The national occurrence of perchlorate in drinking water was analyzed and mapped by compiling data from existing perchlorate occurrence surveys. The existing surveys included studies conducted by utilities for the first Unregulated Contaminant Monitoring Rule and by the states of Arizona, California, Massachusetts, and Texas. Perchlorate was detected in 26 states, Puerto Rico, and the Mariana Islands and was found in at least one source of approximately 5% of the nation's large (> 10,000 population) public water systems. When found, perchlorate was typically present at concentrations of < 12 µg/L. Some water utilities that detected perchlorate have discontinued the use of perchlorate-contaminated sources. On the basis of the results of a 2007 phone survey, it is estimated that at least 50 mgd of potable water production has been taken off line as a result of perchlorate contamination.

A review of perchlorate occurrence in public drinking water systems

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In 1998, perchlorate was added to the US Environmental Protection Agency's (USEPA's) first Contaminant Candidate List (CCL1), indicating USEPA's potential interest in regulating this contaminant in drinking water (USEPA, 1998). Inclusion of perchlorate on the CCL1 was based primarily on the discovery of perchlorate in California drinking water supplies. Of key concern was the environmental release of ammonium perchlorate by two manufacturers in Nevada. These releases were associated with low levels of perchlorate contamination found in Lake Mead and the Colorado River. Water from these sources is used for drinking water, irrigation, and recreation by millions of people in Nevada, California, and Arizona (Pontius et al, 2000). Although concerns regarding the detection of perchlorate in drinking water sources have primarily been an issue in the United States, perchlorate has been detected in water sources outside the United States, including Canada (Backus et al, 2005) and Japan (Kosaka et al, 2007).

Key elements in USEPA's regulatory assessment for perchlorate include quantifying the occurrence of perchlorate in drinking water, gauging its potential for adverse health effects, and determining whether there is a meaningful opportunity to protect public health through its regulation. This article examines the occurrence of perchlorate in drinking water by compiling, quantifying, and mapping data from existing perchlorate occurrence surveys performed by USEPA and state agencies.

BACKGROUND

Perchlorate description. Perchlorate (ClO_4^-) is the most oxidized form of chlorine (+7 valance state). Despite its high oxidation state, perchlorate is relatively stable and mobile in aquatic environments. Salts of perchlorate are used in a number of applications, including as an oxidizer in solid rocket fuel and as a component of fireworks, pyrotechnics, flares, and explosives. It has also been used medicinally as a treatment for hyperthyroidism as well as an analytical chemical reagent. Perchlorate has also been identified in Chilean nitrate fertilizers (CNF; Urbansky et al, 2001). On a volume basis, more perchlorate is used in the production of solid rocket fuel than for all other uses combined (UWRC, 2004). However, perchlorate is not widely dispersed in the environment from the combustion of solid rocket fuel (Rao et al, 2007; Dasgupta et al, 2006; Plummer et al, 2006). Excluding the anthropogenic releases of perchlorate to the environment from Nevada manufacturers described previously, the main contributions of perchlorate to the environment are likely from CNF, industrial and explosive applications, fireworks, and natural formation.

Perchlorate health effects. Perchlorate is classified as a goitrogen (USEPA, 2005a). Goitrogens can adversely affect human health by interfering with normal iodine uptake by the thyroid gland. Through the secretion of two hormones, thyroxine (T_4) and triiodothyronine (T_3), the thyroid gland regulates metabolic activity in all humans and controls development of the central nervous system in fetuses and infants. The presence of iodine is essential for the synthesis of T_4 and T_3 by the thyroid gland. Perchlorate competitively inhibits the transport of iodine into the thyroid gland and, by extension, may inhibit the production of T_4 and T_3. Thus, chronic exposure to trace concentrations of perchlorate does not directly result in adverse health effects, but it may indirectly affect health by upsetting hormonal processes that regulate developmental or normal bodily functions. Pregnant women, infants, children, and people with iodine-deficient diets or preexisting thyroid deficiencies may be more sensitive to the presence of perchlorate than the general population (NRC, 2005).

In 2006, USEPA adopted a reference dose (RfD) for perchlorate of 0.0007 mg/kg/d, which was based on an analysis by the National Research Council (NRC, 2005). (A reference dose is defined as the maximum acceptable daily oral dose for the entire population, including sensitive subpopulations, that will not cause adverse health effects over a lifetime of exposure from all sources.) The RfD calculation was based on a no-observed-effect level (NOEL) of 0.007 mg/kg/d and a 10× intraspecies (within species) uncertainty factor (USEPA, 2005a). Because human data, rather than animal data, were used to derive the perchlorate NOEL, the 10× interspecies (between species) uncertainty factor typically used when only animal data are available was not included for the perchlorate RfD calculation. RfDs are traditionally based on the no-observed-adverse-effect level (NOAEL) and not the NOEL. By definition a NOAEL is an adverse effect equal to or higher than a NOEL when the effect used to establish the NOEL is a precursor to the adverse effect of interest in establishing a NOAEL (Crawford-Brown et al, 2006). Even though the NOEL is considered a more conservative threshold for establishing an RfD, this approach has been criticized in the case of perchlorate as not being sufficiently protective of human health (Ginsberg et al, 2005). Studies have indicated that women with low iodine intake may be at risk for reduced thyroid function as a result of perchlorate exposure below the reference dose (Blount et al, 2006a). A study of urinary perchlorate levels indicated widespread human exposure to perchlorate (Blount et al, 2006b).

The RfD can be translated to a drinking water context through the standard assumption that a 70-kg individual consumes 2 L/d of water and that drinking water is the only

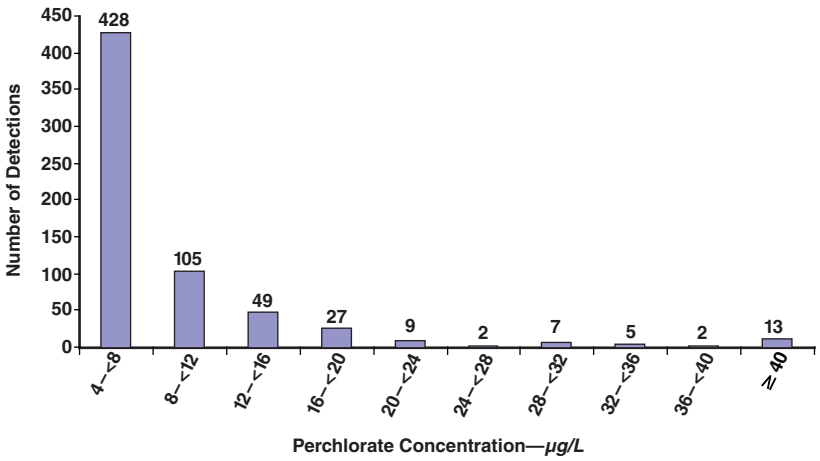
Inclusion of perchlorate on the first Contaminant Candidate List was based primarily on the discovery of perchlorate in California drinking water supplies.

TABLE 1 Perchlorate drinking water limits for various states

State	Limit—*µg/L*	Description
Arizona	14	Health-based guidance level
California	6	Maximum contaminant level
Massachusetts	2	Maximum contaminant level
New Jersey	5	Department of Environmental Protection recommendation
New York	18	Public notification level
Texas	4	Action level

oral exposure pathway. On the basis of these assumptions, the perchlorate RfD converts to a drinking water equivalent level concentration of 24.5 µg/L (USEPA, 2006a). Several studies strongly suggest that drinking water is not the only oral exposure pathway and that diet may be a large contributor to daily perchlorate exposure, including exposure from milk (Kirk, 2003), lettuce (Sanchez, 2005a), and other leafy vegetables (Sanchez, 2005b). Based on FDA's recent total diet study, estimated average perchlorate intakes ranged from 0.08 to 0.39 µg/kg of body weight per day, compared with the NRC RfD of 0.7 µg/kg of body weight per day (Murray et al, 2008).

FIGURE 1 Distribution of UCMR1 perchlorate detections



UCMR1—Unregulated Contaminants Monitoring Rule 1

Current regulatory status. In 1999, perchlorate was included in the first Unregulated Contaminant Monitoring Rule (UCMR1; USEPA, 2001). In 2003, USEPA decided not to regulate nine contaminants from the CCL1, and no decision was issued on perchlorate because the agency was awaiting monitoring results from UCMR1 as well as additional health effects data (USEPA, 2003). Perchlorate was rolled over into the second CCL (CCL2) in 2005, along with 50 other remaining CCL1 contaminants (USEPA, 2005b).

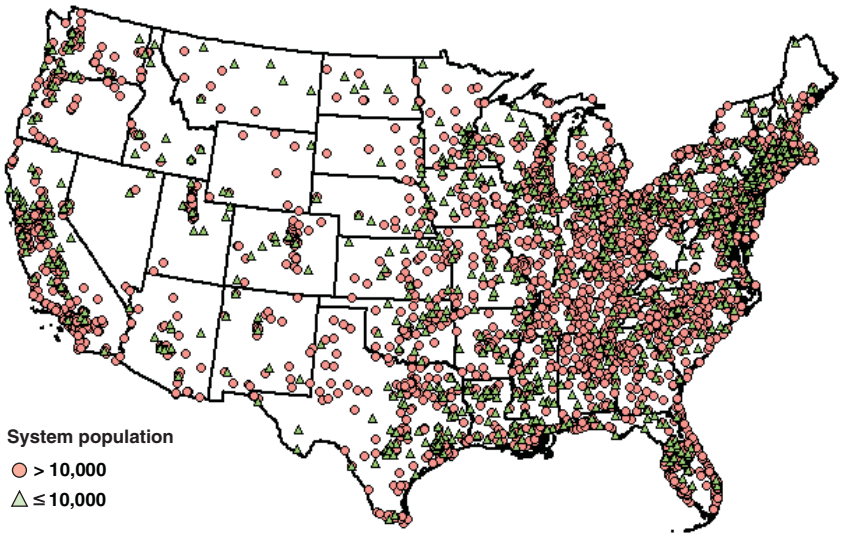
In 2006, USEPA presented a status report on the assessment for perchlorate without proposing a regulatory determination (USEPA, 2006b). In that assessment report, USEPA summarized the available data regarding perchlorate concentrations in food. Since then, the US Food and Drug Administration (FDA) has published the results of a total diet study, which partially fills the information gap noted by USEPA (Murray et al, 2008). Absent a regulatory determination, perchlorate was included in the draft CCL3 (USEPA, 2008a). In October 2008, the USEPA issued a preliminary regulatory determination that a National Primary Drinking Water Regulation for perchlorate would not present "a meaningful opportunity for health risk reduction" (USEPA, 2008b). Three months later, in January 2009, USEPA issued an Interim Drinking Water Health Advisory Level of 15 µg/L based on the analysis performed by the Office of Water (USEPA, 2008c). The Interim Drinking Water Health Advisory was issued to assist state and local officials in advance of a final regulatory determination. USEPA expects to issue a final health advisory concurrent with the final regulatory determination for perchlorate. Before these actions were taken, several states independently established guidelines or enforceable limits for perchlorate in drinking water (Tikkanen, 2006). An overview of these limits is included in Table 1.

Although at the time this article was written USEPA had not made a regulatory determination regarding perchlorate in drinking water, its Office of Solid Waste and Emergency Response had established a preliminary remediation goal (PRG) of 24.5 µg/L in groundwater based on exposure of pregnant women (USEPA, 2006a). The PRG was criticized for not being sufficiently protective of this subpopulation (Ginsberg et al, 2007). The PRG was lowered in January 2009 in conjunction with establishment of the Interim Drinking Water Health Advisory of 15 µg/L (USEPA, 2009). Taken together, all of these actions indicate that the regulatory environment for perchlorate is uncertain.

Initial perchlorate occurrence surveys. After the initial detection of perchlorate in California drinking water supplies, perchlorate occurrence surveys were completed by the American Water Works Service Company (AWWSC) and the Awwa Research Foundation (AwwaRF; now known as the Water Research Foundation). These surveys provided the first national assessments of perchlorate occurrence within the United States. Before completion of the studies reviewed in this article, the AWWSC and AwwaRF studies were the most complete assessment of domestic perchlorate occurrence. In summary, the two surveys indicated that perchlorate contamination existed outside of California and that the rate of perchlorate detection in raw or treated drinking water supplies was on the order of 5% or less. These studies, performed before the adoption of method 314.0 (USEPA, 1999a) for perchlorate detection, also indicated a need for the refinement of perchlorate detection analytics in order to increase the accuracy and repeatability of perchlorate quantification.

American Water Works Service Company survey (AWWSC; Gullick et al, 2001). This survey of AWWSC systems was performed during 1997 and 1998. The survey included sampling of both surface water and ground-

FIGURE 2 Location of systems* in the continental United States sampled for perchlorate by UCMR1



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**Systems were also tested in Alaska, Hawaii, American Samoa, Guam, Puerto Rico, and N. Mariana Islands (not shown).*

water. Forty-two surface water samples were taken from 40 sites in 11 states served by AWWSC. No perchlorate was detected at a concentration exceeding the method reporting limit (MRL) of 4 µg/L for any of the surface water sites. A total of 522 groundwater samples from 367 wells in 17 states served by AWWSC were also analyzed. These included 329 untreated sources and 38 treated sources. Of the 367 wells tested, 18 (4.9%) exceeded the 4-µg/L MRL at least once. The presence of perchlorate was confirmed by a second detection in nine of the 18 wells. Of the remaining nine wells in which perchlorate was detected, the study concluded that five were false-positives caused by analytical abnormalities. Wells with confirmed perchlorate detections were in California and New Mexico.

National assessment of perchlorate contamination occurrence (Wang et al, 2002). The objective of this AwwaRF-sponsored study was to assess perchlorate occurrence in US drinking water supplies using analytical methods available at the time.

The AwwaRF study performed both targeted and nontargeted sampling for perchlorate occurrence. Targeted sampling sites were selected based on a hazard-ranking evaluation methodology that prioritized sampling near locations of known perchlorate release. A total of 160 targeted drinking water samples were collected between May 1999 and July 2000. Of these samples, four groundwater sources and two surface water sources in Maryland, Arizona, and New York tested positive for perchlorate. One additional targeted source, which was unidentified, also tested positive for perchlorate. The nontargeted sampling consisted of collecting 138 surface water or groundwater samples from very large water systems (serving > 100,000 people) in 31 states. No perchlorate was detected in these samples.

ANALYSIS METHODOLOGY

Assumptions regarding occurrence studies. The sources of data incorporated into the assessment described in this article are samples collected by utilities for the UCMR1 and by state-sponsored studies in Arizona, California, Massachusetts, and Texas. No sampling of perchlorate was performed independently to support the assessment presented in this article. Data were analyzed in keeping with the guidelines decribed in the following paragraphs.

- **Scope.** The scope of this analysis was limited to perchlorate occurrence in drinking water sources or in treated drinking water.
- **Data sources.** The data sources for this project were limited to surveys of perchlorate performed by or under the direction of the USEPA or state agencies. Department of Defense, local government, or private surveys of perchlorate occurrence were not included in this analysis.
- **Acceptable analytical methods.** Only perchlorate concentration data obtained using methods based on USEPA method 314.0 or subsequent revisions of that method were considered. Because of this limitation, the results of the AWWSC and AwwaRF studies described previously are not included in the maps or analysis presented in this article.
- **Determination of detection in a source.** A detection of perchlorate was defined as one or more measurements of perchlorate at or above the reporting limit identified for that particular study.
- **Averaging of perchlorate values.** Measurements of perchlorate concentrations from multiple samplings at a source were averaged to provide an estimate of that source's perchlorate concentration. Nondetects were assigned a value of half of the reporting limit for that sample and included in the calculation of the average concentration for the source, if that source had detected perchlorate at or above the reporting limit in a separate sampling. It should be noted that by assigning nondetects a value of half the reporting limit, it is possible for the average concentration of a source with both detects and nondetects to be less than the reporting limit for the

individual samples taken from that source. The perchlorate concentration for sources in which perchlorate was never detected was assumed to be zero.

- **Data quality.** The analytical data (e.g., measured perchlorate concentration) contained in the databases evaluated by this study were assumed to be accurate. No attempt was made to judge the quality or accuracy of any analytical data. If possible, clearly erroneous information related to a sample (e.g., a utility listed in the wrong state) was corrected. If the appropriate correction was not obvious, the erroneous information and the related perchlorate data were excluded from the analysis.
- **Mapping.** Occurrence information was mapped to the highest level of geographic accuracy possible with the available data. The precedence used for mapping the location of perchlorate occurrence was in this order: (1) latitude/longitude of the source, (2) centroid of zip code of the source, (3) centroid of zip code of the administrative unit responsible for the source, and (4) centroid of the nearest city.

ANALYSIS OF UCMR1 DATA

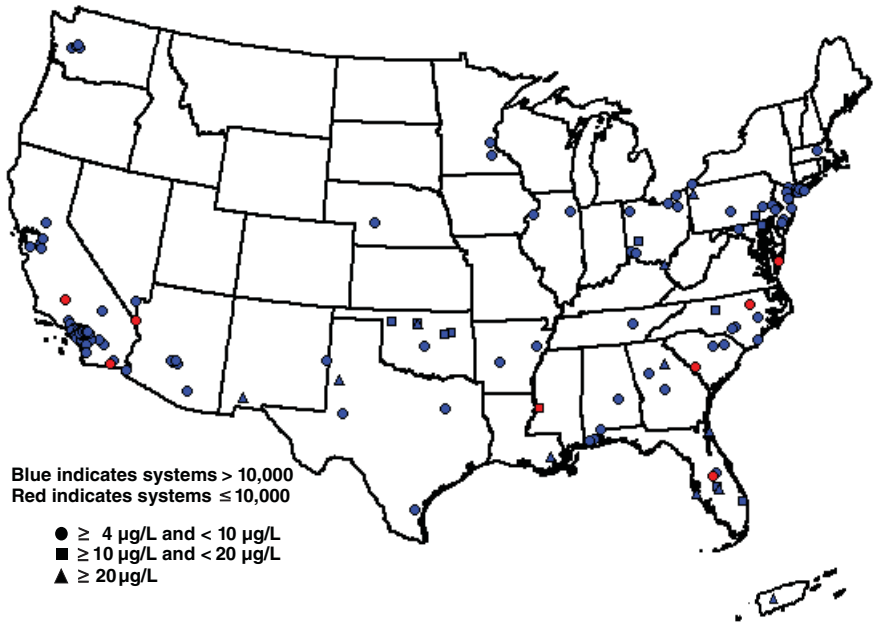
UCMR1 description. Perchlorate was included by USEPA on the list of contaminants to be monitored under the UCMR1 in September 1999 (USEPA, 2001). Sampling began in 2001 and was scheduled to be completed by the end of 2003. However, perchlorate samples collected as early as May 2000 and as late as October 2005 are included in the final UCMR1 database. Under the original UCMR1 plan, approximately 2,800 large systems (> 10,000 people served) and 800 small systems (≤ 10,000 people served) were required to sample for perchlorate. The UCMR1 sampling plan included a census of large systems and a stratified sampling of small systems. Depending on the configuration of the utility, perchlorate samples were drawn either at entry points to the distribution system (67% of all sample locations) or from untreated source water (31% of all sample locations). Approximately 1% of all samples were drawn from other locations. Samples were analyzed per method 314.0 (USEPA, 1999a) and reported to an MRL of 4 µg/L. Sampling frequency depended on source water type. Surface water sources were to be sampled quarterly over a one-year period and groundwater sources twice in a one-year period. In general the actual sampling for perchlorate closely followed this plan, with 3,073 large systems and 797 small systems sampled. The frequency and number of samples taken from each sampling location tended to vary from the original plan. One reason for the deviation from the original plan may be that some sources were taken out of service after perchlorate was detected. Data for the analysis reported in this article were taken from the UCMR1 January 2006 database, released on USEPA's UCMR website (www.epa.gov/safewater/ucmr/data.html).

Summary of UCMR1 results. Overall, out of 34,728 results recorded in the database, perchlorate was detected 647 times or in 1.9% of the samples. The range of detected values extends from 4 µg/L (the MRL) to 420 µg/L. The distribution of detections by range of concentration is shown in Figure 1. Figures 2 and 3 show the location of UCMR1 systems measuring for perchlorate and those detecting perchlorate, respectively. Perchlorate was detected in 160 (4.1%) of the 3,870 systems tested.

Table 2 consolidates the occurrence information by sampling point location. Perchlorate was detected in 387 (2.6%) of the 14,993 sample points. Of the 387 perchlorate detections, about half did not recur in multiple sampling events (i.e., perchlorate was only detected once at the sampling point when more than one sample was collected). Conversely, perchlorate was found in every sample for 28% of the sampling points at which perchlorate was detected.

Additional analysis of the data set was performed to determine the occurrence of perchlorate by source water classification and system size. As shown in Table 3, perchlorate was detected at approximately equal rates for both surface water and groundwater sources. There appears to

FIGURE 3 UCMR1 perchlorate detections



UCMR1—Unregulated Contaminants Monitoring Rule 1

TABLE 2 UCMR1 perchlorate detection by sample points

Category	Number	Total Sample Points—%	Sample Points With Detections—%
Total sample points	14,993		
Sample points with detections	387	2.6	
Sample points with one detection	184	1.3	47
Sample points with single measurement and detection	54	0.4	14
Sample points with two or more detections	42	0.3	11
Sample points with all detections	107	0.7	28

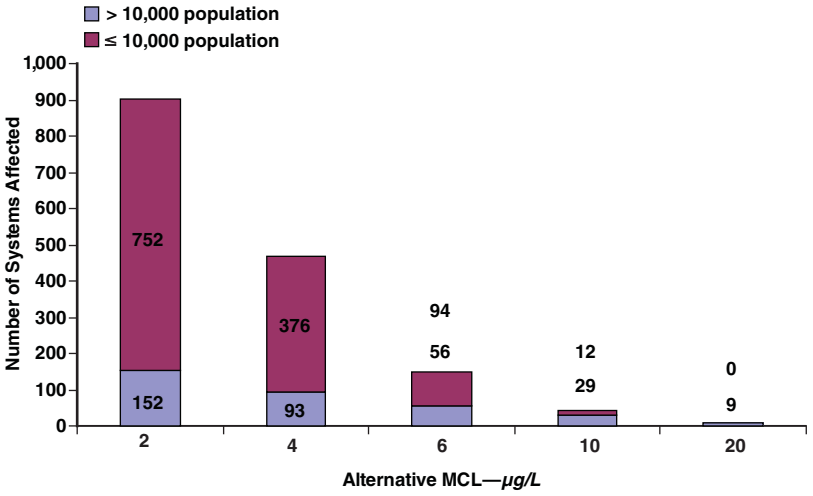
UCMR1—Unregulated Contaminants Monitoring Rule 1

TABLE 3 Summary of perchlorate occurrence by system size and classification

	Systems with Population ≤ 10,000 People			Systems with Population > 10,000 People		
Classification	Sampled	Detected	Percentage	Sampled	Detected	Percentage
Groundwater	572	5	0.9	1,290	64	5.0
Surface water	217	3	1.4	1,727	88	5.1
Unknown	8	0	0	56	0	0
Total	797	8	1	3,073	152	4.9

be a difference in the rate of occurrence between large and small systems, with perchlorate being found more frequently in large systems. However, caution must be applied in interpreting these data. Because small systems were sampled using a stratified sampling strategy (USEPA, 1999b), an unbiased estimate of occurrence for the entire small-system population can only be made by an estimator that is weighted by the sampling probability of each sample within the strata. Lacking these weighting factors, a statistically based occurrence estimate for small systems could not be completed. Thus the information presented in Table 3 for small systems (population ≤ 10,000) represents the rate of perchlorate occurrence within the subset of small systems sampled, not a projection of perchlorate occurrence in the total population of small systems. Occurrence information for large systems is valid without any adjustment because, as previously noted, a census of large systems was performed and the sampled population and total population are the same.

FIGURE 4 Projection of the number of systems that would be affected by alternative perchlorate MCLs



MCLs—maximum contaminant levels

On the basis of data for public water systems with populations > 10,000, an exact prediction can be made of the number of large systems affected by alternative perchlorate maximum contaminant levels (MCLs; Figure 4). As noted, a prediction of the number of small systems affected by alternative perchlorate MCLs cannot be statistically made without the weighted sampling probability of each sample within the strata. However, a projected estimate can be made for small systems by simple extrapolation of the available small-system data, assuming the ratio of small systems affected at a particular

MCL remains identical for the sample and full population. Using this method for small-system prediction, the total number of systems affected by a perchlorate MCL would range from 904 at an MCL of 2 µg/L to 9 at an MCL of 20 µg/L.

Most systems have multiple sources or entry points to the distribution system, and perchlorate may not be present at all these points. A system that has detected perchlorate in only a portion of its sources or entry points may have the option of eliminating the perchlorate-contaminated source. On the other hand, a system detecting perchlorate in most or all of its sources or entry points will probably have no other option than to install perchlorate treatment. As shown in Figure 5, ~ 60% of the systems detecting perchlorate found it in ≤ 50% of their sources or entry points. These systems may have the option of eliminating sources. Twenty-two percent of the systems detected perchlorate in > 75% of their sources or entry points. These systems are less likely to be able to eliminate perchlorate-contaminated sources and will more likely be required to install treatment.

An attempt was made to determine whether there was a geographic relationship between the locations of perchlorate occurrence in drinking water as determined by UCMR1 data (Figure 2) and the locations of known releases of perchlorate into the environment as tracked by USEPA's Federal Facilities Restoration and Reuse Office (FFRRO; USEPA, 2004). The FFRRO list identifies 73 federal government sites operated by the departments of Defense, Energy, and Interior; the National Aeronautics and Space Administration; and 37 private sites where perchlorate release to the environment has been identified. This list should not be considered comprehensive, but it does represent a best effort by USEPA to identify known perchlorate releases at the time of its publication. As is shown in Figure 6, the geographic locations of perchlorate releases identified by FFRRO have little correspondence to the geographic locations of the UCMR1 detections. Perchlorate is frequently found in areas in which there is no identified source of environmental release. For example, perchlorate has been detected by UCMR1 sampling in North Carolina and Minnesota, yet there is no identified release of perchlorate in either state. The implication is that sources of perchlorate release to the environment are more widespread and numerous than indicated by the USEPA FFRRO list. Other possible sources of perchlorate release could include local activities, such as blasting or other uses of explosives, residual contamination from fireworks displays, manufacturing processes or laboratories, or perchlorate-containing fertilizers. The formation of perchlorate by natural processes is also possible and has been documented in several studies (Rao et al, 2007; Plummer et al, 2006).

Perchlorate phone survey and results. As a followup to the evaluation of perchlorate occurrence data from the UCMR1, 160 water systems with perchlorate detections were surveyed by telephone (during May–June 2007) to obtain current information about the use of water sources that had positive perchlorate results (at or above 4 µg/L). Each utility was telephoned at least once for a survey interview. When the appropriate individual was reached, a short list of questions was asked. Not all systems responded to the original request for information or to followup inquiries. A total of 70 systems (43%) responded to one or more of the survey questions.

Responding systems indicated that 192 sources testing positive for perchlorate are still on-line. Of these, 63 required treatment to meet applicable state regulations. The combined production volume for all water sources detecting perchlorate is 45,345 mgd. Some utilities indicated that the perchlorate concentrations had dropped in some sources since the original UCMR1 sampling, so those sources continued to operate. Responding systems reported that since the UCMR1 sampling was completed, 32 sources belonging to a total of 13 systems with a combined production volume of 50 mgd had been taken off line because of the level of perchlorate contamination. Eight systems indicated they would be replacing sources that had been taken off-line. The survey findings are summarized in Table 4.

FIGURE 5 Percentage of sampling points containing perchlorate in systems that have detected perchlorate

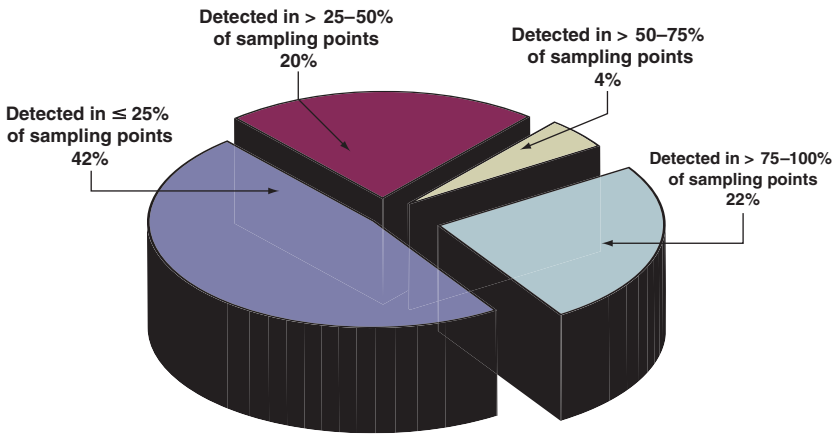


TABLE 4 Perchlorate survey findings

Parameter	Result
Number of systems contacted	160
Number of respondents	70
Number of systems that have taken raw water sources off-line because of perchlorate	13
Number of systems planning to replace raw water sources that were taken off line	8
Annual average production for all affected sources	45,345 mgd
Total known million gallons per day of water taken off line	50
Number of sources testing positive that have been taken off line	32
Number of sources testing positive that are still on line	192
Number of sources testing positive that are being treated or blended	63
Number of systems that blend perchlorate-contaminated water with other water	9
Number of systems that claimed they had no perchlorate	12
Number of systems with test results after UCMR1 showing nondetection	5
Number of systems with perchlorate data beyond UCMR1	35
Number of systems that would put sources back on line if no regulation	3

UCMR—Unregulated Contaminants Monitoring Rule 1

REVIEW OF STATE-SPONSORED PERCHLORATE OCCURRENCE STUDIES

Concurrent with data collection under the UCMR1, several states undertook their own perchlorate sampling programs. A summary of theses studies is shown in Table 5. Additional information regarding the findings of these studies is summarized in Brandhuber and Clark (2005).

Arizona Department of Environmental Quality study (ADEQ, 2004). In 2004 the state of Arizona completed a statewide perchlorate sampling program. The objective of the program was to conduct a comprehensive assessment of perchlorate concentration in Arizona waters. The study was a general assessment of perchlorate occurrence, and both potable and nonpotable sources were sampled.

The survey took 88 perchlorate measurements at 85 sites. Perchlorate was detected in 34 (39%) measurements and at 33 (39%) of the sites. Most sites detecting perchlorate were surface waters on or supplied by the Colorado River at locations downstream of the Kerr-McGee facility near Henderson, Nev. In general, perchlorate concentrations in the 2004 sampling were lower than in samples taken at similar locations before 2004. Arizona attributes the decrease in perchlorate concentrations in Colorado River water and Central Arizona Project water to the initiation of perchlorate treatment at the Kerr-McGee facility.

California Department of Public Health (CDPH, 2008). A preliminary sampling of several hundred wells was initiated in 1997 by the California Department of Health Services (now the California Department of Public Health [CDPH]). The study found perchlorate in both northern and southern California groundwaters. In 1999 CDPH instituted a regular perchlorate monitoring program that is still in operation. Between 2004 and 2008, perchlorate was detected at concentrations exceeding 4 µg/L in 290 sources supplying 85 public water systems. The bulk of these systems are in Los Angeles, Riverside, San Bernardino, and Orange counties. Perchlorate concentrations as high as ~ 100 µg/L have been detected in these systems.

TABLE 5 State perchlorate occurrence studies

State	Detection Level *µg/L*	Date	Number of Sources Detected/Sampled	Maximum Detection *µg/L*	Primary Finding
Arizona	2–4	2004	33/85	820	Decreasing trend in Colorado River and Central Arizona Project water
California	4	2002–07	248/6,000	100	Occurrence primarily in Southern California
Massachusetts	1	2004–05	9/591*	40	Likely anthropogenic sources
Texas	1–4	2003–05	246/560	40	Likely natural sources

*Systems

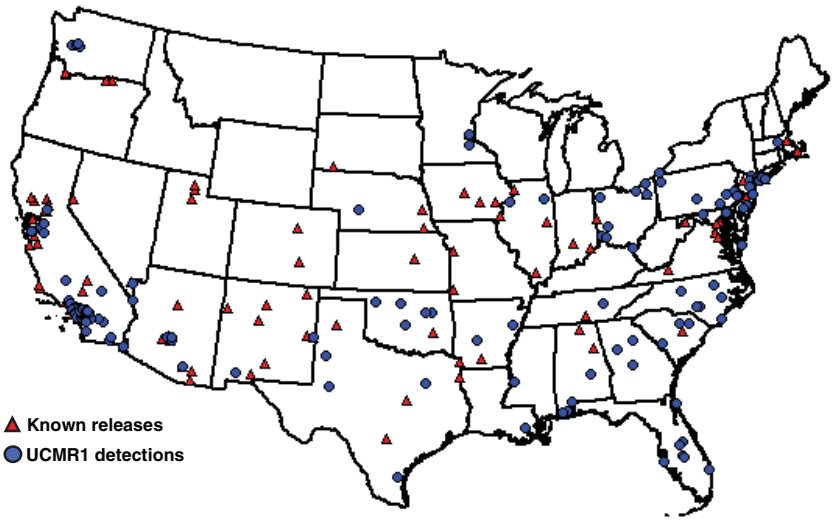
Massachusetts Department of Environmental Protection (MDEP, 2006). The Massachusetts Department of Environmental Protection (MDEP) completed a perchlorate monitoring program in 2004. This program tested a total of 591 community and nontransient–noncommunity public water supplies, representing about 85% of all water suppliers in the state. The study identified 12 water sources supplying nine public water systems in which perchlorate was detected at concentrations exceeding 1 µg/L. For seven of the nine systems detecting perchlorate, the likely cause was anthropogenic activities. In six of the seven cases, the anthropogenic activities involved the use of explosives or fireworks.

Texas Commission on Environmental Quality (TCEQ; Jackson et al, 2004). Initial sampling performed under the UMCR1 detected perchlorate in potable groundwaters in the vicinity of Midland, Texas. As a result, the TCEQ hired the Texas Tech University Water Resources Center to perform a study of perchlorate occurrence in 54 counties in Texas and three counties in eastern New Mexico (Rajagopalan et al, 2006). The study included sampling of irrigation wells, private wells, and wells used by public water systems. Out of 815 wells tested, perchlorate was detected in 246 wells (30%) at levels exceeding 1 µg/L. This study is of particular interest because no credible anthropogenic source of perchlorate has been identified that could be responsible for the consistent detection of perchlorate over such a large geographic area and in some cases in groundwater exceeding an estimated 20,000 years in age (Plummer et al, 2006). Researchers at Texas Tech have proposed that perchlorate contamination of groundwater can be caused by natural sources (Rajagopalan et al, 2006; Dasgupta et al, 2005), under conditions that are distinctive to the region.

INTEGRATED MAP OF UCMR AND STATE-SPONSORED STUDIES

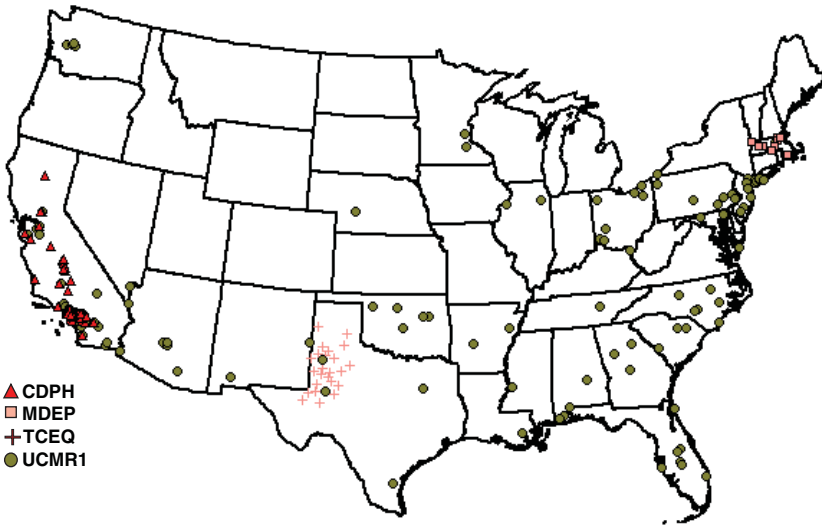
Perchlorate occurrence data obtained by UCMR1 sampling were combined with potable water data from the California, Massachusetts, and Texas studies to develop an integrated map of perchlorate occurrence in drinking water (Figure 7). Because there was no clear distinction between potable and nonpotable sources in the Arizona report, the Arizona data were not included in this map. If the multistate data are taken into consideration, an additional 59 systems have detected perchlorate beyond those identified by the UCMR1. There

FIGURE 6 Comparison of known perchlorate releases and UCMR1 detections



UCMR1—Unregulated Contaminants Monitoring Rule 1

FIGURE 7 Integrated map of perchlorate detection data from the UCMR1 and state surveys in California, Massachusetts, and Texas



CDPH—California Department of Public Health, MDEP—Massachusetts Department of Environmental Protection, TCEQ—Texas Commission on Environmental Quality, UCMR1—Unregulated Contaminants Monitoring Rule 1

are several reasons for these additional detections. In the case of California, both large and small systems have been sampled more frequently and over a longer period of time, increasing the likelihood of a perchlorate detection. In the cases of Massachusetts and Texas, a lower criterion was used (1 versus 4 µg/L) to define a perchlorate detection compared with that of the UCMR1 sampling. Also, in the case of Texas, a number of small systems in the western portion of the state detected perchlorate because of natural conditions unique to the area. Because a census of small systems was not performed by UCMR1, the sample population was probably too small to capture these localized effects in a region like this with many small systems.

CONCLUSIONS

This study consolidated existing potable water perchlorate occurrence information taken from recently completed and ongoing occurrence studies. Maps were developed showing the location of known detections of perchlorate in public drinking water systems to provide insights into the level at which perchlorate has been detected in these systems. The locations at which perchlorate was detected in drinking water systems were compared with known locations of perchlorate releases. A telephone survey was conducted to determine what steps systems have taken to address sources that have had positive detections of perchlorate.

The detection of perchlorate in drinking water was determined to be widespread but at low concentrations. On the basis of UCMR1 data, perchlorate has been detected in drinking water in at least 26 states and Puerto Rico and in approximately 5% of the nation's large public water systems. When detected, perchlorate was typically present at concentrations of < 12 µg/L and was generally found in fewer than half of the sources for systems that sampled multiple sources. No difference was found between surface water and groundwater in the rate of perchlorate occurrence. Extrapolating the results of the occurrence studies reviewed by this report, it appears that nationally < 1% of all drinking water systems would be affected if an MCL of 20 µg/L was established. An MCL of 2 µg/L could affect approximately 4% of US public

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water systems. Given the observed rate of occurrence, regional effects in California and Texas would be greater. Yet water systems in Massachusetts and California have already established regulatory limits of 2 and 6 µg/L, respectively, thereby capping the population exposure potential from public drinking water sources in those states. Significantly, there appears to be little correspondence between perchlorate detection in drinking water and known points of perchlorate release to the environment identified by the USEPA. A survey of systems detecting perchlorate indicated that production of at least 50 mgd has been taken off-line nationally as a result of the presence of perchlorate since monitoring under the UCMR1 was completed.

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