Electrodialysis and Electrodialysis Reversal

AWWA MANUAL M38

First Edition

American Water Works Association

MANUAL OF WATER SUPPLY PRACTICES — M38, First Edition

Electrodialysis and Electrodialysis Reversal

Editor: Phillip Murray
Project Managers: Bill Cobban, Kathleen Faller

Printed in the United States of America

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235

ISBN 0-89867-768-8

Printed on recycled paper.

Contents

Preface

This first edition of AWWA Manual M38 provides detailed information on the classical electrodialysis (ED) and the electrodialysis reversal (EDR) processes and systems. ED and EDR systems employ electrochemical and membrane cell technologies to separate ionic materials in aqueous solutions. These systems have proven useful in food processing, medical applications, and other specialized industrial uses, with major applications being the production of drinking water or pure industrial process water from mineralized sources.

Directed to engineers and operators of ED and EDR systems, this manual provides detailed background information on ED and EDR as they relate to water treatment processes. The manual explains process principles, equipment information, electrodialysis technology, and system design. Information on water chemistry is included to enhance understanding of water processing.

It is hoped that this manual will also assist water process engineers and treatment plant decision makers in understanding the value of ED and EDR technology applied to their water treatment needs.

Acknowledgments

AWWA Manual M38, *Electrodialysis and Electrodialysis Reversal*, evolved primarily from training courses that were given over a six-year period. Several employees of Ionics Inc. of Watertown, Mass., contributed to these training courses. Major credit is given to F.H. Meller, who was responsible for organizing information that forms the basis of this manual.

Special thanks are extended to E.P. Geishecker, L.R. Siwak, and M.M. Cuzzi, all employees of Ionics, without whose help this manual would not have been possible.

* * *

At the time of approval, Membrane Processes Committee members included the following:

William J. Conlon (Chair), Camp Dresser & McKee, Ontario, Calif.
G.L. Amy, University of Colorado, Boulder, Colo.
C.A. Blanck, Richmond, Ind.
R.P. Carnahan, University of South Florida, Tampa, Fla.
P.A. Chadik, University of Florida, Gainesville, Fla.
S.J. Duranceau, Boyle Engineering, Orlando, Fla.
G.M. Dykes, Tallahassee, Fla.
E.P. Geishecker, Ionics Inc., Watertown, Mass.
D.W. Hendricks, Colorado State University, Ft. Collins, Colo.
W.H. Krueger, DuPont Company, Newark, Del.
J.C. Lozier, CH2M Hill, Phoenix, Ariz.
B.W. Lykins Jr., USEPA Drinking Water Research Division, Cincinnati, Ohio
S.A. McClellan, The Dow Chemical Company, West Palm Beach, Fla.
O.J. Morin, Black & Veatch Engineers, Orlando, Fla.
R.K. Noack, HDR Engineering Inc., Austin, Texas
D.L. Rohe, Montgomery Watson, Pasadena, Calif.
W.B. Suratt, Camp Dresser & McKee, Vero Beach, Fla.
J.S. Taylor, University of Central Florida, Orlando, Fla.
D.M. Thompson, City of Jacksonville, Jacksonville, Fla.
M.A. Thompson, Malcolm Pirnie, Newport News, Va.
P.M. Waldron, Ionics Inc., Watertown, Mass.
T.J. Sorg (Division Liaison), USEPA Drinking Water Research Division, Cincinnati, Ohio

Special thanks to *Thomas D. Wolfe*, The Palmyra Group, Rough & Ready, Calif., for his review and contributions to this manual.

Chapter 1

Introduction

Electrodialysis (ED) is an electrically driven membrane process used to demineralize brackish water. Brackish waters lie under approximately two thirds of the United States, and inland rivers, such as the Rio Grande and the lower reaches of the Colorado, also contain high levels of salinity. Water is classified as brackish when mineral content ranges between that of fresh drinking water and that of seawater. Brackish water contains more than 500 mg/L of total dissolved solids (TDS) and seawater more than 30,000 mg/L TDS.

ED and electrodialysis reversal (EDR) reduce TDS in brackish source water by electrically removing contaminants that exceed acceptable levels for drinking and process water. An overview of membrane process applications based on the molecular weights of contaminants appears in Figure 1-1. The ED and EDR processes are competitive with reverse osmosis (RO) in treating brackish waters. Typical ED systems include chemical feed systems for antiscalant and perhaps acid addition, a cartridge filter for prefiltration, the ED unit, and equipment for aeration, disinfection, and stabilization. EDR systems can often operate without fouling and scaling chemical feed, and they can treat high-fouling sources more efficiently than RO. However, it is important to remember that the types of membranes used in ED and EDR systems do not provide a barrier to remove microorganisms as do RO, nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF) membranes.

BASIC WATER CHEMISTRY CONCEPTS

A basic understanding of salts and water is necessary to understand the design, operation, and maintenance of a water demineralization system. A review of water chemistry concepts is provided here.

Ionic Solutions

An *ion* is a charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte solution. For example, common table salt is a typical ionic compound. The chemical name for this crystal is sodium chloride, and the chemical symbol is NaCl. The crystal consists of two types of