MUNICIPAL WASTEWATER TREATMENT:

EVALUATING IMPROVEMENTS IN NATIONAL WATER QUALITY

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IN MEMORIAM

Donald J. O'Connor (1922–1997)

Francis J. Stoddard (1920–1999)

Judith K. Patterson (1951–1997)

DEDICATION

This book attempts to document the water quality benefits associated with the federal funding provided through the Construction Grants Program and Clean Water State Revolving Fund (CWSRF) Program to help plan, design, and construct publicly owned treatment works (POTWs). The effort was initiated at the request of Michael J. Quigley while he served as Director of the Office of Municipal Pollution Control. It is dedicated to the many hardworking and conscientious individuals—including the program advocates and critics alike—who help manage, direct (or in some cases redirect), and implement the Construction Grants and CWSRF Programs, which are among the nation's largest public works programs, in a highly professional and effective manner. They include many program managers and staff at the U.S. Environmental Protection Agency (USEPA), and at state levels, as well as local wastewater authority managers and staff, not to mention the many highly qualified consultants and contractors who help the local authorities conduct the necessary studies, develop the required facilities plans and project design documents, and construct and operate the treatment facilities that were established or upgraded with funding from these highly successful public works programs.

This book could not have been written without the extensive water quality monitoring efforts across the country undertaken by a legion of highly qualified field staff and researchers for many local authorities, state and federal agencies, and colleges and universities. Their efforts produced the extensive water quality data available in the USEPA's STORET database system and in local reports, as well as the water quality models and local assessments that served as the basis for the analyses undertaken and reported on in this book.

CONTENTS

PREFACE

This study was prepared under the sponsorship of several programs in the USEPA Office of Water, primarily to document the water quality benefits associated with the more than 16,000 publicly owned treatment works (POTWs) across the country. This study emphasizes the role of USEPA's Construction Grants Program, which provided \$61.1 billion in federal grants to local authorities from 1972 through 1995 to help support the planning, design, and construction of POTWs to meet the minimum treatment technology requirements established by the secondary treatment regulations or water quality standards (where applicable). The program has also provided more than \$16 billion under the Clean Water State Revolving Fund (CWSRF) Loan Programs as capitalization grants to the states since 1988 to support a wide range of water quality improvement projects. The study was subjected to a formal peer review process that included detailed reviews and input from NOAA, USGS, AMSA, NRDC, NRC/NAS, NWRI, University of North Carolina, Johns Hopkins University, University of Alabama, states, consultants, local authorities, and others.

The book contains 13 chapters, including a background chapter, and chapters addressing biochemical oxygen demand (BOD) loadings before and after the Clean Water Act (CWA), the "worst case" dissolved oxygen (DO) levels in waterways downstream of point sources before and after the CWA, and nine case study assessments of water quality changes associated with POTW discharges.

The book presents the results of a unique, three-way approach for addressing such frequently asked questions as:

1. Has the CWA regulation of POTW discharges been a success?
2. How does the nation's water quality before the 1972 Federal Water Pollution Control Act (FWPCA) Amendments compare with the water quality conditions after secondary and better treatment was implemented?
3. Has the reduction of BOD loadings to surface waters from POTWs resulted in improved water quality in the nation's waterways? If so, to what extent?

By examining the numbers and characteristics of POTWs, their populations served, and BOD loadings on a nationwide basis before and after the CWA, we were able to document changes in the number of people served by POTWs and the level of treatment provided, the amount of BOD discharged to the nation's waterways, and the aggregate BOD removal efficiencies of the POTWs, while providing insight into the likely impact of future discharges if treatment efficiencies aren't improved to accommodate economic growth and expansions in service population.

The authors examined the "worst-case" historical DO levels in waterways located downstream of point sources before and after the CWA in a systematic manner. By identifying water quality station records that related to the water quality impact of point source discharges from the "noise" of millions of historical records archived in the USEPA's STORET database, and by using DO as the study's indicator of water quality responses to long-term changes in BOD loadings from POTWs, the authors evaluated changes in DO for only those stations on receiving waters affected by point sources over time under comparable worst-case low-flow conditions (during July–September in 1961–1965 for before CWA and 1986–1990 for after CWA) using only surface (within 2 meters of the surface) DO data. The authors documented statistically significant improvements in worst-case summer DO conditions at three different spatial scales, in two-thirds of the reaches, catalog units, and major river basins.

Case study assessments were also completed on nine urban waterways with historically documented water pollution problems. These case study sites included the Connecticut River, Hudson-Raritan estuary, Delaware estuary, Potomac estuary, James estuary, Chattahoochee River, Ohio River, Upper Mississippi River, and Willamette River. Most of the these waterways were sites of interstate enforcement cases from 1957 to 1972, were listed as potential waterways for which state-federal enforcement conferences were convened in 1963, or were the subjects of water quality evaluation reports prepared for the National Commission on Water Quality. Two sites were on a 1970 list of the top 10 most polluted rivers. The case study sites did not include, however, any of the 25 river reaches with the greatest before versus after CWA improvements in DO found in our study. The case studies characterized long-term trends in population, point source loadings, ambient water quality, environmental resources, and recreational uses. Validated water quality models for the Delaware, Potomac, and James estuaries and the Upper Mississippi River were used to quantify the water quality improvements that have been achieved by upgrading POTWs to secondary and higher levels of treatment. The case study assessments document that tremendous progress has been made in improving water quality, restoring valuable fisheries and other biological resources, and creating extensive recreational opportunities (angling, hunting, boating, bird-watching, etc.) in all nine case study sites. At many of the sites, there have been significant increases in species diversity and abundance-returned or enhanced populations of valuable gamefish (e.g., bass, bluegill, catfish, perch, crappies, and sturgeon) and migratory fish populations, waterfowl and fish-eating bird populations, opened shellfish beds, and more. Some of the sites have seen a return of abundant mayflies and other pollution-sensitive species, as well as dramatic increases in recreational boating and fishing. Water quality improvements associated with BOD, suspended solids, coliform bacteria, heavy metals, nutrients, and algal biomass have been linked to reductions in municipal and industrial point source loads for many of the case studies.

The unique, three-way approach undertaken by this study quantitatively supports the hypothesis that the 1972 CWA's regulation of wastewater treatment processes at POTWs and industrial facilities has achieved significant success—success in terms of reduction of effluent BOD from POTWs, worst-case (summertime, low-flow) DO improvement in waterways, and overall water quality improvements in urban case study areas with historically documented water pollution problems. It is important to emphasize that the water quality improvements documented in this book have resulted from the combined efforts of state, local, and federal government public funding, and investments by private industry, to upgrade the nation's infrastructure of municipal and industrial wastewater treatment facilities. However, the study also points out that without continued investments and improvements in our municipal wastewater treatment infrastructure, future population growth will erode away many of the CWA achievements in effluent loading reduction.

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- Mr. John Dunn, U.S. Environmental Protection Agency
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ACRONYMS

7Q10 10-year, 7-day minimum flow
AMSA American Metropolitan Sewerage Association
ARC Atlanta Regional Commission (Georgia)
ASIWPCA Association of State and Interstate Water Pollution Control Administration
AWT Advanced wastewater treatment
BOD Biochemical oxygen demand
BOD_5 5-day biochemical oxygen demand
BODu Ultimate biochemical oxygen demand
C:DW Carbon-to-dry weight ratio
CBOD Carbonaceous biochemical oxygen demand
CCMUA Camden County Municipal Utility Authority (New Jersey)
CMSA Combined Metropolitan Statistical Area
CSO Combined sewer overflow
CTDEP Connecticut Department of Environmental Protection
CU Catalog unit
CWA Clean Water Act
CWNS Clean Water Needs Survey
CWSRF Clean Water State Revolving Fund
DDT 2, 2-bis (p-chlorophenyl)-1,1,1-trichlorethane
DECS Delaware Estuary Comprehensive Study
DEL USA Delaware Estuary Use Attainability Study
DEM Dynamic Estuary Model
DNR Department of Natural Resources (Georgia)
DMR Discharge monitoring report
DO Dissolved oxygen
DRBC Delaware River Basin Commission
EPD Environmental Protection Division (Georgia)
FR Federal Register
FWPCA Federal Water Pollution Control Act/Administration
FWQA Federal Water Quality Administration

FY Fiscal year
GAO General Accounting Office
GICS Grants Information and Control System
gpcd Gallons per capita per day
HEP Harbor Estuary Program (NY, NJ)
HUC Hydrologic unit code
IBI Index of Biotic Integrity
ICPRB Interstate Commission on Potomac River Basin
IFD Industrial Facilities Discharge File
INCODEL Interstate Commission on the Delaware River Basin (NJ, DE, PA)
ISC Interstate Sanitation Commission (NJ, NY, CT)
JEM James Estuary Model
JMSRV James River Model
LTI Limno-Tech, Inc. (Ann Arbor, Michigan)
MCES Metropolitan Council Environmental Services (Minneapolis-St. Paul, MN)
mgd Million gallons per day
MPCA Minnesota Pollution Control Agency
MPN Most probable number
MRPA Metropolitan River Protection Act (Georgia)
MSA Metropolitan Statistical Area
MSX Parasitic protozoan (*Haplosporidium nelsoni*) responsible for massive oyster mortalities in Delaware Bay and Chesapeake Bay; MSX is popular name for the disease
mt/day Metric tons per day (1,000 kg per day)
MUA Municipal Utility Authority
MWCC Metropolitan Waste Control Commission (Minneapolis-St. Paul, MN)
MWCOG Metropolitan Washington Council of Governments
N Nitrogen
NAS National Academy of Sciences
NBOD Nitrogenous biochemical oxygen demand
NCWQ National Commission on Water Quality
NH_3— N Ammonia nitrogen
NO_2— N Nitrite nitrogen
NO_3— N Nitrate nitrogen
NOAA National Oceanic and Atmospheric Administration
NPDES National Pollutant Discharge Elimination System
NPS Nonpoint source; also National Park Service
NRC National Research Council
NRDC Natural Resources Defense Council

NURP National Urban Runoff Project
NWPCAM National Water Pollution Control Assessment Model
NWRI National Water Research Institute
NYCDEP New York City Department of Environmental Protection
O Oxygen
O&M Operation and maintenance
ODEQ Oregon Department of Environmental Quality
OMB Office of Management and Budget
ORSANCO Ohio River Valley Sanitation Commission
OTA Office of Technology Assessment
OWM USEPA Office of Wastewater Management
P Phosphorus
PAH Polynuclear aromatic hydrocarbons
PCB Polychlorinated biphenyls
PCS Permit Compliance System
PE Population equivalent
PEM Potomac Eutrophication Model
PL Public Law
PMSA Primary Metropolitan Statistical Area
PO_4—P Phosphate phosphorus
POC Particulate organic carbon
POM Particulate organic matter
POTW Publicly owned treatment works
ppm parts per million (concentration)
ppt parts per thousand (concentration)
QA/QC Quality assurance/quality control
RF1 Reach File Version 1
RF3 Reach File Version 3
SAV Submersed aquatic vegetation
SIC Standard Industrial Classification
SRP Soluble reactive phosphorus
STORET USEPA's STOrage and RETrieval database
SWCB State Water Control Board (Virginia)
SWEM System Wide Eutrophication Model (New York Harbor)
TKN Total Kjeldahl nitrogen
TMDL Total maximum daily load
TN Total nitrogen
TOC Total organic carbon

TP Total phosphorus
TPC Typical pollutant concentration
TSS Total suspended solids
UM Upper Mississippi River milepoint measured from confluence of Ohio River and Upper Mississippi River
USCOE U.S. Army Corps of Engineers
USCB U.S. Census Bureau
USDA U.S. Department of Agriculture
USDOC U.S. Department of Commerce
USDOI U.S. Department of Interior
USEPA U.S. Environmental Protection Agency
USGS U.S. Geological Survey
USPHS U.S. Public Health Service
VIMS Virginia Institute of Marine Science
WEF Water Environment Federation
WIN Water Infrastructure Network
WPCF Water Pollution Control Federation
WQS Water Quality Standard
WRBWQS Willamette River Basin Water Quality Study
WRE Water Resources Engineers (Walnut Creek, California)

CHAPTER 1

Introduction

> I think there is no sense in forming an opinion when there is no evidence to form it on. If you build a person without any bones in him he may look fair enough to the eye, but he will be limber and cannot stand up; and I consider that evidence is the bones of an opinion.
>
> —Attributed to Mark Twain in "Personal Recollections of Joan of Arc."

Today, a student writing a paper on the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500, later to be known as the Clean Water Act or CWA) would be hard-pressed to find a public official who would say the legislation was not a success. Vice President Gore's remarks in October 1997, celebrating the twenty-fifth anniversary of the act, are representative of the good feelings people have about the CWA (USEPA, 1997a; WEF, 1997).

In his speech, the Vice President lauded the cooperative efforts of federal, state, tribal, and local governments in implementing the act's pollution control provisions. He reported that the quality of rivers, lakes, and bays has "improved dramatically." He related success stories involving water-based commerce, agriculture, tourism, fisheries, and quality of life for a variety of locations, including Alaska's St. Paul Harbor, the Chesapeake Bay, Cleveland's Cuyahoga River, the Long Island Sound, and the Houston Ship Channel. With cheers like that ringing in people's ears, it's no wonder that the prevailing public opinion is that the act has been a success. But what if the paper-writing student were to inquire skeptically about the "bones" of this opinion? What scientific evidence could she cite to back up this claim? Was the nation indeed able to buy water quality success with the approximately $200.6 billion in capital costs and $210.1 billion in operation and maintenance costs (current year dollars) invested from 1972 to 1994 by public and private authorities in point source water pollution control?

A centerpiece of the CWA was a dramatic increase in federal support for upgrading publicly owned treatment works (POTWs). From 1970 to 1999, $77.2 billion in federal grants and contributions through the U.S. Environmental Protection Agency's (USEPA's) Construction Grants and Clean Water State Revolving Fund (CWSRF) programs was distributed to municipalities and states for this activity. A 1995 editorial in the Water Environment Federation's research journal noted that no comprehensive national study has ever been done to document whether this investment has paid off in terms of improved water quality (Mearns, 1995). Who could blame the student, then, if she applied Mark Twain's logic and concluded that the public's opinion concerning the success of the CWA was "limber" and could not "stand up."

The purpose of this book is to provide that student with the "bones" to form an opinion that will stand up. Specifically, it was designed to examine whether "significant" water quality improvements [in the form of increased dissolved oxygen (DO) levels] have occurred downstream from POTW discharges since the enactment of the CWA.

BACKGROUND

The framers of the CWA, drawing on the experience of the Ohio River Valley Sanitation Commission (ORSANCO), recognized that two basic sets of users depend on the chemical, physical, and biological integrity of the nation's waterways:

1. Water supply users, people who take delivery of and use water drawn from various surface water and groundwater sources. Whether intentionally or not, these users usually contaminate the water they receive with pollutants such as organic matter, sediments, nutrients, pathogens, and heavy metals. Contaminated water (wastewater) is then collected, transported away from the site, treated, and returned back to a natural waterbody, where it can be withdrawn and cycled again by the same or another water supply system. Figure 1-1 illustrates this process, known as the urban water cycle.
2. Water resource users, people such as fishermen, boaters, and swimmers, who use water in its natural settings—lakes, streams, rivers, and estuaries. This category might even be assumed to encompass the fish, waterfowl, and other living things that depend on clean water to live, reproduce, and thrive. These users can be directly affected by the return flow of wastewater from water supply users.

Meeting the needs of water supply and water resource users has been a problem that has vexed public officials for centuries. Only in the latter part of the twentieth century did it become clear that the secret for keeping both sets of users satisfied is to have all components of the cycle in place and functioning properly. This fundamental concept played a pivotal role in the development of the CWA.

By the mid-1900s, it was becoming more and more apparent that the weak link in the urban water cycle was the wastewater treatment component. Many communities were effectively short-circuiting the cycle by allowing raw or nearly raw sewage to flow directly into lakes, streams, rivers, estuaries, and marine waters. The organic matter contained in this effluent triggered increased growths of bacteria and corresponding decreases in DO levels. This situation, in turn, negatively affected the life functions of fish, shellfish, and other aquatic organisms. In addition, pathogens, nutrients, and other pollutants present in wastewater made body contact unsafe, increased the growth of algae and rooted aquatic plants, and reduced the potential for recreation and other uses. In sum, this weak link in the urban water cycle was greatly affecting the lives and livelihoods of water resource users downstream from POTWs.