Shaping Tomorrow's Built Environment Today

1791 Tullie Circle NE ▪ Atlanta, Georgia 30329-2305 ▪ Tel 678.539.1211 ▪ Fax 678.539.2211 ▪ http://www.ashrae.org

Michael R. Vaughn, P.E.
Manager Research & Technical Services

mvaughn@ashrae.org

TO: Bohanon, Hoy, Chair SSPC 62.1, bohanoneng@gmail.com
Wayne Thomann, Vice-chair SSPC 62.1, thoma010@mc.duke.edu
CC: Michael Pouchak, Research Liaison Section 4.0, mike.pouchak@honeywell.com

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: November 6, 2018

SUBJECT: Research Topic Acceptance Request (1868-RTAR), "Feasibility of predicting indoor formaldehyde, VOC, and CO2 concentrations using simplified inputs to air quality models in new office buildings"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it with comments for further development into a work statement (WS) provided that the key comment(s) and question(s) below are addressed to the satisfaction of your Research Liaison, Michael Pouchak, mike.pouchak@honeywell.com, or RL4@ashrae.net, in the work statement draft.

1. The project is too broad in scope.
2. The objectives list in the specific section is actually a list of actions to accomplish something not clearly defined.

The work statement draft must be approved by the Research Liaison prior to submitting it to RAC.

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later than **August 15, 2020** or it will be dropped from display on the Society's Research Implementation Plan. The next likely submission deadline for a new work statement on this topic is **May 15, 2019** for consideration at RAC's 2019 Annual meeting. The submission deadline after that for work statements is **August 15, 2019** for consideration at the RAC's 2019 fall meeting.

Project ID	**1868**	
Project Title	**Feasibility of predicting indoor formaldehyde, VOC, and CO2 concentrations using simplified inputs to air quality models in new office buildings**	
Sponsoring TC	SSPC 62.1	
Cost / Duration	$200,000 / 24 Months	
Submission History	**1st Submission**	
Classification: Research or Technology Transfer	Basic/Applied Research	
RAC 2018 Fall Meeting Review		
Essential Criteria	**Voted NO**	**Comments & Suggestions**
Background: The RTAR should describe current state of the art with some level of literature review that documents the importance/magnitude of a problem. References should be provided. If not, then note it in your comments.		**2**- Yes, but what term of the building after construction this RTAR assumes. The RTAR says steady state conditions. That means two or three years later after the construction of building. If so, the concentration of comparatively light volatile components will be decreased and the RTAR mainly concerns of CO2 and VOCs from diffusion control emission from the building materials. **9** - Reports some studies with other buildings, but few for offices. Given the number of offices, says this work is needed. Some refs cited. **10** - Not clear the conclusion why a new study is needed because of the size distribution of the offices. In fact it is not reported what kind of commercial buildings were investigated by previous research projects.
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.		**9** - There is a need; if met and validated, could identify poor iaq and address problem. **10** - The need is identified but the scope is too wide. A research project lasting 24 months and with a budget of 200k is unlikely to provide credible and sound answers for so many research questions applicable to so many different situations.
Relevance and Benefits to ASHRAE: Evaluate whether relevance and benefits are clearly explained in terms of: a. Leading to innovations in the field of HVAC & Refrigeration b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards. Is this research topic appropriate for ASHRAE funding? If not, Reject.		**9** - Would help achieve better understanding of iaq.
IF ABOVE THREE CRITERION ARE NOT ALL SATISFIED - MARK "REJECT" BELOW & CONTINUE REVIEW BELOW		
Other Criteria	**Voted NO**	**Comments & Suggestions**
Project Objectives: Based on the background and need, evaluate whether the project objectives are: 1. Aligned with the need 2. Specific 3. Clear without ambiguity 4. Achievable If not, then appropriate feedback should be provided.		**7** - The project is too broad in scope, and it is unlikely that the project will produce useful results. There are too many variables related to emission rates from materials, building tightness, ventilation rates, dynamics of air-chemistry, outdoor environment, occupant behavior. Three buildings is not enough to produce statistically significant models. I would rather see a laboratory or in-situ study where all these variables could be manipulated to determine the importance to IAQ. **9** - Clear, but need to state output and what form it would take. **10 -** Some more details are needed. The objectives list in the specific section is actually a list of actions to accomplish something not clearly defined. 8 - would like refinement of the objectives to descope to a more achievable result
Expected Approach and Budget: Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision. Anticipated funding level and duration:		**4** - In the proposed approach there are too many variables that can influence the results. The Authors should first select the most reliable air quality model and only then being feasibility study for predicting concentrations of contaminants based on simplified inputs. It seems to me that it would be better to first make the study under controlled conditions (chamber or a model house) before any field validation attempts. The project scope is far too large at the moment. **9** - This is a list of bullets and needs to be brought together to form a coherent outline methodology. **15** - Are you sure that you can get VOC emission rates from product manufacturers? Maybe I'm wrong but I'm not. And I question whether 200K is enough for all this work, particularly the field studies. 10 - The amount of work involved in the project would require much more than two years, unless many research institutions could be involved at the same time. In such case the budget should be much higher.
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**2** - Describe what term of building after construction is assumed. Usually within a few months after the construction, the concentrations of VOCs are high. At that term, health troubles will occur. However the RTAR assumes the steady state of the concentrations. Does that mean the state of a few years later after construction? **7** - The project is too broad in scope, and it is unlikely that the project will produce useful results. **9** - Note comments above under 'objectives' and 'expected approach'. However, there are likely to be a lot of factors influencing iaq. The approach involves a lot of assumptions that may be too far removed from everyday iaq behavior. Would a more detailed forensic study of one or two buildings yield a more reliable approach, at least in the first instance? **10 -** The idea behind the RTAR is worth being investigated. However, the research work should be divided in several smaller projects. Those projects need to be coordinated with the purpose of reaching some specific goals. The objectives of each single project (or subproject) shall be clearly quantified and specified. **8** - update achievable objectives
ACCEPT W/COMMENTS		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
ACCEPT W/COMMENTS Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: 07/30/2018

(Please Check to Insure the Following Information is in the RTAR)

Title:

A. Title	x
B Executive Summary	x
C. Background	x
D. Research Need	x
E. Project Objectives	x
F. Expected Approach	x
G. Relevance and Benefits to ASHRAE	x
H. Anticipated Funding Level and Duration	x
I. References	x

Feasibility of predicting indoor formaldehyde, VOC, and CO_2 concentrations using simplified inputs to air quality models in new office buildings

RTAR # 1868

(To be assigned by MORTS)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

ASHRAE Standard 62.1

Research Classification:

Basic/Applied Research	x
Advanced Concepts	
Technology Transfer	

Responsible Committee: SSPC 62.1

Date of Vote: 8/7/2018

For		16
Against	*	2
Abstaining	*	2
Absent or not returning Ballot	*	2
Total Voting Members		22

RTAR Authors

Lead: Lisa Ng

Others:

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date)

TC 2.8: 10-0-0-2 on August 14, 2018
TC 4.10: 10-0-0-0 on June 25, 2018

Expected Work Statement Authors

Lead: Lisa Ng (SSPC 62.1, TC 2.8), Jim Dennison (62.1), Xudong Yang (TC 4.10)

Others:

Potential Co-funders (organization, contact person information):

	Yes	No
Has an electronic copy been furnished to the MORTS?	x	
Has the Research Liaison reviewed the RTAR?		

* Reasons for negative vote(s) and abstentions

- This is too ambitious for a single research project and too limited in the number of buildings.
  - Obtaining emission information from manufacturers is an excellent start but could consume the entire effort. The same could be true for the field sampling and for the model verification. This RTAR is more likely to generate useful and reliable results if broken into more manageable projects in a phased approach.
  - The questions being addressed are significant and the information sought would be highly beneficial. However, to be applicable to more than 3 buildings, there will need to be some indication that the buildings selected are representative of some portion of the buildings stock. Soliciting information from contractors, architects, etc will not provide any indication that the buildings selected are representative.

Response from chair: Proposer worked with Research and Education Subcommittee to improve the original draft that was discussed in Houston. The initial scope proposed exceeded practical budget limits for ASHRAE research. Although it is always better to have more samples and a bigger data base, this limited approach will provide important data for informing future versions of Standard 62.1 and will provide a basis for the next steps in research. The field work is intended to assess feasibility, and is not intended to establish a representative database.

RTAR # 1868

Title:

Feasibility of predicting indoor formaldehyde, VOC, and CO_2 concentrations using simplified inputs to air quality models in new office buildings

Executive Summary 50 words

The proposed research seeks to study the feasibility of using air quality models to predict the concentrations of formaldehyde, selected volatile organic compounds and carbon dioxide in new offices using simplified inputs such as construction drawings and documentation, design airtightness targets, and measurements of the mechanical ventilation airflow.

Background 300 words, with references at the end of this document

The last review of volatile organic compound (VOC) concentrations in buildings was done by Hodgson and Levin [1], who reported typical and maximum indoor concentrations in the literature since 1990. Unfortunately, data was mostly available for residences and only a handful of studies had been published for commercial buildings. Hodgson and Levin [1] also noted that most of the studies did not measure outdoor ventilation, which is a critical piece of information needed to fairly compare concentrations across buildings.

VOC emission rates were reported in ASHRAE Research Project (RP)-1596 [3]. The study was conducted for 14 U. S. retail buildings. Another emissions study was conducted for 19 California retail stores [4]. Similar studies in other types of U. S. commercial buildings are lacking, with only one study conducted in the U. S. by Bennett et al. [5] that included restaurants, offices, and other small/medium commercial buildings.

According to the U. S. Energy Information Administration (EIA) 2015 study [6], offices are most prevalent commercial building types in terms of number of buildings and floor area. The same report also notes that 50 % of commercial buildings have floor areas < 5,000 ft^2, 38 % of buildings with floors between 5,000 ft^2 and 25,000 ft^2, and 10 % of buildings with floor areas between 25,000 ft^2 and 100,000 ft^2. Therefore, a new study of chemical emissions in office buildings is needed.

Research Need 250 words Use the state of the art described above as a basis to specify the need for the proposed effort

This RTAR seeks to demonstrate the feasibility of using air quality models (e.g., mass balance, steady state, multizone modeling) to predict indoor concentrations of formaldehyde, selected VOCs and carbon dioxide (CO_2) using simplified inputs. The information needed for an air quality model could be simplified as follows:

(1) Emission rates of building materials inside a building, typically measured, could be obtained from records of product inventory and manufacturer-supplied product emission testing;

(2) Building envelope airtightness levels, which affect infiltration rates and are typically measured using fan pressurization tests, could be assumed based on the code-requirements or design targets

(3) Total outdoor air change rate, typically measured using tracer gas decay tests, could be estimated using airflow measurements in the supply duct of the air handling system and an assumption about, or simulation of, infiltration rates

(4) New studies of determining CO_2 generation rates have been published by Persily and de Jonge [2], which can be used to estimate CO_2 concentrations for comparison with measurements

Once the buildings are chosen and air quality models developed, measurements of CO_2, formaldehyde and selected VOCs (e.g., acetaldehyde, toluene, and benzene), envelope airtightness, ventilation rates and operation (including air-cleaning devices) should be conducted and compared with the predicted indoor concentrations.

This research project is intended to address that gap in the availability of VOC emission rates measurements in offices. The results of this study could aid in the development of future versions of ASHRAE Standard 62.1 and provide the scientific data for designing spaces with acceptable IAQ.

Project Objectives (150 words maximum)

The objectives of this RTAR are:

(1) To select air quality models for testing (e.g., mass balance, steady state, multizone modeling)

(2) To compare the predicted and measured CO_2, formaldehyde and selected VOCs (e.g., acetaldehyde, toluene, and benzene) concentrations

(3) To conduct a sensitivity on the model inputs in order to determine the most and least important inputs for accuracy of the predicted and measured concentrations

Expected Approach

Describe in a manner that may be used for assessment of project viability, cost, and duration, the approach that is expected to achieve the proposed objectives (200 words maximum).

Check all that apply: Lab testing [x], Computations [ ], Surveys [x], Field tests [x], Analyses and modeling [x], Validation efforts [x] Other (specify) ( )

The proposed RTAR is expected to include the following:

- Surveys: Solicit product inventory records from contractor, estimate building envelope airtightness using code-requirements or design targets
- Surveys: Building envelope airtightness from code requirements or design targets
- Field: Measurements of outdoor ventilation rates
- Field: Measurements of formaldehyde, selected VOCs, and CO_2
- Field: Document ventilation system operation, filters, and air-cleaning devices
- Lab testing: Analysis of VOC samples
- Analyses and modeling: Using literature on building material emissions and manufacturer-provided product emissions testing, determine the range of emissions of each chemical that will be simulated. Using the selected air quality models and simplified inputs, calculate the concentrations of formaldehyde, selected VOCs, and CO_2.
- Validation efforts: Use field measurements to compare with the results of the simulations.
- Analyses and modeling: Conduct a sensitivity on the model inputs in order to determine the most and least important inputs for accuracy of the predicted and measured concentrations

The proposed RTAR is expected to require 2 years for:

- Soliciting architects, general contractors and other professionals for product inventory in three new office buildings (one < 10,000 ft^2, one between 10,000 ft^2 and 50,000 ft^2, and one between 50,000 ft^2 and 100,000 ft^2)
- Accounting of selected building materials (or assemblies)
- Determining emission rates of selected building materials (or assemblies) from manufacturer and literature
- Computer simulations
- Conducting measurements (formaldehyde, selected VOCs, CO_2, ventilation, envelope airtightness)
- Conducting and lab analysis of formaldehyde and selected VOCs
- Reporting of building materials, simulations, and performance of the air quality models using simplified inputs

Relevance and Benefits to ASHRAE

This research supports Goal 4 of ASHRAE's Research Strategic Plan 2010-2018, which is to "significantly advance our understanding of the impact of IEQ on work performance, health symptoms and perceived environmental quality in offices, providing a basis for improvements in ASHRAE standards, guidelines, HVAC&R designs and operation practices." The research will also advance the state of the art by adding to knowledge base of how polluting are new offices. By having this information, ASHRAE is in a better position to produce a ventilation standard that can deliver indoor environments that are acceptable to its human occupants.

Other organizations that may also benefit from this research would be ones that develop "green standards" such as the U. S. Green Building Council (USGBC) and the International WELL Building Institute (IWBI). USGBC develops the LEED certification program, which awards points for energy-saving measures in buildings but also includes credit for increased ventilation above ASHRAE Standard 62.1. IWBI develops the WELL certification program, which focuses on human health and well-being by awarding points for reducing VOCs and improving olfactory comfort.

Anticipated Funding Level and Duration

Funding Amount Range: $ 200,000

Duration in Months: 24

References

1. Hodgson, A. T. and H. Levin (2003). Volatile Organic Compounds in Indoor Air: A Review of Concentrations Measured in North America Since 1990. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-51715.
2. Persily, A. and L. de Jonge. *Carbon dioxide generation rates for building occupants.* Indoor Air, 2017. **27**(5): p. 868-879.
3. Siegel, Jeffrey A., Jelena Srebric, Neil Crain, Elena Nirlo, Marwa Zaatari, Andrew Hoisington, Jorge Urquidi, Shi Shu, Yang-Seon Kim, and Daranee Jareemit (2012). ASHRAE Research Project 1596-RP: Ventilation and Indoor Air Quality in Retail Stores. Austin, TX: The University of Texas at Austin, The Pennsylvania State University.
4. Chan, Wanyu R., Meera Sidheswaran, Douglas Sullivan, Sebastian Cohn, and William J. Fisk (2012). Healthy Zero Energy Buildings (HZEB) Program - Interin Report on Cross-Sectional Study of Contaminant Levels, Source Strengths, and Ventilation Rates in Retail Stores. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-5953E.
5. Bennett, Deborah H., Michael Apte, Xiangmei (May) Wu, Amber Trout, David Faulkner, Randy L. Maddalena, and Douglas P. Sullivan (2011). Indoor Environmental Quality and Heating, Ventilating, and Air Conditioning Survey of Small and Medium Size Commercial Buildings: Field StudyCalifornia Energy Commission. CEC-500-2011-043.
6. EIA. *A Look at the U.S. Commercial Building Stock: Results from EIA's 2012 Commercial Buildings Energy Consumption Survey (CBECS)*. 2015 6/25/18]; Available from: https://www.eia.gov/consumption/commercial/reports/2012/buildstock/index.php.

Feedback to RAC and Suggested Improvements to RTAR Process

Now that you have completed the RTAR process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.