

**TECHNICAL GUIDANCE MANUAL FOR HYDROGEOLOGIC
INVESTIGATIONS AND GROUND WATER MONITORING**

**CHAPTER 12
GROUND WATER QUALITY DATA ORGANIZATION AND
INTERPRETATION**

February 1995

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CHAPTER 12

GROUND WATER QUALITY DATA ORGANIZATION AND INTERPRETATION

Large amounts of ground water quality data can be generated during a hydrogeologic investigation and/or ground water monitoring program. Proper interpretation of the data is necessary to enable sound decisions. It is important that the data be: 1) organized and presented in a manner that is easily understood and 2) checked for technical soundness, statistical validity, proper documentation, and regulatory or programmatic compliance.

Project goals and data evaluation procedures often are dictated by regulatory requirements. For example, an owner or operator of an interim status land-based hazardous waste management unit or a solid waste landfill must use statistics in his/her monitoring program to determine whether contaminants have been released to ground water. The methodology used to evaluate risk to human health and/or the environment also may depend on the regulatory program. Additionally, methods utilized to interpret data may be ordered on a site-specific basis.

VALIDATION

Validation is crucial for the correct assessment of ground water quality data. Data must be systematically compared against a set of criteria to provide assurance that the data are adequate for the intended use. Validation consists of editing, screening, checking, auditing, verification, certification, and review (Canter et al., 1988).

The methods used to define site hydrogeology and collect ground water samples need to be scrutinized. In addition, data should be evaluated using field and trip blank(s) (see Chapter 10) to help verify that sampling techniques were appropriate. Laboratory data validation is completed by a party other than the laboratory performing the analysis. U.S. EPA guidance for validation of chemical analyses (U.S. EPA, 1988a, b) stressed the importance of evaluating analytical methods and procedures such as sample holding times, instrument calibration, method blanks, surrogate recoveries, matrix spikes, and field duplicates.

ORGANIZATION AND INTERPRETATION TOOLS

Ground water quality data should be compiled and presented in a manner convenient for interpretation. Presentation methods include tabular, map, and graphic. Interpretation techniques include statistics and modeling. The appropriate tools depend on the goals of the monitoring program.

TABULAR

Tables of data are the most common form in which the chemical analyses are reported. Tables generally are sorted by well, type of constituent, and/or time of sampling. For most constituents, data are expressed in milligrams per liter (mg/l) or micrograms per liter ($\mu\text{g/l}$). Data should be organized and presented in tabular form or as dictated by regulatory or program requirements. Reports from the laboratory also should be submitted. Some Ohio EPA programs are beginning

to require ground water quality data to be submitted in a computer-based format. However, before submitting data in an electronic format, regulated entities should check with the appropriate program to determine the preferred media. Chapter 2 summarizes the Agency's organization and authority to require monitoring.

MAP

Isopleth maps are contour maps constructed by drawing lines representing equal concentrations of dissolved constituents or single ions (Figure 12.1). These maps, when combined with site-specific geologic/hydrogeologic characteristics (see Chapter 3), are useful in tracking plumes. However, their applicability depends on the homogeneity of ground water quality with depth and the concentration gradient between measuring points. Restricted sampling points in either the vertical or horizontal direction limit usefulness (Sara and Gibbons, 1991). Questionable data or areas lacking sufficient data should be represented by dashed lines.

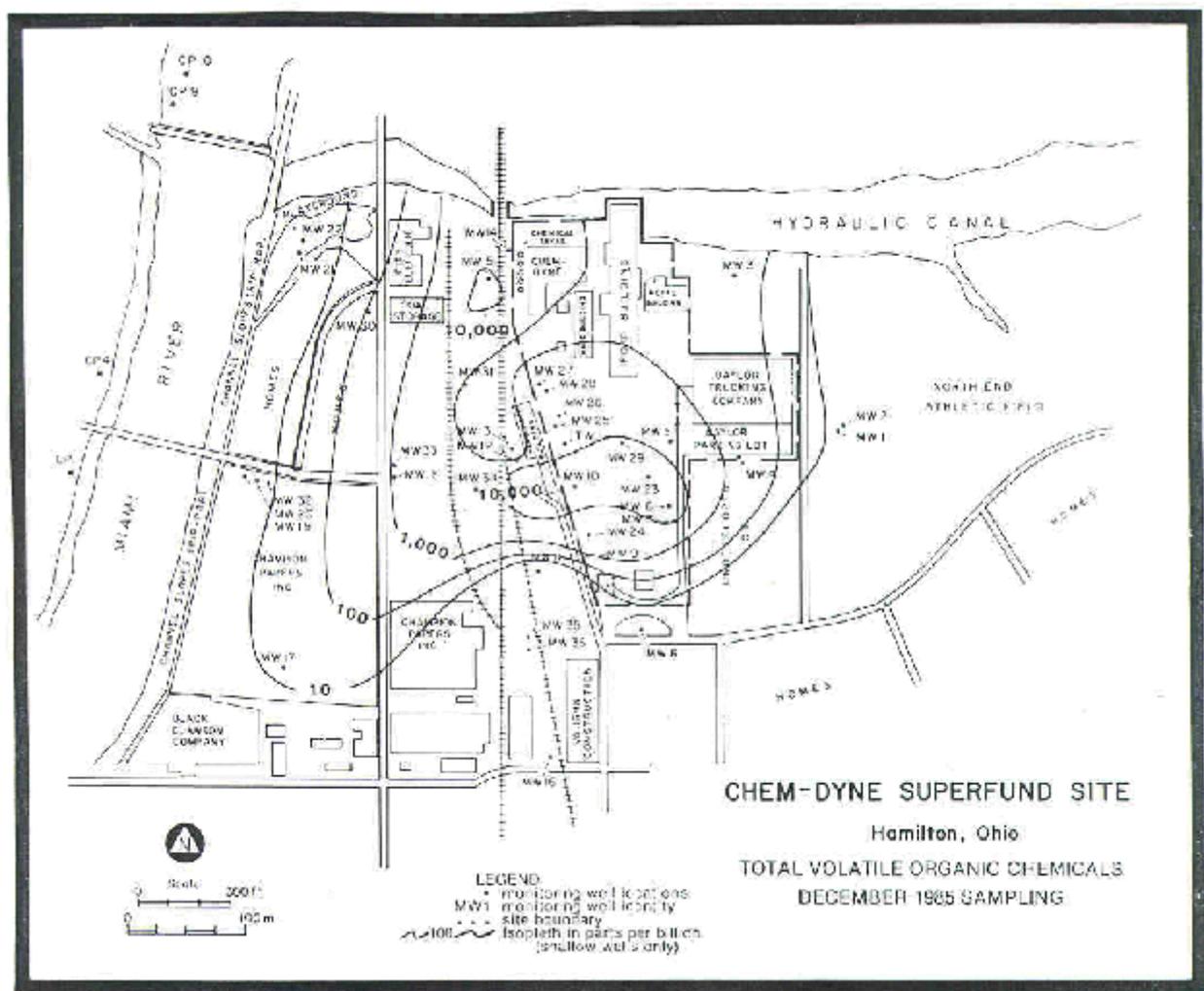


Figure 12.1 Contours of total VOC concentrations (ppb) at the Chem-/Dyne site in Hamilton, Ohio for shallow well data. December 1985 (Source: U.S. EPA, 1989b).

GRAPHICAL

Graphical presentation can be helpful in visualizing areal distribution of contaminants, identifying changes in water quality with time, and comparing waters of different compositions. Typical methods include, but are not limited to, bar charts, XY charts, box plots, trilinear diagrams, and stiff diagrams.

Bar Charts

Bar charts display a measured value on one axis and a category along the other. Historically, bar charts used in water quality investigations were designed to simultaneously present total solute concentrations and proportions assigned to each ionic species for one analysis or group of analyses. These charts displayed total concentrations and were based on data reported in milliequivalents per liter (meq/l) or percent meq/l. Analytes of ground water contamination studies are present as both ionic and non-ionic species and data are reported in units of mg/l or $\mu\text{g/l}$. For such studies, bar charts can be constructed to display concentrations of constituents for single or multiple monitoring wells and/or sampling events. The design and number of the charts should depend on the investigation. Figure 12.2 presents several examples of bar charts that may be useful.

XY Charts

XY charts differ from bar charts in that both axes show measured parameters. Plots of changes in dissolved constituents with time is one example of an XY chart that is extremely useful when evaluating contaminant releases or remedial progress. Even with a relatively slow rate of flow, long-term monitoring can detect gradual changes. Time-series formats can be used to compare individual parameters for a single well with time, multiple parameters for a single well with time (Figure 12.3), or illustrate changes with time for multiple wells for a common parameter (Sara and Gibbons, 1991). It is important that care be used when evaluating data with different levels of quality assurance/quality control. Regulated entities are encouraged to supply data in graphical form showing each parameter for each well plotted against time.

Box Plots

Box plots can be used to compare ground water quality data (generally for the same parameter) between wells. The plots are constructed using the median value and the interquartile range (i.e., 25 and 75 cumulative frequency as measured central tendency and variability) (U.S. EPA, 1992a) (Figure 12.4). They are a quick and convenient way to visualize the spread of data. Complicated evaluations may dictate use of a series of plots. For example, box plots may be constructed using data from wells screened in a particular saturated unit to show horizontal changes in water quality.

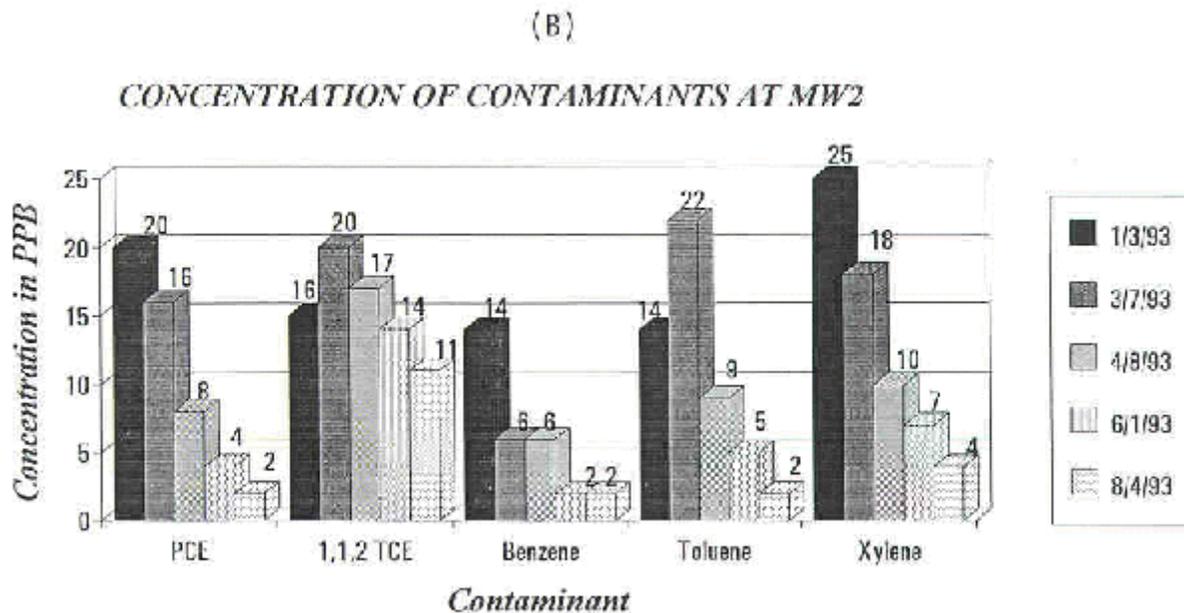
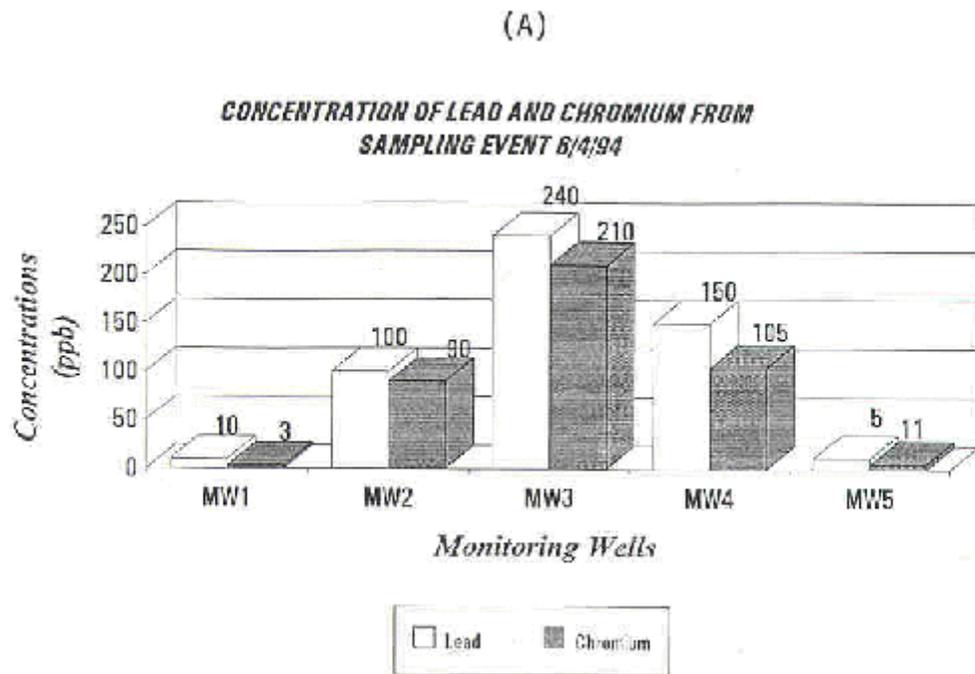


Figure 12.2 Bar Charts. A) Shows concentrations of lead and chromium for one sampling event. B) Shows concentrations of several constituents at one well over multiple sampling events.

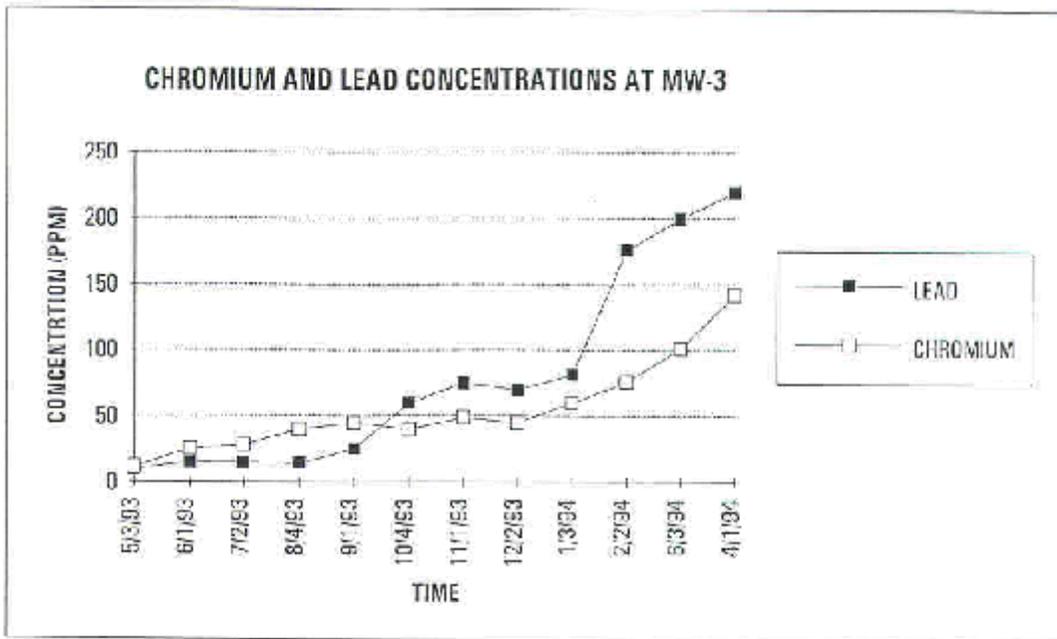


Figure 12.3 Chromium and lead concentrations over time.

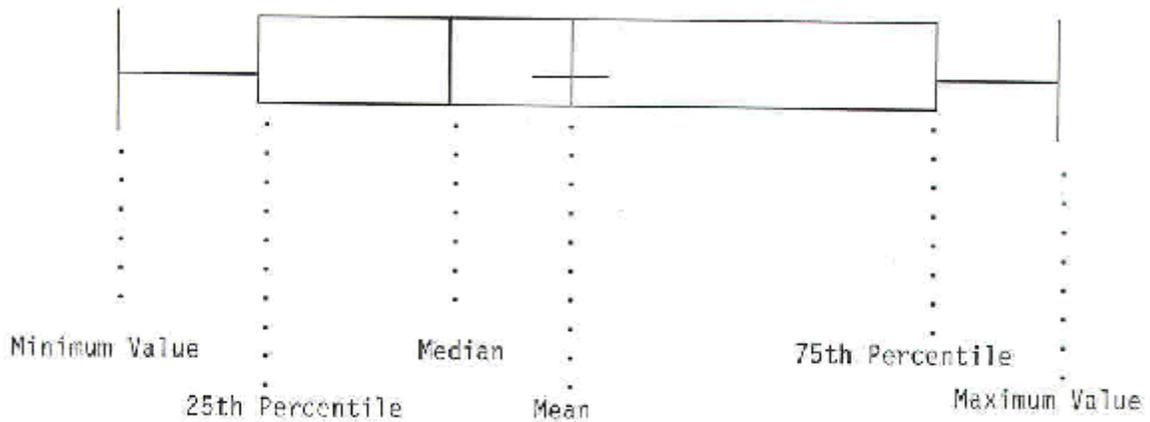


Figure 12.4 Example of a box plot

Stiff Diagrams

Stiff diagrams are another graphical representation of the general chemistry of water. A polygonal shape is created from four parallel horizontal axes extending on either side of a vertical axis. Cations are plotted on the left of the vertical axis and anions are plotted on the right (Fetter, 1994). The diagrams can be relatively distinctive for showing water composition differences or similarities. The width of the pattern is an approximation of total ionic strength (Hem, 1985). One feature is the tendency of a pattern to maintain its characteristic shape as the sample becomes diluted. It may be possible to trace the same types of ground water contamination from a source by studying the patterns. In the case presented in Figure 12.6, seepage of salt water from a brine disposal pit was suspected. Samples analyzed from the pit and the wells demonstrated the same pattern, showing evidence of contamination (Stiff, 1951).

STATISTICS

Ground water quality data also can be evaluated by statistical analysis. This tool can be used to compare upgradient versus downgradient or changes with time. Various regulatory programs may require use of statistics. The reader is referred to Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities (U.S. EPA, 1989a), the addendum to that document (U.S. EPA, 1992b), and Chapter 13 for appropriate methodologies.

MODELING

Ground water modeling is a tool that can assist in the determination of extent and rate of contaminant migration. Models can be used throughout the investigation and remedial processes. Information on modeling can be found in Chapter 14.

DATA INTERPRETATION OBJECTIVES

The mechanism to interpret ground water quality data can vary depending on project objectives and regulatory or program requirements. Data often are evaluated to: 1) determine if a site/facility has impacted ground water (detection monitoring), 2) determine the rate, extent, and concentration of contamination (assessment monitoring), 3) determine the source of contamination, 4) gauge the effectiveness of remedial activities, and/or 5) monitor for potential health or environmental effects. Data must always be evaluated in conjunction with site hydrogeology, contaminant characteristics, and past and present land use.

IDENTIFICATION OF RELEASES TO GROUND WATER

Methods to identify whether contaminants have been released to ground water include professional judgment and statistical analysis.

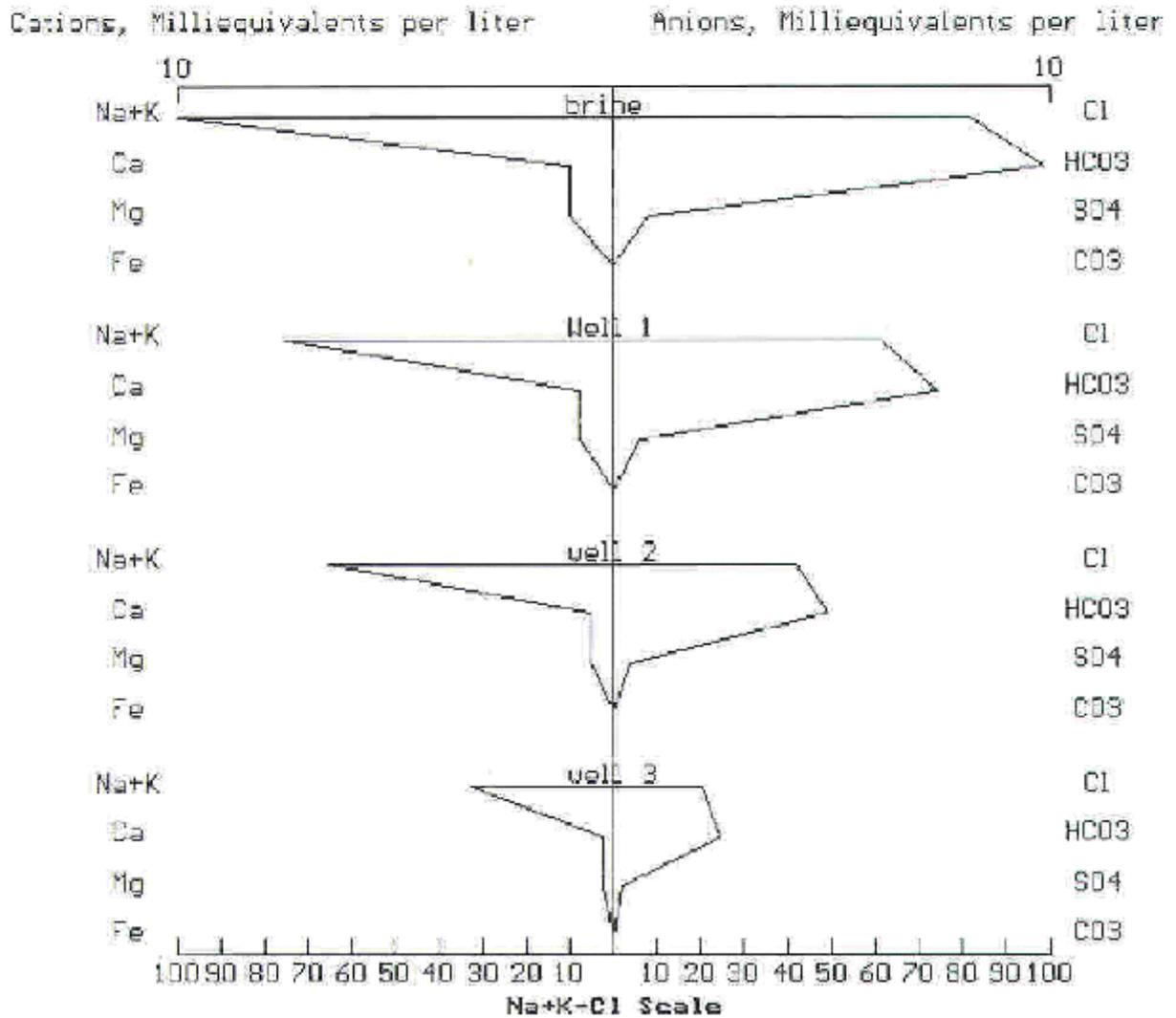
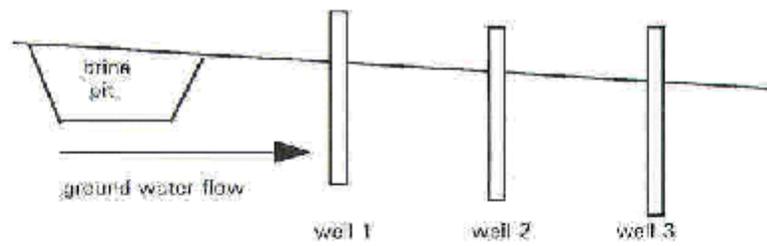


Figure 12.6 Stiff pattern demonstrating seepage of a salt from a brine disposal pit.

Professional judgment involves the use of education and experience. In some cases, a simple visual inspection of downgradient versus upgradient/background data can show obvious differences in chemical quality. The tabular and graphical presentations discussed earlier in this chapter can be used for this evaluation.

When evaluating potential ground water contamination, water quality data often are compared to primary and secondary drinking water standards. As important as it is to protect public health by identifying an exceedance, formulating a conclusion that ground water has been contaminated based solely on the exceedance is not appropriate. Certain inorganic constituents, such as iron and sulfate, can occur naturally in Ohio's ground water at levels above standards; therefore, exceedance for these constituents may not imply contamination. Conversely, values lower than a standard do not necessarily imply that contamination has not occurred. In general, the mere presence of organics, which usually are not naturally occurring, indicates contamination. Data for wells downgradient from a pollution source should be compared to data from an upgradient/background well that has not been affected by the source. If an upgradient/background well does not exist, then the results can initially be compared to known local or regional background values. However, utilization of regional values for evaluating potential contamination should be a part of initial investigations only. Further evaluation should be based on site-specific background sampling. In any ground water contamination investigation, it is essential to obtain background concentrations for chemical constituents of concern, particularly those that may be common to both the local ground water quality and the potential or known contaminant source.

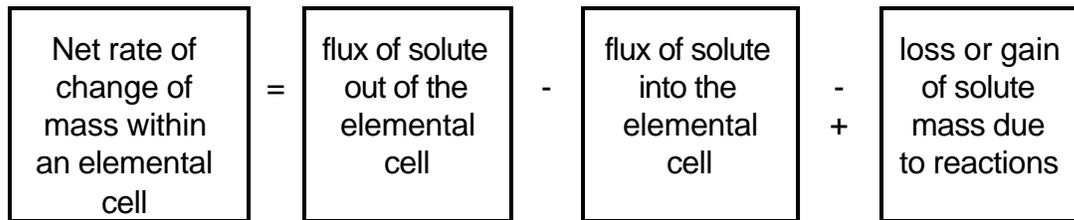
Whether a release has occurred also can be evaluated by **statistical analysis** if adequate data are available. The U.S. EPA (1989a, 1992b) documents and Chapter 13 should be used to determine appropriate methods and application. While statistics are useful to determine if a release occurred, professional judgment still needs to be exercised to ensure that the results represent actual conditions. For example, the results may show either a "false positive" or "false negative" due to naturally occurring variations such as geologic heterogeneity and/or seasonal variability. Determining whether a release has occurred or whether the analysis has triggered a "false positive" generally requires additional investigation.

RATE OF CONTAMINANT MIGRATION

A simple and straight forward method does not exist for determining the rate of contaminant migration. In general, the rate can be estimated by a form of Darcy's Law (see Chapter 3) if it is assumed that the dissolved solute travels at the average linear ground water velocity. The rate of advancement of a dissolved contaminant can be substantially different, however. Mobility of a contaminant can be altered due to adsorption/desorption, precipitation, oxidation, and biodegradation. Mobility of a solute can be affected by the ratio of the size of the molecule to the pore size. The calculated velocity also would not account for a contaminant moving faster than the average linear velocity due to hydrodynamic dispersion. Dispersion affects all solutes, whereas¹ adsorption, chemical reactions, and biodegradation affect specific constituents at different rates. Therefore, a contaminant source that contains a number of different solutes can result in several plumes moving at different rates.

¹ See Chapter 5 for additional explanation on how these parameters influence ground water flow paths.

The equation governing the movement of dissolved species can be developed by utilizing the conservation of mass approach. The equation in statement form, as described by Canter et al. (1988), is:



The mass of solute transported in and out of the cell is controlled by advection and dispersion. Loss or gain of solutes within the cell may be caused by chemical, biological, or adsorption/ desorption reactions. A generalized three-dimensional solute transport equation considering dispersion, advection, and reactions in a homogeneous environment takes the form as (modified from Freeze & Cherry, 1979):

$$\frac{MC}{Mt} \cdot \left[\frac{M}{M_x} \left(D_x \frac{MC}{M_x} \right) \% \frac{M}{M_y} \left(D_y \frac{MC}{M_y} \right) \% \frac{M}{M_z} \left(D_z \frac{MC}{M_z} \right) \right] \quad \text{Dispersion}$$

$$\& \left[\frac{M}{M_x} (\bar{v}_x C) \% \frac{M}{M_y} (\bar{v}_y C) \% \frac{M}{M_z} (\bar{v}_z C) \right] \quad \text{Advection}$$

$$\pm F(c) \quad \text{Reaction}$$

Where:

- C = the concentration of the polluting substance;
- D_x, D_y, D_z = the coefficients of hydrodynamic dispersion in the x, y, z directions;
- v_x, v_y, v_z = velocity vector components in the x, y, and z directions; and
- $F(c)$ = chemical reaction function.

Attempts to quantify contaminant transport generally rely on solving conservation of mass equations. There are essentially two kinds of models available for solving mass transport equations, analytical and semi-analytical, and numerical. Analytical models are developed by considering ideal conditions or using assumptions to simplify the governing equation. These assumptions may not allow a model to reflect conditions accurately. Additionally, even some of the simplest analytical models tend to involve complex mathematics. Numerical modeling techniques incorporate analytical equations that are so complex they necessitate use of computers capable of multiple iterations to converge on a solution (Canter et al., 1988). The numerical approach depends on tedious sensitivity analyses to develop information on the nature of the parameter interaction. Analytical models are used to verify the accuracy of numerical solutions where appropriate. Additional information on numerical, computer-oriented models can be found in Chapter 14.

EXTENT OF CONTAMINANT MIGRATION

The areal or vertical extent of contaminant plumes may range within wide extremes depending on local geologic/hydrogeologic conditions. Determination of extent generally involves sampling monitoring wells at increasing distances and depths from the source. Data for wells downgradient

of the site/facility are compared to background data by visual inspection and/or statistical analysis. All downgradient locations at which significant differences are noted are considered to be within the contaminated area. The use of isopleth maps and time-series formats assist in the determination of extent. Modeling (Chapter 14) can be used to help estimate rate and extent and determine optimum locations for monitoring wells.

SOURCE OF CONTAMINATION

Ground water quality data often are evaluated to determine the source of contamination. In general, isopleth and ground water contour maps are utilized in conjunction with knowledge of area-specific geologic/hydrogeologic characteristics, contaminant properties, and past and present land use to pinpoint the source.

PROGRESS OF REMEDIATION

When gauging the effectiveness/progress of remedial action, changes in water quality can best be illustrated by time-series presentations and a series of isopleth maps prepared throughout the proceedings. The data should be compared to background or standards developed by risk assessment.

RISK ASSESSMENT

Clean-up goals often are established by means of a risk assessment. Both human health and environmental assessments can be conducted. The appropriate methodology depends on the regulatory program involved. Therefore, prior to conducting a risk assessment, the appropriate Ohio EPA Division should be consulted.

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