Environ Sci Pollut Res
DOI 10.1007/s11356-017-9658-1

RESEARCH ARTICLE

# Comparative toxicity of seven rare earth elements in sea urchin early life stages

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Received: 18 January 2017 / Accepted: 27 June 2017


**Abstract** The widespread use of rare earth elements (REEs) in a number of technological applications raises unanswered questions related to REE-associated adverse effects. We have previously reported on the multiple impact of some REEs on the early life stages of the sea urchin *Paracentrotus lividus*. The present investigation was to evaluate REE toxicity to early life stages in two unrelated sea urchin species, *Sphaerechinus granularis* and *Arbacia lixula*. The comparative toxicities were tested of seven REEs, namely yttrium, lanthanum, cerium, neodymium, samarium, europium and gadolinium as chloride salts at concentrations ranging from $10^{-7}$ to $10^{-4}$ M. The evaluated endpoints included developmental defects and cytogenetic anomalies in REE-exposed embryos/larvae, and decreased fertilization success and offspring damage following sperm exposure. The results showed different toxicity patterns for individual REEs that varied according to test species and to treatment protocol, thus showing toxicity scaling for the different REEs. Further, the observed effects were compared with those reported for *P. lividus* either following embryo or sperm exposures. *S. granularis* showed a significantly higher sensitivity both compared to *A. lixula* and to *P. lividus*. This study provides clear-cut evidence for distinct toxicity patterns among a series of REEs. The differences in species sensitivity at micromolar REE levels may warrant investigations on species susceptibility to impacts along polluted coasts.

**Keywords** Rare earth elements · Sea urchins · Developmental defects · Cytogenetic anomalies · *Sphaerechinus granularis* · *Arbacia lixula* · *Paracentrotus lividus*

Responsible editor: Philippe Garrigues

**Electronic supplementary material** The online version of this article (doi:10.1007/s11356-017-9658-1) contains supplementary material, which is available to authorized users.

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## Introduction

There is growing environmental concern raised by the widespread use of REEs in present-day life due to their presence in a huge number of technological applications as reported previously (US Environmental Protection Agency 2012; Gambogi and Cordier 2013; Pagano et al. 2015a,b). This concern is highlighted by the growing number of publications in recent years on REE-associated toxicity to a number of test organisms and cell systems. It should be noted, however, that the vast majority of publications on REE toxicity is confined to four elements (Gd, Y, Ce, La) out of 17 REEs (reviewed by Pagano et al. 2015a,b).

As a consequence, many questions arise on the associated toxicity of relatively poorly studied REEs. This is especially important considering that some of these elements, e.g., Nd, have established industrial applications and are increasingly used in various industrial processes, indicating the potential for environmental health impacts (Feyerabend et al. 2010; Bleiwas and Gambogi 2013; Gambogi and

Published online: 18 July 2017