

Human exposure to aluminium

Christopher Exley

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Human activities have circumvented the efficient geochemical cycling of aluminium within the lithosphere and therewith opened a door, which was previously only ajar, onto the biotic cycle to instigate and promote the accumulation of aluminium in biota and especially humans. Neither these relatively recent activities nor the entry of aluminium into the living cycle are showing any signs of abating and it is thus now imperative that we understand as fully as possible how humans are exposed to aluminium and the future consequences of a burgeoning exposure and body burden. The aluminium age is upon us and there is now an urgent need to understand how to live safely and effectively with aluminium.

Environmental impact

The aim of this critical review of human exposure to aluminium is to provide an holistic interpretation of aluminium's exposome in relation to humans. It should enable a change in our thinking about the myriad ways that humans are exposed to aluminium and importantly it provides a much more complete definition of the body burden of aluminium. The latter must now be the starting place for furthering our understanding of how this burden impacts upon human physiology and potentially its role in human disease.

The aluminium age

Aluminium is the most abundant metal and the third most abundant element in the Earth's crust. In spite of the dynamic, ever changing and evolving nature of the Earth's crust the recycling of aluminium in the lithosphere is essentially complete and aluminium is effectively excluded from the biosphere.¹ It has been the non-availability of biologically reactive aluminium throughout biochemical evolution which today explains its lack of essentiality in all extant biota.² However, the geochemical cycle for aluminium has now become a biogeochemical cycle and primarily through interference due to human activities either indirectly, for example, the acidification of catchments by acid deposition of anthropogenic origin, or directly by the extraction of aluminium from its inert ores. It is now approximately 125 years since the advent of 'The Aluminium Age'. The ability to separate aluminium metal from its ores on an industrial scale changed aluminium from being a largely decorative metal to the most widely used metal of the 21st century.³ Unfortunately the efficiency of extraction and use of this metal by the aluminium industry cannot match that of the geochemical cycling of aluminium since almost half of cast aluminium is destined to end up as waste.⁴ The aluminium industry is burgeoning with the majority of current and projected growth coming from newly extracted aluminium, not recycled aluminium as might be commonly perceived, and all of this aluminium has the potential, at least, to enter and accumulate within the biotic cycle. Once

aluminium has entered the biotic cycle it has little prospect of a quick return to the lithospheric cycle and biota are now subject to an ever increasing burden of potentially biologically available aluminium. The consequences of a burgeoning burden of aluminium in the biotic cycle have already been manifested in the death of fish and trees in acidified surface waters and catchments respectively⁵ while the spread of acid soils is limiting plant growth on over 30% of the Earth's ice-free land.⁶ Human beings have placed themselves at the centre of the Earth's living cycle and humans are not immune from the burgeoning presence of aluminium in this cycle. It is now of critical and urgent importance that we understand human exposure to aluminium.⁷

Aluminium is toxic

Aluminium's success as a modern material with myriad applications comes from a wide breadth of physical and chemical properties which combined with its ubiquity in nature make it an extremely cost effective natural resource. There is also, today, a perception that aluminium is a 'safe' metal with few if any significant implications for human health. This is a view which though seemingly convenient for the aluminium industry is neither supported by observation; for example, aluminium is the cause of dialysis encephalopathy,⁸ nor by decades of animal experimentation demonstrating intoxication. It is truly an anomaly that the perceived innocuousness of aluminium in humans has persisted through to the present day and to the extent that there is no legislation whatsoever limiting human's exposure to aluminium. There is a clear and unambiguous case

The Birchall Centre, Lennard-Jones Laboratories, Keele University, Staffordshire, UK.
E-mail: c.exley@keele.ac.uk; Fax: +44 (0)1782 712378; Tel: +44 (0)1782 734080

