

“Advances in Carbon Capture and Utilization”

Edited by Deepak Pant (Central University of Himachal Pradesh, India), Ashok Kumar Nadda (Jaypee University of Information Technology, India), Kamal Kishore Pant (Indian Institute of Technology Delhi, India) and Avinash Kumar Agarwal (Indian Institute of Technology Kanpur, India), Energy, Environment, and Sustainability Series, Springer Singapore, 2021, 326 pages, ISBN 978-981-16-0637-3, £109.99, €128.22, US\$126.84

Reviewed by Peter Styring

UK Centre for Carbon Dioxide Utilisation,
Department of Chemical and Biological
Engineering, Sir Robert Hadfield Building, The
University of Sheffield, Sheffield S1 3JD, UK

Email: p.styring@sheffield.ac.uk

NON-PEER REVIEWED FEATURE

Received 8th June 2022; Online 17th October 2022

Introduction

“Advances in Carbon Capture and Utilization” is a multi-author book that is edited by Deepak Pant, Ashok Kumar Nadda, Kamal Kishore Pant and Avinash Kumar Agarwal and published by Springer.

In recent years there have been some excellent books that have been published in this field, so the question was how this would compare and what were the ‘advances’? The first thing that was apparent from the table of contents was that this was a book that was not in the mould of its predecessors. There has been a general acceptance that carbon dioxide utilisation involves the breaking of C=O bonds and the formation of new bonds between carbon and other elements, such as hydrogen, nitrogen or in the case of coupling reactions other carbon fragments. In all cases, CO₂ is the feedstock,

but a new chemical is the product. In 2022 the US Department of Energy clarified the situation somewhat by referring to such chemical reactions as chemical conversion, while those processes using CO₂ as a working fluid were moved from utilisation to carbon capture and storage. The Global CO₂ Institute has identified aggregates, cement, synthetic fuels, methanol and polymers as the leading utilisation products in terms of their high mitigation potential and potential revenue generation. In the case of this book the main value-added products are generally overlooked, and some more left-field applications are considered. Furthermore, there is a heavy influence on the technology within a South Asian context. This makes the book very interesting from a new perspective. My only concern is that while there is considerable emphasis on capture, the actual utilisation side is limited.

Advances in Carbon Dioxide Utilisation

Chapter 1 is a general introduction to advances in carbon dioxide utilisation (CDU) and is the sole chapter in Part I. The theme of the book is laid out with an emphasis on some unusual applications of CDU. Aspects of point source carbon capture (PSC) and direct air capture (DAC) are introduced. Soil remediation, a subject of great importance in India, is highlighted as a promising mitigation technology. The references in this section are

limited to Indian authors which is consistent with the approach of focusing on South Asia that is prominent throughout the book.

Carbon Capture and Sequestration

Part II looks at carbon capture as natural phenomenon. Chapter 2 covers 'Carbon Capture: Innovation for a Green Environment'. This considered sorbents and processes for carbon capture and follows a standard format, looking particularly at aqueous amines and industrial capture processes. There is a background to the theory but lacks real world examples, or an appreciation of the extent of technology deployment. In the case of DAC, the emphasis is on materials: a deeper insight into the process and especially the energy requirements of commercial deployment would have been useful here.

Chapter 3 looks at 'Geological Carbon Capture and Storage as a Climate-Change Mitigation Technology'. The areas covered are broad and look at some geological mitigation technologies but then takes an unexpected foray into fuel production, enhances (*sic*) oil recovery (EO) and revisits methods for carbon capture. In this chapter I would have expected to see more detail into mechanisms of geological storage with insights into site geology, rock porosity and the issues surrounding long-term site stability.

Chapter 4 considers 'Soil Carbon Sequestration for Soil Quality Improvement and Climate Change Mitigation. This is a unique analysis in the area and very important from an agricultural perspective. It is an area that is often neglected and so a major contribution to the field. The subject is extensively referenced giving the reader considerable scope for further study. It is clear from the text that this is considered to be sequestration rather than utilisation: the CO₂ is used for example to improve soil stability. However, from a perspective of sequestration, there are questions surrounding the timescale of sequestration and whether or not it meets the criterion of a minimum 100-year sequestration period.

Carbon Management Techniques

Part III looks at 'Advance (*sic*) Carbon Management Techniques'. Chapter 5 focuses on 'Post-combustion of Carbon Capture Technologies: Advancements in Absorbents and Nanoparticles'. Much of this chapter is a resumé of preceding chapters and tends to consider existing absorbents rather than advanced materials. The section on nanoparticles

is disappointingly small at just over one page and therefore lacks detail.

Chapter 6 is 'Carbon Bio-capturing System for Environment Conservation'. The chapter shows promise, then reverts to a reanalysis of capture technologies covered in several of the previous chapters, including geological and ocean storage which are physical rather than biological systems. However, once this is covered there are some good examples of biological processes including photosynthetic and microbial processes and an interesting section on electrobiological conversions.

Chapter 7 looks at 'Simultaneous Wastewater Treatment and Carbon Capture for Energy Production'. There is a very interesting section on microbial fuel cells which are currently attracting global attention. Of course, these are based on laboratory studies so it will be interesting to see if these make it into a full-scale reactor. One of the problems in the treatment of wastewater is the very low CO₂ concentrations that are encountered. Conversions are difficult to find but where shown tend to be in the milligram per day regime. Algae conversions are also covered, and some examples of precommercial applications are given. The chemistry behind biological reactions is interesting and not covered in detail by other general CDU books, although there are some specialist dedicated textbooks in the field, for example by Aresta (1) and Centi (2).

Chapter 8 looks at 'Carbon Dioxide Capture by Ionic Liquids'. This is a very niche area of absorption chemistry where alternatives to amine solvents are being sought. There are long sections of carbon capture technologies using different sorbents and from different CO₂ sources. This repeats sections covered in many of the preceding chapters and it is a while until ionic liquids are introduced. The descriptions of ionic liquids are extensive and there are considerable amounts of data presented on capture capabilities. The authors quite rightly state that ionic liquids are expensive, although there are exceptions, but it would be useful to see this against a base case of amine solvents, or even water itself. There are many known issues surrounding low diffusion coefficients in ionic liquids, but these are not discussed. In general, many of the references are old and are based on small scale laboratory systems. Some of the more recent work on, for example, ionic liquids coated on cellulose and their effects on capture capacity and processability are not covered. This is a good chapter for those interested in carbon capture, but again they do not discuss utilisation. There are examples where

the ionic liquids act as both capture agents and catalysts for reactions, so-called reactive capture, but these are not covered.

Chapter 9 considers 'The Climate Smart Agriculture for Carbon Capture and Carbon Sequestration: The Challenges and Opportunities'. As the title suggests, this is sequestration and not utilisation so again seems out of place in a utilisation context. That said, it is a very interesting chapter and a valuable resource for those considering mitigation in an agricultural context. The chapter is well referenced and will provoke some questions among readers as to the best way forward if we are to achieve net zero in agriculture, one of the large emitters on a global stage.

Chapter 10 follows on from the previous chapter, but focused more locally on 'Quantification of the Soil Organic Carbon and Major Nutrients Using Geostatistical Approach for Lahaul Valley, Cold Arid Region of Trans-Himalaya'. This chapter is less of a review and more of a research paper so does not sit easily within the structure. There are a reasonable number of references so it may be useful for a specific audience but it is unclear if the main body, including a Results and Discussion, has been peer reviewed or if this is new material.

Novel Techniques for Use and Sequestration

Part IV looks at 'Miscellaneous Techniques'. Chapter 11 covers 'Biochar: A Carbon Negative Technology for Combating Climate Change'. Biochar is an area of CDU that is often neglected from inclusion in reviews, so it is refreshing to see an in-depth analysis presented here. The question arises again if this is utilisation, sequestration or just temporary use as retention in the soil is considered to be temporary. The chapter certainly whets the appetite for further investigation of the subject. The development of a circular ecosystem in which waste material becomes an asset is well highlighted and biochar may help to develop sustainable food production while addressing the challenges of climate change.

Chapter 12 'Carbon Sequestration Potential of Different Land Use Sectors of Western Himalaya'. Again, this is a niche application in a particular geographic region. The chapter concentrates mainly on afforestation as a means of mitigation. Again, this is really sequestration rather than utilisation. An analysis of the life cycle of the technology would have been instructive as it is not clear if the afforestation is a permanent storage

solution or a used as a method for managed forestry with the timber being used for sustainable materials production. In the latter case it could be considered to be utilisation, although current thinking requires the CO₂ to be sequestered for at least 100 years.

Part V covers 'Value Addition Techniques'. Chapter 13 is 'Progresses in Bioenergy Generation from CO₂: Mitigating the Climate Change' but this does not truly reflect the contents of the chapter. Indeed, the first part looks at renewable methanol from waste CO₂ and its production from chemical reactions including thermal catalysis and electrocatalysis. This is clearly not bioenergy generation. When biological systems are addressed, there is duplication of the earlier sections on algae sequestration as well as brief reference to bioethanol and biodiesel production. However, there are no details of the chemistry, processes or the global commercialisation of such technologies. Here I would have expected discussions on SkyNRG (The Netherlands) and LanzaTech (USA), technologies which are now part of the synthetic transport fuels supply chain.

Chapter 14 is 'Recent Advances in Enzymatic Conversion of Carbon Dioxide into Value-Added Product'. This is a novel approach to CO₂ utilisation that tends not to appear in other textbooks in the field. The chapter covers enzymatic production of methanol, although not the LanzaTech process, methanation and formic acid. There are some interesting approaches to CDU presented to a range of inorganic and organic materials, including the catalysed carboxylation of both aliphatic and aromatic compounds. This brings a different perspective to the book and presents a possible new line of investigation, using the tools of nature to help in the conversion of CO₂ into value added products.

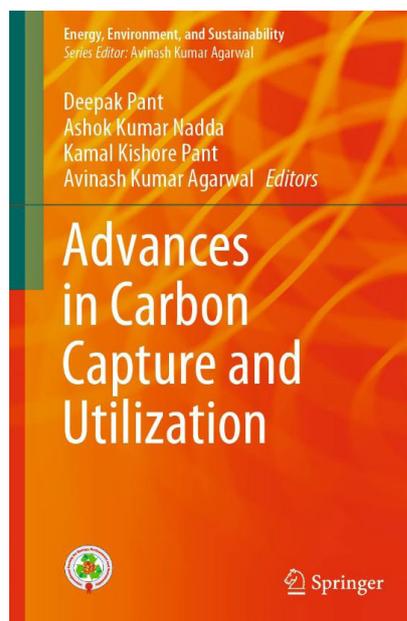
Summary

In summary, this is an interesting book that focuses on carbon capture and to a large extent sequestration. The title of the book does not reflect the approach contained within the chapters fully. There is limited utilisation technology discussed, but where it is, the subject matter differs from the usual technologies discussed in the area. The publication reads more like a series of monologues with many of them having very similar introductions concentrating on capture technologies and materials. There is therefore considerable repetition.

That said, the book will be particularly useful for readers with specific interest in rural applications and the unique ecosystem of South Asia. It is a useful addition to the library of greenhouse gas mitigation technologies, bringing a different approach.

References

1. "Biorefinery: From Biomass to Chemicals and Fuels: Towards Circular Economy", 2nd Edn., eds. M. Aresta, A. Dibenedetto and F. Dumeignil, Walter de Gruyter GmbH, Berlin, Germany, 2021, 649 pp
2. "Green Carbon Dioxide: Advances in CO₂ Utilization", eds. G. Centi and S. Perathoner, John Wiley & Sons Inc, Hoboken, New Jersey, USA, 2014, 326 pp



"Advances in Carbon Capture and Utilization"

The Reviewer



Peter Styring is Professor of Chemical Engineering & Chemistry and Director of the UK Centre for Carbon Dioxide Utilization at The University of Sheffield, UK. He is a former Head of the Chemistry Department. His expertise lies in carbon dioxide capture and utilisation with particular interests in catalysis and the production of low-carbon synthetic transport fuels and fertilisers.