Chapter 9

Tools and Techniques for Water Quality Interpretation

Deepesh Machiwal[1], **Madan K. Jha**[2]
[1] SWE Department, College of Technology and Engineering, MPUAT, Udaipur – 313 001, India
[2]AgFE Department, Indian Institute of Technology Kharagpur, Kharagpur – 721 302, India
E-mail: dmachiwal@rediffmail.com, madan@agfe.iitkgp.ernet.in

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9.1. Abstract

The usefulness of water for human use is determined by its quality. Water quality is also a major determinant for the health of ecosystems. Proper monitoring and assessment of the quality of both surface and ground waters is essential for efficient water quality management, which in turn can ensure human welfare and environmental sustainability. The goal of this chapter is to highlight conventional and modern tools and techniques for interpreting water quality. First of all, an overview of state-of-the-art tools and techniques used for the evaluation of water quality is presented. Thereafter, a case study is presented demonstrating a comprehensive methodology for the evaluation of groundwater quality in a semi-arid region of western India. It is emphasized that adequate and efficient network of water quality monitoring and appropriate selection of tools/techniques for water quality interpretation are the key to sustainable human development on the earth.

9.2. Introduction

The human/animal health, socio-economic development, and the functioning of earth's ecosystems depend on water. In contrast with many other vital resources, there is no substitute for water in most activities and processes where it is needed! Unfortunately, freshwater scarcity has emerged as one of the most pressing problems in the 21st century because of ever-increasing water demands for food, feed, fiber and fuel as well as growing pollution and misuse of freshwater resources (e.g., Zektser, 2000; de Villiers, 2001). At present, one in three people face water shortages, about 1.2 billion people (almost one-fifth of the world's population) live in areas of '*physical water scarcity*' (*i.e.*, where the available water resources cannot meet the demands of the population), and 500 million people are approaching this situation (Molden, 2007). Another 1.6 billion people (almost one quarter of the world's population) face '*economic water scarcity*' (*i.e.*, where countries lack the necessary infrastructure to harness water from rivers and aquifers). Furthermore, about 2.5 billion people lack adequate sanitation, and 884 million people are without access to safe water (UNICEF and WHO, 2008). It has been estimated that half of the population of the developing world is exposed to polluted sources of water that increase disease incidence. Between 1991 and 2000, over 665,000 people died in 2,557 natural disasters, of which 90% were water-related disasters and a vast majority of victims (97%) were from developing countries (IFRC, 2001). If the present trend continues, by 2025 1.8 billion people will be living in countries or regions with '*absolute water scarcity*' (*i.e.*, water supply less than 500 m^3/capita/annum), and two thirds of the world's population could be under '*water stress*' (*i.e.*, water supply less than 1700 m^3/capita/annum) conditions (UN Water, 2007). Thus, in the beginning of 21st century, we face the harsh reality that the current patterns of water development and consumption are not sustainable in many parts of the world. The principle of sustainability demands that freshwater must be used efficiently, equitably, and in an ecologically sound manner for both present and future generations.

In many parts of the world, water is limited by its quality rather than by quantity. Water quality is important not only because of its impact on the availability of freshwater and human health but also because of its intrinsic value (McCutcheon *et al.*, 1993). The availability of clean waters determines the quality of life and environment. Indeed, contamination of water deprives both present and future generations of a birth-right. The dramatically growing pollution of freshwater resources worldwide during past few decades necessitates comprehensive and proper knowledge of contamination levels and accurate assessment of trends in water quality for protecting this vital resource from pollution as well as for identifying efficient and cost-effective measures to control present and future threats of pollution at local/regional levels (Bartram and Ballance, 1996). Reliable water quality data are the basis for such assessments and control measures. Water quality is a consequence of natural physical and chemical state of water (surface or subsurface) as well as alterations caused by human activities (Fetter, 1994). The quality of water is a measure of its suitability as a water supply source for human and animal consumption, irrigation, industrial and other purposes; the suitability of water is decided based on water quality standards and criteria for various uses. The definition of water quality is therefore not objective; rather it is socially defined depending on the desired use of water. Different water uses require different standards of water quality and water quality criteria define desirable characteristics and acceptable levels of constituents for water of various intended uses (Freeze and Cherry, 1979; Todd, 1980; McCutcheon *et al.*, 1993; Fetter, 1994). To establish quality criteria, the measures of *physical*, *chemical*, and *biological* constituents must be specified, together with standard methods for comparing results of water quality analyses (Todd, 1980; McCutcheon *et al.*, 1993). Water quality assessment includes the use of monitoring data to define the condition of water, to provide a basis for detecting trends and to provide information enabling the establishment of cause-effect relationships. Thus, important aspects of water quality assessment are: *interpretation* of water quality data, *reporting* of results, and *recommendations* for future actions (Maybeck *et al.*, 1992).

An important task in water quality assessment is synthesis, compilation, presentation and interpretation of enormous chemical data in a convenient manner for visual inspection (Freeze and Cherry, 1979; Sara and Gibbons, 1991). Several conventional tools and techniques for the graphical interpretation of water quality are described in standard textbooks on groundwater/hydrogeology (Freeze and Cherry, 1979; Karanth, 1987; Sara and Gibbons, 1991). Recently, the need for application of modern approaches and tools such as multivariate statistical techniques (e.g., principal component analysis, hierarchical cluster analysis, discriminant analysis and correspondence analysis), and remote sensing and GIS techniques has been emphasized for the efficient management of water quality (e.g., Jha *et al.*, 2007; Steube *et al.*, 2009).

This chapter deals with state-of-the-art tools and techniques for the interpretation of water quality. In addition, a comprehensive methodology is presented to evaluate groundwater quality along with its application to a hard-rock aquifer system in a semi-arid region of western India.

9.3. Conventional and Modern Tools/Techniques for Water Quality Analysis

The type of water analysis interpretation most commonly required by hydrologists or hydrogeologists is the preparation of a report summarizing the water quality in an aquifer, a drainage basin, or some other area under study. The writer of such a report is confronted with difficulties of typically large amounts of data from a few discrete sources, and this information must be interpolated or extrapolated. The finished water quality report must convey water quality information in ways in which it will be understandable by both the regulatory and technical management staff. As an aid to interpreting groups of chemical analyses, several approaches are discussed that can serve to relate analyses to each other and to provide means of extrapolating data in space and time. The basic methods used for interpretation are inspection and simple mathematical or statistical treatment to bring out resemblances among chemical analyses; procedures for interpolation/extrapolation in space and time using geostatistics; and preparation of graphs, maps, and diagrams to show the relationships developed. Available tools and techniques (conventional as well as modern) for interpreting water quality can be classified into four major groups as shown in Figure 9.1, and a brief description of these tools/techniques are provided in this section.

9.3.1. Graphical Techniques

Numerous graphical methods have been developed over the years for interpreting water quality based on the chemical data of water and they have been widely used by the researchers and practitioners. Collins (1923) presented the first graphical technique in which the concentrations of individual major ions, both cations and anions (*i.e.*, Ca, Mg, $\mathrm{Na+K}$, $\mathrm{HCO_3+CO_3}$, SO_4 and Cl) are indicated by color or patterns on adjoining vertical bars. One example of *Collins diagram* is shown in Figure 9.2(a). The height of the bar is proportional to the total concentration values (in epm) of the cations or anions. As the sum of cations and anions should be equal, the height of the bar should be same for cations and anions. Height differences may arise due to not giving representation to other ions occurring in significant quantities, or due to error in analysis (Karanth, 1987). A *radial* or *vector diagram* shows the concentrations of the major