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Characteristics of water and ion exchange of *Elodea nuttallii* cells at high concentrations of lanthanides

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HIGHLIGHTS

- La, Nd and Lu stimulate the leakage of electrolytes from cells and have no effect on the water permeability of membranes.
- Lanthanide treatment resulted in the decreased water diffusive permeability of the membrane lipid bilayer.
- Lanthanides facilitate the change in the spontaneous curvature of the membrane lipid layer.

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ABSTRACT

Changes of diffusive permeability of membranes of *Elodea nuttallii* cells following a short-term (60 min) treatment with high concentrations of lanthanides were recorded by the ^{1}H NMR-diffusometry and conductometry methods. The 1-h infiltration of segments of *Elodea nuttallii* internodes in 10 mM solutions of nitrates of La, Nd and Lu resulted in the increased leakage of electrolytes from cells, but has no effect on a water diffusive permeability of membranes. In samples subjected to a 30 min pretreatment with a water channel inhibitor $HgCl_2$ the water diffusive permeability of membranes (P_d) drops down under the influence of lanthanides, as well as an outcome of electrolytes. To explain the observed effects the change of spontaneous curvature of membrane lipid layer has been taken into consideration. The interaction of lanthanides with lipids of plasmalemma leads to the negative spontaneous curvature of lipid layer at which membrane channels are unclosed. Blocking of the ionic and water channels by mercury ions compensate the effect of change of spontaneous curvature of lipid layer.

1. Introduction

An increased application of lanthanides in industry and agriculture, and, hence, a growing extraction of rare earth element (REE) containing minerals leads to amplification of concentration of elements of this group in the environment (Kulaksız and Bau, 2013). The majority of REEs is adsorbed by soil particles, but approximately 10% remain solvable (Pang et al., 2001). These solvable lanthanides can migrate through soil, getting to ground waters, and invoking the pollution of rivers and lakes. The extensive use of gadolinium in medical researches has led to the increase of its concentration in lakes, drowned rivers, neritic and groundwater, and also in tap water (Bau et al., 2006; Kulaksız and Bau, 2013, 2007; Lawrence, 2010; Möller et al., 2002; Morteani et al., 2006; Rabiet et al., 2009).

Submersed aquatic plants, including *Elodea nuttallii*, play a key role in the functioning of freshwater ecosystems being natural sorbents of heavy metal ions (Jeppesen et al., 1998). The sorption capacity of cell walls of *Elodea nuttallii* causes a high tolerance of this plant to mercury, cadmium and lanthanum (Larras et al., 2013; Zhang et al., 2015). Biological effects of metals appear after filling of sorption capacity of cell wall and are caused by interaction of metals with cell membranes.

The main function of plasma membranes is the regulation of

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