INFLUENCE OF INDOOR ENVIRONMENT ON SICK BUILDING SYNDROME

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(128012V)

Degree of Doctor of Philosophy

Department of Civil Engineering

University of Moratuwa

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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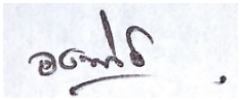

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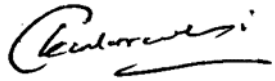
Perera T.M.

The above candidate has carried out research for the PhD thesis under our supervision.

Research Supervisors



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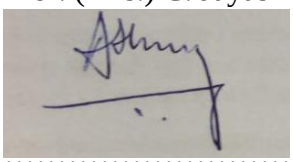

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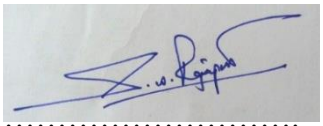

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Dr. S.W. Rajapaksa

ABSTRACT

Influence of indoor environment on sick building syndrome

People spend most of their time indoors, either at home or at work. Therefore, it is essential to maintain a high level of health and safety inside all types of buildings. The phenomenon where the health conditions of the occupants are adversely affected due to the indoor environment, it is called "Sick Building Syndrome" which is abbreviated as the SBS. The origin of indoor air pollutants is mainly categorized into three distinct sources. They are building materials and related human practices during construction and operation stages, outdoor sources and the prevailing ventilation condition of the structure in the discussion.

The importance of studying in-depth of the causes and prevention of SBS, lead this research to identify the effect of different building materials and operational practices on indoor air quality (IAQ) and quantify their impact with respect to its emission and the exposure of the occupants. Further, strategies have been determined to minimize the SBS while developing guidelines to create a healthier built environment.

In order to achieve these objectives, concentrations of Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2), Total Volatile Organic Compounds (TVOCs) and Particulate Matter ($PM_{2.5}$) were measured using Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) and Haz-Dust Particulate Air Monitor. A questionnaire survey was conducted to evaluate the satisfaction of the occupants with the indoor environment that they reside and obtain an idea on their reviews to formulate a relationship between the level of comfort and IAQ. At the same time, the effect of the ventilation condition was assessed using the IAQ results of each of these locations.

Out of all the building materials and related activities, solvent-based wall paint was selected for the detailed analysis due to the identification of a prominent contribution to the indoor air pollution with its usage. Results from the questionnaire survey were able to justify and present a relationship between the indoor air pollutants and the key symptoms related to SBS. At the same time, ventilation condition has been identified as a key factor that contributes to the betterment of IAQ. A Computational Fluid Dynamic (CFD) model was developed using ANSYS-Fluent software, which was used to predict the TVOCs concentration generated from solvent-based wall paint concerning the ventilation rates under the control of environmental and test conditions. The experimental results were used to validate the CFD model before it is recommended for future references. The validated CFD model could be used to predict the building flush-out period and appropriate ventilation condition to dilute the accumulated pollutants inside the buildings.

Keywords: Indoor Air Quality (IAQ), Sick Building Syndrome (SBS), Solvent-based paint, TVOCs dispersion, CFD model

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LIST OF ABBREVIATIONS

ACGIH	*American Congress of Governmental Industrial Hygienists*
ACH	*Air Changes per Hour*
ASHRAE	*American Society of Heating, Refrigerating and Air-Conditioning Engineers*
C	*Computer*
CDF	*Cumulative Distribution Function*
CF	*Carpeted Floor*
CFD	*Computational Fluid Dynamics*
CO	*Carbon Monoxide*
CO_2	*Carbon Dioxide*
dCO_2	*Difference between indoor and outdoor CO_2 concentrations*
DDT	*Dichlorodiphenyltrichloroethane*
DEHP	*Bis (2-ethylhexyl) Phthalate*
DPM	*Discrete Phase Model*
EDCs	*Endocrine Disruptive Chemicals*
EEA	*European Environmental Agency*
ETS	*Environmental Tobacco Smoke*
FIDOL	*Frequency, Intensity, Duration, Offensiveness and Location*
GC	*Gas Chromatography*
GHO	*Global Health Observatory*
GINA	*Global Initiative for Asthma*
H_2S	*Hydrogen Sulfide*
HCHO	*Formaldehyde*
HVAC	*Heating, Ventilation, and Air Conditioning*
IAP	*Indoor Air Pollution*
IAQ	*Indoor Air Quality*
IEQ	*Indoor Environmental Quality*
IPV	*Indoor Permissible Value*
IVC	*Inadequate Ventilation Condition*
MDF	*Medium Density Fiberboard*
MVSC	*Motor Vehicle Service Centre*
NCAR	*National Center for Atmospheric Research*
NIOSH	*National Institute for Occupational Safety and Health*
NO	*Nitric oxide*

NO_2	*Nitrogen Dioxide*
NPA	*Newly Painted Area*
OC	*Organic Carbons*
OSHA	*Occupational Safety and Health Administration*
P	*Probability*
PAHs	*Polyaromatic Hydrocarbons*
PB	*Particle board*
PBDEs	*Polybrominated Diphenyl Ethers*
PCBs	*Polychlorinated Biphenyls*
PM_{10}	*Particulate matter that have a diameter of less than 10 micrometers*
$PM_{2.5}$	*Particulate matter that have a diameter of less than 2.5 micrometers*
PM_5	*Particulate matter that have a diameter of less than 5 micrometers*
PMs	*Particulate matters*
PP	*Photocopiers and Printers*
PVC	*Polyvinyl Chloride*
QS	*Questionnaire Survey*
R^2	*Coefficient of determination*
RH	*Relative Humidity*
RI	*Retention Index*
RMSE	*Root Mean Square Error*
Rn	*Radon*
SBM	*Synthetic Building Materials*
SBS	*Sick Building Syndrome*
SO_2	*Sulfur dioxide*
SSE	*Sum of square Error*
TB	*Tuberculosis*
TF	*Tiled Floor*
TI	*Toxicity Index*
TVOCs	*Total Volatile Organic Compounds*
UDF	*User Defined Function*
USEPA	*United State Environmental Protection Agency*
USEPA IRIS	*United State Environmental Protection Agency -Integrated Risk Information System*
VOCs	*Volatile Organic Compounds*
WHO	*World Health Organization*