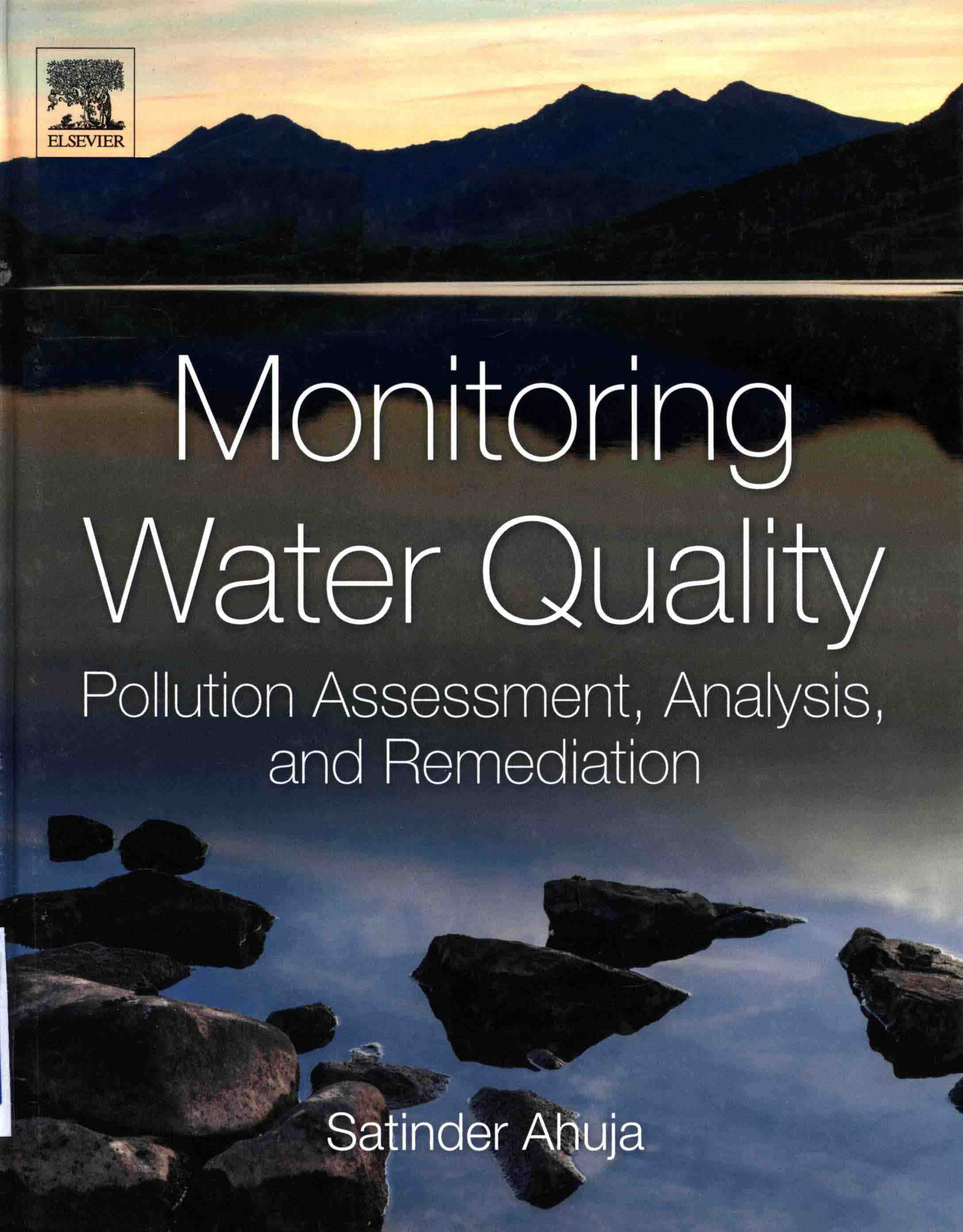

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Monitoring Water Quality

Pollution Assessment, Analysis, and Remediation

Satinder Ahuja

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Monitoring Water Quality

Preface

Water supplies around the world have been polluted to the point where we have to purify water for human consumption. Even rainwater, nature's way of water purification, is not always pure. It is usually contaminated by various pollutants that have been added to our atmosphere. Although Earth is a water planet, fresh water comprises only 3% of the total water available to us. Of that, only 0.06% is easily accessible. This explains why over 80 countries now have a water deficit. The shortage of affordable clean water forces an estimated 1.2 billion people in the world to drink unclean water today. This causes water-related diseases that kill 5 million people a year, mostly children, around the world. The problem will not get any better—the UN estimates that 2.7 billion people will face water shortages by 2025. It is crystal clear that water is a scarce and valuable commodity and we need to sustain its quality to assure water sustainability (see Chapter 1).

Drinking water comes mainly from rivers, lakes, wells, and natural springs. These sources are exposed to a variety of conditions that can contaminate the water. The failure of safety measures relating to production, utilization, and disposal of thousands of inorganic and organic compounds can pollute our water supplies. The majority of water quality problems are now caused by diffuse nonpoint sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These nonpoint source contaminants are more difficult to effectively monitor, evaluate, and control than those from point sources (such as discharges of sewage and industrial waste). It should be noted that a number of water contaminants arise from the materials we use frequently to improve the quality of life (see Chapter 1).

To monitor contaminants in water, it is necessary to perform ultratrace analyses at or below parts-per-billion levels. Selective methodology that allows such separations and quantification is covered in this text. Exposures to environmental concentrations of endocrine-disrupting compounds (EDCs) are now a known threat to both human and ecological health (see Chapter 5). A large body of work has established that EDCs can agonize, antagonize, or synergize the effects of endogenous hormones, resulting in physiological and behavioral abnormalities in aquatic organisms. Among emerging contaminants of concern, the problem of pharmaceuticals and endocrine disruptors is gaining greater importance. Under the rules that the EPA finalized recently, seven sex hormones, six perfluorocarbons, and hexavalent chromium are among the 28 chemicals that utilities will have to test for in drinking water. Water quality monitoring of various contaminants is covered in most of the chapters of this book. Real-time monitoring can enable a quick response to water quality concerns that arise from natural or intentional contamination, and it allows the greatest protection of public health (see Chapter 8).

Contaminants may also come from Mother Nature, even where the soil has not been influenced by pollutants from human beings. For example, natural processes like erosion and weathering of crustal rocks can lead to the breakdown and translocation of arsenic from primary sulfide minerals (see Chapters 1, 11, 12). Other contaminants from nature include manganese, radionuclides, and various other chemicals.

Examples of water problems from point and nonpoint source pollution in less developed countries, as experienced by those in Asia, Africa, and Latin America, and in developed countries, as exemplified by the United States, are discussed in this book (see Chapters 1–4, 7, 10, 11, 13). Also covered at length are various approaches to monitor contaminants, risk assessment, analytical methods, and various remediation methods to achieve the desired water quality (see Chapters 1, 5–14). The active quantitative removal of trace levels of chemicals may require additional process treatments such as the use of in situ-generated radical species. These approaches are generally referred to as advanced oxidation/reduction processes. A variety of techniques for creating radicals in water are discussed in Chapter 9. Low-priced remediation approaches for removing arsenic are described in Chapters 10, 11, 13. Chapter 12 highlights the use of nanoparticles for removal of arsenic.

Continuous monitoring of the entire water supply network is a goal that has been achieved only recently. Historically, most monitoring outside of water treatment plants has been relegated to the occasional snapshot provided by grab sampling for a few limited parameters or the infrequent regulatory testing required by mandates such as the Total Coliform Rule. The development of water security monitoring in the years since September 11, 2001, has the potential to change this paradigm (see Chapter 14).

Many countries have been pushing simply for economic development, only to realize that the environmental costs (resource depletion, pollution, health problems, and frequent occurrences of calamities such as flooding) of such single-minded growth nullify all the gains. To understand the importance of water sustainability, it is important to realize that the three pillars of sustainability, viz., economic, social, and environmental, are intimately interwoven (see Chapters 1 and 15). Sustaining the water quality of our resources will advance only if we have data on contaminants, along with information on natural and human causative factors that affect water quality conditions. This suggests that water quality and sustainability should be given a very high priority in our society.

I believe water quality and sustainability can be achieved with the information and guidance provided in this book. It should be a useful text for academics, practitioners, regulators, and other interested individuals and groups.

Satinder Ahuja
August 16, 2012

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Monitoring Water Quality, Pollution Assessment, and Remediation to Assure Sustainability

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CHAPTER OUTLINE

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1.1 Introduction

Our civilization has managed to pollute our water supplies to the point where we have to purify water for drinking [1,2]. The expressions "clean as freshly driven snow" or "pure rainwater" are not true today. In the past, rain was nature's way of providing freshwater; however, rain is usually contaminated by various pollutants that we add to our atmosphere. The shortage of affordable pure water forces an estimated 1.2 billion people to drink unclean water. As a result, water-related diseases kill 5 million people a year, mostly children, around the world. The problem does not seem to be getting any better—the UN estimates that 2.7 billion people will face water shortages by 2025.

Although earth is composed largely of water, freshwater comprises only 3% of the total water available to us. Of that, only 0.06% is easily accessible. This is reflected by the fact over that 80 countries now have water deficits. It is patently clear that water is a scarce and valuable commodity and we need to sustain its quality and use it judiciously, i.e. assure water sustainability. To achieve sustainability, we must ensure that as we meet our needs, we do not compromise the requirements of future generations [3].

Drinking water comes largely from rivers, lakes, wells, and natural springs. These sources are exposed to a variety of conditions that can contaminate water. The failure of safety measures relating to the production, utilization, and disposal of thousands of inorganic and organic compounds causes pollution of our water supplies. The overwhelming majority of water-quality problems are now caused by diffuse nonpoint sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These nonpoint source contaminants are more difficult to effectively monitor, evaluate, and control than those from point sources, such as discharges of sewage and industrial waste. Many water contaminants arise from the materials we use frequently to improve the quality of life:

- Combustion of coal and oil
- Detergents
- Disinfectants
- Drugs (pharmaceuticals)
- Fertilizers
- Gasoline (combustion products) and additives
- Herbicides
- Insecticides
- Pesticides.

The failure of safety measures relating to production, utilization, and disposal of a large number of inorganic/organic compounds encompassing the entire range of the alphabet, from arsenic to zinc, can cause contamination of our water supplies [4]. For example, whereas zinc in small amounts is desirable, arsenic at concentrations as low as 10 parts per billion (ppb) is quite harmful.

1.1.1 What Is Potable Water?

Expressed simply, potable water is any water suitable for human consumption. National Primary Drinking Water Regulations control water quality in the United States. Water-quality regulations vary in the different parts of the world. For instance, Table 1-1A in the Appendix shows what one municipality in the United States—Brunswick County in North Carolina—does to monitor water quality.

However, it should be noted that some of the contaminants of concern that are not monitored on a regular basis include:

- MTBE (methyl *tertiary* butyl ether)
- Herbicides
- Fertilizers
- Pharmaceuticals
- Perchlorate
- Mercury
- Arsenic

1.1.2 Monitoring Water Quality

Water quality and the monitoring of various contaminants, are discussed in this book. Among emerging contaminants of concern, the problem of pharmaceuticals and endocrine disruptors is gaining greater importance. It was recently reported that liquid formula is the biggest culprit in exposing infants to bisphenol A, a potential hormone-disrupting chemical extracted from plastic containers [5].

Hexavalent chromium, six perfluorocarbons, and seven sex hormones are among the 28 chemicals that utilities will have to test for in drinking water under the rules that the United States Environmental Protection Agency (USEPA) finalized recently [5a].

Contaminants may also come from mother nature, even where the soil has not been degraded by pollutants from human beings. For example, natural processes like erosion and weathering of crustal rocks, can lead to the breakdown and translocation of arsenic from primary sulfide minerals. Contaminants from nature include arsenic, manganese, radionuclides, and a host of other chemicals. Though arsenic contamination of groundwater has now been reported in a large number of countries worldwide, Bangladesh has suffered the most from this contamination. Other countries affected by the arsenic problem include Argentina, Australia, Cambodia, Canada, Chile, China, Ghana, Hungary, India, Mexico, Nepal, Thailand, Taiwan, UK, the United States, and Vietnam.

Prolonged drinking of arsenic-contaminated water can lead to arsenicosis in a large number of people, eventually resulting in a slow and painful death. It is estimated that arsenic contamination of groundwater can seriously affect the health of more than 200 million people worldwide. Arsenic (As) contamination of groundwater can occur from a variety of anthropogenic sources, such as pesticides, wood preservatives, glass manufacture, and other diverse uses of arsenic. These sources can be monitored and controlled. However, this is not so easy with naturally occurring arsenic. The natural content of arsenic in soil is mostly in a range below 10 mg/kg; however, it can cause major crises when it gets into groundwater [2].

Arsenic contamination of groundwater is described below briefly, as it serves as an excellent example of how water purity and quality problems can occur if adequate attention is not paid to monitor all the potential contaminants. In Bangladesh, groundwater contamination was discovered in the 1980s [1,2]. A large number of shallow tube wells (10–40 m), installed with the help of the United Nations Children's Emergency Fund (UNICEF) in the 1970s to solve the problem of microbial contamination of drinking water, were found contaminated with arsenic. The crisis occurred because the main focus was on providing water free of microbial contamination, a problem that was commonly encountered in surface water. Apparently, the project did not include adequate testing to reveal the arsenic. This unfortunate calamity could have been avoided, as analytical methods that can test for arsenic down to the parts-per-billion (ppb) level have been available for many years [6]. At times, speciation of a contaminant is necessary. For example, trivalent arsenic is more toxic than the pentavalent species. This demands a more selective method, and high pressure liquid chromatography-inductively couple plasma -mass spectroscopy (HPLC-ICP-MS) can resolve trivalent and pentavalent arsenic compounds at parts-per-trillion levels [7].

1.1.3 Monitoring Contaminants at Ultratrace Levels

It should be recognized that even with well-thought-out purification and reprocessing systems, trace (at parts-per million level) or ultratrace amounts (below 1 part-per-million level) of every substance present in untreated water is likely to be found in drinking water. To monitor contaminants in water, it is necessary to perform analyses at ultratrace levels. An example of ultratrace-level contaminants in drinking water in Ottawa, Canada, by gas chromatography/mass spectroscopy (GC/MS) is shown in Table 1-1 [8].

At ultratrace levels, sampling and sample preparation should be given great attention.

1.1.3.1 Sampling and Sample Preparation

It is abundantly clear that the sample used for ultratrace analysis (analysis at ppb level) should be representative of the "bulk material." The major considerations are [9]:

(1) Determination of the population of the "whole" from which the sample is to be drawn.
(2) Procurement of a valid gross sample.
(3) Reduction of the gross sample to a sample suitable for analysis.