

The origins of Earth's volatiles

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The decay of ⁴⁰K to ⁴⁰Ar allows calculation of Earth's current ³⁶Ar budget. For example, if $K/U_{BSE} = 13,800$ [1] and average mantle ⁴⁰Ar/³⁶Ar = 10,000-30,000 (based on OIB, MORB and well gas data [2,3]), then only 1 to 3% of Earth's ³⁶Ar is in the mantle ((4-11) × 10³⁷ atoms). This holds regardless of whether the mantle is residual to degassing or largely unrelated to the present atmosphere. It has been argued that much of the mantle's Ar and other volatiles are recycled by subduction in which case primordial degassing was presumably closer to 99%. However, significant Ar recycling is hard to reconcile with the apparent K-Ar age of the mantle of 4.0 Ga.

The upper mantle ³He concentration [4] and atmosphere-corrected noble gas patterns in MORB and OIB sources [2] facilitate calculation of noble gas concentrations in the seismic lower mantle using the above total mantle ³⁶Ar budget. These are 5 to 10 times higher than in the upper mantle. If much of the Ar, Kr and Xe is recycled the mass balance of primordial Ne should be different. In fact ²⁰Ne/³⁶Ar in OIB and MORB sources are similar [2]. This upper / lower mantle mass balance is based on the degree of degassing, which in turn is based on the K/U_{BSE} which assumes chondritic refractory elements (hence U and Th) in the BSE. If instead impact erosion has stripped Earth's incompatible elements [5], depletion of U and Th by ~40% would yield an upper / lower mantle that is roughly balanced in concentrations for K, U, ³⁶Ar and ²⁰Ne.

Earth's atmospheric ²⁰Ne/³⁶Ar is close to that of Venus, Mars, and CI and enstatite chondrites, contrasting with 4 orders of magnitude variation in other solar system reservoirs. This and other evidence suggests that the terrestrial planets acquired most of their volatiles from chondrite like materials and not from fractionated solar nebular gases, consistent with the Kr isotopic composition of the mantle [6]. The ²⁰Ne/²²Ne, ³⁶Ar/³⁸Ar and ²⁰Ne/³⁶Ar ratios of the atmosphere are consistent with a minor solar component, consistent with that in the mantle [2-4]. If carbonaceous or enstatite chondrites are the ultimate starting materials for Earth's volatiles there has been up to 2 orders of magnitude depletion in ¹H, ¹²C, ¹⁴N and ¹³⁰Xe relative to ³He, ²⁰Ne, ³⁶Ar and ⁸⁴Kr. A similar pattern is shown by the atmospheres of Venus and Mars. Like Xe, but unlike other noble gases, C and N form low temperature species [7] with an EUV first ionization potential less than that of H. Therefore, depletion in these elements could be related to ionization with EUV in the inner solar system and / or core formation. The present C/N of Earth and the atmospheres of Mars and Venus are close to chondritic providing evidence that these budgets were established by later chondritic veneers. However, a major fraction of Earth's water (~70% but dependent on assumptions about the mantle inventory) would appear to predate this late acquisition, as argued by Drake [8].

[1] Arévalo Jr et al. (2009) *EPSL* **278**, 361-369. [2] Trieloff & Kunz (2005) *PEPI* **148**, 13-38. [3] Ballentine & Holland (2008) *Phil Trans R Soc A* **366**, 4183-4203. [4] Porcelli & Ballentine (2002) *Rev Min Geochem* **47**, 411-480. [5] O'Neill & Palme (2008) *Phil Trans R Soc A* **366**, 4205-4238. [6] Holland et al. (2009) *Science* **326**, 1522-1526. [7] Lodders (2003) *Ap J* **591**, 1220-1247. [8] Drake (2005) *MAPS* **40**, 1-9.

Nickel removal mechanisms from neutral contaminated drainage by sulfate-reducing passive biofilters

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Contaminated neutral drainage (CND) is generally characterized by low sulfate concentrations, but with metals concentrations exceeding the norms. The treatment of CND by sulfate reducing passive biofilter (SRPB) is an attractive option for the mining industry. The main challenge for its long-term effectiveness lies in the choice and the proportion of the components in the reactive mixture. In this study, two reactive mixtures were tested in duplicate for the treatment of synthetic CND (pH of 6.5 and 7.8) contaminated with nickel (2.26 mg/L Ni) by SRPB. The first mixture was composed of leaf compost, poultry manure, sawdust, and wood chips, whereas in the second, the compost was replaced by peat. The results of the batch tests showed Ni removal efficiencies higher than 90% in all mixtures. However, the mechanisms of Ni removal seemed different in the two mixtures and also over time for the same mixture. The higher rate of sulfate removal in the first mixture indicates that it would promote sulfate reduction, while Ni removal in the second mixture would be essentially related to sorption mechanisms. Overall, the SRPB filled with both mixtures can be effective for the treatment of DNC in order to reduce Ni concentrations to values below the regulatory criteria.

Keywords: Contaminated neutral drainage, Nickel removal, Biofilter, Reactive mixture, Sulfate reduction