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Assessment of Indoor Air pollution through use of Indoor Plants

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ABSTRACT: *The study modeled air quality in the indoor spaces. Air quality "refers to the condition of the air within surrounding Air quality meter, thermometer and lux meter were used for assessment of air quality of indoor spaces for four weeks in Gangotari hostel of CCSHAU, Hisar. For the experimental work six rooms were selected for assessment of indoor air quality of a specific plants was kept in each different rooms i.e.R1 (spider plant), R2 (rubber plant), R3 (bamboo palm), R4 (snake plant), R5 (boston fern) and one room was RC (control room) for comparison in air quality. In all rooms where indoor plants were placed showed improvement in indoor air quality in terms of formaldehyde, suspended particulate matter, after 4th week in control room formaldehyde increased 1.60 percent whereas, room with spider plant formaldehyde decreased by 74.07%, trailed by 73.30% decrease in room with bamboo palm. The suspended particulate matter after 4th week in control room increased by 70.92% but in room with spider plant it reduced by 50.02% trailed by 32.71% decrease in room with rubber plant.*

KEY WORDS: Indoor plants, air quality, formaldehyde, suspended particulate matters

INTRODUCTION

Environment is everything that surrounds us and affects daily lives. In the environment there are interactions between animals, plants, soil, water, and other living and non-living things. Air is one of the important components of environment. Air quality" refers to the condition of the air within surrounding. Good air quality means the air which is clean, clear and free from pollutants such as smoke, dust, industries pollutant, household pollutant and smog among other gaseous impurities. Good air quality is a requirement to preserve the delicate balance of life on earth for humans, plants, animals, living and non-living things and natural resources. Poor air quality is harmful for human health and the environment. Human health, plants, animals and natural resources are susceptible when pollution in the air reaches high concentrations. Air quality can be spoiled by natural or man-made sources. Both natural and manmade sources seriously affect the overall air quality and lead to severe health tribulations for humans.

The indoor space is the main consign for human life and work. With the development of society, economy and the expansion of people's living standard, the function of the indoor space is not only a shelter; more important is to make available a good working and learning environment, and the graceful and comfortable rest of humanity. Provision of a healthy and comfortable indoor space is the crucial function of modern residential construction. Indoor air is the within a building such as house, study room, living room, office, shopping centre, hospital or gym and any kind of indoor space. The indoor environment includes air, heat, humidity, light, sound and many other environmental parameters. Air quality is one of the major environmental health concerns for India. Nowadays our lifestyle and work culture are also forcing us to be in the contact of the indoor environment for the long number of hours leading to coverage of various indoor pollutants. Indoor environment quality, IEQ, is taken into account as indicator of the amount of comfort that isn't confined to the thermal conditions, it includes components like thermal comfort, acoustic comfort, indoor air quality and visual comfort. Indoor environment has a crucial impact on human health and work ability. Indoor sources measure the key reason for indoor air quality that causes inconvenience in homes. The development of air toxin focuses to perilous levels, particularly in current energy-saving but air-tight constructions, speaks for one of the need and worries for human wellbeing today.

Poor ventilation can increase indoor pollutant levels due to poor intensity of emissions from indoor sources. A lack of ventilation in indoors, concentrates air pollution which is hazardous for human health where people spend the majority of their time. World health organization recently estimated that approximately 30 percent of all new or remodeled buildings have varying degrees of indoor air pollution (NASA 2019).

There are several sources of indoor air pollution, including burning of domestic fuels such as coal, wood, paraffin, pesticides used in the home for prevention by mosquito, tobacco smoke, asbestos products, and household cleaning products. Building materials including carpeting and plywood release formaldehyde (H_2CO) gas. Paint and solvents confer volatile organic compounds (VOCs). Lead paint can disintegrate into dust. Intentional air pollution is introduced with the use of air fresheners, incense, and other aromatic items. The volatile organic compounds (VOCs) have been broadly distributed which seriously deteriorates the indoor air quality (IAQ**)**. VOCs are more ordinary in indoor areas than outdoors. This is because air and VOCs get intent in indoor spaces which leads to less air circulation.

Nowadays a number of air purifiers and air humidifiers present in the market. But they do not work and filter the indoor air as professionally as plants work. The house plants are the latest phrase in household cleaning. So growing indoor plants in each room of a house is the best medication to improve the quality of air in the house that too at a minimum cost.

MATERIALS AND METHODS

A Research, materials and methodology deals with a detailed description of methods and techniques employed to explore the possible explanation of the objectives laid down for the study. The study was carried out in experimental phase.

Experimental Work: The experimental work was carried in the Gangotri Hostel of CCSHAU Hisar, so as to provide similar environmental conditions to all the selected plants. Five Healthy plants which help in improving indoor air quality were selected on the basis of available literature. Selected plant species were kept in five almost similar rooms of the Gangotri Hostel, and one room was used as the control room to compare the change in indoor

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air quality. The size of all the rooms was same i.e.8×8and room has one window and one door, to see the effect of plants. The number of plants in each room was increased every week.

The five plants used for experimental work were:
1) Spider plant
2) Rubber plant
3) Bamboo palm
4) Snake plant
5) Boston fern

Plan of keeping indoor plants
Six rooms of Gangotri Hostel were used for keeping the indoor plants in the following manner-

Room	Name of the plant	Week	No. of plant
RC	(Control room) without plant	1st	1
		2rd	3
		3th	4
		4th	4
R1	Room with -Spider plant (*Chlorophytum)*	1st	1
		2rd	3
		3th	4
		4th	4
R2	Room with- Rubber plant(*Ficus elastic)*	1st	1
		2nd	2
		3rd	3
		4th	4
R3	Room with -Bamboo palm (*Chamaedoreaseifrizii)*	1st	1
		2nd	2
		3rd	3
		4th	4
R4	Room with -Snake plant(*Sansevieria trifasciata, future superb)*	1st	1
		2nd	2
		3rd	3
		4th	4
R5	Room with -Boston fern(*Nephrolepisexaltata)*	1st	1
		2nd	2
		3rd	3
		4th	4

Procedure of recording indoor air quality:
The readings the parameters Formaldehyde & Suspended Particulate Matter were recorded using appropriate instrument (Air quality) three times a day i.e. at 8 AM, 2 PM and 6 PM for four week **between 23 January 2019 to 19 February 2019.** Four replication of reading were taken for each parameter to avoid any error and then mean was computed.

Instruments used for assessing indoor air quality

Air quality meter

Five Healthy plants used for the experimental study -1. Spider plant, 2. Bamboo palm, 3. Snake plant, 4. Bosten fern, 5. Rubber plant

Indoor air quality

The indoor air quality was assessed on the basis of Formaldehyde and Suspended Particulate Matters.

Formaldehyde -Formaldehyde is an important precursor to many other materials and chemical compounds. Air quality meter was used to assess the level of the formaldehyde. Air quality meter detects levels of HCHO in the air in the room through laser scattering detection.

Suspended particulate matter (SPM) is finely divided solids or liquids that may be dispersed through the air from combustion processes, industrial activities or natural sources. Air quality meter was used to measure the SPM Air quality meter detects levels of PM1, PM2.5, PM10 in the indoor air through laser scattering detection.

RESULTS

The results of the present study were presented in agreement with the objective contingent through the use of prescribed methodology and standard tools. Systematic research technique was applied and results have been presented and discussed under the following head-

Experimental work
Assessment of indoor air quality-

Assessment of the indoor air quality through use of plants
The air quality of indoors using spider plant, rubber plant, bamboo palm, snake plant and boston fern was assessed on the basis of following parameters.

- Formaldehyde
- Suspended particulate matter

Formaldehyde
Weekly percentage change in amount of formaldehyde in control room and experimental rooms
Table 1and fig 1, presents the day wise change and table 2 and fig 2 depicts the weekly change in the amount of formaldehyde in control and experimental rooms.

Rc (control room): On the day 1 level of formaldehyde was 0.026mg/m^3. After a week the mean value of formaldehyde was 0.023mg/m^3, which was 11.54% less than day 1.After 2ndweek mean value of the level of formaldehyde the was 0.019mg/m^3, which was 26.92 % less than day 1. After 3rd and 4th week change in level of formaldehyde increased by1.48% and 1.60% respectively.

R1 (room with spider plant): On the day 1 level of formaldehyde was 0.018mg/m^3. After a week the mean value of change in formaldehyde was 0.015mg/m3, which was 15.87% less than day 1. After 2nd week the mean value was 0.008mg/m3, which was 46.83% less than day 1. After 3rd and 4th week it was 0.008mg/m^{3}and 0.005mg/m^3 which were 52.86% and 74.07% respectively less as compared to day 1.

R2 (room with rubber plant): On the day 1 level of formaldehyde was 0.020mg/m3. After a week the mean value 0.019mg/m^3, which was 7.14% less than day 1. After 2nd week reduction in the level of formaldehyde was 38.57 %. After 3rd and 4th week the level of formaldehyde was0.010mg/m3 and 0.008mg/m^3 which indicate decrease in 51.08% and 61.61% respectively.

R3 (room with bamboo palm): On the day 1 level of formaldehyde was 0.021mg/m3. After a week mean value was 0.017mg/m^3, which was 24.49% less than day 1. After 2nd week the mean value was 0.007mg/m3, which was 68.08% less than day 1. After 3rd and 4th week the mean value was 0.007mg/m3, (66.10%) and 0.006mg/m3, (73.30%) respectively as compared to day 1.

Table 1: Day wise Percentage change in amount of formaldehyde (mg/m^3) in control room and experimental rooms

No. of Plant	Day	Control Room			Spider plant			Rubber plant			Bamboo palm			Snake plant			Boston fern		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1st week	1	0.026			0.018			0.020			0.021			0.019			0.018		
	2	0.025	0.001	0.10	0.018	0.000	0.00	0.020	0.000	0.00	0.020	0.001	0.10	0.019	0.000	0.00	0.018	0.000	0.00
	3	0.025	0.001	0.10	0.017	0.001	0.10	0.019	0.001	0.10	0.019	0.002	0.20	0.020	-0.001	-0.10	0.017	0.001	0.10
	4	0.024	0.002	0.20	0.016	0.002	0.20	0.020	0.000	0.00	0.014	0.007	0.70	0.020	0.000	0.00	0.020	-0.003	-0.30
	5	0.023	0.003	0.30	0.014	0.004	0.40	0.019	0.001	0.10	0.010	0.011	1.10	0.016	0.004	0.40	0.020	0.000	0.00
	6	0.020	0.006	0.60	0.011	0.007	0.70	0.015	0.005	0.50	0.015	0.006	0.60	0.016	0.000	0.00	0.020	0.000	0.00
	7	0.018	0.008	0.80	0.012	0.006	0.60	0.017	0.003	0.30	0.012	0.009	0.90	0.014	0.002	0.20	0.018	0.002	0.20
		0.023(11.54)			0.015(15.87)			0.019(7.14)			0.016(24.49)			0.018(6.77)			0.019(-3.97)		
2nd week	8	0.015	0.011	1.10	0.009	0.009	0.90	0.019	0.001	0.10	0.008	0.013	1.30	0.015	0.003	0.27	0.017	0.002	0.17
	9	0.017	0.009	0.90	0.008	0.010	1.00	0.007	0.013	1.30	0.006	0.015	1.50	0.006	0.009	0.90	0.016	0.001	0.10
	10	0.013	0.013	1.30	0.008	0.010	1.00	0.019	0.001	0.10	0.007	0.014	1.40	0.011	-0.005	-0.50	0.012	0.004	0.40
	11	0.013	0.013	1.30	0.010	0.008	0.80	0.010	0.010	1.00	0.007	0.014	1.40	0.010	0.001	0.10	0.009	0.003	0.30
	12	0.013	0.013	1.30	0.010	0.008	0.80	0.017	0.003	0.30	0.007	0.014	1.40	0.010	0.000	0.00	0.006	0.003	0.30
	13	0.031	-0.005	-0.50	0.007	0.011	1.10	0.007	0.013	1.30	0.006	0.015	1.50	0.006	0.004	0.40	0.004	0.002	0.20
	14	0.031	-0.005	-0.50	0.007	0.011	1.10	0.007	0.013	1.30	0.006	0.015	1.50	0.006	0.000	0.00	0.004	0.000	0.00
		0.019(26.92)			0.008(46.83)			0.012(38.57)			0.007(68.03)			0.009(51.88)			0.010(46.03)		
3rd week	15	0.024	0.002	0.17	0.010	0.008	0.84	0.015	0.005	0.45	0.005	0.016	1.61	0.011	-0.002	-0.19	0.006	0.003	0.35
	16	0.039	-0.013	-1.34	0.008	0.010	0.97	0.012	0.009	0.85	0.009	0.012	1.22	0.011	0.001	0.05	0.017	-0.010	-1.04
	17	0.025	0.001	0.11	0.007	0.011	1.09	0.007	0.013	1.28	0.006	0.015	1.53	0.007	0.004	0.39	0.007	0.009	0.93
	18	0.025	0.001	0.11	0.007	0.011	1.09	0.007	0.013	1.28	0.006	0.015	1.53	0.007	0.000	0.00	0.007	0.000	0.00
	19	0.024	0.002	0.19	0.007	0.011	1.11	0.010	0.010	0.97	0.006	0.015	1.46	0.007	0.000	-0.02	0.011	-0.004	-0.41
	20	0.023	0.003	0.34	0.014	0.004	0.42	0.010	0.010	1.00	0.010	0.011	1.13	0.014	-0.007	-0.69	0.010	0.002	0.18
	21	0.025	0.002	0.15	0.007	0.011	1.14	0.007	0.013	1.33	0.008	0.013	1.26	0.007	0.007	0.69	0.007	0.003	0.32
		0.026(-1.48)			0.008(52.86)			0.010(51.08)			0.007(66.10)			0.009(52.88)			0.009(48.28)		
4th week	22	0.023	0.003	0.30	0.010	0.008	0.76	0.009	0.011	1.08	0.010	0.011	1.06	0.009	0.000	0.03	0.008	0.002	0.17
	23	0.030	-0.004	-0.40	0.009	0.009	0.93	0.008	0.012	1.23	0.008	0.013	1.29	0.010	-0.002	-0.16	0.008	-0.001	-0.06
	24	0.023	0.003	0.27	0.006	0.012	1.18	0.011	0.009	0.94	0.006	0.015	1.46	0.008	0.002	0.22	0.006	0.002	0.18
	25	0.022	0.005	0.45	0.006	0.012	1.20	0.007	0.013	1.33	0.004	0.017	1.69	0.005	0.003	0.30	0.007	-0.001	-0.07
	26	0.022	0.004	0.38	0.005	0.013	1.30	0.008	0.013	1.25	0.004	0.017	1.73	0.006	-0.001	-0.13	0.007	0.000	-0.02
	27	0.039	-0.013	-1.31	0.003	0.015	1.49	0.005	0.015	1.50	0.004	0.017	1.70	0.006	0.001	0.07	0.005	0.002	0.19
	28	0.020	0.006	0.60	0.003	0.015	1.49	0.007	0.013	1.30	0.003	0.018	1.84	0.009	-0.003	-0.33	0.005	0.000	0.03
4th week		0.026(1.60)			0.005(74.07)			0.008(61.61)			0.006(73.30)			0.008(60.09)			0.007(62.88)		

A = Level of formaldehyde (mg/m^3), B = Change in amount formaldehyde per day, C = Percentage change in amount of formaldehyde , (Figures in parenthesis indicate percentages)

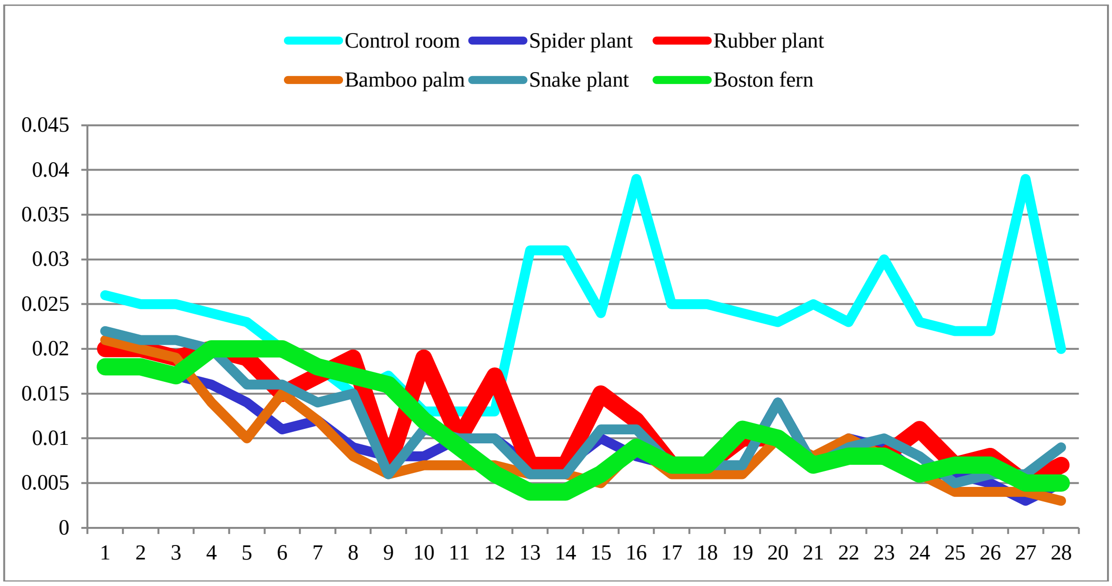

Fig 1:Day wise change in amount of formaldehyde in control room and experimental rooms.

R4 (room with snake plant): On the day 1 level of formaldehyde was 0.019mg/m3, after a week the mean value was 0.018mg/m^3, which was 6.77 % less than day 1. After 2nd week mean value was 0.009mg/m3, which was 51.88% less than day 1. After 3rd and 4th week mean value was 0.009mg/m3, which was lowered by 52.88% and 0.008mg/m3, which was lowered by 60.09% respectively in comparison with day 1.

R5(room with boston fern): On the day 1 level of formaldehyde was 0.018mg/m3, after a week the mean value was 0.019mg/m3, which was increased by 3.97% in comparison to day 1. After 2nd week mean value was 0.010mg/m^3(46.03%) less than day 1. After 3rd and 4th week mean value was 0.009mg/m3 and 0.008mg/m3, which was lowered by 52.88% and 60.09% respectively as per day 1.

Table 2: Weekly percentage change in amount of formaldehyde in control room and experimental rooms

	Percentage change in formaldehyde					
Week	**RC(Control Room)**	**R1(Spider plant)**	**R2(Rubber plant)**	**R3(Bamboo palm)**	**R4(Snake plant)**	**R5(Boston fern)**
1stweek	11.54	15.87	7.14	24.49	6.77	-3.97
2nd week	26.92	46.83	38.57	68.08	51.88	46.03
3rd week	-1.48	52.86	51.08	66.10	52.88	48.28
4th week	1.60	74.07	61.61	73.30	60.09	62.80

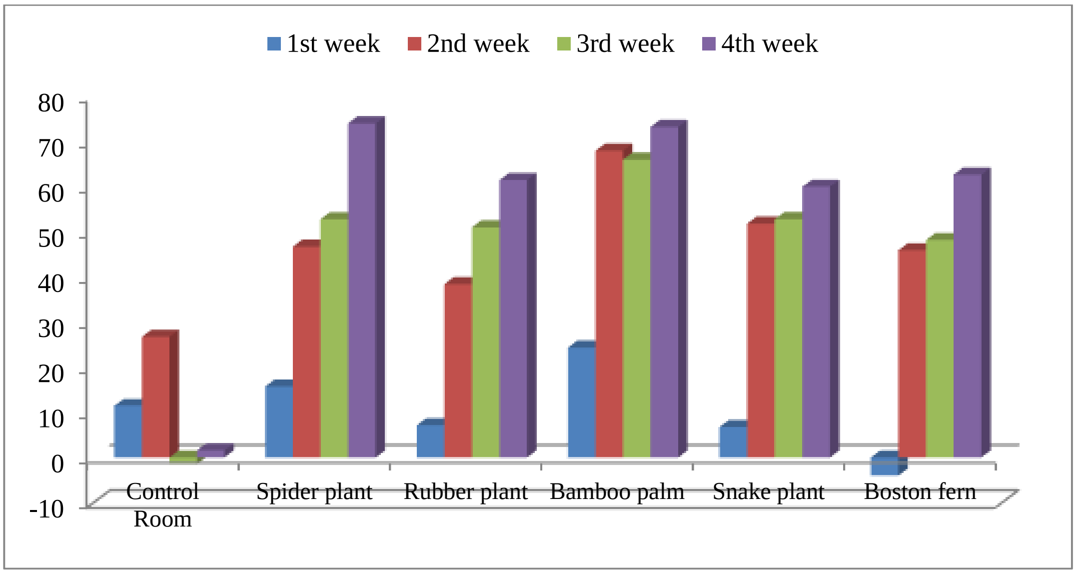

Fig 2: Weekly percentage decrease in amount of formaldehyde in control room and experimental rooms

Comparative analysis of amount of formaldehyde in control room and experimental rooms

Table 2 Fig: 2 contain the data on the change in concentrations of formaldehyde (HCHO) in all selected experimental five rooms in comparison with control room. There was wide change in level of formaldehyde in all five experimental rooms as compared to control room.

R1(room with spider plant): There was 34.16% decrease in amount of formaldehyde as compared to control room after a week, whereas with 2 plants of spider plants in a room formaldehyde decreased by 55.64% as compared to control room. There was 67.84% and 81.76% decrease in formaldehyde with 3 and 4 plants respectively as compared to control room.

R2 (room with rubber plant): There was 19.25 % decrease after 1st week as compared to control room. After 2nd, 3rd and 4thweek decrease was 35.34% , 62.92% and 69.99% respectively.

R3 (room with bamboo palm): There was 44.10% decrease as compared to control room after a week. After 2nd week there was 64.66% and decrease in formaldehyde and in 3rd and 4th week decrease was 73.02% and 78.08% respectively.

R4 (room with snake plant): There was 22.08%, 51.88%, 66.07%and 70.36% decrease in formaldehyde as compared to control room, after 1st2nd, 3rd and 4thweek respectively.

R5 (room with boston fern): In 1st week there was 16.48% decrease. After 2nd, 3rd and 4thweek there was 48.87%, 64.72% and 73.89% decrease in formaldehyde respectively in comparison with control room.

Maximum reduction in formaldehyde in indoors was with the use of spider plants. Hence, spider plant is best for reducing formaldehyde in indoor spaces. *Panyametheekul et al. (2019) found that* Boston fern showed the fastest decrease of the bulk-phase formaldehyde, the concentration was below the detection limit (< 0.01 ppm) after 2 h. After six hours, most plants taken for experiment removed more than 80% of the formaldehyde.

Table 3: Comparative analysis of the amount of formaldehyde in experimental rooms and control room

	Percentage change in formaldehyde in experimental room				
Week	**R1 (Spider plant)**	**R2 (Rubber plant)**	**R3 (Bamboo palm)**	**R4 (Snake plant)**	**R5 (Boston fern)**
1st week	34.16	19.25	44.10	22.08	16.48
2ndweek	55.64	35.34	64.66	51.88	48.87
3rd week	67.84	62.92	73.02	66.07	64.72
4th week	81.76	69.99	78.08	70.36	73.89

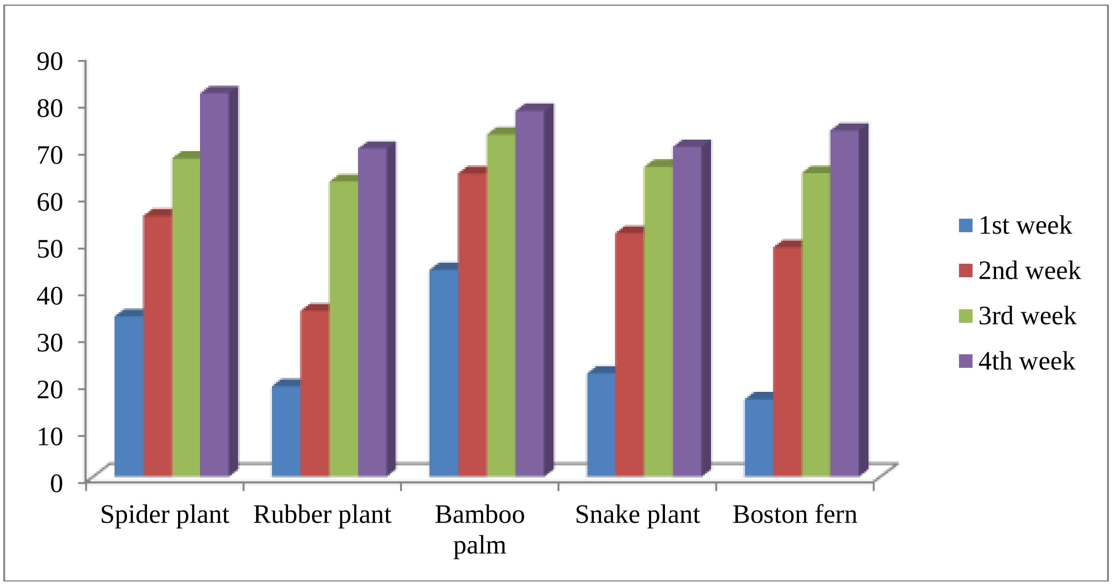

Fig 3: Percentage change in the amount of formaldehyde in experimental rooms in comparison with control room

Suspended particulate matter

Table 3 and fig: 3: present the day wise change and table 2 and fig: 2 depict the weekly change in the amount of suspended particulate matter (SPM) in control room and experimental rooms.

Rc (control room): On the day 1 level of suspended particulate matter was 118.833 µm/m^3. After a week the mean value of suspended particulate matter was 126.417 µm/m^3, which was6.38% more than day 1.After 2nd week mean level of suspended particulate matter the was 161.667 µm/m^3, which was 36.04 % more than day 1. After 3rd and 4th week level of suspended particulate matter increased by 33.46% and 70.92% respectively.

R1 (room with spider plant): On the day 1 level of suspended particulate matter was 123.833µm/m^3. After a week the mean value of suspended particulate matter was 123.691 µm/m^3, which was 0.11% less than day 1. After 2nd week mean level of suspended particulate matter was 119.751 µm which was 3.30% less than day 1. After 3rd and 4th week the level of suspended particulate matter reduced by32.18% and 50.02% respectively as compared to day 1.

R2 (room with rubber plant): On the day 1 level of suspended particulate matter was 127.987µm/m^3. After a week the mean value of suspended particulate matter was 125.774µm/m^3, which was 1.73% less than day 1. After 2nd week the level of suspended particulate was 118.921µm/m^3, which was 7.08 % that less than 1st week. After 3rd and 4th week the decrease in level of suspended particulate matter was 27.32 % and 32.71% respectively as compared to day 1.

R3 (room with bamboo palm): On the day 1 level of suspended particulate matter was 126.765µm/m^3. After a week mean value was 125.311µm/m^3, which was 1.15% less than day 1. After 2nd week the mean value was 121.395µm/m^3, which was 4.24% less than day 1. After 3rd and 4th week the mean value was reduced by 17.18% and 29.70% respectively in comparison with day 1.

Table 4: Day wise change in amount of suspended particulate matter in control room and experimental rooms (µm/m3)

No.	Day	Control room			Spider plant			Rubber plant			Bamboo palm			Snake plant			Boston fern		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1 plant	1	118.831			123.833			127.987			126.765			127.876			127.435		
	2	119.000	-0.167	-16.70	124.833	-1.000	-100.03	127.167	0.820	82.03	126.876	-0.111	-11.10	126.876	1.000	100.00	127.564	-0.129	-12.90
	3	119.000	-0.167	-16.70	123.333	0.500	50.00	127.123	0.864	86.40	126.124	0.641	64.10	126.124	1.752	175.20	127.987	-0.552	-55.20
	4	115.000	3.833	383.30	122.987	0.846	84.60	128.083	-0.096	-9.63	125.876	0.889	88.90	125.876	2.000	200.00	126.876	0.559	55.90
	5	126.000	-7.167	-716.70	123.876	-0.043	-4.30	125.987	2.000	200.00	125.763	1.002	100.20	125.763	2.113	211.30	126.987	0.448	44.80
	6	126.000	-7.167	-716.70	124.987	-1.154	-115.40	122.987	5.000	500.00	122.876	3.889	388.90	122.876	5.000	500.00	125.986	1.449	144.90
	7	131.833	-13.000	-1300.03	121.987	1.846	184.60	121.083	6.904	690.37	122.897	3.868	386.80	122.897	4.979	497.90	124.987	2.448	244.80
Average		**126.417(-6.38)**			**123.691(0.11)**			**125.774(1.73)**			**125.987(1.15)**			**125.470(1.88)**			**126.832(0.47)**		
2 plant	8	179.417	-60.584	-6058.37	122.764	1.069	106.90	122.876	5.111	511.10	123.987	2.778	277.80	123.987	3.889	388.90	125.765	1.670	167.00
	9	157.417	-38.584	-3858.37	121.232	2.601	260.10	123.098	4.889	488.90	123.123	3.642	364.20	122.984	4.892	489.20	122.876	4.559	455.90
	10	164.167	-45.334	-4533.37	120.543	3.290	329.00	122.987	5.000	500.00	122.321	4.444	444.40	122.321	5.555	555.50	122.543	4.892	489.20
	11	159.750	-40.917	-4091.70	118.987	4.846	484.60	121.987	6.000	600.00	121.432	5.333	533.30	121.432	6.444	644.40	120.083	7.352	735.17
	12	159.750	-40.917	-4091.70	118.874	4.959	495.90	119.873	8.114	811.40	120.234	6.531	653.10	120.234	7.642	764.20	120.083	7.352	735.17
	13	155.583	-36.750	-3675.03	117.872	5.961	596.10	119.786	8.201	820.10	119.324	7.441	744.10	120.765	7.111	711.10	119.987	7.448	744.80

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	14	155.583	-36.750	-3675.03	117.987	5.846	584.60	119.876	8.111	811.10	119.345	7.420	742.00	119.345	8.531	853.10	119.876	7.559	755.90
Average		**161.667(-36.04)**			**119.751(3.30)**			**118.92(7.08)**			**121.395(4.24)**			**121.581(4.92)**			**119.101(6.54)**		
3 plant	15	140.167	-21.334	-2133.37	119.321	4.512	451.21	117.325	10.662	1066.20	120.987	5.778	577.80	120.987	6.889	688.90	118.109	9.326	932.60
	16	172.250	-53.417	-5341.70	115.984	7.849	784.90	115.987	12.000	1200.00	120.987	5.778	577.80	120.987	6.889	688.90	115.654	11.781	1178.10
	17	132.250	-13.417	-1341.70	112.583	11.250	1124.97	109.983	18.004	1800.40	118.987	7.778	777.80	118.987	8.889	888.90	110.876	16.559	1655.90
	18	132.250	-13.417	-1341.70	109.987	13.846	1384.60	103.654	24.333	2433.30	112.987	13.778	1377.80	112.987	14.889	1488.90	108.876	18.559	1855.90
	19	169.000	-50.167	-5016.70	108.897	14.936	1493.60	101.832	26.155	2615.50	112.985	13.780	1378.00	112.985	14.891	1489.10	103.333	24.102	2410.17
	20	156.000	-37.167	-3716.70	107.987	15.846	1584.60	97.098	30.889	3088.90	111.765	15.000	1500.00	111.765	16.111	1611.10	101.987	25.448	2544.80
	21	208.250	-89.417	-8941.70	92.321	31.512	3151.20	93.094	34.893	3489.30	108.987	17.778	1777.80	108.987	18.889	1888.90	98.098	29.337	2933.70
Average		**158.595(-33.46)**			**83.987(32.18)**			**93.023(27.32)**			**104.987(17.18)**			**104.987(17.90)**			**98.121(23.00)**		
4 plant	22	234.583	115.750	-1157.03	81.098	42.735	4273.50	92.872	35.115	3511.50	102.987	23.778	2377.80	102.987	24.889	2488.90	97.109	30.326	3032.60
	23	206.917	-88.084	-8808.37	80.324	43.509	4350.90	90.231	37.756	3775.60	101.987	24.778	2477.80	101.987	25.889	2588.90	97.100	30.335	3033.50
	24	201.250	-82.417	-8241.70	79.098	44.735	4473.50	89.098	38.889	3888.90	100.876	25.889	2588.90	100.876	27.000	2700.00	96.876	30.559	3055.90
	25	197.583	-78.750	-7875.03	80.874	42.959	4295.90	89.543	38.444	3844.40	96.987	29.778	2977.80	95.987	31.889	3188.90	98.987	28.448	2844.80

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	26	191.667	-72.834	-7283.37	75.987	47.846	4784.60	88.732	39.255	3925.50	92.987	33.778	3377.80	94.098	33.778	3377.80	96.987	30.448	3044.80
	27	190.583	-71.750	-7175.03	63.167	60.666	6066.63	88.833	39.154	3915.37	90.456	36.309	3630.90	93.098	34.778	3477.80	95.123	32.312	3231.20
	28	199.167	-80.334	-8033.37	61.917	61.916	6191.63	86.925	41.062	4106.20	89.987	36.778	3677.80	93.120	34.756	3475.60	95.833	31.602	3160.17
Average		**203.107(-70.92)**			**61.897(50.02)**			**86.123(32.71)**			**89.120(29.70)**			**93.008(27.27)**			**94.876(25.55)**		

A=Level of suspended particulate matter,B=Change in amount of suspended particulate matter perday,C=Percentage change in amount of suspended particulate matter , (Figures in parenthesis indicate percentages)

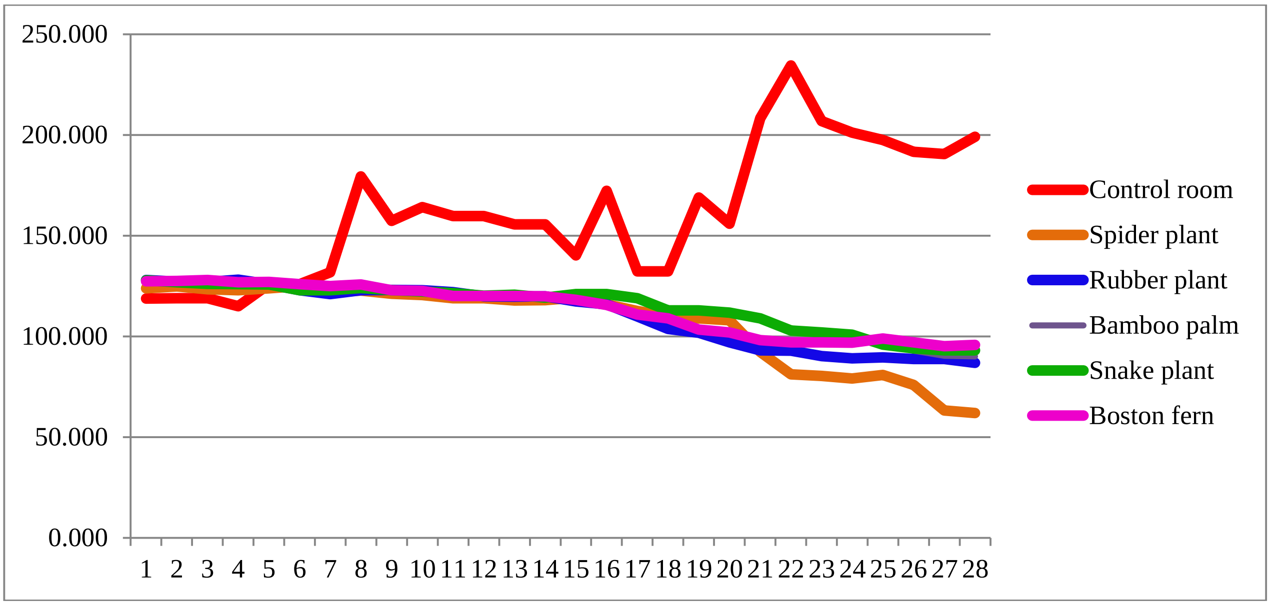

Fig 4:Day wise change in amount of suspended particulate matter in control room and experimental rooms.

R4 (room with snake plant): On the day 1 level of suspended particulate matter was 127.876µm/m^3, after a week the mean value was 125.470µm/m^3, which was reduced by 1.88%. After 2nd week mean value was 121.581µm/m^3, which was 4.92% less than day 1. After 3rd and 4th week mean value was 104.987µm/m^3,and 93.008µm/m^3, which was lowered by 17.18% and 27.27% respectively in comparison with day 1.

R5 (room with boston fern): On the day 1 level of suspended particulate matter was 127.832µm/m^3, after a week the mean value was 126.832µm/m^3, which was decrease by 0.47%. After 2nd week mean value was 119.101µm/m^3, which was 6.54% less than day 1. After 3rd and 4th week suspended particulate matter reduced by 23.00% and25.55%respectively.

Table 5: Weekly percentage change in amount of suspended particulate matter in control room and experimental rooms

	Percentage change in suspended particulate matter					
Week	**RC(Control room)**	**R1(Spider plant)**	**R2(Rubber plant)**	**R3(Bamboo palm)**	**R4(Snake plant)**	**R5(Boston fern)**
1stweek	-6.38	0.11	1.73	1.15	1.88	0.47
2ndweek	-36.04	3.30	7.08	4.24	4.92	6.54
3rdweek	-33.46	32.18	27.32	17.18	17.90	23.00
4thweek	-70.92	50.02	32.71	29.70	27.27	25.55

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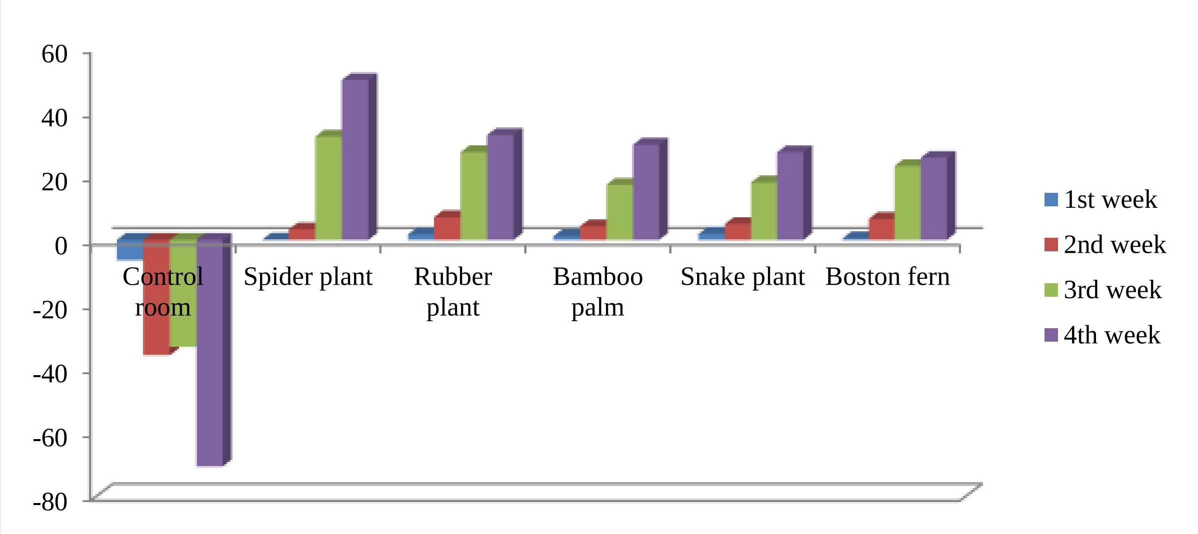

Fig 5: Weekly percentage change in amount of suspended particulate matter in control room and experimental rooms.

Comparative analysis in amount of suspended particulate matter in control room and experimental rooms.

Table 5 and Fig 5 contains the data on the on the concentrations of suspended particulate matter (micrometer) in experimental rooms with indoor plants and control room. There was wide change in all five rooms as compared with control room.

R1 (room with spider plant): There was 2.16% decrease in amount of suspended particulate matter as compared to control room after a week. However, with 2, 3 and 4 plants of spider plants suspended particulate matter decreased by 25.93%, 47.05% and 69.52% respectively as compared to control room.

R2 (room with rubber plant): There was 0.64 % decrease in suspended particulate matter after 1st week as compared to control room. After 2nd week there was 42.746% decrease in as comparison with control room. Whereas, suspended particulate matter decreased by65.572% and 67.59% in 3rd and 4th week respectively in comparison with control room.

R3 (room with bamboo palm): There was 0.87% decrease as compared to control room after 1st week. After 2nd week the decrease33.17% which increased to 33.80% and 56.12 respectively after 3rd and 4th week respectively as compared to control room.

R4 (room with snake plant): There was 0.75% ,24.80% ,33.80% and 54.21% decrease in suspended particulate matter in 1st, 2nd , 3rd and 4th week respectively in comparison with control room.

R5 (room with boston fern): After 1st week there was 0.33% increase as compared with control room. After 2nd week there was 26.32% decrease in suspended particulate matter morever38.13% and 53.29% decrease in 3rd and 4th week respectively in comparison with control room. Highest reduction in the suspended particulate matter was in the room having spider plant. Hence, spider plant is best for decreasing the level of suspended particulate matter from indoor spaces.

Table 6:Comparative analysis of the amount of suspended particulate matter in experimental rooms and control room.

	Percentage change in suspended particulate matter				
Week	**R1 (Spider plant)**	**R2 (Rubber plant)**	**R3 (Bamboo palm)**	**R4 (Snake plant)**	**R5 (Boston fern)**
1st week	2.16	0.64	0.87	0.75	-0.33
2nd week	25.93	42.74	33.17	24.80	26.33
3rd week	47.04	65.57	33.80	33.80	38.13
4th week	69.52	67.12	56.12	54.21	53.29

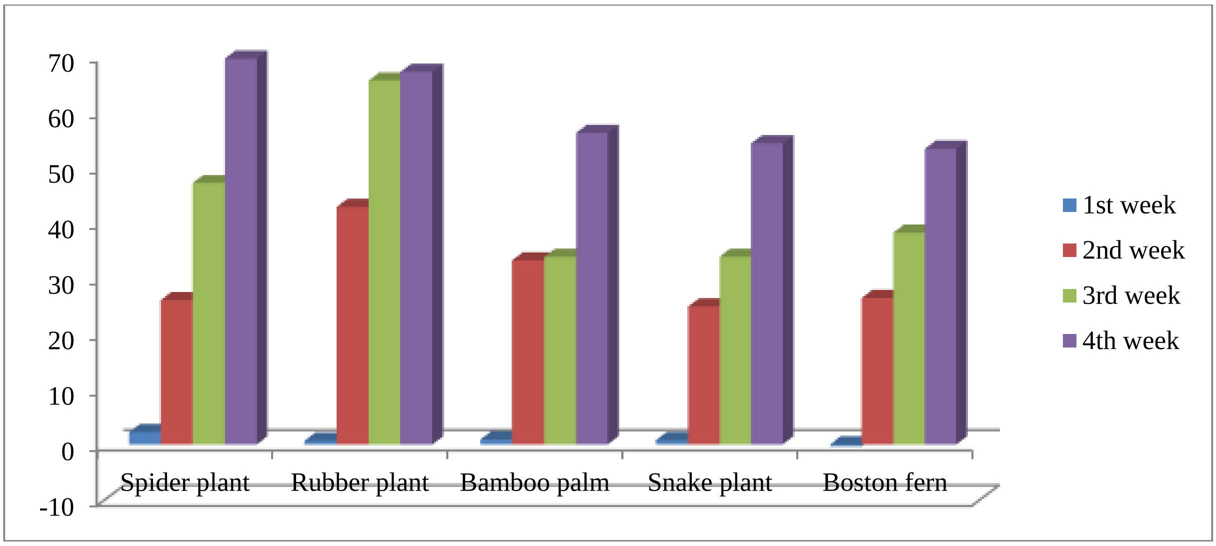

Fig 6: Percentage change in the amount of suspended particulate matter in experimental rooms and control room.

DISCUSSION

Assessment of the indoor air quality through use of plants

From the present investigation it can be concluded that there is an immediate need for improving indoor air quality for wellbeing. Indoor air quality is an international health issue, since city dwellers spend 90% of their time indoors.

This study aimed at providing an overview of indoor SPM (suspended particulate matters) and formaldehyde removal by plants.

As consider the current scenario of the air pollution in the world, there is a growing need for planting ornamental plants which have the maximum capacity to reduce indoor air pollution. The data on the concentrations of suspended particulate matter revealed that suspended particulate matter was reduced in experimental rooms in comparison with control room. In control room after 1st week suspended particulate matter increased by 6.38%, while in R1, R2, R3, R4 and R5 the decrease after a week in comparison to day 1 was 0.11%, 1.73%,1.15%, 1.88% and 0.47%, respectively. In Rc (control room) level of suspended particulate matter after in 4th week increased by 70.92%.The decrease in the suspended particulate matter after 4 weeks was maximum in room having spider plant (50.02%) followed by 32.71% room having rubber plant. The similar results were supported by Seung-Han Hong et al (2017) that is PM 2.5-PM10 reduced up to 50% naturally through use of rubber plant and spider plant. H. Gawrońska et al (2014) also reported that SPM accumulate from indoors through use of spider plants. However in rooms with bamboo palm, snake plant, and boston fern suspended particulate matter come down 29.70%, 27.27% and 25.55% respectively. Likewise Chieraf et al (2011) reported that PM 2.5 in indoors was reduced up to 7% (30µg/m^3) in 2 weeks due to use of bamboo palm in interior. After 3rd and 4th week it reduced by 17.18% and 29.70% respectively in comparison with control room.

There was 2.16% decrease in amount of suspended particulate matter as compared to control room after a week in R1. Though with the use of one plant each in R2, R3 and R4 decrease in amount of suspended particulate matter was 0.64 %, 0.87% and 0.75% respectively in comparison to control room but in R5 after 1st week there was 0.33% increase as compared to control room.

However in rooms with snake plant and boston fern decrease was 54.21% and 53.29% respectively. Biebyvoijant et al (2011) also reported that snake plant reduced 38.89% PM2.5 from interiors in comparison with the room where plants were not kept.

CONCLUSION

Hence it can be concluded that use of indoor plants reduces the level of suspended particulate matter the results were in line with Pegas et.al.2012 that the presence of potted plants likely favored a decrease of about 30% in PM10 concentrations highest reduction in the suspended particulate matter was in the room having spider plant. Correspondingly Lohret al. (1996) reported that the presence of foliage plants in interior spaces change particulate matter (PM) accumulation: accumulation was lower in rooms where plants were present than where plants were absent.

From the present investigation it can be concluded that there is an immediate need for improving indoor air quality for wellbeing. Indoor air quality is an international health issue, since city dwellers spend 90% of their time indoors.

This study aimed at providing an overview of indoor SPM (suspended particulate matters) removal by plants.

Suggestions

- Indoor air pollutant should be removed by using indoor plants as these are the best natural way for removal of dangerous indoor gases and particulate matter.

For improving the air quality in term of formaldehyde of indoor space of size 8×8 ft four plants of spider plants should be used.

References

Asnani B 2004. Information employment of urbon women regarding bioqesthetical and functional uses of houseplants. Unpublished masters thesis Maharana Pratap University of Agricultural Technology, Udaipur.

Abed Esfahani A., 2013. Assessemnt of air pollution tolerance index of higher plants suitable for green belt development in East of Esfahan city, Iran. *Jouranal of Ornamental Horticultural Plants*.3(2):87-94.

A.P.Weerakkodya , T.K.Weerasingheb* ,N.S.Gamagea , R.P.P. M. Dilrukshib , K.G.N.H.Weerasingheb, 2016, Effectiveness Of Environmental Pollution Control Measures Implemented In Stone Crushing Sites Located At Kaduwela Municipality, Sri Lanka, *J. International Journal of Environment and Pollution Research*, 3(5):24-30.

Adamkiewicz, G. 2014. Indoor air quality in green vs conventional multifamily low income housing. *Journal of Environmental science & technology*,**48**(14), 7833-7841.

Belayneh.,2012. Benefits of Medicinal Plants, *Journal of Ethnobiological Ethnomedicine*. 201 (22),8:42-51

Bieby Voijant Tangahu., Siti Rozaimah Sheikh Abdullah., Hassan Basri., Mushrifah Idris, Nurina Anuar and Muhammad Mukhlisi. 2011.*International Journal of Chemical Engineering***5**(21):31-40.

Bortolotto A., Hartig T and Pinto 2015, Medicinal and wild edible plants. Journal of Medicinal plants. 24(3)210-217.

Cheikhyoussef., Shapi M., Matengu K and Ashekele HM.,2011. Ethnobotanical study of indigenous knowledge on medicinal plant use by traditional healers in Oshikoto, Namibia. *Journal of Ethno medical* 5 (4): 406-419.

Edmund Emeka Emodi, 2020, Environmental Quality Of Enugu, Nigeria As Impacted By The Primary Air Pollutants In The Area, *J. International Journal of Environment and Pollution* Research 8(4):1-20.

Gawrońska., B. Bakera, *2015* Indoor air pollutant and respiratory problem. *Journal of Air Quality Atmosphere Health.; 8(3): 265–272.*

Justine T. Nwanakwere and Joan I. Oyedokun .2020, Community Perception on Air Pollution And Public Health: A Case Of Ewekoro And Remo-North Communities In Ogun State, Nigeria, *J. International Journal of Environment and Pollution Research*, 8(1):1-16.

Kalevi Korpela Jessica De, Bloom Marjaana, Sianoja Tytti Pasanen, Ulla Kinnunen , 2017 *Journal of Landscape and Urban Planning* 160(4):38-47.

Kausalya Janardan, 2019. Indoor air quality. *Journal ofBotanical Science Environment Health.3 (4):122-135.*

Lohr VI., Pearson-Mims CH., Goodwin GK., (1996) Interior plants may improve worker productivity and reduce stress in a windowless environment. *Journal of Environment and Horticulture*. 14(4): 97–100.

Lopez, JM, 2005. Levels of selected metals in ambient air PM10 in an urban site of Zaragoza (Spain). *Journal of Environment Research.*;99(2):58-67.

Lee, M.S., Lee, J., Park, B.J. & Miyazaki, Y. (2015) Interaction with indoor plants may reduce psychological and physiological stress by suppressing autonomic nervous system activity in young adults: a randomized crossover study. *Journal Physiology Anthropology*.**34**(1), 21-29.

Micheal., Gabriela Berg., Martin Grude and Kornelia Smalla, 2012.The plant microbiome and its importance for plant and human health. *Journal of Frontiers of Microbiology*, 5(491):491.

Muller R. 2014, Can ornamental potted plants remove volatile organic compounds from indoor air? — a review 21(24)13909–13928.

Majbrit Dela Cruz, 2014. Can ornamental potted plants remove volatile organic compounds from indoor air? — a review. *Journal of Environmental Science Pollution Research.* 12(2):1-20.

Park S H and Mattson RH 2009 ornamental indoor plants in hospital room enhanced health outcomes of patients recovring from surgery. *Journal of Alternative Com peremptory* medicine. 15(3):975-80

Pegas. P.N., Alves C.A., Nunesa T., Bate-Epey E., Evtyugina F., M., PioC.A. 2012 could houseplants improve indoor air quality in schools?*Journal of Toxicology and Environmental Health***75**(22-23):1371-80.

Panyametheekul,S, Thanakorn Rattanapun, T., John Morris, J. , Maneerat Ongwandee, M. 2019 Foliage houseplant responses to low formaldehyde levels. *Journal ofBuilding and Environment*. 1 (147): 67–76.

Reynolds, 2002, Determination of the size distribution of liposomes by SEC fractionation, and PCS analysis and enzymatic assay of lipid content, *Journal of AAPS PharmSciTech.* 3(2):9-15.

Ryan, Catherine O., Browning, William D., Clancy, Joseph O., Andrews, Scott L., Kallianpurkar, Namita B. 2014. "biophilic design patterns: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment". *International Journal of Architectural Research: Archnet-Ijar. 8 (2): 62.*

Sindhu H and Eapen E 2000. Designer with a green thumb. Inside outside. Business India Publications Ltd. Mumbai.

Singh R 2003. A home garden. Women's Era. Delhi press building, New delhi.

Sandeep Kar., 2010. Metallic components of traffic induced urban aerosol, their spatial variation and source apportionment. *Journal of Environment Monitoring Assessment*. 168(2):561-574.

Seung-Han Hong., Dong-Chun Shin., Yong-Jin Lee., Se-Hyung Kim and young wook lim , 2017, Health risk assessment of volatile organic compounds in urban areas, Journal Human and Ecological Risk Assessment: An International Journal 23(6):24-35.

Upadhyay J., Kobayashi N., (2007). Phytomonitoring of air pollutants for environmental quality management. Environmental bioremediation technologies. Berlin Heidelberg New York: Springer-Verlag: .34(5):275–292.

Van der Wat L., Forbes PBC., 2015. Lichens as biomonitors for organic air pollutants. *Journal of Agricultre*.(64): 165–172.

Van Renterghem T, Botteldooren D and Verheyen K.2012. Road traffic noise shielding by vegetation belts of limited depth. *Journal of Sound Vibration.* 2(331): 2404–2425.