2.6 amps
Daisy Chain:	Up to three units on a 9 amp circuit
Stackable:	Up to three units
Inlet/Outlet Connection:	12” dia. collar
Country of Manufacture:	Canada
Warranty:	1 year (excluding filters)
Standards:	CAN/CSA C22.2 No. 113-15 (10th Ed.), UL 507 (9th Ed.)

Dealer Information:

Save time and money!

Toolless access for speedy on site filter changes and change part maintenance

Perfect Seal 360° cylindrical HEPA filter provides up to 25% more surface area than competitor filters, resulting in longer filter life and fewer filter changes

Perfect Seal 360° delivers balanced particulate loading until filter reaches full capacity

Multi functionality for diverse applications – particulate, VOC or combination

Custom colour housings available. Minimum order quantity required. Contact us for details.

1-800-268-7732
www.amaircare.com

airwash®

PRO

PRODUCT MANUAL FOR Airwash®PRO
HEPA AIR FILTRATION SYSTEM

Table of Contents

Rules for Safe Operation

READ AND SAVE
THESE INSTRUCTIONS!

Please read instructions before using the HEPA Air Filtration System (HEPA system).

1. For safety and optimized performance of the HEPA system, this equipment should be operated by trained personnel only.
2. Read this manual carefully. Failure to follow these rules and instructions could cause a malfunction of the air filter or unsatisfactory service and could void the warranty.
3. Follow a regular service and maintenance schedule to ensure efficient operation.

Shipping and Packing List

Package 1 of 1 contains:

1 - HEPA System
1 - HEPA Cartridge
1 - Installation Instructions (this manual)
1 - Registration Card

⚠ WARNING

High Speed Rotating Parts Hazard.

Can cause injury on upon contact.

Disconnect all electrical power supplies and wait for rotating parts to completely stop before servicing.

Do not operate equipment without all access panels and components in place.

⚠ WARNING

Electrical Shock Hazard.

Can cause injury or death.

Disconnect all electrical power supplies before servicing.

Do not operate equipment without access panels and fan guard in place.

⚠ WARNING

Risk of Dust Explosion.

Disconnect all electrical power supplies and wait for rotating parts to still before servicing.

Do not operate equipment without access panels in place.

⚠ WARNING

Risk of Airborne Contaminants Exposure.

Can cause respiratory problems.

Can cause illness.

Do not operate equipment without access panel in place.

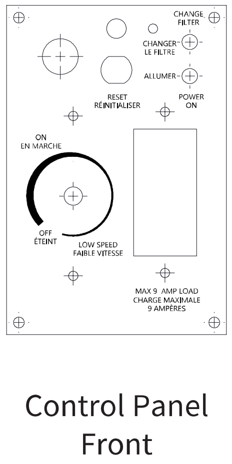
Wear appropriate protective clothing and mask when servicing filters.

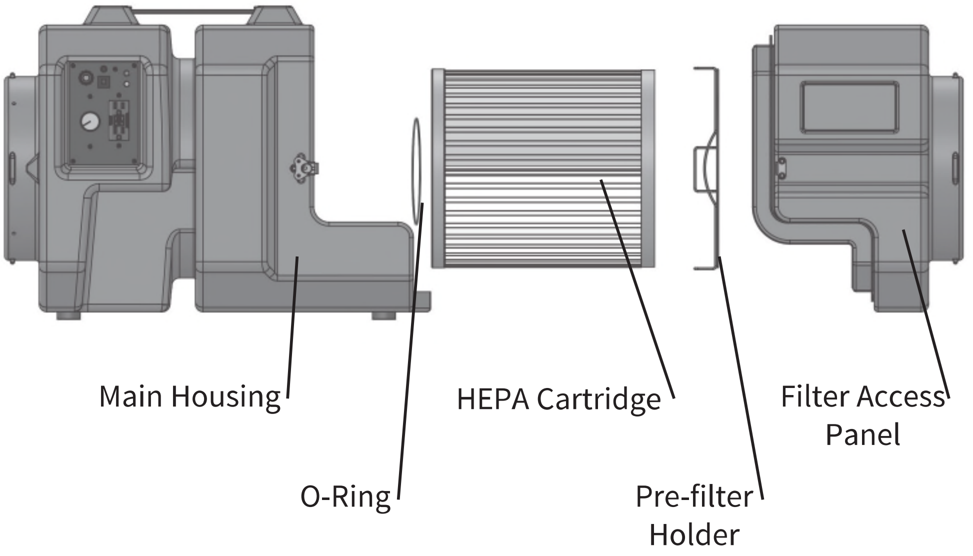
⚠ WARNING

During operation, do NOT stack units more than 2 high.

Parts Identification Diagram - Airwash®PRO Portable Filtration System

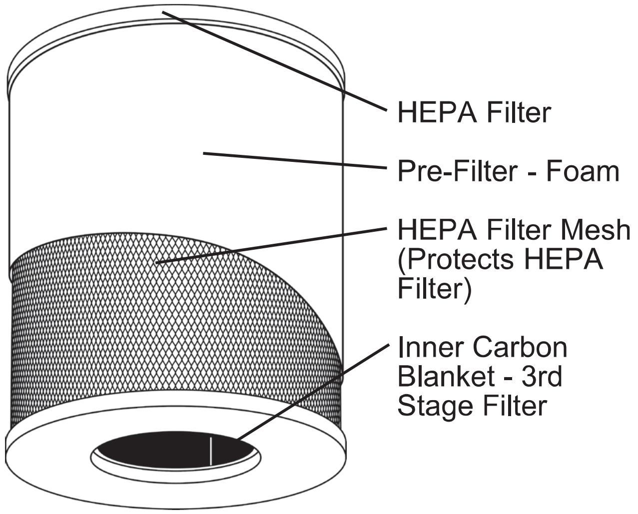
Cabinet Parts



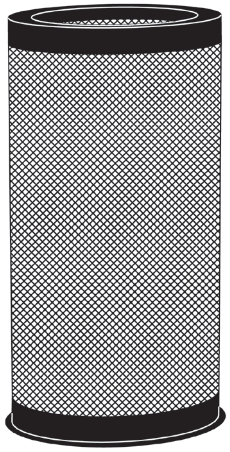


Filter Parts Identification

HEPA Cartridge Parts



Optional Carbon Canister



For third stage increased removal of chemicals and odors.

Located inside the HEPA filter.

Discard inner carbon filter when using the optional carbon canister.

Operating Instructions

⚠ WARNING

Electrical Shock Hazard.

Can cause injury or death.

Disconnect all electrical power supplies before servicing.

Do not operate equipment without access panels in place.

⚠ WARNING

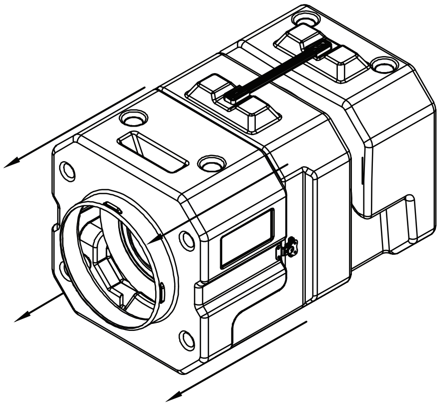
Risk of Airborne Contaminants Exposure.

Can cause respiratory problems.

Can cause illness.

Do not operate equipment without access panel in place.

Wear appropriate protective clothing and mask when servicing filters.



1. Pre-Start:

a. Unplug the unit.

b. Access the cabinet interior by releasing the 2 side mounted clamps and removing the filter access panel.

c. Confirm the interior of the unit is clean and free of contaminants.

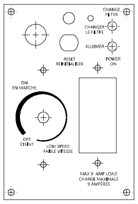
d. The selected HEPA cartridge should be secured to the bulkhead and sealed with a bottom O-Ring.

e. Confirm the selected pre-filter is clean and fitted with the pre-filter holder firmly inside of the filter access panel.

f. Fit the filter access panel to the main housing and secure the 2 side clamps.

2. Operation:

a. Plug the unit power cord into a suitable supply receptacle. The amber “Power On” LED should illuminate to indicate power to the unit controls.



b. Rotate the speed control fully clockwise to the lowest operating speed. Air is drawn into the unit, first through any pre-filters and then through the HEPA cartridge. The clean air is exhausted through the fan guard at the main housing outlet.

c. Rotate the control knob counter clockwise to increase the amount of airflow. A red ”Change Filter” LED will illuminate to indicate reduced airflow through the unit. The unit will continue to operate with reduced CFM until the cause of the restriction has been remedied.

d. To stop the operation, rotate the control knob, fully counter clock-wise.

e. Check operating speed, individual filter loading and inlet port for blockage.

3. Filter Inspection or Replacement:

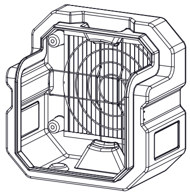
a. Unplug the unit from the electrical supply.

b. Release the 2 side clamps and remove the filter access panel.

c. Use caution and established procedures to avoid unnecessary release of contaminants from the housing, pre-filters and HEPA filter cartridge during inspection or filter replacement.

d. Dispose of used filters carefully using appropriate procedures.

e. Foam sleeve and blanket type pre-filters can be rolled inside out as they are removed from service.

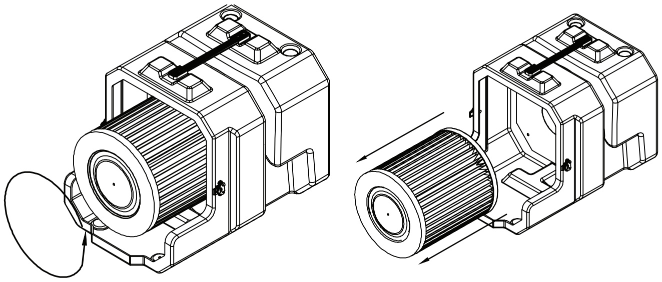


4. Pre-Filter Replacement:

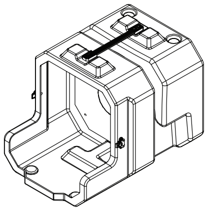
a. Access the pre-filter holder from the interior of the filter access panel. Note the operating position and orientation of the assembled pre-filter. (See Figure #1)
b. To remove, first rotate the pre-filter holder counter-clockwise to release the compression fit.
c. Lift the holder carefully from the filter access panel.
d. Removed pre-filter packs should be bagged and disposed with suitable procedures.
e. Clean the empty filter access panel and holder before fitting the selected replacement pre-filter pack into position.
f. Orient the pre-filter holder with the open slot at the top and the single vertical wire face towards the inlet.
g. Position the holder down onto the pre-filter and push down as the cage is rotated clockwise to engage the compression fit within the filter access panel.
h. Confirm the pre-filter packs are oriented correctly in the assembly, cover the 12 inch diameter inlet opening and are firmly in position.

5. HEPA Cartridge:

a. Inspect the HEPA cartridge with the filter access panel removed.



b. With the main housing secure, place hands flat against the smooth metal end cap of the HEPA cartridge to grip and rotate the cartridge counter clockwise to release it from the bulkhead.
c. The Loaded HEPA cartridge and O-ring should be bagged and disposed with suitable procedures.



d. Clean the empty housing before fitting the replacement O-ring and HEPA cartridge.
e. Press firmly to compress the O-ring as the HEPA cartridge is rotated clockwise to lock it on the bulkhead.

6. VOC Blanket (optional):

a. With the HEPA cartridge removed from the bulkhead, look inside the HEPA cartridge to locate the two ends of the VOC blanket.
b. Pull one end of the old inner carbon filter in and bend it into a loose roll so it can be removed.
c. Remove the inner carbon filter from the HEPA cartridge.
d. Remove plastic shrink wrap from the new inner carbon filter.
e. Unroll the inner carbon filter and roll it up in the opposite direction (this makes the filter follow a more contoured profile against the inner HEPA filter surfaces and helps keep it in place), place the rolled inner carbon filter inside the HEPA cartridge and gently unroll it until the ends ‘butt’ together and the filter is snug against the HEPA filter.

7. VOC Canister (optional):

a. Remove old carbon canister (if installed) by pulling it out from the inside of the HEPA filter.
b. If replacing an inner carbon filter with the carbon canister, remove inner carbon filter by following the steps a. to c. in section 6 (above).
c. Remove the plastic shrink wrap from the new carbon canister.
d. Slide the carbon canister into the HEPA cartridge, smaller end first. The carbon canister should slide all the way in until the metal edges at the base meet the HEPA filter.
e. Support the carbon canister with your fingers so it does not slide out when replacing the HEPA cartridge assembly into the unit.

Troubleshooting

Circuit Breaker:

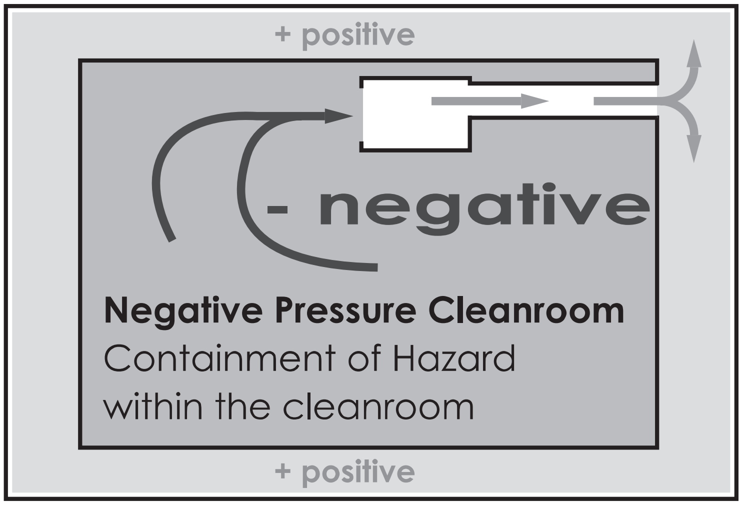
Onboard overload protection is set to trip at 12 amps. If tripped, all power will be lost to the unit and accessories connected to the duplex receptacle on the affected unit. Turn the unit control knob to the off position and unplug all accessory loads. Push the button on the circuit breaker to reset and the amber indicating light should illuminate to confirm power has been restored.

GFCI Trip Indicator:

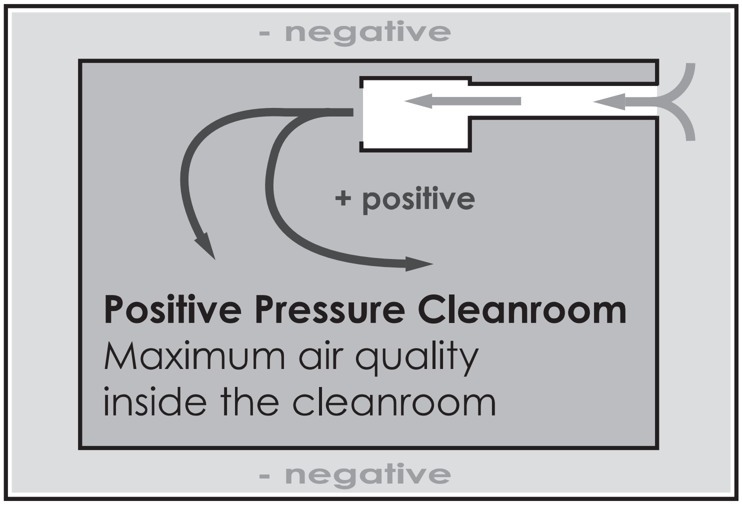
Press the TEST button every month to assure proper operation. A duplex receptacle located with the unit controls can be used to power additional equipment. The receptacle has ground fault circuit protection with light indication, test and reset buttons. To test operation, ensure the main assembly is plugged in to a live circuit and the power on LED is illuminated. Plug a test lamp into the GFCI receptacle and this light should remain on. Push the "TEST" button located on the GFCI receptacle to trip the device. The test lamp should remain off until you firmly push the RESET button located beside the "TEST" button. Power will be restored to the duplex receptacle.

Product Application Guidelines

To Create a Negative Pressure Environment



To Create a Positive Pressure Environment



Electrical Diagram - Control Detail

⚠ WARNING

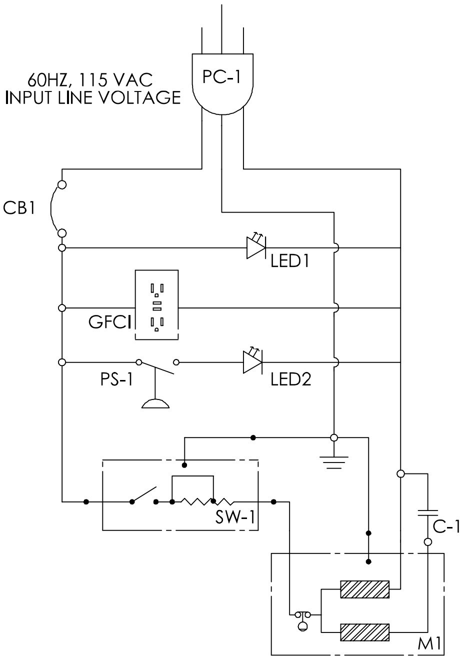
Electrical Shock Hazard.

Can cause injury or death.

Disconnect all electrical power supplies before servicing.

Do no operate equipment without access panels in place.

Do not use this fan with any solid-state speed control device.



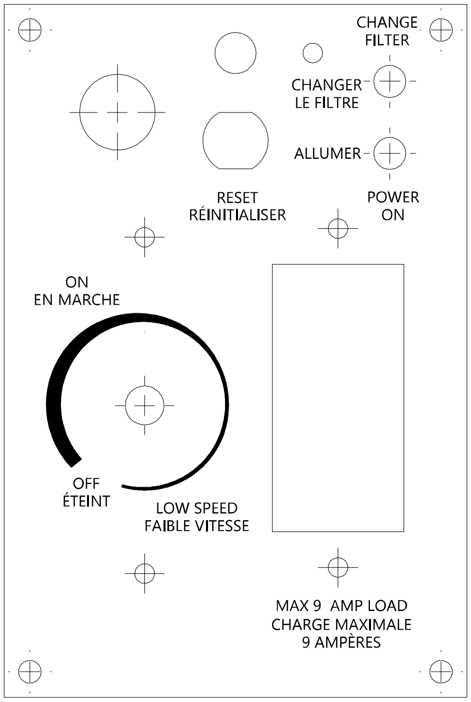


Figure 1.

ITEM NO.	PART NAME	DESCRIPTION	QTY
PC-1	Power cord		1
CB1	Circuit Breaker	12 Amps	1
GFCI	Duplex Receptacle	Ground Fault CI	1
PS-1	Pressure Switch		1
LED1	Amber LED	Power ON	1
LED2	Red LED	Change Filter	1
SW-1	Control Switch	Variable Speed Knob	1
C-1	Capacitor	25 µF	1
M1	Motor	250 Wheel/115V	1

Specifications - Airwash®PRO Portable Filtration System

Power Supply:	120 vac/1 ph. /60 Hz.
Operating Current:	2.6 amps. independent/11.6 amps with loaded receptacle
Variable Speed Control:	3050 RPM max.
Airflow:	690 cfm (1170 cu. m./hr.) nominal on high speed
HEPA Cartridge Efficiency:	99.97% minimum at 0.3 micron particle and above
Dimenstions:	19” W x 20” H x 32” L (482.6mm W x 508 mm H x 812.8 mm L)
Inlet/Outlet Connection:	12” dia. collar
Weight:	42 lb. (19 kg.)
STANDARDS:	This equipment meets the technical requirements of CSA C22.2 No. 113-15

Available Maintenance Parts

Item Number	Item Name	Item Description
90-H-14ME-ET	HEPA Cartridge	14” Easy Twist Filter with O-Ring Seal
91-H-1406-ET	1 “ Pleated Pre-filter	13” x 13” x 1” (1026454)

Optional Accessories

Item Number	Item Name	Item Description
92-H-1401-ET	VOC Blanket	14” Inner Carbon Blanket - Stage 3 filter
94-H-1402-ET	VOC Canister	14” ET Granulated Carbon Canister - Stage 3 filter
94-H-1402-UL	VOC Ultra Canister	25 lb. Granulated Carbon Canister

Appendix B

System Photographs

Photograph Log

Operation, Maintenance, and Monitoring Plan – Building 3 Indoor Air Treatment System
Bristol-Myers Squibb
Syracuse North Campus Restoration Area (Site #C734138)
East Syracuse, New York

Air Treatment System

Photograph Log

Operation, Maintenance, and Monitoring Plan – Building 3 Indoor Air Treatment System
Bristol-Myers Squibb
Syracuse North Campus Restoration Area (Site #C734138)
East Syracuse, New York

ATS Controller

Photograph Log

Operation, Maintenance, and Monitoring Plan – Building 3 Indoor Air Treatment System
Bristol-Myers Squibb
Syracuse North Campus Restoration Area (Site #C734138)
East Syracuse, New York

Pad Pre-Filter

Pleated Pre-Filter

Effluent Port

Appendix C

System Checklists

Weekly Inspection Checklist
Building 3 Indoor Air Treatment System
Bristol-Myers Squibb
East Syracuse, New York

Date: ______________________

Time: ______________________

Inspector(s): ______________________

Item No.	Item	YES	NO	Notes
1	Is the ATU plugged in and running?			
2	Is the ATU in an acceptable location? **ATU should be in main area of Boiler Control Room, and at least 3 feet from room corners and exit doorways.*			
3	Is the power-indicating light ON?			
4	Is the filter change light OFF?			
5	Is signage posted on the ATU?			
6	Is the filter access panel securely attached to the main housing?			
7	Was filter changeout log reviewed and any scheduled changeouts performed?			
8	Is flow rate knob at desired setting? **LOW setting = Knob set at first green tick mark in from clockwise position*			
9	Confirm the doorway weather stripping and door closures are functioning as designed.			

Monthly Check the following:

1	Confirm floor drains are clear of debris (remove if noted) to maintain 1-way valves functionality.			
2	Request Building 3 differential pressure data logs and attach to the corresponding weekly inspection form.			

Notes:

- Notify BMS EHS personnel if the response is NO for any of the checklist items.

Abbreviations:

ATU = air treatment unit

BMS = Bristol-Myers Squibb

EHS = environmental, health and safety

Filter Changeout Log
Building 3 Indoor Air Treatment System
Bristol-Myers Squibb
East Syracuse, New York

Carbon Canister		Foam Pre-Filter		Pad Pre-Filter (13"x13"x1")		Pleated Pre-Filter (13"x13"x2")	
Recommended Changeout Frequency							
Every Month		Every Month		Every 3 Months		Every 3 Months	
Date Performed	Initials	Date Performed	Initials	Date Performed	Initials	Date Performed	Initials

Notes:

- The indoor air treatment unit make/model is: Amaircare AirWash MultiPRO (2Y-A-1KPG-00).

AFC1057554 (pleated pre-filter), 91-A-1407-ET (foam pre-filter), and 94-A-1402-UL (carbon canister).

- If the "change filter" LED is on, the pre-filter elements should be replaced. If the "change-filter" LED remains on after the "reset" button is pressed, a carbon canister changeout may be necessary.

Abbreviations:

LED = light-emitting diode

" = inches

Appendix D

TO-17 QAPP Addendum #3

QUALITY ASSURANCE PROJECT PLAN (QAPP) ADDENDUM #3

Select sections of the project Quality Assurance Project Plan (QAPP) (O'Brien and Gere Engineers, 2013) are updated herein to include Indoor Air and Ambient Air samples which were not previously included in the QAPP or previous QAPP addendums. Specifically, this addendum includes the addition of EPA Method TO-17-Modified.

QAPP Tables

See attached for applicable updates.

Table 1 – Field Sampling Summary: VOC Parameters

Table 2-8 – Laboratory Detection Limits and Regulatory Criteria for VOC Parameters

Table 3-16 – VOC Quality Control Requirements and Corrective Actions

References

O'Brien and Gere Engineers. 2013b. Quality Assurance Project Plan: BMS Syracuse North Campus Restoration Area Site No. C734138. March.

QAPP Tables

Table 1 – Field Sampling Summary: VOC Parameters

Parameter and Method	Matrix	Sample Container and Volume	Preservation	Holding Times	Number of Samples	QC Frequency			
						Field Duplicate	Trip Blank	MS/MSD and Spike Duplicate	Field Blank
VOCs by EPA Method TO-17 Modified	IA/AA	Radiello passive diffusion sampling device (or equivalent)	≤6°C	30 Days	As needed	One per 20 samples or one per matrix (for <20 samples)	NA	NA	NA

Acronyms:
IA = Indoor Air
AA = Ambient Air
VOC = Volatile Organic Compounds
NA = not applicable

Table 2-8 – Laboratory Detection Limits and Regulatory Criteria for VOC Parameters

Target Analyte[3]	CAS Number	Method	Laboratory MDL (ug/m3)	Laboratory QL[1] (ug/m3)	Indoor Air Screening Value[2] (ug/m3)
Radiello 145					
1,1,1-Trichloroethane	71-55-6	USEPA TO-17 Modified	0.006	0.0496	3
1,1,2-Trichloroethane*	79-00-5	USEPA TO-17 Modified	0.0057	0.0174	0.4
1,1-Dichloroethane*	75-34-3	USEPA TO-17 Modified	0.0029	0.0183	0.4
1,1-Dichloroethene*	75-35-4	USEPA TO-17 Modified	0.004	0.0151	0.2
1,2-Dichloroethane*	107-06-2	USEPA TO-17 Modified	0.0019	0.0131	0.4
Benzene	71-43-2	USEPA TO-17 Modified	0.0553	0.0714	9.4
Chloroform*	67-66-3	USEPA TO-17 Modified	0.0044	0.0131	1.1
cis-1,2-Dichloroethene*	156-59-2	USEPA TO-17 Modified	0.0016	0.0184	0.2
Cyclohexane	110-82-7	USEPA TO-17 Modified	0.0012	0.0359	6.3
EthylBenzene	100-41-4	USEPA TO-17 Modified	0.0034	0.0386	5.7
m,p-Xylene	108-38-3	USEPA TO-17 Modified	0.0056	0.0746	11
o-Xylene	95-47-6	USEPA TO-17 Modified	0.0031	0.0403	7.1
Styrene	100-42-5	USEPA TO-17 Modified	0.0085	0.0366	1.4
Tetrachloroethene	127-18-4	USEPA TO-17 Modified	0.007	0.0195	3
Toluene	108-88-3	USEPA TO-17 Modified	0.0254	0.1653	43
trans-1,2-Dichloroethene*	156-60-5	USEPA TO-17 Modified	0.0032	0.0192	--
Trichloroethene	79-01-6	USEPA TO-17 Modified	0.0089	0.0183	0.2
Freon 113*	76-13-1	USEPA TO-17 Modified	0.0055	0.0174	2.5
Radiello 130					
Vinyl Chloride	75-01-4	USEPA TO-17 Modified	1.4	9.3	0.2

Acronyms:
MDL = method detection limit
QL = quantitation limit

Notes:

[1] Laboratory QL and MDL provided by Eurofins Air Toxics LLC and are current as of the date of this QAPP Addendum. The laboratory will report their most recent QL and MDL at the time of analysis. QLs and MDLs are based on a 7 day sampling duration for samples collected using Radiello 145 sampling devices and on an 8 hour sampling duration for samples collected using Radiello 130 sampling devices. MDL values vary from instrument to instrument, listed values are examples only

[2] Indoor Air Screening Values are based on Commercial and Residential (October 2006 NYSDOH, Guidance for Evaluating Soil Vapor Intrusion in the State of New York) and the listed value is the lowest of the two.

[3] Compounds with an asterisk will be qualified as estimated on the final report as the method may demonstrate a low bias for these constituents.

QAPP Table 3-16 – VOC Quality Control Requirements and Corrective Actions

Matrix	**Air**		
Analytical Group	**VOCs**		
Analytical Method	**EPA Method TO-17 Modified**		
Audit	**Frequency**	**Control Limits**	**Corrective Action**
Holding Times	Samples must be analyzed within holding time.	See Table 1.	If holding times are exceeded for initial or any re-analyses required due to QC excursions, notify the QAO since resampling may be required.
Method Blank	After the CCV, before samples and at the end of the sequence	Results less than the laboratory RL.	Inspect the system and re-analyze the Blank. Flag associated data as appropriate.
LCS/ICV	After each initial Calibration Curve and daily prior to analysis.	Recovery 70-130%, 20% of compound list may exceed criterion before corrective action is required. Also, if any VOC exceeds 50%, corrective action is required. For compounds with recoveries greater than 150% and positive detections in the samples, approval to proceed will be granted on a case-by-case basis by QA or management	Verify accuracy of standard. Re-prepare LCS if necessary. If calibration curve and/or system is found to be out of control, perform maintenance and re-calibrate.
LCSD	Each analytical batch – reanalysis of LCS	See LCS recovery acceptance criterion; %RPD < 20%	Evaluate whether the precision outlier is due to recollection failure or the TDU. If so correct system and restart analytical system with BFB

Matrix	**Air**		
Analytical Group	**VOCs**		
Analytical Method	**EPA Method TO-17 Modified**		
Audit	**Frequency**	**Control Limits**	**Corrective Action**
Internal Standard (IS)	As each QC sample and sample are being loaded	**CCVs:** area counts >60% recovery, RT w/in 20 sec of mid-point in ICAL **Blanks and samples**: Retention time (RT) must be within ±0.33 minutes of the RT in the CCV. The IS area must be within ±40% of the CCV's IS area for the Blanks and samples.	**CCV:** Inspect and correct system prior to sample analysis. **Blanks:** Inspect the system and re-analyze the Blank. **Samples:** Analyze re-collected samples to confirm internal standard recoveries. If recovery is out of acceptance criteria in the initial and recollected sample, the initial sample is reported and associated data is qualified if appropriate. If sample matrix is causing a systematic change in internal standard response with each successive run, an End Check spiked at the CCV concentration can help to assess the impact on target compound accuracy.
Analytical Surrogate	Each passive sampler and Lab Blank and QC samples during sample desorption	70-130%	**For blanks:** inspect the system and re-analyze the Blank. **For samples:** If no obvious reason can be ascertained after evaluation of the data, the sample should be reanalyzed to verify out of control recovery. If recovery is out of acceptance criteria in both the initial and recollected sample, the initial sample is reported with the surrogate flagged.
Field Duplicate Analysis	Blank and QC samples during sample desorption	50% RPD for Air; for results that are less than or equal to 5-times the QL, the criterion of plus or minus two-times the QL will be applied to evaluate field duplicates	No corrective action required of the laboratory since the laboratory will not know the identify of field duplicate samples. If these criteria are not met, sample results will be evaluated on a case-by-case basis.
BFB Tune Check	Every 24 hours	TO-15/TO-17 tune criteria.	Correct problem then repeat tune check.
5-Point Calibration	Prior to sample analysis	%RSD < 30% with 2 compounds exceeding up to 40%RSD	Correct problem then repeat Initial Calibration Curve.

Matrix	**Air**		
Analytical Group	**VOCs**		
Analytical Method	**EPA Method TO-17 Modified**		
Audit	**Frequency**	**Control Limits**	**Corrective Action**
Continuing Calibration Verification (CCV)	At the start of each analytical clock	70 – 130 %	Two compounds are allowed to exceed criterion up to 40%D prior to initiation of corrective action. If more than 2 VOCs exceed the 30% D criterion or >10% of the VOCs if the short list is used (20 compounds or less), the CCV tube is re-spiked and the test repeated. If the system still fails the CCV, the system is evaluated. As necessary, a new initial calibration curve is analyzed. CCV recoveries >140% may be approved by QA or management after evaluation.

CCV = continuing calibration verification
ICAL = initial calibration
ICV = initial calibration verification
LCS = laboratory control sample

Appendix E

TO-17 FSAP Addendum #2

Field Sampling and Analysis Plan Addendum #2
Remedial Investigation
BMS Syracuse North Campus Restoration Area

10A. Indoor and Ambient Air VOC Sampling

Procedures for obtaining Rediello samples and laboratory analysis via modified USEPA Method TO-17, are described in this attachment.

how does the diffusive sampler work?

The diffusive sampler is a closed box, usually cylindrical. Of its two opposite sides, one is "transparent" to gaseous molecules which cross it, and are adsorbed onto the second side. The former side is named diffusive surface, the latter is the adsorbing surface (marked with ***S*** and ***A*** in the figure).

Driven by the concentration gradient ***dC/dl***, the gaseous molecules cross ***S*** and diffuse towards ***A*** along the path ***l***, parallel to the axis of the cylindrical box. The molecules, which can be trapped by the adsorbing material, are eventually adsorbed onto ***A*** according to the equation:

$$\frac{dm}{dt} = D\,S\,\frac{dC}{dl} \qquad [1]$$

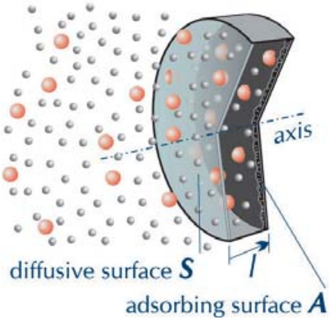
where ***dm*** is the adsorbed mass during time ***dt*** and ***D*** is the diffusion coefficient.

Let ***C*** be the concentration at the diffusive surface and C_0 the concentration at the adsorbing surface, the integral of [1] becomes

$$\frac{m}{t} = D\frac{S}{l}\,(C-C_0) \qquad [2]$$

If the concentration at the adsorbing surface is negligible, the equation can be approximated to

$$\frac{m}{t\,C} = D\frac{S}{l} = Q \quad \text{and then} \quad C = \frac{m}{t\,Q} \qquad [3]$$



In the diffusive sampler, the adsorbing and the diffusive surfaces are two opposing plane of a closed box. Driven by the concentration gradient, the gaseus molecules (coloured in the figure) pass through the diffusive surface and are trapped from the adsorbing surface.

Q is the ***sampling rate*** and has the dimensions of a gaseous flow (if ***m*** is expressed in µg, ***t*** in minutes and ***C*** in $\mu g \cdot l^{-1}$, ***Q*** is expressed in $l \cdot min^{-1}$).

Therefore, if ***Q*** is constant and measured, to calculate the ambient air concentration you need only to quantify the mass of analyte trapped by the adsorbing material and to keep note of the time of exposure of the diffusive sampler.

To improve the analytical sensitivity the collected mass ***m*** should be increased by enlarging ***Q***. As ***D*** is a constant term, one can only try to improve the ***S/l*** ratio, namely the ***geometrical constant*** of the sampler. Unfortunately, in the common axial simmetry sampler, if ***S*** is enlarged, the adsorbing surface ***A*** must be enlarged too, in order to keep the two parallel surfaces at a fixed distance. Since the analytes can be recovered from the axial sampler only by solvent extraction, any increase of ***A*** lead to a proportional increase of the extraction solvent volume, thus the improvement of ***Q*** is canceled out by the effect of dilution.

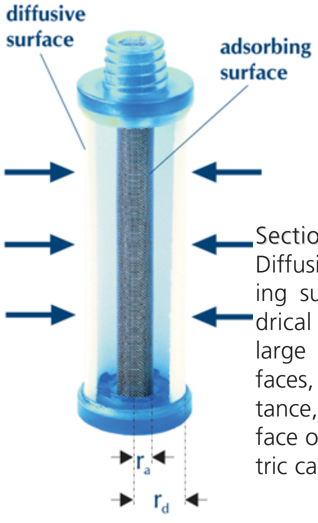
The value of distance ***l*** could also be reduced, but under the critical value of about 8 mm the diffusion law is no longer valid in the case of low air velocity values, since adsorption rate becomes higher than supplying rate of analyte molecules at the diffusive surface.

Cannot we improve ***Q*** then?

The answer is to improve the sampler geometry to a ***radial*** design.

From this idea the **radiello** sampler has been developed, its cylindrical outer surface acting as diffusive membrane: the gaseus molecules move axially parallel towards an adsorbent bed which is cylindrical too and coaxial to the diffusive surface.

When compared to the axial sampler, **radiello** shows a much higher diffusive surface without increase of the adsorbing material amount. Even if the adsorbing surface is quite smaller then the diffusive one, each point of the diffusive layer faces the diffusion barrier at the same distance.



Section of **radiello**. Diffusive and adsorbing surfaces are cylindrical and coaxial: a large diffusive surface faces, at a fixed distance, the small surface of a little concentric cartridge.

As $S=2\pi rh$ (where h is the height of the cylinder) and the diffusive path is as long as the radius r, we can then express equation [1] as follows

$$\frac{dm}{dt} = D\,2\pi\,h\,r\,\frac{dC}{dr} \qquad [4]$$

The integral of equation [4] from r_d (radius of the diffusive cylindrical surface) to r_a (radius of the adsorbing surface) becomes

$$\frac{m}{t\,C} = D\,\frac{2\pi\,h}{\ln\frac{r_d}{r_a}} = Q \qquad [5]$$

the ratio

$$\frac{2\pi\,h}{\ln\frac{r_d}{r_a}}$$

is the geometrical constant of ***radiello***. The calculated uptake rate [5] is therefore proportional to the height of the diffusive cylinder and inversely proportional to the logarithm of the ratio of diffusive ***vs*** adsorbing cylinder radii.

The microporous sintered polyethylene diffusive barrier of ***radiello*** photographed at the electrton microscope; the path length is much longer than the membrane thickness due to the tortuosity of the pores.

While r_a can be easily measured, r_d can only be calculated by exposure experiments. Actually the diffusive membrane has been designed with a thick tubular microporous layer. The actual diffusive path length is therefore much longer than the distance among the diffusive and adsorbing surfaces due to the tortuosity of the path through the pores. A diffusive cylinder of external diameter 8 mm, thickness 1.7 mm and average porosity of 25 µm, coupled to an adsorbing cartridge with radius 2.9 mm creates a diffusive path of 18 mm instead of the straight line path estimation of (8-2.9) = 5.1 mm.

The sampling rate Q is function of diffusive coefficient D, which is a thermodynamic property of each chemical substance. D varies with temperature (T) and pressure (p); therefore also the sampling rate is a function of those variables according to

$$Q = f\,(T,\,p)$$

Q values that will be quoted in the following have been measured at 25 °C and 1013 hPa. As a consequence, they should be corrected so as to reflect the actual sampling conditions.

The correction of Q for atmospheric pressure is usually negligible since its dependence is linear and very seldom we face variations of more than 30 hPa about the average value of 1013 hPa. In the worst case, if corrections for pressure are ignored you make an error of ±3%, usually it is within ±1.5%.

On the other hand, Q depends exponentially on temperature variations, therefore more relevant errors can be introduced if average temperature is significantly different from 25 °C. Moreover, when chemiadsorbing cartridge are used kinetic effects (variations of reaction velocities between analyte and chemiadsorbing substrate) can be evident, apart from thermodynamic ones (variation of D).

It is therefore very important to know the average temperature in order to ensure accuracy of experimental data. See how you can perform on-field temperature measurements on page B3.

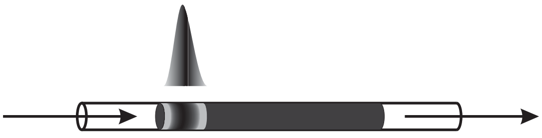
Even if some cartridges adsorb large quantities of water when exposed for a long time in wet atmosphere, generally this does not affect sampling by ***radiello***. Some consequences, neverthless, can sometimes be felt on the analysis. As an example, a very wet graphitised charcoal cartridge could generate ice plugs during cryogenic focusing of thermally desorbed compounds or blow out a FID flame.

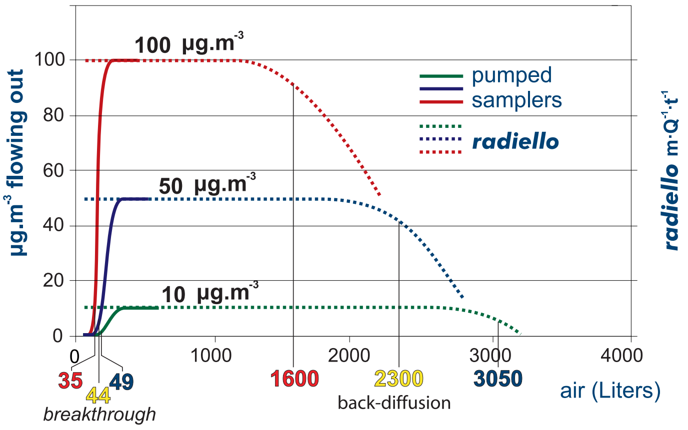
It is therefore important to protect *radiello* from bad weather. See page B1 how this can be easily done.

why is *radiello* so special?

The diffusive sampling does not involve the use of heavy and encumbering pumping systems, does not have energy power supply problems, does not require supervision, is noiseless, is not flammable and does not represent an explosion hazard, can be performed by everybody everywhere and with very low costs.

Moreover, it is not subject to the breakthrough problem, which can be serious when active pumping is performed.





In pumped sampling the adsorbed compound behaves as a chromatographic peak (top): air flow displaces it along the adsorbent bed and its concentration is distributed as a gaussian function. Eventually, the compound comes out from the opposite end. When its concentration in the outlet air is 10% of the concentration in the sampled air we say that the ***breakthrough*** *has been reached or, with a misleading expression, that the tube has been saturated. Any further pumping leads to a loss of analyte and a consequent underestimation of the environmental concentration. The extent of this phenomenon depends weakly on the concentration of target compound but rather on the value of air flow, the overall sampling volume and the chemical compound involved.*

In the graph the case of benzene is displayed, sampled at 25 °C onto an activated charcoal adsorbent bed of the same volume of a code 130 ***radiello*** *cartridge. The breakthrough is reached after 35, 44 or 49 liters of sampled air depending on benzene concentration in air (10, 50 or 100 $\mu g \cdot m^{-3}$ respectively).*

An apparently similar phenomenon is shown by ***radiello*** *also. In this case, however, we cannot speak of breakthrough, since no actual air flow is involved, but rather of* ***backdiffusion****. This consists of a decrease of the value of $m \cdot Q^{-1} \cdot t^{-1}$ (which is equal to the measured concentration, see eqn. [3] on page A1). This term is constant and equal to the actual concentration until the adsorbed mass of analyte is far from the maximum amount allowed by the adsorbing medium capacity. The extent of backdiffusion depends on concentration and exposure time but a decrease of 10% in the $m \cdot Q^{-1} \cdot t^{-1}$ term is observed along with equivalent sampling volumes of magnitude bigger than those seen before: 1600, 2300 and 3050 liters at the concentration of 10, 50 and 100 $\mu g \cdot m^{-3}$.*

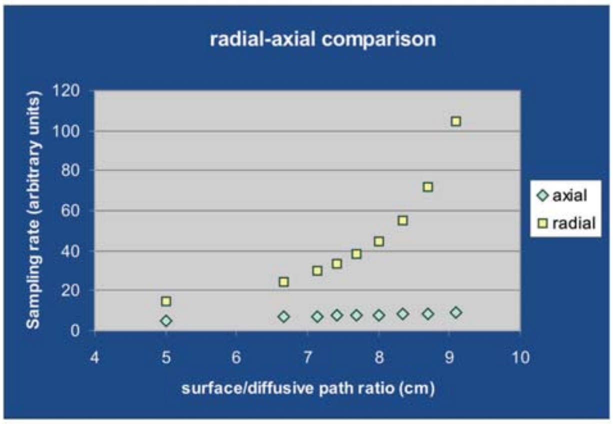
Why diffusive sampling has not been so extensively adopted up to now?

This is due to the fact that the traditional axial symmetry sampler has generally poor sensitivity and reproducibility because of the limits set by its geometry. On one side, uptake rate values are generally low, on the other, they often vary depending on environmental conditions.

These limitations have been overcome by ***radiello***.

By virtue of radial symmetry, uptake rate is:

✓ **high**, since it does not vary linearly but exponentially with the ratio diffusive surface *vs* diffusive path length (see eqn. [5]). With the same dimensions, radiello's uptake rate is at least three times higher than that of any axial diffusive sampler;



For a traditional axial symmetry sampler the uptake rate increases linearly with tha ratio of diffusive surface vs diffusive path length, while for the radial simmetry sampler, the corresponding increase is exponential. This means that, let the diffusive surface vs diffusive path length ratio be 8:1, for the axial sampler the uptake rate value is 8 (regardless of dimensions) while for the radial one it is 45.

- ✓ **constant**, due to the great adsorbing capacity of the adsorbing cartridge;
- ✓ **reproducible**, by virtue of the stiffness of the diffusive membrane and the cartridge and of the close tolerances characterizing all the components of ***radiello***;
- ✓ **invariable with air speed**, due to the tortuosity of the diffusive path inside the microporous diffusive cylindrical surface;
- ✓ **precisely measured**, because it is not calculated but experimentally measured in a controlled atmosphere chamber in a wide range of concentration, temperature, relative humidity, air speed conditions and with or without interferents....

Moreover, ***radiello***

- able to work properly also with bad weather conditions due to the water-repellent diffusive body
- has blank values lower than three times the instrumental noise due to the complex conditioning procedures of the bulk adsorbing (or chemiadsorbing) materials and to the repeated quality controls along the whole production
- has low detection limits and high adsorbing capacities that allow exposure time duration from 15 minutes to 30 days and concentration measurements from 1 ppb to over 1000 ppm
- offers high precision and accuracy over a wide range of exposure values

- allows thermal desorption and HRGC-MS analysis without interferents
- is suited to the sampling of a vast range of gaseous pollutants
- is though and chemically inert, being made of polycarbonate, microporous polyethylene and stainless steel
- is indefinitely reusable in all of its components apart from the adsorbing cartridge; the latter can be recovered if thermal des orption is employed
- it comes from the efforts of one of the main European scientific research institutions that produces it directly by high technology equipment and continuously submits it to severe tests and per forms research and development in its laboratory in Padova

All the images in the manual concern the Environmental Research Center of Padova of the Fondazione Salvatore Maugeri-IRCCS

the components of *radiello*

The essential parts of ***radiello*** are the adsorbing cartridge, the diffusive body, the supporting plate and the adhesive label with the bar code indication. Apart from the adsorbing cartridge, if not differently stated, all of the other components can be repeatedly used for several sampling experiments.

The adsorbing cartridge

Depending on the polluting compound to be sampled, many different adsorbing or chemiadsorbing cartridges have been developed. Their dimensions are neverthless the same for all: 60 mm length and 4.8 or 5.8 mm diameter.

They are contained in glass or plastic tubes wrapped up in a transparent polyethylene thermowelded bag.

The code number, printed onto the bag along with the lot number and expiry date indicates the kind of cartridge.

Apart from the thermal desorption cartridges, all of the other kinds are for single use only. See the application section at the back for codes relevant to the different analytes.

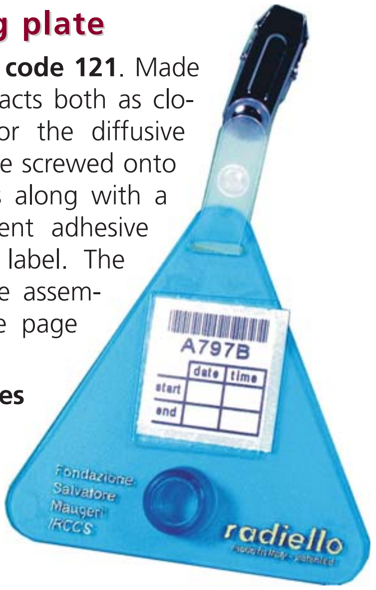
Available in 20 pieces per package.

The cartridge has to be introduced into the diffusive body.

The supporting plate

It is identified by the **code 121**. Made of polycarbonate, it acts both as closure and support for the diffusive body, which has to be screwed onto the thread. It comes along with a clip and a transparent adhesive pocket to hold the label. The three parts are to be assembled before use (see page A6).

Available in 20 pieces per package.



code 121

The diffusive body

Four kinds of diffusive bodies are available, with like outer dimensions: 60 mm height and 16 mm diameter.

The **white** diffusive body, **code 120**, of general use, is made of microporous polyethylene 1.7 mm thick and average porosity 25 ± 5 µm. Diffusive path length is 18 mm.

The **blue** diffusive body, **code 120-1**, has the same properties of the white one but is opaque to light: it is suited to the sampling of light-sensitive compounds.

The **yellow** diffusive body, **code 120-2**, should be used whenever the sampling rate must be reduced; it is made of microporous polyethylene 5 mm thick and average porosity 10 ± 2 µm. Diffusive path length is 150 mm.

The **permeative** diffusive body, **code 120-3**, is a 50 µm thick silicone membrane strengthened by a stainless steel net and a microporous polyethylene cylinder. It is employed for anaesthetic gases and vapours sampling.

Available in 20 pieces per package.

The diffusive body has to be screwed onto the supporting plate.

code 120 **120-1** **120-2** **120-3**

code 190

The label

Self-adhesive, with printed barcode number. Since each barcode number has been printed in only one copy, it allows an unmistakable identification of the sampling tube on field and in the laboratory for the subsequent analysis.

Each package of 20 adsorbing cartridges contains also 21 labels.

If the labels are ordered separately, they are shipped in 198 pieces per package.

how to use radiello

before sampling

assembling the supporting plate

Before using ***radiello***, you have to assemble the supporting plate with the clip, necessary to suspend it, and the adhesive label pocket.

insert the clip strip in the slot, with the peg facing upwards

ply the strip and insert the peg into the hole

peel off the transparent pocket

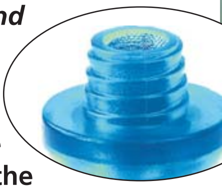
and place it onto the plate in a central position; if you prefer, the pocket can be applied to the rear of the plate, but **BE CAREFUL**, always with the label insertion slot on the side (otherwise, if it starts raining the label can get wet)

user tip

Assemble the supporting plate in your laboratory before the sampling campaign to save time in the field

on-field
to start the sampling

open the plastic bag, draw the cartridge out from the tube and put it in the diffusive body. ***Keep the glass or the plastic tube and stopper in the original plastic bag.***



The lower part of the diffusive body holds a seat for the central positioning of the cartridge. **A correctly centered cartridge should not stick out even by half a millimeter. If it does, the cartridge is not correctly positioned and out of axis.**
BE CAREFUL: do not hold the diffusive body horizontally when you screw it onto the plate, otherwise the cartridge could come out from its seat and stick out.
As a consequence, when the diffusive body is screwed onto the supporting plate the cartridge is bent, the geometry of the sampler is disturbed and the results obtained become unreliable. ***To place the cartridge centrally you need only to tap on the diffusive body.***

Insert a label in the pocket without peeling it off. Keep note of the date and time and expose ***radiello***. Sampling has started.

Keeping the diffusive body in a vertical position, to screw it onto the support plate

user tip

Do not touch the cartridge with your fingers if possible, particularly if it is impregnated with reactive

user tip

even if you can write date and time of the sampling start and end on the adhesive label, we suggest you to keep note of these parameters also separately: after a week exposure with bad weather conditions, your writing might have become illegible!

DO NOT USE MARKER PENS to write on the label: they contain solvents that are sampled by ***radiello***!

after the sampling

Keep note of the date and time of the end of exposure.

Place the cartridge into the tube, peel off the label and stick it onto the tube **such that the barcode is parallel to the axis of the tube.**

If you have performed the sampling of different polluting compounds at the same time, ***BE CAREFUL NOT TO MIX UP THE TUBES***: place the exposed cartridge in its original tube, identified by the code printed on the plastic bag.

IMPORTANT

Always stick the label such that the barcode is parallel to the axis of the tube: any other position will compromise the barcode automated reading by the optic reading device.

radiello maintenance

When exposed outdoors or in a workplace environment, the diffusive body may get dirty from airborne dust. Fine particles (PM_{10}) are especially harmful to yellow diffusive bodies since they can obstruct the pores. When the diffusive bodies are dirty you can wash them as follows.

Immerse the diffusive bodies in a beaker with a soapy solution (e.g. dish detergent) and sonicate them for 20 minutes. As the diffusive bodies float, you may make them sink by putting a smaller beaker on them, with water inside enough to dip it a few centimeters. Rinse the diffusive bodies with plenty of water and then deionized water; let them finally dry in the air.

IMPORTANT: NEVER USE SOLVENTS TO CLEAN THE DIFFUSIVE BODIES!!!

After four or five washings, diffusive bodies need to be replaced: repeatedly adsorbed dust may have penetrated the so deeply that they cannot be removed by washing anymore.

The following table shows the advised washing schedule:

PM_{10} concentration ($\mu g \cdot m^{-3}$)	<30	40	>50
Washing after days of exposure	45	30	15

accessories for *radiello*

vertical adapter

code 122

The diffusive body can be fitted to the supporting plate either in a vertical or horizontal position, the vertical one being more comfortable when ***radiello*** is used for personal sampling.

To assemble ***radiello*** in vertical position you have to screw it to the **vertical adapter code 122**, fitted to the supporting plate.

Available in 20 pieces per package

code 122

Assembeling the vertical Adapter

place the vertical adapter over the mounting point on the plate

The adapter can be removed from the plate by lifting the ridge

IMPORTANT

when mounting the diffusive body be careful to keep it vertical with the thread upside (see page A6).

press the adapter onto the plate with your thumbs till the ridge fits the edge of the plate.

shelter

code 196

For outdoor exposures a mountable polypropylene shelter is available which can be hung from lamp posts.

It has been designed to be mounted easily and without any tools on field, so that it is not cumbersome when you transport it from your laboratory. Once assembled, it ensures the best compromise between protection against bad weather and ventilation.

It can house up to four ***radiello*** and is able to fit a wide range of pole diameters.

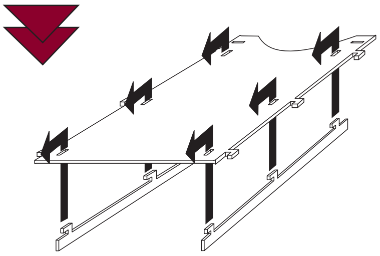
Its colour is quite similar to that of the majority of lampposts: being less visible, it is less subject to acts of vandalism.

Available in 10 pieces per package

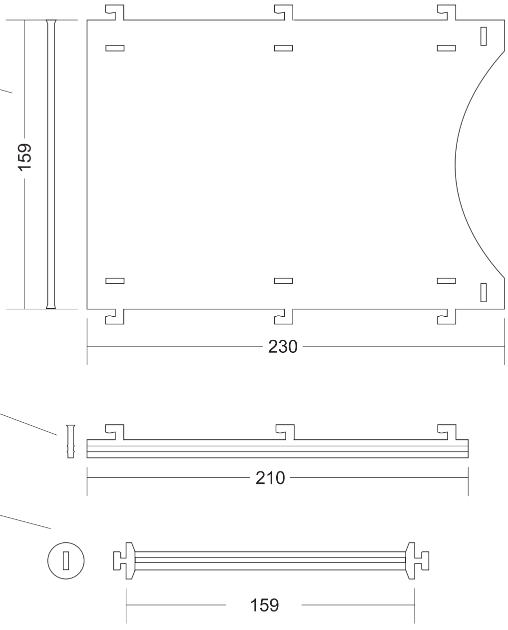
how to assemble the shelter

All of the components are snap-on assembled.

① First of all, insert on this panel (the roof) the two supports that will be used to suspend the samplers.



The shelter is composed of:



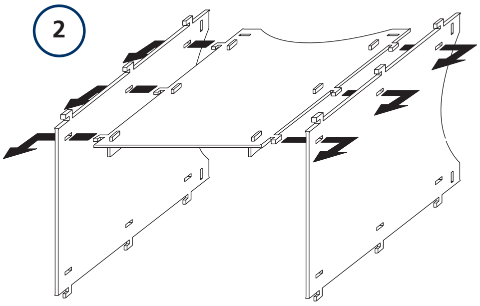
One of the three equivalent panels will act as the roof of the shelter (dimensions in mm)

the two supports where to suspend ***radiello***

two spacers

two strips shown below left

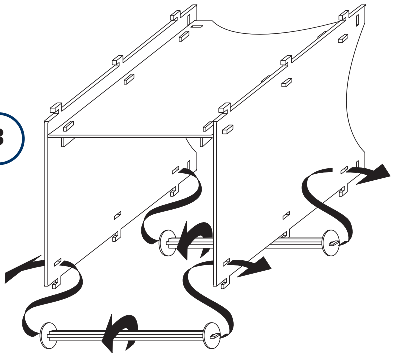
②

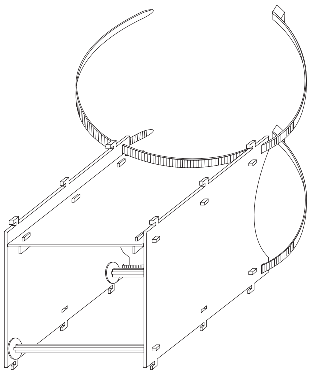


Then fix the two walls on the sides of the roof panel.

The whole becomes rigid by insertion of the two spacers. Fit them to the slots on bottom of the side panels and turn them by 90° (performing this rotation you may feel some resistance, but go on until you hear a clicking sound).

③





④

Finally, insert two plastic strips in the rear vertical slots of the side panels. The **strips** are also available as spare parts, in 100 pieces per package, identified by the **code 198**.

Suspend the shelter to the pole by closure of the strips, but ***DO NOT DRAW SO MUCH THAT THE SHELTER IS DEFORMED***. If the pole has diameter larger than 20 cm, the shelter leans on the curved edges on the rear of the side-walls. If the pole has a smaller diameter, it leans against the curved edge of the roof panel and the rear spacer. If the diameter of the pole is very small the shelter bows down, the wind may make it go round, or the shelter may even slip down to ground. It is then advisable to choose another pole.

user tip

If the pole diameter is larger than the strip length, you can put two or more strips together to extend the fastening system. If the sampling site is very windy, do not introduce more than two ***radiello*** samplers in each shelter, otherwise rain could dampen the outermost samplers.

Volatile organic compounds (VOCs)

chemically desorbed with CS_2

Radiello components to be used:

White diffusive body code 120
Supporting plate code 121
Vertical adapter code 122 (optional)
Adsorbing cartridge code 130

Or: *radiello-ready-to-use* code 123-1 (also see page A8)

Principle

Code 130 cartridge is a stainless steel net cylinder, with 100 mesh grid opening and 5.8 mm diameter, packed with 530 ± 30 mg of activated charcoal with particle size 35-50 mesh. Volatile organic compounds are trapped by adsorption and recovered by carbon disulfide displacement, analysis is performed by FID gas chromatography.

Sampling rates

The table on page D2 lists sampling rate values at 298 K (25 °C) and 1013 hPa, experimentally measured in a standard atmosphere chamber. For other compounds, whose diffusion coefficient[1] is known, sampling rate can be calculated according to equation [5] on page A2, taking into account that white diffusive body and code 130 cartridge give the geometric constant of radiello the value of 14.145 ± 0.110 cm. Several experiments performed in the standard atmosphere chamber demonstrate that the calculated sampling rates seldom deviate by more than ± 10% from the experimentally measured values.

Effect of temperaure, humidity and wind speed

Sampling rates varies from the value at 298 K on the effect of temperature (in Kelvin) as expressed by the following equation

$$Q_K = Q_{298}\left(\frac{K}{298}\right)^{1.5}$$

where Q_K is the sampling rate at the temperature **K** and Q_{298} is the reference value at 298 K. This produces a variation of ± 5% for 10 °C variation (upwards or downwards) from 25 °C.

Sampling rate is invariant with humidity in the range 15-90% and with wind speed between 0.1 and 10 $m \cdot s^{-1}$.

Calculations

The listed sampling rate values already take into account for the desorption efficiency with carbon disulfide. **The average concentration over the exposure time interval is therefore calculated from the mass of analyte found onto the cartridge and exposure time without introducing any corrective factor**, apart from corrections due to average temperature different from 25 °C.

Average concentration over the whole exposure time is calculated according to the following expression

$$C\,[\mu g \cdot m^{-3}] = \frac{m\,[\mu g]}{Q_K\,[ml \cdot min^{-1}] \cdot t\,[min]}\;\mathbf{1{,}000{,}000}$$

where:
m = mass of analyte in µg
t = exposure time in minutes

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[1] Lugg G.A.: Diffusion Coefficients of Some Organic and Other Vapours in Air. *Anal. Chem*. **40-7**:1072-1077 (1968).

Sampling rate values Q at 25°C (298 K)

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
acetone	77	10,000-600·10^6	7.0	**a**
acetonitrile	73	10,000-6·10^6	8.2	**b**
acrylonitrile	75	1,000-50·10^6	2.2	
benzyl alcohol	37	1,000-800·10^6	6.5	
amyl acetate	52	1,000-800·10^6	3.4	
benzene	80	500-500·10^6	1.8	
bromochloromethane	70	50,000-1,000·10^6	1.4	
butanol	74	1,000-500·10^6	5.0	
sec-butanol	64	1,000-300·10^6	5.2	
tert-butanol	62	1,000-300·10^6	5.5	
butyl acetate	60	1,000-1,000·10^6	3.0	
2-butoxyethanol	56	1,000-100·10^6	5.7	
2-butoxyethyl acetate	41	1,000-100·10^6	5.5	
carbon tetrachloride	67	100,000-60·10^6	9.0	
cyclohexane	54	500-500·10^6	4.5	
cyclohexanone	68	5,000-120·10^6	4.2	
cyclohexanol	54	5,000-120·10^6	4.5	
chlorobenzene	68	1,000-1,000·10^6	3.6	
chloroform	75	100,000-60·10^6	9.7	**a**
n-decane	43	500-1,000·10^6	1.1	
diaceton alcohol	43	500-1,000·10^6	4.5	
1,4-dichlorobenzene	51	1,000-1,000·10^6	7.7	
1,2-dichloroethane	77	1,000-500·10^6	8.2	
1,2-dichloropropane	66	500-250·10^6	4.5	
dichloromethane	90	500-60·10^6	8.7	
N,N-dimetylformamide	82	1,000-200·10^6	14.5	**c**
1,4-dioxane	68	1,000-600·10^6	5.5	
n-dodecane	8	1,000-1,000·10^6	4.7	
n-heptane	58	5,000-1,500·10^6	3.0	
n-hexane	66	1,000-1,000·10^6	2.5	
1-hexanol	52	5,000-120·10^6	5.5	
ethanol	102	10,000-500·10^6	7.5	**a-b**
diethyl ether	78	5,000-500·10^6	12.0	**a**
ethyl acetate	78	1,000-1,000·10^6	1.5	
ethylbenzene	68	1,000-1,000·10^6	2.4	
2-ethyl-1-hexanol	43	5,000-500·10^6	10.1	
2-ethoxyethanol	55	500-50·10^6	6.7	**b**
2-ethoxyethyl acetate	54	10,000-100·10^6	2.5	
ethyl-***tert***-butyl ether (ETBE)	61	500-200·10^6	3.0	
isobutanol	77	1,000-300·10^6	2.5	
isobutyl acetate	63	1,000-1,000·10^6	5.2	
isooctane	55	500-1,000·10^6	3.2	
isopropanol	52	10,000-400·10^6	12.0	**b**
isopropyl acetate	66	1,000-1,000·10^6	9.9	
isopropylbenzene	58	1,000-1,000·10^6	2.7	
limonene	43	1,000-1,000·10^6	10.0	
methanol	125	10,000-250·10^6	9.2	**a-b**
methyl acetate	80	1,000-1,000·10^6	12.0	
methyl-***ter***-butyl ether (MTBE)	65	500-200·10^6	2.5	

	Q_{298} ml·min^{-1}	linearity range µg·m^{-3}·min	uncertainty at 2σ %	notes
methylcyclohexane	66	1,000-1,000·10^6	6.5	
methylcyclopentane	70	1,000-1,000·10^6	2.5	
methylethylketone	79	1,000-500·10^6	1.6	
methylisobutylketone	67	1,000-250·10^6	8.7	
methyl metacrylate	68	1,000-500·10^6	2.5	
2-methylpentane	70	1,000-1,000·10^6	2.5	
3-methylpentane	70	1,000-1,000·10^6	2.5	
2-methoxyethanol	35	5,000-100·10^6	11.0	**b**
2-methoxyethyl acetate	56	2,000-100·10^6	3.0	
1-methoxy-2-propanol	55	1,000-350·10^6	6.0	
1-methoxy-2-propyl acetate	60	2,000-350·10^6	6.2	
naphthalene	25	1,000-1,000·10^6	7.0	
n-nonane	48	1,000-1,000·10^6	5.4	
n-octane	53	500-1,000·10^6	3.2	
pentane	74	1,000-1,000·10^6	1.9	
α-pinene	53	1,000-1,000·10^6	7.0	
propyl acetate	65	500-1,000·10^6	7.5	
propylbenzene	57	1,000-1,000·10^6	2.9	
styrene	61	1,000-500·10^6	3.0	
tetrachloroethylene	59	10,000-500·10^6	2.5	
tetrahydrofuran	74	2,000-250·10^6	11.0	**b**
toluene	74	500-1,000·10^6	1.5	
1,1,1-trichloroethane	62	5,000-1,000·10^6	5.5	
trichloroethylene	69	5,000-1,000·10^6	2.4	
1,2,4-trimethylbenzene	50	500-1,000·10^6	6.6	
n-undecane	24	1,000-1,000·10^6	10.0	
m-xylene	70	500-1,000·10^6	2.5	
o-xylene	65	500-1,000·10^6	2.5	
p-xylene	70	500-1,000·10^6	2.5	

Notes:

a = weakly adsorbed compound. If its concentration is higher than the TLV for the workplace environments it may be partially displaced by other compounds that are more strongly trapped if their concentration is also high. If this is the case, it is advisable to reduce sampling time under 8 hours.

b = prolonged exposure of charcoal cartridges at relative average humidity higher than 80% causes adsorption of up to 100 mg of water. Water does not interfere with adsorption mechanisms but is displaced by carbon disulfide and gives raise to a separate layer. Some very water soluble polar compounds will distribute between the two solvents, thus provoking an underestimation of the actual air concentration since only the carbon disulfide is injected in the gas chromatograph. When the concentration of polar compounds has to be determined, the calibration curve should be prepared by spiking 50 µl of water in each tube containing the cartridge and the 2 ml of carbon disulfide standard solution (see Analysis).

c = better reproducibility obtained by use of methanol as extraction solvent instead of carbon disulfide.

Limit of quantitation

The limit of quantitation depends on the instrumentation and on the analytical conditions. The minimum revealable environmental concentration can be estimated on the basis of the equation on page D1, where ***m*** is the minimum revealable mass, experimentally measured for each compound. Under the analytical conditions described on page D4, the limit of quantitation for 7 days exposure usually ranges from 0.05 to 1 µg·m^{-3}, depending on the compound.

Exposure

Code 130 cartridge has a very large loading capacity: about 80 mg, corresponding to an overall VOCs concentration of 3,000-3,500 mg·m^{-3} sampled for 8 hours or 70,000-80,000 µg·m^{-3} sampled for 14 days. Neverthless, if the quantified overall adsorbed mass should be near 80 mg, sampling rate could have deviated from linearity. If this is the case, it is advisable to repeat the sampling experiment reducing exposure time.

Workplace environment

In workplace environments complex mixtures of airborne solvent vapours are often found at concentrations of 2,000-3,000 mg·m^{-3}. The outstanding adsorbing capacity of code 130 cartridges allows you to sample them for the whole working shift of 8 hours. On the other hand, the very high values of sampling rates for a variety of compounds allow you to perform accurate concentration measurements even after very short exposures. For example, 15 minutes are enough to measure 0.1 mg·m^{-3} of benzene.

radiello can therefore be employed to evaluate both *TWA* and *STEL* concentrations.

Other indoor sampling experiments and outdoor campaigns

High sampling rates of ***radiello*** ensure very low limits of detection also for short exposure time intervals. For example, you may measure benzene concentrations as low as 2 µg·m^{-3} with an error not exceeding 4% after 8 hours of exposure. If ***radiello*** is exposed for 7 days, limit of quantitation becomes 0.1 µg·m^{-3}.

Generally speaking, we suggest exposure time duration ranging from 8 hours to 30 days, the ideal value being 7 days.

Storage

The activated charcoal cartridges have undergone a complex conditioning process that ensures an outstanding chromatographic blank level, never exceeding three times the instrumental noise of a FID detector at the lowest attenuation.

Kept in a cool place and away from volatile organic compounds, the cartridges mantain unchanging blank level and adsorbing capacity for at least two years. Expiry date and lot number are printed onto the plastic bag wrapping each cartridge: its integrity stands as warranty seal.

After exposure the cartridges, well capped and kept in a cool and solvent-free place, mantain their content unaltered for at least six months.

Analysis

Extraction

Introduce 2 ml of CS_2 and 100 µl of internal standard solution (see next page) directly in the ***radiello*** glass tube without drawing out the cartridge. **Always use class A volumetric pipettes or dispensers.** Stir from time to time for 30 minutes. If analysis is not performed soon after, draw out the cartridge and discard it.

Calibration

Outdoor environment sampling

If benzene, toluene, ethylbenzene and xylenes (BTEX) have to be analyzed, prepare three or four standard solutions in CS_2 having decreasing concentrations of the analytes in the following ranges (in mg·l^{-1}):

benzene	0.04-17.6	ethylbenzene	0.04-17.7
toluene	0.09-34.8	m-xylene	0.04-17.2
o-xylene	0.04-17.6	p-xylene	0.04-17.2

It is advisable to proceed via consecutive dilutions, starting for example from a stock solution containing 1 ml of each compound in 100 ml. Always use class A volumetric glassware. Introduce 2 ml of each standard solution, along with 100 µl of internal standard, onto a blank code 130 cartridge in its glass tube.

IMPORTANT

always use high purity grade CS_2, for example Fluka Cat. No. 84713 or Aldrich Cat. No. 34,227-0

BE CAREFUL

even refrigerated, CS_2 permeates the tube plastic cap: its volume decreases by 4-5% a day. If the internal standard has been added, it is only matter of unpleasant odour...

Analysis of unknown samples

Identify the sample that has been exposed for the longest time or at the highest expected concentration. Introduce 2 ml of CS_2 but do not add the internal standard, stir and let the sample stand for 30 minutes. Without discarding the cartridge, inject the CS_2 solution in the gas chromatograph with FID detector (see below), identify the compounds appearing in the chromatogram and make an estimation of the order of magnitude of their concentrations.

Prepare a CS_2 solution of the identified compounds with doubled concentration with respect to the sample. Dilute this solution in order to obtain standard solutions of concentration respectively about 0.1, 0.5 and 1 times the concentration estimated in the sample. Introduce 2 ml of each standard solution onto a blank code 130 cartridge in its glass tube, along with the chosen internal standard solution.

The chosen **internal standard** should have a retention time that does not interfere with other compounds in the chromatogram. Compatibly with this requirements, we suggest to employ a solution of **2-fluorotoluene** (e.g. Aldrich F 1,532-3 or Fluka 47520) in CS_2 with concentration of 100 $\mu l \cdot l^{-1}$ for outdoor samples and 2 $ml \cdot l^{-1}$ for workplace samples. Add 2 ml of CS_2 and the internal standard to all of the samples, stir, let the samples stand for 30 minutes and discard the cartridges prior to the analysis.

USER TIP

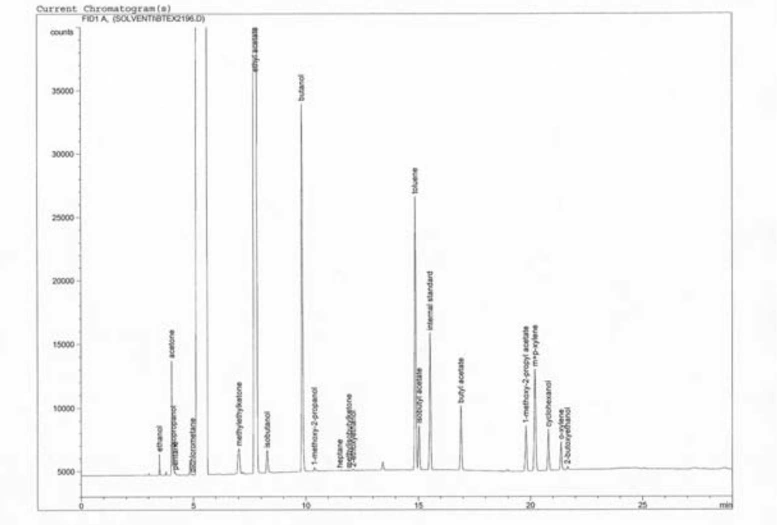
For a very accurate calibration we offer the **preloaded cartridges code 405** (outdoor environment) and **code 406** (workplace environment).

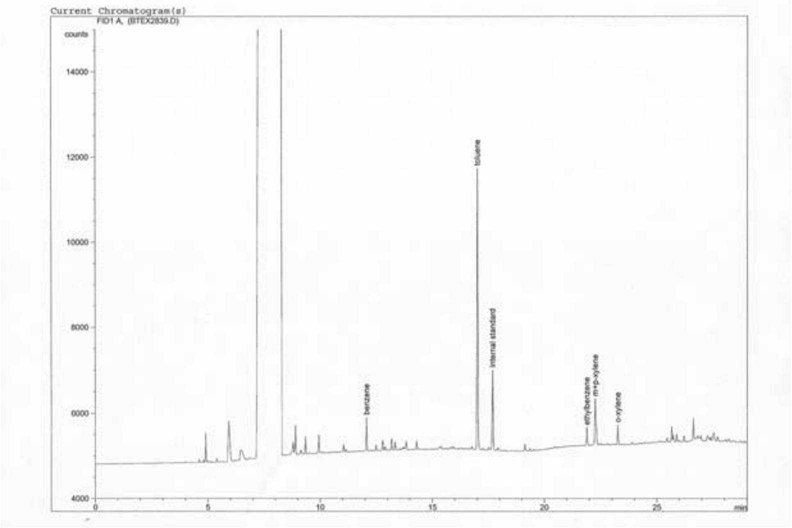
Instrumental analysis (advised)

Capillary gas chromatography with FID detection

outdoor environment samples: 100% dimethylpolysiloxane column 50m x 0.2mm, film thickness 0.5 µm; (e.g. Petrocol DH 50.2, Supelco Cat.No. 24133-U) split injection of 2 µl; split ratio 25:1; nitrogen carrier gas at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 35 °C for 5 minutes, 5 °C/min up to 90 °C, maintain for 3 minutes, 10 °C/min up to 220 °C, final isotherm for 5 minutes.

workplace samples: 100% dimethylpolysiloxane column 0.2 mm·50 m, film 0.5 µm; split injection of 3 µl, split ratio 100:1; carrier N_2 at constant pressure of 20 psi; injector temperature 240 °C; oven initial temperature 50 °C for 5 minutes, 5 °C/min up to 80 °C, 15 °C/min up to 135 °C, 20 °C/min up to 220 °C, final isotherm 10 minutes. Total time: 29 minutes. The retention times for several compounds analyzed under the described conditions are listed in the table on next page.





On top: *FID chromatogram of a real workplace sample*

on the left: *chromatogram of a real urban outdoor sample*

USER TIP

If you perform several analyses, a barcode reader will greatly improve productivity in your laboratory and will also minimize the possibility of errors in the copying of sample labels.

Please contact us to help you in the implementation of the reader.

We have also developed software solutions for the analytical data processing and automated production of analysis reports.