CSIRO PUBLISHING

www.publish.csiro.au/journals/env D. R. Parker, *Environ. Chem.* **2009**, *6*, 1–2. doi:10.1071/EN09016

Perchlorates in the environment – the key current issues

David R. Parker

Soil and Water Sciences Section, Department of Environmental Sciences, University of California, Riverside, CA 92521, USA. Email: dparker@ucr.edu

The perchlorate anion has a unique and profound ability to inhibit iodine uptake by the human thyroid, with potential adverse effects on the growth and development of fetuses, infants, and children. Its occurrence, fate, metabolism, transport and toxicity have been subjects of intensive study for slightly more than a decade, but almost exclusively in the United States (see e.g. refs [1–3] for some reviews). Given its ubiquitous, modern use in 'energetic applications', however, it is almost certain that perchlorate contamination is much more widespread, especially in industrial nations, and a more internationally flavoured literature has just recently begun to emerge (e.g. refs [4–6]). At this juncture, an appropriate question might be: should perchlorate still qualify as an emerging contaminant of concern? In this Research Front, we present a series of papers from widely different perspectives in order to provide a starting point from which this question can be answered.

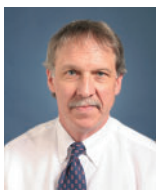
The last five years or so have produced a renaissance of interest in the *natural* occurrence of perchlorate. A topic that for many years seemed no more than yet another curiosity (among many) associated with the unique soils and salt deposits of the Atacama Desert, Chile.[7] In 2005, the journal *Environmental Science and Technology* recognised Dasgupta et al.'s very important paper on atmospheric formation of perchlorate[8] as its 'research article of the year', greatly widening awareness of this reemerging field. But a key question remains: How is perchlorate formed in the atmosphere? In the first of two opinion essays, Roberts[9] offers an atmospheric chemist's perspective on the more likely scenarios for natural perchlorate formation in the troposphere or stratosphere or both. This paper should help sharpen the focus of the research agenda on the atmospheric chemistry of perchlorate. In the second essay, Dasgupta[10] makes a case that the recent focus on perchlorate may have actually served to divert attention away from a broader and more significant public-health problem – iodine deficiency.

In my review,[11] I have attempted to first present a broad overview of the topic, largely for the benefit of readers new to the field. The final, somewhat more detailed section on natural occurrence and microbial attenuation aims to highlight the many remaining research gaps in these areas, as well as the promise afforded by isotope forensics in closing them.

Four Research Papers are also presented here[12]: Kang et al. present some additional work on the photolytic production of perchlorate from aqueous chlorite solutions, including an evaluation of the effectiveness of different UV wavelengths. This study represents a further step in unravelling the complex mechanisms of atmospheric formation of perchlorate. The use of perchlorate isotope forensics, while promising, is still in its infancy, and Hatzinger et al.[13] provide one the first field-based evaluations of the technique in the context of in situ biodegradation. They report that the relative fractionation of the oxygen and chlorine isotopes is not the same as under homogenous laboratory conditions, and may thus not provide fully quantitative evidence for perchlorate biodegradation under field conditions.

Lastly, two papers from Munster and Hanson are included in the Research Front. In the first, they examined the perchlorate levels in runoff from suburban roadways in New York, and report a mean perchlorate level of $\sim 2\ \mu g\ L^{-1}$, high enough to potentially impact neighbouring groundwaters.[14] Likely sources of the perchlorate include road safety flares and deployment of automobile air bags. In the second paper, the various components of an urban lawn environment, including precipitation, soils and vegetation, were examined.[15] Soil-solution perchlorate levels were notably higher at sites amended with organic fertilizer than with traditional chemical fertilizer, presumably due to the inclusion of 'natural' sodium nitrate in the former, but all sites exhibited measurable levels of perchlorate using a sensitive chromatographic method.

There are clearly several remaining questions concerning perchlorate, which has both natural and anthropogenic origins. On behalf of the editorial board, I hope that the research, opinions and background presented here will serve to stimulate broader awareness of the more pressing (and in many cases intriguing) research questions that remain, as well as to encourage participation from scientists new to the perchlorate arena. We welcome feedback on the papers in this Research Front and invite readers to express their views by sending a short letter to the Editor,



David Parker is a professor of soil biogeochemistry at the University of California, Riverside, where he has served on the faculty since 1988. His research interests have mainly been in trace-element speciation and its role in bioavailability, especially to higher plants. In 2003, he became interested in the mechanisms underlying perchlorate uptake by food crops, an interest that has since broadened into the biogeochemical behaviour and natural occurrence of this intriguing oxyanion.

1448-2517/09/010001

at publishing.env@csiro.au. Any such correspondence may be published in subsequent issues of *Environmental Chemistry.*

References

[1] E. T. Urbansky, Perchlorate as an environmental contaminant. *Environ. Sci. Pollut. Res.* **2002**, *9*, 187. doi:10.1007/BF02987487

[2] J. D. Coates, L. A. Achenbach, Microbial perchlorate reduction: Rocket-fuelled metabolism. *Nat. Rev. Microbiol.* **2004**, *2*, 569. doi:10.1038/NRMICRO926

[3] C. W. Trumpolt, M. Crain, G. D. Cullison, S. J. P. Flanagan, L. Siegel, S. Lathrop, Perchlorate: Sources, uses, and occurrences in the environment. *Rem. J.* **2005**, *16*, 65.

[4] K. Kosaka, M. Asami, Y. Matsuoka, M. Kamoshita, S. Kunikane, Occurrence of perchlorate in drinking water sources of metropolitan area in Japan. *Water Res.* **2007**, *41*, 3474. doi:10.1016/J.WATRES.2007.05.011

[5] Y. Shi, P. Zhang, Y. Wang, J. Shi, Y. Cai, S. Mou, G. Jiang, Perchlorate in sewage sludge, rice, bottled water and milk collected from different areas in China. *Environ. Int.* **2007**, *33*, 955. doi:10.1016/J.ENVINT.2007.05.007

[6] H. Gal, Z. Ronen, N. Weisbrod, O. Dahan, R. Nativ, Perchlorate biodegradation in contaminated soils and the deep unsaturated zone. *Soil Biol. Biochem.* **2008**, *40*, 1751. doi:10.1016/J.SOILBIO.2008.02.015

[7] G. E. Ericksen, The Chilean nitrate deposits. *Am. Sci.* **1983**, *71*, 366.

[8] P. K. Dasgupta, P. K. Martinelango, W. A. Jackson, T. A. Anderson, K. Tian, R. W. Tock, S. Rajagopalan, The origin of naturally occurring perchlorate: The role of atmospheric processes. *Environ. Sci. Technol.* **2005**, *39*, 1569. doi:10.1021/ES048612X

[9] J. M. Roberts, Constraints on the possible atmospheric sources of perchlorate. *Environ. Chem.* **2009**, *6*, 3. doi:10.1071/EN08089

[10] P. K. Dasgupta, Opinion: Perchlorate: A cause for iodine deficiency? *Environ. Chem.* **2009**, *6*, 7. doi:10.1071/EN08108

[11] D. R. Parker, Perchlorate in the environment: The emerging emphasis on natural occurrence. *Environ. Chem.* **2009**, *6*, 10. doi:10.1071/EN09001

[12] N. Kang, T. A. Anderson, B. Rao, W. A. Jackson, Characteristics of perchlorate formation via photodissociation of aqueous chlorite. *Environ. Chem.* **2009**, *6*, 53. doi:10.1071/EN08094

[13] P. B. Hatzinger, J. K. Böhlke, N. C. Sturchio, B. Gu, L. J. Heraty, R. C. Borden, Fractionation of stable isotopes in perchlorate and nitrate during in situ biodegradation in a sandy aquifer. *Environ. Chem.* **2009**, *6*, 44. doi:10.1071/EN09008

[14] J. Munster, G. N. Hanson, Perchlorate and ion chemistry of road runoff. *Environ. Chem.* **2009**, *6*, 28. doi:10.1071/EN08085

[15] J. Munster, G. N. Hanson, Perchlorate in an urban lawn environment. *Environ. Chem.* **2009**, *6*, 36. doi:10.1071/EN08087