Sorbent based energy recovery ventilation system for northern residential buildings

Ecem Cerrah, Claire McCague, Majid Bahrami

Simon Fraser University

September, 2018

LAEC
Laboratory for Alternative Energy Conversion

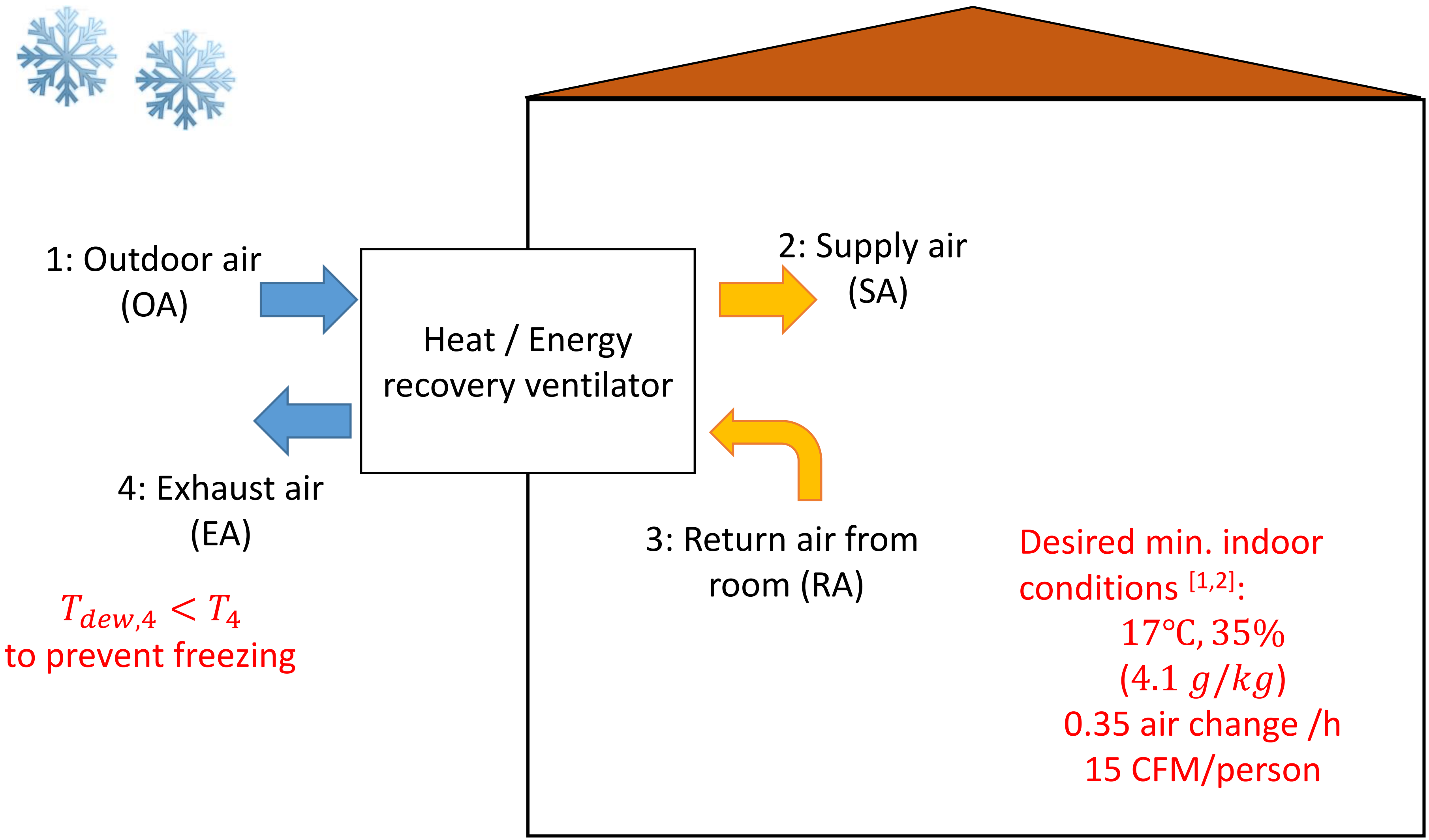
HEAT POWERED CYCLES CONFERENCE 2018

SFU
SIMON FRASER UNIVERSITY

- **De/humidification and ventilation systems**
- Adsorption cooling system (ACS)
- Atmospheric water generation
- HVAC and refrigeration systems
- Thermal management of batteries
- Electronic and power electronics cooling
- Transport phenomena

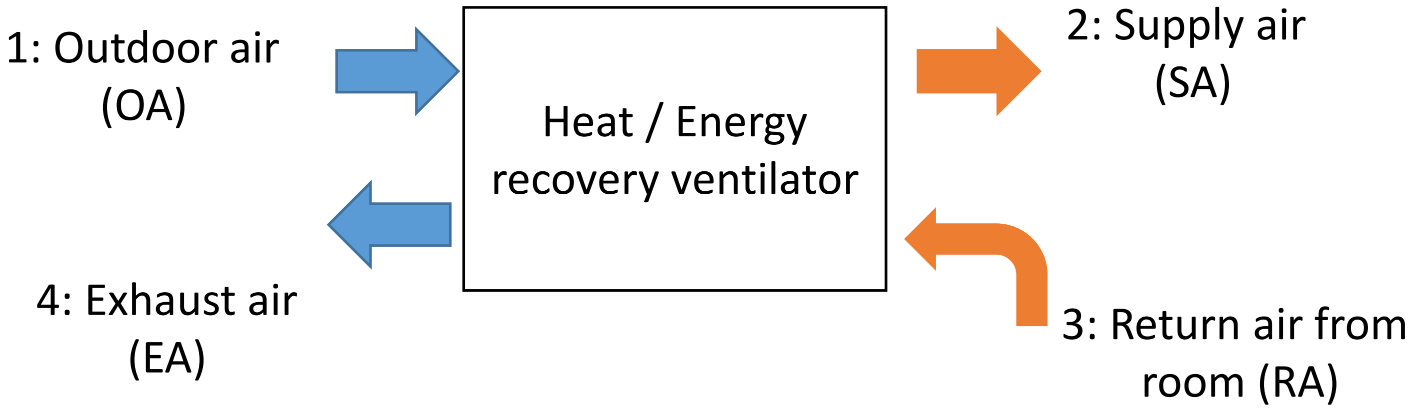
Simon Fraser University (SFU)
Vancouver, Canada

Heat / Energy recovery ventilation (HRV / ERV)



[1] ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy 2010.
[2]ASHRAE 62.2 Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings, 2013

Performance parameters for ERVs



Sensible effectiveness:

$$\varepsilon_s = \frac{(T_2 - T_1)}{(T_3 - T_1)}$$

Typically
0.5-0.85

Latent effectiveness:

$$\varepsilon_L = \frac{(\omega_2 - \omega_1)}{(\omega_3 - \omega_1)}$$

Typically
0.5-0.75

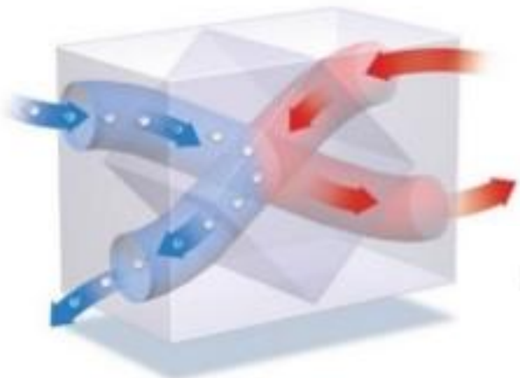
Moisture recovery capacity (MRC), kg/h:

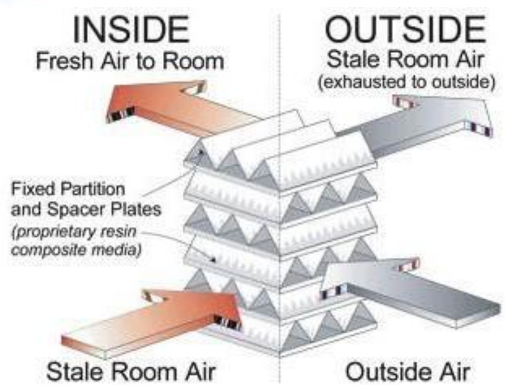
$$MRC = \dot{m}_2 (\omega_2 - \omega_1)$$

Typically
0.2-0.4 kg/h for 35 CFM

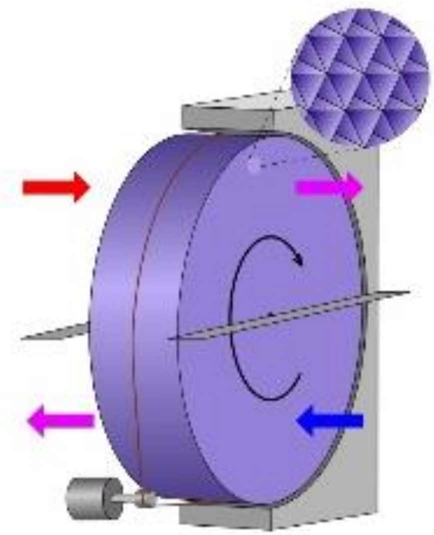
Commercial recovery exchangers

Fixed plate type exchanger





Rotating wheel type exchanger



Heat recovery ventilator (HRV): Aluminum or plastic based

Energy recovery ventilator (ERV): Membrane based (MERV) or desiccant wheel

Frost problem in cold climate

Frost limits[1]

Heat recovery ventilator (HRV) : -5 °C

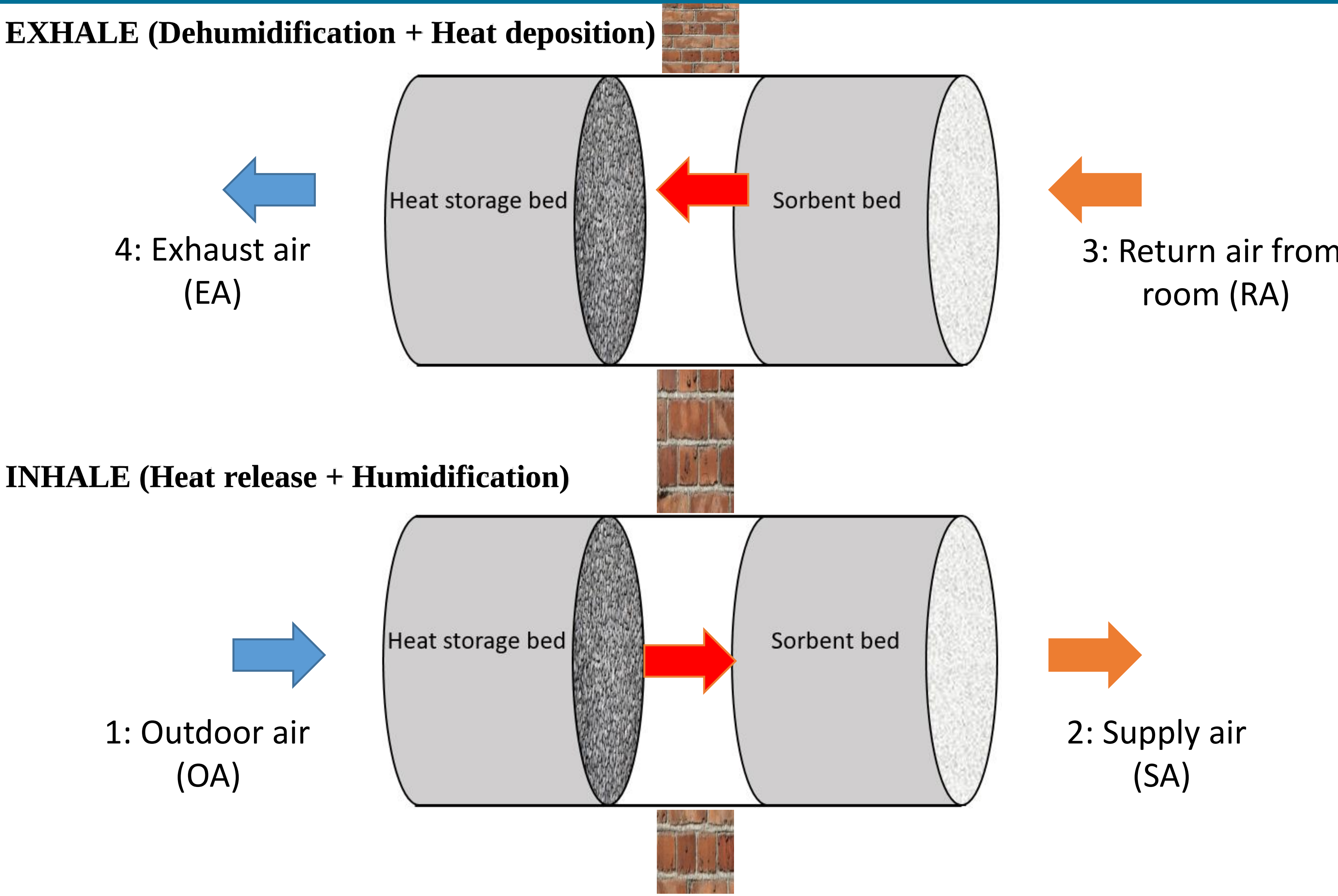
MERV down to : -10 °C

[1]Beattie C, Fazio P, Zmeureanu R, Rao J. Appl Therm Eng 2018;129:1281–91.

VENTIREG: Cold climate ventilation-regeneration system

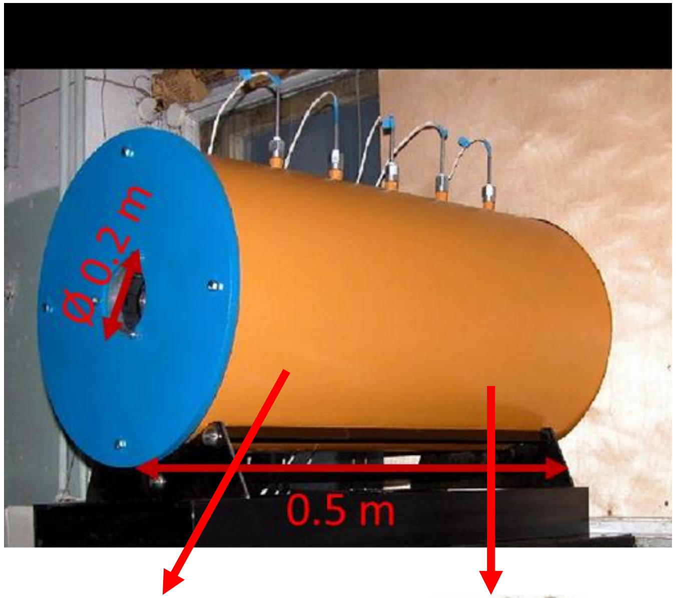
SFU

LAEC Laboratory for Alternative Energy Conversion



Aristov YI, Mezentsev I V., Mukhin VA. Energy Build 2008;40:204–8.

- Tested in West Siberia at outdoor temperature down to -35°C
- No frost problem
- 15 - 80 CFM air flow rate
- 60-96% heat, 70-90% of moisture recovery
- Power consumption due to fans 20 - 40W



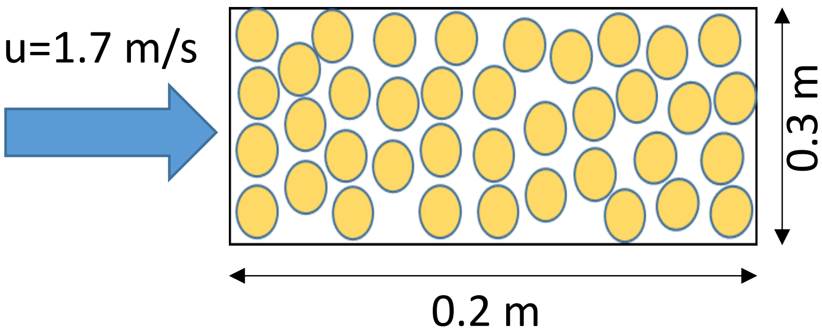
<u>Sorbent bed</u>
Silica, alumina or CaCl2 impregnated alumina (1.8-6 mm)

<u>Heat storage bed</u>
Glass, lead balls or gravels(4-7 mm)

Aristov YI, Mezentsev I V., Mukhin VA. Energy Build 2008;40:204–8.

Is there any room to improve the heat and mass transfer?

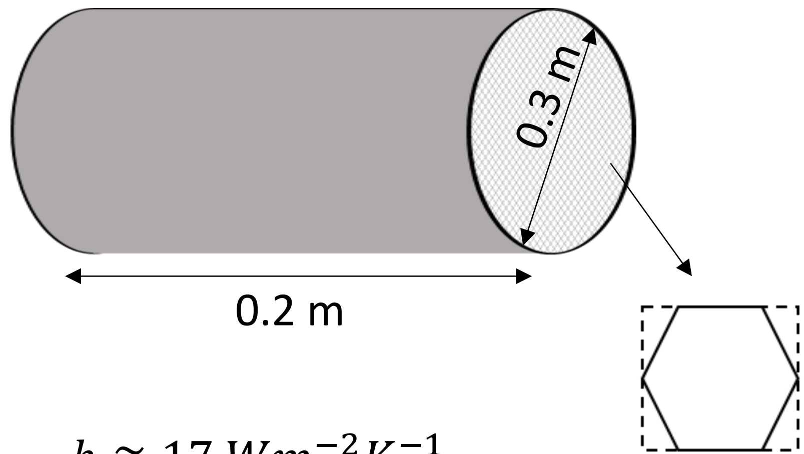
Packed bed



$h \cong 0.09\ Wm^{-2}K^{-1}$

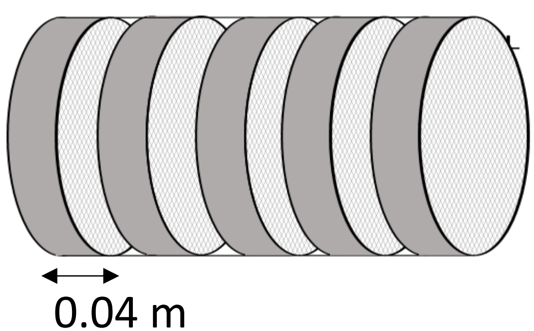
$h_m \cong 0.09\ kgm^{-2}s^{-1}$

Honeycomb structured bed



$h \cong 17\ Wm^{-2}K^{-1}$

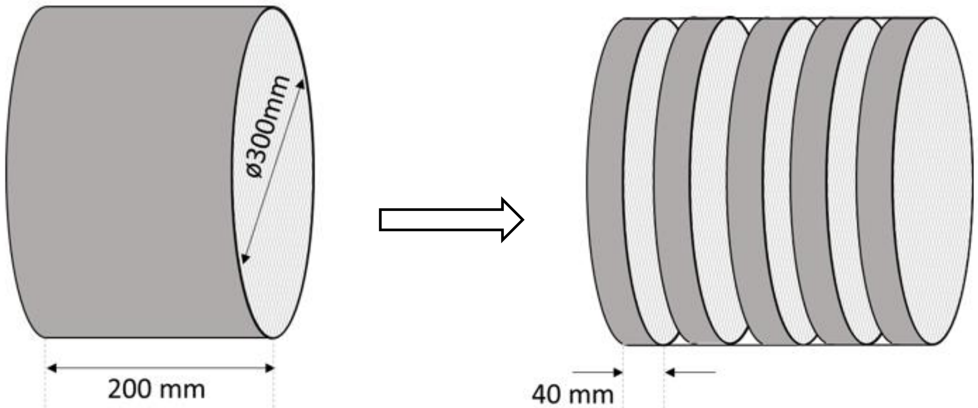
$h_m \cong 0.17x10^{-1}kgm^{-2}s^{-1}$

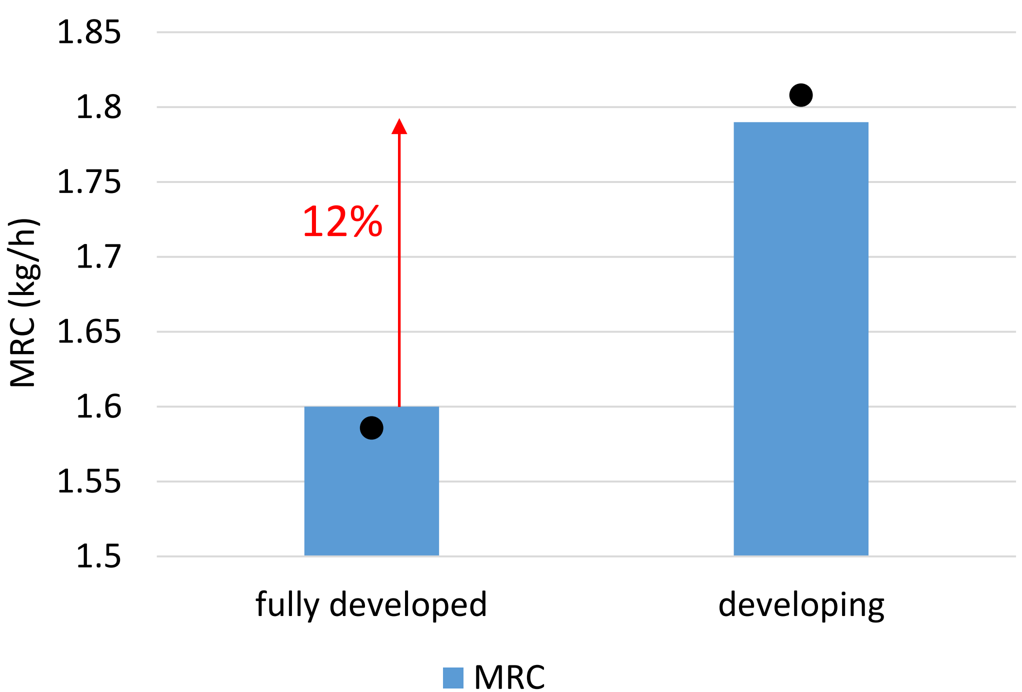


$h \cong 150\ Wm^{-2}K^{-1}$

$h_m \cong 1.5\ x10^{-1}kgm^{-2}s^{-1}$

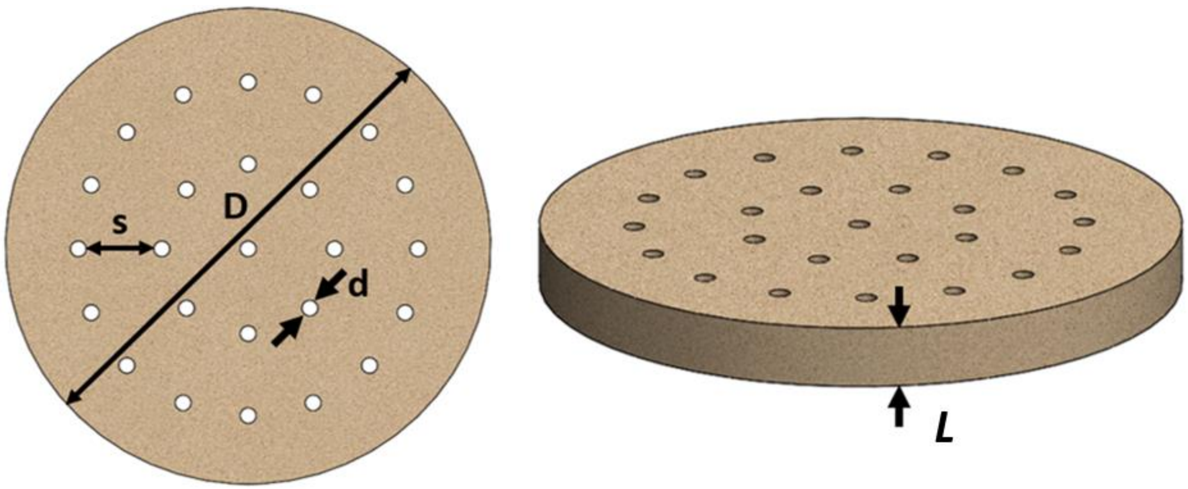
Effect of interrupted boundary layer on MRC





$$MRC = \dot{m}_2\left(\omega_2 - \omega_1\right)$$

Proposed sorbent bed concept



Features of the concept

- Small size silica gel pellets (~0.25-0.5mm)
- $CaCl_2$

High water uptake

- Air channels

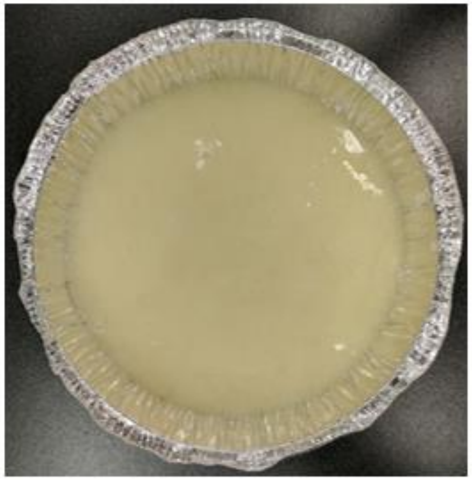
Low pressure drop

- Small thickness, multiple discs (interrupted boundary layer)

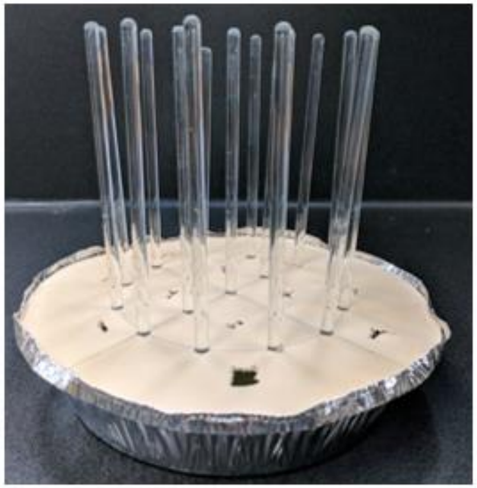
High heat and mass transfer coefficients

Sorbent disks sample preparation

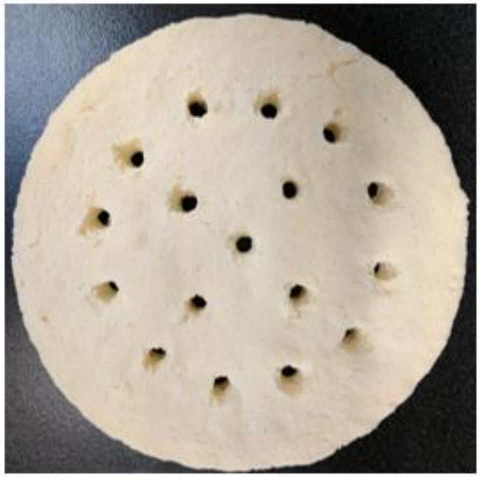
1) Silica gel B150 (0.25-0.5 mm), 27 % $CaCl_2$ and 10% PVA dissolved in water poured in aluminum baking container
2) 17 glass rods inserted
3) Dried in oven with 80-120-200°C temperature steps about 1 hour each
4) Rods and the aluminum container removed



1)



2)



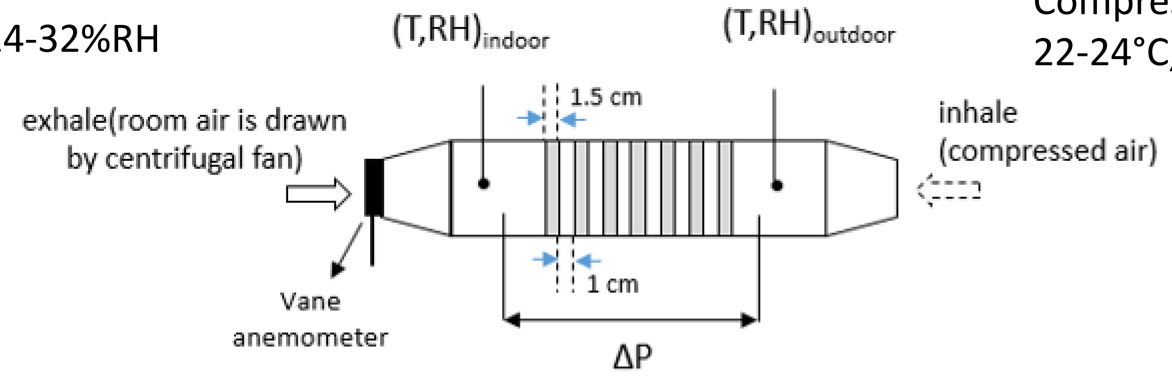
4)

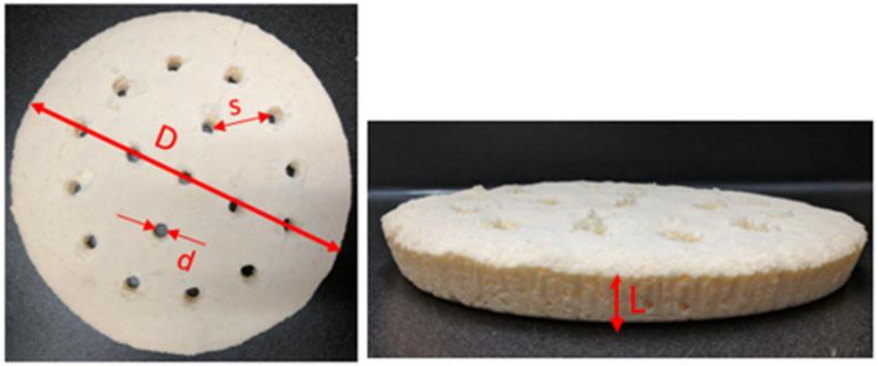
3)

Experimental set-up

Room air
21-22°C, 24-32%RH

Compressed air
22-24°C, 4-5%RH





D ≈ 140 mm, d = 5 mm, s ≈ 20-30 mm, L ≈ 15 mm

<u>Present study</u>

1 kg of silica gel B1501 (7 discs ~0.14 kg each)

Pellet size: 0.25 – 0.5 mm

<u>Reference[1]</u>

3 kg of IK-011-1 (Al_2O_3 with 10-12%$CaCl_2$)

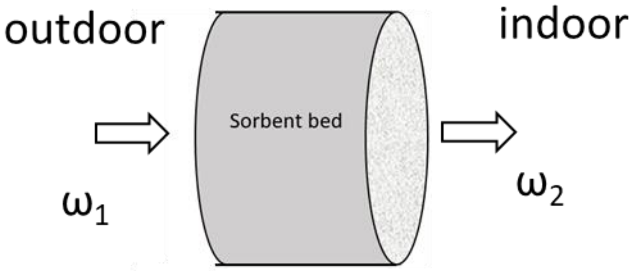
Pellet size: 1.8-4.5 mm in diameter, 6-8 mm in length

Humid air conditions: 20-22°C, 27-30 %RH

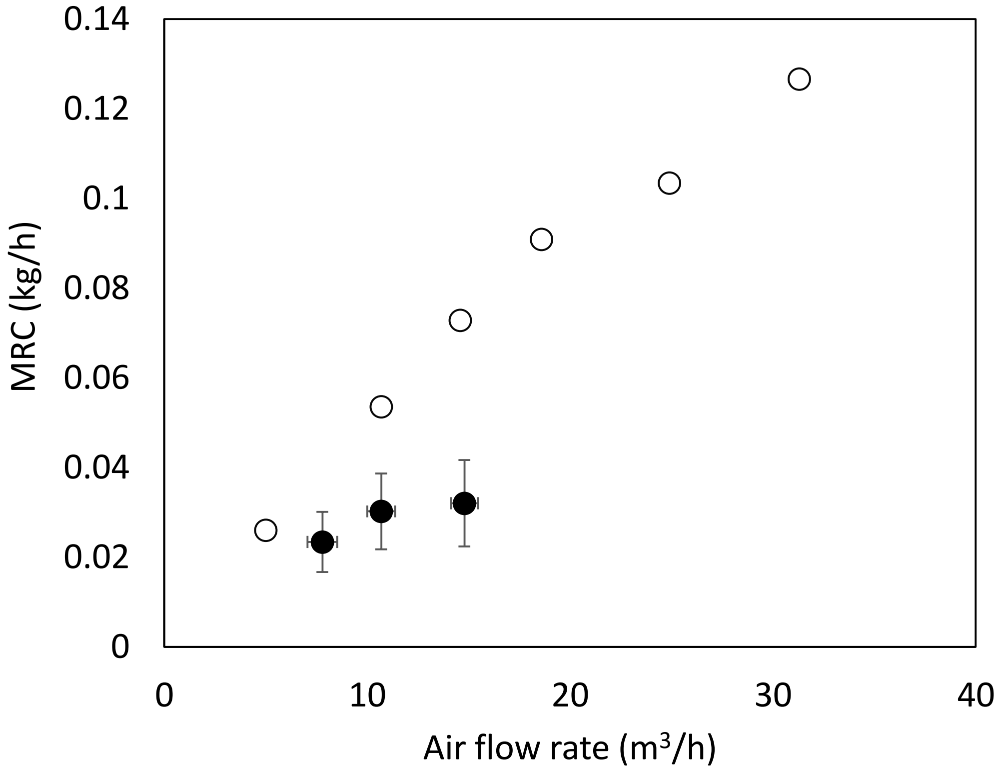
Dry air conditions: 17-20 °C, 1-1.5 %RH

Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

MRC comparison with a packed bed



$$MRC = \dot{m}_2\left(\omega_2 - \omega_1\right)$$



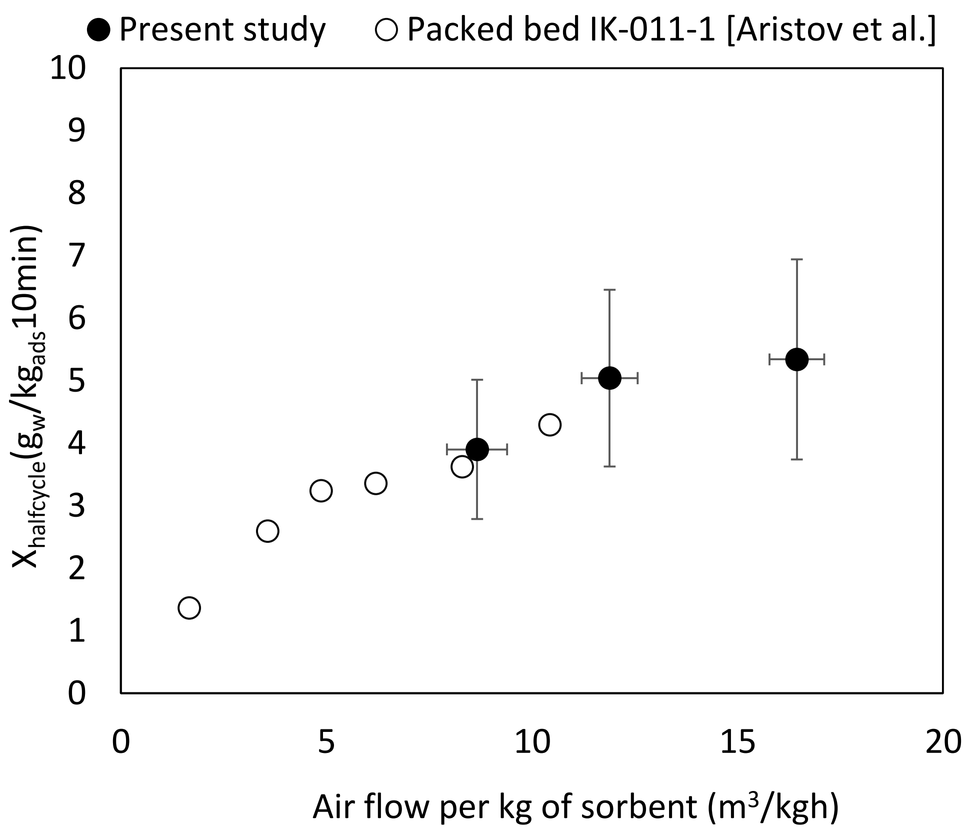
Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

Water uptake in half cycle time

- $X_{halfcycle}$ represents the amount of water adsorbed per kg of sorbent material (uptake) in half cycle time

- Air channel design is optimized to reduce the dead zones between the

$$X_{halfcycle} = \frac{\int_0^{t_{halfcycle}} MRC dt}{M_{sorbent} t_{cycle}}$$



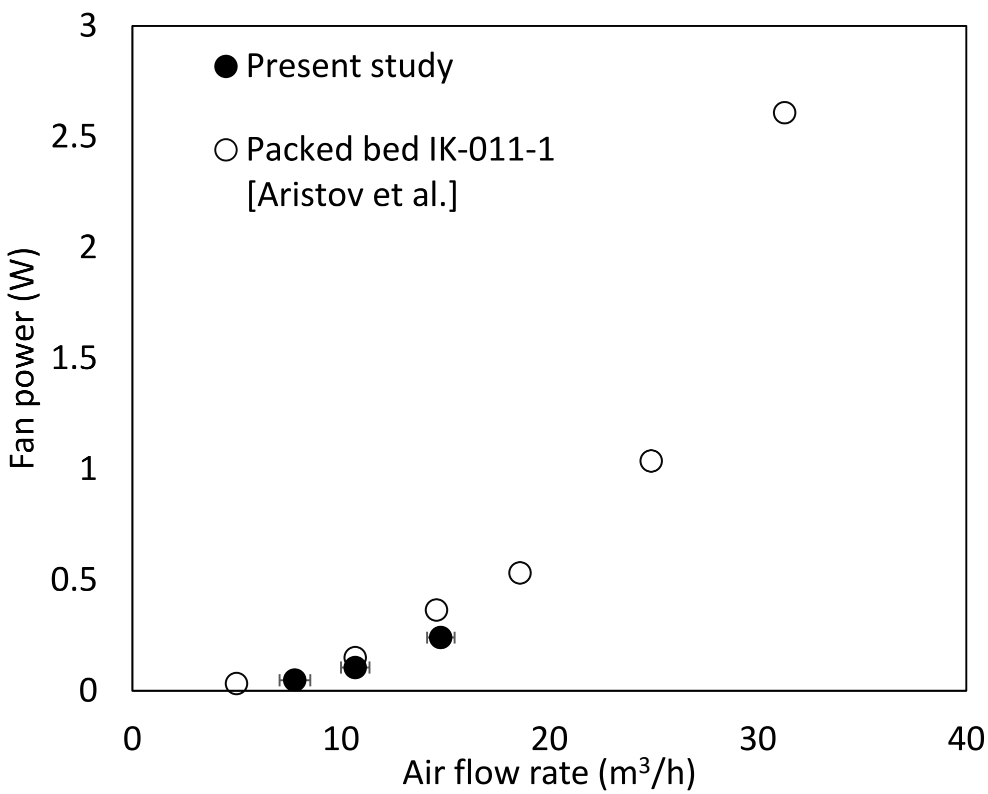
Present study: Silica gel with 27%$CaCl_2$

IK-011-1 (Al_2O_3 with 10-12%$CaCl_2$)

Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

Required fan power

- Operating cost of the system increases for larger scale applications that require higher flow rate



Fan power = Air flow rate x Pressure drop

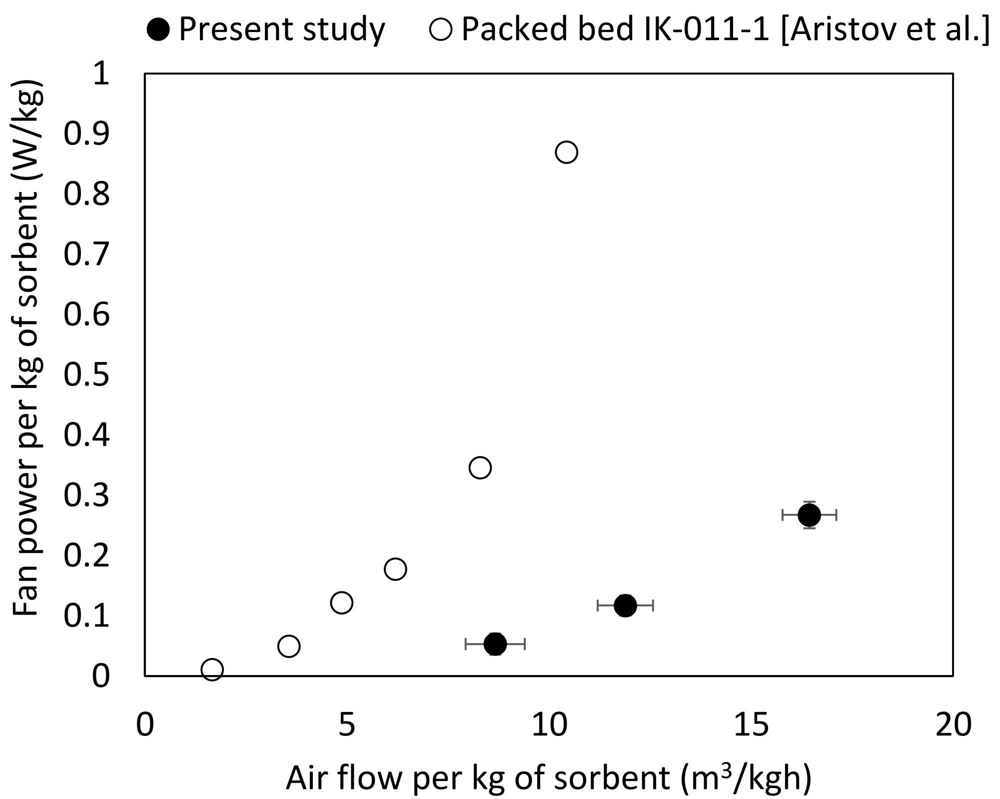
Present study: Silica gel with 27%$CaCl_2$

IK-011-1 (Al_2O_3 with 10-12%$CaCl_2$)

Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

Required fan power per kg of sorbent

- Fan power consumption and air flow are normalized by the sorbent material weight
- The effect of small particle and binder that cause higher pressure drop is compensated by air channels

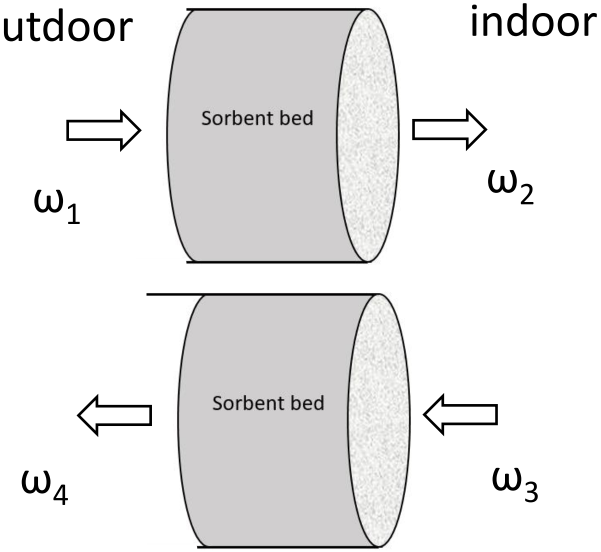


Present study: Silica gel with 27% $CaCl_2$

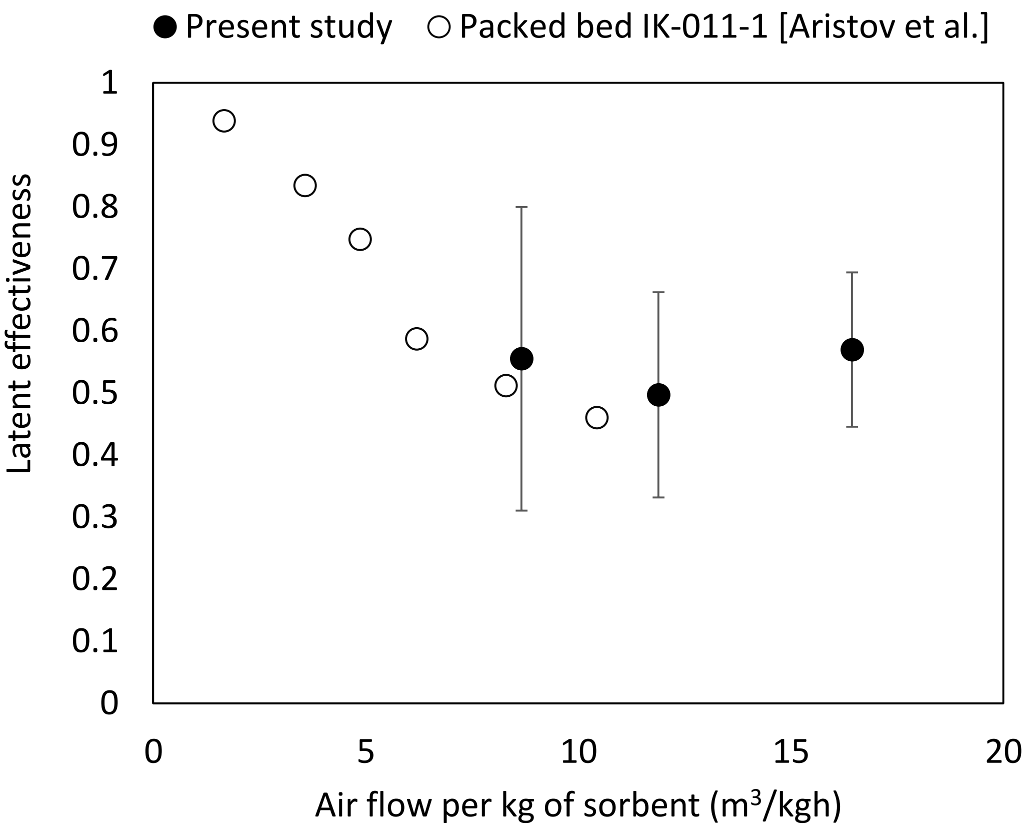
IK-011-1 (Al_2O_3 with 10-12% $CaCl_2$)

Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

Latent effectiveness



$$\varepsilon_L = \frac{(\omega_2 - \omega_1)}{(\omega_3 - \omega_1)}$$



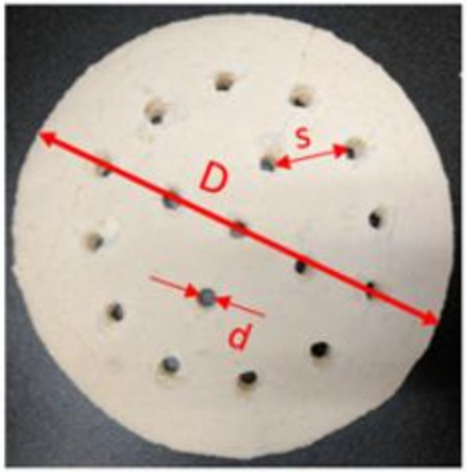
Present study: Silica gel with 27% $CaCl_2$

IK-011-1 (Al_2O_3 with 10-12% $CaCl_2$)

Aristov YI, Mezentsev I V, Mukhin VA. Investigation of the moisture exchange in a stationary adsorbent layer through which air is passed 2005;78:44–50.

Summary & Future Work

- Consolidated silica gel $CaCl_2$ is a promising sorbent in terms of its high uptake property
- Small pellets cause high pressure drop
- Air channel geometry (size, spacing), number of discs and arrangement of discs should be optimized to obtain high MRC, latent effectiveness and low fan power



Black bear poses next to SFU sign in best advertising photo ever

Thanks for your attention

Questions/Comments