Review Article

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The use of indoor plant as an alternative strategy to improve indoor air quality in Indonesia

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Abstract: Indoor air pollution marked with decreased air quality below the set standard. The quality of indoor air is determined by ambient air quality as well as by a harmful substance resulting from the household activity. Indoor air pollution may cause several problems such as sick building syndrome, chronic obstructive pulmonary disease (COPD), asthma, lung cancer, and is responsible for nearly two million death in developing countries. One of the interesting research topics to overcome the indoor air pollution problem is the application of indoor plants. Although there are no established criteria to specify the best indoor plant, several studies have revealed the capability of a particular indoor plant to remove the harmful substances. This paper summarizes important information about indoor air pollution and provides the evidence-based insight of indoor plant usefulness as an alternative way for indoor air remediation.

Keywords: air pollution; air quality; indoor air pollution.

Introduction

Air quality is an important factor that plays a role in public health. In accordance with outdoor air quality, bad indoor air quality has the potential to cause health problems. Clinical problems such as asthma, irritation, allergies, headaches, nausea, and muscle aches may occur when exposed to indoor air pollutants. Furthermore, long-term health problems may arise in continuous exposure for a long time such as chronic obstructive pulmonary disease (COPD) and lung cancer [1].

Most of the people spend 80–90% of their time doing activities indoors such as homes, schools, offices, gymnasiums, and means of transportation [2]. The United State (US) Environmental Protection Agency (EPA) stated that exposure to indoor pollutants is 100 times higher than the exposure to outdoor pollutants due to the high concentration of indoor pollutants [3]. Having a good indoor air situation that meets the established quality standards is important to avoid various potential diseases that may occur in the future, both short and long term.

The source of indoor air pollution

Indoor air quality is a picture of a mixture of pollutants sourced from outside and from inside the room. An assessment of indoor air quality can refer to several parameters, including; Physical quality parameters such as humidity, lighting, temperature, and particulate matter (PM) contained. Chemical parameters which consist of Total Volatile Organic Compound (TVOC), Formaldehyde (HCHO), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Ozone, Carbon dioxide (CO_2), Carbon monoxide, Lead (Pb) and Asbestos as well as biological parameters of the air such as bacterial and fungal contents [4].

Indoor pollutants can occur from residual cigarettes (Environmental Tobacco Smoking/ETS), the use of solid fuels such as coal, and the use of biomass energy. Also, pollutants can come from emissions of building materials and furniture, electronic devices, and other materials in the room that evaporate or sublime at room temperature due to its low boiling point [4]. In developed countries or urban areas, generally, the main types of pollutants in the room are Volatile Organic Compounds (VOCs), radon radiation, asbestos, pesticides, heavy metals, and cigarette smoke. Meanwhile, in

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developing countries and rural, the sources of pollution generally come from the use of solid fuels and the use of biomass energy [5].

Quality standards for indoor air quality have different values from one country to another. The World Health Organization (WHO) has issued global guidelines on indoor air quality to prevent the effects of pollutants and reduce the intensity of exposure to harmful pollutants in space [6]. The quality standards of indoor air quality in Indonesia refer to the regulations of the Ministry of Health of the Republic of Indonesia which contains guidelines on indoor air sanitation [7].

Study-related to the accumulation of pollutant levels in the room has been done in various places and with various types of certain pollutants. Study reports generally indicate that there are levels of pollutants in the room that are higher than they should be. The level of particulate matter originating from inside the room in a household setting is higher than outside in which 46% of PM2.5 derived from organic components in the room related to cooking, hygiene, candle burning, and cigarette activities [8]. Furthermore, a study found that PM2.5 from inside the room is more potent in reducing lung function than PM from outside the room [9]. The degree of pollution is also related to building characteristics such as the year of manufacture, the year of renovation, and the heating system used [10].

The level of pollutants in the room in public places also generally have a higher value than the specified quality standards. Environmental tobacco smoking (ETS) is one of the main source of pollutants in public places is. Cigarettes are the main source of indoor pollution in public facilities such as cafes, restaurants, and other closed public places. The level of PM2.5 found in public places that allow visitors to smoke are found to be much higher than other public places that are not allowed to smoke [11]. A Study conducted in Porto, Portugal, showed that the PM2.5, PM10, and bacterial content in 73 classrooms beyond provisions suggested by WHO. In addition, this study also concluded that high levels of pollutants are associated with a high incidence of sneezing in students [12].

Indoor air pollution in Indonesia

In developing countries, especially in rural areas, pollutants in rooms are sourced from residual combustion. In general, due to the use of solid fuels and biomass, from emissions of building materials, and biological aerosol [13]. In Indonesia, in 2005, it was reported that the use of solid fuels such as coal reached 27.5 million tons. The large industries use most of the solid fuel, while household use reaches 11% or 4.5 million tons. The percentage of the use of coal briquettes has increased along with the scarcity and high prices of non-subsidized fuels and reduced the use of firewood [14]. In the research report on ambient air quality measured at coal briquette burning locations from 2006 to 2011 in several locations in Indonesia, several parameters such as Total Suspended Particulate (TSP), SO_2, and NO_2 were at a level below the quality standard meanwhile the value of hydrocarbon (HC) level was above the specified quality standard [15]. Furthermore, the use of coal briquettes in rooms with less air ventilation increased levels of SO_2, NO, and CO amounting in 22, 44, and 10 times higher from the standards determined respectively [16]. The difference in score may be due to the different methods of research, however in general, it shows a significant increase in the levels of room pollutants. Last, it has been reported that the population of adult living nearby the Pulogadung industrial area of Jakarta having deterioration of lung function and it is might be related to the exposure of the indoor PM2.5 [17].

Potential diseases due to the indoor air pollution

Source of pollution in the room has very broad scope and varies relied on geographical conditions, building materials, habits, and the number of inhabitants. Different types of pollutants also affect the different clinical outcome of the organs involved. Diseases and clinical symptoms caused by indoor pollutants can be both acute and chronic ranging from irritation, infectious diseases to degenerative diseases, and cancer [18]. In 1983, WHO introduced the term Sick Building Syndrome (SBS) to define the condition of the occupants of buildings/rooms that experience acute symptoms and discomfort that occurs when occupants are in a building without any specific cause that can be identified. These complaints can be reduced or even can be completely disappeared when they leave the building or room. In addition to factors such as lighting, traffic noise, it was reported that the concentration of indoor pollutants such as VOCs was one of the main causes of SBS [19, 20].

High levels of air pollutants in the room can also facilitate lung and airway infections. Pollutants generated from the process of using household fuels such as kerosene, coal, and firewood are reported to have the correlation with the incidence of lung infections [21–23]. Other reports also state that indoor pollution produced from the

use of coal and firewood can increase the risk of contracting tuberculosis [24]. Some reports also mention the relationship between increased levels of pollutants in the room with the incidence of asthma and COPD. In a report from a longitudinal cohort study conducted in Baltimore, the United States showed that there was a significant relationship between PM levels and an increase of asthma symptoms among 150 preschool-aged children [25]. In addition, another study has shown a decrease in pulmonary function of school-age children who exposed to indoor PM2.5 particles and do not use inhaled corticosteroids [9]. One study also showed a link between indoor NO_2 exposure with an increase in asthma events where the asthma incidence increased with the increase of concentration [26]. Consistent with the findings, an evidence revealed that exposure to NO_2 can increase allergen effects in asthma patients as shown by Strand V et al. [27] who found that there was an increase in asthma response to pollen in asthma patients after repeated exposure to NO_2 [27]. Meanwhile, exposure to VOCs can cause inflammation of the airways even though the results of a systematic review have not found a significant relationship between VOCs and asthma exposure [28, 29]. Furthermore, in the reports from various meta-analysis mentioned that exposure to indoor pollutants, especially those originating from the use of solid fuels such as coal and firewood can cause COPD and lung cancer [30].

Air purification using an indoor plant

Plants have the ability to absorb and catabolize various toxic substances that exist in the environment or also called phytoremediation, despite this ability is still not optimally utilized as a medium for air purification in the room. The process of air purification by plants has not been widely known but in general, trends in the selection of plants at houses are based on aesthetic considerations, durability, and low maintenance costs. Most of the selected indoor plants are broadleaf species. However, the broadleaf plants are a process of adaptation to the environment. One effect of adaptation is the reduction of stomatal pores on the leaves thus pollutants are only more attached to the leaves and are not absorbed [31]. Based on the National Aeronautics and Space Administration (NASA) research, indoor plants can be useful as natural water-filtration that functions as filters of VOCs such as formaldehyde, benzene, and trichloroethylene [1]. It is recommended to use two plants in each room of 100 square feet (9.3 m^2) [2]. Some examples of indoor plants published by NASA as shown in Table 1 [32].

Currently, the standard criteria for selecting indoor plants have not yet been determined. However, in recent decades, the use of indoor plants as air purification media has received a lot of attention and has been investigated on a broad scale. Tests of the effectiveness of indoor plants as an air purifier pioneered by NASA revealed that plants have the ability in reducing levels of pollutants in the room [33]. Furthermore, the number of research on indoor plants is increasing by testing the capability of the particular species of plants in purifying indoor air.

There were several researches tried to link the use of indoor plants and the clinical benefits. A study conducted by Orwell et al. [34] showed a significant reduction of benzene in a room's air where plants were used [34]. The same result was reported by Hong et al. [35] which revealed the ability of plants called Genus ficus to purify room air by calculating the decrease in levels of VOCs pollutants such as benzene, ethylbenzene, xylene, styrene, formaldehyde, acetaldehyde, and toluene. In this study, pollutant levels were assessed before and after the use of plants. The result is that VOCs levels in the room decreased significantly [35]. A research conducted by Teiri et al. [36] also revealed the efficiency of *Nephrolepis Obliterata* in reducing indoor formaldehyde levels by up to 100% [36]. Research conducted by Aydogan et al. [37] found that several plants such as *Hedera helix*, *Chrysanthemum morifolium*, Dieffenbachia compacta, and *Epipremnum aureum* are effective in

Table 1: Indoor plants as water filtering recommended by National Aeronautics and Space Administration (NASA) (1989) [30].

Types of plants
English ivy (*Hedera helix*)
Green Spider plant (*Chlorophytum elatum*)
Peace lily (*Spathiphyllum* 'Mauna Loa')
Chinese evergreen (*Aglaonema modestum*)
Bamboo palm (*Chamaedorea seifrizii*)
Variegated snake plant, mother-in-law's tongue (*Sansevieria trifasciata* 'Laurentii')
Heartleaf philodendron (*Philodendron cordatum*)
Selloum philodendron (*Philodendron bipinnatifidum*)
Elephant ear philodendron (*Philodendron domesticum*)
Red-edged dracaena (*Dracaena marginata*)
Cornstalk dracaena (*Dracaena fragrans* 'Massangeana')
Weeping fig (*Ficus benjamina*)
Barberton daisy (*Gerbera jamesonii*)
Florist's chrysanthemum (*Chrysanthemum morifolium*)
Aloe vera (*Aloe vera*)
Janet Craig (Dracaena deremensis "*Janet Craig*")
Warneckei (Dracaena deremensis "*Warneckei*")
Banana (*Musa oriana*)

reducing formaldehyde levels up to 90% within 24 h [37]. In addition to effectively reducing VOCs levels and CO and CO_2 levels, indoor plants are also beneficial for reducing PM levels as reported by Penyameethulasi et al. [38] that indoor plants help decrease the number of PM particles. However, it was found that the reduction in the number of particles was not as good as when using a mechanical ventilation system [38]. The number of evidence related to the direct clinical benefits of indoor plants is still limited. Nevertheless, it has been shown that several studies successfully provide a general description of the benefits of plants in a room as reported by Kim et al. [39] which showed a decrease in Peak Expiratory Flow (APE) in asthma patient groups after terminating the use of plants in rooms [39].

Furthermore, several studies also have shown the use of potted plants as a mechanical system for phytoremediation of several indoor air pollutants [40, 41]. There are several factors that can influence the ability of indoor plants to reduce indoor air pollution levels, namely the presence of biostimulant from substrates belonging to the number of microbes in plants. This can occur when pollutants disperse through the potted plant and the substrate then becomes a source of carbon nutrition for some members of the microbes [42]. In addition, other factors that also influence the ability of plants in improving the indoor air quality are the plant vegetation and aerial impact, as some studies have demonstrated that there are differences about pollution inhibitory impression between aerial elements and plant root regions [43]. Nevertheless, several other studies also underline that the two parts are equally important and play a pivotal role together in removing pollutant water, especially in eliminating the VOCs [44, 45].

Conclusions and prospects for future research

Currently, there are few data about indoor air pollutants in Indonesia. Indonesia has a large area coverage and huge variation in socioeconomic, cultural and geographic conditions making it a challenge for Indonesian researchers especially in the field of respiratory health to create indoor pollutant maps in various places including public places such as hospitals, schools, shopping centers, and offices both private and government. The mapping will be useful for making strategies to overcome potential diseases which may arise due to exposure to indoor pollutants either in the short term or long term period of exposure. Additionally, Indonesia also has plants varieties which are likely to be candidates for indoor plants. However, more specific research is needed to determine the standard criteria of a plant to be an indoor plant candidate. Therefore, the opportunity for collaborative research between botanists and respiratory medicine experts to investigate the benefits of plants in clinical field is still wide open.

The use of indoor plants in Indonesia can be one of the environmentally-friendly air-purification strategies with minimal energy consumption and financially affordable.

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