



Review

Application of common duckweed (*Lemna minor*) in phytoremediation of chemicals in the environment: State and future perspective



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H I G H L I G H T S

- Several tonnes of chemicals are produced annually from the global chemical industry.
- Many of these chemicals are released into the environment after their domestic or industrial application.
- These chemicals are difficult to remediate using conventional wastewater treatment methods.
- *Lemna minor* is an effective macrophyte for the treatment of chemicals in the environment using constructed wetlands.

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Over the past 50 years, different strategies have been developed for the remediation of polluted air, land and water. Driven by public opinion and regulatory bottlenecks, ecological based strategies are preferable than conventional methods in the treatments of chemical effluents. Ecological systems with the application of microbes, fungi, earthworms, plants, enzymes, electrode and nanoparticles have been applied to varying degrees in different media for the remediation of various categories of pollutants. Aquatic macrophytes have been used extensively for the remediation of pollutants in wastewater effluents and aquatic environment over the past 30 years with the common duckweed (*L. minor*) as one of the most effective macrophytes that have been applied for remediation studies. Duckweed has shown strong potentials for the phytoremediation of organic pollutants, heavy metals, agrochemicals, pharmaceuticals and personal care products, radioactive waste, nanomaterials, petroleum hydrocarbons, dyes, toxins, and related pollutants. This review covers the state of duckweed application for the remediation of diverse aquatic pollutants and identifies gaps that are necessary for further studies as we find pragmatic and sound ecological solutions for the remediation of polluted environment for sustainable development.

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1. Introduction

Pollution is one of the critical existential problems affecting modern society. The industrial revolution of the last century and the dramatic increased in human population over time has resulted in the generation of an unprecedented amount of waste materials and pollutants into the environment. According to the Lancet Commission on Pollution and Health, air, water and soil pollution were responsible for 16% of deaths worldwide in 2015. About 92% of such deaths occurred in developing countries with children being at high risk (Landrigan et al., 2017). The report further indicated that global pollution cost \$4.6 trillion per year, which is equivalent to 6.2% of economic output worldwide (Landrigan et al., 2017). An earlier report from the World Bank and the Institute for Health Metrics and Evaluation put the cost at US \$5 trillion worldwide in 2013 (World Bank/IHME, 2016). Over the past 50 years, different strategies have been introduced for the remediation of polluted air, land and water. Many of these strategies, driven by government policies and public opinion, favours ecological based treatment as against conventional methods. Ecological based strategies such as the application of microbes, fungi, earthworms, plants, electrode, and nanoparticles have been applied to varying degrees in different media for remediation of different categories of pollutants (Gadd, 2001; Gregory et al., 2004; Nwachukwu and Osuji, 2007; Mmom and Deekor, 2010; Omokeyeke et al., 2013; Ichor et al., 2014; Makky et al., 2014; Ekperusi et al., 2015; Yan and Reible, 2015). This paper evaluates the major concept in phytoremediation and the ecological role of aquatic macrophytes. It also reviewed the application of *L. minor* for the removal of pollutants in aquatic environment, and future areas of interest in the application of the plant for phytoremediation studies.

2. Phytoremediation

Phytoremediation is an aspect of bioremediation that deals with the application of plants for the remediation of polluted environment. It is the potentials of plant species to remove pollutants from

polluted media. Phytoremediation deals with the application of certain plants species to accumulate pollutants in terrestrial and aquatic environment. Plant species selected for phytoremediation have the potentials to accumulate specific or wide range of pollutants (Nwachukwu and Osuji, 2007; Omokeyeke et al., 2013; Udeh et al., 2013). In some cases, plants known as hyper-accumulators have the potentials to bioaccumulate pollutants several times above the plant biomass (Van Epps, 2006). Several species of plants have the potentials to take up, bioaccumulates, immobilize and degrade pollutants in their tissues. Phytoremediation has been applied in the three matrices of the environment such as air, land and water pollution (Van Epps, 2006).

2.1. Phytoremediation in air

Air pollution is one of the greatest challenges of modern society, due to the relative ease of the movement of pollutants in the atmosphere. In the presence of wind, air pollutants such as soot, carbon monoxide, sulphur dioxide and volatile organic hydrocarbons can travel a considerable distance within a short time in the atmosphere, moving across national boundaries within hours or days. Pollutants in the air can be in the form of foul smell or particles generally termed as particulate matter. Foul or repugnant pollutants in the air, are quickly avoided by humans by moving to areas devoid of such pollutants. Except in cases of smog, humans may be unaware of the presence of particulate matter in the atmosphere. Particulate matter (PM) may be in the air for short or long period as aerosols suspension where it can cause significant harm to human health (Dockery and Pope, 1994; Le Tertre et al., 2002). Breathable PM in the air get into human respiratory tract and the bloodstream via the trachea, lungs and alveoli causing increased difficulty in breathing, especially for those with respiratory conditions such as bronchitis and asthma (Kaupp et al., 2000; Morawska and Zhang, 2002; Nemmar et al., 2002; Zanobetti et al., 2003; Silva et al., 2013). Although, there are many technologies to treat pollutants in the atmosphere, one of the safest and cost-effective is the use of trees for the phytoremediation of air