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Comparative toxicities of selected rare earth elements: Sea urchin embryogenesis and fertilization damage with redox and cytogenetic effects

Giovanni Pagano [a,*], Marco Guida [a], Antonietta Siciliano [a], Rahime Oral [b], Fatma Koçbaş [c], Anna Palumbo [d], Immacolata Castellano [d], Oriana Migliaccio [d], Philippe J. Thomas [e], Marco Trifuoggi [f]

[a] "Federico II" University of Naples, Environmental Hygiene, I-80126 Naples, Italy
[b] Ege University, Faculty of Fisheries, TR-35100 Bornova, İzmir, Turkey
[c] Celal Bayar University, Faculty of Arts and Sciences, Department of Biology, TR-45140 Yunusemre, Manisa, Turkey
[d] Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Naples, Italy
[e] Environment Canada, Science & Technology Branch, National Wildlife Research Center – Carleton University, Ottawa, Ontario, Canada K1A 0H3
[f] "Federico II" University of Naples, Department of Chemical Sciences, I-80126 Naples, Italy

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ABSTRACT

Background: Broad-ranging adverse effects are known for rare earth elements (REE), yet only a few studies tested the toxicity of several REE, prompting studies focusing on multi-parameter REE toxicity.
Methods: Trichloride salts of Y, La, Ce, Nd, Sm, Eu and Gd were tested in *Paracentrotus lividus* sea urchin embryos and sperm for: (1) developmental defects in either REE-exposed larvae or in the offspring of REE-exposed sperm; (2) fertilization success; (3) mitotic anomalies in REE-exposed embryos and in the offspring of REE-exposed sperm, and (4) reactive oxygen species (ROS) formation, and malondialdehyde (MDA) and nitric oxide (NO) levels.
Results: REEs affected *P. lividus* larvae with concentration-related increase in developmental defects, 10^{-6} to 10^{-4} M, ranking as: Gd(III) > Y(III) > La(III) > Nd(III)≅Eu(III) > Ce(III)≅Sm(III). Nominal concentrations of REE salts were confirmed by inductively coupled plasma mass spectrometry (ICP-MS). Significant increases in MDA levels, ROS formation, and NO levels were found in REE-exposed embryos. Sperm exposure to REEs (10^{-5} to 10^{-4} M) resulted in concentration-related decrease in fertilization success along with increase in offspring damage. Decreased mitotic activity and increased aberration rates were detected in REE-exposed embryos and in the offspring of REE-exposed sperm.
Conclusion: REE-associated toxicity affecting embryogenesis, fertilization, cytogenetic and redox endpoints showed different activities of tested REEs. Damage to early life stages, along with redox and cytogenetic anomalies should be the focus of future REE toxicity studies.

1. Introduction

Current literature on REE-associated toxicity is mostly confined to three REEs (Ce, La and Gd). Consequently, comparative information for several REEs remains relatively scarce in spite of their widespread industrial utilization and as emerging environmental contaminants (US Environmental Protection Agency, 2012; EU-OSHA, 2013; Gambogi and Cordier, 2013; Snow et al., 2014; Pagano et al., 2015a,b; González et al., 2015).

The present study aimed at providing comprehensive data on multiple toxicity endpoints after exposure to selected REEs in sea urchin early life stages. The sea urchin assay system has been utilized extensively in the past -up to present-day studies- to address questions concerning the effects of a number of agents, including inorganics, organics, and complex mixtures, e.g. whole sediment or industrial effluents. Sea urchins have provided valuable insights on the toxicity mechanisms of many xenobiotics. This extensive body of literature is beyond the scope of this experimental report and will be reviewed in a paper currently in preparation. Multiple toxicity endpoints can be tested in sea urchin early life stages such as effects on fertilization success, embryogenesis, mitotic activity, redox balance, and other endpoints such as gene expression (Stumpp et al., 2011a,b; Evans and Watson-Wynn, 2014; Migliaccio et al., 2014). Thus, sea urchin assays can

* Corresponding author.
E-mail address: gbpagano@tin.it (G. Pagano).

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