GUIDELINES
FOR INDOOR AIR QUALITY IN SRI LANKA
2022

AIR RESOURCE MANAGEMENT AND NATIONAL OZONE UNIT
MINISTRY OF ENVIRONMENT, SRI LANKA

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CONTENTS

ANNEXURES

1 INTRODUCTION

Air pollution is the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. The chemical agents can be in the form of gasses, solid particles, or liquid droplets. In general, air pollution is linked to human activities which include emissions from domestic settings, workplace settings and, transport and power sectors.

Ever since the invention of fire, air pollution has become an integral part of human life. In addition to human activities, natural processes are also contributing to air pollution. It is well known that human activities contribute significantly in deteriorating the quality of air they breathe in.

The term "indoors" refers to the locations with limited air circulation ranging from private residences to public workplaces (offices, schools and healthcare facilities, industries, etc.). Transport systems including cars, buses, trains and airplanes can also be considered as indoors due to limited air circulation. In developed nations, attention has been paid to improving the air quality in indoor settings as well to a certain extent. Unfortunately, developing nations have paid less attention to the indoor air quality concerns even though the impact can be significantly more considering their household cooking, heating, and other indoor and occupational activities.

Clean air is fundamental to health. Recognizing the need of humans for clean air, the World Health Organization (WHO) has published several Air Quality Guidelines to prevent the adverse impacts of air pollution. Especially, the "global update" which was published in 2006 drew attention to the large impact on the health of indoor air pollution in developing countries (WHO Air Quality Guidelines Global Update 2005). Accordingly, the high concentration of particulate matter and gasses are due to indoor combustion sources. As per the latest updates, over 3.8 million people die prematurely from illnesses attributable to household air pollution annually. In these countries, indoor air quality problems are attributable to the lack of technology necessary to mitigate indoor air pollution (e.g. chimneys, hoods; use of clean fuels). This is a huge impact on health; indeed, far larger than that imposed by exposure to outdoor air pollutants.

In view of improving the overall air quality in Sri Lanka, the Ministry of Environment has formulated the "Clean Air Action Plan 2025" and launched it in 2016. The Chapter 3.4 of the said Action Plan describes the indoor air pollution and the Section 4 of Appendix I of the same indicates the actions to be taken to address indoor air pollution. Accordingly, the indoor air quality guidelines are to be developed under the strategy of improving building designs, construction maintenance through building regulations and guidelines to meet the objective of focusing on indoor air quality in building design construction, maintenance and use in the said section of the Action Plan.

The Cabinet of Ministers appointed a Regulatory/Steering Committee to implement the "Clean Air 2025 Action Plan" with a view to achieving better air conditions in the year 2025. Further, the Action Plan describes the indoor air pollution and indicates the actions to be taken to address indoor air pollution. Accordingly, this document is prepared as a very important first step towards interdisciplinary consensus on the issue of indoor air quality. The Ministry of Environment formulated 'National Environmental Action Plan 2022-2030' under the heading of 'Pathway to Sustainable Development.' The action plan also describes measures to be taken to address indoor air pollution under the theme 'Air

Quality Management.' Sri Lanka Green Building Guidelines for state and semi state owned buildings was published in 2017 emphasizing the improvements of indoor air quality. Accordingly, this document is prepared as a very important first step towards interdisciplinary consensus on the issue of indoor air quality.

The objective of this Guidelines is to provide general guidance on improving the indoor air quality of households, offices and public places. Additionally, it is intended to provide acceptable values for selected indoor air pollutants. It also provides information on the potential health effects of indoor air contaminants and practical guidelines to enable users to prevent indoor air quality problems, and to solve problems promptly if they arise. Indoor air quality guidelines for occupational settings need to be developed separately.

2 PURPOSE AND SCOPE

2.1 Purpose

Providing guidance for the protection of health due to exposure to poor indoor air quality, and minimizing the exposure to the selected indoor air pollutants

2.2 Scope

The scope of this guideline is limited to revealing the importance of indoor air quality, understanding the key chemical pollutants present in the indoor environment and their negative health impacts due to the exposure. These exposures can be short-term or long-term leading to acute or chronic health issues. Biological agents too are important as indoor air pollutants. However, they are not considered in this guideline document.

This guideline intends to give general recommendations to help reduce levels of indoor air pollutants in order to decrease the enormous health burden resulting from its exposure.

3 DEFINITION OF INDOOR AIR QUALITY

Indoor Air Quality (IAQ) refers to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. Understanding and controlling common indoor pollutants can reduce health risks (USEPA).

4 DETERIORATION OF INDOOR AIR QUALITY

Several indicators can be used to identify the possible deterioration of indoor air quality. These indicators can be physical, chemical, biological, and environmental depending upon the indoor air quality observations,

4.1 Physical indicators

Physical indicators can be recognized by the appearance and smell. Withering, discolorations, unpleasant smells in and around a closed structure are some of the common examples.

4.2 Chemical indicators

Changes of chemical nature including blackening of copper electric wiring; unusual coloring; cracking; withering signs on households or antique items made out of silver, copper, wood, leathers, etc; gaseous smells; and moisture absorption by hygroscopic substances such as salt, sugars, cellulosic materials in and around surrounding areas are good chemical indicators.

4.3 Biological characteristics

Significant biological indicators include triggering of asthma, allergy by aeroallergens and other airborne ailments amongst the occupants, biofilms, and fruity, earthy and other pungent smells.

5 SOURCES OF INDOOR AIR POLLUTANTS

Indoor air quality can deteriorate due to changing air composition and environmental conditions in various ways. Some of them are due to activities within the building (indoor sources) and some are due to outside conditions (outdoor sources).

5.1 Indoor sources

Air pollutants can be generated indoors due to sources such as combustion process, building materials and equipment, and human activities or processes.

5.1.1 Pollutants from combustion activities

Primarily indoor combustion activities are the key sources of indoor air pollution. Cooking, lighting and heating (in some parts of the country) are the combustions with purpose which are essential for the human life but their exposures to dwellers can be controlled or reduced with appropriate precautions. Majority of the households in Sri Lanka still use solid fuels for cooking activities, and kerosene is used for cooking, heating and lighting in some areas. Using substandard fuel, inefficient technology and poor practices are prevalent in low-income households. Furthermore, often the dwellers are not aware about the health consequences or the strategies to mitigate the exposure. Additionally, emissions from burning candles, joss sticks, tobacco products and mosquito coils contribute to further worsen the indoor air quality. In any combustion process, incomplete combustion leads to human health impacts by release of carbon monoxide (CO), hazardous volatile organic compounds and formation of carcinogenic compounds. These hazardous emissions can be kept away to minimize the exposure. Unfortunately, most of these combustions release the chemicals at the breathing levels and indoor emissions take place in the presence of occupants.

5.1.2 Pollutants derived from building materials and appliances

Presently, various types of chemical-based materials are used for building decorations, furnishing, paints, varnishes, binders, sanitary chemicals, air fresheners, pesticides and fragrances which release chemicals resulting in different indoor air pollutants. Most of these materials contain volatiles or semi-volatiles which can be released from the surfaces introducing an additional burden to the indoor air. Electronic and electrical equipment releases chemicals with heat. Products which contain polymers such as furniture, carpet adhesives are known to release formaldehyde upon degradation. Solvent based paints, adhesives used for building may contain cancer causing agents such as benzene and xylene. The Fabrics and other decorations increase the surface to volume ratio in the indoors serving as ideal places for accumulating dust and other fugitive chemicals. Use of minerals such as granite may release radioactive radon gas to the indoors elevating the risk of cancer.

5.1.3 Pollutants related to other human activities and lifestyles

Human activities release a wide range of pollutants to indoor settings. Regular housekeeping activities such as cleaning, sweeping and dusting make the deposited particles to be airborne increasing the risk of exposure.

If air conditioning is not maintained properly it will contribute to the poor indoor air quality. Chemicals in air fresheners are also known to worsen indoor air quality.

5.2 Infiltration from the outdoor sources

The infiltration of polluted outdoor air to indoors is an integral aspect of assessing indoor air quality. Infiltration is through windows, doors, and other openings. Compared to the outdoors, indoors have a limited air volume, and hence pollutants tend to accumulate in the indoors increasing the exposure. Furthermore, high surface to volume ratio in the indoors promotes the deposition of pollutants into indoor surfaces. Condensing the semi-volatile pollutants into the indoor surfaces creates more exposure risk to the occupants.

Outdoor pollutants that have a significant impact on the indoors include the emissions from the motor vehicles, industrial emissions and smoke emanating from combustion activities including open fires. Furthermore, infiltration of air pollutants in neighboring environments threatens the communities in densely populated areas.

The magnitude of the adverse health outcomes depends on several factors. These include proximity to the pollutant sources, environmental and meteorological conditions, the levels of the pollutants, frequency and length of exposure and individual vulnerability. The outdoor infiltration can be controlled by increasing ventilation.

6 SIGNIFICANCE OF INDOOR AIR QUALITY

6.1 Health Impacts

Indoor air pollutants usually enter the body through inhalation during breathing. While pollutants commonly found in indoor air can cause many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems.

Health impacts due to poor indoor air quality can be acute (i.e., short-term effects) or chronic (i.e., long-term effects). Almost anyone can be at risk, but some are more vulnerable such as unborn, and young children, pregnant mothers, elderly, and people with long-term health issues (e.g., heart diseases, lung diseases).

6.1.1 Short-Term Effects

Some health effects may appear shortly after a single exposure or repeated exposure to a pollutant or mixture of pollutants. These include conditions such as irritation of eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable (e.g., sick building syndrome). Symptoms of certain diseases can be aggravated or worsened (e.g., asthma) soon after the exposure to some indoor air pollutants. Sometimes, eliminating the exposure to the source of air pollution will be adequate to control such symptoms and improve health.

6.1.2 Long-Term Effects

Some health effects of air pollution are chronic and impact the health for a long time. Such conditions include long term lung diseases, lung cancer, heart diseases, stroke, and cataracts, etc. At the same time, health effects may present after years of exposure to air pollutants or only after long or repeated periods of exposure.

A detailed description of the health effects of indoor air pollution and the list of studies done in Sri Lanka are given in Annexure I.

7 IMPORTANCE OF MONITORING INDOOR AIR QUALITY

Concentrations of air pollutants in the indoors vary from one indoor setting to the others. Therefore, in establishing the indoor air quality guidelines, monitoring is essential which enables the identification of pollutants and their levels of concentrations and source of origins, as well as finding strategies to mitigate the exposure etc. The health effects of a given pollutant rely on how they enter the human body which heavily depends on their phase (gas, liquid or solid) and size. Hence, in assessing the health effects, the collection of a representative air sample is vital without altering the phase and size distributions. (Refer to annexure II for futher information)

8 INDOOR AIR QUALITY GUIDELINES

Development of guidelines levels for all indoor air contaminants are impossible. Therefore, it is needed to identify air pollutants that are high priorities depending on the local conditions. Some of the common indoor air contaminants (parameters) and levels proposed in tables given below are based on the available limited epidemiological studies, indoor air quality studies and ambient air pollutant level data. Therefore, this should be considered as an interim national guideline. (Refer to annexure IV for further information).

8.1 Guidelines for households

Table 1-Recommended guideline values for households

Pollutant	Recommended Value for IAQ Guideline for Sri Lanka	Average time
$PM_{2.5}$ (µg/m^3)	75	24 hr
	100	8 hr
PM_{10} (µg/m^3)	150	24 hr
	200	8 hr
CO (mg/m^3)	7	24 hr
	10	8 hr
NO_2 (µg/m^3)	200	1 hr
TVOC (mg/m^3)	1	8 hr

8.2 Guidelines for office and public places

Table 2-Recommended guideline values for office and public places

Pollutant	Proposed IAQ Guideline for Sri Lanka	Average Time
$PM_{2.5}$ (µg/m^3)	50	24 hr
PM_{10} (µg/m^3)	100	24 hr
	200	8 hr
CO (mg/m^3)	10	8 hr
NO_2 (µg/m^3)	200	1 hr
TVOC (mg/m^3)	1	8 hr

9 RECOMMENDATIONS FOR IMPROVING INDOOR AIR QUALITY

9.1 Create awareness among all the stakeholders

The first and foremost task to improve the indoor air quality is to raise awareness of all the stakeholders including the general public. A sound understanding on the issue, identifying the problematic sources & activities, type of pollutants & their health impacts and use of mitigating strategies will speed up the indoor dwellers to lessen health risks and protect their belongings. It could be carried out through;

a. Dissemination of prepared easy to read booklets in all the three languages,

b. Dissemination of posters, cartoons and visuals illustrating indoor air quality issues, possible health impacts and exposure mitigating strategies through print and electronic media

c. Having dialogs with educators, healthcare givers, school children and communities,

9.2 Improve ventilation (i.e. avoid air stagnation)

Exposure of high concentrations of air pollutants causing health problems and material damage due to accumulation of pollutants indoors as a result of poor air circulation. Following recommendations are suggested to improve indoor air quality enabling to reduce the exposure significantly.

a. Measures to expel the indoor pollutants to outdoor effectively.
   - i. Recommend performing cooking activities under a chimney, near a window or confined to outdoor cooking whenever possible
   - ii. Recommend using exhaust fans or maximize the natural ventilation systems to avoid the air stagnation

b. Mechanisms to minimize infiltration from localities with high outdoor pollutant levels.
   - i. Recommend using filtration media for the households located near roadsides, combustion sources, etc.
   - ii. Recommend frequent cleaning filtration systems in air conditioners
   - iii. Recommend using filtered air in libraries, museums, and storages to protect the materials

c. Measures to be taken to minimize discomfort situation due to indoor air pollution
   - i. Recommend improving ventilation when feeling discomfort in indoors
   - ii. Recommend flushing indoors with fresh air after the use of volatiles chemicals
   - iii. Recommend all the cleaning activities with improved ventilation conditions
   - iv. Recommend keeping office equipment under improved ventilation conditions
   - v. Recommend using additional ventilation in indoors with limited vents including washrooms and storerooms

9.3 Measures for avoiding unnecessary indoor combustion activities

a. Recommend to avoid burning of mosquito coils, joss sticks and smoking in indoors

b. Recommend to replace continuous burnings sources in indoor shrines or shift shrines to outdoors

c. Recommended NOT TO use combustion sources as space heaters in airtight spaces

d. Recommended NOT TO use undesirable heating devices including barbecue machines, etc. to warm the indoors.

e. Recommended NOT TO run vehicles in idle condition in closed garages.

9.4 Measures to be taken avoid use of bothersome chemicals in indoors

a. Recommended NOT TO use of volatiles

b. Recommended NOT TO use storing chemicals and open containers

c. Recommend using alternatives replacing the volatiles
   - i. Recommend replacing solvent-based paints by water-based paints
   - ii. Recommend replacing synthetic volatile pesticides by natural pest control methods
   - iii. Recommend not using fragrances and air fresheners

9.5 Use environmentally friendly roofing material indoors (eg Zink Aluminum)

a. Recommended NOT TO cut or abrade asbestos or asbestos containing building materials inside indoor

b. Recommended to apply a protective layer of material on asbestos surfaces preventing the release of asbestos fibers

9.6 Human activities under controlled conditions

a. Recommend using cleaner fuels or use improved cook stoves for cooking

b. Recommend wearing face masks or nose & mouth covers during indoor cleaning activities

c. Recommend minimizing indoor combustions

d. Avoid using plastic and polythene for initiating (lighting) firewood stoves

e. When cooking inside the house, always ensure adequate ventilation by opening windows and doors as much as possible. Pay significant attention to ensuring adequate ventilation specially when cooking using firewood and kerosene as fuel.

f. It is advisable to cook outdoors or in a kitchen away from the main house when using firewood or kerosene. Having a chimney in the kitchen too will limit indoor air pollutants from reaching the breathing zones of householders.

g. Improved firewood cook stoves are recommended than the normal firewood cook stoves.

h. Avoid open burning of wastes of all kinds

i. Excessive watering of indoor plants is not recommended

j. Recommend immediate proper waste disposal methods

k. Recommend minimizing indoor surfaces that has the potential of accumulating pollutants

l. Discourage rearing pets in living areas

ANNEXURE I

Health Impacts due to Indoor Air Pollution

Acute lower respiratory infections

There is substantial evidence that exposure to particulate matter in the home increases the risk of Acute Lower Respiratory Infections (ALRI) in young children, particularly pneumonia. Household air pollution causes more than half of all deaths from pneumonia in children under five years of age.

Chronic lung disease

Household air pollution is an important risk factor as a most specific case of lung diseases in the non-smoking population. Chronic Obstructive Pulmonary Disease (COPD) is a progressive and incompletely reversible airflow obstruction. Household air pollution exposure is an important risk factor for COPD and possibly the most important cause of COPD in non-smoking populations.

Lung cancer

Smoke emitted from combustion sources contain cancer-causing chemicals. (i.e., chemical substances known to increase the risk of cancer). Exposure to such chemicals including particulate matter, is known to increase the risk of lung cancer.

Heart disease and stroke

Fine particles (particulate matter having less than 2.5 microns; $PM_{2.5}$) can penetrate deep into the lungs and enter the bloodstream. Exposure to particulate matter strongly relates to increasing the risk of cardiovascular diseases and strokes significantly.

Cataracts

Cataract is the leading cause of blindness in adults in developing countries. Household air pollution is linked to the formation of cataracts.

Other adverse health outcomes

It has been shown that exposure to poor indoor air quality increases infections, tuberculosis, nasopharyngeal and laryngeal cancers, impairing immune response, low birth weight and stillbirths.

Sick building syndrome

Sick Building Syndrome (SBS) can happen with poor indoor air quality. A terminology (i.e., SBS) associated with indoor air quality which is common with public buildings where occupants will get common discomforts that exist while they are in the building and fade away when they leave the premises. SBS is associated with off-gassing from building materials and emissions from stationery and office equipment. Economically, health complications are not only costly but also lead to loss of productivity.

INDOOR AIR QUALITY STUDIES ASSESS THE IMPACT ON HUMAN HEALTH FROM THE YEAR 1997 TO THE YEAR 2022

(The studies assessing the health outcomes and the studies include only the indoor exposure assessments)

Table 3

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
C.S.Chan, et al. (2018) Evaluation of hazardous airborne carbonyls in five urban roadside dwellings: A comprehensive indoor air assessment in Sri Lanka	Cross Sectional households = 5	Airborne carbonyls	Not assessed	Monitored in 5 households Average Formaldehide = 4.9 ± 1.6$\mu g/m^3$ Average Acetaldehyde = 3.5 ± 0.7$\mu g/m^3$ Average Acetone = 1.2 $\mu g/m^3$	No relevant	Only in the city of Colombo Limited number of households
Pathirathna. M., et al. (2017) Effects of Prenatal Tobacco and Wood-Fuel Smoke Exposure on Birth Weight in Sri Lanka.	Pregnant women = 76, Cohort study	Carbon Monoxide	Birth Weight	Women exposed to second-hand tobacco smoke daily had a significantly lower mean gestational age at delivery (mean ± Standard Error [SE]: 38.0 ± 0.5 weeks) than women who were exposed to second-hand tobacco smoke only once a week (mean ± SE: 39.3 ± 0.3 weeks) ($p < 0.05$). Women who were exposed to tobacco smoke every day delivered neonates with significantly lower mean birth weight (mean ± SE: 2703 ± 135 g) than women who were only exposed once a week (mean ± SE: 3125 ± 147 g) ($p < 0.05$).	No	Small sample size limited the possibility of multiple regression
Ranathunga N., et al. (2019) Effect of household air pollution due to solid fuel combustion on childhood respiratory diseases in a semi-urban population in Sri Lanka	Children under 5 years of age = 262 (air quality levels measured in 115 households) Prospective study	Carbon Monoxide particulate matter 2.5 ($PM_{2.5}$)	Respiratory symptoms and diseases	The incidence of infection induced asthma (RR=1.77, 95%CI;1.098–2.949) was significantly higher among children resident in households using biomass fuel and kerosene (considered as the high exposure group) as compared to children resident in households using Liquefied Petroleum Gas (LPG) or electricity for cooking (considered as the low exposure group), after adjusting for confounders.	Yes	

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
				Maternal education was significantly associated with the incidence of infection induced asthma after controlling for other factors including exposure status. The incidence of asthma among male children was significantly higher than in female children (RR=1.17; 95% CI 1.01–1.37). Having an industry causing air pollution near the home and cooking inside the living area were significant risk factors of rhinitis (RR=1.39 and 2.67, respectively) while spending less time on cooking was a protective factor (RR=0.81). Houses which used biomass fuel had significantly higher concentrations of carbon monoxide (CO) (mean 2.77 ppm vs 1.44 ppm) and particulate matter2.5 ($PM_{2.5}$) (mean 1.09 mg/m^3 vs 0.30 mg/m^3) as compared to houses using LPG or electricity for cooking.		
Ranathunga N., et al. (2021) Effects of indoor air pollution due to solid fuel combustion on physical growth of children under 5 in Sri Lanka: A descriptive cross sectional study	Children under 5 years of age = 262 (air quality levels measured in 115 households) Prospective study	Carbon Monoxide particulate matter 2.5 ($PM_{2.5}$)	Yes	The prevalence of underweight was significantly higher among children in the high exposure group; 20.4% vs 8.2% (p = 0.007). The prevalence of stunting and wasting was higher in the high exposure group as compared to the low exposure group, but the differences were not statistically significant. The mean z-scores of the high exposure group were significantly lower compared to the low exposure group for all three growth parameters; weight-for-age (-1.132 vs. -0.432; p<0.001), height-for-age (-0.63 vs. 0.008; p = 0.001) and weight-for-height (-0.998 vs. -0.636; p = 0.032) Even after adjusting for confounders, high exposure status was a significant predictor of lower mean z-scores in all three anthropometric indices, weight-for-age (p = 0.001), height-for-age (p = 0.004) and weight-for-height (p = 0.04); height-for-age and weight-for-age mean z-scores were less by 0.5 and weight-	Yes	We were able to measure air quality levels in only a subsample of households due to limited resources which is a limitation of our study. Further, we were unable to measure outdoor air pollution levels that may have had an effect on indoor air pollution levels. As the study population was under 5 children who generally stay indoors most of the time during the day, we assumed that exposure to outdoor air pollution will have a minimal effect. All children were from the same geographic area and would likely have been exposed to the same levels of outdoor pollution. We measured air pollution levels over a two-hour period during the preparation of the lunch meal, the main meal that is cooked in

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
				for-height mean z-score by 0.3 in the high exposure group as compared to the low exposure group after adjusting for other variables. Minute to minute data were recorded and the average value of 120 data points (2-hour continuous monitoring) were analyzed. There were significant differences in the concentrations of carbon monoxide ($p<0.001$) and the $PM_{2.5}$ ($p<0.001$) levels between the two groups; the high exposure houses had significantly higher concentrations (as much as 2–3 times more) of pollutants as compared to the low exposure group.		most households. Based on the construction of houses and air circulation within houses it is possible that air pollution levels may have been higher in areas other than in the kitchen where children may have been and beyond the time after we stopped monitoring pollutant levels. We acknowledge this as a limitation and it is likely that it may have affected our results. We were only able to measure CO, CO_2 and $PM_{2.5}$.; this limited our ability to assess interactions with other pollutants.
Ranathunga N., et al. (2022) Effects of Indoor Air Pollution on the Development of Children under Five Years of Age in Sri Lanka	Children under 5 years of age = 262 (air quality levels measured in 115 households) Prospective study	Carbon Monoxide particulate matter 2.5 ($PM_{2.5}$)	Yes	The odds of a child being classified as a "suspect" in the language development domain was significantly higher in children in the high exposure group (a OR = 2.162; 95% CI: 1.185–3.941) as compared to children in the low exposure group, after adjusting for confounding variables. Children under three years (a OR = 0.475; 95% CI: 0.271–0.835) were significantly less likely to be classified as a "suspect" as compared to children >three years in the language domain after controlling for other variables. The odds of a child being classified as "suspect" in the social behavior and play domain was significantly higher in children in the high exposure group (a OR = 1.773; 95% CI: 1.022–3.077) as compared to children in the low exposure group. In the gross motor development domain, a child being identified as "suspect" was significantly higher in children in the high exposure group (a OR = 2.102; 95% CI: 1.046–4.225) after adjusting for the other variables	Yes	The main limitation of this study is that we could not assess some contributing factors such as nutrition in this cohort of children as it may significantly vary even during the course of a week. More studies with larger samples are needed to confirm our findings.

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
Nandasena, et al. (2017) Cooking fuel used at home during pregnancy and birth outcomes among females in Kalutara, Sri Lanka	Pregnant women in the third trimester (n = 475)	Proxy measures only.	Yes	Birth weight of babies born to mothers of households using a clean primary cooking fuel (n=159) was significantly higher than the birth weight of babies born to mothers of households using an unclean primary cooking fuel (n=287) (3.05+0.43 kg vs. 2.97+0.41 kg; p=0.05). Although prematurity was less among mothers in households using a clean primary cooking fuel (3.6%) as compared to mothers of households using an unclean primary cooking fuel (4.9%), the difference in the percentages were not statistically significant. The derived "Cooking fuel score" correlated with the birth weight of singleton babies (p = 0.03).		
Nandasena, et al., (2017) Concentrations of particulate matter fractions and kitchen characteristics among solid fuel and LPG using households in Sri Lanka	426 households	PM$_1$, PM$_{2.5}$, respirable PM, PM$_{10}$, total PM	Exposure study	The predominant cooking fuel (i.e., cooking fuel used > 75% of the time) used in 245 (57.5%) households was LPG while 116 (27.2%) households used wood. Air quality monitoring was done in 322 households; 138 (42.9%) households used a single cooking fuel to prepare the main meal during monitoring (wood - n=68 (49.3%); LPG - n=69 (50.3%) and Kerosene - n=1 (0.7%)). PM$_{2.5}$ concentrations in the kitchen, the bedroom, the living room and in the immediate outdoors of households using only wood and cooking inside a permanent kitchen were 323 µg/m^3 (Inter Quartile Range (IQR): 161 – 529 µg/m^3), 76.0 µg/m^3 (IQR: 54.3- 129 µg/m^3); 70.0 µg/m^3 (IQR: 54.0- 124 µg/m^3) and 124 µg/m^3 (IQR: 58.0- 210 µg/m^3), respectively. PM$_{2.5}$ concentrations in the kitchen of households using only LPG and cooking inside a permanent kitchen were 93.3 µg/m^3 (IQR: 36.0 – 77.0 µg/m^3). The immediate outdoor PM$_{2.5}$concentrations in households using wood were higher in households having a chimney (n=23)		

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
				as compared to those not having a chimney (n=5) ((126 μg/m^3 (IQR = 76 – 210 μg/m^3) vs. 46 μg/m^3 (IQR = 32 – 509 μg/m^3).		
Hetiarachchi et al., (2017) Passenger exposure to fine particulate and black carbon in city of Colombo	12 bus routes include 150 km over 800 minutes in the city of Colombo	PM and BC	Exposure study	Median personal exposure of BC concentration was 13.58 μg/m^3 (inter quartile range = 10.39 – 17.18 μg/m^3). Median personal exposure of $PM_{2.5}$ was 108.39 μg/m^3 (inter quartile range = 92.54 – 176.42 μg/m^3). Speed of the bus is not associated with the total $PM_{2.5}$ concentration (Spearman's rho = 0.444). Median personal $PM_{2.5}$ exposure concentration was higher than the WHO recommended value for 24 hours. Over 12% of $PM_{2.5}$ proportion was BC.	Not relevant	Only in the city of Colombo
Perera, et al. (2017) TVOC measurements and GCMS spectrums at selected polluted environments in Sri Lanka	Realtime TVOC measurements in 11 sites. Ten minutes measurements were carried out in wood using cook stove area; LPG using cook stove area; petroleum station; vehicle spray paint area; tobacco smoking area; incent sticks burning area; outdoor polythine/ and other garbage burning area; vehicle service area; mosquito coil burning area; kerosene using cook stove area and kerosene lamp burning area.			The highest TVOC was observed at the petroleum station; vehicle spray paint area; kerosene using cook stove area.		Limited duration and a limited number of sites.
Kaushalya et al, (2017) Toxic gas emission and dispersion within the Meethotamulla Municipal solid waste disposal site	Concentrations of Oxygen (O_2), CO, CH_4, VOC, and H2S at fourteen different locations of the Meethotamulla municipal solid waste disposal site were measured at the surface level,			Concentrations of Carbon Monoxide (CO) and Methane (CH_4) gases have randomly varied from 1 ppm - 500 ppm and 0.05% - above 5% respectively over the four measurement sessions. The highest concentrations of the gases have been recorded at the level of 1 foot below the surface while showing comparatively low values		

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
	1m above the surface level and 1 foot below the surface level using GasAleartMicro5 PID multi gas analyser. The measurements were repeated Proceedings of Seventh National Symposium on Air Quality Management in Sri Lanka 44 | Organized by Ministry of Mahaweli Development & Environment for four sessions.			at the surface level and 1m above the surface. The measurement of Methane (CH_4) levels at 1 ft below the surface level at some locations fall within its explosive limits with a risk mainly a fire hazard under dry weather conditions.		
Nandasena et al, (2016). Do household cooking fuel type affect the low birth weight in Sri Lanka?	A case-control study (1 case: 2 controls) conducted in Kalutara MOH area. Cases were term babies <2.5 kg and controls were term babies ≥2.5kg. There were 64 LBW and 122 normal birth weight term babies.	Proxy measures only.	Yes	Compared to the mothers with normal birth weight babies, higher proportion of mothers with LBW babies had low income level (49.6% vs. 55.6%, OR = 1.3 (0.7 - 2.4), had exposure to high household air pollution due to cooking fuel (30.1% vs. 42.9%, OR = 1.7 (0.9-3.3), had low hemoglobin levels at booking visit (28.9% vs. 35.9%, OR = 1.4 (0.7- 2.6), had Body Mass Index less than 18.5 (15.6% vs. 25.0%, OR = 1.8 (0.8 - 3.8), had not received micronutrient supplement at pre-pregnancy period (20.3% vs. 24.6%, OR =1.6 (0.7 - 3.4).	Yes	Only a proxy measurement. Confined to Kalutara MOH area. Small sample size.
Chartier et al. (2016). A comparative study of human exposures to household air pollution from commonly used cookstoves in Sri Lanka.	A purposive sample of 53 households was selected from a rural community in Kandy, Sri Lanka based on the stove type (stove type - traditional or Anagi) and ventilation (chimney - present or absent). At each household, 48-h continuous real-time measurements of indoor kitchen $PM_{2.5}$	$PM_{2.5}$	Yes	The median 48-h indoor $PM_{2.5}$ concentration for households using Anagi stoves for cooking and having a chimney was 64 µg/m^3 and households using Anagi stoves for cooking and not having a chimney was 181 µg/m^3. The median 48-h indoor $PM_{2.5}$ concentration for households use traditional stoves for cooking and having a chimney was 70 µg/m^3 and for households use traditional stoves for cooking and not having a chimney was 371 µg/m^3 . Overall, measured indoor $PM_{2.5}$ concentrations ranged from a minimum of 33 µg/m^3 to a maximum of		Confined to a rural cite in Kandy.

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
	and personal (primary cook) $PM_{2.5}$ concentrations were measured using the RTI MicroPEM personal exposure monitors.			940 µg/m^3 , while personal exposure concentrations ranged from 34 to 522 µg/m^3. Linear mixed effects modeling of the dependence of indoor concentrations on stove type and presence or absence of chimney showed a significant chimney effect (65% reduction; $P < 0.001$) and an almost significant stove effect (24% reduction; $P = 0.054$).		
Ranasinghe MH, et al. (2004) Risk of Cataract Formation with Exposure to Biomass Smoke, National Eye Hospital, Colombo 2004	Patients with cataracts (n = 197) and controls (n = 190)	No specific type	Cataract	Cataracts significantly associated with biomass exposure	No	No measurement of exposure
Perera MAKKP et al. (2004) Investigation of Lung Cancer to Human Activities in Sri Lanka, National Cancer Hospital 2004	Lung cancer patients (n = 128) and controls (n = 128)	No specific type	Lung cancer	No significant association with biomass exposure	No	No measurement of exposure
Pathirana SM, et al. (2006) Low Birth Weights of Infants and Exposure to Smoke from Biomass Fuel during Pregnancy. Kegalle and Kalutara districts. 2004	New borns (n = 369)	No specific types	Low birth weight	Low birth weight was associated with fuel type and kitchen characteristics	No	No measurement of exposure
Lankathilaka KN at el. (2000) Indoor air quality and respiratory symptoms among children and women, Kotte Medical Officer of Health area. 1999	Households = 397 children = 604 women = 130	Respirable dust	Respiratory symptoms	Respiratory symptoms were significantly higher in houses using firewood	Yes	Only respirable dust levels were measured

Reference, Study Location and data collection period	Study Design Subject Characteristics and sample size	Exposure air pollutants	Health outcomes	Results	Adjustment for confounding factors	Limitations
Karunasekara KAW et al. (2005) Genetic and environmental risk for asthma in children aged 5-11 year, Gampaha District 1998	Children, 5-11 years, asthmatics (n = 441); non asthmatics (n = 1510)	No specific types are measured	Asthma	Prevalence of asthma was significantly higher in the presence of firewood smoke	Yes	No measurement of exposure
Karunasekara KAW et al. (2001) Risk factors of childhood asthma: a Sri Lanka Study, Colombo North Teaching Hospital 1996-1997	Children 1-10 years, age matched cases and controls (n = 300)	No specific type	Asthma	Dust at home was a significant risk factor for asthma	Yes	No measurement of exposure

ANNEXURE II

Indoor Air Quality Monitoring Procedures

Being complex due to the presence of different pollutant at different levels and complexity due to the non-homogeneity with different micro environments with different sources, monitoring of indoor air quality is a complicated (tedious) process. It requires a stronger understanding of the type of pollutants, emission rates (released quantities), pollutant occurrence frequencies and durations (how often and how long), air exchange rates (how fast the air volume is replaced), the volume of the indoor, number of occupants and the activity pattern of the indoor dwellers.

Since, health implications due to the indoor pollutants vary with the phase and particulate distribution etc. Collection of representative samples is very complex and need high experience, qualified personals for the sampling and analysis. The number of samples, sampling frequency, sampling location and duration of sampling are few of the critical parameters which need to be decided based on the severity of the indoor settings.

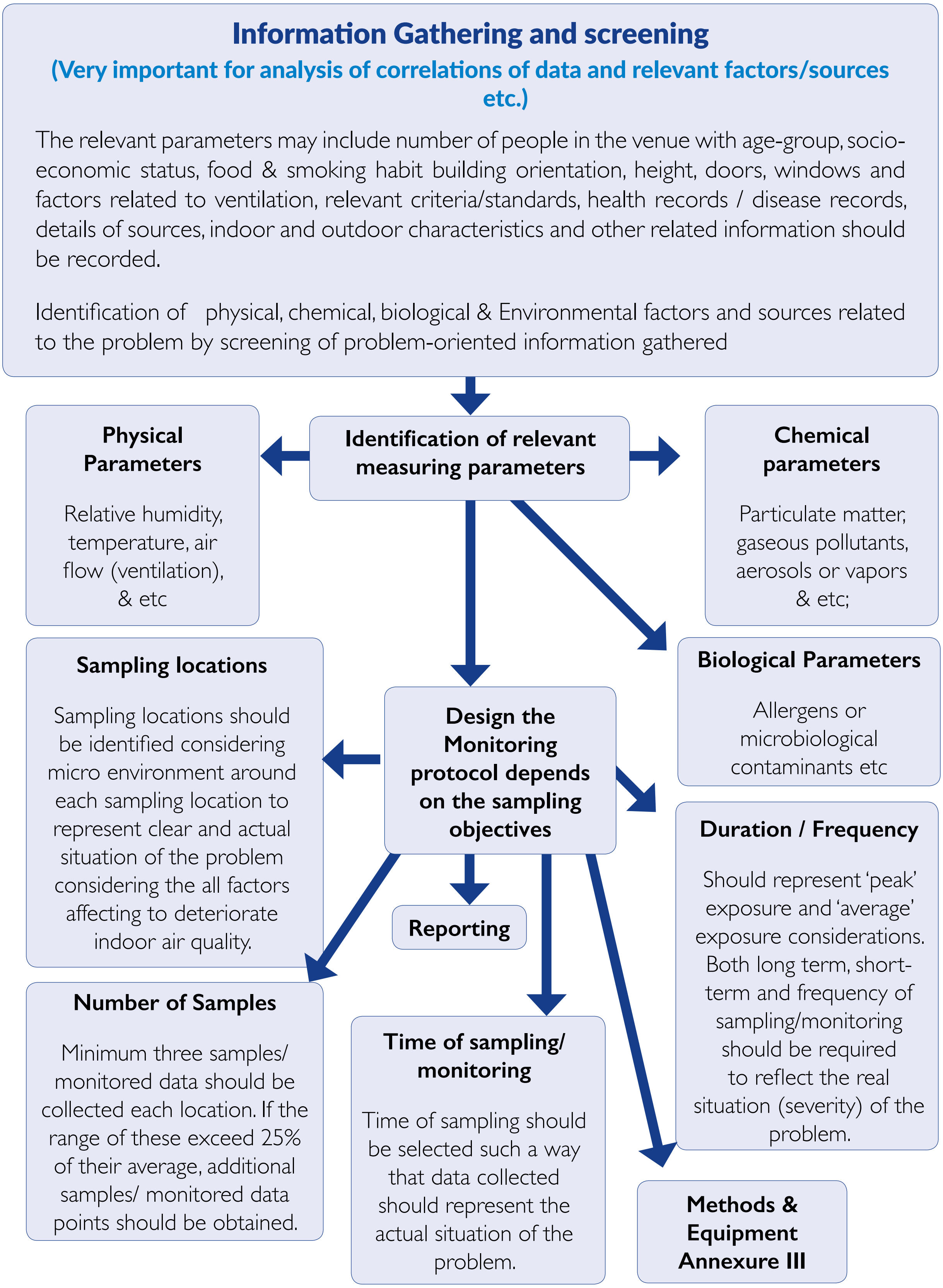
Reliability of sampling and analysis of indoor air quality solely depend on collecting a representative sample. Sampling can be simplified by gathering surrounding information which include people, activities, habits and related environmental characteristics. In addition, physical parameters such as temperature, pressure, and humidity and air exchange rates need to be monitored closely.

The monitoring method and all other data collection is therefore needed to select based on the objective of the monitoring.

BASIC CONSIDERATIONS OF MONITORING PROCEDURE.

Preliminary investigation

(Planning representative sampling with understanding the real situation)



Information Gathering and screening

(Very important for analysis of correlations of data and relevant factors/sources etc.)

The relevant parameters may include number of people in the venue with age-group, socio-economic status, food & smoking habit building orientation, height, doors, windows and factors related to ventilation, relevant criteria/standards, health records / disease records, details of sources, indoor and outdoor characteristics and other related information should be recorded.

Identification of physical, chemical, biological & Environmental factors and sources related to the problem by screening of problem-oriented information gathered

Identification of relevant measuring parameters

Physical Parameters

Relative humidity, temperature, air flow (ventilation), & etc

Chemical parameters

Particulate matter, gaseous pollutants, aerosols or vapors & etc;

Biological Parameters

Allergens or microbiological contaminants etc

Design the Monitoring protocol depends on the sampling objectives

Sampling locations

Sampling locations should be identified considering micro environment around each sampling location to represent clear and actual situation of the problem considering the all factors affecting to deteriorate indoor air quality.

Duration / Frequency

Should represent 'peak' exposure and 'average' exposure considerations. Both long term, short-term and frequency of sampling/monitoring should be required to reflect the real situation (severity) of the problem.

Reporting

Number of Samples

Minimum three samples/ monitored data should be collected each location. If the range of these exceed 25% of their average, additional samples/ monitored data points should be obtained.

Time of sampling/ monitoring

Time of sampling should be selected such a way that data collected should represent the actual situation of the problem.

Methods & Equipment Annexure III

ANNEXURE III

Methods and Equipment

For each of the relevant variables, separate sampling/monitoring instructions accompany the analytical protocol. The preparation of sampling/monitoring instructions must ensure that the finally selected sampling/monitoring and analytical method meet the objectives of investigations. Methods laid down in internationally accepted NIOSH and OSHA or any other methods recommended by relevant authority can be applied for the measurements. Table 3 (given below) describes a few common sampling/monitoring and analytical methods for measurement and analysis of the ambient indoor air pollutants and corresponding exposure factors. The sampling/monitoring instruments must be calibrated against a secondary standard prior to and immediately following sampling/monitoring. Besides, the instruments should be regularly checked for its calibration against primary standards.

Table 4 Guidance for measurement instrumentation

Parameter		Sampling/Monitoring procedure/instrument
Pollutants/ contaminants	PM_{10}, $PM_{2.5}$ and $PM_{1.0}$	Gravimetric/light-scattering/ beta attenuation based instruments
	CO	Non Dispersive Infra- Red (NDIR) spectroscopy
	NOx	Saltzman method or equivalent method or hemiluminescence method
	VOC	Dual section, charcoal tube, polymer absorber based samplers followed by GC
Comfort parameters	Temperature	Thermometer,
	RH	Humidity gauge, Psychomotor,

ANNEXURE IV

Additional information on guideline values and parameters

Table 5. Comparison of recommended Guideline values for residential, WHO AQ guideline, and SL Ambient AQ standards.

Pollutant	Recommended Value for IAQ Guideline for Sri Lanka[1]	WHO AQ Guideline	Average Time	SL Ambient AQ Standards
$PM_{2.5}$ (µg/m^3)	75	25	24 hr	50
	100	-	8 hr	-
PM_{10} (µg/m^3)	150	50	24 hr	100
	200	-	8 hr	-
CO (mg/m^3)	7	7	24 hr	-
	10	-	8 hr	-
NO_2 (µg/m^3)	200	200	1hr	250
TVOC (mg/m^3)	1	-	8hr	-

Table 6. Comparison of recommended Guideline values for office and public places, WHO AQ guideline, and SL Ambient AQ standards.

Pollutant	Proposed IAQ Guideline for Sri Lanka[3]	WHO AQ Guideline	Average Time	SL Ambient AQ Standards (Annual)
$PM_{2.5}$ (µg/m^3)	50	25	24 hr	50
PM_{10} (µg/m^3)	100	50	24 hr	100
	200	-	8 hr	-
CO (µg/m^3)	10	10	8hr	10,000
NO_2 (µg/m^3)	200	200	1hr	250
TVOC (mg/m^3)	1	-	8hr	-

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1. This is an interim target based on the WHO guidelines
2. Assessment of Exposure to Indoor Air Pollutants, WHO Regional Publications, European Series, No. 78, 1997
3. This is an interim target based on the WHO guidelines

4 Assessment of Exposure to Indoor Air Pollutants, WHO Regional Publications, European Series, No. 78, 1997

$PM_{2.5}$ and PM_{10}

The interim targets as recommended by WHO for $PM_{2.5}$ and PM_{10} is given in the table below. This IAQ guideline has adopted Interim target 1 (IT-1) from the available data from studies carried out in the country.

Table 7. WHO air quality guidelines and interim targets for particulate matter: 24-hour concentrations'

	PM_{10}(µg/m^3)	PM_{25}(µg/m^3)	Basis for the selected level
Interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over the AQG value).
Interim target-2 (IT-2)	100	50	Based on published risk coefficients from multi-centre studies and meta-analyses (about 2.5% increase of short-term mortality over the AQG value).
Interim target-3 (IT-3)*	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over the AQG value).
Air quality guideline (AQG)	50	25	Based on relationship between 24-hours and annual PM levels.

[a]99th percentile (3 days/year).

*For management purposes. Based on annual average guideline values; precise number to be determines on basis of local frequency distribution of daily means. The frequency distribution of daily $PM_{2.5}$ or PM_{10} values usually approximates to a log-normal distribution.

The interim target for households: Interim target -1 (IT-1) is proposed for $PM_{2.5}$ and PM_{10} due to lack of sufficient research data and to provide a less stringent target to launch the standard as most households rely on ambient air for air changes. For households, the recommended target level is WHO standard for annual targets which should be the ultimate target in implementing the standard.

Interim targets for offices: Interim target -2 (IT-2) is proposed for $PM_{2.5}$ and PM_{10} as most offices have a ventilation and air conditioning system that is capable of controlling the PM levels through filtration and controlling the amount of ambient air drawn in for fresh air replacement.

Carbon monoxide (CO)

CO is a colorless, odorless gas produced by the incomplete burning of material containing carbon. CO poisoning can cause brain damage and death. Common sources of CO are leaking vented combustion appliances, automobile exhaust, parking garages, etc. When not properly ventilated, emitted CO can build up. People exposed to low levels of CO may feel sick with headache and nausea, and will feel better when exposed to fresh air. However, their symptoms will recur shortly after returning to their place if CO is not eliminated.

Poisoning due to low levels of CO can be confused with influenza symptoms, food poisoning, or other illnesses, and can be a long-term health risk if left unattended. Some of the symptoms of low-level CO poisoning are shortness of breath, mild nausea, and mild headaches. Prolonged exposure to high levels of CO can lead to brain damage and even death. Adequate ventilation is an important control measure.

Chronic carbon monoxide exposure is different from acute exposure in several important respects, as noted above. Thus, a separate guideline is needed to address minimal exposure over 24 hours, rather than the 8-hour period used in the acute guidelines. The latest studies available to us in 2009, especially those epidemiological studies using very large databases and thus producing extremely high-resolution findings, suggest that the appropriate level for carbon monoxide in order to minimize health effects must be positioned below the 8-hour guideline of 10.5 mg/m^3, possibly as low as 4.6–5.8 mg/m^3. This is also essential since the minimal exposure time for this guideline is three times longer.

Due to these poisoning of CO, different agencies have given their standards and guideline values depending on the indoor uses. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for CO is 50 parts per million (ppm) as an 8-hour time-weighted average (TWA); the National Institute for Occupational Safety and Health has a Recommended Exposure Limit (REL) of 35 ppm as a 10-hour TWA. According to the American Conference of Governmental Industrial Hygienists (ACGIH), the threshold limit value for CO is 25 ppm as an 8-hour TWA. The WHO given their guideline values as 7 ppm (24 hrs), 10 ppm (8 hrs) and 35 ppm for 1 hours. The American Society of Heating, Refrigerating and Air-Conditioning Engineering (ASHRAE) standard values for buildings is 9 ppm for 8 hours.

Therefore, the recommended guideline value for residential buildings can be as 5000 ppm (8hrs) and 700 ppm + ambient levels can be considered for commercial and institutional buildings.

Interim targets for households, a 24 hr time interval is proposed given that a typical home will be occupied during a 24 hr period.

Interim targets for offices and industries, an 8 hr time interval is proposed as the typical shift is an 8 hr period.

Nitrogen Dioxide (NO_2)

As an air pollutant, nitrogen dioxide (NO_2) has multiple roles, which are often difficult or sometimes impossible to separate from one another: The current WHO guideline value of 40 μg/m^3 (annual mean) was set to protect the public from the health effects of gaseous NO_2. The rationale for this was that because most abatement methods are specific to NO_X, they are not designed to control other co-pollutants, and may even increase their emissions. If, however, NO_2 is monitored as a marker for complex combustion-generated pollution mixtures, a lower annual guideline value should be used (WHO, 2000).

A number of short-term experimental human toxicology studies have reported acute health effects following exposure to 1-hour NO_2 concentrations in excess of 500 μg/m^3.

Although the lowest level of NO_2 exposure to show a direct effect on pulmonary function in asthmatics in more than one laboratory is 560 µg/m^3, studies of bronchial responsiveness among asthmatics suggest an increase in responsiveness at levels upwards from 200 µg/m^3. Since the existing WHO AQG short-term NO_2 guideline value of 200 µg/m^3 (1-hour) has not been challenged by more recent studies, it is retained. In conclusion, the guideline values for NO_2 remain unchanged in comparison to the existing WHO AQG levels, i.e., 40 µg/m^3 for annual mean and 200 µg/m^3 for 1-hour mean.

Interim targets for Households: Given the lack of data for households on NO2, the less stringent 1 hr target under the WHO guideline is recommended in order to launch the national standard. However, the ultimate target should be the annual target recommended by WHO given the typical occupational patterns in Sri Lankan households

Interim targets for Offices: From the data available the annual WHO target is proposed given that most offices have ventilation and air conditioning system that is capable of controlling the amount of ambient air drawn for replacement of fresh air

Carbon dioxide (CO_2)

CO_2 is a colorless, odorless, and tasteless gas which is the product of completed carbon combustion and the by-product of biological respiration. CO_2 is not considered as a pollutant but it can be used as a rough indicator of the effectiveness of ventilation and excessive population density in a structure, CO_2 increases in buildings with higher occupant densities, and is diluted and removed from buildings based on outdoor air ventilation rates. Therefore, examining levels of CO_2 in indoor air can reveal information regarding occupant densities and outdoor air ventilation rates. High CO_2 levels may indicate a problem with overcrowding or inadequate outdoor air ventilation rates.

CO_2, a by-product of normal cell function, is removed from the body via the lungs in the exhaled air. However, adverse health effects from CO_2 may occur since it is an asphyxiate gas. Exposure to high levels of CO_2 can increase the amount of this gas in the blood, which is referred to as hypercapnia or hypercarbia. As the severity of hypercapnia increases, more symptoms ranging from headache to unconsciousness appear, and it can also lead to death. At concentrations above 15,000 ppm, some loss of mental acuity has been noted. The OSHA PEL is 5,000 ppm as an 8-hour TWA. ASHRAE states that CO_2 concentrations in acceptable outdoor air typically range from 300-500 ppm and their recommended values to maintain indoor CO_2 levels at 700 ppm + ambient level.

Total Volatile Organic Compounds (TVOC)

Volatile organic compounds are a large and diverse group of compounds that volatilize into the air at room temperature. The range of compounds described as VOC varies between different studies, and the definition used here is that of a report by the WHO Regional Office for Europe (1) that classes VOC as organic compounds with a boiling point range of 50 -100 °C to 240 -260 °C. VOC constitute an example of indoor air pollutants that are difficult to consider separately as human health hazards, but they have similar effects and considerable effects on health as a mixture. The total VOC (TVOC) concept, which represents a summation of individual VOCs. As a large number of VOC are common in indoor air, any investigation must select those to be identified and quantified. There is no definitive guidance about which VOC should be of the highest priority because of the poor understanding of the significance for the health of the mixtures of chemicals present indoors. Most studies report those that are present at the highest concentrations and perhaps known irritants and carcinogens. It is also common to report the TVOC concentration, although its value depends on the air-sampling method and analytical procedure applied.

Interim targets for households: Households are well below the 8 hr target set by the WHO, however, this 8 hr standard should be replaced by a 24-hour target given the typical occupational pattern in Sri Lankan households.

Interim targets for Offices and Industries: According to the available data, in most of the sites exceed WHO recommendation. Hence, in order to launch the standard 8-hour target set by the WHO is recommended.

Temperature

Temperature is one of the basic IAQ measurements that has a direct impact on perceived comfort. According to ASHRAE Standard 55, the recommended temperature ranges perceived as "comfortable" are 73 to 79°F (22.8 to 26.1°C) in the summer and 68 to 74.5°F (20.0 to 23.6°C) in the winter.

Humidity

Temperature and humidity together to provide a measure of thermal comfort. Too little humidity in a space may create static build-up and people will sense that their skin feels dry. Too much humidity and people will think it feels “sticky.” According to ASHRAE Standard 55, indoor humidity levels should be maintained between 30 percent and 65 percent for optimum comfort.

Air exchange

The introduction of fresh air helps dilute unwanted pollutants and gets them out of the building faster. ASHRAE Standard 62 presents recommendations pertaining to ventilation, or the amount of fresh air introduced into a given area. It recommends a minimum volume per person over time, depending on the type of space and activity being performed, expressed in cubic feet per minute per person.

ANNEXURE V

Standards and Guidelines for Common Indoor Contaminants developed by other countries and agencies

This section summarizes standards and guidelines for a number of contaminants commonly found indoors, which can be used as acceptable indoor air quality levels. Description of sources the standards and guidelines featured in Table are described below.

1 NAAQS/EPA

The National Ambient Air Quality Standards (NAAQS) were developed by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act (last amended in 1990). These enforceable standards were developed for outdoor air quality, but they are also applicable for indoor air contaminant levels.

2 OSHA

The U.S. Occupational Health and Safety Administration (OSHA) developed enforceable maximum exposures for industrial environments. The standards were developed through a formal rule-making process. The Permissible Exposure Limits (PELs) given in Table below are designed to protect the industrial workers, but do not take into account the possible reactions of sensitive individuals

3 NIOSH

National Institute for Occupational Safety and Health (NIOSH) in USA published guidelines in a set of criteria documents, which contain a review of relevant literature and Recommended Exposure Limits (RELs) for industrial environments.These recommendations are not reviewed regularly, and in some cases, levels are set for health reasons because commonly available industrial hygiene practices do not reliably detect substances at lower levels.

4 MAK

MAK levels were developed in Germany by Deutsche Forschungs Gemeinschaft (DFG), an institution similar to the U.S. National Institutes of Health and the U.S. National Institute for Occupational Safety and Health (NIOSH). These levels are set on a regular basis and receive annual reviews. The limits are enforceable in Germany, and are set for the general population

5 Health Canada

Health Canada has published Residential Indoor Air Quality Guidelines in 2006. The recommended exposure limits of the Residential Indoor Air Quality Guidelines refer to a short-term exposure limits (usually one hour) and a long-term exposure limit (usually 24 hours).

6 WHO/Europe

The World Health Organization's (WHO) Office for Europe, based in Denmark, developed guidelines to be used in non-industrial settings. These guidelines were developed in 1987 and updated in 2000. They are guidelines rather than an enforceable standard intended for application to both indoor and outdoor exposures.

Table 8

Year	Description
2014	WHO guidelines for indoor air quality: household fuel combustion Build on existing WHO air quality guidelines (AQGs) for specific pollutants considering emission rate targets, Community-wide use of clean fuels and household energy technologies and the need to avoid the use of unprocessed coal as a household fuel (The need to avoid the use of kerosene as a household fuel)
2010	WHO guidelines for indoor air quality: (selected pollutants, Number of chemicals commonly present in indoor air). Benzene, Carbon monoxide, Formaldehyde, Naphthalene, Nitrogen dioxide, Particulate matter ($PM_{2.5}$ and PM_{10}), Polycyclic aromatic hydrocarbons, especially benzo-[a]-pyrene, Radon, trichloroethylene, Tetrachloroethylene
2009	WHO guidelines for indoor air quality: Dampness and mold Focused on dampness, associated microbial growth and contamination of indoor spaces
2006	WHO Air quality guidelines Global update 2005 Focused on particulate matter (PM_{10}, $PM_{2.5}$), ozone, nitrogen dioxide and sulfur dioxide
2000	WHO Air quality guidelines for Europe (Second edition) This second edition focused on the pollutants considered in the first edition. Provided a section on indoor air pollutants and added man-made vitreous fibers to radon and tobacco smoke
1987	WHO Air quality guidelines for Europe Containing health risk assessments of 28 chemical air contaminants

7 ANSI/ASHRAE

America National Standards (ANS) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) developed godliness applies to all spaces intended for human occupancy except those within single-family houses, multifamily structures of three stories or fewer above grade, vehicles, and aircraft. This standard defines requirements for ventilation and air-cleaning system design, installation, commissioning, and operation and maintenance. Additional requirements for laboratory, industrial, health care, and other spaces may be dictated by workplace and other standards, as well as by the processes occurring within the space. Although the standard may be applied to both new and existing buildings, the provisions of this standard are not intended to be applied retroactively when the standard is used as a mandatory regulation or code. This standard does not prescribe specific ventilation rate requirements for spaces that contain smoking or that do not meet the requirements in the standard for separation from spaces that contain smoking

8 ACGIH

The American Council of Governmental Industrial Hygienists (ACGIH)recommends Threshold Limit Values (TLV) as maximum exposures for industrial environments. The TLVs are set by committee, who review the existing scientific literature and recommend a guideline concentration. The recommendations are applicable for normal industrial working conditions (i.e., 40 hours a week), and for single contaminant exposure. These recommendations are guidelines, rather than enforceable standards, and are not selected to protect the most sensitive workers.

9 COSHR

The Canadian Occupational Safety and Health Regulations (COSHR) establish requirements for maintaining a healthy and safe working environment, and form part of the Canadian Labour Code (HRSDC, 2005). Within the context of indoor air quality, COSHR requires that indoor contaminant concentrations be kept within the limits set by the ACGIH.

10 Hong Kong

The Government of the Hong Kong Special Administrative Region established two levels of IAQ guideline values (8-hour average) that can be used to certify the indoor air quality of offices and public places. The guideline values were set for 6 individual chemicals, TVOC, PM10, airborne bacteria for Excellent Class and for Good Class IAQ (Hong Kong, 2003).

11 IRK & AOLG German

Between 1996 and 2004, an ad hoc working group of members of the Federal Environmental Agency's Indoor Air Hygiene Commission (IRK) and the Working Group of the Health Ministries of the Länder (AOLG) of Germany established indoor air quality guideline values for 11 individual substances and TVOC for non-industrial settings including residences, offices, and schools. The guidelines consist of two levels: Guide Value II (RW II) and Guide Value I (RW I). Guide Value II (RW II) is based on current toxicological and epidemiological knowledge of a substance. It is the concentration of a substance that, if reached or exceeded, requires immediate action as this concentration could pose a health hazard, especially for sensitive people who reside in these spaces over long periods of time. Guide Value I (RW I) is the concentration of a substance in indoor air for which, when considered individually, there is no evidence at present that even life-long exposure is expected to bear any adverse health impacts. Values exceeding this are associated with a higher-than-average exposure that is undesirable for health reasons.

12 UBA German

The German Environment Agency (UBA) published "Guidelines for the prevention, examination, evaluation, and remediation of mould infestation in indoor spaces" which was amplified by the Indoor Air Hygiene Commission in 2002 and "Guidelines on cause search and remediation of mould infestation in indoor spaces" in 2005. For the first time, these documents enabled the establishment of uniform nationwide recommendations for the search causes, detection, assessment and remediation of indoor mould infestation. There broadly described on mould, mould infestation and mould fungi, effects of indoor mould on human health, causes of mould infestation in buildings, preventative measures against mould infestation, recognize, detect and assess mould.

13 MOEST Nepal

Ministry of Environment, Science and Technology (MOEST), Nepal National Indoor Air Quality Standards and Implementation Guidelines

Table 9

Unless otherwise specified, values are given in parts per million(ppm)

Number in brackets [ ] refers to either a ceiling or to averaging times of less than or greater than eight hours (min-minutes; hr=hours; yr=year; C=ceiling; L=long term. Where no time is specified, the averaging time is eight hours.

	NAAQS/EPA (2000)	OSHA	MAK (2000)	Canadian (1995)	WHO/Europ (2000)	NIOSH (1992)	ACGIH (2001)	COSHR	Hong Kong (2003)	German
Carbon dioxide		5,000	5,000 10,000[1 hr]	3,500 [L]		5,000 30,000 [15 min]	5,000 30,000 [15 min]	Refers reader to ACGIH recommendations	800/1000 [8 hr]	
Carbon monoxide	9 35 [1hr]	50	30 60 [30 min]	11 [8 hr] 25 [1 hr]	90 [15 min] 50 [30min] 25 [1 hr] 10 [8 hr]	35 200 [C]	25		1.7/8.7 [8 hr]	52/5.2 [0.5 h] 13/1.3 [8 h]
Formaldehyde		0.75 2 [15 min]	0.3 1.0	0.1 [L] 0.05 [L]	0.081 (0.1 mg/m^3) [30 min]	0.016 0.1 [15 min]	0.3 [C]		0.024/0.081 [8 hr]	
Lead	1.5 µg/m^3 [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 µg/m^3 [1 yr]	0.1 mg/m^3 [10 hr]	0.05 mg/m^3			
Nitrogen dioxide	0.05 [1 yr]	5 [C]	5 10 [5 min]	0.05 0.25 [1 hr]	0.1 [1 hr] 0.004 [1 yr]	1.0 [15 min]	3 5 [15 min]		0.021/0.08 [8 hr]	0.19 [0.5 h] 0.03 [1 wk]
Ozone	0.12 [1 hr] 0.08	0.1	Carcinogen – no maximum value established	0.12 [1 hr]	0.064 (120 µg/m^3) [8 hr]	0.1 [C]	0.05 – heavy work 0.08 – moderate work 0.1 – light work 0.2 – any work [2 hr]		0.025/0.061 [8 hr]	
Particles <2.5 µm MMAD	15 µg/m^3 [1 yr] 65 µg/m^3 [24 hr]	5 mg/m^3	1.5 mg/m^3 For < 4 µg	0.1 mg/m^3 [1 hr] 0.04 mg/m^3 [L]			3 mg/m^3		0.02/0.18 mg/m^3 [8 hr]	
Particles <10 µm MMAD	50 µg/m^3 [1 yr] 150 µg/m^3 [24 hr]		4 mg/m^3				10 mg/m^3			
Radon	4 pCi/L [1 yr]				2.7 pCi/L [1 yr]				4.1/5.4 pCi/L [8 hr]	
Sulfur dioxide	0.03 [1 yr] 0.14 [24 hr]	5	0.5 1.0	0.38 [5 min] 0.019	0.048 [24 hr] 0.012 [1 yr]	2 5 [15 min]	2 5 [15 min]			
Total particles		15 µg/m^3								

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12 ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
ALRI	Acute Lower Respiratory Infections
AQ	Air Quality
AQG	Air Quality Guideline
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineering
CI	Confidence Interval
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
IAQ	Indoor Air Quality
IR	Infra-Red
LPG	Liquefied Petroleum Gas
MOE	Ministry of Environment
NDIR	Non-Dispersive Infra- Red
NIOSH	National Institute of Occupational Safety and Health
NO2	Nitrogen Dioxide
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PM	Particular Matter
PPM	Parts Per Million
RH	Relative Humidity
RR	Rate Ratio
SBS	Sick Building Syndrome
SE	Standard Error
SL	Sri Lanka
TVOC	Total Volatile Organic Compounds
TWA	Time-Weighted Average
USEPA	United State Environmental Protection Agency
UV	Ultra Violet
WHO	World Health Organization

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