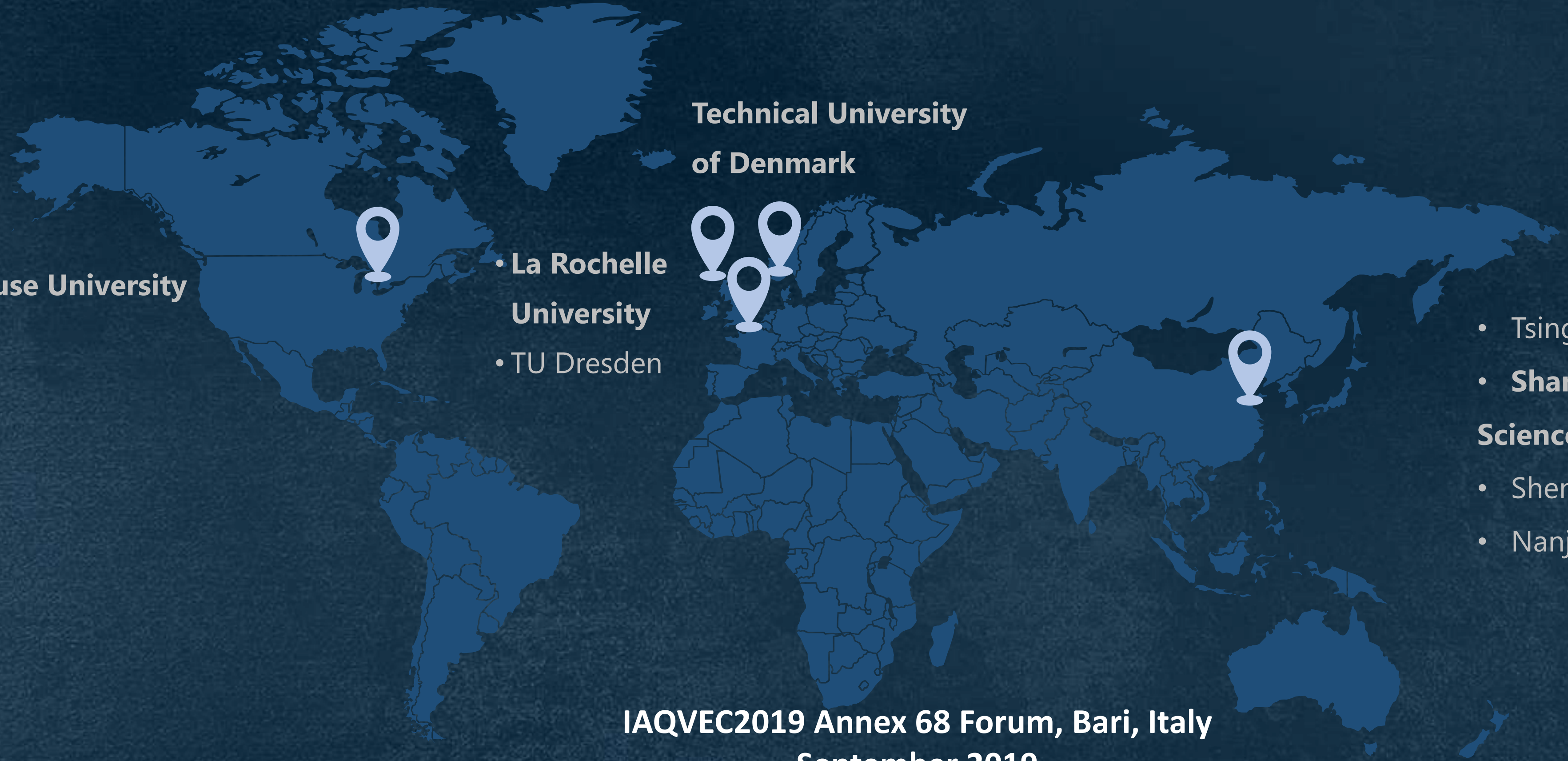
Pollutant Loads in Residential Buildings

Menghao Qin & Jensen Zhang



IAQVEC2019 Annex 68 Forum, Bari, Italy
September 2019

OBJECTIVE OF SUBTASK 2

- This subtask is to collect / provide data about properties for transport, retention and emission of chemical substances in new and recycled materials in residential buildings under the influence of heat, airflow and moisture conditions.

- Collection of results from lab tests on material and room level will be part of this study. Specifically, results will be collected and analysed from tests of emission of harmful compounds under various temperature, humidity and airflow conditions, since such data under combined exposures generally are not available for use today.

- ***Development of reliable methods and data for estimating pollutant loads in residential buildings in the way heating/cooling loads are routinely estimated.***



ACTIVITIES OF SUBTASK 2

- Effects of temperature and relative humidity on emissions
- Definition of reference buildings
- 3 common exercises
- Model-based testing and evaluation of VOC emissions and sorption
- Database of VOC emissions for IAQ simulations

ACTIVITIES AND ROADMAP

Literature survey	Measurement tests	Model improvement
➢ Major pollutant sources from materials and assemblies in residential buildings ➢ Existing emission models and model parameters ➢ Emission standards ➢ Database	➢ Laboratory test of materials under various temperature, humidity and their combined effects	➢ Correlations between emission parameters and key influencing factors ➢ Mass transfer emission models development ➢ Similarity between VOC and moisture transport

Time schedule

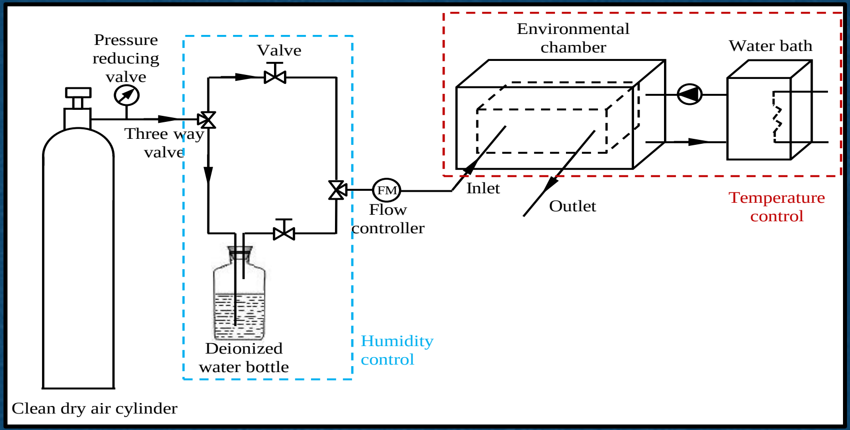
2015	2016	2017-2018	2019
• Stakeholders involve • Preliminary studies	• Literature survey • Preliminary studies	• Measurement test	• Reporting • Database development

Temperature and humidity influences on the emission rate of VOCs in building materials

- Temperature and relative humidity can simultaneously change in indoor environment, which significantly affect the emission rate of formaldehyde and VOCs from building materials.

- Previous studies mainly focus on the single effect of temperature OR relative humidity, and the combined effect is not considered.

- Study on the emissions of formaldehyde and VOCs from building materials can be divided into two approaches: modelling and experimental measurement.



LABORATORY TESTING

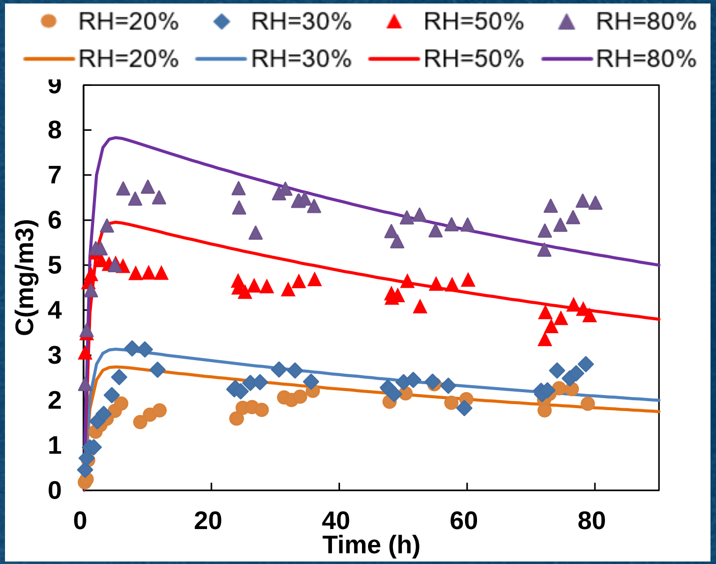
LABORATORY TESTING

The effects of temperature, humidity and the combined effects of them on formaldehyde emissions from a medium-density fiberboard were analyzed.

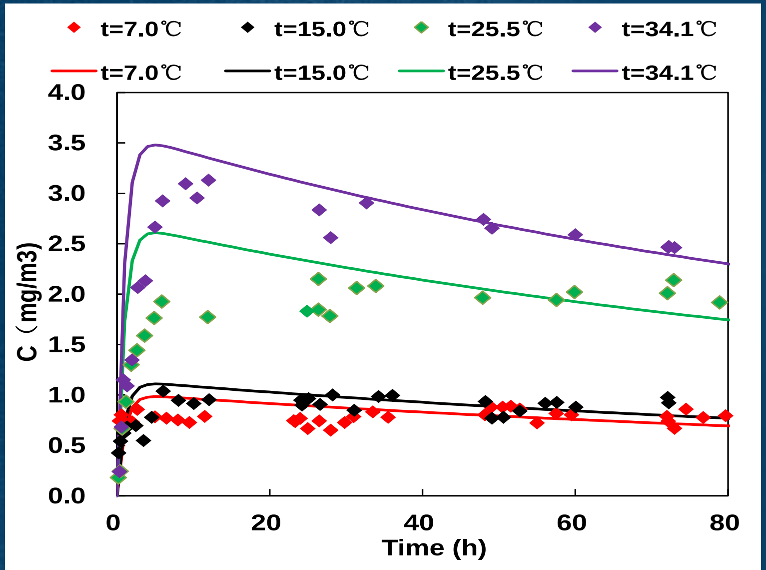
Series No.	Temperature (°C)	RH (%)	AH (g/kg_{air})	Ventilation rate (h^{-1})	Dimensions (mm×mm×mm)	
S1	25.5±0.5	20±5	4.0±0.5	1±0.05	245×140×12	Humidity effect
	25.5±0.5	30±5	6.1±0.5	1±0.05	245×140×12	
	25.5±0.5	50±5	10.4±0.5	1±0.05	245×140×12	
	25.5±0.5	80±5	16.7±0.5	1±0.05	245×140×12	
S2	7.0±0.5	62.0±5	4.0±0.5	1±0.05	245×140×12	Temperature effect
	15.0±0.5	38.6±5	4.0±0.5	1±0.05	245×140×12	
	25.5±0.5	20.0±5	4.0±0.5	1±0.05	245×140×12	
	34.1±0.5	12.0±5	4.0±0.5	1±0.05	122×140×12	
S3	5.2±0.5	50.0±5	2.8±0.5	1±0.05	245×140×12	Combined effect
	15.0±0.5	50.0±5	5.2±0.5	1±0.05	245×140×12	
	25.5±0.5	50.0±5	10.4±0.5	1±0.05	245×140×12	
	35.0±0.5	50.0±5	17.8±0.5	1±0.05	122×140×12	

LABORATORY TESTING

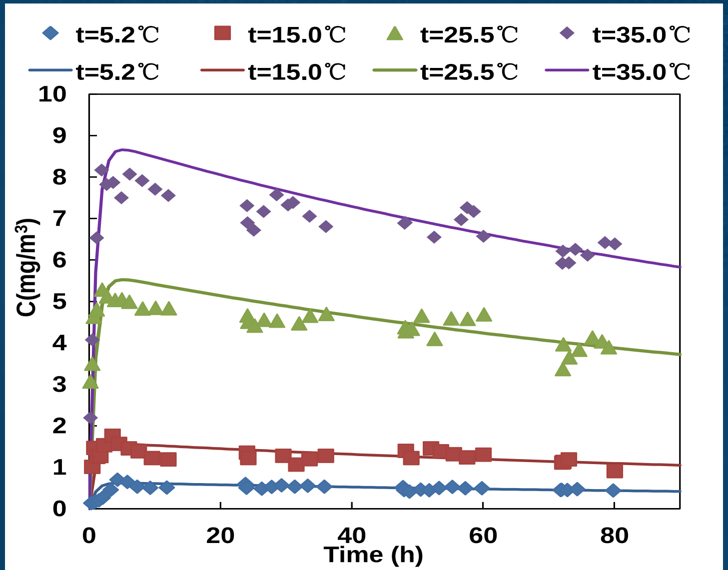
S1



S2



S3

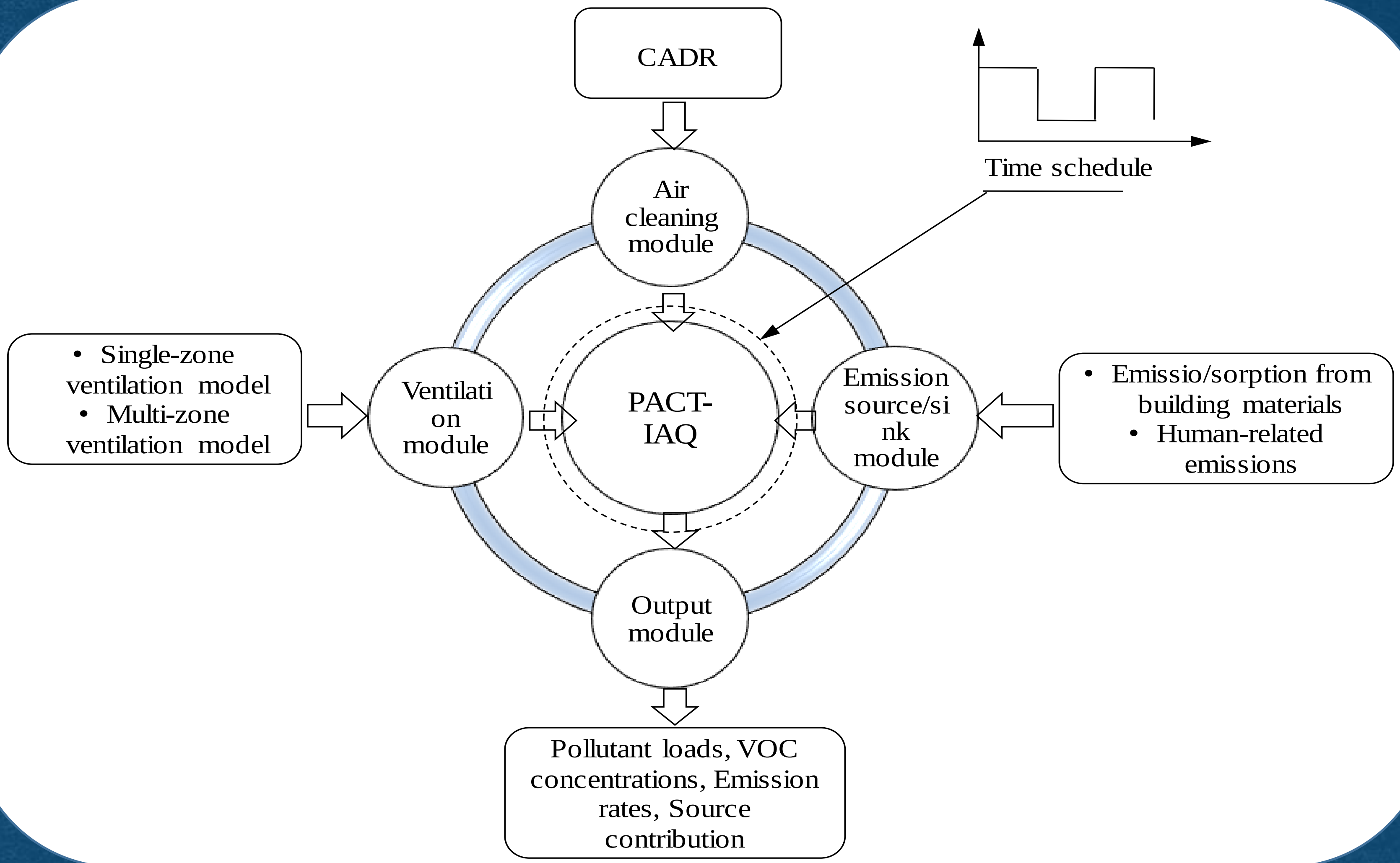


C_0 (mg/m³)	D_m (m²/s)	K (—)
1.75×10⁶	3.40×10⁻¹⁴	6340
2.00×10⁶	3.36×10⁻¹⁴	5514
3.80×10⁶	3.50×10⁻¹⁴	5340
5.20×10⁶	3.14×10⁻¹⁴	3128

C_0 (mg/m³)	D_m (m²/s)	K (—)
7.90×10⁵	3.00×10⁻¹⁴	9467
8.50×10⁵	3.15×10⁻¹⁴	7844
1.75×10⁶	3.40×10⁻¹⁴	6340
4.30×10⁶	3.57×10⁻¹⁴	4570

C_0 (mg/m³)	D_m (m²/s)	K (—)
4.93×10⁵	2.90×10⁻¹⁴	9752
1.14×10⁶	3.15×10⁻¹⁴	7280
3.80×10⁶	3.50×10⁻¹⁴	5340
1.10×10⁷	3.60×10⁻¹⁴	3450

LABORATORY TESTING



A Pre-Assessment and Control Tool for Indoor Air Quality (PACT-IAQ)

REFERENCE BUILDING

PROGRESS REPORT

HVAC SYSTEM (VRV + FRESH AIR HEAT RECOVER SYSTEM + AIR PURIFIER)

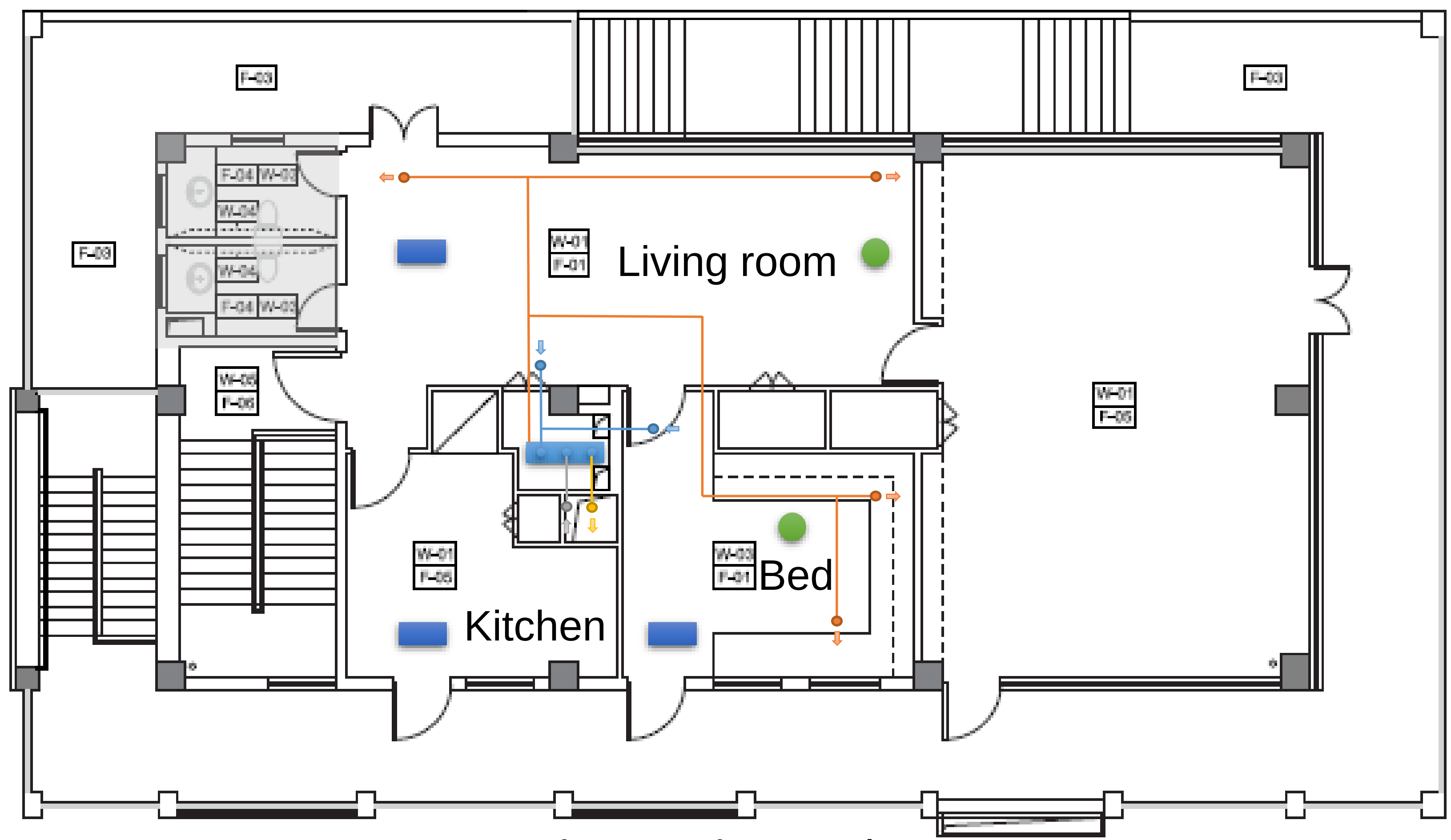


Fig. 1. New air system plan

Indoor Air Inlet (ceiling)
Indoor Air Outlet (ground)
Outdoor Air Inlet (outside)
Outdoor Air Outlet (outside)
Air conditioner
Air purifier
Fresh air total heat exchanger

REFERENCE BUILDING

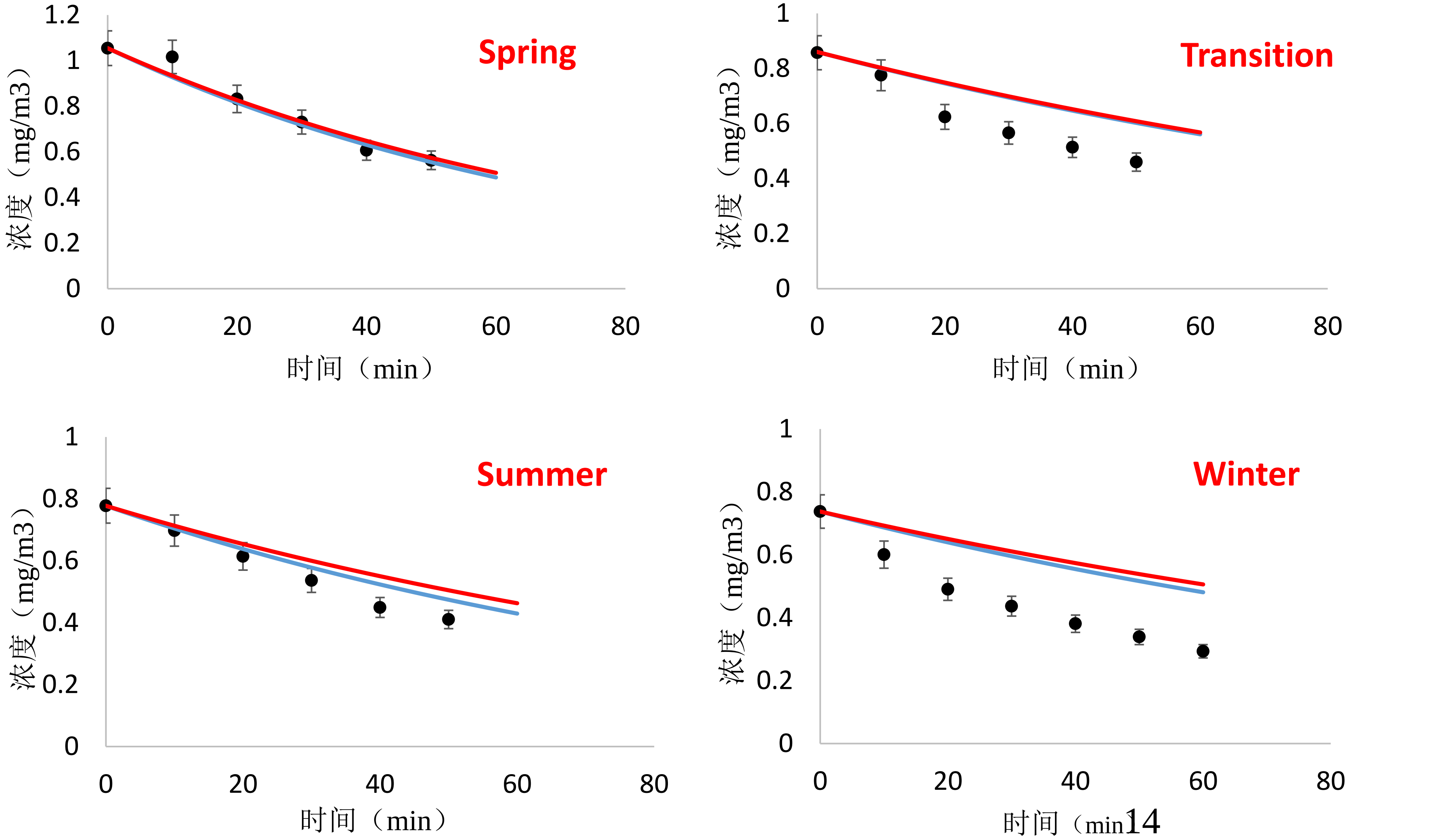
Project Introduction------Thermal Performance –Simulated by EnergyPlus

Material Setting

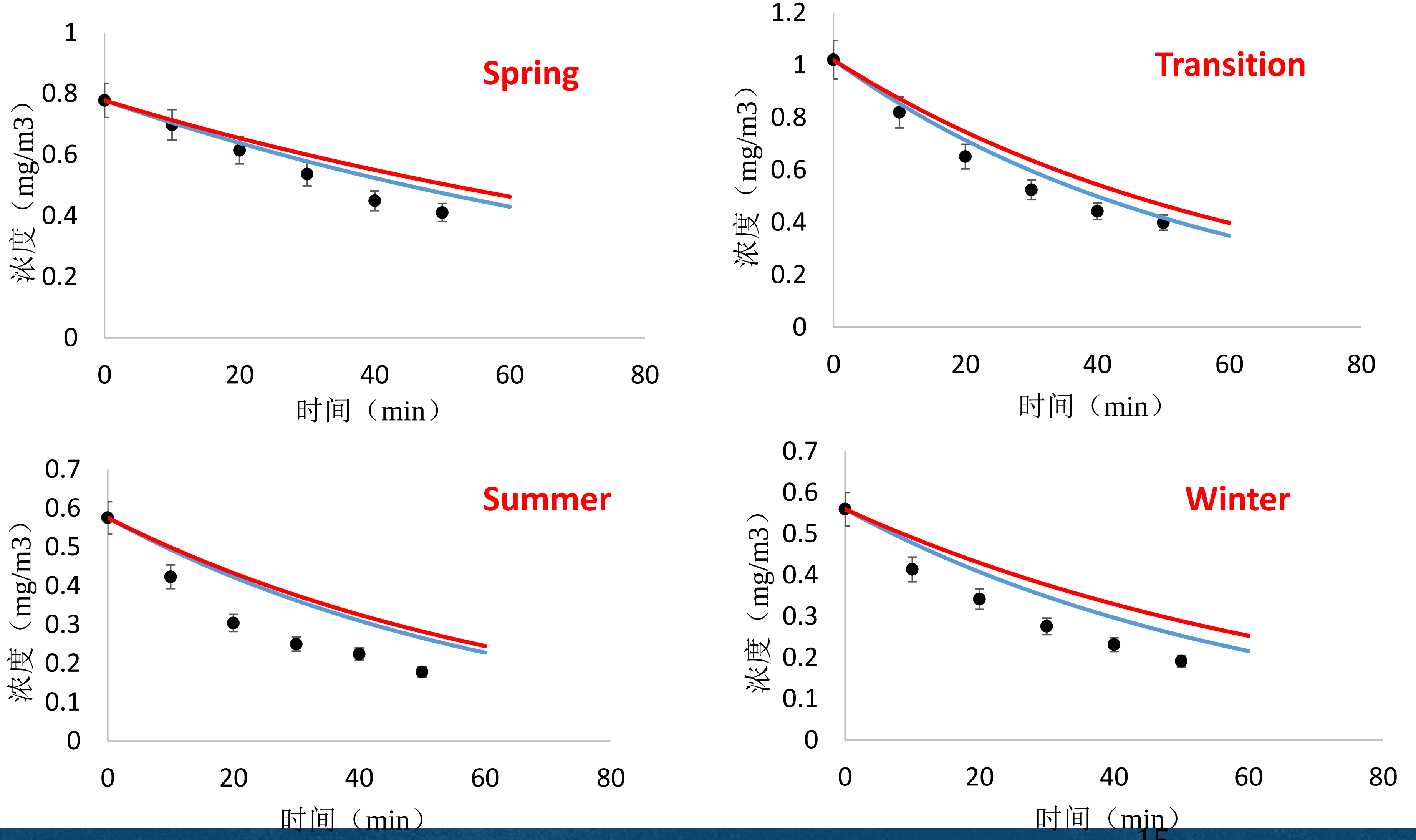
Envelope	Material	thickness (mm)	Conductivity (W·m⁻¹·K⁻¹)	Density (kg/m³)	Specific heat (J/kg-k)	Thermal effusivity (W/(m k))	Conductivity of structure (W·m⁻²·K⁻¹)
exterior wall	Polymer cracking mortar	7	0.930	1800	1050	11.310	0.8422
	Composite foamed cement board	50	0.060	220	250	1049.6	
	Cement mortar	20	0.930	1800	1050	11.310	
	Porous clay brick	200	0.639	1400	1062.3	7.92	
	Lime mortar	10	0.810	1600	1050	9.950	
floor	Cement mortar	20	0.930	1800	1050	11.310	0.6303
	Cast-in-place concrete slab	100	1.740	2400	316	17.06	
	Composite foamed cement board	90	0.060	220	1049.6	1.07	
	Polymer cracking mortar	7	0.930	1800	1050	11.310	
interior wall	Lime mortar	10	0.810	1600	1050	9.950	2.9614
	Porous clay brick	200	0.639	1400	1062	7.920	
	Lime mortar	10	0.810	1600	1050	9.950	
roof	Cement mortar	15	0.930	1800	1050	11.310	0.66
	Polyurethane waterproof coating	2	0.033	1200			
	Cement mortar	20	0.930	1800	1050	11.310	
	Composite foamed cement board	80	0.060	250	1049.6	1.07	
	Cement mortar	15	0.930	1800	1050	11.310	
	Cast-in-place concrete roof board	120	1.740	2400	316	17.060	
ground	Cement morta	20	0.930	1800	1050	11.310	0.6123
	C20 Fine stone concrete	40	1.510	2500	920	17.06	
	Composite foamed cement board	85	0.060	250	1049	1.07	
	Cement morta	20	0.930	1800	1050	11.310	
	Cast-in-place concrete slab	120	1.740	2400	316	17.06	
	Broken stone hardcore	100	1.280	2100	920	15.36	
window	Low-E glass	6	1.7	2500	840	10.69	2.25
	Air gap	12	0.023	1.29	1007	0	
	Low-E glass	6	1.7	2500	840	10.69	

FIELD TEST

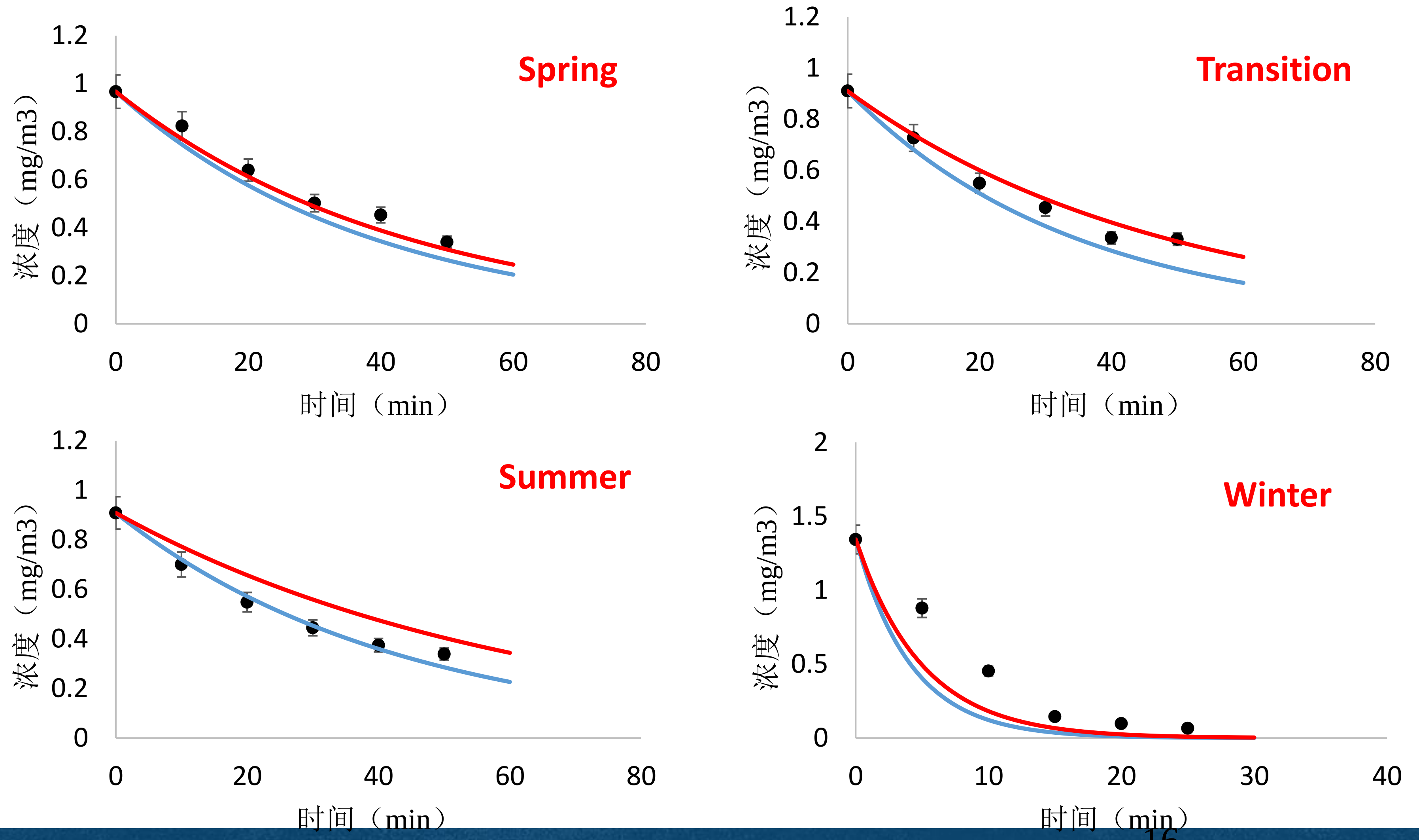
➢ Infiltration



➢ Mechanical ventilation



➢ Nature ventilation



DTU

COMMON EXERCISES

8th July, 2017

Annex 68 – Subtask 2

Common Exercise 1

Definition of a Reference House for Determining the Baseline IAQ and Energy Consumption Conditions

Simulation of IAQ and Energy Consumption of a Reference House or Apartment

Prepared by

Zhenhai Liu, Wenhao Chen, Menghao Qin and Jensen Zhang

Objectives:

1) Develop a procedure for defining a standard reference to represent a typical design and operation condition for the local climate and practice as the baseline for evaluating IAQ and energy efficiency strategies;

2) Compare the baseline conditions of IAQ and Energy consumption of different countries/regions.

Scope:

Define layout and building materials of the reference house; Specify local climate conditions; Define the schedules of equipment and occupancies; Define the pollution loads; Simulate energy consumption and IAQ of reference house.

July 2017

18th July, 2017

Annex 68 – Subtask 2

Common Exercise 2

Full-scale chamber/room scale case exercise

Prepared by

KwangHoon Han, Menghao Qin and Jensen Zhang

Objectives:

Recent wide attention to the value and importance of IAQ requires that environmental engineers and students perform adequate evaluation of human exposure and risk management for indoor environments with a cocktail of indoor pollutants. Emission modeling and evaluation software can help these professionals analyze the exposure impacts of pollutant sources, sinks, ventilation and air cleaning in given environments. Through the current exercise, these professionals will be equipped with the abovementioned quality and skills.

Scope:

In the following three areas of application, modeling tasks will be exercised based on actual pollution measurements collected in a full-scale chamber with sources, ventilation and air cleaning:

July 2017

8th July 2018

Annex 68 – Subtask 2

Common Exercise 3

Development of a Procedure for Estimating the Parameters of Mechanistic Emission Source Models from Chamber Testing Data

Prepared by

Zhenlei Liu[1], Andreas Nicolai[2], Marc Abadie[3], Menghao Qin[4], John Grunewald[2], Jensen Zhang[1]

[1]BEESL Lab, Syracuse University, USA
[2]Dresden University of Technology, Germany
[3]University of La Rochelle, France
[4]Technical University of Denmark, Denmark

Contact: Mr. Zhenlei Liu zliu138@syr.edu
Prof. Jensen Zhang jszhang@syr.edu

July 2018

FINAL REPORT

Final report of subtask 2:

Pollutant loads in residential buildings

Part I

1. **Introduction** (Menghao Qin and Jensen Zhang)
Motivation, problem definition, objectives, scope, and a road map (overview of the thought process and the chapters to follow)

2. **Definition of reference buildings** (Zhenlei Liu and Jensen Zhang)
Use the existing report as draft, reference the conference papers

3. **Model-based testing and evaluation of VOC emissions and sorption** (Zhenlei Liu, Andreas Nikolai, John Grunewald and Jensen Zhang)
JZ to set-up the structure and ZL to fill in the details – reference to earlier conference paper and Jing Xu's dissertation

4. **Effects of temperature and relative humidity on emissions** (Weihui Liang, Menghao Qin, and Xudong Yang)

5. **Database of VOC emissions for IAQ simulations** (Zhenlei Liu, Andreas Nikolai, John Grunewald, Marc Abadie and Jensen Zhang)
ZL leads, provide an overview of the methodology, procedure and reference the journal paper for details, focus on the material clustering/grouping with focus on the materials used in the reference building, major VOCs of interest and the actual data of D_m, K_{ma} *and* C_{m0}.

6. **Summary and Conclusions** (Menghao Qin and Jensen Zhang)

Part II

1. **Summary of Common Exercise 1: Case Studies for Reference Buildings** (Menghao Qin and Jensen Zhang)

   1.1 Syracuse (Jensen Zhang)
   1.2 France (Marc Abadie)
   1.3 Shanghai (Chuanjuan Sun)
   1.4 Denmark (Jakub Kolarik)
   1.5 UK (Esfund Burman)
   1.7 Belgium (Jelle Laverge)
   1.8 Estonia (Ülar Palmiste)
   1.9 Canada (Fitsum Tariku)
   ….

2. **Summary of common exercise 2: Full-scale chamber/room scale case exercise** (Menghao Qin and Jensen Zhang)

3. **Summary of common exercise 3: Development of a Procedure for Estimating the Parameters of Mechanistic Emission Source Models from Chamber Testing Data** (Zhenlei Liu, Menghao Qin and Jensen Zhang)

EXPERT MEETINGS

THANK YOU

Email: menqin@byg.dtu.dk