INDOOR AIR QUALITY IN RESIDENTIAL BUILDINGS IN RAJASTHAN (INDIA) -AN EXPERIMENTAL STUDY

Abstract: Poor IAQ in the urban set up is a major health problem, today. Many household activities such as cooking, heating, cooling, renovation, redecorating etc .release and spread indoor air pollutants in the home. Recently great attention has been paid towards the outdoor air quality. In Indian context no IAQ standards have been set up till date. We spend nearly 80% of our time indoors and surprisingly the air we breathe indoors is even more harmful than outdoors. Thus the present study was undertaken to sere the IAQ of the residential buildings in Udaipur city of Rajasthan, India.**The objectives** of the study were 1.To analyze the IAQ of the residential buildings from polluted and non polluted zones with reference to Gas analysis, Microbial analysis ,Suspended particulate matter, Odour, Noise, Temperature, Relative humidity & Air movement. 2. To compare the existing IAQ with the ASHARAE/WHO/NAQS standards.**Methodology:** The study was conducted in a phased manner. Phase I comprised of household survey, Phase II was of household experiments. Purposive sampling technique was used for sample selection. Ten areas from the city were selected, five from polluted and five from non polluted zones. The total sample constituted of 60 residential buildings. Interview cum observation method was used in phase I and in phase II experiments were conducted to judge the IAQ.**Results:** The results revealed that the levels of CO & NO_2 in the kitchens were high. SO2 was found to be present throughout the houses in some areas of polluted and non-polluted zones. Microorganisms (TVC) was also much higher in the kitchens and bathrooms of the residential buildings. Noise level indoors also crossed the standard limits. The temperatures indoors were quite high in summers and low in winters with relative humidity as high as 50%. Air movement without switching on the fans was below standards giving the impact of a tight house.**Conclusion:** It can be concluded that the IAQ is a hidden source of poor health which nearly 90% of the Indian home makers are unaware. There is a great need to create awareness regarding sources, effects and ways to control indoor air quality.

***Dr.Ritu Singhvi (Ph.D)**Assoc. Prof & Head, , Deptt. Of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology Udaipur Rajasthan, India

** **Prof. N.S.Rathore(Ph.D)**Prof. & Head, RNES,College of technology and engineering Maharana Pratap University of Agriculture and Technology Udaipur Rajasthan, India

Mrs.Hemu Rathore(Ph.D) Research Associate, AICRP- Deptt. Of Family Resource Management, College of Home Science, Maharana Pratap University of Agriculture and Technology Udaipur Rajasthan, India

INTRODUCTION

Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants.

There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in house-keeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

If too little outdoor air enters a home, pollutants can accumulate to levels that can pose health and comfort problems. Unless they are built with special mechanical means of ventilation, homes that are designed and constructed to minimize the amount of outdoor air that can "leak" into and out of the home may have higher pollutant levels than other homes. However, because some weather conditions can drastically reduce the amount of outdoor air that enters a home, pollutants can build up even in homes that are normally considered "leaky".

Outdoor air enters and leaves a house by: infiltration, natural ventilation, and mechanical ventilation. In a process known as infiltration, outdoor air flows into the house through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by air temperature differences between indoors and outdoors and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchen, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the house. The rate at which outdoor air replaces indoor air is described as the air exchange rate. When there is little infiltration, natural ventilation, or mechanical ventilation, the air exchange rate is low and pollutant levels can increase.

Many studies have been conducted on in foreign countries but not much attention is being paid by Indian environmentalist on IAQ in India. However there are studies related to air pollution, but very few on the indoor air quality where 80% of our time is spent.

Hence the present research was undertaken with the goal is to study the indoor air quality of residential building in Udaipur city. 1.)Only the residential buildings were studied as the setup of Indian homes is such that the first thought that came in the mind of the investigator was to study the IAQ of the residential buildings only. The residential builings are poorly ventilated as well as they are very compact. We can say that more number of people are residing in a small area as compared to the western houses.2) To gain knowledge about exposures and effects that are important for peoples perception of indoor air quality. 3)The need was also felt to educate the people on indoor air quality, its sources and its effect on health. Thus a computer module was also developed for the very same purpose.

The objectives of the study were:

1. To analyze the indoor air quality of residential buildings.
2. To compare the existing IAQ with the ASHARAE/WHO/NAQS standards.

METHODOLOGY

The study was conducted in three phases:

Phase - I	Household Survey
Phase - II	Household experiments

Phase I - Household Survey

- To collect the background information of the residential buildings.

Phase II - Household experiments

- Household experiments were conducted to measure the following parameters:
  - Gas analysis
  - Microbial analysis
  - Suspended particulate matter
  - Odour
  - Noise
  - Temperature
  - Relative humidity
  - Air movement

Purposive sampling technique was used for sample selection. With the help of experts from Pollution Control Board, Udaipur city was divided in two zones i.e. polluted and non-polluted. Five areas from each zone in selected for the purpose of the study. Thus in all there were 10 selected areas as under:

Polluted zones	Non polluted zones
1. Bypass- Pratapnagar	1. Gulab Bagh
2. University Road	2. Saheli Nagar
3. Dore Nagar / HM Sector 3	3. Fatehpura
4. Hospital Campus	4. Hindustan Zinc Colony
5. Lake Pichola	5. Government Colony

From each of these selected areas six houses were purposively selected for the study. The total samples was sixty home makers for conducting the household survey to collect background information and sixty residential buildings for conducting the household experiments to judge the existing status of indoor air quality. Care was taken to select only those houses, which were occupied for not less than one year. The reason for selecting houses which were occupied for not less than one year was that the newly constructed houses would have their own sources of increase indoor air pollution such as fine dust, dampness etc as per the Indian conditions. There could be a separate study to study the IAQ of newly constructed areas.

Phase-I: Household Survey:

Interview cum observation method was used to collect data. An interview schedule was developed to gather information related to :

- Location,
- Orientation,
- Ventilation
- Maintenance of the building in general
- Specific details of kitchen, Master bedroom and Bathroom

Phase-II: Household Experiment:

To judge the status of indoor air quality various experiments were conducted with the help of respective equipment and instrument. They were as follows:

Table-1: Parameters of the study and equipment used

S. No.	Parameters	Name of the Equipment
1.	Gas Indoors - ppm	MX 21 Gas detector
2.	Microbial analysis - Count/cubic feet/minute	Petriplate method
3.	Suspended Particulate Matter - Microgram/cubic met	Handy Sampler
4.	Odour - Odour level	Odour Intensity Scale
5.	Noise Pollution - Decibels - dB	Sound level meter
6.	Temperature and Relative Humidity- Degree Celsius and Percentage	Absorption hygrometer
7.	Air movement - m/s	Anemometer

For collecting the information in the **Phase-I** – household survey, home makers were interviewed by the investigator and various responses as per information required on indoor air quality of building and general health of the family members, which were systematically arranged in the interview schedule were recorded. While interviewing, researcher also made keen observation related to various components of building as affecting indoor air quality and were systematically noted.

To assess the status of indoor air quality in the selected residential buildings, experiments were conducted in the field situation under **Phase-II**. Three areas in a house, namely kitchen, bedroom and bathroom were selected. All the experiments were conducted seasonally i.e. in summer and winter season, as the available literature reports that the seasonal variations also bring changes in the pollution level indoors. Likewise pollution level changes during the day, hence the experiments were conducted in the morning, afternoon and evenings respectively. In the kitchen the experiment were conducted before and after cooking as the rise in temperature and emission of gaseous pollutants affects the indoor air quality.

Analysis of Data

Phase–I: The information collected through household survey with regard to (a) Demographic profile of respondents (b) General information abut location, orientation, ventilation, doors, windows and details pertaining to the maintenance of kitchen, bedroom and bathroom was converted into comprehensive tables and means and percentage were calculated.

Phase–II: Mean scores for the various parameters to judge the indoor air quality were calculated. 't' – test was used to test the significant different between the existing status of indoor air quality of residential buildings with the standards of indoor air quality.

RESULTS

Fifty percent of the respondents from polluted and non-polluted zone were ranging between the age group of 21-30 years. 56-66 percent and 66.66 percent of the families from polluted and non-polluted zones were having an income of more than Rs. 10,000/month.

As far as the orientation of the building concerned east and west facing residential buildings were found to be more common irrespective of the zones.

Among selected residential buildings 80% from polluted zones and 66.66 percent from non-polluted zone were situated on planes where as very few were found on hills and in valleys. As far as the area of the house was concerned majority of them had 2400 sq.ft. (60' × 40') of area. An equal number of houses were found to be situated on and away from road in both zones. 66.66 percent and 60 percent from polluted and non-polluted zone respectively did not have garden space in their buildings. Very few homemakers i.e. 10% from non-polluted zone had termites treatment done in their buildings.

With respect to the various constructional features in the buildings it was observed that provision of ventilators was common in kitchen of non-polluted zone (93.33%) while only 60 percent of the kitchens from polluted zones had provision of ventilators. Majority of the kitchens had smoke outlet by means of having either electric chimney or exhaust fans but very few of them have installed these at right place i.e. just above the cooking area (Table 2). Further it was also found that the practices of operating these mechanical means of keeping the kitchen smoke free was rare L.P.G. was the main source of cooking fuel among all the selected houses.

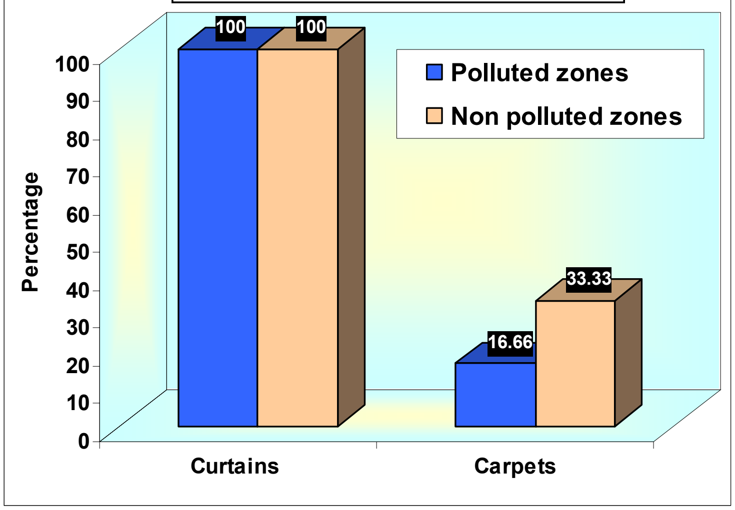
Table-2: Construction features of the kitchen

S.No.	Construction features	Polluted zones	Non polluted zones
	Ventilators		
	Yes	18 (60)	28 (93.33)
	No	12 (40)	2 (6.66)
	Total	**30 (100)**	**30 (100)**
1.	Shape of kitchen		
	U	11 (36.66)	7 (23.33)
	L	1 (36.66)	15 (50)
	One wall	8 (26.66)	8 (26.66)
	Total	**30 (100)**	**30 (100)**
2.	Placement of smoke outlet		
	Above wall of the cooking stove	3 (40)	3 (10.00)
	Side wall of the cooking area	10 (33.33)	17 (56.66)
	Opposite wall of the cooking area	2 (6.66)	
	No	15 (50)	10 (33.33)
	Total	**30 (100)**	**30 (100)**
3.	Operation of exhaust		
	Yes	15 (50)	20 (66.66)
	No	15 (50)	10 (33.33)
	Total	**30 (100)**	**30 (100)**
	Before cooking	-	5 (15)
	During cooking	6 (20)	13 (43.33)
	After cooking	9 (30)	2 (6.66)
4.	Switching off time of exhaust		
	Just after cooking	15 (50)	19 (63.33)
	5 minutes after cooking	-	1 (3.33)
	5-10 minutes after cooking	-	-
	Total	**15 (50)**	**20 (66.66)**

(% In the parenthesis)

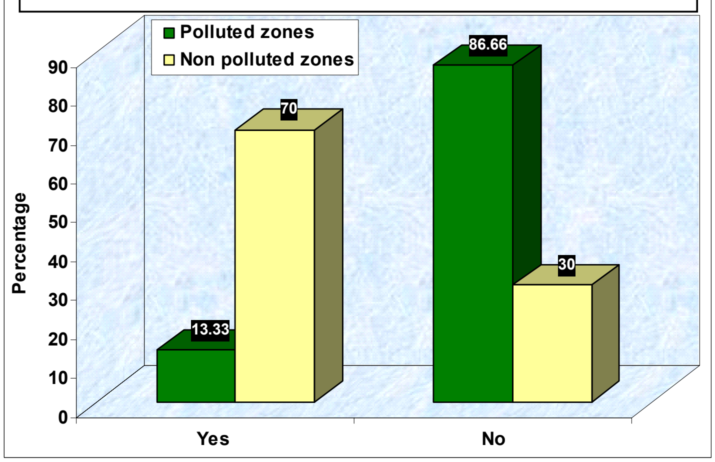
In the bedrooms under the study i.e. 36.66 percent in polluted and 33.33 percent in non-polluted zone has north facing bedrooms with two doors and 2-3 windows air coolers were found to be the most common equipment used during summers by the respondents and on an average it was operated for 8-16 hours / day 16.66 percent and 33.33 percent of the bedrooms had carpets spread in the bedrooms of polluted and non-polluted zone respectively. (Figure1)

Figure –1:Furnishings Used



The features studied in bathroom were ventilation exhaust facility and water stagnation. It was observed that in 20 percent of the bathroom from polluted zone and 100 percent from non-polluted zone had this feature installed. (Figure2)

Figure –2:Facilities of exhaust fan in the bathrooms



The major findings of the household experiments to test the indoor air quality of various selected places were as under.

CO was found to be most common in the kitchens experimented under the study. In summer presence of CO ranged from 1-6 ppm in both the zones where as in winters it raised to 2-7 ppm. The level of CO increased tremendously after cooking is done. Hence it is necessary to operate mechanical devices (exhaust fan and electric chimney) during and after cooking for at least 10 minutes to make the kitchen free from all pollutants. CO content was not found in bedrooms and bathrooms in majority of the areas except twelve houses in two selected areas 1 from each, polluted and non-polluted zone respectively. The presence of CO in the air as per the standards given by ASHARE is 9 ppm indoors. Hence it can be said that none of the houses was having higher level of CO in their indoor air.(Tables 3-6)

Table-3: Level of Carbon Monoxide (CO-ppm) in residential building of polluted zones during summer

S. No.	Name of the zone	Kitchen					Bedroom			Bathroom			Outside		
		M		Aft	E		M	A	E	M	A	E	M	A	E
		B	A		B	A									
1.	Pratapnagar by pass road	1	5	2	1	4	1	1	1	0	0	0	7	5	6
2.	University Road	1	3	0	1	4	0	0	0	1	0	1	4	5	4
3.	Dorenagar / Hiran magri	2	5	1	1	6	1	0	0	0	0	0	5	3	6
4.	Hospital campus	1	3	1	1	3	1	1	1	0	0	0	13	8	18
5.	Lake Pichola	1	3	1	1	2	1	1	1	0	0	0	7	7	8

Table-4: Level of Carbon Monoxide (CO-ppm) in residential building of non-polluted zones during summer

S. No.	Name of the zone	Kitchen					Bedroom			Bathroom			Outside		
		M		Aft	E		M	A	E	M	A	E	M	A	E
		B	A		B	A									
1.	Gulab bagh	2	6	2	2	7	0	0	0	0	0	0	5	4	7
2.	Saheli nagar	1	3	2	1	3	3	2	2	0	0	0	4	5	6
3.	Fatehpura	1	2	1	1	3	0	0	0	0	0	0	5	5	6
4.	Hindustan Zinc	0	2	0	0	3	0	0	0	0	0	0	3	4	3
5.	Government colony	1	3	1	1	3	1	1	1	0	0	0	7	5	6

M – Morning B – Before cooking A – After cooking Aft – Afternoon E- Evening

Table-5: Level of Carbon Monoxide (CO) in residential building of polluted zones during winter

S. No.	Name of the zone	Kitchen					Bedroom			Bathroom			Outside		
		M		Aft	E		M	A	E	M	A	E	M	A	E
		B	A		B	A									
1.	Pratapnagar by pass road	1	5	2	1	5	1	1	1	0	0	0	0	5	8
2.	University Road	1	4	1	1	4	0	0	0	0	0	0	5	5	5
3.	Dorenagar/Hiran mangri	1	6	1	1	5	0	0	0	0	0	0	5	4	7
4.	Hospital campus	1	4	1	1	4	0	0	0	0	0	0	16	10	19
5.	Lake pichola	1	4	1	1	3	0	0	0	0	0	0	9	8	10

Table-6: Level of Carbon Monoxide (CO) in residential building of non-polluted zones during winter

S. No.	Name of the zone	Kitchen					Bedroom			Bathroom			Outside		
		M		Aft	E		M	A	E	M	A	E	M	A	E
		B	A		B	A									
1.	Gulab bagh	3	7	3	2	8	0	0	0	0	0	0	6	5	7
2.	Saheli nagar	1	4	1	1	3	3	3	3	0	0	0	5	8	9
3.	Fatehpura	1	2	1	1	4	0	0	0	0	0	0	5	5	8
4.	Hindustan Zinc	0	1	0	0	3	0	0	0	0	0	0	4	6	5
5.	Government colony	1	4	1	1	4	1	1	1	0	0	0	6	8	6

M – Morning B – Before cooking A – After cooking Aft – Afternoon E- Evening

NO_2 A higher level of concentration of NO_2 was found in the kitchen ranging from 0.1-0.3 ppm which is much higher than the recommended standards i.e. 0.053 ppm.

The level of NO_2 increased by 0.1-0.2 ppm after cooking. The presence of NO_2 in bedrooms and bathrooms was found to be nil in majority of the building.

SO_2 the presence of SO_2 was high (0.1 ppm) in two areas namely university and Lake Pichola as in both the places there was open sewerage lines. Where as rest of the selected areas were free from presence of SO_2 especially during summers. The level of SO_2 increased in winters by 0.1 ppm.

The recommended standards for NO_2 indoor is .053 ppm. Majority of the dwellings were found to have NO_2 levels higher in winters as compared to summers. Among the polluted zones and non-polluted zone, the later had higher levels of NO_2 i.e. as high as .3 ppm indoor and .4-ppm outdoors.

While conducting the experiments the investigator clearly observed that the level of NO_2 was higher in those buildings having poor ventilation facility which is further supported by the study conducted by Nipohdhkar (1997)

The comparative scores of presence of selected gases indoors have shown more or less a similar pattern both in the selected residential buildings of polluted and non-polluted zones.

As per the 't' test values there was a significant difference at 1 percent level in presence of NO_2 indoors with the standard value of 0.053 ppm. Among the selected houses from non polluted zone there was no significant difference in the levels of NO_2 before cooking

All the selected buildings had an average temperature between 31^0 C - 39^0 C in summers and the relative humidity was also above 40%. The relative humidity was maximum 48% and minimum 40% in summers. The reason was the use of room and desert coolers and A.C. due to the scorching heat in the months of May and June. In winters the average temperature and humidity were low.

The results have shown that non-polluted zone buildings had lesser degree of microbial pollution as in the indoor air as low as 10. as compared to polluted zone (67 counts / cubic ft./ min). The reason for this may be attributed to good ventilation in the Bathroom and less humidity. The total viable count of microorganism was quite less in winters as compared to summers. Thus it can be concluded that during winters the microbial pollution decreases hence winters are said to be the season for building health.

The average sound level in the residences of polluted zone in summer and winter showed that the maximum sound level was recorded in the buildings of hospital campus, which was as high as 89.6 dB in the Kitchen and 110dB on road. Similarly the houses investigated from non-polluted zones i.e. in buildings of government colony were highly affected by noise outside i.e. 320 dB as there was heavy traffic and houses were situated on the road and this was one of the reasons to keep the windows closed.

The average sound levels in polluted zone and non-polluted zone. Residential buildings were far above the prescribed standards with the outdoors having nearly double as per the standards given. The sound level varied in the selected areas with the frequency and duration of the operation of equipments. The standard for sound level indoors was 45 dB. (Table7-8)

Table-7: Average sound level (dB) indoors in polluted zones for summer and winters

S. No.	Name of the zone	Kitchen			Bedroom			Bathroom			Outside		
		M	A	E	M	A	E	M	A	E	M	A	E
1.	Bypass	67	42.4	60	72.4	50	62	42.8	40	40	95.8	70	90
2.	University Road	79	78.8	72	76.6	67.7	63	42	41	45	52.4	58	60
3.	Dorenagar/Hiran mangri	75.5	61.4	64	85.5	60.7	71	45	50	49	70	75	85
4.	Hospital campus	85	79	89.6	74	68	76	39	35	40	110	90	100
5.	Lake pichola	74	60.3	67.3	70.4	68	69	74	68	68	82	99	89

Table-8: Average Sound level (dB) indoors in non-polluted zones for summer and winters

S. No.	Name of the zone	Kitchen			Bedroom			Bathroom			Outside		
		M	Aft	E	M	A	E	M	A	E	M	A	E
1.	Gulab bagh	66.3	60	57.5	51	45	70.3	48.4	40	50.4	98.4	80	81
2.	Saheli nagar	51.3	60.8	55.3	58	51	56	54	48	45	80.2	90	79.9
3.	Fatehpura	78	73	70	71	65	65	45	49	44	70	75	72
4.	Hindustan Zinc	66	69	63	59	48	57.2	58	51	49	71	73	72
5.	Government colony	69	70	72	52	55	51.3	60	62	58	101.7	90.1	85.3

The threshold level odour i.e. greasy cooking smell was present in the kitchens of polluted zone. In the bathrooms the smell of humidity and dampness was felt. The outdoors of hospital had an over powering odour of medicines.

The non-polluted zone residential buildings were having less degree of odour indoors as compared to the Polluted Zone areas.

The level of suspended particulate matter (SPM) was comparatively lower in winters than in summers. Among the areas selected for the present study, the buildings situated near By-pass area had highest level of suspended particulate matter indoors i.e. between 72-110 ug/ cub.ft. in summers and 60-100 ug/cubic ft. in winters.

The non-polluted Zone areas were having less pollution from suspended particulate matter as compared to polluted zone areas. Highest levels of pollution indoors was recorded in government colony residential buildings (118, 105, 49, 320 µg/cubic ft.) in Kitchens, bedrooms bathrooms and out doors respectively in summer season.

In winters the level of suspended particulate matter reduced to some extent. Indoor air pollution consists of toxic gases and particles that can harm ones health. These pollutants can built-up rapidly indoors to levels much higher than these usually found outdoors. This is especially true if large amount of pollutant is released indoors. Moreover "tighter" construction in newer homes can prevent pollutants from escaping to the outdoors.

Conclusion:

It can be concluded from the present study that the indoor air quality of residential building in Udaipur city was found to be poor as the gaseous content SO_2, NO_2, microbial, noise, odour and suspended particulate matter was found to be much higher as per the permissible limits recommended by ASHARE / WHO. The CO content of indoor air quality was within the permissible limit i.e. 9 ppm but much higher than the tolerance i.e. 1 ppm. Tolerance limit means that the homemaker started feeling uneasy and had breathing problems

Indoor air quality and its impact on the health of the population is subject of considerable interest and is an important area of public health policy for two main reasons. Firstly everyone is potentially exposed. Secondly, there is a very broad range of individual susceptibility within the population.

There are evidences that the susceptibility of air pollution great among infants, the elderly, and infirm. There is no doubt however that the urgency with to steps are taken to improve indoor air quality will depend very much on how serious the risk of ill health from air pollution is thought to be.

A lot of awareness and education is needed for the general mass so that the indoor environment could be kept safe by taking small measures. Tips for safe indoor air quality, their sources, detection and remedies should reach the masses.

REFERENCES:

1. Gradjean, E. 1973, Ergonomics of the Home London Taylor and Frances ltd.

2. Nipadhakar, V.P. 1997. Is your building sick. Times of India – They Sunday review, Pg-4.

3. Samet, J.M. Marbury, M.C., and Spengler, J.D. "effects and Sources of Indoor Air Pollution, Part-I". American Review of Respiratory Disease 1987; 136: 1486-1508.

4. Samet, J.M., Marbury, M.C. and Spengler, J.D. "Health Effects and Sources of Indoor Air Pollution, Part-II". American Review of Respiratory Disease 1988; 137221-42.

5. **ASHRAE: Ventilation and IAQ standards – Indoor Air Quality –**
   http://ww.flex.net/~lonestar/indoor.htm
   Advice on ways to improve the air quality inside your home or place of business.

Appendix-1

Level of significant difference between the standard (9 ppm) and existing indoors level of CO in polluted zone–summer and winter

Parameters	Kitchen					Bedroom			Bathroom		
	M		Aft	E		M	A	E	M	A	E
	B	A		B	A						
Polluted zone – Summer											
Mean	1.2	3.8	1	1	3.8	0.8	0.6	0.6	0.2	-	0.2
S.D.	±.45	± 1.10	± 0.71	±0	±1.48	±.45	± 0.55	±0.55	± 45	-	± 0.45
t value	28.381**	5.469**	30.772**	35.901**	5.469**	47.998**	70.680**	70.680**	169.248**	-	169.248**
Polluted zone – Winters											
Mean	1	4.6	1.2	1	4.2	0.2	0.2	0.2	-	-	-
S.D.	± 0	± 0.89	± 0.45	± 0	± 0.84	± 0.45	± 0.45	± 0.45	-	-	-
t value	35.901**	4.057**	25.003**	35.901**	4.717**	98.728**	98.728**	98.728**	-	-	-

Level of significant difference between the standard (9 ppm) and existing indoors level of CO in non-polluted zone–summer and winter

Parameters	Kitchen					Bedroom			Bathroom		
	M		Aft	E		M	A	E	M	A	E
	B	A		B	A						
Non Polluted zone – Summer											
Mean	1.2	3.2	1.2	1	3.8	.8	.6	.6	-	-	-
S.D.	±.71	± 1.64	± .84	±.71	±1.79	±1.30	±.89	±..89	-	-	-
t value	26.926**	6.674**	22.343**	26.926**	5.073**	47.998**	70.680**	70.680**	-	-	-
Non Polluted zone –Winters											
Mean	1.2	3.6	1.2	1	4.4	.8	.8	.8	-	-	-
S.D.	± 1.10	± 2.30	± 1.10	± .71	±.2.07	± 1.30	±1.30	±1.30	-	-	-
t value	20.194**	5.346**	20.194**	26.926**	3.895**	47.998**	47.998**	47.998**	-	-	-

**** Significant at 1 percent level**

Appendix-2

Level of significant difference between the standards (0.14 ppm) and existing indoors level of SO_2 in polluted zones – summer and winter

Parameters	Kitchen					Bedroom			Bathroom		
	M		Aft	E		M	A	E	M	A	E
	B	A		B	A						
Polluted zone – Summer											
Mean	.04	.04	.06	.04	.04	.04	.06	.04	.06	.04	.06
S.D.	±.05	±.05	±.05	±.05	±.05	±.05	±.05	±.05	±.05	±.05	±.05
t value	14.959**	14.959**	9.791**	14.959**	14.959**	14.959**	9.791**	14.959**	6.731**	14.959**	6.731*
Polluted zone – Winters											
Mean	.1	.08	.1	.1	.1	.12	.08	.08	.12	.1	.1
S.D.	± .10	± .08	± .10	± .10	±.10	± .11	±.11	±.11	±.11	±.10	±.10
t value	2.693*	6.214**	2.693*	2.693*	2.693*	1.224	4.488**	4.488**	1.274	2.693*	2.693*

Level of significant difference between the standards (0.14 ppm) and existing indoors level of SO_2 in non-polluted zones – summer and winter

Parameters	Kitchen					Bedroom			Bathroom		
	M		Aft	E		M	A	E	M	A	E
	B	A		B	A						
Non-Polluted zone – Summer											
Mean	-	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-	-
t value	-	-	-	-	-	-	-	-	-	-	-
Non-Polluted zone – Winters											
Mean	.04	.04	.06	.04	.04	.06	.06	.06	.06	.04	.06
S.D.	± .05	± .05	± .05	± .05	± .05	± .05	± .05	± .05	± .05	± .05	± .05
t value	14.959**	14.959**	9.791**	14.959**	14.959**	9.791**	9. 791**	9.791**	6.731**	14.959**	6.731**

* 5 percent level of significance ** 1 percent level of significance

Appendix 3

Level of significant difference between the standards (.053 ppm) and existing indoors level of NO_2 in polluted and non-polluted zones– summer and winter

Parameters	Kitchen					Kitchen				
	M		Aft	E		M		Aft	E	
	B	A		B	A	B	A		B	A
Polluted zone – Summer						**Non-Polluted zone – Summer**				
Mean	-	.22	-	.02	0.026	0.06	.26	0.12	.04	0.28
S.D.	-	±.04	± -	±.04	±.05	± 0.05	±.05	± 0.04	±.05	±0.04
t value	-	3.356**	0	3.702**	3.925**	1.945	3.925**	0.957	6.347**	3.682
Polluted zone – Winters						**Non-Polluted zone – Winters**				
Mean	.02	0.26	.22	-	0.3	.06	0.26	0.12	0.04	0.28
S.D.	± .04	± .05	± .08	-	±.0	± .06	± 0.26	± 0.12	± 0.05	±.04
t value	6.347	3.441**	3.356**	-	3.695**	0.499	3.667**	2.438*	1.250	3.473**

* Significant at 5 percent level

** Significant at 1 percent level

Level of significant difference between the standards (100µg/cubic mt.) and existing indoors level of suspended particulate matter indoor in polluted and non-polluted zones – summer and winter

Parameters	Kitchen			Bedroom			Bathroom		
	Mean	S.D.	t value	Mean	SD	t Value	Mean	SD	t value
Summer									
Polluted zones	108.4	± 4.67	.344	111.6	± 8.05	.451	60.2	± 9.07	2.862*
Non polluted zones	91.2	± 15.42	.453	85	± 13.40	.833	45.8	± 3.56	5.238*
Winter									
Polluted zones	92.4	± 8.62	.381	80.8	±12.15	1.012	51.4	± 9.04	4.004*
Non-polluted zone	78.8	± 3.70	1.205	70	± 5.36	1.922	39.4	± 1.67	6.776*

* Significant at 5% level

Appendix-5

Level of significant difference between the standards (45 dB) and existing indoors level of sound level in polluted and non-polluted zones – summer and winter

Parameters	Kitchen			Bedroom			Bathroom		
	Mean	S.D.	t value	Mean	SD	t Value	Mean	SD	t value
Polluted zones									
Morning	76.1	± 6.62	1.900	75.78	± 5.89	1.808	48.56	± 14.38	.355
Afternoon	64.38	± 15.25	1.475	62.88	± 7.85	1.359	46.8	± 13.03	.183
Evening	70.58	± 11.51	1.734	68.2	± 5.81	1.584	48.4	± 11.59	.338
Non-Polluted zones									
Morning	66.12	± 9.61	1.428	58.2	± 7.98	1.023	53.08	± 6.33	.720
Afternoon	66.56	± 5.82	1.500	52.8	± 7.76	0.674	50.00	± 7.91	.486
Evening	63.56	± 7.38	1.360	59.96	± 7.59	1.056	49.28	± 5.56	.400