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Heavy rare earth elements affect early life stages in Paracentrotus lividus and Arbacia lixula sea urchins

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ABSTRACT

Background: Heavy rare earth elements (HREEs) have been scarcely studied for their toxicity, in spite of their applications in several technologies. Thus HREEs require timely investigations for their adverse health effects.
Methods: Paracentrotus lividus and Arbacia lixula embryos and sperm were exposed to trichloride salts of five HREEs (Dy, Ho, Er, Yb and Lu) and to Ce(III) as a light REE (LREE) reference to evaluate: 1) developmental defects (% DD) in HREE-exposed larvae or in the offspring of HREE-exposed sperm; 2) mitotic anomalies; 3) fertilization success; and 4) reactive oxygen species (ROS) formation, and nitric oxide (NO) and malondialdehyde (MDA) levels. Nominal HREE concentrations were confirmed by inductively coupled plasma mass spectrometry (ICP-MS).
Results: HREEs induced concentration-related DD increases in P. lividus and A. lixula larvae, ranging from no significant DD increase at 10^{-7} M HREEs up to ≅100% DD at 10^{-5} M HREE. Larvae exposed to 10^{-5} M Ce(III) resulted in less severe DD rates compared to HREEs. Decreased mitotic activity and increased aberration rates were found in HREE-exposed P. lividus embryos. Significant increases in ROS formation and NO levels were found both in HREE-exposed and in Ce(III) embryos, whereas only Ce(III), but not HREEs resulted in significant increase in MDA levels. Sperm exposure to HREEs (10^{-5}–10^{-4} M) resulted in a concentration-related decrease in fertilization success along with increase in offspring damage. These effects were significantly enhanced for Dy(III), Ho(III), Er(III) and Yb(III), compared to Lu(III) and to Ce(III).
Conclusion: HREE-associated toxicity affected embryogenesis, fertilization, cytogenetic and redox endpoints showing different toxicities of tested HREEs.

1. Introduction

A growing body of literature points to REEs as emergent contaminants displaying multiple toxicity mechanisms and raising environmental health concern (reviewed by Pagano et al., (2015a, 2015b)). In spite of their current and forthcoming applications in a number of technologies, HREEs have received relatively scarce attention in toxicology studies compared to LREEs (e.g. cerium, lanthanum and yttrium). The prospective demand and applications of some HREEs, for example: Dy and Ho in high-power magnets make these elements critical in the short- and mid-term based on projected supply risks and importance to clean-energy technologies (USEPA, 2012; Alonso et al., 2012; EU-OSHA, 2013; Gambogi and Cordier, 2013).

Few studies reported on HREE-associated adverse effects, mostly focusing on one or two elements (Högemann et al., 2000; Hongyan et al., 2002; Qu et al., 2004; Weltje et al., 2004; Fuma et al., 2005; Feng et al., 2007; Zhang et al., 2011; Cui et al., 2012; Liu et al., 2014; Gao et al., 2015; Gonzalez et al., 2015; Martino et al., 2016; Vukov et al., 2016). Another line of studies focused on the current or prospective use of HREEs as contrast agents in X-ray computed tomography imaging

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