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Short communication

Nitrate removal from polluted water by using a vegetated floating system

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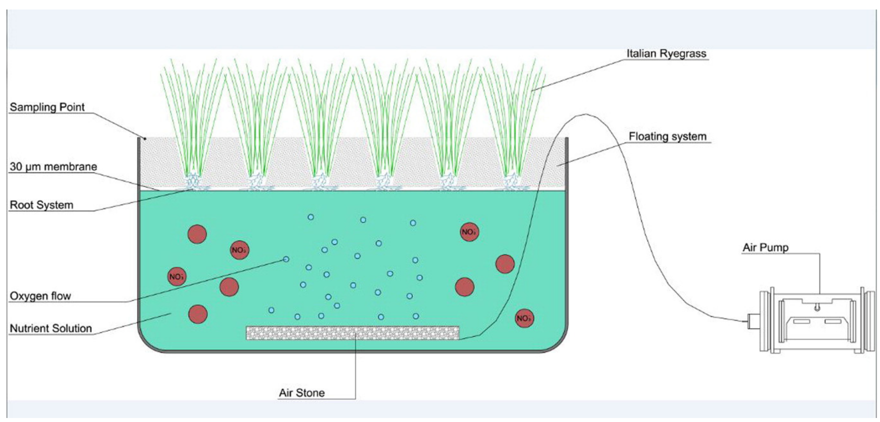
HIGHLIGHTS

- A floating bed vegetated with Italian ryegrass was set up.
- The floating bed permitted almost the complete removal of all the NO_3^- added.
- The experiments indicated that ryegrass is applicable for NO_3^- remediation of water.
- Biomass production and total N content increased proportionally to NO_3^- applied.

GRAPHICAL ABSTRACT



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ABSTRACT

Nitrate (NO_3^-) water pollution is one of the most prevailing and relevant ecological issues. For instance, the wide presence of this pollutant in the environment is dramatically altering the quality of superficial and underground waters. Therefore, we set up a floating bed vegetated with a terrestrial herbaceous species (Italian ryegrass) with the aim to remediate hydroponic solutions polluted with NO_3^-.
The floating bed allowed the plants to grow and achieve an adequate development. Ryegrass was not affected by the treatments. On the contrary, plant biomass production and total nitrogen content (N-K) increased proportionally to the amount of NO_3^- applied. Regarding to the water cleaning experiments, the vegetated floating beds permitted to remove almost completely all the NO_3^- added from the hydroponic solutions with an initial concentration of 50, 100 and 150 mg L^{-1}. Furthermore, the calculation of the bioconcentration factor (BCF) indicated this species as successfully applicable for the remediation of solutions polluted by NO_3^-. In conclusion, the results highlight that the combination of ryegrass and the floating bed system resulted to be effective in the remediation of aqueous solutions polluted by NO_3^-.

1. Introduction

To date, water pollution is one of the most critical environmental issues. Human activities constantly contribute to enhance this phenomenon with different types of contaminants (Palma et al., 2010). Industries release large quantities of toxic compounds to aquatic environments,

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while other significant amounts of pollutants derive from urban wastewater (Islam et al., 2015). Also cropping systems, due to the massive use of fertilizers, pesticides and the spread of livestock wastes, are causing the qualitative alteration of the water resources (Huo et al., 2009; Wu et al., 2013). In this context, great attention has been recently paid to nitrate (NO_3^-). In fact, since the seventies NO_3^- contamination of groundwater has become a relevant problem and an environmental priority (Rivett et al., 2008). Agriculture practices are constantly contributing to this kind of contamination. Excessive fertilization in intensive agricultural areas has caused some serious environmental problems because of water and soil enrichment with NO_3^- of agricultural origin (Ju et al., 2009). Recently nitrate pollution has also been correlated with urban areas. In fact, in the last few years, some urban aquifers showed very similar or even higher NO_3^- concentrations than the surrounding agricultural areas (Shamrukh et al., 2001; Wakida and Lerner, 2005). Nitrate accumulation alters the quality of water bodies and causes the eutrophication of aquatic environments (Gooddy et al., 2014). Furthermore, high concentrations of NO_3^- in water can be very hazardous for human and animal health (Costagliola et al., 2014; Gooddy et al., 2014). In order to face this environmental issue, some countries have established limits to the maximum NO_3^- levels admitted for drinking water (Kross, 2002). The European Union (EU) set this limit to 50 mg L^{-1} (Nitrates Directive, 91/676/EEC) for both surface and ground waters. In spite of this, the European Environment Agency (EEA) denounced very high levels of superficial and groundwater pollution by NO_3^- in 2007. In fact, EEA reported that NO_3^- concentration in waters was very often higher than 25 mg L^{-1} (+80% in Spain, +50% in UK and +32% in Italy, Rivett et al., 2008).

Among the techniques available for contaminants removal from soils and water bodies, phytoremediation and/or phytoextraction is very promising, cost-effective and non-invasive (Pilon-Smits, 2005). This technology takes advantage of the capacity of certain plants to remove various pollutants from contaminated matrices (Pilon-Smits, 2005). To this regard, macrophytes have been widely investigated (Wang et al., 2009). They have been selected for their capacity to take up substances from polluted solutions. In addition, they can stimulate microbial communities, which can further trigger the degradation of the contaminants (Wang et al., 2009). Some authors (Lee et al., 2009) reported that constructed wetlands are effective in the removal of various pollutants, including organic and inorganic nitrogen forms, in water bodies (Cao et al., 2010). In addition, some experiments evidenced the adequacy of *Lolium perenne*, grown in hydroponic solutions and in sand cultures, to remediate inorganic forms of nitrogen (Mattsson and Schjoerring, 2002; Paterson and Sim, 1999). Interestingly, also terrestrial plants, grown on floating beds, were successfully employed in the remediation of wastewater (Li et al., 2010). In fact, compared to macrophytes, floating systems are not influenced and thus limited by environmental factors (Li et al., 2010) since they can be used in controlled climatic conditions. Furthermore, plants can be easily harvested and processed, without exploiting agriculturally fertile areas.

The aim of the present study was thus to assess the potential of Italian ryegrass (*Lolium multiflorum* L.), growing on a floating bed, to remediate NO_3^- polluted water solutions. Italian ryegrass was chosen because it is a vigorous annual plant, which exhibits luxuriant growth and large biomass production. In addition, this species has been already employed in phytoremediation studies aiming at the decontamination of soils and water bodies, polluted by heavy metals and herbicides (Del Buono and Ioli, 2011; Del Buono et al., 2011; Merini et al., 2009; Mimmo et al., 2015) and phosphates (Sharma et al., 2004).

2. Materials and methods

2.1. Floating bed set-up

Fig. 1 shows the setup of the floating bed system. Italian ryegrass seeds were sown onto expanded polystyrene boards (362 × 280 × 60 mm) and directly transferred into rectangular plastic tanks (380 × 285 × 145 mm) filled with 5 L of nutrient solution. Each board contained 20 plant pots. The bottom of the floating polystyrene board was covered with a 30 μm nylon membrane to prevent root penetration into the nutrient solution, i.e. allowing only a physical separation from the solution below the board. Tanks were continuously aerated to avoid radical anoxia and to guarantee the constant mixing of the solution.

2.2. Plant material and growth conditions

Italian ryegrass (*L. multiflorum* L.) seeds were placed in the pots of the floating beds (0.60 g/pot). For the first 2 days, the germination was carried in the dark at 22 °C (relative humidity 90%). Three days after sowing, the seedlings were transferred to controlled climatic conditions: day–night photoperiod 12/12 h, PPFD 100 μmol m^{-2} s^{-1}, temperature day/night of 23/19 °C. The nutrient solution was composed as follows: 0.2 mM $Ca(NO_3)_2 \times 4H_2O$, 0.5 mM $MgSO_4 \times 7H_2O$, 0.7 mM K_2SO_4, 0.1 mM KCl, 0.1 mM KH_2PO_4, 1 μM H_3BO_3, 0.5 μM $MnSO_4 \times H_2O$, 0.5 μM $CuSO_4$, 0.5 μM $ZnSO_4 \times 7H_2O$, 0.01 μM (NH_4)

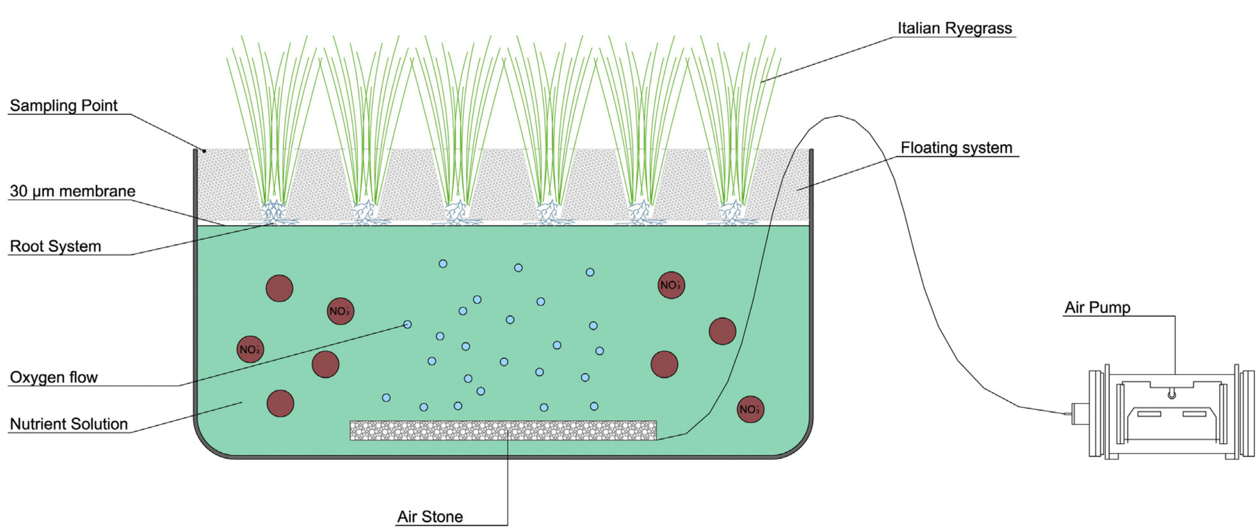

Fig. 1. Schematization of the floating system planted with Italian ryegrass. Seeds were placed in the pots of the polystyrene bed. Tank was then filled with hydroponic solution. Plants were physically separated from the growth media by a membrane, which, however, permitted the direct contact of the roots with the hydroponic solution. The continuous aeration of the aqueous medium was guaranteed by an air-pump. 7 days after sowing the solution was contaminated with NO_3^- at the final concentrations of 50, 100 and 150 mg L^{-1}.