

When chemistry meets biology: the case of aluminium – a review

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Aluminium chemistry is extraordinary and complex because of a large spectrum of inorganic and organometallic complexes of varying stability in solutions. Being reactive, aluminium has the potential to interact with and influence many biomolecules, biochemical pathways, cellular processes and physiological functions, thus causing high Al toxicity. It depends not only on the total Al concentration but also on the abundance of Al chemical forms, Al speciation being highly dependent on the pH and chemical environment of the solution. The oxidative potential of aluminium leads to enhanced oxidative stress, which explains part of Al toxicity mechanisms. Al is a known pro-oxidative, cytotoxic, neurotoxic, immunogenic, pro-inflammatory and mutagenic agent. Usually, organisms are not exposed to relevant levels of aluminium but long-term accumulation causes several human diseases and disturbs plant growth. In contrast to animals and humans, plants evolved specific mechanisms to cope with Al stress. We review the existing knowledge about aluminium chemical properties, bioavailability and cell responses determining Al toxicity not only in humans but also in plants. Extraordinary chemistry of Al and complexity of biological processes require complex researches to link knowledge of Al chemistry and biology of its effects in order to find the best solution to resist the aluminium toxicity.

Key words: aluminium, aluminium bioavailability, aluminium toxicity, aluminium related diseases, plant resistance to aluminium

INTRODUCTION

Aluminium is the third most abundant element in the earth's crust after oxygen and silicon, and the most abundant metal. Its atomic number is 13 and it has one stable isotope, ^{27}Al , and one long-lived radioactive isotope, ^{26}Al . Bound tightly by oxygen and silicon, Al exists naturally in ores generically termed bauxite. Bauxite consists mainly of the hydrated aluminium oxide ($\text{Al}_2\text{O}_3 \times \text{H}_2\text{O}$) minerals, gibbsite, boehmite, and diaspore. Despite its abundance, Al was first isolated as an element only in 1827, and its use as being a silvery metal began only after 1886. The electrolytic process, still employed nowadays, was separately patented in France and the USA in 1886 [1].

The protective layer of oxide in addition to its light weight makes aluminium metal an ideal material for many applications in the industry. The 'aluminium environment' acted upon

by natural selection is changing, and through human activities, not least of which has been the technology to extract aluminium metal from its biologically inert ores, biota are experiencing a burgeoning exposure to biologically reactive aluminium [2].

An increase in anthropogenic acidification of soils, the increased utilization of the metal for industrial purposes, and Al utilization as a flocculent in water treatment and hiding him in food additives or cosmetics make aluminium harmful not only for humans but for all life forms in the earth.

Generally Al is not essential for life but because of extremely high reactivity in its pure elemental form Al has a tremendous impact on life [2]. Aluminium interferes with a wide range of physiological and cellular processes. As Al is highly reactive, there are many potential sites for injury in all living systems. Aluminium is a widely recognized toxicant that inhibits more than 200 biologically important functions and causes various adverse effects in plants, animals, and humans [3]. The mechanism of toxicity of aluminium is invariably biphasic with lower concentrations producing toxic effects through stimulatory

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Aluminium and Alzheimer's Disease C. Exley, 2001-07-03 The subject of aluminium and Alzheimer's disease has been plagued with controversy This controversy has served to obscure much of the scientific research in this field and subsequently has obscured the possibility that aluminium is a contributory factor in the aetiology of Alzheimer's disease This book brings together many of the world's leading scientists researching aluminium and life and contains their critical summaries on the known facts about aluminium toxicity in man and to offer an opinion on the implications of this knowledge on a link between aluminium and Alzheimer's disease The subject areas of the chapters were chosen to reflect the myriad of ways that aluminium is known to impact upon mammalian physiology and function and range from clinical studies through animal models of disease to the detailed biochemistry of aluminium toxicity Chapters are also included on epidemiology and other factors involved in the aetiology of Alzheimer's This is the first time that this subject has been treated in such a comprehensive manner The research detailed in each chapter includes the latest research in the field it has been critically appraised and this appraisal has been used by each author to present an informed opinion of its relevance to aluminium and Alzheimer's disease The chapters are much more than reviews they are a statement of the state of the art and of what the future may hold for research in this field As a whole they show the high quality of research that has been carried out in our efforts to understand the toxicity of aluminium in man and that we are far away from discounting the possibility that aluminium is a contributory factor in the aetiology of Alzheimer's disease

Neurodegenerative Diseases and Metal Ions Astrid Sigel, Helmut Sigel, Roland K. O. Sigel, 2006-07-11 About the Series Metal Ions in Life Sciences links coordination chemistry and biochemistry in their widest sense and thus increases our understanding of the relationship between the chemistry of metals and life processes The series reflects the interdisciplinary nature of Biological Inorganic Chemistry and coordinates the efforts of scientists in fields like biochemistry inorganic chemistry coordination chemistry molecular and structural biology enzymology environmental chemistry physiology toxicology biophysics pharmacy and medicine Consequently the volumes are an essential source for researchers active in these and related fields as well as teachers preparing courses e g in Bioinorganic Chemistry About this Book Volume 1 devoted solely to the vital research area concerning the role of metal ions in neurodegenerative diseases offers in 15 stimulating chapters an authoritative and timely view of this fascinating subject Written by 41 internationally recognized experts *Neurodegenerative Diseases and Metal Ions* highlights supported by 130 illustrations the recent progress made in understanding the role metal ions play in diseases like transmissible spongiform encephalopathies Creutzfeldt Jakob and related diseases Alzheimer's Parkinson's Huntington's Wilson's and Menkes diseases as well as in familial amyotrophic lateral sclerosis and others The interplay between metal ions catecholamines and the formation of reactive oxygen species resulting in oxidative stress is considered as is the metalloneurochemistry of zinc and the neurotoxicity of aluminum cadmium lead and mercury The need for novel drugs which

manipulate metal centered neuropathology is emphasized *Bioinorganic Medicinal Chemistry* Enzo Alessio, 2011-02-25 This book gives a comprehensive overview about medicinal inorganic chemistry Topics like targeting strategies mechanism of action Pt based antitumor drugs radiopharmaceuticals are covered in detail and offer the reader an in depth overview about this important topic

Contemporary Psychiatry Fritz Henn, Norman Sartorius, Hanfried Helmchen, Hans Lauter, 2013-11-11 Contemporary Psychiatry is an international textbook developed on the basis of the experience with its first three German editions making it a work with long and distinguished tradition It combines the German tradition of phenomenology and diagnosis going back to Kraepelin with the Anglo American tradition and the DSM IV diagnostic system In doing so Contemporary Psychiatry becomes a unique source among psychiatric texts offering a truly international approach to state of the art knowledge and future perspectives of psychiatry The four internationally renowned editors were able to acquire the leading specialists as contributors No less than 120 authors from 10 different countries ensure an extremely high standard and guarantee the consideration of cross cultural aspects A special feature of Contemporary Psychiatry is that it includes chapters on psychiatric disorders caused by extreme circumstances such as for example migration torture rape violence and natural and man made disasters National Library of Medicine Current Catalog National Library of Medicine (U.S.), **Current Catalog** National Library of Medicine (U.S.), 1985 First multi year cumulation covers six years 1965 70 *Canadian Journal of Fisheries and Aquatic Sciences*, 2000 *Perils of Progress* John Ashton, Ronald S. Laura, 1999 This work offers a challenge to our society's largely unquestioning commitment to new technologies and practical advice on how to deal with their adverse effects While modern technologies have no doubt brought many benefits the authors argue that our confidence in them is seriously misplaced They consider an array of health and environmental issues including the damaging effects on human health of certain microwaves including those from mobile phones and television transmission towers the effects of aluminium in food and other consumer products and the evidence that the acids in margarines may be more detrimental to health than butter **Nuclear Science Abstracts**, 1976 *Australian Journal of Chemistry*, 1995 **Scientific and Technical Aerospace Reports**, 1994 Advances in Protein Chemistry and Structural Biology, 2015-11-17 The Advances in Protein Chemistry and Structural Biology series is an essential resource for protein chemists Each volume brings forth new information about protocols and analysis of proteins with each thematically organized volume guest edited by leading experts in a broad range of protein related topics Provides cutting edge developments in protein chemistry and structural biology Chapters are written by authorities in their field Targeted to a wide audience of researchers specialists and students **Key-words-in-context Title Index**, 1963

Medical Books and Serials in Print, 1984 *Current Catalog*, 1989 First multi year cumulation covers six years 1965 70 *Schizophrenia Bulletin*, 1994 **Pathogenesis of Neurodegenerative Disorders** Mark P. Mattson, 2001-06-01 As the average life expectancy of many populations throughout the world increases so to does the incidence of such age related

neurodegenerative disorders as Alzheimer's Parkinson's and Huntington's diseases Rapid advances in our understanding of the molecular genetics and environmental factors that either cause or increase risk for age related neurodegenerative disorders have been made in the past decade The ability to evaluate at the cellular and molecular level abnormalities in postmortem brain tissue from patients when taken together with the development of valuable animal and cell culture models of neurodegenerative disorders has allowed the identification of sequences of events within neurons that result in their demise in specific neurodegenerative disorders Though the genetic and environmental factors that promote neurodegeneration may differ among disorders shared biochemical cascades that will ultimately lead to the death of neurons have been identified These cascades involve oxyradical production aberrant regulation of cellular ion homeostasis and activation of a stereotyped sequence of events involving mitochondrial dysfunction and activation of specific proteases Pathogenesis of Neurodegenerative Disorders provides a timely compilation of articles that encompasses fundamental mechanisms involved in neurodegenerative disorders In addition mechanisms that may prevent age related neurodegenerative disorders are presented Each chapter is written by an expert in the particular neurodegenerative disorder or mechanism or neuronal death discussed

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
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