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Indoor phytoremediation using decorative plants: An overview of application principles

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ABSTRACT

A healthy and sustainable indoor space was one of the goals of a building, which was an important concern of architects in designing and using it. Design arrangements can be approached physically, such as the use of air vents, lighting, and layout arrangements. However, now the paradigm of using a natural approach has been intensive. In this regard, this paper focuses on the greening of indoor spaces, both for the prevention and restoration of indoor room quality. The study methodology was a survey of existing research results in many countries, and a selection of up-to-date, current data. The results of the literature research obtained are related to the purpose of indoor greening, which is none other than to achieve the goal of green building. Its main target was biodiversity in the prevention of negative health effects and indoor phytoremediation.

KEYWORDS: Sustainable indoor, natural approach, phytoremediation, biodiversity

INTRODUCTION

Green building has become a paradigm of comfort and health building aimed at human health and the environment. Especially is the effort to create a healthy indoor space, which is generally related to aesthetics and comfort. The use of environmentally friendly building materials has been used, including in the use of furniture (Ragheb *et al.*, 2016; Masood *et al.*, 2017; Pryadko, 2018). However, the development of furniture using excessive architectural and decorative materials can release volatile organic compounds (VOCs). These substances are often released at concentrations above the quality standard in residential buildings, especially in newly decorated houses (Nakaoka *et al.*, 2014; Nakaoka *et al.*, 2018). VOCs are representations of the most important contaminants in the indoor environment, and of course affect the health of their occupants (Rovelli *et al.*, 2019; Deng & Deng, 2018; Bogerd *et al.*, 2020). Indoor VOCs in new buildings were found 10-15 times more than in old buildings in addition to the effect of humidity and temperature (Smith *et al.*, 2017; Zhou *et al.*, 2017; Chiang *et al.*, 2020). For tropical countries, such as Indonesia, this issue is very important and needs serious attention.

Generally, people stay indoors at least 80% of their time (Deng & Deng, 2018), even more than 90% (Wang *et al.*, 2008), therefore, the quality of a healthy environment is very important

for residents. Natural environmental health can be obtained through greening the room, due to the process of plants to eliminate environmental pollutants, which is known as the phytoremediation process (Pettit *et al.*, 2020; Pettit *et al.*, 2018; Zhang *et al.*, 2020). Efforts to improve indoor quality through the phytoremediation process have been conducted in many countries and are the main discussion in this paper. The use of ornamental plants to eliminate indoor pollutants makes the environmental health function stronger (Zorić *et al.*, 2019; Samudro & Mangkoedihardjo, 2020), and simultaneously to ensure the availability of oxygen along with other aesthetic values. Within this framework, this paper specifically discusses the elimination of VOCs using indoor ornamental plants, along with the idea of its basic implementation, with the aim of making buildings healthy from the start and their sustainable use.

METHODS

The method of reducing indoor contamination uses natural processes of ornamental plants. Pollution removal by plants, known as phytoremediation is an effective and efficient technique to prevent damage and restore indoor air quality. Some plants show a high potential to remove formaldehyde from indoor air by means of absorption by plant stems or leaves, plant cell metabolism and decomposition of root microorganisms

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(Teiri *et al.*, 2020; Kwang *et al.*, 2008). Several studies have shown the elimination of air pollutants, which massively represent the ability of potted soil ecosystems, a medium for plant growth (Newman & Reynolds, 2004; Wang *et al.*, 2014; Agarwal *et al.*, 2019).

This study is based on a literature survey of existing research results. Hundreds of research topics are available around the world. This proves that the problem of indoor pollutants and the solution using indoor plants has become the world's attention (Pettit *et al.*, 2020; Cruz *et al.*, 2015; Sevik *et al.*, 2018). For this study, the literatures were selected, which are relevant and current.

Of particular interest to this study are the following two related topics. Firstly, it is various studies on the ability of indoor plants to absorb and/or eliminate VOCs, especially formaldehyde from the room. Secondly, there is an idea related to the application of indoor greening, especially setting space priorities based on the potential for air pollutants generation.

RESULTS AND DISCUSSION

Indoor Contamination

NASA Clean Air Study has recorded the results of quite intensive studies on various types of indoor ornamental plants that are specific for the elimination of VOCs ("NASA Clean Air Study," 2020). Of course, this data can be a starting point for the development of further studies. Especially aimed at areas that have specific types of ornamental plants, but have not received attention for their utilization.

In general, new buildings cannot be separated from the need to use paint, as well as new furniture, mostly using paint. Paints and their various products contain thousands of types of chemicals (Keith, 2011; "Painting, Firefighting, and Shiftwork,," 2010; Onesmo & Rongo, 2018). One of them is formaldehyde, which is present most frequently in paints, and which occurs in the air as a colorless gas releasing a strong odor. It is present in many building materials such as plywood, particleboard, curtains, and other types of foam insulation, as well as many other pieces of furniture to be named individually. Thus, the main sources of formaldehyde in the room include furniture, wood products, wallpaper, cleaners, paints, adhesives, oils, cosmetics, electronic goods, fuels and cigarette smoke (Teiri *et al.*, 2020; van den Broek *et al.*, 2020). In addition, formaldehyde also arises from kitchen activities, building hygiene maintenance, and even personal hygiene products for residents (*Indoor Air Quality*, 2016; Brandão *et al.*, 2018). In the course of time using existing buildings and furniture, formaldehyde can be reduced because it degrades over time. However, quick and early safeguards are best to prevent harmful exposures to residents and/or occupants.

Indoor Phytoremediation

From the experimental results, the negative effects of formaldehyde on test living organisms indicate it has an impact

on the respiratory system, blood health, leukemia, brain, and other carcinogenic risks (Duan *et al.*, 2018; Ge *et al.*, 2019; Zhang *et al.*, 2009; Hadei *et al.*, 2018; Teiri *et al.*, 2018a). In addition is sick building syndrome (Ghaffarianhoseini *et al.*, 2018; Nakayama *et al.*, 2019), such as headaches, nausea, dizzy, eye irritation, mucous membrane, drowsiness, fatigue and discomfort. A recent development used a lower limit for formaldehyde below 1%, to prevent sick building syndrome (Suzuki *et al.*, 2019).

Quite a number of researchers conducted experiments to eliminate formaldehyde using indoor ornamental plants (Meng & Ji, 2012; Wang *et al.*, 2020). An experiment was carried out to measure the efficiency of potted Areca palm, which aims to eliminate total organic pollutants in indoor air. The experiment used 9 potted plants, which were carried out for four months in real indoor. It was found that the elimination efficiency was close to 90% (Bhargava *et al.*, 2020). Areca palm has also been studied and proven its ability to eliminate toluene and xylene ("NASA Clean Air Study," 2020). Other similar research was found by three types of tropical plants, namely *Dracaena fragrans*, *Rhapis excelsa* and *Nephrolepis exaltata*. All of them have the same ability to remove gases from indoor air (Jasmin *et al.*, 2012).

Meanwhile, the formaldehyde content in indoor air is eliminated by the one of the palm species, namely *Chamaedorea elegans*, and with various concentrations of formaldehyde up to 16 mg/m³ over a 48 hour period. The results obtained showed that the maximum purification capacity of formaldehyde was about 1.5 mg/m²/hour, which was achieved with the maximum concentration exposure for 2 days. Other results show that the efficiency was obtained by a ratio of plant area and floor area of 70%: 30%. Bright room eliminates more formaldehyde than dark room (Teiri *et al.*, 2018b).

Experiments on light and dark spaces for formaldehyde elimination were also carried out using *Ficus benjamina* L. and *Ficus japonica* plants. The aerial parts of both species reduced formaldehyde concentrations during the day, but only slightly removed at night. Meanwhile, the root is capable of removing large amounts of formaldehyde during the day and night. The effectiveness of roots in eliminating formaldehyde was mainly due to microorganisms and roots. The results of this study indicate that enhance rhizodegradation was the main process of removing formaldehyde (Kwang *et al.*, 2008; Aydogan & Montoya, 2011).

Formaldehyde elimination was also studied in experiments using plants from the Liliaceae, Agavaceae and Araceae families. The volume of space is 0.8 m³ containing formaldehyde with an initial concentration of 15 mg/m³. Within 3 days, it was recommended that most species from these plant families are effective in removing formaldehyde. However, *Philodendron selloum* is the least resistant to formaldehyde exposure (Zhou *et al.*, 2011).

Experiments using one of the common interior plants of the fern species (*Nephrolepis oblitterata*) were aimed at eliminating

formaldehyde from the air. The maximum concentration of exposed formaldehyde vapor was 11 mg/m³ for 48 hours. The results revealed that *N. obliterated* plants efficiently removed formaldehyde from polluted air at least 90% during the exposure time. It was also known that the soil and roots contribute little to formaldehyde elimination, which is about 25%. The plant species tested have high potential in improving the interior environment from exposure to formaldehyde (Teiri *et al.*, 2018b).

Indoor Biodiversity

The importance and necessity of biodiversity for the implementation of phytoremediation has been corroborated by various studies on the elimination of VOCs, which originate from energy use, namely known as benzene, toluene, ethylbenzene, and xylene (BTEX). Some of the most recent data among the existing studies are presented as follows. The efficiency of toluene phytoremediation increased by an average of 156 mg/m³/hour/m² leaves of *Pinus densilora* and *Salvia elegans* (Kwang Jin Kim *et al.*, 2011). Efficient removal of toluene and xylene was achieved using indoor plants (*Schefflera actinophylla* and *Ficus benghalensis*). The removal efficiency of toluene and xylene was around 13 µg/m³/m² leaf area for 24 hours by *S. actinophylla*, however *F. benghalensis* was only able to remove about half of it. As well as, about half the concentrations of toluene and xylene was translocated from the air to the root zone through the stem, which indicates that the root zone plays an important role in this elimination process (Kim *et al.*, 2016).

There is intensive research to filter out dozens of plant species that are capable of eliminating many VOCs gases. For exposure to each gas as much as 10 ppm within 6 hours, it was found that *Hemigraphis alternata*, *Hedera helix*, *Hoya carnosa*, and *Asparagus densive chlorus* had the highest removal efficiency for all pollutants (Yang *et al.*, 2009). Other types of plants have different and lower removal efficiencies. The difference in efficiency between plant species indicates the need, the importance and necessity of biodiversity in the processing of pollutants by plants (Samudro & Mangkoedihardjo, 2020; Samudro & Mangkoedihardjo, 2020; Ren *et al.*, 2017).

The average benzene removal efficiency of 70% was achieved by four common ornamental plants, namely *Epipremnum aureum*, *Chlorophytum comosum*, *Hedera helix* and *Echinopsis tubiflora*. The last type of plant is interesting to observe, that the high ability of removal efficiency is due to its high ability to transpiration and high chlorophyll content, which the other three types of plants did not have (Gong *et al.*, 2019). The high transpiration of plants indicates that they need a lot of watering while they are used for room remediation. Likewise, the high chlorophyll content of plants indicates the need for sufficient sunlight to utilize it. Therefore, planting conditioning and maintenance needs to be considered (Mangkoedihardjo & Samudro, 2014; Ni *et al.*, 2019) in order to support the maximum capacity of

plants to eliminate polluting gases. Thus, the application of biodiversity, including the diversity of plant conditions and ways of maintaining them, is able to eliminate many pollutants maximally.

CONCLUSION

Biodiversity in indoor phytoremediation is necessary and important. Apart from differences in the ability between plant species to eliminate contaminants, it is also due to the ability of plant parts to process them. There are types of plants whose aerial parts are less capable of eliminating gases, but in fact their ability is more in the root zone, which has the support of microorganisms to eliminate contaminants. Thus, the diversity of phytoremediation processes and microorganisms becomes biological diversity to maintain the health of the indoor environment.

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