

# POPULATION BALANCES

Theory and Applications to  
Particulate Systems in Engineering

DORAI SWAMI RAMKRISHNA



# Population Balances Theory And Applications To Particulate Systems In Engineering

**P. J. Cullen, Rodolfo J.  
Romañach, Nicolas Abatzoglou, Chris D.  
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## **Population Balances Theory And Applications To Particulate Systems In Engineering:**

*Population Balances* Doraiswami Ramkrishna, 2000-08-08 Engineers encounter particles in a variety of systems. The particles are either naturally present or engineered into these systems. In either case, these particles often significantly affect the behavior of such systems. This book provides a framework for analyzing these dispersed phase systems and describes how to synthesize the behavior of the population particles and their environment from the behavior of single particles in their local environments. Population balances are of key relevance to a very diverse group of scientists including astrophysicists, high energy physicists, geophysicists, colloid chemists, biophysicists, materials scientists, chemical engineers, and meteorologists. Chemical engineers have put population balances to most use with applications in the areas of crystallization, gas-liquid, liquid-liquid, and solid-liquid dispersions, liquid membrane systems, fluidized bed reactors, aerosol reactors, and microbial cultures. Ramkrishna provides a clear and general treatment of population balances with emphasis on their wide range of applicability. New insight into population balance models incorporating random particle growth, dynamic morphological structure, and complex multivariate formulations with a clear exposition of their mathematical derivation is presented. *Population Balances* provides the only available treatment of the solution of inverse problems essential for identification of population balance models for breakage and aggregation processes, particle nucleation, growth processes, and more. This book is especially useful for process engineers interested in the simulation and control of particulate systems. Additionally, comprehensive treatment of the stochastic formulation of small systems provides for the modeling of stochastic systems with promising new areas of applications such as the design of sterilization systems and radiation treatment of cancerous tumors. A clear and general treatment of population balances with emphasis on their wide range of applicability. Thus, all processes involving solid-fluid and liquid-liquid dispersions, biological populations, etc. are encompassed. Provides new insight into population balance models incorporating random particle growth, dynamic morphological structure, and complex multivariate formulations with a clear exposition of their mathematical derivation. Presents a wide range of solution techniques: Monte Carlo simulation methods with a lucid exposition of their origin and scope for enhancing computational efficiency. An account of self-similar solutions of population balance equations and their significance to the treatment of data on particulate systems. The only available treatment of the solution of inverse problems essential for identification of population balance models for breakage and aggregation processes, particle nucleation, and growth processes, and so on. A comprehensive treatment of the stochastic formulation of small systems with several new applications. *Modelling Batch Systems Using Population Balances*, **Multiphase Particulate Systems in Turbulent Flows** Wioletta Podgórska, 2019-09-17 *Multiphase Particulate Systems in Turbulent Flows* Fluid-Liquid and Solid-Liquid Dispersions provides methods necessary to analyze complex particulate systems and related phenomena including physical, chemical, and mathematical description of fundamental processes influencing crystal size and shape, suspension rheology, interfacial area, of

drops and bubbles in extractors and bubble columns Examples of mathematical model formulation for different processes taking place in such systems is shown Discussing connections between turbulent mixing mechanisms and precipitation it discusses influence of fine scale structure of turbulence including its intermittent character on breakage of drops bubbles cells plant cell aggregates An important aspect of the mathematical modeling presented in the book is multi fractal taking into account the influence of internal intermittency on different phenomena Key Features Provides detailed descriptions of dispersion processes in turbulent flow interactions between dispersed entities and continuous phase in a single volume Includes simulation models and validation experiments for liquid liquid gas liquid and solid liquid dispersions in turbulent flows Helps reader learn formulation of mathematical models of breakage or aggregation processes using multifractal theory Explains how to solve different forms of population balance equations Presents a combination of theoretical and engineering approaches to particulate systems along with discussion of related diversity with exercises and case studies

*Industrial Chemical Separation* Timothy C. Frank, Bruce S. Holden, 2023-08-07 A fresh new treatment written by industry insiders this work gives readers a remarkably clear view into the world of chemical separation The authors review distillation extraction adsorption crystallization and the use of membranes providing historical perspective explaining key features and offering insights from personal experience The book is for engineers and chemists with current or future responsibility for chemical separation on a commercial scale in its design operation or improvement or for anyone wanting to learn more about chemical separation from an industrial point of view The result is a compelling survey of popular technologies and the profession one that brings the art and craft of chemical separation to life Ever wonder how popular separation technologies came about how a particular process functions or how mass transfer units differ from theoretical stages Or perhaps you want some pointers on how to begin solving a separation problem You will find clear explanations and valuable insights into these and other aspects of industrial practice in this refreshing new survey

Engineering of Submicron Particles Jayanta Chakraborty, 2019-06-10 Brings together in one place the fundamental theory and models and the practical aspects of submicron particle engineering This book attempts to resolve the tricky aspects of engineering submicron particles by discussing the fundamental theories of frequently used research tools both theoretical and experimental The first part covers the Fundamental Models and includes sections on nucleation growth inter molecular and inter particle forces colloidal stability and kinetics The second part examines the Modelling of a Suspension and features chapters on fundamental concepts of particulate systems writing the number balance modelling systems with particle breakage and aggregation and Monte Carlo simulation The book also offers plenty of diagrams software examples brief experimental demonstrations and exercises with answers Engineering of Submicron Particles Fundamental Concepts and Models offers a lengthy discussion of classical nucleation theory and introduces other nucleation mechanisms like organizer mechanisms It also looks at older growth models like diffusion controlled or surface nucleation controlled growth along with new generation models like

connected net analysis Aggregation models and inter particle potentials are touched upon in a prelude on intermolecular and surface forces The book also provides analytical and numerical solutions of population balance models so readers can solve basic population balance equations independently Presents the fundamental theory practical aspects and models of submicron particle engineering Teaches readers to write number balances for their own system of interest Provides software with open code for solution of population balance model through discretization Filled with diagrams examples demonstrations and exercises Engineering of Submicron Particles Fundamental Concepts and Models will appeal to researchers in chemical engineering physics chemistry engineering and mathematics concerned with particulate systems It is also a good text for advanced students taking particle technology courses     Feature Papers Michael Henson,2018-10-04

This book is a printed edition of the Special Issue Feature Papers that was published in Processes     **19th European Symposium on Computer Aided Process Engineering** Jacek Jezowski,Jan Thullie,2009-06-12 The 19th European Symposium on Computer Aided Process Engineering contains papers presented at the 19th European Symposium of Computer Aided Process Engineering ESCAPE 19 held in Cracow Poland June 14 17 2009 The ESCAPE series serves as a forum for scientists and engineers from academia and industry to discuss progress achieved in the area of CAPE CD ROM that accompanies the book contains all research papers and contributions International in scope with guest speeches and keynote talks from leaders in science and industry Presents papers covering the latest research key top areas and developments in computer aided process engineering CAPE     **Chemical Engineering in the Pharmaceutical Industry** David J. am Ende,Mary T. am Ende,2019-03-28 A guide to the development and manufacturing of pharmaceutical products written for professionals in the industry revised second edition The revised and updated second edition of Chemical Engineering in the Pharmaceutical Industry is a practical book that highlights chemistry and chemical engineering The book s regulatory quality strategies target the development and manufacturing of pharmaceutically active ingredients of pharmaceutical products The expanded second edition contains revised content with many new case studies and additional example calculations that are of interest to chemical engineers The 2nd Edition is divided into two separate books 1 Active Pharmaceutical Ingredients API s and 2 Drug Product Design Development and Modeling The active pharmaceutical ingredients book puts the focus on the chemistry chemical engineering and unit operations specific to development and manufacturing of the active ingredients of the pharmaceutical product The drug substance operations section includes information on chemical reactions mixing distillations extractions crystallizations filtration drying and wet and dry milling In addition the book includes many applications of process modeling and modern software tools that are geared toward batch scale and continuous drug substance pharmaceutical operations This updated second edition Contains 30new chapters or revised chapters specific to API covering topics including manufacturing quality by design computational approaches continuous manufacturing crystallization and final form process safety Expanded topics of scale up continuous processing

applications of thermodynamics and thermodynamic modeling filtration and drying Presents updated and expanded example calculations Includes contributions from noted experts in the field Written for pharmaceutical engineers chemical engineers undergraduate and graduate students and professionals in the field of pharmaceutical sciences and manufacturing the second edition of Chemical Engineering in the Pharmaceutical Industry focuses on the development and chemical engineering as well as operations specific to the design formulation and manufacture of drug substance and products

*Problem Solving in Engineering* Larry A. Glasgow, 2025-03-04 Bring mathematical principles to bear on engineering problems with this updated text The evolution of industrial processes has resulted in greater emphasis upon analytical and numerical problem solving Process improvement through experimentation is impractical and consequently engineers must rely upon computational and technical analysis Furthermore the ease with which time series data can be collected and processed has made harmonic signal interpretation routine Thus the ability of engineers to analyze model compute and interpret process phenomena is crucial to professional practice Problem Solving in Engineering meets these needs with a foundational introduction to mathematical techniques in applied sciences and engineering Incorporating examples from a range of scientific fields it communicates principles that can be adapted to many hardware software combinations Now fully updated to reflect the latest research and applications it remains an essential tool for engineers and applied scientists everywhere Readers of the second edition will also find Extensive time devoted to problem formulation Detailed discussion of integro differential equations and the processing and analysis of time series data The use of vorticity transport for the solution of momentum heat and mass transfer problems in two dimensions Examples and problems drawn from aviation telegraphy structural failures railroad operation chemical processes automatic process control seismology neutron diffusion gravitation and quantum theory Many additional narrative type exercises written to appeal to students who find problems in context better suited to their learning style Solutions manual available for qualified instructors Problem Solving in Engineering is ideal for advanced undergraduate graduate students and technical professionals in the physical sciences specifically chemical civil biochemical electrical and mechanical engineering as well as physics chemistry and biology

Applied Mathematics for Science and Engineering Larry A. Glasgow, 2014-07-24 Prepare students for success in using applied mathematics for engineering practice and post graduate studies Moves from one mathematical method to the next sustaining reader interest and easing the application of the techniques Uses different examples from chemical civil mechanical and various other engineering fields Based on a decade s worth of the authors lecture notes detailing the topic of applied mathematics for scientists and engineers Concisely writing with numerous examples provided including historical perspectives as well as a solutions manual for academic adopters **European Symposium on Computer Aided Process Engineering - 12** J. Grievink, J. van Schijndel, 2002-04-29 This book contains 182 papers presented at the 12th Symposium of Computer Aided Process Engineering ESCAPE 12 held in The Hague The Netherlands May 26 29 2002 The objective of

ESCAPE 12 is to highlight advances made in the development and use of computing methodologies and information technology in the area of Computer Aided Process Engineering and Process Systems Engineering The Symposium addressed six themes 1 Integrated Product 2 Process Synthesis 3 Process Dynamics 4 Manufacturing 5 Computational Technologies 6 Sustainable CAPE Education and Careers for Chemical Engineers These themes cover the traditional core activities of CAPE and also some wider conceptual perspectives such as the increasing interplay between product and process design arising from the often complex internal structures of modern products the integration of production chains creating the network structure of the process industry and optimization over life span dimensions taking sustainability as the ultimate driver

Advanced Heat Transfer Greg F. Naterer, 2018-05-03 Advanced Heat Transfer Second Edition provides a comprehensive presentation of intermediate and advanced heat transfer and a unified treatment including both single and multiphase systems It provides a fresh perspective with coverage of new emerging fields within heat transfer such as solar energy and cooling of microelectronics Conductive radiative and convective modes of heat transfer are presented as are phase change modes Using the latest solutions methods the text is ideal for the range of engineering majors taking a second level heat transfer course module which enables them to succeed in later coursework in energy systems combustion and chemical reaction engineering

**Mesoscale Modeling in Chemical Engineering Part I**, 2015-11-26 Focusing Mesoscales of Multiscale Problems in Chemical Engineering a volume in the Advances in Chemical Engineering series provides readers with the personal views of recognized authorities who present assessments of the state of the art in the field and help readers develop an understanding of its further evolution Subjects covered in the book are not limited to the classical chemical engineering disciplines Contributions connecting chemical engineering to related scientific fields either providing a fundamental basis or introducing new concepts and tools are encouraged This volume aims to create a balance between well developed areas such as process industry transformation of materials energy and environmental issues and areas where applications of chemical engineering are more recent or emerging Contains reviews by leading authorities in their respective areas Provides up to date reviews of the latest techniques in the modeling of catalytic processes Includes a broad mix of US and European authors as well as academic industrial research institute perspectives Provides discussions on the connections between computation and experimental methods

*Dynamic Process Modeling*, 2013-10-02 Inspired by the leading authority in the field the Centre for Process Systems Engineering at Imperial College London this book includes theoretical developments algorithms methodologies and tools in process systems engineering and applications from the chemical energy molecular biomedical and other areas It spans a whole range of length scales seen in manufacturing industries from molecular and nanoscale phenomena to enterprise wide optimization and control As such this will appeal to a broad readership since the topic applies not only to all technical processes but also due to the interdisciplinary expertise required to solve the challenge The ultimate reference work for years to come

**Mathematical Modeling of Disperse Two-Phase**

**Flows** Christophe Morel, 2015-07-17 This book develops the theoretical foundations of disperse two phase flows which are characterized by the existence of bubbles droplets or solid particles finely dispersed in a carrier fluid which can be a liquid or a gas Chapters clarify many difficult subjects including modeling of the interfacial area concentration Basic knowledge of the subjects treated in this book is essential to practitioners of Computational Fluid Dynamics for two phase flows in a variety of industrial and environmental settings The author provides a complete derivation of the basic equations followed by more advanced subjects like turbulence equations for the two phases continuous and disperse and multi size particulate flow modeling As well as theoretical material readers will discover chapters concerned with closure relations and numerical issues Many physical models are presented covering key subjects including heat and mass transfers between phases interfacial forces and fluid particles coalescence and breakup amongst others This book is highly suitable for students in the subject area but may also be a useful reference text for more advanced scientists and engineers *Particle Breakage* Agba D. Salman, Mojtaba Ghadiri, Michael Hounslow, 2007-11-01 Particle breakage is an important process within a wide range of solids processing industries including pharmaceuticals food agricultural and mining Breakage of particles can be defined as intentional and unintentional depending on whether it is desired or not Through understanding of the science and underlying mechanisms behind this phenomenon particle breakage can be either minimised or encouraged within an efficient and effective process Particle Breakage examines particle breakage at three different length scales ranging from single particle studies through groups of particles and looking at solid processing steps as a whole This book is the widest ranging book in the field and includes the most up to date techniques such as Distinct Element Method DEM Monte Carlo simulations and Population Balance Equations PBE This handbook provides an overview of the current state of the art and particle breakage From the small scale of a single particle to the study of whole processes for breakage both by experimental study and mathematical modelling Covering a wide range of subjects and industrial applications Allows the reader an understanding of the science behind engineered breakage processes Giving an unrestrictive and interdisciplinary approach *Wastewater Treatment Reactors* Maulin P. Shah, Susana Rodriguez-Couto, 2021-05-12 Wastewater Treatment Reactors Microbial Community Structure analyzes microbial community structure in relation to changes in physico chemical parameters the gene content metagenome or gene expression metatranscriptome of microbial communities in relation to changes in physico chemical parameters physiological aspects of microbial communities enrichment cultures or pure cultures of key species in relation to changes in physico chemical parameters and modeling of potential consequences of changes in microbial community structure or function for higher trophic levels in a given habitat As several studies have been carried out to understand bulking phenomena and the importance of environmental factors on sludge settling characteristics which are thought to be strongly influenced by flocculation sludge bulking foaming and rising this book is an ideal resource on the topics covered Presents the state of the art techniques and applications of omics tools in wastewater treatment reactors



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Pharmaceutical Blending and Mixing P. J. Cullen,Rodolfo J. Romañach,Nicolas Abatzoglou,Chris D. Rielly,2015-05-11 Written in four parts this book provides a dedicated and in depth reference for blending within the pharmaceutical manufacturing industry It links the science of blending with regulatory requirements associated with pharmaceutical manufacture The contributors are a combination of leading academic and industrial experts who provide an informed and industrially relevant perspective of the topic This is an essential book for the pharmaceutical manufacturing industry and related academic researchers in pharmaceutical science and chemical and mechanical engineering

Process Modeling, Simulation, and Environmental Applications in Chemical Engineering Bharat A. Bhanvase,Rajendra P. Ugwekar,2016-10-14 In this valuable volume new and original research on various topics on chemical engineering and technology is presented on modeling and simulation material synthesis wastewater treatment analytical techniques and microreactors The research presented here can be applied to technology in food paper and pulp polymers petrochemicals surface coatings oil technology aspects among other uses The book is divided into five sections modeling and simulation environmental applications materials and applications processes and applications analytical methods Topics include modeling and simulation of chemical processes process integration and intensification separation processes advances in unit operations and processes chemical reaction engineering fuel and energy advanced materials CFD and transport processes wastewater treatment The valuable research presented here will be of interest to researchers scientists industry practitioners as well as upper level students

34th European Symposium on Computer Aided Process Engineering /15th International Symposium on Process Systems Engineering Flavio Manenti,G.V. Rex Reklaitis,2024-06-27 The 34th European Symposium on Computer Aided Process Engineering 15th International Symposium on Process Systems Engineering contains the papers presented at the 34th European Symposium on Computer Aided Process Engineering 15th International Symposium on Process Systems Engineering joint event It is a valuable resource for chemical engineers chemical process engineers researchers in industry and academia students and consultants for chemical industries Presents findings and discussions from the 34th European Symposium on Computer Aided Process Engineering 15th International Symposium on Process Systems Engineering joint event

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