
Concerns over possible waterborne disease forced drinking water supply companies in England and Wales to adopt microfiltration and ultrafiltration technologies rapidly. MF and UF membrane plants are designed to produce water of a consistent quality regardless of throughput and fluctuations in the feedwater quality. To operate well they need to maintain flux and balance the rate of fouling, and chemical cleaning performance is critical to this. Giant steps have been taken into characterizing the foulants scientifically in the last few years while cleaning is reactive and ad hoc. This thesis explores the basis for a corresponding cleaning science for the technology to develop quantitatively. Cleaning performance was defined in terms of a response to combinations of explanatory variables in a materials limited cleaning envelope. The study focused on applying variations of cleanant concentration, applied temperature and soak times to a variety of membranes fouled with different waters and regimes. An experimental design was developed and applied consistently to a number of different sampled sites; allowing an optimised recovery from the polynomial expressions for each treatment, through factorial analysis of the data. The size and variety of the data set analysed allowed comparison and quantification of the different deviations from optimal cleaning response. This effect was seen to vary temporally and with operating regime and the methods usefulness as a practical tool in the membrane plant lifecycle was considered. Cost evaluation of the variation in cleaning response showed that sub-optimal cleaning costs and energy use may be significant and the thesis also illustrated how module geometry affects initial cake deposition and thus cleanability. By demonstrating the potential for cleaning factor analysis, the potential for a combined heuristic and predictive cleaning control science is possible, but will need new strategies to manage technology change.

This multivolume work covers all aspects of membrane science and technology - from basic phenomena to the most advanced applications and future perspectives. Modern membrane engineering is critical to the development of process-intensification strategies and to the stimulation of industrial growth. The work presents researchers and industrial managers with an indespensible tool toward achieving these aims. Covers membrane science theory and economics, as well as applications ranging from chemical purification and natural gas enrichment to potable water. Includes contributions and case studies from internationally recognized experts and from up-and-coming researchers working in this multi-billion dollar field. Takes a unique, multidisciplinary approach that stimulates research in hybrid technologies for current (and future) life-saving applications (artificial organs, drug delivery)

Focusing on the application of membranes in an engineering context, this hands-on computational guide makes previously challenging problems routine. It formulates problems as systems of equations solved with MATLAB, encouraging active learning through worked examples and end-of-chapter problems. The detailed treatments of dead-end filtration include novel approaches to constant rate filtration and filtration with a centrifugal pump. The discussion of crossflow microfiltration includes the use of kinetic and force balance models. Comprehensive coverage of ultrafiltration and diafiltration processes employs both limiting flux and osmotic pressure models. The effect of fluid viscosity on the mass transfer coefficient is explored in detail, the effects of incomplete rejection on the design and analysis of ultrafiltration and diafiltration are analysed, and quantitative treatments of reverse osmosis and nanofiltration process analysis and design are explored. Includes a chapter dedicated to the modelling of membrane fouling.

The chapters of this book are based upon lectures presented at the NATO Advanced Study Institute on Membrane Processes in Separation and Purification (March 21 - April 2, 1993, Curia, Portugal), organized as a successor and update to a similar Institute that took place 10 years ago (P.M. Bungay, H.K. Lonsdale, M.N. de Pinho (Eds.): Synthetic Membranes: Science, Engineering and Applications, NATO ASI Series, Reidel, Dordrecht, 1986). The decade between the two NATO Institutes witnesses the transition from individually researched membrane processes to an applied and established membrane separation technology, as is reflected by the contents of the corresponding proceeding volumes. By and large, the first volume presents itself as a textbook on membrane processes, still valid, while the present volume focuses on areas of separation need as amenable to membrane processing: Biotechnology and Environmental Technology. Accordingly, the contributions to this volume are grouped into "Membranes in Biotechnology" (11 papers), "Membranes in Environmental Technology" (6 papers), and "New Concepts" (4 papers). This is followed by one contribution each on "Energy Requirements" and "Education", i.e., membrane processes within an academic curriculum. The book thus amounts to a state of the art of applied membrane processing and may well augment the more fundamental approach of its predecessor.

Microfiltration and Ultrafiltration Membranes for Drinking Water (M53) American Water Works Association Membrane Principles and Applications Routledge

Membrane processing is a filtration technique in which particles are separated from liquids by being forced through a porous material, or membrane. Applied to dairy products, the separation techniques allow valuable compounds, found in milk, to be isolated for use as ingredients in food processing. A comprehensive overview of membrane separation processes, this book explores various applications such as pressure driven processes, electrical field driven processes, and concentration driven processes, for the recovery of various dairy streams and ingredients. The topics covered place emphasis on new applications, including microfiltration, ultrafiltration, reverse osmosis, electrodialysis, and pervaporation. The text also presents in-depth knowledge of the mechanisms of each membrane separation process, as well as membrane types and the equipment used in these processes. Combining their educational backgrounds and substantial industrial experience in dairy ingredients processes, the authors address cutting-edge technologies that have been thoroughly researched and have great potential to be commercialized in the near future. The book will therefore be of interest to dairy industry professionals and will serve as a source of reference material for professors and students in food science and engineering.

Membrane materials allow for the selective separation of gas and vapour and for ion transport. Materials research and development continues to drive improvements in the design, manufacture and integration of membrane technologies as critical components in both sustainable energy and clean industry applications. Membrane utilisation offers process simplification and intensification in industry, providing low-cost, and efficient and reliable operation, and contributing towards emissions reductions and energy security. Advanced membrane science and
technology for sustainable energy and environmental applications presents a comprehensive review of membrane utilisation and integration within energy and environmental industries. Part one introduces the topic of membrane science and engineering, from the fundamentals of membrane processes and separation to membrane characterization and economic analysis. Part two focuses on membrane utilisation for carbon dioxide (CO2) capture in coal and gas plants, including pre- and post-combustion and oxygen transport technologies. Part three reviews membranes for the petrochemical industry, with chapters covering hydrocarbon fuel, natural gas and synthesis gas processing, as well as advanced biofuels production. Part four covers membranes for alternative energy applications and energy storage, such as membrane technology for redox and lithium batteries, fuel cells and hydrogen production. Finally, part five discusses membranes utilisation in industrial and environmental applications, including microfiltration, ultrafiltration, and forward osmosis, as well as water, wastewater and nuclear power applications. With its distinguished editors and team of expert contributors, Advanced membrane science and technology for sustainable energy and environmental applications is an essential reference for membrane and materials engineers and manufacturers, as well as researchers and academics interested in this field. Presents a comprehensive review of membrane science and technology, focusing on developments and applications in sustainable energy and clean-industry Discusses the fundamentals of membrane processes and separation and membrane characterization and economic analysis Addresses the key issues of membrane utilisation in coal and gas power plants and the petrochemical industry, the use of membranes for alternative energy applications and membrane utilisation in industrial and environmental applications This book covers the ultrafiltration membranes, specifically focusing on the elements that are produced using PVDF technology and out-side-in configuration. It specifically targets ultrafiltration technology as a pretreatment of seawater reverse osmosis desalination process. However, what is described in the book can be leveraged in other ultrafiltration membrane types. It explains how to significantly improve the efficiency of the process. The book focuses on Application of Nanotechnology in Membranes for Water Treatment but not only provides a series of innovative solutions for water reclamation through advanced membrane technology but also serves as a medium to promote international cooperation and networking for the development of advanced membrane technology for Universal well-being and to achieve the common goal of supplying economically, environmentally and societally sustainable freshwater and better sanitation systems. This book is unique because the chapters were authored by established researchers all around the globe based on their recent research findings. In addition, this book provides a holistic coverage of membrane development for water treatment, from the membrane preparation and characterizations to the performance for specific processes and applications. Since that water scarcity has become a global risk and one of the most serious challenges for the scientific community in this century, the publication of this book is therefore significant as it will serve as a medium for a good reference of an alternative solution in water reclamation. This book will provide the readers with a thorough understanding of the different available approaches for manufacturing membranes both with innovative polymeric systems and inorganic nano-materials which could give enhanced functionalities, catalytic and antimicrobial activities to improve the performance of the existing membranes. It will be useful for leading decision and policy makers, water sector representatives and administrators, policy makers from the governments, business leaders, business houses in water treatment, and engineers/ scientists from both industrialized and developing countries as well.


The hypothesis of this research was that by stretching microfiltration or ultrafiltration membranes, their performance, in terms of flux and rejection, could be improved. Stretching a membrane was envisioned to stretch its pores, or change the aspect ration of the pores. It was thought that changing the aspect ratio could lead to improved flux (by increasing the pore area) while also improving the rejection of particles (by decreasing the length of the minor axis). The objective of this research was to study the effects of uniaxial stretching of microporous membranes (and thereby change the aspect ratio) on their performance (measured in terms of flux and particle rejection).

Membrane technologies are currently the most effective and sustainable methods utilized in diversified water filtration, wastewater treatment, as well as industrial and sustainable energy applications. This book covers essential subsections of membrane separation and bioseparation processes from the perspectives of technical innovation, novelty, and sustainability. The book offers a comprehensive overview of the latest improvements and concerns with respect to membrane fouling remediation techniques, issues of bioincompatibility for biomedical applications, and various subareas of membrane separation processes, which will be an efficient resource for engineers.

Microfiltration and ultrafiltration have gained rapid acceptance as processes that provide a reliable and very high level of particle, turbidity, and microorganism removal. This manual contains information on low pressure membranes in their widely diverse applications, operations and system designs.

Promoting a continued and much-needed renaissance in biopharmaceutical manufacturing, this book covers the different strategies and assemblies top-tier technology experts to address the challenges of antibody purification. • Updates existing topics and adds new ones that include purification of antibodies produced in novel production systems, novel separation technologies, novel antibody formats and alternative scaffolds, and strategies for ton-scale manufacturing • Presents new and updated discussions of different purification technologies, focusing on how they can address the capacity crunch in antibody purification • Emphasizes antibodies and innovative chromatography methods for processing

Soon after its publication in 1987, the first edition of Ultrafiltration Handbook became recognized as the leading handbook on ultrafiltration technology. Reviews in professional journals praised it as an authoritative and substantive information resource on this technology. Now a completely, updated and expanded edition is available under the title,
Ultrafiltration and Microfiltration Handbook. This practical handbook systematically covers the basics of this technology from its scientific fundamentals to a wide range of industrial applications. The presentation is clear and concise with the emphasis on practical use. Many schematics and micrographs illustrate membranes, equipment and processes. Numerous tables and graphs provide useful data on specifications and performance. The updated information is useful to all those involved in the use of separation and filtration in industrial processes.

Membrane Characterization provides a valuable source of information on how membranes are characterized, an absolutely limited field that is confined to only brief descriptions in various technical papers available online. For the first time, readers will be able to understand the importance of membrane characterization, the techniques required, and the fundamental theory behind them. This book focuses on characterization techniques that are normally used for membranes prepared from polymeric, ceramic, and composite materials. Features specific details on many membrane characterization techniques for various membrane materials of industrial and academic interest. Contains examples of international best practice techniques for the evaluation of several membrane parameters, including pore size, charge, and fouling. Discusses various membrane models more suitable to a specific application. Provides examples of ab initio calculations for the design, optimization, and scale-up of processes based on characterization data.

This ready reference on Membrane Technologies for Water Treatment, is an invaluable source detailing sustainable, emerging processes, to provide clean, energy saving and cost effective alternatives to conventional processes. The editors are internationally renowned leaders in the field, who have put together a first-class team of authors from academia and industry to present a highly approach to the subject. The book is an instrumental tool for Process Engineers, Chemical Engineers, Process Control Technicians, Water Chemists, Environmental Chemists, Materials Scientists and Patent Lawyers.

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Integrates knowledge on microfiltration and ultrafiltration, membrane chemistry, and characterization methods with the engineering and economic aspects of device performance, device and module design, processes, and applications. The text provides a discussion of membrane fundamentals and an analytical framework for designing and developing new filtration systems for a broad range of technologically important functions. It offers information on membrane liquid precursors, fractal and stochastic pore space analysis, novel and advanced module designs, and original process design calculations.

The book examines the possibility of integrating different membrane unit operations (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrodialysis and gas separation) in the same industrial cycle or in combination with conventional separation systems. It gives careful analysis of the technical aspects, and the possible fields of industrial development. The book reviews many original solutions in water desalination, agro-food productions and wastewater treatments, highlighting the advantages achievable in terms of product quality, compactness, rationalization and optimization of productive cycles, reduction of environmental impact and energy saving. Also included are examples of membrane reactors and their integration with a fuel cell; polymeric membranes in the integrated gasification combined cycle power plants; integrating a membrane reformer into a solar system; and potential application of membrane integrated systems in the fusion reactor fuel cycle. With detailed analysis and broad coverage, the book is divided into two sections: Bio-applications and Inorganic Applications.

Ceramic membrane processes are a rapidly emerging technology for water treatment, yet virtually no information on the performance and fouling mechanisms is available to the industry. Ceramic microfiltration of model feed solutions and a synthetic river water was examined, and a systematic comparison with polymeric counterpart was performed. The results suggested that the models which have been applied to polymeric membranes agreed well with the ceramic membrane filtration data. The fouling was characterized by the initial pore blocking mechanism and transition to the cake filtration mechanism at a later phase. Cake resistance was dominant and readily removable by physical cleaning. The effects of solution chemistry including ionic strength, divalent ion concentration and pH on the flux behavior were comparatively evaluated for ceramic and polymeric ultrafiltration of synthetic water containing model natural organic matter. Experimental evaluations further included resistance-in-series model analysis, organic matter fouling visualization using quantum dots, batch adsorption test, and contact angle measurement, and provided a quantitative a quantitative comparison of fouling characteristics between ceramic and polymeric membranes. The results collectively suggested that the effects of solution chemistry on the fouling behavior with ceramic membranes were mostly similar with polymeric membranes in terms of trends, while the extents varied depending on water quality parameters. Less fouling tendency and better cleaning efficiency were observed with the ceramic membranes, which was a promising finding for ceramic membrane application to surface water treatment. The study further examined a coagulation-ceramic membrane process as a robust option for surface water treatment. The performance of the hybrid system was evaluated using selected surface waters by varying coagulation conditions and types of coagulants. Results suggested that ceramic membranes experienced relatively less fouling and had better cleaning efficiency than polymeric counterpart. The results of this study provide critical information to guide the industry practitioners, consultants, and regulatory agents considering early adoption of this new technology as well as fundamental knowledge upon which further in-depth studies can be built.
Advanced membranes-from fundamentals and membrane chemistry to manufacturing and applications A hands-on reference for practicing professionals, Advanced Membrane Technology and Applications covers the fundamental principles and theories of separation and purification by membranes, the important membrane processes and systems, and major industrial applications. It goes far beyond the basics to address the formulation and industrial manufacture of membranes and applications. This practical guide: Includes coverage of all the major types of membranes: ultrafiltration; microfiltration; nanofiltration; reverse osmosis (including the recent high-flux and low-pressure membranes and anti-fouling membranes); membranes for gas separations; and membranes for fuel cell use Addresses six major topics: membranes and applications in water and wastewater; membranes for biotechnology and chemical/biomedical applications; gas separations; membrane contractors and reactors; environmental and energy applications; and membrane materials and characterization Includes discussions of important strategic issues and the future of membrane technology With chapters contributed by leading experts in their specific areas and a practical focus, this is the definitive reference for professionals in industrial manufacturing and separations and research and development; practitioners in the manufacture and applications of membranes; scientists in water treatment, pharmaceutical, food, and fuel cell processing industries; process engineers; and others. It is also an excellent resource for researchers in industry and academia and graduate students taking courses in separations and membranes and related fields.

Water is accepted as the most important source of life. It is assumed that life began in water and spread from there to the whole world. But water has been polluted anthropogenically since the beginning of the industrial revolution in the late 19th century. At the end of the 20th century, most water sources cannot be used for aquaculture, irrigation, and human use. Therefore, for sustainable development, we have to protect our water sources on Earth, because it's the only planet we have!

Researchers in polymeric membranes as well as R&D professionals will find this work an essential addition to the literature. It concentrates on the method recently developed to study the surfaces of synthetic polymeric membranes using an Atomic Force Microscope (AFM), which is fast becoming a very important tool. Each chapter includes information on basic principles, commercial applications, an overview of current research and guidelines for future research.

This book is a record of a symposium, "Ultrafiltration Membranes and Applications," which was held at the 178th National Meeting of the American Chemical Society in Washington, D.C., September 11-13, 1979. In organizing these sessions, I hoped to provide a comprehensive survey of the current state of ultrafiltration theory, the most recent advancements in membrane technology, and a thorough treatment of existing applications and future directions for ultrafiltration. For me, the symposium was an outstanding success. It was a truly international forum with stimulating presentations and an enthusiastic audience. I hope that some of this spirit has spilled over into this volume, which is intended to reach a much wider audience. I am indebted to the Division of Colloid and Surface Chemistry of the American Chemical Society for their sponsorship. ANTHONY R. COOPER Palo Alto, California March, 1980 vii CONTENTS PART I. FUNDAMENTALS Fifteen Years of Ultrafiltration: Problems and Future Promises of an Adolescent Technology . . . 1 Alan S. Michaels Production, Specification, and Some Transport Characteristics of Cellulose Acetate Ultrafiltration Membranes for Aqueous Feed Solutions 21 S. Sourirajan, Takeshi Matsuura Fu-Hung Hsieh and Gary R. Gilbert Chemical and Morphological Effects of Solute Diffusion Through Block Copolymer Membranes 45 Yatin B. Thakore, Dien-Feng Shieh and Donald J. Lyman Practical Aspects in the Development of a Polymer Matrix for Ultrafiltration. 57 Israel Cabasso Permeability Parameters of a Novel Polyamide Membrane. ... - ... Presenting a useful reference to the current state of membrane technology and its likely future growth, this book covers all aspects of the technology and its applications in the water industry. Drawing on the experience of international experts, Membrane Technology in Water and Wastewater Treatment encompasses many practical applications of specific membranes, including MF, UF, NF, RO and EDR, in the treatment of ground and surface water, backwash water, seawater, and industrial and domestic wastewater. Novel applications, process enhancements and the latest systems are also discussed. This book is an excellent guide to membrane technology and will be of great interest to water companies, industrialists, legislative bodies and anyone with an interest in the technology or its applications.

Soon after its publication in 1987, the first edition of Ultrafiltration Handbook became recognized as the leading handbook on ultrafiltration technology. Reviews in professional journals praised it as an authoritative and substantive information resource on this technology. Now a completely, updated and expanded edition is available under the title Pressure-driven membrane filtration processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) provide opportunities for the dairy industry to better utilize milk by separating its components based on size. However, widespread adoption of some of these processes has yet to be realized due to membrane fouling. Membrane fouling is the accumulation of soil, or foulant, on the surface or within the pores of a membrane. Fouling prolongs processing times, increases energy and cleaning costs, decreases separation efficiency, and, in severe cases, may lead to irreversible clogging of the membrane. Microfiltration can be used to remove serum proteins (SP) from skim milk. The process' SP removal efficiency directly influences the technology's financial feasibility. Our first objective was to quantify the capacity of 0.14 [MICRO
SIGN Im ceramic Isoflux MF membranes to remove SP from skim milk. The Isoflux membranes' manufacturer claims that using these membranes will reduce localized membrane fouling at the inlet end of the membrane that results from using high cross-flow velocities (5 - 7 m/s) to mitigate overall membrane fouling. Contrary to theoretical cumulative SP removal percentages of 68%, 90%, and 97% after 1, 2, and 3 stages of 3X MF processing, respectively, the 3X Isoflux process removed only 39.5%, 58.4%, and 70.2% after 1, 2, and 3 stages, respectively. Several design aspects of the membrane are thought to have resulted in this inefficiency. Ultrafiltration can be used to concentrate SP and reduce the lactose content of cheese whey or MF permeate of skim milk to produce 80% whey protein concentrates (WPC80) or 80% serum protein concentrates (SPC80), respectively. The objectives of our second study were to determine if adding annatto color to milk or bleaching whey or MF permeate of skim milk with hydrogen peroxide (H2O2) or benzoyl peroxide (BPO) influenced UF flux, diafiltration flux, or membrane fouling during production of WPC80 or SPC80. Addition of annatto color to milk had no effect on flux or fouling. Bleaching with or without added color increased flux during processing. Bleaching with H2O2 produced higher flux than bleaching with BPO. While bleaching with BPO reduced membrane fouling during WPC80 production, it did not impact membrane fouling during SPC80 production. Bleaching with H2O2 led to the largest reduction in fouling for both production processes.

Detailed technical information on MF and UF treatment processes for water operators, engineers, and utility management.