



Contaminant Candidate List Regulatory Determination Support Document for Manganese

**Contaminant Candidate List
Regulatory Determination Support Document
for Manganese**

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**CONTAMINANT CANDIDATE LIST
REGULATORY DETERMINATION SUPPORT DOCUMENT
FOR MANGANESE**

EXECUTIVE SUMMARY

Manganese was a 1998 Contaminant Candidate List (CCL) regulatory determination priority contaminant. Manganese 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 manganese 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* (FR) Notice (USEPA, 2002; 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 manganese, 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 the three statutory criteria.

Manganese is a naturally occurring element that is a component of over 100 minerals. Of the heavy metals, it is surpassed in abundance only by iron (Agency for Toxic Substances and Disease Registry (ATSDR), 1997). Because of the natural release of manganese into the environment by the weathering of manganese-rich rocks and sediments, manganese occurs ubiquitously at low levels in soil, water, air, and food. In the United States, most manganese ore is smelted to produce ferromanganese, which is a manganese-iron alloy (ATSDR, 1997). The latter is used primarily in the production of steel to improve stiffness, hardness, and strength. Other manganese compounds are produced through reactions of various elements and compounds with either manganese ores or ferromanganese (ATSDR, 1997). Some common manganese compounds include manganese chloride, manganese sulfate, manganese (II, III) oxide, manganese dioxide, and potassium permanganate (see Table 2-1). These

compounds are used in a variety of products and applications including water and wastewater treatment, matches, dry-cell batteries, fireworks, fertilizer, varnish, livestock supplements, and as precursors for other manganese compounds (ATSDR, 1997). Releases of manganese to the environment, reported through the Toxic Release Inventory (TRI), are widespread.

Neither manganese nor any manganese compounds are regulated in drinking water. However, a non-enforceable guidance level for aesthetic quality, a Secondary Maximum Contaminant Level (SMCL) of 0.05 mg/L, does exist for manganese (ATSDR, 1997). Manganese and manganese compounds are regulated and/or monitored by other federal programs, including the National Pollution Discharge Elimination System (NPDES), the Clean Air Act Hazardous Air Pollutants list, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the TRI. Other federal agencies and organizations have issued recommendations for occupational exposure.

Low-level manganese 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, with detections approaching 100% of surface water sites and greater than 62% of ground water sites. Stream bed sediments and aquatic biota tissues show detections of 100%, by sample and by site. Urban basins generally have more surface and ground water manganese detections that are greater than the health reference level (HRL) of 0.30 mg/L than basins in other land use categories. Higher median and 99th percentile concentrations are also typical in urban basins. Although manganese detection frequencies are high in ambient waters, stream bed sediments, and aquatic biota tissue, manganese occurrence at levels of public health concern is low.

Manganese has also been detected in ground water public water systems (PWSs) samples collected through the National Inorganic and Radionuclide Survey (NIRS). Occurrence estimates are relatively high with approximately 68% of all samples showing detections, affecting about 55% of the national population served. Only about 3% of the NIRS systems, however, showed occurrence levels exceeding the HRL of 0.30 mg/L, affecting approximately 2.3 million people nationally. Additional data from ground water and surface water PWSs from select States were examined through independent analyses and also show substantial low-level manganese occurrence.

There is evidence that manganese may have adverse health effects in humans at high doses through inhalation, most importantly as a neurotoxin (producing ataxia, or coordination impairment, anxiety, dementia, a "mask-like" face, involuntary movements, or a syndrome similar to Parkinson's disease). Nevertheless, oral exposure at levels common in Western diets is not known to produce adverse health effects. In addition, because manganese is an essential nutrient, concern over potential toxic effects from high oral exposure must be balanced against concern for adverse effects from manganese deficiency. The level of manganese detected in PWSs is far below the average daily intake of manganese through non-water sources.

Because manganese is generally not considered to be very toxic when ingested with the diet, and since drinking water accounts for a relatively small proportion of manganese intake, regulation would not likely present a meaningful opportunity for health risk reduction for persons served by PWSs.

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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 United States Environmental Protection Agency's (EPA) regulatory determination for manganese. Information regarding manganese'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, 1998b; 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 five 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 twenty-four months, and promulgated by eighteen months later. EPA has determined that there is sufficient information to support a regulatory determination for manganese.

1.3 Statutory History of Manganese

While neither manganese nor any of its compounds are regulated in drinking water, a non-enforceable guidance level for aesthetic quality, a Secondary Maximum Contaminant Level (SMCL) of 0.05 mg/L, does exist (ATSDR, 1997). Also, manganese and manganese compounds are regulated and/or monitored by other federal programs. The discharge of manganese to surface waters is regulated as total manganese under the National Pollution Discharge Elimination System (NPDES) (ATSDR, 1997). Both manganese and manganese compounds are listed as a Hazardous Air Pollutants under Section 112(b) of the Clean Air Act and subject to Best Available Control Technology limits (USEPA, 2000f). Also, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or “Superfund”) includes manganese compounds as hazardous substances, although no reporting thresholds are assigned to this broad class (USEPA, 1998a). Manganese is also a Toxic Release Inventory (TRI) chemical. The TRI was established by the Emergency Planning and Community Right-to-Know Act (EPCRA), which requires certain industrial sectors to publicly report the environmental release or transfer of chemicals included in this inventory.

Finally, manganese and some of its compounds are listed as air contaminants by the Occupational Safety and Health Administration (OSHA). This listing establishes different permissible exposure limits (PELs) for various manganese compounds to regulate workplace exposure (ATSDR, 1997).

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 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; (2) the actual and estimated national percent of PWSs with detections above the health reference level; 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 and the national population exposed above the health reference level.

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.

For each contaminant EPA estimated the number of PWSs with detections $> \frac{1}{2}$ HRL and $>$ HRL, the population served at these benchmark 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 Unregulated Contaminant Monitoring (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., National Water Quality Assessment (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 manganese with an NPDWR. This decision is based on the finding that since the toxicity of manganese by oral ingestion is low, regulation of manganese in drinking water may not present a meaningful opportunity for health risk reduction for persons served by public water systems. All CCL regulatory determinations and further analysis are formally presented in the *Federal*

Register Notices (USEPA, 2002; 67 FR 38222, and USEPA, 2003a; 68 FR 42898). The following sections summarize the data used by the Agency to reach its decision.

2.0 CONTAMINANT DEFINITION

Manganese is a naturally occurring element that constitutes approximately 0.1% of the earth's crust. It does not occur in the environment in its pure metal form, but is ubiquitous as a component of over 100 minerals including many silicates, carbonates, sulfides, oxides, phosphates, and borates (ATSDR, 1997). It occurs ubiquitously naturally at low levels in soil, water, air, and food. Of the heavy metals, manganese is surpassed in abundance only by iron (ATSDR, 1997).

Manganese compounds are also produced in the United States through a variety of industrial processes. Manganese ore is commonly smelted to produce ferromanganese, which is a manganese-iron alloy (ATSDR, 1997). Other manganese compounds produced through reactions of various elements and compounds with either manganese ores or ferromanganese include manganese chloride, manganese sulfate, manganese (II, III) oxide, manganese dioxide, and potassium permanganate (ATSDR, 1997).

2.1 Physical and Chemical Properties

Table 2-1 lists summary information regarding the physical and chemical properties of manganese and a few of its important compounds. Also included are the Chemical Abstract Service (CAS) Registry Numbers and molecular formulas.

2.2 Environmental Fate/Behavior

The environmental fate and behavior of manganese depends upon the form found in, or released into, the environment, and the physical and chemical characteristics of the environment itself. Some generalities can be made, however, regarding its behavior in air, water, and soil.

Naturally occurring manganese and its compounds, as well as anthropogenically released manganese, do not evaporate. However, manganese and its compounds do enter the air as particulate matter through soil erosion and industrial emissions. The half-life of airborne particulate matter is on the order of days with the smallest particles capable of longer suspension times. Removal of particulate matter is largely through dryfall, but some is removed by precipitation (ATSDR, 1997).

The transport and partitioning of naturally occurring and anthropogenically released manganese in water depends upon the solubility of the compound(s) present, which in turn depends upon the Eh

(oxidation-reduction potential), pH, and the anions available in solution. Ionic manganese is positively charged (Mn^{2+}). Manganese is also transported in water as suspended sediment (ATSDR, 1997).

Some of the common manganese compounds are insoluble, but a number of them have low to moderate solubility (Table 2-1). Though manganese can exist in water in any of four oxidation states, Mn(II) is the most common and is usually associated with the carbonate anion (CO_3^{2-}) to form MnCO_3 . This compound has a relatively low solubility at 65 mg/L (ATSDR, 1997). Manganese may be oxidized at high pH or Eh and is also subject to microbial activity (ATSDR, 1997).

The mobility of soluble manganese in soil depends upon the cation exchange capacity (CEC) of the soil and the amount of soil organic matter. A soil with high CEC and rich in organic matter has an abundance of negatively charged particles to attract manganese cations. These reactions form various manganese oxides. These oxides are themselves important adsorption sites for other metals (Drever, 1988). Manganese can adsorb to other oxides through ligand exchange reactions (ATSDR, 1997).

At low concentrations, manganese cations that react with negatively charged particles in the soil (i.e., organic matter, clay) may not be readily released. Also, the oxidation state of manganese may be altered by microbial activity (ATSDR, 1997).

3.0 OCCURRENCE AND EXPOSURE

This section examines the occurrence of manganese in drinking water. While no complete national database exists of the occurrence of unregulated or regulated contaminants in drinking water from public water systems 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 manganese are also estimated, and the occurrence data are examined for 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 manganese, is also reviewed.

3.1 Occurrence

3.1.1 Use and Environmental Release

In the United States, most manganese ore is smelted to produce ferromanganese which is a manganese-iron alloy (ATSDR, 1997). The latter is used primarily in the production of steel to improve stiffness, hardness, and strength. The ore is mined in open pit or shallow underground mines, though little has been mined in the U.S. since 1978 (ATSDR, 1997; USGS, 2000). Almost all of the

Table 2-1: Physical and chemical properties

Identification						
	<i>manganese</i>	<i>manganese chloride</i>	<i>manganese sulfate</i>	<i>manganese (II, III) oxide</i>	<i>manganese dioxide</i>	<i>potassium permanganate</i>
CAS number	7439-96-5	7773-01-5	7785-87-7	1317-35-7	1313-13-9	7722-64-7
Molecular Formula	Mn	MnCl ₂	MnSO ₄	Mn ₃ O ₄	MnO ₂	KMnO ₄
Physical and Chemical Properties						
Boiling Point	1,962 °C	1,190 °C	850 °C (decomposes)	no data	no data	no data
Melting Point	1,244 °C	650 °C	700 °C	1,564 °C	loses oxygen at 535 °C	< 240 °C (decomposes)
Molecular Weight	54.94 g/mol	125.85 g/mol	151.00 g/mol	228.81 g/mol	86.94 g/mol	158.04 g/mol
Log K _{oc}	no data	no data	no data	no data	no data	no data
Log K _{ow}	no data	no data	no data	no data	no data	no data
Water Solubility	decomposes	723 g/L at 25 °C	520 g/L at 5 °C	insoluble	insoluble	63.8 g/L at 20 °C
Vapor Pressure	1 mmHg at 1,292 °C	10 mmHg at 778 °C	no data	no data	no data	no data
Henry's Law Constant	no data	no data	no data	no data	no data	no data

after ATSDR, 1997

manganese ore used in steel production in the U.S. is imported (see Table 3-1; ATSDR, 1997). Large quantities of ferromanganese are imported as well (USGS, 2000). Table 3-2 provides further information, by State, of the widespread manufacture and processing of manganese.

Table 3-1: Imports of manganese and ferromanganese to the U.S. (thousand metric tons, gross weight)

	1984	1988	1995	1996	1997	1998	1999 [†]
manganese ore	308	499	394	478	355	332	535
ferromanganese	—	—	310	374	304	339	325

years 1984 and 1988: ATSDR, 1997

years 1995 to 1999: USGS, 2000

[†] estimated

Manganese compounds are produced through reactions of various elements and compounds with either manganese ores or ferromanganese (ATSDR, 1997). Some common manganese compounds include manganese chloride, manganese sulfate, manganese (II, III) oxide, manganese dioxide, and potassium permanganate (ATSDR, 1997). Usage of these compounds are varied, implying widespread environmental release. Significantly, approximately 80% of the potassium permanganate used in the U.S. is expended in wastewater and drinking water. Manganese dioxide is used in the production of matches, dry-cell batteries, fireworks, and as a precursor for other manganese compounds. Manganese chloride is also used as a precursor for other manganese compounds. A large proportion (60%) of U.S. manganese sulfate is used as a fertilizer, while the remainder is used in varnish, fungicides, and as a livestock supplement. An organic manganese compound, methylcyclopentadienyl manganese tricarbonyl (MMT), was used as an anti-knock additive in unleaded gasoline before it was banned in 1977. However, a 1995 court decision required EPA to re-register MMT and this process is ongoing (ATSDR, 1997).

3.1.2 Environmental Release

Manganese is listed as a TRI chemical. In 1986, the Emergency Planning and Community Right-to-Know Act (EPCRA) established the TRI of hazardous chemicals. Created under the Superfund Amendments and Reauthorization Act (SARA) of 1986, EPCRA is also sometimes known as SARA Title III. The 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, 2000d).

Under these conditions, facilities are required to report the pounds per year of manganese released into the environment both on- and off-site. The on-site quantity is subdivided into air emissions, surface water discharges, underground injections, and releases to land (see Table 3-3). For manganese, releases to land constitute most of the on-site releases, with an abrupt decrease occurring in 1989. It is unclear whether this sharp decrease is real or a function of changes in TRI reporting requirements in the late 1980s and early 1990s (see discussion below). Land releases have fluctuated modestly since that year with no trend evident. Air emissions are also an important mode of on-site release. Though the first four years of record for air emissions are markedly higher, no trend is apparent for the remainder. Surface water discharges and underground injection are less significant on-site releases, with underground injections sharply decreasing in 1994. Low levels of underground injection have continued to the present. Off-site releases of manganese are considerable. Though in 1990 there is a large drop when compared to previous years, the late 1990s show a steady increase in pounds released. These TRI data for manganese were reported from 49 States with the exception of Alaska and Puerto Rico (USEPA, 2000b).

TRI data are also available for the release of manganese compounds (Table 3-4). Releases to land again constitute the largest proportion of on-site releases. With the exception of 1997 and 1998, releases to land have generally decreased over the period of record. Air emissions are also an important mode of release and no trend is evident in the data. Significantly, surface water discharges and underground injections are much more important for the compounds than for elemental manganese, and have been generally increasing (dramatically in some years) since the early 1990s.

Increases in surface water discharges and underground injections have contributed to increases in total on- and off-site releases in recent years. The latter have returned to, or exceeded, the higher levels seen in the late 1980s and early nineties. Off-site releases, a large component of total releases, are also at their highest levels since reporting began in 1988. These TRI data for manganese compounds were reported from all 50 States (USEPA, 2000b).

Although the TRI data can be useful in giving a general idea of release trends, it is far from exhaustive and has significant limitations. For example, only industries that meet TRI criteria (at least 10 full-time employees and manufacture and processing of quantities exceeding 25,000 lbs/yr, or use of more than 10,000 lbs/yr) are required to report releases. These reporting criteria do not account for releases from smaller industries. Threshold manufacture and processing quantities also changed from 1988-1990 (dropping from 75,000 lbs/yr in 1988 to 50,000 lbs/yr in 1989 to its current 25,000 lbs/yr in 1990) possibly creating misleading data trends. Finally, the TRI data is meant to reflect releases and should not be used to estimate general exposure to a chemical (USEPA, 2000c; USEPA, 2000a).

Table 3-2: Manganese manufacturers and processors by State

State ^a	Number of facilities	Range of maximum amounts on site in thousands of	Activities and uses ^c
AL	23	0-50,000	1,2,3,4,5,6,7,8,9,11,12,13
AR	15	0-1,000	1,2,3,4,5,7,8,9,10,11,12,13
AZ	2	1-100	1,2,3,4,5,6,7,8,9
CA	39	0-1,000	1,2,3,4,5,6,7,8,9,10,11
CO	12	0-100	2,3,4,9,10
CT	11	0-1,000	1,5,7,9
FL	11	1-1,000	1,5,8,9,10,13
GA	20	0-1,000	1,2,3,5,7,8,9,10,12
HI	1	1-10	2,3,8,13
IA	32	1-10,000	1,2,3,4,5,7,8,9,12
ID	1	10-100	1,4
IL	71	0-10,000	1,2,3,4,5,6,7,8,9,10,11,12
IN	63	0-10,000	1,3,4,5,6,7,8,9,10,11,12,13
KS	4	0-1,000	1,5,7,8,9
KY	29	0-10,000	1,2,3,4,5,6,7,8,9,10,12,13
LA	5	0-1,000	1,2,3,5,6,7,8,9,13
MA	17	0-1,000	8,9,10,12
MD	9	0-1,000	1,2,3,4,6,8,9,10,12
ME	7	1-1000	7,9,13
MI	62	0-50,000	1,2,3,4,5,7,8,9,10,11,12,13
MN	12	0-1,000	1,3,5,8,9,10,12,13
MO	27	0-1,000	1,2,3,5,7,8,9,12,13
MS	7	1-100	8,9
NC	24	0-1,000	1,2,3,5,8,9,10,12
ND	1	10-100	1,5,9,11
NE	10	0-50,000	1,2,3,5,8,9,10,12
NH	7	0-100	8,9,13
NJ	16	1,000	1,2,3,4,5,7,8,9,10,12
NM	1	10-100	9
NV	2	0-100	1,2,3,5,7,13
NY	37	0-10,000	1,2,3,4,5,7,8,9,10,13
OH	93	0-50,000	1,2,3,4,5,6,7,8,9,10,11,12
OK	24	0-1,000	1,3,4,5,7,8,9,10,12,13
OR	13	0-10,000	2,3,8,9,10
PA	97	0-100,000	1,2,3,4,5,6,7,8,9,10,11,12
PR	3	0-1,000	8,9,11
RI	1	10-100	9
SC	23	0-1,000	1,5,7,8,9,10
SD	3	0-1,000	1,5,8,9,12
TN	24	0-10,000	1,2,3,4,5,6,7,8,9,10,11,12
TX	36	0-10,000	1,2,3,4,5,6,7,8,9,10,11,12
UT	11	0-10,000	1,2,3,5,6,7,8,9,11
VA	23	0-1,000	1,5,8,9,10,11,12,13
WA	19	0-1,000	2,3,7,8,9,10
WI	67	0-1,000	1,2,3,5,6,7,8,9,10,12,13
WV	11	0-10,000	1,2,3,4,5,7,8,9,10,13
WY	1	10-100	10,12

^aPost office State abbreviations used^bData in TRI are maximum amounts on site at each facility^cActivity and Use Codes:

- | | |
|-------------------------------|----------------------------------|
| 1. Produce | 8. As a formulation component |
| 2. Import | 9. As a product component |
| 3. For on-site use/processing | 10. For repackaging |
| 4. For sale/distribution | 11. As a chemical processing aid |
| 5. As a byproduct | 12. As a manufacturing aid |
| 6. As an impurity | 13. Ancillary or other uses |
| 7. As a reactant | |

source: ATSDR, 1997 compilation of 1991 TRI data

Table 3-3: Environmental releases (in pounds) for manganese in the United States, 1988-1998

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1998	970,658	260,403	3	9,995,895	15,967,545	27,194,504
1997	751,743	146,364	7	9,920,481	16,209,483	27,028,078
1996	816,733	117,571	8	10,111,563	15,191,636	26,237,511
1995	699,897	117,277	17	8,279,054	12,753,204	21,849,449
1994	818,600	89,332	10	8,452,582	14,076,682	23,437,206
1993	901,827	243,999	504	7,530,152	12,150,694	20,827,176
1992	721,047	235,307	304	6,543,600	11,997,270	19,497,528
1991	1,113,160	143,105	272	9,906,511	14,590,589	25,753,637
1990	1,168,809	139,358	881	9,031,215	11,364,721	21,704,984
1989	2,444,211	150,965	556	7,984,172	20,559,164	31,139,068
1988	1,586,675	321,993	255	20,229,826	20,087,660	42,226,409

source: USEPA, 2000b

Table 3-4: Environmental releases (in pounds) for manganese compounds in the United States, 1988-1998

Year	On-Site Releases				Off-Site Releases	Total On- & Off-site Releases
	Air Emissions	Surface Water Discharges	Underground Injection	Releases to Land		
1998	1,566,352	4,471,582	7,755,610	52,820,578	45,269,882	111,884,004
1997	1,549,505	4,202,876	14,412,830	50,141,026	47,233,186	117,539,423
1996	1,828,684	2,119,241	15,630	40,334,426	33,543,677	77,841,658
1995	2,928,644	1,627,184	3,590	41,832,058	25,994,951	72,386,427
1994	3,060,424	857,825	5,930	38,228,464	25,840,954	67,993,597
1993	2,324,442	685,737	8,740	47,763,821	22,780,860	73,563,600
1992	2,079,044	733,728	22,569	63,490,137	17,297,544	83,623,022
1991	1,531,832	709,557	15,327	66,559,047	27,250,630	96,066,393
1990	2,276,084	721,787	2,842	83,331,787	35,789,554	122,122,054
1989	1,847,528	907,866	1,005,518	85,191,013	33,004,908	121,956,833
1988	1,801,463	681,469	6,816,070	84,227,842	20,670,921	114,197,765

source: USEPA, 2000b

In summary, manganese and many of its compounds are naturally occurring and found at low levels in soil, water, air, and food. Furthermore, manganese compounds are produced in the United States from manganese ore and are in widespread use. Most ferromanganese is used in steel production, while other manganese compounds are used in a variety of applications, from fertilizers and industrial products to water treatment. Recent statistics regarding import for consumption indicate production and use are robust (Table 3-1). Manganese and its compounds are also TRI chemicals (Tables 3-3 and 3-4). Industrial releases have occurred since 1988 in all 50 States. Off-site releases constitute a considerable amount of total releases. Releases to land are the most significant on-site releases.

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 the United States Geological Survey's (USGS) 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 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 engage 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 (1991-1996) targeted 20 study units, and the second round monitored another 16, beginning in 1994.

Manganese is an analyte for both surface and ground water NAWQA studies, with a Minimum Reporting Level (MRL) of 0.001 mg/L. Manganese occurrence in bed sediments and aquatic biota tissue is also assessed, with MRLs of 4 mg/kg and 0.1 mg/kg, respectively.

Manganese 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). EPA has analyzed these data after further data quality review, and occurrence results are presented below. The descriptive statistics generated from the manganese NAWQA data broadly characterize the frequency of manganese detections by sample and by site. Furthermore, detection frequencies above a HRL of 0.30 mg/L are also presented for all samples, and by site. The HRL is a preliminary health effect level used for this analysis (see section 3.3.1.4 for further discussion of the HRL and its development). The median and 99th percentile concentrations are included as well, to characterize the spread of manganese concentration values in ambient waters sampled by the NAWQA program.

3.2.2 Results

Typical of many inorganic contaminants, manganese occurrence in ambient surface and ground waters is high (Table 3-5). This is not surprising, considering that manganese constitutes approximately 0.1% of the earth's crust (of the heavy metals, it is surpassed in abundance only by iron), and the element and its compounds are used in many products. Significantly, manganese compounds are used in wastewater and drinking water treatment.

Detection frequencies are consistently greater for surface water than for ground water, possibly because surface waters are more sensitive to anthropogenic releases. Median concentrations are also generally higher for surface water (median concentration for all sites is 0.016 mg/L in surface water and 0.005 mg/L in ground water). However, manganese detection frequencies greater than the HRL are consistently higher in ground water, and 99th percentile ground water concentrations are as much as eight times larger than corresponding 99th percentile surface water concentrations. Locally high concentrations in ground water, higher than any seen in surface water, are not surprising given the possibility of long contact times between ground water and rocks enriched in manganese. Contact times between surface waters and naturally occurring manganese are orders of magnitude shorter, hence concentrations are lower. Furthermore, surface waters subject to large anthropogenic inputs of manganese are more easily diluted by waters integrated from other parts of the watershed, where manganese concentrations may be lower.

Table 3-5 illustrates that low-level manganese occurrence is ubiquitous. Surface water detection frequencies by site are greater than 95% for all land use categories. Median concentrations and HRL exceedances (by site) are greater in urban and agricultural basins compared to basins characterized as mixed land use or forest/rangeland. This distribution of manganese occurrence is probably influenced

by the wide use of manganese compounds in both industry and agriculture. Mixed land use basins are generally larger than either urban or agricultural basins, and the lower occurrence in these basins may reflect some dilution of the contaminant. The 99th percentile concentrations for surface water range from 0.4 mg/L-0.8 mg/L. The frequency of detections exceeding the MRL and HRL by site for all sites are approximately 96.9% and 10.2%, respectively. These figures indicate that although manganese is nearly ubiquitous in surface water, detections at levels of public health concern are relatively low.

For ground water, detections by site are higher in urban and forest/rangeland areas than in mixed or agricultural lands. Over 80% of urban and forest/rangeland sites reported detections, while approximately 63-64% of mixed and agricultural land use sites detected manganese. The finding that ground water manganese occurrence is higher in forest/rangeland areas than in either mixed or agricultural sites may result from natural variation in manganese occurrence in soil and rock. Urban areas have the highest median and 99th percentile concentrations (0.015 mg/L and 5.6 mg/L, respectively), as well as the highest detection frequencies (by site: 85.3%) and HRL exceedances (both by sample [17.2%] and by site [21%]). These results suggest that urban releases of manganese and manganese compounds can leach to ground water.

Detection frequencies and HRL exceedances by site for all ground water sites are approximately 70.1% and 13.8%, respectively. Again, these figures suggest that while manganese occurrence in ground water is high, detections at levels of public health concern are modest.

Manganese was detected at 100% of NAWQA stream bed sediment sampling sites. The median and 99th percentile concentrations in bed sediments are 1.1 mg/kg (dry weight) and 9.4 mg/kg (dry weight), respectively. The occurrence of manganese in stream sediments is pertinent to drinking water concerns because, though many manganese compounds are either insoluble or have low solubility and are transported in water as suspended sediment, some desorption of the compound from sediments into water will occur through equilibrium reactions, although at very low rates.

In aquatic biota tissue, detections are also 100% for all samples and sites (Table 3-6). However, concentration percentiles for tissues are substantially lower than for bed sediments: the median for biotic tissue is 0.01 mg/kg (dry weight) and the 99th percentile is 2.9 mg/kg (dry weight). Significant manganese concentrations in aquatic biota tissues would imply a potential for bioaccumulation. Although manganese was detected in aquatic biota tissues at 100% of samples and sites, low concentration percentiles suggest that the element does not bioaccumulate appreciably.

3.3 Drinking Water Occurrence

3.3.1 Analytical Approach

3.3.1.1 National Inorganic and Radionuclide Survey

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 (IOC) (including 10 regulated IOCs), 2 regulated radionuclides, and 4 unregulated radionuclides. Manganese 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 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 manganese 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 manganese 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)

Table 3-5: Manganese detections and concentrations in streams and ground water

	Detection frequency > MRL*		Detection frequency > HRL*		Concentrations (all samples; mg/L)	
	<u>% samples</u>	<u>% sites</u>	<u>% samples</u>	<u>% sites</u>	<u>median</u>	<u>99th percentile</u>
<i>surface water</i>						
urban	99.1 %	99.6 %	4.6 %	13.0 %	0.036	0.7
mixed	92.4 %	98.5 %	1.3 %	6.4 %	0.012	0.4
agricultural	96.3 %	97.2 %	3.7 %	12.3 %	0.019	0.7
forest/rangeland	90.9 %	96.4 %	5.0 %	6.6 %	0.011	0.8
all sites	94.0 %	96.9 %	3.0 %	10.2 %	0.016	0.7
<i>ground water</i>						
urban	74.7 %	85.3 %	17.2 %	21.0 %	0.015	5.6
mixed	56.9 %	62.9 %	8.9 %	9.0 %	0.002	1.3
agricultural	61.4 %	64.0 %	11.9 %	12.8 %	0.004	1.6
forest/rangeland	75.3 %	81.3 %	10.9 %	13.8 %	0.012	2.9
all sites	64.1 %	70.1 %	12.8 %	13.8 %	0.005	2.9

* The Minimum Reporting Level (MRL) for manganese in water is 0.001 mg/L and the Health Reference Level (HRL) is 0.30 mg/L.
The HRL is a preliminary health effect level used for this investigation.

Table 3-6: Manganese detections and concentrations in bed sediments and aquatic biota tissues (all sites)

	Detection frequency > MRL*		Concentrations (all samples; mg/kg dry weight)	
	<u>% samples</u>	<u>% sites</u>	<u>median</u>	<u>99th percentile</u>
<i>sediments</i>	100 %	100 %	1.1	9.4
<i>aquatic biota tissues</i>	100 %	100 %	0.01	2.9

* The Minimum Reporting Levels (MRLs) for manganese in sediments and biota tissues are 4 µg/g and 0.1 µg/g, respectively.

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 manganese. The data represent more than 37,000 analytical results from about 4,000 PWSs, primarily collected from 1993 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

The data used in the State data analyses were limited to only those data with confirmed water source and sampling type information. Only standard SDWA compliance samples were used; “special” samples, or “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 providing the 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 3-7 for manganese are derived from analysis of the NIRS data. Included are the total number of samples, the percent samples with detections, the 99th percentile concentration of all samples, the 99th percentile concentration of samples with detections, and the median concentration of samples with detections. The percentages of PWSs and population served indicate the proportion of PWSs and PWS population served for which 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 HRL; or a detection(s) greater than the HRL. The HRL used for this analysis is 0.30 mg/L.

The HRLs were derived for contaminants not considered to be “linear” carcinogens by the oral route of exposure. EPA derived the HRL using a Reference Dose (RfD) approach as follows: $HRL = (RfD \times 70 \text{ kg}) / (2L \times \text{relative source contribution (RSC)})$, where:

RfD = an estimate of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a No Observed Adverse Effect Level (NOAEL), Lowest Observed Adverse Effect Level (LOAEL), or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used;

70 kg = The assumed body weight of an adult;

2L = The assumed daily water consumption of an adult;

RSC = The relative source contribution, or the level of exposure believed to result from drinking water when compared to other sources (e.g., air), and is assumed to be 20% unless noted otherwise.

EPA used only the best available peer reviewed data and analyses in evaluating adverse health effects. Health effects information is available for manganese in the Integrated Risk Information System (IRIS). IRIS is an electronic EPA database containing reviewed information (both inside and outside of the Agency) on human health effects that may result from exposure to various chemicals in the environment. These chemical files contain descriptive and quantitative information on RfDs for chronic noncarcinogenic health effects and hazard identification; slope factors; and unit risks for carcinogenic effects.

In Table 3-7, national occurrence is estimated by extrapolating the summary statistics for manganese to national numbers for systems, and population served by systems, from the *Water Industry Baseline Handbook, Second Edition* (USEPA, 2000e). 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 85,681,696 persons (see Table 3-7). To arrive at the national occurrence estimate for the HRL, 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 [i.e., the national estimate for the total number of ground water PWSs with detections at the HRL of 0.30 mg/L (40,388) is the product of the percentage of ground water PWSs with detections (68%) and the national estimate for the total number of ground water PWSs (59,440)].

The nationally extrapolated occurrence estimates for manganese 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 manganese are presented here, however, to provide additional perspective.

In Table 3-8, occurrence data on manganese 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) was used to augment the NIRS study which lacked surface water data. Included in the table are the same summary statistics as in Table 4-1, with additional information describing the relative distribution of manganese 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 3-8).

3.3.1.5 Additional Drinking Water Data from 1996 AWWA Survey

To augment the SDWA drinking water data analysis described above, results from a 1996 American Water Works Association (AWWA) survey are reviewed. The survey, called WaterStats, is a cooperative project of AWWA and AWWA Research Foundation. The WaterStats survey database stores results from the 1996 WaterStats survey of water utilities in the United States and Canada in terms of facilities, scale of operation, and major inputs and outputs. A total of 794 AWWA

member utilities responded to the survey with ground water and/or surface water information. However, the actual number of respondents for each data category varies because not all participants in the survey responded to every question.

3.3.2 Results

The NIRS data in Table 3-7 show that approximately 68% of ground water PWSs (an estimate of approximately 40,000 systems nationally) had detections of manganese, affecting about 55% of the ground water PWS population served (approximately 47.5 million people nationally). At an HRL of 0.30 mg/L, approximately 6.1% of the NIRS PWSs had detections greater than half the HRL (about 3,600 ground water PWSs nationally), affecting approximately 4.6% of the population served (estimated at 3.9 million people nationally). The percentage of NIRS PWSs with detections greater than the HRL of 0.30 mg/L was approximately 3.2% (about 1,900 ground water PWSs nationally), affecting 2.6% of the population served (estimated at approximately 2.3 million people nationally) (Table 3-7).

Drinking water data for manganese from the supplemental individual States vary among States (Table 3-8). Manganese has not been required for monitoring under the SDWA, though these States had obviously conducted some monitoring. The number of systems with manganese data for Illinois and Oregon is far less than the number of PWSs in these States. Hence, it is not clear how representative these data are. Alabama, California, and New Jersey have substantial amounts of data and PWSs represented. Because the NIRS data only represent manganese occurrence in ground water PWSs, the supplemental State data sets provide some perspective on surface water PWS occurrence. For example, the median concentration of detections for the States ranged from 0.02 mg/L to 0.15 mg/L, higher than the NIRS data (0.01 mg/L). For detections by PWSs, 3 of the 5 States (California, Illinois, and Oregon) had higher ground water PWS detections.

For simple detections, the supplemental State data show a range from 30% to 56% of ground water PWSs (Table 3-8). These figures are lower than the NIRS ground water PWS results: 68% greater than the MRL (Table 3-7). The supplemental State data show considerably greater percentages of simple detections for surface water PWSs, with higher variability as well: 12% - 97% greater than the MRL. 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).

The supplemental State data sets indicate ground water PWS detections greater than the HRL of 0.30 mg/L between 0.6% and 11% (Table 3-8). Again, this range brackets the NIRS national average of PWS above the HRL of 0.30 mg/L (3.2%) (Table 3-8). Notably, surface water PWSs showed fewer exceedances of the HRL than ground water PWSs at this higher concentration; ranging from 0% to 3.1%.

Reviewing manganese occurrence by PWS population served shows that from 0.1% - 43% of the States' ground water PWS populations were served by systems with detections greater than the HRL of 0.30 mg/L (Table 3-8). Comparatively, 2.6% of the NIRS ground water PWS population served experienced detections greater than the HRL of 0.30 mg/L (Table 3-7). Populations served by surface water PWSs with detections greater than the HRL of 0.30 mg/L ranged from 0% - 14.5% 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 manganese, approximately 80% of the PWSs reporting occurrence data for these 5 States also reported population data.

3.3.2.1 Occurrence in AWWA PWSs

The AWWA sponsored 1996 WaterStats Survey showed manganese occurrence above levels of health concern to be generally similar to those reported in the NIRS data and the supplemental State data. In finished ground water samples, approximately 3% of survey respondents (serving close to 1.6 million people) had maximum detections of manganese greater than the HRL of 0.30 mg/L. The 99th percentile concentration and the median concentration were 0.80 mg/L and 0.021 mg/L, respectively. For finished surface water samples, approximately 1.5% of survey respondents (serving about 1.7 million people) reported maximum detections greater than the HRL of 0.30 mg/L. The 99th percentile concentration and the median concentration in finished surface water samples were 0.64 mg/L and 0.013 mg/L, respectively.

Approximately 11% of the participating ground water PWSs (serving about 5.1 million people) had maximum detections of manganese in raw water greater than the HRL of 0.30 mg/L. The 99th percentile of concentration and the median concentration were 9.0 mg/L and 0.09 mg/L, respectively. Surface water PWSs showed comparable results, with approximately 12.8% of survey respondents (serving about to 10.5 million people) having maximum detections of manganese in raw water greater than the HRL of 0.30 mg/L. The 99th percentile of concentration and the median concentration in raw surface waters were 3.08 mg/L and 0.092 mg/L, respectively.

3.4 Conclusion

Manganese and its compounds are TRI chemicals. Industrial releases have been reported since 1988 in all 50 States. Off-site releases constitute a considerable amount of total releases, with releases to land the most significant on-site releases.

Low-level manganese occurrence in ambient waters and bed sediments monitored by the USGS NAWQA program is ubiquitous, with detections approaching 100% of surface water sites and greater than 62% of ground water sites. Stream bed sediments and aquatic biota tissues show detections of 100% by sample and by site. Urban basins generally have more surface and ground water manganese

Table 3-7: Manganese occurrence in ground water systems (NIRS survey)

	Health Reference Level = 0.30 mg/L	National System & Population Numbers¹
Frequency Factors		
Total Number of Samples/Systems	989	59,440
99 th Percentile Concentration (all samples)	0.63 mg/L	--
Minimum Reporting Level (MRL)	0.001 mg/L	--
99 th Percentile Concentration of Detections	0.72 mg/L	--
Median Concentration of Detections	0.01 mg/L	--
Total Population	1,482,133	85,681,696
Occurrence by Sample/System		National Extrapolation HRL = 0.30
% Ground Water PWSs with detections (> MRL) Range of Sampled States	67.9% 8.3 - 100%	40,388 N/A
% Ground Water PWSs > 1/2 Health Reference Level (HRL) Range of Sampled States	6.1% 0 - 31.6%	3,606 N/A
% Ground Water PWSs > HRL Range of Sampled States	3.2% 0 - 21.0%	1,923 N/A
Occurrence by Population Served		
% Ground Water PWS Population Served with detections Range of Sampled States	55.4% 0.3 - 100%	47,502,000 N/A
% Ground Water PWS Population Served > 1/2 HRL Range of Sampled States	4.6% 0 - 89.2%	3,940,000 N/A
% Ground Water PWS Population Served > HRL Range of Sampled States	2.6% 0 - 89.2%	2,256,000 N/A

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

Table 3-8: Occurrence summary of ground and surface water systems, by State, for

Frequency Factors	Alabama	California	Illinois	New Jersey	Oregon
Total Number of Samples	1,343	31,998	344	3,196	172
Number of Ground Water Samples	934	29,923	275	2,795	90
Number of Surface Water Samples	409	2,075	69	401	82
Percent of Samples with Detections	30.2%	16.5%	44.2%	39.7%	39.5%
Percent of Ground Water Samples with Detections	28.1%	17.5%	50.2%	40.6%	61.1%
Percent of Surface Water Samples with Detections	35.0%	1.9%	20.3%	33.7%	15.9%
99 th Percentile Concentration (all samples)	0.13 mg/L	0.71 mg/L	0.96 mg/L	0.42 mg/L	1.6 mg/L
Minimum Reporting Level (MRL)	Variable ¹	Variable ¹	Variable ¹	Variable ¹	Variable ¹
99 th Percentile Concentration of Detections	0.56 mg/L	1.52 mg/L	57 mg/L	0.89 mg/L	6.7 mg/L
Median Concentration of Detections	0.02 mg/L	0.15 mg/L	0.04 mg/L	0.02 mg/L	0.05 mg/L
Total Number of PWSs	434	2,516	227	1,179	84
Number of Ground Water PWSs	365	2,293	160	1,147	54
Number of Surface Water PWSs	69	223	67	32	30
Total Population Served	3,662,222	45,388,246	1,995,394	7,472,565	1,306,283
Ground Water Population	1,820,214	27,840,774	724,635	2,386,396	301,440
Surface Water Population	1,837,743	30,675,992	1,270,179	3,687,076	1,117,782
Occurrence by System					
% PWSs with detections (> MRL)	46.5%	28.2%	41.4%	53.5%	46.4%
Ground Water PWSs with detections	41.6%	29.8%	50.6%	52.3%	55.6%
Surface Water PWSs with detections	72.5%	11.7%	19.4%	96.9%	30.0%
Health Reference Level (HRL) = 0.03 mg/L					
% PWSs > 1/2 HRL	1.8%	17.2%	9.3%	5.8%	13.1%
Ground Water PWSs > 1/2 HRL	1.4%	18.5%	11.9%	5.7%	20.4%
Surface Water PWSs > 1/2 HRL	4.4%	3.6%	3.0%	9.4%	0.0%
% PWSs > HRL	0.9%	10.1%	4.4%	2.5%	6.0%
Ground Water PWSs > HRL	0.6%	10.9%	5.0%	2.5%	9.3%
Surface Water PWSs > HRL	2.9%	1.8%	3.0%	3.1%	0.0%
Occurrence by Population Served					
% PWS Population Served with detections	71.9%	49.3%	36.5%	85.7%	58.0%
Ground Water PWS Population with detections	50.9%	66.2%	66.3%	70.4%	41.8%
Surface Water PWS Population with detections	73.4%	10.5%	19.5%	100.0%	56.8%
Health Reference Level (HRL) = 0.03 mg/L					
% PWS Population Served > 1/2 HRL	5.9%	34.8%	16.5%	15.3%	4.6%
Ground Water PWS Population > 1/2 HRL	0.8%	52.6%	29.1%	10.4%	19.9%
Surface Water PWS Population > 1/2 HRL	0.7%	4.4%	9.4%	23.3%	0.0%
% PWS Population Served > HRL	2.4%	27.2%	14.7%	9.1%	3.2%
Ground Water PWS Population > HRL	0.1%	42.8%	24.2%	4.9%	14.0%
Surface Water PWS Population > HRL	0.6%	4.2%	9.4%	14.5%	0.0%

manganese¹ See section 3.3.1.4 for details

detections greater than the HRL than basins in other land use categories do, and higher median and 99th percentile concentrations. Although manganese detection frequencies are high in ambient waters, stream bed sediments, and aquatic biota tissue, manganese occurrence at levels of public health concern is low.

Manganese has been detected in ground water PWS samples collected through the NIRS study. Occurrence estimates are relatively high, with approximately 68% of all samples showing detections affecting about 55% of the national population served. The 99th percentile concentration of all samples is 0.63 mg/L. Exceedances of the HRL at 0.30 mg/L affect approximately 2.3 million people nationally.

Additional SDWA compliance 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 manganese occurrence. These data provide perspective on the NIRS estimates that only include data for ground water systems. The supplemental State data show ground water systems reported higher manganese detections in 3 of the 5 States (California, Illinois, and Oregon). 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 description of the health effects and dose-response information associated with exposure to manganese is summarized below. For additional detail, please refer to the *Health Effects Support Document for Manganese* (USEPA, 2003b).

4.1 Hazard Characterization and Mode of Action Implications

The primary route of exposure to toxic levels of manganese is through the inhalation of manganese dust. Oral exposure to levels of toxicological concern is less common. The major adverse health effect of manganese exposure is neurotoxicity, which is characterized at high doses by ataxia (i.e., coordination impairment), increased anxiety, dementia, a “mask-like” face, involuntary movements, or a syndrome similar to Parkinson’s disease. While the precise mechanisms of manganese neurotoxicity are not known, the observed effects of manganese on the globus pallidus region of the brain suggest that a likely mechanism involves impairment of the neurotransmitter dopamine, which is involved in coordination of movement.

While manganese is potentially harmful at high concentration levels, it is also an essential nutrient in developing infants. For this reason, the adverse effects from manganese deficiency may, at times, be of greater concern than potential toxicity from over-exposure. An added complication is the fact that

many inhibitors of manganese absorption, such as phytates and plant fiber, are commonly found in infant diets, thus lowering the actual absorption of ingested manganese. Absorption of the mineral from manganese-rich foods may also be inhibited by the presence of co-occurring plant proteins that bind manganese and decrease its bioavailability. For example, although the manganese content in a soy-based formula is higher than the manganese content in human milk, the actual absorption of manganese from the formula may not be substantially greater, since soy milk is high in phytate and vegetable protein. Human and cow milk contain different proteins that also bind manganese, but in some cases, the presence of these proteins actually enhances manganese transport across the gut wall, increasing absorption.

Other instances in which high dietary levels of manganese may not necessarily correspond to high dose levels include vegetarian diets and tea drinkers. Many vegetables contain high manganese levels but have high fiber and phytate levels. Likewise, tea contains high manganese levels, but the accompaniment of tannin, another inhibitor of manganese absorption, decreases the absorption of manganese.

Several studies have explored the intake level of manganese at which it may be considered safe in humans. Although the Estimated Safe and Adequate Daily Dietary Intake (ESADDI) for manganese has been established at 2-5 mg/day for adults (NRC, 1989), Davis and Greger (1992) have found that a daily intake of 15 mg/day for 90 days results in no adverse effects in women; the only effect seen was an increase in superoxide dismutase activity. In 2001, the Institute of Medicine (IOM) undertook a review of Dietary Reference Intakes for a number of substances. An adequate intake level for manganese was set at 2.3 mg/day for men and 1.8 mg/day for women (IOM, 2001). The IOM report also sets a tolerable upper intake level of 11 mg/day for adults, based on a review by Greger (1999). It suggested that people eating Western type and vegetarian diets may have intakes as high as 10.9 mg/day.

4.2 Dose-Response Characterization and Implications in Risk Assessment

The dose-response relationship for neurological effects of manganese by ingestion is not well-characterized in animals or humans. Epidemiological data for humans indicate that intakes as high as 11 mg/day (0.16 mg/kg-day) may not cause any adverse effects in adult humans. Additional evidence, based on a study where women received daily supplements of 15 mg manganese for 90 days, suggests a safe level as high as 15 mg/day (Davis and Greger, 1992).

A review of acute animal toxicity studies indicates that manganese has a low to moderate oral toxicity. For example, the oral dose of manganese compounds at which 50% of rats died is in the range of 400-2,000 mg/kg. While some animal studies have also reported developmental and reproductive effects at high doses for certain manganese compounds, most data from oral exposure suggest that manganese has a low developmental toxicity.

EPA has calculated a RfD, or an estimate of a daily exposure via ingestion to the human population that is likely to be safe, for manganese. The RfD for manganese in food is 0.14 mg/kg-day, based on dietary surveys which have reported daily manganese intake of 10 mg in average 70 kg adults without adverse effects. As a precautionary measure for drinking water, EPA recommends applying a modifying factor (MF) of 3 to yield a value of 0.047 mg/kg-day. One concern addressed by this MF is the potential for humans to absorb greater levels of manganese by drinking water during early morning, when the gut is empty, than by exposure in food.

There is no information available regarding the carcinogenicity of manganese in humans; animal studies have reported mixed results. The USEPA classified manganese as Group D, or not classifiable as to human carcinogenicity. The Reference Concentration (RfC), an estimate of daily exposure via inhalation that is likely to be safe, for manganese is 5×10^{-5} mg/m³ (USEPA, 1998c). The RfC was derived using data from two epidemiological studies of workers exposed to manganese dioxide dust in an occupational setting (Roels et al., 1987; Roels et al., 1992).

4.3 Relative Source Contribution

Relative source contribution analysis compares the magnitude of exposures expected via consumption of drinking water with those estimated for other relevant media such as food, air, and soil. Occurrence data for manganese provides the basis for estimating the amounts of manganese ingested via drinking water in the exposed population. According to the NIRS data, the median and 99th percentile concentrations for manganese in ground water public water supplies are above the MRL of 0.001 mg/L. This is not surprising considering the ubiquity of manganese in the earth's crust.

Taking the median concentration of detections from the NIRS data (0.01 mg/L), and assuming a daily intake of 2 L of drinking water by a 70 kg adult, the average daily dose would be 2.8×10^{-4} mg/kg-day. The corresponding dose for a 10 kg child consuming 1 L/day of drinking water would be 1.0×10^{-3} mg/kg-day. These values are lower than the levels that the IOM (2001) considers to be safe and adequate. The IOM has determined that a daily intake of 2.3 mg manganese for men and 1.8 mg for women is adequate, while the daily adult intake expected from drinking water is 0.02 mg manganese. The IOM also determined that a daily intake of 1.9 mg manganese is adequate for boys and 1.6 mg is adequate for girls, while the daily intake expected from drinking water is 0.01 mg for children (IOM, 2001). The National Research Council proposed even higher recommended intakes of manganese: their ESADDI for manganese is 2-5 mg for adults (NRC, 1989).

4.4 Sensitive Populations

Potentially sensitive sub-populations include the elderly, pregnant women, iron-deficient individuals, and individuals with impaired liver function. Because excretion by the liver is the primary route of

manganese elimination, individuals with impaired liver function may be especially susceptible to manganese toxicity (Layrargues et al., 1998). Infants and neonates, whose capacity for excretion through the bile is not fully developed, may also be potentially susceptible to manganese toxicity (Fechter, 1999). Although animal studies have indicated an increased potential in neonates for gastrointestinal absorption of manganese, as well as decreased excretion potential, the degree to which these findings apply to human infants is unknown. There are no data to indicate that children are more sensitive to manganese than adults. Those who are iron deficient may also experience greater susceptibility to manganese absorption and toxicity (Finley, 1999; Finley et al., 1994).

4.5 Exposure and Risk Information

Estimates of exposed populations were described in the occurrence section of this document. National population estimates for manganese exposure were derived using summary statistics from the NIRS, in addition to supplemental surface water occurrence data, that was separately submitted to EPA from five States.

Based on available data, approximately 47.5 million people are served by ground water public water systems with detections above the MRL. Furthermore, an estimated 4.0 million people (4.6% of the population) are served by ground water with levels above one-half the HRL of 0.30 mg/L. In addition, an estimated 2.3 million people (2.6% of the population) are served by ground water with levels above the HRL.

Considering that manganese is an essential nutrient which is commonly found in normal diets, the estimated daily exposure to manganese from public water systems is far below the expected daily intake from diet. When average daily intakes from drinking water are compared with intakes from food, air and soil, drinking water accounts for a relatively small proportion of manganese intake. On the basis of these observations, the impact of regulating manganese concentrations in drinking water on health risk reduction is likely to be small.

4.6 Conclusion

While there is evidence that manganese may have adverse health effects in humans at high doses through inhalation, studies indicate that oral ingestion at levels commonly found in western diets have no noticeable adverse effects. In addition, because manganese is an essential nutrient, concern over potential toxic effects from high oral exposure must be balanced against concern for adverse effects from manganese deficiency. Through a special study of contaminant occurrence in ground water systems (NIRS), it is estimated that manganese occurs at levels above the HRL (0.30 mg/L) in approximately 1,900 ground water systems nationwide (about 3.2% of the nation's ground water PWSs), affecting approximately 2.3 million people nationwide (2.6 % of the U.S. PWS population-served). However, the HRL concentration is far less than the average daily intake of manganese

through non-water sources. It is therefore unlikely that manganese in drinking water will occur at concentrations that are of public health concern or that regulation represents a meaningful opportunity for health risk reduction in persons served by public water systems. All CCL regulatory determinations and further analysis are formally presented in the *Federal Register* Notices (USEPA, 2002; 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.

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. Manganese can be measured by several well-documented analytical methods (see Table 5-1).

5.2 Treatment Technology

Treatment technologies also do not influence the determination of whether or not a contaminant should be regulated. But, before a contaminant can be regulated with an NPDWR, treatment technologies must be readily available. Manganese is one of three inorganic contaminants listed as Regulatory Determination Priorities on the CCL. The treatment data for these inorganic compounds was obtained from EPA's technology and cost documents, the Office of Research and Development's (ORD) National Risk Management Research Laboratory (NRMRL) Treatability Database, and published studies. The technologies reviewed include conventional treatment, ion exchange, reverse osmosis, lime softening, and chemical precipitation.

Conventional treatment usually includes pre-treatment steps of chemical coagulation, rapid mixing, and flocculation, followed by floc removal via sedimentation or flotation. After clarification, the water is then filtered. Common filter media include sand, and dual- and tri-media (e.g., silica sand, garnet sand, or anthracitic coal).

Table 5-1: Analytical Methods for Manganese

Method	Type	Method Detection Limit (µg/L)
EPA 200.7	Inductively Coupled Plasma Optical Emission Spectrometry (ICP)/Atomic Emission Spectrometry	1.0
SM 3120 B	ICP/Atomic Emission Spectrometry	Estimated Detection Limit (EDL) 2.0
EPA 200.8	ICP/Mass Spectrometry	0.02
SM 3111B	Atomic Absorption, direct aspiration	Instrument Detection Level (IDL) 10 Optimum conc. range 100-10,000
EPA 200.9	Stabilized Temperature Graphite Furnace AA Spectrometry	0.3
SM 3113 B	Atomic Absorption, Furnace	EDL 0.2 Optimum conc. range 1-30

Ion exchange involves the selective removal of charged inorganic species from water using an ion-specific resin. The surface of the ion exchange resin contains charged functional groups that hold ionic species by electrostatic attraction. As water containing contaminant ions passes through a column of resin beds, charged ions on the resin surface are exchanged for the contaminant species in the water.

Reverse osmosis (RO) is similar to other membrane processes, such as ultrafiltration and nanofiltration, since water passes through a semi-permeable membrane. However, in the case of RO, the principle involved is not filtration. Instead, it involves the use of applied hydraulic pressure to oppose the osmotic pressure across a non-porous membrane, forcing the water from the concentrated solution side to the dilute solution side. The water does not travel through pores, but rather dissolves into the membrane, diffuses across, then dissolves out into the permeate. Most inorganic and many organic contaminants are rejected by the membrane and will be retained in the concentrate.

In the lime-softening process, the pH of the water being treated is raised sufficiently to precipitate calcium carbonate and, if necessary, magnesium hydroxide. Calcium and magnesium ions in water cause hardness. After mixing, flocculation, sedimentation, and pH readjustment, the softened water is filtered.

Results of a preliminary technology assessment and review indicate that all of the above-mentioned techniques remove manganese from water. However, data indicate that chemical precipitation is the most effective option.

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 proposal of a Maximum Contaminant Level Goal (MCLG) and promulgation of a NPDWR 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.

There is evidence that manganese may have adverse health effects in humans at high doses through inhalation, most importantly as a neurotoxin (producing ataxia, anxiety, dementia, a “mask-like” face, involuntary movements, or a syndrome similar to Parkinson’s disease). Nevertheless, oral exposure at levels common in Western diets is not known to produce adverse health effects. In addition, because manganese is an essential nutrient, concern over potential toxic effects from high oral exposure must be balanced against concern for adverse effects from manganese deficiency. Potentially sensitive subpopulations include the elderly, pregnant women, iron-deficient individuals, and individuals with impaired liver function. Manganese is not a known carcinogen.

Manganese is a naturally occurring element that constitutes approximately 0.1% of the earth’s crust. Industrially, manganese compounds are produced in the United States from manganese ore and are in widespread use in the steel, fertilizer and water treatment industries. Releases have been reported since 1988 in all 50 States. Monitoring data indicate that low-level manganese occurrence in ambient waters and bed sediments monitored by the USGS NAWQA program is ubiquitous, with detections approaching 100% of surface water sites and greater than 62% of ground water sites. Stream bed sediments and aquatic biota tissues show detections of 100% by sample and by site. Although

manganese detection frequencies are high in ambient waters, stream bed sediments, and aquatic biota tissue, manganese occurrence at levels of public health concern is low.

Manganese has been detected in ground water public water system (PWS) samples collected through the NIRS study. Occurrence estimates are relatively high with approximately 68% of all sampled PWSs showing detections, indicating that manganese is present in PWSs that serve about 55% of the national population. Exceedances of the HRL of 0.30 mg/L affect 2.6% of the population, or approximately 2.3 million people nationally. The 99th percentile concentration of all samples is 0.63 mg/L. Additional SDWA compliance 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 manganese occurrence.

The levels of manganese frequently detected in PWSs are far below the average daily intake of manganese through non-water sources: for example, the median concentration of detects in the NIRS survey is 0.01 mg/L, while studies have indicated that for a 70 kg adult, a daily manganese intake of 10 mg through diet presents no adverse effect.

Because manganese ingestion is not known to present adverse health effects at low levels, and because drinking water contributes only a small portion of normal oral intake, it is unlikely that regulation of manganese in drinking water would represent a meaningful opportunity for health risk reduction in persons served by public water systems. All CCL regulatory determinations and further analysis are formally presented in the *Federal Register* Notices (USEPA, 2002; 67 FR 38222, and USEPA, 2003a; 68 FR 42898).

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APPENDIX A: Abbreviations and Acronyms

ATSDR	- Agency for Toxic Substances and Disease Registry
AWWA	- American Water Works Association
CAS	- Chemical Abstract Service
CCL	- Contaminant Candidate List
CEC	- cation exchange capacity
CERCLA	- Comprehensive Environmental Response, Compensation & Liability Act
CWS	- Community Water System
Eh	- oxidation-reduction potential
EPA	- Environmental Protection Agency
EPCRA	- Emergency Planning and Community Right-to-Know Act
ESADDI	- estimated safe and adequate daily dietary intake
FR	- Federal Register
g/mol	- grams per mole
HRL	- Health Reference Level
IOC	- inorganic compound
IOM	- Institute of Medicine
IRIS	- Integrated Risk Information System
K _{oc}	- organic carbon partition coefficient
K _{ow}	- octanol-water partitioning coefficient
L	- liter
LOAEL	- lowest observed adverse effect level
MCL	- maximum contaminant level
MCLG	- maximum contaminant level goal
MF	- modifying factor
mg	- milligram
mg/kg-day	- milligram per kilogram per day
mm Hg	- millimeter mercury
MMT	- methylcyclopentadienyl manganese tricarbonyl
MRL	- Minimum Reporting Level
NAWQA	- National Water Quality Assessment Program
NDWAC	- National Drinking Water Advisory Council
NIRS	- National Inorganic and Radionuclide Survey
nm	- nanometer
NOAEL	- no observed adverse effect level
NPDES	- National Pollution Discharge Elimination System
NPDR	- National Primary Drinking Water Regulation
NRC	- National Research Council
NRMRL	- National Risk Management Research Laboratory
NTNCWS	- Non-Transient Non-Community Water System
OGWDW	- Office of Ground Water and Drinking Water
ORD	- Office of Research and Development
OSHA	- Occupational Safety and Health Administration
PEL	- permissible exposure limit
pH	- the negative log of the concentration of H ⁺ ions

ppm	- part per million
PWS	- Public Water System
RfC	- reference concentration
RfD	- reference dose
RO	- reverse osmosis
RSC	- relative source contribution
SARA	- Superfund Amendments and Reauthorization Act
SDWA	- Safe Drinking Water Act
SMCL	- Secondary Maximum Contaminant Level
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
µg	- micrograms
>MCL	- percentage of systems with exceedances
>MRL	- percentage of systems with detections