

Full Length Research Paper

Correlation between some components of interior plants and their efficiency to reduce Formaldehyde, Nitrogen and Sulfur Oxides from indoor air

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Abstract

Air pollution has become an extremely serious problem on human health especially in developing countries. Sixteen ornamental plant species commonly used for interior plantscapes were screened for their ability to remove three common indoor pollutants of formaldehyde, nitrogen oxides (NO_x) and sulfur oxides (SO_x). Also, some components of the selected plants such as, ascorbic acid, chlorophyll, pH, relative water content, leaf osmotic pressure as well as stomatal number, length and width on the lower and upper leaf surfaces were assessed to determine the relationship between these components and plant removal efficiency. Among the tested plants, *Chlorophytum comosum Variegatum* displayed superior removal efficiency for HCHO and SO_x as 1830 µg day⁻¹ and 2120 µg day⁻¹ and *Spathiphyllum wallisii* for NO_x as 3200 µg day⁻¹. Also, it was found that stomatal density can be used as an indicator for the efficiency of indoor plants in the absorption of air pollutants; especially for HCHO, SO_x or NO_x.

Keywords: Indoor pollutants; interior plants; HCHO; SO_x; NO_x; stomata; APTI

INTRODUCTION

Indoor air, being the lifeline for building occupants, should be protected from the harmful effect of pollution (World Health Organization, 2011). The air pollutants or substances selected for this study, formaldehyde (HCHO), nitrogen oxides (NO_x), and sulfur oxides (SO_x) are common indoor air pollutants. HCHO is a pungent gas that can irritate a person's eyes, nose, throat, and lungs. The risks posed by air pollutants are to lung disease, including respiratory tract infections, asthma, and lung cancer (Public Health Agency of Canada, 2005). The risk of formaldehyde poses to a person's health depends on the concentration of HCHO in the air, the length of exposed, and the person's individual sensitivity to HCHO. The American Air Resources Board has identified formaldehyde as a toxic air contaminant, based on its potential to contribute to cancer risk (Granholm, 2004). Reducing indoor formaldehyde from

indoor air will reduce the risks to human (World Health Organization, 2011).

Nitrogen dioxide (NO₂) acts mainly as an irritant affecting the mucosa of the eyes, nose, throat, and respiratory tract. Extremely high-dose exposure (as in a building fire) to NO_x may result in pulmonary edema and diffuse lung injury. Continued exposure to high NO_x levels can contribute to the development of acute or chronic bronchitis. Low level of NO_x exposure may cause increased bronchial reactivity in some asthmatics, decreased lung function in patients with chronic obstructive pulmonary disease and increased risk of respiratory infections, especially in young children. In homes with gas stoves, kerosene heaters, or un-vented gas space heaters, indoor levels often exceed outdoor levels (Kornartit et al., 2010). Generally, the risk of pollutants poses to a person's health depends on the concentration, the length of exposed, and the person's individual sensitivity (World Health Organization, 2002).

Health effects caused by exposure to high levels of SO_x include breathing problems, respiratory illness, changes in the lung's defenses, and worsening

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respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are the most sensitive to SO_x (Chapd, 2010). Indoor plants are a healthy option to reduce formaldehyde by helping cleanse the breathing space, besides; reducing indoor NO_x and SO_x are a significant goal for interior landscapers, through using the selection of highly efficient plants to reduce the risk to human health (Xu et al., 2011).

The most important step to reduce exposure to the selected pollutants HCHO, NO_x and SO_x is to increase indoor air quality through reducing levels of these pollutants, while at the same time reducing indoor CO₂. The most promising method to achieve this aim is by using suitable indoor plant species (Burchett et al., 2007).

The responses of plants to pollutants may provide a simple link concerning phytoremediation of air pollutants to admit air pollution abatement. To develop the use of plants as phytoremediators it requires an appropriate selection of some plant constituents or characters to be investigated. This study is based on the approach of Singh et al., 1991, which was directed to outdoor air pollution responses. The researchers developed a method of using plants to indicate severity of urban air pollution by deriving an Air Pollution Tolerance Index (APTI). The APTI for each species tested involved measurements that were carried out on levels of ascorbic acid, chlorophyll a and b, relative water content, and leaf extract pH. These characters were studied in this work as well as osmotic pressure of leaf sap, stomatal density, stomata length and stomata width in both sides of plant leaves of the selected indoor foliage plants.

It is evident that a better understanding of the phytoremediation potential of a diverse range of indoor plants is also needed. In this study, a cross-section of indoor plants, sixteen species were tested for these properties for the first time, these being among the most commonly used international species and for interior landscapes. The species were screened for their ability to reduce HCHO, NO_x and SO_x and were also analyzed to find the relationships between some of plant components and plant efficiency to air pollution abatement.

Material and Methods

Plants material and growth conditions

Dieffenbachia picta, *Epipremnum aureum*, *Codiaeum variegatum*, *Cordyline terminalis*, *Spathiphyllum wallisii*, *Euonymus japonicus*, *Syngonium podophyllum*, *Aglaonema pictum*, *Ruscus hypoglossum*, *Chlorophytum comosum*, *Dracaena marginata*, *Yucca elephantipes*, *Sansevieria trifasciata*, *Schefflera actinophylla*, *Chlorophytum comosum Variegatum* and *Ficus benjamina* (Table 1) were obtained from commercial

source. Similar individuals of each species were chosen as replicates. Plants were individually planted in 18-cm-diameter pots containing a standard potting medium. The plants were acclimated for several weeks to approximately the same environmental conditions of lighting, temperature, relative humidity, etc., in order to minimize stress.

Gases exposure and monitoring

Individual plants were placed in a growth chamber. It is a 250 L gas-tight test chambers covered with 100 micron plastic. The growth chamber exposed to 50 fold normal pollutant concentrations as 3000 µg/m³, 5000 µg/m³ and 4000 µg/m³ of HCHO, NO_x and SO_x, respectively. Plants were individually placed in the chamber, and then injected with either HCHO or NO_x or SO_x. Plants were left in the chambers for 24 hours. Three replications of each species were tested. An empty chamber was injected with each pollutant and left without plants as a control. The gas concentration within the chamber was determined after 24 h and compared with the control.

A randomized complete design was used with three experiments. Each experiment consisted of the individual pollutant and the tested species.

APTI values were determined by calculating the ascorbic acid, chlorophyll, pH and relative water contents in leaf samples. Ascorbic acid was estimated by 2, 6 - dichlorophenol indophenol dye following the method of (Madhoolika, 1985). Chlorophyll was calculated by spectrophotometer and pH was determined by digital pH meter. Relative water content of leaf material was estimated by taking the initial weight and dry weight of leaf material. The air pollution tolerance indexes were determined following the method of (Singh and Rao, 1983), the formula being as follows:

$$APTI = [A (T+P) + R]/10$$

Where A = ascorbic acid content (mg/g), T = total chlorophyll (mg/g), P = pH of leaf extract, and R = relative water content of leaf (%).

The stomata numbers were measured from an imprint of the lower and upper leaf surface peeling it off (Hamill et al., 1992). The stomata density was measured at 100x magnification per cm².

Total soluble solids (TSS) were determined by refractometer (stalks) according to Association of Official Analytical Chemists, (1996). Leaf osmotic pressure was calculated by multiplying total soluble solids in leaf sap by the factor 0.36 (William, 1980).

RESULTS AND DISCUSSION

The results showed that the removal efficiency of each gas pollutant by the studied plants varied according to the pollutant and the species. The ability of every indoor plant to remove HCHO, NO_x and SO_x from sealed

Table 1. Family, Latin binomial, common name, and Leaf area of test plants exposed to three indoor air pollutants (Formaldehyde, Nitrogen and sulfur oxides) over 24 hours

No.	Family	Latin binomial	Common name	Leaf area (m ² /plant)
1	Araceae	<i>Dieffenbachia picta</i> Jacq	Dumb cane	0.06
2	Araceae	<i>Epipremnum aureum</i>	Pothos	0.06
3	Euphorbiaceae	<i>Codiaeum variegatum</i> L.	Croton	0.02
4	Agavaceae	<i>Cordyline terminalis</i>	Hawaiian Ti	0.05
5	Araceae	<i>Spathiphyllum wallisii</i> Regal	Peace lily	0.11
6	Celastraceae	<i>Euonymus japonicus</i>	Japanese Spindle	0.04
7	Araceae	<i>Syngonium podophyllum</i> Schott	Arrowhead vine	0.10
8	Araceae	<i>Aglaonema pictum</i> (Roxb.) Kunth	Chinese evergreen	0.28
9	Asparagaceae	<i>Ruscus hypoglossum</i>	Mouse Thorn	0.23
10	Asparagaceae	<i>Chlorophytum comosum</i> Thunb	Spider plant	0.13
11	Agavaceae	<i>Dracaena marginata</i>	Red-edge Dracaena	0.15
12	Agavaceae	<i>Yucca elephantipes</i>	spineless yucca	0.18
13	Agavaceae	<i>Sansevieria trifasciata</i> Prain	Snake plant	0.39
14	Araliaceae	<i>Schefflera actinophylla</i> (Hayata) Merr	Dwarf Umbrella Tree	0.13
15	Asparagaceae	<i>Chlorophytum comosum</i> Variegatum Thunb	spider plant	0.29
16	Moraceae	<i>Ficus benjamina</i> L.	Weeping fig	0.31

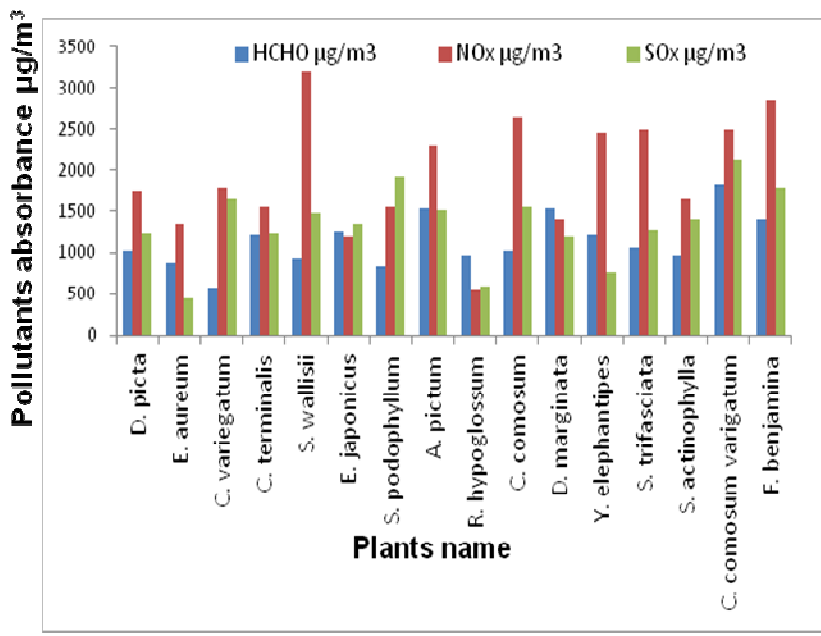


Figure 1. Removal of HCHO, NO_x and SO_x from the air inside sealed experimental chambers using test plants

experimental chambers are demonstrated in Figure. 1. *Chlorophytum comosum variegatum*, *D. marginata* and *A. pictum* plants were more efficient in reducing HCHO. Meanwhile, *S. wallisii*, *F. benjamina* and *C. comosum* absorbed more NO_x than the other tested plants and *C. comosum variegatum*, *C. variegatum*, *S. podophyllum* removed more SO_x than the other species.

APT_I values were calculated for the tested plants in an effort to find a relationship between the removal

efficiency of studied plants and these biochemical parameters that could indicate the tolerance or sensitivity to the contaminants (Table 2 and Figure. 2). It is clearly shown that there was no specific trend in this concern.

Air pollutants may get absorbed, accumulated, metabolized or integrated in the plant metabolism. Besides, it may be toxic or injury plants in various ways depending on plant species and pollutant type and

Table 2. Stomata density, stomata length, stomata width, total soluble solids, osmotic pressure and air pollution tolerance index of tested plants exposed to three representative indoor air pollutants (Formaldehyde, Nitrogen and sulfur oxides) over 24 hours

Plant	Stomata density/ cm ²	Stomata length μm	Stomata width μm	TSS	O P	APTI
<i>D. picta</i>	3700	64.13	31	3	1.08	13.95
<i>E. aureum</i>	3900	30.32	13.55	3	1.08	11.92
<i>C. variegatum</i>	16400	37.13	25.7	6	2.16	13.04
<i>C. terminalis</i>	11000	25.84	15.81	7	2.52	12.29
<i>S. wallisii</i>	7900	43.28	24.65	4	1.44	13.13
<i>E. japonicus</i>	24500	27.14	18.57	5.5	1.8	13.47
<i>S. podophyllum</i>	9500	27.29	12.12	3.2	1.15	11.48
<i>A. pictum</i>	4800	55.43	33.24	2	0.72	12.37
<i>R. hypoglossum</i>	6000	24.59	16.72	5	1.8	14.53
<i>C. comosum</i>	10800	39.36	14	1.9	0.68	11.21
<i>D. marginata</i>	10200	37.41	34.29	2.9	1.04	15.92
<i>Y. elephantipes</i>	9000	35.71	31.43	10.6	3.81	39.21
<i>S. trifasciata</i>	4700	38.57	25.71	4.1	1.47	13.87
<i>S. actinophylla</i>	14900	28.71	14.62	5.9	2.12	13.79
<i>C. comosum variegatum</i>	12600	47.44	26	1.8	0.64	11.06
<i>F. benjamina</i>	21800	35	18.48	6	2.16	14.56

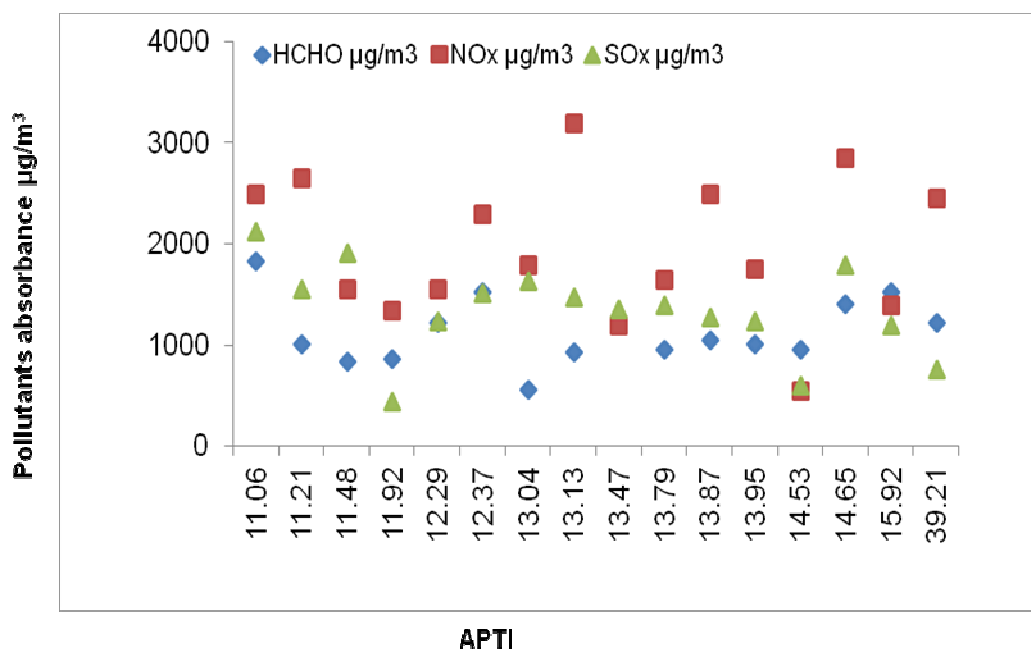


Figure 2. Relationships between plant efficiency to remove HCHO, NO_x and SO_x and APTI of test plants

concentration. The sensitive species may be used as air pollution indicator. On the other hand the presented data of the APTI components and plant morphology indicated that there are relationships between APTI and plant tolerance or sensitivity to the pollutants. In the present study, out of Sixteen species examined, *Y. elephantipes*, *D. marginata*, *F. benjamina* and *R. hypoglossum* showed their tolerance to the tested air pollutants, since exposure to the pollutants did not result in any apparent damage to these four species. On the same time, the remaining plants species showed varying degrees of

sensitive responses when exposed to the studied pollutants. The levels of injuries depend on the species. The types of injury resulting from pollutant exposure are exemplified in Figures. 7 and 8.

SO_x injury appears as large brown area or yellow areas changes to brown areas in both sides of the leaf shown in Figure. 7. While symptoms of NO_x injury have included chlorosis, there are different foliar symptoms as shown in Figure. 8.

The results shown in Table 2 also, indicated that there were no relationships evident between the studied

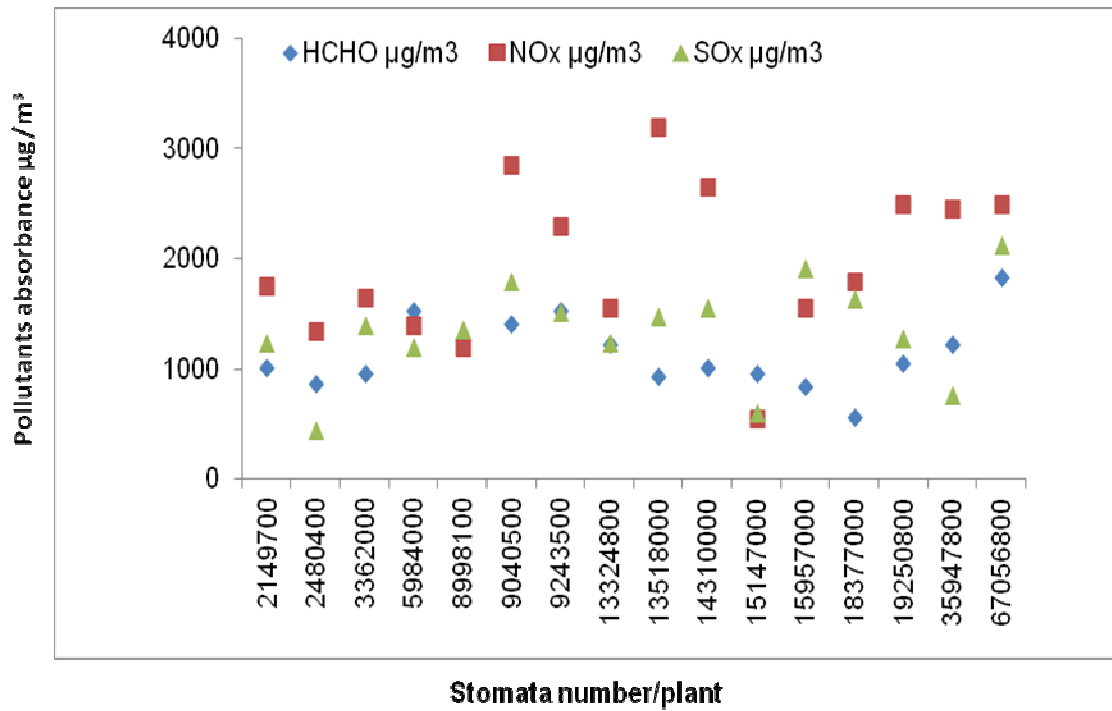


Figure 3. Relationships between plant efficiency to remove HCHO, NO_x and SO_x and stomata number of test plants

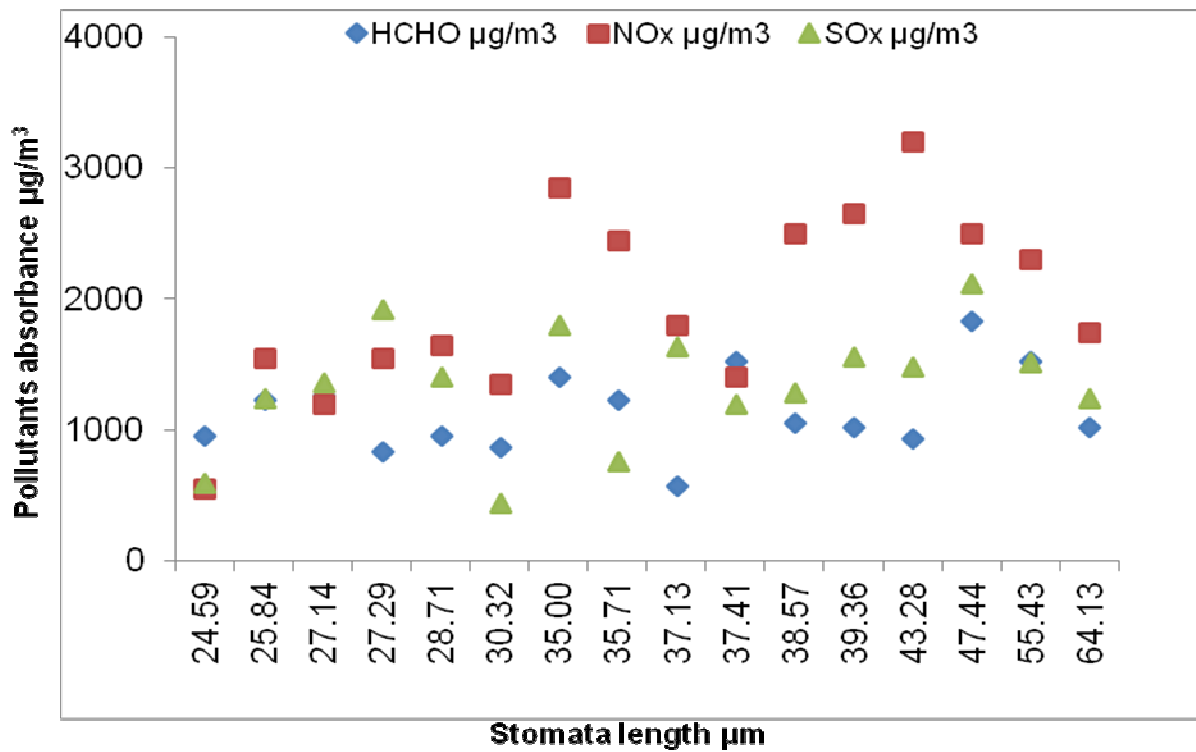


Figure 4. Relationships between plant efficiency to remove HCHO, NO_x and SO_x and stomata length (µm) of test plants

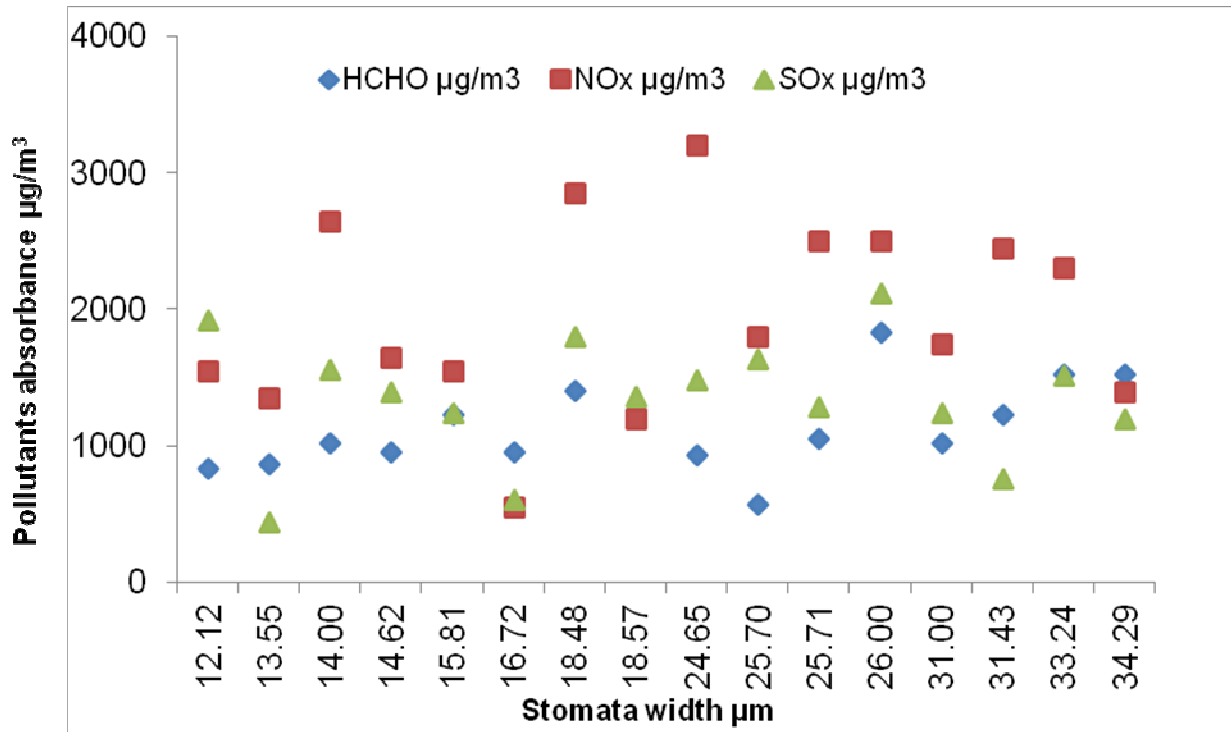


Figure 5. Relationships between plant efficiency to remove HCHO, NO_x and SO_x and stomata width(µm) of test plants

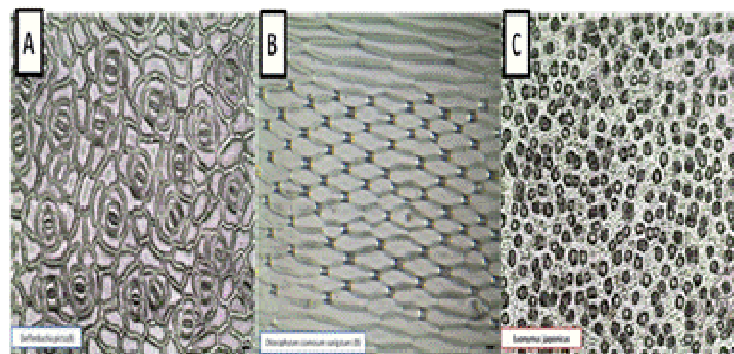


Figure 6. Various types of stomata density, length and width of *D. picta* (A), *C.comosum variegatum* (B) and *E. japonicus* (C) bar 50 µm

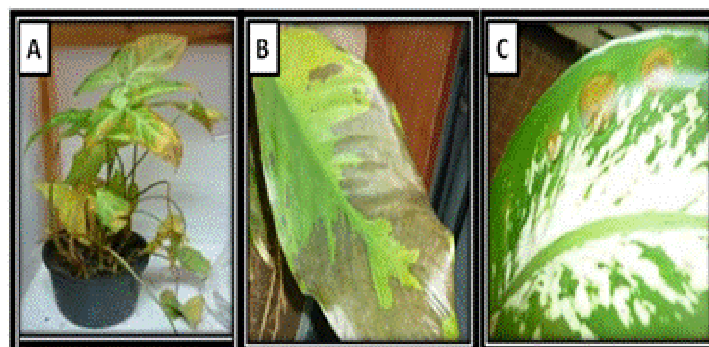


Figure 7. SO_x injury on leaves of *S. podophyllum* (A), *S. wallisii* (B) and *D. picta* (C).

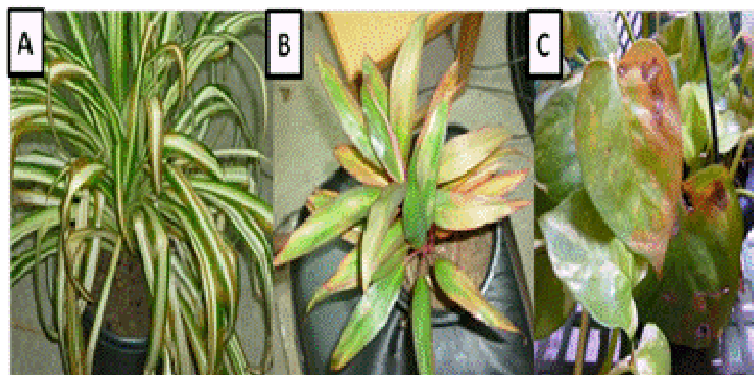


Figure 8. NO_x injury on leaves of *C. comosum variegatum* (A), *C. terminalis* (B) and *E. aureum* (C)

pollutants HCHO, NO_x and SO_x and the studied plant characters or components as TSS and, OP. The data from the same Table 2 indicated that there was a parallel link between pollutants abatement from the growth chamber and stomata density on both sides of leaves. Figures. 3 and 6 showed a close parallels between pollutant abatement and stomata number per plant ($r = 0.48, 0.32, 0.36$ for HCHO, NO₂ and SO₂ respectively). The results are in harmony with those of Martin et al., (2002) which indicated that there stomatal responses were involved in responses to the pollutant SO_x. They are also in line with the finding of Papinchak et al., (2009), they revealed that the plant's ability to reduce pollutants from surrounding environment appears to be depending on the uptake of pollutants through the stomata. Also, Sukumaran, (2012) concluded that the differences between plants in their stomatal number were found to be significant in pollutants uptake efficiency. The results also indicated that there were a relationship between HCHO, NO_x and SO_x abatement and either stomata length and width as shown in figures 4 and 5.

In summary, the results of this study confirm that the competencies of the plants under investigation were clearly linked to some characteristics or components of the plant, in particular the stomatal density, length and width of their foliage. Therefore, stomata number per plant can be used for primary rudimentary knowledge about the efficiency of specific plant for indoor air pollution abatement. Also, this work is in accordance with the results of the previous work by Boubel, et al., (2008) where the indoor plants showed efficiency in decreasing the concentration of specific indoor pollutants. The investigation has also provided information on the efficiency of the plants to remove these pollutants, and helps lay the foundation for developing enhanced efficiency among houseplants for air pollution removal. More researches are required with other species, to investigate the linkage between this leaf characteristic and possible removal of other air pollutants.

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