Use of Plants to Clean Polluted Air: A Potentially Effective and Low-Cost Phytoremediation Technology

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Air pollution poses a great threat to human health, and it has become a worldwide problem that needs to be urgently dealt with. Many measures have been taken to reduce air pollution and improve air quality. These methods are generally costly and require special equipment. Some plants have the ability to assimilate, degrade, or modify toxic pollutants in air into less toxic ones. It is proposed here to develop plant-based technology to clean polluted air at low cost. This air phytoremediation technology has many potential advantages in contrast with traditional air pollution treatment methods. It is simple, potentially cheap, and easily implemented. Plants to be used for air phytoremediation have the potential to reduce pollutants in air and improve air quality; they also fix carbon dioxide through photosynthesis and help to decrease greenhouse gases in the atmosphere. The selected plants can also be used as raw materials for production of energy and bio-based chemicals. However, little research has been carried out on air phytoremediation technology, especially in the basic research area. This editorial gives a brief discussion about air phytoremediation to stimulate more research on this technology and further improve its effectiveness in practical use.

Keywords: Plants; Air pollution; Air phytoremediation technology

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Air Pollution: A Great Challenge for Sustainable Development

With the increase of population and the development of modern industry, more pollutants are entering the atmosphere, contributing to air pollution (Burns *et al.* 2020). Vehicles and traditional power factories are among the main sources of air pollution (Chen *et al.* 2014; Zhu *et al.* 2018; Zeng *et al.* 2019). The exhausts from automobile engines contain many kinds of pollutants, notably particulates (soot of various sizes), carbon monoxide, nitrogen oxides (NOx), volatile organic compounds (VOCs), and small amounts of heavy metals. Traditional power factories, which produce electricity by burning fossil fuels such as coal, gas, and oil, discharge a range of air pollutants, notably sulfur dioxide (SOx), NOx, and particulates. Besides the toxic pollutants, these vehicles and factories also release huge amounts of carbon dioxide, a key cause of global warming and climate change when it rises and accumulates in the atmosphere (Zhu *et al.* 2013a,b; Woodford 2018). Air pollution has become a trigger for headache problems worldwide. According to a recent WHO report, nearly 91% of the world's population lives in areas where the level of airborne pollutants exceeds WHO permissible limits (Health Effects Institute 2018). Pollutants, including carbon monoxide, SOx, NOx, VOCs, and particulates with toxic

metals, can cause dozens of diseases and threaten human health (Burns *et al.* 2020). Many efforts have been made to prevent air pollution (Kelly and Zhu 2016; Zhu *et al.* 2016; Zeng *et al.* 2019). One route to reducing the harm of air pollution to human health is to reduce the emission of air pollutants. For example, high standard gasoline and a highly efficient auto-exhaust catalysts are used to reduce the emission of pollutants from vehicles. The wet, dry, and semi-dry desulfurization systems for flue gas, selective catalytic reduction of NOx, activated carbon adsorption of VOCs, and electric precipitation of particulates are used to decrease the emission of pollutants in flue gas from the traditional power factories. The reduction of the emission of pollutants is often carried out *via* the complicated physical and chemical process, such as adsorption and catalysis. Such procedures are generally expensive because of high equipment investment and operational costs (Cao *et al.* 2019; Burns *et al.* 2020).

Another route is to remove the pollutants from the polluted air. Photo-catalysis, activated carbon adsorption, and pot-plants are useful methods to remove indoor air pollutants (Pettit *et al.* 2018; Bhave and Yeleswarapu 2020; Dhanabalan *et al.* 2020). However, little research has been carried out on the removal of ambient air pollutants. Removal of these pollutants often depends on slow natural degradation processes. When their removal rate is less than their emission, serious air pollution will occur. Therefore, there is an urgent need to develop simple, cheap, and effective methods to remove pollutants from ambient air.

Air Phytoremediation: An Effective Way to Clean Polluted Air at Low Cost

Air phytoremediation (AP) is an environmental remediation technology that uses green plants to remove the pollutants from polluted air (Gawronski *et al.* 2017). Some plants have the ability to assimilate, degrade, or modify toxic pollutants in air into less toxic ones, which makes it possible to remove the airborne pollutants *via* the AP technology (Omasa *et al.* 2012). Some reports indicate that air pollutants can be effectively removed by plants. For example, *Brassica* species absorb SO_2 and NO_2 from polluted air and utilize it as a nutrient for their growth, *Spinacia oleracea* and *Brassica oleracea* uptake Cd, Sn, Zn, and Pb from air particulates through their leaves; *Chenopodium murale* removes volatile hydrocarbons; *Zea mays* removes phenolic compounds; and *Zamioculcas zamiifolia* removes formaldehyde (Gawronski *et al.* 2017; Pettit *et al.* 2018; Kumar *et al.* 2019).

Compared with the traditional air pollution treatment methods, AP technology has many advantages:

1) It is a green technology and will not cause secondary pollution (Brilli *et al.* 2018);
2) It can be simple, cheap, and easily implemented (Gawronski *et al.* 2017);
3) The AP plants not only can remove air pollutants, but they also fix carbon dioxide through photosynthesis;
4) The AP plants can be used as raw materials for energy and bio-based chemicals production (Zhu *et al.* 2015a,b, 2017);
5) The AP plants can beautify the environment *via* urban greening.

At present, AP technology is mainly used to remove indoor air pollutants (Brilli *et al.* 2018). Because of the lack of basic research, the treatment of ambient air pollutants is rarely carried out *via* the AP technology, although it presents many potential advantages. The AP is basically a biochemical process in plant cells of leaves (Kumar *et al.* 2019). The plant leaves act as a sink for air pollutants and particulates. The AP process is closely related with the plant species and the microbial association on their leaves (Weyens *et al.* 2015; Wei *et al.* 2017). For AP technology to become a powerful weapon to fight against air pollution, more studies should be carried out in the following aspects:

1) Identification of the microbial associations on plant leaves and their role in the air pollutants' degradation process;
2) Investigation of the biochemical process including the uptake of air pollutants and their metabolism in plants;
3) Investigation of the physiological processes and mechanisms of air pollutants on the physiological, anatomical, and genetic changes of plant leaves;
4) Selection or construction of more efficient plant species that degrade air-pollutants *via* modern biotechnology;
5) Development of new technology for comprehensive utilization of the AP plants; for example, using AP plants as raw materials for energy and bio-based chemicals production.
6) Determination of which types of air pollution, *e.g.* volatile organic compounds, particulates, nitrogen oxide gases, *etc*., can be effectively decreased by application of AP technology, and whether the benefits are large enough to justify further research and/or plantings.

With the deepening understanding of the physiological processes and mechanisms involved in phytoremediation, AP technology has potential to become a mainstream air pollution treatment method and play an important role in improving air quality.

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