Ceratophyllum demersum: An aquatic macrophyte for the phytormediation of water pollutants

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Abstract

Water bodişies all over the World are at risk due to continuous contamination from different resources. Water contamination is affecting the environment by the continuous transfer of pollutants from one source to another including living organisms. Water pollution can be minimized or reduced by using different techniques including phytoremediation using plants. Phytoremediation is a cost-effective and sustainable way of overcoming the issue of contamination. However, the selection of proper plants in accordance with pollutants is highly significant. Coontail (*Ceratophyllum demersum*-L) is a submerged, aquatic macrophyte of fresh water bodies. The plant is well-known aquarium plant and can reach 1-3 m tall and exhibits a large bushy mass. *C. demersum* is a hyperaccumulator plant used for the phytoremediation of a broad range of pollutants ranging from heavy metals to radioactive elements, organic and inorganic compıunds and elements. In recent years, extensive studies on the phytoremediation of heavy metals like Cd, Cr, Ni, Cu, Zn, Co, Pb, etc have been documented. In this study, the potential of *C. demersum* plants for phytoremediation of different pollutants has been summarized and discussed. In this regard, collection of plant material, pollutants type, and conecntration, exposure time, methodologies used for detection of pollutants have been discussed.

Keywords: Aquatic, Macrophytes, Phytoremediation, Pollutants

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Introduction

Phytoremediation also known as agro-remediation, botano remediation, green remediation, or vegetative remediation (Kushwaha *et al.*, 2018) refers to the remediation of contaminated soil or water body with the aid of specialized plants (Nedjimi, 2021). The technique is considered eco-friendly, cost-effective, and easy to handle with zero or minimum hazardous products compared to other techniques (Ali *et al*., 2020). The basic phenomenon of phytoremediation is is the removal of various types of pollutants by plant intake followed by accumulation in their bodies or converted them into non-toxic pollutants and discharged into the outer environment. Different phytoremediation technologies include phytoaccumulation, phytodegradation, phytoextraction, rhizofiltration, phytotransformation, phytostabilization, and phytovolatilization. The selection of proper plants in accordance with the target pollutant and environmental conditions regulates the whole phytoremediation process (Kanwar *et al*., 2020).

The in situ remediations of water bodies contaminated with pollutants of different types is a challenge that needs aquatic plants. To date, approximately 400 plants have been identified as hyperaccumulator plants (Prasad and Freitas, 2003), and the number of aquatic plants is limited. Among these plants, hornwort or coontail (*Ceratophyllum demersum* L.) is one of the significant hyperaccumulator plant used successfully for the phytoremediation of different types of pollutants (Ansari *et al*., 2020). Coontail is a submerged aquatic macrophyte and preferred to grow in standing or emotive muddy water with low light illumination (Syed *et al*., 2018). The biomass production of this plant is very high and can be multiplied by vegetative propagation or by seed. It can elongate up to 30-60 cm long with dark green and 1-4 cm long sessile leaves. The flowers are very small, and unisexual, and the fruit acts as a seed (Parsons *et al*., 2001).

The steps involved in the phytoremediation studies include; (i) selection of proper plant according to the pollutant, (ii) preparation or collection of water samples contaminated with pollutant, (iii) culture of plants in a contaminated medium under specified culture conditions, (iv) analysis of plant and water samples using different techniques, and (v) interpretation of the results. Utilization of *C. demersum* plants for phytoremediation of a wide array of pollutants have been documented in recent years. In this study, phytoremediation potential of *C. demersum* plant has been summarized from different aspects ranging from plant collection to pollutant type and assessing the efficiency of the phytoremediation system.

Phytoremediation studies using C. demersum

Phytoremediation of contaminated water bodies is a relatively complex process due to containing numerous kinds of pollutants at different concentration. Therefore, the selection of proper plant with experimental conditions is highly significant. The overall phytoremediation studies can be summarized into three major components (Fig. 1).

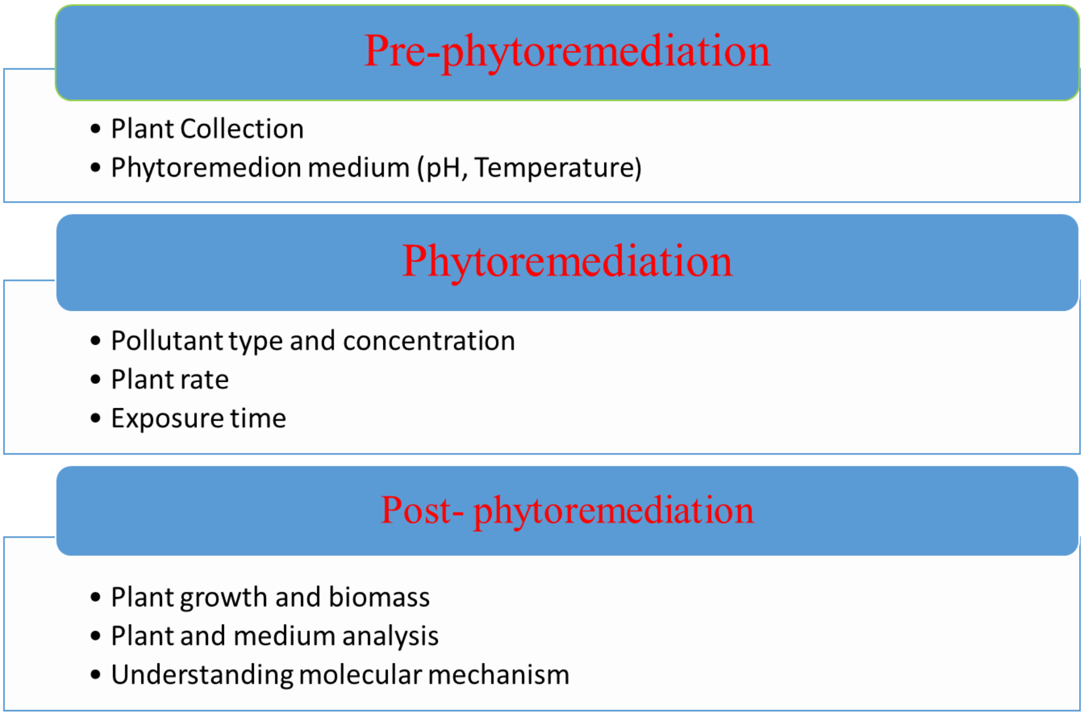

Figure 1: An overview of phytoremediation studies of *C. Demersum.*

Pre-phytoremediation

The pre-phytoremediation comprises different factors like procurement of plants, and experimental conditions like temperature, pH, light, etc. The study on *C. demersum* plants for phytoremediation studies revealed the use of collected plants from natural resources like ponds, lakes, rivers, etc (Polechońska *et al*., 2018; Vacula *et al*., 2020), procurement from the local aquariums, or propagated through the plant tissue culture studies (Dogan *et al*., 2018; Aasim *et al*., 2020). Before the phytoremediation studies, the collected plants are generally acclimatized in water (Aasim *et al*., 2020), or in specialized culture mediums like Hoagland solutions (Dogan *et al*., 2018). The pH of the phytoremediation medium is an important factor and neutral (pH 7.0) was used by different researchers (Dogan *et al*., 2018; Aasim *et al*., 2020). However, slight acidic (Poklonov *et al*., 2016) to slight saline medium (Ewadh *et al*., 2020) depending on the type of pollutant have also been used for phytoremediation studies of *C. demersum* plants. On the other hand, the optimum temperature of the phytoremediation medium also affects the uptake or removal of pollutants. The studies under the lab conditions revealed the temperature range of 20-30°C (Fagbote *et al*., 2013; Poklonov *et al*., 2016) for different pollutants. However,

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the use of room temperature is the most preferable for the phytoremediation studies of *C. demersum*.

Phytoremediation

The type of pollutant, concentration, and pollutant source (salt) is the most significant factors for the phytoremediation studies. The phytoremediation studies on *C. demersum* revealed a wide array of pollutants ranging from heavy metals to radioactive, trace elements to organic/inorganic compounds. An overview of phytoremediation studies revealed the maximum use of *C. demersum* plants against lead, cadmium, Zinc, nickel, chromium, copper, arsenic, manganese, cobalt, vanadium, iron, aluminum, and mercury. On the other hand, *C. demersum* has been used for the phytoremediation of nitrogenous-based compounds, organic pollutants, and dyes in other studies. In these studies, researchers used the different masses of plants for phytoremediation studies ranging from a minimum of 1-2 g/L (Srivastava *et al*., 2014) to 12.5 g/L (Dogan *et al*., 2018). However, it is direly needed to optimize the plant rate for in-situ phytoremediation studies. The exposure time of plants in the phytoremediation studies revealed a wide range of 6 -12 h (Pavan Kumar *et al*., 2004) to a maximum of 56 days (Markich *et al*., 2013). A study reported by Mahmoud *et al*. (2018) revealed the tolerance (%) of *C. demersum* against different heavy metals. Their results indicated a tolerance (%) of 96.26% for Pb after 4 days using 10 mg/L, 95.89% at 3 mg/L Al after 8 days, and 80.84% at 0.1 mg/L Cd after 8 days. Most recently, *C. demersum* plants were cultured in the Cd and Ni-containing medium for 8 days, and results revealed 86.5% and 79.0%, absorption respectively (Parnian *et al*., 2022). In another study, 0, 0.8, 3.2, and 10 µg/L of microcystin-LR (MC-LR) were investigated using *C. demersum* plants, and results revealed a 99% reduction ratio of MC-LR after 14 days of exposure. The maximum accumulation of MC-LR was recorded at 10 µg/L of MC-LR (Dong *et al*., 2022).

Post- phytoremediation

The post-phytoremediation emphasized the efficiency of phytoremediation based on the initial and final concentration of pollutant with the aid of different equipment like atomic absorption spectrophotometer (AAS) or Flame AAS (Aasim *et al*., 2020), GF-AAS (Maleva *et al*., 2018), ICP-MS (Nuwansi *et al*., 2018), Fluorate-02-5m fluorescence analyzer (Poklonov *et al*., 2016), UV/Vis Microplate SP (Ewadh *et al*., 2020), Plasma mass spectroscopy (Duman *et al*., 2014), HPLC (Xue *et al*., 2012), Spectroflourimeter (Aravind and Prasad 2005), AFS (Jiang *et al*., 2020), MP-AES (Johnson *et al*., 2019), ESR spectroscopy (Aravind *et al*., 2005), and UV/VIS SP (Mishra *et al*., 2014). Besides that, researchers also investigated the impact of pollutants on plant biomass and biochemical parameters like antioxidant enzymes, and plant pigments (Dogan *et al*., 2018). A study by Hak *et al*. (2020) revealed the toxic impact of Cu and Zn on the relative

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growth rate and chlorophyll content of *C. demersum with the passage of time.* The studies on phytoremediation also emphasized the molecular mechanism of phytoremediation using *C. demersum*. Results revealed an elevated MDA level (Dogan *et al*., 2018), Superoxide radical (O_2^-) and hydrogen peroxide (H_2O_2) level (Mishra *et al*., 2014), and electrical conductivity (EC) (Jambunathan *et al*., 2010).

Conclusion

Bioremediation techniques like phytoremediation are an efficient and cost-effective way to overcome the contamination issue of water bodies. The hyperaccumulator plant like *C. demersum* plant proved to be an efficient plant for the phytoremediation of different types of pollutants. Although the use of aquatic plants for in-situ phytoremediation is a risky process and needs preventive measures to hinder the plant growth and spread in the water body, there is direly need to investigate the in-situ phytoremediation studies against different types of contaminated water.

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