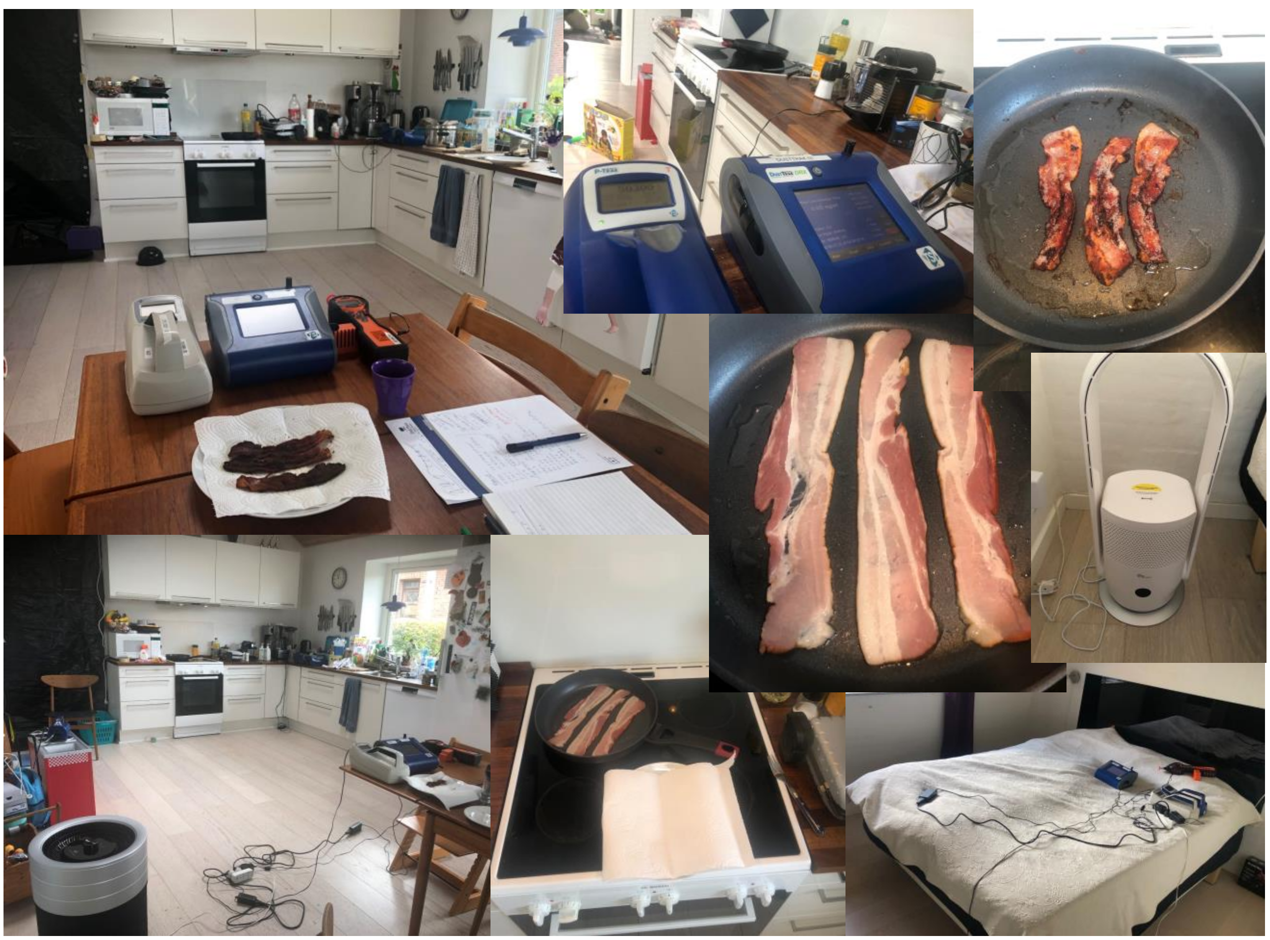
GREEN TRANSITION
DENMARK

Air purifiers' capability to reduce exposure to pollution generated in private homes



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Abstract
Air pollution is one of the main risk factors for human health. People cannot do much to reduce their exposure to outdoor air pollution. However, people spend more than 90% of their time indoor where candles, cooking, wood stoves/fireplaces, etc. can cause significant air pollution. Increased awareness about indoor air pollution has boosted the sale of air purifiers for private homes significantly.

The purpose of this study was to investigate the efficiency of eight mobile air purifiers to reduce the exposure to particle pollution and volatile organic compounds (VOCs) from pollution sources inside private homes compared to the efficiency of a cooker hood, manual airing, and mechanical ventilation.

We conclude that through draught and an efficient cooker hood during cooking were more efficient than the best air purifiers tested whereas opening just one window was less efficient. The mechanical ventilation was less efficient in reducing exposure to particles from candles than good purifiers. Some mobile air purifiers significantly reduce particle exposure from pollution sources in homes while other purifiers have limited or no significant effect. We cannot conclude on VOC removal based on the measurements. Air purifiers with HEPA filters and other efficient mechanical filters typically show high removal of particles. However, the capacity of the air purifier should fit the room size; and the location of the purifier in the room, the distance to the pollution source as well as the air movements in the room are crucial for the purifier's capability to reduce exposure. Even though good air purifiers might remove more than 99% of the particle pollution during filtration, these purifiers will *not* reduce the exposure 99% as people inhale the polluted air in the room before the purifiers can clean it.

Resumé (Danish abstract)
Luftforurening er en af de vigtigste risikofaktorer for folkesundheden. Vi kan ikke selv gøre meget for at reducere vores eksponering til udendørs luftforurening, men vi opholder os i mere end 90 % af vores liv indenfor, hvor bl.a. stearinlys, madlavning og brændeovne/pejse kan forårsage høj luftforurening. Øget fokus på skadelig luftforurening har sat markant skub i salget af luftrensere til private hjem.

Formålet med projektet var at undersøge otte mobile luftrenseres evne til at reducere eksponeringen for forurening med partikler og flygtige organiske stoffer (VOC'er) fra forureningskilder i private hjem sammenholdt med effekten af en emhætte, manuel udluftning og mekanisk ventilation.

Det konkluderes, at gennemtræk og en effektiv emhætte er mere effektiv til at fjerne stegepartikler end den bedste luftrenser, mens det var mindre effektivt kun at åbne et vindue. Mekanisk ventilation var mindre effektiv til at reducere eksponering til partikler fra lys end de mest effektive luftrensere. Nogle mobile luftrensere kan reducere eksponeringen for partikler fra forureningskilder markant, mens andre luftrensere har begrænset eller ingen signifikant effekt. Der kunne ikke drages konklusioner for VOC-fjernelse ud fra de udførte målinger. Luftrensere med HEPA-filtre eller effektive mekaniske filtre giver typisk høj fjernelse af partikler. Luftrensernes kapacitet skal passe til rum-størrelsen, og placeringen af luftrenseren i rummet samt afstanden til forureningskilden – ligesom luftens bevægelse i rummet – er afgørende for luftrenserens evne til at reducere eksponering. Selvom de bedste luftrensere fjerner over 99 % af partiklerne under filtrering, så kan de ikke reducere eksponeringen med 99 %, da personer i boligen når at inhalere den forurenede luft, inden den bliver renset af luftrenseren.

Preface

This report contains results from testing of eight mobile air purifiers with different technologies in a private home compared to the efficiency of a cooker hood, manual airing, and mechanical ventilation.

Testing was performed by Green Transition Denmark in collaboration with the Danish Technological Institute and the Danish Consumer Council. The project was funded by the philanthropic Realdania Organization and The Danish Landowners' Investment Foundation.

As a parallel part of the project, 29 air purifiers were tested in a laboratory at the Danish Technological Institute.

Project leader: Dr. Kaare Press-Kristensen, senior advisor on air quality & climate, Green Transition Denmark. Contact info: kaare@rgo.dk / (+45) 22811027.

Background

Air pollution is one of the main risk factors for human health. On a global level, air pollution kills as many people as does tobacco smoking. And even in the richer part of the world, air pollution is still a major cause of mortality and morbidity. In the EU, outdoor air pollution causes about 11% of all deaths and health costs of 800-900 billion euros every year, according to the World Health Organisation. Even in Denmark, where the air is some of the cleanest in the EU, outdoor air pollution is still one of the main risk factors, according to DCE at Aarhus University; it causes 7-8% of all deaths, and health costs amounting to around 12.5 billion euros annually.

People cannot do much to reduce their exposure to outdoor air pollution. However, people spend more than 90% of their time indoor where candles, cooking, wood stoves/fireplaces, cleaning detergents and degassing from products can cause significant air pollution. Traditionally, solutions have been to do frequent airing, use a powerful cooker hood, replace candles and wood stoves/fireplaces with electric alternatives, avoid products with toxic chemicals, and to install mechanical ventilation. However, these solutions are not possible for everyone. Furthermore, outdoor air might be polluted with traffic exhaust in cities and wood smoke in residential areas thereby causing high indoor air pollution when airing.

Hence, the increased awareness about adverse health effects related to air pollution boosted the sale of air purifiers for private homes significantly over the last decades. Lately, mobile air purifiers have been heavily marketed as mitigation for airborne diseases as well. But how efficient are air purifiers with different “clean air” technologies in reducing the exposure to particles and gasses in private homes compared to a cooker hood, manual airing, and mechanical ventilation?

Purpose

The key purpose is to investigate how efficient eight different mobile air purifiers are in reducing the exposure to particle pollution and VOCs from typical pollution sources inside private homes compared to the efficiency of a cooker hood, manual airing, and mechanical ventilation.

Experimental set-up

Measurements are performed in a new private house (Nordic Ecolabel) from 2011 with standard mechanical ventilation (Nilan Comfort 300) and a typical cooker hood (ASKO) for private homes.

Air purifiers are tested in:

a) A large living room-kitchen-dining area with vaulted ceiling: Volume/area of 165 m^3/43.6m^2.
b) A bedroom (incl. walk-in closet) without vaulted ceiling: Volume/area of 30.5 m^3/12m^2.

The eight mobile air purifiers tested are, respectively:

1) Air purifier 1: Very high particle removal during lab tests.
2) Air purifier 2: High VOC reduction in lab tests.
3) Air purifier 3: UV-C-based device.
4) Air purifier 4: Representing ionisation technology.
5) Air purifier 5: Medium removal during lab tests.
6) Air purifier 6: Medium removal during lab tests.
7) Air purifier 7: High particle removal during lab tests.
8) Air purifier 8: Representing cold plasma technology.

In appendix 1, technical details on the tested air purifiers are given.

The air purifiers are tested for their ability to reduce the particle number concentration, fine particulate matter, and Volatile Organic Compounds (VOCs) generated from frying bacon in the kitchen and using scented candles in the bedroom. Particle numbers are measured with two P-Tracks (particle size interval 20-1,000nm) and a Condensation Particle Counter 3007 (CPC-3007; particle size interval 10-1,000nm) from TSI. Fine particulate matter ($PM_{2.5}$) is measured with Dust Trak's from TSI. VOCs are measured with a Tiger TVOC Detector from ION Science. All devices are newly calibrated prior to testing, and average minute concentrations are used for all measurements.

The experimental set-up is designed to mimic a real-life scenario, reflecting how people would use the devices. Therefore, parts of the set-up choices are reflecting this. For instance, during measurements, the air purifiers are placed on a typical convenient spot (likely placement, not always recommended placement) in the kitchen and in the bedroom, and they are tested on auto-function or highest level with all enclosed technologies in use. However, they have been placed at the recommended height specified in the manual of the air purifiers. Further, it should be noted that the kitchen has a larger volume/area than recommended for most of the tested air purifiers (cf. appendix 1), which allows us to test how much each air purifier can reduce exposure in larger - or connected - rooms.

Kitchen measurements

For the kitchen measurements (frying bacon), the efficiencies of air purifiers are compared with:

1) Reference measurements (no purifiers, cooker hood, or mechanical ventilation in operation).
2) Manual airing (roof skylight partly open and another measurement with through draught).
3) Using the existing cooker hood in the kitchen (on next-highest level; level 3 out of 4).

For frying bacon, a *Bosch* ceramic electric stove (model HCE62412OU; 11 years old) is used; the diameter of the heater is 21cm. The cooker hood above the stove is an *Asko* (model CW4640s; suction power: 760m^3/hour; 11 years old), where level 3 of 4 is used during measurements; level 3 is chosen as the highest level (level 4) is quite nosy and may therefore be used more infrequently.

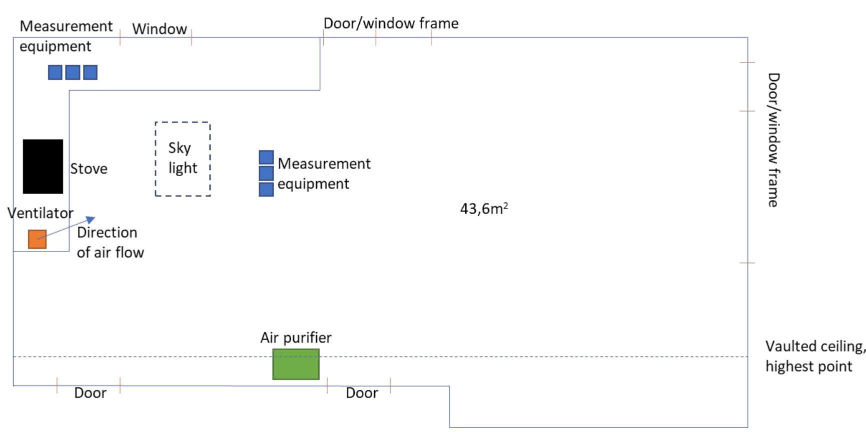
The distance between the stove and the cooker hood is 63cm. The pan is a new (washed off) *Pyrex optimum* aluminium frying pan, applicable for induction, gas, ceramic, and electric stoves, with a diameter of 28cm and an extra resistant non-stick coating. The bacon is from *Smart cooking*, smoked and dry salted in slices. Each package contains 150g corresponding to 6-7 slices per package. The content of fat, carbohydrates, protein, and salt is 33g (12g saturated), 2.8g (1.2g sugar), 15g, and 2.7g, respectively.

Instruments used for measuring particle number and particle mass concentrations are placed next to the stove on the kitchen table, as well as on the dining table. This represents positions where people are most likely to be during an activity like cooking food. This also allows for determining particle exposure at two relevant positions, rather than just measuring room concentration. Only one VOC device was used. This was placed on the dining table.

The ventilator used for mimicking human activity and mixing the air is *Bright* (50Hz, 2000W); set on “ventilator” (no heat) and maximum power. It is placed on top of the kitchen cupboard (2.35m above floor level) to make sure that the air is fully mixed. The mixing of the air in the room is checked during measurements with a P-Trak in 1m, 3m, and 5m height. Doors/windows are kept closed except for when testing manual airing with roof skylight partly open and with through draught

The experimental set-up during kitchen measurements is illustrated in figure 1.

Figure 1: Photos and sketch of set-up in the living room-kitchen-dining area.

The test duration with bacon is one hour and the procedure starts with pouring 5ml of rapeseed oil on the cold frying pan (room temperature), spreading it out, putting three slices of bacon parallel and centrally on the frying pan, placing the frying pan on the cold stove, and starting up the stove on level 7 out of 9. The bacon is fried for 12 minutes in total: After 8 minutes, the bacon is turned. After an additional 3 minutes, the bacon is turned again. After another minute, the frying pan is removed from the heat, which is turned off, the bacon is put on a plate with a paper towel and the plate is placed on the dining table for 48 minutes. The pan is left on a cold part of the stove.

Before starting the next measurement, airing for a minimum of 13 min. is made by opening all doors and windows, the frying pan is cleaned with soap and water and dried off, and the stove is cleaned carefully with a damp cloth. The air quality is checked with a P-Track (1m, 3m and 5m height) 4-5 minutes after closing windows/doors (before starting measurements) to be sure air quality is as outside.

This procedure is repeated once with each air purifier, and with manual airing (roof skylight partly open and through draught, respectively) and cooker hood (on next-highest level; level 3 out of 4).

Bedroom measurements

For the bedroom measurements (with scented candles), the efficiencies of purifiers are compared with:

1) Reference measurements (no air purifiers or mechanical ventilation in operation).
2) Mechanical ventilation in the house on medium (2 out of 4) and highest level (level 4).

For measurements with scented candles, two different types of candles were used simultaneously:

1) *Urd*, “Wild flowers” scented candle.
   Duration: 22 hours.
   Weight 120g: 80% soy wax, 20% paraffine
   Contains: citronellol, geraniol, eucalyptus oil.
   Height/Diameter: 7.5cm/7cm

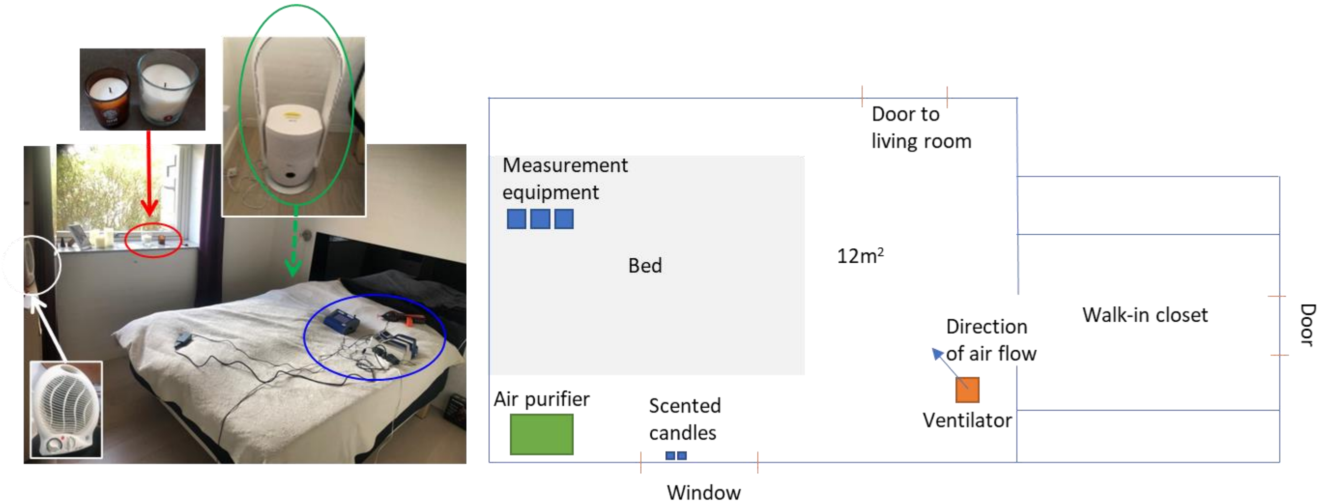
2) *Bolsius since 1870*, ”True scents vanilla” scented candle.
   Duration: ±43 hours.
   Weight not stated: 50% plant-based wax.
   Contains: natural extracts, plant-based wax, palm oil-free, cotton wick.
   Height/Diameter: 9.5cm/9.5cm

The candle wick is cut to a length of 11mm, and for air mixing and mimicking human activity the same ventilator, as used in the kitchen, is set at the same function as well. The ventilator is placed approximately 1m above ground level and 2m from the candles blowing in the opposite direction of the candles to have least disturbance of the flame. Doors/windows are kept closed except for when entering to blow out candles during measurement. When entering/exiting the room, the door is quickly, but gently, opened (30-40cm) and (immediately) closed to have a minimum of “disturbance”. The candles are lit with a gas lighter.

Instruments for measuring particle number, particle mass and VOC concentrations were placed on the far side of the bed.

The experimental set-up during the bedroom measurements is illustrated in figure 2.

Figure 2: Photos and sketch of set-up in the bedroom/walk-in closet.



The two candles are placed on the window shelf approximately 10cm apart (wick to wick). The candles are lit; after 20 minutes, the candles are blown out. Another 10 minutes passes before the measurement is ended. Hence, total duration of the measurement is 30 minutes. Before starting the next measurement, airing for minimum 10 minutes is made by opening all doors and windows. The air quality is checked with a P-Track (0,5m, 1m and 2m height) 4-5 minutes after closing windows/doors before starting a new measurement to be sure air quality is the same as outside.

Results

Reference measurements

Three reference measurements are performed in the kitchen and the bedroom on different days to test reproducibility/validity of the experimental set-up and to find the reference exposure. During reference measurements, pollution sources (frying bacon in the kitchen and scented candles in the bedroom) are active whereas no air purifiers, cooker hood or mechanical ventilation are in operation and windows/doors are closed. Graphs from measurements are found in appendix 2.

From the measurements in the kitchen, the graphs (appendix 2) show that particle number and particle mass are quite similar in the reference measurements indicating relatively high reproducibility. Furthermore, quite similar levels and shapes of particle graphs (increase after 10 min., peaking after 20-25 min., and a steady drop after 25 min.) measured both at the kitchen counter (1.5m from frying pan) and the dining table (3.5m from frying pan) indicate a good air mixture in the room. Manual measurements with a P-Track (at 1m, 3m, and 5m height) during reference measurements indicate fully mixed air after 25 min. The graphs for VOCs are more fluctuating but show similar patterns.

From the measurements in the bedroom, the graphs (appendix 2) show that particle number and particle mass are quite similar in the reference measurements indicating high reproducibility. The different shapes of particle number and particle mass graphs are because particle mass ($PM_{2.5}$) is mainly formed when the candles are blown out after 20 min. (in the figures, the first minute of measurement is set to time = 0, and the smoke might affect measurements in minute 19 to 20 i.e. this causes the increase to occur before minute 20 on the graphs). Manual measurements with a P-Track (at 0.2m, 1m, and 2m height) showed mixed air. Graphs for second/third VOC measurement are uniform.

Based on the reference measurements, the experimental set-up is assessed to be well suited for the planned investigations of mobile air purifiers.

Table 1 provides calculated average reference exposures (concentrations) in the kitchen and bedroom during the reference measurements. Before calculating the exposures, each reference measurement is adjusted to the same initial concentrations (to an initial concentration of 0.012 mg/m^3 for particle mass, 2,100 particles per cm^3 for particle number measured by P-Track, and 0.111 ppm for VOC).

Table 1: Reference exposures (average reference concentrations with only pollution sources active)

	Particle mass (mg/m^3)		**Particle number** (part./cm^3)		**VOC** (ppm)	
	Kitchen [a)]	**Bedroom**	**Kitchen** [a)]	**Bedroom** [b)]	**Kitchen**	**Bedroom**
Reference exposure	0.755	0.025	58,250	133,500	1.205	1.310

a) Particle mass from Dust Track on dining table and particle number from P-Track (kitchen table). b) Data from P-Track.

Average particle mass concentrations in each reference measurement in the kitchen and in the bedroom are within ± 25% and ± 15%, respectively, of the concentration shown in table 1.
Average particle number concentrations and VOCs in each reference measurement in the kitchen and bedroom are within ± 10% of the concentrations shown in table 1.

Efficiency of air purifiers

Each air purifier is tested with active pollution sources (frying bacon in the kitchen and scented candles in the bedroom) and no cooker hood or mechanical ventilation in operation (windows/doors closed). The cooker hood and manual airing are individually tested as alternatives to air purifiers when frying bacon. Mechanical ventilation is tested as an alternative to air purifiers when using scented candles in the bedroom. Graphs from measurements are found in appendix 3.

The measurements clearly show that some mobile air purifiers can significantly reduce exposure to particles from pollution sources in private homes while other purifiers have limited or no significant effect. Mobile air purifiers with HEPA and other efficient mechanical filters typically show high particle removal; at least where the room size (bedroom) fit their capacity (appendix 1). The overall results from the measurements in the private home are aligned with laboratory results.

The measurements do not give a clear picture on VOC removal. The initial VOC concentrations show high variations during the measurements indicating other significant pollution sources in the private home (maybe kitchen waste, laundry, dirt, etc.) than bacon and scented candles. Furthermore, VOC concentrations during measurements sometimes showed significant spontaneous increases (appendix 3), maybe due to persons moving around in the room. Hence, the VOC measurements are not conclusive and will not be used further in this study.

Figure 3 and 4 show graphs for particle removal during kitchen measurements (frying bacon) with an efficient air purifier (air purifier 1) and a less efficient air purifier (air purifier 8) compared to using the cooker hood and manual airing (roof skylight partly open and through draught).

Figure 3: Particle number in kitchen measurements

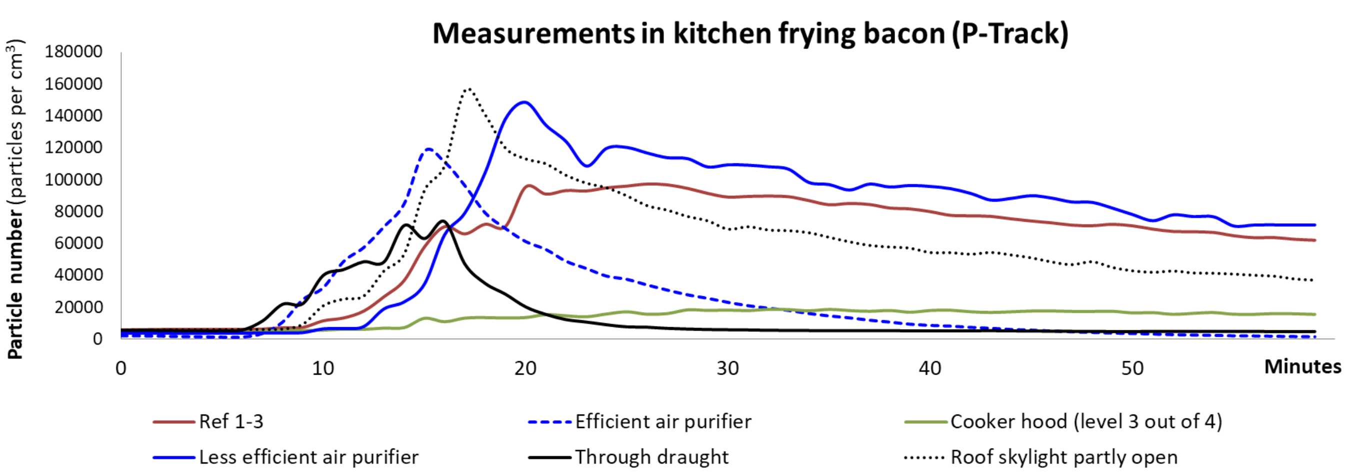
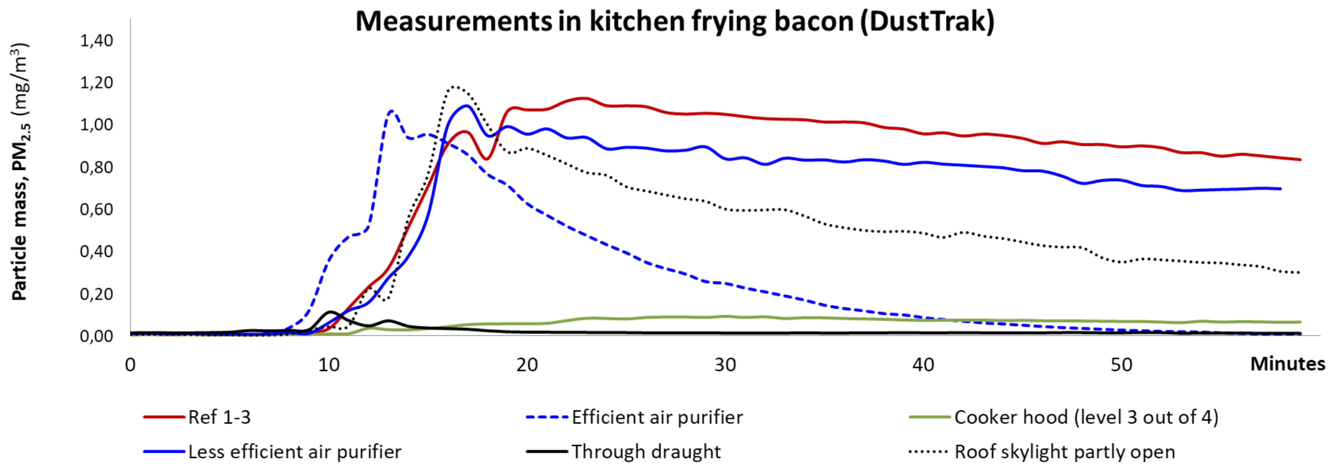


Figure 4: Particle mass ($PM_{2.5}$) in kitchen measurements



From figure 3 and 4 are seen that air purifier 1 (best of tested) significantly reduces exposure to fine and ultrafine particles compared to reference measurements whereas air purifier 2 does *not* seem to reduce exposure significantly compared to reference measurements. However, using an efficient cooker hood or through draught are much more efficient than the best air purifier in reducing the average exposure whereas opening just one window (roof skylight partly open) was less efficient.

Figure 5 and 6 show graphs for particle removal from bedroom measurements (using scented candles) with air purifier 1 (efficient air purifier) and air purifier 8 (less efficient air purifier) compared to using mechanical ventilation on the highest level (level 4).

Figure 5: Particle number in bedroom measurements

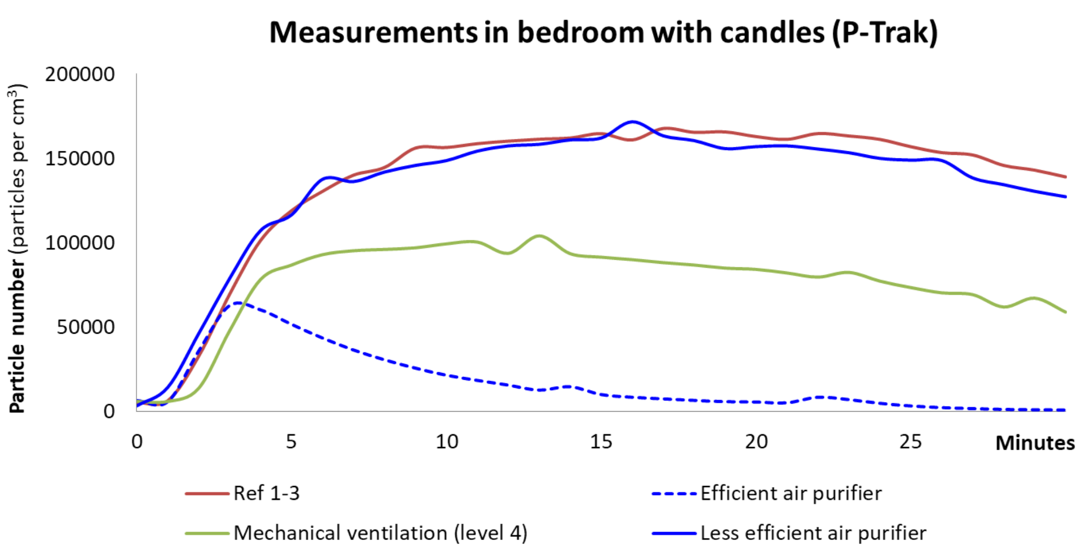
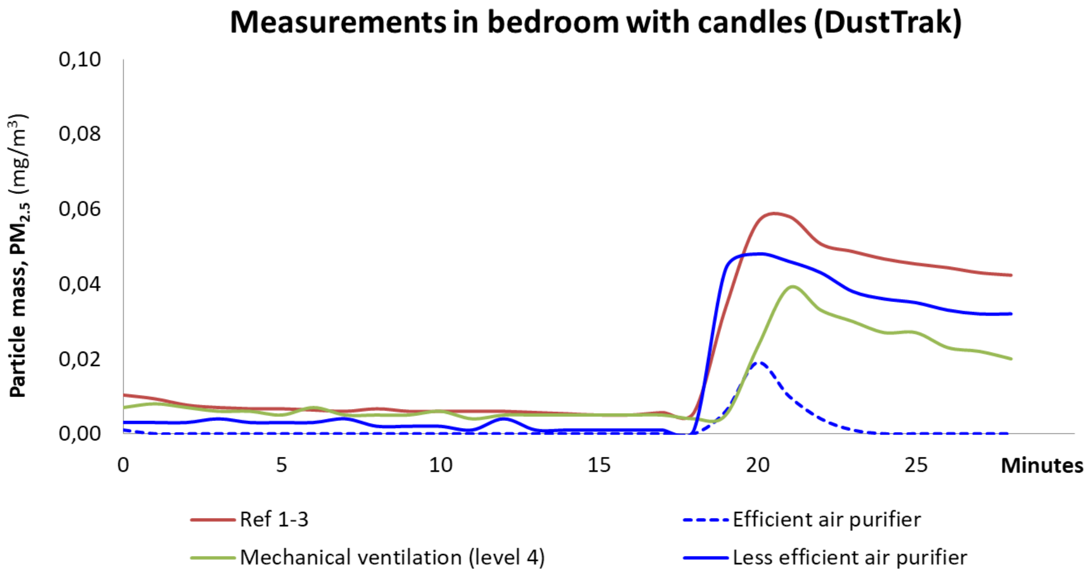


Figure 6: Particle mass ($PM_{2.5}$) in bedroom measurements



From figure 5 and 6 are seen that air purifier 1 significantly reduces exposure to fine and ultrafine particles compared to reference measurements whereas air purifier 8 does *not* seem to reduce exposure significantly compared to reference measurements. Furthermore, air purifier 1 seems to be much better in reducing exposure than the mechanical ventilation of the house. The increase in particle mass after 18-19 minutes is caused by smoke from blowing out the candles (candles are blown out after 20 min. but on the graphs, the first minute of measurement is set to time = 0, and the smoke might affect measurements in minute 19 to 20 i.e. this causes the increase to occur before minute 20 on the graphs).

The air purifier that show the best test-results reduces particle exposure by more than 90% in a smaller room (bedroom) compared to reference exposure. However, most of the purifiers tested show much lower reductions. And even though a good air purifier might remove more than 99% of the particle pollution during filtration, this purifier will *not* reduce the exposure 99% as people inhale polluted air before the purifier can clean it.

Discussion

This study investigates how efficient eight different mobile air purifiers are in reducing the exposure to particle pollution and VOCs from normal pollution sources inside private homes. However, it does not investigate how efficient air purifiers are in reducing the average exposure to particle pollution in a private home on a daily basis (efficient air purifiers can reduce pollution levels to far below outdoor levels in periods without active pollution sources in the home).

It was decided to use a small ventilator during measurements to mimic human activity causing air movements (air mixture) in a reproducible way. This resulted in fully mixed air in the kitchen and the bedroom. This will probably overestimate the efficiency for those air purifiers that are not mixing the air sufficiently, but partly compensate for the kitchen being a larger room (especially in volume due to vaulted ceiling) than the recommended room size for most purifiers. However, this made it possible to see how efficient air purifiers might be in larger rooms, which may also represent a situation where air purifiers are placed in a room with open doors to connecting rooms.

The test results rely on stable pollution sources (frying bacon in the kitchen and scented candles in the bedroom) providing almost the same pollution level during each measurement, as reflected in the reference measurements. However, some of the results indicate that the pollution source (especially frying bacon) for some reason may emit more particles during some of the test-cycles; although, not to a level that will significantly affect the results of an efficient air purifier. Furthermore, there should be no other significant pollution sources in the room that affect the results, which - as indicated above – is probably not the case for VOCs. Hence, the results for VOC should only be used with this in mind.

If the cooker hood had been used on the highest level (level 4 out of 4) it would probably have reduced the exposure from frying bacon even more than when used on level 3 during the measurements (table 2). This might have been a fairer comparison since air purifiers were tested on the highest level (or auto-function). On the other hand, the test of the cooker hood, being very efficient just on level 3, highlights the importance of a good cooker hood placed over the stove. And as the cooker hood is quite noisy at level 4, it may be more likely that people use lower levels to avoid noise.

The CPC-3007 is technically only made to measure precise particle numbers up to 100,000 particles/cm^3 and results from graphs with higher numbers should, of course, only be used with this in mind. However, all results for the reduced exposure in this report are based on P-Track measurements (can measure up to 500,000 particles/cm^3).

Part of the experimental set-up is also made with the thought in mind on how people would behave. For instance, the placement of the air purifier has been thought to be where it would most likely be placed in the home. Some air purifiers, however, require a certain distance to other objects (e.g., the wall). To fulfil such a requirement would be problematic in the bedroom, as the only place the purifier could be placed then, would be on the bed or by the end of the bed, both being very inconvenient.

In future measurements, we recommend testing air purifiers three-five times in each room and to do long-term testing (for one month or longer with the air purifier on and one month with it off). Also, investigate the lifetime of filters and filter efficiency during the filter lifetime. However, the resources needed for such investigations were outside the scope of this study.

Conclusion

Through draught and an efficient cooker hood during cooking were more efficient than the air purifiers that showed the best test-results whereas opening just one window was less efficient. Mechanical ventilation was less efficient in reducing exposure to particles from candles than efficient purifiers. Some mobile air purifiers significantly reduce particle exposure from pollution sources in homes while other purifiers have limited or no significant effect. We cannot conclude on VOC removal based on measurements. Air purifiers with HEPA filters and other efficient mechanical filters typically show high removal of particles. However, the capacity of the air purifier should fit the room size; and the location of the purifier in the room, the distance to the pollution source as well as the air movements in the room are crucial for the purifier's capability to reduce exposure. Even though efficient air purifiers might remove more than 99% of the particle pollution during filtration, these purifiers will not reduce the exposure by 99% as people inhale the polluted air in the room before purifiers can clean it.

Appendices

Appendix 1: Details on the eight tested air purifiers.

Appendix 2: Graphs from reference measurements.

Appendix 3: Graphs from air purifiers, cooker hood, etc.

Appendix 1: Details on the eight tested air purifiers

The data and statements on the air purifiers (APs) in the table below are taken directly from the supplier manual for each air purifier.

Air Purifier	Technologies	Efficiency	Other statements	Declared room size	Recom-mended room size
AP 1	HEPA, activated carbon filter, UV-LED photocatalytic oxidation, ionisator	99.97% for particles of 0.01 my (µ).	Fast removal of 99.97% of all bacteria, viruses, pollen, mould, and other particles down to the size of 0.1 my (µ).	80 m^2	65 m^2
AP 2	Catalytic filter, HEPA- and activated carbon filter	Captures 99.95% of contaminants down to 0.1 microns.	Detects dust, allergens, and pollen. Even depletes formaldehyde …also have the powerful Air Multiplier™-technology, which cleans the entire room.	-	-
AP 3	UVC-light	74% reduction in bacteria counting and 81.5% reduction of fungal spores	Removes odour nuisances, fungal spores, bacteria and decreases contamination, and disinfect the indoor climate.	60 m3	30-35 m2
AP 4	Filter free IonFlow-technology	Removes 97% of all viruses along with the smallest damaging particles from the air.	This air purifier is therefore ideal for everyone suffering from asthma or allergies, and individuals that often have a cold.	50 m^2	-
AP 5	HEPA filter (High-Efficiency Particulate Absorption Filter), activated carbon filter, antivirus filter, negative ion generator	-	Very efficient air purifier for larger rooms, where the air purifier makes sure of a clean, fresh, and healthy indoor climate.	Larger rooms	-

Brand	Technologies	Efficiency	Other statements	Declared room size	Recom-mended room size
AP 6	Particle-/HEPA-filter and UV-sterilisator	Sterilisation rate: 99.97%	An air purifier is an efficient way of securing a good and healthy indoor climate, which is important to our health.	25 m^2	-
AP 7	5 step cleaning system: ionisator, activated carbon filter, fine particle filter, antibacterial coating, and a mesh pre-filter	-	Get a reliable and efficient air purifier for your house and get rid of health hazardous particles in the indoor air.	60/25 m^2	-
AP 8	Cold Plasma	-	Changes and cleanses air in rooms of up to 40 m^3. When the air is sucked in and blown through the changeable filter, the air is efficiently cleaned from bacteria, viruses, fungal spores, allergens, odour nuisances and smoke. F7-filter captures ultrafine particles of sizes down to 0.1 My (µ).	50 m^2	-

Appendix 2: Graphs from reference measurements

During reference measurements, pollution sources (frying bacon in the kitchen and scented candles in the bedroom) were active whereas no air purifiers, cooker hood or mechanical ventilation were in operation and windows and doors were closed.

Measurements in the kitchen were conducted on the kitchen table (around 1.5m from the frying pan) and on the dining table (around 3.5m from the frying pan). Measurements in the bedroom were conducted on the bed (around 2m from the scented candles).

The results for particle number, particle mass, and VOCs are shown in figures below.

Kitchen frying bacon

Figure 1.1: Particle number - P-Track on kitchen table

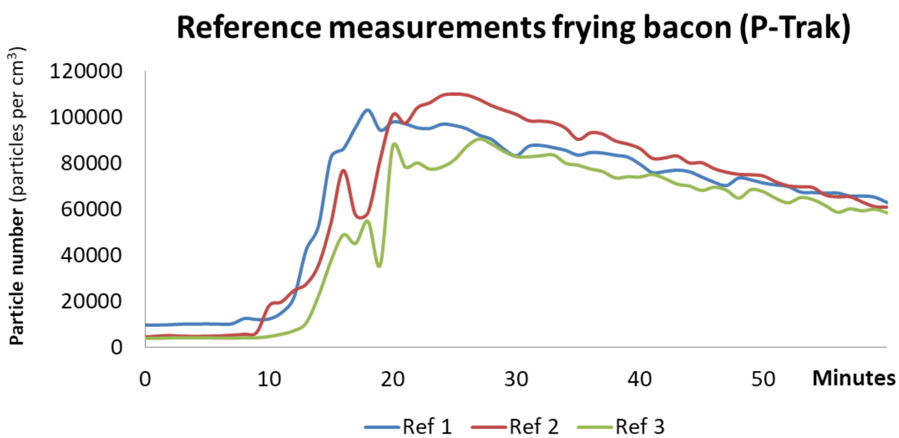


Figure 1.2: Particle number - CPC-3007 on dining table

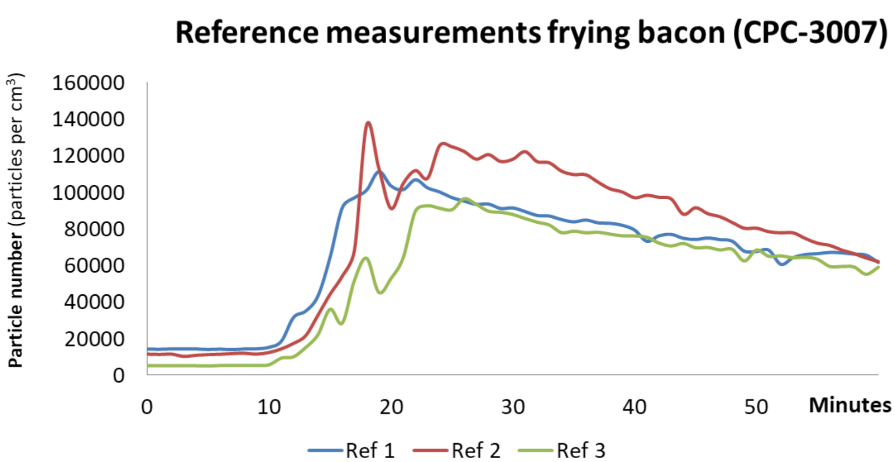


Figure 1.3: Particle mass ($PM_{2.5}$) - DustTrak on kitchen table

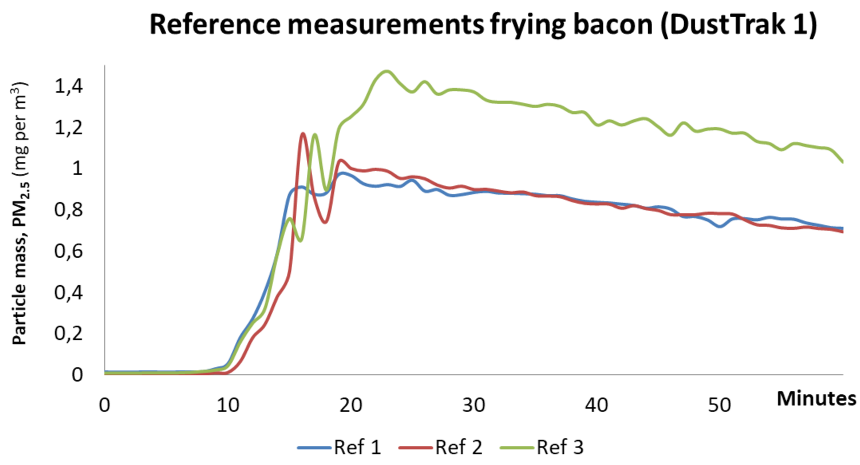


Figure 1.4: Particle mass ($PM_{2.5}$) - DustTrak on dining table

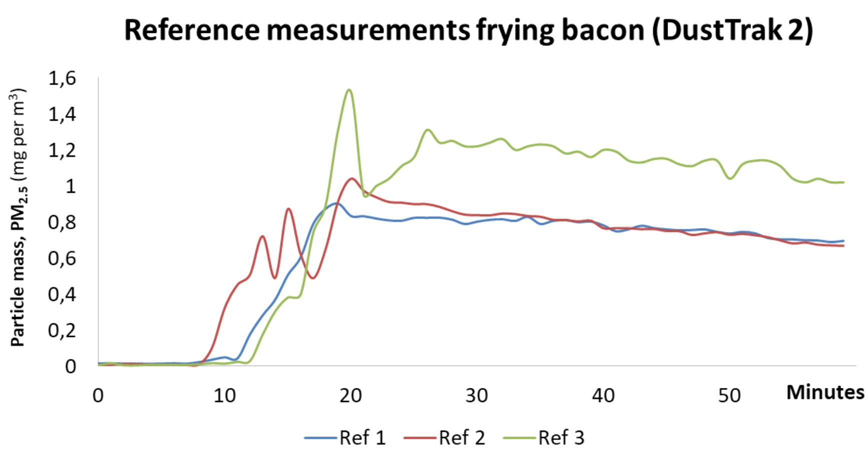
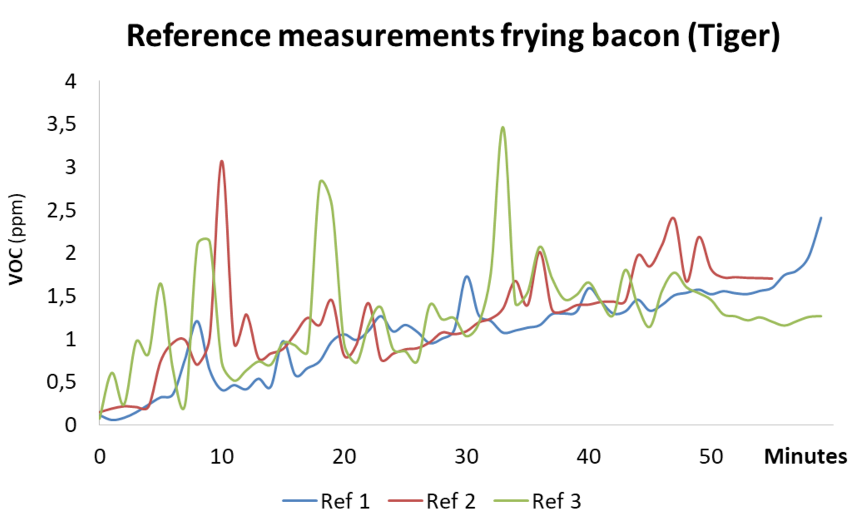


Figure 1.5: VOCs – Tiger TVOC Detector on dining table



Bedroom using candles

Figure 1.6: Particle number - P-Track on bed

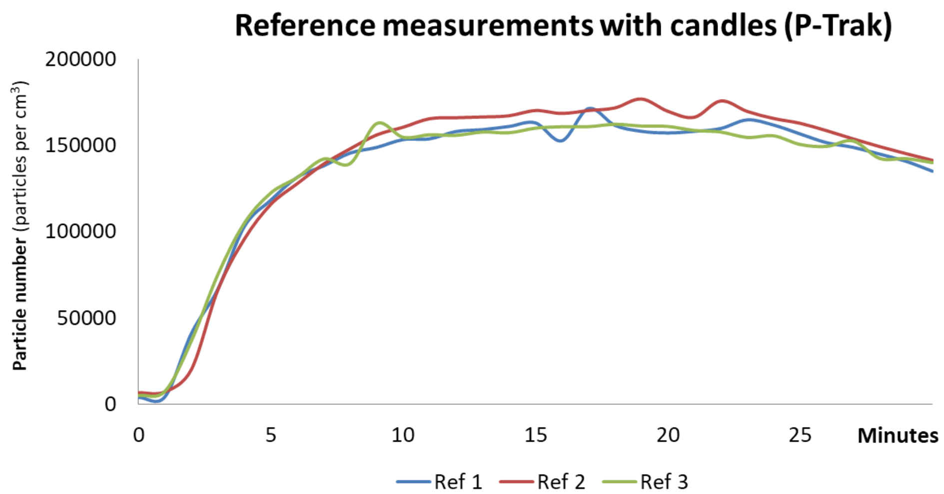


Figure 1.7: Particle number - CPC-3007 on bed

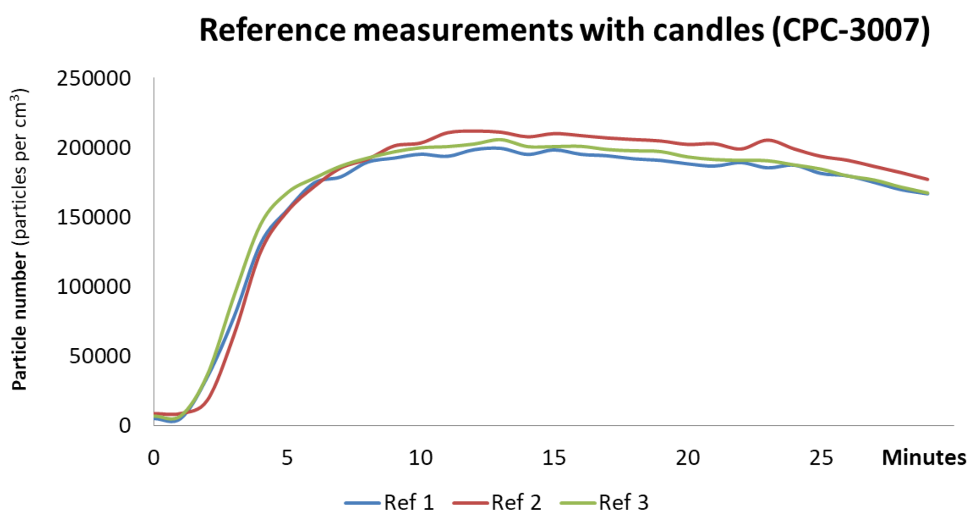


Figure 1.8: Particle mass ($PM_{2.5}$) - DustTrak on bed

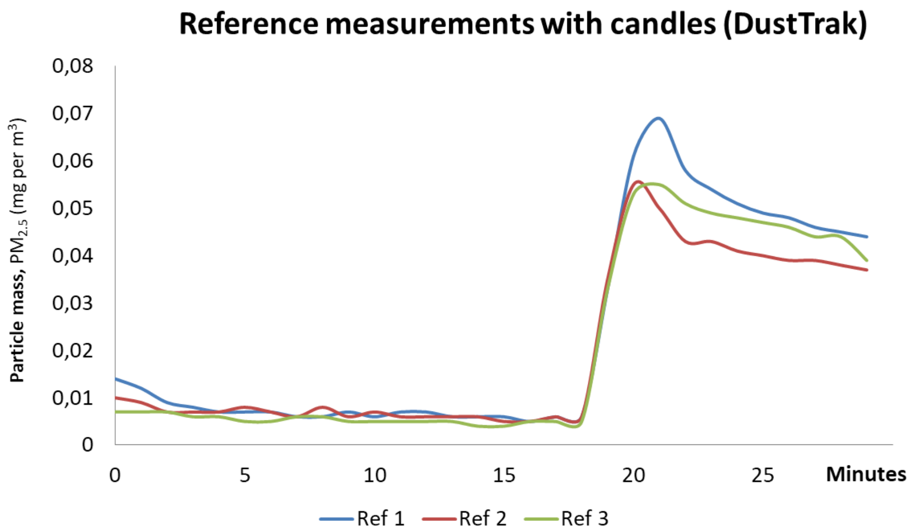
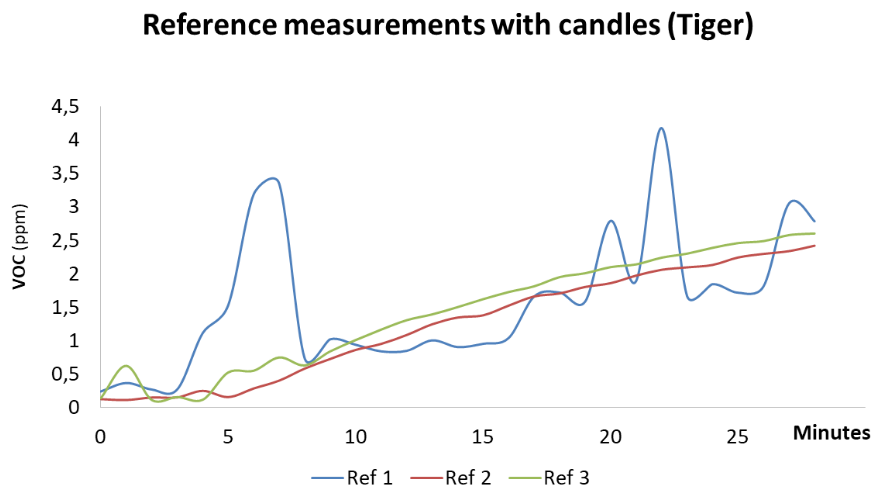


Figure 1.9: VOCs – Tiger TVOC Detector on bed



During first reference measurements (blue graph in figure 1.9 above) a person entered the room after 3 minutes and again after 20 minutes to manually measure the particle number in the room to see if the air was fully mixed. This causes clear peaks, probably due to perfume. Due to this disturbance, we have only used reference measurement 2 and 3 in this report.

Appendix 3: Graphs from air purifiers, cooker hood, etc.

During tests of air purifiers, pollution sources (frying bacon in the kitchen and using scented candles in the bedroom) where active while no cooker hood or mechanical ventilation were in operation and windows/doors were closed. Cooker hood and manual airing were individually tested as alternative to air purifiers when frying bacon. Mechanical ventilation was tested as alternative to air purifiers when using scented candles in the bedroom.

Measurements in the kitchen were conducted on the kitchen table (around 1.5m from the frying pan) and on the dining table (around 3.5m from the frying pan). Measurements in the bedroom were conducted on the bed (around 2m from the scented candles). The P-Track and the CPC-3007 showed very similar relative reduction in particle number pollution during measurements in the bedroom. Hence, only a P-Track was used in most experiments.

The results for particle number, particle mass, and VOCs are shown in figures below.

Air Purifier 1: AP1

Figure 2.1.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

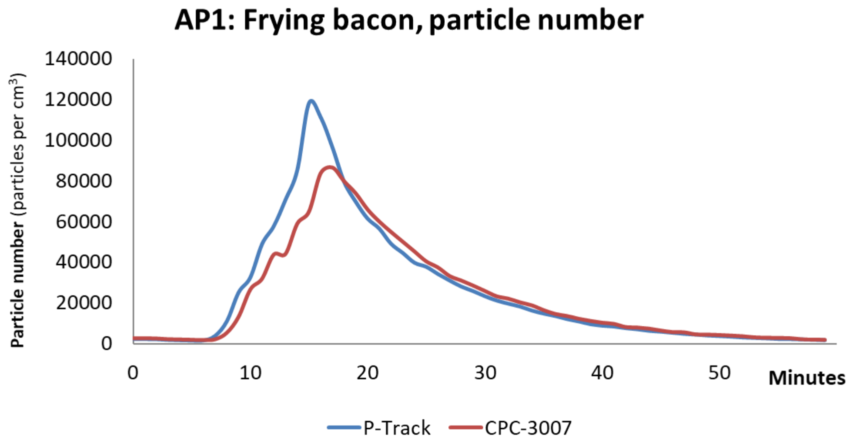


Figure 2.1.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

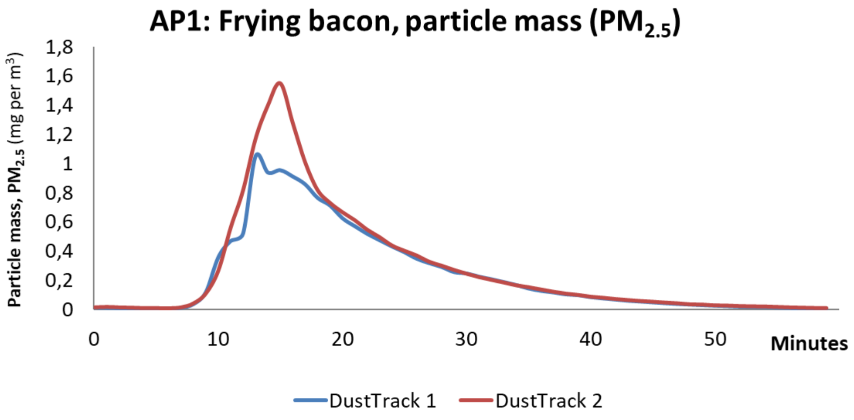


Figure 2.1.3: VOCs (Tiger TVOC Detector on dining table).

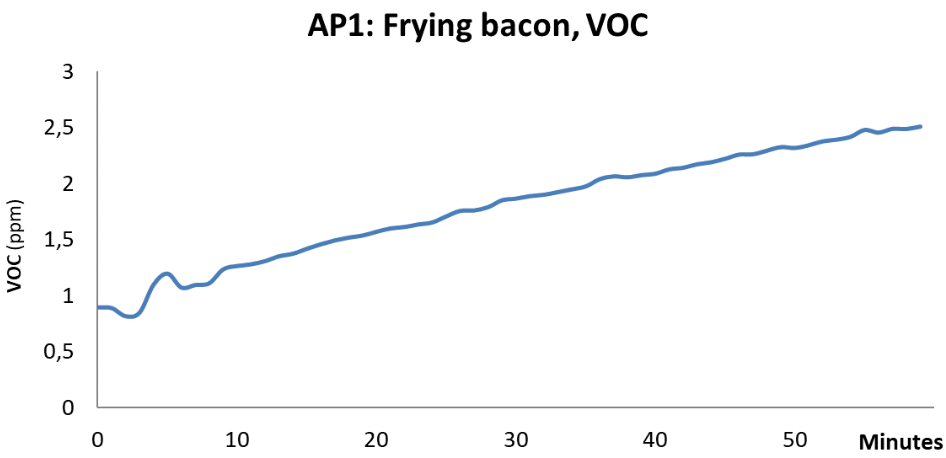


Figure 2.1.4: Particle number (P-Track and CPC-3007 on bed).

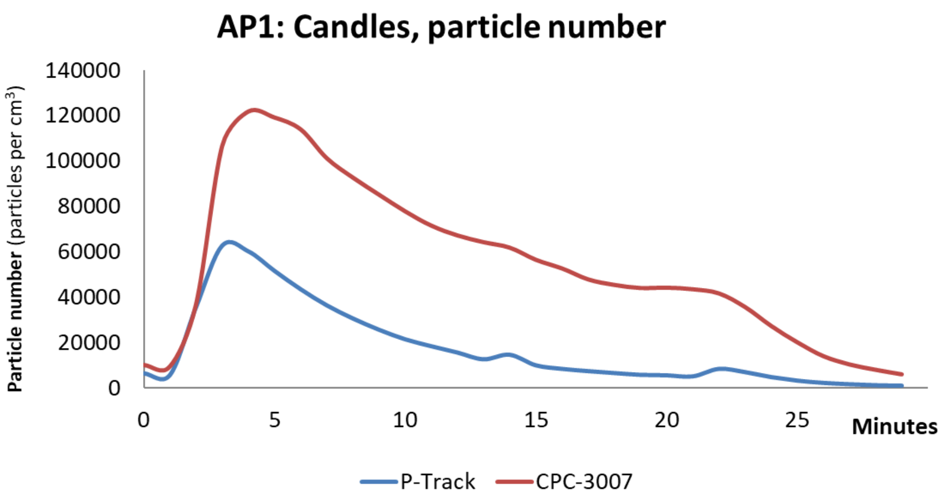


Figure 2.1.5: Particle mass ($PM_{2.5}$) - DustTrak on bed

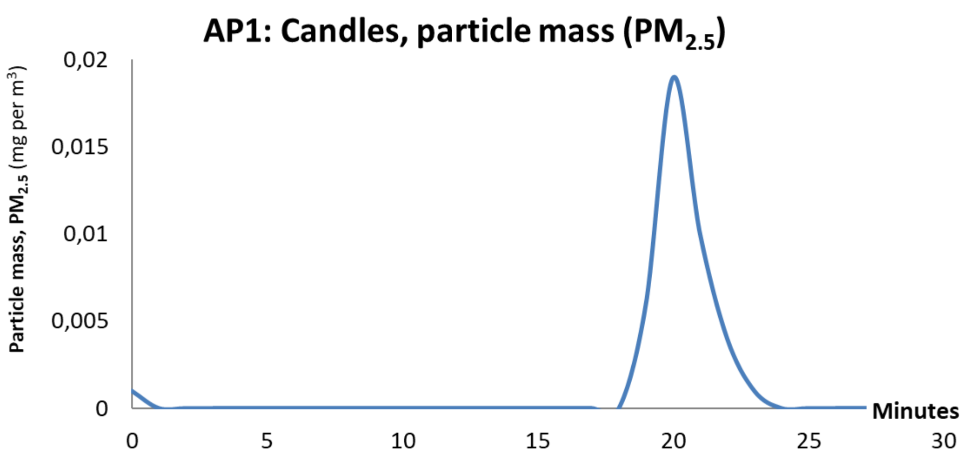
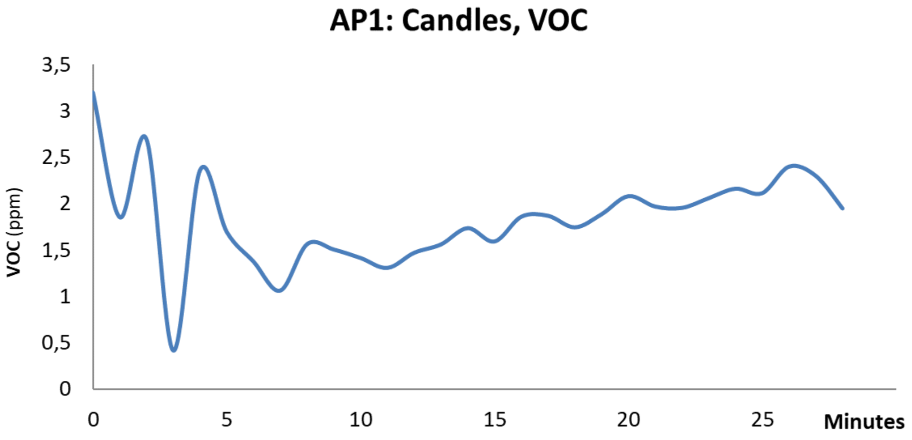


Figure 2.1.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 2: AP2

Figure 2.2.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

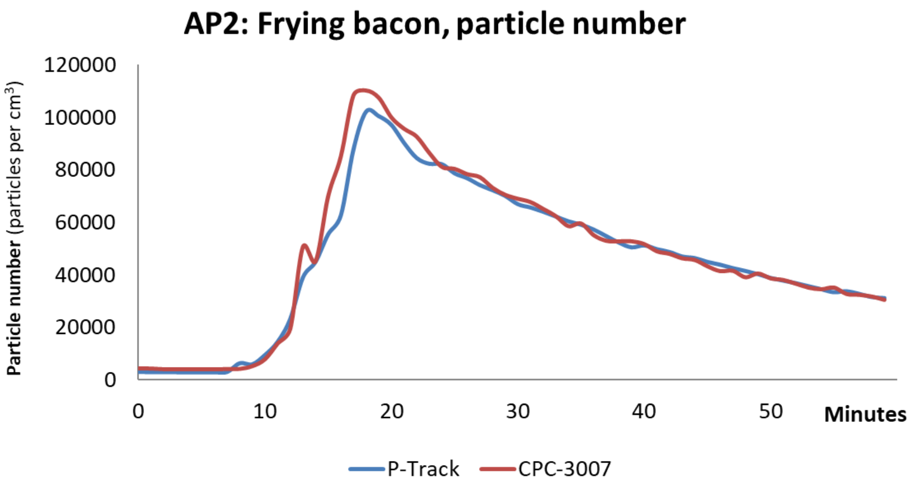


Figure 2.2.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

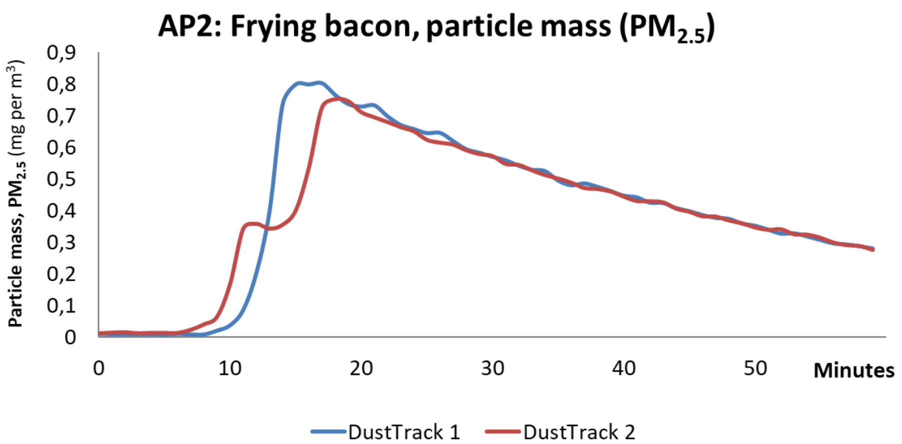


Figure 2.2.3: VOCs (Tiger TVOC Detector on dining table).

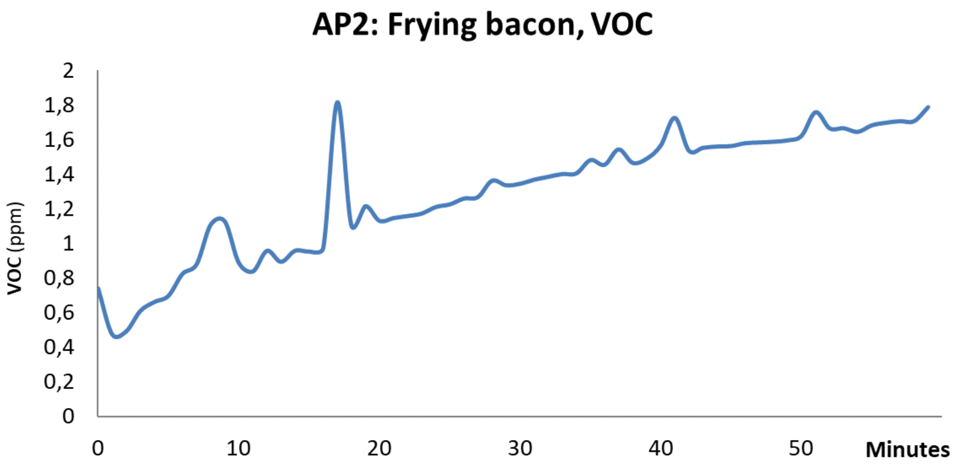


Figure 2.2.4: Particle number (P-Track on bed).

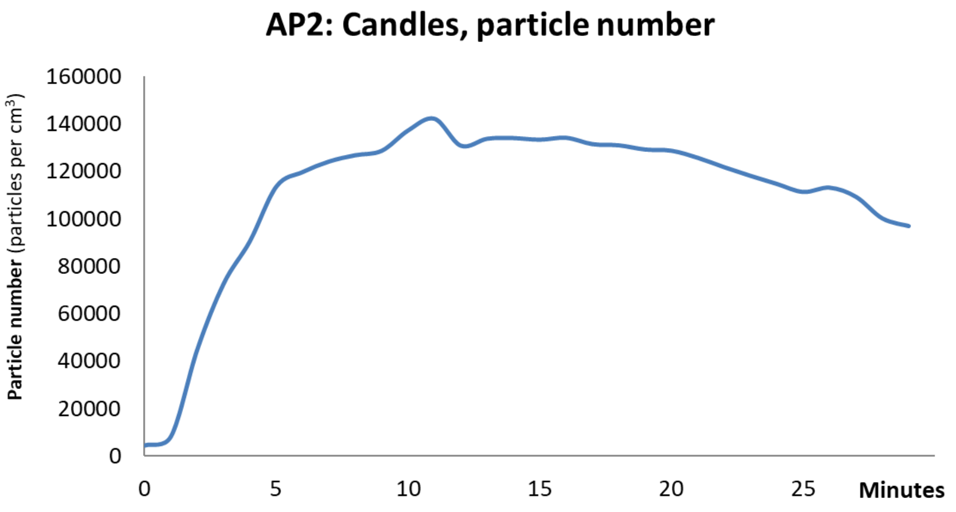


Figure 2.2.5: Particle mass ($PM_{2.5}$) - DustTrak on bed

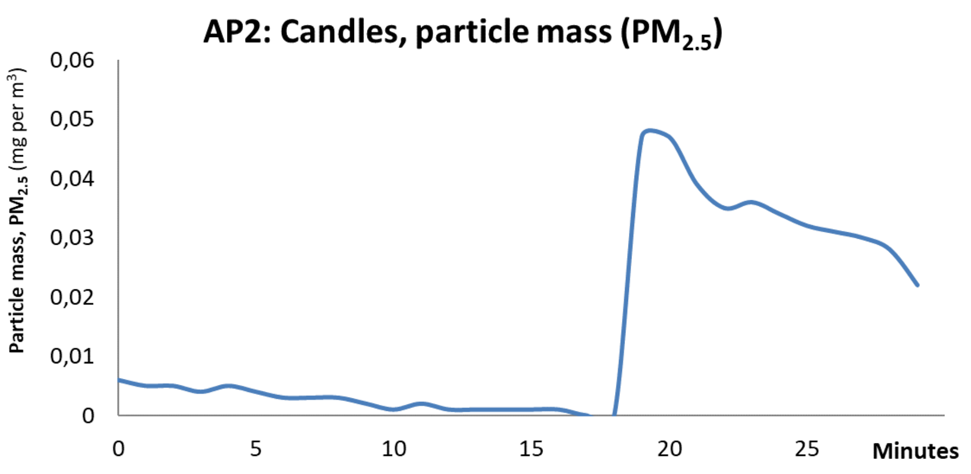
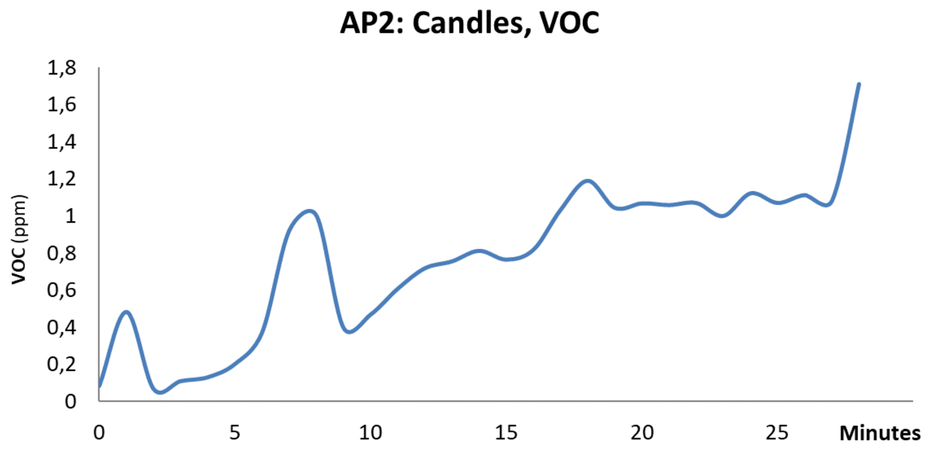


Figure 2.2.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 3: AP3

Figure 2.3.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

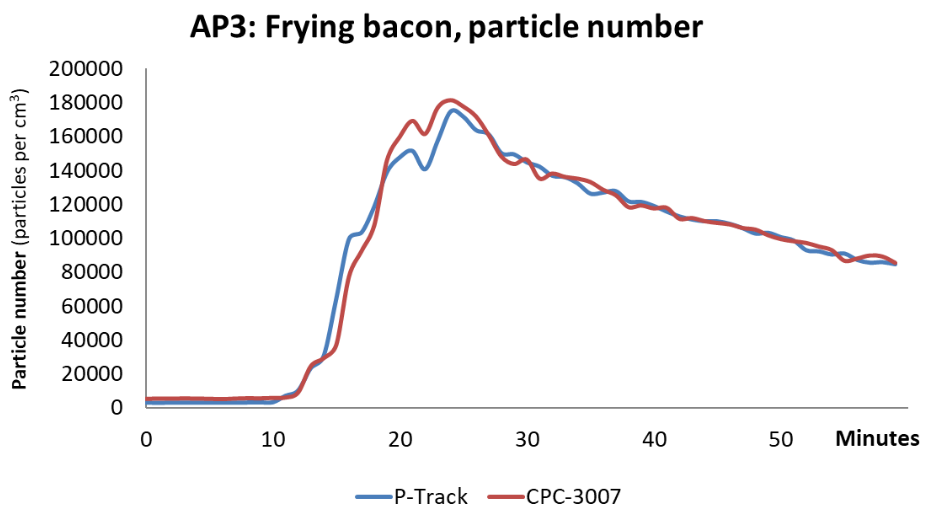


Figure 2.3.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

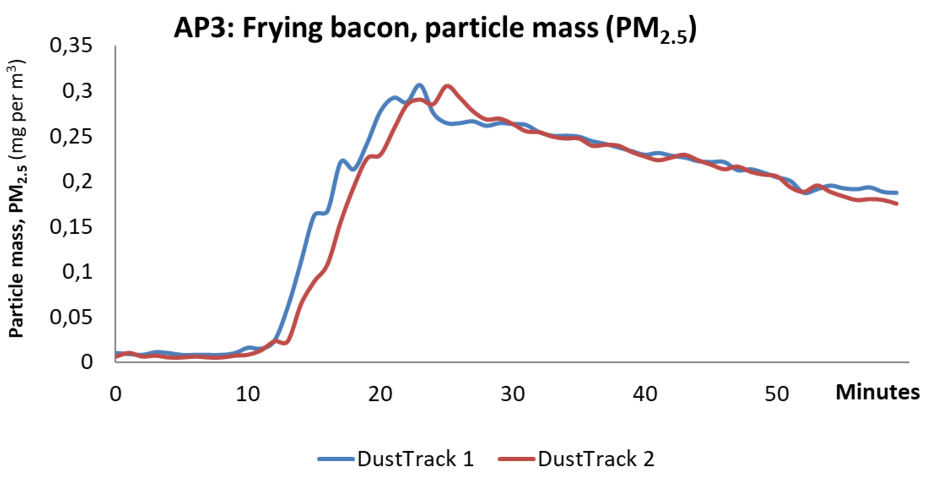


Figure 2.3.3: VOCs (Tiger TVOC Detector on dining table).

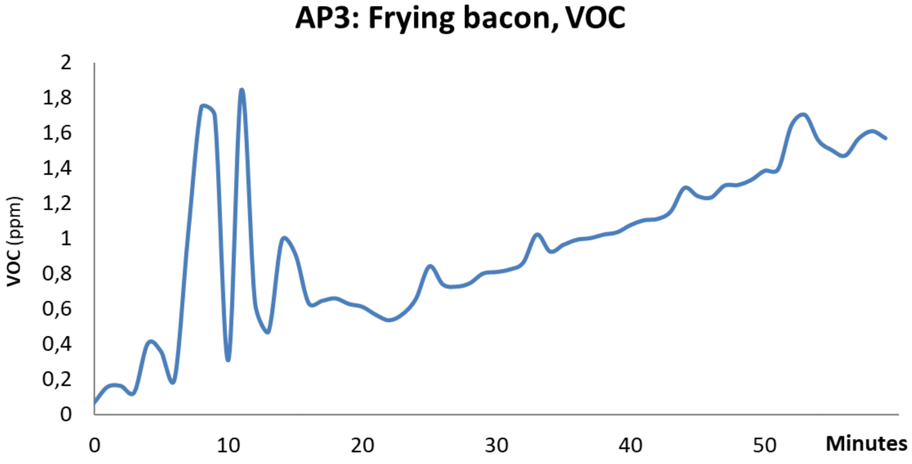


Figure 2.3.4: Particle number (P-Track on bed).

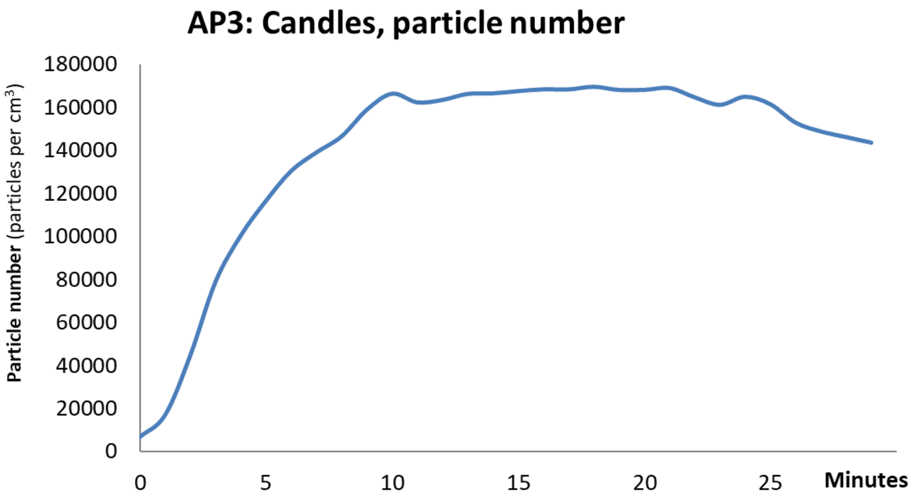


Figure 2.3.5: Particle mass ($PM_{2.5}$) - DustTrak on bed

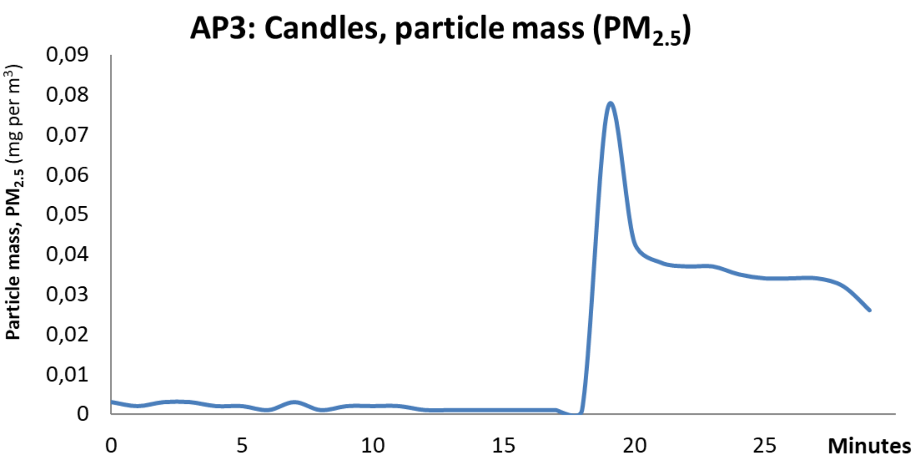
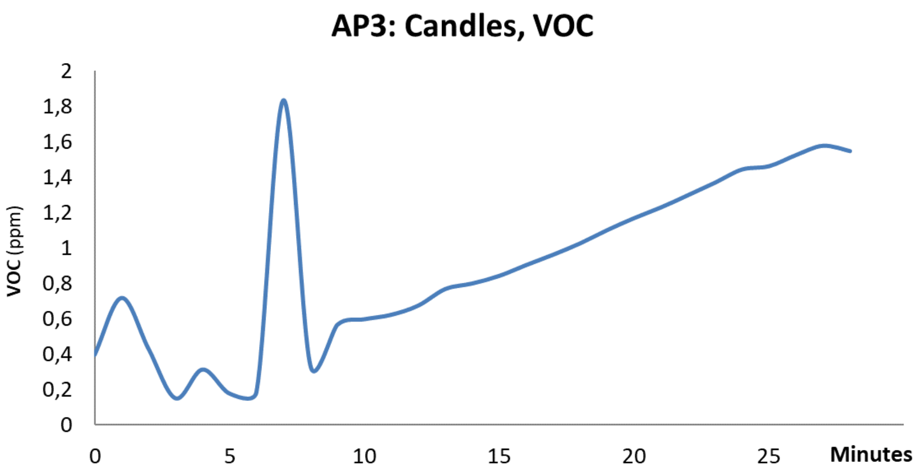


Figure 2.3.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 4: AP4

Figure 2.4.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

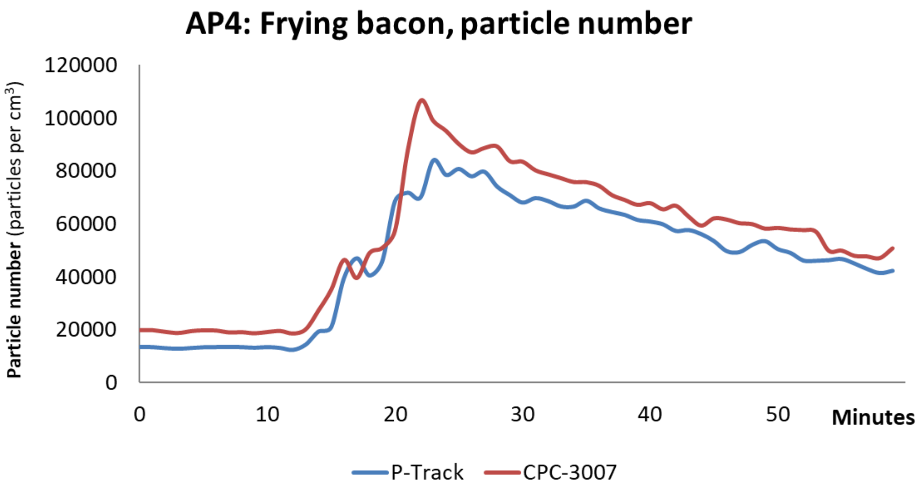


Figure 2.4.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

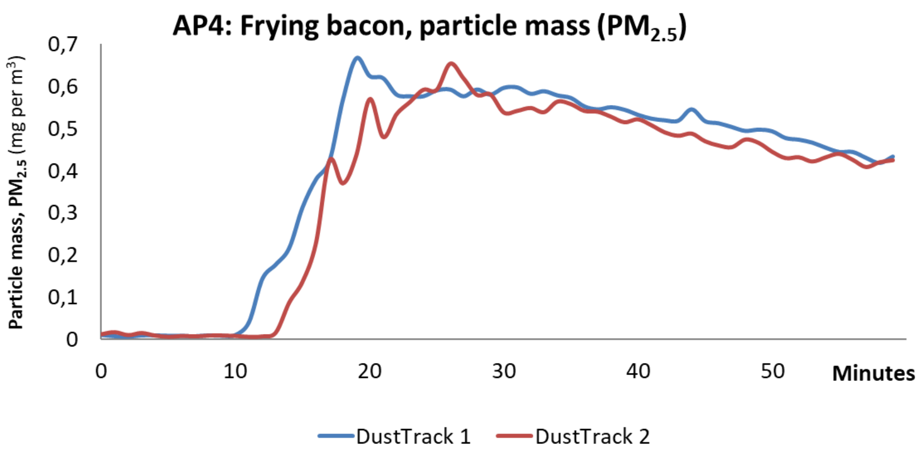


Figure 2.4.3: VOCs (Tiger TVOC Detector on dining table).

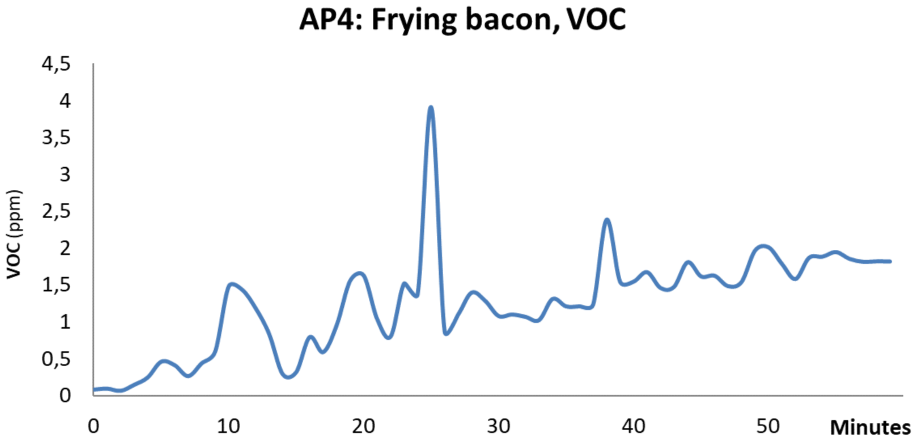


Figure 2.4.4: Particle number (P-Track on bed).

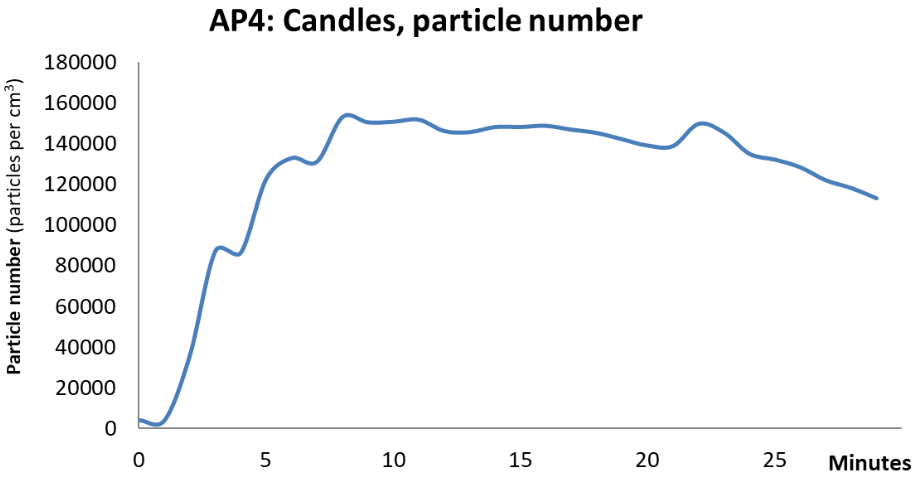


Figure 2.4.5: Particle mass ($PM_{2.5}$) – DustTrak on bed

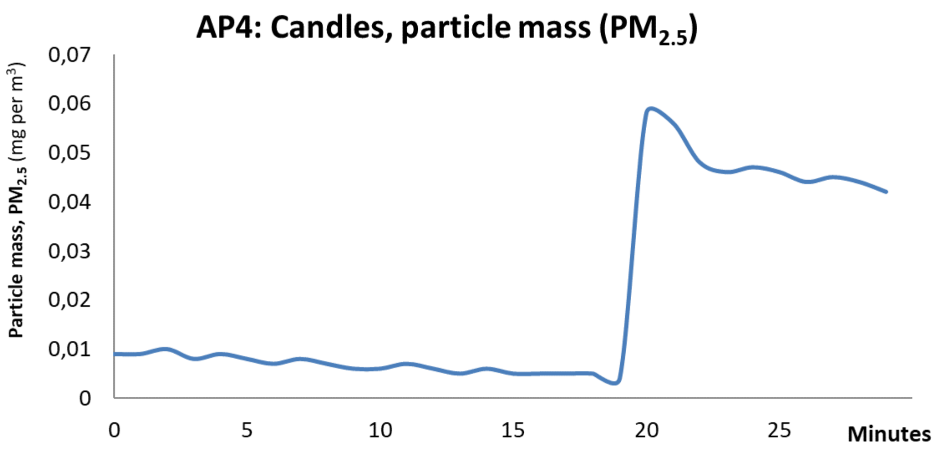
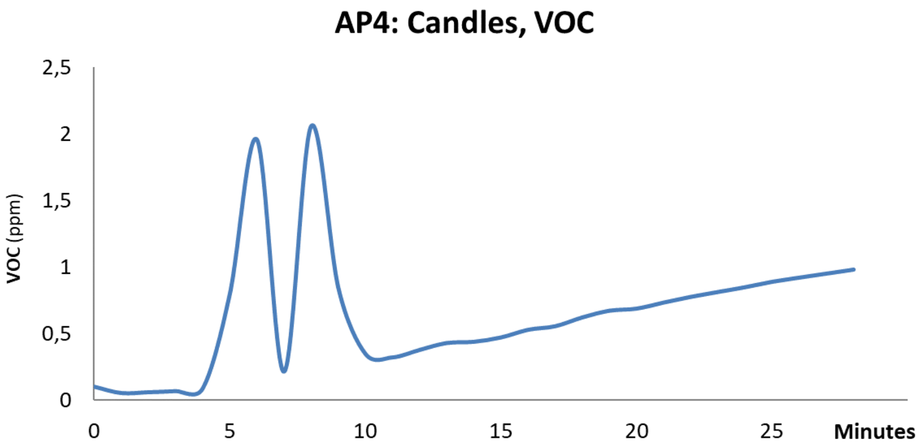


Figure 2.4.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 5: AP5

Figure 2.5.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

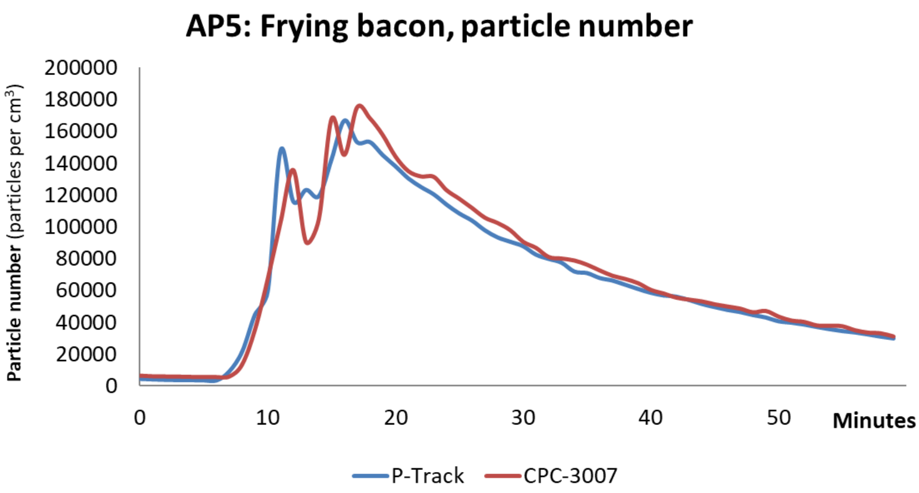


Figure 2.5.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

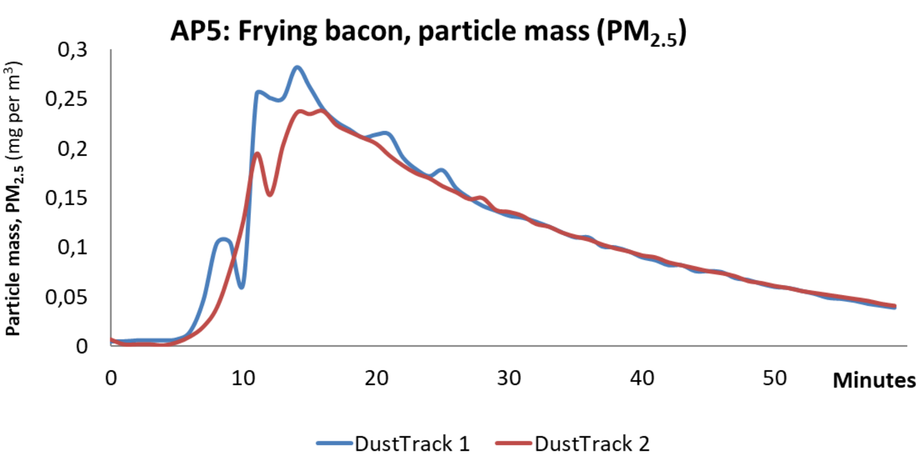


Figure 2.5.3: VOCs (Tiger TVOC Detector on dining table).

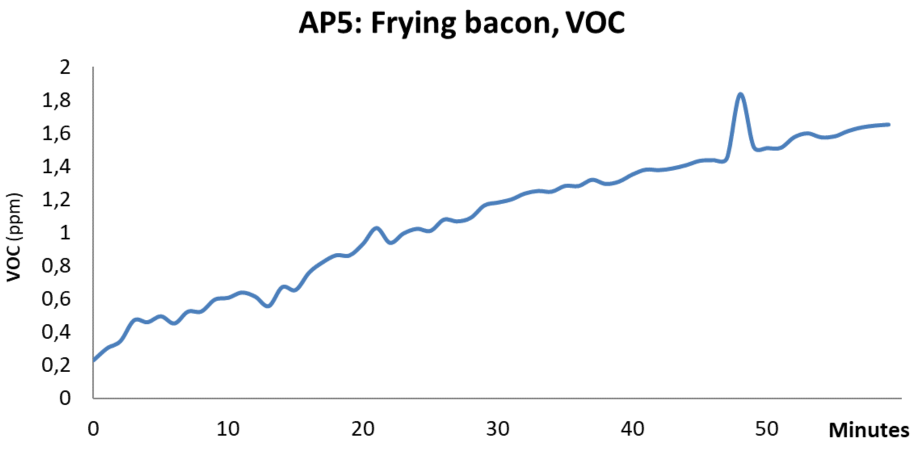


Figure 2.5.4: Particle number (P-Track on bed).

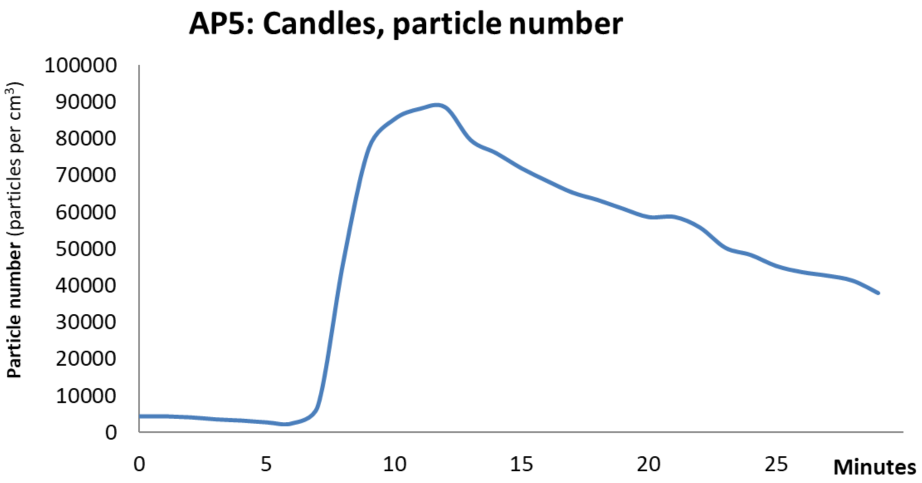


Figure 2.5.5: Particle mass ($PM_{2.5}$) – DustTrak on bed

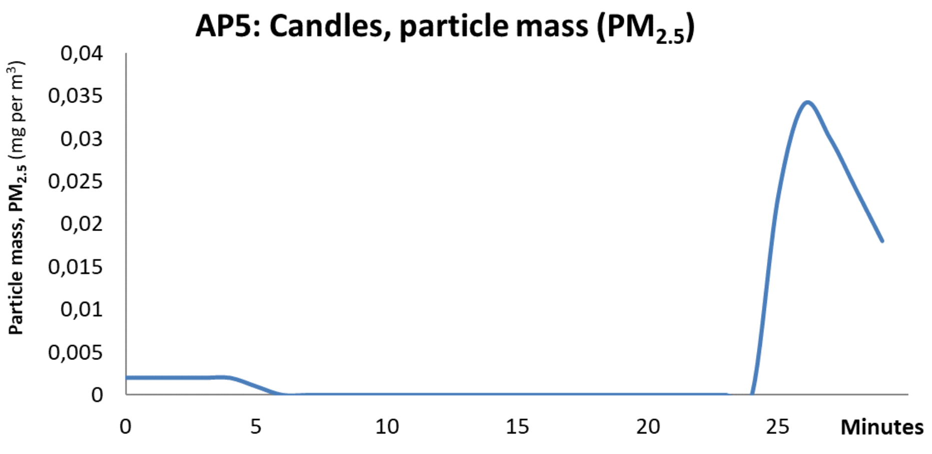
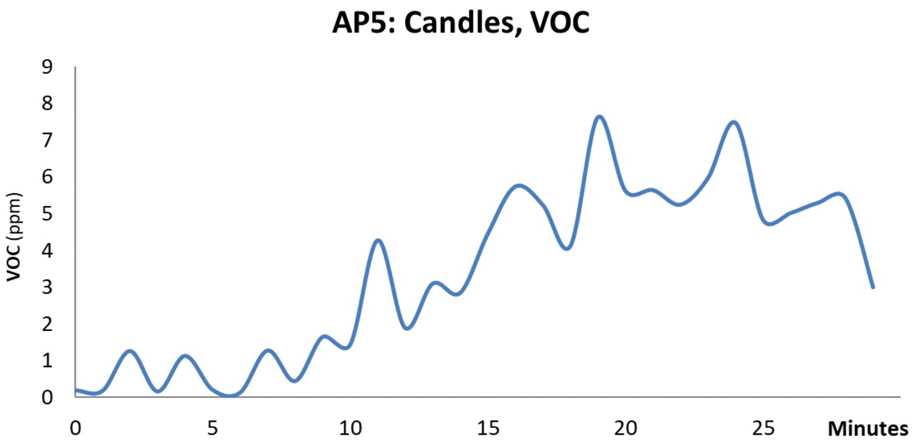


Figure 2.5.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 6: AP6

Figure 2.6.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

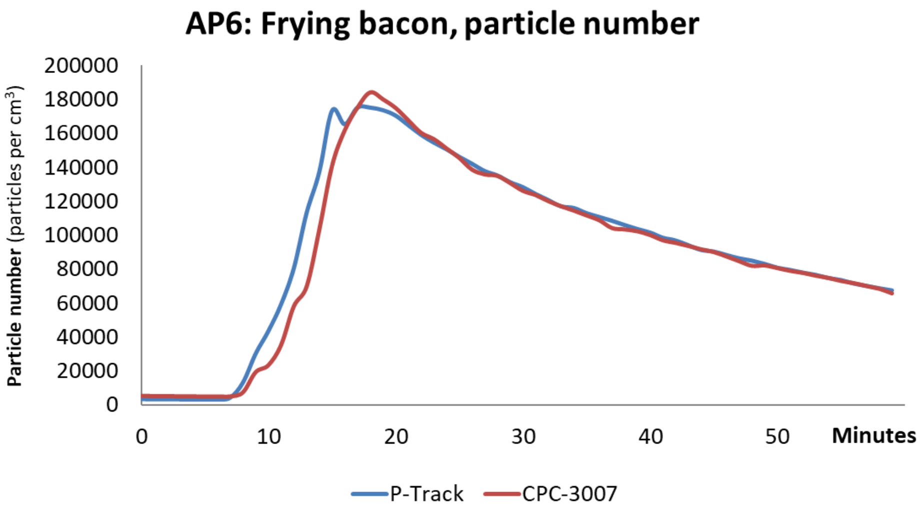


Figure 2.6.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

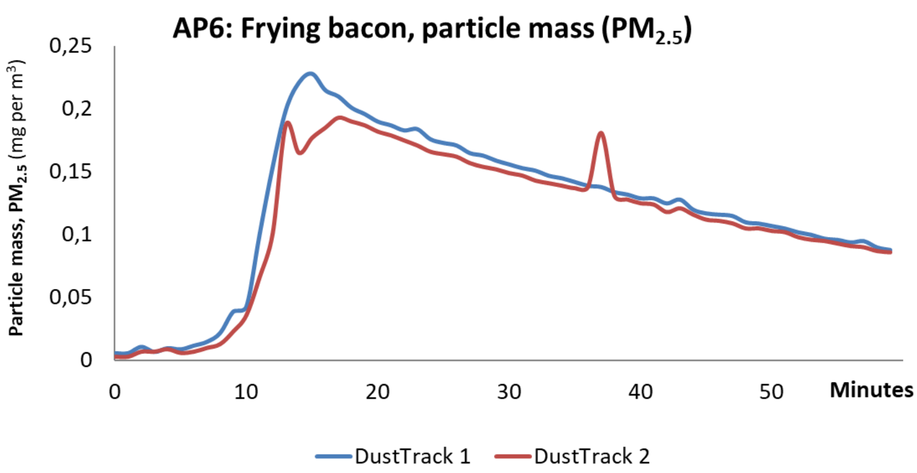


Figure 2.6.3: VOCs (Tiger TVOC Detector on dining table).

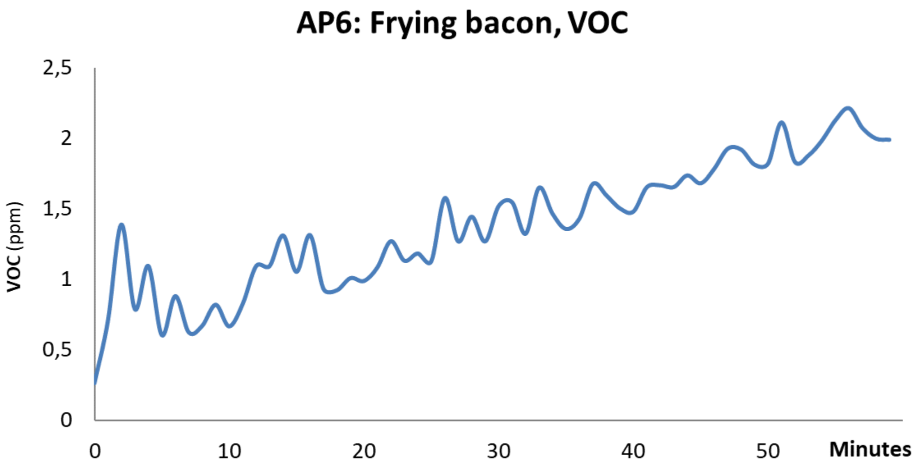


Figure 2.6.4: Particle number (P-Track and CPC-3007 on bed).

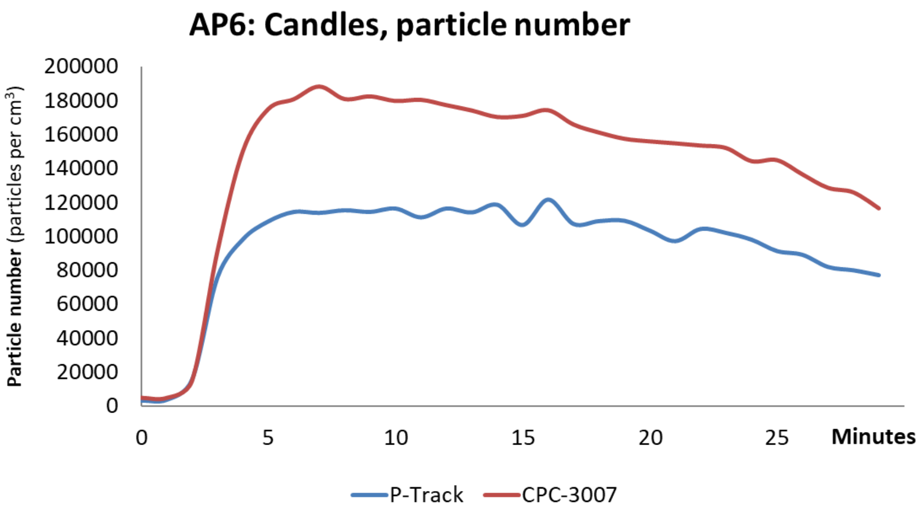


Figure 2.6.5: Particle mass ($PM_{2.5}$) – DustTrak on bed

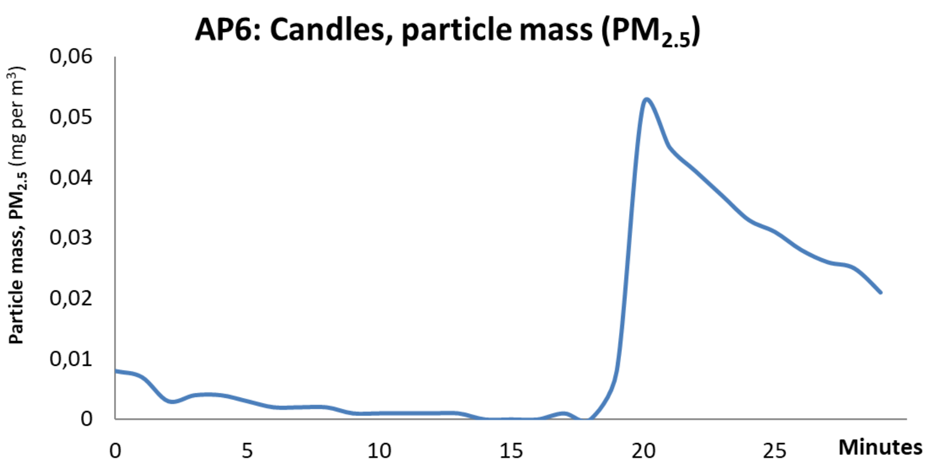
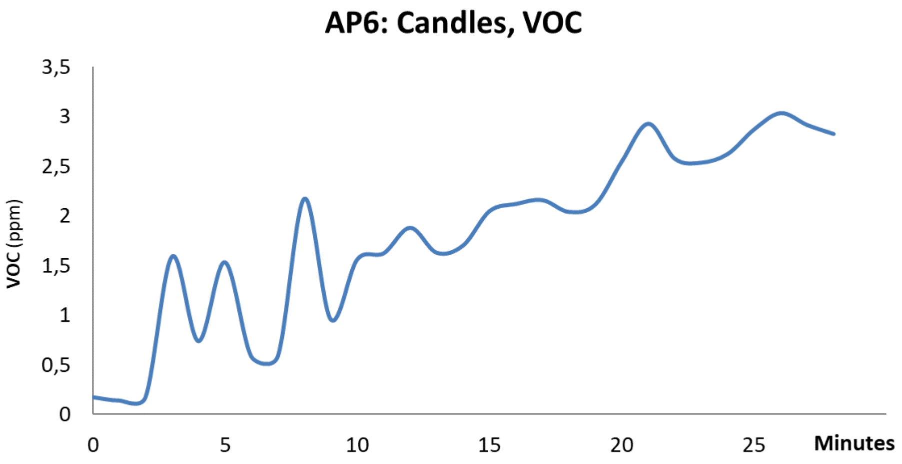


Figure 2.6.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 7: AP7

Figure 2.7.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

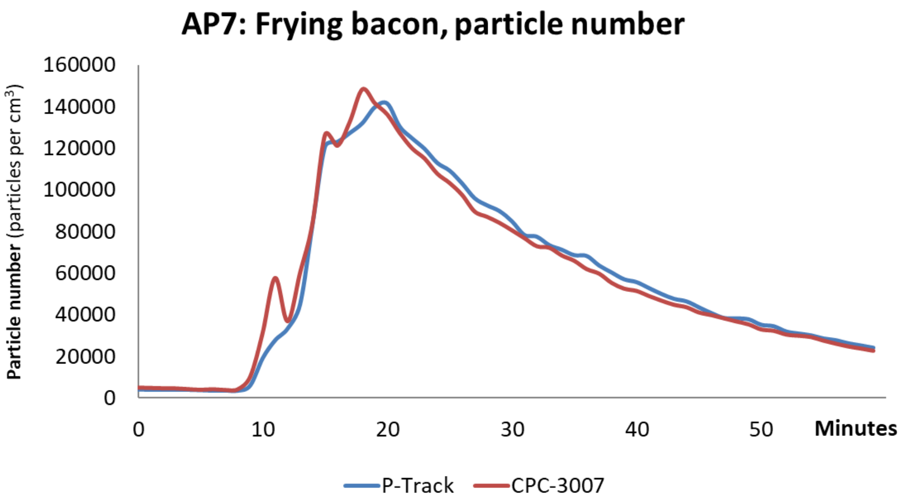


Figure 2.7.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

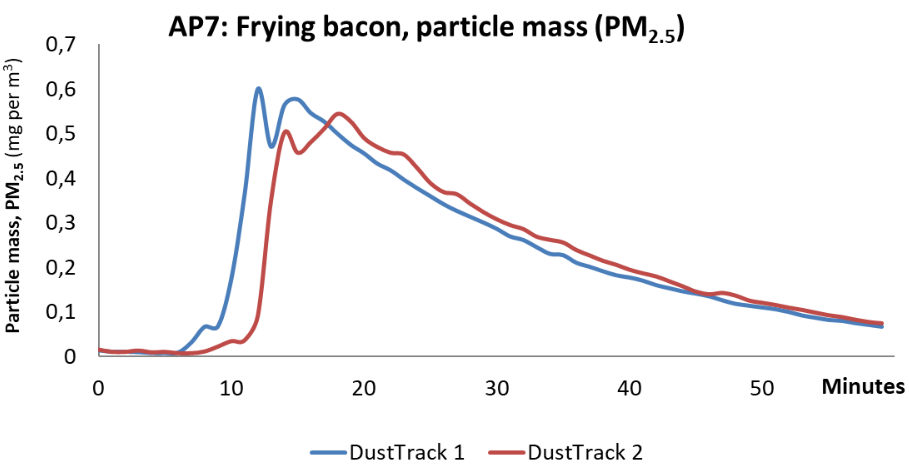


Figure 2.7.3: VOCs (Tiger TVOC Detector on dining table).

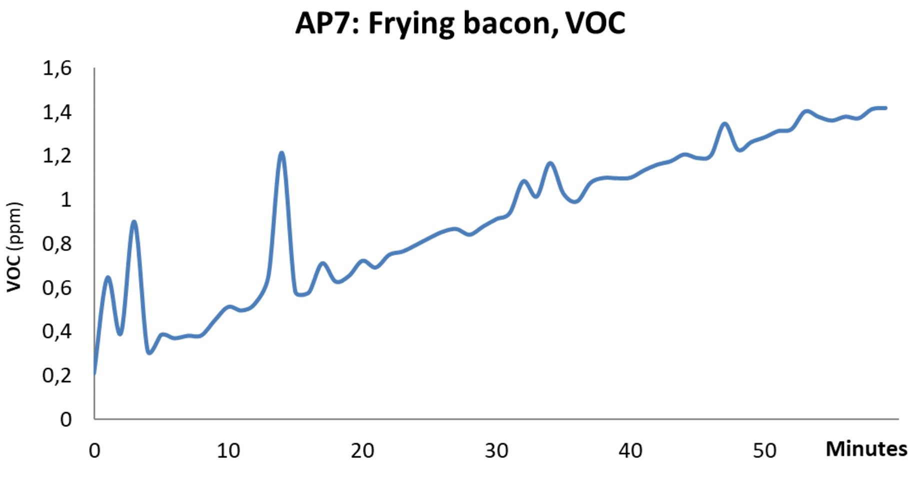


Figure 2.7.4: Particle number (P-Track on bed).

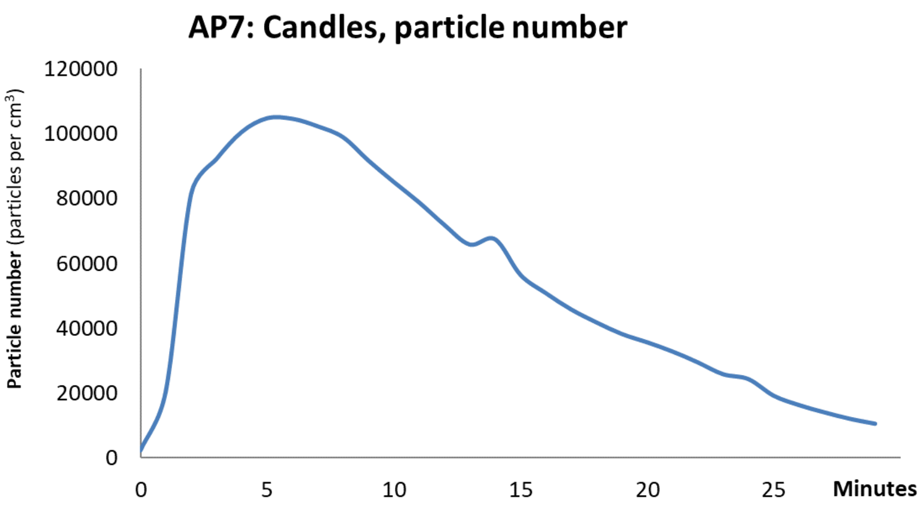


Figure 2.7.5: Particle mass ($PM_{2.5}$) – DustTrak on bed

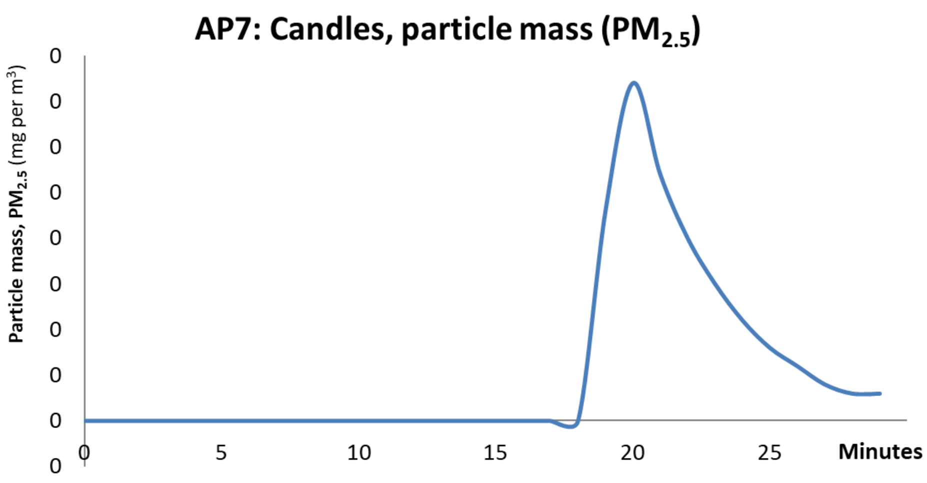
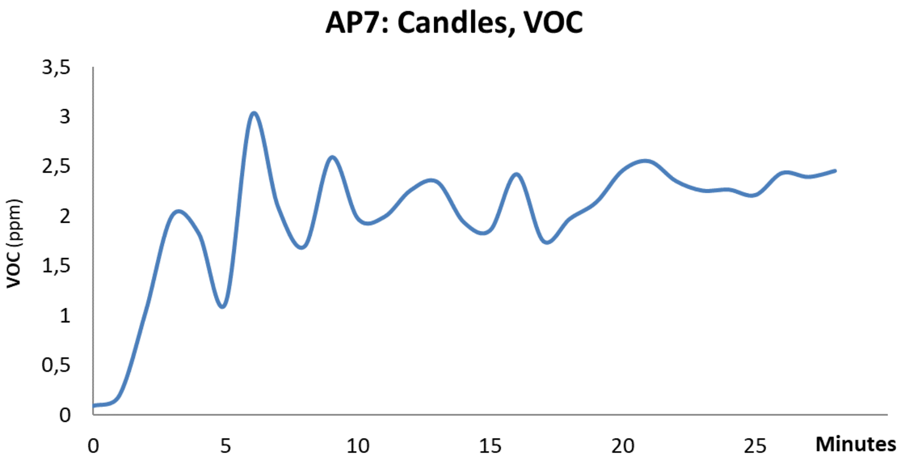


Figure 2.7.6: VOCs – Tiger TVOC Detector on bed



Air Purifier 8: AP8

Figure 2.8.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

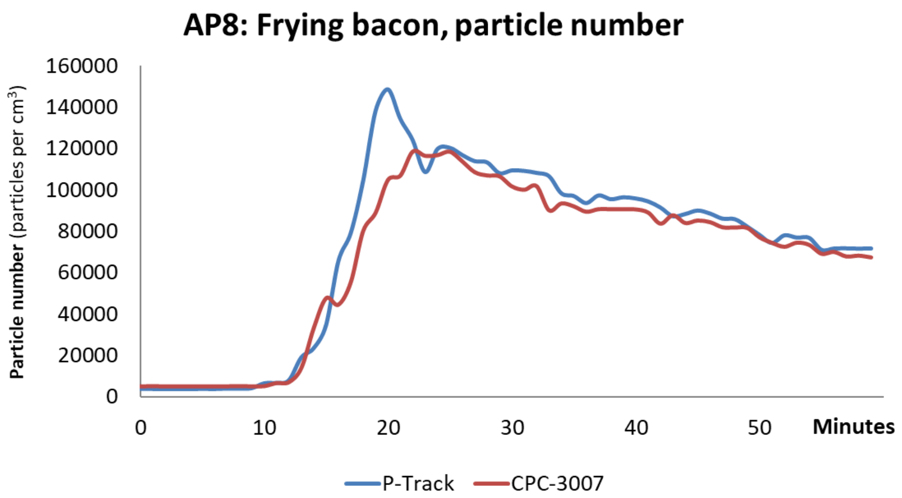


Figure 2.8.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

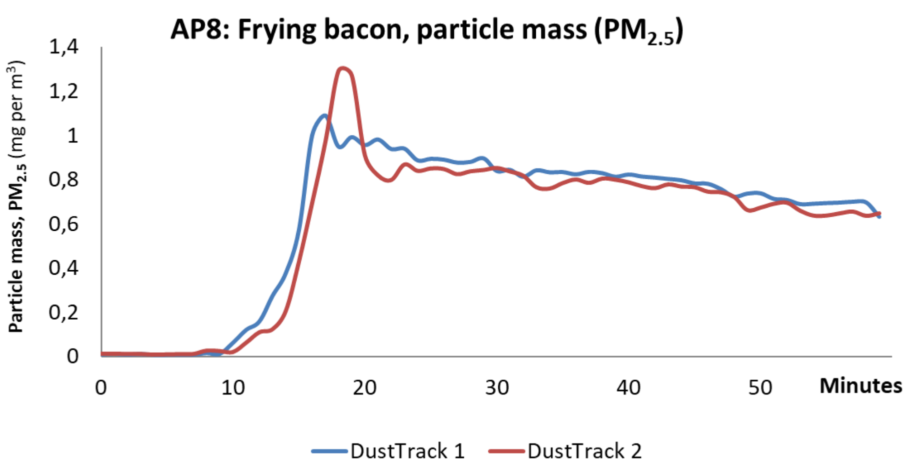


Figure 2.8.3: VOCs (Tiger TVOC Detector on dining table).

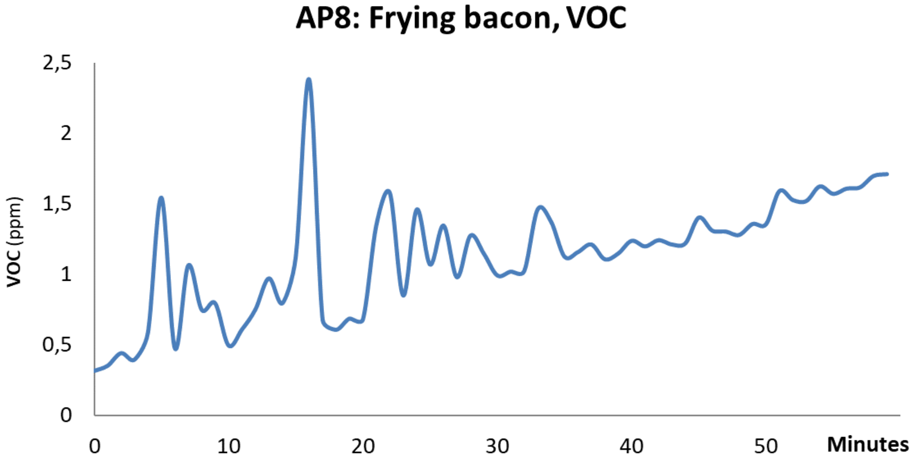


Figure 2.8.4: Particle number (P-Track on bed).

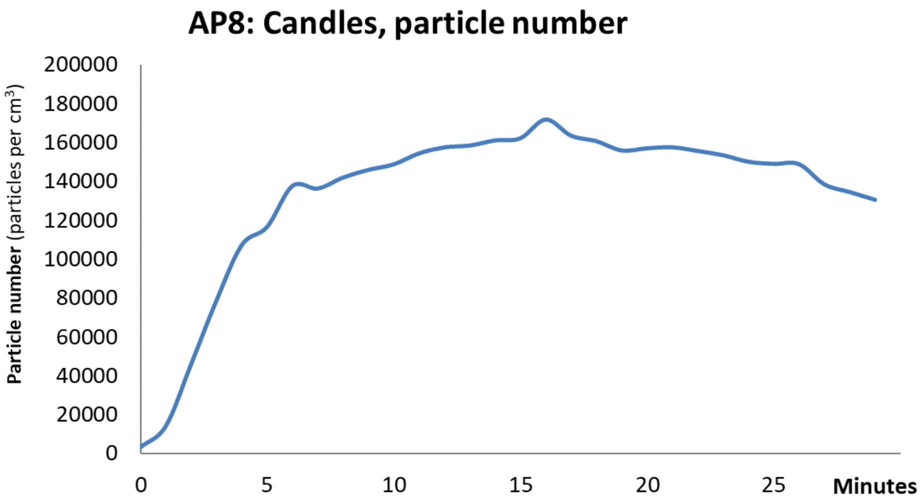


Figure 2.8.5: Particle mass ($PM_{2.5}$) – DustTrak on bed

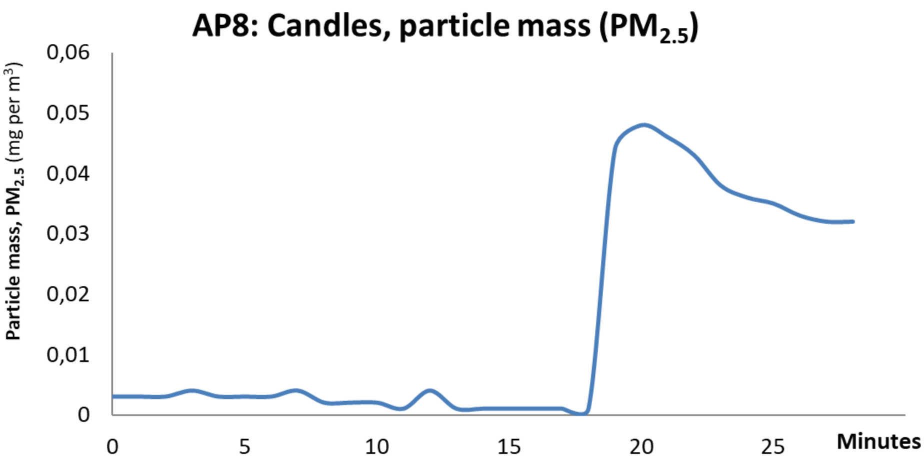
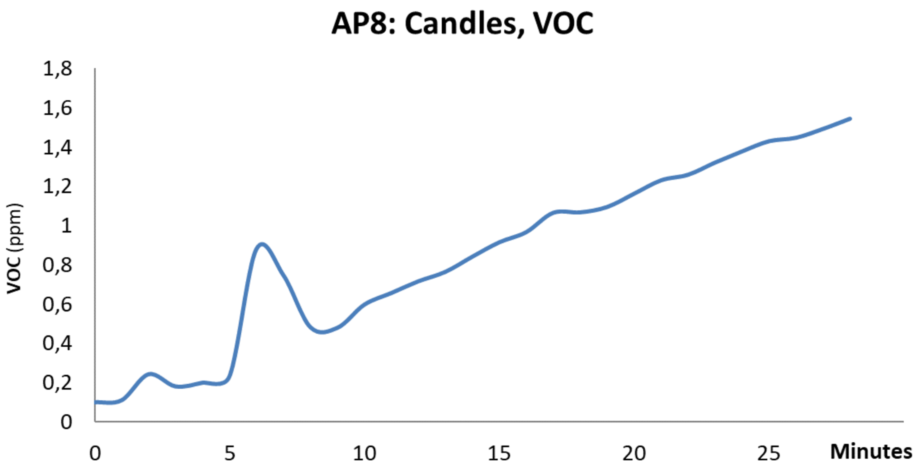


Figure 2.8.6: VOCs – Tiger TVOC Detector on bed



Cooker hood

Figure 2.9.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

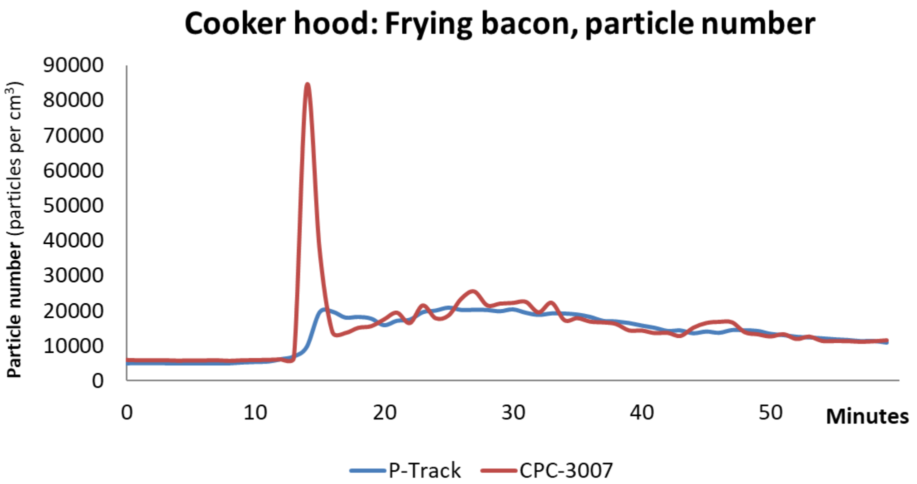


Figure 2.9.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

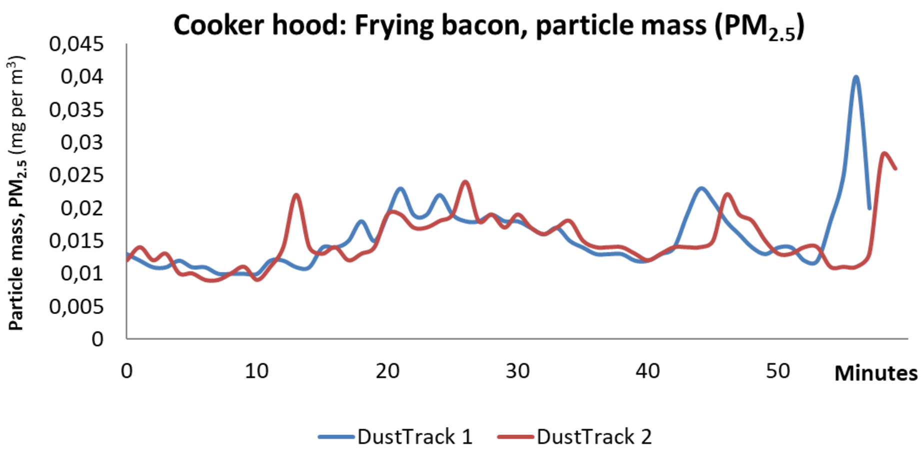
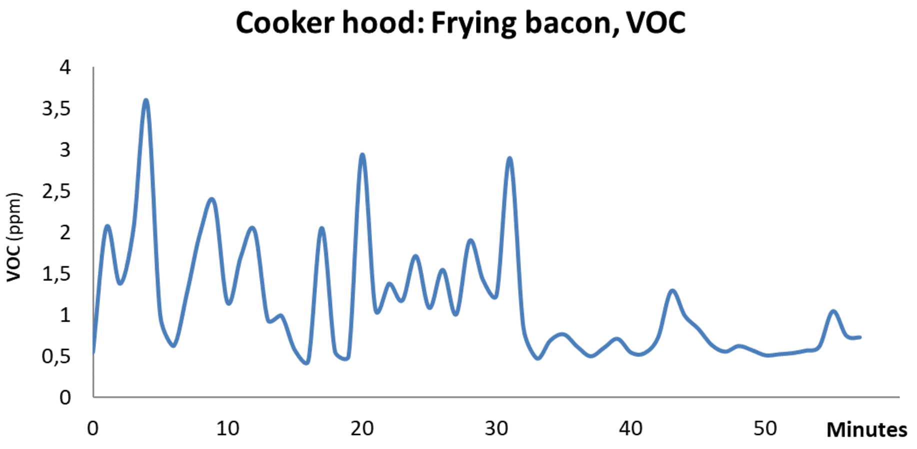


Figure 2.9.3: VOCs (Tiger TVOC Detector on dining table).



Manual airing

Figure 2.10.1: Particle number (P-Track on kitchen table and CPC-3007 on dining table).

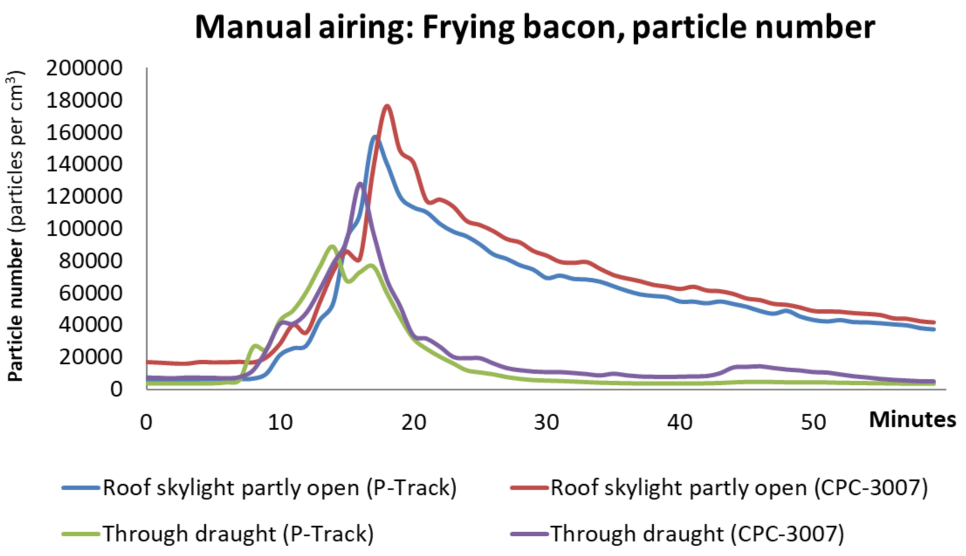


Figure 2.10.2: Particle mass, $PM_{2.5}$ (Dust Trak 1 on kitchen table and Dust Trak 2 on dining table).

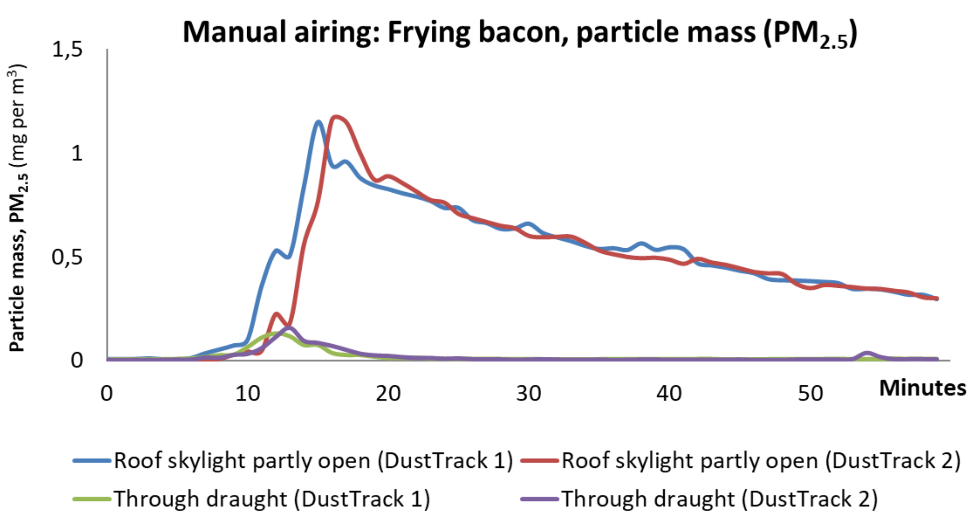
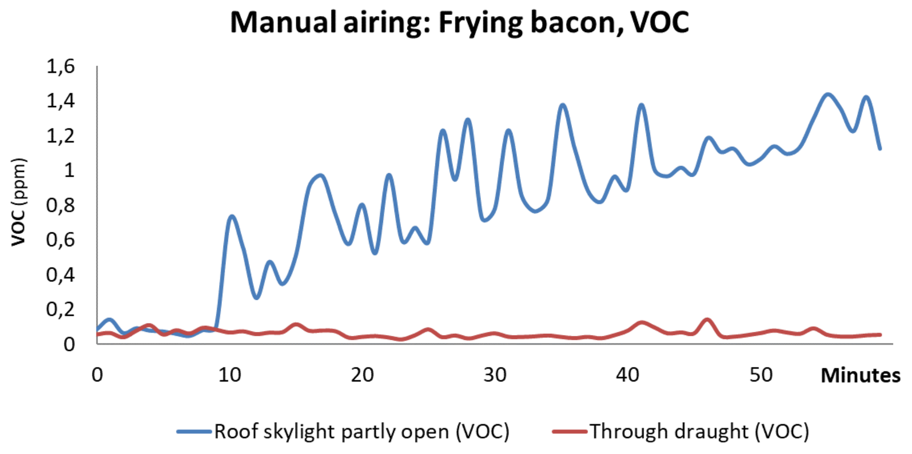


Figure 2.10.3: VOCs (Tiger TVOC Detector on dining table).



Mechanical ventilation

Figure 2.11.1: Particle number (P-Track and CPC-3007 on bed).

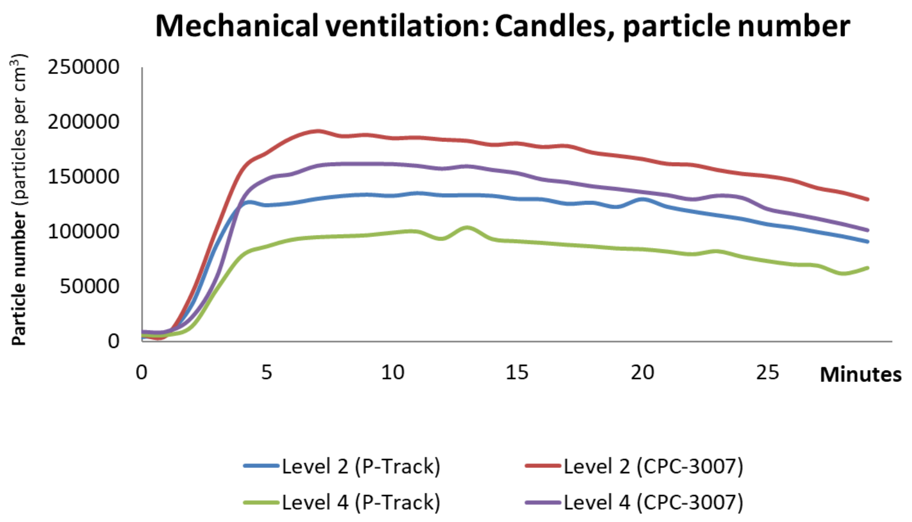


Figure 2.11.2: Particle mass ($PM_{2.5}$) - DustTrak on bed

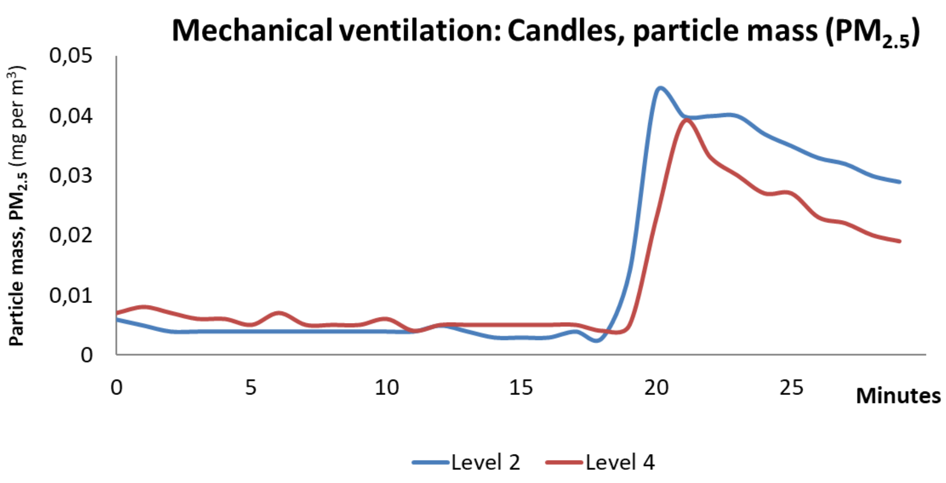


Figure 2.11.3: VOCs – Tiger TVOC Detector on bed