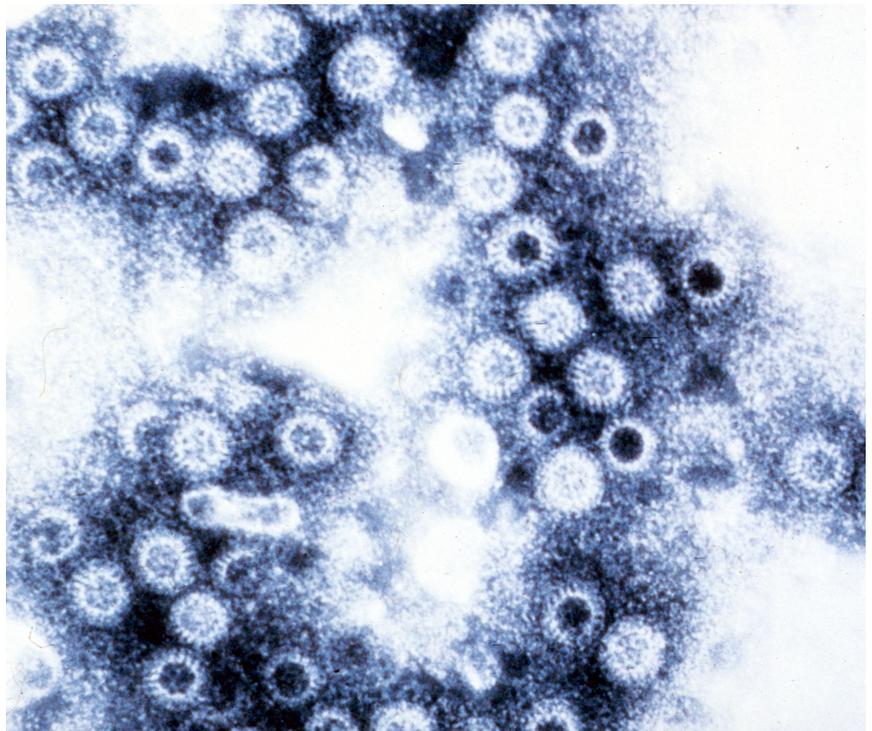


Surface Water Quality



April 2002

This booklet is part of a series of educational brochures and slide sets that focuses on various aspects of water source protection. The series has been prepared jointly by the University of California Agricultural Extension Service and the California Department of Health Services.

For further information about this and other documents in the series, contact the project team leader (see below) or visit the following website:

www.dhs.ca.gov/ps/ddwem/dwsap/DWSAPindex.htm

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Cover photo: Rotavirus, a waterborne infectious agent that causes childhood viral diarrhea. Consists of ds-RNA and is stable in the range pH 3–10. Each virus shown is 70–80 nanometers across.

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This booklet describes a number of water quality parameters commonly used to evaluate rivers, lakes, and reservoirs that serve as sources of drinking water. Each parameter is defined and its typical range identified. In addition, the importance of each parameter in water-source vulnerability analyses is noted.

The latter part of this booklet describes the drinking water contaminants that are of greatest concern according to the U.S. Environmental Protection Agency (EPA). Typical activities that might introduce these pollutants into surface water are also identified.

Water Quality Parameters

Reservoirs, streams, and other water bodies used as sources of drinking water must be monitored.

By measuring key chemical and biological parameters, a treatment plant operator can know first-hand the condition of his or her plant's water source. This enables the operator to optimize the performance of the treatment plant.

Table 1 lists the parameters typically monitored and the detection limit for each. Also in Table 1 are the goals for accuracy, precision, and completeness, which we define as follows:

- *Accuracy*: the degree to which a measurement agrees with an accepted reference or true value.
- *Precision*: a measure of mutual agreement among data; usually expressed in terms of the standard deviation.
- *Completeness*: the amount of valid data obtained from a measurement system compared to the amount that was expected and needed to meet the project's data goals.

pH

pH is a measure of the relative acidity or alkalinity of a sample. It is equal to the negative of the log of the hydrogen concentration in moles per liter ($-\log[\text{H}^+]$). The pH scale ranges from 1 to 14, with 1 being the most acidic and 14 being the most alkaline (least acidic). Solutions with a pH less than 7.0 are typically classified as acidic; those greater than 7.0 as alkaline. A pH of exactly 7.0 (or very close to 7.0) is considered neutral. pH values in surface waters typically range between 6.0 and 9.0 (Sawyer, et al., 1994).

The pH of a water source influences the chemical composition of the water, including the water's alkalinity species, nutrient forms, precipitation and dissolution mechanisms, and reactions related to speciation of metals and formation of complexes. pH is influenced by carbon dioxide input from the atmosphere, by microbial activity, and by plant



Figure 1. Inlet pipe at water supply reservoir.

photosynthesis (Goldman and Horne, 1994). Acid mine drainage, acid rain, agricultural runoff, industrial and municipal waste discharges, and discharges from other point and non-point sources can result in an increase or decrease in pH of receiving water, depending on the waste characteristics. A heavy influx of contaminants that have high concentrations of hydrogen ions can lower the pH of a water body to levels below those at which aquatic biota can survive. pH is also an important parameter in the design and operation of chemical coagulation, disinfection, and softening processes for water treatment.

Conductivity

Conductivity is the measure of a solution's ability to transfer electric current. The higher the conductivity of a solution, the greater its potential to transfer electrical currents. The conductance of a solution is dependent on three parameters:

- temperature (temperature increases the conductivity of a solution),
- types of ions present, and
- quantity of ions present.

Multivalent ions (i.e., those with ionic charges of greater than +1 or less than -1) contribute more to conductivity than monovalent (+1 or -1) charged ions. Multivalent ions common in waste streams include ferrous iron (Fe^{3+}), bivalent metals (M^{2+}), and sulfate (SO_4^{2-}).

Most often, equipment for measuring conductivity gives results based on a temperature of 25°C. Such measurements can be adjusted to correct for other ambient temperatures (Peavy, et al., 1985). Because hydrogen ions (H^+) and hydroxyl ions (OH^-) exhibit higher conductance, due to their increased mobility, extreme pH levels are an important consideration when measuring conductance (Sawyer, et al., 1994).

Table 1: Water Quality Parameters and Sampling Protocols*

<u>Parameter</u>	<u>Sample Matrix</u>	<u>Detection Limit</u>	<u>Accuracy</u>	<u>Analytical Precision</u>	<u>Reporting Precision</u>	<u>QA Protocol</u>
pH	water	n/a	0.1 units	0.02 units	0.1 units	replicate 10% daily
Dissolved Oxygen	water	n/a	0.1 mg/L	0.05 mg/L	0.1 mg/L	replicate 10% daily
Temperature	water	n/a	n/a	n/a	1 °C	replicate 10% daily
Turbidity	water	n/a	n/a	5.0%	1 NTU	duplicate 1 per day
Conductivity	water	n/a	4.8%	8.3%	1 µmho	replicate 10% daily
Nitrate	water	0.1 mg-N/L	5.8%	24.0%	0.1 mg-N/L	duplicate 1 per day
Nitrite	water	0.1 mg-N/L	5.0%	24.0%	0.1 mg-N/L	duplicate 1 per day
Ammonia	water	0.1 mg-N/L	1.7%	17.4%	0.1 mg-N/L	duplicate 1 per day
Ortho-phosphate	water	0.01 mg-P/L	12.6%	34.5%	0.1 mg-P/L	duplicate 1 per day
Coliform Presence	water					duplicate 1 per day
BOD	water					duplicate 1 per day
Flow	water	n/a	n/a	n/a	1 cfs	n/a

* 'n/a'= not applicable; 'mg-N/L'= milligrams per liter as nitrogen; 'mg-P/L'= milligrams per liter as phosphorous; 'BOD'= biological oxygen demand; 'cfs' cubic feet per second; 'NTU'= nephelometry turbidity unit; 'µmho'=micro Siemens

Measurement of conductivity is often used as an indirect method of estimating the dissolved solids content of a solution. Chapra (1997) reports a relationship between total dissolved solids and conductivity (as derived from W. F. Langelier and using correlation by L. L. Russell):

$$\text{TDS (mg/L)} = 0.64 \times \text{Conductivity (µmhos/cm)}$$

Discharge (Flow)

Discharge refers to the volume of water flowing per unit time through a reach of a stream or from a lake. Discharge is measured in numerous ways. Some of the methods rely on devices such as staffing gauges, weirs, or flumes. Another method involves calculation using multiple measurements of flow velocity and of the cross-sectional area through which the flow occurs. Specifically, the latter method involves measuring the velocity at various points along a line perpendicular to the flow path, typically at a depth of 0.6 times the total depth from the surface. The velocity measured within each increment is multiplied by the increment’s area to obtain that segment’s flow contribution. The incremental flows are then added across the length of the reach to obtain the total flow.

A stream’s or lake’s discharge is an important consideration with respect to water chemistry, potential scouring, erosion, changes in morphology, and turbidity

levels. Discharge calculations are also useful for determining nutrient loadings and other contaminant loadings from multiple inputs. The following equation may be used to determine the loading of a contaminant:

$$\text{Load} = Q \times Z \times 8.34$$

where: Q = discharge in millions of gallons per day (mgd)

Z = concentration of contaminant in milligrams per liter (mg/L)

load = pounds of contaminant per day

Dissolved Oxygen

Dissolved oxygen (DO) concentrations in surface water are proportional to both temperature and atmospheric pressure. At one atmosphere of pressure, DO ranges from 14.6 mg/L, at a temperature of 0°C, to 7 mg/L, at a temperature of 35°C. These concentrations decrease with an increase in atmospheric pressure; therefore, a source at a higher elevation will contain less oxygen than a source with the same temperature at a lower elevation (Goldman and Horne, 1994).

Dissolved oxygen is a very important parameter in maintaining the growth and reproduction of fish and other aquatic organisms (Sawyer, et al., 1994; Goldman

and Horne, 1994). Typically, a DO concentration of at least 2 mg/L is necessary to maintain higher aquatic life forms, with 4 milligrams per liter necessary to maintain game fish (Peavy, et al., 1985).

The primary pathways by which oxygen enters water, becoming DO, are diffusion from the atmosphere and photosynthesis. Diffusion of oxygen is a function of temperature and pressure, as mentioned previously; it therefore can be accelerated by wind and turbulence. Dissolved oxygen concentrations in surface waters typically vary throughout the day; these are known as *diel variations*. In most waters, the production of DO reaches a maximum in the afternoon, declining as the sun goes down and plants and algae decrease photosynthesis and increase respiration. Because of diel variations, oxygen concentrations reach a minimum in the early morning hours before the sun comes up (Goldman and Horne, 1994).

Low DO concentrations may indicate highly polluted water and anaerobic conditions. Such conditions can cause low productivity, unpleasant odors, and, in extreme cases, fish kills (Peavy, et al., 1995).

Suspended Solids

Suspended solids are the matter in a sample that is not dissolved and which can be observed or perceived. Such solids consist of organic components, such as plant cells and other biological debris, and inorganic components, such as soil particles. The concentrations of these solids are increased by erosion, by turbulence that causes re-suspension of sediments, and by algal blooms (Peavy, et al., 1985).

Suspended solids are usually measured by filtering a sample of water and drying and weighing the material remaining on the filter. When measured in this manner, suspended solids are often referred to as *filterable solids*. Most waters also contain smaller unfilterable solids (dissolved solids) that are lost through the filter (Sawyer, et al., 1994). Suspended solids may also be measured qualitatively with turbidity tests.

Suspended solids in surface water provide adsorption sites with which chemicals or biological materials may react. This is important because suspended solids provide sites for microorganisms, including cysts and pathogens, to survive. They also can cause discoloration and can make water more turbid. Sometimes suspended solids arise from spills or discharges of industrial impurities, disease-causing organisms and algae, or oil and grease (Peavy, et al., 1985).



The potency of a waterborne organic waste is often expressed in terms of its biochemical oxygen demand, or BOD.

Temperature

The temperature of a lake, stream, or reservoir is greatly affected by variations in ambient air temperature. Changes in canopy cover, variations in water depths, and mixing with water from runoff or from other streams and rivers can also have an impact on temperature (Goldman and Horne, 1994).

In terms of water chemistry, temperature is extremely important, as it governs biological activity, the rate of chemical reactions, and the solubility of gases. In general, higher temperature increases biological activity and metabolic rates. Higher temperature also increases algal growth rates and the solubilities of most chemicals. However, elevated temperatures can decrease the solubility of oxygen, with a net negative impact on fish and other oxygen-dependent organisms (Peavy, et al., 1985; Goldman and Horne, 1994).

Turbidity

Turbidity is a qualitative measurement of the amount of suspended solids in a solution. In general, the higher the turbidity, the greater the concentration of suspended solids. Measuring turbidity involves determining the extent to which light is scattered or absorbed by particles. Turbidity is of concern in source waters used as drinking water because it provides “hiding places” for microorganisms. Excessive turbidity can reduce the efficiency of disinfection, thereby increasing chlorine demand and potentially fostering the formation of trihalomethanes (carcinogenic disinfection byproducts).

In addition, the components of turbidity provide chemical and biological adsorption sites, they can result in discoloration, and they can result in an aesthetically unpleasant water supply.

Turbidity is typically measured with a photometer. The unit of measurement is the Nephelometry Turbidity Unit, or NTU.

Nutrients

Aquatic plants and animals depend on certain elements for growth and reproduction; these are called nutrients. The primary nutrients of importance in water quality are nitrogen, phosphorus, and carbon.

Nitrogen

Nitrogen is important in the production of biological components such as protein and chlorophyll. Forms of inorganic nitrogen in surface water systems include ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). The nitrogen cycle, shown in Figure 1, demonstrates the exchange of nitrogen in the environment. Ammonia and ammonium represent the reduced forms of nitrogen and are usually found in anaerobic conditions; the ammonia form is toxic to fish and other aquatic organisms at very low concentrations. Nitrite and nitrate are the oxidized forms of nitrogen. These are found in aerobic conditions and are more favorable forms of nitrogen for most biota. However, there is the potential for the partially oxidized nitrite ion to reach groundwater and become oxidized to nitrate. Nitrate in groundwater represents a human

health threat and is a significant problem for drinking water suppliers (Goldman and Horne, 1994).

Phosphorus

Phosphorus compounds occur in nature as constituents of soil, in plant and animal tissues, and in animal waste. Phosphorus occurs in water as phosphate (PO_4^{3-}) and has a tendency to adsorb to soil particles. Phosphates are not toxic compounds and do not pose a human health risk. However, they do pose significant water quality problems due to their status as a limiting nutrient to many aquatic plants. Their presence usually results in overproduction of plants and algae and the increased potential for eutrophication. In addition, phosphates can interfere with coagulation processes in water treatment at very low concentrations. Activities that can lead to phosphate contamination include: (1) runoff from agricultural, feed lot, and grazing areas, and (2) municipal and industrial wastewater.

Carbon and Organic compounds

Organic compounds—those containing carbon—are divided into two categories: biodegradable, and nonbiodegradable or refractory. Both types are discussed below.

Biodegradable Organic Compounds

Biodegradable compounds are those used as a food source by microorganisms. These consist of proteins, starches, and fats, as well as acids, alcohols, and esters. Biodegradable organics are utilized by either aerobic

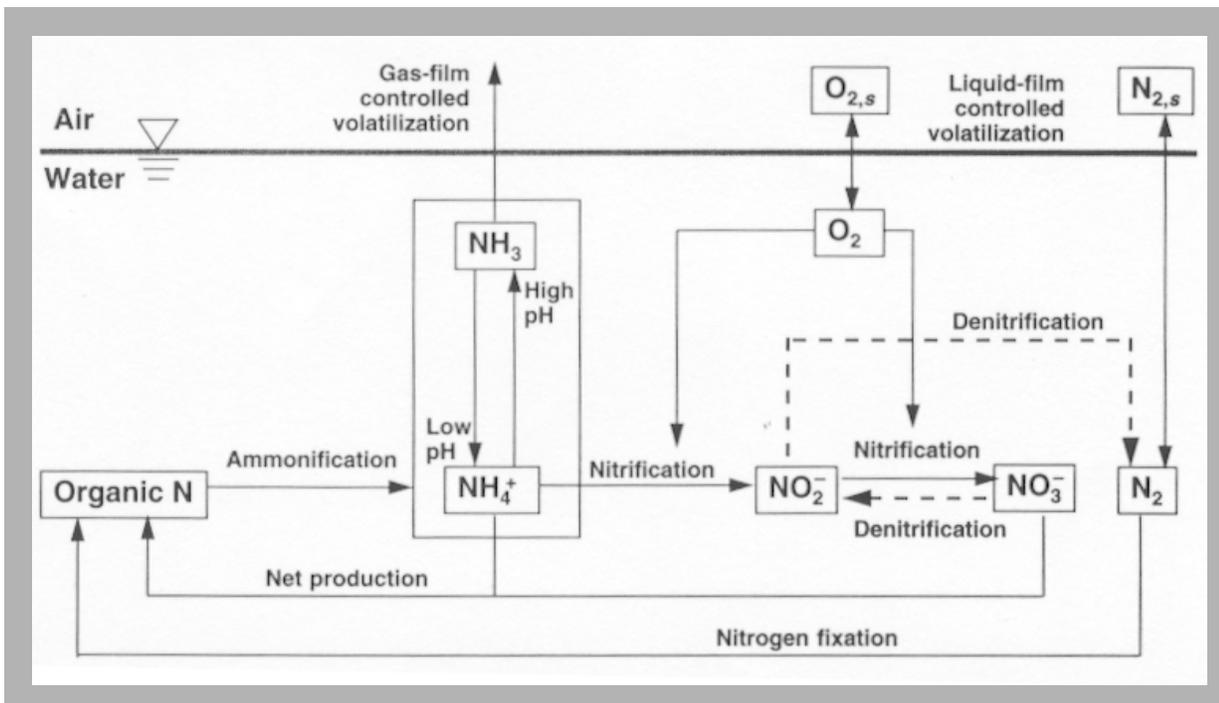


Figure 1. The nitrogen cycle.

or anaerobic microorganisms, depending on conditions of the environment. The end products of anaerobic utilization are generally unstable and will be oxidized upon introduction of oxygen (Sawyer, et al., 1994).

Biochemical oxygen demand (BOD) is the standard parameter used to measure the amount of biodegradable organics in water. The BOD of a water sample represents the amount of oxygen required for utilization of the organics by microbes, usually over a five day period. This parameter is important in determining the potential for oxygen depletion in a given system (Peavy, et al., 1985).

Nonbiodegradable Organic Compounds

Nonbiodegradable organics are compounds that microorganisms cannot break down within a reasonable amount of time. Examples include: cellulose, a plant constituent; benzene, a compound found in detergents and petroleum products; organochlorine compounds; pesticides; and other industrial compounds (Peavy, et al., 1985). The concentration of nonbiodegradable organics in a water sample is calculated by measuring the total organic carbon (TOC) content of the sample and then subtracting the ultimate BOD.

Pathogens

Pathogens are organisms that are capable of transmitting diseases to humans. Pathogens typically require an animal host and are not native to aquatic environments; however, many are capable of living in aquatic systems for extended periods of time (Peavy, et al., 1985). Table 2 lists several pathogens prevalent in surface waters and the diseases they transmit.

The presence or absence of most pathogens is determined by using one or more *indicator organisms*.

An indicator organism is an organism that is present or not present when the organism of interest is present or not present. Also, by definition, an indicator organism is easily measured without disrupting the sample and is not itself a pathogen (Peavy, et al., 1985). Coliform bacteria are lactose-fermenting organisms that are non-pathogenic. This group of organisms contains a subgroup of organisms called fecal coliforms. Fecal coliforms are found in the intestinal tract of warm-blooded animals and are excreted with feces, as are pathogens. It is, therefore, standard to determine the presence of fecal coliforms with the assumption that pathogens are present along with them.

Giardia lamblia are not measured using coliform bacteria. *Giardia* are counted by filtering a large sample of water and separating the solids from the filter. The solids are then stained with a fluorescent green antibody. The antibody is particular only to *Giardia*, making the organisms relatively easy to count (Biovir, undated).

Contaminants of Concern

National primary drinking water regulations are legally-enforceable standards that apply to public water systems. These regulations list contaminants of concern (COCs) and the corresponding *maximum contaminant levels* (MCLs). For details about the regulations, visit the EPA’s website (<http://www.epa.gov/ogwdw/>).

The contaminants of concern discussed in this text are grouped as follows: inorganic chemicals, organic chemicals, radioactive compounds, and pathogens. Tables 3, 4, and 5 list numerous common inorganic, organic, and biological contaminants regulated by the EPA and the related potentially contaminating activities (PCAs).

Table 2: Waterborne Pathogens & Related Diseases*

<u>Type of Pathogen</u>	<u>Name</u>	<u>Related Disease</u>
Bacteria	Salmonella typhi	Typhoid fever, enteric fever
Bacteria	Vibrio comma	Cholera
Virus	Enteric cyopathogenic human orphan (ECHO)	Aseptic meningitis, infantile diarrhea, epidemic exanthm
Virus	Unknown	Infectious hepatitis
Protozoa	Entamoeba histolytica	Amoebiasis (amoebic dysentery, amoebic enteritis, amoebic colitis)
Protozoa	Giardia lamblia	Giardiasis (Backpackers disease)

* after Peavy et al. 1983

Table 3: Inorganic Contaminants That Affect Quality of Surface Waters* **

<u>Contaminant</u>	<u>MCL (mg/L)</u>	<u>Type of Source</u>	<u>Examples</u>
Arsenic	0.05 mg/L	Commercial / Industrial	Automobile Body Shops and Repair Shops; Chemical or Petroleum Processing; Construction and Demolition; Electrical or Electronic Manufacturing; Fleet, Trucking, or Bus Terminals; Food Processing; Home Manufacturing; Machine Shops; Medical or Vet Offices; Metal Plating, Finishing, and Fabricating; Military Installations; Photo Processing and Printing; Research Laboratories; Retail Operations; Wood, Pulp and Paper Processing
		Residential / Municipal	Airports (Maintenance and Fueling Areas); Golf Courses and Parks; Landfills or Dumps; Public Buildings and Civic Organizations; Schools; Utility Stations
		Agricultural/Rural	Orchards, Herbicides, Erosion of Natural Deposits
Cadmium	0.005 mg/L	Commercial / Industrial	Automobile Body Shops and Repair Shops; Boat Repair and Refinishing; Chemical or Petroleum Processing; Construction and Demolition; Drinking Water Treatment; Dry Goods Manufacturing; Electrical or Electronic Manufacturing; Fleet, Trucking and Bus Terminals; Food Processing; Hardware, Lumber, and Parts Stores; Home Manufacturing; Machine Shops; Metal Plating, Finishing and Fabricating; Military Installations; Office Building or Complex; Photo Processing, and Printing; Medical or Vet Offices; Railroad Yards; Maintenance and Fueling Areas; Research Laboratories; Retail Operations; Synthetics or Plastics Producers; Underground Storage Tanks; Wood, Pulp, and Paper Processing
		Residential / Municipal	Airports: Maintenance and Fueling Areas; Landfills or Dumps; Public Buildings and Civic Organizations; Schools; Utility Stations; Wastewater
Chromium	0.1 mg/L	Commercial / Industrial	Metal Plating, Finishing and Fabricating, Erosion of natural deposits
Copper	Treatment Technique (Goal: 1.3 mg/L)	Commercial / Industrial	Automobile Body Shops and Repair Shops; Chemical or Petroleum Processing; Construction and Demolition; Dry Goods Manufacturing; Electrical or Electronic Manufacturing; Food Processing; Hardware, Lumber and Parts Stores; Home Manufacturing; Junk, Scrap and Salvage Yards; Machine Shops; Medical or Vet Offices; Metal Plating, Finishing and Fabricating, Office Building or Complex; Photo Processing and Printing; Synthetics or Plastics Producers, Transportation Corridors; Wood, Pulp and Paper Processing; Erosion of natural deposits
Fluoride	4 mg/L	Commercial / Industrial	Construction or Demolition; Fertilizer Factories; Aluminum Factories
Lead	Treatment Technique (Goal: 0.015 mg/L)	Commercial / Industrial	Automobile Body Shops and Repair Shops; Boat Repair and Refinishing; Cement or Concrete Plants; Chemical or Petroleum Processing; Construction and Demolition; Dry Goods Manufacturing; Electrical and Electronic Manufacturing; Fleet, Trucking and Bus Terminals; Food Processing; Furniture Repair and Manufacturing; Hardware, Lumber and Parts Stores; Home Manufacturing; Junk, Scrap and Salvage Yards; Machine Shops;

Table 3: Inorganic Contaminants That Affect Quality of Surface Waters*, **
(continued)

<u>Contaminant</u>	<u>MCL (mg/L)</u>	<u>Type of Source</u>	<u>Examples</u>
Lead	Treatment Technique (Goal: 0.015 mg/L)	Commercial / Industrial (continued)	Medical or Vet Offices; Metal Plating, Finishing and Fabricating; Military Installations; Mines or Gravel Pits; Office Building or Complex; Photo Processing or Printing; Railroad Yards, Maintenance and Fueling Areas; Research Laboratories; Retail Operations; Synthetics or Plastics Producers; Underground Storage Tanks; Wholesale Distribution Activities; Wood Preserving and Treating; Wood, Pulp and Paper Processing
		Residential / Municipal	Airport Maintenance and Fueling Areas; Drinking Water Pipe Corrosion, Golf Courses and Parks; Landfills or Dumps; Public Buildings and Civic Organizations; Schools; Utility Stations; Wastewater; Erosion of natural deposits
Inorganic Mercury	0.002	Commercial / Industrial	Automobile Body Shops and Repair Shops; Boat Repair and Refinishing; Chemical or Petroleum Processing; Electrical or Electronic Manufacturing; Fleet, Trucking and Bus Terminals; Food Processing; Furniture Repair or Manufacturing; Hardware, Lumber and Parts Stores; Home Manufacturing; Machine Shops; Office Building or Complex; Photo Processing or Printing, Medical or Vet Offices; Metal Plating, Finishing and Fabricating; Military Installations; Railroad Yards, Maintenance, and Fueling Areas; Research Laboratories; Retail Operations; Synthetics or Plastics Producers; Wood, Pulp and Paper Processing
		Residential / Municipal	Airport Maintenance and Fueling Areas; Landfills or Dumps; Public Buildings and Civic Organizations; RV and Mini Storage; Schools; Utility Stations; Wastewater
		Agricultural/Rural	Crops - Irrigated + Non irrigated; Erosion of Natural Deposits
Nitrate	10	Commercial / Industrial	Boat Repair and Refinishing; Historic Waste Dumps and Landfills
		Residential / Municipal	Apartments and Condominiums; Camp Grounds and RV Parks; Golf Courses and Parks; Housing; Landfills or Dumps; Septic Systems Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Crops - Irrigated + Non irrigated; Lagoons and Liquid Waste; Pesticide, Fertilizer and Petroleum Storage Sites; Rural Homesteads; Erosion of Natural Deposits
Nitrite	1	Commercial / Industrial	Boat Repair and Refinishing; Historic Waste Dumps and Landfills
		Residential / Municipal	Apartments and Condominiums; Camp Grounds and RV Parks; Golf Courses and Parks; Housing; Landfills or Dumps; Septic Systems; Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Lagoons and Liquid Waste; Pesticide, Fertilizer and Petroleum Storage Sites; Rural Homesteads; Crops - Irrigated + Non irrigated; Erosion of Natural Deposits

* from EPA, 2000

** *MCL' = Maximum Contaminant Level; 'Treatment Technique' = Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

Inorganic chemicals

Following is a brief description of several inorganic COCs commonly found in surface water sources.

Fluoride

Fluoride is a naturally occurring element found in certain igneous and metamorphic rocks. It can be introduced to the environment through natural erosive processes or land disturbances associated with construction and land development (Peavy, et al., 1985). Usually found in low concentrations in surface and groundwater sources, fluoride is sometimes added to drinking water to help prevent tooth decay in children. Fluoride can be toxic at high concentrations (approximately 5 mg/L or higher); however, additions to drinking water rarely exceed 1.5 to 2 mg/L. Concentrations greater than 2 mg/L can result in tooth discolorations and mottling, and, in excessive dosages, skeletal abnormalities. The EPA has set a maximum contaminant level for fluoride at 4 mg/L (Peavy, et al., 1985; EPA, 2000).

Metals

Surface water sources typically contain several metals considered non-toxic; these include sodium, iron, manganese, and copper. These metals are introduced

by natural dissolution of minerals or are released in industrial, agricultural, or domestic wastewaters. Non-toxic metals can cause problems associated with corrosion, taste and odor, and color (Peavy, et al., 1985).

Other metals become toxic even at extremely low levels; these include arsenic, barium, cadmium, chromium, lead, mercury, and silver. Arsenic, cadmium, lead and mercury represent *cumulative pollutants*—they *biomagnify* through the food chain, threatening biota at higher trophic levels. The presence of toxic metals may be attributed to natural processes; however, such metals usually can be traced to industrial and mining discharges (Peavy, et al., 1985).

Metals are measured in a laboratory using atomic absorption spectrophotometry (Peavy, et al., 1985).

Nutrients

As mentioned earlier in this paper, nitrate and phosphorus are of particular concern because they are limiting nutrients for aquatic plants and algae. Their presence thus can cause algal blooms that are difficult to control and which result in taste and odor problems. They can also foster formation of trihalomethanes during drinking water treatment (Sawyer, et al., 1994).

Table 4: Organic Contaminants That Affect Quality of Surface Waters*

<u>Contaminant</u>	<u>MCL (mg/L)</u>	<u>Type of Source</u>	<u>Examples</u>
Benzene	0.005 mg/L	Commercial / Industrial	Automobile Body Shops and Repair Shops; Boat Repair and Refinishing; Cement or Concrete Plants; Chemical and Petroleum Processing; Construction and Demolition; Dry Goods Manufacturing; Electrical or Electronic Manufacturing; Fleet, Trucking and Bus Terminals; Food Processing; Hardware, Lumber and Parts Stores; Home Manufacturing; Junk, Scrap or Salvage Yards; Machine Shops; Medical or Vet Offices; Metal Plating, Finishing and Fabricating; Military Installations; Office Building or Complex; Photo Processing and Printing; Railroad Yards, Maintenance and Fueling Areas; Research Laboratories; Retail Operations; Synthetic or Plastics Production; Synethetics or Plastics Producers; Underground Storage Tanks; Wholesale Distribution Activities; Wood, Pulp and Paper Processing
		Residential / Municipal	Airports (Maintenance and Fueling Areas); Drinking Water Treatment; Golf Courses and Parks; Landfills or Dumps; Public Buildings and Civic Organizations; Utility Stations; Schools
		Agricultural/Rural	Crops - Irrigated + Non irrigated
Total Trihalomethanes	0.10 mg/L; as of 01/01/02: 0.080 mg/L	Residential / Municipal	Drinking Water Treatment

* from EPA, 2000

Table 5: Biological Contaminants That Affect Quality of Surface Waters*

<u>Contaminant</u>	<u>MCL</u>	<u>Type of Source</u>	<u>Examples</u>
Coliform	<5% of samples	Commercial / Industrial	Boat Repair and Refinishing
		Residential / Municipal	Apartments and Condominiums; Camp Grounds or RV Parks; Housing; Septic Systems; Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Lagoons and Liquid Waste; Rural Homesteads
Cryptosporidium	as of 1/1/02): 99% removal/inactivation	Commercial / Industrial	Boat Repair and Refinishing
		Residential / Municipal	Apartments and Condominiums; Camp Grounds or RV Parks; Housing; Septic Systems; Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Dairies; Lagoons and Liquid Waste Disposal Sites; Rural Homesteads; Wildlife feeding or migration zones
Giardia Lamblia	99.9% removal/inactivation	Commercial / Industrial	Boat Repair and Refinishing
		Residential / Municipal	Apartments and Condominiums; Camp Grounds or RV Parks; Housing; Septic Systems; Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Lagoons and Liquid Waste; Rural Homesteads
Viruses	Treatment Technique (a required process intended to reduce the level of a contaminant in drinking water)	Commercial / Industrial	Waste Water
		Residential / Municipal	Apartments and Condominiums; Camp Grounds or RV Parks; Housing; Septic Systems; Waste Transfer and Recycling; Wastewater
		Agricultural/Rural	Auction Lots; Boarding Stables; Confined Animal Feeding Operations; Dairies; Grazing lands; Lagoons and Liquid Waste; Rural Homesteads; Wildlife migration or feeding zones
Turbidity**	Treatment Technique	Commercial / Industrial	Construction and Demolition; Home Manufacturing; Mines or Gravel Pits
		Residential / Municipal	Camp Grounds or RV Parks; Golf Courses and Parks; Housing Developments; Industrial Parks; Stormwater discharge sites; Transportation Corridors
		Agricultural/Rural	Crops - Irrigated + Non irrigated; Managed Forests; Animal grazing lands; Animal feedlots; Dairies

* from EPA, 2000

** At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.

Nitrogen presents a significant health risk when present in drinking water. Nitrogen causes methemoglobinemia, or “blue baby” syndrome, a disease in which oxygen in the blood stream is replaced by nitrate, suffocating babies that have not developed the bacteria necessary to reduce nitrate (Peavy, et al., 1985). Nutrients can originate from a variety of PCAs, including municipal wastewater discharges, commercial and industrial runoff, animal feed lots, and agricultural runoff. Nitrate has an MCL of 10 mg/L (EPA, 2000).

Organic chemicals

Several organic chemicals are potential or confirmed human carcinogens. These, therefore, represent a significant threat when present in drinking water sources. Organic contaminants can be categorized into three source groups:

- products of natural decomposition,
- products of domestic and commercial activities, and
- byproducts of disinfection.

Products of natural decomposition are usually benign. Examples of these include humic acids (from plants and algae), tannins, and other BOD.

Examples of organic chemicals from domestic and commercial activities include perchloroethylene (PCE), trichloroethylene (TCE), and methyl tertiary butyl ether (MTBE). PCE is typically associated with dry-cleaning businesses, TCE with electronics, manufacturing, mechanical maintenance, and fueling facilities. MTBE is most known as a fuel additive (EPA, 2000). Other organic chemicals from commercial and domestic sources are gasoline, composed mainly of BTEX (benzene, toluene, ethylbenzene, xylene) and pesticides such as DDE, DDT, and alachlor.

Organic disinfection byproducts include trihalomethanes and haloacetic acids. Trihalomethanes (THMs) are compounds formed upon addition of oxidants during disinfection of a water source that contains high amounts of organic components. Common THMs include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Any of these can be a significant water quality problem, due to their carcinogenicity. An MCL for total THMs is set at 0.10 mg/L.

Radioactive compounds

Radioactive compounds most prevalent in surface water include radon, radium, and uranium. Radon, the most common, is considered a carcinogen. Humans come into contact with it most often by exposure to airborne particulates.

Pathogens

Pathogens can enter surface water from agricultural land uses such as animal feedlots, as well as from recreational uses. There are three main categories of pathogens: bacteria, viruses, and protozoa.

Bacteria are single-celled organisms typically associated with gastrointestinal disorders. Diseases transmitted by bacteria include cholera and typhoid.

Viruses are parasites that require a host in which to live. These organisms are typically associated with nervous system disorders such as meningitis and hepatitis.

Protozoa represent the lowest form of complex animal life. They can be found both free-living or parasitic, and are highly adaptable. Aquatic protozoa are capable of forming a cystic stage under extreme environmental conditions. These cysts are difficult to penetrate with traditional disinfection techniques. Filtration is therefore required as a treatment method for complete removal of such organisms.

Infections associated with protozoa are typically gastrointestinal. *Giardia lamblia* is perhaps the most well known protozoan. Often introduced to a water system via animal waste, it causes the disease giardiasis, more commonly known as “backpackers disease.”

Possible Contaminating Activities

Contamination of surface waters can result from all types of commercial-industrial, residential-municipal, and agricultural activities, as summarized by EPA (2000). Potential sources of contaminants can be divided into two main categories: point sources, and nonpoint sources.

Point Sources

Point sources are sources that are easily identifiable, by the presence of a discharge pipe or other appurtenance. Typically non-diffuse, they often are associated with industrial and municipal systems (Corbitt, 1990).

Nonpoint Sources

Nonpoint sources are not as easily identified as are point sources. Characterized as diffuse, they are typically associated with land management activities such as agriculture (especially irrigated agriculture) and mining. Nonpoint sources also include rainfall runoff from industrial and urban areas (Corbitt, 1990). Several nonpoint sources are described in detail below.

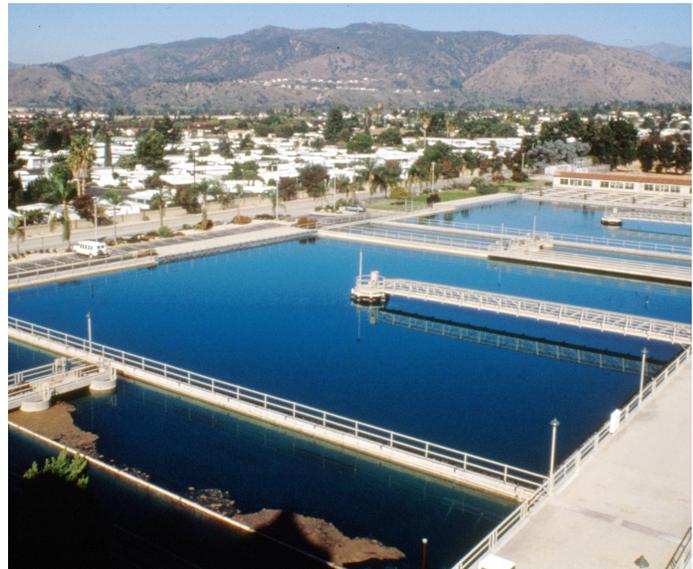
Commercial or Industrial Sources

Possible contaminating activities of the commercial or industrial type are typically related to urban activities.

They include: manufacturing, maintenance, and repair of automobiles, airplanes, and other forms of transportation; chemical, electronic, and machine manufacturing; food production; petroleum and film processing; fueling areas; construction activities; and many other types of activities. Commercial and industrial PCAs are primary contributors of inorganic compounds, particularly metals (EPA, 2000).

Residential or Municipal Sources

Residential and municipal PCAs arise from civil facilities such as airports; water and wastewater treatment facilities; public buildings, such as schools and government buildings; landfills; and golf courses. PCAs can also originate from residential developments. Residential and municipal sources contribute all types of organic, inorganic, and biological wastes (EPA, 2000).



Water treatment plant, Laverne, California.

Agricultural Sources

Possible contaminating activities originating from agricultural activities are, according to the EPA, one of the biggest problems associated with nonpoint source pollution. Pollutants associated with agricultural runoff include pesticides, sediments, and nutrients (EPA, 2000).

Concentrated animal facilities, such as stables and dairy farms, represent a significant source of nutrients, sediments, and pathogens. These are introduced to surface waters by surface water runoff, and can be introduced to groundwater via infiltration.

Other PCAs

Below are descriptions of other types of PCAs that don't correspond to the three categories previously discussed.

Fires

Fire, whether natural or accidentally or purposely set, can greatly affect surface water quality. The impact of fire on water quality will vary as a function of soil type, slope of the burned area, vegetative type, and percent cover. It all depends on burn intensity and duration, and on the type(s) of fire control practices used. In general, fire results in increased problems associated with erosion. Turbidity, total solids, and nutrients may increase following a fire.

Geological Hazards

Geological hazards include landslides and faults. These activities can result in increased erosion, sedimentation, and nutrient concentrations.

Golf Courses

Many golf courses rely on heavy irrigation (chiefly sprinkling) and on fertilizer to maintain fairways and

greens in an attractive and playable condition. This can lead to nonpoint source pollution problems. Runoff from such operations plus the occasional use of wastewater treatment plant effluent (if any) for irrigation, can impair the quality of nearby creeks or ponds. These activities can introduce high nutrient levels, as well as organic compounds associated with the use of pesticides and fertilizers.

Grazing Animals

Grazing animals can pose a threat to water quality. Grazing in riparian areas can cause erosion, resulting in increased turbidity and increased suspended solids. Furthermore, animals grazing near surface waters can cause increased nutrient concentrations and the introduction of pathogens.

Surfacing of Groundwater

The surfacing of contaminated groundwater can impair the quality of streams and lakes. Water quality parameters affected include metals (particularly iron), nutrients, and some inorganic chemicals.

Logging

Logging can pose a threat to water quality by increasing erosion and sedimentation, leading to elevated turbidity.

Mine runoff

Considerable water quality problems occur as a result of mine runoff. Most significant of these are decreased pH levels, high concentrations of heavy metals, and erosion and sedimentation.

Pesticide or herbicide use

Pesticide and herbicide use represents a significant source of organic chemical contamination. Examples

of such contaminants include dibromochloropropane (DBCP), a contaminant currently of concern to the drinking water industry.

Recreational use

Recreational uses of surface waters include swimming, boating, and fishing, as well as uses associated with the riparian areas surrounding bodies of water, such as hiking and horseback riding. Swimming and other body-contact sports can cause an increase in the levels of pathogens, nutrients, and turbidity. Sports associated with motorized equipment, such as boating, can introduce organic contaminants, such as methyl tertiary

butyl ether (MTBE) and other hydrocarbons, particularly benzene, toluene, ethylbenzene, and xylene (BTEX). Motorized sporting equipment can also cause resuspension of solids from the bottom of the water body, resulting in increases in turbidity. Activities that occur along river and stream banks and along the shores of lakes, such as hiking and biking, can increase erosion and result in increased solids and high turbidities.

Traffic accidents and spills

Traffic accidents and spills can introduce several types of contaminants to surface water bodies if improperly managed.

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