SpringerBriefs in Environmental Science

For further volumes:

<http://www.springer.com/series/8868>

Mikhail Butusov • Arne Jernelöv

Phosphorus

An Element that could have
been called Lucifer

Mikhail Butusov
The International Center for Advanced
and Comparative EU-Russia Research
Vienna, Austria

Arne Jernelöv
Institute for Futures Studies
Stockholm, Sweden

ISSN 2191-5547 ISSN 2191-5555 (electronic)
ISBN 978-1-4614-6802-8 ISBN 978-1-4614-6803-5 (eBook)
DOI 10.1007/978-1-4614-6803-5
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013934218

© Mikhail Butusov and Arne Jernelöv, 2013

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Phosphorus: An Element That Could Have Been Called Lucifer

Mikhail Butusov and Arne Jernelöv

Introduction

Is Phosphorus a Sustainability Bottleneck?

In 1669 the German alchemist Henning Brand was the first to produce and identify phosphorus as an element. In his search for gold he heated a large volume of human urine to evaporate the water. In the very end he overheated the condensate somewhat. When he carefully checked the remains for traces of gold, he noticed a faint glow. It came from an element he did not know. He had produced white phosphorus, which emitted some light when it was oxidized in air. He initially called it the bearer of light. According to the tradition at the time, he could have used Greek or Latin as the basis for the scientific name. He opted for Greek, and light bearer became Phosphorus. Had he opted for Latin, it would have been Lucifer. Given what might await mankind, if we run out of the element as fertilizer in agriculture, Lucifer might have been a more appropriate choice.

Our book starts with depiction of the role of phosphorus in the creation of life and its evolution. Then it outlines in which vital biological processes different phosphates participate to sustain the life of all flora and fauna, from DNA molecules through building up body tissues. The most crucial function of phosphates is in agriculture. This role was noticed long ago, but only in the nineteenth century did the discovery of mineral fertilizers make it possible to sustain the needs of the growing global population, thus initiating a “green revolution.” For many decades, the complexity of the interactions “fertilizer–soil–plant roots” was underestimated, thus causing massive environmental and economic damage, such as intensive mining of the depleted natural phosphate reserves that continues worldwide, decay of the natural soil structure, land desertification, and eutrophication of waters. The lessons of what happened, on a much lesser scale, before the nineteenth century because of the scarcity of phosphates, have been forgotten during recent decades. In the meantime, the production of natural phosphates reached its peak a few years ago. What are the potential consequences? In our opinion, to help avoid a forthcoming global disaster, immediate implementation of phosphate recycling technologies, for example, from municipal wastes, should be fostered.

Contents

1	The Role of Phosphorus in the Origin of Life and in Evolution	1
1.1	How Many Origins of Life?	1
1.2	Nucleic Acids, Phosphorus, and the Road to Life	2
1.3	Where Did It All Happen?	4
1.4	First Life and a Second Step	5
1.5	The Worst Environmental Catastrophe Ever.....	5
1.6	The Role of Phosphorus.....	6
1.7	Changing Atmosphere and Changing Temperatures.....	6
1.8	The Huronian Ice Age.....	7
1.9	And On It Goes	8
1.10	The Cryogenian Ice Age	8
1.11	Was This Really the Chain of Events?.....	10
1.12	A Very Short Summary	11
1.13	May Be Not Totally Essential After All.....	11
	References	12
2	Phosphorus in the Organic Life: Cells, Tissues, Organisms	13
2.1	The Cell Membrane	13
2.2	DNA and RNA	14
2.3	ATP.....	14
2.4	Sinew, Cartilage, Bone, and Enamel.....	16
	References	17
3	Phosphorus in Social Life.....	19
3.1	Phosphorus and Our Body	19
3.2	Phosphorus and Social Development.....	20
	References	22

4	Silent Underground Life	23
4.1	Soil: The Central Part of the Phosphorus Chain	23
4.2	Phosphorus and Mineral Fertilizers	24
4.3	What Really Occurs to Phosphates in Soil?.....	25
4.4	Should the Effective Fertilizer Be Water Soluble?.....	26
4.5	Plant Roots in Competition for the Nutrients in Soil	33
	References	35
5	Fertilizers: 100 Years of Supremacy	37
5.1	Rock Phosphate: The Only Remaining Natural Phosphorus Resource	37
5.2	Production of P Fertilizers	40
5.3	Additional Technologies Used in Production of P Fertilizers.....	42
5.4	Environmental Consequences of P Fertilizer Production and Application	42
5.4.1	Mining Sites	43
5.4.2	Processing Sites.....	43
5.4.3	After-Processing Waste	44
5.4.4	Application (Fertilization) Pollution	45
5.4.5	Runoffs from Farms	46
5.5	P Fertilizers: Global Price Dynamics.....	47
5.5.1	P Rock Producers Mining and Supplementary Costs	48
5.5.2	Long-Haul Transportation Costs	48
5.5.3	Additional Price Uncertainty Factors.....	49
5.5.4	Uncertainties at Supply and Demand Sides	50
	References	51
6	Nonfertilizer Uses of Phosphorus	53
6.1	Phosphorus in the Elementary Form	53
6.2	Organic Phosphorus Compounds.....	54
6.3	Metallurgy	54
6.4	Detergents	54
6.5	Processing of Radioactive Materials	55
6.6	Food Industries, Cosmetics, and Hygiene.....	55
	Reference.....	55
7	Eutrophication	57
7.1	The Processes Behind Eutrophication.....	57
7.2	Sources of Eutrophication	58
7.3	Eutrophication of Coastal Seas	59
7.3.1	The Baltic	59
7.3.2	Chesapeake Bay	62
7.3.3	The Seto Inland Sea	62

7.4	Lake Eutrophication and Methods for Restoration	64
7.4.1	Dredging.....	64
7.4.2	Aeration/Oxygenation	65
7.4.3	Other Methods for Destratification	66
7.4.4	Chemical Precipitation of Phosphate	67
	References	68
8	The Politics of P	69
8.1	International Politics of P.....	69
8.1.1	Guano and a Virtual Peruvian Monopoly.....	69
8.1.2	The Guano Island Act and Some of Its Consequences	72
8.2	Rock Phosphate and the New Game	75
8.2.1	Nauru.....	76
8.3	Domestic Politics of P.....	79
	References	80
9	Peak Phosphorus	81
9.1	Principles of Hubbert's Linearization	81
9.2	Applying Hubbert Linearization to Phosphates	85
	References	88
10	Phosphate Recycling or Welcome from Lucifer?	89
10.1	Point Sources.....	90
10.1.1	Waste Streams of Phosphate Mines and Processing Plants	90
10.1.2	Waste from Slaughterhouses	91
10.1.3	Municipal Sewage Discharge	92
10.1.4	Sludge Management Options	94
10.1.5	P Recycling from Sewage Water Streams	98
10.2	Recycling from Agricultural Activities.....	100
	References	101