11.as Jornadas de Climatização

2011 October 13th

AIR FILTRATION in HVAC Systems

REHVA GUIDEBOOK NO 11

Jan Gustavsson
Sweden

”Filtration Guidebook”

- **Aimed for**
  - designers, manufacturers, installers and building owners
  - in education
- **Including**
  - pollutants and their effect on indoor quality and the roll of air filters to improve IAQ
  - criteria for selecting air filters
    - efficiency
    - energy (air flow resistance)
    - hygienic consideration
    - life cycle costs (LCC) and environmental impact (LCA)
  - Air filters in real life
  - operation of air filter from air intake to disposal of soiled filters

Work on the Filtration Guidebook

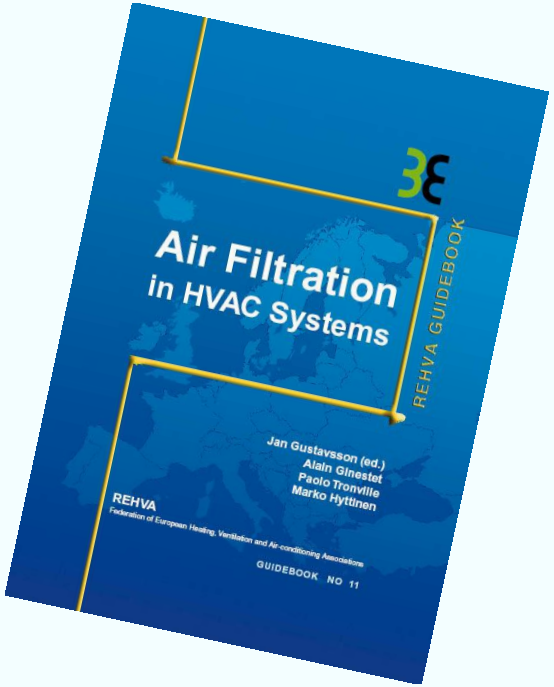
Team work

Task Force

Jan Gustavsson (Ed.)	**Sweden**
Alain Ginestet	**France**
Paolo Tronville	**Italy**
Marko Hyttinen	**Finland**

Reviewers

Denis Bémer	**France**
Carmine Casale	**Italy**
Gian Vincenzo Fracastoro	**Italy**
Jorma Railio	**Finland**
Olli Seppänen	**Finland**
Minna Väkevä	**Finland**

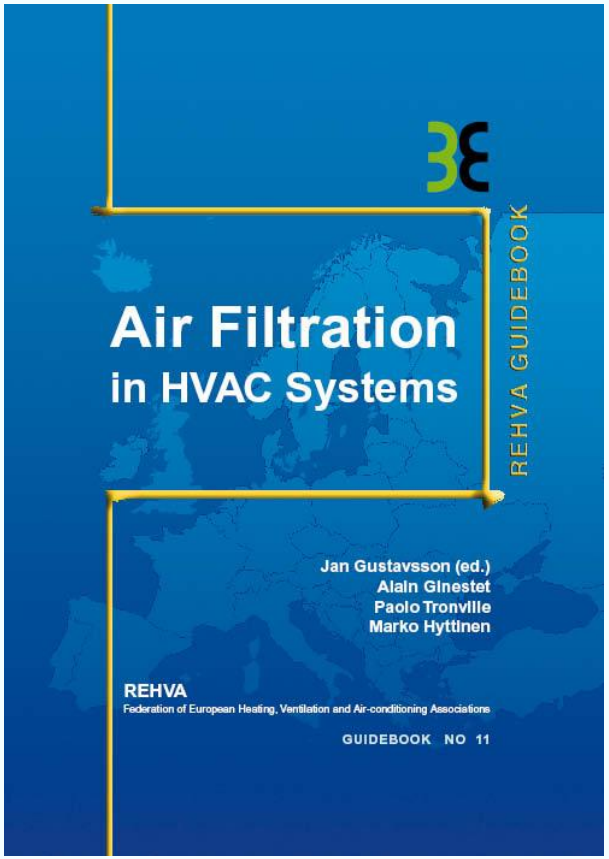


Acknowledgments

Language: **Derrick Braham, UK**

Layout: **Jarkko Narvanne, Finland**

Contents of the guidebook



1. Air Filtration in a nutshell
2. Terminology
3. Use of air filters - WHY
4. General engineering criteria
5. Filtration principle
6. Particulate air filter test methods
7. Particulate air filters
8. Gas phase air filters
9. Particulate air filters in service
10. Hygienic consideration of air filters
11. Application and selection of air filters
12. Certification of air filters
13. Air filtration check list
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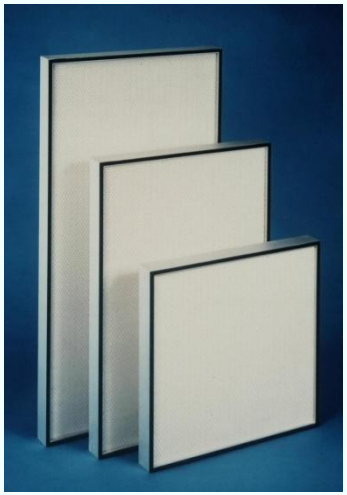
G-FILTER

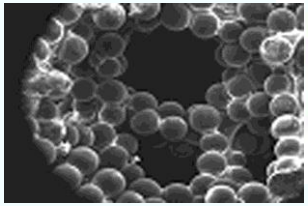
F-FILTER

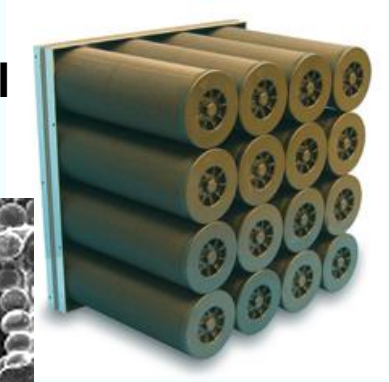
WHY AIR FILTRATION
and
WHICH QUALITY ?



HEPA, ULPA

Chemical
FILTER





Filtration - costs

Air flow	1 m^3/s =1000 L/s
Operation time	6000 hours
Air Filters	F7 + F7
Average pressure drop	120Pa + 100Pa
Filter Replacement	2 times/year
Filter cost	30 €/filter
Fan Efficiency	0.5
Energy price	0.1 €/ kWh
Air flow/person	20 L/s
People served by 1 m^3/s	50
Energy (Q Pa T/η_{fan}/1000)	2640 kWh/year
Energy cost	264 €/year
Filter cost	120 €/year
Total cost	384 €/year
Cost / person	8 €/year
	0,15 €/week
	0,03 €/day

What are we talking about?

Filtration - costs

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A piece of cake?
But important

Why air filters – Clean industry ?

Goal = Output
Good relationship between cleanliness and quality.

Money talks

Why air filters - Offices?

Goal = lower costs?

Few studies – Filtration vs. IAQ and costs

Improved air filtration (First and Rosenfeld 1997)

Financial benefits from improved indoor environment exceed the filtration cost by a factor of 20

Reduction of exposure to particles (Bekö et al 2007)

- Considering pollutants, morbidity, mortality, productivity, working period, cleaning, energy and filtration cost etc.
- Considering different stakeholders; employers, building owner and society

Regardless of perspective, particle filtration is anticipated to lead to annual savings significantly exceeding the running costs for filtration

HOWEVER

Why Air filters - Offices?

However

Economic losses resulting from even a small decrease in productivity caused by sensory pollutants emitted from soiled air filters have the potential to substantially exceed the annual economic benefits of filtration

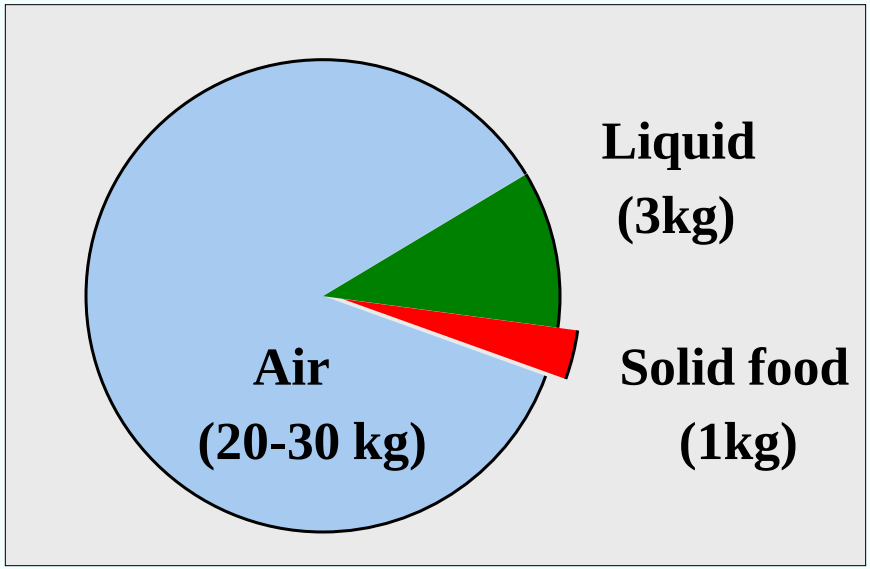
Why Air filters - Ventilation system

Old problem
”With no cleaning the ventilation will be short-lived”

- **Keep the system clean**
  - keep the designed Air Flow
    - influence Temperature, RH
    - reduce indoor contaminants from humans, building materials, equipment
  - keep the efficiency of equipment
    - fan, heating, cooling etc.
- **Keep indoor surfaces clean**
- **Avoid Microorganisms in the system**
- **Remove Outdoor contaminants**

Why Air filters - Hygiene (IAQ)

Intake of Air and Food - 24 hours



Indoors
80% - 90% of time

What are the requirements for Air?

WHO - IAQ

Healthy indoor air is a human right and all groups, individuals or organizations associated with a building have a responsibility to work to achieve an acceptable air quality

- **Principle 1.** ***The human right to health***

  - everyone has the right to breathe healthy indoor air

  - influence on quality of life (not only health)

- **Principle 2.** ***Respect for autonomy (self-determination)***

  everyone has the right to expect others to respect their individual judgement in their own evaluation of personal exposure and its effect.

- **Principle 3. "*do no harm*"**

  ignorance about indoor air quality is no excuse

- **Principle 4. "*doing good*"**

  …responsibility to promote good IAQ

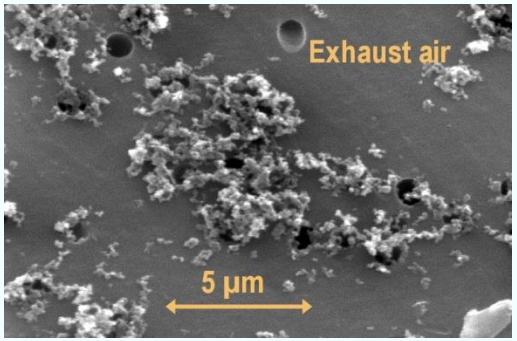
- **-**

- **Principle 9….**

We have a responsibility

We know

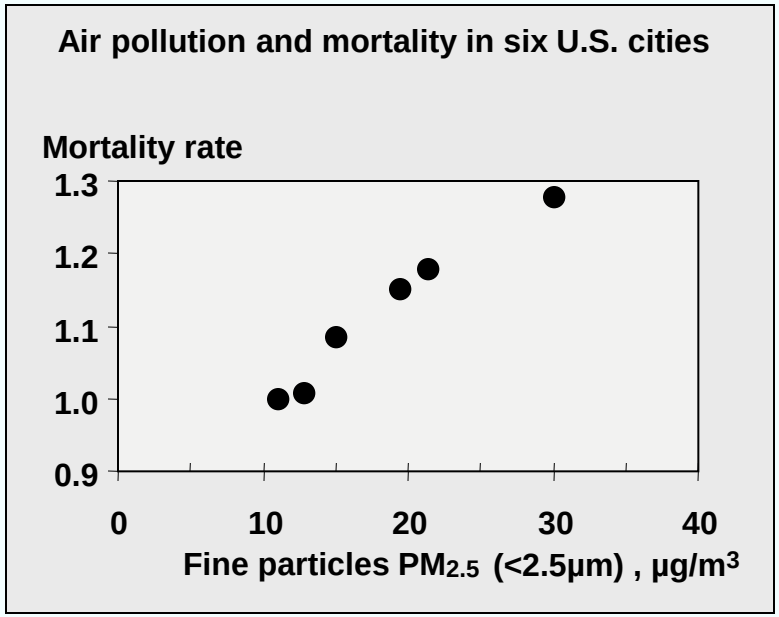
- **Outdoor pollutants (types , levels and sizes) in most big cities**
- **Exposure to urban air pollution is associated with a broad range of acute and chronic health effects**
- **50% of Outdoor airborne pollutants are carried into buildings and have a large impact on Indoor Air Quality**



- **The most widespread indoor cause and source for these health impacts is outdoor air**
- **Productivity influenced by pollutants**
- **Comfort influenced by pollutants**
- **No technical problem to take most of the pollutants in air filters**

We know - example

Fine particles - underestimated health risk

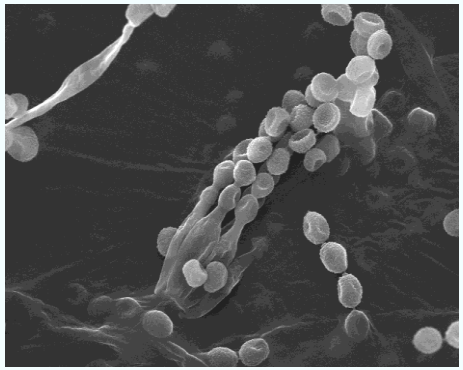


Ultra-, Nano- or Fine- particles

- **Clear connection between fine particles and health effects as mortality and respiratory problems**
- **Effect on the development of children's lung capacity**
- **Underestimated risk (long term)**
- **WHO - no harmless concentration limit**
- **Official requirements under review**
  - Europe and U.S.
  - PM_{10} to $PM_{2.5}$

Air Filters – IAQ problems

An Air filter is one component in a ventilation system and cannot contribute to better IAQ by itself, but is a prerequisite for the system and other components to work properly but it can also be a source of IAQ problem



- Manufacturing
- Release of particles/gases/microorganisms in operation
- Decrease in efficiency
- Smell from removed pollutants
- Microbial in filters
  - **Survive** and release VOC(Ketones, alcohols...)
  - **Die** and release endotoxins, gases/particles
  - **Grow** and give off microorganisms, spores
- Replacing filters
- Dumping/Disposal
- Global environment (LCA)

Perceived air

Several studies have shown filters to have a negative effect on perception of indoor air quality

- Influence from new filters is negligible after some days ”off-gassing”
- Soiled air filters
  - Negative effect of perceived indoor air quality

Filter	0.05 olf/m^2 floor area
Low pollution office	0.10
People	0.07

  - Increase sick building syndromes
  - Decrease productivity
  - Release microorganisms, endotoxins etc..

Standards - Recommendations

- Maximum permissible concentrations of pollutants are set by national regulations and WHO but no standard values, relevant to health protection or limit values based on technical parameters are available for Indoor Air Quality.
- Comfort criteria are sometimes specified and are normally related to air flow rates, CO_2 concentrations or indirectly by discomfort
- VDI 6022, EN 13779 and REHVA (No 9) define requirements on air filters and systems to achieve good IAQ and avoid hygienic problems based on some studies and practical experiences

No specific criteria for pollutants in IAQ design

AIR FILTERS vs. IAQ

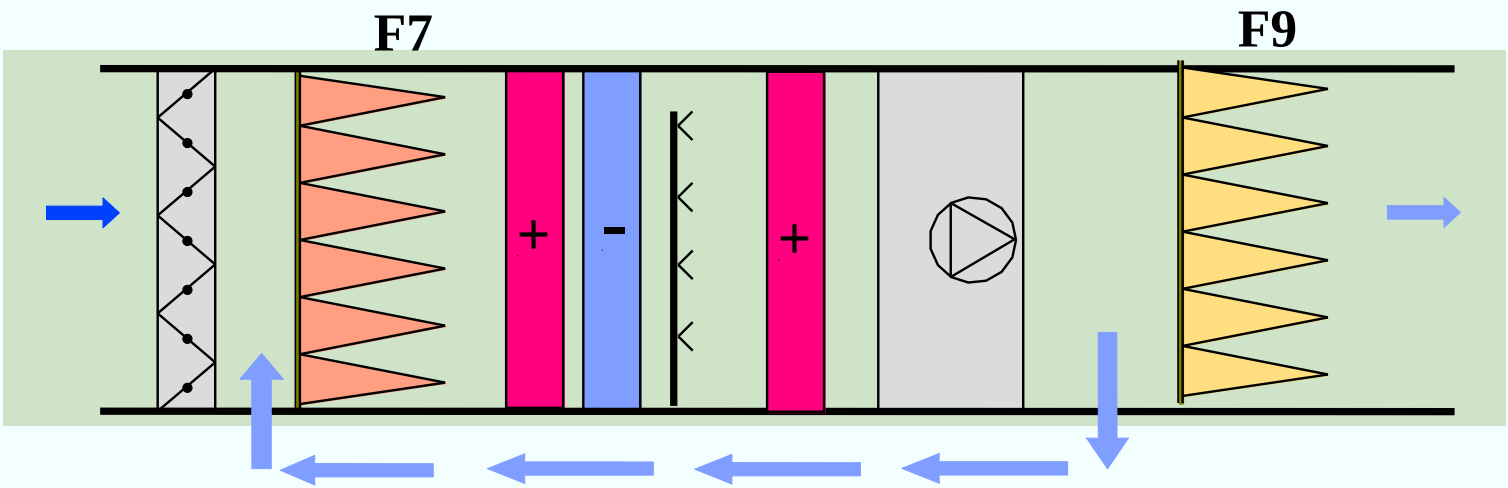
There are some recommendations for filter-classes based on experiences and a few studies

Filter Class vs. Indoor Air Class EN13779

Outdoor Air Quality	**Indoor Air Quality**			
	IDA 1 (high)	IDA 2 (medium)	IDA 3 (moderate)	IDA 4 (Low)
ODA 1 (pure air)	F9	F8	F7	F5
ODA 2 (dust)	F7+F9	F6+F8	F5+F7	F5+F6
ODA 3 (very high concentrations of dust or gases)	F7+GF*)+F9	F7+GF*)+F9	F5+F7	F5+F6

*)GF Gas filter

Hygienic aspects - Design



Humidity

Max. 90 % RH (peaks)

Max. 80 % RH (avg. 3 days)

Two step filtration is recommended

Min. F5 or if possible F7 in the 1st stage

Min. F7 or if possible F9 in the 2nd stage

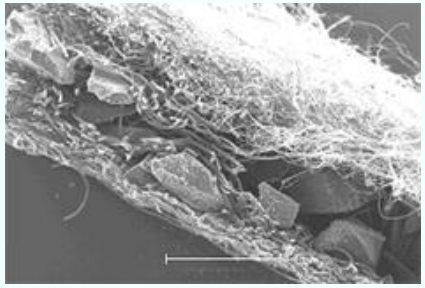
Min. F7 if only one filter step is used

For hygienic reasons the filters should be replaced frequently

- The first filter step should be replaced after 2000 hours operation
- The second filter (or the filter in the recycled system) after 4000 h
- The efficiency may not decrease during operation.

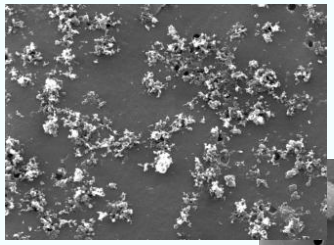
Acceptability of filtered air

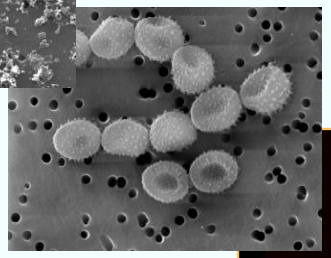
- Chemical reactions with filtrated dust reacts with reactive outdoor air gases such as ozone and oxidation products can be formed, which could explain some of the negative effect of perceived air.
- Activated carbon is effective against O_3
- Some new studies indicate that a combination of particle filters and activated carbon will remove a significant fraction of ozone and improve the acceptability of the filtered air.
- These filters could replace commonly existing filters and would have particle removal efficiencies comparable to standard filters. They will improve the indoor air quality with little or no modifications to the air handling system.

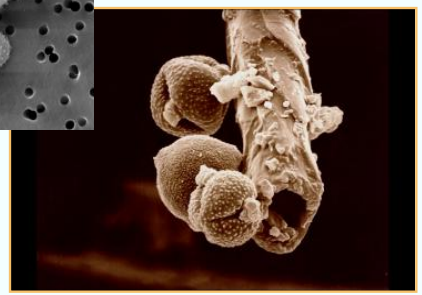


Air filters- possibilities

- **Protect Ventilation system**
  - Keep the function of the system
  - Stop contaminants from entering the system
- **Hygienic reasons**
  - Particles
  - Micro-organisms
  - Allergens
  - Carcinogens
  - Gases, ozone
- **Productivity, comfort**





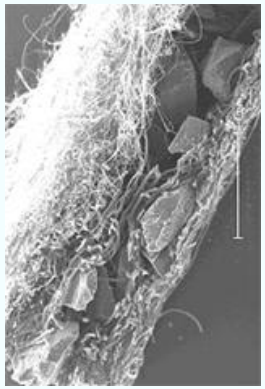


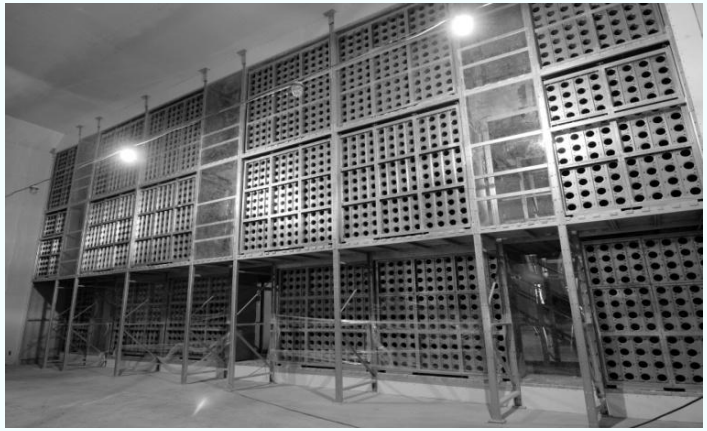
But; Carefully design and operation is a must

Air Filtration today – tomorrow

- **Today - Use existing knowledge – Air Filtration Guidebook**
  - Efficiency
  - Operation time and conditions
  - Filter and energy design (LCC/LCA)
  - Replacement and disposal
- **Tomorrow**
  - Guidelines for Indoor Environment based on pollutants.
  - Comfort criteria and air filters
  - Requirements based on real filter efficiencies. Not on classifications as F7, F8. The meaning of classes will change
  - Air filters in real life
  - Criteria for LCC and LCA calculations
  - Benchmarking of existing installations






Filtration Guidebook covers Air Filters from theory to applications

THANKS for your attention