Accepted Manuscript

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PII: S1002-0721(17)30190-4

DOI: 10.1016/j.jre.2017.10.003

Reference: JRE 99

To appear in: *Journal of Rare Earths*

Received Date: 24 April 2017

Revised Date: 20 October 2017

Accepted Date: 23 October 2017

Please cite this article as: Caigui L, Yangwu D, Jian L, Sipin Z, Zhenya W, Xiaobin G, Xianping L, Exogenous rare earth element-yttrium deteriorated soil microbial community structure, *Journal of Rare Earths* (2018), doi: .

Exogenous rare earth element-yttrium deteriorated soil microbial community structure

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Abstract: In this study, we selected yttrium as the representative of REEs to investigate the impacts of exogenous yttrium on soil physicochemical properties and microbiota. The results showed that exogenous yttrium has no significant effect on soil physical properties but a significantly negative impact on soil chemical properties. The results of high-throughput sequencing demonstrate that exogenous yttrium significantly decreases the number of OTUs, ACE, Chao1, and Shannon indices while increases the Simpson index (P<0.05), indicating the low soil microbial diversity. The relative abundances of soil microbes are significantly changed at phylum and genus level. Principal component analysis (PCA) showed the significant difference of microbial community between yttrium treatments (YCl_3-250 and YCl_3-500) and non-yttrium treatment (CK) and the similarity of that between YCl_3-250 and YCl_3-500. *Proteobacteria* and *Bacteroidetes* are found to be the most tolerant phyla to exogenous yttrium while *Verrucomicrobia* the most sensitive phylum. Redundancy analysis (RDA) results suggest that exogenous yttrium affects soil microbiota only through changing the soil chemical properties but not soil physical properties, and C/N ratio is the key environmental factor.

Keywords: Soil physicochemical properties; Soil microbial community; High-throughput sequencing; rare earths

Due to their unique physicochemical characteristics, rare earth elements (REEs), consisting of lanthanides, scandium and yttrium, have a wide range of applications in more than 13 industrial fields[1, 2], including the aeronautical and space, electronic and IT, biomedical and agricultural sectors. China has been the largest REEs resources possessor, exploiter, and supplier in the world[3]. Ionic rare earth (IRE) ore is an important type of RE resources because of its richness in high-value medium and heavy REEs. IRE mines are distributed mainly in the adjacent seven provinces of southern China, including in Jiangxi, Guangdong, Fujian, Hunan, Guangxi, Zhejiang and Yunnan[4].

The intensive exploitation of IRE in China has caused a variety of serious eco-environmental problems, including severe desertification, water and soil erosion, and especially the accumulation of REEs in the mining area[5-8]. It is reported that REEs content in soils of REEs mining area in southern China ranged from 396 to 2314 mg/kg, and even the lowest content of REEs is twice higher than that of the China's average concentration[9]. Meanwhile, REEs content in soil of IRE mining area in Longnan county ranged from 538.73 to 1625.76 mg/kg[10], whose average value (976.94 mg/kg) is 4.53 and 5.09 times that of soil background value in Jiangxi province[11] (211.0 mg/kg) and China[12] (187.60 mg/kg). The accumulation of REEs in soil generally leads to the change of soil quality, which affects agricultural safety and human health in the long run.

Soil biological properties are an important indicator of soil quality. Soil microorganisms not only play a key role in circulation of nutritive materials (organic matter, N, P, and K *etc.*), energy flow in ecosystems and bioremediation[13], but also are far more sensitive to pollution than soil animals or plants[14]. A shift in soil microbial community structure generally reflects the alteration of soil quality[15]. Previous studies about the effect of REEs on soil biological properties have obtained contradictory results and are limited[16]. d'Aquino et al.[17] found that REEs stimulated the growth of soil fungi and were accumulated in fungal biomass. In addition, Pol et al.[18] reported that REEs significantly raised the methanol dehydrogenase activity and promoted the growth of methanotrophic microbes. In contrast, other studies showed that REEs had an adverse effect and were used as antimicrobial reagents (e.g., Ce[19] and Pr[20]) and mutagens[21]