Contaminant Candidate List Regulatory Determination Support Document for Sodium

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Regulatory Determination Support Document
for Sodium

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This document is designed to provide supporting information regarding the regulatory determinations for sodium as part of the Contaminant Candidate List (CCL) evaluation process. This document is not a regulation, and it does not substitute for the Safe Drinking Water Act (SDWA) or the Environmental Protection Agency's (EPA's) regulations. Thus, it cannot impose legally-binding requirements on EPA, States, or the regulated community, and may not apply to a particular situation based upon the circumstances. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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CONTAMINANT CANDIDATE LIST REGULATORY DETERMINATION SUPPORT DOCUMENT FOR SODIUM

EXECUTIVE SUMMARY

Sodium was a 1998 Contaminant Candidate List (CCL) regulatory determination priority contaminant. Sodium was one of the contaminants considered by the U.S. Environmental Protection Agency (EPA) for a regulatory determination. The available data on occurrence, exposure, and other risk considerations suggest that regulating sodium may not present a meaningful opportunity to reduce health risk. EPA presented preliminary CCL regulatory determinations and further analysis in the June 3, 2002 *Federal Register* Notice (USEPA, 2002a; 67 FR 38222), and confirmed the final CCL regulatory determinations in the July 18, 2003 *Federal Register* Notice (USEPA, 2003a; 68 FR 42898).

To make this regulatory determination for sodium, EPA used approaches guided by the National Drinking Water Advisory Council's (NDWAC) Work Group on CCL and Six-Year Review. The Safe Drinking Water Act (SDWA) requirements for National Primary Drinking Water Regulation (NPDWR) promulgation guided protocol development. The SDWA Section 1412(b)(1)(A) specifies that the determination to regulate a contaminant must be based on a finding that each of the following criteria are met: (i) "the contaminant may have adverse effects on the health of persons"; (ii) "the contaminant is known to occur or there is substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern"; and (iii) "in the sole judgement of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems." Available data were evaluated to address each of the three statutory criteria.

Sodium (Na) is a naturally occurring element ubiquitous in the environment. It is the sixth most abundant element in the Earth's crust and the most abundant anion in the hydrosphere. Sodium in the ocean is associated with chlorine in the form of sea salt. In the lithosphere, most sodium minerals exist as soluble salts found primarily in evaporite deposits and silicate minerals, and more rarely as halides or aluminohalides. The sodium cation (Na^+) is necessary for a number of biochemical processes in many living organisms.

Sodium chloride (NaCl) is the most economically and industrially important form of sodium with thousands of uses. Among other things, salt is used as a flavor enhancer or food preservative, as a road deicer, in water softening treatment, in powdered soaps and detergents, as the electrolyte in saline solutions, in rubber manufacture, and as a pesticide. Sodium chloride is also used in oil and gas

exploration, textile and dyeing industries, metal processing, pulp and paper production, tanning and leather treatment, and in the chemical industry to manufacture other chemicals. Widespread environmental releases of five other sodium compounds reported through the Toxic Release Inventory (TRI) underscore the heavy use and release of sodium in the environment.

A Health Advisory (HA) has until now never been issued for sodium, though a Drinking Water Equivalent Level (DWEL) is available. The DWEL of 20 mg/L is a non-enforceable guidance level considered protective against non-carcinogenic adverse health effects and is based on an American Heart Association recommendation issued in 1965. Also, EPA has issued a non-enforceable guidance of 250 mg/L for salinity and dissolved solids in ambient waters (USEPA, 1997; 62 FR 52194).

The sale, use, and distribution of pesticide products containing sodium chloride and sodium bromide are controlled under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund") also includes sodium and many of its compounds on its list of hazardous substances. A number of sodium compounds are also listed as hazardous constituents under the Resource Conservation and Recovery Act (RCRA).

Sodium occurrence in ambient waters and stream bed sediments monitored by the United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program is ubiquitous, approaching 100% of water and sediment sampling sites for all land use categories. Although sodium detection frequencies are high, sodium occurrence at levels of public health concern is low. Less than 6% of all surface water sites and less than 8% of all ground water sites report detections greater than 120 mg/L, a benchmark concentration level used for this analysis.

Sodium has been detected in ground water PWS samples collected through the National Inorganic and Radionuclide Survey (NIRS) study. Occurrence estimates are high with 100% of samples showing detections, affecting 100% of the national population served. The 99th percentile concentration of all samples is 517 mg/L. About 13.2% of the NIRS systems exceeded the 120 mg/L benchmark level, affecting approximately 7.1 million people nationally. Additional data, including both ground water and surface water PWSs from select States, were examined through independent analyses and also show substantial sodium occurrence.

The weight of evidence favors the conclusion that high sodium intakes can have an adverse effect on blood pressure, especially for sodium-hypertensives. Hypertension affects almost 50 million people in the United States, and along with factors such as body weight, alcohol intake, and cholesterol, is a risk factor for heart disease. However, hyptertension is influenced more by lifestyle, behavior, and other nutrient intake than by sodium intake.

Sodium is known to occur in public water systems and in a few cases at levels of public health concern, particularly for salt-sensitive hypertensives. However, at these same concentrations, taste is generally affected and would likely lead consumers to decrease consumption. In addition, when compared with other intake routes, sodium from drinking water has a minor impact. For these reasons, regulation of sodium is unlikely to present a meaningful opportunity for health risk reduction for persons served by public water systems. However, EPA may choose to issue a non-enforceable Drinking Water Advisory, based on current health effects, taste effects, and occurrence data, to provide guidance to communities that may be exposed to elevated concentrations of sodium chloride or other sodium salts in their drinking water. In addition, under EPA-required sodium monitoring, test results must be reported to State and local public health authorities, who may advise sensitive populations of any risk they may face.

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1.0 INTRODUCTION

1.1 Purpose and Scope

This document presents scientific data and summaries of technical information prepared for, and used in, the U.S. Environmental Protection Agency's (EPA) regulatory determination for sodium. Information regarding sodium's physical and chemical properties, environmental fate, occurrence and exposure, and health effects is included. Analytical methods and treatment technologies are also discussed. Furthermore, the regulatory determination process is described to provide the rationale for the decision.

1.2 Statutory Framework/Background

The Safe Drinking Water Act (SDWA), as amended in 1996, requires the EPA to publish a list of contaminants (referred to as the Contaminant Candidate List, or CCL) to assist in priority-setting efforts. The contaminants included on the CCL were not subject to any current or proposed National Primary Drinking Water Regulations (NPDWR), were known or anticipated to occur in public water systems, and were known or suspected to adversely affect public health. These contaminants therefore may require regulation under SDWA. The first Drinking Water CCL was published on March 2, 1998 (USEPA, 1998c; 63 FR 10273), and a new CCL must be published every five years thereafter.

The 1998 CCL contains 60 contaminants, including 50 chemicals or chemical groups, and 10 microbiological contaminants or microbial groups. The SDWA also requires the Agency to select 5 or more contaminants from the current CCL and determine whether or not to regulate these contaminants with an NPDWR. Regulatory determinations for at least 5 contaminants must be completed 3½ years after each new CCL.

Language in SDWA Section 1412(b)(1)(A) specifies that the determination to regulate a contaminant must be based on a finding that each of the following criteria are met:

Statutory Finding i: the contaminant may have adverse effects on the health of persons;

Statutory Finding ii: the contaminant is known to occur or there is substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and

Statutory Finding iii: in the sole judgement of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.

The geographic distribution of the contaminant is another factor evaluated to determine whether it occurs at the national, regional or local level. This consideration is important because the Agency is charged with developing national regulations and it may not be appropriate to develop NPDWRs for regional or local contamination problems.

EPA must determine if regulating this CCL contaminant will present a meaningful opportunity to reduce health risk based on contaminant occurrence, exposure, and other risk considerations. The Office of Ground Water and Drinking Water (OGWDW) is charged with gathering and analyzing the occurrence, exposure, and risk information necessary to support this regulatory decision. The OGWDW must evaluate when and where this contaminant occurs, and what would be the exposure and risk to public health. EPA must evaluate the impact of potential regulations as well as determine the appropriate measure(s) for protecting public health.

For each of the regulatory determinations, EPA first publishes in the *Federal Register* the draft determinations for public comment. EPA responds to the public comments received, and then finalizes regulatory determinations. If the Agency finds that regulations are warranted, the regulations must then be formally proposed within 24 months, and promulgated 18 months later. EPA has determined that there is sufficient information to support a regulatory determination for sodium.

1.3 Statutory History of Sodium

Sodium chloride (NaCl), otherwise known as halite, salt, sea salt, or table salt, is the most economically and industrially important form of sodium, with an estimated 14,000 direct and indirect uses. Among other things, salt is used as a flavor enhancer or preservative in food, as a road deicer, in water softening treatment, in powdered soaps and detergents, as the electrolyte in saline solutions, in rubber manufacturing, and as a pesticide. Sodium chloride is also used in oil and gas exploration, textile and dyeing industries, metal processing, pulp and paper production, tanning and leather treatment, and in the chemical industry (Kostick, 1993; Gornitz, 1972). Because salt has so many human end uses and is abundant in the ocean, sodium is ubiquitous in the environment.

A Health Advisory (HA) for sodium has never been issued, though a Drinking Water Equivalent Level (DWEL) is available. The DWEL of 20 mg/L is a non-enforceable guidance level considered protective against non-carcinogenic adverse health effects and is based on an American Heart Association recommendation issued in 1965. Also, EPA has issued a non-enforceable guidance of 250 mg/L for salinity and dissolved solids in ambient waters (USEPA, 1997; 62 FR 52194).

The sale, use, and distribution of pesticides, including those containing sodium, is controlled under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA was most recently amended in 1996 under the Food Quality Protection Act (FQPA). FIFRA requires registration of all pesticides with EPA, as well as certain labeling, application, and use restrictions. Moreover, pesticide manufacturing plants must be registered, and the manufacturer must provide EPA with scientific data regarding the product's efficacy and demonstrating that it does not pose an unreasonable risk to people or the environment (USEPA, 1998a).

Pesticide products containing sodium chloride and sodium bromide have been registered under FIFRA since 1954 and 1975, respectively. Currently, thirty-two sodium bromide pesticide products and two pesticide products containing sodium chloride are registered in the United States (USEPA, 1993).

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or "Superfund") includes sodium and many of its compounds on its list of hazardous substances. CERCLA's listing requires reporting of releases over a certain "reportable quantity" which, for elemental sodium, is ten pounds (USEPA, 1998b). A number of sodium compounds are also listed as hazardous constituents under the Resource Conservation and Recovery Act (RCRA) (USEPA, 1998b). Furthermore, data are available for five sodium compounds through the Toxic Release Inventory (TRI). The TRI was established by the Emergency Planning and Community Right-to-Know Act (EPCRA). EPCRA requires certain industrial sectors to publically report the environmental release or transfer of chemicals included in this inventory (USEPA, 2000a).

1.4 Regulatory Determination Process

In developing a process for the regulatory determinations, EPA sought input from experts and stakeholders. EPA asked the National Research Council (NRC) for assistance in developing a scientifically sound approach for deciding whether or not to regulate contaminants on the current and future CCLs. The NRC's Committee on Drinking Water Contaminants recommended that EPA: (1) gather and analyze health effects, exposure, treatment, and analytical methods data for each contaminant; (2) conduct a preliminary risk assessment for each contaminant based on the available data; and (3) issue a decision document for each contaminant describing the outcome of the preliminary risk assessment. The NRC noted that in using this decision framework, EPA should keep in mind the importance of involving all interested parties.

One of the formal means by which EPA works with its stakeholders is through the National Drinking Water Advisory Council (NDWAC). The NDWAC comprises members of the general public, State and local agencies, and private groups concerned with safe drinking water, and advises the EPA Administrator on key aspects of the Agency's drinking water program. The NDWAC provided specific recommendations to EPA on a protocol to assist the Agency in making regulatory determinations for current and future CCL contaminants. Separate but similar protocols were developed for chemical and microbial contaminants. These protocols are intended to provide a consistent approach to evaluating contaminants for regulatory determination, and to be a tool that will organize information in a manner that will communicate the rationale for each determination to stakeholders. The possible outcomes of the regulatory determination process are: a decision to regulate, a decision not to regulate, or a decision that some other action is needed (e.g., issuance of guidance).

The NDWAC protocol uses the three statutory requirements of SDWA Section 1412(b)(1)(A)(i)-(iii) (specified in section 1.2) as the foundation for guiding EPA in making regulatory determination decisions. For each statutory requirement, evaluation criteria were developed and are summarized below.

To address whether a contaminant may have adverse effects on the health of persons (statutory requirement (i)), the NDWAC recommended that EPA characterize the health risk and estimate a health reference level (or, in the case of sodium, a benchmark) for evaluating the occurrence data for each contaminant.

Regarding whether a contaminant is known to occur, or whether there is substantial likelihood that the contaminant will occur, in public water systems with a frequency, and at levels, of public health concern (statutory requirement (ii)), the NDWAC recommended that EPA consider: (1) the actual and estimated national percent of public water systems (PWSs) reporting detections above half the health reference level (or benchmark); (2) the actual and estimated national percent of PWSs with detections above the health reference level (or benchmark); and (3) the geographic distribution of the contaminant.

To address whether regulation of a contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems (statutory requirement (iii)) the NDWAC recommended that EPA consider estimating the national population exposed above half the health reference level (or benchmark) and the national population exposed above the health reference level (or benchmark).

The approach EPA used to make regulatory determinations followed the general format recommended by the NRC and the NDWAC to satisfy the three SDWA requirements under section 1412(b)(1)(A)(i)-(iii). The process was independent of many of the more detailed and comprehensive risk management factors that will influence the ultimate regulatory decision making process. Thus, a decision to regulate is the beginning of the Agency regulatory development process, not the end.

Specifically, EPA characterized the human health effects that may result from exposure to a contaminant found in drinking water. Based on this characterization, the Agency estimated a health reference level (HRL) for each contaminant. In the case of sodium, a benchmark was chosen based on taste effects, which occur at lower concentrations than health effects.

For each contaminant EPA estimated the number of PWSs with detections >½HRL (or benchmark) and >HRL (or benchmark), the population served at these values, and the geographic distribution, using a large number of occurrence data (approximately seven million analytical points) that broadly reflect national coverage. Round 1 and Round 2 UCM data, evaluated for quality, completeness, bias, and representativeness, were the primary data used to develop national occurrence estimates. Use and environmental release information, additional drinking water data sets (e.g., State drinking water data sets, EPA National Pesticide Survey, and Environmental Working Group data reviews), and ambient water quality data (e.g., NAWQA, State and regional studies, and the EPA Pesticides in Ground Water Database) were also consulted.

The findings from these evaluations were used to determine if there was adequate information to evaluate the three SDWA statutory requirements and to make a determination of whether to regulate a contaminant.

1.5 Determination Outcome

After reviewing the best available public health and occurrence information, EPA has made a determination not to regulate sodium with an NPDWR. This determination is based on the finding that regulation of sodium may not present a meaningful opportunity for health risk reduction for persons served by public water systems. However, EPA may issue an advisory to provide guidance to communities that may be exposed to drinking water contaminated with sodium chloride or other sodium salts. All CCL regulatory determinations and further analysis are formally presented in the *Federal Register* Notices (USEPA, 2002a; 67 FR 38222; and USEPA, 2003a; 68 FR 42898). The following sections summarize the data used to reach this decision.

2.0. CONTAMINANT DEFINITION

Sodium (Na) is a naturally occurring element ubiquitous in the environment. It is the sixth most abundant element in the Earth's crust and the most abundant anion in the hydrosphere (the hydrosphere is all water, including atmospheric and oceanic water, on earth; Gornitz, 1972). The sodium cation (Na^+) is necessary for biochemical processes like sodium pumps and concentration gradients in many living organisms (Madigan et al., 1997). The earth's oceans contain roughly 18.4 quadrillion short tons (1 short ton = 2000 lbs) of sodium associated with chlorine in the form of sea salt (Kostick, 1993). In the lithosphere, most sodium minerals exist as soluble salts found primarily in evaporite deposits, as intricate rock-forming silicates, or as rare halides or aluminohalides (Gornitz, 1972).

Sodium chloride (NaCl), otherwise known as halite, salt, sea salt, or table salt, is the most economically and industrially important form of sodium, with an estimated 14,000 direct and indirect uses. Among other things, salt is used as a flavor enhancer or preservative in food, as a road deicer, in water softening treatment, in powdered soaps and detergents, as the electrolyte in saline solutions, in rubber manufacturing, and as a pesticide. Sodium chloride is also used in oil and gas exploration, textile and dyeing industries, metal processing, pulp and paper production, tanning and leather treatment, and in the chemical industry to manufacture such chemicals as chlorine, sodium metal, sodium hydroxide, sodium carbonate, and sodium sulfate (Kostick, 1993; Gornitz, 1972).

2.1 Physical and Chemical Properties

Sodium is an alkali metal located in group 1A of the periodic table, and has an atomic weight of 22.99 g/mol, melting point of 97.82 °C, and boiling point of 892 °C. Sodium metal is a soft solid with a shiny metallic luster and is an excellent conductor of electricity. Sodium does not occur in nature in its pure form because the metal readily gives up its single valence electron, making it highly reactive (Brown et al., 1994). Elemental sodium reacts violently with water to form sodium hydroxide and hydrogen gas, and oxidizes in the presence of oxygen to sodium monoxide. Sodium commonly occurs as sodium halides (NaCl, NaBr), sodium carbonates (Na_2CO_3, $NaHCO_3$), sodium sulfates (Na_2SO_4, $NaHSO_4$), sodium hydride (NaH), or sodium nitrate ($NaNO_3$) (Gornitz, 1972).

2.2 Environmental Fate and Transport

A sodium salt is formed when the sodium cation replaces some or all of the hydrogen cations in an acid. Sodium salts that occur in seawater can be classified as "cyclic" salts because they traverse different atmospheric, terrestrial, and aquatic environments before returning to the ocean. More specifically, cyclic salts are conveyed from the ocean into the atmosphere by spray and then transported inland dissolved in suspended water droplets. The salts are transferred to the soil through precipitation or dry deposition and eventually leach to freshwater streams and ground water. From these freshwater reservoirs, the salts return to the ocean, thus completing the cycle (Fairbridge, 1972). Sodium chloride that has been used in industry and released into the environment either directly or by means of landfills is also expected to cycle back to the ocean (Kostick, 1993).

Sodium salts can occur on earth as evaporite deposits, formed when the rate of evaporation exceeds the rate of precipitation plus runoff. Ancient deposits were formed chiefly by the evaporation of retreating seas (Kostick, 1993; Feldman and Cruft, 1972). Recent evaporite deposits are predominantly non-marine in origin and occur in hot, arid climates or in windy, restricted basins (Feldman and Cruft, 1972). Evaporite deposits of halite (NaCl) can become deformed under increasing temperatures and pressures, disrupting surrounding sediment layers and forming salt domes. Salt domes can extend vertically downward more than 20,000 feet and are common in the Gulf Coast region of the United States (Gornitz, 1972; Kostick, 1993).

Sodium salts are water soluble and can leach to freshwater (Fairbridge, 1972). Sodium does not adsorb strongly to clay, and therefore can be leached from clay sedimentary rock (Creasey, 1972). Sodium salts are natural constituents of ground water because of the abundance of evaporite minerals in the earth's crust. Ground water sodium levels may be increased in areas where salt is used to deice highways (Hackett, 1972).

3.0 OCCURRENCE AND EXPOSURE

This section examines the occurrence of sodium in drinking water. While no complete national database exists of unregulated or regulated contaminants in drinking water from public water systems (PWSs) collected under SDWA, this report aggregates and analyzes existing federal and State data that have been screened for quality, completeness, and representativeness. Populations served by PWSs exposed to sodium are estimated, and the occurrence data are examined for regional or other special trends. To augment the incomplete national drinking water data and aid in the evaluation of occurrence, information on the use and environmental release, as well as ambient occurrence of sodium, is also reviewed.

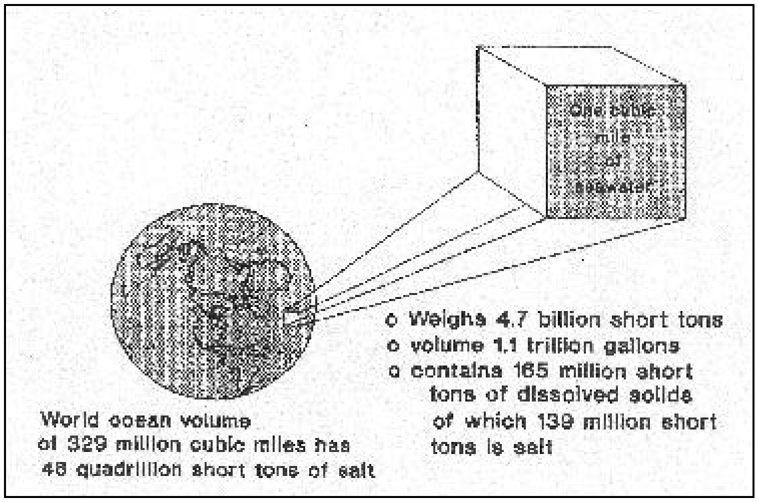
3.1 Use and Environmental Release

3.1.1 Production and Use

The earth's oceans contain approximately 46 quadrillion short tons (1 short ton = 2,000 lbs) of sodium chloride, or 18.4 quadrillion short tons of sodium (sodium chloride is 40% sodium by weight) (Figure 3-1). Sodium chloride is also known as salt, sea salt, halite, or table salt.

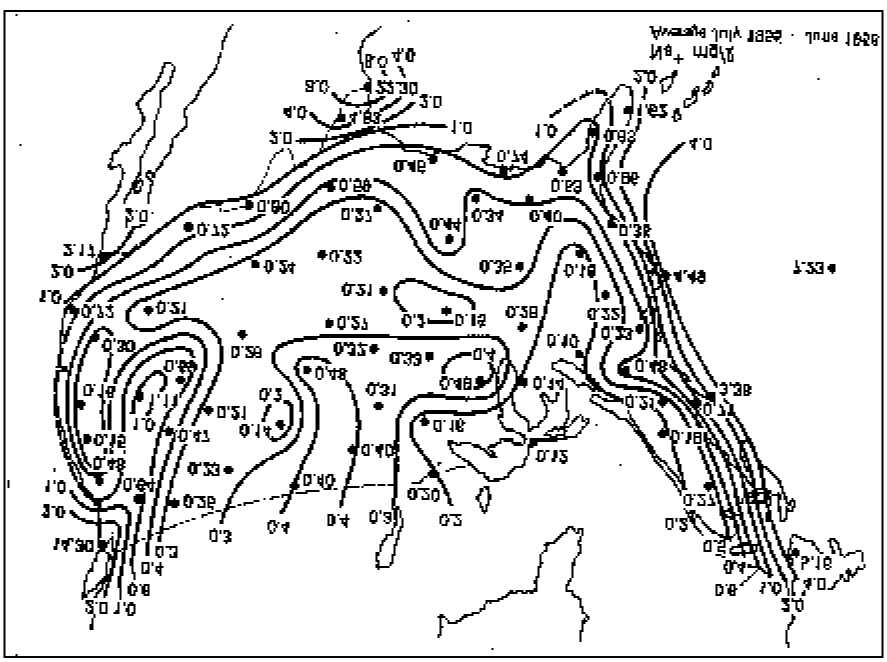
Sodium is transported from the ocean to the atmosphere by spray and is suspended in water droplets until it is either precipitated or introduced to the soil by dry deposition (Fairbridge, 1972). Sodium levels in precipitation are higher near coastal areas and decrease further inland (Figure 3-2).

Figure 3-1: Abundance of sodium chloride (salt) in the ocean



after Kostick, 1993

Figure 3-2: Average sodium concentrations in precipitation over the United States



after Drever, 1997

Table 3-1: End uses of sodium chloride in 1990 (in thousands of short tons)

Sectors and subsectors	Short tons of NaCl consumed	Percent of Total
Chemicals:		
.................Chlorine and sodium hydroxide manufacture	19,182	
.................Manufacture of other chemicals, like sodium carbonate and sodium	2,046	
....................................Total chemicals	21,228	47
Ice control/stabilization:		
...................Government	10,757	
...................Commercial	545	
....................................Total ice control	11,302	25
Food processing		
...................Meat packers	598	
...................Dairy	140	
...................Canning	318	
...................Baking	171	
...................Grain mill processing	97	
...................Other food processing	298	
...................Grocery wholesale	671	
..................................Total food processing	2,293	5
General Industrial		
...................Textiles and dyeing	227	
...................Metal processing	346	
...................Rubber	45	
...................Oil	793	
...................Pulp and paper	283	
...................Tanning and leather	109	
...................Other industrial	288	
....................................Total general industries	2,091	5
Agricultural		
..................Feed retailers and/or dealers-mixers	1,101	
..................Feed manufacturers	546	
..................Direct-buying and user	55	
...................Distributors	619	
.... Total agricultural	2,321	5
Distributors		
..................Grocery wholesale and/or retailers	223	
..................Institutional wholesalers and end users	96	
...................U.S. Government resale	9	
..................Other wholesale and/or retailers	1,851	
....................................Total distributors	2,030	5
Water treatment		
...................Government	297	
...................Commercial	198	
...................Distributors	1,123	
....................................Total water treatment	1,618	4
Other	2,030	4
....................................Grand total		100

after Kostick, 1993

Sodium chloride is the most economically and industrially important form of sodium, with an estimated 14,000 direct and indirect uses (Kostick, 1993). As depicted in Table 3-1, sodium chloride use can be broken down into eight major categories: chemical (47%), ice control (25%), food processing (5%), general industrial (5%), agricultural (5%), distributors (5%), water treatment (4%), and miscellaneous (4%).

Two sodium end uses with the most probable immediate effect on drinking water quality are water treatment and road deicing. In water treatment, sodium is used as a softener by substituting the sodium cation, Na^{+}, for calcium (Ca^{2+}) and magnesium (Mg^{2+}), both of which make water "hard." Water is considered "hard" when calcium and magnesium ions occur in high concentrations and leave caked mineral deposits in household and commercial equipment. Various softening processes exchange sodium cations for calcium and magnesium cations and release sodium directly into the drinking water supply (Kostick, 1993). Many sodium salts are used for water treatment, for example sodium chloride, sodium hydroxide, sodium bicarbonate, and sodium carbonate.

Sodium chloride that has been used to deice roads can also be a problem for drinking water systems. The salt and ice mixture creates a brine with a lower freezing point than water, effectively melting ice (Kostick, 1993). Sodium chloride is a cheap and effective solution to frozen roads, but can become an environmental concern when run-off affects local vegetation and soil quality, as well as ground water and surface water supplies. In one study, sodium levels eight times the norm were detected forty-five feet from the highway in areas where deicing salt had been used for 18 years (USEPA, 1990). A different study, undertaken by the Federal Government and University researchers, found that highway deicing with sodium chloride made a significant impact on the salinity of the nation's streams between the years 1974-1981. Data for the investigation came from the National Water Quality Surveillance System and from United States Geological Survey (USGS) National Stream Quality Accounting Network sampling stations (Smith et al., 1987).

The United States produces more sodium chloride than any other country in the world, with other major producers including Russia, England, Germany, Canada, and France (Gornitz, 1972; Kostick, 1993). From 1990 to 1998, United States NaCl consumption was between three to ten million metric tons greater than its production (1 metric ton = 2,205 lbs), with imports three to thirteen times higher than exports (Table 3-2).

Although these figures suggest that the U.S. relies on foreign sources to meet consumption needs, most imports were supplied by foreign subsidiaries of major U.S. sodium chloride producers (Kostick, 1998). For the years 1994-1998, United States salt statistics analyzed by State indicate that Louisiana sold, or used, the most sodium (35%), followed by Texas (23%), New York (11%), Kansas (7%), and Utah (4%) (Kostick, 1994; Kostick 1995; Kostick, 1996; Kostick, 1997; Kostick, 1998).

Table 3-2: U.S. sodium chloride statistics, 1990-1998 (in thousands of metric tons)

Year	Production	Exports	Imports	Consumption, reported*
1998	41,200	731	8,770	44,200
1997	41,400	748	9,160	49,500
1996	42,200	869	10,600	52,800
1995	42,100	670	7,090	46,500
1994	40,100	742	9,630	47,200
1993	39,200	688	5,870	44,400
1992	36,000	992	5,390	39,700
1991	36,300	1,780	6,190	40,600
1990	36,800	2,270	5,970	no data

after Kostick,1994 and Kostick, 1998
Reported consumption is sales or use as reported by the salt companies including their imports and exports.

3.1.2 Environmental Release

Beyond raw production and use data, the disposal and release of sodium products to the environment is of special concern to drinking water systems. The end use of some sodium products involves direct environmental application, as with pesticides like sodium chloride or sodium bromide (USEPA, 1993). Other sodium products are dispersed post-consumption to the environment or are disposed of in landfills. Table 3-3 outlines the environmental fate of products from general sodium chloride use categories.

Dispersive losses of sodium chloride are those released to the environment directly after consumption. Examples include salt in run-off following highway deicing, effluents in industrial sewage, or salt released into the drinking water supply following water softening treatment. Sodium chloride can also be dispersed to the environment through use in dry cleaning compounds, perfume, gasoline additives, pharmaceuticals, and cosmetics. Products disposed of in landfills include those products brought to municipal sanitary landfills or toxic/hazardous landfills (Kostick, 1993).

Table 3-3: Environmental fate of post-consumer sodium chloride, 1990 (in millions of short tons)

Dispersive Losses		*Disposed to Landfill and Incineration*	
Chemicals–as waste effluent, sewage	12.5	Chemicals–plastics, glass, paper	8.7
Food–through excretion, assimilation	2.1	Food–discarded waste food	0.2
Industrial–as waste effluent, sewage	1.7	Industrial–rubber, textiles	0.4
Agriculture–through excretion, assimilation	2.3	Agricultural	0
Water treatment–through sewage	1.6	Water treatment	0
Deicing–runoff	11.3	Deicing	0
Other	3.2	Other	1.0
Total	34.7	Total	10.3

after Kostick, 1993

The environmental release of some potentially toxic sodium compounds, including sodium azide, sodium dicamba, sodium dimethyldithiocarbamate, sodium hydroxide, and sodium nitrite, is regulated by the TRI (USEPA, 2000b). The Toxic Release Inventory of hazardous chemicals was established by the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986. EPCRA is also sometimes known as SARA Title III. EPCRA mandates that larger facilities publicly report when TRI chemicals are released into the environment. This public reporting is required for facilities with more than 10 full-time employees that annually manufacture or produce more than 25,000 pounds, or use more than 10,000 pounds, of a TRI chemical (USEPA, 1996; USEPA, 2000a).

Facilities are required to report the pounds per year of TRI chemicals released into the environment both on- and off-site. Forty-two States reported releases of sodium azide, sodium dicamba, sodium dimethyldithiocarbamate, or sodium nitrite (1995-1998). Only AK, HI, ID, MT, NV, NM, ND, and VT reported no releases of any of these compounds. In 1988, all fifty States, Puerto Rico, the Virgin Islands, and American Samoa reported releases of sodium hydroxide (USEPA, 2000c). Sodium hydroxide, also known as caustic soda or lye, is used in such industries as pulp and paper, organic and inorganic chemical production, petroleum, soaps and detergents, water treatment, and textiles (Kostick, 1993). The compound is important because of its myriad of uses and its toxicity. In 1988, the TRI reported on- and off-site releases of sodium hydroxide totaling approximately 108 million pounds. The on-site quantity is subdivided into air emissions, surface water discharges, underground injections, and releases to land. Approximately thirteen million pounds of sodium hydroxide, or roughly 20% of total on-site releases, were discharged directly to surface water in 1988. The chemical was taken off of the TRI list in 1989 (USEPA, 2000c).

In conclusion, because sodium has so many human end uses and is abundant in the ocean, sodium is ubiquitous in the environment. Two sodium uses of particular significance to drinking water supplies are salt for highway deicing and salt for water softening treatment. Sodium chloride is the most economically and industrially important form of sodium, with an estimated 14,000 direct and indirect uses. The United States is the largest sodium chloride producing country in the world, with production quantities averaging 40 million metric tons from 1990-1998.

The disposal and release of sodium products to the environment is of great concern to drinking water supplies. Approximately 34.7 million short tons of sodium chloride were dispersed to the environment post-consumption in 1990, while roughly 10.3 million short tons were disposed of in landfills. The Toxic Release Inventory has reported releases of toxic sodium compounds like sodium azide, sodium dicamba, sodium dimethyldithiocarbamate, or sodium nitrite in 42 States. Sodium hydroxide, though listed as a TRI chemical only for reporting year 1988, had documented releases in all 50 States as well as Puerto Rico, the Virgin Islands, and American Samoa.

3.2 Ambient Occurrence

To understand the presence of a chemical in the environment, an examination of ambient occurrence is useful. In a drinking water context, ambient water is source water existing in surface waters and aquifers before treatment. The most comprehensive and nationally consistent data describing ambient water quality in the United States are being produced through USGS's National Water Quality Assessment (NAWQA) program. NAWQA, however, is a relatively young program and complete national data are not yet available from their entire array of sites across the nation.

3.2.1 Data Sources and Methods

The USGS instituted the NAWQA program in 1991 to examine water quality status and trends in the United States. NAWQA is designed and implemented in such a manner as to allow consistency and comparison between representative study basins located around the country, facilitating interpretation of natural and anthropogenic factors affecting water quality (Leahy and Thompson, 1994).

The NAWQA program consists of 59 significant watersheds and aquifers referred to as "study units." The study units represent approximately two thirds of the overall water usage in the United States and a similar proportion of the total population served by public water systems. Approximately one half of the nation's land area is represented (Leahy and Thompson, 1994).

To facilitate management and make the program cost-effective, approximately one third of the study units at a time are engaged in intensive assessment for a period of 3 to 5 years. This is followed by a period of less intensive research and monitoring that lasts between 5 and 7 years. In this way, all 59 study units rotate through intensive assessment over a ten-year period (Leahy and Thompson, 1994). The first round of intensive monitoring (1991-96) targeted 20 study units and the second round monitored another 16 beginning in 1994.

Sodium is an analyte for both surface and ground water NAWQA studies, with a Minimum Reporting Level (MRL) of 0.2 mg/L. Sodium occurrence in bed sediments is also assessed (MRL = 0.005%).

Sodium data from the first two rounds of intensive NAWQA monitoring have undergone USGS quality assurance checks and are available to the public through their NAWQA Data Warehouse (USGS, 2001). Occurrence results are presented below. The descriptive statistics generated from the sodium NAWQA data broadly characterize the frequency of sodium detections by sample and by site. Furthermore, detection frequencies above a benchmark level of 120 mg/L are also presented for all samples, and by site (see Section 3.3.1.4 for further discussion of this benchmark level and its development). The median and 99^{th} percentile concentrations are included as well to characterize the spread of sodium concentration values in ambient waters sampled by the NAWQA program.

3.2.2 Results

Typical of many inorganic contaminants, sodium occurrence in ambient surface and ground waters is high (Table 3-4). This is not surprising, considering that sodium is the sixth most abundant element in the Earth's crust, the most abundant anion in the hydrosphere, and is used in many products. Surface and ground water detection frequencies are similar, between 90% and 100% in all cases, though ground water detections are somewhat lower. Median sodium concentrations and benchmark exceedances are also similar between surface and ground water, but ground water benchmark exceedances are generally higher than surface water exceedances, while median concentrations are lower for ground water. The 99^{th} percentile concentrations are variable but are generally higher for ground water.

Table 3-4 illustrates that low-level sodium occurrence is ubiquitous. Surface water detection frequencies are 100% for all land use categories. Detection frequencies > 120 mg/L (by site) are similar for urban, mixed, and agricultural areas, while forest/rangeland areas show extremely low frequencies of benchmark exceedances. These results are understandable because forest/rangeland basins are not as affected by anthropogenic inputs of sodium (like agrochemical applications) as other land use categories.

Median concentrations for sodium in surface waters range from 4.7 mg/L in forest/rangeland areas to 21.9 mg/L in urban areas. The median level in urban basins is substantially higher than in other land use categories and may reflect the effects of road salt applications, more prevalent in areas with greater population densities. The 99th percentile concentrations are similar for all land use categories except for forest/rangeland areas, with a lower 99th percentile concentration. Simple detections and detections exceeding the benchmark by site, for all sites, are approximately 100% and 5.5%, respectively. These figures indicate that although sodium is ubiquitous in surface water, detection frequencies at levels exceeding the benchmark concentration level are relatively low.

For ground water, detections approach 100% of sites for all land use categories. Urban areas show the greatest median concentration and frequency of benchmark exceedances. Forest/rangeland areas show no detections greater than the benchmark, and exhibit the lowest median and 99th percentile values. These results suggest that urban and agricultural releases of sodium can leach to ground water, as forest/rangeland areas have such consistently low detection values. Detection frequencies above the MRL and the benchmark level for all sites are approximately 99.9% of sites and 7.5% of sites, respectively. Again, sodium detection frequencies in ground water at levels exceeding the benchmark concentration level are low compared to sodium occurrence.

Similar to surface and ground water, 100% of bed sediment sampling sites showed detections in all land use categories. Sodium concentrations in bed sediments are measured by the percent of sodium by weight in the sediment sample analyzed. The median concentrations range from 0.4% (forest/rangeland basins) to 0.8% (urban basins) and the 99th percentile concentrations range from 1.8% (forest/rangeland and agricultural) to 2.0% (urban). Again, similar to surface and ground waters, urban basins and forest/rangeland basins occupy the extremes of the concentration percentile spectrum. However, bed sediment concentration percentiles are generally comparable across land use types. The occurrence of sodium in stream sediments is pertinent to drinking water concerns because some desorption of the compound from sediments into water will occur through equilibrium reactions, although at very low rates.

Table 3-4: Sodium detections and concentrations in streams and ground water

	Detection frequency > MRL*		Detection frequency > 120mg/L**		Concentration (all samples; mg/L)	
	% samples	% sites	% samples	% sites	median	99th percentile
surface water						
urban	100 %	100 %	4.4 %	6.2 %	21.9	310
mixed	100 %	100 %	2.9 %	6.6 %	12.2	270
agricultural	100 %	100 %	4.6 %	6.0 %	11.0	330
forest/rangeland	100 %	100 %	0.1 %	0.5 %	4.7	97
all sites	100 %	100 %	3.6 %	5.5 %	11.0	298
ground water						
urban	90.7 %	99.7 %	9.3 %	11.0 %	13.2	410
mixed	93.1 %	100.0 %	6.4 %	6.8 %	9.7	502
agricultural	93.1 %	99.9 %	6.4 %	6.8 %	8.1	788
forest/rangeland	94.9 %	100.0 %	0.0 %	0.0 %	2.9	33
all sites	93.0 %	99.9 %	6.6 %	7.5 %	8.8	480

** The Minimum Reporting Level (MRL) for sodium in water is 0.2 mg/L.*
*** See Section 3.3.1.4 for a discussion of this benchmark level used to evaluate the occurrence data for sodium.*

3.3 Drinking Water Occurrence

3.3.1 Analytical Approach

3.3.1.1 National Inorganic and Radionuclide Survey (NIRS)

In the mid-1980s, EPA designed and conducted the National Inorganic and Radionuclide Survey (NIRS) to collect national occurrence data on a select set of radionuclides and inorganic chemicals being considered for National Primary Drinking Water Regulations. The NIRS database includes 36 inorganic compounds (IOCs) (including 10 regulated IOCs), 2 regulated radionuclides, and 4 unregulated radionuclides. Sodium was one of the 36 IOCs monitored.

The NIRS provides contaminant occurrence data from 989 community PWSs served by ground water. The NIRS does *not* include surface water systems. The selection of this group of PWSs was designed so that the contaminant occurrence results are statistically representative of national occurrence. Most of the NIRS data are from smaller systems (based on population served by the PWS) and each of these statistically randomly selected PWSs was sampled a single time between 1984 and 1986.

The NIRS data were collected from PWSs in 49 States. Data were not available for the State of Hawaii. In addition to being statistically representative of national occurrence, NIRS data are designed to be divisible into strata based on system size (population served by the PWS). Uniform detection limits were employed, thus avoiding computational (statistical) problems that sometimes result from multiple laboratory analytical detection limits. Therefore, the NIRS data can be used directly for national contaminant occurrence analyses with very few, if any, data quality, completeness, or representativeness issues.

3.3.1.2 Supplemental IOC Data

One limitation of the NIRS study is a lack of occurrence data for surface water systems. To provide perspective on the occurrence of sodium in surface water PWSs relative to ground water PWSs, SDWA compliance monitoring data that were available to EPA were reviewed from States with occurrence data for both ground and surface water.

The State ground water and surface water PWS occurrence data for sodium used in this analysis were submitted by States for an independent review of the occurrence of regulated contaminants in PWSs at various times for different programs (USEPA, 1999). In the USEPA (1999) review, occurrence data from a total of 14 States were noted. However, because several States contained data that were incomplete or unusable for various reasons, only 12 of the 14 States were used for a general overview analysis. From these 12 States, 8 were selected for use in a national analysis because they provided the best data quality and completeness and a balanced national cross-section of occurrence data. These eight were Alabama, California, Illinois, Michigan, Montana, New Jersey, New Mexico, and Oregon.

Only the Alabama, California, Illinois, New Jersey, and Oregon State data sets contained occurrence data for sodium. The data represent approximately 36,000 analytical results from more than 5,500 PWSs mostly during the period from1993 to 1997, though some earlier data are also included. The number of sample results and PWSs vary by State.

3.3.1.3 Data Management and Analysis

The data used in the State analyses were limited to only those data with confirmed water source and sampling type information. Only standard SDWA compliance samples were used; “special” samples, “investigation” samples (investigating a contaminant problem that would bias results), or samples of unknown type were not used in the analyses. Various quality control and review checks were made of the results, including follow-up questions to the States that provided data. Many of the most intractable data quality problems encountered occurred with older data. These problematic data were, in some cases, simply eliminated from the analysis. For example, when the number of problematic data were insignificant relative to the total number of observations they were dropped from the analysis (for further details see USEPA, 1999).

3.3.1.4 Occurrence Analysis

The summary descriptive statistics presented in Table 3-5 for sodium are derived from analysis of the NIRS data. Included are the total number of samples, the 99^{th} percentile concentration of all samples, and the median concentration of all samples. The percentages of PWSs and population served indicate the proportion of PWSs and PWS population served whose analytical results showed a detection(s) of the contaminant (simple detection, > MRL) at any time during the monitoring period; or a detection(s) greater than half the benchmark level; or a detection(s) greater than the benchmark level.

The benchmark level used to evaluate the occurrence information for sodium is 120 mg/L, which was derived from the National Research Council’s dietary guideline (NRC, 1989a) for adults of 2.4 g/day for sodium from sodium chloride (table salt). The Drinking Water Equivalent concentration is 1.2 g/L given a drinking water intake of 2 L/day. A Relative Source Contribution (RSC) of 10% was applied, giving rise to the benchmark of 120 mg/L ([2400mg/2L]* 0.10).

In Table 3-5, national occurrence is estimated by extrapolating the summary statistics for sodium to national numbers for systems, and population served by systems, from the *Water Industry Baseline Handbook, Second Edition* (USEPA, 2000d). From the handbook, the total number of ground water community water systems (CWSs) plus ground water non-transient, non-community water systems (NTNCWSs) is 59,440, and the total population served by ground water CWSs plus ground water NTNCWSs is approximately 85.6 million persons (see Table 3-5). To arrive at the national occurrence estimates, the national estimate for ground water PWSs (or population served by ground water PWSs) is simply multiplied by the percentage for the given summary statistic (e.g., the national estimate for the total number of ground water PWSs with detections (i.e., > MRL; 59,440) is the product of the percentage of ground water PWSs with detections (100%) and the national estimate for the total number of ground water PWSs (59,440)).

The nationally extrapolated occurrence estimates for sodium are not presented in the *Federal Register* Notice. While the NIRS data were collected in a statistically appropriate fashion suitable for extrapolation, the data available for many CCL regulatory determination priority contaminants were not a strict statistical sample. National extrapolations of these data can be problematic. Also, the NIRS data only represent ground water PWSs. Thus, national extrapolations from NIRS data do not represent national occurrence for all PWSs. Therefore, to maintain consistency across all CCL regulatory determination priority contaminants, a straight-forward presentation, and data integrity, only the actual occurrence results for all CCL regulatory determination priorities are presented in the *Federal Register* Notice for stakeholder review. The nationally extrapolated occurrence values for sodium are presented here, however, to provide additional perspective.

In Table 3-6, occurrence data on sodium directly submitted by the States of Alabama, California, Illinois, New Jersey, and Oregon for *A Review of Contaminant Occurrence in Public Water Systems* (USEPA, 1999) were used to augment the NIRS study which lacked surface water data. Included in the table are the same summary statistics as Table 3-5, with additional information describing the relative distribution of sodium occurrence between ground water and surface water PWSs in the 5 States.

The State data analysis was focused on occurrence at the system level because a PWS with a known contaminant problem usually has to sample more frequently than a PWS that has never detected the contaminant. The results of a simple computation of the percentage of samples with detections (or other statistics) can be skewed by the more frequent sampling results reported by the contaminated site. The system level of analysis is conservative. For example, a system need only have a single sample with an analytical result greater than the MRL, i.e., a detection, to be counted as a system with a result "greater than the MRL."

When computing basic occurrence statistics, such as the number, or percent, of samples, or systems, with detections of a given contaminant, the value (or concentration) of the MRL can have important consequences. For example, the lower the reporting limit, the greater the number of detections (Ryker and Williamson, 1999). As a simplifying assumption, a value of half the MRL is often used as an estimate of the concentration of a contaminant in samples/systems whose results are less than the MRL. However, for these occurrence data this is not straightforward. This is in part related to State data management differences as well as real differences in analytical methods, laboratories, and other factors.

The situation can cause confusion when examining descriptive statistics for occurrence. Because a simple meaningful summary statistic is not available to describe the various reported MRLs, and to avoid confusion, MRLs are not reported in the summary table (Table 3-6).

3.3.2 Results

The NIRS data in Table 3-5 show that approximately 100% of ground water PWSs (this extrapolates to all 59,440 systems nationally) had detections of sodium, affecting about 100% of the ground water PWS population served (approximately 85.6 million people nationally). Approximately 23% of the NIRS PWSs had detections greater than ½ the benchmark level of 120 mg/L (about 13,500 ground water PWSs nationally), affecting approximately 18.5% of the population served (estimated at 15.9 million people nationally). The percentage of NIRS PWSs with detections greater than the benchmark level of 120 mg/L was approximately 13% (about 8,000 ground water PWSs nationally), affecting 8.3% of the population served (estimated at approximately 7.1 million people nationally)

Drinking water data for sodium from the supplemental individual States vary among States (Table 3-6). Sodium monitoring has not been required under SDWA, though these States had obviously conducted some monitoring. Alabama, California, New Jersey, and Oregon have substantial amounts of data and PWSs represented. However, the number of systems with sodium data for Illinois is far less than the number of PWSs in this State. Hence, it is not clear how representative these data are. Because the NIRS data only represent sodium occurrence in ground water PWSs, the supplemental State data sets provide some perspective on surface water PWS occurrence.

For simple detections, the supplemental State data show a range from 99.3% to 100% of ground water PWSs (Table 3-6). These figures are comparable to the NIRS ground water PWS results: 100% greater than the MRL (Table 3-5). The supplemental State data show 100% simple detections for surface water PWSs. Comparisons made between data for simple detections need to be viewed with caution because of differences in MRLs between the State data sets and the NIRS study, and among the States themselves (see Section 3.3.1.4), though these numbers for sodium are very comparable. For further perspective, the median concentration of all samples for the NIRS data (16.4 mg/L) is bracketed by the range of median concentrations from the States' data (5.26 mg/L to 31 mg/L).

The supplemental State data sets indicate that ground water PWS detections greater than the benchmark level of 120 mg/L are between 3% and 15% (Table 3-6). The NIRS national average is within this range at 13.2% of PWS greater than the benchmark level of 120 mg/L (Table 3-5). As might be expected, surface water PWSs showed slightly fewer exceedances of the benchmark level than ground water PWSs, ranging from 0% - 3%.

Reviewing sodium occurrence by PWS population served shows that from 0.5% - 50% of the States' ground water PWS populations were served by systems with detections greater than the benchmark level of 120 mg/L (Table 3-6). However, the figure of 50% is the maximum among the supplementary States. Three of the 5 States show ground water PWS populations receiving more than 120 mg/L at percentages lower than that for NIRS, which is 8.3%. Populations served by surface water PWSs with detections greater than 120 mg/L ranged from 0% - 1.4% among the five supplemental States. Population figures for the supplemental States are incomplete and are only reported for those systems in the database that have reported their population data. For sodium, approximately 82% of the PWSs reporting occurrence data for these 5 States also reported population data.

Table 3-5: Sodium occurrence in ground water systems (NIRS survey)

Frequency Factors	Benchmark Level = 120 mg/L	National System & Population Numbers[1]
Total Number of Samples/Systems	989	59,440
99th Percentile Concentration (all samples)	517 mg/L	--
Median Concentration (all samples)	16.4 mg/L	--
Minimum Reporting Level (MRL)	0.91 mg/L[2]	--
Total Population	1,482,133	85,681,696
Occurrence by Samples/System		**National Extrapolation**
% Ground Water PWSs with detections (> MRL)	100%	59,440
Range of Cross-Section States	100%	N/A
% Ground Water PWSs > 60 mg/L (1/2 benchmark level)	22.6%	13,463
Range of Cross-Section States	0 - 100%	N/A
% Ground Water PWSs > 120 mg/L (benchmark level)	13.2%	7,873
Range of Cross-Section States	0 - 73.7%	N/A
Occurrence by Population Served		
% Ground Water PWS Population Served with detections	100%	85,682,000
Range of Cross-Section States	100%	N/A
% Ground Water PWS Population Served > 60 mg/L	18.5%	15,859,000
Range of Cross-Section States	0 - 100%	N/A
% Ground Water PWS Population Served > 120 mg/L	8.3%	7,147,000
Range of Cross-Section States	0 - 89.5%	N/A

[1] Total PWS and population numbers are from EPA's March 2000 Water Industry Baseline Handbook.

[2] Because all data reported for sodium were detections, the minimum value is presented here instead of the MRL for sodium.

Table 3-6: Occurrence summary of ground and surface water systems by State for sodium

Frequency Factors	Alabama	California	Illinois	New Jersey	Oregon
Total Number of Samples	1,327	27,494	383	4,417	2,319
Number of Ground Water Samples	917	25,111	313	3,941	1,506
Number of Surface Water Samples	410	2,383	70	476	813
Percent of Samples with Detections	99.3%	99.5%	100%	99.0%	98.8%
Percent of Ground Water Samples with Detections	99.0%	99.6%	100%	99.1%	98.8%
Percent of Surface Water Samples with Detections	99.8%	99.5%	100%	98.1%	100%
99^{th} Percentile Concentration (all samples)	260 mg/L	209 mg/L	370 mg/L	150 mg/L	166 mg/L
Median Concentration (all samples)	5.26 mg/L	31 mg/L	25 mg/L	14 mg/L	9.78 mg/L
Minimum Reporting Level (MRL)	Variable[1]	Variable[1]	Variable[1]	Variable[1]	Variable[1]
Total Number of PWSs	435	2,433	227	1,444	1,032
Number of Ground Water PWSs	366	2,214	160	1,411	863
Number of Surface Water PWSs	69	219	67	33	169
Total Population Served	3,662,222	45,375,106	1,995,394	6,350,025	2,101,401
Ground Water PWS Population Served	1,820,214	27,791,117	724,635	2,478,067	1,261,661
Surface Water PWS Population Served	1,837,743	30,740,138	1,270,179	3,871,958	1,497,224
Occurrence by System					
% PWSs with detections (> MRL)	100%	99.8%	100%	99.4%	99.4%
Ground Water PWSs with detections	100%	99.8%	100%	99.4%	99.3%
Surface Water PWSs with detections	100%	100%	100%	100%	100%
Benchmark Level = **120 mg/L**					
% PWSs > 1/2 Benchmark Level	22.3%	29.4%	19.4%	11.0%	10.5%
Ground Water PWSs > 1/2 Benchmark Level	26.2%	30.5%	26.3%	11.0%	11.7%
Surface Water PWSs > 1/2 Benchmark Level	1.5%	18.3%	3.0%	12.1%	4.1%
% PWSs > Benchmark Level	9.7%	11.4%	10.6%	3.6%	2.8%
Ground Water PWSs > Benchmark Level	11.5%	12.2%	15.0%	3.6%	3.1%
Surface Water PWSs > Benchmark Level	0.0%	2.7%	0.0%	3.0%	1.2%
Occurrence by Population Served					
% PWS Population Served with detections	100%	100%	100%	100.0%	100.0%
Ground Water PWS Population with detections	100%	100%	100%	99.9%	99.9%
Surface Water PWS Population with detections	100%	100%	100%	100%	100%
Benchmark Level = **120 mg/L**					
% PWS Population Served > 1/2 Benchmark Level	17.5%	76.5%	11.2%	13.7%	3.5%
Ground Water PWS Population > 1/2 Benchmark	33.2%	69.4%	30.2%	21.2%	4.6%
Surface Water PWS Population > 1/2 Benchmark	0.0%	77.2%	0.3%	8.9%	1.1%
% PWS Population Served > Benchmark Level	5.0%	33.3%	8.7%	1.8%	0.4%
Ground Water PWS Population > Benchmark Level	8.1%	49.4%	24.0%	4.3%	0.5%
Surface Water PWS Population > Benchmark Level	0.0%	1.4%	0.0%	0.2%	0.1%

[1] *See Section 3.3.1.4 for details*

3.4 Conclusion

The Toxic Release Inventory has reported releases of toxic sodium compounds like sodium azide, sodium dicamba, sodium dimethyldithiocarbamate, or sodium nitrite in 42 States. Sodium hydroxide, though only listed as a TRI chemical for reporting year 1988, had documented releases in all 50 States as well as Puerto Rico, the Virgin Islands, and American Samoa.

Low-level sodium occurrence in ambient waters and stream bed sediments monitored by the USGS NAWQA program is ubiquitous, approaching 100% of water and sediment sampling sites for all land use categories. Forest/rangeland basins show the lowest frequency of benchmark level exceedances, median concentrations, and 99^{th} percentile concentrations across all land use categories for ambient waters and bed sediments. Benchmark level exceedances, median, and 99^{th} percentile concentrations are generally similar for all other land use categories, although urban and agricultural basins sometimes exhibit higher levels. Although sodium detection frequencies are high in ambient waters and stream bed sediments, sodium occurrence at levels of public health concern is low.

Sodium has been detected in ground water PWS samples collected through the NIRS study. Occurrence estimates are high with 100% of samples showing detections affecting 100% of the national population served. The 99^{th} percentile concentration of all samples is 517 mg/L. At the benchmark level of 120 mg/L, 13.2% of the NIRS systems showed exceedances, affecting approximately 7.1 million people nationally.

Additional SDWA data from the States of Alabama, California, Illinois, New Jersey, and Oregon, including both ground water and surface water PWSs, were examined through independent analyses and also show substantial levels of sodium occurrence. These data provide perspective on the NIRS estimates that only include data for ground water systems. The supplemental State data show that all five States reported almost 100% detections in both ground water and surface water systems. At detections above the benchmark level of 120 mg/L, surface water PWS detection frequencies are generally lower than those for ground water. If national data for surface water systems were available, the occurrence and exposure estimates would be substantially greater than from NIRS alone.

4.0 HEALTH EFFECTS

A full description of the health effects associated with exposure to sodium are presented in *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on Sodium* (USEPA, 2003). A summary of the pertinent findings are presented below.

4.1 Hazard Characterization and Mode of Action Implications

Sodium is physiologically necessary for maintaining normal body fluid volume, blood pressure, and cell function. The major source of sodium generally comes from the intake of food, with only a small contribution from drinking water. Normal sodium level in the blood is about 154 mEq/L.

According to the National Research Council, the estimated minimum daily requirements for sodium are 120–225 mg for infants (0 months-1 year), 300-400 mg for children (2-9 years), and 500 mg for individuals 10 years and older (NRC, 1989a). Sodium requirements increase during pregnancy and lactation. The American Heart Association and the National Institutes of Health recommend that healthy adults restrict their sodium intake to no more than 2,400 mg/day in order to lower the risk of hypertension (AHA, 2000; NIH, 1993). Typically, the average sodium intake ranges from 3,500 to 4,500 mg/day (Karanja et al., 1999).

About 3% of the U.S. population is on sodium restricted diets. In general, sodium exposure is limited to levels of 250, 500, 1,000 or 2,000 mg/day in these diets. A no-added-salt diet restricts only foods that are high in sodium. However, these so called no-added-salt diets still average about 4,000 mg of sodium per day, indicating the abundance of sodium in the food supply (Cataldo and Whitney, 1986). Individuals on sodium restricted diets may need to consider the level of sodium in drinking water supply when planning their diet (Cataldo and Whitney, 1986).

Experimental studies performed on rats and human adults suggest a positive correlation between excessive sodium intake and hypertension (NAS, 1977; WHO, 1979; NIH, 1993). One study, based upon 10,079 subjects in 32 countries, reports an increase in systolic pressure of 2.2 mm Hg for every 2,300 mg increase in sodium intake (ICRG, 1988; Elliot et al., 1989). Extreme hypertension is associated with coronary artery disease and stroke (Stamler, 1991). In addition, high sodium intake may result in increased heart muscle thickness in response to increased blood pressure (Schmieder et al., 1988).

Despite consistent reports on adults, blood pressure and sodium intake reports on children are inconsistent. While some studies associate an increase in blood pressure with a high sodium diet (Calabrese and Tuthill, 1977, 1981; Tuthill and Calabrese, 1979), other studies fail to find a correlation (Pomrehn et al., 1983; Faust, 1982; Armstrong et al., 1982; Tuthill et al., 1980).

Earlier clinical trial studies have indicated that lower sodium intake does not yield convincing evidence for risk reduction of cardiovascular disease in populations with normal blood pressures (Muntzel and Drueke, 1992; Salt Institute, 2000; NIH, 1993; Callaway, 1994; Kotchen and McCarron, 1998; McCarron, 1998). However, results of the recent Dietary Approaches to Stop Hypertension (DASH) trials at Brigham and Women's Hospital suggest that restricted dietary intake of sodium is, in fact, beneficial for many people with hypertension (Harsha et al., 1999; Sacks et al., 2001). In addition to sodium restriction, lifestyle and dietary changes such as weight reduction, exercise, stress reduction, and adequate dietary potassium, calcium, and magnesium are effective non-medicinal treatments against hypertension. Limiting cholesterol, dietary fat, and alcohol intake is also recommended (Whitney et al., 1987).

While sodium salts are generally not considered acutely toxic to humans, acute effects and death have been reported in cases of very high sodium intake (RTECS, 2000; WHO, 1979). The effects of high sodium levels from ingestion appear to be more severe for infants than adults because infant kidneys are not yet able to process the sodium (Sax, 1975).

Data on the reproductive toxicity of sodium are sparse. In a study done on rats, excessive sodium chloride (1,570 mg sodium/kg body weight) caused fetal and maternal toxic effects. Maternal toxicity effects included decreased pregnancy rates and decreased body weight gain, while fetotoxic effects included high mortality rate (Karr-Dullien and Bloomquist, 1979). Developmental effects were observed only in a strain of rat pups bred to be hypertensive that were fed high sodium diets for up to 4 months after birth. No developmental effects in rat strains with normal blood pressure were noted in this study.

Although sodium is not considered carcinogenic, it may influence genotoxic events, thus increasing the likelihood of tumor development. High oral doses of sodium chloride in the presence of carcinogens may cause damage to the gastrointestinal tract and lead to an increase in DNA synthesis and cell regeneration. Gastric tumors could, therefore, be a potential adverse health effect (Tatematsu et al., 1975; NRC, 1989b; Takahashi et al., 1983).

4.2 Dose-Response Characterization and Implications in Risk Assessment

Although numerous human studies have examined sodium intake and blood pressure effects, they cannot serve to characterize dose-response relationships. First, the results are inconsistent; second, the sodium intake measurements are indirect (as determined by the amount of sodium excreted in the urine); and third, the results are influenced by other factors such as nutrients in the diet, lifestyle, and behavioral patterns rather than sodium itself (Muntzel and Drueke, 1992; Salt Institute, 2000; NIH, 1993; Callaway, 1994; Kotchen and McCarron, 1998; McCarron, 1998).

Dose-response data are controversial. As noted above, the American Heart Association recommends that healthy adults restrict their sodium intake to 2,400 mg/day (2000). In the DASH study, sodium sensitive individuals who reduced their sodium intake by 2,300 mg/day from average levels of 3,500**S**4,500 mg/day lowered their systolic blood pressure by 3.7 mm Hg (compared to 1 mm Hg in normal individuals). Furthermore, hypertensive individuals that increase dietary calcium, potassium, magnesium, and fiber (by following the high fruit and vegetable DASH diet), but do not change sodium levels, achieve similar reductions in systolic pressure (Harsha et al., 1999). A combination of the DASH diet with sodium restriction yields additional reductions in blood pressure among hypertensive and normotensive subjects (Sacks et al., 2001). Thus, dose-response effects are difficult to characterize because they are population and lifestyle dependent.

4.3 Relative Source Contribution

Food is the principle source of exposure to sodium. Of the total amount of sodium present in food, only a relatively low amount (10%) is naturally occurring (Sanchez-Castillo et al., 1987a,b). The majority of dietary sodium comes from sodium chloride that is added during food processing and preparation. Sanchez-Castillo et al. estimate that 15% of dietary sodium comes from salt added during cooking and at the table, whereas 75% is from salt added during food processing and manufacture (1987a,b). The first National Health and Nutrition Examination Survey reported that approximately 32% of the sodium chloride consumed comes from baked goods and cereals, 21% from meats, and 14% from dairy products (Abraham and Carroll, 1981). Using data from a two-year dietary survey, Subar et al. found that 23.4% of the dietary salt intake comes from table salt and processed foods such as cold cuts and other processed meats, condiments, and snack foods (i.e. chips, popcorn; 1998). Yeast breads provide 10.9% of the sodium, cheese, 5.6%, and ham, 4.1%. Together, these foods contribute 44.1% of total sodium intake.

Reported dietary intakes of sodium from various studies range from 1,800 mg/day to 5,000 mg/day, depending on the methods of assessment used (Abraham and Carroll, 1981; Dahl, 1960; Pennington et al.; 1984, Karanja et al., 1999; Kurtzweil, 1995). The amount of discretionary sodium intake is highly variable and can be quite large. The Food and Drug Administration found that most American adults tend to eat between 4,000 and 6,000 mg of sodium/day, while individuals on a sodium-restricted diet usually ingest less than 1,000 to 3,000 mg/day (Kurtzweil, 1995). In the assessment of pretreatment diets for the participants in the DASH trials, sodium levels range from about 3,500 to 4,500 mg/day (Karanja et al., 1999).

If the relative source is calculated from the median value for sodium in drinking water (16 mg/L) using 4,000 mg sodium/day as a baseline for dietary sodium and 2 L/day as a water intake, drinking water contributes only 0.8% of the total dietary sodium. If the relative source is calculated from the 99th percentile value (about 500 mg/L), drinking water contributes 25% of the daily sodium. If the 2.4 g/day recommended intake is used as a baseline, systems at the median concentration contribute 1.3% of the recommended intake, but systems at the 99th percentile contribute 41.6% of the total. Habitual intake of 2 L of water per day at this concentration is not advisable. However, the palatability of the water could be adversely affected by high sodium concentration, which would likely diminish total water intake and lead to corrective measures.

4.4 Sensitive Populations

Populations expected to have an increased sensitivity to sodium include infants/children, individuals with hypertension, the elderly (blood pressure increases with age), African Americans (the incidence of hypertension is disproportionally high among African Americans) and individuals with renal diseases.

Several studies indicate that younger children are more sensitive to high sodium levels than are adults (Elton et al. 1963; Gauthier, 1969; DeGenaro and Nyhan, 1971). This heightened sensitivity is associated with the immature kidney's decreased ability to control sodium levels. On a mg sodium per kg body weight basis, however, the sodium requirement for infants and children is greater than for adults (NRC, 1989a).

The elderly are also more sensitive to high sodium exposure because they have a higher incidence of cardiovascular disease (including hypertension) than younger subjects (Sowers and Lester, 2000). In addition, since the elderly tend to have a higher taste threshold for salt, they may also have a higher dietary salt intake (Hyde and Feller, 1981; Stevens, 1996). African-Americans, in particular, are more susceptible to sodium-induced adverse health effects because of high incidence of hypertension (Sullivan, 1991; Svetkey et al., 1996).

Individuals with decreased renal function comprise another group that is sensitive to high sodium intake. One study demonstrates that 4,600 mg/day of sodium chloride significantly elevates systolic blood pressure in patients with chronic renal failure (Muntzel and Drueke, 1992). In addition, Muntzel and Drueke postulated that abnormal kidney function is a factor in salt retention by salt-sensitive individuals. Sodium retention has also been reported in rats given high doses of sodium chloride, following partial nephrectomy (Muntzel and Drueke, 1992). Dietary sodium restrictions are recommended for individuals with acute or chronic renal problems and for those with nephrotic syndrome (Whitney, et al. 1987). Renal problems are associated with about 10% of the population with hypertension (Whitney, et al. 1987).

Among the sodium-sensitive population, dietary restrictions alone are insufficient for preventing adverse heath effects that result from high sodium levels. Programs for hypertensives include weight reduction, exercise, stress reduction, and adequate dietary potassium, calcium, and magnesium, in addition to sodium restriction. As mentioned earlier, limiting cholesterol, dietary fat, and alcohol intake is also recommended. At blood pressures over 95/160 mm Hg (diastolic/systolic), diet and behavior modification are often combined with pharmaceutical measures.

4.5 Exposure and Risk Information

While nearly the entire public water system population is exposed to sodium through their drinking water, only about 7 million, or 8%, are exposed to water at concentrations above the 120 mg/L benchmark, a level that comprises about 10% of the dietary guideline for sodium. The dietary guideline level, however, is habitually exceeded by most of the U.S. population by 1,100 to 2,100 mg/day (Abraham and Carroll, 1981; Dahl, 1960; Pennington et al., 1984; Karanja et al., 1999; Kurtzweil, 1995).

4.6 Conclusion

Despite the evidence that sodium may have adverse health effects in humans by contributing to hypertension, data from studies indicate that the most effective hypertension reduction programs do not involve supplementation or restriction of a single element. Instead, a well balanced, nutritionally sound diet combined with other behavioral changes such as exercise and stress reduction are the most effective measures. In addition, since sodium levels in drinking water are usually low, water from public water systems is unlikely to significantly contribute to adverse health effects. For these reasons, regulation may not present a meaningful opportunity for health risk reduction for persons served by public drinking water systems. However, the EPA may issue a Drinking Water Advisory to provide guidance to communities that may be exposed to drinking water contaminated with sodium chloride or other sodium salts. All CCL regulatory determinations and further analysis are formally presented in the *Federal Register* Notices (USEPA, 2002a; 67 FR 38222; and USEPA, 2003a; 68 FR 42898).

5.0 TECHNOLOGY ASSESSMENT

If a determination has been made to regulate a contaminant, SDWA requires development of proposed regulations within 2 years of making the decision. It is critical to have suitable monitoring methods and treatment technologies to support regulation development according to the schedules defined in the SDWA.

5.1 Analytical Methods

The availability of analytical methods does not influence EPA's determination of whether or not a CCL contaminant *should* be regulated. However, before EPA actually regulates a contaminant and establishes a Maximum Contaminant Level (MCL), there must be an analytical method suitable for routine monitoring. Therefore, EPA needs to have approved methods available for any CCL regulatory determination contaminant before it is regulated with an NPDWR. These methods must be suitable for compliance monitoring and should be cost effective, rapid, and easy to use. Sodium can be measured by well-documented analytical methods (see Table 5-1).

Table 5-1: Analytical methods for sodium

Method	Type	Method Detection Limit (µg/L)
EPA 200.7	Inductively Coupled Plasma Optical Emission Spectroscopy (ICP)/Atomic Emission Spectrometry	30
SM 3111 B	Atomic Absorption (AA), Direct Aspiration	IDL 2 Optimum concentration range 30-1000

5.2 Treatment Technology

Because sodium is being dealt with through guidance, treatment technologies have not been reviewed.

6.0 SUMMARY AND CONCLUSIONS - DETERMINATION OUTCOME

Three statutory criteria are used to guide the determination of whether regulation of a CCL contaminant is warranted: 1) the contaminant may adversely affect the health of persons; 2) the contaminant is known or is likely to occur in public water systems with a frequency, and at levels, of public health concern; and 3) regulation of the contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems. As required by SDWA, a decision to regulate a contaminant commits the EPA to propose a Maximum Contaminant Level Goal (MCLG) and promulgate a National Primary Drinking Water Regulation for the contaminant. A decision not to regulate a contaminant is considered a final Agency action and is subject to judicial review. The Agency can choose to publish a Health Advisory (a nonregulatory action), or other guidance for any contaminant on the CCL, that does not meet the criteria for regulation.

The weight of evidence favors the conclusion that sodium concentrations greater than 120 mg/L can have an effect on blood pressure, especially for sodium-hypertensives. Hypertension affects almost 50 million people in the United States. Control of body weight, adequate intake of nutrients such as potassium, calcium and magnesium, sodium restriction, exercise, and stress all influence blood pressure. In addition to hypertension, cholesterol, dietary fat and alcohol intake are risk factors for cardiovascular problems.

Sodium is known to occur in nearly all public water systems and, in a few cases, at levels of public health concern for salt-sensitive hypertensives (greater than 120 mg/L). However, these concentrations exceed the taste threshold of 30 mg/L and affected consumers would likely reduce their intake and implement corrective measures.

Based on available monitoring data, 7.1 million people are exposed to sodium at levels above the benchmark level of 120 mg/L, a concentration that would provide about 10% of the dietary guideline for sodium. The majority of sodium intake is from salt added to food during processing or preparation. An estimate of daily sodium intake in American diets, and median sodium concentrations in water, show that water contributes only 0.8% of the total dietary sodium. Sensitive populations include the elderly, because blood pressure increases and taste sensitivity to salt decreases with age, infants and children, and African Americans. Sodium may have a stronger effect on hypertensive individuals with renal disease. Those with normal blood pressure may be influenced by sodium to a lesser extent. Blood pressure is influenced more by nutrients in the diet, lifestyle, and behavioral patterns rather than by sodium intake.

In conclusion, sodium generally occurs at low levels in drinking water, and when it occurs at high levels the taste may be expected to cause people to reduce their consumption. In addition, drinking water is only a minor source of dietary sodium compared with food, and sodium is only one factor among many that contributes to hypertension and heart disease. Therefore, regulation of sodium in drinking water is unlikely to represent a meaningful opportunity for health risk reduction. The most effective means to protect the health of PWS users is to identify groups who are more sensitive than the general population, and provide dietary guidance through the public health community. The EPA may issue an advisory to provide guidance to communities that may be exposed to elevated concentrations of sodium chloride or other sodium salts in their drinking water. The advisory would provide appropriate cautions for individuals on low-sodium or sodium-restricted diets. In addition, EPA presently requires periodic monitoring of sodium at the entry point to the distribution system. This requirement provides the public health community with information on sodium levels in drinking water to be used in counseling patients and is the most direct route for gaining the attention of the affected population. All CCL regulatory determinations are formally presented in the *Federal Register* Notices (USEPA, 2002a; 67 FR 38222; and USEPA, 2003a; 68 FR 42898).

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Appendix A: Abbreviations and Acronyms

AA	- atomic absorption
CAS	- Chemical Abstract Service
CCL	- Contaminant Candidate List
CDC	- Center for Disease Control and Prevention
CERCLA	- Comprehensive Environmental Response, Compensation & Liability Act
CWS	- community water system
DWEL	- drinking water equivalent level
EPA	- Environmental Protection Agency
EPCRA	- Emergency Planning and Community Right-to-Know Act
FIFRA	- Federal Insecticide, Fungicide, and Rodenticide Act
FQPA	- Food Quality Protection Act
FR	- Federal Register
g/mol	- grams per mole
GW	- ground water
HA	- Health Advisory
HAL	- Health Advisory level
HRL	- Health Reference Level
ICP	- inductively coupled plasma
ICRG	- Intersalt Cooperative Research Group
IDL	- instrument detection level
IOC	- inorganic compound
MCL	- maximum contaminant level
MCLG	- maximum contaminant level goal
mEq/L	- milliequivalent per liter
mg	- milligram
mg/kg-day	- milligram per kilogram per day
mm Hg	- millimeter mercury
MRL	- minimum reporting level
Na	- sodium
NaCl	- sodium chloride (salt)
NAS	- National Academy of the Sciences
NAWQA	- National Water Quality Assessment Program
NDWAC	- National Drinking Water Advisory Council
NIH	- National Institutes for Health
NIRS	- National Inorganic and Radionuclide Survey
nm	- nanometer
NPDWR	- National Primary Drinking Water Regulation
NRC	- National Research Council

NTNCWS	- non-transient non-community water system
OGWDW	- Office of Ground Water and Drinking Water
PGWD	- Pesticides in Ground Water Database
pH	- the negative log of the concentration of H^+ ions
ppm	- part per million
PWS	- public water system
RCRA	- Resource Conservation and Recovery Act
RTECS	- Registry of Toxic Effects of Chemical Substances
SARA	- Superfund Amendments and Reauthorization Act
SDWA	- Safe Drinking Water Act
SDWIS/FED	- Federal Safe Drinking Water Information System
SOC	- synthetic organic compound
SW	- surface water
TRI	- Toxic Release Inventory
UCM	- Unregulated Contaminant Monitoring
UCMR	- Unregulated Contaminant Monitoring Regulation/Rule
USEPA	- United States Environmental Protection Agency
USGS	- United States Geological Survey
VOC	- volatile organic compound
µg	- micrograms
>MCL	- percentage of systems with exceedances
>MRL	- percentage of systems with detections