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D'ici, on voit + loin !

"PANDORA" - AN OPEN-ACCESS DATABASE OF INDOOR POLLUTANT EMISSION RATES FOR IAQ MODELING

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AIVC 20 October 2026, Webinar – Indoor Air Quality (IAQ) Databases

1

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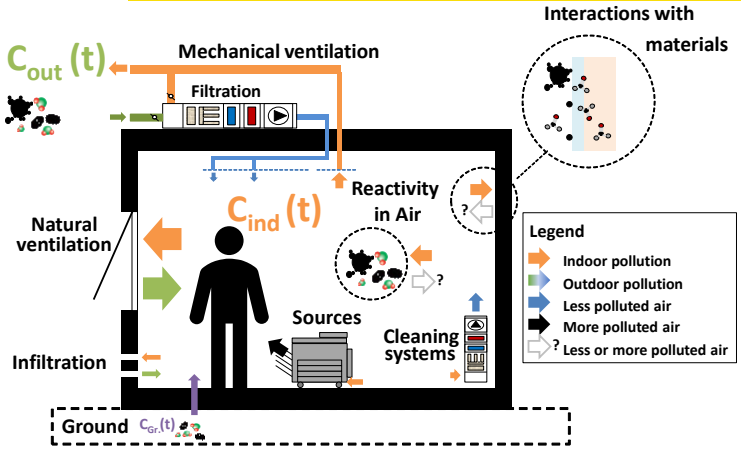
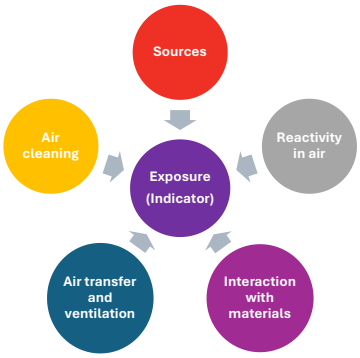
OUTLINE AGENDA

- Introduction
- What is PANDORA?
- Annex86 – Subtask 2 developments
- Smart'Air on-going developments
- Conclusion

2

INTRODUCTION





$$\rho_{air} V \frac{dC_{ind}}{dt} = E + \sum_{i=1}^{n_r} K_i \prod_j C_j + \rho_{air} \sum_{p=1}^{n_p} S_p h_p (C_p - C_{ind}) + \sum_{k=1}^{n_k} q_k^+ C_k - \sum_{l=1}^{n_l} q_l^- C_{ind} - \sum_{f=1}^{n_f} \xi_f q_f^- C_f$$

WHY PANDORA?

The modeling gap

- Indoor concentration studies are abundant; source-specific emission rates are much harder to find.
- Reported quantities differ by source, pollutant, unit, time dependence and experimental protocol.
- A structured database makes source selection, quality assessment and model input more transparent.

Published measurements → **Standardized emission models** → **IAQ model inputs**

PANDORA connects the literature to predictive indoor-air calculations.

PANDOR$_{WH}$A$_T$?

- **PANDORA**: A comPilAtion of iNDoOR Air pollutant emissions from specific sources
  - Database: **emission rates (ER)** of both gaseous and particulate pollutants from Occupants and Occupant Activities, Cleaning Products and Air Fresheners, Construction and Decoration Materials, Furniture, Heating and Cooking Appliances, Electrical Equipment…

- Historical developments:
  - 2009-…: Developed at University of La Rochelle using Microsoft Access.
  - 2011: Paper published in HVAC&R research.
  - …-2019: Available as a simple tree view webpage and sending data on demand.
  - 2021: Major structural update (Clean-up + Convert + Database structuring), dedicated web-app with a basic system of search (source/pollutant).
  - 2022-2025: IEA EBC - Annex 86 – Subtask 2
    - Updating the database with ER from literature (2014-now)
    - Analyzing PANDORA's data
  - 2025: Paper published in Journal of Building Engineering

https://db-pandora.univ-lr.fr/

Pandora

PANDORA = DATABASE OF EMISSION RATES

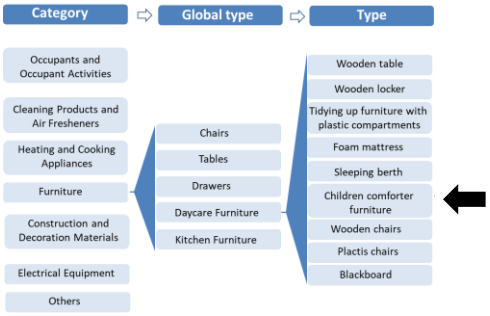
- Diversity of reporting Emission Rates in literature:
  - **Gaseous** pollutant:
    - Pollutant mass / time (**µg/h**)
    - Pollutant mass / time / surface area for materials (**µg/(m².h)**) or SER
    - Pollutant mass / source unit for occupant activities such as the use of printers, copy machines, smoking cigarette… (**µg/unit**)
    - Pollutant mass / combustible mass or energy units for combustion products (**µg/g or µg/J**)
  - **Particulate** pollutant:
    - Particle number / time / particle size (and particle density) (**#$_{0.1µm}$/h**)
    - Particle mass / time / particle size (**µg$_{PM2.5}$/h**)
  - Continuous (**Steady-state**) / dynamic with time (**Transient**) / period of time

#	Description	Equation[1]
01	Gas - Steady-State - Emission Rate (µg/unit)	$S = a$
02	Gas - Steady-State - Emission Rate (mg/h)	$S = a$
03	Gas - Steady-State - Emission Rate (mg/m².h)	$S = a$
04	Gas - Steady-State - Emission Rate (mg/g)	$S = a$
05	Gas - Steady-State - Emission Rate (µg/(h.person))	$S = a$
06	Gas - Steady-State - Discrete Emission Data Model - Temp/RH (µg/h)	$S(T, RH) = a_i \text{ at } T_i \text{ and } RH_i$
07	Gas - Steady-State - Discrete Emission Data Model - Temp/RH (µg/(h.m²))	$S(T, RH) = a_i \text{ at } T_i \text{ and } RH_i$
08	Gas - Steady-State - Metabolism dependant (µg/(h.person))[2]	$S(BMR, M) = 3197 \times BMR \times M$
09	Gas - Steady-State - T/RH - House (mg/(h.m²floor))[3]	$S(T, RH) = H \times C_e \times \frac{(1 + A \times (T - 25))(1 + B \times (RH - 25))}{\frac{1}{a_i} + \frac{1}{k \times L}}$
10	Gas - Transient - Discrete Emission Data Model (µg/h)	$S(t) = a_i \text{ at } t = t_i$
11	Gas - Transient - Discrete Emission Data Model (µg/m².h)	$S(t) = a_i \text{ at } t = t_i$
12	Gas - Transient - Discrete Emission Data Model (µg/(h.unit))	$S(t) = a_i \text{ at } t = t_i$
13	Gas - Transient - Discrete Emission Data Model (µg/(h.g))	$S(t) = a_i \text{ at } t = t_i$
14	Gas - Transient - Peak Model (mg/m².h)	$S(t) = a_1 \, e^{-0.5 \left(\frac{\ln \frac{t}{t_p}}{\sigma_g} \right)^2}$
15	Gas - Transient - Power Law Model (mg/m².h)	$S(t) = a_1 \times t_p^{-a_2} \text{ if } t \leq t_p$ $S(t) = a_1 \times t^{-a_2} \text{ if } t > t_p$
16	Gas - Transient - Single Exponential Decay Model (µg/h)	$S(t) = a_1 \, e^{-a_2 t}$
17	Gas - Transient - Double Exponential Decay Model (mg/(h.m²))	$S(t) = a_1 \, e^{-a_2 t} + a_3 \, e^{-a_4 t}$
18	Gas - Transient - Single Exponential Growth Model (µg/h)	$S(t) = a_1 + a_2 (1 - e^{-a_3 t})$
19	Gas - Transient - Steps (mg/h)	$S(t) = a_i \text{ if } t(i-1) < t < t(i), t(0) = 0$
20	Particles - Steady-State - [dpmin; dpmax] (#/min)	$S(t) = a$
21	Particles - Steady-State - [dpmin; dpmax] (µg/unit)	$S(t) = a$
22	Particles - Steady-State - [dpmin; dpmax] (mg/min)	$S(t) = a$
23	Particles - Steady-State - Log-Normal Distribution (#/min)	$S(t) = \sum S_i \int \frac{1}{d_p (2\pi)^{0.5} \ln GSD_i} e^{\frac{(\ln d_p - \ln MD_i)^2}{2(\ln GSD_i)^2}} d d_p$
24	Particles - Steady-State - Log-Normal Distribution (mg/min)	$S(t) = \sum S_i \int \frac{1}{d_p (2\pi)^{0.5} \ln GSD_i} e^{\frac{(\ln d_p - \ln MD_i)^2}{2(\ln GSD_i)^2}} d d_p$
25	Particles - Transient - Steps (mg/h)	$S(t) = a_i \text{ if } t(i-1) < t < t(i), t(0) = 0$

[1] S: Emission rate (unit depends on model); a: mean, min, max, median and/or standard deviation (unit depends on model); t: time (h); a_i: constants (unit depends on model); t_p: time constant (h); d_p: particle diameter (µm); GSD: Geometric Mean Diameter (µm); GSD: Geometric Standard Deviation (-).
[2] BMR: Basal Metabolic Rate (MJ/d); M: metabolic rate (met).
[3] H: ceiling height (m); A, B, and C_e: fitted parameters; L: effective emitting material loading rate in the house (m²/m²); a_i: average air exchange rate for 1h (/h); k: mass transfer constant (m/s).

DATABASE STRUCTURE AND INFORMATION

Definition of Source



Category
Furniture

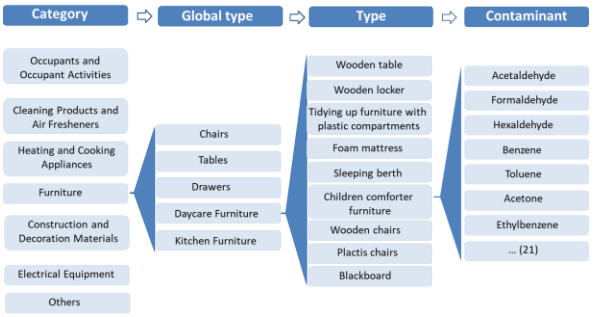
Sub-category
Day-nursery furniture

Source
Name: Children comforter furniture (MBR-03A) - Test 1
Description: S=7.36 m2. Meuble composé de panneaux PPSM (panneau de particules surfacés mélaminés) BTF (Basse teneur en formladehyde) - Furniture made of formaldehyde low emission particle board with melamine coating Measurements made in a 1 m3 (or more) test chamber. T=23 ± 2 °C, RH = 50 ± 5 %
Location: Day-care
Country: France

Reference
Author: Roux M.-L.
Title: Contribution de mobilier à la qualité de l'air intérieur dans les crèches (MOBAIR-C)Contribution of furnitures to the indoor air quality of day-nurseries
Journal: Report
Year: 2012

DATABASE STRUCTURE AND INFORMATION

Pollutant



Pollutant
Group: VOC (Volatile Organic Compounds)
Name: Formaldehyde
CASN: 50-00-0

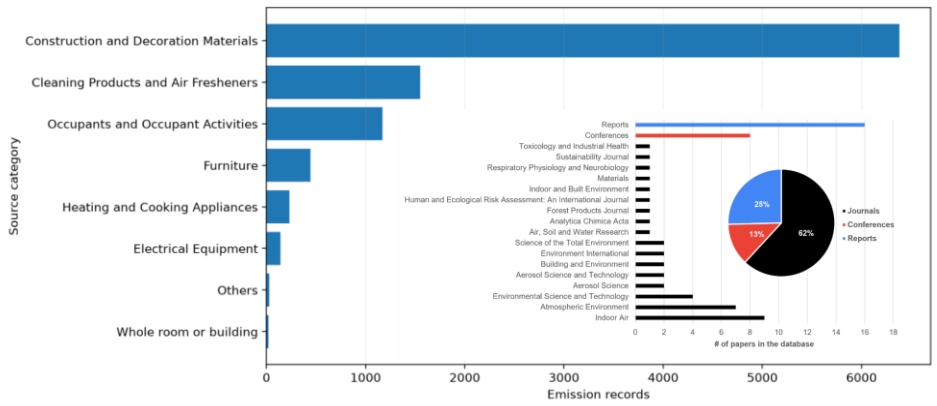
Pollutant emission
Emission Model: Gas - Transient - Discrete Emission Data Model (µg/(h.m²))
Equation: S = ai at t=ti
Unit: µg/(h.m²)

a1 = 6.7 µg/(h.m²)	**t1 =** 1 days
a2 = 6.5 µg/(h.m²)	**t2 =** 3 days
a3 = 5.6 µg/(h.m²)	**t3 =** 28 days

RECORDS IN PANDORA

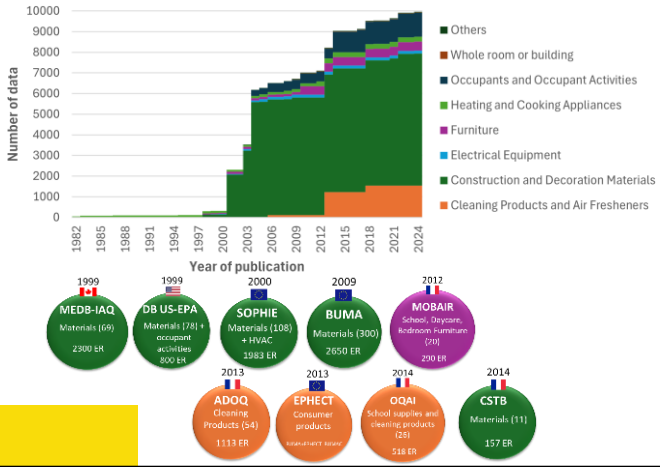
Emission records	Pollutants	Source types	References	Models
9,968	777	747	64	25

Emission records by source category

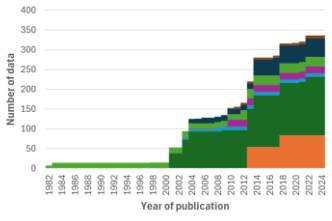


RECORDS IN PANDORA

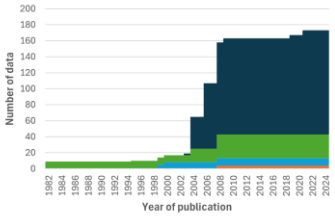
Sources



Formaldehyde



Particles



PANDORA

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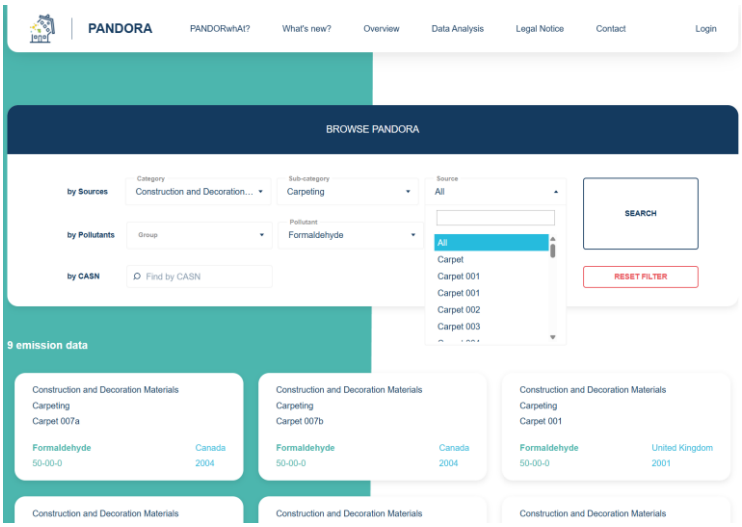

PANDORA

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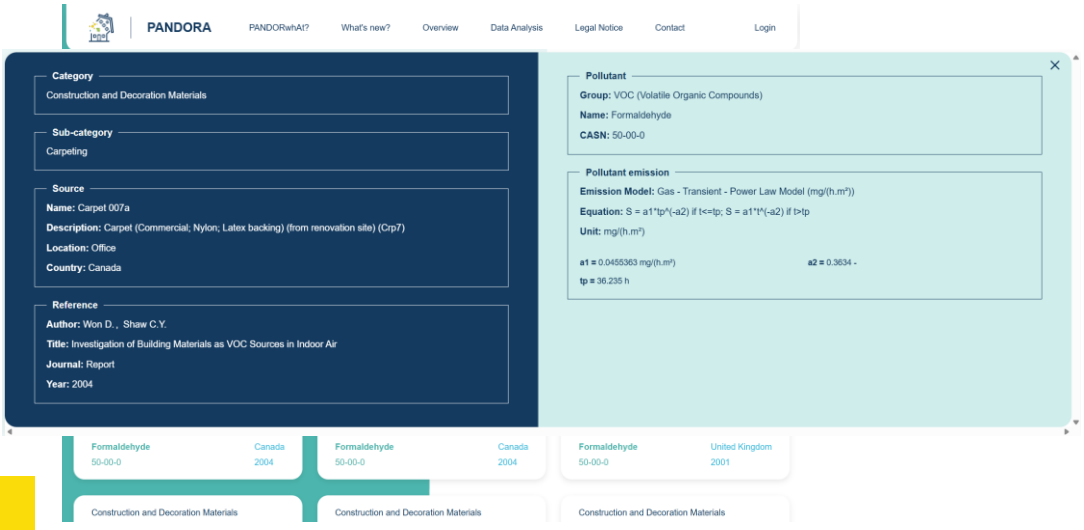


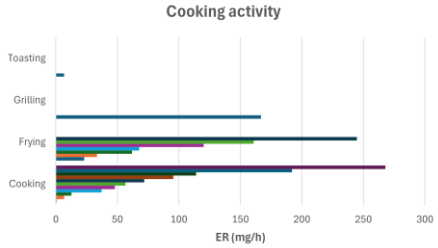
ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

- **IAQ modelers' needs:**
  - > Pollutants of interest:
    - $PM_{2.5}$,
    - Formaldehyde,
    - (Benzene),
    - (and TVOC).
  - > Sources:
    - Construction and Decoration Materials,
    - Furniture,
    - Occupants and Occupant Activities.

Total harm in residential buildings
(Benjamin Jones, "The harm paradigm for IAQ", Presentation at LBNL, 2024)

ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

- **$PM_{2.5}$**:
  - > Integration of spectral distributions to calculate **$PM_{2.5}$**;
  - > Graphs/data for *occupants' activity*
  - > *File: min/P25/P50/Mean/P75/max*

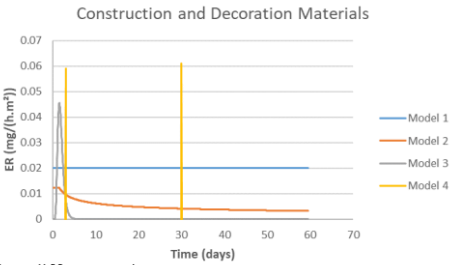


PM25_Sources.txt 80,87 Kio

1	PM2.5			
2	Cooking activity			
3	Emission rates	(mg/h)		
4		Cooking	Frying	Grilling
5	count	11.00	7.00	1.00
6	mean	82.1	101.7	166.8
7	std	83.0	79.4	NaN
8	min	0.5	23.1	166.8
9	25%	24.9	47.7	166.8
10	50%	56.7	67.7	166.8
11	75%	104.7	140.5	166.8
12	max	267.9	244.8	166.8
13				
14	PM2.5			
15	Using aerosols			
16	Emission rates	(mg/h)		
17		Candles	Incenses	Air Fresheners
18	count	5.00	13.00	4.00
19	mean	27.4	156.8	56.2

ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

+ **Formaldehyde**: *Construction and Decoration materials = f(t)*
  > Observation: lots of SER for some pollutant/source couples
  > Objectives: SER statistics at t=3, 28, and 365 days
  > Challenge: Different ER models

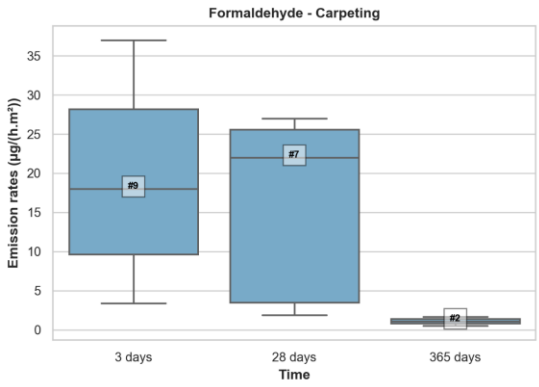


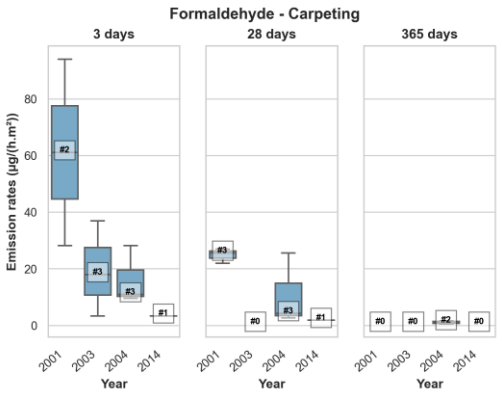
  > Solution: definition of a set of rules to calculate statistics for different times
    - Model 1: **Value for t=3 days and t=28 days only** (not so many data, age of material usually unknown);
    - Models 2 and 3: **calculation for each time** (equations have been usually calculated for times lower than 30 days, sometimes 60 days; calculations for t=365 days are extrapolation and should be considered with caution);
    - Model 4:
      - t=3 days: the closest time **lower or equal to 3 days;**
      - t=28 days: the closest time **lower or equal to 30 days** (to account for a lot of data at t=30 days instead of 28 days);
      - t=365 days: the closest time **higher than 6 months** (currently no available data in PANDORA).

  > Same methodology for **Benzene** and **TVOC**.

ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

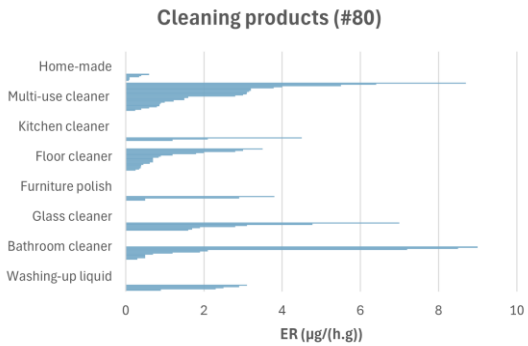
+ Statistics (formaldehyde):

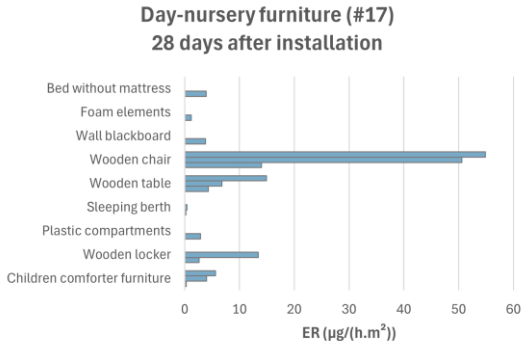




ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

- Summary charts (formaldehyde):

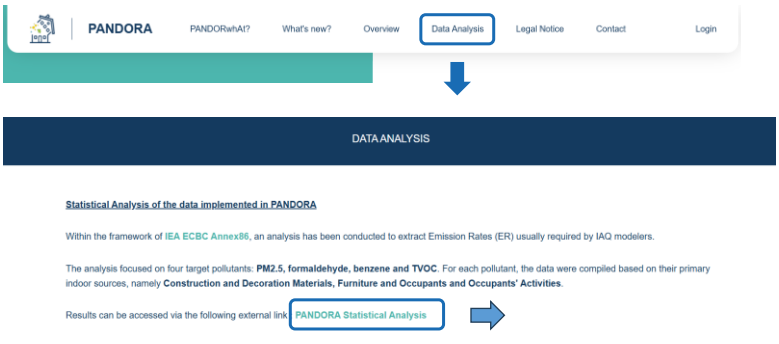




+ downloadable statistics in .txt files

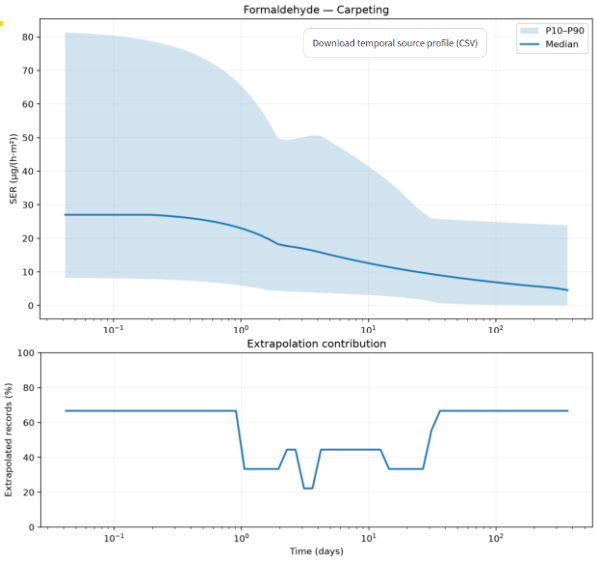
ADDITIONAL DEVELOPMENTS - IEA EBC ANNEX86

- Access through PANDORA website



UNDER DEVELOPMENTS – SMART'AIR PROJECT

- Time-dependent VOC emissions for surface materials & furniture:
  - > SER = f(t)



19

UNDER DEVELOPMENTS – SMART'AIR PROJECT

- Time-dependent VOC emissions for surface materials & furniture:
  - > SER = f(t)
  - > Quality matrix

Formaldehyde

Global Type	1 d	3 d	7 d	28 d	90 d	365 d	Materials / refs
Acoustical Materials	D3 / L2 / T2 †	D3 / L2 / T2	D3 / L2 / T4	D3 / L2 / T4	D3 / L2 / T4	D3 / L2 / T4	9 / 3
Carpeting	D3 / L2 / T3 †	D3 / L2 / T2 †	D3 / L2 / T3 †	D3 / L2 / T3	D3 / L2 / T4	D3 / L2 / T4	9 / 4
Cushions	D5 / L4 / T4 †	D5 / L4 / T1	D5 / L4 / T1	D5 / L4 / T1	D5 / L4 / T4	D5 / L4 / T4	1 / 1
Day-nursery furniture	D2 / L4 / T1 †	D2 / L4 / T1	D2 / L4 / T1	D2 / L4 / T1	D2 / L4 / T4	D2 / L4 / T4	17 / 1
Finishes	D3 / L2 / T4 †	D3 / L2 / T2 †	D3 / L2 / T3 †	D3 / L2 / T2	D3 / L2 / T4	D3 / L2 / T4	8 / 4
Flooring	D1 / L1 / T4 †	D1 / L1 / T1 †	D1 / L1 / T2 †	D1 / L1 / T2	D1 / L1 / T4	D1 / L1 / T4	33 / 6
Furnishing Materials	D4 / L3 / T1	D4 / L3 / T1	D4 / L3 / T1	D4 / L3 / T2	D4 / L3 / T2	D4 / L3 / T2	4 / 2
Installation Materials	D3 / L2 / T4 †	D3 / L2 / T2 †	D3 / L2 / T2 †	D3 / L2 / T1	D3 / L2 / T4	D3 / L2 / T4	7 / 4
Insulation Materials	D3 / L2 / T2 †	D3 / L2 / T1	D3 / L2 / T3	D3 / L2 / T3	D3 / L2 / T4	D3 / L2 / T4	9 / 3
Interior Panels	D1 / L1 / T3 †	D1 / L1 / T1	D1 / L1 / T2	D1 / L1 / T2	D1 / L1 / T4	D1 / L1 / T4	36 / 5
Structural Materials	D1 / L1 / T3 †	D1 / L1 / T1	D1 / L1 / T2	D1 / L1 / T2	D1 / L1 / T3	D1 / L1 / T3	22 / 5
Wall Covering	D3 / L2 / T3 †	D3 / L2 / T1	D3 / L2 / T1	D3 / L2 / T3	D3 / L2 / T3	D3 / L2 / T3	8 / 3

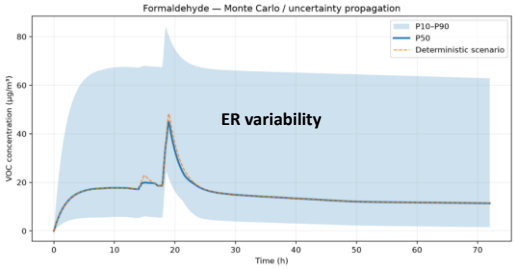
D — Data depth	D1 ≥20 materials; D2 10–19; D3 5–9; D4 2–4; D5 1
L — Literature support	L1 ≥5 references; L2 3–4; L3 2; L4 1
T — Temporal support	T1 ≤10% extrapolated; T2 >10–25%; T3 >25–50%; T4 >50%
†	At least one material trajectory is evaluated before its first supported observation (backward extrapol.)

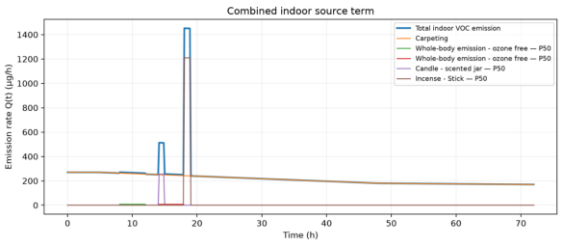
20

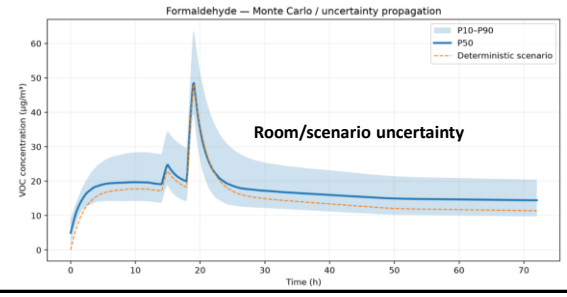
UNDER DEVELOPMENTS – SMART'AIR PROJECT

$$\frac{dC}{dt} = \frac{\sum_i Q_i(t)}{V} + ACH\, C_{out} - (ACH + k)C$$

- Database companion tool:
  - > Database overview
  - > VOC emissions
  - > Particle emissions
  - > IAQ one-zone model



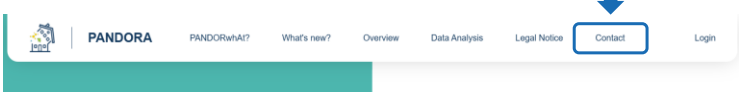




CONCLUSION

- Advances in the development of PANDORA, an open-access database of indoor pollutant emission rates for IAQ modeling
- Current Content: ~9,968 emission rates from various sources
- Limitations:
  - > Not statistically representative
  - > Bias toward older, high-emission rates
- Future Improvements:
  - > Add filters (year, country…) for easier searches
  - > Enable researcher contributions with preformatted data
  - > Add ER from identified recent publications on building materials and furnishings, consumer products, office and household equipment, cooking and combustion sources, tobacco and alternative smoking products, human emissions, whole-building emissions

We would be grateful if you could share your emission data with us!



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25