ISHRAE

Indoor Environmental Quality Standard

Second version: 2018-2019

Index

Foreword

Introduction

Indoor Environmental Quality (IEQ) refers to the environmental conditions inside regularly occupied space that is determined by many factors, including indoor air quality (IAQ), thermal comfort, visual comfort, acoustic comfort as well as ergonomics. IEQ has an impact on health, comfort, and safety, which in turn affects productivity of occupants.

Research has shown that poor IEQ can have short and long term health effects. Indoor air pollutants can lead to health disorders such as headaches, allergies, asthma, and other respiratory diseases. Furthermore, conditions such as temperature, relative humidity, noise and lighting levels outside the acceptable comfort ranges could increase the stress level in human body, thus creating health issues like sleep disorder, digestive problems, and memory and concentration impairment besides resulting into discomfort of occupant.

In a good indoor environment, work efficiency of occupants gets enhanced, learning results are better among students and absenteeism is lower. This in-turn increases workplace productivity and test scores in schools, which is supported by research.

This standard identifies thermal comfort, indoor air quality, comfort and acoustic comfort as four critical elements of IEQ. Each of these elements have been covered by defining their threshold levels of IEQ parameters. Three levels for defining threshold values have been created: Class A (Aspirational), Class B (Acceptable) and Class C (Marginally acceptable). The defined threshold levels become more stringent for Class B and Class A. Some parameters have been omitted in Class B and Class C as the standard is applicable to variety of buildings ranging from unconditioned residences to large air conditioned commercial complexes. Class A is comparable with international standards.

This standard is designed in such a way that an IEQ rating system can be evolved. Any building evaluated using this standard, can be assessed as Class A, Class B, and Class C while complying with any individual parameter. It is possible that for one parameter; example IAQ, a building may perform better than Class A, whereas, for some other, it might not even meet threshold level as Class C.

There are several other IEQ elements and parameters that could have been included in this standard. However, wherever reliable supporting data, published studies, and affordable measuring instruments are not easily available, this version of the standard has excluded such elements and parameters. It is also envisaged that effect of most such parameters is likely to be covered through occupant satisfaction survey. Efforts have been made to utilise the knowledge and research presented in several India specific studies.

IEQ considerations need not be a constraint for energy efficiency in buildings. An integrated design approach that considers both indoor environmental quality and energy efficiency is crucial for the long term sustainability of buildings in India.

1. Scope

This standard defines the classification of built environment based on threshold values for below mentioned Indoor Environment Quality elements in a regularly occupied space of residential and non-residential buildings with low and moderate level of activities. This standard is applicable for Naturally ventilated , Mixed mode and Air conditioned building types.

The IEQ parameters under the scope of this standard are :

a. Indoor air quality
b. Thermal comfort
c. Visual comfort
d. Acoustic comfort

This standard also defines the test requirement and test method for measurement of the IEQ parameters.

Out of Scope

The below type of built environment is out of scope of this standard.

a) Spaces used for high intensity activities.
b) Special purpose built environment for Specific requirements such as Operation Theatres, Intensive Care Units, clean room, scientific laboratories, industry and other specialized applications.
c) Indoor environmental quality parameters such as water quality, odours ergonomics, electromagnetic radiations, vibrations and others.

2. Normative References

The following standards contain provision which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS 5182 – Part 2: *Methods for Measurement of Air Pollution, Part 2: Sulphur Dioxide*

IS 5182 – Part10: *Methods for Measurement of Air Pollution, Part 10: Carbon Monoxide*

IS 5182 – Part 9: *Methods for measurement of air pollution, Part 9: Oxidants*

IS 36461: *Code of Practice for Interior Illumination*

IS 3646-1: Code of practice for interior illumination

NBC 2005: *the National Building Code of India 2005*

Central Pollution Control Board - Indoor Air Pollution Monitoring Guidelines, 2014

Central Pollution Control Board – *the Noise Pollution (Regulation and Control) Rules, 2000*

ISO 3382 – Part 1: *Acoustics — Measurement of room acoustic parameters — Part 1: Performance spaces*

ISO 3382 – Part 2: Acoustics — *Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

ISO 3382 – Part 3: Acoustic parameters — *Part 3: Open plan offices*

ISO 18233: Acoustics — *Application of new measurement methods in building and room acoustics*

ISO 1996-2: Acoustics -- *Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels*

ISO 16283-1: Acoustics — *Field measurement of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation*

ISO 16283-1: Acoustics — *Field measurement of sound insulation in buildings and of building elements — Part 2: Impact sound insulation*

ISO 16017-1: *Indoor, ambient and workplace air -- Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling*

ISO 16000-3: *Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air -- Active sampling method*

ISO 16000-5: *Sampling strategy for volatile organic compounds (VOCs)*

ISO 16000-6: *Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS or MS-FID*

ISO 16000-15: *Sampling strategy for nitrogen dioxide (NO2)*

ISO 16000-16: *Detection and enumeration of moulds — Sampling by filtration*

ISO 16000 -17: *Detection and enumeration of moulds — Culture-based method*

ISO 16000 -18: *Detection and enumeration of moulds — Sampling by impaction*

ISO 16000 -19: *Sampling strategy for moulds*

ISO 16000 -20: *Detection and enumeration of moulds -- Determination of total spore count*

ISO 16000 -21*: Detection and enumeration of moulds —Sampling from materials*

ISO 16000-26: *Sampling strategy for carbon dioxide (CO_2)*

ISO 16000-34: *Strategies for the measurement of airborne particles (PM 2.5 fraction)*

ISO 16000-37: *Strategies for the measurement of PM 2.5*

ISO 7730 - *Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

IEC 60268 – Part 16: *Objective rating of speech intelligibility by speech transmission index.*

IEC 61672: *Electro acoustics – Sound level meters – Part 1: Specifications*

ANSI S1.13 Measurement of Sound Pressure Levels in Air

ASHRAE 55-2013: *Thermal Environment Conditions for Human Occupancy*

ASHRAE HANDBOOK – 2011: *HVAC Applications*

ASTM E – 1130: *Objective measurement of speech privacy using Articulation Index.*

ASTM E – 1374: *Guide for open office acoustics and applicable standards.*

ASTM International Designation E336-97:*Standard Test Method for Measurement of Airborne Sound Insulation in Buildings*

ANSI S12.60: *Guidelines for classroom acoustics.*

BS8233:1999 —So*und Insulation and noise reduction for buildings – Code of practice.*

BS EN ISO 717-1:1997 Acoustics *—Rating of sound insulation in buildings and of building elements – Part 1 Airborne sound insulation*.

WELL v2 ™- *The WELL Building Standard ™*

REHVA Guidebook nº 14: *Indoor Climate Quality Assessment*

CIBSE: *The SLL Code for Lighting*

IS SP 72 National Lighting Code -2010

EN-12464-1 Light and lighting - Lighting of work places - Part 1:

3. Terms and Definitions

3.1. General

This section of the standard provides the general terms and definitions applicable to this standard. The Indoor Environment Quality (IEQ) specific parameter wise terms and definitions are provided in subsequent clauses.

3.1.1. Accuracy

It is the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy specifications usually contain the effect of errors due to gain and offset parameters.

3.1.2. Indoor Environmental Quality Elements

In this standard the term ‘elements’ refer to thermal comfort, indoor air quality, lighting and acoustic related dimensions of indoor environment.

3.1.3. Indoor Environmental Quality (IEQ)

Indoor environmental quality (IEQ) refers to the quality of a built environment in relation to the health and wellbeing of those who occupy space within it

3.1.4. Range

The upper and lower limits to which an instrument can measure a value or signal

3.1.5. Representative Occupant

An individual or composite or average of several individuals that is representative of the population occupying a space for 15 minutes or more. In this standard, the term ‘occupant’ refers to ‘representative occupant’.

3.1.6. Resolution

Resolution is the ability to 'resolve' differences; that is, to draw a distinction between two things. High resolution means being able to resolve small differences. In a digital system, resolution means the smallest increment or step that can be taken or seen. In an analog system, it means the smallest step or difference that can be reliably observed.

3.2. Thermal comfort

3.2.1. General

The IEQ parameter - Thermal comfort related terms and definitions are provided in this section of the standard.

3.2.2. Acceptable thermal environment

Thermal environment that a substantial majority of the occupants find thermally acceptable.

3.2.3. Adaptive model

A model that relates indoor design conditions or acceptable ranges of indoor environment parameters, such as temperature, to outdoor meteorological or climatological parameters. It also encompasses gradual diminution of the people’s response to repeated environmental stimulation and subsumes all processes which building occupants undertake in order to improve the comfort of the indoor environment.

3.2.4. Average air speed

The air speed surrounding a representative occupant averaged with respect to location and time. The spatial average is for three heights as defined for average air temperature.

3.2.5. Average air temperature

The air temperature surrounding a representative occupant averaged with respect to location and time.

3.2.6. Clo

A unit used to express the thermal insulation provided by garments and clothing ensembles, where 1 clo = 0.155 m^2 K/W.

3.2.7. Draft

The unwanted local cooling of the body caused by air movement.

3.2.8. Floor temperature

The surface temperature of the floor where it is in contact with the occupant's feet.

3.2.9. Local thermal discomfort

The thermal discomfort caused by locally specific conditions such as a vertical air temperature difference between the feet and the head, by radiant temperature asymmetry, by local convective cooling (draft), or by contact with a hot or cold floor.

3.2.10. Metabolic rate

The rate of transformation of chemical energy into heat and mechanical work by metabolic activities of an individual, per unit of skin surface area and expressed in units of met, equal to 58.2 W/m^2, which is the energy produced per unit skin surface area of an average person seated at rest.

3.2.11. Mean Radiant Temperature

The uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.

3.2.12. Mixed Mode

"Mixed-mode" refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and mechanical systems that include air distribution equipment and refrigeration equipment for cooling.

3.2.13. Operative Temperature:

A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effect of the mean radiant temperature and air temperature and is the mean of these two under specific conditions. It is also known as dry resultant temperature or resultant temperature.

3.2.14. Radiant Temperature Asymmetry

The difference between the plane radiant temperature (t_{pr}) in opposite directions. The vertical radiant temperature asymmetry is with plane radiant temperatures in the upward and downward directions. The horizontal radiant temperature asymmetry is the maximum radiant temperature asymmetry for all horizontal directions. The radiant temperature asymmetry is determined at waist level, 0.6 m for a seated occupant and 1.1 m for a standing occupant.

3.2.15. Relative Humidity

Ratio of the partial pressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water vapour that may be contained at its dry bulb temperature.

3.2.16. Thermal comfort

The condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

3.2.17. Thermal environment

The environmental conditions that affect a person's thermal balance with surroundings.

3.2.18. Vertical air temperature difference

Air temperature difference between head and ankle level of occupant.

3.3. Indoor air quality

3.3.1. General

The IEQ parameter - Indoor Air Quality related terms and definitions are provided in this section of the standard.

3.3.2. Indoor Air Quality

Air quality that refers to the nature of unconditioned or conditioned air that circulates throughout the space where one works or lives, that is, the air one breathes when indoors.

3.3.3. Particulate Matter

A complex mixture of tiny particles that consists of dry solid fragments, solid cores with liquid coatings, and small droplets of liquid. These particles vary greatly in shape, size and chemical composition, and can be made up of many different materials such as metals, soot, soil, and dust. Particulate matter that has an aerodynamic diameter of 10 µm and below is referred to as PM_{10}. Particles that are 2.5 µm aerodynamic diameters and smaller are $PM_{2.5}$. Thus all $PM_{2.5}$ is included in PM_{10}, although the converse is not true.

3.3.4. Volatile Organic Compounds (VOCs)

Organic, and therefore carbon and hydrogen containing, materials which evaporate and diffuse easily at ambient temperature. VOCs are emitted by a wide array of building materials, paints and common consumer products.

3.3.5. Total Volatile Organic Compounds (TVOCs)

Sum of the concentrations of identified and unidentified volatile organic compounds eluting between and including n-hexane and n-hexadecane.

3.3.6. Colony-forming unit

Is a measure of viable bacterial or fungal cells. In direct microscopic counts where all cells, dead and living, are counted, but CFU measures only viable cells. For convenience the results are given as (colony-forming units per cubic meter) or CFU/m^3 for air (grab) sample or CFU/m^2 for surface (swab) sample.

3.4. Visual comfort

3.4.1. General

The IEQ parameter - Visual comfort related terms and definitions are provided in this section of the standard.

3.4.2. Back Ground Area

In indoor work places, particularly a large part of the area surrounding an active and occupied task area which needs to be illuminated. This area is known as the 'background area'. Should be a border at least 3 m wide adjacent to the immediate surrounding area within the limits of the space.

3.4.3. Circadian Rhythm

Internal clock that keeps the body's hormones and bodily processes on a roughly 24 hour cycle, even in continuous darkness.

3.4.4. Correlated Colour Temperature

Spectral distribution of electromagnetic radiation of a blackbody at a given temperature. For example, the colour temperature during the daytime is approximately 15,000 K, while during sunset is approximately 1,850K.

3.4.5. Daylight factor

Ratio of the luminance at a point on a given indoor plane due to the light received directly or indirectly from the sky of assumed or known luminance distribution, to the luminance on a horizontal plane from an unobstructed hemisphere of the same sky. The contribution to direct sunlight to both luminance is excluded. It is expressed in percentage.

3.4.6. Disability Glare

Disability glare is the loss of retinal image contrast as a result of intra-ocular light scatter, or stray light. It has been described as a reduction of visual acuity caused by light elsewhere in the field of vision. Disability glare can be produced directly or by reflection.

3.4.7. Discomfort Glare

Glare that causes discomfort without necessarily impairing the vision of objects. Discomfort glare can be produced directly or by reflection

3.4.8. Equivalent Melanopic Lux (EML)

A measure of light used to quantify how much a light source will stimulate melanopsin's light response.

3.4.9. Glare

Glare is the sensation produced by bright areas within the visual field, such as lit surfaces, parts of the luminaries, windows and/or roof lights. Glare shall be limited to avoid errors, fatigue and accidents. Glare is the visual sensation produced by bright areas within the field of view and may be experienced either as discomfort glare or disability glare. Glare may also be caused by reflections in specular surfaces usually known as veiling reflections or reflected glare.

Note:

- Disability glare is more common in exterior lighting but may also be experienced from spotlights or large bright sources such as a window in a relatively poorly lit space.
- In interior workplaces discomfort glare usually arises directly from bright luminaires or windows. If the discomfort glare limits are met then disability glare is not usually a major problem.

3.4.10. Illuminance

Illuminance is the incident luminous flux density on a differential element of surface located at a point and oriented in a particular direction, expressed in lumens per unit area. Since the area involved is differential, it is customary to refer to this as illuminance at a point. The unit of measurement is lux

3.4.11. Illuminance of the immediate surrounding areas

A zone of at least 0.5 m width surrounding the task area within the field of vision.

3.4.12. Lux

Unit of illuminance, one lux being equivalent to one lumen per square meter.

3.4.13. Reflected Glare

The variety of ill effects on visual efficiency and comfort produced by unwanted reflection in and the task area.

3.4.14. Task Area

The partial area in the workplace in which the visual task is located and carried out.

3.4.15. Working plane

The reference surface defined as the plane at which work is usually done.

3.5. Acoustic comfort

3.5.1. General

The IEQ parameter - Acoustic comfort related terms and definitions are provided in this section of the standard.

3.5.2. A-Weighted Decibel

Ten times the common logarithm of the square of the ratio of time-averaged A-weighted sound pressure to the reference sound pressure of 20 micro-pascals. Unit of A weighted decibel

3.5.3. Decibel

Ten times the common logarithm of the square of the ratio of the sound pressure to the reference sound pressure of 20 micropascals.

3.5.4. Indoor Ambient Noise

The all-encompassing Noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants.

3.5.5. Noise Criteria

Noise criteria is a single numerical index commonly used to define design goals for the maximum allowable noise in a given space. The noise criterion equals the lowest curve which is not exceeded in the spectra ranging from 63 – 8000 Hz.

3.5.6. Noise Isolation Class

Noise Isolation Class is a method for rating a partition's ability to block airborne noise transfer.

Note: Similar to a field STC test, NIC is often specified on certain projects (such as spaces with operable walls, hotels, education facilities). For a field STC test, the individual transmission loss measurements are modified based on the reverberation time, the size of the room and the size of the test partition. The NIC does not include these modifications and simply measures the transmission loss between 125 and 4,000Hz.

3.5.7. Octave Band

Band of frequencies in which the upper limit of the band is twice the frequency of the lower limit.

3.5.8. Pink noise

Pink noise is acoustical energy distributed uniformly by octave throughout the audio spectrum (the range of human hearing, approximately 20 Hz to 20 kHz).

3.5.9. Privacy Index

Privacy Index is a measure for rating speech privacy performance (or lack of speech intelligibility) of an architectural space.

3.5.10. Reverberant sound or Reverberation

The sound in an enclosed space, which results from, repeated reflections at the boundaries.

3.5.11. Reverberation time

Reverberation time is the time required for a steady-state sound to reach one millionth or -60dB of its original intensity.

3.5.12. Sound

A vibrational disturbance, exciting hearing mechanism, transmitted in a predictable manner determined by the medium through which it propagates. To be audible the disturbance shall have to fall within the frequency range of 20Hz to 20000 Hz.

3.5.13. Sound Level Difference

Difference between the sound pressure level in the source room and the sound pressure level in the receiving room.

3.5.14. Sound pressure level

Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to the square of a reference value, p_o, expressed in decibels

$$L_p = 10log\frac{p^2}{p_0^2}dB$$

Where the reference sound pressure value p_o is 20 Pa;

L_p is Sound pressure level.

p is the sound pressure

3.5.15. Sound Source

Equipment or phenomena which generate sound. Source room is the room containing sound source.

3.5.16. Sound Transmission Class

The Sound Transmission Class is a single number rating of the effectiveness of a material or construction assembly to retard the transmission of airborne sound. It is also known as Sound Reduction Index (SRI).Sound Transmission Class rates a partition's resistance to airborne sound transfer at the speech frequencies (125-4000 Hz). The higher the number, the better the isolation.

3.5.17. Speech Transmission Index

Speech transmission index is a parameter that defines the clarity of the sound inside a space. It is rated between 0 and 1, 0 being worst and 1 being best.

3.5.18. Standardized Level Difference

Difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reverberation time of 0.5 s for dwellings.

3.5.19. Third Octave Band

Band of frequencies in which the upper limit of the band is 2⅓ times the frequency of the lower limit.

3.5.20. Time-averaged sound level

A-weighted equivalent sound pressure level in dB measured over a period of time t.

3.5.21. Weighted Level Difference

Single number quantity that characterises airborne sound insulation between rooms but which is not adjusted to reference conditions.

3.5.22. Weighted Standardized Level Difference

Single number quantity that characterises airborne sound insulation between rooms.

4. Classification

The built environment is classified as Class A - Aspirational, Class B – Acceptable and Class C – Minimum acceptable based on the measured values for individual parameters of IEQ elements as specified in the Table 2 and 3 for Thermal comfort, Table 5, for IAQ, Table 12 for Visual comfort and Table 13 & 14 for Acoustic comfort.

5. Abbreviations, symbols and units

5.1. Abbreviations

AHU	Air Handling Unit
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
BEAM	Building Environment Assessment Method
CCT	Correlated Colour Temperature
CFL	Compact Fluorescent Lamp
EML	Equivalent Melanopic Lux
HVAC	Heating Ventilating and Air Conditioning
IAQ	Indoor Air Quality
IEC	International Electrotechnical Commission
IEQ	Indoor Environmental Quality
IS	Indian Standard
ISHRAE	Indian Society of Heating, Refrigerating, and Air Conditioning Engineers
ISO	International Organization for Standarization
NBC	National Building Code
NC	Noise Criteria
NCB	Balanced Noise Criteria
NIC	Noise Isolation Class
PM	Particulate Matter
RH	Relative Humidity
STC	Sound Transmission Class
STI	Sound Transmission Index
TVOC	Total Volatile Organic Compound

5.2. Symbols

a	Ambient
C_6H_6	Benzene
CH_2O	Formaldehyde
CO	Carbon monoxide
CO_2	Carbon dioxide
D	Sound Level Difference
D_{nt}	Standardisation Level Difference
$D_{nt, w}$	Weighted Standardisation Level Difference
D_w	Weighted Difference Level
$L_{Aeq,T}$	A-weighted equivalent sound pressure level in dB measured over a period of time t.
NO_2	Nitrogen dioxide
O_3	Ozone
SO_2	Sulphur dioxide
T	Reverberation Time
t_a	Ambient Temperature
t_{mr}	Mean Radiant Temperature
t_o	Operative Temperature
t_{pr}	Plane Radiant Temperature
ϑ	Velocity

5.3. Units

°C	degree Celsius
µg	Microgram
clo	Clothing Insulation
CFU	Colony Forming Units
dB	Decibel
$D_{nT,w}$	Weighted Standardized Level Difference
Hz	Hertz
K	Kelvin
L	Lux
m	Meter
met	Metabolic Rate
Pa	Pascal
ppm	Parts Per Million
s	Second
W	Watt

6. Indoor Environmental Quality elements and parameters - tests and testing methods

6.1. General

This section of the standard defines testing method of every parameter of four IEQ elements. Measurement sampling shall be representative of locations where the occupants are known to, or, are expected to spend their time. All measurements shall be carried out at steady indoor conditions. The sampling duration must represent both, “peak” and “average” indoor exposure. For any IEQ parameter, wherever the representative measurement location is specified in particular, it supersedes this clause.

6.2. Thermal comfort

6.2.1. General

Thermal conditions play a critical role in influencing occupant comfort and well-being. This standard specifies thermal environmental conditions acceptable for healthy adults at

a. Atmospheric pressure equivalent to altitudes up to 3000 m
b. Indoor spaces designed for human occupancy for periods not less than 15 minutes.

This standard specifies set of thermal conditions which are based upon adaptive thermal comfort approach. It also encompasses gradual diminution of the people’s response to repeated environmental stimulation and subsumes all processes which building occupants undertake in order to improve the comfort of the indoor environment.

Thermal comfort is affected by physical and physiological parameters as shown in Figure 1.

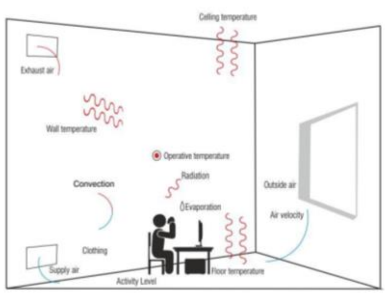

Figure 1 Factors affecting thermal comfort in an indoor environment

Physical parameters

a. Air temperature
b. Vertical air temperature difference
c. Mean radiant temperature
d. Radiant temperature asymmetry
e. Floor surface temperature
f. Relative Humidity
g. Air speed

Note: The details of above parameters are specified in Annex A

Physiological factors

a. Metabolic rate
b. Clothing insulation

Note: Effects of these physiological factors on thermal comfort are out of scope of this standard.

6.2.2.Thermal comfort threshold values

The values for quality of thermal environment for representative occupant of a space shall be as specified in table 1

Table 1: Conditions for thermal comfort measurement

Air velocity	Weather condition	Level of activity	Reference table for Threshold Values
Up to 0.2m/s	Summer / winter	Low and medium	Table 3
Above 0.2m/s	Summer / winter	Low and medium	Chart 1

Table 2. Acceptable range of thermal comfort parameters with air velocity up to 0.2 m/s and low / medium activity level in summer / winter condition

Parameters	Units		Class A	Class B	Class C
Operative Temperature	°C	If air velocity < 0.2 m/s	Table 3		
		If air velocity > 0.2 m/s	Calculate using Chart 1		
Relative Humidity	%		30 – 70	30 – 70	a. 30 – 70 (where, humidity control exists) b. Building must demonstrate 80% occupant satisfaction with respect to relative humidity (where, humidity controls does not exists)
Radiant Temperature Asymmetry	°C	Warm Ceiling	<7	-	-
		Cool Wall	<13	-	-
		Cool Ceiling	<18	-	-
		Warm Wall	<35	-	-
Vertical Air Temperature Difference	°C		4	-	-
Floor Surface Temperature (only for floor based cooling/heating)	°C		17 - 31	-	-
Occupant Satisfaction	%		90	80	-

Table 3. Acceptable range of operative temperature with air velocity up to 0.2 m/s

Level of Activity	Type of Building/Space	Operative Temperature (°C)

		Summer (Cooling season) ~0.5 clo	Winter (Heating season) ~1.0 clo
Low	Offices, Conference room, Auditorium, Cafeteria / Restaurant, Classroom	24.5 ± 2.5	22.0 ± 3.0
Medium	Retail stores, Shopping Malls	23.0 ± 3.0	19.0 ± 4.0

Calculating operative temperature for air velocity up to 0.2 m/s

The operative temperature shall be calculated as below.

$$t_o = \frac{(t_{mr} + \left(t_a \times \sqrt{10\vartheta}\right))}{1 + \sqrt{10\vartheta}}$$

where, ϑ = air velocity

t_a= air temperature

t_{mr} = mean radiant temperature

It is also acceptable to approximate this relationship for occupants engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s.

$$t_o = \frac{(t_{mr} + t_a)}{2}$$

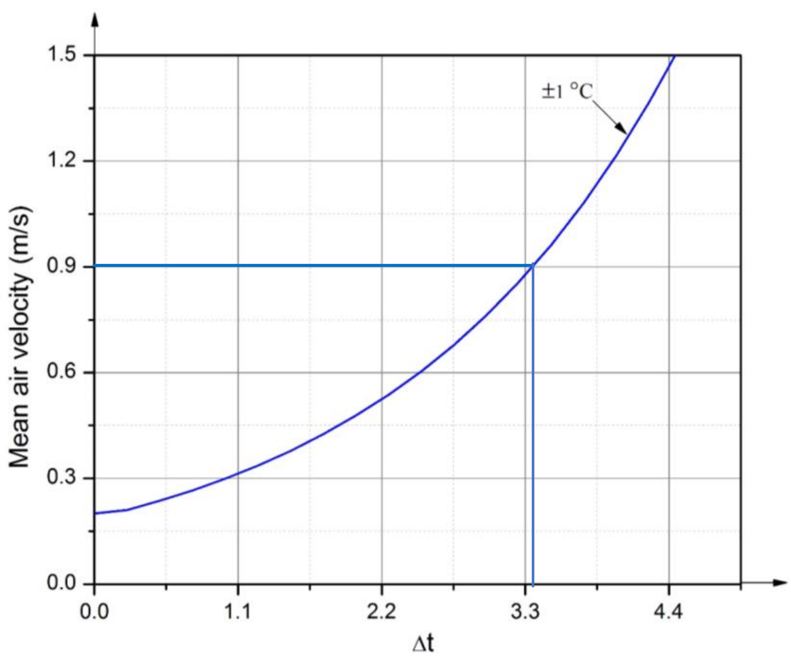

Chart 1. Required Air Speed to Offset Increased Temperature

Example: If in a given room, an occupant is involved in the moderate level of activity, air speed in room is 0.9 m/s and operative temperature is 27°C, then by using above mentioned graph Δt is 3.3°C. It makes acceptable room air temperature as 27°C + 3.3°C.

6.2.3. Testing Methods of Thermal comfort

The representative sample locations shall be the locations where most extreme values of the thermal parameters are observed or estimated to occur (e.g., potentially occupied areas near windows, diffuser outlets, corners, and entries).

At locations where occupancy distribution cannot be observed or estimated, the measurement locations shall include:

a. The center of the room or space
b. 1.0 m inward from the center of each of the walls.
c. In the case of exterior walls with windows, the measurement location shall be 1.0 m inward from the center of the largest window.

The measurement method at selected locations shall be as defined in Table 4.

Table 4 Testing methods of thermal comfort

Parameter	Measurement Methodology
Air temperature & Average air speed (The temperature of the air surrounding the occupant.)	a. Air temperature and average air speed (ϑ_a) shall be measured at the 0.1 m, 0.6 m, and 1.1 m levels for seated occupants at plan locations. * b. Measurements for standing occupants shall be made at the 0.1 m, 1.1 m, and 1.7 m levels. * c. Speed is averaged over an interval not less than 1 minute and not more than 3 minutes. Variations that occur over a period greater than 3 minutes shall be treated as multiple different air speeds. d. The spatial average is the numerical average of the air temperature at the ankle level, the waist level, and the head level. These levels are 0.1 m, 0.6 m, and 1.1 m for seated occupants and 0.1 m, 1.1 m, and 1.7 m for standing occupants. Time averaging is over a period not less than 3 minutes and not more than 15 minutes.
Vertical air temperature difference	a. Shall be calculated by arithmetic difference of air temperature measured at 0.1 m and 1.1 m levels for seated occupants. b. Calculations for standing occupants shall be made for air temperature measured at 0.1 m and 1.7 m levels.
Mean radiant temperature	a. Shall be measured at the 0.6 m level for seated occupants and the 1.1 m level for standing occupants.
Operative temperature	a. Shall be measured or calculated at the 0.6 m level for seated occupants and the 1.1 m level for standing occupants.
Floor temperature	a. Shall be measured at the surface by contact thermometer or infrared thermometer.
Radiant temperature asymmetry	a. Shall be measured in the affected occupants' locations, with the sensor oriented to capture the greatest surface temperature difference.

** Mean value of these parameters at respective location shall be considered for calculating operative temperature*

6.3. Indoor air quality

6.3.1.General:

Indoor air is considered to be healthy when the air does not contain contaminants in harmful concentrations and is acceptable when the majority of people feel satisfied. A human being breathes about 12,000 litres of air every day and is vital for our health. Exposure to hazardous airborne agents present in indoor spaces causes adverse effects such as respiratory and cardiovascular diseases, allergy, and irritation of the respiratory tract and possibly leads to cancer.

Main source of indoor air pollutants are from outdoor air, household cooking (especially cooking with biomass or frying), tobacco smoking, polluted ambient air, cleaning agents, resuspension of dust during the cleaning activities, construction materials & paints, copy machines & printers as well as other human activities. Respectively, ambient air pollutant sources are vehicle emissions, thermal power plants, biomass burning, construction work, unattended debris, open sewage pipes, fossil fuel based power generators and various industrial processes as seen in Figure 2.

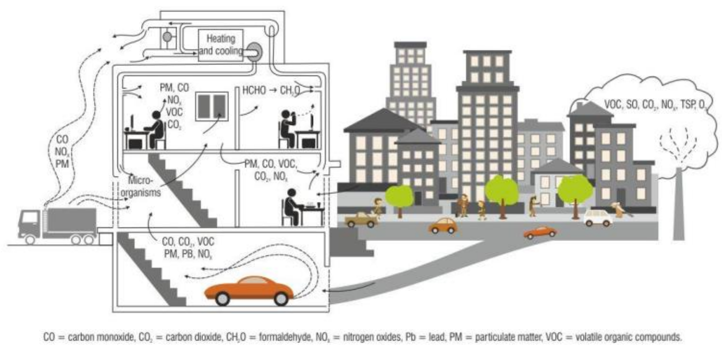

Figure 2 Indoor air pollutants in a typical built environment

Note: Details of the pollutants and their effects are given in Annex B.1

6.3.2.Indoor air quality parameters Threshold values

Threshold values for select indoor air quality parameters in an occupied space for Class A, Class B and Class C are given in Table 5.

Table 5 Threshold values for indoor air quality parameters

Parameters		Units	Classification		
			Class A	Class B	Class C
Basic IAQ parameters	CO_2	ppm	Ambient + 350	Ambient + 500	Ambient + 700
	PM 2.5	µg/m^3	<15	<25	<25
	CO	ppm	<2	<9	< 9
	TVOC (equivalent to isobutylene)	µg/m^3	<200	<400	<500
Complementary IAQ parameters	PM 10	µg/m^3	<50	<100	<100
	CH_2O	µg/m^3	<30	<100	-
	SO_2	µg/m^3	<40	<80	-
	NO_2	µg/m^3	<40	<80	-
	O_3	µg/m^3	<50	<100	-
	Total Microbial Count	CFU/m^3	Indoor ≤ ambient	Indoor ≤ ambient	-
Occupant Satisfaction		%	90	80	-

Note 1:Depending upon the building location, interiors and other local factors, pollutants that significantly affect human health should be also considered and corresponding threshold standard should be referred.

Note 2: In case the values of TVOC are higher than the specified threshold value as given in table 5, individual VOCs shall be analysed. At least the following VOCs that are toxic and common in indoor environments, need to be analysed.

Table 5a. Threshold value for various VOCs in IAQ

Parameter	***Unit***	***Threshold value***
Formaldehyde (HCHO)	*µg/m^3*	*30*
Toluene	*µg/m^3*	*300*
Acetone (2-propanone) (C_3H_6O)	*µg/m^3*	
Benzene	*µg/m^3*	*3*
Acetaldehyde	*µg/m^3*	*140*
Epichlorohydrin (106-89-8)	*µg/m^3*	*3*
Naphthalene (91-20-3)	*µg/m^3*	*9*

In case a wider range of VOCs are analysed, the following threshold values should be used to evaluate the harmfulness of each VOC:

Table 5b: Threshold of VOCs for detailed analysis

Carbon disulfide	800 µg/m^3	Carbon tetrachloride	40 µg/m^3
Chlorobenzene	1000 µg/m^3	Chloroform	300 µg/m^3
Dichlorobenzene (1, 4-)	800 µg/m^3	Dichloroethylene (1,1)	70 µg/m^3
Dioxane (1, 4-)	3000 µg/m^3	Ethylbenzene	2000 µg/m^3
Ethylene glycon	400 µg/m^3	Ethylene glycon monoethyl ether	70 µg/m^3
Ethylene glycon monoethyl ether acetate	300 µg/m^3	Ethylene glycon monomethyl ether	60 µg/m^3
Ethylene glycon monomethyl ether acetate	90 µg/m^3	Hexane (n-)	7000 µg/m^3
Isophorone	2000 µg/m^3	Isopropanol	7000 µg/m^3
Methyl chloroform	1000 µg/m^3	Methylene chloride	400 µg/m^3
Methyl *t-butyl ether*	8000 µg/m^3	Phenol	200 µg/m^3
Propylene glycol monomethyl ether	7000 µg/m^3	Styrene	900 µg/m^3
Tetrachloroethylene (Perchloroethylene)	35 µg/m^3	Trichloroethylene	600 µg/m^3
Vinyl acetate	200 µg/m^3	Xylenes, technical mixture (m-, o-, p-xylene combined)	700 µg/m^3

The measurement duration shall depend on the parameter and type of space as defined below. IAQ measurements needs to be planned and executed based on the ISO 16000-1 and ISO 16000-32 standards, as appropriate.

6.3.3.Testing Methods of Indoor Air Quality parameters

IAQ measurements / monitoring shall be carried out as follows:

6.3.3.1. Sampling :

The general sampling strategy shall be as defined in ISO 16000-1.
For formaldehyde, the sampling strategy shall be as defined in ISO 16000-2.
The sampling for TVOC shall be as defined in ISO 16000-5.
The sampling for NO_2 shall be as defined in ISO 16000-15.
The sampling for CO_2 shall be as defined in ISO 16000-26.

Note:

It is not recommended to carry out the particulate matter or microbial count measurements in a rain fall season as the low outdoor PM concentration and high microbial background contamination may skew the results and results do not represent the average indoor air conditions.

When IAQ measurements are carried out, the ventilation system shall operate in a 'normal' operation mode at least previous 48 hours and during the measurement. Example: if the ventilation normally operates from 8 am to 6 pm with 50% speed, the previous two days this operation mode shall be followed and ventilation shall not be boosted or operated longer periods.

6.3.3.2. Measurement conditions:

IAQ measurements shall be carried out only after the flush out period of minimum 24 hours in a newly constructed or refurbished space as the initial emissions of indoor impurities are much higher during that period.

IAQ measurements and monitoring shall be carried out either following Path A or Path B:

6.3.3.3. Path A:

Measurement of all basic IAQ parameters two times in each season, three times a day, example morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm, 18 results per year, all complementary IAQ parameters twice a year three times a day, 6 results per year and formaldehyde & microbial count measurements twice a year once a day, 2 results per year, all as a short term measurement example 3-15 min average value. The methodology for measurements at selected location shall be as defined below are as defined in Table 10.

6.3.3.4. Path B:

Continuous monitoring of basic IAQ parameters (CO in case of combustion) with results recorded at least once an hour round the year, 8760 results per year), measurement of all basic IAQ parameters once a year (to validate the continuous monitoring sensors), all complementary IAQ parameters (and CO if not continuously monitored) twice a year three times a day (6 results per year), and formaldehyde & microbial count measurements once a day (2 results per day), all as a short term measurement.

Table 10 Measurement location and conditions for indoor air quality parameters

Parameter	Measurement Methodology (Path A)	Measurement Methodology (Path B)
CO_2*	a. Shall be measured when there is minimum 90% of occupants present. b. Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the same activity. C. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year) For B & C Class - measured twice a year three times a day (6 results per year), all as short term measurements	a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity c. Lab Measurement once a year (to validate the continuous monitoring sensors) d. Historical data should be available for at least previous 3 months ** (recommended to keep data for continuous improvement)
CO	a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window) to ensure that the air intakes are not too close to roadways, loading docks or other local sources of CO.	a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) ONLY if combustion activity present in building

	b. For underground car parking in the building, the measurement shall also be done in occupied spaces at the floor level near the doorways leading to the car parking. c. For buildings with combustion devices, the measurement shall also be carried out in each space with combustion equipment while combustion device is in use. D. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year) For B & C Class - measured twice a year three times a day (6 results per year), all as short term measurements	b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity ONLY if combustion activity present in building c. Lab Measurement once a year (to validate the continuous monitoring sensors) if required d. For underground car parking in the building, the continuous monitoring shall be done in occupied space at the floor level near the doorways leading to the car parking space
PM 2.5*	a. Shall be measured at least in three locations that are served with a same outdoor air intake unit / method **as well as in the spaces with combustion devices**. B. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year) For B & C Class - measured twice a year three times a day (6 results per year), all as short term measurements	a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity c. Lab Measurement once a year (to validate the continuous monitoring sensors) d. Historical data should be available for at least previous 3 months ** (recommended to keep data for continuous improvement)

PM 10*	a. Shall be measured at least three locations that are served with a same outdoor air intake unit / method **as well as in the spaces with combustion devices.** B. To be measured twice a year three times a day (6 results per year), all as short term measurements	a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity c. Lab Measurement once a year (to validate the continuous monitoring sensors) d. Historical data should be available for at least previous 3 months (recommended to keep data for continuous improvement) OR Same as Path A
CH_2O**	a. Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the similar activity. B. measurements twice a year once a day (2 results per year), all as a short term measurement.	Same as Path A
SO_2	a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window). b. In case values of SO_2 concentration are higher than the specified threshold value as given in section 6.3.2 at air intake, additional measurements need to be taken inside the space.	Same as Path A
NO_2	a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window). b. In case values of NO_2 concentration are higher than the specified threshold value as given in section 6.3.2 at intake, additional measurements need to be taken inside the space.	Same as Path A
O_3	a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window).	Same as Path A

	b. Shall be measured in the indoor spaces that have sources of internal generation of ozone. c. In case values of O_3 concentration are higher than the specified threshold value as given in section 6.3.2 at air intake, additional measurements need to be taken inside the space.	
TVOC	a. Shall be measured at least in 2 locations per floor and wing or in one location for each set of rooms with the similar activity, one measurement in the perimeter zone (within 1.5 m from the façade and one in the centre of the space.. b. In case the values of TVOC are higher than the specified threshold value as given in section 6.3.2, at least the individual VOCs listed in appendix X recommended to be analysed and the threshold values given in Appendix *X*.	a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity c. Lab Measurement once a year (to validate the continuous monitoring sensors) d. Historical data should be available for at least previous 3 months (recommended to keep data for continuous improvement OR Same as Path A
Total Microbial Count[#]	a. Shall be measured in spaces where there are visible signs of moisture damage or where there is a high risk of water leakage. B. measurements twice a year once a day (2 results per year), all as a short term measurement.	Same as Path A

* Reference value shall be measured near the air intake in to the building (AHU air intake or air vent or open window) for comparison and to find source of contaminate. This shall be done simultaneously (within 2 hours) with corresponding indoor air measurements.
** Measurements shall also be taken in locations where the most extreme values of the thermal parameters are observed or estimated to occur (e.g., potentially occupied areas near windows, diffuser outlets, corners, and entries).
# Above point in * and ** are applicable.

6.3.3.5. Test method and measurement:

The testing for various IAQ elements shall be done as per the reference standard specified below. The measurement equipment, accuracy, uncertainty of measurement shall conform to requirement as specified in the standards below.

Table 11a: IAQ Parameter Test method and measurement equipment – for Path A measurement

IAQ element	Test method
CO_2	ISO 16000-26 Sampling strategy for Carbon dioxide (CO_2); *Note: Except for the screening measurement using sampling tubes, the CO_2 concentration is recorded continuously using an automatic instrument.*
CO	Annex C of ISO 16000-26 Sampling strategy for Carbon dioxide (CO_2); *Note: Except for the screening measurement using sampling tubes, the CO_2 concentration is recorded continuously using an automatic instrument.*
NO_2	ISO 16000-15 Sampling strategy for Nitorgen dioxide (NO_2);
Formaldehyde	ISO 16000-3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air – Active sampling method or ISO 16000 – 4: Determination of formaldehyde – Diffusive sampling method
VOCs	ISO 16000 – 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and gas chromatography using MS or MS-FID
O_3	ISO 13964 : Determination of Ozone in ambient air – Ultraviolate photometric method
PM 10 and PM 2.5	ISO 16000-34: Strategies for the measurement of airborne particles

PARAMETER	**SENSOR QUALITY SPECIFICATIONS FOR PATH B**
CO2	Data Output Interval - 10 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH - 10-85% (non condensing) Measurement Range : 400ppm - 5000ppm Resolution : 5 ppm maximum Accuracy: 400 - 2000ppm : ±5% 2000 - 5000ppm : ±5% Lower Detection Limit - 400ppm Recalibration capability – Required
CO	Data Output Interval - 1 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH : 10-85% (non condensing) Measurement Range from : 0ppm till 1,500ppm Resolution: 1 ppm maximum Accuracy: 2% of reading Lower Detection Limit - 0ppm Recalibration capability – Required

PM2.5	Data Output Interval - 10 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH - 10-85% (non condensing) Measurement Range: 0 ug/m^3 to 500 ug/m^3 Resolution : 1 ug/m^3 Accuracy: 0 - 150 ug/m3 : ±5ug/m^3 150 - 500 : ±5ug/m^3 Lower Detection Limit - 0 ug/m^3 Recalibration capability – Required
TVOC	Data Output Interval - 10 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH - 10-85% (non condensing) Installation - should have ability to install permanent Measurement Range: 150 ug/m^3 to 2000 ug/m^3 Resolution of 10 ug/m^3 Accuracy: 150 - 600 ug/m3 : ±20ug/m^3 600 - 2000 : ±20ug/m^3 Lower Detection Limit - 150 ug/m^3 Recalibration capability – Required

6.4. Visual comfort

6.4.1. General

Light has significant impact on many bodily functions, including the nervous system, circadian rhythms, pituitary gland, endocrine system, pineal gland and alertness as these are affected by different wavelengths of light.

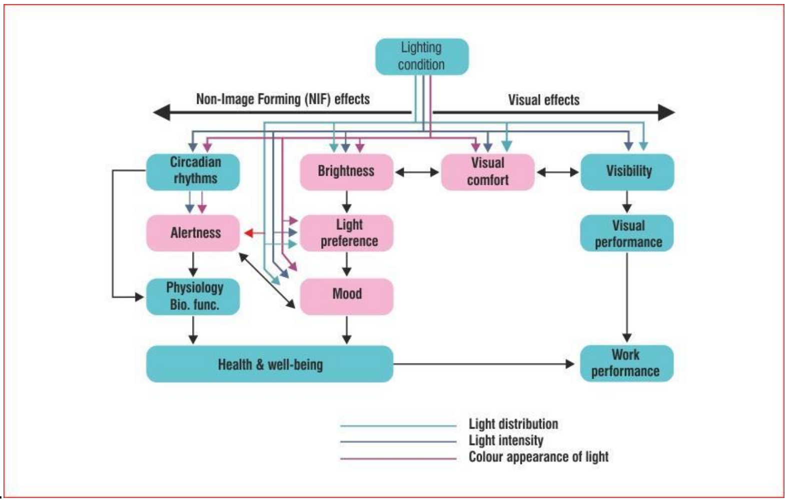

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Figure 3 Effects of lighting condition

Variations over time in lighting conditions, in terms of intensity, illumination levels, distribution, ambient lighting and colour temperature, can stimulate alertness and well-being of people as shown in Figure 3.

Note: Details of the circadian rhythm are given in Annex C.1

6.4.2. Threshold values for visual comfort parameters

The threshold values of parameters affecting visual comfort are defined in Table 12. Threshold illuminance level depending upon type of space is defined in Table 13.

Table 12 Threshold values of parameters for lighting comfort

Parameters	Units	Type of Space	Classification		
			Class A	Class B	Class C
Illuminance	Illuminance should be as per the value/ range defined in NLC 2010 at the task				
Circadian Lighting Design (for workspaces)	Equivalent Melanopic Lux (EML)		At least 240 EML in regularly occupied spaces, through electric light only.	At least 150 EML in regularly occupied spaces, through electric light only.	
Uniformity of illuminance at Task area			0.7	0.7	0.7
Uniformity of illuminance at Immediate surrounding area			0.5	0.5	0.5
Illuminance of the immediate surrounding areas			As per the above table given in NLC 2010		
Percentage of the workstations meeting the required illuminance at task plane	%		100	90	90
Occupant Satisfaction	%		90	80	-
Controllability of lighting environment			Yes	Yes	No

Table 13 Threshold Illuminance level depending upon type of space

Building	Type of space	Illuminance (Lux)
Residential	Living room	300
	Bed room	100
Child care institutions	Child care institutions, Nursery schools	300
	Day nurseries	300
Places of assembly	Auditoriums	100
	Libraries	500
	Cinemas (Seating area)	200
	Court rooms	300
	Museums	300
Commercial	Retail shops	300
	Department stores	300
	Supermarkets	300
	Computer rooms, large	500
	Computer rooms, small	500
Hotels	Lobbies	100
	Reception rooms	300
	Hotel rooms (during night-time)	100
	Hotel rooms (during daytime)	100
Offices	Small offices	300
	Conference rooms	500
	Landscaped offices (Open plan office)	500
	Office cubicles	500
Restaurants	Cafeterias	300
	Restaurants	300
	Kitchens	500
Schools	Classrooms	300
	Corridors	100
	Teacher rooms	300

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Table 14: Instrumentation Specifications

Equipment Type	Purpose	Measurement Uncertainty and Range	Meter Characteristics
Illuminance Meter	Establish functional performance of baseline and new lighting equipment	Uncertainty: 3% Range: ≤0. 1 fc (0.01 lux) to ≥10,000 fc (100,000 lux)	<3% deviation from cosine function for reported single value or ≤10% at incidence angle of 60° for multiple angle reported values. Spectral response within 10% of the CIE spectral luminous efficiency function

6.4.3. Measurement methodology - Illuminance grid

Grid systems shall be created to indicate the points at which the illuminance values are calculated and verified for the task area(s), immediate surrounding area(s) and background area(s).

Grid cells approximating to a square are preferred, the ratio of length to width of a grid cell shall be kept between 0,5 and 2. The maximum grid size shall be:

$$p = 0{,}2 \cdot 5^{\log_{10}(d)} \quad (1)$$

where

p δ 10 m

d is the longer dimension of the calculation area (m), however if the ratio of the longer to the shorter side is 2 or more then d becomes the shorter dimension of the area, and p is the maximum grid cell size (m).

The number of points in the relevant dimension is given by the nearest whole number of d/p.

The resulting spacing between the grid points is used to calculate the nearest whole number of grid points in the other dimension. This will give a ratio of length to width of a grid cell close to 1.

A band of 0.5 m from the walls is excluded from the calculation area except when a task area is in or extends into this border area.

An appropriate grid size shall be applied to walls and ceiling and a band of 0,5 m may be applied also.

NOTE 1 :The grid point spacing should not coincide with the luminaire spacing.

NOTE 2 : Formula (1) (coming from CIE x005-1992) has been derived under the assumption that p is proportional to log (d), where:

p = 0,2 m for d = 1 m;

p = 1 m for d = 10 m;

p = 5 m for d = 100 m.

Values of grid point spacing

Typical values of grid point spacing are given in Table based on Formula above.

Table XX — Recommended number of grid points

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Length of the area	Maximum distance between grid points	Minimum number of grid points
m	M	
0.40	0.15	3
0.60	0.20	3
1.00	0.20	5
2.00	0.30	6
5.00	0.60	8
10.00	1.00	10
25.00	2.00	12
50.00	3.00	17
100.00	5.00	20

Measure and Record Illuminance

• Schedule and take all measurements to minimize the effects of other light sources and location conditions on the results.

• Schedule measurements for both baseline and post-installation when there is no daylight in the space. This typically requires taking measurements after sunset. Adjacent electric lighting need not be blocked or turned off as long as it is noted and remains the same for both the baseline and the post-installation measurements.

• Ensure that potential temporary obstructions such as occupants, temporary materials, and furniture are removed for both the baseline and the post-installation measurements.

6.5. Acoustic comfort

6.5.1. General

Sound is a pressure fluctuation in the air. In general, the greater the amplitude of the pressure fluctuation, the "louder" the sound will be perceived by people. Loudness is a subjective measure of the amplitude that varies from one person to the next and will depend on many parameters, some of which are nonphysical. Sound pressure level is this objective measure. The total ambient sound that exists at a given point in space is usually due to a composite of many different sounds with different strengths and frequency content. The composite sound may be a combination of background noise and sound from a single identifiable source; it may be a combination from several individual sources; and it may include reflections from room surfaces or reflecting objects. This standard is primarily concerned with the measurement of the level of the composite sound at a given point or in measuring changes in that level caused by a certain sound of interest. The acoustical parameters such as Nose criteria, Reverberation time and Speech transmission index are representative of acoustical comfort.

6.5.2. Threshold values for acoustical parameters

Threshold values for acoustical parameters for typical space are given in Table 13 . Additionally, values for the acoustical parameter - Noise isolation (applicable for Class A) are given in Table 14. The noise criterion (NC) values shall be arrived using NC curves as given in 6.3.3.

Table 13 Requirements of Acoustic comfort

No	Types of Buildings	Noise Criterion			Reverberation time			Speech Transmission Index		
		A	B	C	A	B	C	A	B	C
1	**Residences, Apartments, Condominiums**	30	35	40	<0.8s	NA	NA	*0.6	*0.5	*NA
								Applicable for Atriums & corridors		
2	**Hospitality**									
	Individual rooms or suites	30	35	40	<0.8s	<0.6s	<1.0	0.6	0.5	NA
	Meeting / banquet rooms	30	35	40	<0.5s			0.7	0.6	0.5
	Corridors, lobbies	40	45	45	NA			NA	NA	NA
	Service / Support areas	40	45	50	NA			0.5	NA	NA
	All day dining and restaurants	45	50	50	<1.2s	<1.5s	<1.75 s	0.6	0.5	NA
3	**Office buildings**									
a.	Executive and private offices	30	35	40	<0.6s	<0.7s	<0.8s	0.6	0.5	NA
b.	Conference rooms	30	35	35	<0.6s			0.7	0.6	0.5

c.	Teleconference rooms	25 (max)			<0.6s			0.7	0.6	0.5
d.	Open – plan offices	35	40	40	<0.8s			0.6	0.5	NA
e.	Corridors and lobbies	40	45	45	NA			NA	NA	NA
f.	Collaborative space				<0.8s			0.5	NA	NA
g.	Cafeteria/Town Hall	40	45	45	<1.0s	<1.2s	<1.2s	0.6	0.5	NA
4	**Education**									
a.	Class rooms up to 70 m^2	40 (max)						0.6	0.5	NA
b.	Class rooms over 70 m^2	35 (max)			<0.6s	<0.8s	<1.0s	0.6	0.5	NA
c.	Large lecture rooms, without speech amplification	35 (max)						0.6	0.55	0.5
5	**Libraries**	35	40	40	<1.0s	<1.2s	<1.2s	0.6	0.5	NA
6	**Health care***									
a.	Open Ward	35	35	45	<1.0s			0.7	0.6	0.5
b.	Individual rooms or suites	30	35	40	<0.8s			0.7	0.6	0.5
c.	Meeting rooms / Conference room	25	30	35	<0.6s	<0.8s	<1.0s	0.5	NA	NA
d.	Teleconferencin g rooms	25	NA	NA	<0.6s			0.7	0.6	0.5
e.	Operating Rooms	35	40	45	<0.8s			0.6	0.5	NA
f.	Corridors, lobbies	35	45	45	<1.0s			NA	NA	NA
g.	Testing/research lab, minimal speech	45	50	55	<0.8s			0.5	NA	NA
h.	Research lab, extensive speech	40	45	50	<0.8s			0.7	0.6	0.5
i.	Auditoria, large lecture rooms	25	30	NA	< 0.8s			0.6	0.5	NA

Note 1: In this table are given the performance requirements in terms of recommended dBA noise level (ideal), the not to exceed noise level (max), and the maximum acceptable reverberation time (T60) for many spaces including offices.

Note 2: For the Class A and Class B, a building should score 90% and 80% respectively on the occupant satisfaction survey. There is no such requirement to achieve Class C.
Note 3: Any other type of space not mentioned in the Table 14 shall meet requirements of the nearest representative category of that space.
Note 4: For more details on Reverberation Time, refer graph with respect to volume & application in annexure
*Note 6 : * values measured in unoccupied condition*

Table 14 Threshold Noise Isolation Criteria level depending upon type of space

Building	Type of space	Dw / NIC
Office	Between two offices	38dB
	Where privacy is important	48dB
	Cellular offices	40dB
Residential	Partitions separating a water closet (WC) from a noise sensitive room	38 dB
Hospitality	Partitions and floors between rooms and corridors	50 dB
Hospital or Health care*	Patient Room to Patient Room / Public Space	40 dB
	Patient Room to Service Area	50 dB
	Patient Room to Corridor (with entrance)	25 dB.
	Consultation Room to Public Space / Patient Rooms	40 dB.
	Consultation Room to Corridor (with entrance)	25 dB.

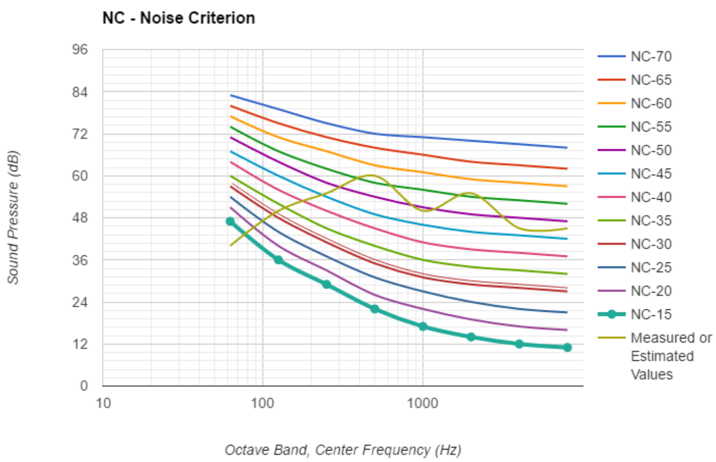
Note:
Weighted Level Difference (Dw) *a single integer number found by comparing the measured spectrum with the 'standard' curves for airborne and impact insulation.*
The Dw value is where the curve meets the 500 Hz curve and the unfavourable deviation is 32 dB. Dw will be identical to $D_{nT,w}$ when T = 0.5 seconds.
Noise Isolation Class NIC *a single number rating of the degree of speech privacy achieved through the use of an acoustical ceiling and sound absorbing screens in an open office. NIC has been replaced by the articulation class rating method.*

6.5.3. Estimating NC - Noise Criterion

For a measured noise spectrum as below:

Freq. Hz	62.5	125	250	500	1000	2000	4000	8000
dB	40	50	55	60	50	55	45	45

Plot the measured values on the NC Curve. The NC curve tangent to the value at 1000 Hz is NC – 57 as depicted in the graph below. Hence, the NC value = 57dB



6.5.4. The procedure for testing RT 60

1. The sound source (Speaker) to be placed at 1.2m above the floor level and the pink noise of about 90dB was generated which was provided with the analyser (sound level meter).
2. The analyzer is calibrated by using 1000Hz calibrator before starting the measurement in order to eliminate minor errors due to instrumentation.
3. The analyser to be placed at the height of 1.2m from the floor level with face of the mic head perpendicular to the sound source face for grazing incidence. The loudspeaker and microphone/analyser are all in the same line.
4. The files of each measurement shall be stored and recorded.
5. The recorded files shall be processed to give a final report of measurement.

Note: For the small rooms the ideal point to measure the Reverberation Time (RT) is at the center of the room/area.

6.5.5. The procedure for testing the Impact sound isolation L'nTw

The measurement shall be done as defined in ISO 140-7:

a. The equipment shall comply with as defined in ISO 140 - 7.
b. The standard tapping machine shall be mounted on a horizontal platform with legs in line with the floor.
c. The test procedure and evaluation shall be in accordance with Clause 5 of ISO 140 - 7
d. A standardized impact sound generator shall be used, consisting hammers of standardized weight that drop from a standard height at a standard repetition rate.
e. The vibration from the tapping machine is transmitted through the building structure into the air in the receiving room. This sound level (L2) is measured and compared to building regulation after correction for reverberation time (T2) and possible influence of background noise (B2).
f. The tapping machine shall have 5 hammers each weighing 500 g and dropping from a height of 40 mm every two seconds, giving an operating frequency of 10 Hz.
g. The tapping machine should be placed minimum at 1meter away from the perimeter of the specimen to be tested.
h. The results shall be presented in accordance with ISO 140 - 7.
i. The impact sound levels measured in the receiving room must be normalised using a reference equivalent absorption area (A) of 10 m^2.
j. A single figure rating ($L'_{nT,w}$) shall be calculated in accordance with ISO 717-24 .

6.5.6. Procedure for testing the Speech Transmission Index

a. The test shall use the speakers existing in the room and the Speech Transmission Index Public Address system (STIPA) of about 100dB generated and is provided with the sound level meter.
b. The analyser to be placed at the height of 1.2m from the floor level with face of the microphone head perpendicular to the sound source face for grazing incidence. The loudspeaker and microphone shall have to be placed on same line.
c. The testing shall be carried out at different places in the hall.

Note: The Sound level meter is calibrated by using 1000Hz calibrator before starting the measurement in order to eliminate minor errors due to instrumentation.

7. Occupant satisfaction survey

7.1. General

Subjective methods quantify the responses of occupants to an environment using subjective scales. Such scales are based upon psychological continua (or constructs) that are relevant to the psychological phenomenon of interest. It is important to know the properties of the scales in order to correctly interpret the results. Scales of sensation (e.g. hot or cold), preference, comfort, annoyance, smell and stuffiness are often used in occupant comfort assessment.

Advantages of subjective methods are that they are simple to administer and are directly related to the psychological phenomenon. Many aspects of occupant comfort, which are difficult to quantify or cannot be directly measured such as glare, smell, but are very important for evaluating occupant comfort, can be covered through such surveys.
The following are the minimum questions required for gaining feedback for the long term satisfaction of occupants for thermal comfort, indoor air quality, lighting comfort and acoustic comfort in the building.

7.2. Survey Questions

1. Personal details :

   a. Please specify your gender
      Male / Female
   b. Please specify your weight (kg)
      40 – 50; 51 – 60; 61-70; 71 – 80; 81 and above
   c. Please specify your age
      21 – 25; 25 – 30; 31 – 35; 36 – 40; 41 – 45; 45 – 50; 51 – 60; 61 and above
   d. Please specify your height
      Below 150 cm; 151 cm – 160 cm; 162 cm – 170 cm; 171 cm and above
   e. Please specify your residing years in present city: 1 year / 2 years / 3 years / >3 years

8. Please rate your satisfaction with temperature conditions of your normal work area.

	1	2	3	4	5	6	7	
Unsatisfactory								Satisfactory

9. Please rate your satisfaction with local thermal discomfort conditions of your normal work area (e.g. vertical air temperature difference between feet and head, local convective cooling, hot or cold floor).

	1	2	3	4	5	6	7	
Unsatisfactory								Satisfactory

10. Please rate your satisfaction with the air movement available to you in your normal work area.

	1	2	3	4	5	6	7	
Unsatisfactory								Satisfactory

11. Please rate your satisfaction with the overall humidity in your normal work area.

	1	2	3	4	5	6	7	
Unsatisfactory								Satisfactory

12. Please rate your satisfaction with the overall air quality in your normal work area (e.g. stuffiness, staleness).

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

13. Odours in your normal work area.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

14. Please rate your satisfaction with fresh air in your normal work area.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

15. Your work area's layout enables you to work without unwanted noise interruptions.

Disagree	1	2	3	4	5	6	7	Agree

16. Your normal work area provides adequate sound privacy (not being overheard by others).

Disagree	1	2	3	4	5	6	7	Agree

17. Please rate your satisfaction with the overall noise in your normal work area.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

18. Please rate your satisfaction with regard to acoustical privacy in enclosed rooms

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

18. Please rate your satisfaction with overall noise level in common areas like cafeteria, breakout area, etc

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

19. Please rate your satisfaction with regard noise from machineries (AHU,HVAC ducts, AC units, chillers, DG, Servers..etc)

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

20. Please rate your satisfaction with the lighting level on workplane/ table top.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

21. Do the lighting fixtures cause direct or indirect (reflections in computer screen) glare at your workstation? Please rate your experience

High Glare (Irritating)	1	2	3	4	5	6	7	No glare (very comfortable)

22. Within your field of view do you see lot of contrast difference (bright and dark surfaces).

Yes (lot of bright and dark patches	1	2	3	4	5	6	7	No (well balanced brightness of surfaces)

20. Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of light, glare, reflections, contrast).

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

21. Please rate your satisfaction with the external view from your normal work area.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

22. Please rate your satisfaction with lighting controls in your normal work area (provisions of controls for blinds on windows or provision of dimming or controlling lighting equipment in the room)

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

23. Please rate your satisfaction with the access to daylight from your normal work area.

Unsatisfactory	1	2	3	4	5	6	7	Satisfactory

8. Documentation methodology

8.1. Report format

Table 15 - The measurement report shall contain following information:

Name of the project			
Name of the responsible person			
Location of the project/ Project address			
Sampling time			
Sampling date			
Building type	Commercial ( )	Residential ( )	Mixed ( )
Building usages			
Schedule (usage)			
Building	Naturally Ventilated ( )	Air Conditioned ( )	Mixed Mode ( )
Year of construction			
No. of floors			
No. of occupants present at the time of sampling			
No. of sampling locations			
Floor plan of the building attached	Yes ( )		No ( )
Sampling locations marked on the floor plan	Yes ( )		No ( )
List of all the national or international standards followed for IEQ assessment:			
Any observation about sampling locations:			
Remark:			

8.2. Format for reporting measured values of different parameters

Table 16: IEQ Reporting format

Element	Parameters	Measured values	Units	Classification (Class A / Class B/ Class C)	Remarks
Thermal Comfort	Air temperature				
	Air speed				
	Floor surface temperature (where applicable)				
	Radiant temperature asymmetry				
	Relative humidity				
	Operative temperature				
	Vertical air temperature difference				
Indoor air qauality	Carbon dioxide				
	PM 2.5				
	PM 10				
	Carbon Monoxide				
	Total Volatile Organic Compounds				
	Formaldehyde				
	Sulphur dioxide				
	Nitrogen dioxide				
	Ozone				
	Total microbial count				
Lighting comfort	Illuminance				
	Circadian Lighting Design				
	Uniformity of illuminance*				
	Illuminance of the immediate surrounding areas**				
	Percentage of the task area meeting the required illuminance				
Acoustic comfort	Noise Criteria (NC)				
	Reverberation time				
	Noise background				

8.3. Format for reporting results of satisfaction survey

Occupant satisfaction survey presented in section 7.2, questions from 8 to 11, 10to 13, 14 to 16, 17 to 23 are to evaluate satisfaction level corresponding to thermal comfort, indoor air quality, lighting comfort and acoustic comfort respectively.

Care should be taken to avoid administering occupant satisfaction survey on a potentially biased subject who is not a regular occupant of the building, or have been under some medical treatment or any other similar reason. The survey must be administered to all occupants in a building and the response rate should be 40% of occupants surveyed. The survey designed to gain long term feedback should be administered before physical measurements are undertaken, and no changes should be made to the normal operation of the building between survey administration and physical measurement.

Questions are administered on a seven point scale where 1 is the worst and 7 is the best score. In each case the % of satisfied occupants is denoted as all those rating 4, 5, 6 and 7 on this scale. Where, there is more than one question under each category, the average satisfaction across all the constituent questions is to be considered.

For every element 90% and 80% satisfaction level should be met for building being classified as Class A and Class B respectively. Occupant satisfaction survey is not applicable to Class C building except when assessing humidity.

Format for reporting results of satisfaction survey shall be following:

Table 17: Occupant satisfaction survey report format

Elements	**Occupant satisfaction (%)**	**Classification (Class A / Class B/ Class C)**	**Remarks**
Thermal comfort			
Indoor air quality			
Lighting comfort			
Acoustic comfort			

Annexure A

Thermal comfort

A1. Calculation of Operative Temperature (to)

Operative temperature can be defined as uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effect of the mean radiant temperature, air temperature and velocity as shown in Figure 8. It is also known as dry resultant temperature or resultant temperature.

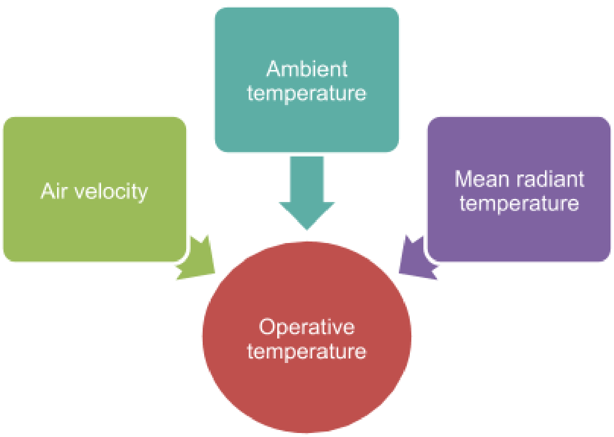


Figure A1 Parameters influencing operative temperature

A1. Factors leading to local thermal discomfort

A1.1 Radiant Temperature Asymmetry

The thermal radiation field about the body may be non-uniform due to hot and cold surfaces and direct sunlight. This asymmetry may cause local discomfort and reduce the thermal acceptability of the space. In general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by hot and cold vertical surfaces.

Radiant temperature asymmetry may occur in an enclosed space because of cold and warm walls as well as warm and cold ceiling. People are more sensitive to warm ceiling than other three.

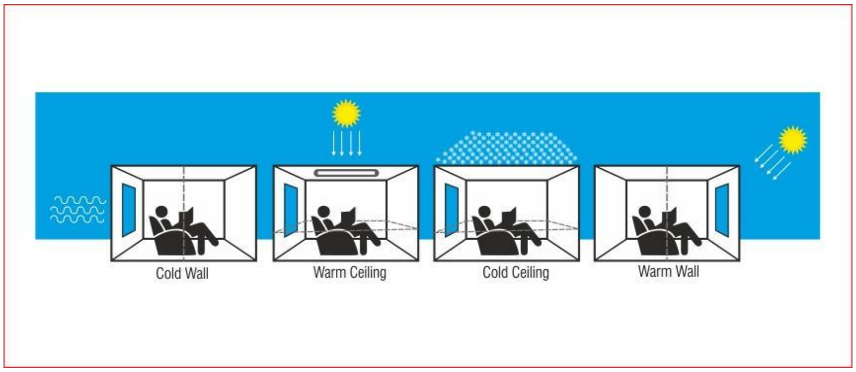


Figure A2 Radiant Temperature Symmetry caused by a cold wall, a warm ceiling, a cold ceiling, or a warm wall

A1.2 Vertical Air Temperature Difference and floor surface temperature

As demonstrated in Figure A3, an individual may feel local discomfort when temperature difference between warm head and cold feet increases beyond defined limit in Table 2. Occupants may also feel discomfort in the enclosed spaces where floor is colder or warmer than defined limit. It is applicable only when a person is wearing light indoor shoes

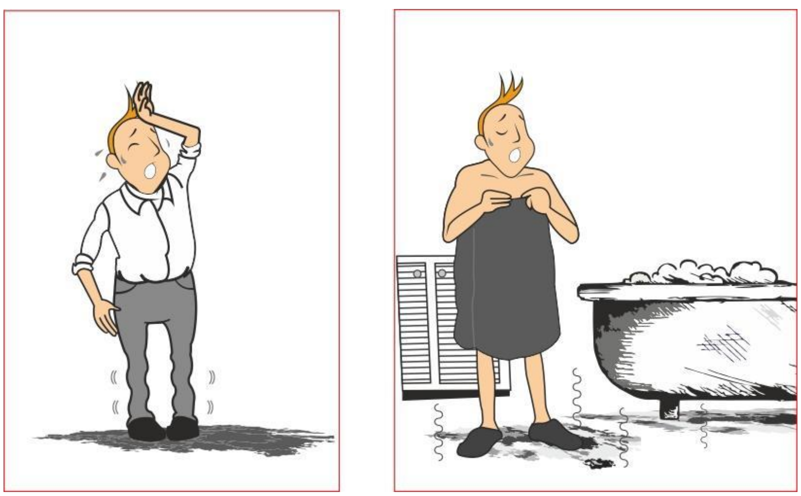


Figure A3 Local thermal discomfort caused by vertical air temperature difference (left) and floor surface temperature (right)

A1.3 Measurement Sensor location for thermal comfort

For the measurement of thermal comfort for sitting position and standing position of the occupant, the measurement probes shall be located as shown in Figure A4.

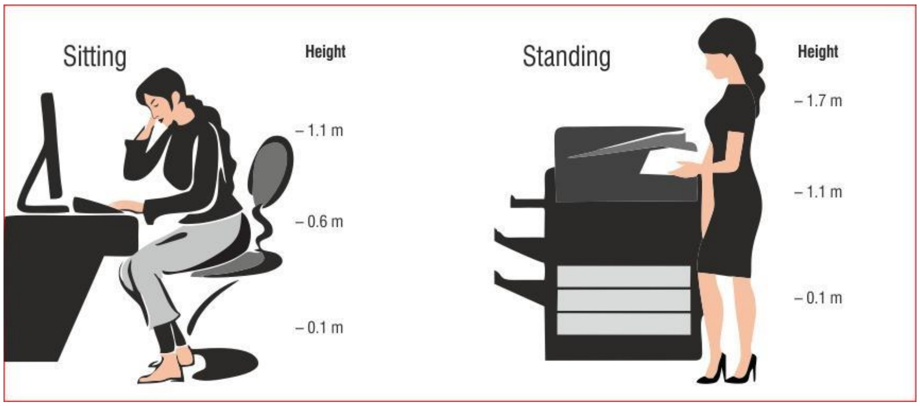


Figure A4 Position of the probes at different height according to standing and sitting position

Annexure B
Indoor air quality

B.1 Definition of Indoor Air Pollutants

B1.1 Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is a colourless, odourless gas vital to life on Earth. Carbon dioxide exists in the Earth's atmosphere as a trace gas at a concentration of about 0.045 percent (450 ppm) by volume.

Main source of CO_2 in buildings is people. CO_2 in indoor air is not itself a pollutant or a health risk in typical indoor concentrations. However, high levels of CO_2 reduce human comfort and productivity significantly. CO_2level, that is relatively easy to measure and is used as a general indicator of ventilation system efficiency.

B1.2 Respirable Suspended Particulate Matter (RSPM)

Respirable Suspended Particulate Matter (RSPM) refers to those dust particles that are small enough (less than 10 µm) to penetrate the nose and upper respiratory system and deep into the lungs. Smaller the particulate size is, higher is the health risk as the smaller particulates penetrates deeper into alveoli.

Respirable Suspended Particulate Matter (RSPM) is one of the main ambient air pollutants in India. Main sources of particulate matter are vehicle emissions, household cooking (especially cooking with biomass and frying), thermal power plants, biomass burning, construction work, unattended debris, fossil fuel (such as diesel) based power generation and various industrial processes.CO_2 shall also be measured at ambient to find threshold values as specified in the standard.

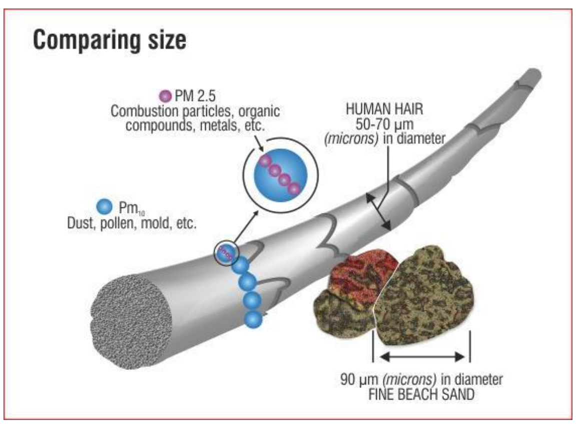


Figure B1 Comparison of PM size with human hair diameter and beach sand particle size

B1.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that is slightly less dense than air. Main source of CO are vehicles (combustion engines), fuel-burning appliances (e.g. furnaces, chullahs, gas stoves, cooking ranges, fossil fuel based water heaters, gas and kerosene room heaters), diesel generators, fireplaces and charcoal that is burned in enclosed areas. CO is toxic to humans when encountered in concentrations above about 35 ppm. It is a serious health risk and may cause an immediate death.

B1.4 Total Volatile Organic Compounds (TVOC)

Sum of the concentrations of identified and unidentified volatile organic compounds eluting between and including n-hexane and n-hexadecane.

The main sources of TVOC in buildings are furniture, construction materials, paints and cleaning products. Sometimes human activities and office equipmentalso increases the VOC level.

The prevalent TVOCs in indoor air are typically Formaldehyde, Benzene, Toluene, Ethylbenzene, O-xylene, Dodecane, Limonene, and Halogenated hydrocarbons. However, there are hundreds of other VOC that may reduce the indoor air quality. In case, TVOC level is high, more detailed analysis are required to find out which specific TVOC concentrations are high.

B1.5 Formaldehyde (CH_2O)

Formaldehyde (CH_2O) is a colourless gas with a pungent odour and is highly reactive. Formaldehyde occurs in indoor air often due to the use of certain wood-based construction boards and furnishing. Increased concentrations may also be caused by other products, like certain disinfectants, cleaning agents, adhesives and paints. Table 13 provides overview of the most important formaldehyde sources in the indoor environment.
Inhalation exposure to Formaldehyde in humans can result in respiratory symptoms as well as eye, nose, and throat irritation.
In high humidity and temperature, Formaldehyde emission increases considerably. Therefore, the relative humidity and air temperature needs to be measured simultaneously.

Table B1 Sources of Formaldehyde in indoor environment

The following standards need to be followed when measuring CH_2O: ISO 16000 – 2, 3 and 4, as appropriate.

Source	Examples for use
Adhesive, glue	Wallpaper pastes; gluing tiles, veneer, panelling, carpets and vinyl floor
Combustion processes	Gas stove operation
Disinfectants	Sprays and solutions for surface disinfection
Internal combustion engines[a]	Transportation
Particle board and other pressed - wood products	Walls (outdoors and indoors), ceilings, false ceilings, floors, baseboards, doors and doorframes, stairs, plywood panelling, furniture
Tobacco	Tobacco smoke
Treated textiles	Furnishings
Urea-formaldehyde foams	Wall cavity insulation, roof insulation
Wallpaper, lacquers, varnishes, paints	Interior decoration
[a] Might be important with heavy traffic	

B1.6 Ozone (O_3)

A triatomic compound, very reactive form of oxygen that is bluish irritating gas of pungent odour. It is a major air pollutant in the lower atmosphere but a beneficial component of the upper atmosphere, and used for oxidising, bleaching, disinfecting, and deodorising.

Ambient ground level Ozone (O_3) is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Inside the building some equipment like copiers and printing machines, some room air purification technologies (e.g. ionization, some UV-lights and ozonisers) produce Ozone. Ozone levels are typically highest on hot, sunny days.
Even relatively low levels of Ozone can cause health effects. Breathing Ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Ozone shall also be measured in spaces that have equipment producing ozone. Best time for Ozone measurement is during summer (sunny and warm days).The Ozone shall be measured as per IS 5182 – Part 9.

B1.7 Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a highly reactive and toxic gas with a pungent, irritating and rotten smell. The largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities. Other sources include industrial processes such as extracting metal from ore, and the burning of high sulphur containing fuels by locomotives, large ships, and non-road equipment. SO_2 can react with other compounds in the atmosphere to form small particulates.

Short term exposures to SO_2 (up to 24 hours) can cause adverse respiratory effects including bronchiolitis and increased asthma symptoms. Particulates carrying SO_2 penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, aggravate existing heart disease and may lead to premature death.

Emissions that lead to high concentrations of SO_2 generally also lead to the formation of other oxides of Sulphur (SO_x). Therefore SO_2 is used as the indicator for the larger group of gaseous sulphur oxides.

SO_2 shall be measured in the air intake in to the building (each AHU air intake or air vent or open window).At air intake, for values of SO2 concentration higher than the specified threshold value as given in section 6.2.2, additional measurements need to be taken inside the space.

The following standards needs to be followed when measuring SO_2: IS 5182 – part 2, as appropriate.

B1.8 **Nitrogen dioxide (NO_2)**

Nitrogen dioxide (NO_2) is one of highly reactive gasses known as oxides of Nitrogen (NO_x).Other nitrogen oxides include nitrous acid and nitric acid.

The major source of $NO_2$is high temperature combustion as in vehicles and power plants. NO_2 react with ammonia, moisture, and other compounds to form small particulates. Ozone (O_3) is generated when NO_2 and VOCs react in the presence of heat and sunlight.
Even short term NO_2 exposures (less than 24 hours) can cause adverse respiratory effects including airway inflammation in healthy people and increased respiratory symptoms in people with asthma.

NO2 shall be measured at air intake to building, (e.g. AHU air intake, air vent, open window) and after the filters in case of mechanical ventilation. The measurement inside the building shall be done in two locations - one near the main doors and the other one in the main occupied area.
The following standards needs to be followed when measuring NO_2: ISO 16000-15 and IS 5182 - part 6, as appropriate.

B1.9 Total Microbial Count

It is a quantitative measurement of the number of colony forming units of micro-organisms in 1 cubic metre sample of air.

One of the major purposed of the microbial count measurement is to compare indoor and outdoor air samples and find any visible or hidden mould growth. Therefore, it is important to use same method for both measurements and carry them out at the same time. Due to differences in sampling times, volumes, and principles, the results given by different devices and methods are not comparable. Several air samples needs to be collected in different parts of the building and at different times. The outdoor air samples, that are collected simultaneously with each indoor air sample (same day and in same weather conditions), are needed for comparison. The air handling unit or ventilation system may be a source of microbiological contamination. Therefore in each measurement zone, one sample shall be collected from the supply air near the terminal unit.
When there is dampness and mould in a building, airborne fungal and bacteria concentrations of indoor air are often (but not always) higher than the concentrations in ambient air at the same time. For fungal spores and bacteria, the seasonal variation is considerable. Therefore measurements shall be taken only during summer and winter months.

There are no established health-based guidelines or standards for fungal or bacteria concentrations in the indoor air because different types of fungi or bacteria may have different health effects. There is also not enough research of “healthy” buildings during different seasons available in India to give India specific target values for fungal count levels. Furthermore, there are no uniformly accepted or valid, quantitative environmental sampling methods with which to assess exposures to mould and other agents associated with damp indoor environments.

Relative humidity measurements are recommended together with total microbial count measurements. The following standards need to be followed when measuring total fungal count: ISO 16000 – 16, 17, 18, 19, 20 and 21, as appropriate.
Note: Even then measurements in different seasons or weather conditions cannot be compared.

B2. Important types of indoor environment and sources of air pollutants

Type of indoor environment	Emitting sources or processes (examples)
Private dwellings and living rooms	
a. General sources	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air, heating appliances, microbial growth
b. Special areas	
Kitchens	Gas appliances, cooking, cleaning products
Living rooms, bedrooms, bathrooms	Tobacco smoke, fireplaces, biocide-containing products, cosmetics, disinfectants
Basements, hobby rooms	Hobby activities, tobacco smoke, soil outgassing
Garages	Fuel, solvents
Public buildings	
a. General sources	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air
b. Special areas	
Offices	Office machines and supplies
School and day care centers	Teaching materials, toys
Hospitals	Disinfectants, cleaning agents, anesthetics, sterilizing agents
Garages	Fuel, automobiles
Swimming pools	Outgassing from water
Transport vehicles	Fuel tanks, internal combustion engines, internal fitting materials, outdoor air

B3. Sources of indoor air pollutants and their most important emissions

Ask this	Process/activity	Products used, sources in a narrower sense	Substances emitted
Biological sources			
People, domestic animals	Breathing		Carbon dioxide, water vapour, odours substances from food; bacteria and viruses
	Sweating		Water vapour. Odoriferous substances
	Digestion, excretion, skin scaling		Intestinal gases. Odoriferous substances and excrement, decomposition products or pathological excretions, bacteria and viruses, allergenic dust
Cockroaches, dust mites and other insects	Excretion		Allergenic dusts
Rats, mice and other pets	Excretion		Allergenic dusts, bacteria, viruses. Odoriferous substances
	Loss of hair and scaling		Allergenic dust
House plants	Evaporation		Terpenes and other odoriferous substances, water vapour
Mould growth	Primary and secondary metabolism, spore release		Fungal propagules, bacterial cells and components, microbial VOC, mycotoxins
Building products, building equipment			
Building and materials	Product processing, outgassing, ageing, abrasion, decomposition	Building substances, building preservatives and corrosion prevention agents, insulating materials, sealing materials, paints, concrete additives Scrubbers, filters, insulating and sealing	Various gaseous and particles, e.g. solvents, plasticizers, monomers, oligomers, wood preservatives, flame-proofing agents, fibres (asbestos, minerals wool), radon (e.g. from granite), amines and ammonia

		materials, deposits, heat exchangers	
Ventilation and air-conditioning system	Product processing, renovation, outgassing	Furniture, floor coverings, domestic textiles, paints and varnishes, wall coverings	Microorganisms (e.g. legionella), biocides, fibres, odoriferous substances
Room furnishings	Product processing, renovation, outgassing		Monomers and oligomers from plastics, resins, surface coatings, adhesives (e.g. formaldehyde), fibres, solvents, plasticizers, stabilizers, biocides
Indoor activity			
Cooking and heating appliance	Combustion processes (heating, cooking), open fires	Coal, heating oil, gas, wood, foodstuff	Gases (municipal, bottled, natural), heating oil vapour, carbon dioxide, carbon monoxide, nitrogen oxides, water vapour, suspended particulate matter, hydrocarbons and many other organic substances (combustion and carbonization products)
Hygiene and personal care	Body and cosmetic care	Cosmetics and consumer products; shower and bath water	Solvents, propellants, perfumes, inorganic and organic aerosols (dyes, pigments, lacquers, resins), halocarbon
Sanitation products	Cleaning and care procedure; pest control	Detergents and cleaning agents, polishes, disinfectants, pesticides	Water, ammonia, chlorine, organic solvents, insecticides, bactericides and chlorine compounds, domestic dust
Home office	Office activities	Office supplies, EDP equipment, copiers	Organic solvents, low-volatility organic substances (plasticizers, flame proofing agents), toner components, ozone
Hobby and DIY (do-it-yourself) products	DIY activities, renovation, painting and the like	Paints, lacquers, adhesives, sprays, handicraft products, soldering irons	Inorganic and organic gaseous and aerosol-type substances, particularly propellants and solvents, dusts, suspended
		Tobacco products	

Tobacco Garage store room	Smoking Storage	Fuels, paints, lacquers, cleaning agents, etc.	particulate matter, metal vapours, monomers, biocides Carbon monoxide, nitrogen oxides, nicotine, aldehyde, nitrosamines and numerous other organic substances (e.g. polycyclic aromatic hydrocarbons, aerosols) Fuel vapours, exhaust gas, solvents
Transportation			
Vehicles	Vehicle (car, use of vehicle, trucks, caravan, public transport)	Fuels, plastic and rubber materials, insulating material, ventilation	Vehicle exhaust gases and particles, carbon monoxide, nitrogen oxides, hydrocarbons, polycyclic aromatics, benzene, lead-containing suspended particulate matter, diesel soot), plasticizers (e.g. phthalates) and other additives, aldehyde, monomers (e.g. styrene), ozone (aircraft cabins)
Outdoor air pollution			
Emissions due to human activities Natural emissions Livestock	Ventilation, infiltration and diffusion through building exterior Ventilation, penetration of soil gases, windborne dust Excretion	Trade and industrial establishments, traffic, house fire, agriculture, outside burning Plants in flower, occurrence of radium in soil, sea spray, soil re-suspension, natural decay Intestinal gases, odoriferous substances and excrement decomposition [products or pathological excretions; bacteria and viruses, allergenic dust	Inorganic and organic gases and aerosols, solvents, ammonia, odorous substances, PAHs Pollen, radon, methane, sea salts, particles, microbes Ammonia and Sulphur compounds

B4. Typical pollutants and their sources in indoor environment

Pollutants	Sources
Inorganic components	
Carbon monoxide (CO)	Open fires, tobacco smoke, vehicle exhaust gases
Carbon dioxide (CO_2)	Open fires, tobacco smoke, people, vehicle exhaust gases
Nitrogen dioxide (NO_2)	Open fires, gas appliances, tobacco smoke, vehicle exhaust gases (in vehicle)
Sulphur dioxide (SO_2)	Sulphur-containing fuels
Ozone (O_3)	Photocopiers, laser printers
Ammonia	Flooring, concrete, levelling agents, mortar/plasters
Radon	Uranium and radium deposits close to the surface, building materials (granite, pumice stone and tuffaceous rock), artificial plaster
Mercury	Broken thermometer, plaints
Lead	Paints
Particles	
Settled dusts	Tracked-in dusts
Asbestos	Insulating materials, freeable asbestos
Fibrous dusts	Mineral wool, building materials
Aerosols	Tobacco smoke
Suspended particulate matter (PM) PM2.5 PM 10 TPM (total particulate matter)	Fuel combustion., cooking, fungi spores, pollen, animals, humans, bacteria, windblown dust

Annexure C

Lighting comfort

C1. Circadian Lighting Design

Light is one of the main drivers of the circadian system, which starts in the brain and regulates physiological rhythms throughout the body's tissues and organs, affecting hormone levels and the sleep-wake cycle. Circadian rhythms as shown in Figure C1 are kept in sync by various cues, including light which the body responds to in a way facilitated by intrinsically photosensitive retinal ganglion cells (ipRGCs): the eye's non-image-forming photoreceptors. Through ipRGCs, lights of high frequency and intensity promote alertness, while the lack of this stimulus signals the body to reduce energy expenditure and prepare for rest.

This feature promotes lighting environments for circadian health. The biological effects of light on humans can be measured in Equivalent Melanopic Lux (EML), a proposed alternate metric that is weighted to the ipRGCs instead of to the image forming photo receptors - cones, which is the case with traditional lux.

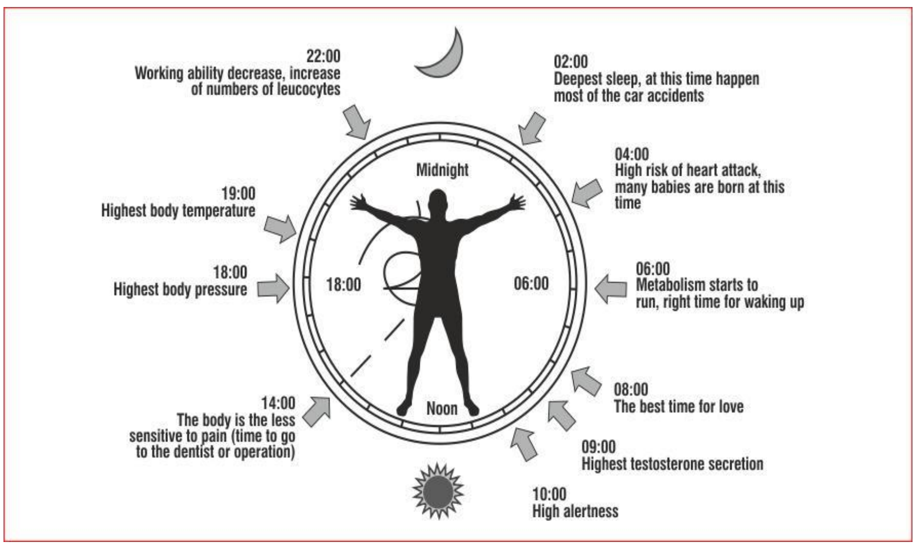


Figure C1 Circadian rhythms in humans

C1.1 Glare

Glare is the result of sudden large changes in brightness of the light source, which leads to lower efficiency of the vision. An occupant under the effect of glare fails to notice subtle changes and details of a scene. It is mainly classified into two types Direct Glare and Reflected Glare

C1.2 Direct Glare

Direct Glare is caused when within an occupant's field of vision, the luminaires of a room are without glare control thereby making the task area and surfaces very bright resulting in glare. The effects of it are fatigue, frequent mistakes and loss of concentration.

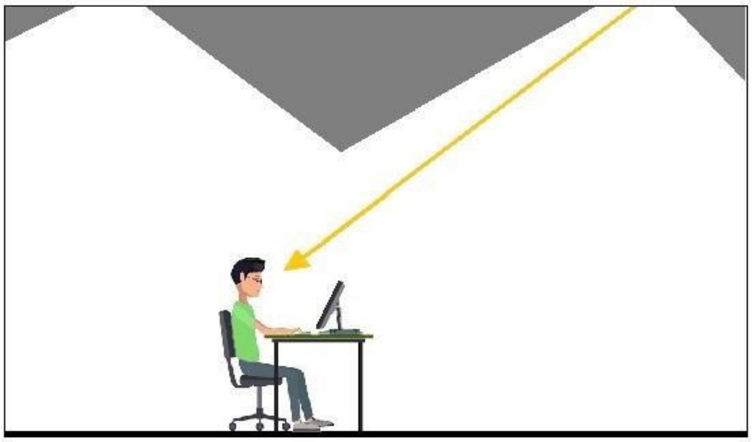


Figure C2 Direct glare

C1.3 Reflected Glare

Reflected Glare is caused due to reflections coming from light sources or surfaces of excessive brightness which is the result of incorrect Luminaire arrangement and incorrect workstation position. The effects of it are fatigue, frequent mistakes and loss of concentration.

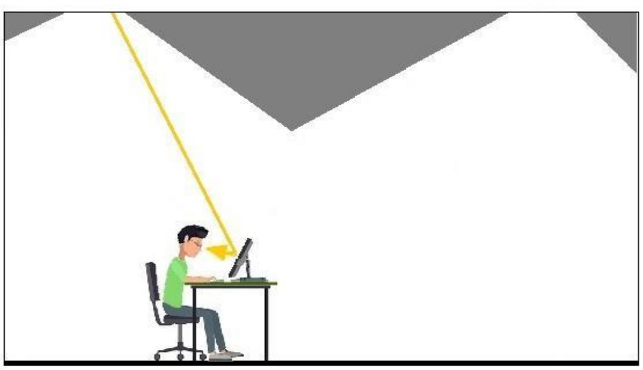


Figure C3 Reflected glare

In general, Glare mainly experienced either as physiological effect known as Disability glare or psychological glare known as Discomfort glare

C1.4 Disability glare

Disability glare is direct impairment of visibility and visual capacity by the effect of glare. As an effect of glare occurs due to luminance from immediate background light source disability glare is happed. Discomfort does not necessarily causes by disability glare.

C1.5 Discomfort glare

Discomfort glare is disturbance, which impairs our sense of wellbeing by the effect of glare. The level of discomfort occurs due to glare is depends upon size of glare source and the luminance. Discomfort glare does not necessarily impairs object observation. As passing of time discomfort tends to increase and causes nervous tension and fatigue. Object observation impairment does not necessarily causes by discomfort glare

C 2. Basic Light Level Measurement Protocols

Light level (i.e., illumination) measurements are critical to comparing the capabilities of different lighting technologies. It is important to measure only the light being provided by the technologies being tested, which represents the actual illumination provided by the system being measured. The following guidelines will help to ensure accurate and representative light level data.

Follow these guidelines for all measurements as applicable:

• Where possible, use the same calibrated illuminance measurement meter (see Section 2.1). If the same meter is not available, use the same make and model of calibrated meter to minimize underlying differences in accuracy and internal meter spectrum correction characteristics.

• When taking measurements, verify that occupants and objects/materials are not blocking any light to the meter head. The use of a remote meter head cabled to the meter body is recommended to prevent the operator from blocking the meter's "view" of the lighting system being measured. Measurement points that are shaded, even partially, by obstructions that are not moveable should be noted for potential elimination.

• Identify the appropriate task plane at which to take the measurements. For most outdoor areas and indoor corridors, gathering spaces, and warehousing or manufacturing spaces, this plane will be the ground or floor surface (where walking is the primary task). For most other indoor areas, the task plane will be a typical office desk height (30 inches above the floor).

• Identify the measurement locations by marking and/or mapping. It is important to measure the same locations for the baseline and post-installation lighting systems, or the same representative type of locations if fixtures are relocated for the retrofit. Therefore, it is necessary to provide some permanent record of measurement point locations.

– For interior areas, mapping (e.g., using a sketch or marked-up plans with dimensions) is usually the best option because marking on measurement surfaces will often not be allowed or will not be retained between measurements. Make sure to reference the measurement points to some permanent features of the space because desks and other furniture may be moved between the baseline and post-installation measurements.

• Photographs of the test site conditions, meter setup, and measurement layout are recommended to provide a record of the conditions to be applied for repeated sets of measurements. These will help identify obstructions and other conditions that may affect readings. Note that using photos for color comparisons of baseline and retrofit installations may not provide accurate results because camera model settings including white (color) balance and exposure may vary. If photos are to be used for comparison purposes, the camera color accuracy should be assessed, and appropriate caveats noted.

• Record time and ambient temperature at start and finish of measurements.

Annex D (Normative)

Recommended methodology to calculate Equivalent Melanopic Lux (EML) for different type of lighting conditions

To calculate the Equivalent Melanopic Lux (EML), multiply the visual lux (L) designed for or measured in a building by Melanopic ratio (R).

$$EML = L \times R$$

Where values of ratio R are given in Table D1

Table D1 Light source and melanopic ratio corresponding to different CCT (K)

CCT (K)	Colour Appearance	Light Source	Melanopic Ratio
2950	Warm	Fluorescent	0.43
2700		LED	0.45
2800		Incandescent	0.54
4000	Intermediate	Fluorescent	0.58
4000		LED	0.76
5450	Cool	CIE E (Equal Energy)	1.00
6500		Fluorescent	1.02
6500		Daylight	1.10
7500		Fluorescent	1.11

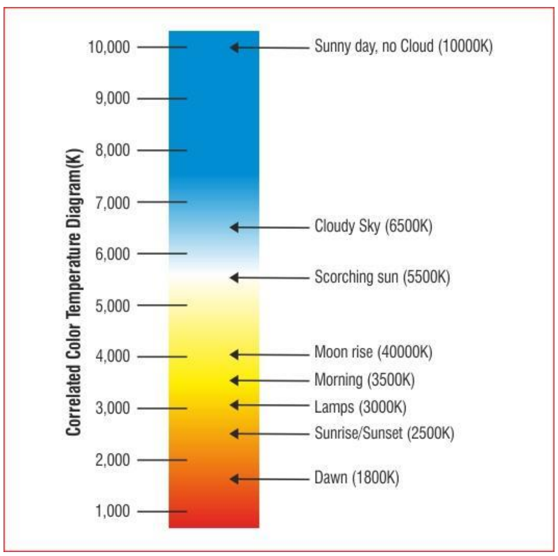


Figure D1 Correlated Colour Temperature (K) corresponding to typical lighting conditions

Example 1:

If incandescent lights provide 200 lux in a space, they will produce equivalent melanopic lux of:

$$EML=200x0.54$$
$$EML=108$$

Example 2:

If fluorescent lighting of 6500 K CCT provides 200 lux in a space, then the EML will be

$$EML = 1.02x200$$

EML = which is 204 EML.

Example 3:

If CFL of CCT 6500 and LED of CCT 4000 combine provide 300 lux, then the EML can be calculated by the following method:

Lux levels provided by CFL is 100(can be determined by switching off LEDs)

$$EML_{CFL}=100 \times 1.02=102 \text{ EML}$$

Lux levels provided by LED is 200(can be determined by switching off CFLs)

$$EML_{LED}=200 \times 0.76=152 \text{ EML}$$

Total EML shall be calculated

$$EML_{total}=EML_{CFL} + EML_{LED}=254$$

Example 4:

If fluorescent lighting of 7500 K CCT and daylighting provide 500lux

Lux levels provided by daylight is 400(can be determined by switching off fluorescent lights)

$$EML_{daylight}=400 \times 1.10=440 \text{ EML}$$

Lux levels provided by fluorescent are 100(total lux –daylight lux)

$$EML_{fluorescent} =100 \times 1.11=111$$
$$EML_{total}=EML_{fluorescent}+ EML_{daylight}=551$$

4. **Recommended methodology to calculate lighting comfort parameters**

If the Illuminance at three points (varies according to size of task area) of task area (varies according to the nature of activity) are 515 Lux, 535 Lux and 550 Lux, further the Illuminance at three points (varies according to size of immediate surroundings area) of immediate surroundings area are 430 Lux, 465 Lux and 495 Lux then Illuminance of task area shall be calculated by averaging the measured illuminance within the task area

Illuminance=515+535+5503

Illuminance=533 Lux

Uniformity of Illuminance shall be calculated by ratio of minimum illuminance to average illuminance within the task area

Uniformity of Illuminance=515533

Uniformity of Illuminance=0.9

Illuminance of the immediate surrounding areas shall be calculated by averaging the measured illuminance within the immediate surrounding areas

Illuminance of immediate surroundings=430+465+4953

Illuminance of immediate surroundings=463 Lux

Ratio between a task area illuminance and immediately adjacent surroundings illuminance = 533463=1.15

Percentage of the task area meeting the required illuminance

If in a conference room there are five occupants, the measured illuminance of their task areas are 510 Lux, 580 Lux, 455 Lux, 550 Lux and 535 Lux. Thus 4 out 5 locations are meeting the threshold value, and then the Percentage of the task area meeting the required illuminance can be calculated by

Percentage of the task area meeting the required illuminance=4*1005=80 %

Annexure E (Normative)

Recommended methodology to calculate lighting comfort parameters

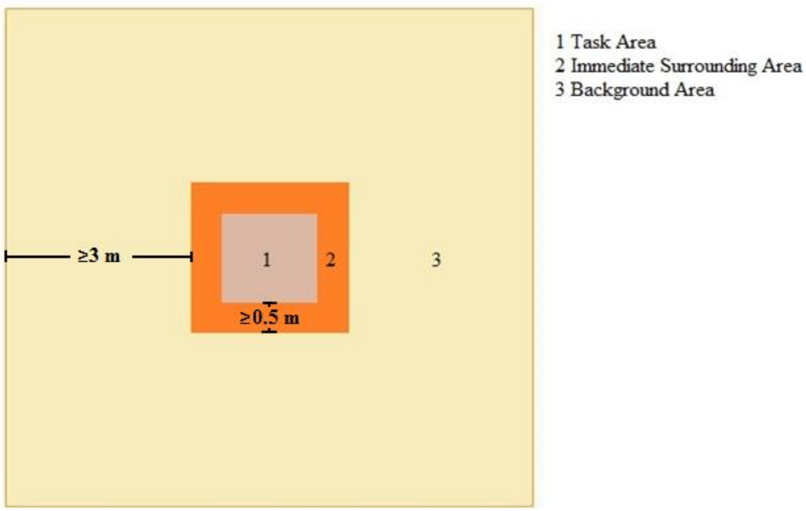


Figure E1 Task, immediate surrounding and background areas

Area where the visual task is performing defined as the task area. The visually relevant elements such as background contrast, size of objects, presentation time and luminance of objects are used to determine the visual performance required for the visual task. The reference surface of the visual task can be vertical, horizontal or inclined.

At least 0.5 m band width area surrounding the task area within the field of vision is defined as the immediate surrounding area.

Background area is defined as the band of at least 3 m wide adjacent to the immediate surrounding area within the limits of the space**.**

Annexure F
Acoustic comfort

F.1 Reverberation time,

T60, is a metric which describes the length of time taken for a sound to decay by 60 dB from its original level. The optimal reverberation time for any room depends on both the intended use of the space and the volume of the space, and additionally, reverberation is frequency dependent. The clarity of speech and music at any location within a room is dependent on the size, shape, and surface materials in the space, and as such, the clarity is highly dependent on the reverberation time. Short reverberation times are recommended for speech, whereas longer reverberation times are recommended for music.

Not only does the reverberation affect quality of sound, but it also affects the level (dB) of sound within the space from all sources including noise. In spaces with long reverberation, the sound of voices and footsteps take longer to dissipate, contributing to higher levels of ambient noise. The added noise produced by reverberation can decrease speech intelligibility and in some situations cause additional stress.

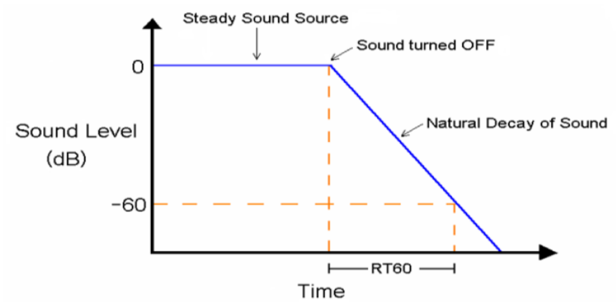


Figure F1: Reverberation time

F 2 Weighted Level Difference (Dw)

The Table F1 shows the Dw values and its reaction

Table F1 D_w Values and its Reaction

Dw / NIC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed
55	Superior soundproofing; most sounds inaudible