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Comparison of Phytoremediation Potential of Pothos and Sansevieria under Indoor Air Pollution

Vida Akhavan Markazi[1], Rohangiz Naderi[2*], Elham Danaee[3], Sepideh Kalatejari[1] and Fereshteh Nematollahi[4]

[1]Department of Horticulture Science and Agronomy, Science and Research Branch, Islamic Azad University,Tehran, Iran
[2*]Department of Horticulture College of Agriculture and Natural Resource University of Tehran, Iran
[3]Department of Horticultural Science, Garmsar Branch, Islamic Azad University, Garmsar, Iran
[4]Department of Chemistry, East Tehran Branch, Islamic Azad University, Iran

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*Corresponding author's email: rnaderi@ut.ac.ir

Abstract

Indoor air pollution is one of the most important environmental subjects in the world with serious side effects on human health. We report the result of a three replications and factorial design experiment that assesses the effect of plants (*Epipremnum aureum* and *Dracaena trifasciata*) on the removal of indoor air pollution. To gain the objects, potted plants were placed individually in 125 liters airtight glass containers (chamber) which had a small valve to inject and sucking airs. Each plant was exposure to, benzene 25 and 50 µl/l, acetone 25 and 50 µl/l, ethanol 50 µl/l and methanol 50 µl/l during a day (24 hours). According to the biochemical examination electrolyte leakage (%) of pothos was decreased especially in acetone 25 µl/l versus on treated sansevieria increased. Total chlorophyll content of sansevieria in all treatments was increased, while it was decreased when pothos exposure to benzene 25, benzene 50 µl/l and methanol 50 µl/l. Catalase activity and superoxide dismutase showed converse results. In both plant species catalase activity was decreased especially in acetone 50, however superoxide dismutase activity was increased in all treatments and in sansevieria exposure to benzene 50 µl/l more than others. There was no significant change in proline content of pothos, although there was significant increase in acetone 50 µl/l and ethanol 50 µl/l of sansevieria. The results indicate when plants exposure to the benzene, tissue cells damaged more than other treatments while, acetone had least amount of tissue cell damage. According to this paper results, both plant species have the potential of indoor air pollution phytoremediation but, pothos had higher adaptability in pollutant indoor area.

Keywords: Indoor plants, Indoor pollutants, Pothos, Sansevieria, Volatile organic compounds.

INTRODUCTION

In urban spaces, citizens spend more than 85 to 90 percent of their time indoors, often unaware that they may be constantly exposed to air pollution. According to the US Environmental Protection Agency (US EPA), indoor pollutants are among the five most important and dangerous pollutants for public health that have negative effects on public health around the world and, sometimes the amount of indoor pollutants can be up to 10 times higher than outdoor and the concentration of some pollutants in indoor environments can be more than 100 times the permissible concentration (Gawronska and Bakera, 2015). Humans are directly involved in the composition of indoor air through the body's metabolism, clothing, use of personal care equipment, and activities such as cooking, cleaning, etc. (Weschler, 2016). The importance of indoor air quality for human health has greatly increased in developed countries, especially for those who spend 90% of their time indoors in homes and offices. Indoor pollutants typically come from building and amenities, human activities inside the building, and the entry of outside air into homes. Indoor pollutants include volatile organic compounds (VOCS), fine particles, ozone, nitrogen dioxide, sulfur dioxide, radon, lead, and biological contaminants. Indoor air pollution is very dangerous for children, because children breathe faster and get more air into their bodies. Air freshener chemical sprays, door and wall paints and cupboards, carpets, rugs and sofas, household cleaners, laundry detergents, cigarette smoke, Teflon dish smoke, stove, radon gas, fireplace, handicraft chemicals are the sources of pollution inside homes (Molaahmad Nalousi *et al*., 2016).

The physicochemical behavior of SVOCs indoors is challenging and may also be of significant importance to human health and well-being. Several processes occurring indoors, such as indoor diffusion, exchange with the outdoors, deposition of indoor surfaces, removal by filtration, and indoor chemistry, increase the concentration of indoor air pollutants. Concentrations of indoor air pollutants are measured by several processes including indoor diffusion, exchange with outdoors, internal surface deposition, removal by filtration, and indoor chemistry. Indoor chemistry refers to the physical and chemical reactions that occur indoors and is more different from outdoor atmosphere chemistry for reasons such as lack of direct sunlight and rain, extreme temperature changes, high surface to volume ratio and concentration of organic compounds and causes many side effects for exposed people (Davamani *et al*., 2020). Indoor air pollution is one of the most important environmental issues in the world. According to the Institute for Health Metrics and Evaluation (IHME), 2.6 million people died in 2016 due to insufficiency due to indoor air pollution. Indoor pollutants consist of several toxic gases such as volatile organic compounds (VOC), trichloroethylene (TCE), xylene, toluene and formaldehyde, octane, α-pinene, benzene, carbon monoxide (CO), nitrogen dioxide (NO_2), detoxifiers Pests, etc. (Davamani *et al*., 2020). The results of many studies show that plants have the ability to remove particles, minerals and volatile organic compounds. The various mechanisms by which plants remove indoor contamination include microbial degradation (rhizosphere microorganisms), plant fluid extraction, uptake through the stomata, enzymatic catalysis within tissues, and direct evaporation from leaves or indirectly by plant transpiration (Sharma *et al*., 2019). There are many reports about the effect of ornamental plants on the removal of pollutants inside the building. Plant biofilters have been proposed as an effective technology for cleaning enclosed spaces. Plants such as *Sansevieria* and spider plants have an effective role in reducing volatile organic compounds. They can also reduce CO_2 emitted from plants CAM and C_3. According to the results of this study, the simultaneous use of *Sansevieria trifasciata* and *Chlorophytum comosum* in plant biofilters has been very effective in reducing volatile organic compounds and particulate matter ($PM_{2.5}$). These plant biofilters can also effectively remove formaldehyde, acetone, benzene and xylene from the environment in closed spaces with low CO_2 emissions and balanced light levels (Siswanto *et al*., 2020). In another study on the potential of 11 plant species to reduce the ultra-fine particulate matter *in vitro*, it was observed that *Dracaena deremensis compacta* and *Juniperus chinensis* had the highest rate (5.5%) of reducing ultra-fine particulate matter. A linear relationship was established between the number of plants in the test chambers and the percentage of particulate matter reduction for *Juniperus* and the other 4 plants with the highest rate of particulate matter reduction (Stapleton and Ruiz-Rudolph, 2018). In another study, the effect of *Zamioculcas zamiifolia* on reducing some volatile organic compounds in closed environments was tested. It was observed that the plant has the ability to reduce the concentration of benzene, toluene, ethyl benzene and xylene from closed environments and, can clean all 4 gases from the environment. Benzene, which is a smaller molecule than other gases, was absorbed faster by plants and showed no signs of plant poisoning in the leaves and roots. Also, control chlorophyll and treated plants were not significantly different (Sriprapat *et al*., 2014).

The aim of this study was to evaluate and compare the efficiency of two species of sansevieria and pothos ornamental houseplants in removing some contaminants from closed environments on a laboratory scale.

MATERIALS AND METHODS

Experiment details

In order to investigate the effect of indoor plants in the purification of pollutants, this study was conducted between 2018-2020 at Sciences and Research Branch of Tehran Islamic Azad University laboratory. This research was designed in three replications and factorial design in a completely random block. In order to treat plants by VOC_S gases, glass chambers with the same volume and area (cm of height × cm of length ×50 cm of width) were prepared. Each glass had a small valve for injecting or pumping air and they were completely air tight. two plant species of *Sansevieria trifasciata* 'Hahnii' and *Epipremnum aureum* 'Jessenia' were used. Plants were bought from a greenhouse in north of Iran and after arriving they kept under laboratory conditions for acclimatization about one month. Each pothos pot diameter was 25 cm and sansevieria pots were 15 cm and their volume (number, length and width of leaves) was measured. A pot of plant was placed inside the chambers and sealed by aquarium silicone sealant then, specific concentration of contaminations -benzene 25 and 50 µl/l, acetone 25 and 50 µl/l, ethanol 50 µl/l and methanol 50 µl/l- inject to the chambers. Immediately after injection (0), 6 and 24 hours later, the air inside the chamber pumped by Hamilton gas tight syringe and pollution concentration calculated by gas chromatography machine (GC) model number SHIMADZU 2010 Plus. In order to investigate indoor air pollution removal potential of the plants, biochemical characteristics of them such as Ion leakage percentage, chlorophyll content, proline content and activity of antioxidant enzymes were evaluated.

Ion leakage measurement

To measure the percentage of ion leakage, 200 mg of plant leaves were first marinated at 40 °C for 30 minutes and then at 100 °C for 15 minutes. After the temperature of the solutions reached the ambient temperature, their electrical conductivity was measured with an EC meter and the percentage of cell membrane stability was calculated according to the following formula (Danaee and Abdossi, 2018).

$$\text{Membrane stability index (\%)} = [1-(C1/C2)] \times 100$$

Leaf chlorophyll content assessment

To measure the total leaf chlorophyll content, 0.5 g of plant leaves were prepared and ground in liquid nitrogen. Then 80% acetone was used to extract leaf chlorophyll. The adsorbents were immersed in 8 ml of methanol and kept in the dark at room temperature for 24 hours. Then the absorbed light of the extracts was read and recorded by spectrophotometer at 645 and 663 nm (Abdossi and Danaee, 2019).

$$\text{Chl.} = 20.2\ (A645) + 8.02\ (A663) \times V/\ (1000 \times W)$$

Proline content measurement

Proline content was measured using the method proposed by Bates *et al*. (1973). First, the plant extract was extracted using 3% sulfuric acid then, the color phase of the samples was isolated using ninhydrin reagent and glacial acetic acid. The absorption of plant leaf samples at 520 nm was read and recorded by spectrophotometer.

Extraction of enzyme solution

Superoxide dismutase: The activity of superoxide dismutase enzyme was determined by Beauchamp and Fridovich (1971) method by measuring the ability of the enzyme to prevent the photochemical reduction of nitroblo-tetrazolium (NBT).

Catalase: The activity of this enzyme was measured by the method proposed by Abi (1984). In this method, enzymatic activity was measured by calculating the hydrogen peroxide content decomposed by the enzyme. Calculation of reduction of H_2O_2 absorption at 240 nm was performed with a spectrophotometer.

Guaiacol peroxidase: The activity of guaiacol peroxidase was measured at 470 nm. Enzymatic activity was based on the tetragyakol content and was obtained using a quenching coefficient of 26.6 µmol/cm (Tang and Newton, 2005).

To statistical calculations, SAS 9.1, MSTAT-C and Excel software were used to analyze the results obtained from the data.

RESULTS AND DISCUSSION

According to the results of analysis of variance the effect of benzene, acetone, methanol and ethanol on pothos and sanseveria, there was significant difference on proline content, catalase and superoxide dismutase enzyme activity, total chlorophyll content at 1% level, also there was significant difference at 1% level between two plant species (Table 1).

Table 1. Analysis of variance the effect of benzene, acetone, ethanol and methanol on pothos and sansevieria.

S.o.V	df	MS					
		Ion leakage	Total chlorophyll	Proline	CAT	SOD	GPX
Plant	1	7974**	343.5**	0.112**	0.008**	0.583**	0.815**
Treatments	6	217.5^{ns}	31.5**	0.0328**	0.013**	0.946**	0.0027^{ns}
Plant × Treatments	6	414.7*	9.74**	0.0308**	0.003**	0.627**	0.0012^{ns}
Error	70	137.3	0.304	0.00059	0.0003	0.0357	0.0061
CV (%)	-	22.76	5.81	32.92	20.18	9.58	32.37

*, **and ^{ns} show significance at the $P < 0.05$ and $P < 0.01$ and non-significance, respectively.

Pollutant gases produce free radicals and reactive oxygen species in plants that it causes occurrence of oxidative stress and damage of plant cell membranes. As the permeability of the membrane increases, more electrolytes are happened and causing cell death. In the present study, according to Fig. 1, the electrolyte leakage (%) in treated sansevieria plants increased except at acetone 50 µl/l and ethanol 50 µl/l, but this increase was not observed in pothos. The lowest percentage of ion leakage was observed in acetone treatment with a concentration of 25 µl/l with Pan average of 34.99% in pothos leaves and the highest in sansevieria under acetone 25 µl/l with an average of 73.13%, which had no significance deference with other treatments. This indicates that the sansevieria is under stress and has shown less resistance than the pothos.

Many studies have reported adverse effects of pollutant gases on cell membranes. In a study, it was reported that the lowest ion leakage in the leaves of control plants (without stress) and the highest leakage from the leaf cells of *Brachylaena discolor* plants were recorded under the stress of pollutant gases which is due to increased production and activity of reactive oxygen species (ROSs) (Areington *et al*., 2015). Air pollution increases membrane peroxidation in plants. Oxidation of proteins and lipids occurs under the influence of polluting gases. Increasing stress by altering the unsaturated fatty acids of the cell membrane affects the structure and properties of the cell membrane, resulting in increased ion leakage from the cell membrane. Thus, by the decomposition of the membrane due to the stress of pollutants, the production of free radicals is increased. It causes lipid peroxidation and increases the permeability of cell membranes and as a result, the secretion of osmolytes in plants becomes more sensitive (Akbari, 2015).

Total chlorophyll content under the influence of pollutant gases has shown a significant increase in sansevieria. In pothos there was no significant deference between control and treatments except acetone 50 µl/l that was the least amount of chlorophyll (Fig. 2). Examining the effect of air pollution on the chlorophyll content of *Moltkiopsis ciliate*, *Tevatia neralfoia* and *Zygophyllum* plants it was found that in response to air pollution, the content of photosynthetic pigments increased significantly (Ali and El-Yemeni, 2010). The pigment content of chlorophyll a, chlorophyll b and total chlorophyll in the air-polluted area increased by 8.39%, 8.96% and 8.58% in the leaves of *Eucalyptus camaldulensis* (Seyyednejad and Koochak, 2011), respectively.

Increased air pollution, in addition to affecting the structure of the plant, also disrupts the function of various parts of the plant, such as chlorophyll content. Measurement of chlorophyll content is an important factor in evaluating the effects of air pollutants on plants, which plays a key role in plant metabolism. Contaminants, depending on the type, affect the chlorophyll content and increase or decrease it. The leaves of *Mangifere indica* showed an increase of 12.8% in chlorophyll content against air pollution, which is consistent with the results of the present study. Research has shown that the chlorophyll a, b and total chlorophyll content of in *Albizzia lebbeck* and *Callistemon citrinus* increased under air pollution stress (Seyyednejad *et al*., 2011). According to the researchers, air pollution stress in some plants increases the fresh and dry weight of infected leaves and thus leads to an increase in total chlorophyll content of the leaf (Seyyednejad *et al*., 2011).

The increase in photosynthetic pigments such as chlorophyll due to air pollution stress can be due to the increase in the number of leaves and thus increase the photosynthetic level of the plant. Maintaining and increasing plant chlorophyll exposed to air pollution can be a sign of plant tolerance and resistance to air pollution that, high resistance of sansevieria (Lu *et al*., 2018) to indoor benzene and pothos (Yan *et al*., 2015) to various types of gaseous pollutants have been reported. In another experiment, it was stated that the total chlorophyll content in *Chlorophytum comosum* plants decreased significantly with increasing benzene concentration compared to control plants and, at higher concentrations (35000 µl/l) it even caused the destruction of plants (Sriprapat and Thiravetyan, 2016), which is contrary to the results of the present study. Based on the results of research, the effect of benzene on two plants of *Schefflera arboricola* and *Spathiphyllum wallisii* was investigated. In this comparison, the total chlorophyll content in schefflera plant from 3.2 to 3.85 mg/g (16.4% increases before and after treatment benzene) and was observed in spatiophyllum from 2.8 to 3.6 mg/g (22.2% increase before and after benzene treatment) (Parseh *et al*., 2018). Teiri *et al*. (2018) reported decrease in chlorophyll content of *Chamaedorea elegans* by formaldehyde and they suggested using ornamental potted plants as an effective method to phytoremediation VOCs in houses and offices.

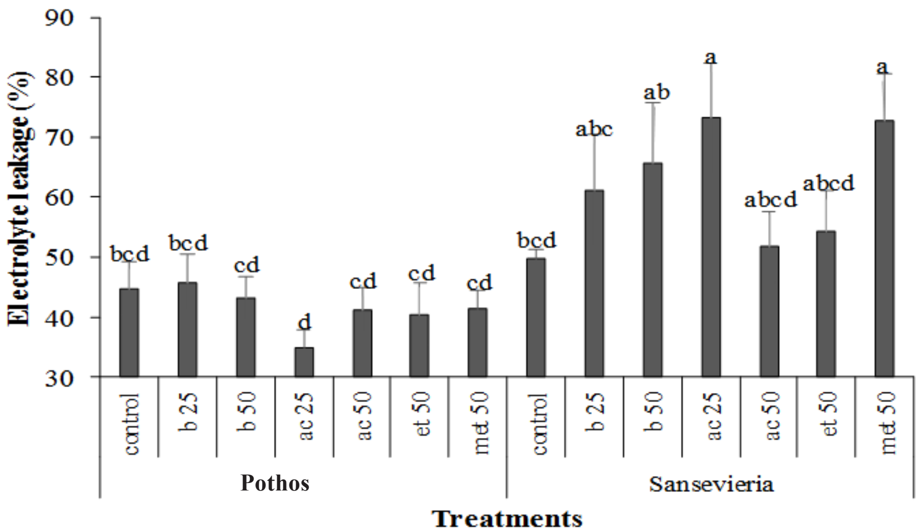

Fig. 1. Effect of benzene, acetone, ethanol and methanol on electrolyte leakage in pothos and sansevieria leaves.

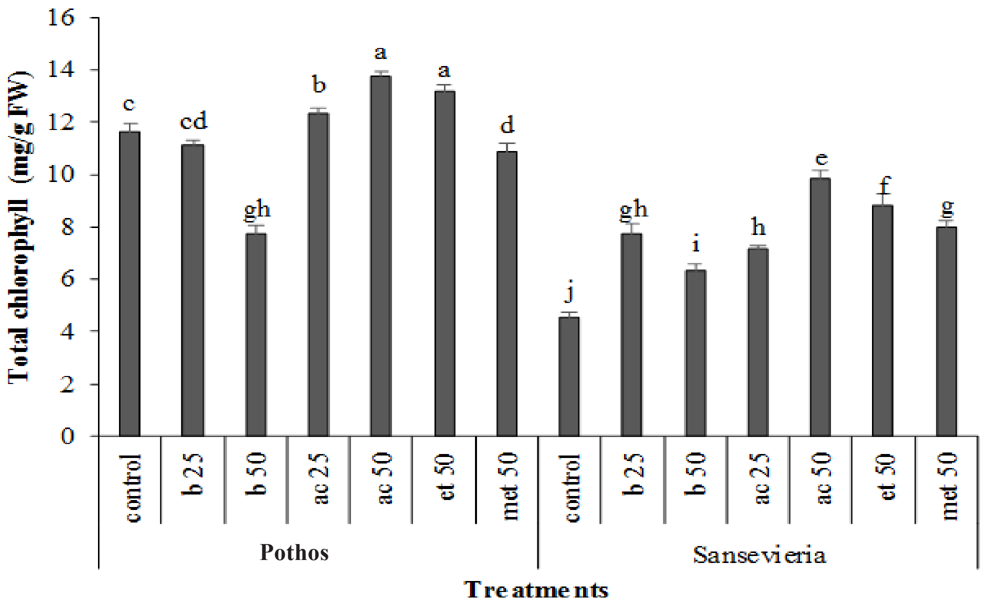

Fig. 2. Effect of benzene, acetone, ethanol and methanol on total chlorophyll content in pothos and sansevieria leaves.

Proline is one of the main components of plant defense mechanisms against stress, which increases under biological and non-biological stress (Muhammad *et al*., 2013). According to Fig. 3, the highest of proline content was in sansevieria leaf tissue exposure to acetone 50 µl/l with an average of 0.293 µmol/g fresh weight, which made a significant difference with other treatment levels. Then ethanol treatment with a concentration of 50 µl/l with an average of 0.217 µmol/g fresh weight had the greatest effect on increasing the proline content in sansevieria. In pothos, amount of treatments was similar together and there was no significant difference with control.

Based on these results, pothos has shown more resistance when exposed to contaminants, and thus its defense mechanisms are much less active against stress than sansevieria. In the study of the effect of air pollutants on the proline content of *Eucalyptus camaldulensis*, it was reported that given the relationship between proline content and lipid peroxidation, proline accumulation can prevent damage to cell membranes and thus causes cell stability under air pollution stress (Seyyednejad and Koochak, 2011). The results show that the proline content increases with increasing stress intensity, which may be due to the degradation of proteins (Sorrori *et al*., 2021). According to a report, the proline content increases under the influence of indoor pollutants in 20 plant species, which is the result of increasing the synthesis and preventing the degradation of proline. According to this study, the resistance to pollutants varies in different species and this increase in resistance is directly related to the accumulation of proline (Agbaire, 2016).

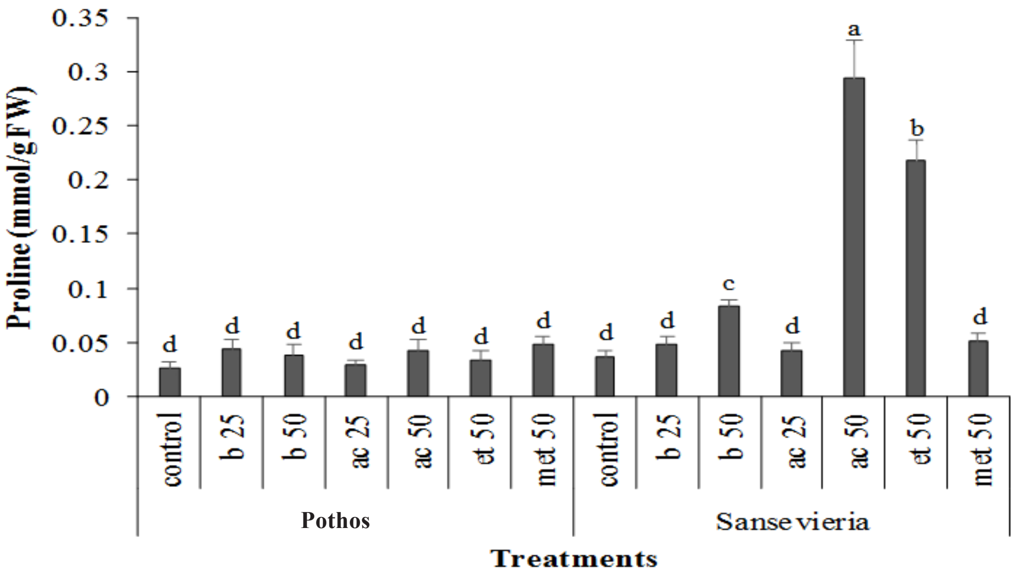

Fig. 3. Effect of benzene, acetone, ethanol and methanol on proline content in pothos and sansevieria leaves.

A number of plant enzymes are able to metabolically modify, degrade, or catalyze the processes that lead to the absorption of airborne contaminants through their pores (Brilli *et al*., 2018). The activity of antioxidant enzymes such as superoxide dismutase (SOD), guaiacol peroxidase (GPO), catalase (CAT) under the stress conditions causes a balance between stress-induced compounds and antioxidant activity of plant tissues. Oxidative stress due to gaseous pollutants seems to occur as a result of response to abiotic stress conditions. One of the first free radicals produced during various stresses is the superoxide radical. It has been stated that the toxicity of pollutant gases causes the production of superoxide radicals and the enzyme superoxide dismutase plays a key role in the plant's defense mechanism against these pollutants by eliminating this radical (Gill and Tuteja, 2010). In both plant species used in this study, observed increase in superoxide dismutase enzyme activity and the most increase was in benzene 50 µl/l with an average of 2.81 units per minute/mg protein of sansevieria leaf tissue (Fig. 4). Also in this study, the activity of guaiacol peroxidase enzyme was not affected by pollutant gases, but it was different in sansevieria and pothos plants (Fig. 5). Enzyme activity was 0.34 units per minute/mg protein in pothos leaf and 0.14 units/mg protein in Sansevieria leaf which were significantly different from each other. It has been stated that biological and abiotic stresses such as air pollution have been shown to increase the production of free radicals such as reactive oxygen species (ROSs), all of which have detrimental effects on the activity of organic molecules within plant tissue.

Accordingly, plants have antioxidant defense mechanisms against free radicals. It has been stated that in various bio stresses, the enzyme guaiacol peroxidase degrades hydrogen peroxide and thus participates in the plant defense system. However, its activity varies depending on the type of stress as well as plant species, followed by different plant reactions (Gill and Tuteja, 2010). The mechanism of action of the enzyme guaiacol peroxidase appears to be part of the ascorbate-glutathione cycle, which removes a variety of ROS, especially hydrogen peroxide, during exposure to pollutants in plants and protects plants under environmental stress (Achille *et al*., 2015). Among the antioxidant enzymes in plants, the guaiacol peroxidase enzyme has been known as an indicator of sensitivity to air pollution and is used as a specific signal to assess the severity of damage caused by air pollution. However, it should be noted that the activity of this enzyme cannot be used as an indicator for a specific type of gaseous pollutants in the air and can only be considered as a general indicator when oxidative stress occurs. In this regard, and in confirmation of the results obtained in the present study, it was reported that increasing the benzene content increased the activity of peroxidase in three plants *Epipremnum aureum*, *Chlorophytum comosum* and *Hedera helix*, which could be due to the increased expression of genes involved in the synthesis of this enzyme (Gong *et al*., 2019).

Catalase activity in this study decreased in both sansevieria and pothos due to contaminants compared to control. The lowest leaf catalase activity of sansevieria was associated with acetone 50 µl/l with a mean of 0.004 U/g F.W. (Fig. 6). This indicates the negative effect of certain concentrations of pollutants on increasing the activity of this enzyme in sansevieria and pothos. Catalase enzyme is a hetero-tetrameric enzyme capable of directly decomposing hydrogen peroxide (H_2O_2) into water and oxygen. The presence of this enzyme under stress conditions is necessary to reduce the activity of oxygen free radicals (ROS_S) in plants (Garg and Manchanda, 2009). Catalase has been is reported to be one of the antioxidant enzymes that is highly active during severe stress and the presence of oxygen free radicals (ROSs) (Gill and Tuteja, 2010), which is not consistent with the results of the present study. In this study, the high activity of catalase enzyme under the influence of acetone treatment with low concentration in sansevieria indicates the negative effect of this gas on the plant and has caused stress in the plant. However, higher gas concentrations cause plant adaptation and stability, thus minimizing catalase activity. The activity of the enzyme catalase in plant tissues plays an important role in the removal of hydrogen peroxide (H_2O_2). According to the researchers, increasing the activity of catalase under the influence of gaseous pollutants has removed peroxide from the plant and reduced oxidative damage to the cell membrane of *Crassula portulacea* and *Cymbidium* Golden Elf. It has also been reported that plants sensitive to gaseous pollutants act as bio-indicators and catalase activity reaches a high level as soon as stress occurs. However, in resistant plants, the catalase content did not change or even decrease compared to the control (Liu *et al*., 2014).

CONCLUSION

According to the results of present study, both used plant species *Epipremnum aureum* (pothos) and *Dracaena trifasciata* (sansevieria) were able to purify contaminated closed area by violatile organic compounds (VOC_S) such as benzene, acetone, ethanol and methanol. Benzene more than other used contaminations damaged tissue cell of plants while under acetone treatments it was the least amount. In general higher adaptability of pothos in pollutant indoor area considering minimal tissue damage and stress establish this fact that potential of phytoremediation in pothos is higher compared to sanseveiria.

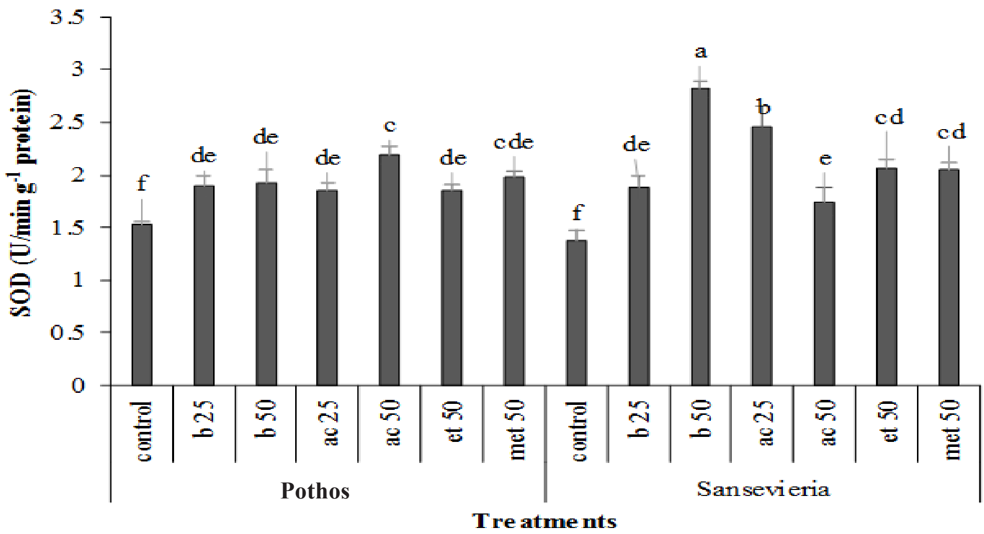

Fig. 4. Effect of benzene, acetone, ethanol and methanol on superoxide dismutase activity in pothos and sansevieria leaves.

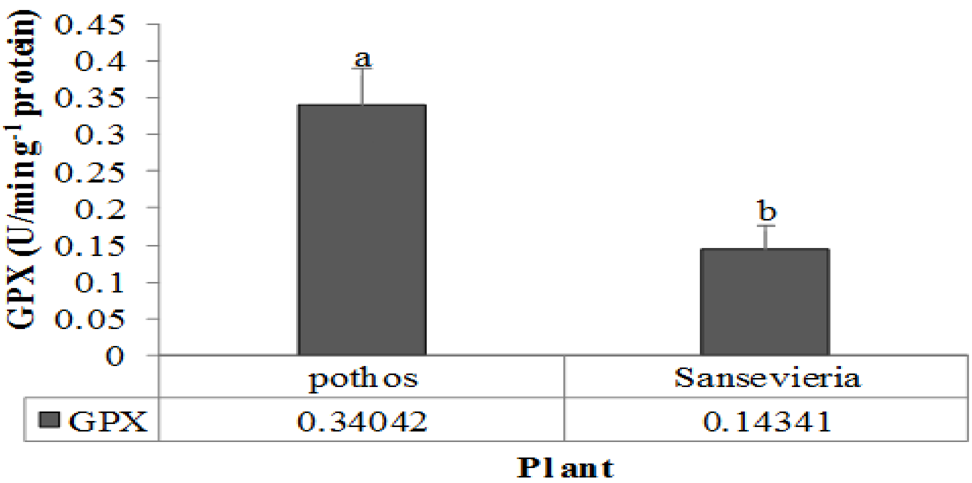

Fig. 5. Effect of benzene, acetone, ethanol and methanol on guaiacol peroxidase activity in pothos and sansevieria leaves.

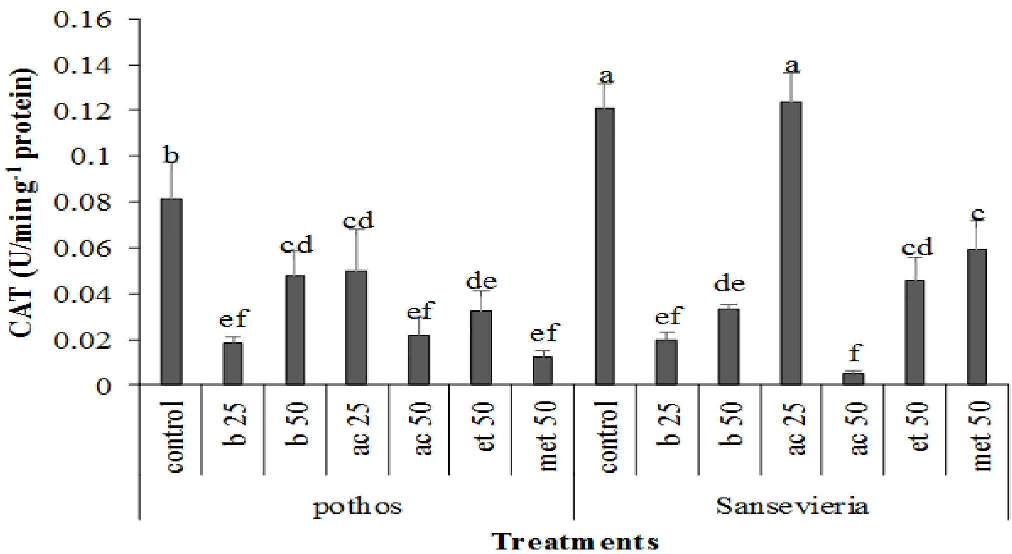

Fig. 6. Effect of benzene, acetone, ethanol and methanol on leaf tissue catalase activity in pothos and sansevieria leaves.

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