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Technology for Improvement of Indoor Air Quality: Removal of Allethrin, by local House Plant *Polyscia fructicosa (L.)* Harms

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Abstract

Technology for improvement of indoor air quality by removal of allethrin, a poisonous pesticide using *Polyscia fructicosa*,a local house plant effectively, is researched upon in this study. Allethrin is released from burning of mosquito coil as harmful toxic fumes. Mostly Indoor Air quality (IAQ) suffers, due to lack of ventilation. Well grown *Polyscia fructicosa* plants were established in potting media having composition of vermicompost, enricher ,, consortium of *Sphingomonas* and activated charcoal for enhancing phytoremediation. After favourable growth of plants & bacterial translocation to various plants parts like roots , stem , leaves etc plants were exposed to burning mosquito coil toxic smoke gases & were monitored for physically visible symptoms anomalies, pollution Indication Index (PII) and Gas Chromatography-Mass Spectrometry (GC-MS). All tested plants showed no physical injury symptoms, PII in most of the cases was 0. Post mosquito coil smoke exposure GCMS analysis showed high levels of allethrins, up to 3.40-13.57 µg/g. When GCMS analysis of experimental plant was done after 20 days, it was observed that levels of allethrin reduced to 0. This may suggest that allethrins are metabolized by *Polyscia* with the help of *Sphingomonas*. This evidence shows that indoor potted plants with standardized size of pot and soil mixtures can be used to mitigate indoor organic air pollution. This low-cost, portable, green technology can be successfully used in close spaces and can meet with social, economic and environmental needs.

Keywords: Indoor Pollution, Mosquito coil,Allethrin,House plant, *Polyscia fructicosa*, *Sphingomonas*

Introduction

Indoor pollution is defined as "The presence in indoors air the physical, chemical and biological contaminants not normally present in outdoor air of high quality". In today's world people spend more than 90% of their time inside close spaces, where levels of many common organic pollutants can be twelve times higher than outside [1]. Indoor air pollution ranks among the top five major hazardous health issues and is a global concern [2]. Major impact of indoor air pollution is seen in hospitals, offices, factories, malls, residential complexes, IT parks etc. Indoor pollution is now considered by many experts to be one of the major threats to human health. Toxicity of some Volatile Organic Compounds (VOCs) is tested and it is seen that they are hazardous to health [3]. The sources of Indoor air pollutants include asbestos, pesticides, fibers from clothing, curtains, carpets, insulation, etc., fungi and bacteria, human coughs, sneezes, sweat, etc., tobacco smoke, ozone, chemicals from detergents, solvents, and cleaning fluids, etc. Different types of Indoor Pollutants and their sources are: D.Trans-Elthrin and CO-mosquito repellents, para dichlorobenzene and napthalene-room freshners, paints, NO_2 and CO-smoke in the kitchen, alcohol and acetone-cosmetics, formaldehyde-grocery bags, paper towels, paints, floor coverings, air freshners, xylene-computer and video screens, ammonia-cleaning products, trichloroethelene-perfumes [4].

High temperature and humidity levels can also increase concentrations of some pollutants. Long term exposure to these chemical vapours has brought dramatic increase in the number of health issues. These Indoor pollutants, even at very low levels, can cause Sick Building Syndrome and symptoms of headache, sore eyes, nose and throat, or nausea [5]. Dust, moulds and fuel burning, gases through repellents, gases from smoke of joss sticks etc. also add up to Indoor pollutants. The pioneering screening studies on indoor-air VOC removal by plants [6-8] showed reductions in VOC levels with over 50 species. Wolverton suggested that both plants and potting-mix microorganisms could be involved in the process. Indoor plants were tested in situ for their ability to remove VOCs in buildings [9,10].

Allethrin is an insecticide which is widely used as a mosquito repellent in mosquito coil. It is noted that several hundred tonnes per year of allethrin, prallethrin, bioallethrin, esbiothrin and other pyrethroid are manufactured. These insecticides are used throughout the world [11]. Allethrin can also act as dermal and respiratory allergen. Direct skin contact with allethrin causes itching, burning and tingling feeling. When inhaled, it may cause nausea, vomitting, diarrhoea and asthma. It is especially dangerous for infants, young children and pregnant women [12].

In Pune, Maharashtra, India due to serious diseases like dengue, chickungunya many people are forced to use mosquito repellent in gaseous form. Gaseous forms of mosquito repellent are common source of dangerous indoor pollutant allethrin. In this paper, allethrin absorption capacity of commonly occurring indoor plant *Polyscia fructicosa*is described and the quantitative data of research is presented.

Methodology

The present research work is carried out at the Research Lab, Know How Foundation, Pune, MS, India. *Polyscia fructicosa* (Ming

Aralia) a commonly cultivated species is chosen as the test plant (Figure 1).

Figure 1: Monitor chosen for exposure, *Polyscia fructicosa*

It is commonly used as a houseplant. The plant is evergreen perennial herb with stems growing erect. There is generally a crown of leaves. The leaves are elongated, robust with expanded surface. Plants are native to humid, shady tropical forest habitat. The plant was chosen due to its easy growth in all types of mediums tested in the laboratory. This plant requires less maintenance, is fast growing and its lamina is broad enough to show injury symptoms. This plant is tested for its ability to absorb indoor pollutants.

One year old plants of *Polyscia*, were grown in 4 inches 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 (1/2 kg)+1 gm Activated charcoal+2 ml broth/ froth *Sphingomonas* consortium . Activated charcoal is added to expand the absorption surface for pollutants. Consortium of *Sphingomonas* is added to help the plant in metabolism of pollutants. *Sphingomonas* group of bacteria helps in the process of phytoremediation is isolated in the laboratory from known sources. All horticultural practices were taken care of. The factors such as local growing conditions, growth pattern were studied The plants used in these experiments were kept for several weeks so that bacteria *Sphingomonas* gets translocated in different plant parts like leaves , stem etc in more or less the same environmental conditions of lighting and temperature to minimize any stress resulting from the change in environment.

A glass chamber, of 1 m3 is used for the exposure experiments. Dimensions of glass chamber for control were 1 m3 (Figure 2). A battery-operated fan was placed in the chamber for continuous air circulation representing in situ conditions. Thermo-hygrometer (HUMIDITY AND TEMPERATURE METER 920 P) 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. Mosquito coil was weighed before placing it in the chamber. Mosquito Coil was lit and placed in front of the fan and chamber door was kept closed. It was arranged so that smoke of the coil will be passed through test plant with the help of fan. Plants were exposed for 7 hours till the coil is burnt. A control plant was placed in the control chamber without burning any coil.

Figure 2: Treatment Chamber.

The air filled with gaseous pollutants was monitored with the advanced air quality meter (MAKE: SMILEDRIVE) during the burning of coil and after the whole coil was burnt up (Table 1). Three replicates of plants were exposed for testing. The leaves of plant were counted before the experiment.The plant was removed from the chamber after exposure and the leaves were studied for any visible injury symptom after eight days. For each exposed plant, the following parameters were considered: 1) Visible injury after eight days 2) PII 3) GCMS analysis. 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. After each treatment leaves of treated plants were collected for analysis. All samples were analysed on a TRIPLE QUADRUPOLE GC/MS/MS (AGLILENT 7000C) WITH ELECTROSPRAY IONISATION (ESI) at MAARC Lab, Nanded phata, Pune. Analysis was done by following method.

	During the burning of the coil	After the coil was burnt
Level of pollution	High	Low
HCHO	0.887 mg/m^3	0.019
TVOC	9.999 mg/m^3	0.173
PM 2.5	999 µg/m^3	023
PM 10	999 µg/m^3	025

Table 1: Reading on advanced air quality monitor during and after burning of coil.

Sample extraction for GCMS

Samples were crushed using a laboratory grinder. The crushed material was weighed (10 ± 0.1 g) in a centrifuge tube (50 mL). Ethyl acetate (10 mL) was added to the weighed samples. Sodium sulfate (10 g) was added to the mixture and it was vortexed for 3 minutes. The vortexed samples were centrifuged at 10°C at 5000 rpm for 5 minutes. 1 mL supernatant was taken into an Eppendorf containing Primary Secondary Amine (PSA) (0.25 g). The Eppendorf was centrifuged at 5000 rpm at 10°C for 5 minutes. The clean sample was filtered using 0.25 µm nylon filter and injected to the GC/MS/MS.

Sample analysis

The extracted sample was analysed on a triple quadrupole GC/MS/MS (Aglilent 7000C) with Electrospray Ionisation (ESI). The peak was observed at 21 minutes. It was quantified using m/z 123 and 79.0 and 77.2 as qualifier ions. Allethrin was quantified using 5 calibration standards (10 µg/L to 200 µg/L). The samples were compared to the five point linearity. Laboratory fortified recovery standards were run with every batch and the results were reported based on the recovery (70-130% of spiked value).

Results

All plants were monitored for visible injury after exposure. No visible injury was observed in all three sets of the plants as compared to control. Leaf color and leaf injury was observed for more than eight days, but no injury observed neither leaf colour changed. PII calculated after the treatment was 0.

Result of GCMS analysis of *Polyscia fructicosa*

Results of GCMS analysis showed significant findings. Control set did not show any absorption as established in the chromatogram (Figure 3). In the first set of treatment, it was observed that allethrins were absorbed by the plant as established by GCMS chromatograms (Figure 4). The absorption was 571.0505 ppb. It was observed that allethrins were absorbed by the plant in the second set as established by GCMS chromatograms (Figure 5).

The absorption was 1357.2002 ppb. Allethrins were absorbed by the plant in the third set as established by GCMS chromatograms (Figure 6). The absorption was 339.9827 ppb. Compiled graph (Figure 7) shows the absorption of allethrins by *Polyscia fructicosa* for all sets exposed.

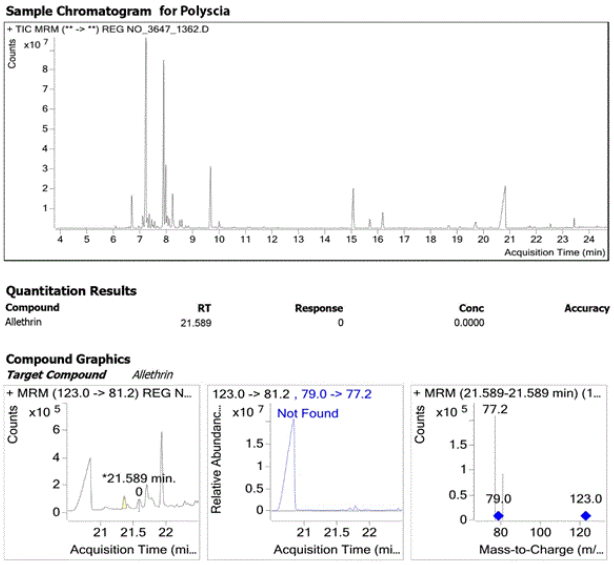

Figure 3: Chromatogram on GC-MS, for control of *Polyscia fructicosa*.

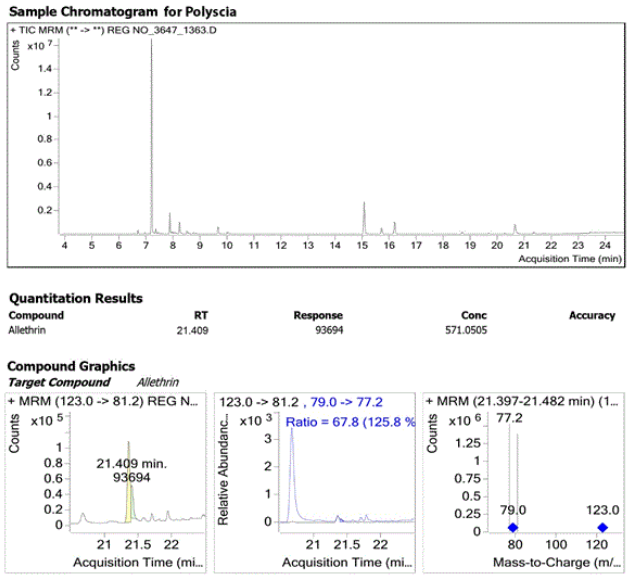

Figure 4: Chromatogram on G C M S for first set of *Polyscia fructicosa*.

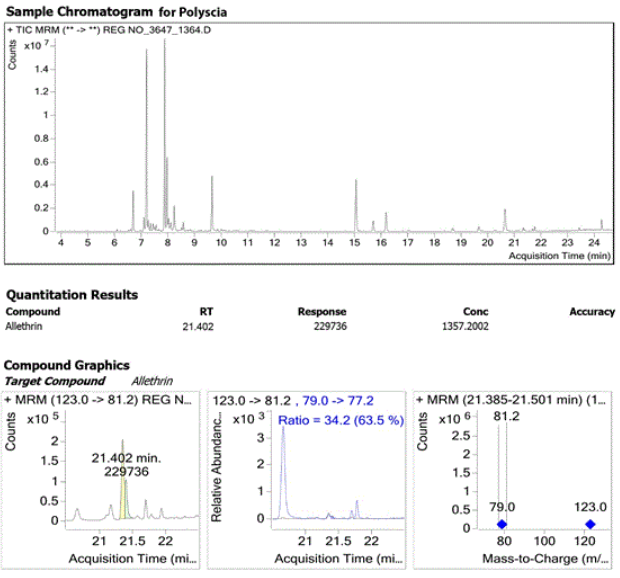

Figure 5: Chromatogram on GC-MS for second set of *Polyscia fructicosa*.

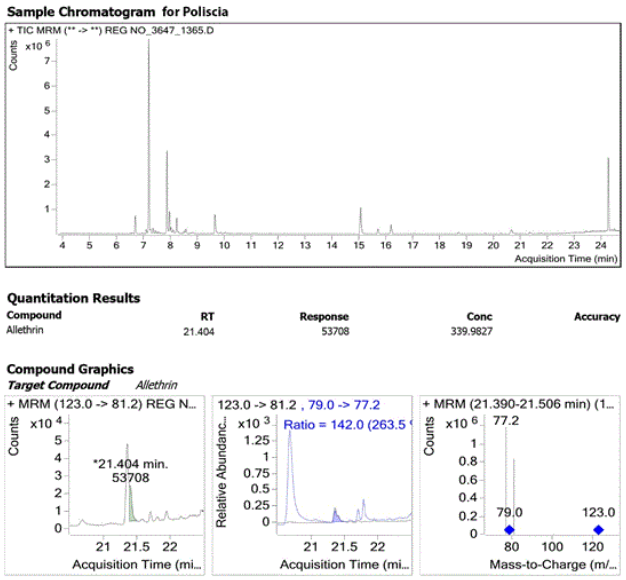

Figure 6: Chromatogram on GC-MS for third set of *Polyscia fructicosa*.

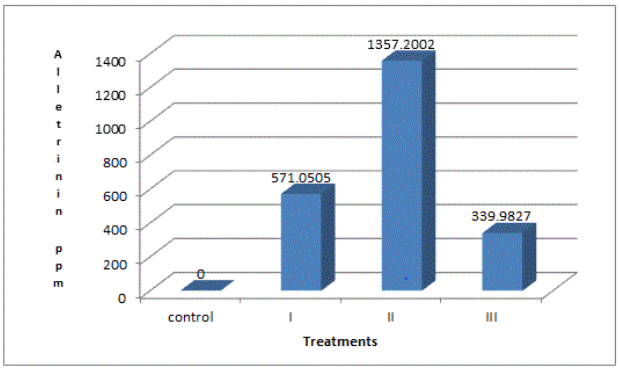

Figure 7: Compiled graph showing absorption of allethrins by *Polyscia fructiosa*.

Discussions

Use of indoor plants for improving indoor air quality is taking roots in today's world. It is very well discussed in the previous research work by [13]. After exposure of *Polyscia fructicosa* to smoke from mosquito coil, the leaves were analyzed on A TRIPLE QUADRUPOLE GC/MS/MS (AGLILENT 7000C) WITH ELECTROSPRAY IONISATION (ESI) for exact quantity of pollutants absorbed. The absorbed values of alletrin range from 3.40-13.57 µg/g.

Ability of house plants' to remove VOCs from indoor air is reviewed in this research article. Laboratory based studies indicate that plant induced removal of VOCs is a combination of direct (e.g. absorption) and indirect (e.g. biotransformation by microorganisms) mechanisms [14,15]. In this research, it was observed that plant showed range of absorption in allethrin levels due to addition of activated charcoal and

consortium of *Sphingomonas*. In similar work it is shown that Allethrin could be transformed by *Acidomonas sp.* (Gram negative bacteria) to products that are low molecular weight, which could then be more efficiently absorbed and translocated by plants. Thus, a combination of bio- and phyto-remediation in the immediate vicinity of the plant root mass (rhizosphere) could enhance the degradation process of allethrin [16]. Researchers reviewed the state of art of vegetation systems and their effect on the Indoor Environmental Quality (IEQ), based on scientific studies from the past 30 years. Several studies have indicated that green systems may improve indoor air quality and that they have different pathways for pollutant removal of VOCs. The plant root zone in potted plants may be an effective area for removing VOCs under controlled conditions [17]. *Sphingomonas*, a group of gram negative bacteria added in the potting mixture has helped the plant to absorb pollutants in our research. Scientists isolated a bacterium capable of utilizing allethrin, to degrade allethrin present in used mats and the environment [18]. The isolated *Acidomonas sp.*, grew in minimal medium with 16 m M allethrin as sole source of carbon and degraded >70% of it in 72 h, with negligible residual metabolites in the medium. *Sphingomonas* is also a gram negative bacteria, was isolated in our research for fast metabolism of alletrins. It can be said that this bacterium has used absorbed alletrin and digested it. It is true as when exposed plants were analysed after 20 days on GCMS, no alletrins were detected.

The capacity of the indoor potted-plant/growth medium microcosm to remove air-borne VOCs which contaminate the indoor environment, using three plant species, *Howea forsteriana Becc.* (Kentia palm), *Spathiphyllum wallisii Schott.* '*Petite*' (Peace Lily) and *Dracaena deremensis Engl.* (Janet Craig) is studied. The selected VOCs were benzene and n-hexane, both common contaminants of indoor air. The findings provide the first comprehensive demonstration of the ability of the potted-plant system to act as an integrated bio filter in removing these contaminants. Under the test conditions used, it was found that the microorganisms of the growth medium were the "rapid-response" agents of VOC removal, the role of the plants apparently being mainly in sustaining the root microorganisms [19]. The research findings are leading towards developing varieties of plants including *Polyscia fructicosa*, with *Sphingomonas* as associated microflora and activated charcoal as best absorbent, with enhanced indoor pollution absorption capacities. Aesthetics and psychological comfort of the indoor environment can have positive impact due to such absorbent plants.

Conclusions

Polyscia fructicosa, a low light survivor, maintenance free indoor plant has demonstrated the ability to absorb significant quantity of allethrins, a poisonous pesticide released from smoke of mosquito coil. In this research it is also indicated that plant leaves and microorganisms are involved in removing and digesting this poisonous chemicals. Activated charcoal has also helped in adsorption. Data of absorption per gram of plant sample 3.40-13.57 µg/g, can establish *Polyscia fructicosa* helpful for quality of indoor environment, especially where mosquito repellents releasing poisonous gas are used. Specific pot size, potting mixture with bacterial inoculum, quantity of activated charcoal, age of plant should be taken into consideration for effective removal of allethrins from indoor environment. The plant's ability to absorb allethrins is well established in laboratory studies, the capacity of plants to absorb this pollutant in the complex environments like home, offices, institutions etc requires further investigations to check the full capacity of plants in real-life settings.

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