

Reverse Osmosis and Nanofiltration

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Second Edition



**American Water Works
Association**

Science and Technology

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MANUAL OF WATER SUPPLY PRACTICES—M46, Second Edition

Reverse Osmosis and Nanofiltration

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Preface

Reverse osmosis (RO) and nanofiltration (NF) are membrane technologies that can be applied to the treatment of various water sources for the production of drinking water. Membrane technologies can remove organic and inorganic substances from water and can replace or be adjuncts to such traditional treatment methods as sand filtration, primary disinfection, lime and soda softening, ion exchange, and evaporative processes. RO and NF are both pressure-driven membrane processes with similar process configurations and equipment. The main differences between the processes are primary treatment focus (demineralization or salt reduction for RO and hardness and/or organics removal for NF) and the degree of necessary applied pressure (higher for RO). However, the two membrane processes exhibit far more similarities than differences, thus their inclusion in the same manual.

RO was commercialized in the United States in the 1960s and has been used for water desalting applications ever since. NF developed from research and development technology as a lower cost membrane process for softening water and removing organic color.

Membrane technology of all types became particularly applicable to drinking water production in the late 1980s when the amendments to the US Environmental Protection Agency's Safe Drinking Water Act (SDWA) required higher-quality drinking water. The amendments were based on health effects research and the ability to detect contaminants at increasingly lower detection limits using sensitive analytical techniques. Because of their ability to remove or reduce many of the substances addressed by SDWA, membranes will play an increasingly important role in enabling water utilities to meet these regulations.

This manual was developed to provide an overview of RO and NF technology for operators, administrators, engineers, scientists, educators, and anyone seeking an introduction to these processes. An introductory chapter, which discusses an overview of RO and NF processes and applications, is followed by chapters discussing RO and NF process design, facility design, and operations and maintenance. The information contained in these chapters includes history, regulations, theory, terminology, water resources, pretreatment, process technology, posttreatment, concentrate disposal, and membrane and system components, configuration, maintenance, chemistry, costing, and safety.

As this is the second edition of AWWA Manual M46, *Reverse Osmosis and Nanofiltration*, the Membrane Processes Committee and the American Water Works Association welcome comments and suggestions for improving future editions. Please send them as an e-mail attachment to the Water Quality Engineer at eharring@awwa.org or in hard copy to 6666 West Quincy Avenue, Denver, CO 80235.

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Chapter 1

Introduction

Brent Alspach

This first chapter provides a general introduction to the reverse osmosis (RO) and nanofiltration (NF) membrane treatment processes. The subjects addressed in this chapter should serve as the basic foundation for a broader understanding of RO and NF processes as applied to potable water, industrial process water, tertiary wastewater, and reclaimed water treatment, and include a general overview of the technology (i.e., types of processes, history of development, general RO/NF system description, and typical performance), specific applications, and membrane materials and configurations. Successive chapters will build on these concepts to provide more detailed information about process design (chapter 2), facility design and construction (chapter 3), and operations and maintenance (O&M) (chapter 4). For readers unfamiliar with RO and NF, a typical facility is shown in Figure 1-1. This picture shows the 10-mgd Scottsdale Water Campus, an RO system treating reclaimed water for aquifer recharge. The RO process itself consists of numerous skids with long horizontal pressure vessels containing the membrane elements, as shown in the center of the picture. The prefiltration (i.e., cartridge filters) to remove particulate matter upstream of the RO process is shown in the foreground at the bottom of the picture, and the high pressure pumps are aligned along the left side.

OVERVIEW

This section first provides a brief overview of the different types of membrane processes. The discussion subsequently narrows to RO and NF processes—the focus of this manual—presenting a brief history of the development of RO and NF membranes and the basics of RO and NF systems.

Types of Membrane Processes

The five membrane processes commonly used in the production of drinking water are RO, NF, ultrafiltration (UF), microfiltration (MF), and electrodialysis/electrodialysis reversal (ED/EDR). Although all five are classified as membrane processes, the technologies and applications are very different in some cases. In general, there are three groups of similar membrane processes: MF/UF, RO/NF, and ED/EDR. Four