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Phytoremediation of Formaldehyde in Indoor Environment With Common House Plants and Pseudomonas Chlororaphis

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ABSTRACT

Low light survivor house plants were assessed for their formaldehyde removal capacity from indoor environment. Low ventilation leading to poor air circulation in indoor environment has become a matter of grave concern as it leads to health issues. Phytoremediation technology is being studied in such situations. The capacity of plants in absorbing indoor pollutants can be enhanced through use of bacteria helping phytoremediation process. The gaseous formaldehyde of about 5 ppm was released into the static chamber of volume 1 m^3. Selected test plants were *Aglaonema commutatum*, *Chlorophytum comosum*, *Sansevieria trifasciata* and *Epipremnum aureum*. Medium in which plants were growing was inoculated with *Pseudomonas chlororaphis*, which helps the process of phytoremediation. Activated charcoal was also added in the medium, to increase the absorptive surface. The exposure given was for 24 hours. Experiment was replicated for three times. Air quality in the chamber was monitored on advanced Formaldehyde meter, at the start of the experiment and after 24 hours. Leaves of the plants were analysed by DNPH on LCMS method for quantification of Formaldehyde. Quantification of Formaldehyde from leaves ranged between 0.03–4.7 ppm. Formaldehyde meter showed reduction in formaldehyde quantity ranges from 1.999 to 0 ppm in 24 hours. This clearly indicates that selected plants have enhanced limited capacity of formaldehyde absorption in synergy with *Pseudomonas chlororaphis*.

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Introduction

Indoor air pollution is a major global public health threat. It is up to 12 times higher than the outdoor air pollution. Indoor air quality has become a growing concern due to the increasing proportion of time people spend indoors, combined with reduced building ventilation rates resulting from an increasing awareness of building energy use [1].

Formaldehyde (HCHO) is a common indoor air pollutant which is released through many household sources. It is a gas in its natural state. Formaldehyde levels ranges from 0.10 to 3.68 parts per million (ppm) in homes. Higher levels have been found in new manufactured or mobile homes than in older conventional homes. The permissible exposure limit (PEL) for Formaldehyde in the workplace is 0.75 parts Formaldehyde per million parts of air (0.75 ppm) measured as an 8-hour time-weighted average [2].

Many building products, many wood-based structures release formaldehyde gas [3]. It is also released through perfumes, room spray, smoke from mosquito coils and incense sticks [4]. Formaldehyde is an important base chemical in the process industry [5]. Formaldehyde can cause sensory irritation and nasopharyngeal cancer. It has a 30-min average concentration guideline value of 0.1 mg/m3 [6]. Formaldehyde is dangerous due to carcinogenic effects on human being.

A substantial body of literature has demonstrated the ability of the potted-plant system to remove volatile organic compounds (VOCs) from indoor air. These findings have largely originated from laboratory scale chamber experiments, with several studies drawing different conclusions regarding the primary VOC removal mechanism, and removal efficiencies [7].

Many potted house plant species have the ability to absorb VOCs from indoor air [8]. The plants act as 'sinks' and consequently reduce the VOC concentration in the air. Psychological and social benefits for humans are also correlated with house plants [9,10].

Plants are known to absorb gaseous Formaldehyde and can metabolize it. The pollutant enters plant leaves through stomata and cuticles. It is also absorbed by the abaxial surface of leaves and even younger leaves. Once absorbed by the leaves, it generally enters the Calvin cycle after a two-step enzymatic oxidation to CO_2 Approximately 60% to 90% of 14C-Formaldehyde was recovered from the plants [11]. Microorganisms found in the potting mixture of indoor plants are also involved in the removal of VOCs. Plants excrete significant amounts of carbon into the root zone that stimulates the development of microorganisms in the rhizosphere [12].

This paper presents the result of studies on the ability of four low light survivor house plants, to absorb formaldehyde in the indoor environment. Quantification studies by DNPH using LCMS are also carried out to know the exact quantity absorbed by these plants. Role of Pseudomonas chlororaphis, bacteria helping phytoremediation process is also highlighted. Effective use of activated charcoal in the medium is also discussed.

Material and methods

Aglaonema commutatum (Chinese evergreen)), *Chlorophytum comosum* (*Spider plant*), *Sansevieria trifasciata* (Mother in laws tongue) and *Epipremnum aureum* (Pothos) are commonly cultivated species as house plants are chosen as a test plants. Plants are native to humid, shady tropical habitat. Plants were chosen due to their easy growth in all types of mediums tested in the laboratory. Plants require less maintenance, are fast growing. They were chosen to test their ability to absorb formaldehyde, a common indoor pollutant.

Experimental plants were purchased from local vendors. They were repotted in 10 cm diameter pot with 2 kg of potting mixture. Composition of the potting mixture was kept standard for growing all test plants. The standard composition used was vermicompost (1.5 kg) + enricher (½ kg) + 1 gm activated charcoal + 2 ml *Pseudomonas chlororaphis* liquid culture. Activated charcoal was added for large absorption surface and *Pseudomonas chlororaphis* was added to the medium for enhancing activity to absorb and break poisonous pollutants. All horticultural practices were taken care of. The factors such as local growing conditions and growth patterns were studied. Acclimatization of experimental plants within the indoor environment was done with temp 22±2°C, 35±5% relative humidity. The light conditions were adjusted to the survival of selected plant. A glass chamber, of 1 m3 meter was used for the exposure experiments (Figure1). Dimensions of glass chamber for control were 1 m3. All research experiments were carried out at the Research Lab, Know How Foundation, Bavdhan, Pune, MS, India.

Figure 1: Exopsure chamber with *Aglaonema commutatum* (representative plant)

Exposure to Formaldehyde

The concentration in the glass chamber was noted on Advance Formaldehyde Detector (Make - Smiledrive) and accordingly adjusted to 5 ml/ lit with the help of pouring formalin on potassium permanganate. Little variation in initial concentration was observed which varied between 0.3 to 0.4 ml/lit.

A battery-operated fan was placed in the chamber for continuous air circulation. Thermo-hygrometer was kept in the chamber for monitoring temperature and humidity. Reading for light intensity was taken on photometer. Test plants with all standards were kept in the treatment chamber. Air monitoring in the chamber was done on advanced air detector (Make:Smiledrive). Plants for control were placed in the control chamber. The air filled with gaseous pollutants was monitored after insertion of formaldehyde dose and after 24 hours. Three sets of plants were exposed for testing. Data expressed in the terms of average of three replicates.

The plant was removed from the chamber after exposure and the leaves were studied for any visible injury symptom. For each exposed plant the following parameters were considered: 1) Visible injury 2) PII 3) LCMS analysis by D.N.P.H. method. A Pollution Indication Index (PII) was then calculated by the formula: Pollution Indication Index (PII) = [Number of leaves exposed (E))/(Number of leaves affected (A)] × (100)

Results and discussions

After exposure, all plants were monitored for visible injury. At the end of 10 days, no visible injury was observed in all replicates of the plants as compared to control. Treated plants did not show change in leaf color even after ten days. PII calculated after the treatment was 0.

Test plants showed average formaldehyde removal capacity ranging from 0.03–4.7 ppm for m–3 area, by DNPH on LCMS over 24 hours. These values are taken on the basis of result of three plants tested (Table 1, Figure 2).

Table 1: Quantification of formaldehyde by DNPH on LCMS (In ppm)

Sr Number	Name of plant	Set I	Set II	Set III
1	Control	0	0	0
2	*Aglaonema*	1.227	0.576	0.5231
3	*Chlorophytum*	0.116	0.0352	0.0453
4	*Sansevieria*	0.343	0.0567	0.0588
5	*Epipremnum*	4.744	3.92	4.543

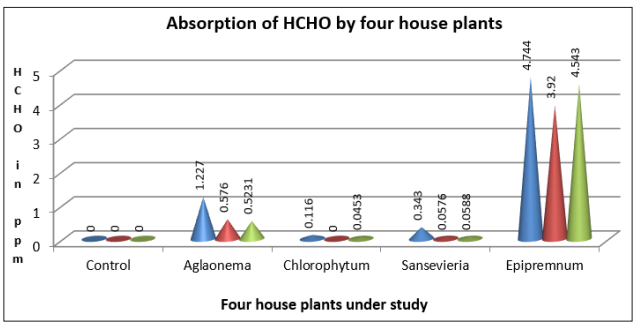
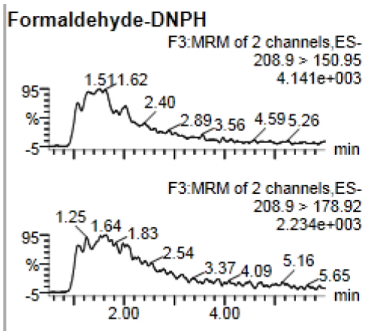


Figure 2: Graphical representation of formaldehyde absorption on LCMS by four house plants

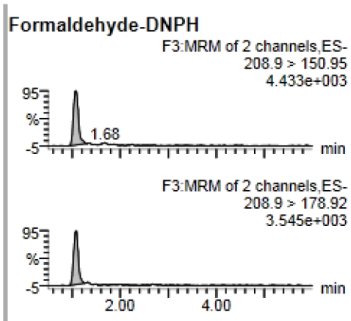
Formaldehyde quantification results as chromatogram of LCMS by DNPH are represented in Figs. 3-6.

Fig 3: Chromatogram for Aglaonema, showing HCHO concentration on LCMS



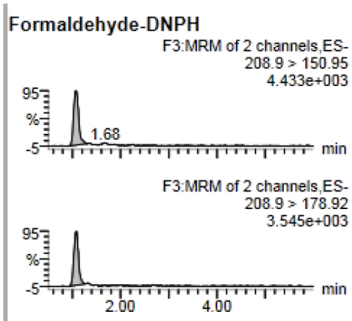
#	Name	RT	Area	Conc. (µg/L)	Dilution Factor
1	Formaldehyde-DNPH				0.0

Fig 3-a: Control



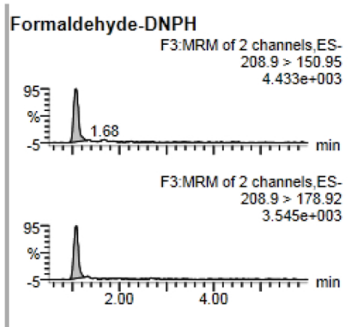
#	Name	RT	Area	Conc. (µg/L)	Dilution Factor
1	Formaldehyde-DNPH	1.07	510	1227.31	25.0

Fig 3-b: Set I



#	Name	RT	Area	Conc. (µg/L)	Dilution Factor
1	Formaldehyde-DNPH	1.07	510	576	25.0

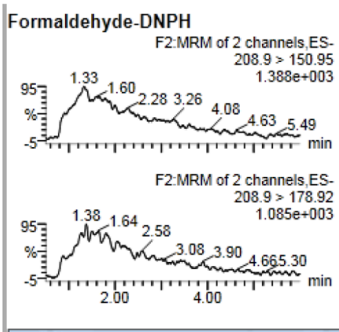
Fig 3-c: Set II



#	Name	RT	Area	Conc. (µg/L)	Dilution Factor
1	Formaldehyde-DNPH	1.07	510	523.1	25.0

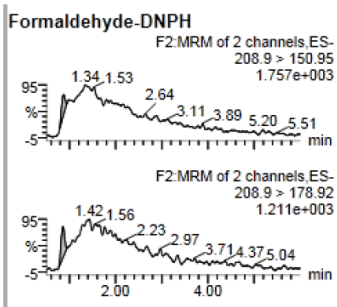
Fig 3-d: Set III

FIG 4: Chromatogram for Chlorophytum, showing HCHO concentration on LCMS



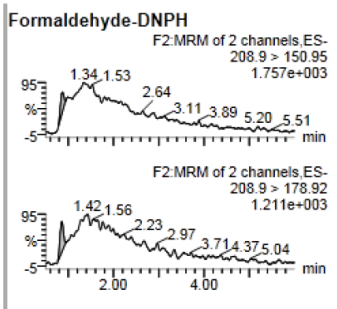
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH				25.0

Fig 4 a: Control



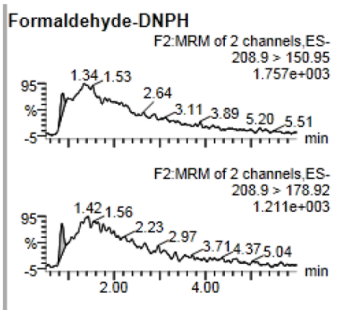
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.87	57	116.17	25.0

Fig 4 b: Set I



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.87	57	35.2	25.0

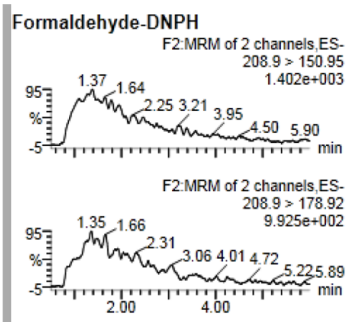
Fig 4 c: Set II



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.87	57	45.3	25.0

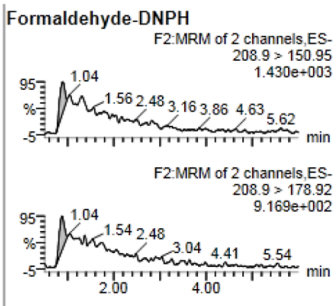
Fig 4 d: Set III

Fig 5: Chromatogram for Sansevieria, showing HCHO concentration on LCMS



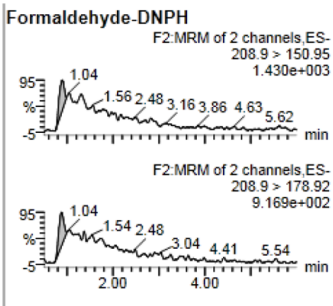
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH				25.0

Fig. 5 a: Control



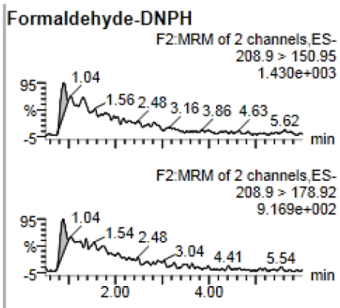
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.90	105	343.62	25.0

Fig. 5 b: Set I



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.90	105	56.7	25.0

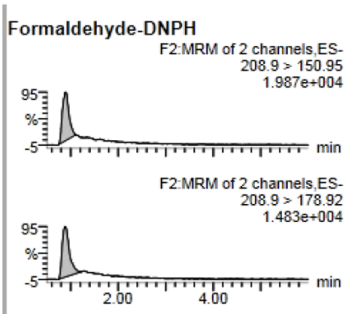
Fig. 5 c: Set II



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.90	105	58.8	25.0

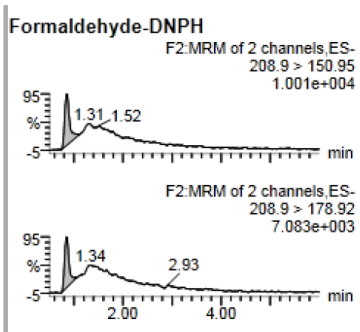
Fig. 5d: Set III

Fig. 6: Chromotagram for Epipremnum, showing HCHO concentration on LCMS



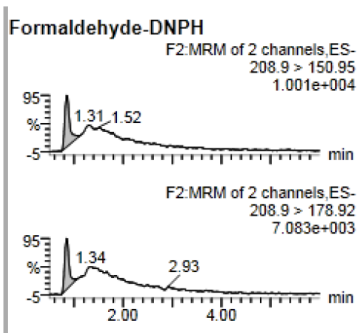
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH				25.0

Fig. 6a: Control



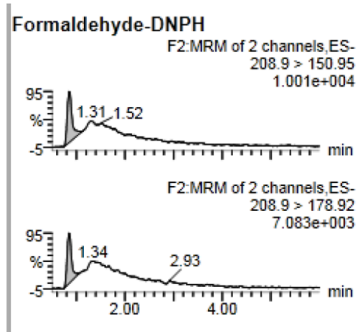
#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.85	1035	4744.41	25.0

Fig. 6b: Set I



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.85	1035	3920	25.0

Fig. 6c: Set II



#	Name	RT	Area	Conc. (µg/kg)	Dilution Factor
1	Formaldehyde-DNPH	0.85	1035	4543	25.0

Fig. 6d: Set III

Results of Formaldehyde Detector

When formaldehyde levels were monitored before and after insertion of test plants, it was observed that the initial highest level of HCHO on formaldehyde detector was 1.999 ppm reduced to 0 ppm after 24 hours, after insertion of experimental plants.

Ability of test plants plants to remove formaldehyde may be enhanced due to the activity of *Pseudomonas* bacteria added in the mixture. In similar experiments Spathiphyllum wallisii was found to be best absorber of formaldehyde with the help of *Spingomonas* consortium Ghate [12]. Evans et al has demonstrated the ability of gram-negative bacteria [13]. They have shown oxidative metabolism of Phenanthrene by soil *Pseudomonas*.

Potted-plants can reliably reduce total volatile organic compound (TVOC) loads, a major class of indoor pollutants, by 75%, to below 100 ppb is shown in laboratory studies, with nine 'indoor plant' species. Field studies in 60 offices, have shown that eighty six species of plants were assessed for the efficiency of volatile formaldehyde removal. Specifically, the phytoremediation potential was assessed by exposing the plants to gaseous formaldehyde in airtight chambers and measuring the rate of removal of formaldehyde as per time and area of chamber. Most effective species tested were *Osmunda japonica*, *Selaginella tamariscina*, *Davallia mariesii, Polypodium formosanum, Psidium guajava*, *Lavandula* spp., *Pteris dispar*, *Pteris multifida*, and *Pelargonium* spp. Highest Formaldehyde removal efficiency is observed in ferns. *N. obliterata* plant considerably removed formaldehyde vapors from the polluted air during continues long time fumigation [3]. Xu et al. reported formaldehyde removal efficiencies of about 95% for spider plant-soil system, 53% for *Aloe vera*-soil system, and 84% for golden pothos-soil system with an inlet concentration range of 1-11 mg/m [14].

In similar chamber study experiments, we observed that all test plants could absorb formaldehyde in the range of 0.0352 to 4.744 ppm. This activity was enhanced by addition of *Pseudomonas* chloraphis and activated charcoal in the medium. It also observed that *Epipremnum aureum* is the best absorber of formaldehyde among all plants tested; it is indicated by the highest absorption on LCMS.

Conclusions

This paper explains the formaldehyde absorption capacity of four house plants. Formaldeyde is a common indoor pollutant released through many household sources. Plant showed excellent absorption capacity on DNPH by LCMS indicated by the range of absorption from 0.0352 - 4.744 ppm. This is much higher than the permissible limits of formaldehyde. The mechanisms of how formaldehyde (HCHO) is removed by potted plant were related to the plant species, the soil and the microorganisms in the soil, the growing media of the plant, light intensity, temperature and HCHO concentration in indoor air.

To know the full capacity of absorption by house plants in real-life settings, investigations on site experiments were initiated in this research work. Our laboratory results show that house plants have a potential to alter indoor air in turn it will affect the health and well-being of the inhabitants.

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