Drinking Water Quality: Disinfection By-product Contaminant Levels

Type of EPHT Indicator	Hazard, Exposure
Measures	Level of Contaminant in Finished Water 1. Quarterly distribution of number of Community Water Systems (CWS) by mean HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 2. Yearly distribution of number of CWS by maximum HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 3. Yearly distribution of number of CWS by mean HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 4. Average Concentration of HAA5, by Year. 5. Quarterly distribution of number of CWS by mean TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM). 6. Yearly distribution of number of CWS by maximum TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM). 7. Yearly distribution of number of CWS by mean TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM). 8. Average Concentration of TTHM, by Year. Potential Population Exposure to Contaminants in Finished Water 9. Quarterly distribution of population served by Community Water Systems (CWS) by mean HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 10. Yearly distribution of population served by CWS by maximum HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 11. Yearly distribution of population served by CWS by mean HAA5 concentration (cut-points: (0-15), (>15-30), (>30-45), (>45-60), (>60-75), (>75) µg/L HAA5). 12. Quarterly distribution of population served by CWS by mean TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM). 13. Yearly distribution of population served by CWS by maximum TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM). 14. Yearly distribution of population served by CWS by mean TTHM concentration (cut-points: (0-20), (>20-40), (>40-60), (>60-80), (>80-100), (>100) µg/L TTHM).
Derivation of Measures	Disinfection byproducts measures will be developed from water system attribute and water quality data stored in state Safe Drinking Water Act (SDWA) databases such as the Safe Drinking Water Information System (SDWIS/State). Trihalomethanes comprise chloroform, bromodichloromethane, dibromochloromethane, bromoform and their sum, denoted total trihalomethanes (TTHM). Haloacetic acids comprise trichloroacetic acid, dichloroacetic acid, monochloroacetic acid, dibromoacetic acid, monobromoacetic acid, and their sum, denoted HAA5. Data will be cleaned and transformed to a standard format. Analytical results of drinking water samples (usually taken at entry points to the distribution system or representative sampling points after treatment) will be used in conjunction with information about each CWS (such as service population and latitude and longitude of representative location of the CWS service area) to generate the measures.
Units	concentration of HAA5, µg/L

	concentration of TTHM, µg/L
Geographic Scope	State and Community Water System
Geographic Scale	The finest detail will be approximate point location of the community water distribution system represented by water withdrawal point, water distribution extents, principal county served, or principal city served.
Time Period	2000-Most Recent Year Available
Time Scale	Calendar year
Rationale	**Disinfection By Products and Public Health** Disinfection byproducts (DBP) are formed when disinfectants used to inactivate microbial contaminants in water react with materials, primarily organic matter, in the water (Bellar et al. 1974, Rook 1974, Cedergren et al. 2002, Sadiq and Rodriguez 2004). Several hundred DBPs in over a dozen chemical classes have been identified (Woo et al. 2002, Krasner et al. 2006). Most commonly, DBPs form when chlorine reacts with naturally occurring organic matter in the source water. DBPs have been associated with both cancer and adverse pregnancy outcomes. High DBP levels, mainly for THMs, have been linked to bladder, colon and rectal cancer (King and Marrett 1996, Cantor et al. 1998, Amy et al. 2005, Villanueva et al. 2004, Villanueva et al. 2007), with bladder cancer reported most frequently. Although findings about adverse pregnancy outcomes have been less definitive, DBPs have been implicated in fetal loss (Swan et al. 1998, Waller et al. 1998, King et al. 2000, Dodds et al. 2004) and a variety of adverse birth outcomes involving growth (Bove et al. 1995, Gallagher et al. 1998, Wright et al. 2004, Infante-Rivard 2004, Toledano et al. 2005) and birth defects (Dodds et al. 1999, Klotz and Pyrch 1999, Dodds and King 2001, Cedergren et al. 2002, Shaw et al. 2003). In contrast, however, other research has found little effect on birth outcomes (Savitz et al., 2006). Animal, microbial, in vitro and modeling studies have also pointed to toxicity or carcinogenicity of a wide variety of DBPs (Boorman 1999, Komulainen 2004). Numerous studies have indicated that different DBPs among the THMs and HAAs have different health effects. A number of studies have suggested that iodinated and brominated DBPs are more toxic than their chlorinated counterparts (Plewa et al. 2002, 2004, Richardson 2005). It is therefore appropriate that the tracking network follow individual DBP species and not just class totals (c.f. Singer 2006). **Sources of DBPs** DPB levels tend to be highest in water derived from surface sources because ground water generally has little organic matter (Symons et al. 1975, Whitaker et al. 2003). Ground water can, however, produce relatively high levels of the more brominated DBPs when the water, due either to geological circumstances (Whitaker et al. 2003) or salt water intrusion in coastal areas (von Gunten 2003), has elevated levels of bromide. Bromate and chlorite are formed primarily after disinfection by ozone and chlorine dioxide, respectively. Sampling for these DBPs is required only for treatment plants that use the disinfectants that form them. Ozonation and chlorine dioxide are less common mechanisms of disinfection so these two DBPs will not be tracked initially. The disinfection processes that produce these two byproducts are likely to be used more often in the future so bromate and

	chlorite should be considered for eventual incorporation into the tracking network. **DBP Regulation and Monitoring** Safe Drinking Water Act (SDWA) regulation of DBPs began with the 1979 Total Trihalomethane Rule. This rule set an interim MCL for total trihalomethanes (TTHM), defined as the sum of four trihalomethanes, of 0.10 mg/L for community water systems (CWS) serving 10,000 or more people and using a disinfectant. The Stage 1 Disinfectants and Disinfection Byproducts Rule of 1998 (US EPA 1998) reduced the MCL for TTHM to 0.080 mg/L, added MCLs for the sum of five haloacetic acids (HAA5) of 0.060 mg/L, bromate of 0.010 mg/L and chlorite of 1.0 mg/L, and increased the scope of the rule to cover all CWS that disinfect. The rule had phased compliance with a date of 1 January 2002 for public water systems (PWS) with 10,000 or more people with a surface water or ground water under direct influence source and a date of 1 January 2004 for all other affected PWSs. The Stage 2 Disinfectants and Disinfection Byproducts Rule of 2006 (US EPA 2006) did not alter MCLs but did change how compliance with MCLs will be calculated and requires that PWSs evaluate their distribution systems for appropriate sampling locations. The results of this evaluation may affect the number and location of samples. The scope of the rule also increased to cover consecutive systems that receive finished water from other systems. The first reporting deadline for compliance with the Stage 2 rule was in 2006 but it will be a number of years before the rule requires the new compliance calculations based on routine DBP samples. Currently, therefore, Safe Drinking Water Act standards exist for two classes of halogenated organic DBPs, trihalomethanes (THM) and haloacetic acids (HAA), and for two inorganic compounds, bromate and chlorite (US EPA, 2007). Given the near ubiquity of chlorine disinfection, the THMs and HAAs are useful indicators of risk for other DBPs because they occur at high levels and are easily measured. In summary, evidence suggests that disinfection byproducts adversely affect human health. The THMs and HAAs are the most commonly formed DBPs that are routinely tracked in state Safe Drinking Water Act databases. Measures based on these contaminants thus provide a window into potential human exposure to DBPs in publicly provided drinking water. They show where people are potentially exposed to high levels of DBPs. These water supply systems are candidates for enhancement of source water quality, infrastructure improvements or other interventions to reduce DBP exposure.
Use of Measure	These measures assist by providing data that can be used for surveillance purposes. • Distribution measures provide information on the number of CWS and the number of people potentially exposed to nitrate at different concentrations. • Maximum concentrations provide information on the peak potential exposure to nitrate at the state level. • Mean concentrations at the CWS level provide information on potential exposure at a smaller geographic scale.
Limitations of The Measure	The current measures are derived for CWS only. Transient non-community water systems, which are regulated by EPA, may also be an important source of DBPs exposure. Measures do not account for the variability in sampling, numbers of sampling repeats, and variability within systems. Concentrations in drinking water cannot be directly converted to exposure, because water consumption varies by climate, level of physical activity, and between people (EPA 2004). Due to errors in estimating populations, the measures may overestimate or underestimate the number of affected people.

Data Sources	Iowa Department of Natural Resources
Limitations of Data Sources	Safe Drinking Water Act compliance data include only a handful of the hundreds of known DBPs (Weinberg et al. 2002), most of which occur in chemical classes other than THMs and HAAs. While compliance sampling for THMs and HAAs is directed at the DBPs thought to be most commonly produced by chlorination, non-regulated DBPs exist even among the THMs and HAAs. Concern has also been expressed about iodinated THMs and HAAs which, while present in lower concentrations than the brominated and chlorinated THMs, are thought to be toxic at lower doses (e.g. Plewa et al. 2004). THMs and HAAs may not be the most satisfactory indicators of DBP levels in waters subject to alternative disinfection methods that produce different DBPs in different proportions than chlorination (Richardson 2002, Weinberg et al. 2002) and may result in high levels of unregulated DBPs. Little is known about the quantitative occurrence of these DBPs in the distribution system (Richardson et al. 2002, Krasner et al. 2006). While the health effects of different DBPs may vary, with some suspected to be hazardous, few have been characterized for their effects on human health (Woo et al. 2002). Correlations among different DBPs can be relatively low (King et al. 2004, Rodriguez et al. 2004a) so that the measured concentrations of THMs and HAAs may not be good predictors of exposure to other DBPs or overall DBP exposure. THM4 or HAA5, which are the only available data in some state databases, may therefore tell little about the relative concentrations of the THMs or HAAs. DBP levels vary seasonally (Singer et al. 1981, Whitaker et al. 2003, Rodriguez et al. 2004b). Quarterly samples may not capture maximum levels and may not even adequately reflect short term levels. They may therefore be inadequate for estimating exposure during critical periods of a pregnancy, which may be as short as tow to three weeks, especially if peak exposure matters more than average exposure. Furthermore, these fluctuations make it difficult to characterize levels with a single number such as an annual average and thus pose challenges to the development of meaningful synopses of patterns and trends. DBP levels are spatially and temporally labile within a distribution system (Rodriguez et al. 2004b). THM levels increase with time after disinfection and therefore with distance from the treatment plant (Chen and Weisel 1998, Rodriguez and Sérodes 2001). HAA levels may increase or decrease (Chen and Weisel 1998, Rodriguez et al. 2004b), depending upon distribution system conditions. Rechlorination further increases DBP levels. For all but small distribution systems it is therefore impossible to adequately characterize DBP levels with a single value. DBP sampling locations may change over time, making it more difficult to compare measurements from year to year. Better estimation of DBP levels will require spatial and hydraulic modeling of distribution systems. Water supply systems sample for DBPs on different schedules that range from quarterly to triennially. Different sampling frequencies complicate comparisons among different water supply systems. Long intervals between samples, although allowed only where THM and HAA levels have been found to be well under the MCL, create greater uncertainty about levels between sampling dates and require stronger assumptions when estimating exposure during short term

	events such as pregnancies. When allowed, annual or triennial monitoring takes place during the month of warmest weather and may therefore overestimate average DBP levels. Water supply systems that have disinfection waivers generally have no DBP sample results. While the default assumption that these water supply systems have DBP concentrations of zero is generally reasonable, low levels of DBPs can be found in raw ground water, e.g., from surface contamination or from movement of chlorinated water from onsite wastewater treatment systems into ground water. Human behavior greatly influences exposure, complicating efforts to estimate exposure from tap water measurements (Nieuwenhuijen et al. 2000, Kaur et al. 2004, Nuckols et al. 2005). Among the influences on exposure are showering and bathing time, consumption of tap water, use of bottled water, and exposure to water at workplaces or other locations outside the home. Moreover, ascertaining DBP levels in drinking water does not address other routes of exposure such as swimming (Villanueva et al. 2007, Zwiener et al. 2007). This consideration is not strictly a limitation of the measure but pertains to using the measure as an indicator of exposure. Some state SDWA databases may contain only totals for THMs and HAAs and may not record sample results for individual DBPs. Measures involving individual THMs and HAAs cannot be calculated for these states.
Related Indicators	Public Water Use
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