The Handbook of Environmental Chemistry

Founded by Otto Hutzinger

Editors-in-Chief: Damià Barceló • Andrey G. Kostianoy

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Indoor Air Pollution

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Aims and Scope

Since 1980, *The Handbook of Environmental Chemistry* has provided sound and solid knowledge about environmental topics from a chemical perspective. Presenting a wide spectrum of viewpoints and approaches, the series now covers topics such as local and global changes of natural environment and climate; anthropogenic impact on the environment; water, air and soil pollution; remediation and waste characterization; environmental contaminants; biogeochemistry; geo-ecology; chemical reactions and processes; chemical and biological transformations as well as physical transport of chemicals in the environment; or environmental modeling. A particular focus of the series lies on methodological advances in environmental analytical chemistry.

Series Preface

With remarkable vision, Prof. Otto Hutzinger initiated *The Handbook of Environmental Chemistry* in 1980 and became the founding Editor-in-Chief. At that time, environmental chemistry was an emerging field, aiming at a complete description of the Earth's environment, encompassing the physical, chemical, biological, and geological transformations of chemical substances occurring on a local as well as a global scale. Environmental chemistry was intended to provide an account of the impact of man's activities on the natural environment by describing observed changes.

While a considerable amount of knowledge has been accumulated over the last three decades, as reflected in the more than 70 volumes of *The Handbook of Environmental Chemistry*, there are still many scientific and policy challenges ahead due to the complexity and interdisciplinary nature of the field. The series will therefore continue to provide compilations of current knowledge. Contributions are written by leading experts with practical experience in their fields. *The Handbook of Environmental Chemistry* grows with the increases in our scientific understanding, and provides a valuable source not only for scientists but also for environmental managers and decision-makers. Today, the series covers a broad range of environmental topics from a chemical perspective, including methodological advances in environmental analytical chemistry.

In recent years, there has been a growing tendency to include subject matter of societal relevance in the broad view of environmental chemistry. Topics include life cycle analysis, environmental management, sustainable development, and socio-economic, legal and even political problems, among others. While these topics are of great importance for the development and acceptance of *The Handbook of Environmental Chemistry*, the publisher and Editors-in-Chief have decided to keep the handbook essentially a source of information on "hard sciences" with a particular emphasis on chemistry, but also covering biology, geology, hydrology and engineering as applied to environmental sciences.

The volumes of the series are written at an advanced level, addressing the needs of both researchers and graduate students, as well as of people outside the field of "pure" chemistry, including those in industry, business, government, research establishments, and public interest groups. It would be very satisfying to see these volumes used as a basis for graduate courses in environmental chemistry. With its high standards of scientific quality and clarity, *The Handbook of Environmental Chemistry* provides a solid basis from which scientists can share their knowledge on the different aspects of environmental problems, presenting a wide spectrum of viewpoints and approaches.

The Handbook of Environmental Chemistry is available both in print and online via www.springerlink.com/content/110354/. Articles are published online as soon as they have been approved for publication. Authors, Volume Editors and Editorsin-Chief are rewarded by the broad acceptance of *The Handbook of Environmental Chemistry* by the scientific community, from whom suggestions for new topics to the Editors-in-Chief are always very welcome.

Damià Barceló
Andrey G. Kostianoy
Editors-in-Chief

Preface

In the year 1751 John Arbuthnot published “An Essay concerning the Effects of Air on Human Bodies” [1] and gave a comprehensive review of the scientific state of the art of his time. He summarized his knowledge and his findings in a number of “Practical Aphorisms” such as “Private Houses ought to be perflated once a Day, by opening Doors and Windows, to blow off the Animal Steams” and a second example “Houses for the sake of Warmth fenc’d from Wind, and where the Carpenters Work is so nice as to exclude all outward Air, are not the most wholsom.”

His thoughts are still valid and his treaty is still valuable – not in all details. Building technologies and practices have changed much and Indoor Science became a very broad, inter-disciplinary field of knowledge.

Going through the agenda of international conferences on indoor air and recent publications, there are still a number of topics, which have been discussed already in the eighteenth and nineteenth centuries, such as moisture and dampness [2], mould and bacteria [3], and bad odours and carbon dioxide [4].

Relatively early research on hygienic conditions in urban dwellings and establishments by Pettenkofer and others in the eighteenth and nineteenth centuries covered some of still today relevant topics in indoor air quality. Pettenkofer developed some basic principles. From a hygienic point of view he analysed the indoor living conditions and came to the conclusion that science could contribute significantly in improving everyday life by defining rules for indoor environmental quality and health.

He revealed [5–8] that human emissions and activities must be taken into consideration and

– He developed a concept for chamber studies of indoor emission sources [6]. He summarized: “substances which pass off from the skin and lungs require as close an investigation as those that are eliminated by the urine. Hitherto no method has been devised, or apparatus constructed, adequate to the conditions of such an inquiry. . . . The present state of physiology requires conditions of inquiry in which a man can breathe and move freely without any apparatus attached to his body. . . This can only be done by placing the man in an accurately measurable current of air, which can be tested for certain constituents before it comes in contact with him, and can be investigated again after the air has taken up the gaseous matters thrown off by the skin and lungs."

– He underlined the importance of source control to ensure good indoor air quality [7]. Still today – despite all the technical means, which are at hand nowadays to enhance ventilation and to clean air – it is a valid principle; in Pettenkofer's words: "If I had a nuisance in my room, I should be a fool if I kept it there and trusted to stronger ventilation. The rational way is to do away with the pollutions, not to keep them and to fight them by ventilation."
– And through his thorough studies on human bio-effluents [7] he could deduce general rules for ventilation and for the acceptable limit of carbon dioxide in indoor environments. The carbon dioxide abundance of 1,000 parts per million, which he proposed, is consistent with current understanding of the value that marks the threshold of significantly degraded air by human bio-effluents. According to Pettenkofer, this concentration "is, in my mind, the measure only for all the other alterations which take place in the air simultaneously and proportionately, in consequence of respiration and perspiration; its increase shows to what degree the existing air has been already in the lungs of the persons present. On an average, in spaces in which the air kept good, there existed a ventilation of more than 2100 cubic feet per head and hour." – a rate of about 16.5 l/s per person, not far from the value prescribed in today's ventilation standards.

Still today, human occupants play a significant role in indoor chemistry – may be an even more significant role than at the times of Pettenkofer, because we are still emitting bio-effluents but we add nowadays a variety of personal care products which introduce a large number of chemicals into indoor environments and may be reactive with other components in air, as recently reviewed by Weschler [9].

Even though England, France and Germany may have been the homes of the first scientific treatment of indoor air quality, meanwhile Indoor Air Science has become a worldwide subject and a matter of concern and we try to reflect this in this volume of the *Handbook of Environmental Chemistry*.

The range of indoor spaces is broad: from very basic households with open fire and simple cook-stoves to sophisticated urban architecture and to mobile indoor environments like aircraft cabins, cars and public transport systems.

The first edition of this volume of the *Handbook of Environmental Chemistry* on Indoor Air Pollution was published in the year 2004 [10]. It focused on the analysis of basic factors determining indoor air quality. Still a lot of research is dealing with emission scenarios [11], pathways of contaminants, toxicological effects of individual compounds as well as of their mixtures and epidemiological evaluation of the effects of indoor air pollution. Human well-being and performance are becoming often the focus of indoor air research [12]. The second edition follows the same concept by updating most of the reviews. Tunga Salthammer and Godwin Ayoko give broad reviews in this volume on emission processes and on the large variety of volatile organic pollutants. Furthermore, new topics are introduced, such as the reflections of Carl-Gustaf Bornehag on the relation of chronic illnesses and indoor chemical exposure.

Beyond these basics of Indoor Sciences, it must be indicated that a number of recent developments will open new horizons for indoor air research:

(a) During the last few years we became aware that climate change may result in new challenges in building research and indoor air quality studies [13, 14]. Challenges due to climate change bring more severe periods of heat, heavy rainfalls and high humidity or – on the contrary – extreme regional dryness. Changing meteorological conditions will alter architecture and building equipment as well as living habits of the people. Smart technologies will serve people under various circumstances but will require new ways of management of the buildings and may lead to challenges in the management of indoor air quality: more sensors will be installed in houses, control devices must be followed and maintained and a risk of introducing un-voluntarily new sources of odours and chemicals may follow.
(b) As a consequence of increasing energy prices and of the limits of fossil energy resources, more emphasis is now put on energy efficiency of buildings. This changes definitely the concepts for ventilation because buildings are becoming tight structures. Effects are manifold: less exposure to ambient air pollutants, change to mechanical ventilation, more significant influence of indoor pollution sources, new factors influencing function, comfort and cosiness of a building. Traditional building considered ventilation as a design characteristic to be guaranteed by adequate orientation of a building, the good choice of building materials and a concept considering dimension and function of windows and doors [15]. It is a certain risk that we forget Pettenkofer's statement: "If I had a nuisance in my room, I should be a fool if I kept it there and trusted to stronger ventilation." Modern technical equipment makes it easy to fight nuisances by increasing ventilation but source control will always be the most favourable way to guarantee a safe and cosy indoor environment.
(c) Special emphasis must be put on those households using traditional cookstoves. They are worldwide still large in number as the following diagram (published by Kirk Smith et al.) shows [16, Fig. 1]:

Over the last two decades many intervention strategies and modernization processes have been launched to improve living conditions and health in rural areas as well as in the rapidly developing urban agglomerations in Asia, Africa and Latin America by implementing new designs of stoves which help to create better indoor air quality. Lidia Morawska has – coming from an Australian background – updated her review on indoor particles, combustion products and fibres and covered a wide range of non-gaseous pollutants resulting from a wide variety of human activities, i.e. from tobacco smoke.

Whereas in the Northern hemisphere cooking is mostly a minor factor in indoor air quality, it determines largely indoor air quality in households and certain establishments in the Southern hemisphere. Kalpana Balakrishnan provides an updated report on the situation focusing on India in this volume. More reports

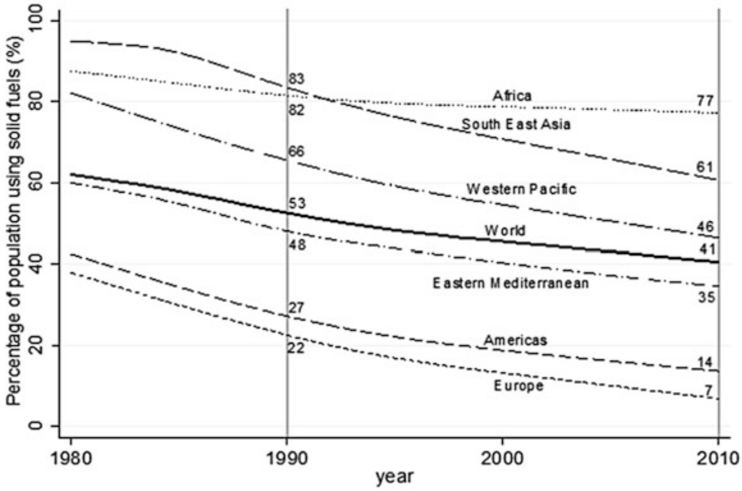

Fig. 1 Percentage of population using solid fuels for cooking 1980–2010

Fig. 2 Open fire in a Nicaraguan household – before intervention

from Africa, Latin America [17, 18] and Asia [19] have brought forward similar findings and led to a wide range of activities and changes, such as demonstrated in the pictures from a kitchen in San Carlos, Nicaragua (Figs. 2 and 3).

Fig. 3 Improved kitchen and new stove in a rural kitchen in Nicaragua – after intervention

(d) In the industrialized world intervention strategies in order to improve building quality focus on building certification as a market-oriented tool to strengthen energy efficiency and indoor air quality in the building sector.

More and more applied research is dealing with concepts to prevent indoor air pollution: Green Buildings should be energy efficient and free from pollutants – clean, proper and comfortable. Building certification may be one concept to deal with these requirements but specific points have to be made also in architecture, building design, technical equipment and control mechanisms during building and renovation activities. Economic aspects will play a crucial role in defining the target lines for a Green Building [20].

Internationally accepted standards for Green Buildings tend to evaluate the environmental impact of a building throughout its entire life cycle. This takes account of not only factors such as energy efficiency, use of natural light and use of environmentally friendly building materials that are available at a regional level, but also transport routes or the integration of the building into the public transport network. According to these concepts indoor air quality is

Certification System	Owner	Whole-building sustainability	Building Types	Third-party Certification
Green Globes®	Green Building Initiative (GBI)	Green Globes is comprised of seven key areas: energy, indoor environment, site, water, resources, emissions, and project/ environmental management.	Green Globes certifies new buildings and significant renovation, existing buildings, building emergency management, building intelligence, and fit-up.	Green Globes Assessors provide third-party certification services.
LEED®	U.S. Green Building Council (USGBC)	LEED is comprised of five key areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.	LEED certifies new construction and major renovations, existing buildings, commercial building interiors, core and shell construction, schools, retail, healthcare, and homes.	The Green Building Certification Institute (GBCI) provides third-party certification services.
Living Building Challenge™	International Living Building Institute (ILBI)	Living Building Challenge is comprised of seven performance areas: site, water, energy, health, materials, equity and beauty.	Living Building Challenge certifies development at four scales: building, neighborhood, village/campus, and city.	A third-party auditor is responsible for performing document review and onsite verification.

Fig. 4 Summary of Green Building Certification Systems [21, 22]

just one aspect to be dealt with, yet a crucial one. The following table shows a summary of the Green Building Certification Systems in the USA (Fig. 4).

In more countries national certification schemes have evolved and have been put into practice. In Germany the market for the certification of Green Buildings is mainly shared between three systems:

DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen): a system which is based on European norms and standards but adaptable to a large range of local conditions. To that extent the DGNB system may be applied in a wide range of geographical, social and technical settings.

Secondly LEED plays a major role in Germany and thirdly the BREE system (Building Research Establishment Environmental Assessment Method) is well known and often used [23]. Additionally CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) from Japan may be mentioned – a system widely spread in Asia.

Finally, Jiming Hao and Tianle Zhu give a comprehensive view in this volume on Chinese standards and strategies to overcome existing problems in indoor air quality: a combination of traditional cooking behaviour and home equipment with modern home decoration and refurbishment products contributes to the deterioration of indoor air quality – not to talk about ambient air quality and its contribution to indoor air pollution. Wherever you are, indoor air quality is a work in progress – much has to be done to improve and guarantee indoor air quality – 266 years after John Arbuthnot's statement "Private houses ought to be perflated once a day . . . ."

Nürnberg, Germany Peter Pluschke

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