

MODELING DISSOLVED OZONE AND BROMATE ION FORMATION IN OZONE CONTACTORS

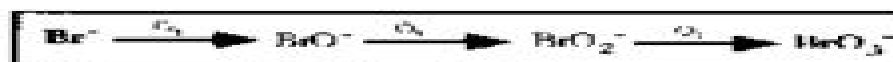
MOHAMED SIDDIQUI, GARY AMY, KENAN OZEKIN and PAUL WESTERHOFF
University of Colorado, Boulder, CO 80309, U.S.A.

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Abstract. Many drinking water utilities that use source waters with significant bromide ion levels are currently seeking disinfection regimes that will minimize the formation of brominated disinfection byproducts while providing adequate disinfection. While ozonation appears to be a promising option for achieving these goals, the uncertainty of future drinking water regulations has developed a need for predicting actual disinfection byproduct formation prior to the costly investment for upgrading existing treatment facilities. The models developed in this paper provide comparisons of ozonation application methods, providing a basis for minimizing bromate and aiding in future design considerations. Theoretical and empirical models for the determination of ozone transferred, dissolved ozone concentrations, and bromate formation have been derived and compared with pilot-scale and full-scale data; a good agreement has been observed between the actual data and the predicted data, showing the validity of these models. True-batch bromate formation more closely simulated pilot-scale and full-scale data. Bromate formation in one stage vs two stage ozone contactors and different reactor configurations have been compared. Ozone gas phase concentration appears to have an effect on bromate formation as well.

1. Introduction

Ozone is a strong oxidant and it oxidizes bromide ion Br^- in water to bromate ion BrO_3^- through two different pathways. BrO_3^- can form through both a molecular ozone (O_3) pathway and a hydroxyl radical ($\text{OH}\cdot$)* pathway, depending on the dissolved organic carbon (DOC), br^- content, and pH of the source waters (Richardson *et al.*, 1981 and Yates and Strenstrom, 1993). By the molecular ozone pathway, Br^- is first oxidized by dissolved ozone to hypobromite ion (OBr^-) which is then further oxidized to BrO_3^- as shown below.



This reaction is pH-dependent since BrO_3^- is in equilibrium with hypobromous acid (HOBr). The molecular ozone theory suggests that BrO_3^- formation is directly driven by dissolved ozone (DO_3) and the OH radical theory indicates that dissolved ozone plays only an indirect role by decomposing O_3 to produce radicals which further react with bromine species to produce BrO_3^- :

* OH radicals are produced as a result of the decomposition of molecular ozone (O_3) at pH>8.0. O_3 is highly selective as an oxidant whereas OH radicals are non-selective. The reaction rates of OH radicals with bromine species are many orders of magnitude faster than with O_3 .

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Modeling Dissolved Ozone Behavior in Ozone Contactors Philip C. Singer, Christopher S. Hull, AWWA Research Foundation, 2000 **Chemical Water and Wastewater Treatment VIII** Hermann H. Hahn, Erhard Hoffmann, Hallvard Ødegaard, 2004-11-01 In the wake of the Millennium Declaration and the Johannesburg resolutions many countries have begun to address or re write their policies regarding water supply and wastewater disposal The goal is to provide high quality drinking water for more people and to safely dispose of spent waters from a large portion of the population than today This book as its predecessors provides information and technical solutions to accomplish this mammoth task It is the outcome of collective experience and know how exchanged between experts in the field of water technology from all over the world from the Americas from central and southern Africa from Europe and from different parts of Asia The Chemical Water and Wastewater Treatment Series provides authoritative coverage of the key current developments in the chemical treatment of water and wastewater in theory or practice and related problems such as sludge production and properties and the reuse of chemicals and chemically treated waters and sludges Chemical Water and Wastewater Treatment VIII is a valuable resource for managers scientists plant operators and others interested in chemical water and wastewater treatment technology

Ozonation of Water and Waste Water Christiane Gottschalk, Judy Ann Libra, Adrian Saupe, 2009-12-09 The leading resource on ozone technology this book contains everything from chemical basics to technical and economic concerns The text has been updated to include the latest developments in water treatment and industrial processes Following an introduction the first part looks at toxicology reaction mechanisms and full scale applications while Part B covers experimental design equipment and analytical methods mass transfer reaction kinetics and the application of ozone in combined processes **American Book Publishing Record** ,2000 Improvement of the Ozonation Process Through the Use of Static Mixers C. Mysore, J. Leparc, Daniel W. Smith, S. Craik, G. Finch, R. Lake, P. Agutter, C. de Traversay, D. Wolbert, Gary Amy, 2004-01-01 Among the known disinfectants ozone has been demonstrated to be very effective in inactivating protozoans Current and proposed regulations impose additional treatment requirements for *Cryptosporidium parvum* These regulatory trends tend to place more stringent performance demands on disinfection systems and have therefore increased the need for improvements in the design The static mixer offers one alternative method for improving the efficiency of the dissolution of ozone and optimizing its use in the disinfection process The overall objective of this research was to quantify the potential benefits of ozone application through the use of static mixers in terms of increased transfer efficiency disinfection capacity and enhanced chemical reactions at laboratory pilot and full scale systems Specific goals were to identify and quantify the effect of several water quality parameters and environmental engineered factors on the disinfection capacity of the ozone static mixer system and assess bromate formation under optimum conditions for microbial inactivation Originally published by AwwaRF for its subscribers in 2003 This publication can also be purchased and

downloaded via Pay Per View on Water Intelligence Online click on the Pay Per View icon below [Selected Water Resources Abstracts](#) ,1991 **Ozone in Food Processing** Colm O'Donnell,Brijesh K. Tiwari,P. J. Cullen,Rip G. Rice,2012-02-13 This book is the first to bring together essential information on the application of ozone in food processing providing an insight into the current state of the art and reviewing established and emerging applications in food processing preservation and waste management The chemical and physical properties of ozone are described along with its microbial inactivation mechanisms The various methods of ozone production are compared including their economic and technical aspects Several chapters are dedicated to the major food processing applications fruit and vegetables grains meat seafood and food hydrocolloids and the effects on nutritional and quality parameters will be reviewed throughout Further chapters examine the role of ozone in water treatment in food waste treatment and in deactivating pesticide residues The international regulatory and legislative picture is addressed as are the health and safety implications of ozone processing and possible future trends [Rev Chilena de Ingenieria](#) ,2008-10 **Indexes** United States. Environmental Protection Agency,1983 **Dissertation Abstracts International** ,2008 **Water Research** ,1989 **EPA Publications Bibliography** United States. Environmental Protection Agency,1987 **Water Quality International "96** International Association on Water Quality. Conference,1996 **Pollution Abstracts** ,1996 Indexes material from conference proceedings and hard to find documents in addition to journal articles Over 1 000 journals are indexed and literature published from 1981 to the present is covered Topics in pollution and its management are extensively covered from the standpoints of atmosphere emissions mathematical models effects on people and animals and environmental action Major areas of coverage include air pollution marine pollution freshwater pollution sewage and wastewater treatment waste management land pollution toxicology and health noise and radiation **EPA Publications Bibliography** ,1983 **Chemical Abstracts** ,2002 **Books In Print 2004-2005** Ed Bowker Staff,Staff Bowker, Ed,2004 **EPA publications bibliography, 1977-1983** ,1983 **Elements of Environmental Engineering** Kalliat T. Valsaraj,Elizabeth M. Melvin,2009-06-09 Revised updated and rewritten where necessary but keeping the clear writing and organizational style that made previous editions so popular Elements of Environmental Engineering Thermodynamics and Kinetics Third Edition contains new problems and new examples that better illustrate theory The new edition contains examples with practical flavor such as global warming ozone layer depletion nanotechnology green chemistry and green engineering With detailed theoretical discussion and principles illuminated by numerical examples this book fills the gaps in coverage of the principles and applications of kinetics and thermodynamics in environmental engineering and science New topics covered include Green Chemistry and Engineering Biological Processes Life Cycle Analysis Global Climate Change The author discusses the applications of thermodynamics and kinetics and delineates the distribution of pollutants and the interrelationships between them His demonstration of the theoretical foundations of chemical property estimations gives students an in depth understanding of the limitations of thermodynamics

and kinetics as applied to environmental fate and transport modeling and separation processes for waste treatment His treatment of the material underlines the multidisciplinary nature of environmental engineering This book is unusual in environmental engineering since it deals exclusively with the applications of chemical thermodynamics and kinetics in environmental processes The book s multimedia approach to fate and transport modeling and in pollution control design options provides a science and engineering treatment of environmental problems **Journal** ,1983

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