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Cleaning up black carbon using plant strategies

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Abstract

Black carbon aerosol is able to absorb solar radiation and the earth's surface, which results in the warming of the air. In addition, aerosols that are directly absorbed through inhalation can have a negative impact on human health. Meanwhile, the ability of air to reduce the level of pollution is the deconcentrating of pollutants through abiotic mechanisms in the form of distribution, dilution, precipitation and washing when it rains. To strengthen the abiotic approach, this study aims to develop a biotic strategy by preparing plants capable of deconcentrating black carbon. The research method is based on a literature review, which specifically addresses the issue of black carbon. Literature is collected from the Mendeley platform and enriched through resource searches in open-access journals. The results obtained are cleaning priorities for the closest source of aerosol generation, plant placement in priority areas, selection of plant species, intensification of vegetation quality and management of land cover extensification. The contribution of biotic strategies and phytoremediation pathways enhances the aerosol cleaning process. Plant maintenance and regeneration determine the sustainability of aerosol phytoremediation.

Keywords

Air pollution, aerosol capture, phytoremediation pathway, plant strategies, sustainable practices

Introduction

Aerosols are microparticles in solid or liquid form suspended in the air originating from natural and anthropogenic activities. The nature of aerosols that absorb sunlight on a bright day and infrared radiation from the earth's surface at night, mainly refers to black carbon (BC) (1-4). Aerosols containing BC produce a warming effect on the air, which distinguishing it from reflectors of radiation, such as aerosols from volcanic eruptions and sulfur dioxide emissions (5, 6).

Sources of BC generation are particulate soot that comes from burning fossil fuels and coal, as well as the use of rubber-based products. Based on the source of origin, BC is widespread from indoor buildings to the air, water, and land environment through various human movement activities. Meanwhile, the main content of BC is a polycyclic aromatic hydrocarbon (PAH), which has carcinogenic properties (7). Therefore, the potential negative effects of BC are environmental multimedia, both on abiotic and biotic elements. In addition, the negative effects of BC have the potential to threaten human health, which are associated with sick building syndrome (8), and upper respiratory infections, cardiovascular disease, cancer and birth defects (9).

The problem of BC dispersion and its negative effects need to be controlled to maintain the quality of environmental health. Control of BC can be through an abiotic environmental approach. Reducing the use of fossil fuels and coal by increasing the use of renewable energy has been promoted globally (10-12). Carbon reduction can use carbon capture and storage (CCS) technology through various means including membranes and carbonation (13), carbon-based material recycling (14), and other methods that are compatible and mutually supportive. Abiotic control also works naturally in the air (15). Ambient air volume is capable of diluting pollutants (16). Air dynamics with changes in pressure and temperature are able to disperse pollutants, both convectively and diffusively (17). It is a common fact that the rainy season is also able to wash pollutants from the air onto land and water.

However, this research focuses on biotic control with the use of plants. Besides, plants are essential creatures for the needs of all living things because of their ability to produce oxygen, plants are considered capable of processing various pollutants. Thus, the aim of this study is to provide plant strategies to reduce BC concentrations in aerosols. This plant empowerment strategy includes controlling BC at the building and environmental scale.

Materials and Methods

This study method uses the Mendeley Manager platform to collect literature using search terms: black carbon, phytoremediation. Selection of literature using criteria: open access journals, in English, discussing plant processes in removing air pollutants. Sources of scientific information were also collected from open-access journals using selection criteria: black carbon processes, plant processes, experience in different places and results of recent research.

The problems of black carbon were identified as sources of generation, environmental distribution, interactive nature between black carbon and the environment, and negative effects on the environment and humans. The formulation of the problem solution is focused on preparing plant empowerment strategies to overcome air cooling and reduce negative effects on health. The role of plants identified phytoremediation pathways and the ability of plants to process black carbon.

Results and Discussion

Plant Strategies

Placement on aerosol sources

Plant placement effectively is at the source of aerosol generation. This is because once a pollutant is released into the air, its control involves more environmental media (18) in addition to prolonging pollutant transport. This strategy directs the placement of plants in buildings and transport roads. Buildings that have the potential to produce BC aerosols are related to the activity of using fossil fuels, and equipment made from rubber. Next up is the source of aerosol-generating on transportation roads. Placement of plants along roadsides and road medians is effective in preventing spread to the wider environment. Some studies have proven that the presence of plants along the road shortens the transport of pollutants while reducing the concentration of pollutants (19, 20).

Priority areas

Both indoor and outdoor places have physical media in the form of air, water and soil. In general, buildings have a much larger volume of air than the volume of soil and water. Direct short-term control of BC aerosols may depend on dilution of the pollutant by air, and long-term control of various soil and water reactions in the long term. Therefore, the priority areas in a building are indoor, carport, facade, yard and fence. There is a considerable amount of research on the ability of houseplants to remove indoor pollutants (21-23). Plants that have an air-cooling effect are preferred, because they have a high transpiration rate and are easy to grow indoors, such as Bird's nest fern (*Asplenium nidus* Linn.) (24) and *Murraya exotica* L (25). For outdoor plants, there are Kadam (*Anthocephalus chinensis* L.), Benjamin fig. (*Ficus benjamina* L.), Dhauri (*Lagerstroemia floribunda* L.), Mango (*Mangifera indica* L.), and Yellow Goldmohur (*Peltophorum africanum* L.) (26).

Plant selection

It is important to pay attention to the selected plants which are not for human consumption, and the existence of plant species that actually endanger human health (27). One case of poisoning by the indoor plant Nerium oleander gave clinical symptoms characterized by drowsiness, nausea, vomiting, diarrhea and clinical features including cardiovascular and central nervous system (28). Thus, the strategy of selecting plant species for both indoor and outdoor is important and necessary, so that the purpose of environmental health does not have side effects on human health.

Plant selection also needs to consider the ability to capture aerosols. Aerial plants, especially leaves, are an effective medium for capturing aerosols. In this case, it is necessary to consider choosing the type of plant with narrow leaves rather than broad leaves (29). For the same weight, narrow leaves have a larger total area than broad leaves, as the principle of particle deposition in solid media (30). Therefore, with narrow-leaved plants are expected to be able to capture a lot of aerosols.

The next selection consideration is plants that are capable of processing aerosol substances deposited in their growth media. The particulate aerosols caught by the leaves in turn fall into the growth medium, either due to gravity or water spraying. Coupled with particulates that are directly caught by the growth medium, all particulates need to be stabilized in place, so as not to spread out of the growth medium. In this regard, plant species with high transpiration capacity are needed. The rate of transpiration of plants from their growth media is an indicator of the ability of plants to absorb contaminants from their growth media (31-33). This transpiration rate is important to maximize pollutants stability in the growing medium and undergo a process of elimination by plants.

An equally important consideration is the selection of local wisdom plant species. This consideration relates to social acceptance in its implementation. In some places people have used plants of local wisdom (34, 35). There are plants that have become cultural beliefs of the community and as herbal medicinal plants (36).

Plant diversity

The strategy for intensifying the use of plants can be in the form of increasing the quality of vegetation cover. Quality improvement is in the form of increasing biodiversity (37-39) for existing greenspaces in order to eliminate various kinds of pollutants. Various types of outdoor plants have been adequately investigated for their ability to remove aerosols, especially PAHs (40-42).

In addition to species diversity, plant height diversity is also required. Plant height diversity can be formed when maintenance and periodic pruning. Plant height diversity can be formed when maintenance and periodic pruning. This activity aims to regenerate and increase gas absorption capacity (43-45), while maximizing aerosol capture.

Canopy extension

In the management strategy, extensification of greenspace is a land cover method of any landscape to reduce evaporation (46) and treat aerosol (47, 48). The existence of greenspace is proven, among others, to be able to move gas from the air to the vegetation area (49, 50). Therefore, the vegetation cover absorbs many of the pollutants contained in the aerosol to minimize dispersal into the air. In addition to the aerosol pollutant reduction effect, the presence of greenspace provides a cooling effect due to the shade of the trees from exposure to sunlight (51).

Phytoremediation pathway

Plant processes

In general, phytoremediation describes the process of plants in eliminating pollutants from the environment. It is a part of phytotechnology that studies and prepares solutions to environmental problems by empowering plants (52). Plant empowerment is focused on environmental quality management and treatment for various pollutants and media (53). In connection with global warming that is increasingly evident today, an increase in the earth's surface temperature can increase water evapotranspiration (54) and the earth's surface in the form of aerosols, which carry various physical, chemical and biological substances into the air (55, 56). Considering the role of plants in removing pollutants (57, 58), the aerosol pathway in the phytoremediation process is described as presented in Fig.1.

Upward movement of aerosols can be influenced by plant leaf crowns through inhibition, filtration and absorption of leaf stomata. Some of the dissipated aerosol can be deposited on the leaves, which are washed into the soil when it rains. Some aerosols with a density exceeding air are directly deposited on the ground. Gaseous aerosols absorbed by leaf stomata can be processed in plants, and aerosols dissolved in water can be processed by plants through various processes in the root zone and in plants (59, 60).

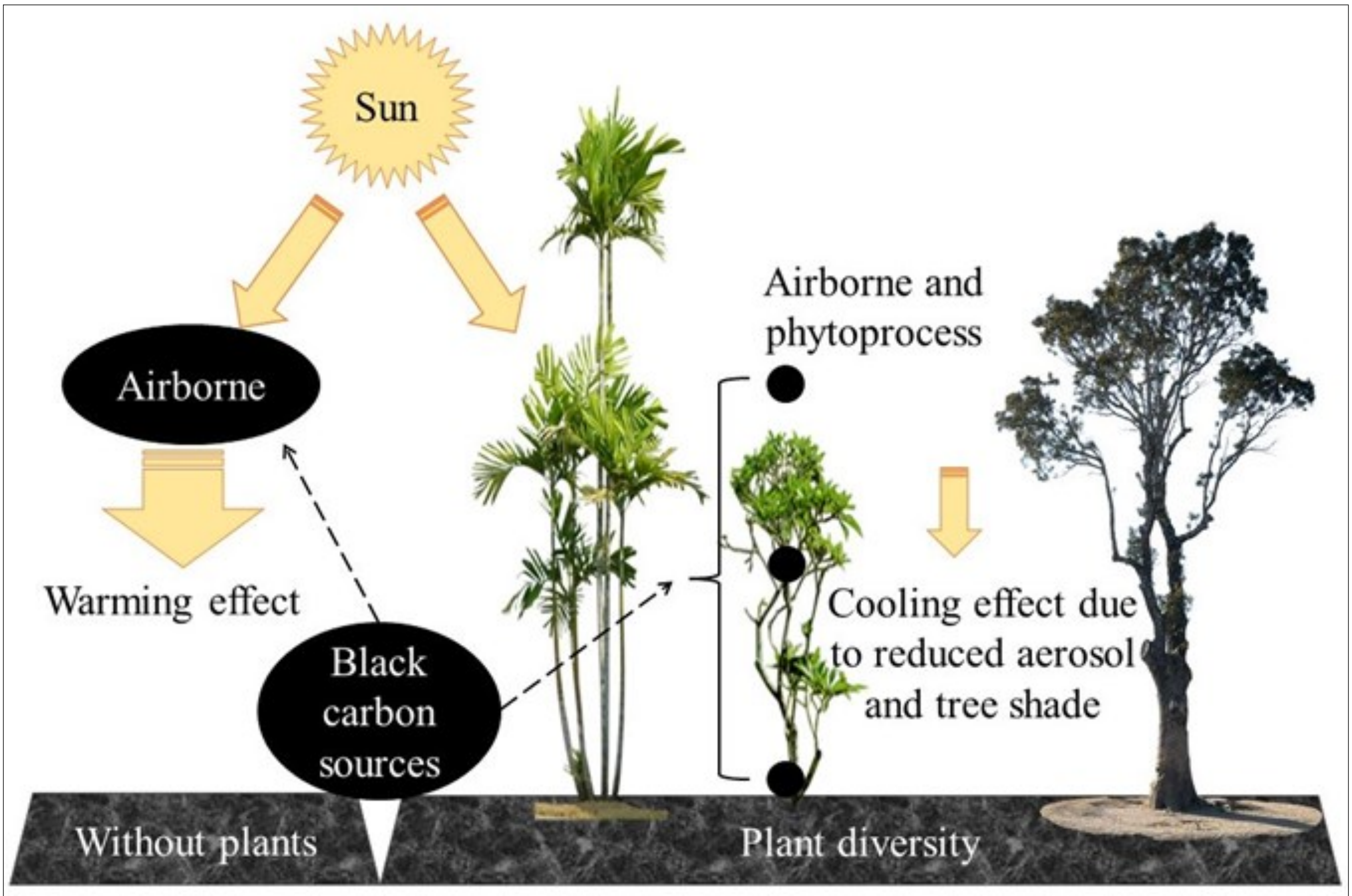

Fig. 1. Aerosol capture phytoremediation pathways.

Therefore, there are phytoremediation pathways that operate based on interactions between aerosols and plant leaves via air transport and dilution mechanisms. This air path can be referred to as aerosol capture phytoremediation. This is followed by a phytoremediation pathway that works between aerosols and plant media, i.e., soil for terrestrial plants and water for aquatic plants.

The output of aerosol processing by plants is a decrease in aerosol concentration. In addition to the foliage shading effect, for the capture of heat-absorbing BC, the phytoremediation output is in the form of an air-cooling effect.

Sustainable design

For the sustainability of aerosol phytoremediation is plant maintenance. The implementation required is regeneration in the form of pruning branches, twigs, and leaves. Leaf pruning is a must with the aim of increasing gas and particulate assimilation capacity (61, 62). The assimilation capacity includes the absorption of carbon dioxide, which carries various gaseous pollutants. In this regard, ecologically, the ability of plant functions can be maximized if exposure to solar energy can be absorbed efficiently. For each type of plant, high solar energy efficiency will be obtained for heterogeneous canopy conditions and pruning of leaves at the bottom. The rough canopy allows solar radiation to be captured by many of the leaves. Multilayered leaves allow for maximum absorption. Meanwhile, the lower leaves, which do not receive enough solar energy, undergo the breakdown of biomass into carbon dioxide. Thus, in order to increase the assimilation capacity of gaseous pollutants and prevent the loss of biomass, the correct pruning pattern is the upper and lower leaves.

Sustainable aerosol capture phytoremediation is also designed for buildings and transportation roads. Humans live about 80-90% a day in buildings (63-65), wherever they are. Meanwhile, the duration of exposure to BC aerosol is in the building. Therefore, the habit of placing decorative plants, and familiarizing them with new ones is a strategic design to combat BC aerosols. The strategic value of decorative plants in buildings is the prevention of sick building syndrome (8, 18), especially the health effects of occupants.

Transport roads also need to be designed with plant placement. Its placement in road medians and/or roadsides is effective for deconcentrating aerosols. Its strategic value is mainly to localize the horizontal distribution of aerosols (57, 66, 67), while the effect of upward scattering of aerosols can be accomplished by air dilution.

Conclusion

Cleansing of carbon black aerosol emissions is carried out through deconcentration of various media. Air works for dilution and dispersal. The existence of plants is to capture the spread of aerosols, and together with the growth medium to carry out pollutant treatment. For the effectiveness of aerosol capture phytoremediation, priority strategies, including plant placement in aerosol sources, buildings, transportation roads, plant diversity and canopy expansion. This aerosol phytoremediation must be continuous, requiring periodic maintenance and regeneration by means of pruning of upper and lower leaves.

It is recommended to provide design criteria for plant placement, both indoor and outdoor, as well as plant regeneration protocols. Empirical studies are needed on plant species capable of eliminating specific pollutants. This includes the aerosol deconcentration rate, which is locally accepted as it dictates its implementation.

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Authors contribution

HS carried out conception, design, acquisition of data, analysis and interpretation of data, drafting the manuscript, and revising it, focusing on indoor environment. GS carried out as HS contributes, focusing on outdoor environment. SM conducted as contributed by HS and GS with the addition of processes, strategies and correspondence. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no potential conflict of interest affecting this work.

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