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# Arsenic in Drinking Water Rule Economic Analysis

Developed for:

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# Chapter 1: Executive Summary

## 1.1 Regulatory Background

An enforceable standard of 50 µg/L currently exists for arsenic in community water systems under the National Interim Primary Drinking Water Regulations (40 CFR 59566). In §1412(b)(12)(A) of the SDWA, as amended in 1996, Congress specifically directed EPA to issue a final rule by January 1, 2001. Congress recently changed the deadline for the final rule to June 22, 2001 (Public Law 106-377).

This document analyzes the impacts of the revised rule, which changes the current standard as follows:

(1) Reduces the current MCL for arsenic in community water systems from 50 µg/L to 10 µg/L;
(2) Requires non-transient non-community (NTNC) water systems to come into compliance with the new standard; and
(3) Revises the current monitoring requirements to make them consistent with the Standard Monitoring Framework (40 CFR 141.23(c)).

## 1.2 Health Effects of Arsenic

Arsenic's carcinogenic role was noted over 100 years ago (NCI, 1999) and has been studied ever since. The Agency has classified arsenic as a Class A human carcinogen, "based on sufficient evidence from human data. An increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic."

A 1999 NRC report on arsenic states that "epidemiological studies ... clearly show associations of arsenic with several internal cancers at exposure concentrations of several hundred micrograms per liter of drinking water." Ten epidemiological studies covering eight organ systems have quantitative data for risk assessment (NRC, 1999, Table 4-1). The organ systems where cancers in humans have been identified include skin, bladder, lung, kidney, nasal cavity, liver, and prostate.

Table 10-6 of the same NRC report provides risk parameters for three cancers: bladder, lung, and liver cancer. Considering all cancers in aggregate, the NRC states that "considering the data on bladder and lung cancer in both sexes noted in the studies ... a similar approach for all cancers could easily result in a combined cancer risk on the order of 1 in 100" (at the current MCL of 50 µg/L).

New data provide additional health effects information on both carcinogenic and noncarcinogenic effects of arsenic. A recent study by Tsai et al. (1999) of a population that has been studied over many years in Taiwan has provided standardized mortality ratios (SMRs) for 23 cancerous and non-cancerous causes of death in women and 27 causes of death in men at statistically significant levels in an area of Taiwan with elevated arsenic exposures (Tsai et al., 1999). SMRs are an expression of the ratio between deaths that were observed in an area with elevated arsenic levels and those that were expected to occur, based on the mortality experience of the populations in nearby areas without elevated arsenic levels. Drinking water (250-1,140 µg/L) and soil (5.3-11.2 mg/kg) in the Tsai et al. (1999) population study had very high arsenic content.

Tsai et al. (1999) identified "bronchitis, liver cirrhosis, nephropathy, intestinal cancer, rectal cancer, laryngeal cancer, and cerebrovascular disease" as possibly "related to chronic arsenic exposure via drinking water," which had not been reported before. In addition, the study area had upper respiratory tract cancers previously only related to occupational inhalation. High male mortality rate (SMR > 3) existed for bladder, kidney, skin, lung, and nasal cavity cancers and for vascular disease. However, the authors noted that the mortality range was marginal for leukemia, cerebrovascular disease, liver cirrhosis, nephropathy, and diabetes. Females also had high mortalities for laryngeal cancer. There are, of course, possible differences between the population and health care in Taiwan and the United States. For example, arsenic levels in the U.S. are not as high as they were in the study area of Taiwan. However, the study gives an indication of the types of health effects that may be associated with arsenic exposure via drinking water.

Arsenic interferes with a number of essential physiological activities, including the actions of enzymes, essential cations, and transcriptional events in cells (NRC, 1999). A wide variety of adverse health effects have been associated with chronic ingestion of arsenic in drinking water, occurring at various exposure levels.

## 1.3 Regulatory Alternatives Considered

In regulating a contaminant, EPA first sets a maximum contaminant level goal (MCLG), which establishes the contaminant level at which no known or anticipated adverse health effects occur. MCLGs are non-enforceable health goals. For this rulemaking, EPA is setting an MCLG of zero. EPA then sets an enforceable maximum contaminant level (MCL) as close as technologically possible to the MCLG. In addition, EPA may use its discretion in setting the MCL by choosing an MCL that is protective of public health while also ensuring that the quantified and non-quantified costs are justified by the quantified and non-quantified benefits of the rule. For this rulemaking, EPA is setting an MCL of 10 µg/L. Chapter 3 describes the process by which EPA determined both the MCLG and the MCL.

EPA considered a range of MCLs in developing the final Arsenic Rule, including MCLs of 3, 5, 10, and 20 µg/L. EPA evaluated the following five factors to determine the revised MCL:

- The analytical capability and laboratory capacity;
- The likelihood of water systems choosing various compliance technologies for several sizes of systems based on source water properties;
- The national occurrence of arsenic in water supplies;

- Quantified and non-quantified costs and health risk reduction benefits likely to occur at the MCLs considered; and
- The effects on sensitive subpopulations.

After evaluating the above factors, EPA considered an MCL of 3 µg/L since this is the level that has been determined to be as close to the MCLG as is feasible. However, the Agency is using its discretionary authority in §1412(b)(6)(A) to consider setting MCL at a less stringent level. The statute requires that the alternative less stringent level be one which maximizes health risk reduction at a level where costs and benefits are also considered. As a result, EPA considered the alternative MCL options of 5, 10, and 20 µg/L.

The Agency also considered two regulatory options related to the applicability of the revised MCL. Specifically, EPA investigated applying both the monitoring and treatment requirements of the Arsenic Rule to both community water systems (CWSs) and NTNCs. A CWS is defined as a system that provides piped water to at least 25 people or with at least 15 service connections year-round. An NTNC is a public water system that is not defined as a CWS and that regularly serves at least 25 of the same people for at least six months of the year. After considering the costs and benefits of the revised rule with regard to both CWSs and NTNCs, EPA is requiring both CWS and NTNC water systems to comply with all facets of the revised rule. The benefit-cost analysis upon which this decision is based is provided in Chapters 5, 6, and 7 of this Economic Analysis (EA). Transient non-community systems, which provide potable water to continuously changing populations, will not be subject to the revised rule.

The revised rule also includes modifications to the current monitoring requirements, including the availability of monitoring waivers. A detailed discussion of these changes can be found in Chapter 3.

## 1.4 Benefits and Costs of the Proposed Rule

Quantitative risk metrics (e.g., slope factors or reference doses) are necessary to evaluate cancer or non-cancer risks. Although arsenic causes numerous health effects, bladder and lung cancer are the only endpoints for which an Agency-approved metric for evaluating arsenic-related risk currently exists. This cancer slope factor (SF) for bladder and lung cancer is used to calculate cases potentially avoided due to the revised arsenic standard. Benefits estimates for avoided cases of bladder and lung cancer were calculated using mean population risk estimates at various MCL levels. Lifetime risk estimates were converted to annual risk factors and applied to the exposed population to determine the number of cases avoided. These cases were divided into fatalities and non-fatal cases avoided, based on survival information. The avoided premature fatalities were valued based on the VSL estimates discussed in Chapter 5, as recommended by EPA current guidance for cost/benefit analysis. The avoided non-fatal cases were valued based on the willingness to pay estimates for the avoidance of chronic bronchitis. The upper bound estimates include the possibility of the incidence rate being understated, depending on the survival rate for bladder cancer in the study area of Taiwan.

Numerous other health effects that are likely to be avoided as a result of this rule may generate significant benefits, and should not be discounted based on the fact that they cannot be quantified at this time. The estimated total national monetized benefits of the proposed rule and the other rule options considered are provided in Exhibit 1-1.

**Exhibit 1-1**
**Total Annual Cost, Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in PWSs**
**($ millions)**

| Arsenic Level (µg/L) | Total Annual Cost (7%) | Annual Bladder Cancer Health Benefits [1,2] | Annual Lung Cancer Health Benefits [1,2] | Total Annual Health Benefits [1,2] | Potential Non-Quantifiable Health Benefits |
|---|---|---|---|---|---|
| 3 | $792.1 | $58.2 - $156.4 | $155.6 - $334.5 | $213.8 - $490.9 | • Skin Cancer<br>• Kidney Cancer<br>• Cancer of the Nasal Passages<br>• Liver Cancer<br>• Prostate Cancer<br>• Cardiovascular Effects<br>• Pulmonary Effects<br>• Immunological Effects<br>• Neurological Effects<br>• Endocrine Effects<br>• Reproductive and Developmental Effects |
| 5 | $471.7 | $52.0 - $113.3 | $139.1 - $242.3 | $191.1 - $355.6 | |
| 10 | $205.6 | $38.0 - $63.0 | $101.6 - $134.7 | $139.6 - $197.7 | |
| 20 | $76.5 | $20.1 - $21.5 | $46.1 - $53.8 | $66.2 - $75.3[3] | |

[1] May 1999 dollars.
[2] These monetary estimates are based on cases avoided given in Exhibit 5-9 (a-c).
[3] For 20 µg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus, the number of estimated cases avoided and estimated benefits are higher at 20 µg/L using the risk estimates adjusted for arsenic in cooking water and food.

For the revised MCL of 10 µg/L, the estimated monetized bladder and lung cancer health benefits range from $139.6 million to $197.7 million. More detail about these benefit estimates are found in Chapter 5. Exhibit 1-2 shows the estimated national cost of compliance of the revised rule and the other rule options that were considered. At the revised MCL of 10 µg/L, the estimated national cost of compliance is $180.4 million at a discount rate of three percent, and $205.6 million at a discount rate of seven percent.

## Exhibit 1-2
## Total National Cost of Compliance ($ millions)

| | CWS | | NTNC | | TOTAL | |
|---|---|---|---|---|---|---|
| **Discount Rate** | **3%** | **7%** | **3%** | **7%** | **3%** | **7%** |
| **MCL = 3 ■g/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $665.9 | $756.5 | $27.2 | $29.6 | $693.1 | $786.0 |
| Monitoring/ Administrative | $2.2 | $3.0 | $1.0 | $1.4 | $3.2 | $4.4 |
| State Costs | $1.4 | $1.6 | $0.1 | $0.2 | $1.5 | $1.7 |
| TOTAL COST | $669.4 | $761.0 | $28.3 | $31.1 | $697.8 | $792.1 |
| **MCL =5 ■g/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $394.4 | $448.5 | $16.3 | $17.6 | $410.6 | $466.1 |
| Monitoring/ Administrative | $2.0 | $2.8 | $1.0 | $1.3 | $2.9 | $4.1 |
| State Costs | $1.1 | $1.3 | $0.1 | $0.2 | $1.2 | $1.4 |
| TOTAL COST | $397.5 | $452.5 | $17.3 | $19.1 | $414.8 | $471.7 |
| **MCL = 10 ■g/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $169.6 | $193.0 | $7.0 | $7.6 | $176.7 | $200.6 |
| Monitoring/ Administrative | $1.8 | $2.5 | $0.9 | $1.3 | $2.7 | $3.8 |
| State Costs | $0.9 | $1.0 | $0.1 | $0.2 | $1.0 | $1.2 |
| TOTAL COST | $172.3 | $196.6 | $8.1 | $9.1 | $180.4 | $205.6 |
| **MCL =20 ■g/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $60.7 | $69.0 | $2.6 | $2.8 | $63.3 | $71.8 |
| Monitoring/ Administrative | $1.7 | $2.4 | $0.9 | $1.3 | $2.6 | $3.7 |
| State Costs | $0.7 | $0.8 | $0.1 | $0.2 | $0.9 | $1.0 |
| TOTAL COST | $63.2 | $72.3 | $3.6 | $4.2 | $66.8 | $76.5 |

The net benefits and benefit-cost ratios of each regulatory option are provided in Exhibit 1-3. At the revised MCL of 10 µg/L, the net benefits range from a high of $17.3 million to a low of a negative $40.8 million, at a discount rate of three percent. These net benefits correspond to benefit-cost ratios of 0.8 and 1.1 (also at a three percent rate of discount).

**Exhibit 1-3**
**Net Benefits and Benefit-Cost Ratios of Each Regulatory Option**
**($ millions)**

| | MCL (µg/L) | 3 | 5 | 10 | 20 |
|---|---|---|---|---|---|
| **3% Discount Rate** | | | | | |
| lower bound | Net Benefits | $ (484.0) | $ (223.7) | $ (40.8) | $ (0.6) |
| lower bound | Benefit/Cost Ratio | 0.3 | 0.5 | 0.8 | 1.0 |
| upper bound | Net Benefits | $ (206.8) | $ (59.2) | $ 17.3 | $ 8.5 |
| upper bound | Benefit/Cost Ratio | 0.7 | 0.9 | 1.1 | 1.1 |
| **7% Discount Rate** | | | | | |
| lower bound | Net Benefits | $ (578.3) | $ (280.6) | $ (66.0) | $ (10.3) |
| lower bound | Benefit/Cost Ratio | 0.3 | 0.4 | 0.7 | 0.9 |
| upper bound | Net Benefits | $ (301.1) | $ (116.1) | $ (7.9) | $ (1.2) |
| upper bound | Benefit/Cost Ratio | 0.6 | 0.8 | 1.0 | 1.0 |

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs and NTNCs and State costs for administration of water programs.

As mentioned above, there are a number of important non-monetized benefits of reducing arsenic exposure that are not included in the net benefit and benefit-cost calculations. Chief among these are certain health impacts known to be caused by arsenic. Such nonquantifiable benefits may include skin cancer, kidney cancer, cancer of the nasal passages, liver cancer, prostate cancer, cardiovascular effects, pulmonary effects, immunological effects, neurological effects, endocrine effects, and customer peace-of-mind benefits from knowing their drinking water has been treated for arsenic. For example, a number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Early reports linking inorganic arsenic contamination of drinking water to skin cancer came from Argentina (Neubauer, 1947, reviewing studies published as early as 1925) and Poland (Tseng et al., 1968). However, the first studies that observed dose-dependent effects of arsenic associated with skin cancer came from Taiwan (Tseng et al., 1968; Tseng, 1977). These studies focused EPA's attention on the health effects of ingested arsenic. Studies conducted in the U.S. have not demonstrated an association between inorganic arsenic in drinking water and skin cancer. However, these studies may not have included enough people in their design to detect these types of effects.

The potential monetized benefits associated with skin cancer reduction would not change the total benefits of the rule to an appreciable degree, even if the assumption were made that the risk of skin cancer were equivalent to that of bladder cancer, using EPA's 1988 risk assessment. Skin cancer is highly treatable (at a cost of illness of less than $3,500 for basal and squamous cell carcinomas versus a cost of illness of $178,000 for non-fatal bronchitis) in the U.S., with few fatalities (less than one percent).

In addition to potentially reducing the risk of skin cancer, there are also a large number of other health-related benefits associated with arsenic reduction, as presented in Exhibit 1-1, which are not monetized in this analysis due to lack of appropriate data.

Other benefits not monetized in this analysis include customer peace of mind from knowing drinking water has been treated for arsenic and reduced treatment costs for currently unregulated contaminants that may be co-treated with arsenic. To the extent that reverse osmosis is used for arsenic removal, these benefits could be substantial. Reverse osmosis and activated alumina are the primary point-of-use treatments for small systems. (These benefits of avoided treatment cannot currently be monetized; however, they can be readily monetized in the future, as decisions are made about which currently unregulated contaminants to regulate.)

# Chapter 2: Need for the Revised Rule

## 2.1 Introduction

The Safe Drinking Water Act (SDWA), as amended in 1996, requires EPA to identify and regulate substances in drinking water that may have an adverse effect on public health and that are known or anticipated to occur in public water supplies. National Primary Drinking Water Regulations (NPDWRs) address risks to public health, and secondary regulations address aesthetic qualities (such as taste, odor, or color) that relate to public acceptance of drinking water. For NPDWRs, EPA must either establish a Maximum Contaminant Level (MCL) or, if it is not economically or technically feasible to monitor the contaminant in drinking water, specify a treatment technique to remove the contaminant or reduce its concentration in the water supply.

An enforceable standard of 50 µg/L currently exists for arsenic in community water systems under the National Interim Primary Drinking Water Regulations (40 CFR 59566). In §1412(b)(12)(A) of the SDWA, as amended in 1996, Congress specifically directed EPA to propose a NPDWR for arsenic by January 1, 2000, and issue the final regulation by January 1, 2001. Congress recently changed the deadline for the final rule to June 22, 2001 (Public Law 106-377).

This document analyzes the impacts of the rule, which revises the current standard as follows:

1) Reduces the current MCL for arsenic in community water systems from 50 µg/L to 10 µg/L;
2) Requires nontransient non-community water systems (NTNC) to comply with the new standard; and
3) Revises the current monitoring requirements to make them consistent with the Standard Monitoring Framework (40 CFR 141.23(c)).

Executive Order 12866, *Regulatory Planning and Review*, requires EPA to estimate the costs and benefits of the Arsenic Rule in an *economic analysis* document (EA). This chapter of the EA discusses the public health concerns being addressed by the rule, describes the history of regulatory efforts concerning arsenic, and discusses the economic rationale for the rule. Subsequent chapters will accomplish the following:

- Discuss the regulatory options considered by EPA (Chapter 3),
- Present the results of the baseline analysis (Chapter 4),
- Examine the benefits of the rule (Chapter 5),
- Present the results of the cost analysis (Chapter 6),
- Compare the costs and benefits of the rule and the regulatory options considered by EPA (Chapter 7), and
- Discuss the potential economic impacts of the rule (Chapter 8).

## 2.2 Public Health Concerns To Be Addressed

This section describes the public health concerns addressed by the final Arsenic Rule. A description of potential health effects associated with arsenic, including effects in sensitive subpopulations, along with the sources of human exposure to arsenic, is presented. In addition, the section describes current controls that address exposure to arsenic.

### 2.2.1 Health Effects of Arsenic

Arsenic is a naturally occurring element present in the environment in both organic and inorganic forms. Inorganic arsenic, considered to be the more toxic form, is found in ground water, surface water, and many foods. Chronic exposure to high levels of inorganic arsenic in drinking water has been found to result in a variety of adverse health effects, including skin and internal cancers and cardiovascular and neurological effects.

Exposures to organic forms of arsenic also occur through ingestion of food and metabolism of ingested inorganic arsenic. Experimental data on the effects of organic forms of arsenic are not as well characterized as those for inorganic arsenic, and thus are the subject for future research. Limited data on the primary organic forms in fish and shellfish (arsenobetaine and arsenocholine) suggest that these forms are relatively nontoxic. Other forms of organoarsenicals in foods have been even less well characterized. Recent *in vitro* toxicity evidence indicates that the trivalent form of monomethylarsonic acid is more toxic than either the trivalent (arsenite) or pentavalent (arsenate) forms of inorganic arsenic. Additional data are needed in this area before the toxicological significance of the trivalent form of monomethylarsonic acid is clear.

In 1996, EPA requested that the National Research Council of NAS conduct an independent review of the arsenic toxicity data. NRC was asked to review EPA's current criteria (50 µg/L and 0.018 µg/L), evaluate use of recent Taiwan data and other studies to assess the carcinogenic and non-carcinogenic health effects of arsenic, and recommend changes to EPA's risk characterization for arsenic. NRC issued its report on March 23, 1999 (NRC, 1999). The health effects of inorganic arsenic are summarized below and are described in more detail in Chapter 5.

#### *Cancer*

There is a large human database available for inorganic arsenic, unlike most environmental contaminants. However, there is substantial debate among the scientific community over the interpretation of these data and their application in risk assessment. NRC found that a number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Increased mortality from internal cancers of liver, bladder, kidney, and lung have also been reported.

EPA has identified arsenic as a group A "known" human carcinogen, based on increased risks of lung cancer in workers exposed to airborne arsenic and dose-dependent increases in skin cancer risk in Taiwan.

### Non-Cancer Health Effects

In addition to cancer, NRC (1999) reported that arsenic exposures have been linked to other adverse health effects. These include thickening of the skin, effects on the nervous system such as tingling and loss of feeling in limbs, hearing impairment, effects on the heart and circulatory system, diabetes, developmental effects, and effects on the gastrointestinal system and liver. Many of these effects are observed at concentrations where cancer effects were observed in the epidemiology studies.

### Sensitive Subpopulations

Certain sensitive individuals may be at a greater risk of serious illness from exposure to arsenic than the general population. The NRC report (1999) noted that human sensitivity to the toxic effects of inorganic arsenic exposure is likely to vary based on genetics, metabolism, diet, health status, sex, and other possible factors. For example, reduced ability to methylate arsenic (convert inorganic arsenic into less acutely toxic and more readily excreted forms) may result in retention of more arsenic in the body and increased risk of toxic effects. However, there is insufficient evidence at the present time to characterize the influence of such factors as age, sex, nutrition, and genetic polymorphism on the expression of arsenic toxicity (NRC, 1999).

The following groups have been cited in various studies as possibly being particularly susceptible to health effects from arsenic:

- **Children** are identified as especially susceptible because their dose of arsenic will be, on average, higher than that of adults exposed to similar concentrations due to their higher fluid and food intake relative to body weight. The NRC report cited one study that suggests that children may have a lower arsenic-methylation efficiency than adults.

- **Pregnant and lactating women** are especially vulnerable because of possible adverse reproductive and developmental effects of arsenic.

- **People with poor nutritional status** may have a reduced ability to methylate arsenic.

- **Individuals with pre-existing diseases that affect specific organs**—in particular, kidney and liver problems—may be more susceptible to the effects of arsenic because these organs act to detoxify arsenic in the body.
  In addition, arsenic can directly damage these and other organ systems, as described above. Individuals with pre-existing damage or congenital defects in these systems are more susceptible to health effects from exposure to arsenic. The elderly are more likely as a group to have pre-existing conditions in the susceptible organ systems.

Section 5.2.4 discusses the susceptibility of these subgroups in more detail. Due to a lack of available data, no quantitative analysis of the specific risks to sensitive populations was performed as part of this EA.

### 2.2.2 Sources and Mechanisms of Exposure

Arsenic (As) is an element that occurs in the earth's crust. Accordingly, there are natural sources of exposure. Erosion and weathering of rocks deposit arsenic in water bodies and lead to the uptake of arsenic by animals and plants. Consumption of food and water is the major source of arsenic exposure for the majority of U.S. citizens. People may also be exposed from industrial sources, as arsenic is used in semiconductor manufacturing, petroleum refining, wood preservatives, animal feed additives, and herbicides.

Arsenic can combine with other elements to form inorganic and organic arsenicals. In general, inorganic derivatives are regarded as more toxic than the organic forms. While food contains both inorganic and organic arsenicals, primarily inorganic forms are present in water.

Recently, EPA developed estimates of human exposure to arsenic in drinking water, food, and air using data from numerous Federal sampling surveys analyzing the occurrence of arsenic in public water supplies, dietary foods, and ambient air. EPA's national air sampling databases indicate very low concentrations of arsenic in both urban and non-urban locations, at levels typically ranging from about 0.003 to 0.03 $\mu g/m^3$. Air is therefore an insignificant source of arsenic intake, typically representing less than one percent of overall exposure.

EPA reviewed several local and regional studies for comparison purposes. Using the Total Diet Study of the Food and Drug Administration (FDA), recent dietary analyses indicate that the average adult's total arsenic intake is about 53 µg/day. The FDA analytical methodology does not differentiate between the organic and inorganic forms of arsenic. For most people living in the U.S., inorganic arsenic exposure is primarily from food and water sources. Since the inorganic forms are considered to be more toxic, it is important to estimate the amount of inorganic arsenic in the diet. To accomplish this estimation, EPA used the FDA data along with a separate study that characterized arsenic species in foods. This separate characterization indicated that about 20 percent of daily intake of dietary arsenic is in the inorganic form. Conversely, most arsenic present in drinking water is in the form of inorganic arsenic species.

Accounting for the organic forms of arsenic in food, the dietary intake of inorganic arsenic was estimated to be approximately 14 µg/day. An adult drinking 2 L/day of water containing 10 µg/L of arsenic would obtain 20 µg/day from drinking water, so that drinking water would contribute about 60 percent of total intake of inorganic arsenic. On the other hand, an adult drinking water containing 2 µg/L of arsenic would obtain almost 80 percent of the daily inorganic arsenic from food.

## 2.3 Regulatory History

This section provides a chronology and overview of regulatory actions affecting arsenic in drinking water and recent efforts that have led to this rulemaking. It also summarizes the major studies and data collection efforts that highlighted the need for a new rule.

**Current MCL:** In 1975, EPA set the National Interim Primary Drinking Water Regulation at 50 µg/L (40 FR 59566, December 24, 1975). This standard was equal to the standard set in 1942 by the U.S. Public Health Service for interstate water carriers, which was not based on a risk assessment. EPA based the MCL on daily consumption of two liters of water providing approximately 10 percent of total ingested arsenic of 900 µg/day. Commenters recommended an MCL of 100 µg/L based on no observed adverse health effects. EPA noted long-term chronic effects at 300 to 2,750 µg/L, but no chronic effects at 120 µg/L (US EPA, 1975, pg. 59576, EPA-570/9-76-003).

**Water Quality Criteria:** In 1980, EPA announced the availability of Water Quality Criteria Documents to protect surface water bodies from pollutants under the Clean Water Act (45 FR 79318, November 28, 1980). These criteria are used as guidance to the States in establishing surface water quality standards and discharge limits for effluents. The criterion for protection of human health from ingestion of arsenic in contaminated water and aquatic organisms was 2.2 nanograms per liter (ng/L), or 0.0022 µg/L. In 1992, the Clean Water Act criterion was recalculated based on an updated risk assessment to yield 0.018 µg/L for arsenic (57 FR 60848, December 22, 1992).

**1983 Notice prior to proposal:** In an Advance Notice of Proposed Rulemaking (ANPRM) published October 5, 1983 (48 FR 45502), EPA requested comment on whether the arsenic MCL should consider carcinogenicity, other health effects, and nutritional requirements; and whether MCLs are necessary for separate valence states.

**1985 Proposed MCLG:** In 1985, EPA proposed a non-enforceable Maximum Contaminant Level Goal (MCLG) of 50 µg/L based on an NAS conclusion that 50 µg/L balanced toxicity and possible essentiality. EPA also requested comment on alternate MCLGs of 100 µg/L based on non-carcinogenic effects and 0 µg/L based on carcinogenicity (50 FR 46936, November 13, 1985).

**1986 SDWA Amendments:** The 1986 SDWA Amendments converted the 1975 interim arsenic standard to a NPDWR, subject to revision by 1989.

**1988 Risk Assessment Forum Report:** EPA's Risk Assessment Forum wrote the *Special Report on Ingested Inorganic Arsenic: Skin Cancer; Nutritional Essentiality* (EPA/625/3-87/013), in part, to evaluate the validity of applying the Taiwan 1968/1977 data to dose-response assessments in the U.S. At the 50 µg/L standard, the calculated U.S. lifetime risk ranged from $1 \times 10^{-3}$ to $3 \times 10^{-3}$.

**1989:** After reviewing EPA's arsenic health effects studies in June 1988, the Science Advisory Board (SAB) stated in its August 14, 1989, report the following:

- The essentiality of arsenic is suggestive but not definitive;
- Hyperkeratosis may not be a precursor of skin cancer;
- The Taiwan data are adequate to conclude that high doses of ingested arsenic can cause skin cancer;
- The Taiwan study is inconclusive to determine cancer risk at levels ingested in the U.S.; and
- As (III) levels below 200 to 250 µg per day may be detoxified.

SAB concluded that the dose-response is non-linear and reported that the 1988 Forum Report did not apply non-linearity in its risk assessment.

**1989:** Uncertainty about arsenic risk assessment issues caused the Agency to miss the 1989 deadline for proposing a revised NPDWR, and a citizen suit was filed against EPA. A consent decree was entered by the court in June 1990 and was amended several times thereafter before being dismissed after passage of the 1996 SDWA Amendments.

**The Safe Drinking Water Act Amendments of 1996,** in §1412(b)(12)(A), directed EPA to take the following actions for arsenic:

- Develop an arsenic health effects research strategy within 180 days of enactment;
- Consult with the National Academy of Sciences, other Federal agencies, and interested public and private entities in conducting the studies;
- Propose a revised MCL by January 1, 2000; and
- Issue a final rule by January 1, 2001.

In addition SDWA, as amended in 1996, directed EPA to:

- Assess health effects for sensitive populations;
- List both compliance and/or variance treatment technologies for small systems;
- Evaluate the incremental costs and benefits of different regulatory options, accounting for the changes that may result from implementation of other rules;
- Issue an MCL that maximizes health benefits at a cost that is justified by the benefits;
- Review MCLs every six years or sooner.

The 1996 amendments also made the following changes:

- The effective date of MCLs is three to five years after promulgation of the final rule, rather than 18 months.

- Compliance for non-microbial contaminants can be achieved by use of point-of-use (POU) or point-of-entry (POE) devices that are maintained by the small public water system.

Congress authorized $2.5 million per year from 1997 to 2000 for the studies. Congress appropriated $1 million to EPA for arsenic research in 1996 and 1997 and $1 million to the American Water Works Association Research Foundation in subsequent years.

EPA proposed the arsenic regulation on June 22, 2000, in the *Federal Register*. At the same time, EPA is proceeding with its Arsenic Research Plan, which will address a variety of issues related to exposure, treatment, and health effects.[1] In EPA's appropriations bill for 2001, Public Law 106-377, Congress directed EPA to issue the final arsenic rule by June 22, 2001, one year after proposal.

**NRC Report:** In 1996, EPA requested that the National Research Council of NAS conduct an independent review of the arsenic toxicity data and evaluate the scientific validity of EPA's 1988 risk assessment for arsenic in drinking water. In addition, NRC was asked to review EPA's current criteria (50 µg/L and 0.018 µg/L), evaluate use of recent Taiwan data and other studies to assess the carcinogenic and non-carcinogenic health effects of arsenic, and recommend changes to EPA's risk characterization for arsenic. NRC issued its report on March 23, 1999. The report had several main conclusions:

- The Taiwan studies provide the best available evidence on the human health effects of arsenic, and are supported by studies in Chile and Argentina that report similar results. These studies show that chronic ingestion of inorganic arsenic at high doses causes bladder and lung cancer, as well as skin cancer.

- Factors such as genetics, nutrition, and amount of arsenic in food can affect the U.S. risk assessment.

- Non-cancer chronic effects include skin effects, cardiovascular and cerebrovascular disease, diabetes, and reproductive effects.

- The molecular processes of arsenic toxicity are not well understood. Research can help characterize the dose-response relationship for both cancer and non-cancer endpoints, especially at low doses.

- The current 50 µg/L MCL is not adequately protective of human health and therefore requires downward revision as promptly as possible.[2]

[1] The Arsenic Research Plan is published at http://www.epa.gov/ORD/WebPubs/final/arsenic.pdf.

[2] The NRC report is available at http://www.nap.edu/readingroom/enter2.cgi?0309063337.html.

## 2.4 Rationale for the Regulation

This section discusses the economic rationale for choosing a regulatory approach to address the public health consequences of drinking water contamination. EPA provides the economic rationale in response to Executive Order Number 12866, *Regulatory Planning and Review,* which states:

> [E]ach agency shall identify the problem that it intends to address (including, where applicable, the failures of the private markets or public institutions that warrant new agency action) as well as assess the significance of that problem (§1, b(1)).

In addition, guidance from the Office of Management and Budget dated January 11, 1996, states that "in order to establish the need for the proposed action, the analysis should discuss whether the problem constitutes a significant market failure." Therefore, the economic rationale presented in this section should not be interpreted as EPA's approach to implementing the SDWA. Instead, it is EPA's justification, as required by the Executive Order, for a *regulatory approach* to this public health issue.

### 2.4.1 Statutory Authority

Section 1412(b)(1)(A) of the SDWA requires EPA to establish National Primary Drinking Water Regulations for contaminants that may have an adverse public health effect; that are known to occur or that present a substantial likelihood of occurring once in public water systems (PWSs), at a frequency and level of public concern; and that present a meaningful opportunity for health risk reduction for persons served by PWSs. This general provision is supplemented by additional requirements that EPA proposed a revised MCL for arsenic by January 1, 2000 (§1412(b)(1)(A)), and issue a final regulation by June 22, 2001 (Public Law 106-377).

### 2.4.2 Economic Rationale for Regulation

In addition to the statutory directive to regulate arsenic, there is also economic rationale for government regulation. In a perfectly competitive market, market forces guide buyers and sellers to attain the best possible social outcome. A perfectly competitive market occurs when there are many producers of a product selling to many buyers, and both producers and buyers have complete knowledge regarding the products of each firm. Also, there must not be any barriers to entry into the industry, and producers in the industry must not have any advantage over potential new producers. Several factors in the public water supply industry do not satisfy the requirements for a perfect market and lead to market failures that may require regulation.

First, water utilities are natural monopolies. A natural monopoly exists because it is not economically efficient to have multiple suppliers competing to build multiple systems of pipelines, reservoirs, wells, and other facilities.[3] Instead, a single firm or government entity performs these functions generally under

[3]Mansfield (1975) states that natural monopolies exist because the average cost of producing the product reaches a minimum at an output rate that is enough to satisfy the entire market at a price that is profitable. Multiple

public control.  Under monopoly conditions, consumers are provided only one level of service with respect to the quality of the product, in this case drinking water quality.  If consumers do not believe that the market of safety in public health production is adequate, they cannot simply switch to another water utility or perceived higher quality source of supply (e.g., bottled water) without incurring additional cost.

Second, high information and transaction costs impede public understanding of the health and safety issues concerning drinking water quality.  The types of health risks potentially posed by trace quantities of drinking water contaminants involve analysis and distillation of complex toxicological data and health sciences.  EPA recently developed the Consumer Confidence Report rule to make water quality information more easily available to consumers.  The Consumer Confidence Report rule requires community water systems to mail their customers an annual report on local drinking water quality.  However, consumers will still have to analyze this information for its health risk implications.  Even if informed consumers are able to engage utilities regarding these health issues, the costs of such engagement, known as "transaction costs" (in this case measured in personal time and commitment), present another significant impediment to consumer expression of risk preference.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants that would not otherwise occur in the existing market environment of public water supply.  The regulations set minimum performance requirements for all public water supplies in order to reduce the risk confronted by all consumers from exposure to drinking water contaminants.  SDWA regulations are not intended to restructure market mechanisms or to establish competition in supply.  Rather, SDWA standards establish the level of service to be provided in order to better reflect public preference for safety.  The Federal regulations remove the high information and transaction costs by acting on behalf of all consumers in balancing the risk reduction and the social costs of achieving this reduction.

producers competing would produce the product at higher than minimum long-run average cost.  Competition to achieve lower average costs would drive prices down until a single supplier was victorious.

# Chapter 3: Consideration of Regulatory Alternatives

## 3.1 Regulatory Approaches

The Safe Drinking Water Act (SDWA) establishes EPA's responsibility for ensuring the quality of drinking water and defines the mechanisms available to the Agency to protect public health. Specifically, the SDWA requires EPA to set enforceable MCLs when technically or economically feasible or otherwise establish treatment technique requirements for specific contaminants in drinking water. In meeting this mandate, EPA sets water quality standards by identifying which contaminants should be regulated and establishing the levels of the contaminant that water systems must attain. This section discusses the approach EPA used in determining the regulatory alternatives that were considered.

### 3.1.1 Determining the Standard

In regulating a contaminant, EPA first sets a maximum contaminant level goal (MCLG), which establishes the contaminant level at which no known or anticipated adverse health effects occur. MCLGs are non-enforceable health goals. For this rulemaking, EPA set an MCLG of zero. EPA then sets an enforceable maximum contaminant level (MCL) as close as technologically possible to the MCLG. In addition, EPA may use its discretion in setting the MCL by choosing an MCL that is protective of public health while also ensuring that the quantified and non-quantified costs are justified by the quantified and non-quantified benefits of the rule. For this rulemaking, EPA is setting an MCL of 10 µg/L. The following sections describe the process by which EPA determined both the MCLG and the MCL.

### 3.1.2 Determining the MCLG

**Carcinogens:** For many years, Congress supported a goal of zero tolerance for carcinogens in food and water, and that goal was incorporated into the SDWA of 1974. Under this policy, contaminants that are classified as probable human carcinogens have had MCLGs set at zero. EPA's Office of Science and Technology (OST) (in the Office of Water) develops a cancer risk range that quantifies the probability that a person will develop cancer during a lifetime of ingesting water containing the regulated contaminant.

Data used in risk estimates usually come from lifetime exposure studies in animals. To predict the risk for humans, the oral doses used in animal studies are corrected for differences in animal and human size and surface area.

In 1986, EPA published *Guidelines for Carcinogen Risk Assessment* in the Federal Register (51 FR 33992). At that time EPA's default assumptions included low-dose linearity to extrapolate the cancer risk range, which assumes that carcinogenic effects do not exhibit a threshold and that carcinogens pose risks to humans at any concentration. EPA proposed revised *Guidelines for Carcinogen Risk Assessment* in 1996 (61 FR 17960).

**Non-carcinogens:** MCLGs for non-carcinogens are based on Reference Doses (RfDs) and their Drinking Water Equivalent Levels (DWELs).

The Reference Dose (RfD, formerly the Acceptable Daily Intake, or ADI), estimates the daily amount of chemical a person, including sensitive humans, can ingest over a lifetime with little risk of causing adverse health effects. RfDs are usually expressed in milligrams of chemical per kilogram of body weight per day (mg/kg/day). Data from chronic (usually two years) or sub-chronic (usually 90 days) studies of humans or animals provide estimates of the No- or- Lowest-Observed-Adverse-Effect Level (NOAEL or LOAEL). The NOAEL (or LOAEL) is divided by a total uncertainty factor (UF) of 1 to 10,000 to obtain the RfD. In the final National Primary Drinking Water Regulations published on January 30, 1991 (56 FR 3532), EPA applies a UF of 1, 3, or 10 when a NOAEL from a human study is used to account for intraspecies variation and an uncertainty factor of 100 to a human LOAEL to account for lack of a NOAEL and for species variation. The UFs provide a margin for variations in species responses, data gaps, and less than lifetime exposures. Scientific judgement is used to select the total UF for specific risk assessments.

The DWEL is calculated by multiplying the RfD by an assumed adult body weight of 70 kg (approximately 154 pounds) and dividing by an average adult water consumption of 2 liters per day (L/day). The DWEL assumes that 100 percent of the exposure comes from drinking water. The MCLG is then determined by multiplying the DWEL by the percentage of the total daily exposure contributed by drinking water (relative source contribution), set at 20 percent by default when adequate data are not available, but set between 20 and 80 percent when adequate data are available to estimate exposure. Based on the 1993 RfD (1993 Draft Criteria) for arsenic (0.3 µg/kg/day), the calculated DWEL would be 0.3 µg/kg/day times 70 kg divided by 2 L/day, or 10 µg/L. Due to the three-fold uncertainties noted in the Integrated Risk Information System (IRIS) file on arsenic, the DWEL could be 3 to 30 µg/L. It should be noted that the toxicological studies used to determine the effect level and the derivation of the RfD are different from the analysis conducted in 1975. Additionally, the current policy on relative source contribution, including the default policy, are also different from those used in 1975.

### 3.1.3 Determining an MCL

Once an MCLG is established, EPA sets an enforceable standard—in most cases, a Maximum Contaminant Level (MCL). The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. EPA must set the MCL as close to the MCLG as feasible. The SDWA defines feasible as the level that may be achieved with the use of the best available technology, treatment techniques, and other means that EPA finds are available (after examination for efficacy under field conditions), taking cost to large systems into consideration.

After determining an MCL based on affordable technology for large systems, EPA must complete an economic analysis to determine whether the benefits of the standard justify the costs. If not, EPA may adjust the MCL to a level that "maximizes health risk reduction benefits at a cost that is justified by the benefits" (§1412(b)(6)).

### 3.1.4 Variances

The 1996 SDWA identifies two classes of technologies for small systems: compliance and variance technologies. A compliance technology is one that achieves compliance with the MCL or treatment technique requirement. The 1996 Amendments require EPA to list affordable compliance technologies for three categories of small systems: those serving 25 to 500 people, those serving 501 to 3,300 people, and those serving 3,301 to 10,000 people. If EPA cannot identify an affordable compliance technology for a particular system category, it must then identify a variance technology instead. The variance technology must achieve the maximum reduction that is affordable, considering the size of the system and the quality of the source water, and must be protective of public health. If EPA lists such a variance technology, small systems will be eligible to apply to the States for a small system variance. States are authorized to grant variances from standards for systems serving up to 3,300 people if the system cannot afford to comply with a rule and the system installs the EPA-approved variance technology. States can grant variances to systems serving 3,301 to 10,000 people with EPA approval.

### 3.1.5 Analytical Methods

The determination of an MCL depends on the ability of laboratories to reliably measure the contaminant at the MCL. The SDWA directs EPA to set an MCL "if in the judgement of the Administrator, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems (§1401 (1)(c)(ii))." EPA must therefore evaluate the available analytical methods to determine a Practical Quantitation Limit (PQL), which is the minimum reliable quantification level that most laboratories can be expected to meet during day-to-day operations. EPA has approved several analytical methods to support compliance monitoring of arsenic at the current MCL (40 CFR 141.23). In 1994, EPA evaluated available data and determined the PQL for arsenic to be 2.0 µg/L at an acceptance limit of ± 40 percent. In its July 1995 report, EPA's Science Advisory Board recommended that EPA set the PQL for arsenic using acceptance limits similar to those applied for other inorganics. Based on more recent information and these recommendations from the SAB, in 1999 EPA derived a PQL of 3 µg/L using an acceptance limit of ± 30 percent for arsenic (EPA, 1999a).

Available data estimate that over 75 percent of EPA Regional and State laboratories and at least 62 percent of non-EPA laboratories are capable of achieving acceptable results at 3 µg/L within a 30 percent acceptance window. While the PQL represents a stringent target for laboratory performance, the Agency believes that most laboratories, using appropriate quality assurance and quality control procedures, have the capacity to achieve this level on a routine basis.

## 3.2 Regulatory Alternatives Considered and Final Rule

This section describes the components of the final rule and the alternatives that were considered by the Agency.

### 3.2.1 Applicability

The Agency investigated applying the monitoring and treatment requirements of the proposed rule to both community water systems (CWSs) and non-transient non-community (NTNC) water systems. A CWS is defined as a system that provides piped water to at least 25 people or with at least 15 service connections year-round. An NTNC system is a public water system that is not defined as a CWS and that regularly serves at least 25 of the same people for at least six months of the year. After considering the costs and benefits of the proposed rule with regard to both CWSs and NTNC systems, EPA proposes to require both CWSs and NTNC water systems to comply with all facets of the proposed rule. The benefit-cost analysis upon which this decision is based is provided in Chapters 5, 6, and 7 of this EA. Transient non-community systems, which provide potable water to continuously changing populations, will not be subject to the proposed rule. The rule applies to CWSs and NTNC systems that produce water primarily from either ground or surface water sources.

### 3.2.2 Maximum Contaminant Level

EPA considered a range of MCLs in developing the proposed Arsenic Rule, including MCLs of 3, 5, 10, and 20 µg/L. EPA evaluated the following five factors to determine the proposed MCL:

- The analytical capability and laboratory capacity;
- The likelihood of water systems choosing various compliance technologies for several sizes of systems based on source water properties;
- The national occurrence of arsenic in water supplies;
- Quantified and non-quantified costs and health risk reduction benefits likely to occur at the MCLs considered; and
- The effects on sensitive subpopulations.

An MCL of 3 µg/L was considered since this is the level that has been determined to be as close to the MCLG as is feasible. However, the Agency is using its discretionary authority in §1412(b)(6)(A) to set MCL at a less stringent level. The statute requires that the alternative, less stringent level be one that maximizes health risk reduction at a level where costs and benefits are balanced.

As a result, EPA considered the alternative MCL options of 5, 10, and 20 µg/L.

### 3.2.3 Monitoring

The current monitoring requirements for arsenic (40 CFR 141.23(l)) apply to community water systems only. EPA is changing the current monitoring requirements to require systems to monitor for arsenic in accordance with the provisions of 40 CFR 141.23(c), the Standard Monitoring Framework (SMF). This change will make the arsenic requirements consistent with the requirements for inorganic contaminants (IOCs) regulated under the Phase II/V regulations. The revised rule would make the following changes to the monitoring requirements for arsenic:

- NTNC systems will be required to monitor for arsenic for the first time.
- MCL exceedances will trigger quarterly monitoring, as opposed to the current requirements for three additional samples within one month when exceedances occur.
- The State will determine when the system is “reliably and consistently” below the MCL, after a minimum number of samples following an exceedance (two samples for ground water systems and four for surface water systems), and can return to the default sampling frequency. (Currently, the system automatically returns to the default monitoring frequency when a minimum of two consecutive samples are below the MCL.)
- The State may grant a nine-year monitoring waiver to a system if it finds that arsenic detections are the result of natural occurrence and not of human activity. (Currently, no monitoring waivers are permitted.)

### 3.2.4 Compliance Technologies and Variances

EPA reviewed several technologies as best available technology (BAT) candidates for arsenic removal. Those technologies capable of removing arsenic from source water that fulfill the SDWA requirements for BAT determinations for arsenic are as follows:

- Anion exchange;
- Activated alumina (AA);
- Reverse osmosis (RO);
- Modified coagulation/filtration;
- Modified lime softening; and
- Oxidation/filtration (including greensand filtration).[1]

EPA has further determined that these technologies are affordable for all system size categories and has therefore not identified a variance technology for any system size or source water combination at the proposed MCL.

### 3.2.5 Monitoring Waivers

Under the final Arsenic Rule (§141.23(c)(3)), States may grant a nine-year monitoring waiver from sampling requirements to water systems based on the analytical results from previous sampling and a vulnerability assessment or the assessment from an approved source water assessment program (provided that the assessments were designed to collect all of the necessary information needed to complete a vulnerability assessment for a waiver). States issuing waivers must consider the requirements in 40 CFR 141.23(c)(2)-(6). In order to qualify for a waiver, there must be three previous samples from a sampling point (annual for surface water and three rounds for ground water) with analytical results reported below the MCL. Grandfathered data collected after January 1, 1990,

[1] Oxidation/filtration is BAT only when the Fe/As ratio is > 20:1.

that are consistent with the analytical methodology and detection limits of the proposed regulation may be used for issuing sampling point waivers.

The current arsenic regulations §141.23(l)-(q) do not permit the use of monitoring waivers. However, a State could now use the analytical results from the three previous compliance periods (1993 to 1995, 1996 to 1998, and 1999 to 2001) to issue ground water sampling point waivers. Surface water systems must collect annual samples; thus, a State could use the previous three years' sampling data (1999, 2000, and 2001) to issue sampling point waivers. One sample must be collected during the nine-year compliance cycle in which the waiver is effective, and the waiver must be renewed every nine years. Vulnerability assessments must be based on a determination that the water system is not susceptible to contamination and arsenic is not a result of human activity (i.e., it is naturally occurring).

Not all States have required systems to report arsenic results below 50 µg/L. In this case, the States would not have adequate data to grant waivers until enough data are available to make the determinations.

EPA believes that some States may have been regulating arsenic under the proposed standardized inorganic framework. If so, those States will have to ensure that existing monitoring waivers have been granted using data reported below the new MCL. Otherwise, States will have to notify the systems of the new lower reporting requirements that need to be met to qualify for a waiver for the MCL.

### 3.2.6 Implementation

The following schedule is proposed for implementation of the rule:

- States must submit applications for primacy revisions within two years after promulgation, unless a State requests and is granted a two-year extension.
- The rule will be effective five years after promulgation.
- All systems must complete initial sampling by December 31, 2007.

# Chapter 4: Baseline Analysis

## 4.1 Introduction

This chapter presents baseline information to describe the operational and financial characteristics of water systems in the absence of the Revised Arsenic Rule. The baseline information provides a basis for EPA's analysis of the costs, benefits and economic impacts of the regulatory options considered. This chapter includes data on the number of water systems regulated, the population affected, current treatment practices, raw and treated water quality, and socio-economic impacts.

The baseline is assumed to be current conditions, as reflected by the most recent available data. In some cases, changes in the industry have occurred or will occur that are not reflected in the available data; for example, changes in operations induced by a regulation that will take effect prior to the Arsenic Rule.

## 4.2 Industry Profile

### 4.2.1 Definitions

According to EPA's definition, public water systems (PWSs) include community water systems (CWSs) and non-community water systems (NCWSs). NCWSs are further classified as either transient or non-transient. The rule will affect all public water systems except for transient non-community water systems. The following definitions will help the reader follow the discussion in this chapter:

- **Public water systems (PWSs)** serve 25 or more people or have 15 or more service connections and operate at least 60 days per year. A PWS can be publicly or privately-owned.
- **Community water systems (CWSs)** serve at least 15 service connections used by year-round residents, or regularly serve at least 25 year-round residents.
- **Non-community water systems (NCWSs)** do not have year-round residents, but serve at least 15 service connections used by travelers or intermittent users for at least 60 days each year, or serve an average of 25 individuals for at least 60 days a year.
- **Non-transient non-community water systems (NTNCs)** serve at least 25 of the same persons over six months per year (e.g., factories, schools, office buildings, and hospitals).
- **Transient non-community water systems (TNCs)** serve fewer than 25 of the same persons over six months per year (e.g., many restaurants, rest stops, parks).

Public water systems are also classified by their water source: surface water (e.g., drawn from lakes, streams, rivers, etc.) or ground water (e.g., drawn from wells or springs).

### 4.2.2 Sources of Industry Profile Data

EPA uses two primary sources of data to characterize the universe of water systems: the Safe Drinking Water Information System (SDWIS) and the Community Water System Survey (CWSS).

EPA's SDWIS contains data on all PWSs as reported by States and EPA Regions. This source reflects both mandatory and optional reporting components. States must report the system location, system type (CWS, NTNC, or TNC), primary raw water source (ground water or surface water), and violations. Optional reporting fields include type of treatment and ownership type. Because providing some data is discretionary, EPA does not have complete data on every system for these parameters. This is particularly common for non-community systems.

The second source of information, the CWSS, is a detailed survey of surface and ground water CWSs conducted by EPA in 1995 and published in 1997 (EPA, 1997b). The CWSS is stratified to represent the complete population of CWSs across the U.S. The CWSS includes information such as revenues, expenses, treatment practices, source water protection measures, and plant capacity. There is no equivalent survey such as the CWSS to define treatment practices in non-community water systems.

### 4.2.3 Number and Size of Public Water Systems

Exhibit 4-1 shows the number of systems in the U.S. by source water (ground or surface) and system size (measured by the number of people served), based on the December 1998 SDWIS data.[1] In the U.S. there are a total of 63,984 ground water systems and 11,843 surface water systems, including CWSs and NTNCs. All are potentially affected by the Arsenic Rule.

Some ground water sources (e.g., riverbank infiltration/galleries) are directly impacted by adjacent source water bodies and are separately identified in SDWIS as ground water under the direct influence of surface water (GWUDI). Since these systems would have similar occurrence as surface water systems, GWUDI systems are considered surface water systems in this analysis. SDWIS also provides system data by ownership. As previously described, PWSs include both publicly-owned and privately-owned systems. This detail is also provided in Exhibit 4-1, where any system referred to as "other" in the SDWIS database has been presented as a privately-owned system.

The majority (95 percent) of PWSs are small systems that serve fewer than 10,000 people. Eighty-nine percent of PWSs serve 3,300 people or fewer; 77 percent serve fewer than 1,000 people; 67 percent serve fewer than 500 people; and 34 percent serve fewer than 100 people.

[1]The cost and benefit analyses are conducted using the 1997 SDWIS freeze. The 1998 SDWIS freeze is presented here, as it was the most recent representation of the regulated entities.

**Exhibit 4-1**
**Total Number of Systems by Size, Type, and Ownership**

| SOURCE | <100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 | 10,001-50,000 | 50,001-100,000 | 100,001-1,000,000 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | | | | **CWS** | | | | | |
| **Ground Water** | | | | | | | | | |
| Public | 1,335 | 4,678 | 2,868 | 4,167 | 1,993 | 1,011 | 105 | 50 | 16,207 |
| Private | 12,942 | 10,380 | 1,821 | 1,547 | 466 | 205 | 26 | 11 | 28,303 |
| Total | 14,277 | 15,058 | 4,689 | 5,714 | 2,459 | 1,216 | 131 | 61 | 44,510 |
| **Surface Water** | | | | | | | | | |
| Public | 394 | 1,117 | 917 | 2,012 | 1,656 | 1,436 | 260 | 217 | 8,009 |
| Private | 698 | 886 | 303 | 408 | 188 | 171 | 40 | 44 | 3,053 |
| Total | 1,092 | 2,003 | 1,220 | 2,420 | 1,844 | 1,607 | 300 | 261 | 11,062 |
| Total | 15,369 | 17,061 | 5,909 | 8,134 | 4,303 | 2,823 | 431 | 322 | 54,352 |
| | | | | **NTNCWS** | | | | | |
| **Ground Water** | | | | | | | | | |
| Public | 1,725 | 3,108 | 1,163 | 337 | 23 | 9 | 0 | 0 | 6,365 |
| Private | 7,965 | 3,930 | 815 | 355 | 39 | 5 | 0 | 0 | 13,109 |
| Total | 9,690 | 7,038 | 1,978 | 692 | 62 | 14 | 0 | 0 | 19,474 |
| **Surface Water** | | | | | | | | | |
| Public | 58 | 63 | 19 | 24 | 6 | 3 | 1 | 1 | 175 |
| Private | 213 | 232 | 87 | 56 | 17 | 1 | 0 | 0 | 606 |
| Total | 271 | 295 | 106 | 80 | 23 | 4 | 1 | 1 | 781 |
| Total | 9,961 | 7,333 | 2,084 | 772 | 85 | 18 | 1 | 1 | 20,255 |

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

### 4.2.4 System Size and Population Served

All PWSs are potentially subject to the requirements of the Arsenic Rule, with the exception of TNCs. The majority of systems to be regulated are community water systems, which also serve, on average, more people than NTNCs. Exhibit 4-2 provides information on the average populations served by CWSs for each system size category, and the total population served by NTNCs.

**Exhibit 4-2**
**Total Population Served of Water Systems by Source Water, System Type, and Service Population Category**

| Service Population Category | Community | | Non-Transient Non-Community |
|---|---|---|---|
| | Ground Water | Surface Water | |
| < 100 | 859,777 | 61,450 | - |
| 101–500 | 3,741,017 | 570,448 | - |
| 501–1,000 | 3,457,163 | 921,449 | - |
| 1,001–3,300 | 10,631,422 | 4,797,855 | - |
| 3,301–10,000 | 14,095,015 | 10,995,980 | - |
| 10,001–50,000 | 25,004,779 | 36,819,575 | - |
| 50,001–100,000 | 8,609,455 | 20,500,370 | - |
| 100,001-1,000,000 | 14,575,556 | 65,375,183 | - |
| > 1,000,000 | 2,855,494 | 28,658,586 | - |
| **Total** | **83,829,678** | **168,700,896** | **31,968,181** |

Source: EPA, Safe Drinking Water Information System (SDWIS), December 1998 freeze.

Those NTNCs determined to be affected by the Arsenic Rule are presented in Exhibit 4-3 by type of system. The NTNC populations were taken from the 1998 SDWIS freeze. The NTNCs are much smaller than CWSs on average and vary substantially in their characteristics. Schools account for more than half of the affected NTNCs (8,414 of 20,255), followed by office parks (950), daycare centers (809), food manufacturing facilities (768), and non-food related retailers (695). Prisons serve the largest number of people on average (1,820). All other system types serve an average of 500 people or fewer.

**Exhibit 4-3**
**Characteristics of NTNC Systems Affected by the Revised Rule**

| Service Area Type | SYSTEM CHARACTERISTICS | | | |
|---|---|---|---|---|
| | Number of Systems | Average Population Served Per System | Design Flow (mgd) | Average Daily Flow (mgd) |
| Daycare Centers | 809 | 76 | 0.0051 | 0.0011 |
| Highway Rest Areas | 15 | 407 | 0.0089 | 0.0020 |
| Hotels/Motels | 351 | 133 | 0.0189 | 0.0045 |
| Interstate Carriers | 287 | 123 | 0.0029 | 0.0006 |
| Medical Facilities | 367 | 393 | 0.1166 | 0.0339 |
| Mobile Home Parks | 104 | 185 | 0.0262 | 0.0065 |
| Restaurants | 418 | 370 | 0.0039 | 0.0008 |
| Schools | 8414 | 358 | 0.0333 | 0.0085 |
| Service Stations | 53 | 230 | 0.0051 | 0.0011 |
| Summer Camps | 46 | 146 | 0.0218 | 0.0053 |
| Water Wholesalers | 266 | 173 | 0.1637 | 0.0494 |
| Agricultural Products/Services | 368 | 76 | 0.0199 | 0.0048 |
| Airparks | 101 | 60 | 0.0026 | 0.0005 |
| Construction | 99 | 53 | 0.0009 | 0.0002 |
| Churches | 230 | 50 | 0.0053 | 0.0011 |
| Campgrounds/RV Parks | 123 | 160 | 0.0214 | 0.0052 |
| Fire Departments | 41 | 98 | 0.0186 | 0.0045 |
| Federal Parks | 20 | 39 | 0.0065 | 0.0014 |
| Forest Service | 107 | 42 | 0.0014 | 0.0002 |
| Golf and Country Clubs | 116 | 101 | 0.0118 | 0.0027 |
| Landfills | 78 | 44 | 0.0053 | 0.0011 |
| Mining | 119 | 113 | 0.0123 | 0.0028 |
| Amusement Parks | 159 | 418 | 0.0171 | 0.0041 |
| Military Bases | 95 | 395 | 0.0695 | 0.0192 |
| Migrant Labor Camps | 33 | 63 | 0.0102 | 0.0023 |
| Misc. Recreation Services | 259 | 87 | 0.0025 | 0.0005 |
| Nursing Homes | 130 | 107 | 0.0411 | 0.0107 |
| Office Parks | 950 | 136 | 0.0077 | 0.0017 |
| Prisons | 67 | 1820 | 0.5322 | 0.1820 |
| Retailers (Non-food related) | 695 | 174 | 0.0038 | 0.0008 |
| Retailers (Food related) | 142 | 322 | 0.0058 | 0.0012 |
| State Parks | 83 | 165 | 0.0048 | 0.0010 |
| Non-Water Utilities | 497 | 170 | 0.0133 | 0.0031 |
| Manufacturing: Food | 768 | 372 | 0.0454 | 0.0120 |
| Manufacturing: Non-Food | 3845 | 168 | 0.0157 | 0.0038 |
| **TOTAL** | **20,255** | | | |

Source: EPA, 1999. Geometries and Characteristics of Public Water Systems, updated with the December 1998 SDWIS freeze.

### 4.2.5 Number of Entry Points

If water systems employ more than one water supply source, they may have more than one treatment facility. For estimation purposes this analysis assumes a treatment facility at every entry point to the distribution system. As a result, the total number of entry points is an important determinant of compliance costs. Exhibit 4-4 presents the distribution of entry points per ground water CWS by system service population category.

**Exhibit 4-4**
**Average Number of Entry Points per Ground Water System**

| Upper Bound 95% Confidence | Service Population Category | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | < 100 | 101-500 | 501-1,000 | 1,001 - 3,300 | 3,301 - 10,000 | 10,001 - 50,000 | 50,001 - 100,000 | > 100,000 |
| Percentile | | | | | | | | |
| Mean | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 9 |
| 5th | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 50th (median) | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 |
| 95th | 2 | 3 | 3 | 5 | 5 | 12 | 22 | 28 |

Source: EPA, 1999. *Geometries and Characteristics of Public Water Systems*, Table 5.2.

In this respect, surface water systems are unlike ground water systems in that little variation in the number of entry points was reported among surface water systems. Even for large population categories, the majority of surface water systems reported only one or two entry points. (EPA, 1999a). This finding was supported by data recently collected from the Information Collection Request for large surface water systems. Appendix C describes how the entry point distribution was incorporated into the cost analysis for this rule.

### 4.2.6 Number of Households

Another method for estimating the effect of regulations on customers is to determine the cost per household. This measure is often used instead of per capita cost because it is a more accurate representation of how customers are billed: per household, not per person.

Exhibit 4-5 shows that household consumption does not vary substantially across size category or ownership type. The mean water consumption ranges from 81,000 gallons per year to 127,000 gallons per year per household.

**Exhibit 4-5**
**Water Consumption per Residential Connection**

| Population | System Type | Mean Water Consumption* (kgal/yr) |
|---|---|---|
| < 100 | Public | 81 |
| | Private | 92 |
| 101-500 | Public | 93 |
| | Private | 110 |
| 501-1,000 | Public | 97 |
| | Private | 88 |
| 1,001-3,300 | Public | 82 |
| | Private | 102 |
| 3,301-10,000 | Public | 87 |
| | Private | 124 |
| 10,001-50,000 | Public | 108 |
| | Private | 110 |
| 50,001-100,000 | Public | 122 |
| | Private | 96 |
| 100,001-1,000,000 | Public | 127 |
| | Private | 114 |

Source: *EPA, 1997. *CWSS, Vol. II: Detailed Summary Result Tables and Methodology Report,* Table 1-14;

### 4.2.7 Production Profile

Exhibit 4-6 shows the average design capacity (in thousands of gallons) of CWS plants by source, ownership, and system size categories. Design capacity is the maximum amount of water a plant can deliver. Exhibit 4-7 provides the daily production of CWSs (in thousands of gallons) for the same categories. Daily production is the average amount of water a plant delivers in a day.

**Exhibit 4-6**
**Design Capacity of CWS Plants**
**by Source, Ownership, and System Size**
**(Thousands of Gallons)**

| Primary Source/ Ownership Type | Service Population Category | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | <25 | 25-100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 | 10,001-50,000 | 50,001-100,000 | 100,001-1,000,000 | >1,000,000 |
| **Ground Water** | 6.27 | 21.86 | 86.86 | 251.0 | 619.5 | 1,864 | 6,673 | 20,785 | 67,379 | 392,939 |
| Public | 4.84 | 29.46 | 123.67 | 305.0 | 740.3 | 2,152 | 7,365 | 22,614 | 67,994 | 401,175 |
| Private | 6.50 | 21.34 | 77.30 | 232.1 | 560.6 | 1,683 | 6,347 | 18,234 | 75,629 | - |
| Purchased-Public | - | 5.71 | 27.37 | 81.4 | 223.0 | 801 | 3,380 | 19,796 | 26,765 | - |
| Purchased-Private | 0.89 | 4.99 | 24.78 | 79.5 | 200.6 | 824 | 2,748 | 8,690 | - | - |
| **Surface Water** | 1.30 | 20.32 | 92.60 | 239.3 | 617.9 | 1,818 | 6,682 | 19,707 | 69,224 | 554,759 |
| Public | 1.14 | 25.79 | 130.90 | 318.2 | 807.8 | 2,218 | 7,887 | 22,337 | 77,298 | 584,889 |
| Private | 3.19 | 18.13 | 75.69 | 214.2 | 527.3 | 1,582 | 6,165 | 15,869 | 61,381 | 296,609 |
| Purchased-Public | 0.04 | 5.71 | 29.01 | 81.8 | 241.1 | 854 | 3,698 | 13,206 | 43,650 | - |
| Purchased-Private | 1.12 | 4.99 | 24.65 | 73.6 | 213.8 | 719 | 2,933 | 12,788 | 29,270 | - |
| **GW under influence** | - | 22.16 | 87.20 | 247.5 | 631.6 | 1,779 | 7,499 | 18,482 | - | - |
| Public | - | 33.29 | 111.32 | 291.2 | 760.0 | 2,077 | 8,992 | 20,195 | - | - |
| Private | - | 21.53 | 81.77 | 227.4 | 618.5 | 1,802 | - | - | - | - |
| Purchased-Public | - | - | 30.21 | 97.1 | 209.3 | 461 | 2,319 | - | - | - |
| Purchased-Private | - | 2.54 | 29.83 | 94.3 | - | 905 | - | - | - | - |

Source: EPA, *Geometries and Characteristics of Public Water Systems*, Table B1.5.3.

**Exhibit 4-7**
**Daily Production of CWS Plants**
**by Source, Ownership, and System Size**
**(Thousands of Gallons)**

| Primary Source/ Ownership Type | Service Population Category | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | <25 | 25-100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 | 10,001-50,000 | 50,001-100,000 | 100,001-1,000,000 | >1,000,000 |
| **Ground water** | 1.35 | 5.33 | 24.40 | 78.50 | 212 | 715 | 2,914 | 10,187 | 37,224 | 259,751 |
| Public | 0.96 | 6.72 | 33.20 | 90.50 | 243 | 796 | 3,129 | 10,900 | 37,095 | 267,256 |
| Private | 1.39 | 4.80 | 20.30 | 69.30 | 18 | 635 | 2,802 | 9,121 | 44,760 | - |
| Purchased-Public | - | 5.11 | 23.50 | 68.20 | 182 | 634 | 2,585 | 14,496 | 19,455 | - |
| Purchased-Private | 0.85 | 4.54 | 21.60 | 67.30 | 166 | 656 | 2,119 | 6,502 | - | - |
| **Surface Water** | 0.39 | 6.91 | 33.70 | 90.70 | 244 | 753 | 2,932 | 9,069 | 33,667 | 295,680 |
| Public | 0.28 | 7.51 | 41.60 | 106.20 | 284 | 823 | 3,133 | 9,387 | 34,749 | 293,439 |
| Private | 0.95 | 6.15 | 28.60 | 87.30 | 230 | 748 | 3,225 | 8,907 | 38,094 | 206,950 |
| Purchased-Public | 0.04 | 5.11 | 24.90 | 68.50 | 197 | 675 | 2,821 | 9,766 | 31,351 | - |
| Purchased-Private | 1.06 | 4.54 | 21.50 | 62.40 | 176 | 575 | 2,258 | 9,472 | 21,215 | - |
| **GW under influence** | - | 5.41 | 24.50 | 77.30 | 217 | 679 | 3,313 | 8,951 | - | - |
| Public | - | 7.70 | 29.50 | 86.00 | 250 | 765 | 3,907 | 9,611 | - | - |
| Private | - | 4.85 | 21.30 | 67.70 | 207 | 686 | - | - | - | - |
| Purchased-Public | - | - | 25.90 | 80.90 | 171 | 370 | 1,789 | - | - | - |
| Purchased-Private | - | 2.36 | 25.9 | 79.4 | - | 719 | - | - | - | - |

Source: EPA, *Geometries and Characteristics of Public Water Systems*, Table B1.5.1.

### 4.2.8 Treatment Profile

Exhibit 4-8 below presents information regarding in-place treatment technologies that affect arsenic concentrations in delivered water. The current treatment in-place will determine the likely remedy that systems will select in order to come into compliance with the new MCL.

**Exhibit 4-8**
**Percentage of CWSs with Various Treatments in Place**

| Primary Source/ Type of Treatments | Service Population Category | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | < 100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 | 10,001-50,000 | 50,001-100,000 | 100,001-1,000,000 | > 1,000,000 |
| **Ground Water Systems** | | | | | | | | | |
| Ion Exchange | 0.7% | 1.6% | 3.8% | 1.9% | 4.6% | 3.3% | 1.2% | 0.0% | - |
| Reverse Osmosis | 0.0% | 1.2% | 0.0% | 0.9% | 1.2% | 0.7% | 1.2% | 0.0% | - |
| Coagulation/ Flocc. | 1.5% | 5.4% | 4.2% | 3.4% | 8.1% | 15.1% | 24.2% | 25.2% | - |
| Lime/Soda Ash Softening | 2.1% | 3.7% | 4.1% | 5.2% | 7.0% | 12.2% | 17.4% | 32.4% | - |
| Disinfection | 52.8% | 77.9% | 84.0% | 79.7% | 86.8% | 96.5% | 86.3% | 96.4% | - |
| **Surface Water Systems** | | | | | | | | | |
| Ion Exchange | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | - |
| Reverse Osmosis | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | - |
| Coagulation/ Flocc. | 27.5% | 52.6% | 70.2% | 78.5% | 95.4% | 94.5% | 93.7% | 99.5% | - |
| Lime/Soda Ash Softening | 3.9% | 8.1% | 20.5% | 17.5% | 10.8% | 6.9% | 5.7% | 5.1% | - |
| Disinfection | 92.8% | 94.1% | 100.0% | 100.0% | 96.0% | 98.0% | 100.0% | 100.0% | |

Source: EPA, *Cost and Technology Document for the Arsenic Rule*, Tables 6-1and 6-2.

## 4.3 Occurrences of Arsenic

EPA has relied on a variety of data sources to evaluate the occurrence of arsenic in community water systems and non-transient non-community systems. This information supports EPA's assessment of baseline conditions, including (1) the number of systems expected to exceed various MCL options, and (2) the population exposed to different levels of arsenic.

In 1992, EPA conducted an analysis of the number of systems that would be impacted by various arsenic MCL options, ranging from 0.5 µg/L to > 50 µg/L. These projections were based on the following national surveys:

- 1984-1986 National Inorganic and Radionuclide Survey (NIRS) for ground water systems;
- 1976-1977 National Organic Monitoring Survey for surface water systems;
- 1978-1980 Rural Water Survey for surface water systems; and
- 1978 Community Water Supply Survey for surface water systems.

These data sources have several limitations. First, the surveys used for surface water systems were conducted primarily before 1980. It is likely that arsenic occurrence has changed in the past two decades due to changes in raw water sources or the addition of filtration treatment to comply with the Surface Water Treatment Rule (SWTR). In addition, many of the survey responses had relatively high minimum reporting limits (5 µg/L). Therefore, it is statistically difficult to extrapolate low-level arsenic occurrence.

EPA (1999c) used the MCL compliance monitoring data from 25 States to develop an improved estimate of national baseline arsenic occurrence. The estimates based on this data are comparable to those based on the other sources listed above.

EPA used statistical techniques to assess:

(1) the national distribution of mean arsenic concentrations in water systems,
(2) the distribution of source means within systems, and
(3) the number of systems with at least one source above various MCLs.

Exhibit 4-9 shows the percentage of systems with an arsenic occurrence in excess of ten different concentration levels, ranging from 2 µg/L to 50 µg/L. Less than one percent of ground water and surface water systems have a concentration level of arsenic greater than 50 µg/L. In contrast, 27 percent of ground water systems and 10 percent of surface water systems have an arsenic concentration greater than 2 µg/L. Exhibit 4-10 provides a summary of the number of systems expected to exceed various MCLs.

**Exhibit 4-9**
**Arsenic Occurrence in CWSs at Various Concentration Levels (µg/L)**

| Source | % of systems greater than (■g/L) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2** | **3** | **5** | **10** | **15** | **20** | **25** | **30** | **40** | **50** |
| **GW** | 27.3 | 19.9 | 12.1 | 5.3 | 3.1 | 2.0 | 1.4 | 1.1 | 0.64 | 0.43 |
| **SW** | 9.8 | 5.6 | 3.0 | 0.80 | 0.46 | 0.32 | 0.24 | 0.19 | 0.13 | 0.10 |

Source: EPA, 2000. *Arsenic Occurrence in Public Drinking Water Supplies.*

**Exhibit 4-10**
**Statistical Estimates of Numbers of Systems with Average Finished Arsenic Concentrations in Various Ranges**

| System size (population served) | Number of systems with mean arsenic concentration (µg/L) in the range of: | | | |
|---|---|---|---|---|
| | >3 to 5 | >5 to 10 | >10 to 20 | >20 |
| **Ground Water CWS** | | | | |
| Number of Systems | 3,384 | 2,949 | 1,432 | 870 |
| % of systems | 7.8% | 6.8% | 3.3% | 2.0% |
| **Surface Water CWS** | | | | |
| Number of Systems | 270 | 239 | 51 | 34 |
| % of systems | 2.5% | 2.2% | 0.5% | 0.3% |
| **Ground Water NTNCWS** | | | | |
| Number of Systems | 1,677 | 1,995 | 635 | 405 |
| % of systems | 8.6% | 10.3% | 3.3% | 2.1% |
| **Surface Water NTNCWS** | | | | |
| Number of Systems | 20 | 17 | 4 | 2 |
| % of systems | 2.5% | 2.2% | 0.5% | 0.3% |

# Chapter 5: Benefits Analysis

## 5.1 Nature of Regulatory Benefits

The benefits associated with reductions of arsenic in drinking water arise from a reduction in adverse human health effects. To a lesser degree benefits may also accrue from an avoidance of expensive consumer behaviors aimed at avoiding exposure, such as the purchase of bottled water.

The value to consumers of a reduction in the risk of adverse health effects includes the following components:

- The avoidance of medical costs and productivity losses associated with illness;
- The avoidance of the pain and suffering associated with illness;
- The losses associated with risk and uncertainty of morbidity, also called the "risk premium"; and
- The reduction in risk of premature mortality.

This conceptual valuation framework goes beyond valuing out-of-pocket medical costs and lost time to include the value consumers place on avoiding pain and suffering and the risk premium. The risk premium represents the damages associated with risk and uncertainty, captured in the expression of consumers' willingness to pay for the reduction in risk of illness (Freeman, 1979).

This chapter first presents information on the multiple adverse health effects associated with arsenic, followed by a quantitative risk analysis of a two arsenic-related endpoints, bladder cancer and lung cancer. Because a large number of potential health effects cannot be quantified, it is likely that the estimated benefits associated with avoidance of bladder and lung cancer underestimate the total benefits of a reduction of arsenic in drinking water.

## 5.2 Health Effects

### 5.2.1 Overview

Exposure to arsenic has many potential health effects, which have been described in two recent publications: *Arsenic in Drinking Water* by the National Research Council (NRC, 1999), and the Agency for Toxic Substances and Disease Registry's *Draft Toxicological Profile for Arsenic* (ATSDR, 1998, updated September 2000). These two sources provide descriptions of health effects that are summarized in this section, along with additional information provided from the recent literature.

Ingestion of inorganic arsenic can result in both cancer and non-cancer health effects (NRC, 1999). Exposure may also occur via other routes of exposure including inhalation and dermal exposure. There is a large human effects database available for inorganic arsenic. However, the effects of organic forms of arsenic are not as well characterized as those of inorganic arsenic. Limited information suggests that the major organoarsenicals found in fish and shellfish (arsenobetaine and arsenocholine) have little or no toxicity.

It appears that some of the metabolites of inorganic arsenic may possess some toxicity. The final rule addresses both organic and inorganic forms of arsenic.

The nature of the health effects avoided by reducing arsenic levels in drinking water is a function of characteristics unique to each individual and the level and timing of exposure. Therefore, the relationship between exposure and response is quite complex. This section describes potential health effects but does not conclude that there are specific effects that occur due to the current levels of arsenic in our country's drinking water.

### 5.2.2 Carcinogenic Effects

Arsenic's carcinogenic role was noted over 100 years ago (NCI, 1999) and has been studied since that time. The Agency has classified arsenic as a Class A human carcinogen, "based on sufficient evidence from human data. An increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic." (EPA, IRIS Web site, extracted 8/99).

The International Agency for Research on Cancer (IARC) concluded that inhalation of inorganic arsenic caused skin and lung cancer in humans. The 1999 NRC report on arsenic states that "epidemiological studies ... clearly show associations of arsenic with several internal cancers at exposure concentrations of several hundred micrograms per liter of drinking water" (NRC, 1999). Ten epidemiological studies, covering eight organ systems, present quantitative data useful for risk assessment (NRC, 1999, Table 4-1). The organ systems where cancers in humans have been identified include skin, bladder, lung, kidney, nasal, liver, and prostate.

Table 10-6 of the NRC report provides risk parameters for three cancers: bladder, lung, and liver cancer. Considering all cancers in aggregate, the NRC states in their Risk Characterization section that "considering the data on bladder and lung cancer in both sexes noted in the studies in chapter 4, a similar approach for all cancers could easily result in a combined cancer risk on the order of 1 in 100" (at the current MCL of 50 µg/L; NRC, 1999).

New data provide additional health effects information on both carcinogenic and non-carcinogenic effects of arsenic. A recently study by Tsai et al. (1999) of a population that has been studied over many years in Taiwan has provided statistically significant standardized mortality ratios (SMRs) for 23 cancerous and non-cancerous causes of death in women and 27 causes of death in men. SMRs are an expression of the ratio between deaths that were observed in an area with elevated arsenic levels and those that were expected to occur, based on the mortality experience of the populations in nearby areas without elevated arsenic levels. Drinking water (250-1,140 µg/L) and soil (5.3-11.2 mg/kg) in the Tsai et al. (1999) population study had very high arsenic content.

Tsai et al. (1999) identified "bronchitis, liver cirrhosis, nephropathy, intestinal cancer, rectal cancer, laryngeal cancer, and cerebrovascular disease" as possibly "related to chronic arsenic exposure via drinking water."

In addition, the study area had upper respiratory tract cancers previously only related to occupational inhalation. High male mortality rate (SMR > 3) existed for bladder, kidney, skin, lung, and nasal cavity cancers and for vascular disease. However, the authors noted that the mortality range was marginal for leukemia, cerebrovascular disease, liver cirrhosis, nephropathy, and diabetes. Females also had high mortalities for laryngeal cancer. The SMRs calculated by Tsai et al. (1999) used the one cause of death noted on the death certificates. Many chronic diseases, including some cancers, do not result in mortality. Consequently, the impact indicated by the SMR will underestimate the total impact of these diseases.

There are, of course, differences between the population and health care in Taiwan and the United States. For example, arsenic levels in the U.S. are not nearly as high as they were in the study area of Taiwan. However, the study gives an indication of the types of health effects that may be associated with arsenic exposure via drinking water.

### 5.2.3 Non-carcinogenic Effects

Arsenic interferes with a number of essential physiological activities, including the actions of enzymes, essential cations, and transcriptional events in cells (NRC, 1999). A wide variety of adverse health effects have been associated with chronic ingestion of arsenic in drinking water, occurring at various exposure levels.

Effects on specific organ systems reported in humans exposed to arsenic are listed below in Exhibit 5-1 (NRC, 1999). Exhibit 5-1 provides descriptive information on the specific diseases and/or symptoms associated with categories of diseases.

**Exhibit 5-1**
**Adverse Noncarcinogenic Health Effects Reported in Humans in NRC (1999) as Potentially Associated with Arsenic, by Organ System Affected***

| | |
|---|---|
| Cutaneous effects | 1. hyperpigmentation<br>2. hyperkeratoses<br>3. melanosis |
| Gastrointestinal and hepatic effects | 4. noncirrhotic portal hypertension<br>5. gastrointestinal hemorrhage secondary to esophageal varices<br>6. hepatic enlargement<br>7. splenic enlargement<br>8. periportal fibrosis of the liver<br>9. obliterative intimal hypertrophy of intrahepatic venules resulting in obstruction of portal venous flow, increased splenic pressures, and hypersplenism, and cirrhosis of the liver<br>10. diarrhea<br>11. cramping |
| Cardiovascular and peripheral vascular effects | 12. peripheral vascular disease (blackfoot disease)<br>13. gangrene of the feet<br>14. coldness and numbness in the extremities<br>15. intermittent claudication<br>16. ulceration<br>17. spontaneous amputation<br>18. Raynaud's syndrome<br>19. acrocyanosis<br>20. ischemic heart disease |
| Cardiovascular and peripheral vascular effects (in children) | 21. arterial spasms in fingers and toes<br>22. esenteric artery thrombosis<br>23. cerebrovascular disease<br>24. extensive coronary occlusions<br>25. cerebrovascular occlusions<br>26. ischemia of the tongue<br>27. Raynaud's syndrome<br>28. gangrene in extremities |
| Hematological effects | 29. anemia - normocytic, megoblastic<br>30. leukopenia - neutropenia, lymphopenia, eosinophilia<br>31. thrombocytopenia<br>32. reticulocytosis<br>33. erythroid hyperplasia |
| Pulmonary effects | 34. chronic cough<br>35. restrictive and obstructive lung disease<br>36. emphysema |
| Immunological effects | 37. impaired immune response (more specific effects observed in human cell studies and animal studies—see source) |
| Neurological effects | 38. peripheral neuropathy |
| Endocrine effects | 39. diabetes mellitus |
| Reproductive and developmental effects | 40. spontaneous abortion<br>41. perinatal death<br>42. stillbirth<br>43. low birth weight<br>44. birth defects including coarctation of the aorta and others<br>45. neural tube defects<br>46. ophthalmic abnormalities<br>47. numerous skeletal abnormalities<br>48. urogenital abnormalities<br>49. growth retardation |

Source: NRC (1999).
*Notes in parenthesis indicate where health effects were observed in animal studies rather than human studies. NRC reports results of numerous animal reproductive and developmental studies and notes that there are "very few" human studies.

### 5.2.4 Susceptible Subgroups

This section discusses the nature of special susceptibilities and identifies population subgroups that may be at higher risk than the general population when exposed to arsenic.

#### *Definition*

A susceptible subgroup exhibits a response that is different or enhanced when compared to the responses of most people exposed to the same level of arsenic (ATSDR, 1998). Many diseases affect certain subgroups of the population disproportionately. The subgroups may be defined by age, gender, race, ethnicity, socioeconomic status, pre-existing medical conditions, behavioral or physiological differences, or other characteristics. For example, there are pre-existing medical conditions that will increase susceptibility to most toxins, such as a pre-existing disease in the toxin's target organ. Very few diseases affect all population groups (ages, sexes, races) equally. For purposes of evaluating potential benefits to different segments of the population, it is useful to evaluate whether there are susceptible subpopulations that require consideration. The benefit of reducing their exposure may be considerably higher than the benefit associated with reducing exposure among the general population (on a per capita basis).

Special susceptibilities may be indicated by known differences in biological processes that are essential to detoxification of a toxin. In addition to identifying susceptible subgroups based on biological processes, susceptible subgroups are often identified by observing higher-than-average rates of the disease of interest. Increases in the rates of reported diseases may be due to a variety of factors. Some of these indicate an increased susceptibility; others are matters of personal choice and may not be considered relevant in a benefits analysis. One way to approach this issue is to evaluate increased susceptibility when it is based on an increased risk of disease due to factors *reasonably beyond the control of the subpopulation.* Factors that are usually beyond the control of the individual that may cause increased susceptibility include:

- Constitutional limitations (e.g., illnesses, genetic abnormalities, birth defects such as enzyme deficiencies);
- Concurrent synergistic exposures that cannot reasonably be controlled (e.g., at home or in the workplace); and
- Normal constitutional differences (i.e., differences based on sex, age, race, ethnicity, etc.).

Other factors that are not usually considered beyond the individual's control include personal choices, such as smoking, drinking, and drug use. Choice of place of residence or work may or may not be treated as a relevant factor. Ultimately, the types of factors that should be included in identifying susceptible subgroups is a matter of public policy.

No studies were located by ATSDR (1998) that focused exclusively on evaluating unusual susceptibility to arsenic. However, some members of the population are likely to be especially susceptible due to a variety of factors. These factors include increased dose (intake per unit of body weight) in children, genetic predispositions, and dietary insufficiency (ATSDR, 1998), as well as pre-existing health conditions.

### *Children*

One often-identified potential susceptible subgroup is children. Due to their increased fluid and food intake in relation to their body weight (NAS, 1995), their dose (milligrams per kilogram of body weight per day - mg/kg/day) of arsenic will be, on average, greater than that of adults. For example, an intake of 1.2 liters per day in a 70 kg adult yields an overall water intake of 0.017 liters per kg of body weight. An infant who consumes 1 liter per day and weighs 10 kg is consuming 0.1 liter per kg of body weight, which is more than 5 times the water intake per kg of an adult. Any contaminant that is present in the water will be delivered at a correspondingly higher level, on a daily basis. Foy et al. noted that in studies of some chronic exposures, children appear to be more severely affected, probably due to a higher exposure per body weight (1992 citation, reported in ATSDR, 1998). In certain circumstances, the increased daily dose in children can be effectively considered for non-carcinogenic effects because toxicity is evaluated in terms of exposures that can range from relatively short-term to long-term exposure. However, carcinogenic effects (i.e., bladder cancer) are evaluated based on a lifetime of exposure, which takes into consideration the elevated dose that occurs in children. Because the health effects measured in this benefits assessment are bladder and lung cancer, a sensitivity analysis to consider higher doses of arsenic during childhood was not necessary. However, the numerous potential non-carcinogenic effects listed in Exhibit 5-1 may be of greater concern for children than adults. Avoidance of these effects constitutes an unquantified benefit of the rule.

### *Genetic Predispositions and Dietary Insufficiency*

Methylation of arsenic plays a role in the detoxification of inorganic arsenic, and individuals who are deficient in essential enzymes for this process, or who have a dietary deficiency of methyl donors (choline or methionine), may be at greater risk following inorganic arsenic exposure (Buchet and Lauwerys, 1987; Vahter and Marafante, 1987; Brouwer et al., 1992 cited in ATSDR, 1998). However, liver disease may not increase risk at low levels of arsenic exposure since there is a greater production of DMA in these patients. (Buchet et al., 1982; Geubel et al., 1988 cited in ATSDR, 1998). Therefore, these factors are not expected to increase risk levels for a significant portion of the U.S. population.

### *Individuals with Pre-existing Organ Susceptibilities*

Individuals may have increased susceptibilities based on specific organ-related factors. Those with pre-existing diseases (e.g., kidney disease), as well as those with congenital defects (a single kidney) will be at greater risk from a toxin that either causes additional damage to that organ, or that relies on that organ for detoxification.

In the case of arsenic, both the kidneys and liver are used to detoxify and remove the contaminant. Both single high doses and long-term low doses may cause an accumulation of arsenic in the liver and kidneys, which can impair function. In addition, these organs may be directly damaged by arsenic exposure. A review of Exhibit 5-1 indicates that other organ systems are targets of arsenic toxicity, including the cardiovascular system (heart, veins, arteries), hematopoietic system, endocrine system, cutaneous system, pulmonary system, gastrointestinal system, immune system, and peripheral nervous system. In individuals with pre-existing damage to these systems or congenital defects in the systems, the likelihood of risk is greater. Due to the higher incidence of most types of disease among the elderly, they are more likely to have pre-existing conditions in these organ systems.

#### *Individuals Exposed via Non-water Sources*

Although arsenic is ubiquitous at low levels, it is not generally found at levels of concern in food or air, in the absence of elevated local sources. Where background levels are high, however, (e.g., elevated levels in water) it is reasonable to consider the contribution to total exposure that may occur from soil, food, and other local sources. When anthropogenic sources are known to generate elevated arsenic levels in water (e.g., a local smelter), it is more likely that other media may be contaminated as well. The total exposure from all sources is a critical component of evaluating potential health risks and the benefits of avoiding contaminated drinking water in these cases. A reduction in arsenic in drinking water will reduce the overall exposure to individuals in living in contaminated areas (e.g., around certain Superfund sites) or workers exposed to arsenic on the job. Total exposure from all sources is of particular concern for non-cancer risks, because background levels from non-drinking water sources will determine whether the total exposure leads to an exceedence of a threshold for effects.

## 5.3 Quantitative Benefits of Avoiding Cancer

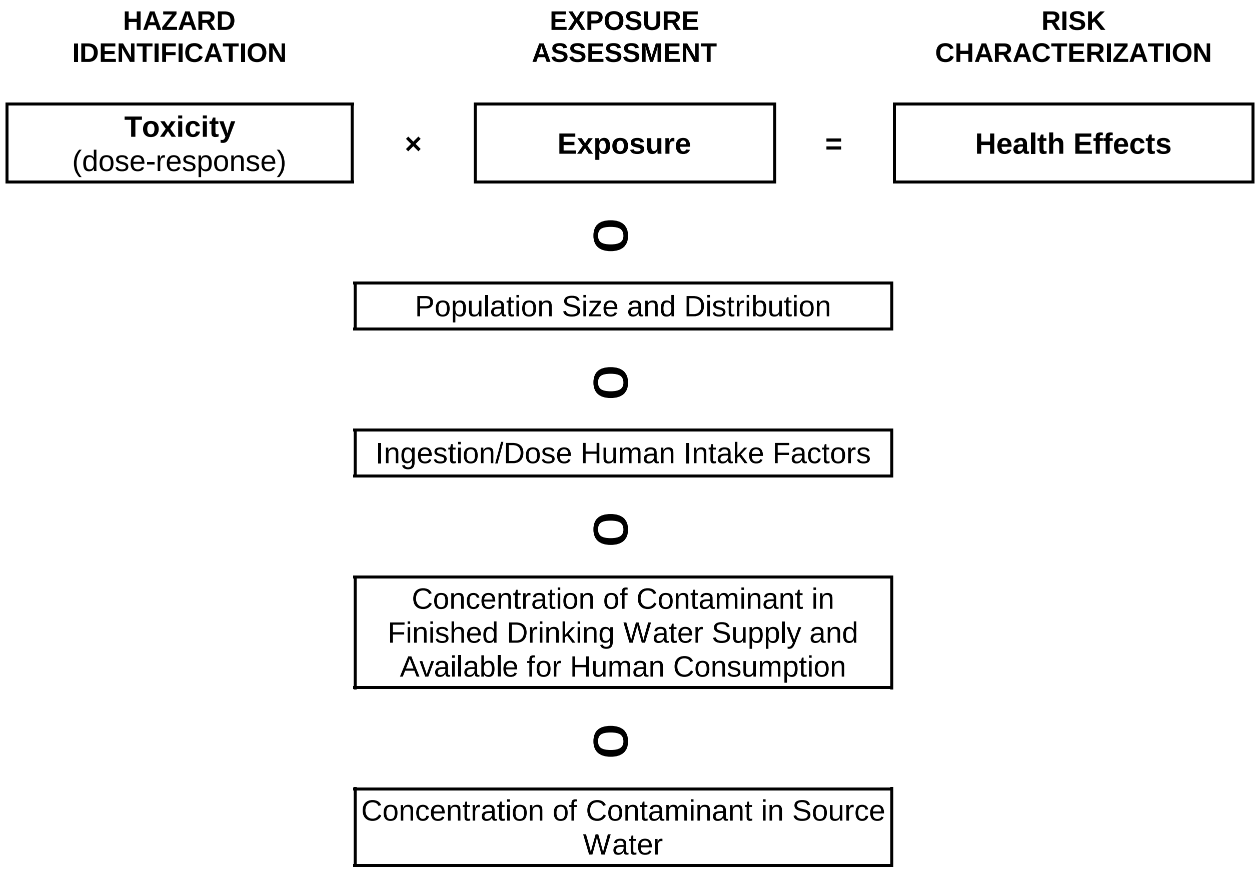
### 5.3.1 Risk Assessment for Cancer Resulting from Arsenic Exposure

As noted, arsenic ingestion has been linked to a multitude of health effects, both cancerous and non-cancerous. These health effects include cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Arsenic ingestion has also been associated with cardiovascular, pulmonary, immunological, neurological, endocrine, and reproductive and developmental effects. A complete list of the arsenic-related health effects reported in humans has been shown in Exhibit 5-1. Of all the health effects noted above, current research on arsenic exposure has only been able to define scientifically defensible risks for bladder and lung cancer. That is, EPA has adequate data to perform a risk assessment on bladder and lung cancer. Because there is currently a lack of strong evidence on the risks of other arsenic-related health effects, the Agency has based its assessment of the quantifiable health risk reduction benefits on the risks of arsenic induced bladder and lung cancers.

Risk assessment is based on the analysis of scientific data to determine the likelihood, nature, and magnitude of harm to public health associated with particular agents, and involves three main analytical components: hazard identification (dose-response assessment), exposure assessment, and risk characterization.

Exhibit 5-2 illustrates the steps in a traditional risk assessment process for characterizing the potential human cancer associated with contaminants in drinking water.

**Exhibit 5-2**
**Components of the Bladder Cancer Risk Assessment**




### 5.3.2 Community Water Systems

The following sections summarize how risk reductions were calculated for populations in community water systems exposed to arsenic concentrations. The approach for this analysis included five components. First, relative exposure factor distributions were developed, which incorporate data from the recent EPA water consumption study with age, sex, and weight data. Second, arsenic occurrence distributions were calculated for the population exposed to arsenic levels above 3 µg/L. Third, risk distributions for bladder and lung cancer were chosen for the analysis from Morales et al. (2000). Fourth, EPA developed estimates of the projected bladder and lung cancer risks faced by exposed populations using Monte-Carlo simulations, bringing together the relative exposure factor, occurrence, and risk distributions. These simulations resulted in upper bound estimates of the actual risks faced by U.S. populations exposed to arsenic concentrations at or above 3 µg/L in their drinking water. Finally, EPA made adjustments to the lower bound risk estimates to reflect exposure to arsenic in cooking water and in food in Taiwan. A more detailed description of the risk methodology is provided in Appendix B.

### *Water Consumption*

EPA recently updated its estimates of per capita daily average water consumption (EPA, 1999). The estimates used data from the combined 1994, 1995, and 1996 Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the U.S. Department of Agriculture (USDA). The CSFII is a complex, multistage area probability sample of the entire U.S. and is conducted to survey the food and beverage intake of the U.S. Per capita water consumption estimates are reported by source. Sources include community tap water, bottled water, and water from other sources, including water from household wells and rain cisterns, and household and public springs. For each source, the mean and percentiles of the distribution of average daily per capita consumption are reported. The estimates are based on an average of two days of reported consumption by survey respondents. The estimated mean daily average per capita consumption of community tap water by individuals in the U.S. population is 1 liter/person/day. For total water, which includes bottled water, the estimated mean daily average per capita consumption is 1.2 liters/person/day. These estimates of water consumption are based on a sample of 15,303 individuals in the 50 States and the District of Columbia. The sample was selected to represent the entire population of the U.S. based on 1990 Census data.

The estimated 90th percentile of the empirical distribution of daily average per capita consumption of community tap water for the U.S. population is 2.1 liters/person/day; the corresponding number for daily average per capita consumption of total water is 2.3 liters/person/day. In other words, current consumption data indicate that 90 percent of the U.S. population consumes approximately 2 liters/person/day, or less.

Water consumption estimates for selected subpopulations in the U.S. are described in the CSFII, including per capita water consumption by source for gender, region, age categories, economic status, race, and residential status and separately for pregnant women, lactating women, and women in childbearing years. The water consumption estimates by age and sex were used in the computation of the relative exposure factors discussed below.

### *Relative Exposure Factors*

Lifetime male and female relative exposure factors (REFs) for each of the broad age categories used in the water consumption study were calculated, where the life-long REFs indicate the sensitivity of exposure of an individual relative to the sensitivity of exposure of an "average" person weighing 70 kilograms and consuming 2 liters of water per day, which is a "high end" water consumption estimate according to the EPA water consumption study referred to above (EPA, 1999). In these calculations, EPA combined the water consumption data with data on population weight from the 1994 Statistical Abstract of the U.S. Distributions for both community tap water and total water consumption were used because the community tap water estimates may underestimate actual tap water consumption. The weight data included a mean and a distribution of weight for male and females on a year-to-year basis. The means and standard deviations of the life-long REFs derived from this analysis are shown in Exhibit 5-3.

**Exhibit 5-3**
**Life-Long Relative Exposure Factors**

| | Community Water Consumption Data | Total Water Consumption Data |
|---|---|---|
| **Male** | *Mean* = 0.60<br>*s.d.* = 0.61 | *Mean* = 0.73<br>*s.d.* = 0.62 |
| **Female** | *Mean* = 0.64<br>*s.d.* = 0.6 | *Mean* = 0.79<br>*s.d.* = 0.61 |

### *Arsenic Occurrence*

EPA recently updated its estimates of arsenic occurrence and calculated separate occurrence distributions for arsenic found in ground water and surface water systems. These occurrence distributions were calculated for systems with arsenic concentrations of 3 μg/L or above. Arsenic occurrence estimates are described in more detail in Chapter 4.

### *Risk Distributions*

In its 1999 report, *Arsenic in Drinking Water,* the NRC analyzed bladder cancer risks using data from Taiwan. In addition, the NRC examined evidence from human epidemiological studies in Chile and Argentina, and concluded that risks of bladder and lung cancer had comparable risks to those "in Taiwan at comparable levels of exposure" (NRC, 1999). The NRC also examined the implications of applying different statistical analyses to the newly available Taiwanese data for the purpose of characterizing bladder cancer risk. While the NRC's work did not constitute a formal risk analysis, they did examine many statistical issues (e.g., measurement errors, age-specific probabilities, body weight, water consumption rate, comparison populations, mortality rates, choice of model) and provided a starting point for additional EPA analyses. The report noted that "poor nutrition, low selenium concentrations in Taiwan, genetic and cultural characteristics, and arsenic intake from food" were not accounted for in their analysis (NRC, 1999, p. 295). In the June 22, 2000, proposed rulemaking, EPA calculated bladder cancer risks and benefits using the bladder cancer risk analysis from the 1999 NRC report. We also estimated lung cancer benefits in a "What If" analysis based on the statement in the 1999 NRC report that "some studies have shown that excess lung cancer deaths attributed to arsenic are 2-5 fold greater than the excess bladder cancer deaths" (NRC, 1999).

In July 2000, a peer-reviewed article by Morales et al. (2000) was published, which presented additional analyses of bladder cancer risks as well as estimates of lung and liver cancer risks for the same Taiwanese population analyzed in the NRC report. EPA summarized and analyzed the new information from the Morales et al. (2000) article in a Notice of Data Availability published on October 20, 2000 (65 FR 63027). Although the data used were the same as used by the NRC to analyze bladder cancer risk in their 1999 publication, Morales et al. (2000) considered more dose-response models and evaluated how well they fit the Taiwanese data, for both bladder cancer risk and lung cancer risk. Ten risk models were presented in Morales et al. (2000). After consultation with the primary authors (Morales and Ryan), EPA chose Model 1 with no comparison population for further analysis.

EPA believes that the models in Morales et al. (2000) without a comparison population are more reliable than those with a comparison population. Models with no comparison population estimate the arsenic dose-response curve only from the study population. Models with a comparison population include mortality data from a similar population (in this case either all of Taiwan or part of southwestern Taiwan), whose exposure is assumed to be zero. Most of the models with comparison populations resulted in dose-response curves that were supralinear (higher than a linear dose-response) at low doses. The curves were "forced down" at zero dose because the comparison population consists of a large number of people with low risk and assumed zero exposure. EPA believes, based on discussions with the authors of Morales et al. (2000), that models with a comparison population are less reliable, for two reasons. First, there is no basis in the data on arsenic's carcinogenic mode of action to support a supralinear curve as being biologically plausible. To the contrary, the conclusion of the NRC Panel (NRC, 1999) was that the mode of action data led one to expect dose responses that would be either linear or less than linear at low dose. However, the NRC indicated that available data are inconclusive and "...do not meet EPA's 1996 stated criteria for departure from the default assumption of linearity" (NRC, 1999). Second, models that include comparison populations assume that the exposure of the comparison population is zero, and that the study and comparison populations are the same in all important ways except for arsenic exposure. Both of these assumptions may be incorrect: NRC (1999) notes that "the Taiwanese-wide data do not clearly represent a population with zero exposure to arsenic in drinking water"; and Morales et al. (2000) agree that "[t]here is reason to believe that the urban Taiwanese population is not a comparable population for the poor rural population used in this study." Moreover, because of the large amount of data in the comparison populations, the model results are relatively sensitive to assumptions about this group. For these reasons, EPA believes that the models without comparison populations are more reliable than those with them.

Of the models that did not include a comparison population, EPA believes that Model 1 fits the data best, based on the Akaike Information Criterion (AIC), a standard criterion of model fit, applied to the Poisson models. EPA did not consider the multi-stage Weibull model for additional analysis, because of its greater sensitivity to the omission of individual villages (Morales et al., 2000) and to the grouping of responses by village (NRC, 1999), as occurs in the Taiwanese data. In Model 1, the dose effect is assumed to follow a linear function, and the age effect is assumed to follow a quadratic function. The Agency decided that the more exhaustive statistical analysis of the data provided by Morales et al. (2000), as analyzed by EPA, would be the basis for the new risk calculations for the final rule (with further consideration of additional risk analyses) and other pertinent information.

### *Estimated Risk Reductions*

Estimated risk reductions for bladder and lung cancer at various MCL levels were developed using Monte-Carlo simulations. Monte-Carlo analysis is a technique for analyzing problems where there are a large number of combinations of input values, which makes it impossible to calculate every possible result. A random number generator is used to select input values from pre-defined distributions. For each set of random numbers, a single scenario's result is calculated. As the simulation runs, the model is recalculated for each new scenario that continues until a stopping criterion is reached.

These simulations combined the distributions of relative exposure factors (REFs), occurrence at or above 3 µg/L, and risks of bladder and lung cancer taken from the Morales et al. (2000) article. The simulations resulted in upper bound estimates of the actual risks faced by populations exposed to arsenic concentrations at or above 3 µg/L in their drinking water.

### *Lower Bound Analyses*

Two adjustments were made to the risk distributions resulting from the simulations described above, reflecting uncertainty about the actual arsenic exposure in the Taiwan study area. First, the Agency made an adjustment to the lower bound risk estimates to take into consideration the effect of exposure to arsenic through water used in preparing food in Taiwan. The Taiwanese staple foods were dried sweet potatoes and rice (Wu et al., 1989). Both the 1988 EPA *Special Report on Ingested Inorganic Arsenic* and the 1999 NRC report assumed that an average Taiwanese male weighed 55 kg and drank 3.5 liters of water daily, and that an average Taiwanese female weighed 50 kg and drank 2 liters of water daily. Using these assumptions, along with an assumption that Taiwanese men and women ate one cup of dry rice and two pounds of sweet potatoes a day, the Agency re-estimated risks for bladder and lung cancer, using one additional liter of water consumption for food preparation (i.e., the water absorbed by hydration during cooking). This adjustment was discussed and used in the October 20, 2000 NODA (65 FR 63027).

Second, an adjustment was made to the lower bound risk estimates to take into consideration the relatively high arsenic concentration in the food consumed in Taiwan as compared to the U.S. The food consumed daily in Taiwan contains about 50 µg, versus about 10 µg in the U.S. (NRC, 1999, pp. 50–51). Thus, the total consumption of inorganic arsenic (from food preparation and drinking water) is considered, per kilogram of body weight, in the process of these adjustments. To carry them out, the relative contribution of arsenic in the drinking water that was consumed as drinking water, on a µg/kg/day basis, was compared to the total amount of arsenic consumed in drinking water, drinking water used for cooking, and in food, on a µg/kg/day basis.

Other factors contributing to lower bound uncertainty include the possibility of a sub-linear dose-response curve below the point of departure. The NRC noted "Of the several modes of action that are considered most plausible, a sub-linear dose response curve in the low-dose range is predicted, although linearity cannot be ruled out" (NRC, 1999). The recent Utah study (Lewis et al., 1999) provides some evidence that the shape of the dose-response curve may well be sub-linear at low doses. Because sufficient mode of action data were not available, an adjustment was not made to the risk estimates to reflect the possibility of a sub-linear dose-response curve. Additional factors contributing to uncertainty include the use of village well data rather than individual exposure data, deficiencies in the Taiwanese diet relative to the U.S. diet (selenium, choline, etc.), and the baseline health status in the Taiwanese study area relative to U.S. populations. The Agency did not make adjustments to the risk estimates to reflect these uncertainties because applicable peer-reviewed, quantitative studies on which to base such adjustments were not available.

Estimated risk levels for bladder and lung cancer combined at various MCL levels are shown in Exhibit 5-4 (a-c). The risk estimates without adjustments for exposure uncertainty through cooking water and food are shown Exhibit 5-4 (a). These estimates incorporate occurrence data, water consumption data, and male and female risk estimates. Lower bounds show estimates using community water consumption data; upper bounds show estimates using total water consumption data. Exhibit 5-4 (b) shows estimated risk levels for bladder and lung cancer combined at various MCL levels with adjustments for exposure uncertainty through cooking water and food. These estimates incorporate occurrence data, water consumption data, and male risk estimates, with lower bounds reflecting community water consumption data and upper bounds reflecting total water consumption data. There are no adjustments for other factors that contribute to uncertainty, such as the use of village well data as opposed to individual exposure data. Exhibit 5-4 (c) is a combination of Exhibit 5-4 (a) and Exhibit 5-4 (b), with the lower bounds taken from Exhibit 5-4 (b), and the upper bounds taken from Exhibit 5-4 (a). Thus Exhibit 5-4 (c) reflects the range of estimates before and after the exposure uncertainty adjustments for cooking water and for food, along with the incorporation of water consumption data, occurrence data, and cancer risk estimates. These estimates were used to estimate the range of potential cases avoided at the various MCL levels.

The upper bound risk estimates in Exhibits 5-4 (a-c) reflect the following:

- The total water consumption estimates from the EPA water consumption study;
- The occurrence distributions of arsenic in U.S. ground and surface water systems;
- Male and female risk estimates from Morales et al. (2000);
- Not adjusting for arsenic exposure from cooking water in Taiwan; and
- Not adjusting for arsenic exposure from food in Taiwan.

The lower bound risk estimates in Exhibits 5-4 (a-c) reflect the following:

- The community water system estimates of water consumption from the EPA water consumption study;
- The occurrence distributions of arsenic in U.S. ground and surface water systems;
- Male risk estimates from Morales et al. (2000);
- Adjusting for arsenic exposure from cooking water in Taiwan; and
- Adjusting for arsenic exposure from food in Taiwan.

**Exhibit 5-4 (a)**
**Cancer Risks for U.S. Populations**
**Exposed at or Above MCL Options, After Treatment[1,2]**
**(Without Adjustment for Arsenic in Food and Cooking Water)**

| MCL (µg/L) | Mean Exposed Population Risk | 90th Percentile Exposed Population Risk |
|---|---|---|
| 3 | .93 -1.25 x $10^{-4}$ | 1.95 - 2.42 x $10^{-4}$ |
| 5 | 1.63 - 2.02 x $10^{-4}$ | 3.47 - 3.9 x $10^{-4}$ |
| 10 | 2.41 - 2.99 x $10^{-4}$ | 5.23 - 6.09 x $10^{-4}$ |
| 20 | 3.07 - 3.85 x $10^{-4}$ | 6.58 - 8.37 x $10^{-4}$ |

[1]Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the arsenic study group.
[2]The estimated risks are male and female risks combined.

**Exhibit 5-4 (b)**
**Cancer Risks for U.S. Populations**
**Exposed at or Above MCL Options, After Treatment[1,2]**
**(With Adjustment for Arsenic Exposure in Food and Cooking Water)**

| MCL (µg/L) | Mean Exposed Population Risk | 90th Percentile Exposed Population Risk |
|---|---|---|
| 3 | .11 -.13 x $10^{-4}$ | .22 - .26 x $10^{-4}$ |
| 5 | .27 - .32 x $10^{-4}$ | .55 - .62 x $10^{-4}$ |
| 10 | .63 - .76 x $10^{-4}$ | 1.32 - 1.54 x $10^{-4}$ |
| 20 | 1.1 - 1.35 x $10^{-4}$ | 2.47 - 2.89 x $10^{-4}$ |

[1]Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the arsenic study group.
[2]The estimated risks are for males.

**Exhibit 5-4 (c)**
**Cancer Risks for U.S. Populations**
**Exposed at or Above MCL Options, After Treatment[1]**
**(Lower Bound With Food and Cooking Water Adjustment,**
**Upper Bound Without Food and Cooking Water Adjustment)**

| MCL (µg/L) | Mean Exposed Population Risk | 90th Percentile Exposed Population Risk |
|---|---|---|
| 3 | .11 -1.25 x $10^{-4}$ | .22 - 2.42 x $10^{-4}$ |
| 5 | .27 - 2.02 x $10^{-4}$ | .55 - 3.9 x $10^{-4}$ |
| 10 | .63 - 2.99 x $10^{-4}$ | 1.32 - 6.09 x $10^{-4}$ |
| 20 | 1.1 - 3.85 x $10^{-4}$ | 2.47 - 8.37 x $10^{-4}$ |

[1]Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the arsenic study group.

### 5.3.3 Non-Transient Non-Community Water Systems

#### *Determination of System and Individual Exposure Factors*

In the past, the Agency has directly used SDWIS population estimates for assessing the risks posed to users of NTNC water systems. In other words, it was assumed that the same person received the exposure on a year-round basis. Under this approach it was generally assumed that all NTNC users were exposed for 270 days out of the year and obtained 50 percent of their daily consumption from these systems. As a comparison, TNC users are assumed to use the system for only ten days per year.

With the recent completion of *Geometries and Characteristics of Public Water Systems* (EPA, 1999a), however, the Agency has developed a more comprehensive understanding of NTNC water systems. These systems provide water in due course as part of operating another line of business. Many systems are classified as NTNC, rather than TNC, water systems solely because they employ sufficient workers to trigger the "25 persons served for over six months out of the year" requirement. Client utilization of these systems is actually much less and more similar to exposure in TNC water systems. For instance, it is fairly implausible that highway rest areas along interstate highways serve the same population on a consistent basis (with the exception of long distance truckers). Nevertheless, there are highway rest areas in both NTNC and TNC system inventories. The *Geometries and Characteristics of Public Water Systems* report suggests that population figures reported in SDWIS that have been used for past risk assessments generally appear to reflect the number of workers in the establishment coupled with peak day customer utilization.

Under these conditions, use of the SDWIS figures for population greatly overestimates the actual individual exposure risk for most of the exposed population and also severely underestimates the number of people exposed to NTNC water.[1] Adequately characterizing individual and population risks necessitates some adjustment of the SDWIS population figures. For chronic contaminants, such as arsenic, health data reflect the consequences of a lifetime of exposure. Consequently, risk assessment requires the estimation of the portion of total lifetime drinking water consumption that any one individual would receive from a particular type of water system. In turn, one needs to estimate the appropriate portions for daily, days per year, and year per lifetime consumption. These estimates need to be prepared for both the workers at the facility and the "customers" of the facility.

This adjustment was accomplished through a comprehensive review of government and trade association statistics on entity utilization by Standard Industry Classification (SIC) code.

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[1]For example, airports constitute only about a hundred of the NTNC water systems. Washington's Reagan National and Dulles, Dallas/Fort Worth, Seattle/Tacoma, and Pittsburgh airports are the five largest of the airports. SDWIS reports that these five airports serve about 300,000 people. In actuality, the Bureau of Transportation Statistics (BTS) suggest that they serve about eleven million passengers per year. Examination of this information and other BTS statistics suggests that these airports serve closer to seven million unique individuals over the course of a year and that exposure occurs on an average of ten times per year per individual customer, not 270 times.

These figures, coupled with SDWIS information relating to the portion of a particular industry served by non-community water systems, made possible the development of two estimates needed for the risk assessment: customer cycles per year and worker per population served per day. These numbers are required to distinguish the more frequent and longer duration exposure of workers from that of system customers.[2] A more detailed characterization of the derivation of these numbers is contained in the docket. Exhibit 5-5 provides the factors used in the NTNC risk assessment to account for the intermittent nature of exposure.

**Exhibit 5-5**
**Exposure Factors Used in the NTNC Risk Assessment**

| NTNCWS | # cycles per yr | worker/ pop/day | worker fraction daily | worker days/yr | worker exposure years | customer fraction daily | days of use/yr | customer exposure years |
|---|---|---|---|---|---|---|---|---|
| Water wholesalers | 1.00 | 0.000 | - | - | - | 0.25 | 270 | 70 |
| Nursing homes | 1.00 | 0.230 | 0.50 | 250 | 40 | 1.00 | 365 | 10 |
| Churches | 1.00 | 0.010 | 0.50 | 250 | 40 | 0.50 | 52 | 70 |
| Golf/country clubs | 4.50 | 0.110 | 0.50 | 250 | 40 | 0.50 | 52 | 70 |
| Food retailers | 2.00 | 0.070 | 0.50 | 250 | 40 | 0.25 | 185 | 70 |
| Non-food retailers | 4.50 | 0.090 | 0.50 | 250 | 40 | 0.25 | 52 | 70 |
| Restaurants | 2.00 | 0.070 | 0.50 | 250 | 40 | 0.25 | 185 | 70 |

[2]For example, travel industry statistics provide information on total numbers of hotel stays, vacancy rates, traveler age ranges, and average duration of stay. These figures can be combined with the SDWIS peak day population estimates to allocate daily population among workers, customers, and vacancies. The combination of these factors provides an estimate of the number of independent customer cycles experienced in a year.

**Exhibit 5-5**
**Exposure Factors Used in the NTNC Risk Assessment (continued)**

| NTNCWS | # cycles per yr | worker/ pop/day | worker fraction daily | worker days/yr | worker exposure years | customer fraction daily | days of use/yr | customer exposure years |
|---|---|---|---|---|---|---|---|---|
| Hotels/motels | 86.00 | 0.270 | 0.50 | 250 | 40 | 1.00 | 3.4 | 40 |
| Prisons/jails | 1.33 | 0.100 | 0.50 | 250 | 40 | 1.00 | 270 | 3 |
| Service stations | 7.00 | 0.060 | 0.50 | 250 | 40 | 0.25 | 52 | 54 |
| Agricultural products/services | 7.00 | 0.125 | 0.50 | 250 | 40 | 0.25 | 52 | 50 |
| Daycare centers | 1.00 | 0.145 | 0.50 | 250 | 10 | 0.50 | 250 | 5 |
| Schools | 1.00 | 0.073 | 0.50 | 200 | 40 | 0.50 | 200 | 12 |
| State parks | 26.00 | 0.016 | 0.50 | 250 | 40 | 0.50 | 14 | 70 |
| Medical facilities | 16.40 | 0.022 | 0.50 | 250 | 40 | 1.00 | 6.7 | 10.3 |
| Campgrounds/RV | 22.50 | 0.041 | 0.50 | 180 | 40 | 1.00 | 5 | 50 |
| Federal parks | 26.00 | 0.016 | 0.50 | 250 | 40 | 0.50 | 14 | 70 |
| Highway rest areas | 50.70 | 0.010 | 0.50 | 250 | 40 | 0.50 | 7.2 | 70 |
| Misc. recreation service | 26.00 | 0.016 | 0.50 | 250 | 40 | 1.00 | 14 | 70 |
| Forest Service | 26.00 | 0.016 | 1.00 | 250 | 40 | 1.00 | 14 | 50 |
| Interstate carriers | 93.00 | 0.304 | 0.50 | 250 | 40 | 0.50 | 2 | 70 |
| Amusement parks | 90.00 | 0.180 | 0.50 | 250 | 10 | 0.50 | 1 | 70 |
| Summer camps | 8.50 | 0.100 | 1.00 | 180 | 10 | 1.00 | 7 | 10 |
| Airports | 36.50 | 0.308 | 0.50 | 250 | 40 | 0.25 | 10 | 70 |
| Military bases | | 1.000 | 0.50 | 250 | 40 | | | |
| Non-water utilities | | 1.000 | 0.50 | 250 | 40 | | | |
| Office parks | | 1.000 | 0.50 | 250 | 40 | | | |
| Manufacturing: Food | | 1.000 | 0.50 | 250 | 40 | | | |
| Manufacturing: Non-food | | 1.000 | 0.50 | 250 | 40 | | | |
| Landfills | | 1.000 | 1.00 | 250 | 40 | | | |
| Fire departments | | 1.000 | 1.00 | 250 | 40 | | | |
| Construction | | 1.000 | 1.00 | 250 | 40 | | | |
| Mining | | 1.000 | 1.00 | 250 | 40 | | | |
| Migrant labor camps | | 1.000 | 1.00 | 250 | 40 | | | |

Once the population adjustment factors were derived, it was possible to determine the actual population served by NTNC water systems. Exhibit 5-6 provides a breakout of these figures by type of establishment.

Although not included in Exhibit 5-6, there are other equally important characteristics to note about these systems. With notable exceptions (such as the airports in Washington, DC, and Seattle), the systems generally serve a fairly small population on any given day. In fact, 99 percent of the systems serve fewer than 3,300 users on a daily basis. This means that water production costs will be relatively high on a per gallon basis.

**Exhibit 5-6**
**Composition of NTNCs**
**(Percentage of Total NTNCWS Population Served by Sector)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Schools | 9.7 | Medical Facilities | 8 | Interstate Carriers | 7.1 | Campgrounds | 1.3 |
| Manufacturing | 2.7 | Restaurants | 0.9 | State Parks | 8.6 | Misc. Recreation | 1.8 |
| Airports | 26.1 | Non-food Retail | 1.6 | Amusement Parks | 17.7 | Other | 3.5 |
| Office Parks | 0.6 | Hotels/Motels | 9.2 | Highway Rest Area | 1.0 | | |

### *Risk Calculation*

Calculations of individual combined risk for bladder and lung cancer were prepared for each industrial sector. Even within a given sector, however, risk varies as a function of an individual's relative water consumption, body weight, vulnerability to arsenic exposure, and the water arsenic concentration. Computationally, risks were estimated by performing Monte-Carlo modeling. The approach used was similar to the modeling technique applied in estimating the community water system risk estimation, but with two notable exceptions. First, each realization in a given sector was multiplied by the portion of lifetime exposure factor presented in Exhibit 5-6 to reflect the decreased consumption associated with the NTNC system. Second, relative exposure factors were limited to age-specific ratings where appropriate.[3] For example, in the case of school children, water consumption rates and weights for 6- to 18-year-olds were used.

To illustrate the process, it was assumed that a child would attend only NTNCWS-served schools for all twelve years, a somewhat improbable likelihood. Further, it was assumed that a child would get half of his or her daily water consumption at school (for an average first grader this would correspond to roughly nine ounces of water per school day). Finally, it was assumed that the child would have perfect attendance and attend school for 200 days per year.

The distribution of overall population risks was determined as part of the same simulation by developing sector weightings to reflect the total portion of the NTNCWS population served by each sector. Population weighted proportional sampling of the individual sectors provided an overall distribution of risk among those exposed at NTNC systems.

[3]For example, water consumption among school children was weighted to reflect consumption between ages 6 and 18, while factory worker consumption was weighted over ages 20 to 64.

Exhibit 5-7 presents a summary of the risk analyses for regulation of arsenic in NTNC water systems. Exhibit 5-8 presents risk figures for three particular sets of individuals: children in daycare centers and schools, and construction workers. Construction and other strenuous activity workers comprise an extremely small portion of the population served by NTNC systems (less than 0.1 percent), but face the highest relative risks of all NTNCWS users ($90^{th}$ percentile risks of 0.4 to 2.3 x $10^{-4}$ lifetime risk).

**Exhibit 5-7**
**Mean Cancer Risks (Bladder and Lung combined),**
**Exposed Population, and Annual Cancer Benefits in NTNCs**

| Arsenic Level (µg/L) | Mean Exposed Population Risk ($10^{-4}$) | | Total Bladder and Lung Cancer Cases Avoided per Year | |
|---|---|---|---|---|
| | lower bound | upper bound | lower bound | upper bound |
| 3 | 0.0000657 | 0.000952 | 0.6 | 2.25 |
| 5 | 0.000162 | 0.00157 | 0.53 | 1.78 |
| 10 | 0.000374 | 0.00243 | 0.36 | 1.13 |
| 20 | 0.00064 | 0.00322 | 0.16 | 0.53 |
| baseline | 0.000853 | 0.00391 | 0.65 | 2.98 |

**Exhibit 5-8**
**Sensitive Group Evaluation of Lifetime Combined Cancer Risks**

| Group | Mean Risk | $90^{th}$ Percentile Risk |
|---|---|---|
| Forest Service, Construction and Mining Workers | 0.2 - 1.2 x $10^{-4}$ | 0.4 - 2.3 x $10^{-4}$ |
| School Children | 0.2 - 1.4 x $10^{-5}$ | 0.5 - 2.8 x $10^{-5}$ |
| Day Care Children | 1.1 - 7.3 x $10^{-6}$ | 0.25 - 1.5 x $10^{-5}$ |

However, there is considerable uncertainty about these exposure numbers, as it is quite likely that they overestimate consumption. It is not possible to determine from the analysis of NTNC systems the extent to which there is overlap of individual exposure between the various sectors. NTNC establishments generally constitute a small portion of their SIC sectors. In conjunction with the observation that NTNC populations would only serve about 11 percent of the total population if all sectors were mutually exclusive, it would seem reasonable to treat the SIC groups independently. However, it is equally plausible that there are communities where one individual might go from an NTNC day care center to a series of NTNC schools and then work in an NTNC factory. Unfortunately, the Agency presently has no basis for quantitatively estimating the extent to which this would occur.

## 5.4 Risk Assessment Results and Benefit Estimates

### 5.4.1 Cases Avoided

The lower and upper bound risk estimates from Exhibit 5-4 (c) were applied to the exposed population to generate cases avoided for CWS systems serving fewer than one million customers. Because the actual arsenic occurrence was known for the very large systems (those serving over a million customers), their system-specific arsenic occurrence distributions could be directly computed. The system specific arsenic distributions allowed direct calculation of avoided cancer cases. The process, described in detail in Appendix B, utilizes the same risk estimates from Morales et al. (2000) that were used in deriving the number of cases avoided in smaller CWS systems. Cases avoided for NTNC systems were also computed separately, utilizing factors developed to account for the intermittent nature of the exposure.

An upper bound adjustment was made to the number of bladder cancer cases avoided to reflect a possible lower mortality rate in Taiwan than was assumed in the risk assessment process described earlier. We also made this adjustment in the June 22, 2000, proposal. In the Taiwan study area, information on arsenic related bladder and lung cancer deaths was reported. In order to use these data to determine the probability of contracting bladder and lung cancer as a result of exposure to arsenic, a probability of mortality given the onset of arsenic induced bladder and lung cancer among the Taiwanese study population must be assumed. The study area in Taiwan is a section where arsenic concentrations in the water are very high by comparison to those in the U.S., and is an area of low incomes and poor diets, where the availability and quality of medical care is not of high quality by U.S. standards. In its estimate of bladder cancer risk, the Agency assumed that within the Taiwanese study area, the probability of contracting bladder cancer was relatively close to the probability of dying from bladder cancer (that is, that the bladder cancer incidence rate was equal to the bladder cancer mortality rate).

We do not have data on the rates of survival for bladder cancer in the Taiwanese villages in the study and at the time of data collection. We do know that the relative survival rates for bladder cancer in developing countries overall ranged from 23.5 percent to 66.1 percent in 1982-1992 (*Cancer Survival in Developing Countries*, International Agency for Research on Cancer, World Health Organization, Publication No. 145, 1998). We also have some information on annual bladder cancer mortality and incidence for the general population of Taiwan in 1996. The age-adjusted annual incidence rates of bladder cancer for males and females, respectively, were 7.36 and 3.09 per 100,000, with corresponding annual mortality rates of 3.21 and 1.44 per 100,000 (correspondence from Chen to Herman Gibb, January 3, 2000). Assuming that the proportion of males and females in the population is equal, these numbers imply that the mortality rate for bladder cancer in the general population of Taiwan, at present, is 45 percent. Since survival rates have most likely improved over the years since the original Taiwanese study, this number represents a lower bound on the survival rate for the original area under study (that is, one would not expect a higher rate of survival in that area at that time). This has implications for the bladder cancer risk estimates from the Taiwan data. If there were any persons with bladder cancer who recovered and died from some other cause, then our estimate underestimated risk; that is, there were more cancer cases than cancer deaths. Based on the above discussion, we think bladder cancer incidence could be no more than two times bladder cancer mortality; and that an 80 percent mortality rate would be plausible.

Thus, we have adjusted the upper bound of cases avoided, which is used in the benefits analysis, to reflect a possible mortality rate for bladder cancer of 80 percent. Because lung cancer mortality rates are quite high, about 88 percent in the U.S. (EPA, 1998b), the assumption was made that all lung cancers in the Taiwan study area resulted in fatalities.

The number of bladder, lung, and combined bladder and lung cases avoided at each MCL are shown in Exhibits 5-9 (a), 5-9 (b), and 5-9 (c). These cases avoided include both CWS and NTNC cases. The number of bladder cancer cases avoided range from 28.6 to 76.8 at an MCL of 3 µg/L, 25.6 to 55.7 at an MCL of 5 µg/L, 18.7 to 31.0 at an MCL of 10 µg/L, and 9.9 to 10.6 at an MCL of 20 µg/L. The number of lung cancer cases avoided range from 28.6 to 61.5 at an MCL of 3 µg/L, 25.6 to 44.5 at an MCL of 5 µg/L, 18.7 to 24.8 at an MCL of 10 µg/L, and 8.5 to 9.9 at an MCL of 20 µg/L. The number of combined bladder and lung cancer cases avoided range from 57.2 to 138.3 at an MCL of 3 µg/L, 51.1 to 100.2 at an MCL of 5 µg/L, 37.4 to 55.7 at an MCL of 10 µg/L, and 19.0 to 19.8 at an MCL of 20 µg/L.

The cases avoided were divided into premature fatality and morbidity cases based on U.S. mortality rates. In the U.S. approximately one out of four individuals who is diagnosed with bladder cancer actually dies from bladder cancer. The mortality rate for the U.S. is taken from a cost of illness study recently completed by EPA (EPA, 1998b). For those diagnosed with bladder cancer at the average age of diagnosis (70 years), the probabilities of dying of that disease during each year post-diagnosis were summed over a 20-year period to obtain the value of 26 percent. Mortality rates for U.S. bladder cancer patients have decreased overall by 24 percent from 1973 to 1996. For lung cancer, mortality rates are much higher. The comparable mortality rate for lung cancer in the U.S. is 88 percent.

**Exhibit 5-9 (a)**
**Annual Bladder Cancer Cases Avoided**
**from Reducing Arsenic in CWSs and NTNCs**

| Arsenic Level (µg/L) | Reduced Mortality Cases* | Reduced Morbidity Cases* | Total Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 7.4 - 20.0 | 21.2 - 56.9 | 28.6 -76.8 |
| 5 | 6.6 - 14.5 | 18.9 - 41.2 | 25.6 - 55.7 |
| 10 | 4.9 - 8.0 | 13.8 - 22.7 | 18.7 - 31.0 |
| 20 | 2.6- 2.8 | 7.3 - 7.8 | 9.9 - 10.6 |

* The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate from Exhibit 5-9(c) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the upper-end risk estimate from Exhibit 5-9(c) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.

**Exhibit 5-9 (b)**
**Annual Lung Cancer Cases Avoided**
**from Reducing Arsenic in CWSs and NTNCs**

| Arsenic Level (μg/L) | Reduced Mortality Cases* | Reduced Morbidity Cases* | Total Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 25.2 - 54.1 | 3.4 - 7.4 | 28.6 - 61.5 |
| 5 | 22.5 - 39.2 | 3.1 - 5.3 | 25.6 - 44.5 |
| 10 | 16.4 - 21.8 | 2.2 - 3.0 | 18.7 - 24.8 |
| 20 | 7.4 - 8.7** | 1.0 - 1.2** | 8.5 - 9.9** |

* The lower and upper-end estimates of lung cancer cases avoided are calculated using the risk estimates from Exhibit 5-9 (c) and assume that the conditional probability of mortality among the Taiwanese study group was 100 percent.
**For 20 μg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus, the number of estimated cases avoided is higher at 20 μg/L using the estimates adjusted for uncertainty.

**Exhibit 5-9 (c)**
**Annual Total Cancer Cases Avoided**
**from Reducing Arsenic in CWSs and NTNCs**

| Arsenic Level (μg/L) | Reduced Mortality Cases* | Reduced Morbidity Cases* | Total Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 32.6 - 74.1 | 24.6 - 64.2 | 57.2 - 138.3 |
| 5 | 29.1 - 53.7 | 22.0 - 46.5 | 51.1 - 100.2 |
| 10 | 21.3 - 29.8 | 16.1 - 25.9 | 37.4 - 55.7 |
| 20 | 10.2 - 11.3** | 8.5 - 8.8 | 19.0 - 19.8** |

* The lower-end estimate of bladder cancer cases avoided and the lung cancer estimates assume that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the assumption that the conditional probability of mortality among the Taiwanese study group was 80 percent.
**For 20 μg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus the number of estimated cases avoided is higher at 20 μg/L using the estimates adjusted for uncertainty.

### 5.4.2 Economic Measurements of the Value of Risk Reduction

The evaluation stage in the analysis of risk reductions involves estimating the value of reducing the risks. The following sections describe the use of benefits valuation techniques to estimate the value of the risk reductions attributable to the regulatory options for arsenic in drinking water. First, the approach for valuing the reductions in fatal risks is described, followed by a description of the approach for valuing the reductions in non-fatal risks.

The benefits described in the primary analysis of this Economic Analysis are assumed to begin to accrue on the effective date of the rule and are based on a calculation referred to as the "value of a statistical life" (VSL).

Of the many VSL studies, the Agency recommends using estimates from 26 specific studies that have been peer reviewed and extensively reviewed within the Agency.[4] These estimates, which are derived from wage-risk and contingent valuation studies, range from $0.7 million to $16.3 million and approximate a Wiebull distribution with a mean of $4.8 million (in 1990 dollars). Most of these 26 studies examine willingness to pay in the context of voluntary acceptance of higher risks of immediate accidental death in the workplace in exchange for higher wages. This value is sensitive to differences in population characteristics and perception of risks being valued. This value could also be updated to include changes in income from 1990 to 1999, which reflects the difference between the study population and the affected population, and would increase monetary benefits since income growth in that time period has been positive.

EPA updated the VSL estimate from *The Benefits and Costs of the Clean Air Act, 1970 to 1990* report to a value of $5.8 million in 1997 dollars, according to internal guidance on economic analyses (Bennett, 2000). In order to directly compare the estimated national costs of compliance, the VSL used in this analysis was updated from the January 1997 value to $6.1 million in May 1999 dollars, using the Consumer Price Index (CPI-U) for all items.

Several factors may influence the estimate of economic benefits associated with avoided cancer fatalities, including:

1. A possible "cancer premium" (i.e., the additional value or sum that people may be willing to pay to avoid the experiences of dread, pain and suffering, and diminished quality of life associated with cancer-related illness and ultimate fatality);
2. The willingness of people to pay more over time to avoid mortality risk as their income rises;
3. A possible premium for accepting involuntary risks as opposed to voluntary assumed risks;
4. The greater risk aversion of the general population compared to the workers in the wage-risk valuation studies;
5. "Altruism" or the willingness of people to pay more to reduce risk in other sectors of the population; and
6. A consideration of health status and life years remaining at the time of premature mortality.

Use of certain of these factors may significantly increase the present value estimate. EPA therefore believes that adjustments should be considered simultaneously. The Agency also believes that there is currently neither a clear consensus among economists about how to simultaneously analyze each of these adjustments, nor are there adequate empirical data to support definitive quantitative estimates for all potentially significant adjustment factors. As a result, the primary estimates of economic benefits presented in the analysis of this rule rely on the unadjusted estimate.

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[4] U.S. Environmental Protection Agency, *The Benefits and Costs of the Clean Air Act, 1970 to 1990*, October 1997, Appendix I; and U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analysis (Review Draft)*, June 1999, Chapter 7.

To assess the impacts of these other factors, EPA presents a sensitivity analysis that examines the impacts of changes in assumptions of the latency period and incorporation of income growth, etc. This sensitivity analysis is given in Section 5.5.

To estimate the monetary value of reduced fatal risks (i.e., risks of premature death from cancer) predicted under different regulatory options, VSL estimates are multiplied by the number of premature fatalities avoided. VSL does not refer to the value of an identifiable life, but instead to the value of small reductions in mortality risks in a population. A “statistical” life is thus the sum of small individual risk reductions across an entire exposed population. For example, if 100,000 people would each experience a reduction of 1/100,000 in their risk of premature death as the result of a regulation, the regulation can be said to “save” one statistical life (i.e., 100,000 x 1/100,000). If each member of the population of 100,000 were willing to pay $20 for the stated risk reduction, the corresponding value of a statistical life would be $2 million (i.e., $20 x 100,000). VSL estimates are appropriate only for valuing small changes in risk; they are not values for saving a particular individual’s life.

Estimates of the willingness to pay to avoid treatable, non-fatal cancers are the ideal economic measures used to value reductions in nonfatal risks. Unfortunately, this information is not available for bladder or lung cancer. However, willingness to pay (WTP) data to avoid chronic bronchitis is available and has previously been employed by the Office of Ground Water and Drinking Water (the microbial/disinfection by-product [MDBP] rulemaking) as a surrogate to estimate the WTP to avoid non-fatal bladder cancer. A WTP central tendency estimate of $607,162 (in May 1999 dollars) is used to monetize the benefits of avoiding non-fatal cancers (this value was updated from the $536,000 value EPA updated to 1997 dollars from the Viscusi et al. [1991] study).

To ground-truth the use of the chronic bronchitis WTP value as a proxy for WTP for the avoidance of non-fatal cases of bladder cancer, EPA has also developed cost-of-illness estimates for bladder cancer, as reported in Exhibit 5-10. These estimates of direct medical costs are derived from a study conducted by Baker et al. (1989), which uses data from a sample of Medicare records for 1974-1981. These data include the total charges for inpatient hospital stays, skilled nursing facility stays, home health agency charges, physician services, and other outpatient and medical services. EPA combined these data with estimates of survival rates and treatment time periods to determine the average costs of initial treatment and maintenance care for patients who do not die of the disease. This value of $178,405, at a three percent discount rate, serves as a low-end estimate of the WTP to avoid bladder cancer and does not include the value of avoided pain and suffering, lost productivity, or risk premium.

**Exhibit 5-10**
**Lifetime Avoided Medical Costs for Survivors**
**(preliminary estimates[1])**

| Type of Cancer | Date Data Collected | Number of Cases Studied | Estimated Mortality Rate | Mean Value per Non-fatal Case (Discount Rate) [1] |
|---|---|---|---|---|
| Bladder | 1974-1981 | 5% of 1974 Medicare patients (sample from national statistics) | 26% (after 20 years) | \$178,405 (3%) \$147,775 (7%) (for typical individual diagnosed at age 70) |

Source: U.S. Environmental Protection Agency, *Cost of Illness Handbook (draft)*, September 1998.
[1] May 1999 dollars.

### 5.4.3 Estimates of Cancer Health Benefits of Arsenic Reduction

Benefits estimates were calculated based on the number of bladder and cancer cases avoided, as given in Exhibits 5-9 (a-c). The total cases avoided were divided into fatal and non-fatal cases, based on survival information (EPA, 1998b). The avoided premature fatalities were valued based on the VSL estimates discussed earlier, as recommended by current EPA guidance for cost/benefit analysis (EPA, 2000c). The avoided non-fatal cases were valued based on the willingness to pay estimates for the avoidance of chronic bronchitis.

The results of the benefits valuation are presented in Exhibit 5-11. Total annual health benefits resulting from bladder cancer cases avoided range from \$58.2 to \$156.4 million at an MCL of 3 µg/L, \$52.0 to \$113.3 million at an MCL of 5 µg/L, \$38.0 to \$63.0 million at an MCL of 10 µg/L, and \$20.1 to \$21.5 million at an MCL of 20 µg/L. Total annual health benefits from avoided cases of lung cancer range from \$155.6 to \$334.5 million at an MCL of 3 µg/L, \$139.1 to \$242.3 million at an MCL of 5 µg/L, \$101.6 to \$134.7 million at an MCL of 10 µg/L, and \$46.1 to \$53.8 million at an MCL of 20 µg/L. In addition, other potential non-quantifiable health benefits are summarized in Exhibit 5-11.

**Exhibit 5-11**
**Total Annual Cost, Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in PWSs**
**($ millions)**

| Arsenic Level (µg/L) | Total Annual Cost (7%) | Annual Bladder Cancer Health Benefits[1,2] | Annual Lung Cancer Health Benefits[1,2] | Total Annual Health Benefits[1,2] | Potential Non-Quantifiable Health Benefits |
|---|---|---|---|---|---|
| 3 | $792.1 | $58.2 - $156.4 | $155.6 - $334.5 | $213.8 - $490.9 | • Skin Cancer<br>• Kidney Cancer<br>• Cancer of the Nasal Passages<br>• Liver Cancer<br>• Prostate Cancer<br>• Cardiovascular Effects<br>• Pulmonary Effects<br>• Immunological Effects<br>• Neurological Effects<br>• Endocrine Effects<br>• Reproductive and Developmental Effects |
| 5 | $471.7 | $52.0 - $113.3 | $139.1 - $242.3 | $191.1 - $355.6 | |
| 10 | $205.6 | $38.0 - $63.0 | $101.6 - $134.7 | $139.6 - $197.7 | |
| 20 | $76.5 | $20.1 - $21.5 | $46.1 - $53.8 | $66.2 - $75.3[3] | |

[1] May 1999 dollars.
[2] These monetary estimates are based on cases avoided given in Exhibit 5-9 (a-c).
[3] For 20 µg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus, the number of estimated cases avoided and estimated benefits are higher at 20 µg/L using the estimates adjusted for uncertainty.

## 5.5 Latency and Other Adjustments: A Sensitivity Analysis

For the final rulemaking analysis, some commenters have argued that the Agency should consider an assumed time lag or latency period in its benefits calculations. The term "latency" can be used in different ways, depending on the context. For example, health scientists tend to define latency as the period beginning with the initial exposure to the carcinogen and ending when the cancer is initially manifested (or diagnosed), while others consider latency as the period between manifestation of the cancer and death. Latency, in this case, refers to the difference between the time of initial exposure to environmental carcinogens and the actual mortality. Use of such an approach might reduce significantly the present value of health risk reduction benefits estimates.

In the Arsenic Rule, the Agency included qualitative language on the latency issue, including descriptions of other adjustments that may influence the estimate of economic benefits associated with avoided cancer fatalities. The Agency also agreed to ask the Science Advisory Board (SAB) to conduct a review of the benefits transfer issues and possible adjustment factors associated with economic valuation of mortality risks. A summary of the SAB's recommendations is shown in the following section.

### 5.5.1 SAB Recommendations

EPA brought this issue before the Environmental Economics Advisory Committee (EEAC) of EPA's SAB in a meeting held on February 25, 2000, in Washington, DC. The SAB submitted a final report on their findings and recommendations to EPA on July 27, 2000.

The EEAC report made a number of recommendations on the adjustment factors and benefit-cost analysis in general. A copy of the final SAB report has been placed in the record for this rulemaking.

The SAB EEAC noted that benefit-cost analysis, as described in the Agency's Guidelines (for economic analysis), is not the only analytical tool, nor is efficiency the only appropriate criterion for social decision making, but notes that it is important to carry out such analyses in an unbiased manner with as much precision as possible. In its report, the SAB recommended that the Agency continue to use a wage-risk based VSL as its primary estimate; any appropriate adjustments that are made for timing and income growth should be part of the Agency's main analysis, while any other adjustments should be accounted for in sensitivity analyses to show how results would change if the VSL were adjusted for some of the major differences in the characteristics of the risk and of the affected populations.

Specifically, the SAB report recommended that (1) health benefits brought about by current policy initiatives (i.e., after a latency period) should be discounted to present value using the same rate that is used to discount other future benefits and costs in the *primary* analysis; (2) adjustments to the VSL for a "cancer premium" should be made as part of a *sensitivity* analysis; (3) adjustments to the VSL for voluntariness and controllability should be made as part of a *sensitivity* analysis; (4) altruism should be addressed in a *sensitivity* analysis and separately from estimation of the value of a statistical cancer fatality, and the circumstances under which altruism can be included in a benefit-cost analysis are restrictive; (5) estimates of VSLs accruing in future years should be adjusted in the *primary* analysis to reflect anticipated income growth, using a range of income elasticities; (6) adjustments to the VSL for risk aversion should be made in a *sensitivity* analysis; (7) it is *theoretically* appropriate to calculate WTP for individuals whose ages correspond to those of the affected population, but more research should be conducted in this area; and (8) no adjustment should be made to the VSL to reflect health status of persons whose cancer risks are reduced.

After considering the SAB's recommendations, EPA has developed a sensitivity analysis of the latency structure and associated benefits for the Arsenic Rule, as described in the next section. This analysis consists of health risk reduction benefits that reflect adjustments for discounting, incorporation of a range of latency period assumptions, adjustments for growth in income, and incorporation of other factors such as voluntariness and controllability. Although the SAB recommended accounting for latency in a primary benefits analysis, the Agency believes that in the absence of any sound scientific evidence on the duration of particular latency periods for arsenic-related cancers, discounted benefits estimates for arsenic are more appropriately accounted for in a sensitivity analysis. Sensitivity analyses are generally reserved for examining the effects of accounting for highly uncertain factors, such as the estimation of latency periods, on health risk reduction benefits estimates.

Defining a latency period is highly uncertain because the length of the latency period is often poorly understood by health scientists. In some cases, information on the progression of a cancer is based on animal studies, and extrapolation to humans is complex and uncertain. Even when human studies are available, the dose considered may differ significantly from the dose generally associated with drinking water contaminants (e.g., involve a high level of exposure over a short time period, rather than a long-term, low level of exposure).

The magnitude of the dose may in turn affect the resulting latency period. Information on latency may be unavailable in many cases, or, if available, may be highly uncertain and vary significantly across individuals.

### 5.5.2 Analytical Approach

For the latency sensitivity analysis, the health benefits have been broken into separate treatments of morbidity and mortality. The mortality component of the total benefits is examined in this analysis because a cancer latency period (i.e., the time period between initial exposure to environmental carcinogens and the actual fatality) impacts arsenic-related fatalities only. For purposes of this analysis, the Agency examined the impacts of various latency period assumptions, adjustments for income growth, and incorporation of other adjustments, such as voluntariness and controllability, on bladder and lung cancer fatalities associated with arsenic in drinking water.

Because the latency period for arsenic-related bladder and lung cancers is unknown, EPA has assumed a range of latency periods from 5 to 20 years. While both lung and bladder cancer have relatively long average latencies, the lower end of the latency period is substantially less. As can be seen by inspection of the Surveillance, Epidemiology, and End Results (SEER) data of the National Cancer Institute, significant incidence of both cancers occurs in individuals in the 15- to 19-year-old age groups. This strongly indicates a short latency period for whatever the cause of the cancer may have been.

Moreover, the mode of action for arsenic is suspected to be one that operates at a late stage of the cancer process and that may advance the expression of cancers initiated by other causes (sometimes referred to as "promoting out" the cancerous effect). Therapeutic treatment with the drug cyclophosphamide, which causes cell toxicity, has been seen to induce bladder cancer in as little as 7 to 15 years in affected patients. This was of course a high dose treatment, but the example serves to illustrate the ability of an agent to advance the development of cancer.

For these reasons, we believe latency periods of 5, 10, and 20 years serve as reasonable approximations, in the absence of definitive data on arsenic-induced cancers, of the latency periods for the sensitivity analysis.

Exhibit 5-12 shows the sensitivity of the primary analysis VSL estimate ($6.1 million, 1999 dollars) to changes in latency period assumptions and also with the incorporation of income growth and other adjustment factors. As is shown in Exhibit 5-12, the adjusted VSL is greater than the primary VSL ($6.77 million versus $6.1 million) at an income elasticity of 1.0, with adjustments for income growth only. The lowest adjusted VSL value ($3.44 million) is yielded over a 20-year latency period that includes discounting and income growth only (income elasticity = 0.22). Assuming a seven percent discount rate, the highest adjusted VSL is also $6.77 million (adjusted for income growth only [income elasticity = 1.0]). The lowest adjusted VSL is $1.61 million (discounted over 20 years).

The first row of both the three and seven percent discount rate panels in Exhibit 5-12 shows the VSL used in the primary analysis. Because this value has not been adjusted for discounting over an assumed and *unknown* latency period, this value does not deviate from the original $6.1

million used in the primary benefits analysis. The second and third rows of both the three and seven percent panels show the adjustments to the primary VSL to account for changes in WTP for fatal risk reductions associated with real income growth from 1990 to 1999. As real income grows, the WTP to avoid fatal risks is also expected to increase at a rate corresponding to the income elasticity of demand, as discussed below. This income growth, from the years 1990 to 1999, accounts for the differences in incomes of the VSL study population versus the population affected by the Arsenic Rule. This does not include any income adjustments over a latency period because of methodological issues that have not yet been resolved. However, pending the resolution of these issues, EPA may include an adjustment for income growth over a latency period in future analyses, as recommended by the SAB.

The fourth and fifth rows of both the three and seven percent panels illustrates the impacts of adjusting the primary VSL for discounting and income growth over a range of assumed latency periods. As is shown in Exhibit 5-12, this value decreases from $5.84 million assuming a five-year latency period to $3.75 million assuming a 20 year latency period (at a three percent discount rate and income elasticity of 1.0). At a seven percent discount rate, this value decreases from $4.83 million to $1.75 million.

**Exhibit 5-12**
**Sensitivity of the Primary VSL Estimate to Changes in Latency Period Assumptions, Income Growth, and Other Adjustments**
**($ millions, 1999)**

| Adjustment Factor | | Latency Period (Years) | | |
|---|---|---|---|---|
| | | 5 | 10 | 20 |
| **3 % Discount Rate** | | | | |
| Primary Analysis (No VSL Adjustment) | | 6.1 | 6.1 | 6.1 |
| Adjusted for Income Growth[1] | elasticity = 0.22 | 6.22 | 6.22 | 6.22 |
| | elasticity = 1.0 | 6.77 | 6.77 | 6.77 |
| Adjusted for Income Growth[1] and Discounting | elasticity = 0.22 | 5.37 | 4.63 | 3.44 |
| | elasticity = 1.0 | 5.84 | 5.04 | 3.75 |
| Adjusted for Income Growth[1], Discounting, and 7% Increase for Voluntariness and Controllability | elasticity = 0.22 | 5.74 | 4.95 | 3.69 |
| | elasticity = 1.0 | 6.25 | 5.39 | 4.01 |
| Break-Even for Other Characteristics (as a percentage of the primary VSL estimate) | | | | |
| | elasticity = 0.22 | 6 % | 19 % | 40 % |
| | elasticity = 1.0 | -2 % | 12 % | 34 % |
| **7 % Discount Rate** | | | | |
| Primary Analysis (No VSL Adjustment) | | 6.1 | 6.1 | 6.1 |
| Adjusted for Income Growth[1] | elasticity = 0.22 | 6.22 | 6.22 | 6.22 |
| | elasticity = 1.0 | 6.77 | 6.77 | 6.77 |
| Adjusted for Income Growth[1] and Discounting | elasticity = 0.22 | 4.44 | 3.16 | 1.61 |
| | elasticity = 1.0 | 4.83 | 3.44 | 1.75 |
| Adjusted for Income Growth[1], Discounting, and 7% Increase for Voluntariness and Controllability | elasticity = 0.22 | 4.75 | 3.38 | 1.72 |
| | elasticity = 1.0 | 5.17 | 3.68 | 1.87 |
| Break-Even for Other Characteristics (as a percentage of the primary VSL estimate) | | | | |
| | elasticity = 0.22 | 22 % | 45 % | 72 % |
| | elasticity = 1.0 | 15 % | 40 % | 69 % |

1. This adjustment reflects the change in WTP based on real income growth from 1990 to 1999.

The sixth and seventh rows of the three and seven percent panels illustrate the effects of incorporating a seven percent increase for voluntariness and controllability as recommended for a sensitivity analysis in the SAB report on valuing fatal cancer risk reductions (SAB, 2000). One member of the SAB committee noted in the SAB report that this adjustment may be as high as two times the primary VSL, but this value is highly speculative. The seven percent adjustment accounts for empirical evidence in the literature that indicates individuals may place a higher willingness to pay (WTP) on risks where exposure is neither voluntary nor controllable by the individual.

In adjusting for both income growth and voluntariness and controllability, EPA used a range of income elasticities from the economics literature. Income elasticity is the percent change in demand for a good (in this case, WTP for fatal risk reductions) for every one percent change in income. For example, an income elasticity of 1.0 implies that a 10 percent higher income level results in a 10 percent higher WTP for fatal risk reductions. In a recent study (EPA, 2000c), EPA reviewed the literature related to the income elasticity of demand for the prevention of fatal health impacts. Based on data from cross-sectional studies of wage premiums, a range of elasticity estimates for serious health impacts was developed, ranging from a lower-end estimate of 0.22 to an upper-end estimate of 1.0.

There are several other characteristics that differ between the VSL estimates used in the primary analysis and an ideal estimate specific to the case of cancer risks from arsenic. These include a cancer premium, differences in risk aversion, altruism, age of the individual affected, and a morbidity component of the VSL mortality estimate. Very little empirical information is available on the impact that these characteristics have on VSL estimates; thus, they are not accounted for directly in this sensitivity analysis. A more complete discussion of the other characteristics identified by economists as having a potential impact on WTP to reduce mortality risks can be found in Chapter Seven of the Agency's *Guidelines for Preparing Economic Analyses* (EPA, 2000c), which is available in the docket for this final rulemaking.

However, it is possible to use a "break even" analysis to address the question: what would the impact on VSL of these additional characteristics need to be to produce the $6.1 million VSL used in the primary benefits analysis (described earlier in this chapter). The last two rows of the three and seven percent panels of Exhibit 5-12 attempt to answer this question in percentage terms. For example, at a three percent discount rate over a ten year latency period and income elasticity of 1.0, a factor of 12 percent (as shown in the bottom row of the three percent panel of Exhibit 5-12) indicates that if accounting for these characteristics would increase VSL by more than 12 percent then the primary analysis will tend to understate the value of risk reductions. If accounting for these characteristics would not increase VSL by at least 12 percent then the primary analysis may overstate benefits (a negative percentage indicates that the primary analysis understates benefits unless the combined impact of these additional characteristics actually reduces VSL estimates).

Some researchers believe that the value of some of these characteristics will substantially add to the unadjusted VSL (one study suggests that a cancer premium alone may be worth an additional 100 percent of primary VSL value [Revesz, 1999]). Some researchers also believe that some of these characteristics have a negative effect on VSL, suggesting that some of these factors offset one another. Until we know more about these various factors we cannot explicitly make adjustments to existing VSL estimates.

The SAB noted in their report that these characteristics require more empirical research prior to incorporation into the Agency's primary benefits analysis, but could be explored as part of a sensitivity analysis.

### 5.5.3 Results

Exhibit 5-13 illustrates the impacts of changes in VSL adjustment factor assumptions on the estimated benefits for the range of fatal bladder and lung cancer cases avoided in the final Arsenic Rule, assuming a three percent discount rate. The results of this analysis at a seven percent discount rate are given in Exhibit 5-14. These results were calculated by applying the adjusted VSLs from Exhibit 5-12 to the lower- and upper-bound estimates of fatal bladder and lung cancer cases avoided as shown in Exhibit 5-9 (c). For purposes of this sensitivity analysis, EPA presented combined bladder and lung cancer cases avoided in Exhibits 5-13 and 5-14. Health risk reduction benefits attributable to reduced arsenic levels in both CWSs and NTNCWSs are presented in these exhibits as well.

It is important to note that the monetized benefits estimates shown in this section reflect *quantifiable* benefits only. As shown in Section 5.2, there are a significant number of *non-quantifiable* benefits associated with regulating arsenic in drinking water. As a result, the monetized benefits presented in the following exhibit represent a lower-bound estimate. Were EPA able to quantify some of the currently non-quantifiable health effects and other benefits associated with arsenic regulation, monetized benefits estimates could be significantly higher than what are shown in the exhibit.

**Exhibit 5-13. Sensitivity of Combined Annual Bladder and Lung Cancer Mortality Benefits Estimates to Changes in VSL Adjustment Factor Assumptions ($ millions, 1999, 3% discount rate)[1]**

| Arsenic Level (Fg/L) | | 3 | 5 | 10 | 20 |
|---|---|---|---|---|---|
| **5 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 176-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 175-398 | 156-288 | 114-160 | 55-61 |
| | E = 1.0 | 190-433 | 170-314 | 124-174 | 60-66 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 187-425 | 167-308 | 122-171 | 59-65 |
| | E = 1.0 | 204-463 | 182-336 | 133-186 | 64-71 |
| **10 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 176-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 151-343 | 135-249 | 99-138 | 47-52 |
| | E = 1.0 | 164-373 | 147-271 | 107-150 | 51-57 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 161-367 | 144-266 | 105-148 | 50-56 |
| | E = 1.0 | 176-399 | 157-289 | 115-161 | 55-61 |
| **20 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 176-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 112-255 | 100-185 | 73-103 | 35-39 |
| | E = 1.0 | 122-278 | 109-201 | 80-112 | 38-42 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 120-273 | 107-198 | 79-110 | 38-42 |
| | E = 1.0 | 131-297 | 117-215 | 85-119 | 41-45 |

1. The lower- and upper-bound benefits estimates correspond to the lower- and upper-bound risk estimates and cancer cases avoided as shown in section III.D.2 of this preamble.
2. This adjustment reflects the change in WTP based on real income growth from 1990 to 1999. E = income elasticity.

**Exhibit 5-14**
**Sensitivity of Combined Annual Bladder and Lung Cancer Mortality Benefits Estimates to Changes in VSL Adjustment Factor Assumptions**
**($ millions, 1999, 7% discount rate)[1]**

| Arsenic Level (Fg/L) | | 3 | 5 | 10 | 20 |
|---|---|---|---|---|---|
| **5 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 178-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 145-329 | 129-238 | 95-132 | 45-50 |
| | E = 1.0 | 157-358 | 141-259 | 103-144 | 50-55 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 155-352 | 138-255 | 102-142 | 49-54 |
| | E = 1.0 | 168-383 | 150-278 | 110-154 | 53-58 |
| **10 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 178-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 103-234 | 92-170 | 67-94 | 32-36 |
| | E = 1.0 | 112-255 | 100-185 | 73-103 | 35-39 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 110-251 | 98-182 | 72-101 | 35-38 |
| | E = 1.0 | 120-273 | 107-198 | 78-110 | 38-42 |
| **20 Year Latency Period Assumption** | | | | | |
| Primary Analysis (No VSL Adjustment) | | 199-452 | 178-328 | 130-182 | 62-69 |
| Adjusted for Income Growth[2] | E = 0.22 | 203-461 | 181-334 | 133-186 | 63-70 |
| | E = 1.0 | 221-502 | 197-364 | 144-202 | 69-77 |
| Adjusted for Income Growth[2] and Discounting | E = 0.22 | 53-119 | 47-86 | 34-48 | 16-18 |
| | E = 1.0 | 57-130 | 51-94 | 37-52 | 18-20 |
| Adjusted for Income Growth[2], Discounting, and 7% Increase for Voluntariness and Controllability | E = 0.22 | 56-127 | 50-92 | 37-51 | 18-20 |
| | E = 1.0 | 61-139 | 54-100 | 40-56 | 19-21 |

1. The lower- and upper-bound benefits estimates correspond to the lower- and upper-bound risk estimates and cancer cases avoided as shown in section III.D.2 of this preamble.
2. This adjustment reflects the change in WTP based on real income growth from 1990 to 1999. E = income elasticity.

As shown in Exhibits 5-13 and 5-14, the highest range of adjusted benefits estimates at the 10 µg/L MCL ($144 - $202 million at three percent and seven percent) are yielded when benefits are adjusted for income growth only with an income elasticity of 1.0.  The lowest adjusted benefits estimates at the 10 µg/L MCL ($73 - $103 million at three percent, $34 - $48 million at seven percent) are yielded under the assumption of a 20-year latency period that includes adjustments for discounting and income growth (income elasticity = 0.22).  These results indicate the high degree of sensitivity of benefits estimates to different assumptions of a latency period and income elasticity and also the inclusion of adjustments for income growth and voluntariness and controllability.

## 5.6 Other Benefits of Reductions in Arsenic Exposure

It is well established that the public often avoids the use of tap water that is suspected to be contaminated.  In this context, contamination may suggest biological, chemical, or other water quality issues.  When public perception of water quality declines, consumers purchase bottled water if they have the means to do so.

In addition or as an alternative, they may avoid the use of tap water, ingesting and cooking with other liquids, substituting pre-mixed baby formula, and using other strategies to limit ingestion. Consumer avoidance of tap water sources usually results in costs to the consumers, either in the cost of obtaining substitute fluids or potential health impacts of reduced fluid intake.  In addition, there are numerous cases where government agencies have provided bottled water due to biological or chemical contamination.  The levels of contamination at which the government activities occur vary depending on a variety of factors.

The relationship between arsenic in tap water and changes in consumer behavior or government interventions is a complex one.  Factors that impact the choice to avoid tap water depend on public information that is provided on levels of contamination, potential health effects, individual aversions to risk taking, and other considerations.  A quantitative evaluation of these responses and the potential benefits of avoiding associated costs to the consumer or governments is not included in this benefits assessment.  However, it is clear that many consumers purchase bottled water (a multimillion dollar industry) or invest in other methods of improving drinking water quality, such as point-of-use (POU) devices, specifically to avoid ingestion of contaminants such as arsenic.  Thus, it is reasonable to conclude that a reduction in arsenic contamination will have the long-term effect of restoring some level of consumer confidence in the water supply.

# Chapter 6: Cost Analysis

## 6.1 Introduction

This chapter presents the national cost estimates for the Arsenic Rule. The costs associated with the rule include: (1) costs borne by water systems to comply with the new MCL standard and modified monitoring requirements, and (2) costs to the States to implement and enforce the rule. Section 6.2 describes the inputs and methodologies used to estimate costs, including the following:

- A description of the technologies that may be used by systems to achieve the MCL (Section 6.2.1);
- The unit costs of different technologies for complying with the MCLs (Section 6.2.2);
- System and State unit costs for monitoring and administration functions (Section 6.2.3); and
- The methods used to predict systems' compliance methods (Section 6.2.4) and the methods used to calculate costs (Section 6.2.5).

Section 6.3 presents the results of the cost analysis, including the following:

- A summary of national costs for the different regulatory options (Section 6.3.1);
- Costs by system size and type for the MCL options (Section 6.3.2); and
- Household costs (Section 6.3.3).

Section 6.4 discusses the uncertainty inherent in the distribution of estimated national compliance costs.

## 6.2 Methodology

### 6.2.1 Description of Available Technologies

In 1993, EPA developed a document entitled *Treatment and Occurrence—Arsenic in Potable Water Supplies* (EPA, 1993), which summarized the results of pilot-scale studies examining low-level arsenic removal, from 50 micrograms per liter (µg/L) down to 1 µg/L or less. EPA convened a panel of outside experts in January 1994 to review this document and comment on the ability of the technologies to achieve various MCLs. The Agency has since sought stakeholder input on the use of various technologies for arsenic removal under different conditions, and has incorporated that input into its estimates of technology performance and costs. The results are documented in the *Cost and Technology Document for the Arsenic Rule* (EPA, 2000d). The technology cost functions and removal efficiencies presented in that document are used as inputs for the cost analyses presented in this EA.

Some technologies generate wastes that require disposal or pre-treatment (e.g., pre-oxidation or corrosion control) in order to be effective. These associated requirements were identified for different technologies and system types, and their costs were included in the costs of treatment where relevant.

In addition to these centralized treatment options, small systems may elect to use point-of-use (POU) devices to achieve compliance with the MCLs.  POU involves treatment at the tap.  The available POU technologies for arsenic removal are essentially smaller versions of reverse osmosis and activated alumina.  These technologies will have to be maintained by the water system, involving some additional recordkeeping and maintenance costs.

The result of the review of technologies that would effectively remove arsenic and bring a water system into compliance is summarized in Exhibit 6-1.  The list includes 13 treatment trains available to systems, consisting of various combinations of compliance technologies, waste disposal technologies, or pre-treatment technologies as required.

**Exhibit 6-1**
**Arsenic Rule Treatment Trains by Compliance Technologies Component with Associated Removal Efficiencies**

| Treatment Technology | | Waste Disposal Technology | | | | Corrosion Control | Pre-Oxidation° | Removal Efficiency |
|---|---|---|---|---|---|---|---|---|
| | | POTW | Non-Hazardous Landfill | Mechanical De-Watering | Non-Mechanical De-Watering | | | |
| 1 | Modify Lime Softening | | | | | | T | 90% |
| 2 | Modify Coagulation/Filtration | | | | | | T | 95% |
| 3 | Anion Exchange (<20 mg/L SO4) | T | | | | | T | 95% |
| 4 | Anion Exchange (20-50 mg/L SO4) | T | | | | | T | 95% |
| 5 | Coagulation Assisted Microfiltration | | T | T | | | T | 90% |
| 6 | Coagulation Assisted Microfiltration | | T | | T | | T | 90% |
| 7 | Oxidation Filtration (Greensand) | T* | | | | | T | 50% |
| 8 | Activated Alumina (pH 7 - pH 8) | | T** | | | | T | 95% |
| 9 | Activated Alumina (pH 8 - pH 8.3) | | T** | | | | T | 95% |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6) | | T** | | | T | T | 95% |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6) | | T** | | | T | T | 95% |
| 12 | POU Activated Alumina | | | | | | T | 90% |
| 13 | POU Reverse Osmosis | | | | | | T | 90% |

° pre-oxidation incorporated into treatment trains based on a separate decision tree

* POTW for backwash stream

** non-hazardous landfill (for spent media)

### 6.2.2 Unit Costs and Compliance Assumptions

EPA estimated the costs of the various compliance technologies, including the centralized treatment technologies associated waste disposal technologies, and POU treatment technologies, excluding pre-treatment costs. Pre-treatment costs were separate treatment costs that apply to a particular set of systems (some systems would already have pre-treatment in place). Costs of each treatment train are estimated as functions of system size, design flow (used to calculate capital costs) and average flow (used to calculate operating and maintenance costs). Exhibits 6-2 (a) and 6-2 (b) presents a summary of unit compliance technology costs by cost component for the treatment trains listed in Exhibit 6-1, annualized over 20 years at a seven percent discount rate. Costs are in May 1999 dollars and are based on average and design flows for median populations of each system size category.

The unit costs are provided to demonstrate the range of costs across the treatment technologies for an MCL of 10µg/L, assuming either an influent arsenic concentration of 11µg/L (low range estimates shown in Exhibit 6-2(a)) or an influent arsenic concentration of 50µg/L (high range estimates shown in Exhibit 6-2(b)). EPA calculated these average unit costs for a single contaminated entry point, assuming a publicly-owned ground water system with the average number of entry points per system in that size category. Note that the capital and operating ad maintenance (O&M) cost components are listed separately for the treatment and waste disposal components of the treatment train. These costs are annualized over 20 years at a seven percent discount rate. Detailed descriptions of the assumptions and methodologies used to develop the underlying cost curves are available in the *Cost and Technology Document for the Arsenic Rule* (EPA, 2000d).

**Exhibit 6-2a**
**System Compliance Technology Costs Assuming Influent Concentration of 11 μg/L and MCL of 10 μg/L (Dollars)**

| Size Category | Treatment Train No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| < 100 | | | | | | | |
| | Treatment Capital Costs | $ 8,999 | $ 7,483 | $ 21,957 | $ 22,724 | $ 127,885 | $ 127,885 |
| | Treatment O&M Costs | $ 484 | $ 260 | $ 5,104 | $ 8,604 | $ 22,361 | $ 20,585 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 29,900 | $ 20,686 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 381 | $ 387 | $ 6,946 | $ 2,131 |
| | Annual Costs (7%) | $ 1,333 | $ 966 | $ 7,930 | $ 11,510 | $ 44,200 | $ 36,740 |
| 101-500 | | | | | | | |
| | Treatment Capital Costs | $ 13,688 | $ 8,966 | $ 21,957 | $ 37,150 | $ 265,526 | $ 265,526 |
| | Treatment O&M Costs | $ 1,416 | $ 482 | $ 5,104 | $ 9,470 | $ 23,619 | $ 22,400 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 43,354 | $ 118,165 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 412 | $ 455 | $ 12,863 | $ 2,177 |
| | Annual Costs (7%) | $ 2,708 | $ 1,328 | $ 7,962 | $ 13,804 | $ 65,638 | $ 60,795 |
| 501-1,000 | | | | | | | |
| | Treatment Capital Costs | $ 14,756 | $ 9,316 | $ 21,957 | $ 40,669 | $ 295,452 | $ 295,452 |
| | Treatment O&M Costs | $ 1,766 | $ 565 | $ 5,104 | $ 9,791 | $ 24,090 | $ 23,081 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 46,424 | $ 141,947 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 424 | $ 480 | $ 14,929 | $ 2,195 |
| | Annual Costs (7%) | $ 3,159 | $ 1,444 | $ 7,974 | $ 14,483 | $ 71,290 | $ 66,563 |
| 1,001-3,300 | | | | | | | |
| | Treatment Capital Costs | $ 24,087 | $ 12,655 | $ 38,991 | $ 120,712 | $ 526,687 | $ 526,687 |
| | Treatment O&M Costs | $ 4,760 | $ 1,266 | $ 5,104 | $ 12,431 | $ 28,088 | $ 28,088 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 73,454 | $ 330,519 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 525 | $ 696 | $ 29,102 | $ 2,364 |
| | Annual Costs (7%) | $ 7,034 | $ 2,460 | $ 9,682 | $ 24,894 | $ 113,839 | $ 111,366 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1.

**Exhibit 6-2a (continued)**
**System Compliance Technology Costs Assuming Influent Concentration of 11 µg/L and MCL of 10 µg/L (Dollars)**

| Size Category | Treatment Train No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 3,301-10,000 | | | | | | | |
| | Treatment Capital Costs | $ 64,447 | $ 40,103 | $ 38,991 | $ 211,802 | $ 1,069,210 | $ 1,069,210 |
| | Treatment O&M Costs | $ 14,961 | $ 4,833 | $ 5,104 | $ 20,403 | $ 38,522 | $ 38,522 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 121,208 | $ 762,407 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 869 | $ 1,434 | $ 32,307 | $ 9,170 |
| | Annual Costs (7%) | $ 21,045 | $ 8,618 | $ 10,027 | $ 42,203 | $ 183,196 | $ 220,583 |
| 10,001-50,000 | | | | | | | |
| | Treatment Capital Costs | $ 247,207 | $ 168,801 | $ 38,991 | $ 362,184 | $ 1,793,771 | $ 1,793,771 |
| | Treatment O&M Costs | $ 35,250 | $ 17,001 | $ 5,104 | $ 31,688 | $ 55,413 | $ 55,413 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 209,000 | $ 1,610,846 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 1,593 | $ 2,984 | $ 45,793 | $ 50,349 |
| | Annual Costs (7%) | $ 58,584 | $ 32,934 | $ 10,750 | $ 69,233 | $ 290,253 | $ 427,134 |
| 50,001-100,000 | | | | | | | |
| | Treatment Capital Costs | $ 455,707 | $ 315,625 | $ 38,991 | $ 529,645 | $ 2,368,818 | $ 2,368,818 |
| | Treatment O&M Costs | $ 61,149 | $ 32,533 | $ 5,104 | $ 54,032 | $ 59,325 | $ 59,325 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,085 | $ 5,085 | $ 309,158 | $ 2,381,322 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 2,516 | $ 4,962 | $ 52,569 | $ 66,722 |
| | Annual Costs (7%) | $ 104,165 | $ 62,326 | $ 11,780 | $ 109,470 | $ 364,675 | $ 574,426 |
| 100,001-1,000,000 | | | | | | | |
| | Treatment Capital Costs | $ 1,462,373 | $ 918,353 | $ 38,991 | $ 1,873,015 | $ 6,887,505 | $ 6,887,505 |
| | Treatment O&M Costs | $ 309,897 | $ 177,044 | $ 5,104 | $ 168,459 | $ 96,658 | $ 96,658 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,085 | $ 5,085 | $ 954,312 | $ 9,517,736 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 12,132 | $ 25,570 | $ 178,509 | $ 237,418 |
| | Annual Costs (7%) | $ 447,935 | $ 263,730 | $ 21,396 | $ 371,308 | $ 1,015,379 | $ 1,882,614 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1.

## Exhibit 6-2a (continued)
## System Compliance Technology Costs Assuming Influent Concentration of 11 μg/L and MCL of 10 μg/L (Dollars)

| Size Category | Treatment Train No. | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|
| < 100 | | | | | | | | |
| | Treatment Capital Costs | $ 15,023 | $ 13,629 | $ 13,629 | $ 45,787 | $ 45,787 | $ 4,671 | $ 13,619 |
| | Treatment O&M Costs | $ 7,711 | $ 4,414 | $ 6,944 | $ 6,050 | $ 6,643 | $ 6,725 | $ 4,433 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 446 | $ 12 | $ 22 | $ 5 | $ 8 | $ - | $ - |
| | Annual Costs (7%) | $ 9,949 | $ 5,712 | $ 8,253 | $ 10,377 | $ 10,972 | $ 7,390 | $ 6,372 |
| 101-500 | | | | | | | | |
| | Treatment Capital Costs | $ 63,059 | $ 29,131 | $ 29,131 | $ 62,507 | $ 62,507 | $ 27,027 | $ 78,866 |
| | Treatment O&M Costs | $ 8,540 | $ 6,065 | $ 10,087 | $ 7,494 | $ 8,437 | $ 39,804 | $ 26,552 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 571 | $ 78 | $ 150 | $ 34 | $ 51 | $ - | $ - |
| | Annual Costs (7%) | $ 15,437 | $ 8,892 | $ 12,986 | $ 13,428 | $ 14,388 | $ 43,652 | $ 37,781 |
| 501-1,000 | | | | | | | | |
| | Treatment Capital Costs | $ 73,464 | $ 32,912 | $ 32,912 | $ 66,586 | $ 66,586 | $ 34,915 | $ 101,897 |
| | Treatment O&M Costs | $ 8,904 | $ 6,684 | $ 11,265 | $ 8,036 | $ 9,110 | $ 51,591 | $ 34,475 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 618 | $ 103 | $ 197 | $ 44 | $ 67 | $ - | $ - |
| | Annual Costs (7%) | $ 16,830 | $ 9,893 | $ 14,569 | $ 14,365 | $ 15,462 | $ 56,562 | $ 48,983 |
| 1,001-3,300 | | | | | | | | |
| | Treatment Capital Costs | $ 170,709 | $ 60,846 | $ 60,846 | $ 97,616 | $ 97,616 | $ 97,980 | $ 286,071 |
| | Treatment O&M Costs | $ 12,006 | $ 11,930 | $ 21,255 | $ 12,627 | $ 14,814 | $ 146,709 | $ 98,728 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 1,016 | $ 313 | $ 602 | $ 135 | $ 203 | $ - | $ - |
| | Annual Costs (7%) | $ 29,509 | $ 17,986 | $ 27,600 | $ 21,977 | $ 24,231 | $ 160,659 | $ 139,458 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1. In Treatment Trains 8 -11, waste disposal O&M costs include only non-hazardous landfill tipping fees, and therefore, are quite low.

**Exhibit 6-2a (continued)**
**System Compliance Technology Costs Assuming Influent Concentration of 11 µg/L and MCL of 10 µg/L (Dollars)**

| Size Category | Treatment Train No. | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|
| 3,301-10,000 | | | | | | | | |
| | Treatment Capital Costs | $ 421,562 | $ 159,129 | $ 159,129 | $ 205,374 | $ 205,374 | $ 296,207 | $ 865,248 |
| | Treatment O&M Costs | $ 22,659 | $ 29,916 | $ 55,506 | $ 28,369 | $ 34,369 | $ 449,875 | $ 305,030 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 2,381 | $ 1,033 | $ 1,988 | $ 447 | $ 671 | $ - | $ - |
| | Annual Costs (7%) | $ 65,205 | $ 45,970 | $ 72,514 | $ 48,202 | $ 54,426 | $ 492,048 | $ 428,222 |
| 10,001-50,000 | | | | | | | | |
| | Treatment Capital Costs | $ 787,837 | $ 324,276 | $ 324,276 | $ 386,442 | $ 386,442 | $ 682,321 | $ 1,993,842 |
| | Treatment O&M Costs | $ 45,012 | $ 67,654 | $ 127,369 | $ 61,397 | $ 75,399 | $ 1,047,475 | $ 714,269 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 5,951 | $ 2,545 | $ 4,895 | $ 1,102 | $ 1,653 | $ - | $ - |
| | Annual Costs (7%) | $ 125,809 | $ 100,809 | $ 162,873 | $ 98,976 | $ 113,530 | $ 1,144,622 | $ 998,147 |
| 50,001-100,000 | | | | | | | | |
| | Treatment Capital Costs | $ 1,168,062 | $ 512,683 | $ 512,683 | $ 593,012 | $ 593,012 | $ 1,150,447 | $ 3,362,537 |
| | Treatment O&M Costs | $ 73,549 | $ 122,590 | $ 231,264 | $ 109,500 | $ 134,983 | $ 1,778,028 | $ 1,216,748 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 9,606 | $ 4,476 | $ 8,608 | $ 1,938 | $ 2,906 | $ - | $ - |
| | Annual Costs (7%) | $ 193,892 | $ 175,459 | $ 288,265 | $ 167,413 | $ 193,866 | $ 1,941,826 | $ 1,695,498 |
| 100,001-1,000,000 | | | | | | | | |
| | Treatment Capital Costs | $ 4,098,917 | $ 2,257,773 | $ 2,257,773 | $ 2,506,335 | $ 2,506,335 | $ 5,567,338 | $ 16,283,352 |
| | Treatment O&M Costs | $ 370,791 | $ 629,270 | $ 1,199,321 | $ 548,870 | $ 682,540 | $ 8,780,565 | $ 6,073,580 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 47,683 | $ 24,581 | $ 47,274 | $ 10,642 | $ 15,962 | $ - | $ - |
| | Annual Costs (7%) | $ 805,863 | $ 866,968 | $ 1,459,713 | $ 796,092 | $ 935,082 | $ 9,573,229 | $ 8,391,963 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1. In Treatment Trains 8 -11, waste disposal O&M costs include only non-hazardous landfill tipping fees, and therefore, are quite low.

## Exhibit 6-2b
## System Compliance Technology Costs Assuming Influent Concentration of 50 μg/L and MCL of 10 μg/L (Dollars)

| Size Category | Treatment Train No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| < 100 | | | | | | | |
| | Treatment Capital Costs | $ 8,999 | $ 7,483 | $ 26,970 | $ 29,332 | $ 193,923 | $ 193,923 |
| | Treatment O&M Costs | $ 484 | $ 260 | $ 5,365 | $ 8,924 | $ 21,251 | $ 21,251 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 36,236 | $ 65,339 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 392 | $ 412 | $ 9,187 | $ 2,148 |
| | Annual Costs (7%) | $ 1,333 | $ 966 | $ 8,676 | $ 12,478 | $ 52,164 | $ 47,872 |
| 101-500 | | | | | | | |
| | Treatment Capital Costs | $ 13,688 | $ 8,966 | $ 43,632 | $ 117,795 | $ 508,282 | $ 508,282 |
| | Treatment O&M Costs | $ 1,416 | $ 482 | $ 5,365 | $ 11,527 | $ 26,696 | $ 26,696 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 71,219 | $ 316,779 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 490 | $ 621 | $ 24,844 | $ 2,301 |
| | Annual Costs (7%) | $ 2,708 | $ 1,328 | $ 10,346 | $ 23,640 | $ 106,241 | $ 106,877 |
| 501-1,000 | | | | | | | |
| | Treatment Capital Costs | $ 14,756 | $ 9,316 | $ 43,632 | $ 126,653 | $ 564,187 | $ 564,187 |
| | Treatment O&M Costs | $ 1,766 | $ 565 | $ 5,365 | $ 12,469 | $ 28,148 | $ 28,148 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 77,743 | $ 358,515 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 526 | $ 699 | $ 29,269 | $ 2,367 |
| | Annual Costs (7%) | $ 3,159 | $ 1,444 | $ 10,383 | $ 25,497 | $ 118,010 | $ 117,611 |
| 1,001-3,300 | | | | | | | |
| | Treatment Capital Costs | $ 24,087 | $ 12,655 | $ 43,632 | $ 218,240 | $ 1,103,278 | $ 1,103,278 |
| | Treatment O&M Costs | $ 4,760 | $ 1,266 | $ 5,365 | $ 19,699 | $ 37,737 | $ 37,737 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 3,955 | $ 3,955 | $ 124,926 | $ 793,148 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 836 | $ 1,362 | $ 40,238 | $ 8,074 |
| | Annual Costs (7%) | $ 7,034 | $ 2,460 | $ 10,692 | $ 42,035 | $ 193,909 | $ 224,820 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1.

**Exhibit 6-2b (continued)**
**System Compliance Technology Costs Assuming Influent Concentration of 50 µg/L and MCL of 10 µg/L (Dollars)**

| Size Category | Treatment Train No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 3,301-10,000 | | | | | | | |
| | Treatment Capital Costs | $ 64,447 | $ 40,103 | $ 43,632 | $ 490,994 | $ 2,255,079 | $ 2,255,079 |
| | Treatment O&M Costs | $ 14,961 | $ 4,833 | $ 5,365 | $ 45,678 | $ 56,923 | $ 56,923 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,085 | $ 5,085 | $ 285,807 | $ 2,123,020 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 1,897 | $ 3,637 | $ 48,028 | $ 42,687 |
| | Annual Costs (7%) | $ 21,045 | $ 8,618 | $ 11,860 | $ 96,141 | $ 344,793 | $ 512,872 |
| 10,001-50,000 | | | | | | | |
| | Treatment Capital Costs | $ 247,207 | $ 168,801 | $ 43,632 | $ 923,917 | $ 3,571,834 | $ 3,571,834 |
| | Treatment O&M Costs | $ 35,250 | $ 17,001 | $ 5,365 | $ 75,188 | $ 65,568 | $ 65,568 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,085 | $ 5,085 | $ 513,238 | $ 4,281,260 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 4,124 | $ 8,409 | $ 72,683 | $ 95,250 |
| | Annual Costs (7%) | $ 58,584 | $ 32,934 | $ 14,087 | $ 171,288 | $ 523,853 | $ 902,095 |
| 50,001-100,000 | | | | | | | |
| | Treatment Capital Costs | $ 455,707 | $ 315,625 | $ 43,632 | $ 1,378,931 | $ 5,074,043 | $ 5,074,043 |
| | Treatment O&M Costs | $ 61,149 | $ 32,533 | $ 5,365 | $ 110,599 | $ 76,604 | $ 76,604 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,085 | $ 5,085 | $ 717,287 | $ 6,653,715 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 6,967 | $ 14,501 | $ 110,698 | $ 145,696 |
| | Annual Costs (7%) | $ 104,165 | $ 62,326 | $ 16,930 | $ 255,741 | $ 733,963 | $ 1,329,318 |
| 100,001-1,000,000 | | | | | | | |
| | Treatment Capital Costs | $ 1,462,373 | $ 918,353 | $ 43,632 | $ 3,623,972 | $ 18,245,297 | $ 18,245,297 |
| | Treatment O&M Costs | $ 309,897 | $ 177,044 | $ 5,365 | $ 328,792 | $ 203,223 | $ 203,223 |
| | Waste Disposal Capital Costs | $ - | $ - | $ 5,571 | $ 5,571 | $ 2,275,373 | $ 28,628,219 |
| | Waste Disposal O&M Costs | $ - | $ - | $ 36,579 | $ 77,955 | $ 477,280 | $ 672,537 |
| | Annual Costs (7%) | $ 447,935 | $ 263,730 | $ 46,588 | $ 749,350 | $ 2,617,509 | $ 5,300,288 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1.

**Exhibit 6-2b (continued)**
**System Compliance Technology Costs Assuming Influent Concentration of 50 µg/L and MCL of 10 µg/L (Dollars)**

| Size Category | Treatment Train No. | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|
| < 100 | | | | | | | | |
| | Treatment Capital Costs | $ 24,983 | $ 20,733 | $ 20,733 | $ 53,449 | $ 53,449 | $ 4,671 | $ 13,619 |
| | Treatment O&M Costs | $ 7,747 | $ 5,021 | $ 8,098 | $ 6,580 | $ 7,302 | $ 6,725 | $ 4,433 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 464 | $ 36 | $ 69 | $ 16 | $ 23 | $ - | $ - |
| | Annual Costs (7%) | $ 10,943 | $ 7,014 | $ 10,125 | $ 11,641 | $ 12,371 | $ 7,390 | $ 6,372 |
| 101-500 | | | | | | | | |
| | Treatment Capital Costs | $ 104,869 | $ 57,733 | $ 57,733 | $ 94,204 | $ 94,204 | $ 27,027 | $ 78,866 |
| | Treatment O&M Costs | $ 9,495 | $ 10,104 | $ 17,779 | $ 11,029 | $ 12,829 | $ 39,804 | $ 26,552 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 694 | $ 240 | $ 461 | $ 104 | $ 156 | $ - | $ - |
| | Annual Costs (7%) | $ 20,462 | $ 15,794 | $ 23,690 | $ 20,025 | $ 21,877 | $ 43,652 | $ 37,781 |
| 501-1,000 | | | | | | | | |
| | Treatment Capital Costs | $ 104,869 | $ 57,733 | $ 57,733 | $ 94,204 | $ 94,204 | $ 27,027 | $ 78,866 |
| | Treatment O&M Costs | $ 9,495 | $ 10,104 | $ 17,779 | $ 11,029 | $ 12,829 | $ 39,804 | $ 26,552 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 694 | $ 240 | $ 461 | $ 104 | $ 156 | $ - | $ - |
| | Annual Costs (7%) | $ 20,462 | $ 15,794 | $ 23,690 | $ 20,025 | $ 21,877 | $ 43,652 | $ 37,781 |
| 1,001-3,300 | | | | | | | | |
| | Treatment Capital Costs | $ 283,894 | $ 166,171 | $ 166,171 | $ 213,095 | $ 213,095 | $ 97,980 | $ 286,071 |
| | Treatment O&M Costs | $ 15,866 | $ 28,169 | $ 52,180 | $ 26,840 | $ 32,470 | $ 146,709 | $ 98,728 |
| | Waste Disposal Capital Costs | $ 3,955 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 1,511 | $ 963 | $ 1,853 | $ 417 | $ 626 | $ - | $ - |
| | Annual Costs (7%) | $ 44,547 | $ 44,818 | $ 69,718 | $ 47,372 | $ 53,211 | $ 160,659 | $ 139,458 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1. In Treatment Trains 8 -11, waste disposal O&M costs include only non-hazardous landfill tipping fees, and therefore, are quite low.

**Exhibit 6-2b (continued)**
**System Compliance Technology Costs Assuming Influent Concentration of 50 µg/L and MCL of 10 µg/L (Dollars)**

| Size Category | Treatment Train No. | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|
| 3,301-10,000 | | | | | | | | |
| | Treatment Capital Costs | $ 701,070 | $ 468,896 | $ 468,896 | $ 545,004 | $ 545,004 | $ 296,207 | $ 865,248 |
| | Treatment O&M Costs | $ 35,414 | $ 90,018 | $ 169,031 | $ 81,254 | $ 99,783 | $ 449,875 | $ 305,030 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 4,721 | $ 3,183 | $ 6,122 | $ 1,378 | $ 2,067 | $ - | $ - |
| | Annual Costs (7%) | $ 106,791 | $ 137,461 | $ 219,413 | $ 134,077 | $ 153,294 | $ 492,048 | $ 428,222 |
| 10,001-50,000 | | | | | | | | |
| | Treatment Capital Costs | $ 1,310,195 | $ 977,574 | $ 977,574 | $ 1,102,719 | $ 1,102,719 | $ 682,321 | $ 1,993,842 |
| | Treatment O&M Costs | $ 76,430 | $ 207,386 | $ 393,274 | $ 183,031 | $ 226,620 | $ 1,047,475 | $ 714,269 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 9,975 | $ 7,840 | $ 15,079 | $ 3,394 | $ 5,091 | $ - | $ - |
| | Annual Costs (7%) | $ 210,559 | $ 307,502 | $ 500,628 | $ 290,514 | $ 335,800 | $ 1,144,622 | $ 998,147 |
| 50,001-100,000 | | | | | | | | |
| | Treatment Capital Costs | $ 1,942,521 | $ 1,557,893 | $ 1,557,893 | $ 1,738,984 | $ 1,738,984 | $ 1,150,447 | $ 3,362,537 |
| | Treatment O&M Costs | $ 128,791 | $ 357,213 | $ 679,531 | $ 312,954 | $ 388,534 | $ 1,778,028 | $ 1,216,748 |
| | Waste Disposal Capital Costs | $ 5,085 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 16,683 | $ 13,785 | $ 26,512 | $ 5,968 | $ 8,952 | $ - | $ - |
| | Annual Costs (7%) | $ 329,314 | $ 518,052 | $ 853,098 | $ 483,070 | $ 561,634 | $ 1,941,826 | $ 1,695,498 |
| 100,001-1,000,000 | | | | | | | | |
| | Treatment Capital Costs | $ 6,816,616 | $ 6,933,014 | $ 6,933,014 | $ 7,632,284 | $ 7,632,284 | $ 5,567,338 | $ 16,283,352 |
| | Treatment O&M Costs | $ 674,190 | $ 1,917,857 | $ 3,661,282 | $ 1,666,275 | $ 2,075,085 | $ 8,780,565 | $ 6,073,580 |
| | Waste Disposal Capital Costs | $ 5,598 | $ - | $ - | $ - | $ - | $ - | $ - |
| | Waste Disposal O&M Costs | $ 86,549 | $ 75,712 | $ 145,611 | $ 32,778 | $ 49,166 | $ - | $ - |
| | Annual Costs (7%) | $ 1,404,708 | $ 2,647,996 | $ 4,461,320 | $ 2,419,486 | $ 2,844,684 | $ 9,573,229 | $ 8,391,963 |

NOTE: Average costs were calculated assuming a publicly-owned groundwater system with a single contaminated entry point, based on median population and the average number of entry points per system in the service size category, for the treatment train technologies described in Exhibit 6-1. In Treatment Trains 8 -11, waste disposal O&M costs include only non-hazardous landfill tipping fees, and therefore, are quite low.

### 6.2.3 Monitoring and Administrative Costs

#### *Monitoring Costs*

Monitoring under the current Arsenic Rule occurs annually for surface water systems, and triennially for ground water systems. Currently, when triggered by a violation the system must perform three additional tests within the month. Under the revised rule to be promulgated in January 2001, systems will still perform monitoring annually (for surface water systems) or every three years (for ground water systems); however, when triggered by a violation, the system will perform quarterly monitoring rather than three more samples in one month. All surface water systems must collect samples no later than December 31, 2006, and all ground water systems must collect samples by December 31, 2007, to demonstrate compliance with the revised MCL.

If quarterly monitoring is required it will continue until the State determines that the system is "reliably and consistently" below the MCL or until the PWS installs treatment. States are able to make this determination after ground water systems have taken two quarterly samples and surface water systems have taken four quarterly samples. Additionally, States may grant a nine-year monitoring waiver to qualifying systems, an option not previously available. To be eligible for a waiver, a system must meet the following criteria:

1. Demonstrate adequate source water protection by completing a vulnerability assessment; and
2. Demonstrate that three previous samples were below the MCL.

The monitoring requirements will impose new costs for some systems as follows:

- NTNCs will incur the full costs of the monitoring requirements for the first time, unless they are located in States that already require NTNCs to monitor for arsenic. For NTNCs that are currently required to monitor for arsenic, the incremental monitoring costs will depend on how the revised national requirements compare with the current State requirements. (It is assumed that States currently require NTNCs to monitor using the ground water requirements. It is also assumed that 96 percent of NTNCs use ground water sources, and 4 percent use surface water.)

- CWSs may incur additional costs if they find exceedances more frequently at the revised MCL.

The cost of monitoring includes preparing and analyzing the sample. Collecting the sample, arranging for delivery to the laboratory, and reviewing the results of the analysis is assumed to require one hour of the system operator's time (at an estimated cost of $28 per hour). EPA has assumed that all systems are equipped to collect samples. Therefore, no additional costs are assumed for installation of taps, re-piping of wells or other investments to permit sampling. EPA has assumed that systems will utilize one of two laboratory methods: (1) stabilized temperature platform graphite furnace atomic absorption (STP-GFAA) or (2) graphite furnace atomic absorption (GFAA). Both techniques cost $40 per sample.

Total net monitoring costs were estimated over a 20-year period at discount rates of three and seven percent. The net costs are equal to the difference between the cost of the revised monitoring requirements and the cost of the current monitoring requirements. Cost and hour burden to the system and the State are listed below in Exhibit 6-3. The cost of routine monitoring, triggered monitoring, waiver application and public notification are all included in the total system costs. Miscellaneous costs related to sending samples to be analyzed and sending public notification to customers are also included in the system cost.

**Exhibit 6-3**
**Unit Resources Required for Monitoring, Implementation, and Administration***

| System Size Category | < 10,000 people | | > 10,000 people | |
|---|---|---|---|---|
| **State Activity** | **Hours** | **Rate** | **Hours** | **Rate** |
| Review a waiver application | 8 | $41.47 | 8 | $41.47 |
| Record monitoring of a sample result | 1 | $41.47 | 1 | $41.47 |
| Issue a single violation letter | 4 | $41.47 | 4 | $41.47 |
| Review a single permit | 16 | $41.47 | 32 | $41.47 |
| | **<3,000 people** | | **>3,300 people** | |
| **System Activity** | **Hours** | **Rate** | **Hours** | **Rate** |
| Apply for a waiver | 16 | $15.03 | 16 | $29.03 |
| Take a sample | 1 | $15.03 | 1 | $29.03 |
| Report a sample | 1 | $15.03 | 1 | $29.03 |
| Prepare and Send Public Notification | 8 | $15.03 | 8 | $29.03 |

Source: *Information Collection Request for the Public Water System Supervision Program*.
*Estimates are provided in May 1999 dollars, updated from 1997 dollars using the CPI-U for all items.

States will also be required to spend time responding to systems that report MCL exceedances or systems that request a waiver (Exhibit 6-3). Hour burdens for States to review waiver applications, record monitoring of a sample, and issue a violation letter are the same for small and large systems. The number of hours required to review a single permit is twice as large for systems serving more than 10,000 people than for systems serving less than 10,000 people. The unit cost for all activities is consistent across all activities and size categories ($41.47 per hour) (EPA, 1997).

Exhibit 6-3 also shows that the number of hours required at the system level to perform the responsibilities related to monitoring is the same for systems serving fewer than 3,300 people and systems serving more than 3,300 people. However, the hourly rate for systems serving more than 3,300 people ($29.03) is almost double the rate for systems serving fewer than 3,300 people ($15.03).

During the first year of implementation all systems will incur costs related to routine monitoring. In addition, systems in violation will incur costs related to triggered quarterly monitoring. Under the revised rule, a percentage of the systems will have monitoring waivers in subsequent years when monitoring is otherwise required. Monitoring waivers are not granted under the existing rule; therefore, the number of systems required to conduct routine monitoring under the revised rule is less than that under the existing rule. For this reason, the annual net cost of monitoring between the revised rule and the existing rule may be negative, or less expensive, after the initial year of implementation. The inputs and methodology associated with this analysis are presented in detail in the *Information Collection Request for the Proposed Arsenic in Drinking Water Rule.*

### *Administrative Costs*

States and systems will incur administrative costs to implement the revised arsenic program under the Arsenic Rule. States and systems will need to allocate time for their staff to establish and maintain the programs necessary to comply with the revised arsenic standard and the new monitoring requirements. Exhibit 6-4(a) lists the one-time State activities involved in starting up the program following promulgation of the rule. For example, start-up activities may include developing and adopting State regulations that meet the new Federal arsenic requirements. Resources are estimated in terms of full-time equivalents (FTEs), which EPA has assumed to cost $64,480 per FTE, including overhead and fringe. Systems also have start-up costs for reviewing the rule and training operators. Exhibit 6-4(b) lists the one-time system start-up activities. The two primary activities that systems will perform to comply with the revised arsenic rule are reading and understanding the rule and operator training. For all systems the estimated time required to review the rule is eight hours. Systems serving fewer than 10,000 people require an estimated time of 16 hours to train operators; the estimated time for systems serving more than 10,000 people is 32 hours. The rate for all start-up activities for systems serving fewer than 10,000 people is $15.03 per hour and $29.03 per hour for systems serving more than 10,000 people.

**Exhibit 6-4(a)**
**Estimated One-Time State Resources Required for Initiation of the Arsenic Rule**

| Administrative Activity | Estimated State Resources (FTE) | Estimated Cost |
|---|---|---|
| **One Time Start-up Activities** | | |
| Regulation Adoption and Program Development | 0.2 | $12,900 |
| System Training and Technical Assistance (CWS) | 0.5 | $32,240 |
| System Training and Technical Assistance (NTNC) | 0.5 | $32,240 |
| Staff Training (CWS) | 0.12 | $7,740 |
| **National Total*** | 73.92 | $4,767,840 |

*National totals include estimates for all States, territories, and Tribes.

**Exhibit 6-4(b)**
**Estimated One-Time System Resources Required for Initiation of the Arsenic Rule**

| System Size Category | < 10,000 people | | > 10,000 people | |
|---|---|---|---|---|
| **One Time Start-up Activity** | **Hours** | **Rate** | **Hours** | **Rate** |
| Reading and Understanding Rule | 8 | \$15.03 | 8 | \$29.03 |
| Operator Training | 16 | \$15.03 | 32 | \$29.03 |

Source: *Information Collection Request for the Public Water System Supervision Program*.

### 6.2.4 Predicting Compliance Decisions (Compliance Decision Tree)

There is substantial variability in how systems will elect to comply with the Arsenic Rule. Choices of compliance method will vary depending on baseline source water arsenic concentrations, system size and location, types of treatment currently in place, and availability of alternative sources. In addition, the source water pH, total dissolved solids, sulfides, and other salts can change the effectiveness of technologies in removing arsenic.

The EA reflects this variability by predicting a range of compliance responses for different system types and sizes. The compliance decision tree specifies the percentage of systems in different categories that will choose specific compliance options, given the removal required by the MCL option and the baseline occurrence of arsenic in source water. For example, for a target MCL of 10 µg/L, the decision tree specifies the probability of different compliance choices for systems with different baseline influent concentrations (e.g., <10 µg/L, 10-20 µg/L, etc.), different sizes (e.g., population < or > 1,000), different sources (ground water or surface water), and different existing treatment facilities. The compliance choices are defined by a treatment technology and (where relevant) a waste disposal option, and/or pre-treatment technology.

EPA presented a draft of the compliance decision tree at an American Water Works Association (AWWA) technical workgroup meeting in February 1999 and made revisions based on the comments received at that meeting. The final compliance decision tree, as well as a discussion of the assumptions made during its development, is provided in Appendix A ("Cost Analysis Appendix") by system size and type.

### 6.2.5 Calculating Costs

Different methods were used to assess costs for three different categories of systems. A Monte-Carlo simulation model (SafeWaterXL) was used to estimate costs for community water systems, excluding the largest CWSs. A deterministic spreadsheet analysis was performed for NTNC water systems, while a separate case-by-case analysis were performed for the very large systems (serving more than one million people) that are expected to exceed one or more MCL options in the baseline. The costs for the three system categories were then summed to calculate total national costs.

The methodology for calculating the costs for each of these system categories is described separately below, beginning with a description of the SafeWaterXL model. In addition, a detailed description of the SafeWaterXL model is provided in Appendix C.

### *CWS Costs*

The national cost of compliance across CWSs (except those serving over one million people) was estimated using SafeWaterXL, a Monte-Carlo simulation model developed in Microsoft® Excel using the Crystal Ball© Monte-Carlo simulation add-in. SafeWaterXL forecasts a distribution of costs around the mean compliance cost expected for each system size category. The Monte-Carlo model provides the flexibility to incorporate as many data as are available, while maintaining uncertainty bounds to prevent any individual input from skewing the results. When sample data are not available as single point estimates, this technique is an invaluable tool.

Historically, most drinking water regulatory impact analyses used point estimates to describe the average system-level costs. By using SafeWaterXL, this analysis contains more detailed descriptions of system-level cost. SafeWater XL describes system-level costs in terms of a distribution. From the distribution, mean and median costs are available, as well as percentile costs.

#### *Model Structure*

SafeWaterXL determines regulatory compliance costs for individual systems and subsequently calculates a national average. To do so, each system is assigned a random concentration from an occurrence distribution. This system concentration is distributed across the number of sites of possible contamination for that system. The average number of sites per system is determined based on the distribution of system intake sites for the size category as estimated from the CWSS. However, SafeWaterXL does not assume that all sites are equally likely to exceed the MCL standard. The likelihood of contamination is determined on a site-by-site basis. The sum of the mean arsenic concentration of all sites within a system must equal the mean arsenic concentration of the system. Given this upper bound, each site is assigned a concentration based on the assumed relative standard deviation around the mean system occurrence.

The model then compares the concentration at each site to the revised MCL standard; no costs are incurred for those sites whose concentrations fall below the specified MCL. If the site is determined to be in violation of the MCL, then SafeWaterXL calculates the percent reduction in arsenic concentration required to reduce the site concentration to 80 percent of the MCL standard (this is a safety factor that includes a 20 percent excess removal to account for system over-design).[1] A treatment train is then assigned to the site based on a decision tree for the size and type of the system. The decision tree and the selected treatment train reflect the removal efficiencies of the chosen technology. For example, a technology is chosen based on matching

[1]No blending is assumed for the POU technologies.

the removal efficiencies and the percentage removal required at the site (SafeWaterXL identifies three categories of required removal: < 50 percent, 50-90 percent, > 90 percent).[2]

In this manner, capital and O&M costs are calculated at the site level for the selected treatment train. The system's cost of compliance is then determined by summing across the treating sites. For each system in SDWIS in which a violation is expected, a cost is calculated with this method, thereby creating an estimate of national compliance costs. Since household costs are also calculated for each system, a similar distribution of the cost of compliance at the household level is also created.

In order to develop more detailed results, the compliance decision tree is employed at the site level, so that only those sites requiring treatment would incur costs. The resulting total national compliance cost is expected to be a truer representation of the impact of the Arsenic Rule on systems. The sections below will describe the data needed to develop cost estimates for the entire universe of systems affected by the Arsenic Rule. After the discussion of data requirements, the SafeWaterXL model is described as it is used for this rule.

### *Model Inputs*

*Number of Systems:* The universe of public and private ground and surface water systems is taken from the Safe Drinking Water Information System (SDWIS), EPA's national regulatory database for the drinking water program. Based on data extracted in December 1998, a total of 54,352 CWSs and 20,255 NTNCs are subject to the new requirements under the Arsenic Rule. It is necessary to compile this data by system size, water source, and ownership, as costs may vary by these characteristics. SafeWaterXL calculates costs for public and private systems (the latter also includes "other" or "ancillary" systems), and surface and ground water systems. A summary table of this breakdown is provided in Chapter 4, "Baseline Analysis."

*Entry Points per System:* SafeWaterXL estimates each system's cost of compliance at the treatment site level. This modeling approach is used because a system may include more than one treatment site. Entry points are used as a proxy for potential or actual points of treatment. For example, a given water system may have three entry points: one entry point that currently treats, while two may not have treatment in place. Data on the distribution of the number of system entry points for each size category and type were extracted from the Community Water Supply Survey (CWSS). Linear interpolation was used to estimate values for the number of sites in cases where there were no survey data (see Chapter 4, "Baseline Analysis"). SafeWater XL uses this modified distribution of entry points for each system size and source water category.

*Population Served by System:* A system's size is determined by the number of people served by that system. These numbers were extracted from the SDWIS database (see Chapter 4, "Baseline Analysis"). Systems are grouped into eight categories to help identify systems with related characteristics so that any data or resources may be pooled during analysis.

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[2]The > 90 percent removal efficiency category is not relevant under the revised MCL of 10 µg/L.

SafeWaterXL recognizes the following size categories:

- < 100
- 101-500
- 501-1000
- 1,001-3,300
- 3,301-10,000
- 10,001-50,000
- 50,001-100,000
- 100,001-1,000,000.

*Flow Rate Parameters:* A system's size is further defined by its flow, which is calculated as a power law function of the population served. These functions were derived by EPA, and their derivation can be found in the Model Systems report (EPA, 1999b). The equation form is shown below.

$$Average\ \ Flow \quad a_A \cdot (Population)^{b_A}$$

$$Design\ \ Flow \quad \max \begin{cases} 2 \cdot Average\ \ Flow \\ a_D \cdot (Population)^{b_D} \end{cases}$$

| | | | |
|---|---|---|---|
| *Where:* | $a_A$, $b_A$, $a_D$, $b_D$ | = | the regression parameters derived for flow vs. population |
| | Population | = | the population served by the appropriate system type and primary source. |

The regression parameters used in the cost model are provided in Exhibit 6-5. Values are provided for design and average flow for public and private ground water and surface water supplies. SafeWaterXL divides the resulting system design flow and average daily flow (kgpd) equally among all entry points. Treatment costs are calculated only at the sites that exceed the MCL and only for the minimum portion of flow that must be treated in order to achieve the new concentration standard, a process referred to as "blending."

**Exhibit 6-5**
**Flow Regression Parameters**
**by Water Source and System Ownership**

| | Average Flow | | Design Flow | |
|---|---|---|---|---|
| | a | b | a | b |
| **Ground Water** | | | | |
| Public | 0.08558 | 1.05840 | 0.54992 | 0.95538 |
| Private | 0.06670 | 1.06280 | 0.41682 | 0.96078 |
| Public-Purch | 0.04692 | 1.10190 | 0.31910 | 0.99460 |
| Private-Purch | 0.05004 | 1.08340 | 0.32150 | 0.97940 |
| **Surface Water** | | | | |
| Public | 0.14004 | 0.99703 | 0.59028 | 0.94573 |
| Private | 0.09036 | 1.03340 | 0.35674 | 0.96188 |
| Public-Purch | 0.04692 | 1.11020 | 0.20920 | 1.04520 |
| Private-Purch | 0.05004 | 1.08340 | 0.20580 | 1.00840 |

*Average Consumption per Household:* Household costs depend on the average annual consumption per residential connection. These mean estimates are provided in Chapter 4, "Baseline Analysis." Depending on the system's characteristics, SafeWaterXL multiplies the appropriate mean consumption per year (kgal) with the system's computed cost per thousand gallons to arrive at the average annual cost of compliance per household for a community water system.

*Mean System Occurrence:* Arsenic occurrence data are based on EPA's *Arsenic Occurrence in Public Drinking Water Supplies* report (EPA, 2000) and are represented by a lognormal distribution. Baseline occurrence is distinguished between ground and surface water systems and is provided in Chapter 4 ("Baseline Analysis") as a lognormal distribution. The distribution is truncated at 50 µg/L, the current arsenic standard, because it is assumed that all arsenic reductions attributable to the new standard start at the previous standard (i.e., all systems are currently in compliance with the current standard).

For use in the SafeWaterXL model, EPA performed a regression analysis that weighted actual occurrence data by National Arsenic Occurrence Survey region. The analysis resulted in the distribution of ground and surface water systems exceeding arsenic concentrations greater than 3, 5, 10, and 20 µg/L as presented in Exhibit 6-6.

**Exhibit 6-6**
**Arsenic Occurrence Distribution**
**(Log-Normal Regression Results)**

| Source | % of systems greater than (µg/L) | | | |
|---|---|---|---|---|
| | 3 | 5 | 10 | 20 |
| GW | 19.7 | 12.0 | 5.3 | 2.0 |
| SW | 5.6 | 3.0 | 1.12 | 0.37 |

For ground water systems, the percentages displayed in Exhibit 6-6 above were based on a lognormal distribution with a mean of -0.25071 and a log standard deviation of 1.58257. Among surface water systems, the percentages were based on a lognormal distribution with mean -1.67805 and a log standard deviation of 1.7425.

*Relative Intra-System Standard Deviation of Arsenic Concentrations:* The relative intra-system standard deviation of the site concentrations within a system is calculated using data from a 25 State arsenic occurrence study (EPA, 2000b). SafeWaterXL uses a default value of 0.64. This standard deviation is applied to the mean system concentration to generate individual entry points concentrations within the system.

*Compliance Decision Trees:* The decision trees represent EPA's best estimate of the treatment train technologies system operators will choose to achieve a particular percentage reduction in arsenic concentration. Decision trees are specific to the system's size categories and source water. These are provided in Appendix A.

*Removal Efficiencies, Treatment Target, and Blending:* Each treatment train is associated with an arsenic removal efficiency that is assumed to be constant across system types. The removal efficiencies for the 13 treatment trains available under the Arsenic Rule were presented in Exhibit 6-1. SafeWaterXL employs these efficiencies, using the blending principle, to determine the amount of flow that requires treatment in order for the entry point to meet the treatment target. Blending uses the entry point concentration and treatment train removal efficiency to determine the fraction of flow required to obtain the treatment target. The treatment target is set at 80 percent of the MCL and represents the level to which systems will be over-designed to ensure compliance with the MCL.

SafeWaterXL employs the blending principle through the following equation at the entry point level:

$$Fraction\ of\ flow\ treated = \frac{\left(\frac{TreatmentTarget}{SiteConcentration}\ \ 1\right) \times (\%\ Site\ Flow)}{\%\ Removal\ Efficiency}$$

| | | | |
|---|---|---|---|
| *Where*: | Treatment Target | = | the target MCL with 80 percent safety factor |
| | Site Concentration | = | arsenic concentration at the site |
| | % Removal Efficiency | = | percent removal efficiency of treatment train chosen |
| | % Site Flow | = | percent of total flow at that site. |

Note that the blending technique is used only for those systems expected to require less than 90 percent removal in order to achieve compliance with the new MCL standard. In addition, SafeWaterXL does not employ this technique for those systems that select treatment trains involving POU devices.

*Equipment Life, Discount Rate and Capitalization Rates:* System and State implementation costs are tracked for a 20-year period. This time frame was selected because water systems often finance their capital improvements over a 20-year period. This period of analysis may result in an overestimate of annualized costs because many types of equipment last longer than 20 years.

Two different adjustments are made in this analysis in order to render future costs comparable with current costs, reflecting the fact that a cost outlay today is a greater burden than an equivalent cost outlay sometime in the future. The first adjustment is made when the cost estimates that are derived are being used as an input in benefit-cost analysis. In this instance, costs are annualized using a social discount rate so that the costs of each regulatory option can be directly compared with the annual benefits of the corresponding regulatory option. Annualization is the same process as calculating a mortgage payment; the result is a constant annual cost to compare with constant annual benefits.

The choice of an appropriate social discount rate has been, and continues to be, a very complex and controversial issue among economists and policy makers alike. Therefore, the Agency compares costs and benefits using two alternative social discount rates, in part to determine the effect the choice of social discount rate has on the analysis. The annualized costs of each regulatory option are calculated and displayed using both a seven percent discount rate, required by the Office of Management and Budget (OMB), and a three percent discount rate, which the Agency believes more closely approximates the true social discount rate.

The second adjustment is made when the cost estimates that are derived are being used as an input into an economic impact analysis, such as an affordability analysis or an analysis of system-level costs or household-level costs. In these cases, rather than use a social discount rate when determining the annualized costs, an actual cost-of-capital rate is used instead. This rate should reflect the true after-tax cost of capital water systems face, net of any government grants or subsidies. The cost of capital rates used in this analysis are shown in Exhibit 6-7.

**Exhibit 6-7**
**Summary of Recommended Cost of Capital Estimates**
**(as of March 1998)**

| Ownership Type | Size Category | Estimated After-Tax Cost of Capital |
|---|---|---|
| **NON-SMALL** | | |
| Investor owned | 10,001-50,000 | 5.26% |
| | >50,000 | 5.94% |
| Publicly owned | 10,001-50,000 | 5.26% |
| | >50,000 | 5.23% |
| **SMALL** | | |
| Private | 1-500 | 4.17% |
| | 501-10,000 | 4.17% |
| Public | 1-500 | 5.10% |
| | 501-10,000 | 5.20% |

Source: *Development of Cost of Capital Estimates for Public Water Systems* (Draft Final Report). Prepared for U.S. EPA by Apogee/Hagler Bailly, Inc. under subcontract to International Consultants, Inc. June 1998.

### *NTNC Costs*

The cost for NTNCs is estimated using the mean values for system population for each system service category, as shown in Chapter 4. As with the CWSs, cost is annualized over a 20-year period, at discount rates of three and seven percent. Assumptions regarding the monitoring schedule correspond to the monitoring schedule for small ground water systems, including hour burdens and hourly labor rates. The remaining assumptions required for determining cost are described below.

*Number of Systems, Sites per System, and the Population Served:* The non-transient non-community water supply treatment decisions are modeled similarly to those for community water supplies. The number of non-transient non-community water supplies is taken from EPA's SDWIS, and include those systems as described in *Geometries and Characteristics of Public Water Supplies* (see Exhibit 6-8). For each service area type, the report lists the number of systems and the average population served. The non-food manufacturing service area combines 16 categories that were listed separately in the report. For this service area, the number of systems is the sum of the 16 categories, and the average population served is the mean of the individual populations weighted by the number of corresponding systems. Each of these systems has only a single site.

*System Flows and Treatment Choices*: For each service area, both design and average flows have been derived by the Agency using literature values and best engineering judgment. There are no primary survey data for non-community water systems that are equivalent to the CWSS-provided data for the community water system flow calculations (Smith, 1999). The design flow is used to calculate the treatment capital costs, while the average flow is used in the operating and maintenance cost equations.

For the non-transient non-community water supplies, one of two treatment technologies was chosen based on the level of the design flow. For service areas with design flows less than 2,000 gallons per day, POE activated alumina is used; for all others, centralized activated alumina is chosen (Kapadia, 1999a). Both treatment trains include pre-oxidation, and the centralized activated alumina also includes non-hazardous landfilling of the spent media (Kapadia, 1999a).

*Mean Arsenic Occurrence:* The arsenic occurrence distribution used for ground water community water supplies is also used for non-transient non-community water supplies. The number of systems exceeding the MCL for each service area was calculated from the percent of the distribution between the MCL and 100 µg/L. For this analysis, 100 µg/L was chosen as the upper concentration limit because the non-transient non-community supplies have not been previously regulated, and occurrence values above the 50 µg/L regulatory level are possible.

*Removal Efficiencies, Treatment Target, and Blending*: The removal efficiency associated with both POE activated alumina and centralized activated alumina is 95 percent. The NTNC model uses this efficiency with the blending principle in the case of centralized activated alumina to determine the amount of flow that requires treatment in order for the site to meet the treatment target. The treatment target is set at 80 percent of the MCL and represents the level to which systems will be over-designed to ensure compliance with the MCL. For POE activated alumina systems, all the flow is treated, which may result in finished water below the treatment target concentration.

*Equipment Life, Discount Rate, and Capitalization Rates:* As with the community water supplies, the system implementation costs are tracked for a 20-year period. For the two service areas using POE activated alumina, construction and forest service, the equipment is assumed to last ten years with purchases in year zero and year ten. For the centralized activated alumina the equipment is estimated to last 20 years. The cost estimates are annualized in the same manner as those for the community water supplies.

## Exhibit 6-8
## Non-Transient Non-Community System Characteristics and Compliance Decision Tree

| Service Area Type | SYSTEM CHARACTERISTICS | | | | DECISION TREE | |
|---|---|---|---|---|---|---|
| | Number of Systems | Average Population Served Per System | Design Flow (mgd) | Average Daily Flow (mgd) | Activated Alumina Point of Entry | Centralized Activated Alumina |
| Daycare Centers | 809 | 76 | 0.0051 | 0.0011 | | ↵ |
| Highway Rest Areas | 15 | 407 | 0.0089 | 0.0020 | | ↵ |
| Hotels/Motels | 351 | 133 | 0.0189 | 0.0045 | | ↵ |
| Interstate Carriers | 287 | 123 | 0.0029 | 0.0006 | | ↵ |
| Medical Facilities | 367 | 393 | 0.1166 | 0.0339 | | ↵ |
| Mobile Home Parks | 104 | 185 | 0.0262 | 0.0065 | | ↵ |
| Restaurants | 418 | 370 | 0.0039 | 0.0008 | | ↵ |
| Schools | 8414 | 358 | 0.0333 | 0.0085 | | ↵ |
| Service Stations | 53 | 230 | 0.0051 | 0.0011 | | ↵ |
| Summer Camps | 46 | 146 | 0.0218 | 0.0053 | | ↵ |
| Water Wholesalers | 266 | 173 | 0.1637 | 0.0494 | | ↵ |
| Agricultural Products/Services | 368 | 76 | 0.0199 | 0.0048 | | ↵ |
| Airparks | 101 | 60 | 0.0026 | 0.0005 | | ↵ |
| Construction | 99 | 53 | 0.0009 | 0.0002 | ↵ | |
| Churches | 230 | 50 | 0.0053 | 0.0011 | | ↵ |
| Campgrounds/RV Parks | 123 | 160 | 0.0214 | 0.0052 | | ↵ |
| Fire Departments | 41 | 98 | 0.0186 | 0.0045 | | ↵ |
| Federal Parks | 20 | 39 | 0.0065 | 0.0014 | | ↵ |
| Forest Service | 107 | 42 | 0.0014 | 0.0002 | ↵ | |
| Golf and Country Clubs | 116 | 101 | 0.0118 | 0.0027 | | ↵ |
| Landfills | 78 | 44 | 0.0053 | 0.0011 | | ↵ |
| Mining | 119 | 113 | 0.0123 | 0.0028 | | ↵ |
| Amusement Parks | 159 | 418 | 0.0171 | 0.0041 | | ↵ |
| Military Bases | 95 | 395 | 0.0695 | 0.0192 | | ↵ |
| Migrant Labor Camps | 33 | 63 | 0.0102 | 0.0023 | | ↵ |
| Misc. Recreation Services | 259 | 87 | 0.0025 | 0.0005 | | ↵ |
| Nursing Homes | 130 | 107 | 0.0411 | 0.0107 | | ↵ |
| Office Parks | 950 | 136 | 0.0077 | 0.0017 | | ↵ |
| Prisons | 67 | 1820 | 0.5322 | 0.1820 | | ↵ |
| Retailers (Non-food related) | 695 | 174 | 0.0038 | 0.0008 | | ↵ |
| Retailers (Food related) | 142 | 322 | 0.0058 | 0.0012 | | ↵ |
| State Parks | 83 | 165 | 0.0048 | 0.0010 | | ↵ |
| Non-Water Utilities | 497 | 170 | 0.0133 | 0.0031 | | ↵ |
| Manufacturing: Food | 768 | 372 | 0.0454 | 0.0120 | | ↵ |
| Manufacturing: Non-Food | 3845 | 168 | 0.0157 | 0.0038 | | ↵ |
| **TOTAL** | **20,255** | | | | | |

Source: Geometries and Characteristics of Public Water Systems, EPA, May 1999.

### *Very Large CWS Costs*

EPA evaluated the regulatory costs of compliance for very large systems that will be subject to the new Arsenic Rule. The nation's 25 largest drinking water systems (i.e., those serving one million people or more) supply approximately 38 million people and generally account for about 15 to 20 percent of all compliance-related costs. Accurately determining these costs for future regulations is critical. As a result, EPA has developed compliance cost estimates for the arsenic and radon regulations for each individual system that serves more than one million persons. These cost estimates help EPA to more accurately assess the cost impacts and benefits of the Arsenic Rule. The estimates also help the Agency identify lower cost regulatory options and better understand current water systems' capabilities and constraints.

The system costs were calculated for the 24 public water systems that serve a retail population of more than one million persons and one public water system that serves a wholesale population of 16 million persons. The following are distinguishing characteristics of these very large systems:

(1) A large number of entry points from diverse sources;
(2) Mixed sources (i.e., ground and surface water);
(3) Occurrence not conducive to mathematical modeling;
(4) Significant levels of wholesaling;
(5) Sophisticated in-place treatment;
(6) Retrofit costs dramatically influenced by site-specific factors; and
(7) Large amounts of waste management and disposal, which can contribute substantial costs.

Generic models cannot incorporate all of these considerations; therefore, in-depth characterizations and cost analyses were developed using several existing databases and surveys.

The profile for each system contains information such as design and average daily flows, treatment facility diagrams, chemical feed processes, water quality parameters, system layouts, and intake and aquifer locations. System and treatment data were obtained from the following sources:

(1) The Information Collection Rule (1997);
(2) The Community Water Supply Survey (1995);
(3) The Association of Metropolitan Water Agencies Survey (1998);
(4) The Safe Drinking Water Information System (SDWIS); and
(5) The American Water Works Association WATERSTATS Survey (1997).

While these sources contained much of the information necessary to perform cost analyses, the Agency was still missing some of the detailed arsenic occurrence data in these large water systems. Where major gaps existed, especially in ground water systems, occurrence data obtained from the States of Texas, California, and Arizona; the Metropolitan Water District of Southern California Arsenic Study (1993); the National Inorganic and Radionuclides Study (EPA, 1984); and utility data were used. Based on data from the studies, detailed costs estimates were derived for each of the very large water systems.

Cost estimates were generated for each system at several MCL options. The total capital costs and operational and maintenance (O&M) costs were calculated using the profile information gathered on each system, conceptual designs (i.e., vendor estimates and *RS Means*), and modified EPA cost models (i.e., Water and WaterCost models). The models were modified based on the general cost assumptions developed in the Phase I Water Treatment Cost Upgrades (EPA, 1998c).

EPA consulted with the system operators to determine how each system would comply with various MCL options and to assess the costs of their compliance responses. Preliminary cost estimates were sent to all of the systems for their review. Approximately 30 percent of the systems responded by submitting revised estimates and/or detailed arsenic occurrence data. Based on the information received, EPA revised the cost estimates for those systems. EPA developed cost estimates for three very large systems that are expected to have arsenic levels above the revised MCL. These systems are located in Houston, TX, Phoenix, AZ, and Los Angeles, CA. This analysis resulted in the estimated costs listed in Exhibit 6-9.

**Exhibit 6-9**
**Annual Treatment Costs for Three Large CWSs Expected to Undertake or Modify Treatment Practice to Comply with the Arsenic Rule**
**($ millions)**

| Large CWSs | Population Served | MCL (μg/L) | | | |
|---|---|---|---|---|---|
| | | 3 | 5 | 10 | 20 |
| **Phoenix, AZ** | 1,360,751 | | | | |
| Annual cost (3%) | | $ 11.6 | $ 5.5 | $ 2.2 | $ 0.0 |
| Annual cost (7%) | | $ 13.2 | $ 6.3 | $ 2.5 | $ 0.0 |
| **Houston, TX** | 2,216,830 | | | | |
| Annual cost (3%) | | $ 15.0 | $ 2.7 | $ 0.9 | $ 0.5 |
| Annual cost (7%) | | $ 16.0 | $ 2.9 | $ 1.0 | $ 0.5 |
| **Los Angeles, CA** | 3,700,000 | | | | |
| Annual cost (3%) | | $ 1.8 | $ 1.8 | $ - | $ - |
| Annual cost (7%) | | $ 1.8 | $ 1.8 | $ - | $ - |

* Exhibit updated on December 28, 2000 to reflect minor changes in cost estimates which have not been incorporated into subsequent exhibits. The impact is a $0.07 million overestimation of national costs (less than 0.5% of total national costs)

## 6.3 Results

This section presents the results of the national cost analysis. Unless otherwise specified, national costs are presented in May 1999 dollars throughout this chapter.

### 6.3.1 National Costs

Exhibit 6-10 shows the total national cost breakdown across the four MCL options for the Arsenic Rule. The system and state cost components of the total annual compliance costs are presented at discount rates of three and seven percent. Expected system costs include treatment costs, monitoring costs, and administrative costs of compliance. State costs include monitoring and administrative costs of implementation. These cost components are also displayed.

CWS costs are approximately $668.0 million at the 3 μg/L MCL, $396.0 million at the 5 μg/L MCL, $171.4 million at the 10 μg/L MCL, and $62.4 million at the 20 μg/L MCL (at a three percent discount rate). State costs associated with CWS administration, at a three percent discount rate, are approximately $1.4 million at the 3 μg/L MCL, $1.1 million at the 5 μg/L MCL, $0.9 million at the 10 μg/L MCL, and $0.7 million at the 20 μg/L MCL.

The cost to NTNCs ranges from $28 million at the 3 μg/L MCL, $16 million at the 5 μg/L MCL, $7.9 million at the 10 μg/L MCL, and $3.5 million at the 20 μg/L MCL (at a three percent discount rate). State costs associated with NTNC administration, at a three percent discount rate, are approximately $0.1 million for each MCL.

**Exhibit 6-10**
**Annual National System and State Compliance Costs**
**($ millions)**

| | CWS | | NTNC | | TOTAL | |
|---|---|---|---|---|---|---|
| **Discount Rate** | **3%** | **7%** | **3%** | **7%** | **3%** | **7%** |
| **MCL = 3 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $665.9 | $756.5 | $27.2 | $29.6 | $693.1 | $786.0 |
| Monitoring/ Administrative | $2.2 | $3.0 | $1.0 | $1.4 | $3.2 | $4.4 |
| State Costs | $1.4 | $1.6 | $0.1 | $0.2 | $1.5 | $1.7 |
| TOTAL COST | $669.4 | $761.0 | $28.3 | $31.1 | $697.8 | $792.1 |
| **MCL =5 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $394.4 | $448.5 | $16.3 | $17.6 | $410.6 | $466.1 |
| Monitoring/ Administrative | $2.0 | $2.8 | $1.0 | $1.3 | $2.9 | $4.1 |
| State Costs | $1.1 | $1.3 | $0.1 | $0.2 | $1.2 | $1.4 |
| TOTAL COST | $397.5 | $452.5 | $17.3 | $19.1 | $414.8 | $471.7 |
| **MCL = 10 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $169.6 | $193.0 | $7.0 | $7.6 | $176.7 | $200.6 |
| Monitoring/ Administrative | $1.8 | $2.5 | $0.9 | $1.3 | $2.7 | $3.8 |
| State Costs | $0.9 | $1.0 | $0.1 | $0.2 | $1.0 | $1.2 |
| TOTAL COST | $172.3 | $196.6 | $8.1 | $9.1 | $180.4 | $205.6 |
| **MCL =20 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $60.7 | $69.0 | $2.6 | $2.8 | $63.3 | $71.8 |
| Monitoring/ Administrative | $1.7 | $2.4 | $0.9 | $1.3 | $2.6 | $3.7 |
| State Costs | $0.7 | $0.8 | $0.1 | $0.2 | $0.9 | $1.0 |
| TOTAL COST | $63.2 | $72.3 | $3.6 | $4.2 | $66.8 | $76.5 |

### 6.3.2 Costs by System Size and Type

This section presents the overall national compliance costs for water systems and for states at three and seven percent discount rates. Exhibit 6-11 shows a detailed breakout of national treatment costs by CWS size category for the various MCLs.

Exhibits 6-12 through 6-15 show the national treatment costs for NTNC systems by NTNC system service type for each MCL.

**Exhibit 6-11**
**Total Annual CWS Treatment Costs Across MCL Options by System Size ($ millions)**

| System Size | MCL (μg/L) | | | |
|---|---|---|---|---|
| | 3 | 5 | 10 | 20 |
| **3% Discount Rate** | | | | |
| <100 | $ 19.8 | $ 12.3 | $ 5.5 | $ 2.1 |
| 101-500 | $ 42.6 | $ 25.7 | $ 11.5 | $ 4.3 |
| 501-1,000 | $ 25.5 | $ 15.2 | $ 6.7 | $ 2.5 |
| 1001-3300 | $ 83.8 | $ 50.5 | $ 22.0 | $ 8.1 |
| 3,301-10,000 | $ 95.1 | $ 55.9 | $ 24.3 | $ 9.0 |
| 10,001-50,000 | $ 179.1 | $ 108.7 | $ 47.0 | $ 16.7 |
| 50,001-100,000 | $ 66.0 | $ 39.0 | $ 16.7 | $ 6.2 |
| 100,001-1,000,000 | $ 124.3 | $ 75.2 | $ 32.3 | $ 11.3 |
| >1,000,000 | $ 29.7 | $ 11.8 | $ 3.8 | $ 0.6 |
| Total | $ 665.9 | $ 394.4 | $ 169.6 | $ 60.7 |
| **7% Discount Rate** | | | | |
| <100 | $ 21.3 | $ 13.2 | $ 5.9 | $ 2.3 |
| 101-500 | $ 46.4 | $ 28.0 | $ 12.5 | $ 4.6 |
| 501-1,000 | $ 28.9 | $ 17.2 | $ 7.6 | $ 2.8 |
| 1001-3300 | $ 97.4 | $ 58.8 | $ 25.6 | $ 9.4 |
| 3,301-10,000 | $ 109.2 | $ 64.2 | $ 27.9 | $ 10.3 |
| 10,001-50,000 | $ 205.4 | $ 124.7 | $ 53.9 | $ 19.2 |
| 50,001-100,000 | $ 75.0 | $ 44.3 | $ 19.0 | $ 7.0 |
| 100,001-1,000,000 | $ 140.5 | $ 85.0 | $ 36.5 | $ 12.7 |
| >1,000,000 | $ 32.5 | $ 13.0 | $ 4.3 | $ 0.6 |
| Total | $ 756.5 | $ 448.5 | $ 193.0 | $ 69.0 |

**Exhibit 6-12**
**Total Annual NTNC Treatment Costs at MCL 3 μg/L by System Service Type**
**(3% Discount Rate)**

| Service Area Type | # of Systems Above the MCL | Average Population Served Per System | Average Annual System Cost | Annual National Costs |
|---|---|---|---|---|
| Daycare Centers | 159 | 76 | $5,217 | $831,099 |
| Highway Rest Areas | 3 | 407 | $5,466 | $16,144 |
| Hotels/Motels | 69 | 133 | $6,153 | $425,252 |
| Interstate Carriers | 57 | 123 | $5,074 | $286,723 |
| Medical Facilities | 72 | 393 | $13,540 | $978,452 |
| Mobile Home Parks | 20 | 185 | $6,666 | $136,496 |
| Restaurants | 82 | 370 | $5,140 | $423,058 |
| Schools | 1,657 | 358 | $7,177 | $11,890,922 |
| Service Stations | 10 | 230 | $5,217 | $54,445 |
| Summer Camps | 9 | 146 | $6,353 | $57,538 |
| Water Wholesalers | 52 | 173 | $16,456 | $861,907 |
| Agricultural Products/Services | 72 | 76 | $6,221 | $450,734 |
| Airparks | 20 | 60 | $5,059 | $100,600 |
| Construction | 19 | 53 | $4,733 | $92,258 |
| Churches | 45 | 50 | $5,229 | $236,789 |
| Campgrounds/RV Parks | 24 | 160 | $6,329 | $153,287 |
| Fire Departments | 8 | 98 | $6,132 | $49,505 |
| Federal Parks | 4 | 39 | $5,309 | $20,908 |
| Forest Service | 21 | 42 | $4,783 | $100,771 |
| Golf and Country Clubs | 23 | 101 | $5,661 | $129,308 |
| Landfills | 15 | 44 | $5,226 | $80,268 |
| Mining | 23 | 113 | $5,697 | $133,490 |
| Amusement Parks | 31 | 418 | $6,025 | $188,625 |
| Military Bases | 19 | 395 | $9,883 | $184,863 |
| Migrant Labor Camps | 6 | 63 | $5,554 | $36,090 |
| Misc. Recreation Services | 51 | 87 | $5,050 | $257,531 |
| Nursing Homes | 26 | 107 | $7,748 | $198,316 |
| Office Parks | 187 | 136 | $5,386 | $1,007,456 |
| Prisons | 13 | 1,820 | $45,861 | $605,012 |
| Retailers (Non-food related) | 137 | 174 | $5,133 | $702,366 |
| Retailers (Food related) | 28 | 322 | $5,261 | $147,101 |
| State Parks | 16 | 165 | $5,199 | $84,966 |
| Non-Water Utilities | 98 | 170 | $5,763 | $563,970 |
| Manufacturing: Food | 151 | 372 | $8,066 | $1,219,753 |
| Manufacturing: Non-Food | 757 | 168 | $5,944 | $4,500,232 |
| **TOTAL** | **3,988** | | | **$27,206,235** |

## Exhibit 6-13
## Total Annual NTNC Treatment Costs at MCL 5 µg/L by System Service Type (3% Discount Rate)

| Service Area Type | # of Systems Above the MCL | Average Population Served Per System | Average Annual System Cost | Annual National Costs |
|---|---|---|---|---|
| Daycare Centers | 97 | 76 | $5,196 | $504,051 |
| Highway Rest Areas | 2 | 407 | $5,428 | $9,763 |
| Hotels/Motels | 42 | 133 | $6,069 | $255,418 |
| Interstate Carriers | 34 | 123 | $5,062 | $174,207 |
| Medical Facilities | 44 | 393 | $12,959 | $570,242 |
| Mobile Home Parks | 12 | 185 | $6,547 | $81,640 |
| Restaurants | 50 | 370 | $5,124 | $256,824 |
| Schools | 1,009 | 358 | $7,024 | $7,086,564 |
| Service Stations | 6 | 230 | $5,196 | $33,020 |
| Summer Camps | 6 | 146 | $6,255 | $34,500 |
| Water Wholesalers | 32 | 173 | $15,679 | $500,052 |
| Agricultural Products/Services | 44 | 76 | $6,132 | $270,563 |
| Airparks | 12 | 60 | $5,048 | $61,134 |
| Construction | 12 | 53 | $4,733 | $56,180 |
| Churches | 28 | 50 | $5,207 | $143,590 |
| Campgrounds/RV Parks | 15 | 160 | $6,233 | $91,929 |
| Fire Departments | 5 | 98 | $6,050 | $29,740 |
| Federal Parks | 2 | 39 | $5,282 | $12,667 |
| Forest Service | 13 | 42 | $4,783 | $61,364 |
| Golf and Country Clubs | 14 | 101 | $5,610 | $78,033 |
| Landfills | 9 | 44 | $5,205 | $48,676 |
| Mining | 14 | 113 | $5,644 | $80,527 |
| Amusement Parks | 19 | 418 | $5,950 | $113,424 |
| Military Bases | 11 | 395 | $9,548 | $108,754 |
| Migrant Labor Camps | 4 | 63 | $5,511 | $21,804 |
| Misc. Recreation Services | 31 | 87 | $5,040 | $156,519 |
| Nursing Homes | 16 | 107 | $7,556 | $117,780 |
| Office Parks | 114 | 136 | $5,354 | $609,795 |
| Prisons | 8 | 1,820 | $43,104 | $346,270 |
| Retailers (Non-food related) | 83 | 174 | $5,117 | $426,424 |
| Retailers (Food related) | 17 | 322 | $5,237 | $89,168 |
| State Parks | 10 | 165 | $5,179 | $51,542 |
| Non-Water Utilities | 60 | 170 | $5,705 | $339,983 |
| Manufacturing: Food | 92 | 372 | $7,853 | $723,165 |
| Manufacturing: Non-Food | 461 | 168 | $5,874 | $2,708,131 |
| **TOTAL** | **2,429** | | | **$16,253,442** |

**Exhibit 6-14**
**Total Annual NTNC Treatment Costs at MCL 10 µg/L by System Service Type (3% Discount Rate)**

| Service Area Type | # of Systems Above the MCL | Average Population Served Per System | Average Annual System Cost | Annual National Costs |
|---|---|---|---|---|
| Daycare Centers | 43 | 76 | $5,168 | $222,846 |
| Highway Rest Areas | 1 | 407 | $5,377 | $4,299 |
| Hotels/Motels | 19 | 133 | $5,956 | $111,420 |
| Interstate Carriers | 15 | 123 | $5,047 | $77,207 |
| Medical Facilities | 20 | 393 | $12,174 | $238,133 |
| Mobile Home Parks | 6 | 185 | $6,387 | $35,405 |
| Restaurants | 22 | 370 | $5,103 | $113,692 |
| Schools | 448 | 358 | $6,818 | $3,057,578 |
| Service Stations | 3 | 230 | $5,168 | $14,599 |
| Summer Camps | 2 | 146 | $6,124 | $15,014 |
| Water Wholesalers | 14 | 173 | $14,628 | $207,398 |
| Agricultural Products/Services | 20 | 76 | $6,012 | $117,930 |
| Airparks | 5 | 60 | $5,034 | $27,101 |
| Construction | 5 | 53 | $4,733 | $24,974 |
| Churches | 12 | 50 | $5,177 | $63,471 |
| Campgrounds/RV Parks | 7 | 160 | $6,104 | $40,017 |
| Fire Departments | 2 | 98 | $5,938 | $12,977 |
| Federal Parks | 1 | 39 | $5,245 | $5,592 |
| Forest Service | 6 | 42 | $4,783 | $27,278 |
| Golf and Country Clubs | 6 | 101 | $5,542 | $34,263 |
| Landfills | 4 | 44 | $5,176 | $21,517 |
| Mining | 6 | 113 | $5,572 | $35,340 |
| Amusement Parks | 8 | 418 | $5,848 | $49,558 |
| Military Bases | 5 | 395 | $9,095 | $46,053 |
| Migrant Labor Camps | 2 | 63 | $5,452 | $9,589 |
| Misc. Recreation Services | 14 | 87 | $5,027 | $69,397 |
| Nursing Homes | 7 | 107 | $7,298 | $50,567 |
| Office Parks | 51 | 136 | $5,310 | $268,864 |
| Prisons | 4 | 1,820 | $39,380 | $140,629 |
| Retailers (Non-food related) | 37 | 174 | $5,097 | $188,796 |
| Retailers (Food related) | 8 | 322 | $5,205 | $39,394 |
| State Parks | 4 | 165 | $5,153 | $22,794 |
| Non-Water Utilities | 26 | 170 | $5,627 | $149,069 |
| Manufacturing: Food | 41 | 372 | $7,566 | $309,707 |
| Manufacturing: Non-Food | 205 | 168 | $5,780 | $1,184,505 |
| **TOTAL** | **1,080** | | | **$7,036,973** |

**Exhibit 6-15**
**Total Annual NTNC Treatment Costs at MCL 20 µg/L by System Service Type**
**(3% Discount Rate)**

| Service Area Type | # of Systems Above the MCL | Average Population Served Per System | Average Annual System Cost | Annual National Costs |
|---|---|---|---|---|
| Daycare Centers | 16 | 76 | $5,135 | $83,500 |
| Highway Rest Areas | 0 | 407 | $5,318 | $1,603 |
| Hotels/Motels | 7 | 133 | $5,823 | $41,085 |
| Interstate Carriers | 6 | 123 | $5,029 | $29,013 |
| Medical Facilities | 7 | 393 | $11,259 | $83,054 |
| Mobile Home Parks | 2 | 185 | $6,201 | $12,962 |
| Restaurants | 8 | 370 | $5,078 | $42,666 |
| Schools | 169 | 358 | $6,577 | $1,112,336 |
| Service Stations | 1 | 230 | $5,135 | $5,470 |
| Summer Camps | 1 | 146 | $5,970 | $5,520 |
| Water Wholesalers | 5 | 173 | $14,025 | $74,986 |
| Agricultural Products/Services | 7 | 76 | $5,873 | $43,442 |
| Airparks | 2 | 60 | $5,018 | $10,187 |
| Construction | 2 | 53 | $4,733 | $9,418 |
| Churches | 5 | 50 | $5,143 | $23,777 |
| Campgrounds/RV Parks | 2 | 160 | $5,953 | $14,718 |
| Fire Departments | 1 | 98 | $5,808 | $4,786 |
| Federal Parks | 0 | 39 | $5,203 | $2,091 |
| Forest Service | 2 | 42 | $4,783 | $10,287 |
| Golf and Country Clubs | 2 | 101 | $5,462 | $12,734 |
| Landfills | 2 | 44 | $5,142 | $8,061 |
| Mining | 2 | 113 | $5,488 | $13,127 |
| Amusement Parks | 3 | 418 | $5,729 | $18,310 |
| Military Bases | 2 | 395 | $8,568 | $16,360 |
| Migrant Labor Camps | 1 | 63 | $5,383 | $3,570 |
| Misc. Recreation Services | 5 | 87 | $5,012 | $26,091 |
| Nursing Homes | 3 | 107 | $6,997 | $18,282 |
| Office Parks | 19 | 136 | $5,259 | $100,420 |
| Prisons | 1 | 1,820 | $35,041 | $47,189 |
| Retailers (Non-food related) | 14 | 174 | $5,073 | $70,861 |
| Retailers (Food related) | 3 | 322 | $5,167 | $14,748 |
| State Parks | 2 | 165 | $5,121 | $8,544 |
| Non-Water Utilities | 10 | 170 | $5,536 | $55,308 |
| Manufacturing: Food | 15 | 372 | $7,231 | $111,625 |
| Manufacturing: Non-Food | 77 | 168 | $5,670 | $438,184 |
| **TOTAL** | **407** | | | **$2,574,315** |

### 6.3.3 Costs per Household

Household level costs are considered a good proxy for the affordability of rule compliance with regard to CWSs, since water systems recover costs at the household level through increased water rates. This of course assumes that non-residential customers of water systems, such as businesses, can pass along any increase in water costs to their customers through increased prices on their goods or services. In order to calculate the number of households served by systems that will treat, the expected number of treating systems is multiplied by the average number of households per system (varies by system type and size). Exhibit 6-16 presents the total number of households served by CWSs that treat, by size category.

**Exhibit 6-16**
**Number of Households in CWSs Expected to Treat**
**by Size Category and MCL (µg/L) Option**

| | <100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 | 10,001-50,000 | 50,001-100,000 | 100,001-1,000,000 | Total |
|---|---|---|---|---|---|---|---|---|---|
| **3** | 94,484 | 368,092 | 360,709 | 1,002,937 | 1,619,822 | 3,228,544 | 1,453,603 | 3,014,841 | 11,143,032 |
| **5** | 58,774 | 228,149 | 219,872 | 623,156 | 1,019,288 | 2,077,421 | 905,886 | 1,938,268 | 7,070,814 |
| **10** | 26,369 | 104,373 | 101,866 | 288,986 | 475,599 | 997,880 | 469,157 | 936,602 | 3,400,833 |
| **20** | 10,439 | 40,089 | 40,498 | 116,517 | 193,541 | 405,714 | 188,798 | 364,907 | 1,360,503 |

SafeWaterXL determines household costs separately for each affected CWS, by first dividing the CWS's annual compliance cost by the CWS's average daily flow (1,000 gallons per day), and then multiplied by 365 days to determine the CWS's cost of compliance per 1,000 gallons produced. Finally, the CWS's cost of compliance per 1,000 gallons (kgal) is multiplied by the average annual consumption per residential connection (kgal), to arrive at the average annual cost of compliance per household for the CWS. The estimates of average annual consumption per residential connection used in this analysis are provided in Chapter 4, "Baseline Analysis."

Given expected household costs for each individual system, the average is then calculated for each size category. Exhibit 6-17 shows the average annual household costs by system size, across the four regulatory options.

The range of household costs for the MCL of 10 µg/L ranges from less than $1 to approximately $327; the costs for the MCL of 3 µg/L range from less than $7 to $317; the costs for the MCL of 5 µg/L, range from less than $3 to $318; and the costs for the MCL of 20 µg/L range from less than $1 to $351.

In the smallest two size categories, average household costs decrease as the MCL decreases. This somewhat counterintuitive result is due to the $500.00 affordability cap assumed in the SafeWater XL simulations. As more systems are forced over the affordability cap, the systems' costs are fixed at the costs associated with the POU technology. This results in lower average household costs for these systems.

**Exhibit 6-17**
**Average Annual Household Costs Across MCL Options by System Size**

| System Size | MCL (μg/L) | | | |
|---|---|---|---|---|
| | 3 | 5 | 10 | 20 |
| <100 | $317.00 | $318.26 | $326.82 | $351.15 |
| 101-500 | $166.91 | $164.02 | $162.50 | $166.72 |
| 501-1,000 | $74.81 | $73.11 | $70.72 | $68.24 |
| 1,001-3,300 | $63.76 | $61.94 | $58.24 | $54.36 |
| 3,301-10,000 | $42.84 | $40.18 | $37.71 | $34.63 |
| 10,001-50,000 | $38.40 | $36.07 | $32.37 | $29.05 |
| 50,001-100,000 | $31.63 | $29.45 | $24.81 | $22.63 |
| 100,001-1,000,000 | $25.29 | $23.34 | $20.52 | $19.26 |
| >1,000,000 | $7.41 | $2.79 | $0.86 | $0.15 |
| All categories | $41.34 | $36.95 | $31.85 | $23.95 |

Exhibits 6-18 through 6-21 compare the distribution of annual household costs across public water systems serving fewer than 10,000 people, for MCLs of 3, 5, 10, and 20, respectively. The exhibits demonstrate the maximum annual costs that different percentages of households in treating systems face. Comparison of Exhibits 6-18 through 6-21 illustrates that regulatory compliance costs decrease across MCLs. This observation is depicted by the consistent shift to the left of cost curves across system size categories, when comparing incremental increases in the MCL.

**Exhibit 6-18**
**Annual Treatment Costs Per Household Across CWSs Expected to Treat and Serving < 10,000 People**
**MCL 3 µg/L**

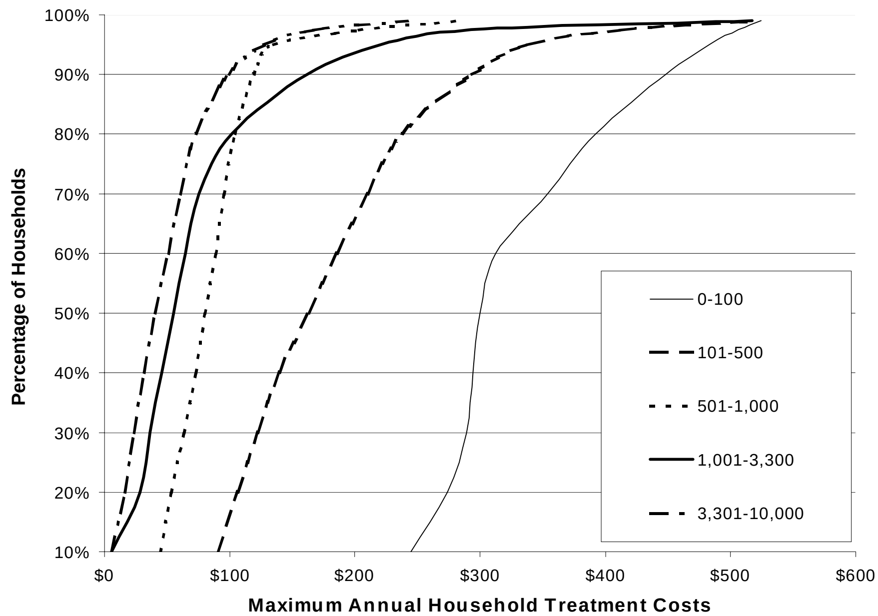



**Exhibit 6-19**
**Annual Treatment Costs Per Household Across CWSs Expected to Treat and Serving < 10,000 People**
**MCL 5 µg/L**

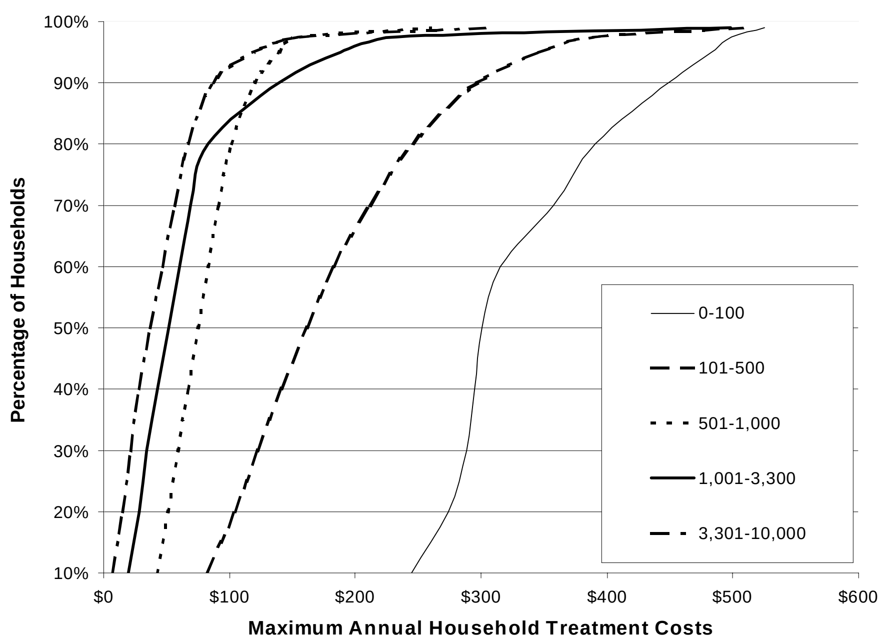


**Exhibit 6-20**
**Annual Treatment Costs Per Household Across CWSs Expected to Treat and Serving < 10,000 People**
**MCL 10 µg/L**

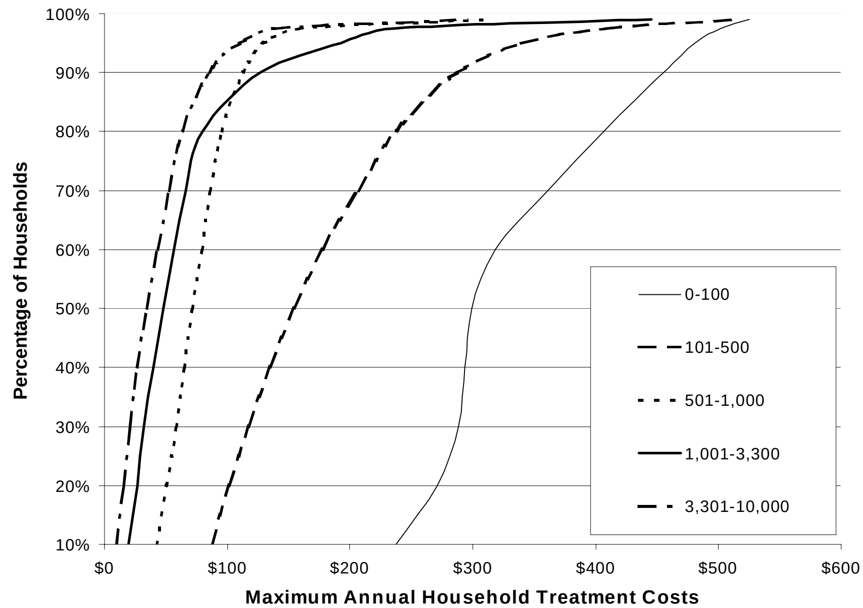
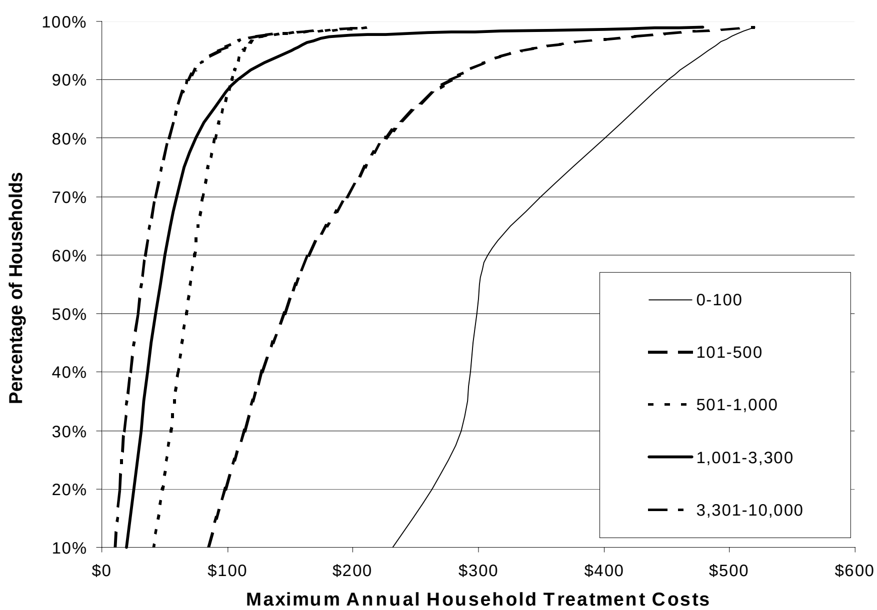



**Exhibit 6-21**
**Annual Treatment Costs Per Household Across CWSs Expected to Treat and Serving < 10,000 People**
**MCL 20 µg/L**



## 6.4 National Compliance Costs Uncertainty Analysis

The national cost estimates discussed throughout this chapter were developed within the SafeWaterXL modeling framework so that EPA could fully describe the variation in compliance costs among systems in a single size category (rather than just the average cost for systems within a size category). Hence, for each CWS size category, a distribution of compliance costs was estimated. These distributions are now used to access the uncertainty inherent in the national cost estimates.

A parametric bootstrap model was developed to estimate the distribution of national compliance costs.[3] The following steps were followed:

1. The distribution of costs for each CWS size and ownership cluster was pulled from the SafeWaterXL model results for an MCL of 10 µg/L.

2. The number of CWSs expected to modify or install treatment in each CWS size and ownership cluster was pulled from the SafeWaterXL model results for an MCL of 10 µg/L.

3. For each CWS size and ownership cluster, the model pulled a number of observations from the distribution of costs associated with that CWS size and ownership cluster (from step 1). The number of observations pulled was equal to the number of CWSs expected to modify or install treatment in each CWS size and ownership cluster (from step 2).

4. The observations (from step 3) were summed across all CWS size and ownership clusters to calculate a single estimate of national costs for CWSs.

5. No cost distributions are available for the NTNC systems and the very large CWSs. Therefore, after each single estimate of national costs for CWSs (from step 4) was calculated, the mean costs for very large CWSs and NTNC systems were added to it to calculate a single total national cost estimate.

6. Steps 3 through 5 were repeated 3,000 times to calculate a distribution of total national costs.

The distribution of total national costs is shown in Exhibit 6-22. The simulated mean national costs is \$199 million, and the simulated standard deviation is \$19 million. Also, the cumulative distribution of total national costs is shown in Exhibit 6-23. As this exhibit shows, the $10^{th}$ and $90^{th}$ percentile confidence interval for total national costs are \$190 million and \$227 million respectively.

[3] Only treatment costs were included in the uncertainty analysis. Also, the uncertainty analysis was conducted assuming a commercial discount rate. Although this commercial discount rate varies by CWS size and ownership, it approximates five percent for all PWSs.

**Exhibit 6-22**
**National Compliance Costs Uncertainty Analysis**
**Frequency Distribution (MCL 10 µg/L)**

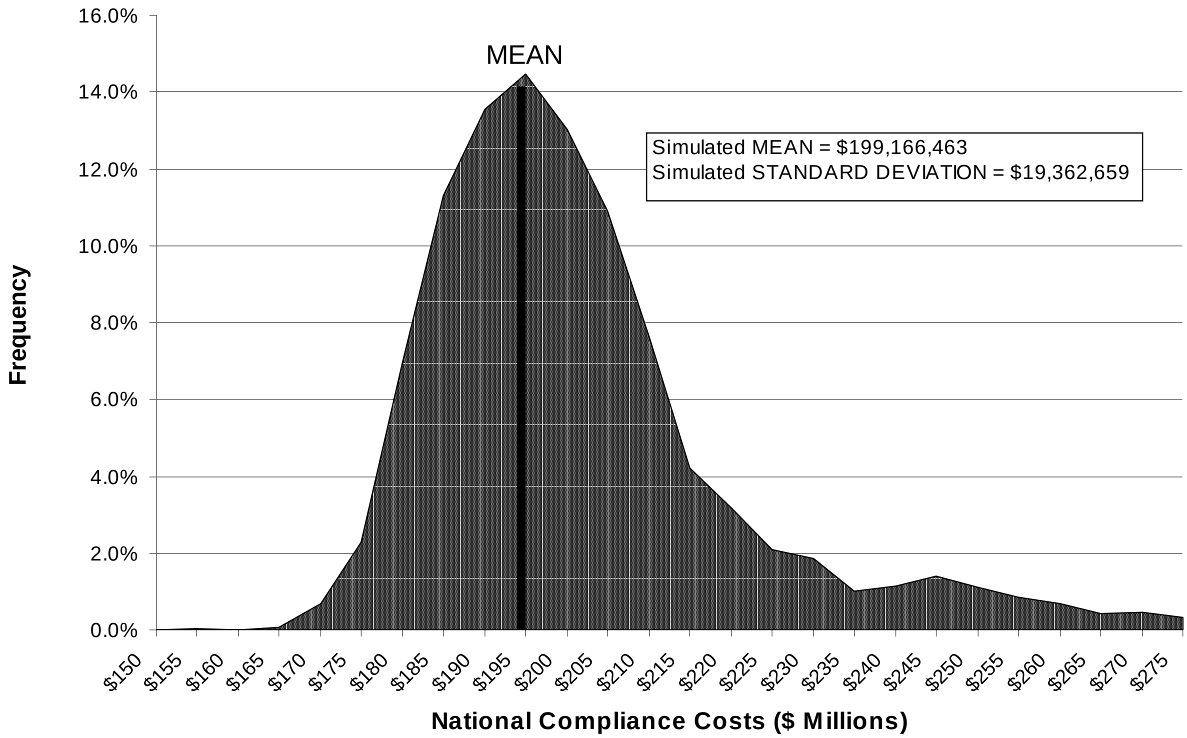
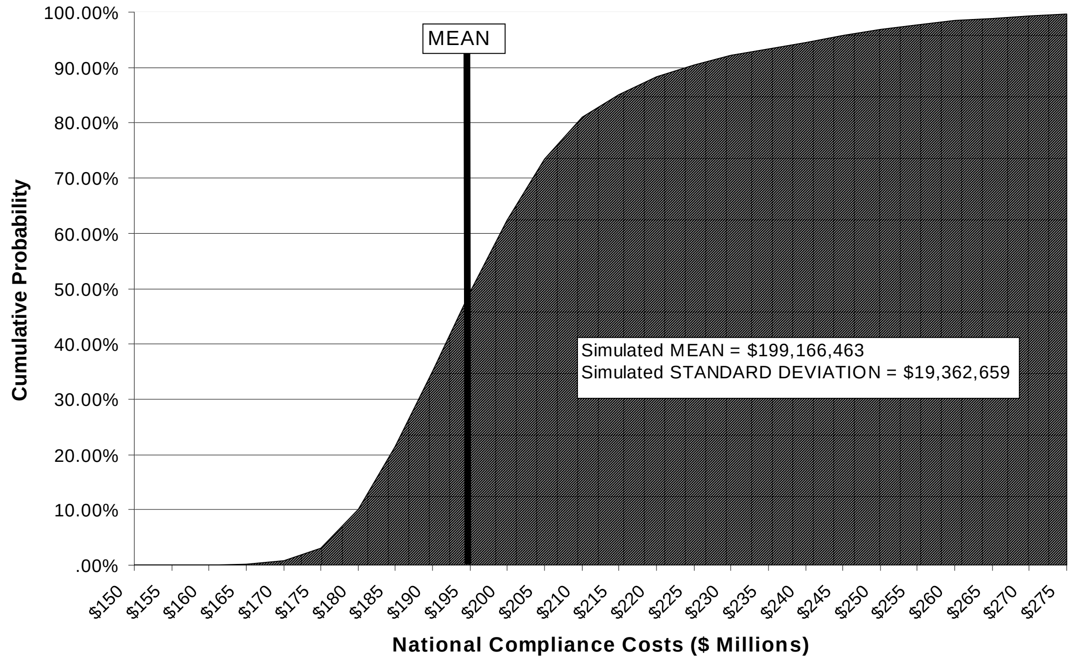


**Exhibit 6-23**
**National Compliance Costs Uncertainty Analysis**
**Cumulative Distribution (MCL 10 µg/L)**



# Chapter 7: Comparison of Costs and Benefits

## 7.1 Introduction

In this EA, EPA has analyzed the costs and benefits of regulating arsenic concentrations in drinking water to four different MCL standards. The four options considered reflect increasing levels of protection against exposure to arsenic in drinking water, employing a range of MCLs from 20 µg/L to 3 µg/L. As the MCL provisions for the four options become increasingly strict, the associated costs and benefits also increase incrementally. Chapter 5 ("Benefits Analysis") describes in detail the estimated national health benefits of the Arsenic Rule options, while Chapter 6 ("Cost Analysis") describes the projected national compliance cost estimates. This chapter presents a summary and comparison of the national costs and benefits and a cost-effectiveness analysis for each of the MCL options.

## 7.2 Summary of National Costs and Benefits

### 7.2.1 National Cost Estimates

National compliance costs to public water systems (PWSs) for treatment (both annualized capital and operating and maintenance costs), monitoring and administrative activities, and costs to States, including any one-time start-up costs, for regulatory implementation and enforcement, were estimated and described in Chapter 6. The national costs for PWSs to comply with the four MCL options range from $66.8 million (MCL=20 µg/L) to $697.8 million (MCL=3 µg/L) annually based on a discount rate of three percent. Assuming a seven percent discount rate, the range of total national cost for community water systems ranges from $76.5 million to $792.1 million annually.

### 7.2.2 National Benefits Estimates

Chapter 5 contains a detailed summary of the methodology used to estimate a range of national health benefits from avoided cancer cases as a result of the four Arsenic Rule MCL options. The dollar value of the estimated health benefits associated with each of the four rule options was calculated based on lower and upper bound estimates of avoided bladder and lung cancer cases. The national benefits range from $66.2 million (MCL=20 µg/L) to $213.8 million (MCL=3 µg/L) annually, based on the lower bound estimates of cancer cases avoided. Under the upper bound scenario, the health benefits from avoided cancer increase from $75.3 million at an MCL of 20 µg/L to $490.9 million annually at an MCL of 3 µg/L.

## 7.3 Comparison of Benefits and Costs

This section presents a comparison of total national benefits and costs for each of the Arsenic Rule options considered. Three separate analyses are considered, including a summary of benefit/cost ratios and net benefits, a direct comparison of aggregate national costs and benefits, and the results of a cost-effectiveness analysis of each regulatory option.

### 7.3.1 National Net Benefits and National Benefit-Cost Comparison

Exhibit 7-1 describes the net benefits and the benefit/cost ratios under various MCL options for PWSs at three and seven percent discount rates. Except for the upper bound benefit scenario at a discount rate of three percent, the net benefits are negative and decreasing as the Arsenic Rule MCL options become increasingly more stringent. For the same categories, the benefit/cost ratios are less than one and decrease as the MCL becomes more stringent. For nearly all of the options, costs outweigh the quantified benefits, with benefit/cost ratios all below or equal to one. For example, the ratios range from 0.3 (MCL=3 µg/L) to 1.0 (MCL=20 µg/L) at a seven percent discount rate. For the upper bound scenario at three percent the benefit/cost ratio exceeds one at an MCL of 10 µg/L and 20 µg/L. Of the MCL options examined, the net benefits and benefit/cost ratio are maximized at an MCL of 10 µg/L and a three percent discount rate.

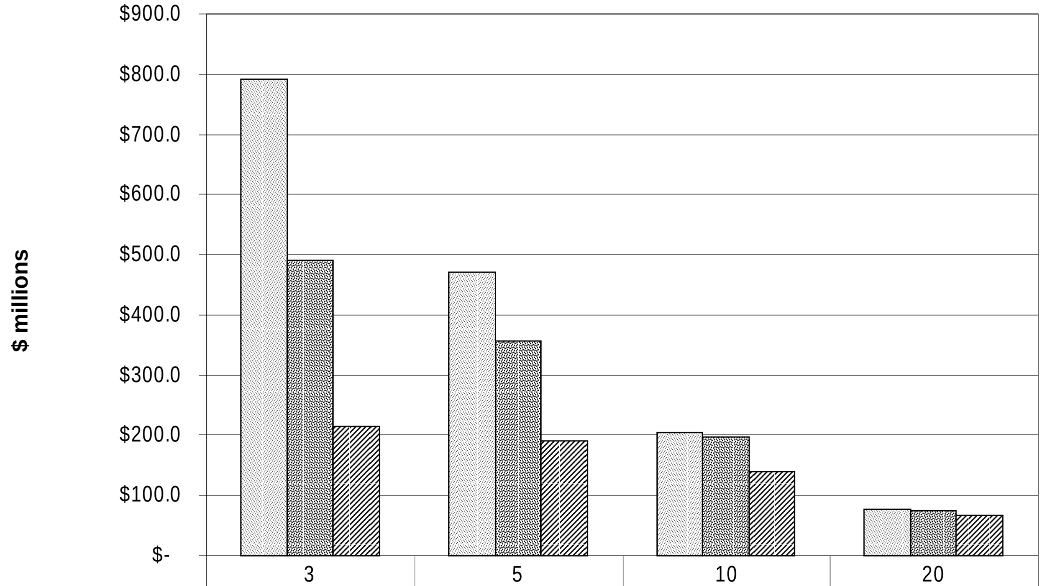
**Exhibit 7-1**
**Summary of Annual National Net Benefits and Benefit-Cost Ratios**
**($ millions)**

| MCL (µg/L) | | 3 | 5 | 10 | 20 |
|---|---|---|---|---|---|
| **3% Discount Rate** | | | | | |
| lower bound | Net Benefits | $ (484.0) | $ (223.7) | $ (40.8) | $ (0.6) |
| | Benefit/Cost Ratio | 0.3 | 0.5 | 0.8 | 1.0 |
| upper bound | Net Benefits | $ (206.8) | $ (59.2) | $ 17.3 | $ 8.5 |
| | Benefit/Cost Ratio | 0.7 | 0.9 | 1.1 | 1.1 |
| **7% Discount Rate** | | | | | |
| lower bound | Net Benefits | $ (578.3) | $ (280.6) | $ (66.0) | $ (10.3) |
| | Benefit/Cost Ratio | 0.3 | 0.4 | 0.7 | 0.9 |
| upper bound | Net Benefits | $ (301.1) | $ (116.1) | $ (7.9) | $ (1.2) |
| | Benefit/Cost Ratio | 0.6 | 0.8 | 1.0 | 1.0 |

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs and NTNCs and State costs for administration of water programs.

Exhibit 7-2 graphically depicts the absolute difference between the total value of national costs and benefits under each proposed MCL at a seven percent discount rate.

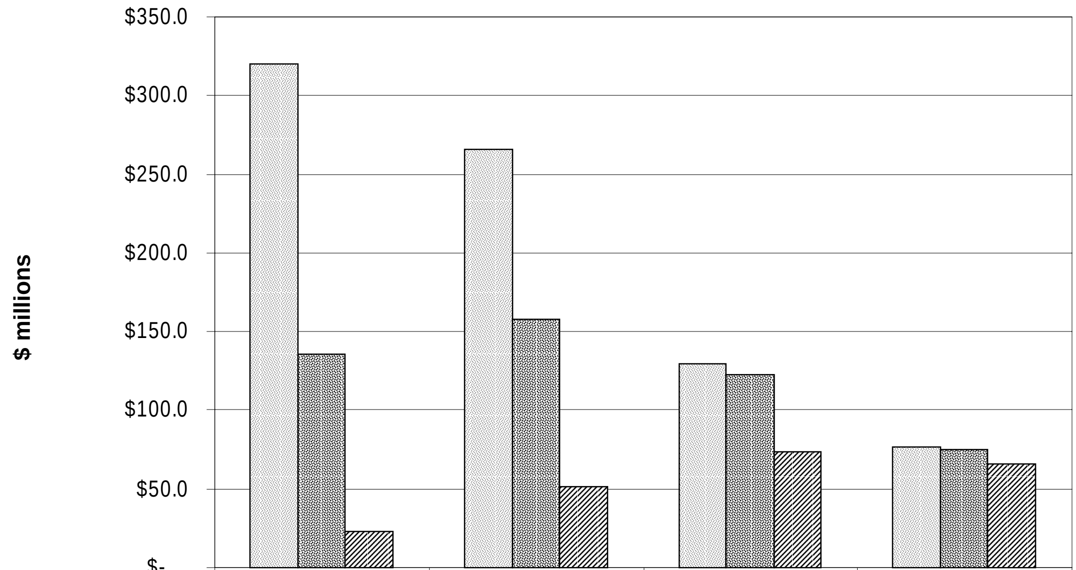
**Exhibit 7-2**
**Comparison of Costs and Benefits**
**(7% Discount Rate, in $ millions)**




| | 3 | 5 | 10 | 20 |
|---|---|---|---|---|
| Costs | $792.1 | $471.7 | $205.6 | $76.5 |
| Benefits (upper bound) | $491.0 | $355.6 | $197.7 | $75.3 |
| Benefits (lower bound) | $213.8 | $191.1 | $139.6 | $66.2 |

Exhibit 7-3 depicts the incremental costs and benefits of the rule as one moves from a less stringent standard to a more stringent standard. Moving to an MCL of 20 µg/L from the current MCL of 50 µg/L results in incremental costs of $76.5 million and incremental benefits of between $66.2 million and $75.3 million. A move from 20 µg/L to 10 µg/L results in incremental costs of $129.1 million and incremental benefits of between $73.4 million and $122.4 million. Moving beyond an MCL of 10 µg/L towards a more stringent standard results in incremental costs that far outweigh the incremental benefits, even under the upper bound benefits scenario.

**Exhibit 7-3**
**Comparison of Incremental Costs and Benefits**
**(7% Discount Rate, in $ millions)**




| | 3 | 5 | 10 | 20 |
|---|---|---|---|---|
| Costs | $320.5 | $266.0 | $129.1 | $76.5 |
| Benefits (upper bound) | $135.4 | $157.9 | $122.4 | $75.3 |
| Benefits (lower bound) | $22.7 | $51.5 | $73.4 | $66.2 |

Exhibit 7-4 shows the results of an analysis in which the average national cost of achieving each unit reduction in cases of cancer avoided was calculated. The average annual cost per cancer case avoided was computed at each MCL option, for both three and seven percent discount rates. At a three percent discount rate, the cost per cancer case avoided ranges from $5.0 million to $12.2 million at an MCL of 3 µg/L, from $4.1 million to $8.1 million at an MCL of 5 µg/L, from $3.2 million to $4.8 million at an MCL of 10 µg/L, and from $3.4 million to $3.5 million at an MCL of 20 µg/L. At a seven percent discount rate, the cost per cancer case avoided ranges from $5.7 million to $13.8 million at an MCL of 3 µg/L, from $4.7 million to $9.2 million at an MCL of 5 µg/L, from $3.7 million to $5.5 million at an MCL of 10 µg/L, and from $3.9 million to $4.0 million at an MCL of 20 µg/L.

**Exhibit 7-4**
**Cost per Cancer Case Avoided**
**($ millions)**

| Arsenic Level (μg/L) | lower bound** | upper bound** |
|---|---|---|
| **3% Discount Rate** | | |
| **3** | $ 12.2 | $ 5.0 |
| **5** | $ 8.1 | $ 4.1 |
| **10** | $ 4.8 | $ 3.2 |
| **20** | $ 3.5 | $ 3.4 |
| **7% Discount Rate** | | |
| **3** | $ 13.8 | $ 5.7 |
| **5** | $ 9.2 | $ 4.7 |
| **10** | $ 5.5 | $ 3.7 |
| **20** | $ 4.0 | $ 3.9 |

**Lower/upper bounds correspond to estimates of bladder cancer cases avoided.

### 7.3.2 Cost-Effectiveness

Cost-effectiveness analysis is another commonly used measure of the economic efficiency with which regulatory options are meeting the intended regulatory objectives. Exhibit 7-5 is a comparison of annual national costs (computed at a seven percent discount rate) and annual cases of cancer avoided at each MCL option. The two lines represent the cost per cancer case avoided under the lower and upper bound estimates of cancer cases avoided. These plotted lines depict the trend in marginal cost and benefits (expressed as health effects avoided) between each point on these curves (corresponding to each MCL option). Points along these lines represent each increment of cost that is incurred in order to achieve the next increment of risk reduction, i.e., additional cancer case avoided. The steepness of the curves under both benefits scenarios suggests that additional increments of risk reduction and benefits are achieved at increasingly greater cost to the nation.

**Exhibit 7-5**
**Comparison of Annual Costs to Cases of Cancer per Year**
**(7% Discount Rate)**

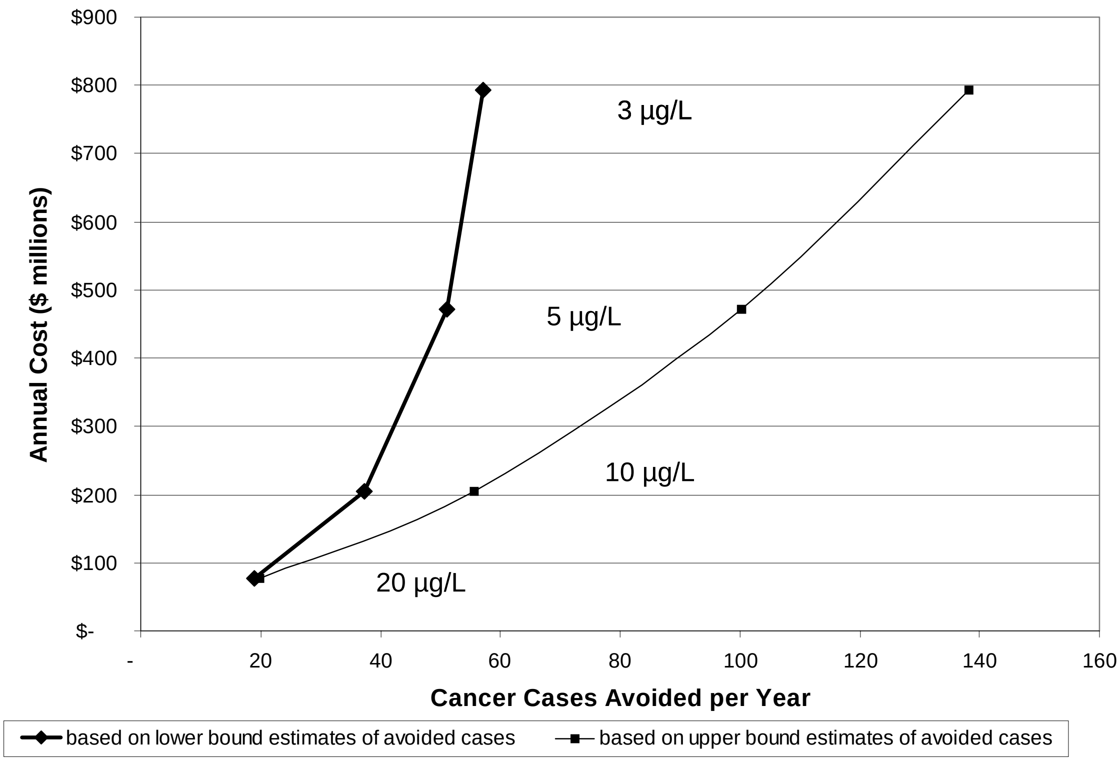
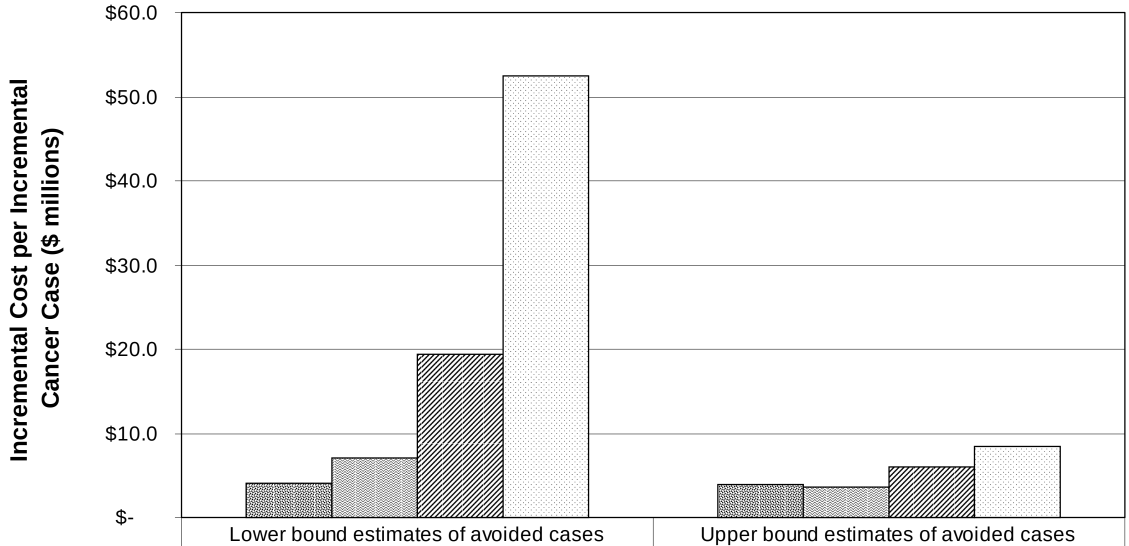



Exhibit 7-6 further reinforces the fact that as the MCL becomes more stringent, the incremental cost per cancer case avoided increases. For example, the additional cases of cancer avoided in moving from an MCL of 10 µg/L to 5 µg/L are achieved at a cost per case of $3.6 million annually under the high bound and seven percent discount rate scenario. Similarly, in moving from an MCL of 5 µg/L to a more stringent MCL of 3 µg/L, the cost per case avoided increases to $2.4 million per year under this same scenario.

**Exhibit 7-6**
**Incremental Cost per Incremental Cancer Case Avoided**
**(7% Discount Rate, in $ millions)**




| | Lower bound estimates of avoided cases | Upper bound estimates of avoided cases |
|---|---|---|
| MCL 20 ug/L | $4.0 | $3.9 |
| MCL 10 ug/L | $7.0 | $3.6 |
| MCL 5 ug/L | $19.4 | $6.0 |
| MCL 3 ug/L | $52.5 | $8.4 |

## 7.4 Other Benefits

Chapter 5 discusses a number of important non-monetized benefits of reducing arsenic exposure. Chief among these are certain health impacts known to be caused by arsenic. Such nonquantifiable benefits may include skin cancer, kidney cancer, cancer of the nasal passages, liver cancer, prostate cancer, cardiovascular effects, pulmonary effects, immunological effects, neurological effects, endocrine effects, and customer peace-of-mind benefits from knowing their drinking water has been treated for arsenic. For example, a number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Early reports linking inorganic arsenic contamination of drinking water to skin cancer came from Argentina (Neubauer, 1947, reviewing studies published as early as 1925) and Poland (Tseng et al., 1968). However, the first studies that observed dose-dependent effects of arsenic associated with skin cancer came from Taiwan (Tseng et al., 1968; Tseng, 1977). These studies focused EPA's attention on the health effects of ingested arsenic. Studies conducted in the U.S. have not demonstrated an association between inorganic arsenic in drinking water and skin cancer. However, these studies may not have included enough people in their design to detect these types of effects.



5 µg/L

The potential monetized benefits associated with skin cancer reduction would not change the total benefits of the rule to an appreciable degree, even if the assumption were made that the risk of skin cancer were equivalent to that of bladder cancer, using EPA's 1988 risk assessment. Skin cancer is highly treatable (at a cost of illness of less than $3,500 for basal and squamous cell carcinomas versus a cost of illness of $178,000 for non-fatal bronchitis) in the U.S., with few fatalities (less than one percent).

In addition to skin cancer, there are also a large number of other health effects associated with arsenic, as presented in Exhibit 7-7, which are not monetized in this analysis, due to lack of appropriate data.

**Exhibit 7-7**
**Total Annual Cost, Estimated Monetized Total Cancer Health Benefits, and Non-Quantifiable Health Benefits from Reducing Arsenic in PWSs**
**($ millions)**

| Arsenic Level (µg/L) | Total Annual Cost (7%) | Annual Bladder Cancer Health Benefits[1,2] | Annual Lung Cancer Health Benefits[1,2] | Total Annual Health Benefits[1,2] | Potential Non-Quantifiable Health Benefits |
|---|---|---|---|---|---|
| 3 | $792.1 | $58.2 - $156.4 | $155.6 - $334.5 | $213.8 - $490.9 | • Skin Cancer<br>• Kidney Cancer<br>• Cancer of the Nasal Passages<br>• Liver Cancer<br>• Prostate Cancer<br>• Cardiovascular Effects<br>• Pulmonary Effects<br>• Immunological Effects<br>• Neurological Effects<br>• Endocrine Effects<br>• Reproductive and Developmental Effects |
| 5 | $471.7 | $52.0 - $113.3 | $139.1 - $242.3 | $191.1 - $355.6 | |
| 10 | $205.6 | $38.0 - $63.0 | $101.6 - $134.7 | $139.6 - $197.7 | |
| 20 | $76.5 | $20.1 - $21.5 | $46.1 - $53.8 | $66.2 - $75.3[3] | |

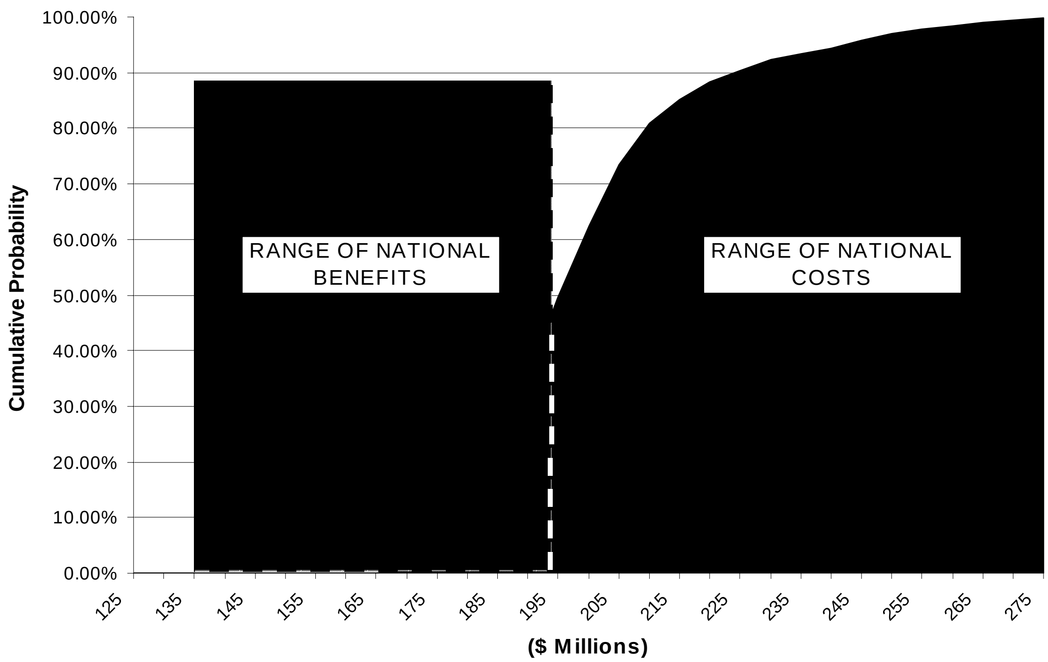
[1] May 1999 dollars.
[2] These monetary estimates are based on cases avoided given in Exhibit 5-9 (a-c).
[3] For 20 µg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus the number of estimated cases avoided and estimated benefits are higher at 20 µg/L using the estimates adjusted for uncertainty.

Other benefits not monetized in this analysis include customer peace of mind from knowing drinking water has been treated for arsenic and reduced treatment costs for currently unregulated contaminants that may be co-treated with arsenic. To the extent that reverse osmosis is used for arsenic removal, these benefits could be substantial. Reverse osmosis is the primary point-of-use treatment, and it is expected that very small systems will use this treatment to a significant extent. (These benefits of avoided treatment cannot currently be monetized; however, they can be readily monetized in the future, as decisions are made about which currently unregulated contaminants to regulate.)

## 7.5 Benefits-Costs Uncertainty Analysis

The uncertainty surrounding the national cost of compliance was described in Chapter 6. Exhibit 7-8 superimposes the distribution of national compliance costs onto the range of monetized benefits associated with the rule at an MCL of 10 µg/L. This exhibit illustrates that there is approximately a 50 percent probability that the costs of the rule will be lower than the monetized benefits of the rule under the upper bound benefit assumption.

**Exhibit 7-8**
**National Compliance Costs and Benefits Uncertainty Analysis**
**Cumulative Cost Distribution vs. Benefits Range (MCL 10 µg/L)**



# Chapter 8: Economic Impact Analyses

## 8.1 Introduction

The Environmental Protection Agency (EPA) is required to perform a series of analyses that addresses the distribution of regulatory impacts associated with the Arsenic Rule. This chapter presents analyses that support EPA's compliance with the following Federal mandates:

- Executive Order 12886 (Regulatory Planning and Review);
- Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996;
- National Affordability determination required by the 1996 amendments to the Safe Drinking Water Act (SDWA);
- Unfunded Mandates Reform Act (UMRA) of 1995;
- Technical, Financial, and Managerial Capacity Assessment required by Section 1420(d)(3) of the 1996 amendments to the Safe Drinking Water Act (SDWA);
- Executive Order 13045 (Protection of Children From Environmental Health Risks and Safety Risks);
- Executive Order 12989 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations);
- Paperwork Reduction Act;
- Health Risk Reduction and Cost Analysis (HRRCA) as required by Section 1412(b)(3)(C) of the 1996 SDWA Amendments; and
- Initial Regulatory Flexibility Analysis (IRFA).

These analyses draw on the cost analyses presented in Chapter 6 and an analysis of administrative requirements presented in a separate document, *Information Collection Request for the Arsenic Rule*.

Several of these Federal mandates require an explanation of why the rule is necessary, the statutory authority upon which it is based, and the primary objectives it is intended to achieve. Background information on the problems addressed by the rule, and EPA's statutory authority for promulgating the rule, are presented in Chapter 2. In this chapter, Section 8.2 presents the RFA and SBREFA analysis of impacts on small entities. Also described are the economic impacts of the rule on households. Section 8.3 discusses coordination of the Arsenic Rule with other Federal rules. The minimization of economic burden, UMRA, system capacity assessments, and the Paperwork Reduction Act are addressed in Sections 8.4, 8.5, 8.6, and 8.7, respectively. Section 8.8 discusses the rule's protection of children's health, Section 8.9 addresses environmental justice issues, and Section 8.10 contains the HRRCA.

## 8.2 Regulatory Flexibility Act and Small Business Regulatory Enforcement Fairness Act

The RFA provides that, whenever an agency promulgates a proposed or final rule under section 553 of the Administrative Procedure Act, after being required by that section or any other law to publish a general notice of rulemaking, the agency must prepare an initial and final regulatory flexibility analysis. The agency must prepare such an analysis when proposing a rule (or promulgating a final rule) unless the head of the agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. EPA did not certified that the proposed regulation would not have a significant economic impact on a substantial number of small entities. Consequently, the Agency prepared an initial analysis of the proposal and, because it has not certified the final rule, has now completed a final regulatory flexibility analysis. EPA prepared these analyses in compliance with the requirements of the RFA

Under the RFA, the term "small entity" means "small business," "small governmental jurisdiction" and "small organization." These terms are further defined by the Act. In the case of a "small business," the term has the same meaning as a "small business concern" under section 3 of the Small Business Act. (Regulations of the Small Business Administration (SBA) at 13 CFR 121.201 have defined small businesses for Standard Industrial Classification (SIC) codes.) "Small governmental jurisdiction" means the government of cities, counties, towns and villages, among others, with a population of less than 50,000. A "small organization" is any not-for-profit enterprise that is independently owned and operated. The RFA authorizes an agency to establish other definitions of such terms which are appropriate to the agency's activities and publish such definitions in the Federal Register after consultation with SBA and opportunity for public comment. 5 U.S.C. § 601(3), (4) & (5).

### 8.2.1 Description of the Initial Regulatory Flexibility Analysis

The Regulatory Flexibility Act requires EPA to complete an Initial Regulatory Flexibility Analysis (IRFA) addressing the following:

1. The need for the rule;
2. The objectives of and legal basis for the rule;
3. A description of, and where feasible, an estimate of the number of small entities to which the rule will apply;
4. A description of the reporting, record keeping, and other compliance requirements of the rule, including an estimate of the types of small entities that will be subject to the requirements and the type of professional skills necessary for preparation of reports or records;
5. An identification, to the extent practicable, of all relevant Federal rules that may duplicate, overlap, or conflict with the rule; and
6. A description of "any significant regulatory alternatives" to the rule that accomplish the stated objectives of the applicable statutes, and that minimize any significant economic impact of the rule on small entities. Significant regulatory alternatives may include:

- Establishing different compliance or reporting requirements or timetables that take into account the resources of small entities;
- Clarifying, consolidating, or simplifying compliance and reporting requirements under the rule for small entities;
- Using performance rather than design standards; and
- Exempting small entities from coverage of the rule or any part of the rule.

If the initial assessment determines that a substantial number of small entities may face significant impacts as a result of the rule, then a formal regulatory flexibility analysis may be required.

### *Defining "Small Entities" Affected by the Rule*

The Regulatory Flexibility Act (RFA) defines small entities as including "small businesses," "small governments," and "small organizations" (5 USC 601). The RFA references the definition of "small business" found in the Small Business Act, which authorizes the Small Business Administration (SBA) to further define "small business" by regulation. The SBA defines small business by category of business using Standard Industrial Classification (SIC) codes (13 CFR 121.201). For example, in the manufacturing sector, the SBA generally defines small business in terms of number of employees; in the agriculture, mining, electric, gas, and sanitary services sectors, the SBA generally defines small businesses in terms of annual receipts (ranging from $0.5 million for crops to $25 million for certain types of pipelines). The RFA also authorizes an agency to adopt an alternative definition of "small business" "where appropriate to the activities of the Agency" after consultation with the SBA and opportunity for public comment.

For the revised Arsenic Rule small entities are defined as those water systems that meet the following criteria:

- A "small business" is any small business concern that is independently owned and operated and not dominant in its field as defined by the Small Business Act (15 USC 632). Examples of public water systems within this category include small, privately owned, public water systems and for-profit businesses where provision of water may be ancillary, such as mobile home parks or day care centers.

- A "small organization" is any not-for-profit enterprise that is independently owned and operated, not dominant in its field, and operates a public water system. Examples of small organizations are churches, schools, and homeowners associations.

- A "small governmental jurisdiction" is a city, county, town, school district or special district with a population of less than 50,000 (5 USC 601) that operates a public water system.

In 1998, EPA proposed that PWSs with populations of 10,000 or fewer persons be defined as "small entities" within the context of the Consumer Confidence Report (CCR) rulemaking (63 FR 7620, February 13, 1998). EPA requested public comments on this alternative definition.

For this rulemaking, the SBA Office of Advocacy agreed with the Agency's alternative definition. EPA intends to define "small entity" in the same way for RFAs under SBREFA for all future drinking water regulations, including the revised Arsenic Rule.

EPA selected this alternative definition for small water systems for several reasons:

- A large proportion (94 percent) of all PWSs are small entities, although they serve a minority of the population. Larger PWSs (those serving over 10,000 persons) serve the majority of the population receiving water from public water systems.

- Certain key financial ratios (e.g., total debt as a ratio of total revenue) show a distinct break point at the 10,000 or fewer system size level.[1] In general, the size of a PWS is an important financial characteristic, as larger systems can spread investments in fixed assets across a broader customer base. Smaller water systems typically serve primarily residential customers. Larger systems have fewer residential customers as a percentage of total water sales and more commercial customers. Annual sales revenue per connection is significantly higher for nonresidential than for residential connections.[2] Similarly, larger publicly owned systems are more likely to have rated bond issuances, another indicator of financial strength.[3]

- In the 1996 Amendments to the Safe Drinking Water Act (SDWA), several measures creating regulatory relief defined small community water systems as those serving 10,000 or fewer customers. One provision allows for alternative means of delivery of the CCRs by systems serving 10,000 or fewer persons. Another used the same cutoff for modifications to monitoring requirements and for certain penalty provisions delegated to the States.[4]

- EPA has previously used this criterion in both rulemaking and implementation activities pertaining to PWSs. The total trihalomethane (TTHM) rule promulgated by EPA in 1979 applied only to systems serving more than 10,000 persons. EPA chose the 10,000 cutoff in 1979 primarily out of a concern that smaller systems would have to divert resources from other activities to comply with the rule. In 1992, EPA initiated a regulatory negotiation process that resulted in regulatory actions to provide additional protection from microbial contaminants in drinking water while reducing health risks from disinfection byproducts. The Interim Enhanced Surface Water Treatment Rule promulgated from this process

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[1] *Community Water Systems Survey, Volume I: Overview*, U.S. EPA Office of Water, p. 26. January 1997.

[2] *Id*., p. 14.

[3] *Id*., p. 28.

[4] *House Report No. 104-632* (Commerce Committee), June 24, 1996 in *US Code Congressional and Administrative News* (USCCAAN), 1996, 4, pp. 1373, 1401 and 1409, discussing §§132(b) and 1418(a) of the House bill.

applied only to systems serving more than 10,000. The companion rule, the Stage 1 Disinfection Byproducts Rule, deferred compliance with part of the requirements for systems serving 10,000 or fewer persons.

For purposes of this analysis, therefore, "small entity" refers to any public water system that serves 10,000 or fewer persons. Exhibit 8-1 shows the universe of small PWSs potentially affected by the new arsenic standard.

**Exhibit 8-1**
**Profile of the Universe of Small Water Systems**
**Regulated Under the Arsenic Rule**

| Type Water System | System Size Category | | | | |
|---|---|---|---|---|---|
| | <100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 |
| **Publicly-Owned:** | | | | | |
| CWS | 1,729 | 5,795 | 3,785 | 6,179 | 3,649 |
| NCWS | 1,783 | 3,171 | 1,182 | 361 | 29 |
| **Privately-Owned:** | | | | | |
| CWS | 13,640 | 11,266 | 2,124 | 1,955 | 654 |
| NCWS | 8,178 | 4,162 | 902 | 411 | 56 |
| **Total Systems:** | | | | | |
| CWS | 15,369 | 17,061 | 5,909 | 8,134 | 4,303 |
| NCWS | 9,961 | 7,333 | 2,084 | 772 | 85 |
| **TOTAL** | 25,330 | 24,394 | 7,993 | 8,906 | 4,388 |

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

### *Determining What Number Constitutes a Substantial Number*

In this analysis approximately 71,013 PWSs are defined as small entities. EPA SBREFA guidance has several different criteria for what constitutes a substantial number of affected entities.[1] One of the criteria is that no more than 20 percent of systems affected by the revised Arsenic Rule may experience economic impacts of one percent of their revenues or greater.

### *Measuring Significant Impacts*

To evaluate the impact that a small entity is expected to incur as a result of the rule, this analysis calculates the entity's ratio of annualized compliance costs as a percentage of sales (for privately owned systems) or the entity's ratio of annualized compliance costs as a percentage of annual governmental revenue or expenditures (for publicly owned systems). EPA guidance suggests using one percent as a threshold for determining significance, although additional factors may be considered. If compliance costs are less than one percent of sales or revenues, the regulation may in most cases be presumed to have no significant impact on a substantial number of small entities.[5]

[5] *Id.*

### *Categorizing Systems*

EPA categorized affected small entities according to the categories identified in the SBREFA guidance (i.e., small business, small government, and small organization). Public water system inventories, managed by EPA and other organizations, traditionally categorize public water systems by size and by the characteristics of the population served (i.e., community water system, non-community water system). Therefore, detailed information by SIC or data on revenues or sales are not readily available.

### *Estimating Revenue by RFA Category*

The estimated revenues for small entities in Exhibit 8-2 are from the Bureau of the Census[6]; EPA chemical monitoring reform rulemaking; and additional data on independent privately owned CWSs, special districts, and authorities, which are from the CWS Survey. Exhibit 8-2 also shows the numbers of small businesses, governments, and organizations, obtained using information from EPA's Baseline Handbook.[7] These numbers were used to determine the weighted averages of estimated average revenue, as described in the column "Average Estimated Revenues per System."

Small government systems include municipal, county, State, Federal, military, and special district systems. Data on revenue for townships and municipalities were obtained from the *1992 Census of Governments*, converted to 1999 dollars by applying a conversion factor calculated from the national income and product account tables of the U.S. Bureau of Economic Analysis.[8] Specifically, the price deflators for 1992 and 1999 were obtained from Table 7.11, *Chain-Type Quantity and Price Indexes for Government*, Chain-Type Price Indexes for State and Local Governments. The average revenue for all small government PWSs was calculated at $2,333,119.

Small businesses include both CWSs and NTNCWSs, such as privately owned community water systems, mobile home parks, country clubs, hotels, manufacturers, hospitals, and other establishments. For this analysis, all hospitals and day care centers were assumed to be businesses. Although some hospitals may be nonprofit, they have unusually high revenues and were included in the small business category to make the estimated revenue for small organizations more conservative. Estimated average revenue for the small businesses affected by the revised Arsenic Rule is $2,675,582.

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[6] *1992 Census of Governments*, GC92 (4)-4: Finances of Municipal and Township Governments, U.S. Dept. of Commerce, Bureau of the Census.

[7] *Drinking Water Baseline Handbook* Second Edition, EPA Contract No. 68-C6-0039. Prepared by International Consultants, Inc.

[8] Methodology recommended by Bruce E. Baker, State and Local Governments, Government Division, U.S. Bureau of Economic Analysis.

**Exhibit 8-2**
**Annual Cost of Compliance Costs as a Percentage of Revenues by Type of Small Entity**
**(PWSs that are Expected to Modify or Install Treatment at an MCL = 10 µg/L)**

| | Number of Systems | Average Estimated Revenues per System | Average Compliance Cost Per System | Cost to Revenue Ratio |
|---|---|---|---|---|
| **Water Systems that will Modify or Install Treatment** | | | | |
| **Small Government** | 1,116 | $2,333,119 | $41,999 | 1.8001% |
| **Small Business** | 2,318 | $2,675,582 | $13,466 | 0.5033% |
| **Small Organizations** | 472 | $5,990,914 | $6,828 | 0.1140% |
| **All Small Entities** | 3,907 | $2,978,546 | $20,816 | 0.6989% |
| **Water Systems that will Only Monitor** | | | | |
| **Small Government** | 20,587 | $2,333,119 | $37 | 0.0016% |
| **Small Business** | 38,131 | $2,675,582 | $39 | 0.0015% |
| **Small Organizations** | 8,389 | $5,990,914 | $53 | 0.0009% |
| **All Small Entities** | 67,106 | $2,984,958 | $40 | 0.0014% |
| **All Water Systems** | | | | |
| **Small Government** | 21,703 | $2,333,119 | $2,195 | 0.0941% |
| **Small Business** | 40,449 | $2,675,582 | $809 | 0.0302% |
| **Small Organizations** | 8,861 | $5,990,914 | $414 | 0.0069% |
| **All Small Entities** | 71,013 | $2,984,605 | $1,183 | 0.0396% |

Small organizations include primarily nonprofit NTNCWSs such as schools and homeowners associations. The estimates for small nonprofit organizations serving more than 500 people are actually higher than those for small businesses because the total number of such systems is small, and a large proportion of these organizations are schools and colleges with large budgets. This category also includes 50 percent of systems classified as "other." The average estimated revenue for small organizations affected by the revised Arsenic Rule is $2,978,546.

EPA also calculated the average estimated revenue for all small entities. This estimate is weighted to account for the number of small entities in each category (government, business, and organization) affected by the revised Arsenic Rule. This overall average is $2,833,552.

### *Conducting the Screening Analysis*

The final task of the initial assessment is to conduct the screening analysis and determine whether the rule is expected to result in significant economic impacts on a substantial number of small entities. The screening analysis involves the following three steps:

(1) *Estimate the compliance cost of the rule to small PWSs.* Estimated average per-system compliance costs associated with the revised Arsenic Rule were taken from the estimate prepared by EPA and presented in Chapter 6.

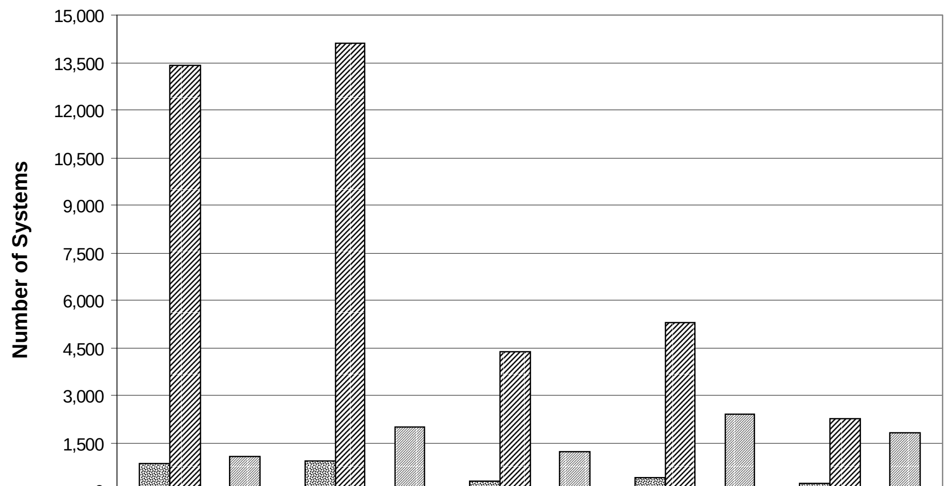
(2) *Obtain data on the number of small PWSs and their revenues or expenditures.* The number of small PWSs expected to modify or install treatment are found in Exhibit 8-2. These numbers are derived from the results of the SafeWaterXL model described in Chapter 6.

(3) *Compute small entity impacts*. Using the data obtained in the preceding steps, EPA calculated the ratio of total annual compliance costs as a percentage of revenues or expenditures. These ratios, converted into percentages, are presented in Exhibit 8-2 in the column "Cost to Revenue Ratio."

### 8.2.2 Initial Regulatory Flexibility Analysis Results

The results of the initial regulatory flexibility analysis are summarized below. As seen in Exhibits 8-2 and 8-3, at a maximum contaminant level (MCL) of 10 µg/L, 3,907 small PWSs are expected to have to modify or install treatment.

**Exhibit 8-3**
**Number of CWSs Expected to Undertake or Modify Treatment Practice**
**MCL 10 µg/L**




| | <100 | 101-500 | 501-1,000 | 1,001-3,300 | 3,301-10,000 |
|---|---|---|---|---|---|
| Treating GW systems | 855 | 940 | 310 | 421 | 215 |
| Not treating GW systems | 13,422 | 14,118 | 4,379 | 5,293 | 2,244 |
| Treating SW systems | 11 | 21 | 12 | 24 | 18 |
| Not treating SW systems | 1,081 | 1,982 | 1,208 | 2,396 | 1,826 |

Exhibit 8-3 compares the number of CWSs expected to be affected by the promulgation of the new standard to the number of systems not expected to undertake or modify any of their existing treatment practices. Six percent of small CWSs and NTNC water systems are expected to have to modify or install treatment.

EPA compared the ratio of compliance cost to revenue to the threshold value for significant impacts of one percent under the revised arsenic standard of 10 µg/L. In Exhibit 8-2, the ratios are displayed separately for small governments, small businesses, and small organizations, and cumulatively for all small entities.

A significant impact is generally defined as costs equal to or greater than one percent of revenues. Costs are equal to or greater than one percent of revenues only among small government entities that are expected to modify or install treatment at the revised MCL. The vast majority of water systems will see impacts less than one percent of their annual revenue. However, EPA's estimates show a number of small systems that will incur significant costs. Therefore, EPA is not certifying this rule as having no significant impact on small entities.

### 8.2.3 Summary of EPA's Small Business Consultations

As required by section 609(b) of the RFA, as amended by SBREFA, EPA also conducted outreach to small entities and convened a Small Business Advocacy Review Panel to obtain advice and recommendations of representatives of the small entities that potentially would be subject to the rule's requirements.

EPA identified 22 representatives of small entities, in this situation small systems, that were most likely to be subject to the proposal. In December 1998, EPA prepared and distributed to the small entity representatives (SERs) an outreach document on the Arsenic Rule titled "Information for Small Entity Representatives Regarding the Arsenic in Drinking Water Rule" (EPA, 1998 ).

On December 18, 1998, EPA held a SER conference call for small systems from Washington, DC, to provide a forum for input on key issues related to the planned proposal of the Arsenic in Drinking Water Rule. These issues included, but were not limited to, issues related to the rule development, such as arsenic health risks, treatment technologies, analytical methods, and monitoring. Fifteen SERs from small water systems participated on the call from the following States: Alabama, Arizona, California, Georgia, Massachusetts, Montana, Nebraska, New Hampshire, New Jersey, Utah, Virginia, Washington, and Wisconsin.

Efforts to identify and incorporate small entity concerns into this rulemaking culminated with the convening of a SBAR Panel on March 30, 1999, pursuant to section 609 of RFA/SBREFA. The four person Panel was headed by EPA's Small Business Advocacy Chairperson and included the Director of the Standards and Risk Management Division within EPA's Office of Ground Water and Drinking Water, the Administrator of the Office of Information and Regulatory Affairs with the Office of Management and Budget, and the Chief Counsel for Advocacy of the SBA. For a 60-day period starting on the convening date, the Panel reviewed technical background information related to this rulemaking, reviewed comments provided by the SERs, and met on several occasions. The Panel also conducted its own outreach to the SERs and held a conference call on April 21, 1999, with the SERs to identify issues and explore alternative approaches for accomplishing environmental protection goals while minimizing impacts to small entities. Consistent with the RFA/SBREFA requirements, the Panel evaluated the assembled materials and small-entity comments on issues related to the elements of the IRFA (See Section 8.2.1) . A copy of the June 4, 1999, Panel report is included in the docket for the Arsenic Rule (U.S. EPA, 1999).

The revised rule addresses all of the recommendations on which the Panel reached consensus. In addition, to help small systems comply with the Arsenic Rule, EPA is committed to addressing several other Panel recommendations regarding guidance, which are discussed in detail in the pages to follow.

### *Treatment Technologies, Waste Disposal, and Cost Estimates*

The Panel recommended the following: further develop the preliminary treatment and waste disposal cost estimates; fully consider these costs when identifying affordable compliance technologies for all system size categories; and provide information to small water systems on possible options for complying with the MCL, in addition to installing any listed compliance technologies.

In response to these recommendations, the Treatment and Cost document describes development of cost estimates for treatment and waste disposal; identification of affordable compliance technologies, including the consideration of cost; and options for complying with the MCL other than installing compliance technologies, such as selecting to regionalize.

Regarding point-of-use (POU) devices, the Panel recommended the following: continue to promote the use of POU devices as alternative treatment options for very small systems where appropriate; account for all costs, including costs that may not routinely be explicitly calculated; consider liability issues from POU/point-of-entry (POE) devices when evaluating their appropriateness as compliance technologies; and investigate waste disposal issues with POE devices.

In response to these recommendations, EPA included in the revised rule's preamble an expanded description regarding available POU compliance treatment technologies and conditions under which POU treatment may be appropriate for very small systems; a description of the components that contribute to the POU cost estimates; and a discussion that clarifies that water systems will be responsible for POU operation and maintenance to prevent liability issues from customers maintaining equipment themselves.

### *Relevance of Other Drinking Water Regulations*

The Panel recommended the following: include discussion of the co-occurrence of arsenic and radon in the Arsenic Rule; take possible interactions among treatments for different contaminants into account in costing compliance technologies and determining whether they are nationally affordable for small systems; and encourage systems to be forward-looking and test for multiple contaminants to determine if and how they would be affected by the upcoming rules. In response, the revised rule's preamble includes a discussion on the co-occurrence analysis of radon and arsenic: the treatment section of the preamble describes the relationship of treatment for arsenic with other drinking water rules and how this issue was taken into account in cost estimates. In addition, the preamble encourages systems to consider other upcoming rules when making future plans for monitoring or treatment.

### *Small Systems Variance Technologies and National Affordability Criteria*

The Panel recommended the following: include a discussion of the issues surrounding appropriate adjustment of its national affordability criteria to account for new regulatory requirements; consider revising its approach to national affordability criteria, to the extent allowed by statutory and regulatory requirements, to address the concern that the current cumulative approach for adjusting the baseline household water bills is based on chronological order rather than risk; and examine the data in the 1995 Community Water Supply Survey to determine if in-place treatment baselines can be linked with the current annual water bill baseline in each of the size categories for the revised Arsenic Rule.

In response to these recommendations, the treatment section of the revised rule's preamble includes an expanded discussion about the national affordability criteria and how it may be adjusted to account for new regulations. In addition, information regarding methodology and rationale is available to explain the national affordability approach.

### *Monitoring and Arsenic Species*

The Panel recommended the following: that EPA consider allowing States to use recent compliance monitoring data to satisfy initial sampling requirements or to obtain a waiver; and that EPA continue to explore whether or not to make a regulatory distinction between organic and inorganic arsenic based on compliance costs and other considerations.

In response, the monitoring section of the rule's preamble describes the allowance of monitoring data that meet analytical requirements and have reporting limits sufficiently below the revised MCL and collected after 1990.

### *Considerations in Setting the MCL*

The Panel recommended the following: in performing its obligations under SDWA, EPA should take cognizance of the scientific findings, the large scientific uncertainties, the large potential costs (including treatment and waste disposal costs), and the fact that this standard is scheduled for review in the future; give full consideration to the provisions of the Executive Order 12866 and to the option of exercising the new statutory authority under SDWA §1412(b)(4)(C) and §1412(b)(6)(A) in the development of the Arsenic Rule; and fully consider all of the "risk management" components of its rulemaking effort to ensure that the financial and other impacts on small systems are factored into its decision-making processes.  The Panel also recommended that EPA take into account both quantifiable and non-quantifiable costs and benefits of the standard and the needs of sensitive sub-populations.

In response to all these recommendations, EPA has described in detail the factors that were considered in setting in the MCL and provides the rationale for this selection.

### *Applicability of Proposal*

The Panel recommended that EPA carefully consider the appropriateness of extending the scope of the rule to non-transient non-community water systems (NTNCWSs).

In response, EPA has broadened the rule to include NTNCWSs. EPA has described the basis for this decision in the MCL section of the preamble, which includes a discussion of the incremental costs and benefits attributable to coverage of these water systems.

### *Other Issues*

The Panel recommended that EPA encourage small systems to discuss their infrastructure needs for complying with the Arsenic Rule with their primacy agency to determine their eligibility for Drinking Water State Revolving Fund (DWSRF) loans, and if eligible, to ask for assistance in applying for the loans. In response, the UMRA analysis has been expanded to discuss funding options for small systems and to encourage systems to be proactive in communicating with their primacy agency.

Regarding health effects, the Panel recommended the following: further evaluate the Utah study and its relationship to the studies on which the NRC report was based and give it appropriate weight in the risk assessment for the revised arsenic standard; and examine the NRC recommendations in the light of the uncertainties associated with the report's recommendations, and any new data that may not have been considered in the NRC report. In response to these recommendations, the benefits analysis includes a discussion of the qualitative benefits evaluation and use of research data.

## 8.2.4 Small System Affordability

Section 1415(e)(1) of SDWA allows States to grant variances to small water systems (i.e., systems having fewer than 10,000 customers) in lieu of complying with an MCL if EPA determines that there are no nationally affordable compliance technologies for that system size/water quality combination. The system must then install an EPA-listed variance treatment technology (§1412(b)(15)) that makes progress toward the MCL, if not necessarily reaching it. To list variance technologies, three showings must be made:

(1) EPA must determine, on a national level, that there are no compliance technologies that are affordable for the given small system size category/source water quality combination.

(2) If there is no nationally affordable compliance technology, then EPA must identify a variance technology that may not reach the MCL but that will allow small systems to make progress toward the MCL (it must achieve the maximum reduction affordable). This technology must also be listed as a small systems variance technology by EPA in order for small systems to be able to rely on it for regulatory purposes.

(3) EPA must make a finding on a national level, that use of the variance technology would be protective of public health.

States must then make a site-specific determination for each system as to whether or not the system can afford to meet the MCL based on State-developed affordability criteria. If the State determines that compliance is not affordable for the system, it may grant a variance, but it must establish terms and conditions, as necessary, to ensure that the variance is adequately protective of human health.

In the Agency's draft national-level affordability criteria published in the August 6, 1998 *Federal Register*, EPA discussed the affordable treatment technology determinations for the contaminants regulated before 1996. The national-level affordability criteria were derived as follows. First an "affordability threshold" was calculated. The affordability threshold was based on the total annual household water bill as a percentage of household income. In developing this threshold value, EPA considered the percentage of median household income spent by an average household on comparable goods and services such items as housing (28 percent), transportation (16 percent), food (12 percent), energy and fuels (3.3 percent), telephone (1.9 percent), water and other public services (0.7 percent), entertainment (4.4 percent) and alcohol and tobacco (1.5 percent).

Another of the key factors that EPA used to select an affordability threshold was cost comparisons with other risk reduction activities for drinking water. Section 1412(b)(4)(E)(ii) of the SDWA identifies both point-of-entry and point-of-use devices as options for compliance technologies. EPA examined the projected costs of these options. EPA also investigated the costs associated with supplying bottled water for drinking and cooking purposes. The median income percentages that were associated with these risk reduction activities were: POE (> 2.5 percent), POU (2 percent) and bottled water (> 2.5 percent).

Based on the foregoing analysis, EPA developed an affordability criteria of 2.5 percent of median household income, or about $750, for the affordability threshold (EPA, 1998). The median water bill for households in each small system category was then subtracted from this threshold to determine the additional expenditure per household that was considered affordable for new treatment. This difference is referred to as the "available expenditure margin." Based on EPA's 1995 Community Water System Survey, median water bills were about $250 per year for small system customers. Thus, an average available expenditure margin of up to $500 per year per household was considered affordable for the contaminants regulated before 1996. EPA next identified treatment technologies for all pre-1996 contaminants with average per household costs below $500 per year. Therefore, it was not necessary to list any small system variance technologies for existing contaminant rules.

Applying this criterion to the case of arsenic in drinking water, EPA has determined that affordable technologies exist for all system size categories and has therefore not identified a variance technology for any system size or source water combination at an MCL of 10 µg/L (see Exhibit 8-4). In other words, annual household costs after installation of the compliance technology are projected to be below the available affordability threshold for all system size categories for MCLs of 3, 5, 10, and 20 µg/L.

**Exhibit 8-4**
**Mean Annual Costs to Households Served by CWSs, by Size Category**

| System Size | MCL ($\mu$g/L) | | | |
|---|---|---|---|---|
| | 3 | 5 | 10 | 20 |
| **<100** | $317.00 | $318.26 | $326.82 | $351.15 |
| **101-500** | $166.91 | $164.02 | $162.50 | $166.72 |
| **501-1,000** | $74.81 | $73.11 | $70.72 | $68.24 |
| **1,001-3,300** | $63.76 | $61.94 | $58.24 | $54.36 |
| **3,301-10,000** | $42.84 | $40.18 | $37.71 | $34.63 |
| **10,001-50,000** | $38.40 | $36.07 | $32.37 | $29.05 |
| **50,001-100,000** | $31.63 | $29.45 | $24.81 | $22.63 |
| **100,001-1,000,000** | $25.29 | $23.34 | $20.52 | $19.26 |
| **>1,000,000** | $7.41 | $2.79 | $0.86 | $0.15 |
| **All categories** | $41.34 | $36.95 | $31.85 | $23.95 |

EPA recognizes that individual water systems may have higher than average treatment costs, fewer than average households to absorb these costs, or lower than average incomes, but believes that the affordability criteria should be based on characteristics of typical systems and should not address situations where costs might be extremely high or low or excessively burdensome. EPA believes that there are other mechanisms that may address these situations to a certain extent. In any case, EPA believes that small system variances should be the exception and not the rule.

EPA expects the available expenditure margin to be lower than $500 per household per year for the Arsenic Rule because some sources of data, for example the Current Population Survey, indicate that water rates are currently increasing faster than median household income. Thus, the "baseline" for annual water bills will rise as treatment is installed for compliance with regulations promulgated after 1996, but before the Arsenic Rule is promulgated.

EPA notes, however, that high water costs are often associated with systems that have already installed treatment to comply with an NPDWR. Such in-place treatment facilities may facilitate compliance with future standards. EPA's approach to establishing the national-level affordability criteria did not incorporate a baseline for in-place treatment technology. Assuming that systems with high baseline water costs would need to install a new treatment technology to comply with an NPDWR may thus overestimate the actual costs for some systems.

To investigate this issue, during the derivation of the national-level affordability criteria, EPA examined a group of five small surface water systems with annual water bills above $500 per household per year. All of these systems had installed disinfection and filtration technologies to comply with the Surface Water Treatment Rule. If these systems were required to install treatment to comply with the revised arsenic standard, modification of the existing processes would be much more cost-effective than adding a new technology. As a result, because these systems have already made the investment in treatment technology, and the cost is incorporated into current annual household water bills, costs to the household may not increase substantially.

Installing new technologies may interfere with in-place treatment or require additional treatment to address side effects, which will increase costs over the arsenic treatment technology base costs. For example, EPA assumed that CWSs would put corrosion control in place when the percent removal required was greater than 90 percent.

EPA believes that there is another mechanism in the SDWA to address cost impacts on small systems composed primarily of low-income households. Systems that meet criteria established by the State could be classified as disadvantaged communities under §1452(d) of the SDWA. They can receive additional subsidization under DWSRF, including forgiveness of principal. Under DWSRF, States must provide a minimum of 15 percent of the available funds for loans to small communities and have the option of providing up to 30 percent of the grant to provide additional loan subsidies to the disadvantaged systems, as defined by the State.

## 8.3 Coordination With Other Federal Rules

Several Federal drinking water rules are under development involving treatment requirements that may relate to the treatment of arsenic for this drinking water rule. Although it is very difficult to determine how compliance with the Arsenic Rule might affect compliance with other drinking water regulations, the following briefly describes each rule, the impact the Arsenic Rule may have on that rule, and/or how each rule may impact the arsenic standard. The Arsenic Rule will be promulgated in a similar time frame as the Ground Water Rule, the Radon Rule, and the Microbial and Disinfection By-Product Rule.

### 8.3.1 Ground Water Rule (GWR)

The goals of the GWR are to: (1) provide a consistent level of public health protection; (2) prevent waterborne microbial disease outbreaks; (3) reduce endemic waterborne disease; and (4) prevent fecal contamination from reaching consumers. To ensure public health protection, EPA has the responsibility to develop a GWR that not only specifies the appropriate use of disinfection, but also addresses other components of ground water systems. This general provision is supplemented with an additional requirement that EPA develop regulations specifying the use of disinfectants for ground water systems as necessary. To meet these requirements, EPA is working with stakeholders to develop a final GWR by Spring 2001.

The GWR will result in more systems using disinfection. If a system does add a disinfection technology, it may contribute to arsenic pre-oxidation. This largely depends on the type of disinfection technology employed. For example, if a system chooses a technology such as ultraviolet radiation, it may not affect arsenic pre-oxidation. However, if it chooses chlorination, it will contribute to arsenic pre-oxidation. Arsenic pre-oxidation from arsenic (III) to arsenic (V) will enhance the removal efficiencies of the technologies. Another option is that systems may use membrane filtration for the GWR. In that case, depending on the size of the membrane, some arsenic removal can be achieved. Thus, the GWR is expected to alleviate some of the burden of the Arsenic Rule.

### 8.3.2 Radon

EPA proposed the Radon Rule in November 1999. One option for compliance with the Radon Rule that systems may employ is coagulation and assisted microfiltration. This technology will be sufficient to meet the revised arsenic standard as well. Thus, the Radon Rule is expected to alleviate some of the burden of the Arsenic Rule.

### 8.3.3 Microbial and Disinfection By-Product Regulations

To control disinfection and disinfection by-products and to strengthen control of microbial pathogens in drinking water, EPA has developed a group of interrelated regulations, as required by the SDWA. These regulations, referred to collectively as the Microbial Disinfection By-product (M/DBP) Rules, are intended to address risk trade-offs between the two different types of contaminants.

EPA proposed a Stage 1 Disinfectants/Disinfection By-Products Rule (DBPR) and Interim Enhanced Surface Water Treatment Rule (IESWTR) in July 1994. EPA issued the final Stage 1 DBPR and IESWTR in November 1998.

The Agency has finalized and is currently implementing a third rule, the Information Collection Rule, that will provide data to support development of subsequent M/DBP regulations. These subsequent rules include a Stage 2 DBPR and a companion Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Stage 1 DBPR and IESWTR will primarily affect large surface water systems; thus, EPA does not expect much overlap with small systems treating for arsenic. Stage 2 DBPR and possibly the LT2ESWTR, however, could have significance as far as arsenic removal is concerned. For systems removing DBP precursors, systems may use nanofiltration. The use of nanofiltration would also be relevant for removing arsenic, and as a result, would ease some burden when systems implement these later rules.

## 8.4 Minimization of Economic Burden

The revised Arsenic Rule includes several provisions that will insure that the economic burden to water systems is minimized, while still ensuring that the public health objectives of the rule are met. First, the rule is developed around the concept of a performance target known as the maximum contaminant level (MCL). Rather than prescribe a single treatment technique that must be installed in all water systems, EPA is only requiring those systems that currently provide finished water with an arsenic concentration above the target to undertake or modify treatment. As seen above, this will exclude the vast majority of systems from having to undertake any additional treatment under the revised Arsenic Rule. In addition, if a system does have to undertake or modify treatment, EPA is allowing systems to choose from a broad list of technologies and is encouraging systems to choose the treatment technique that minimizes their total costs.

Second, EPA is allowing States to grant nine-year monitoring waivers to those systems that have a history of arsenic monitoring results below the revised MCL, and that do not show a substantial risk of future arsenic contamination. This provision of the rule will further reduce the cost to systems that currently provide finished water with low arsenic concentrations.

Finally, EPA is allowing small systems with finished water concentrations above the revised MCL to install POU technologies. This option will further allow small systems to minimize their total cost of compliance with the revised rule.

## 8.5 Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), P.L. 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments, and the private sector. Under UMRA Section 202, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures to State, local, and Tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year.

Before promulgating an EPA rule for which a written statement is needed, Section 205 of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule. The provisions of Section 205 do not apply when they are inconsistent with applicable law. Moreover, Section 205 allows EPA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if the Administrator publishes an explanation why the more "costly" alternative was preferred for the final rule.

Prior to establishing any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, EPA must develop a small government agency plan under Section 203 of the UMRA. The plan must provide for notifying potentially affected small governments; enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates; and informing, educating, and advising small governments on compliance with the regulatory requirements.

EPA has determined that this rule contains a Federal mandate that may result in expenditures of $100 million or more for State, local, and Tribal governments, in the aggregate and the private sector in any one year. Accordingly, under Section 202 of the UMRA, EPA is obligated to prepare a written statement addressing:

1. The authorizing legislation;

2. Cost-benefit analysis including an analysis of the extent to which the costs of State, local, and Tribal governments will be paid for by the Federal government;

3. Estimates of future compliance costs and disproportionate budgetary effects;

4. Macro-economic effects;

5. A summary of EPA's consultation with State, local, and Tribal governments and their concerns, including a summary of the Agency's evaluation of those comments and concerns; and

6. Identification and consideration of regulatory alternatives and the selection of the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule.

The legislative authority for the Arsenic Rule is discussed in Chapter 2. Items two through five are addressed below, with the exception of future compliance costs, which are discussed in Chapter 6. Regulatory alternatives, the last item, are addressed in Chapters 3, 6, and 7.

### 8.5.1 Social Costs and Benefits

Chapters 5, 6, and 7 contain a detailed cost-benefit analysis in support of the Arsenic Rule. At a seven percent discount rate, the Arsenic Rule is expected to have a total annualized cost of $792.1 million for a MCL of 3 µg/L, $471.7 million for a MCL 5 µg/L, $205.6 million for a MCL of 10 µg/L, and $76.5 million for a MCL of 20 µg/L.

EPA estimates that the Arsenic Rule will have total health benefits as a result of avoided bladder and lung cancer cases of approximately $213.8 to $490.9 million if the MCL were set at 3 µg/L, $191.1 to $355.6 million if the MCL were set at 5 µg/L, $139.6 to $197.7 million if the MCL were set at 10 µg/L, and $66.2 to $75.3 million if the MCL were set at 20 µg/L. These monetized health benefits of reducing arsenic exposures in drinking water are attributable to the reduced incidence of fatal and non-fatal bladder cancer and lung cancer. Currently under baseline assumptions (no control of arsenic exposure), there are annual fatal cancers and non-fatal cancers associated with arsenic exposures through CWSs. At an arsenic MCL level of 3 µg/L, an estimated 33 to 74 fatal cancers and 25 to 64 non-fatal cancers per year are prevented; at a arsenic level of 5 µg/L, an estimated 29 to 54 fatal cancers and 22 to 47 non-fatal cancers per year are prevented; at 10 µg/L, 21 to 30 fatal and 16 to 26 non-fatal cancers per year are prevented; and at 20 µg/L, 10 to 11 fatal and approximately 9 non-fatal cancers per year are prevented. A more detailed discussion of the total cancer risk and health benefits calculation may be found in Chapter 5, "Benefits Analysis."

In addition to quantifiable benefits, in Chapter 5, EPA has identified many potential non-quantifiable benefits associated with reducing arsenic exposures in drinking water. These potential benefits are not able to be quantified at this time, but may include reduced risk of skin cancer and numerous non-cancerous health effects. In addition, certain non-health related benefits may exists, such as ecological improvements and an increase in consumers' perception of drinking water.

### 8.5.2 State Administrative Costs

States will incur a range of administrative costs in complying with the Arsenic Rule. Administrative costs can include program management, inspections, and enforcement activities. EPA estimates that the total annual costs of State administrative activities for compliance with the MCL at a seven percent discount rate are approximately $1.7 million for an MCL of 3 µg/L, $1.4 million for an MCL of 5 µg/L, $1.2 million for an MCL of 10µg/L, and $1.0 million for an MCL of 20µg/L.

Various Federal programs exist to provide financial assistance to State, local, and Tribal governments in complying with this rule. The Federal government provides funding to States that have a primary enforcement responsibility for their drinking water programs through the Public Water Systems Supervision (PWSS) Grants program. Additional funding is available from other programs administered either by EPA or other Federal agencies. These include the Drinking Water State Revolving Fund (DWSRF) and Housing and Urban Development's Community Development Block Grant Program. For example, the SDWA authorizes the Administrator of the EPA to award capitalization grants to States, which in turn can provide low-cost loans and other types of assistance to eligible public water systems. The DWSRF also assists public water systems with financing the costs of infrastructure needed to achieve or maintain compliance with SDWA requirements. Each State will have considerable flexibility to determine the design of its program and to direct funding toward its most pressing compliance and public health protection needs. States may also, on a matching basis, use up to ten percent of their DWSRF allotments for each fiscal year to assist in running the State drinking water program.

Under PWSS Program Assistance Grants, the Administrator may make grants to States to carry out public water system supervision programs. One State use of these funds is to develop primacy programs. States may "contract" with other State agencies to assist in the development or implementation of their primacy program. However, States may not use program assistance grant funds to contract with regulated entities (i.e., water systems). PWSS Grants may be used by States to set up and administer a State program that includes such activities as public education, testing, training, technical assistance, development and administration of a remediation grant and loan or incentive program (excludes the actual grant or loan funds), or other regulatory or non-regulatory measures.

### 8.5.3 Future Compliance Costs and Disproportionate Budgetary Effects

To meet the requirement in Section 202 of the UMRA, EPA analyzed future compliance costs and possible disproportionate budgetary effects of the MCL options. The Agency believes that the cost estimates, shown in Exhibit 8-5 and discussed in more detail in Chapter 6, accurately characterize future compliance costs of the revised rule.

With regard to the disproportionate impacts, EPA considered available data sources in analyzing the disproportionate impacts upon geographic or social segments of the nation or industry. To the extent that there may be disproportionate impacts to low-income or other segments of the population, EPA will prepare a small entity compliance guide, a monitoring/analytical manual, and a small systems technology manual that will assist the public and private sector. To fully consider the potential disproportionate impacts of this revised rule, EPA also developed three other measures:

(1) Reviewing the impacts on small versus large systems;
(2) Reviewing the costs to public versus private water systems; and
(3) Reviewing the household costs for the revised rule.

The first measure, the national impacts on small versus large systems, is shown in Exhibit 8-5. Small systems are defined as those systems serving 10,000 people or less, and large systems are those systems serving more than 10,000 people.

The second measure of disproportionate impacts evaluated is the relative total costs to public versus private water systems, by size. Exhibit 8-5 also presents the annual system level costs for public and private systems by system size category for MCLs of 3 µg/L, 5 µg/L, 10 µg/L, and 20 µg/L. The costs are slightly lower for private systems across system sizes for all options. For example, for systems serving less than 100 people at the 10 µg/L MCL public system costs are $7,948, and private system costs are $6,335.

**Exhibit 8-5**
**Average Annual Cost per CWS Exceeding the MCL, by Ownership**

| System Size | Treatment and Monitoring Costs | | Total Cost |
|---|---|---|---|
| | Public | Private | All Systems |
| **MCL = 3 µg/L** | | | |
| <100 | $ 8,020 | $ 6,388 | $ 6,546 |
| 101-500 | $ 15,319 | $ 12,033 | $ 13,042 |
| 501-1,000 | $ 25,069 | $ 21,659 | $ 23,720 |
| 1,001-3,300 | $ 61,375 | $ 51,687 | $ 58,672 |
| 3,301-10,000 | $ 133,297 | $ 112,397 | $ 129,531 |
| 10,001-1,000,000 | $ 648,756 | $ 621,841 | $ 644,176 |
| >1,000,000 | $ 10,360,933 | -- | $ 10,360,933 |
| **MCL = 5 µg/L** | | | |
| <100 | $ 8,065 | $ 6,384 | $ 6,551 |
| 101-500 | $ 14,845 | $ 11,762 | $ 12,712 |
| 501-1,000 | $ 24,406 | $ 21,175 | $ 23,146 |
| 1,001-3,300 | $ 59,998 | $ 49,055 | $ 56,911 |
| 3,301-10,000 | $ 124,483 | $ 103,388 | $ 120,621 |
| 10,001-1,000,000 | $ 601,335 | $ 584,831 | $ 598,488 |
| >1,000,000 | $ 4,129,338 | -- | $ 4,129,338 |
| **MCL = 10 µg/L** | | | |
| <100 | $ 7,948 | $ 6,335 | $ 6,494 |
| 101-500 | $ 14,503 | $ 11,357 | $ 12,358 |
| 501-1,000 | $ 23,424 | $ 20,042 | $ 22,100 |
| 1,001-3,300 | $ 55,789 | $ 46,243 | $ 53,086 |
| 3,301-10,000 | $ 114,790 | $ 98,138 | $ 111,646 |
| 10,001-1,000,000 | $ 543,053 | $ 477,614 | $ 531,584 |
| >1,000,000 | $ 1,340,716 | -- | $ 1,340,716 |
| **MCL = 20 µg/L** | | | |
| <100 | $ 7,785 | $ 6,209 | $ 6,361 |
| 101-500 | $ 13,814 | $ 11,065 | $ 11,902 |
| 501-1,000 | $ 21,733 | $ 18,877 | $ 20,595 |
| 1,001-3,300 | $ 51,116 | $ 42,869 | $ 48,779 |
| 3,301-10,000 | $ 105,155 | $ 85,201 | $ 101,374 |
| 10,001-1,000,000 | $ 482,300 | $ 443,463 | $ 475,909 |
| >1,000,000 | $ 189,916 | -- | $ 189,916 |

*Costs were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; note that systems serving over 1 million people are public surface water systems.

The third measure, household costs, can also be used to gauge the impact of a regulation and to determine whether there are disproportionately higher impacts in particular segments of the population. A detailed analysis of household cost impacts by system size is presented in Chapter 6. The costs for households served by public and private water systems are presented in Exhibit 8-6. As expected, cost per household increases as system size decreases. Cost per household is usually higher for households served by smaller systems than larger systems. This holds because smaller systems produce less water than large systems and are therefore unable to utilize economies of scale. Consequently, each household must bear a greater percentage share of the system's costs.

Exhibit 8-6 presents the costs per household for systems exceeding the MCL. For each size category there is a moderate difference in annual cost per household for 3 µg/L, 5 µg/L, 10 µg/L, and 20 µg/L across source and ownership. In general, costs per household are higher for private systems than for public systems. This difference could be attributable to a discrepancy in the cost of capital for public versus private entities. For public systems, the cost per household ranges from approximately $5 to $288 per year at 5 µg/L and from approximately $5 to $285 per year at 10 µg/L (excluding systems serving more than one million people). For private systems, the ranges are $4 to $317 per year, and $4 to $314 per year for an MCL of 5 µg/L and 10 µg/L, respectively.

To further evaluate the impacts of these household costs, the average costs per household were compared to median household income data for each system-size category. The result of this calculation, presented in Exhibit 8-7 for public and private systems, indicate a household's likely share of incremental costs in terms of its household income. For all system sizes and MCLs, average household costs as a percentage of median household income are less than one percent.

Among NTNCs, the average annual system cost ranges from approximately $5,000 to $39,000 at the revised MCL of 10 µg/L. These results for systems exceeding the MCL are presented in Exhibit 8-8. At 3 µg/L, 5 µg/L, and 20 µg/L, the average NTNC system cost ranges from $5,000 to $46,000, $5,000 to $43,000 and $5,000 to $35,000, respectively. More detail on the costs to NTNCs at these arsenic concentrations are presented in Chapter 6.

**Exhibit 8-6**
**Annual Compliance Costs per Household for CWSs Exceeding MCLs**

| System Size | Groundwater | | Surface Water | |
|---|---|---|---|---|
| | Public | Private | Public | Private |
| **MCL = 3 $\mu$g/L** | | | | |
| <100 | $ 285.93 | $ 319.62 | $ 218.47 | $ 231.50 |
| 101-500 | $ 134.47 | $ 190.51 | $ 54.75 | $ 72.52 |
| 501-1,000 | $ 79.11 | $ 76.64 | $ 15.22 | $ 13.98 |
| 1,001-3,300 | $ 64.50 | $ 84.32 | $ 5.77 | $ 7.52 |
| 3,301-10,000 | $ 45.79 | $ 65.42 | $ 3.74 | $ 4.33 |
| 10,001-1,000,000 | $ 40.77 | $ 39.67 | $ 5.39 | $ 4.62 |
| >1,000,000 | -- | -- | $ 7.41 | -- |
| **MCL = 5 $\mu$g/L** | | | | |
| <100 | $ 287.87 | $ 316.80 | $ 212.32 | $ 229.78 |
| 101-500 | $ 130.86 | $ 185.83 | $ 54.03 | $ 72.33 |
| 501-1,000 | $ 76.45 | $ 74.18 | $ 14.91 | $ 14.14 |
| 1,001-3,300 | $ 62.56 | $ 79.01 | $ 5.68 | $ 7.03 |
| 3,301-10,000 | $ 42.18 | $ 59.84 | $ 3.52 | $ 4.23 |
| 10,001-1,000,000 | $ 36.99 | $ 36.22 | $ 5.00 | $ 4.26 |
| >1,000,000 | -- | -- | $ 2.79 | -- |
| **MCL = 10 $\mu$g/L** | | | | |
| <100 | $ 285.03 | $ 314.11 | $ 214.23 | $ 229.02 |
| 101-500 | $ 126.46 | $ 180.21 | $ 52.72 | $ 71.01 |
| 501-1,000 | $ 72.51 | $ 69.87 | $ 14.23 | $ 13.93 |
| 1,001-3,300 | $ 56.76 | $ 73.42 | $ 5.51 | $ 6.81 |
| 3,301-10,000 | $ 38.08 | $ 55.35 | $ 3.13 | $ 4.03 |
| 10,001-1,000,000 | $ 31.72 | $ 30.78 | $ 4.55 | $ 3.99 |
| >1,000,000 | -- | -- | $ 0.86 | -- |
| **MCL = 20 $\mu$g/L** | | | | |
| <100 | $ 275.00 | $ 306.52 | $ 204.17 | $ 228.82 |
| 101-500 | $ 120.19 | $ 174.69 | $ 51.42 | $ 68.96 |
| 501-1,000 | $ 66.07 | $ 65.39 | $ 14.52 | $ 13.39 |
| 1,001-3,300 | $ 50.44 | $ 67.25 | $ 5.21 | $ 6.48 |
| 3,301-10,000 | $ 33.86 | $ 48.00 | $ 2.84 | $ 3.69 |
| 10,001-1,000,000 | $ 26.59 | $ 26.02 | $ 4.14 | $ - |
| >1,000,000 | -- | -- | $ 0.15 | -- |

*Costs to households were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; note that systems serving over 1 million people are public surface water systems.

**Exhibit 8-7**
**Annual Compliance Costs per Household for CWSs Exceeding MCLs, as a Percent of Median Household Income**

| System Size | Groundwater | | Surface Water | |
|---|---|---|---|---|
| | Public | Private | Public | Private |
| **MCL = 3 $\mu g/L$** | | | | |
| <100 | 0.72% | 0.81% | 0.55% | 0.58% |
| 101-500 | 0.34% | 0.48% | 0.14% | 0.18% |
| 501-1,000 | 0.20% | 0.19% | 0.04% | 0.04% |
| 1,001-3,300 | 0.16% | 0.21% | 0.01% | 0.02% |
| 3,301-10,000 | 0.12% | 0.17% | 0.01% | 0.01% |
| 10,001-1,000,000 | 0.10% | 0.10% | 0.01% | 0.01% |
| >1,000,000 | -- | -- | 0.02% | -- |
| **MCL = 5 $\mu g/L$** | | | | |
| <100 | 0.73% | 0.80% | 0.54% | 0.58% |
| 101-500 | 0.33% | 0.47% | 0.14% | 0.18% |
| 501-1,000 | 0.19% | 0.19% | 0.04% | 0.04% |
| 1,001-3,300 | 0.16% | 0.20% | 0.01% | 0.02% |
| 3,301-10,000 | 0.11% | 0.15% | 0.01% | 0.01% |
| 10,001-1,000,000 | 0.09% | 0.09% | 0.01% | 0.01% |
| >1,000,000 | -- | -- | 0.01% | -- |
| **MCL = 10 $\mu g/L$** | | | | |
| <100 | 0.72% | 0.79% | 0.54% | 0.58% |
| 101-500 | 0.32% | 0.45% | 0.13% | 0.18% |
| 501-1,000 | 0.18% | 0.18% | 0.04% | 0.04% |
| 1,001-3,300 | 0.14% | 0.19% | 0.01% | 0.02% |
| 3,301-10,000 | 0.10% | 0.14% | 0.01% | 0.01% |
| 10,001-1,000,000 | 0.08% | 0.08% | 0.01% | 0.01% |
| >1,000,000 | -- | -- | 0.00% | -- |
| **MCL = 20 $\mu g/L$** | | | | |
| <100 | 0.69% | 0.77% | 0.51% | 0.58% |
| 101-500 | 0.30% | 0.44% | 0.13% | 0.17% |
| 501-1,000 | 0.17% | 0.16% | 0.04% | 0.03% |
| 1,001-3,300 | 0.13% | 0.17% | 0.01% | 0.02% |
| 3,301-10,000 | 0.09% | 0.12% | 0.01% | 0.01% |
| 10,001-1,000,000 | 0.07% | 0.07% | 0.01% | 0.00% |
| >1,000,000 | -- | -- | 0.00% | -- |

*Costs to household were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; median household income in May 1999 was $39,648 updated from the 1998 annual median household income from the Census Bureau.

**Exhibit 8-8**
**Total Annual NTNC Treatment Costs at MCL 10 µg/L by System Service Type**
**(3% Discount Rate)**

| Service Area Type | # of Systems Above the MCL | Average Population Served Per System | Average Annual System Cost | Annual National Costs |
|---|---|---|---|---|
| Daycare Centers | 43 | 76 | $5,168 | $222,846 |
| Highway Rest Areas | 1 | 407 | $5,377 | $4,299 |
| Hotels/Motels | 19 | 133 | $5,956 | $111,420 |
| Interstate Carriers | 15 | 123 | $5,047 | $77,207 |
| Medical Facilities | 20 | 393 | $12,174 | $238,133 |
| Mobile Home Parks | 6 | 185 | $6,387 | $35,405 |
| Restaurants | 22 | 370 | $5,103 | $113,692 |
| Schools | 448 | 358 | $6,818 | $3,057,578 |
| Service Stations | 3 | 230 | $5,168 | $14,599 |
| Summer Camps | 2 | 146 | $6,124 | $15,014 |
| Water Wholesalers | 14 | 173 | $14,628 | $207,398 |
| Agricultural Products/Services | 20 | 76 | $6,012 | $117,930 |
| Airparks | 5 | 60 | $5,034 | $27,101 |
| Construction | 5 | 53 | $4,733 | $24,974 |
| Churches | 12 | 50 | $5,177 | $63,471 |
| Campgrounds/RV Parks | 7 | 160 | $6,104 | $40,017 |
| Fire Departments | 2 | 98 | $5,938 | $12,977 |
| Federal Parks | 1 | 39 | $5,245 | $5,592 |
| Forest Service | 6 | 42 | $4,783 | $27,278 |
| Golf and Country Clubs | 6 | 101 | $5,542 | $34,263 |
| Landfills | 4 | 44 | $5,176 | $21,517 |
| Mining | 6 | 113 | $5,572 | $35,340 |
| Amusement Parks | 8 | 418 | $5,848 | $49,558 |
| Military Bases | 5 | 395 | $9,095 | $46,053 |
| Migrant Labor Camps | 2 | 63 | $5,452 | $9,589 |
| Misc. Recreation Services | 14 | 87 | $5,027 | $69,397 |
| Nursing Homes | 7 | 107 | $7,298 | $50,567 |
| Office Parks | 51 | 136 | $5,310 | $268,864 |
| Prisons | 4 | 1,820 | $39,380 | $140,629 |
| Retailers (Non-food related) | 37 | 174 | $5,097 | $188,796 |
| Retailers (Food related) | 8 | 322 | $5,205 | $39,394 |
| State Parks | 4 | 165 | $5,153 | $22,794 |
| Non-Water Utilities | 26 | 170 | $5,627 | $149,069 |
| Manufacturing: Food | 41 | 372 | $7,566 | $309,707 |
| Manufacturing: Non-Food | 205 | 168 | $5,780 | $1,184,505 |
| **TOTAL** | **1,080** | | | **$7,036,973** |

### 8.5.4 Macroeconomic Effects

As required under UMRA Section 202, EPA is required to estimate the potential macro-economic effects of the regulation. These include effects on productivity, economic growth, full employment, creation of productive jobs, and international competitiveness. Macro-economic effects tend to be measurable in nationwide econometric models only if the economic impact of the regulation reaches 0.25 percent to 0.5 percent of Gross Domestic Product (GDP). In 1998, real GDP was $7,552 billion; thus, a rule would have to cost at least $18 billion annually to have a measurable effect. A regulation with a smaller aggregate effect is unlikely to have any measurable impact unless it is highly focused on a particular geographic region or economic sector. The macro-economic effects on the national economy from the Arsenic Rule should be negligible based on the fact that, assuming 100 percent compliance with an MCL, the total annual costs are approximately $792 million at the 3 µg/L level, $472 million at the 5 µg/L level, $206 million at the 10 µg/L level, and $77 million at the 20 µg/L level (at a seven percent discount rate).

### 8.5.5 Consultation with State, Local, and Tribal Governments

Under UMRA section 204, EPA is to provide a summary of its consultation with elected representatives (or their designated authorized employees) of affected State, local, and Tribal governments in this rulemaking. EPA initiated consultations with governmental entities and the private sector affected by this rulemaking through various means. This included five stakeholder meetings announced in the *Federal Register* and open to anyone interested in attending in person or by phone, and presentations at meetings of the American Water Works Association (AWWA), the Association of State Drinking Water Administrators (ASDWA), the Association of California Water Agencies (ACWA), and the Association of Metropolitan Water Agencies (AMWA). Participants in EPA's stakeholder meetings also included representatives from the National Rural Water Association, AMWA, ASDWA, AWWA, ACWA, Rural Community Assistance Program, State departments of environmental protection, State health departments, State drinking water programs, and a Tribe. EPA also made presentations at Tribal meetings in Nevada, Alaska, and California.

To address the Arsenic Rule's impact on small entities, the Agency consulted with representatives of small water systems and convened a Small Business Advocacy Review Panel in accordance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA). Two of the small entity representatives were elected officials from local governments. EPA also invited State drinking water program representatives to participate in a number of workgroup meetings. In addition to these consultations, EPA participated in and gave presentations at AWWA's Technical Workgroup for Arsenic. State public health department and drinking water program representatives, drinking water districts, and ASDWA participated in the Technical Workgroup meetings. A summary of State, local, and Tribal government concerns on this rulemaking is shown in the next section.

In order to inform and involve Tribal governments in the rulemaking process, EPA staff attended the 16$^{th}$ Annual Consumer Conference of the National Indian Health Board on October 6-8, 1998, in Anchorage, Alaska. Over 900 attendees representing Tribes from across the country were in attendance. During the conference, EPA conducted two workshops for meeting participants. The objectives of the workshops were to present an overview of EPA's drinking water program, solicit comments on key issues of potential interest in upcoming drinking water regulations, and to solicit advice in identifying an effective consultative process with Tribes for the future.

EPA, in conjunction with the Inter Tribal Council of Arizona (ITCA), also convened a Tribal consultation meeting on February 24-25, 1999, in Las Vegas, Nevada, to discuss ways to involve Tribal representatives, both Tribal council members and tribal water utility operators, in the stakeholder process. Approximately 25 representatives from a diverse group of Tribes attended the two-day meeting. Meeting participants included representatives from the following Tribes: Cherokee Nation, Nezperce Tribe, Jicarilla Apache Tribe, Blackfeet Tribe, Seminole Tribe of Florida, Hopi Tribe, Cheyenne River Sioux Tribe, Menominee Indian Tribe, Tulalip Tribes, Mississippi Band of Choctaw Indians, Narragansett Indian Tribe, and Yakama Nation.

The major meeting objectives were to:

(1) Identify key issues of concern to Tribal representatives;
(2) Solicit input on issues concerning current Office of Ground Water and Drinking Water regulatory efforts;
(3) Solicit input and information that should be included in support of future drinking water regulations; and
(4) Provide an effective format for Tribal involvement in EPA's regulatory development process.

EPA staff also provided an overview on the forthcoming Arsenic Rule at the meeting. The presentation included the health concerns associated with arsenic, EPA's current position on arsenic in drinking water, the definition of an MCL, an explanation of the difference between point-of-use and point-of-entry treatment devices, and specific issues for Tribes. The following questions were posed to the Tribal representatives to begin discussion on arsenic in drinking water:

(1) What are the current arsenic levels in your water systems?
(2) What are Tribal water systems' affordability issues in regard to arsenic?
(3) Does your Tribe use well water, river water, or lake water?
(4) Does your Tribe purchase water from another drinking water utility?

The summary for the February 24-25, 1999, meeting was sent to all 565 Federally recognized Tribes in the United States.

EPA also conducted a series of workshops at the Annual Conference of the National Tribal Environmental Council, which was held on May 18-20, 1999, in Eureka, California. Representatives from over 50 Tribes attended all, or part, of these sessions. The objectives of the workshops were to provide an overview of forthcoming EPA regulations affecting water systems; discuss changes to operator certification requirements; discuss funding for Tribal water systems; and discuss innovative approaches to regulatory cost reduction. Meeting summaries for EPA's Tribal consultations are available in the public docket for this rulemaking.

### 8.5.6 State, Local, and Tribal Government Concerns

State and local governments raised several concerns, including the high costs of the rule to small systems; the burden of revising the State primacy program; the high degree of uncertainty associated with the benefits; and the high costs of including non-transient non-community water systems (NTNCWSs). EPA modified the revision of State primacy in order to decrease the burden of the revised arsenic regulation in response to State concerns, to minimize paperwork and documentation of existing programs that would manage the arsenic regulation.

Tribal representatives were generally supportive of regulations that would ensure a high level of water quality but raised concerns over funding for regulations. With regard to the revised Arsenic Rule, many Tribal representatives saw the health benefits as highly desirable, but felt that unless additional funds were made available, implementing the regulation would be difficult for many Tribes.

EPA understands the State, local, and Tribal government concerns with the above issues. The Agency believes the options for small systems in this rulemaking will address stakeholder concerns pertaining to small systems and will help to reduce the financial burden to these systems.

### 8.5.7 Regulatory Alternatives Considered

As required under Section 205 of the UMRA, EPA considered several regulatory alternatives in developing an MCL for arsenic in drinking water. In preparation for this consideration, EPA evaluated arsenic levels of 3 µg/L, 5 µg/L, 10 µg/L, and 20 µg/L. EPA also evaluated national costs and benefits of States choosing to reduce arsenic exposure in drinking water. EPA believes that the regulatory approaches to arsenic described in the revised rule's preamble are the most appropriate to accomplish the SDWA objectives.

### 8.5.8 Impacts on Small Governments

In developing this rule, EPA consulted with small governments pursuant to section 203 of the UMRA to address impacts of regulatory requirements in the rule that might significantly or uniquely affect small governments. In preparation for the revised Arsenic Rule, EPA conducted analysis on small government impacts and included small government officials or their designated representatives in the rulemaking process. EPA conducted stakeholder meetings on the development of the Arsenic Rule that gave a variety of stakeholders, including small governments, the opportunity for timely and meaningful participation in the regulatory development process. Groups such as the National Association of Towns and Townships, the National League of Cities, and the National Association of Counties participated in the rulemaking process. Through such participation and exchange, EPA notified potentially affected small governments of requirements under consideration during the development of the revised rule and provided officials of affected small governments with an opportunity to have meaningful and timely input into the development of the regulatory proposal.

In addition, EPA will educate, inform, and advise small systems, including those run by small governments, about the Arsenic Rule requirements. One of the most important components of this process is the Small Entity Compliance Guide, required by the Small Business Regulatory Enforcement Fairness Act of 1996 after the rule is promulgated. This plain-English guide will explain what actions a small entity must take to comply with the rule. Also, the Agency is developing fact sheets that concisely describe various aspects and requirements of the Arsenic Rule.

## 8.6 Effect of Compliance with the Arsenic Rule on the Technical, Financial, and Managerial Capacity of Public Water Systems

Section 1420(d)(3) of the SDWA as amended requires that, in promulgating an NPDWR, the Administrator shall include an analysis of the likely effect of compliance with the regulation on the technical, financial, and managerial capacity of public water systems. The following analysis has been performed to fulfill this statutory obligation.

Overall water system capacity is defined in EPA guidance (EPA 816-R-98-006) (EPA 1998) as the ability to plan for, achieve, and maintain compliance with applicable drinking water standards. Capacity has three components: technical, managerial, and financial.

Technical capacity is the physical and operational ability of a water system to meet SDWA requirements. Technical capacity refers to the physical infrastructure of the water system, including the adequacy of source water and the adequacy of treatment, storage, and distribution infrastructure. It also refers to the ability of system personnel to adequately operate and maintain the system and to otherwise implement requisite technical knowledge. A water system's technical capacity can be determined by examining key issues and questions, including:

- Source water adequacy. Does the system have a reliable source of drinking water? Is the source of generally good quality and adequately protected?

- Infrastructure adequacy. Can the system provide water that meets SDWA standards? What is the condition of its infrastructure, including well(s) or source water intakes, treatment, storage, and distribution? What is the infrastructure's life expectancy? Does the system have a capital improvement plan?

- Technical knowledge and implementation. Is the system's operator certified? Does the operator have sufficient technical knowledge of applicable standards? Can the operator effectively implement this technical knowledge? Does the operator understand the system's technical and operational characteristics? Does the system have an effective operation and maintenance program?

Managerial capacity is the ability of a water system to conduct its affairs in a manner enabling the system to achieve and maintain compliance with SDWA requirements. Managerial capacity refers to the system's institutional and administrative capabilities. Managerial capacity can be assessed through key issues and questions, including:

- Ownership accountability. Are the system owner(s) clearly identified? Can they be held accountable for the system?

- Staffing and organization. Are the system operator(s) and manager(s) clearly identified? Is the system properly organized and staffed? Do personnel understand the management aspects of regulatory requirements and system operations? Do they have adequate expertise to manage water system operations? Do personnel have the necessary licenses and certifications?

- Effective external linkages. Does the system interact well with customers, regulators, and other entities? Is the system aware of available external resources, such as technical and financial assistance?

Financial capacity is a water system's ability to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA requirements. Financial capacity can be assessed through key issues and questions, including:

- Revenue sufficiency. Do revenues cover costs? Are water rates and charges adequate to cover the cost of water?

- Credit worthiness. Is the system financially healthy? Does it have access to capital through public or private sources?

- Fiscal management and controls. Are adequate books and records maintained? Are appropriate budgeting, accounting, and financial planning methods used? Does the system manage its revenues effectively?

A complete technical, financial, and managerial capacity study is provided in the revised rule's preamble.

## 8.7 Paperwork Reduction Act

The information collected as a result of this rule will allow the States and EPA to evaluate PWS compliance with the rule. For the first three years after promulgation of this rule, the major information requirements pertain to reading and understanding the rule and operator training. Responses to the request for information are mandatory (Part 141). The information collected is not confidential.

EPA is required to estimate the burden on PWSs for complying with the revised rule. Burden means the total time, effort, or financial resources expended by persons to generate, maintain, retain, disclose, or provide information to or for a Federal agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to a collection of information; search data sources; complete and review the collection of information; and transmit or otherwise disclose the information.  The Information Collection Rule for the revised Arsenic Rule estimated a total burden of 3.09 million hours for 10 µg/L.

## 8.8 Protecting Children from Environmental Health Risks and Safety Risks

Executive Order (EO) 13045 (62 FR 19885, April 23, 1997) applies to any rule initiated after April 21, 1997, or proposed after April 21, 1998, that (1) is determined to be "economically significant" as defined under EO 12866 and (2) concerns an environmental health or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, EPA must evaluate the environmental health or safety effects of the planned rule on children, and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by EPA.

As described in Chapter 5 ("Benefits Analysis"), there are insufficient toxicological data to distinguish morbidity and mortality differences by age groups.  No studies were located by ATSDR (1998) that focused exclusively on evaluating unusual susceptibility to arsenic. However, some members of the population are likely to be especially susceptible. For example, Chapter 5 describes several non-carcinogenic effects that may be of greater concern to children than adults, such as cardiovascular or reproductive effects.  Similarly, arsenic has been suggested to pose significant problems in fetal development.  This increased susceptibility may be due to a variety of factors.  These factors include increased dose (intake per unit of body weight) in children, genetic predispositions, and dietary insufficiency (ATSDR, 1998), as well as pre-existing health conditions.

## 8.9 Environmental Justice

Executive Order 12898 establishes a Federal policy for incorporating environmental justice into Federal agency missions by directing agencies to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Executive Order requires the Agency to consider environmental justice issues in the rulemaking and to consult with Environmental Justice (EJ) stakeholders.

The Agency has considered environmental justice related issues concerning the potential impacts of this regulation and has determined that there are no substantial disproportionate effects. Because the Arsenic Rule applies to all community water systems, the majority of the population, including minority and low-income populations will benefit from the additional health protection.

## 8.10 Health Risk Reduction and Cost Analysis

Section 1412(b)(3)(C) of the 1996 Amendments requires EPA to prepare a Health Risk Reduction and Cost Analysis (HRRCA) in support of any NPDWR that includes an MCL. According to these requirements, EPA analyzed each of the following in revising the Arsenic Rule:

1. Quantifiable and non-quantifiable health risk reduction benefits for which there is a factual basis in the rulemaking record to conclude that such benefits are likely to occur as the result of treatment to comply with each level;

2. Quantifiable and non-quantifiable health risk reduction benefits for which there is a factual basis in the rulemaking record to conclude that such benefits are likely to occur from reductions in co-occurring contaminants that may be attributed solely to compliance with the MCL, excluding benefits resulting from compliance with other proposed or promulgated regulations;

3. Quantifiable and non-quantifiable costs for which there is a factual basis in the rulemaking record to conclude that such costs are likely to occur solely as a result of compliance with the MCL, including monitoring, treatment, and other costs, and excluding costs resulting from compliance with other proposed or promulgated regulations;

4. The incremental costs and benefits associated with each alternative MCL considered;

5. The effects of the contaminant on the general population and on groups within the general population, such as infants, children, pregnant women, the elderly, individuals with a history of serious illness, or other sub-populations that are identified as likely to be at greater risk of adverse health effects due to exposure to contaminants in drinking water than the general population;

6. Any increased health risk that may occur as the result of compliance, including risks associated with co-occurring contaminants; and

7. Other relevant factors, including the quality and extent of the information, the uncertainties in the analysis, and factors with respect to the degree and nature of the risk.

This analysis summarizes EPA's estimates of the costs and benefits associated with various arsenic levels. The summary tables below characterize aggregate costs and benefits, impacts on affected entities, and tradeoffs between risk reduction and compliance costs.

### 8.10.1 Quantifiable and Non-Quantifiable Health Risk Reduction Benefits

Arsenic ingestion has been linked to a multitude of health effects, both cancerous and non-cancerous. These health effects include cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Arsenic ingestion has also been attributed to cardiovascular, pulmonary, immunological, neurological, endocrine, and reproductive and developmental effects. A complete list of the arsenic-related health effects reported in humans is shown in Chapter 5. EPA has performed a risk assessment on bladder cancer and lung cancer. EPA then evaluated the health benefits attributable to these total cancer cases avoided.

The quantifiable health benefits of reducing arsenic exposures in drinking water are attributable to the reduced number of fatal and non-fatal bladder and lung cancers. The range of mean bladder and lung cancer risks for exposed populations at or above arsenic levels of 3, 5, 10, and 20 µg/L in PWSs was described in Chapter 5. Exhibit 8-9 shows the health risk reductions (number of total bladder cancers avoided and the proportions of fatal and non-fatal bladder cancers avoided) at 3, 5, 10, and 20 µg/L, corresponding to the range of mean bladder cancer risks reported. Similarly, Exhibit 8-10 shows the total lung cancer cases avoided as a result of reduced arsenic exposure in PWSs. The sum of bladder cancer cases avoided and lung cancer cases avoided is shown in Exhibit 8-11.

**Exhibit 8-9**
**Annual Bladder Cancer Cases Avoided from Reducing Arsenic in CWSs[1] and NTNCs**

| Arsenic Level (µg/L) | Reduced Mortality Cases** | Reduced Morbidity Cases** | Total Bladder Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 7.4 - 20.0 | 21.2 - 56.9 | 28.6 - 76.8 |
| 5 | 6.6 - 14.5 | 18.9 - 41.2 | 25.6 - 55.7 |
| 10 | 4.9 - 8.0 | 13.8 - 22.7 | 18.7 - 31.0 |
| 20 | 2.6 - 2.8 | 7.3 - 7.8 | 9.9 - 10.6 |

* The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate from Exhibit 5-9(c) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the upper-end risk estimate from Exhibit 5-9(c) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
**Assuming 20-year mortality rate in the U.S. of 26 percent.
***Cases avoided from NTNCS are included.

**Exhibit 8-10**
**Annual Lung Cancer Cases Avoided from Reducing Arsenic in CWSs and NTNCs**

| Arsenic Level (µg/L) | Reduced Mortality Cases** | Reduced Morbidity Cases** | Total Lung Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 25.2 - 54.1 | 3.4 - 7.4 | 28.6 - 61.5 |
| 5 | 22.5 - 39.2 | 3.1 - 5.3 | 25.6 - 44.5 |
| 10 | 16.4 - 21.8 | 2.2 - 3.0 | 18.7 - 24.8 |
| 20 | 7.4 - 8.7*** | 1.0 - 1.2*** | 8.5 - 9.9*** |

* The lower and upper-end estimates of lung cancer cases avoided are calculated using the risk estimates from Exhibit 5-9 (c) and assume that the conditional probability of mortality among the Taiwanese study group was 100 percent.
**Assuming 20-year mortality rate in the U.S. of 88 percent.
***For 20 ppb, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus the number of estimated cases avoided is higher at 20 using the estimates adjusted for uncertainty.
****cases avoided from NTNCS are included.

**Exhibit 8-11**
**Annual Total Cancer Cases Avoided from Reducing Arsenic in CWSs and NTNCs**

| Arsenic Level (µg/L) | Reduced Mortality Cases** | Reduced Morbidity Cases** | Total Cancer Cases Avoided* |
|---|---|---|---|
| 3 | 32.6 - 74.1 | 24.6 - 64.2 | 57.2 - 138.3 |
| 5 | 29.1 - 53.7 | 22.0 - 46.5 | 51.1 - 100.2 |
| 10 | 21.3 - 29.8 | 16.1 - 25.9 | 37.4 - 55.7 |
| 20 | 10.2 - 11.3*** | 8.5 - 8.8 | 19.0 - 19.8*** |

* The lower-end estimate of bladder cancer cases avoided and the lung cancer estimates assume that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the assumption that the conditional probability of mortality among the Taiwanese study group was 80 percent.
**Assuming 20-year mortality rate in the U.S. of 26 percent for bladder cancer and 88 percent for lung cancer.
***For 20 ppb, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus the number of estimated cases avoided is higher at 20 using the estimates adjusted for uncertainty.
****Cases avoided from NTNCS are included.

The Agency developed monetized estimates of the health benefits associated with the risk reductions from arsenic exposures. The approach used in this analysis for the measurement of health risk reduction benefits is the monetary value of a statistical life (VSL) applied to each fatal cancer avoided. For non-fatal cancers, willingness to pay (WTP) data to avoid chronic bronchitis is used as a surrogate to estimate the WTP to avoid non-fatal bladder cancers. A WTP central tendency estimate of $607,162 (May 1999$) is used to monetize the benefits of avoiding non-fatal cancers (this value was updated from the $536,000 value EPA updated to 1997 dollars from the Viscusi et al. 1991 study).

The total national costs of the revised Arsenic Rule are summarized in Exhibit 8-12, along with the annual bladder cancer and lung cancer health benefits, and any non-quantifiable health benefits from other arsenic health effects. Total annual health benefits resulting from bladder cancer cases avoided range from $58.2 to $156.4 million at an MCL of 3 µg/L, $52.0 to $113.3 million at an MCL of 5 µg/L, $38.0 to $63.0 million at an MCL of 10 µg/L, and $20.1 to $21.5 million at an MCL of 20 µg/L. Total annual health benefits resulting from lung cancer cases avoided range from $155.6 to $334.5 million at an MCL of 3 µg/L, $139.1 to $242.3 million at an MCL of 5 µg/L, $101.6 to $134.7 million at an MCL of 10 µg/L, and $46.1 to $53.8 million at an MCL of 20 µg/L.

**Exhibit 8-12**
**Total Annual Cost, Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in PWSs**
**($ millions)**

| Arsenic Level (μg/L) | Total Annual Cost (7%) | Annual Bladder Cancer Health Benefits[1,2] | Annual Lung Cancer Health Benefits[1,2] | Total Annual Health Benefits[1,2] | Potential Non-Quantifiable Health Benefits |
|---|---|---|---|---|---|
| 3 | $792.1 | $58.2 - $156.4 | $155.6 - $334.5 | $213.8 - $490.9 | • Skin Cancer<br>• Kidney Cancer<br>• Cancer of the Nasal Passages<br>• Liver Cancer<br>• Prostate Cancer<br>• Cardiovascular Effects<br>• Pulmonary Effects<br>• Immunological Effects<br>• Neurological Effects<br>• Endocrine Effects<br>• Reproductive and Developmental Effects |
| 5 | $471.7 | $52.0 - $113.3 | $139.1 - $242.3 | $191.1 - $355.6 | |
| 10 | $205.6 | $38.0 - $63.0 | $101.6 - $134.7 | $139.6 - $197.7 | |
| 20 | $76.5 | $20.1 - $21.5 | $46.1 - $53.8 | $66.2 - $75.3[3] | |

[1] May 1999 dollars.
[2] These monetary estimates are based on cases avoided given in Exhibit 5-9 (a-c).
[3] For 20 μg/L, the proportional reduction from the lower level risk base case is greater than the proportional reduction from the higher level risk base case. Thus the number of estimated cases avoided and estimated benefits are higher at 20 μg/L using the estimates adjusted for uncertainty.

Reductions in arsenic exposures may also be associated with non-quantifiable benefits. EPA has identified several potential non-health non-quantifiable benefits associated with regulating arsenic in drinking water. These benefits may include any customer peace of mind from knowing that their drinking water has been treated for arsenic. To the extent that the Arsenic Rule can reduce households' perception of the health risks associated with arsenic in drinking water, household averting actions and costs to avoid these risks, such as buying bottled water or installing home treatment systems, could also be reduced.

### 8.10.2 Quantifiable and Non-Quantifiable Costs

The costs of reducing arsenic to various levels are summarized in Exhibit 8-13, which shows that as expected, aggregate arsenic mitigation costs increase with decreasing arsenic levels. Total national costs at a seven percent discount rate range are $792.1 million per year at 3 μg/L; $471.1 million per year at 5 μg/L; $205.6 million per year at 10 μg/L; $76.5 million per year at 20 μg/L.

**Exhibit 8-13**
**Summary of the Total Annual National Costs of Compliance**
**($ millions)**

| | CWS | | NTNC | | TOTAL | |
|---|---|---|---|---|---|---|
| **Discount Rate** | **3%** | **7%** | **3%** | **7%** | **3%** | **7%** |
| **MCL = 3 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $665.9 | $756.5 | $27.2 | $29.6 | $693.1 | $786.0 |
| Monitoring/ Administrative | $2.2 | $3.0 | $1.0 | $1.4 | $3.2 | $4.4 |
| State Costs | $1.4 | $1.6 | $0.1 | $0.2 | $1.5 | $1.7 |
| TOTAL COST | $669.4 | $761.0 | $28.3 | $31.1 | $697.8 | $792.1 |
| **MCL =5 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $394.4 | $448.5 | $16.3 | $17.6 | $410.6 | $466.1 |
| Monitoring/ Administrative | $2.0 | $2.8 | $1.0 | $1.3 | $2.9 | $4.1 |
| State Costs | $1.1 | $1.3 | $0.1 | $0.2 | $1.2 | $1.4 |
| TOTAL COST | $397.5 | $452.5 | $17.3 | $19.1 | $414.8 | $471.7 |
| **MCL = 10 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $169.6 | $193.0 | $7.0 | $7.6 | $176.7 | $200.6 |
| Monitoring/ Administrative | $1.8 | $2.5 | $0.9 | $1.3 | $2.7 | $3.8 |
| State Costs | $0.9 | $1.0 | $0.1 | $0.2 | $1.0 | $1.2 |
| TOTAL COST | $172.3 | $196.6 | $8.1 | $9.1 | $180.4 | $205.6 |
| **MCL =20 μg/L** | | | | | | |
| System Costs | | | | | | |
| Treatment | $60.7 | $69.0 | $2.6 | $2.8 | $63.3 | $71.8 |
| Monitoring/ Administrative | $1.7 | $2.4 | $0.9 | $1.3 | $2.6 | $3.7 |
| State Costs | $0.7 | $0.8 | $0.1 | $0.2 | $0.9 | $1.0 |
| TOTAL COST | $63.2 | $72.3 | $3.6 | $4.2 | $66.8 | $76.5 |

EPA also assessed the cost impact of reducing arsenic in drinking water at the household level. Exhibit 8-14 examines the cost per household for each system size category. As shown in the table, costs per household decrease as system size increases. However, costs per household do not vary significantly across arsenic levels. This is because costs do not vary significantly with removal efficiency; once a system installs a treatment technology to meet an MCL, costs based upon the removal efficiency that the treatment technology will be operated under remain relatively flat. Usually, per household costs are, however, somewhat lower at less stringent arsenic levels. This is due to the assumption that some systems would blend water at these levels and treat only a portion of the flow in order to meet the target MCL. However, in the smallest two size categories, average household costs decrease as the standard becomes more stringent. This somewhat counterintuitive result is due to the $500.00 affordability cap assumed in the SafeWater XL simulations. As more CWSs are forced over the affordability cap, the systems' costs are fixed at the costs associated with the POU technology. This results in lower average household costs for these systems.

**Exhibit 8-14**
**Mean Annual Costs per Household in CWSs**

| System Size | MCL (µg/L) | | | |
|---|---|---|---|---|
| | 3 | 5 | 10 | 20 |
| <100 | $317.00 | $318.26 | $326.82 | $351.15 |
| 101-500 | $166.91 | $164.02 | $162.50 | $166.72 |
| 501-1,000 | $74.81 | $73.11 | $70.72 | $68.24 |
| 1,001-3,300 | $63.76 | $61.94 | $58.24 | $54.36 |
| 3,301-10,000 | $42.84 | $40.18 | $37.71 | $34.63 |
| 10,001-50,000 | $38.40 | $36.07 | $32.37 | $29.05 |
| 50,001-100,000 | $31.63 | $29.45 | $24.81 | $22.63 |
| 100,001-1,000,000 | $25.29 | $23.34 | $20.52 | $19.26 |
| >1,000,000 | $7.41 | $2.79 | $0.86 | $0.15 |
| All categories | $41.34 | $36.95 | $31.85 | $23.95 |

Exhibit 8-15 illustrates the cost per bladder cancer case avoided, based on national cost estimates which include all the costs of treatment, O&M, monitoring and administrative costs to CWSs and NTNCs, and all State start-up costs and State costs for administration of water programs. At a three percent discount rate, cost per case ranges from approximately $12.2 million at an arsenic level of 3 µg/L (lower bound estimate of avoided bladder cancer cases) to $3.4 million at an MCL of 20 µg/L (upper bound of avoided bladder cancer cases). Similarly, the range at a seven percent discount rate is $13.8 million to $3.9 million.

**Exhibit 8-15**
**Cost per Cancer Case Avoided**
**($ millions)**

| Arsenic Level (µg/L) | lower bound** | upper bound** |
|---|---|---|
| **3% Discount Rate** | | |
| **3** | $ 12.2 | $ 5.0 |
| **5** | $ 8.1 | $ 4.1 |
| **10** | $ 4.8 | $ 3.2 |
| **20** | $ 3.5 | $ 3.4 |
| **7% Discount Rate** | | |
| **3** | $ 13.8 | $ 5.7 |
| **5** | $ 9.2 | $ 4.7 |
| **10** | $ 5.5 | $ 3.7 |
| **20** | $ 4.0 | $ 3.9 |

**Lower/upper bounds correspond to estimates of bladder cancer cases avoided.

# Appendix A: Decision Tree and Large System Costs

## A.1 Introduction

The purpose of this appendix is to present the rationale behind the development of the decision tree and associated decision matrix. It includes an overview of the decision tree structure and major factors impacting the decision- making process. The following list outlines the contents of this appendix:

- **Background**- Presents a brief history of the arsenic regulation and the statutory requirements impacting EPA and the decision-making process.
- **Major Factors Affecting the Decision Tree** - Presents the rationale for selecting parameters which impact the decision tree, including MCL, population, water type, region, and co-occurrence of solutes.
- **Additional Factors Affecting the Decision Tree** - Presents other parameters in the process which impact the decision tree, including: corrosion control, pre-oxidation, regionalization, and alternative technologies.
- **Development of a Decision Tree** - Presents the logic used for developing the decision tree for treatment of arsenic to a final revised MCL of 10 µg/L.
- **Very Large System Methodology** - Discusses the cost estimates for the Nation's 25 largest drinking water systems.

## A.2 Background

In 1998 and 1999, EPA conducted technology and cost evaluations for the removal of arsenic from drinking water. These evaluations looked into the effectiveness of various removal technologies and the capital and operations and maintenance (O&M) costs associated with each process. The following were evaluated and determined effective to varying degrees:

- Modified Coagulation/Filtration (modifications to existing C/F plants);
- Coagulation Assisted Microfiltration (CMF);
- Modified Lime Softening (modifications to existing LS plants);
- Activated Alumina (AA);
- Ion Exchange (IX);
- Greensand Filtration (GF); and
- Point-of-Use (POU) Treatment Options.

The technology and cost evaluation yielded a document entitled *Technologies and Costs for the Removal of Arsenic From Drinking Water* (EPA, 2000c). The document includes detailed evaluations of the above technologies, capital and O&M cost estimates for each of the listed technologies, as well as other technologies that were considered ineffective or unproven.

EPA used the information contained in the technologies and costs (T&C) document to develop a regulatory decision tree. The decision tree was then used to fashion a decision matrix which contains the probability that a given system will choose a treatment technology based on the percent removal required to meet the final revised MCL of 10 µg/L . The decision matrix, unit cost curves for treatment and waste disposal (illustrated in the T&C), treatment-in-place data and occurrence estimates were used to develop national cost of compliance estimates.

## A.3 Major Factors Affecting the Decision Tree

This section explains the rationale behind selecting each particular decision factor. Specifically, this section will discuss the following:

- the MCL target;
- influent arsenic concentration;
- population;
- region where the system is located;
- source water;
- whether a system has existing treatment in place;
- co-occurrence of solutes; and
- waste disposal issues.

### A.3.1 MCL Target

Target treatment concentration (8 µg/L) which is equal to 80 percent of the final revised MCL of 10 µg/L was selected as the basis for the development of the Arsenic Rule decision tree. The selection of a target treatment concentration was the first step in the decision process and was essential for determining all other branches of the decision tree.

### A.3.2 Influent Arsenic Concentration

Given the MCL, the influent arsenic concentration determines what percent removal of arsenic is needed, if any, and lays the groundwork for remaining decisions in the tree; therefore, the influent arsenic concentration was of major importance in developing the decision tree. Given the maximum influent arsenic level of 50 µg/L and at the final MCL of 10 µg/L, no systems would need to have a removal efficiency greater than 90 percent to treat for arsenic. Percent removal is critical for determining what additional technologies may be feasible. For example, if a ground water system has an influent arsenic level of 50 µg/L, and the target treatment concentration is 8 µg/L, then approximately 80 percent removal is required.[1]

[1]Required removal percentages in the decision tree are based on worst cast scenarios and therefore correspond with the upper bound of the arsenic concentration range for each category.

### A.3.3 System Size

System size, or population, also plays a significant role in determining the treatment options available to a system, as well as the affordability of a particular technology. EPA established nine size categories to be used in the decision tree and EA process:

- 25 to 100;
- 101-500;
- 501-1,000;
- 1,001-3,300;
- 3,301-10,000;
- 10,001-50,000;
- 50,001-100,000;
- 100,001-1,000,000; and
- greater than 1,000,000.

Exceptions were made in the decision tree for particular systems. The Agency considered point-of-use (POU) treatment as a viable option only for the two smallest categories of groundwater systems. Systems serving greater than 1,000,000 were addressed on a case-by-case basis by EPA, and therefore, were not considered within the scope of the decision tree process.

In developing the probability of choosing a given technology for each of the size categories, the Agency considered several factors such as available data on in-place treatments from Community Water System Survey (CWSS). The logic used for developing the probabilities for each of the size categories is detailed in section A.5 below.

### A.3.4 Region

The region of the nation that a system resides in does not effect the treatment options available. Therefore, the decision tree is structured in such a way that, regardless of the region, the branches are identical, and in fact refer to the same pages within the decision tree. However, the number of systems that may select a particular option as defined in the decision matrix, is region-specific.

EPA has decided that the nation can be divided into three regions for the purpose of the decision making process: 1) Southwest Region; 2) Northwest Region; and 3) East Region. The regions were selected based upon availability of water (i.e., scarcity of water) and availability of land. In the Southwest Region, for example, water may be scarce and treatment technologies that generate large volumes of reject water, such as RO, may not be appropriate. In the East Region, water scarcity is much less a concern than the availability of land. Technologies or disposal options that require significant amounts of land are less likely to be utilized in the East Region. The Northwest Region, by comparison, is less affected by the scarcity of water or land availability than either of the other two regions.

### A.3.5 Source Water

The source of the system's raw water, either ground water or surface water, plays a major role in determining the technologies that may already be in use by a system and what treatment options are available if a system needs to install a new facility.

For example, greensand filtration is affected by the level of iron in the raw water. Influent levels greater than 300 mg/L (ppm) are conducive to removal of arsenic by greensand filtration. Surface waters typically have low iron content, whereas ground waters often have levels in excess of 300 mg/L (Subramanian, et al., 1997). Accordingly, greensand filtration was not considered a viable removal technology for surface water systems, but is viable for ground water systems.

To determine the types of treatment that are currently being utilized throughout the country by source, EPA reviewed the Community Water Systems Survey (CWSS). EPA determined there are few surface water systems utilizing RO, IX or AA. As a result, when approximating the treatment in place options, RO, IX, and AA were omitted for surface water systems.

Arsenic removal is significantly more efficient when arsenic is present as arsenate ($As^{5+}$). Research has demonstrated many of the technologies considered perform poorly when arsenite ($As^{3+}$) is the predominant form (EPA, 2000). Arsenite can be easily oxidized to arsenate using conventional oxidation methods, such as chlorination and potassium permanganate addition. Ground waters typically contain higher levels of $As^{3+}$, whereas $As^{5+}$ is the dominant species in surface waters. As a result, ground water systems are more likely to install pre-oxidation and use higher oxidant doses, whereas surface water systems may be able to get by with little or no pre-oxidation capacity.

### A.3.6 Systems with Treatment In-Place

Information on in-place treatment technologies for all the flow categories of surface and ground water systems was obtained from Table 6.2 of "Geometries and Characteristics of Public Water Systems (EPA, 1999b) ." The Agency determined that many existing treatment facilities will be able to achieve the necessary arsenic removal with little or no modification to their plant. Exhibit A- 1 below outlines the treatment technologies included in the decision tree, the percent removal assumed capable without modification or polishing, and the maximum percent removal.

### A.3.7 Systems without Treatment In-Place

Many factors affect the decision tree when considering the addition of a treatment option for systems with no current treatment in place. Source water type and quality, system size, required arsenic removal, and removal achievable by a particular technology are all major considerations. Many of these considerations have been discussed earlier in Section 4.

For ground water systems without treatment in-place, the most suitable treatment technologies are IX and AA. For surface water systems with no treatment in-place, AA with and without pH adjustment and coagulation microfiltration are the most suitable. Modified CF and LS are for those surface water systems that already have CF or LS in-place.

The SDWA identifies POE and POU treatment units as potentially affordable technologies, but stipulates that POE and POU treatment systems "shall be owned, controlled and maintained by the public water system, or by a person under contract with the public water system to ensure proper operation and compliance with the maximum contaminant level or treatment technique and equipped with mechanical warnings to ensure that customers are automatically notified of operational problems."

Preliminary affordability determinations have shown that POU technologies will only be considered viable for small systems. These determinations have shown the cost breakpoint to be in the area of 200 persons served. This estimate does not account for waste disposal costs, which would make central treatment estimates more expensive, thus increasing the breakpoint. As a result only POU AA and POU RO compliance strategies were included in the decision tree for the groundwater systems in the two smallest flow categories.

**Exhibit A-1**
**Treatment Technologies for Systems with Treatment In-Place and Percent Removals Assumed and Achievable**

| Treatment Technology | Percent Removal of In-Place System | Maximum Percent Removal[1] |
|---|---|---|
| Coagulation/Filtration[2] | 50 | 95 |
| Lime Softening[2] | 50 | 90 |
| Coagulation Assisted Microfiltration | NA | 90 |
| Ion Exchange | NA | >95 |
| Activated Alumina | NA | >95 |
| Reverse Osmosis | NA | >95 |
| Greensand Filtration[3] | NA | 80 |
| POU Activated Alumina | NA | >90 |
| POU Reverse Osmosis | NA | >90 |

1 - For Percent Removals of In-Place Systems that are very close to Maximum Percent Removals (e.g., 95 percent and > 95 percent) polishing steps may be required.
2 - Maximum Percent Removal involves modification to existing system in the form of additional chemical feed systems, pumping, piping, etc.

NA - Not Applicable

### A.3.8 Co-Occurrence of Solutes

There are a number of solutes and water quality parameters that may effect the viability of a particular treatment option. Total dissolved solids (TDS), silica, sulfate and iron can all be major detractors/benefactors for the use of a particular technology. The decision tree simply cannot account for each individual situation where the influent water quality plays a role in selecting the treatment option. Utilities are encouraged to read the T&C document (EPA, 2000d) to gather additional information on parameters which impact the performance of a particular technology.

The decision tree uses influent sulfate and iron levels as decision factors in selecting treatment technologies. For ground water sources, both sulfate and iron levels are considered. Ion exchange is not considered a feasible treatment option when sulfate levels exceed 50 mg/L and greensand filtration is not considered viable when the iron level falls below 300 mg/L. Sulfate has been shown to decrease the effectiveness of ion exchange processes for arsenic removal; therefore, an upper bound sulfate concentration of 50 mg/L was used in the final rule for determination of ion exchange usage. Iron, on the other hand, significantly improves the effectiveness of greensand filtration (Subramanian, et al., 1997). Greensand filtration is best suited for ground waters (which typically contain higher levels of iron than surface waters) with high influent levels of iron (300 mg/L). For purposes of approximating national cost, greensand filtration is not considered a treatment option for surface water systems.

### A.3.9 Waste Disposal

Waste handling and disposal options are specific to the treatment technology selected, therefore the availability of disposal options does not vary by system size in the decision tree. However, the probability that a system will utilize a particular option does vary with system size.

#### A.3.9.1 Mechanical Dewatering

Mechanical dewatering processes include centrifuges, vacuum-assisted dewatering beds, belt filter presses, and plate and frame filter presses. Such processes generally have high capital, as well as high O&M costs, compared to similar capacity non-mechanical dewatering processes (e.g., storage lagoons). Due to the high costs, such processes are generally not suitable for very small water systems.

Filter presses have been used in industrial processes for years and have been increasing in the water treatment industry over the past several years. The devices have been successfully applied to both lime softening process sludge and coagulation/filtration process sludge. Filter presses require little land, have high capital costs, and are labor intensive.

Centrifuges have also been used in the water industry for years. Centrifugation is a continuous process requiring minimal time to achieve the optimal coagulation/filtration. Centrifuges have low land requirements and high capital costs. They are more labor intensive than non-mechanical alternatives, but less intensive than filter presses. Again, due to the capital and O&M requirements, centrifuges are more suitable for larger water systems.

### A.3.9.2 POTW Discharge

Indirect discharge (POTW discharge) is a commonly used method of disposal for filter backwash and brine waste streams. Coagulation/filtration and lime softening sludge materials have also been successfully disposed of in this manner. The primary cost associated with POTW discharge is that of the piping. Additional costs associated with POTW discharge may include lift stations, additional piping for access to the sewer system, and any cost incurred by the POTW in accommodating the increased demands on the POTW.

### A.3.9.3 Sanitary Landfill Disposal

Two forms of sanitary landfill are commonly used for disposal of water treatment byproducts: monofills and commercial nonhazardous waste landfills. In some parts of the country, decreasing landfill availability, rising costs, and increasing regulations are making landfill disposal more expensive. Costs associated with the development of monofills are generally less than those associated with commercial nonhazardous water landfill.

## A.4 Additional Factors Affecting the Decision Tree

### A.4.1 Pre-Oxidation

As mentioned above, inorganic arsenic occurs in two primary valence states, arsenite (As III) and arsenate (As V). As(III) is dominant in ground waters while surface waters more typically contain As(V). As(III) is easily oxidized to As(V) by conventional oxidation technologies such as chlorination and potassium permanganate addition. Each of the treatment technologies considered in the decision tree remove As(V) more readily than As(III) and as a result may require pre-oxidation.

In estimating national costs, it was assumed that only systems without pre-oxidation in-place would add the necessary equipment. It is expected that no surface water systems will need to install pre-oxidation for arsenic removal and that about fewer than 50 percent of the groundwater systems may need to install pre-oxidation for arsenic removal. Ground water systems without pre-oxidation should determine if pre-oxidation is necessary by determining if the arsenic is present as As (III) or As (V). Ground water systems with predominantly As (V) will probably not need pre-oxidation to meet the MCL. For single tap (POU) treatment options, centralized pre-oxidation is required. Exhibit A-2 shows the number of systems that were assumed to require addition of pre-oxidation.

**Exhibit A-2: Systems Needing to Add Pre-Oxidation**

| System Size | Percent of Ground Water Systems |
|---|---|
| 25-100 | 54 |
| 101-500 | 30 |
| 501-1000 | 24 |
| 1001-3300 | 24 |
| 3300-10K | 27 |
| 10001-50K | 13 |
| 50,001-100K | 41 |
| 100,001-1M | 16 |

### A.4.2 Corrosion Control

Many of the treatment technologies considered in the decision tree (e.g. AA, and IX) remove hardness and alkalinity. Removal of hardness and alkalinity can reduce the pH of finished water and lead to corrosion problems within the system. Hardness and alkalinity, at the appropriate levels, act as buffers against corrosion in the treatment plant and distribution system. At these levels, alkalinity and hardness form protective coatings (metal hydroxides), control pH and enhance the buffer effect against corrosion. Where appropriate, corrosion control costs were included with arsenic treatment in the decision tree. It was assumed that the in-place lime softening and coagulation/flocculation plants had adequate corrosion control in-place.

### A.4.3 Alternative Technologies

*Technologies and Costs for the Removal of Arsenic from Drinking Water* (EPA, 2000) evaluated four arsenic removal technologies that were not included in the decision tree:

- Sulfur-Modified Iron,
- Granular Ferric Hydroxide,
- Iron Filings, and
- Iron Oxide Coated Sand.

The technologies were not included in the decision tree for reasons which are summarized below.

#### A.4.3.1 Sulfur-Modified Iron

A patented Sulfur-Modified Iron (SMI) process for arsenic removal has recently been developed. During this process, powdered iron, powdered sulfur, and the oxidizing agent ($H_2O_2$ in preliminary tests) are thoroughly mixed and added to the water to be treated. The oxidizing agent serves to convert As(III) to As(V). Arsenic removal utilizing the SMI process seems to be dependent on the iron to arsenic level as well as pH.  Flow distribution problems were evident, as several columns became partially plugged during operation.

All experimentation on the SMI process has been at the bench-scale level, and involves only batch processes.  The literature is unclear about removal efficiency since results varied from less than 10 to 99 percent, depending on conditions.  It appears that O&M for such a system would be expensive and would require a highly trained operator.  Finally, by the admission of the researchers, disposal costs might outweigh the increased adsorption capacity.

### A.4.3.2  Granular Ferric Hydroxide

*Granular ferric hydroxide* is a technology that may combine very long run length without the need to adjust pH.  The technology has been demonstrated for arsenic removal full-scale in England (Simms et al, 2000).  A pilot-scale study for activated alumina was also conducted on that water and showed run lengths much longer than observed in pilot-scale studies in the United States.  Due to the lack of published data showing performance for a range of water qualities, granular ferric hydroxide was not designated a BAT.  In addition, there is little published information on the cost of the media, so it is difficult to evaluate cost.  Granular ferric hydroxide is being investigated in several ongoing studies and may be an effective technology for removing arsenic.

### A.4.3.3  Iron Filings

The Iron Filings process is essentially a filter technology, much like greensand filtration, wherein the source water is filtered through a bed of sand and iron filings.  Unlike some technologies (i.e. ion exchange), sulfate is actually introduced in this process to encourage arsenopyrite precipitation.

While this process seems to be quite effective, its use as a drinking water treatment technology appears to be limited.  There is no indication that this technology can reduce arsenic levels below approximately 25 ppb.  This technology also suffers from a study design which failed to test its effectiveness at influent levels of concern in drinking water.  Since the study design called for such high influent levels - 470 to 20,000 ppb - there is no data to indicate how the technology performs at normal source water arsenic levels, which most certainly are below the 470 ppb level used in experimentation.  This technology needs to be further evaluated before it should be recommended as an approved arsenic removal technology for drinking water.

### A.4.3.4  Iron Oxide Coated Sand

Iron oxide coated sand (IOCS) is a rare process that has shown some tendency for arsenic removal.  IOCS consists of sand grains coated with ferric hydroxide which are used in fixed bed reactors to remove various dissolved metal species.  Factors such as pH, arsenic oxidation state, competing ions, EBCT, and regeneration time have significant effects on the removals achieved with IOCS.  Like other processes, the media must be regenerated upon exhaustion.  IOCS has only been tested at bench-scale.  High levels of arsenite could reduce IOCS effectiveness because the bonding is strong and may permanently damage the media.  Natural organic matter may also be problematic for arsenic removal. IOCS also takes a considerable amount of time to produce in a laboratory setting. At full-scale this would likely result in high capital cost.

## A.5 Development of a Decision Tree

### A.5.1 Surface Water Systems

The following describes the logic used for developing the decision tree for treatment of arsenic in surface water systems in order to comply with the final MCL. For actual breakout of percentages used in the decision tree, refer to the Exhibits A-7 to A-22.

1. Information on in-place treatment technologies for all the flow categories of surface water systems was obtained from Table 6.2 of “Geometries and Characteristics of Public Water Systems” (EPA, 1999b). This table is shown below as Exhibit A-3. Information provided in the document on in-place treatments was based on data from Community Water System Survey (CWSS), which EPA conducted in 1995 to obtain data to support its development and evaluation of drinking water regulations.

2. Exhibit A-3 shows the percentage of systems with in-place Lime/Soda Ash Softening. It was assumed that these systems would modify the existing treatment to comply with the final MCL.

**Exhibit A-3: Percent of Surface Water Systems with In-Place Treatment**

| System Size | Lime/ Soda Ash Softening | Coagulation Flocculation | Filtration |
|---|---|---|---|
| 25-100 | 3.9% | 27.5% | 78.5% |
| 101-500 | 8.1% | 52.6% | 71.2% |
| 501-1000 | 20.5% | 70.2% | 79.3% |
| 1001-3300 | 17.5% | 79% | 81.7% |
| 3300-10K | 10.8% | 95.4% | 86.5% |
| 10001-50K | 6.9% | 94.5% | 96.3% |
| 50,001-100K | 5.7% | 93.7% | 88% |
| 100,001-1M | 5.1% | 99.5% | 93.4% |

3. Exhibit A-3 was also used to estimate the percentage of systems with existing coagulation/filtration processes. In-place coagulation/flocculation was based on the smaller (in terms of percent use) of filtration and coagulation/flocculation. The Agency believes this is a conservative assumption for several reasons. The first is that the CWSS data on in-place treatments was gathered in 1995 and 1996, which may not be reflective of requirements under surface water treatment and disinfection by-product rules that were

adopted in later years. The second is that no arsenic removal is assumed for systems with filtration when the percentage is higher than the percentage for coagulation/flocculation.

4. The percent of remaining technologies likely to be used for arsenic treatment for each flow category was obtained by subtracting from 100, the percentages assigned for modified lime softening and modified coagulation /filtration per step 2 and 3 above. The remaining technologies that were considered in the decision tree for treatment of arsenic in surface water include coagulation microfiltration and activated alumina (AA). Systems choosing AA may also choose to pH adjust. This decision is primarily dependent on system size. Systems that serve less than 500 people (see step 6 below) are less likely to pH adjust their raw water supplies because of technical complexity and need for skilled labor. The Agency classified these systems in two natural pH categories. Systems that have raw water with pH between 7 and 8 and systems with pH in raw water greater than 8. For systems that are likely to adjust pH to 6, the Agency considered two run length options, low end (15,400 BV) and high end (23,100 BV).

5. Based on the Agency's best professional judgement, the Agency believes that for systems serving more than 500 people, the selection of treatment for arsenic would likely be distributed among pH adjusted AA with high end run length, pH adjusted AA with low end run length, and coagulation microfiltration in 40:40:20 ratio. Coagulation/ microfiltration is more expensive than activated alumina. However, some surface water systems may select it because they may get filtration credits or precursor removal along with arsenic removal. The benefits of this treatment approach could not be quantified.

6. For systems serving less than 500 people, it is assumed that there will be no usage of coagulation microfiltration technology, primarily because of its high capital cost, technical complexity and need for skilled labor. The Agency believes for this group, about 65 percent of systems with natural pH between 7 and 8 would likely use AA, about 23 percent systems with natural pH greater than 8 would likely use AA and remaining systems would evenly use pH adjusted activated alumina options.

### A.5.2 Ground Water Systems

The next section describes the logic used for developing the decision tree for treatment of arsenic to a MCL of 10 ug/L for ground water systems.

1. Information on in-place treatment technologies for all the flow categories of ground water systems was obtained from Table 6.1 of "Geometries and Characteristics of Public Water Systems" (EPA, 1999b). The information provided in the document on in-place treatments was based on data from Community Water System Survey (CWSS), which EPA conducted in 1995 to obtain data to support its development and evaluation of drinking water regulations.

2. For systems serving less than 10,000 people, the Agency selected roughly half the percentage of systems with in-place of lime softening and coagulation/ flocculation (Exhibit A-4). These systems would modify their existing treatment to meet arsenic

MCL. For systems serving more than 10,000 people, the Agency assumed 4 percent for each technology as the maximum percentage of systems with existing lime softening and coagulation/ flocculation treatments. There was a concern that the much higher percentages in might be due to mixed systems (groundwater and surface water) rather than groundwater systems. Thus much lower percentages were used to estimate existing treatment. Systems with existing treatment will modify it to meet the arsenic MCL.

**Exhibit A-4: Percent of Ground Water Systems with In-Place Treatment**

| System Size | Lime/ Soda Ash Softening | Coagulation Flocculation |
|---|---|---|
| 25-100 | 2.1% | 1.5% |
| 101-500 | 3.7% | 2.0% |
| 501-1000 | 4.1% | 4.2% |
| 1001-3300 | 5.2% | 3.4% |
| 3300-10K | 7.0% | 8.1% |
| 10001-50K | 12.2% | 15.1% |
| 50,001-100K | 17.4% | 24.2% |
| 100,001-1M | 32.4% | 25.2% |

3. For systems serving less than 100 people and requiring 50-90 percent removal of arsenic, the decision tree assumed a 5 percent usage for each POU option (RO and AA). For systems requiring less than 50 percent removal of arsenic, a 2 percent usage of each POU option was assumed. POU options were used less if lower removal of arsenic was desired because systems would have an opportunity for blending, which would make central treatment more cost effective.

4. In the decision tree, for systems serving between 100-500 people and requiring 50-90 percent removal of arsenic, the Agency assumed a 3 percent usage for each POU treatment option. For systems requiring less than 50 percent removal of arsenic, the Agency assumed a 1 percent usage of each POU option. The Agency’s assumption of POU usage for this size system is based on the fact that the economic feasibility of POU treatment for systems serving between 70 and 120 households. Therefore, this option would be less preferred by systems in this size in comparison to systems serving less than 100 people. With the increase in households, the management of this treatment strategy becomes progressively complex and cost prohibitive. For systems serving more than 500 people, the Agency did not consider any usage.

5. Anion Exchange (AX). The proposed rule decision tree utilized anion exchange to a great extent. The upper bounds were based on the co-occurrence of sulfate (Table IX-7 of the proposed rule). This table is replicated below as Exhibit A-5. Many comments on the

proposed rule noted other problems that would limit the use of anion exchange. The first was that the brine stream could be considered hazardous waste. Based on a review of this issue, the evaporation pond and chemical precipitation options were eliminated. Discharge to a POTW was not affected by this issue because of the domestic sewage exclusion in 40 CFR 261.4. In addition, the Agency received comments suggesting that stringent technically based local limits (TBLL) for arsenic and total dissolved solids (TDS) in various jurisdictions nationwide would limit the use of publicly owned treatment works (POTW) for discharge of anion exchange waste brine. Therefore, after examining other potential restrictions on POTW discharge of waste brine, the Agency believes lowering the usage of anion exchange with brine disposal to a POTW in the decision tree would be appropriate. In addition, the upper sulfate concentration has been reduced to 50 mg/L because of concerns about its effect on TDS increase.

**Exhibit A-5: Ground Water: Arsenic and Sulfate Co-occurrence**

| Influent Arsenic | Likelihood of Sulfate (percent) | | |
|---|---|---|---|
| | <25 mg/L | 25-120 mg/L | >120 mg/L |
| <10 ug/L | 48 | 33 | 19 |
| 10-20 ug/L | 35 | 39 | 26 |
| >20 ug/L | 33 | 38 | 30 |

It was assumed that sulfate concentration and percent waste brine volume (in relation to background wastewater volume) are factors that would determine anion exchange selection for arsenic treatment. Percent waste volume was related to removal efficiency. Requiring lower removal efficiencies allow systems to treat a smaller volume of water than at a higher removal efficiency. Systems will blend an untreated portion with a treated portion of water to reduce costs while still complying with the MCL. Based on volume considerations, the option with sulfate less than or equal to 20 mg/L was selected about three times more frequently than the option with sulfate between 20 and 50 mg/L. The brine volume to background wastewater volume also contributed to correlation between anion exchange use and system size.

An increase in total dissolved solids from salt used for regeneration would likely restrict the use of anion exchange in the arid Southwest. However, arsenic occurrence is not limited to just the Southwest. There are areas in the mid-west and Northeast with arsenic above the MCL. The upper bound for systems (small systems) using anion exchange with POTW discharge was 7 percent. For many system size categories, anion exchange with sulfate less than 20 mg/L is the least expensive option. However, it is only be selected by 5 percent or less of the systems because of potential adverse impacts from disposing the brine in the sanitary sewer system.

6. Table IX-9 of the proposed rule presented the co-occurrence of iron and arsenic. This table is replicated below as Exhibit A-6. Approximately 18 percent of the systems had iron concentration above the secondary standard of 300 ug/L. One reference indicated that a 20:1 Fe/As ratio could remove up to 80 percent of the arsenic. It was assumed that two thirds of the systems above the secondary standard would have sufficient iron to achieve high arsenic removals.

**Exhibit A-6: Ground Water: Arsenic and Iron Co-occurrence**

| Influent Arsenic | Likelihood of Iron (percent) | |
|---|---|---|
| | <300 ug/L | >300 ug/L |
| <10 ug/L | 82 | 18 |
| 10-20 ug/L | 81 | 19 |
| >20 ug/L | 71 | 29 |

Based on the Agency's best professional judgement, the Agency believes that for groundwater systems serving less than 500 people, the selection of AA would likely be distributed among systems in a 3:1 ratio for systems with a raw water natural pH between 7 and 8 and systems with a raw water pH greater than 8. This is based on raw groundwater data from the USGS National Water Information System that was analyzed in the co-occurrence report. Projections on the percent of systems with raw water pH greater than 8 were made for each region. The highest percentage for any region was approximately 25 percent. As a conservative estimate, this was assumed nationwide.

For groundwater systems serving more than 500 people, the Agency believes that the selection of AA would likely be distributed evenly among pH adjusted AA with high end run length (23,100 BV) and pH adjusted AA with low end run length (15,400 BV). The Agency also believes that there would be a small percentage of systems serving more than 500 people that would continue to use AA without pH adjustment. However, the Agency believes the usage of AA technology without pH adjustment would decrease with increasing system size.

For groundwater systems serving 1,000 to10,000 people, the Agency assumed a 10 percent usage of coagulation microfiltration distributed evenly among mechanical dewatering and non-mechanical dewatering options. For systems serving more than 10K people, the Agency assumed a increased usage (14 percent) of coagulation microfiltration with mechanical dewatering dominating in these size categories because of space consideration.

## Exhibit A-7
## Probability Decision Tree: Ground Water Systems Serving #100 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 5.0 | 3.0 | 2.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 2.0 | 1.0 | 1.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 12.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 56.0 | 63.0 | 70.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 19.0 | 21.0 | 23.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 12 | POU Activated Alumina and pre-oxidation | 2.0 | 5.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 2.0 | 5.0 | 2.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-8
## Probability Decision Tree: Ground Water Systems Serving 101-500 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 5.0 | 3.0 | 2.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 2.0 | 1.0 | 1.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 12.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 56.0 | 63.0 | 64.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 19.0 | 21.0 | 22.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 2.0 | 3.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 3.0 |
| 12 | POU Activated Alumina and pre-oxidation | 1.0 | 3.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 1.0 | 3.0 | 1.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-9
## Probability Decision Tree: Ground Water Systems Serving 501-1,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 5.0 | 3.0 | 2.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 2.0 | 1.0 | 1.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 12.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 25.0 | 30.0 | 31.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 25.0 | 30.0 | 30.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 25.0 | 30.0 | 30.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-10
## Probability Decision Tree: Ground Water Systems Serving 1,001-3,300 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 5.0 | 3.0 | 2.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 2.0 | 1.0 | 1.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 5.0 | 5.0 | 5.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 5.0 | 5.0 | 5.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 12.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 17.0 | 16.0 | 17.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 25.0 | 33.0 | 33.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 25.0 | 33.0 | 33.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-11
## Probability Decision Tree: Ground Water Systems Serving 3,301-10,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 3.0 | 3.0 | 3.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 5.0 | 3.0 | 2.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 2.0 | 1.0 | 1.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 8.0 | 8.0 | 8.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 24.0 | 25.0 | 26.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 26.0 | 27.0 | 27.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 26.0 | 27.0 | 27.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-12
## Probability Decision Tree: Ground Water Systems Serving 10,001-50,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 3.0 | 1.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 12.0 | 12.0 | 12.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 11.0 | 11.0 | 11.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 32.0 | 33.0 | 34.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 32.0 | 33.0 | 33.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-13
## Probability Decision Tree: Ground Water Systems Serving 50,001-100,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 3.0 | 1.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 12.0 | 12.0 | 12.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 7.0 | 7.0 | 7.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 34.0 | 35.0 | 36.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 34.0 | 35.0 | 35.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-14
## Probability Decision Tree: Ground Water Systems Serving 100,001-1,000,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | **<50%** | **50-90%** | **>90%** |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 12.0 | 12.0 | 12.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 37.0 | 37.0 | 37.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 37.0 | 37.0 | 37.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-15
## Probability Decision Tree: Surface Water Systems Serving #100 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 28.0 | 28.0 | 28.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 44.0 | 44.0 | 44.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 16.0 | 16.0 | 16.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-16
## Probability Decision Tree: Surface Water Systems Serving 101-500 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 8.0 | 8.0 | 8.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 53.0 | 53.0 | 53.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 24.0 | 24.0 | 24.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 9.0 | 9.0 | 9.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 3.0 | 3.0 | 3.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 3.0 | 3.0 | 3.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-17
## Probability Decision Tree: Surface Water Systems Serving 501-1,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 21.0 | 21.0 | 21.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 70.0 | 70.0 | 70.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-18
## Probability Decision Tree: Surface Water Systems Serving 1,001-3,300 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 18.0 | 18.0 | 18.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 79.0 | 79.0 | 79.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

**Exhibit A-19**
**Probability Decision Tree: Surface Water Systems Serving 3,301-10,000 People**

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 11.0 | 11.0 | 11.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 87.0 | 87.0 | 87.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-20
## Probability Decision Tree: Surface Water Systems Serving 10,001-50,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 5.0 | 5.0 | 5.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 95.0 | 95.0 | 95.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-21
## Probability Decision Tree: Surface Water Systems Serving 50,001-100,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 6.0 | 6.0 | 6.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 88.0 | 88.0 | 88.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backwash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 3.0 | 3.0 | 3.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit A-22
## Probability Decision Tree: Surface Water Systems Serving 100,001-1,000,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 5.0 | 5.0 | 5.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 93.0 | 93.0 | 93.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## A.6 Very Large System Cost Methodology

EPA must conduct a thorough cost-benefit analysis, and provide comprehensive, informative, and understandable information to the public about its regulatory efforts. As part of these analyses, EPA evaluated the regulatory costs of compliance for very large systems, who would be subject to the new arsenic drinking water regulation. The nation's 25 largest drinking water systems (i.e., those serving a million people or more) supply approximately 38 million people and generally account for about 15 to 20 percent of all compliance-related costs. Accurately determining these costs for future regulations is critical. As a result, EPA has developed compliance cost estimates for the arsenic and radon regulations for each individual system that serves greater than 1 million persons. These cost estimates help EPA to more accurately assess the cost impacts and benefits of the arsenic regulation. The estimates also help the Agency identify lower cost regulatory options and better understand current water systems' capabilities and constraints.

The system costs were calculated for the 24 public water systems that serve a retail population greater than 1 million persons and one public water system that serves a wholesale population of 16 million persons. Exhibit A-23 lists these 25 public water systems. The distinguishing characteristics of these very large systems include:

- a large number of entry points from diverse sources;
- mixed (i.e. ground and surface) sources;
- occurrence not conducive to mathematical modeling;
- significant levels of wholesaling;
- sophisticated in-place treatment;
- retrofit costs dramatically influenced by site-specific factors; and
- large amounts of waste management and disposal which can contribute substantial costs.

Generic models cannot incorporate all of these considerations; therefore, in-depth characterizations and cost analyses were developed utilizing several existing databases and surveys.

The profile for each system contains information such as design and average daily flows, treatment facility diagrams, chemical feed processes, water quality parameters, system layouts, and intake and aquifer locations. System and treatment data were obtained from the following sources:

- The Information Collection Rule (1997);
- The Community Water Supply Survey (1995);
- The Association of Metropolitan Water Agencies Survey (1998);
- The Safe Drinking Water Information System (SDWIS); and
- The American Water Works Association WATERSTATS Survey (1997)

While these sources contained much of the information necessary to perform cost analyses, the Agency was still missing some of the detailed arsenic occurrence data in these large water systems. Where major gaps existed, especially in groundwater systems, occurrence data obtained from the States of Texas, California, and Arizona, the Metropolitan Water District of Southern California Arsenic Study (1993), the National Inorganic and Radionuclides Study (EPA, 1984), and utilities were used. Based on data from the studies, detailed costs estimates were derived for each of the very large water systems.

**Exhibit A-23**
**List of Large Water Systems That Serve More Than 1 Million People**

| | PWS ID # | Utility Name |
|---|---|---|
| 1 | AZ0407025 | Phoenix Municipal Water System |
| 2 | CA0110005 | East Bay Municipal Utility District |
| 3 | CA1910067 | Los Angeles-City Dept. of Water and Power |
| 4 | CA1910087 | Metropolitan Water District of Southern California |
| 5 | CA3710020 | San Diego- City of |
| 6 | CA3810001 | San Francisco Water Department |
| 7 | CA4310011 | San Jose Water Company |
| 8 | CO0116001 | Denver Water Board |
| 9 | FL4130871 | Miami-Dade Water And Sewer Authority-Main System |
| 10 | GA1210001 | City of Atlanta |
| 11 | IL0316000 | City of Chicago |
| 12 | MA6000000 | Massachusetts Water Resource Authority |
| 13 | MD0150005 | Washington Suburban Sanitation Commission |
| 14 | MD0300002 | Baltimore City |
| 15 | MI0001800 | City of Detroit |
| 16 | MO6010716 | St. Louis County Water County |
| 17 | NY5110526 | Suffolk County Water Authority |
| 18 | NY7003493 | New York City Aqueduct System |
| 19 | OH1800311 | City of Cleveland |
| 20 | PA1510001 | Philadelphia Water Department |
| 21 | PR0002591 | San Juan Metropolitano |
| 22 | TX0570004 | Dallas Water Utility |
| 23 | TX1010013 | City of Houston- Public Works Department |
| 24 | TX150018 | San Antonio Water System |
| 25 | WA5377050 | Seattle Public Utilities |

Cost estimates were generated for each system at several MCL options. The total capital costs and operational and maintenance (O & M) costs were calculated using the profile information gathered on each system, conceptual designs (i.e., vendor estimates and RS Means), and modified EPA cost models (i.e., Water and WaterCost models). The models were modified based on the general cost assumptions developed in the Phase I Water Treatment Cost Upgrades (EPA, 1998).

Preliminary cost estimates were sent to all of the systems for their review. Approximately 30 percent of the systems responded by submitting revised estimates and/or detailed arsenic occurrence data. Based on the information received, EPA revised the cost estimates for those systems. Based on the results, only 3 of the very large systems had capital and/or O&M expenditures for complying with a MCL of 10 µg/L. More detailed costs estimates for each very large water system can be found in Radon and Arsenic Regulatory Compliance Costs for the 25 Largest Public Water Systems document, which is located in the water docket.

# Appendix B: Assumptions and Methodology for Estimating Cancer Risks Avoided and Benefits

## B.1 Community Water Systems Serving Fewer than One Million People

### B.1.1 Introduction

EPA's estimation of the number of cancer cases resulting from current levels of exposure to arsenic from drinking water in community water systems serving fewer than one million people, and the number of those cases that would be avoided following implementation of a specified arsenic MCL are obtained using the following basic risk algorithm.

$$R_{Ind} = C(As)_{Ind} * [DW_{Ind} * DW_{Adj}] * R_{Unit} \qquad \textit{Equation B-1}$$

The components of this risk algorithm are as follows.

$\mathbf{C(As)_{Ind}}$ is the concentration of arsenic in drinking water that a given individual is exposed to, on average, over the course of his or her lifetime. $C(As)_{Ind}$ is obtained from the occurrence assessment distributions for surface water and ground water and is expressed in units of µg/L.

$\mathbf{DW_{Ind}}$ is the daily drinking water consumption for a given individual, and is incorporated in this model as a lifetime weighted average expressed in units of L/kg-day. As a lifetime weighted average, this drinking water consumption value reflects differences in water consumption per kilogram body weight that is observed to occur over an individual's lifetime. This variable is also a function of the individual's sex.

$\mathbf{DW_{Adj}}$ is an adjustment factor constant ( = 70 kg ÷ 2 L/day) that is applied to the weighted average drinking water consumption values for individuals to account for the fact that the unit cancer risk factor (as described below) is based upon an assumed lifetime average daily intake of 2 L/day and a lifetime average body weight of 70 kg.

It should be noted that the quantity $[DW_{Ind} * DW_{Adj}]$ is also referred to in this modeling effort as the Lifetime Relative Exposure Factor (LREF). The LREF reflects a particular individual's lifetime exposure to arsenic from drinking water, given that person's $DW_{Ind}$ value relative to an "average" individual consuming 2 L/day of water and weighing 70 kg. An LREF value less than one indicates the person has less lifetime exposure (and therefore less risk) than such an "average person" used to derive the unit risk factor; similarly a value greater than one indicates a higher lifetime exposure and greater risk than that "average person".

$\mathbf{R_{Unit}}$ is the unit cancer risk factor for the specific endpoint of concern (e.g., bladder cancer, or lung cancer). This factor is in units of "expected cases per person per µg/day." It is important to note that these unit risks, as derived from the Morales (2000) study are <u>lifetime</u> risks, that were developed with an underlying assumption of 70 years of exposure and a lifetime average water consumption of 2 L/day and body weight of 70 kg. It should also be noted that the Morales (2000) cancer risk factors used in this modeling, which are derived from an analysis of the Taiwan data, are specific to a particular cancer endpoint (bladder, lung) and are sex-dependent.

The benefit modeling performed in support of the arsenic regulation utilizes Equation B-1 in a Monte Carlo simulation framework that provides information on the aggregate number of cases of cancer occurring (and avoided) in the overall population, as well as a characterization of the distribution of risks experienced by different individuals in the exposed population as a result of individual variability in exposure conditions. Because some of the factors that result in individual variability in exposure and risk are sex and source water dependent, the Monte Carlo model also incorporates information on fraction of males and females in the population, and on the proportion of individuals using surface water versus ground water as their primary community water supply source.

As an overview of how the simulation model operates, it can be viewed as being similar to taking a representative sample from the population exposed to arsenic in drinking water from community water systems and using the results obtained from that sample to characterize the overall risks of the population. In this modeling, a total of 2,000 iterations (samples) were used for each model run.

In each iteration, an individual is selected, and identified as male or female and as a ground water or surface water user, based on estimated probabilities associated with those characteristics. Then, a value is selected for each of the parameters in Equation B-1, based on the underlying probability distributions developed for each of those variables, and specific to the sex and source water as specified for that individual as appropriate.

The Equation B-1 calculation is carried out to determine that individual's lifetime cancer risk, $R_{Ind}$. The results of all 2,000 iterations are aggregated, and the average individual risk across all iterations is determined. This average risk value, multiplied by the number of individuals in the populations served by the affected water systems, provides the number of cases of cancer expected.

To complete the benefits modeling, a baseline with no reduction in the MCL (or arsenic levels in drinking water) is run first, with subsequent runs reflecting reductions in occurrence levels corresponding to the particular MCL being evaluated. The number of cancer cases estimated for these runs at the various MCL options is subtracted from the baseline cancer cases to obtain the estimate of cases avoided.

The following sections provide further discussion of the components of the model, including further information on how upper and lower bounds for the benefits estimates were established, how additional adjustments have been made to account for the differences in dietary intake of arsenic, and to reflect differences in cancer mortality rates between the affected US population and the Taiwan population that served as the basis of the unit risk factors.

### B.1.2 Arsenic Concentrations in Finished Water of Community Water Systems Serving Fewer than One Million People

This section provides further information on the variable $C(As)_{Ind}$ in Equation B-1.

EPA has developed lognormal arsenic occurrence distributions for the nation's community ground water and surface water systems serving fewer than one million people. These arsenic occurrence distributions, which reflect the probability of arsenic concentrations occurring at various levels in finished drinking water in surface and ground water systems, are used in the benefits model to characterize the variability in arsenic drinking water concentrations experienced by different individuals using these public water supplies.

Although the arsenic occurrence distributions were developed to characterize the full distribution of finished water arsenic concentrations, the benefits modeling focused only on the portion of those distribution exceeding 3 µg/L, the lowest MCL option considered by EPA. EPA used the separate lognormal occurrence probability distributions for ground water and surface to first determine the number of people served by community water systems from each of those two source waters (and the total) expected to have arsenic present above 3 µg/L.

In the Monte Carlo simulation model, the selection of a value for $C(As)_{Ind}$ of Equation B-1 in each iteration involved two steps. First, using relative probabilities derived from the lognormal occurrence distributions, an individual was selected and identified as being served by either ground or surface water having an arsenic above 3 µg/L. In the second step, a specific finished water arsenic concentration was chosen at random from the appropriate ground or surface water occurrence distribution in the range exceeding 3 µg/L.

By including a sufficient number of iterations in the Monte Carlo model, the full range of individual variability in exposure to different arsenic concentrations in the range of interest for both surface water and ground water sources is obtained.

In the baseline analysis (that is, with no change to the 50 µg/L MCL), the selected finished water arsenic concentration value was used directly in the risk equation. In the model runs for various MCL options, that value was compared to the MCL. If that value was less than or equal to the MCL, it was also kept. If however the selected value exceeded the MCL, then it was multiplied by a factor of 0.8 of the MCL value reflecting an assumption that systems would treat to a level of 80% of the MCL. So, for example, if an iteration of a model run examining the 10 µg/L MCL option produced a finished water arsenic value of 25 µg/L, that value was changed to 8 µg/L. If the model run were for the option of a 20 µg/L MCL, that value would be changed to 16 µg/L.

It should be noted that for the purposes of the benefits modeling, the concentration used is implied to be a lifetime average exposure level for the individual in that iteration.

### B.1.3 Drinking Water Consumption

This section provides further information on the variables $DW_{Ind}$ and $DW_{Adj}$ in Equation B-1.

The variable $DW_{Ind}$ reflects the differences (variability) in individual water consumption within the exposed population. In Equation B-1, the variable $DW_{Ind}$ is expressed in units of L/kg-day reflecting differences in consumption among individuals in the population as a function of body weight. This value is a lifetime average water consumption rate for individuals, recognizing that consumption of water per kg body weight changes over a lifetime, particularly between infancy, childhood and adulthood.

EPA obtained the distribution of individual weighted average lifetime water consumption values in terms of L/kg-day by integrating available data on the distribution of water consumption, in units of L/day, by males and females in the US in various age ranges with information on the distribution of body weights for males and females within those same age ranges.

The age and sex specific distributions of drinking water consumption in L/day are provided by data from the Continuing Survey of Food Intakes by Individuals (CSFII) for the years 1994-1996 conducted by the U.S. Department of Agriculture (USDA) and presented in EPA (1999). The data were collected from a sample population of 15,303 individuals in the 50 states and the District of Columbia that was chosen to be representative of the US population based on the 1990 census data.

The collection and analysis of drinking water consumption data in the CSFII provided the basis for several alternative ways of viewing drinking water consumption, in particular, how to include various direct water sources – for example, from community tap water, bottled water, household wells – consumed directly as a beverage, and indirect water that is water from such sources that is added to other foods during preparation at home or by food service establishments.

For the purposes of the arsenic benefits analysis, EPA chose to use two alternative sets of drinking water distributions to characterize lower and upper bounds of risk.

For the lower bound analyses, EPA used the CSFII drinking water distribution limited to the community tap water source, but which included both direct and indirect consumption of that water. This lower bound distribution reflects an overall average individual consumption (across all ages and both sexes) of approximately 1.0 L/day, with a $90^{th}$ percentile value of approximately 2.1 L/day.

For the upper bound analyses, EPA used the CSFII drinking water distribution for total water, which includes community tap water, bottled water, and other sources, and also reflects both direct and indirect consumption of that water. This upper bound distribution reflects an overall average individual consumption (across all ages and both sexes) of approximately 1.2 L/day, with a $90^{th}$ percentile value of approximately 2.3 L/day.

For the purposes of the arsenic benefits analysis, it was necessary to integrate the age and sex specific water consumption distributions (in L/day) with information available from Statistical Abstracts (1994) providing body weight distributions for the same sex-age categories included in the CSFII data. A submodel was run for this portion of the benefits analysis that effectively generated $DW_{Int}$ values for individuals by "constructing" a lifetime weighted average water consumption value in units of L/kg-day. Five age categories, based on the manner in which CSFII data were presented, were used for building these lifetime consumption values. These age categories were:

< 1
1 – 10
11 – 19
20 – 64
65 – 70

Again, CSFII provided water consumption information separately for males and females in each of these categories, and Statistical Abstracts (1994) provided body weight distributions for these categories. In the simulation, an individual is selected, male or female according to the proportions of 51.9% male, 48.1% female. A value for water consumption in L/day and an average body weight for each of the five age categories is selected, and an average intake for each age category is computed by dividing the water consumption value selected by the body weight selected.

The individual's lifetime weighted average ($DW_{Ind}$ in Equation B-1) is then computed by averaging across the five age groups, weighting each appropriately for the number of years spent in that age range.

An additional adjustment factor had to be incorporated into Equation B-1 in order to account for the fact that the cancer unit risk factors used were calculated with an underlying assumption that it applied to an "average" person weighing 70 kg and consuming 2 L/day over the entire 70 year lifetime (or 0.0286 L/kg-day). Since drinking water consumption is being modeled in this analysis to explicitly account for the variability in water consumption as a function of body weight, proceeding without this adjustment would overestimate the cancer risk for those individuals with a lifetime weighted average consumption of less than 0.0286 L/kg-day, and similarly would underestimate it for those consuming more than 0.0286 L/kg-day as a lifetime average.

Because, as noted from the CSFII data, average water consumption across all age and sex groups is closer to 1.0 – 1.3 L/day and because lifetime average body weights are (especially for females) lower than 70 kg, failing to make this adjustment would in the aggregate overestimate cancer risk.

By applying the $DW_{Adj}$ adjustment factor of 70 kg/(2 L/day) to the water consumption values obtained in the simulation, this correction for the underlying basis of the risk value is accomplished.

The water consumption and adjustment discussed above are described in greater detailed in the RIA and its accompanying Appendix B. In that analysis, the product of the water consumption and the adjustment factor are described as the Lifetime Relative Exposure Factors (LREF), which reflects the exposure and risk relative to the 70 kg, 2 L/day (i.e., 0.0286 L/kg-day) person. In that more detailed analysis, it is shown that the overall distribution of these factors tends to be lognormal with means and standard deviations as shown in Exhibit B-1 for both males and females and the lower and upper bound water consumption distributions. In essence, these LREF values indicate that, on average, individual exposure and risk are about 60% to 80% of what they would be if every individual were assumed to be a 70 kg, 2 L/day person.

**Exhibit B-1**
**Summary of Lifetime Relative Exposure Factors (LREF):**
**(Product of $DW_{Ind}$ * $DW_{Adj}$. Overall Distributions are Lognormal)**

| | Community Water Consumption Data | Total Water Consumption Data |
|---|---|---|
| **Male** | *Mean* = 0.60<br>*s.d.* = 0.61 | *Mean* = 0.73<br>*s.d.* = 0.62 |
| **Female** | *Mean* = 0.64 | *Mean* = 0.79 |

## B.1.4 Cancer Risk Factors

This section provides further information on the variable $R_{Unit}$ in Equation B-1.

In its 1999 report, "Arsenic in Drinking Water," the NRC analyzed bladder cancer risks using data from Taiwan. In addition, NRC examined evidence from human epidemiological studies in Chile and Argentina, and concluded that risks of bladder and lung cancer had comparable risks to those "in Taiwan at comparable levels of exposure" (NRC, 1999). The NRC also examined the implications of applying different statistical analyses to the newly available Taiwanese data for the purpose of characterizing bladder cancer risk. While the NRC's work did not constitute a formal risk analysis, they did examine many statistical issues (e.g., measurement errors, age-specific probabilities, body weight, water consumption rate, comparison populations, mortality rates, choice of model) and provided a starting point for additional EPA analyses. The report noted that "poor nutrition, low selenium concentrations in Taiwan, genetic and cultural characteristics, and arsenic intake from food" were not accounted for in their analysis (NRC, 1999, pg. 295). In the June 22, 2000 proposed rule, EPA calculated bladder cancer risks and benefits using the bladder cancer risk analysis from the NRC report (NRC, 1999). We also estimated lung cancer benefits in a "What If" analysis based on the statement in the 1999 NRC report that "some studies have shown that excess lung cancer deaths attributed to arsenic are 2-5 fold greater than the excess bladder cancer deaths" (NRC, 1999).

In July, 2000, a peer reviewed article by Morales et al. (2000) was published, which presented additional analyses of bladder cancer risks as well as estimates of lung and liver cancer risks for the same Taiwanese population analyzed in the NRC report. EPA summarized and analyzed the new information from the Morales et al. (2000) article in a NODA published on October 20, 2000 (65 FR 63027; EPA, 2000). Although the data used were the same as used by the NRC to analyze bladder cancer risk in their 1999 publication, Morales et al. (2000) considered more dose-response models and evaluated how well they fit the Taiwanese data for both bladder cancer risk and lung cancer risk. Ten risk models were presented in Morales et al. (2000) used with and without one of two comparison populations. After consultation with the primary authors (Morales and Ryan), EPA chose Model 1 with no comparison population for further analysis.

EPA believes that the models in Morales et al. (2000) without a comparison population are more reliable than those with a comparison population. Models with no comparison population estimate the arsenic dose-response curve only from the study population. Models with a comparison population include mortality data from a similar population (in this case either all of Taiwan or part of southwestern Taiwan) with low arsenic exposure. Most of the models with comparison populations resulted in dose-response curves that were supralinear (higher than a linear dose response) at low doses. The curves were "forced down" near zero dose because the comparison population consists of a large number of people with low risk and low exposure. EPA believes, based on discussions with the authors of Morales et al. (2000), that models with a comparison population are less reliable, for two reasons. First, there is no basis in data on arsenic's carcinogenic mode of action to support a supralinear curve as being biologically plausible. To the contrary, the conclusion of the NRC panel (NRC, 1999) was that the mode of action data led one to expect dose responses that would be either linear or less than linear at low dose. However, the NRC indicated that available data are inconclusive and "...do not meet EPA's 1996 stated criteria for departure from the default assumption of linearity."(NRC, 1999)

Second, models that include comparison populations assume that the study and comparison populations are the same in all important respects except for arsenic exposure. Yet Morales et al. (2000) agree that "[t]here is reason to believe that the urban Taiwanese population is not a comparable population for the poor rural population used in this study." Moreover, because of the large amount of data in the comparison populations, the model results are sensitive to assumptions about this group. Evidence that supports these arguments are that the risks in the comparison groups are substantially lower than in similarly exposed members of the study group and the shape of the estimated dose-response changes sharply as a result. For these reasons, EPA believes that the models without comparison populations are more reliable than those with them. Of the models that did not include a comparison population, EPA believes that Model 1 best fits the data, based on the Akaike Information Criterion (AIC), a standard criterion of model fit, applied to Poisson models. In Model 1, the relative risk of mortality at any time is assumed to increase exponentially with a linear function of dose and a quadratic function of age.

Morales et al. (2000) reported that two other models without comparison populations also fit the Taiwan data well: Model 2, another Poisson model with a nonparametric instead of quadratic age effect, and a multi-stage Weibull (MSW) model. Under Model 2, the points of departure for male and female bladder and lung cancer are from 1% to 11% lower than under Model 1, but within the 95% confidence bounds from Model 1. Model 2 therefore implies essentially the same bladder and lung cancer risks as Model 1. Under the MSW model, compared to Model 1, points of departure are 45% to 60% higher for bladder cancer and for female lung cancer, and 38% lower for male lung cancer. EPA did not consider the MSW model for further analysis, because this model is more sensitive to the omission of individual villages (Morales et al., 2000) and to the grouping of responses by village (NRC, 1999), as occurs in the Taiwanese data. However, if the MSW model were correct, it would imply a 14% lower combined risk of lung and bladder cancers than Model 1, among males and females combined.

Considering all of these results, the Agency decided that the more exhaustive statistical analysis of the data provided by Morales et al. (2000), as analyzed by EPA, would be the basis for the new risk calculations for the final rule (with further consideration of additional risk analyses) and other pertinent information. The Agency views the results of the alternative models described above as an additional uncertainty which was considered in the decision concerning the selection of the final MCL.

The specific lifetime risk measures provided in the Morales (2000) study that were used in this benefits analysis, and their conversion to the $R_{Unit}$ values of cases per person per µg/L are shown in Exhibit B-2, below.

**Exhibit B-2**
**Risk Measures from Morales (2000) and as Used in this Benefit Analysis**

| | Bladder Cancer | | Lung Cancer | |
|---|---|---|---|---|
| | **Males** | **Females** | **Males** | **Females** |
| $ED_{01}$ (µg/L) | 395 | 252 | 364 | 258 |
| Mean for $R_{Unit}$ (cases/person per µg/L) | $2.53 \times 10^{-5}$ | $3.97 \times 10^{-5}$ | $2.75 \times 10^{-5}$ | $3.88 \times 10^{-5}$ |
| | | | | |
| $LED_{01}$ (µg/L) | 326 | 211 | 294 | 213 |
| Upper 95% CL for $R_{Unit}$ (cases/person per µg/L) | $3.07 \times 10^{-5}$ | $4.74 \times 10^{-5}$ | $3.40 \times 10^{-5}$ | $4.69 \times 10^{-5}$ |

The $ED_{01}$ values provided by Morales (2000) indicate that this is the arsenic concentration in drinking water that if consumed by an individual over a lifetime (with the assumption of 2 L/day and 70 kg body weight) has a 0.01 risk (i.e., 1% probability) of resulting in the indicated form of cancer. The $LED_{01}$ is the lower 95% confidence bound on the dose producing that 0.01 risk

To be used in the benefits calculation shown in Equation B-1, these risk measures are converted to the units of cases/person per µg/L needed for $R_{Unit}$ by simply dividing 0.01 by the corresponding $ED_{01}$ or $LED_{01}$ µg/L values.

In the Monte Carlo simulation, the $R_{Unit}$ value was incorporated as normal distribution with parameters based on the mean and upper 95% confidence limit as shown in Exhibit 3-D.2

### B.1.5 Upper and Lower Bound Considerations

In carrying out the arsenic benefits analysis, differing assumptions were used in an effort to establish upper and lower bounds on the estimated risks and avoided cases of cancer associated with the arsenic MCL. Some of the factors considered in the upper and lower bound estimates were noted in the preceding discussions. These are discussed more fully here.

For the upper bound analyses, EPA used:

- The surface water and ground water occurrence distributions as provided in the occurrence analyses;
- The drinking water consumption distribution using the total water consumption data from CSFII (i.e., averaging approximately 1.2 L/day)
- The unit cancer risk factor distribution based on the $R_{Unit}$ values shown in Exhibit 3.D.2.

For the lower bound analyses, EPA used:

- The surface water and ground water occurrence distributions as provided in the occurrence analyses (same as upper bound);
- The drinking water consumption distribution using the community (tap) water consumption data from CSFII (i.e., averaging approximately 1.0 L/day)
- The unit cancer risk factor distribution based on the $R_{Unit}$ values shown in Exhibit B-2 for males only (applied to both males and females), with further downward adjustments for potential contributions from water used in cooking and from food in the Taiwan population used to derive the risk factors

The use of the two different drinking water consumption distributions in establishing upper and lower bounds estimates were discussed previously. The other two adjustments noted in the third bullet for the lower bound estimates are described further here. Both of these adjustments reflect possible contributions to the cancer cases observed in the Taiwan study associated with arsenic in the water or food for that population that would not necessarily apply to the US population.

First, the Agency made an adjustment to the lower bound risk estimates to take into consideration the effect of exposure to arsenic through water used in preparing food in Taiwan. The Taiwanese staple foods were dried sweet potatoes and rice (Wu et al., 1989). Both the 1988 EPA "Special Report on Ingested Inorganic Arsenic" report and the 1999 NRC report assumed that an average Taiwanese male weighed 55 kg and drank 3.5 liters of water daily, and that an average Taiwanese female weighed 50 kg and drank 2 liters of water daily. Using these assumptions, along with an assumption that Taiwanese men and women ate one cup of dry rice and two pounds of sweet potatoes a day, the Agency re-estimated risks for bladder and lung cancer, using one additional liter water consumption for food preparation (i.e., the water absorbed by hydration during cooking). This adjustment was discussed and used in the October 20, 2000 NODA (65 FR 63027).

Second, an adjustment was made to the lower bound risk estimates to take into consideration the relatively high arsenic concentration in the food consumed in Taiwan as compared to the U.S. The food consumed daily in Taiwan contains about 50 μg, versus about 10 μg in the U.S. (NRC, 1999, pp. 50–51). Thus the total consumption of inorganic arsenic (from food preparation and drinking water) is considered, per kilogram of body weight, in the process of these adjustments. To carry them out, the relative contribution of arsenic in the drinking water that was consumed as drinking water, on a μg/kg/day basis, was compared to the total amount of arsenic consumed in drinking water, drinking water used for cooking, and in food, on a μg/kg/day basis.

Other factors contributing to lower bound uncertainty include the possibility of a sub-linear dose-response curve below the point of departure. The NRC noted "Of the several modes of action that are considered most plausible, a sub-linear dose response curve in the low-dose range is predicted, although linearity cannot be ruled out." (NRC,1999). The recent Utah study (Lewis et al., 1999), described in section 5.G.1(b), provides some evidence that the shape of the dose-response curve may well be sub-linear at low doses. Because sufficient mode of action data were not available, an adjustment was not made to the risk estimates to reflect the possibility of a sub-linear dose-response curve. Additional factors contributing to uncertainty include the use of village well data rather than individual exposure data, deficiencies in the Taiwanese diet relative to the U.S. diet (selenium, choline, etc.), and the baseline health status in the Taiwanese study area relative to U.S. populations. The Agency did not make adjustments to the risk estimates to reflect these uncertainties because applicable peer-reviewed, quantitative studies on which to base such adjustments were not available.

### B.1.6 Estimated Population Risk Values

The Monte Carlo simulation performed for this benefits analysis using the risk algorithm shown in Equation B-1 produce distributions of individual risk values ($R_{Ind}$) for the baseline and the various MCL options considered, and for both the upper and lower bound sets of assumptions. Exhibit B-3 provides some summary statistics for the resulting distribution of risks. Note that the "exposed population" addressed in this table are those individuals using community ground or surface water supplies serving fewer than one million people having arsenic levels greater than 3 µg/L.

The key outputs resulting from this Monte Carlo simulation for estimating cancer cases avoided are the mean risk values shown in Exhibit B-3. The application of these mean risk values to estimate cases avoided is described in the following section.

**Exhibit B-3**
**Cancer Risks for U.S. Populations**
**Exposed At or Above MCL Options, after Treatment**
**(Lower Bound With Food and Cooking Water Adjustment)**

| | Mean Risk for Exposed Population (Lower and Upper Bounds) | 90th Percentile Risk for Exposed Population (Lower and Upper Bounds) |
|---|---|---|
| 3 | 0.11 -1.25 x $10^{-4}$ | 0.22 - 2.42 x $10^{-4}$ |
| 5 | 0.27 - 2.02 x $10^{-4}$ | 0.55 - 3.9 x $10^{-4}$ |
| 10 | 0.63 - 2.99 x $10^{-4}$ | 1.32 - 6.09 x $10^{-4}$ |
| 20 | 1.10 - 3.85 x $10^{-4}$ | 2.47 - 8.37 x $10^{-4}$ |

### B.1.7 Estimated Cancer Cases and Cases-Avoided

To estimate the number of cancer cases avoided for the various MCL options it is necessary to first calculate the number of cases expected at the baseline risk level (no change in the MCL, or 50 μg/L), and then for each MCL option. Baseline mean risk values and estimated mean risk levels for the various MCL options (shown in Exhibit B-3) are multiplied by the total number of people served by community ground and surface water systems serving fewer than one million people. Because the lower bound risk adjustments are also made to the baseline risk (the risk at 50 μg/L), the baseline number of expected cases in the adjusted risk scenario is not the same (it's lower, just as the adjusted risks are lower) as the baseline number of expected cases in the unadjusted risk scenario. The number of cases avoided at each MCL alternative is determined by subtracting the number of cases remaining at each option from the appropriate baseline number of cases. Thus, to estimate cases avoided, the number of remaining cases expected at the lower risk levels are subtracted from the number of cases expected at the lower baseline level, and the number of remaining cases expected at the higher risk levels are subtracted from the number of cases expected at the higher baseline level.

An upper bound adjustment was made to the number of bladder cancer cases avoided to reflect a possible lower mortality rate in Taiwan than was assumed in the risk assessment process described earlier. EPA also made this adjustment in the June 22, 2000, proposal. In the Taiwan study area, information on arsenic related bladder and lung cancer deaths was reported. In order to use these data to determine the probability of contracting bladder and lung cancer as a result of exposure to arsenic, a probability of mortality given the onset of arsenic induced bladder and lung cancer among the Taiwanese study population must be assumed. The study area in Taiwan is a section where arsenic concentrations in the water are very high by comparison to those in the U.S., and an area of low incomes and poor diets, where the availability and quality of medical care is not of high quality, by U.S. standards. In its estimate of bladder cancer risk, the Agency assumed that within the Taiwanese study area, the probability of contracting bladder cancer was relatively close to the probability of dying from bladder cancer (that is, that the bladder cancer incidence rate was equal to the bladder cancer mortality rate).

We do not have data on the rates of survival for bladder cancer in the Taiwanese villages in the study and at the time of data collection. We do know that the relative survival rates for bladder cancer in developing countries overall ranged from 23.5% to 66.1 % in 1982-1992 ("Cancer Survival in Developing Countries," International Agency for Research on Cancer, World Health Organization, Publication No. 145, 1998). We also have some information on annual bladder cancer mortality and incidence for the general population of Taiwan in 1996. The age-adjusted annual incidence rates of bladder cancer for males and females, respectively, were 7.36 and 3.09 per 100,000, with corresponding annual mortality rates of 3.21 and 1.44 per 100,000 (correspondence from Chen to Herman Gibb, January 3, 2000). Assuming that the proportion of males and females in the population is equal, these numbers imply that the mortality rate for bladder cancer in the general population of Taiwan, at present, is 45%. Since survival rates have most likely improved over the years since the original Taiwanese study, this number represents a lower bound on the survival rate for the original area under study (that is, one would not expect a higher rate of survival in that area at that time). This has implications for the bladder cancer risk estimates from the Taiwan data. If there were any persons with bladder cancer who recovered and died from some other cause, then our estimate underestimated risk; that is, there were more cancer cases than cancer deaths. Based on the above discussion, we think bladder cancer incidence could be no more than 2 fold bladder cancer mortality; and that an 80% mortality rate would be plausible. Thus we have adjusted the upper bound of cases avoided, which is used in the benefits analysis, to reflect a possible mortality rate for bladder cancer of 80%. Because lung cancer mortality rates are quite high, about 88% in the U.S.(US EPA, 1998b), the assumption was made that all lung cancers in the Taiwan study area resulted in fatalities.

The total number bladder and lung cases avoided at each MCL are shown in Exhibit 3-D.3. These cases avoided include CWS and NTNC cases. The number of bladder and lung cancer cases avoided range from 57.2 to 138.3 at an MCL of 3 Fg/L, 51.1 to 100.2 at an MCL of 5 Fg/L, 37.4 to 55.7 at an MCL of 10 Fg/L, and 19.0 to 19.8 at an MCL of 20 Fg/L. The cases avoided were divided into premature fatality and morbidity cases based on U.S. mortality rates. In the U.S. approximately one out of four individuals who is diagnosed with bladder cancer actually dies from bladder cancer. The mortality rate for the U.S. is taken from a cost of illness study recently completed by EPA (US EPA, 1998b). For those diagnosed with bladder cancer at the average age of diagnosis (70 years), the probability for dying of that disease during each year post-diagnosis were summed over a 20-year period to obtain the value of 26 percent. Mortality rates for U.S. bladder cancer patients have decreased overall by 24 percent from 1973 to 1996. For lung cancer, mortality rates are much higher. The comparable mortality rate for lung cancer in the U.S. is 88% (US EPA, 1998b).

## B.2 Community Water Systems Serving More than One Million People

A separate analysis of the number of cancer cases and cases avoided was performed for community water systems serving more than one million people each. This analysis was based upon specific information available for each on the occurrence of arsenic in specific sources (entry points) for those systems, the flows for those entry points, and the number of people served by those specific systems.

Only three systems serving more than one million people were found to have arsenic levels in one or more entry point exceeding 3 µg/L: Phoenix, Houston, and Los Angeles.

The basic risk algorithm used for systems serving fewer than one million people as shown in Equation B-1 was also used for calculating cancer cases and cases avoided for the systems serving more than one million people.

There were two primary difference in the application of Equation B-1 for the systems serving more than one million people relative to its application for systems serving fewer than one million. First, the analysis was not done as a Monte Carlo simulation, but was based on average values for the variables in the equation. For example. the $R_{Unit}$ values used were equivalent to the mean risk values for the upper and lower bound risks as shown previously in exhibit B-2 (with the various adjustments made to the lower bound value for the potential impacts of other intakes as described earlier).

The water consumption and adjustment factors [$DW_{Ind}$ * $DW_{Adj}$] were simplified and used as average values rather than distributions.

The arsenic water concentrations [$C(As)_{Ind}$] used were calculated separately for each of the three very large systems using system-specific data. These calculations were carried out as follows.

Data was available on the arsenic concentration at each of the ground water and surface water entry points at each of these three very large systems. Data were also available on the average daily flow for the ground water and surface water sources in total.

EPA used that information to calculate an initial average arsenic concentration, $C_{Initial}$, for that portion of the system exceeding a particular MCL option as follows.

$$C_{Initial} = \frac{C_{GA}\left[\frac{EP_{GA}}{EP_{GT}} \bullet \frac{F_G}{F_T}\right] + C_{SA}\left[\frac{EP_{SA}}{EP_{ST}} \bullet \frac{F_S}{F_T}\right]}{\left[\frac{EP_{GA}}{EP_{GT}} \bullet \frac{F_G}{F_T}\right] + \left[\left[\frac{EP_{SA}}{EP_{ST}} \bullet \frac{F_S}{F_T}\right]\right]}$$

where:
$C_{GA}$ =the average arsenic concentration in the ground water entry points affected at that MCL option
$C_{SA}$ = the average arsenic concentration in the surface water entry points affected at that MCL option
$EP_{GA}$ = the number of ground water entry points affected at that MCL option
$EP_{GT}$ = the total number of ground water entry points in that system
$EP_{SA}$ = the number of surface water entry points affected at that MCL option
$EP_{ST}$ = the total number of surface water entry points in that system
$F_G$ = the total average daily flow from all ground water sources
$F_S$ = the total average daily flow from all surface water sources
$F_T$ = the total average daily flow from all water sources

These $C_{Initial}$ values were used for $C(As)_{Ind}$ in Equation B-1 to calculate the number of baseline cases in the population affected by the particular MCL option. The number of individuals in the population affected for a particular option at each of the very large systems was calculated as being the same portion of the total population served by that system as the portion of total flow affected at the given MCL option.

The post-regulatory cases remaining were calculated using the same procedure, except that a constant value was used for $C(As)_{Ind}$ that was equal to 0.8 * MCL value.

## B.3 Non-Transient Non-Community Water Systems

### B.3.1 Data Inputs

Most of the data described above under the CWS risk model is also used in the NTNC risk model. This includes water consumption, body weight, and lifetime risk estimates. Also, the ground water arsenic concentrations at each MCL used in the CWS risk model are used in the NTNC risk model.

#### B.3.1.1 NTNC Service Categories, Population and Exposure Time

The main differences between the CWS and NTNC risk models are how population is distributed among the different types of establishments that make up the NTNC category of systems, and the extent to which the worker and customer populations within a service category are exposed to arsenic (both in terms of length of exposure and drinking water consumed).

In addition to the CWS data already discussed, Exhibits B-4 and B-5 provide all of the data inputs necessary to model the bladder cancer risk associated with NTNC systems. First, note that in Exhibit B-4, the NTNC universe has been divided into 35 service categories. This was accomplished using the system descriptions in SDWIS (EPA, 1999b). For each service category, the total number of NTNCs and the population served by these NTNCs is taken from SDWIS. The population served by each NTNC often varies daily; the SDWIS population numbers are interpreted to mean the peak population served (both workers and customers).

The next data field in Exhibit B-4 is the number of customer cycles per year, or the number of times each year the customer base turns over. For example, if this parameter equals one, then the same customer's are served each day. If the value is seven, then seven sets of customers use the facility. The next field is the number of workers per person per day. For example, if the value is 0.1, as in the case of summer camps, then 10 percent of the peak population served (from SDWIS) is assumed to be workers. Both the number of customer cycles per year assumptions and workers per person per day data assumptions were made after investigating numerous data sources, including trade-journals and trade association information.

The next set of data fields in Exhibit B-4 are assumptions about the characteristics of the workers in each service type. The percent of workers' daily consumption is the percentage of drinking water consumed on a work day that is consumed at work. This value is assumed to be either 50 percent or 100 percent, depending on the service category. The number of days a person works is assumed to be 250 for all service categories. The number of years a person works at the NTNC establishment is assumed to be either 40 or 10, depending on the service category.

Information regarding customer behavior is provided in the next set of data fields in Exhibit B-4. The percent of customers' daily consumption is the percentage of total drinking water consumed on a day that the customer visits the NTNC, that is consumed at the NTNC. This value is assumed to be either 25 percent, 50 percent or 100 percent, depending on the service category. The number of days a customer visits the NTNC is provided for each service category. For example, the value for nursing homes of 365 indicates that nursing home customers are served by the nursing home year round, while the value for churches of 52 indicates that churches are assumed to serve their customers once per week. The number of years a person is assumed to visits each service category is also provided.

Finally, the total exposed worker and customer populations for each service category are provided in Exhibit B-4. These numbers are calculated as follows:

$$TC_c = (P_c * CC_c) * (1 - WP_c)$$

$$TW_c = P_c * WP_c$$

where:
TC = total number of customers
TW = total number of workers
P = SDWIS population
WP = workers per person per day
CC = number of customer cycles per year
c = NTNC service category

Exhibit B-5 provides the final set of data required to estimate bladder cancer risk from NTNCs. The percent of worker lifetime exposure is the percent of lifetime water consumption which is consumed at the NTNC by a worker. The percent of customer lifetime exposure is the percent of lifetime water consumption consumed at the NTNC by a customer. These numbers are calculated as follows:

$$PWLE_c = \frac{PWDC_c * DW_c * YW_c}{365 * 70}$$

$$PCLE_c = \frac{PCDC_c * DC_c * YC_c}{365 * 70}$$

where;
PWLE = percent of worker lifetime exposure
PCLE = percent of customer lifetime exposure
PWDC = percentage of workers daily consumption
PCDC = percentage of customers daily consumption

DW = worker days per year
DC = customer days per year
YW = worker years
YC = customer years

Returning to Exhibit B-5, the worker age bracket is the age range (corresponding to the age ranges used in the CWS risk analysis) that a NTNC worker is assumed to fall in. For all service categories, the worker age bracket is assumed to be 20-64 years of age. The customer age bracket is the age range (corresponding to the age ranges used in the CWS risk analysis) that a NTNC customer is assumed to be in. For most service categories, the customer age bracket is assumed to be 0-70 years of age (all ages). However, certain service categories only serve certain age groups (e.g. nursing homes and schools), therefore more specific age ranges are assumed.

## Exhibit B-4
## NTNC Population and Exposure Time Data

| | Number of Systems | Total SDWIS Population | Number of Customer Cycles/Year | Worker Per Person Per Day | Percent of Worker's Daily Consumption | Worker Days Per Year | Worker Years | Percent of Customer's Daily Consumption | Customer Days Per Year | Customer Years | Total Worker Population | Total Customer Population |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Wholesalers | 266 | 66,018 | 1.00 | 0 | n/a | n/a | n/a | 25.0% | 270.00 | 70.00 | 0 | 66,018 |
| Mobile Home Parks | 104 | 19,240 | 1.33 | 0.046 | 50.0% | 250 | 40 | 100.0% | 270.00 | 35.00 | 885 | 24,412 |
| Nursing Homes | 130 | 13,910 | 1.00 | 0.23 | 50.0% | 250 | 40 | 100.0% | 365.00 | 10.00 | 3,199 | 10,711 |
| Churches | 230 | 11,500 | 1.00 | 0.01 | 50.0% | 250 | 40 | 50.0% | 52.00 | 70.00 | 115 | 11,385 |
| Golf and Country Clubs | 116 | 11,716 | 4.50 | 0.11 | 50.0% | 250 | 40 | 50.0% | 52.00 | 70.00 | 1,289 | 46,923 |
| Retailers (Food related) | 142 | 45,724 | 2.00 | 0.07 | 50.0% | 250 | 40 | 25.0% | 185.00 | 70.00 | 3,201 | 85,047 |
| Retailers (Non-food related) | 695 | 120,930 | 4.50 | 0.09 | 50.0% | 250 | 40 | 25.0% | 52.00 | 70.00 | 10,884 | 495,208 |
| Restaurants | 418 | 154,660 | 2.00 | 0.07 | 50.0% | 250 | 40 | 25.0% | 185.00 | 70.00 | 10,826 | 287,668 |
| Hotels/Motels | 351 | 46,683 | 86.00 | 0.27 | 50.0% | 250 | 40 | 100.0% | 3.40 | 40.00 | 12,604 | 2,930,759 |
| Prisons/Jails | 67 | 121,940 | 1.33 | 0.1 | 50.0% | 250 | 40 | 100.0% | 270.00 | 3.00 | 12,194 | 145,962 |
| Service Stations | 53 | 12,190 | 7.00 | 0.06 | 50.0% | 250 | 40 | 25.0% | 52.00 | 54.00 | 731 | 80,210 |
| Agricultural Products/Services | 368 | 27,968 | 7.00 | 0.125 | 50.0% | 250 | 40 | 25.0% | 52.00 | 50.00 | 3,496 | 171,304 |
| Daycare Centers | 809 | 61,484 | 1.00 | 0.145 | 50.0% | 250 | 10 | 50.0% | 250.00 | 5.00 | 8,915 | 52,569 |
| Schools | 8,414 | 3,086,012 | 1.00 | 0.073 | 50.0% | 200 | 40 | 50.0% | 200.00 | 12.00 | 225,279 | 2,860,733 |
| State Parks | 83 | 106,895 | 26.00 | 0.016 | 50.0% | 250 | 40 | 50.0% | 14.00 | 70.00 | 1,710 | 2,734,802 |
| Medical Facilities | 367 | 163,631 | 16.40 | 0.022 | 50.0% | 250 | 40 | 100.0% | 6.70 | 10.30 | 3,600 | 2,624,510 |
| Campgrounds/RV Parks | 123 | 19,680 | 22.50 | 0.041 | 50.0% | 180 | 40 | 100.0% | 5.00 | 50.00 | 807 | 424,645 |
| Federal Parks | 20 | 780 | 26.00 | 0.016 | 50.0% | 250 | 40 | 50.0% | 14.00 | 70.00 | 12 | 19,956 |
| Highway Rest Areas | 15 | 6,105 | 50.70 | 0.01 | 50.0% | 250 | 40 | 50.0% | 7.20 | 70.00 | 61 | 306,428 |
| Misc. Recreation Services | 259 | 22,533 | 26.00 | 0.016 | 50.0% | 250 | 40 | 100.0% | 14.00 | 70.00 | 361 | 576,484 |
| Forest Service | 107 | 4,494 | 26.00 | 0.016 | 100.0% | 250 | 40 | 100.0% | 14.00 | 50.00 | 72 | 114,974 |
| Interstate Carriers | 287 | 35,301 | 93.00 | 0.304 | 50.0% | 250 | 40 | 50.0% | 2.00 | 70.00 | 10,732 | 2,284,963 |
| Amusement Parks | 159 | 76,462 | 90.00 | 0.18 | 50.0% | 250 | 10 | 50.0% | 1.00 | 70.00 | 13,763 | 5,642,896 |
| Summer Camps | 46 | 6,716 | 8.50 | 0.1 | 100.0% | 180 | 10 | 100.0% | 7.00 | 10.00 | 672 | 51,377 |
| Airports | 101 | 326,860 | 36.50 | 0.308 | 50.0% | 250 | 40 | 25.0% | 10.00 | 70.00 | 100,673 | 8,255,830 |
| Military Bases | 95 | 67,525 | n/a | 1 | 50.0% | 250 | 40 | n/a | n/a | n/a | 67,525 | 0 |
| Non-Water Utilities | 497 | 84,490 | n/a | 1 | 50.0% | 250 | 40 | n/a | n/a | n/a | 84,490 | 0 |
| Office Parks | 950 | 181,600 | n/a | 1 | 50.0% | 250 | 40 | n/a | n/a | n/a | 181,600 | 0 |
| Manufacturing: Food | 768 | 285,696 | n/a | 1 | 50.0% | 250 | 40 | n/a | n/a | n/a | 285,696 | 0 |
| Manufacturing: Non-Food | 3,356 | 588,792 | n/a | 1 | 50.0% | 250 | 40 | n/a | n/a | n/a | 588,792 | 0 |
| Landfills | 78 | 3,432 | n/a | 1 | 100.0% | 250 | 40 | n/a | n/a | n/a | 3,432 | 0 |
| Fire Departments | 41 | 4,018 | n/a | 1 | 100.0% | 250 | 40 | n/a | n/a | n/a | 4,018 | 0 |
| Construction | 99 | 5,247 | n/a | 1 | 100.0% | 250 | 40 | n/a | n/a | n/a | 5,247 | 0 |
| Mining | 119 | 13,447 | n/a | 1 | 100.0% | 250 | 40 | n/a | n/a | n/a | 13,447 | 0 |
| Migrant Labor Camps | 33 | 2,079 | n/a | 1 | 100.0% | 250 | 40 | n/a | n/a | n/a | 2,079 | 0 |
| | | | | | | | | | | **Subtotal =** | **1,662,407** | **30,305,774** |
| | | | | | | | | | | **TOTAL =** | | **31,968,181** |

**Exhibit B-5**
**NTNC Percent of Lifetime Exposure and Age at Exposure**

| | Percent of Worker Lifetime Exposure | Percent of Customer Lifetime Exposure | Worker Age Bracket | Customer Age Bracket |
|---|---|---|---|---|
| Water Wholesalers | 0.00% | 18.49% | n/a | all |
| Mobile Home Parks | 19.57% | 36.99% | 20 to 64 | all |
| Nursing Homes | 19.57% | 14.29% | 20 to 64 | 65+ |
| Churches | 19.57% | 7.12% | 20 to 64 | all |
| Golf and Country Clubs | 19.57% | 7.12% | 20 to 64 | all |
| Retailers (Food related) | 19.57% | 12.67% | 20 to 64 | all |
| Retailers (Non-food related) | 19.57% | 3.56% | 20 to 64 | all |
| Restaurants | 19.57% | 12.67% | 20 to 64 | all |
| Hotels/Motels | 19.57% | 0.53% | 20 to 64 | all |
| Prisons/Jails | 19.57% | 3.17% | 20 to 64 | 20 to 64 |
| Service Stations | 19.57% | 2.75% | 20 to 64 | 16 to 70 |
| Agricultural Products/Services | 19.57% | 2.54% | 20 to 64 | all |
| Daycare Centers | 4.89% | 2.45% | 20 to 64 | <5 |
| Schools | 15.66% | 4.70% | 20 to 64 | 6 to 18 |
| State Parks | 19.57% | 1.92% | 20 to 64 | all |
| Medical Facilities | 19.57% | 0.27% | 20 to 64 | all |
| Campgrounds/RV Parks | 14.09% | 0.98% | 20 to 64 | all |
| Federal Parks | 19.57% | 1.92% | 20 to 64 | all |
| Highway Rest Areas | 19.57% | 0.99% | 20 to 64 | all |
| Misc. Recreation Services | 19.57% | 3.84% | 20 to 64 | all |
| Forest Service | 39.14% | 2.74% | 20 to 64 | all |
| Interstate Carriers | 19.57% | 0.27% | 20 to 64 | all |
| Amusement Parks | 4.89% | 0.14% | 20 to 64 | all |
| Summer Camps | 7.05% | 0.27% | 20 to 64 | 11 to 19 |
| Airports | 19.57% | 0.68% | 20 to 64 | all |
| Military Bases | 19.57% | 0.00% | 20 to 64 | n/a |
| Non-Water Utilities | 19.57% | 0.00% | 20 to 64 | n/a |
| Office Parks | 19.57% | 0.00% | 20 to 64 | n/a |
| Manufacturing: Food | 19.57% | 0.00% | 20 to 64 | n/a |
| Manufacturing: Non-Food | 19.57% | 0.00% | 20 to 64 | n/a |
| Landfills | 39.14% | 0.00% | 20 to 64 | n/a |
| Fire Departments | 39.14% | 0.00% | 20 to 64 | n/a |
| Construction | 39.14% | 0.00% | 20 to 64 | n/a |
| Mining | 39.14% | 0.00% | 20 to 64 | n/a |
| Migrant Labor Camps | 39.14% | 0.00% | all | n/a |

### B.3.2 The NTNC Risk Model

Just like the CWS risk analysis, the NTNC risk analysis is a Monte-Carlo based simulation model. This section will explain each step is the simulation. The Monte-Carlo simulation is conducted at each MCL option (50, 20, 10, 5 and 3 Fg/L). In addition, for each MCL option, the simulation is carried out for both the "Lower Bound" and "Upper Bound" scenarios just like in the CWS case. Therefore, the simulation model is carried out ten times. Each of these ten "runs" of the model is independent of the other, and can be discussed in isolation. Therefore, this section will include a generalized discussion of the model. The inputs that are used will depend on the MCL option and scenario being evaluated at the time. It is important not to confuse a "run" of the model" as just described, and a model iteration. Each run of the model consists of 10,000 iterations. Within a single iteration, the model pulls a value for each variable from its input distribution (e.g. body weight) and calculates a value for each output variable (e.g. lifetime risk). This is done for 10,000 times for each model run. The results of the model run is the distribution of the 10,000 values for each output variable.

The first step of each iteration is to calculate the relative exposure factor for each sex and age category. This is done exactly as it was done in the CWS risk analysis. As shown in the following equations, the relative exposure factor is a function of daily water consumption and body weight.

$$REF_{mai} = \left(\frac{70}{2}\right) * \left(\frac{C_{mai}}{W_{mai}}\right)$$

$$REF_{fai} = \left(\frac{70}{2}\right) * \left(\frac{C_{fai}}{W_{fai}}\right)$$

where;
REF = relative exposure factor
C = daily water consumption (L)
W = body weight (kg)
i = model iteration number
a = age category
m = male
f = female

Next, the lifetime risk of bladder cancer (1/100,000 people) is calculated for workers and customers of each sex for each service category. The next four equations, therefore are:

$$WLR_{fci} = PWLE_{ci} * AS_{gi} * (RF_i / 50) * \left( \frac{\sum_a (REF_{fai} * Z_{ac})}{\sum_a Z_{ac}} \right) *100$$

$$WLR_{mci} = PWLE_{ci} * AS_{gi} * (RF_i / 50) * \left( \frac{\sum_a (REF_{mai} * Z_{ac})}{\sum_a Z_{ac}} \right) *100$$

$$CLR_{mci} = PCLE_{ci} * AS_{gi} * (RF_i / 50) * \left( \frac{\sum_a (REF_{mai} * Z_{ac})}{\sum_a Z_{ac}} \right) *100$$

$$CLR_{fci} = PCLE_{ci} * AS_{gi} * (RF_i / 50) * \left( \frac{\sum_a (REF_{fai} * Z_{ac})}{\sum_a Z_{ac}} \right) *100$$

where;
WLR = worker lifetime risk (per 100,000 people)
CLR = customer lifetime risk (per 100,000 people)
AS = arsenic concentration (Fg/L)
RF = risk of bladder cancer at 50 Fg/L, 2 liters consumption per day, and 70 kg body weight
Z = years spent in age category
g = ground water

The sex of the worker and customer is then chosen for the iteration to determine the worker and customer risk for each service category:

$$WLR_{ci} = \begin{cases} WLR_{mci} & \text{if} \quad RN_1 \leq MP \\ WLR_{fci} & \text{otherwise} \end{cases}$$

$$CLR_{ci} = \begin{cases} CLR_{mci} & \text{if} \quad RN_1 \leq MP \\ CLR_{fci} & \text{otherwise} \end{cases}$$

where;
$RN_1$ = random number between 0 and 1
MP = percentage of the population that is male

Finally, the lifetime risk for the model iteration is determined by choosing among the 70 combinations of worker and customer risk over of the 35 service categories. This is accomplished using a population weighted probability distribution. First, the total worker and customer populations served are computed.

$$TC = \sum_c TC_c$$

$$TW = \sum_c TW_c$$

Next, the probability that the lifetime risk for the model iteration will be equal to the worker lifetime risk associated with a service category is calculated:

$$WPR_c = \frac{TW_c}{(TW + TC)}$$

where;
WPR = probability of choosing lifetime risk estimate for any iteration to be equal to the lifetime risk estimate of a worker in a given service category

Likewise, the probability that the lifetime risk for the model iteration will be equal to the customer lifetime risk associated with a service category is calculated:

$$CPR_c = \frac{TC_c}{(TW + TC)}$$

where;
CPR = probability of choosing lifetime risk estimate for any iteration to be equal to the lifetime risk estimate of a customer in a given service category

Given these probabilities, the lifetime risk estimate for each model iteration is chosen as follows:

$$LR_i = \begin{cases} WLR_{ci} \quad \text{with} \quad \text{Pr obability } WPR_c \\ \vdots \\ CLR_{ci} \quad \text{with} \quad \text{Pr obability } CPR_c \end{cases}$$

where;
LR = Lifetime risk (1/100,000)

In order to calculate the expected number of cancer cases associated with the model run, the mean lifetime risk is multiplied by the exposed population as follows:

$$CA = \left( \frac{\sum_{i=1}^{N} LR_i}{N} \right) * \frac{(TC + TW)}{100{,}000}$$

where;
CA = expected number of  bladder cancer cases
N = number of iterations

# Appendix C. Cost Model Methodology

## C.1 Introduction

EPA used the regulatory cost model, SafeWaterXL, in estimating the annual national costs of compliance for the Arsenic in Drinking Water Rule. SafeWaterXL is a Monte-Carlo simulation model developed in Microsoft Excel using the Crystal Ball add-in.[1] The model is programmed in Visual Basic for Applications, the procedures and functions of which command for example, the user interface and much of the business logic required. These procedures and functions call on data and equations stored in Microsoft Excel spreadsheets, such as data on specific system characteristics (e.g., the number of people served, the type and source of the water system, the decision tree).

SafeWaterXL determines regulatory compliance costs for individual systems and subsequently calculates a national average cost based on the mean value of these data points. SafeWaterXL describes system-level costs in terms of a distribution, from which mean costs and percentile costs are available. Mean costs reflect the costs of treatment trains selected. Treatment trains consist of two main cost components, capital (the cost of constructing or installing equipment) and operation and maintenance (O&M, annual cost of operating equipment and performing routine maintenance) costs for: pre-treatment pre-oxidation technology (if necessary), treatment technology, and waste disposal technology. This modeling approach presents information critical to the assessment of system-level impacts and technology affordability by providing the average compliance costs for each water system type and size category, and the range of costs within each system size and type category.

In understanding how SafeWaterXL calculates annual national cost of compliance, it is important to distinguish between an "iteration" and a "run" of the model. A single iteration of the model represents a single system. This allows for variability in the water system configuration, current treatment in place, and source water quality to be captured in the compliance cost estimates. A model "run" uses data from the aggregate number of iterations to calculate summary cost information for different system size categories. For any individual "run," only a single source water type may be evaluated, and the results are stratified by sixteen groups: 8 size categories and 2 ownership types (public/private).

## C.2 Data Inputs and Procedure (Single Model Iteration)

The fundamental steps required to conduct an iteration of SafeWaterXL are summarized below:

1. A system is selected from data files. A system is defined by the population it serves.
2. Each system is assigned a random concentration from an occurrence distribution.

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[1]For Windows 95/98/NT: Excel 2000, registered trademark of Microsoft Corporation; Crystal Ball Version 4.0, registered trademark of Decisioneering, Inc.

3. The selected arsenic concentration for the system is distributed across the number of sites (entry points) of possible contamination for that system based on the relative intra-system standard deviation (RSD).
4. The concentration at each site is compared to the revised MCL standard to determine if the site is in violation of the revised standard.
5. If the site is in violation of the revised MCL, the percentage removal of arsenic required in order to reach the treatment target is calculated.
6. Based on the percentage removal required to meet the treatment target and on the decision tree for the size and type of the system, a treatment train is then assigned to the site.
7. Using the removal efficiency of the treatment train chosen, the percentage of flow that must be treated in order for the entry point to meet the treatment target, is calculated.
8. The percentage of flow that needs to treated is applied to the design flow, which is then used to derive the capital costs of the components of the treatment train (the sum of: treatment capital, waste disposal capital, and any pre-treatment capital costs).
9. Similarly, the percentage of flow that needs to treated is also applied to the average flow, which is then used to derive the operation and maintenance costs of the components of the treatment train (the sum of: treatment O&M, waste disposal O&M, and any pre-treatment O&M costs).
10. The system's total annual treatment costs are calculated for the selected treatment train at various discount rates, by summing the treatment costs (annualized capital plus annual O&M cost components) across all treating sites.
11. This annual system cost is used to derive the cost per thousand gallons (cost/kgal) delivered by the water system.
12. Annual household costs are then calculated based on the system's unit cost of delivery (cost per thousand gallons) and the average annual household consumption per year.
13. If household costs are determined to exceed an affordability threshold of $500, a less expensive treatment technology (POU device) is chosen and new costs are calculated (Steps 7-12 above are repeated using data for POU devices).
14. Otherwise, the results are forecasted for each iteration and another system is selected for the next iteration.

This procedure is conducted for all of the size categories and national costs are then calculated. Each step listed above is now described in detail.

- A system is selected from data files.

The basic unit of analysis within the cost model is an individual CWS. The SafeWaterXL model estimates regulatory cost based on a universe of CWSs using a December 1997 freeze of the Safe Drinking Water Information System (SDWIS) dataset, which allows costs to community water systems to be delimited by various system characteristics: source, ownership, and size. SDWIS contains data on all public water systems as reported by States and EPA Regions. This information is used to determine each system's primary raw water source (ground or surface water), its ownership type (public or private), and the population served by the system (service size category). Note that in SDWIS, systems under any influence of surface water are classified as surface water systems.

Included in this group are surface water systems that receive a portion of their flow from ground water sources. In SafeWaterXL, these "mixed systems" were reclassified as ground water systems if they were determined to rely on ground water for more than 50 percent of their water supply. Based on data from the Community Water System Survey (CWSS)[2], systems were systematically reassigned in order to maintain the same average number of people served for the subset of systems. Approximately nine and twelve percent of non-purchased and purchased surface water systems were reclassified as a result.

The universe of systems modeled in SafeWaterXL also excludes the largest systems, those serving more than 900,000 people. These very large systems, although few in number, are significant contributors to the national cost of compliance estimate. Therefore, for the Arsenic in Drinking Water Rule, EPA did an independent analysis on the 25 very large systems (both ground and surface water source systems) to determine which would be affected at various MCL options. In addition, among the smallest systems (serving <100 people), approximately 150 ground water system were found to serve fewer than 25 people, but for modeling purposes were all assumed to serve 25 people. Due to the sheer number of systems in this size category (>14,000 systems), the effect of this modification was found to be insignificant.

In total, the resulting number of systems are distributed between two data files which the model calls on for system information. The criterion for these two files is source water: ground or surface. Then, within each file, CWSs[3] are first grouped by size category, resulting in eight different worksheets of data corresponding to each delimited category (25-100; 101-500; 501-1,000; 1,100-3,300; 3,301-10,000; 10,001-50,000; 50,001-100,000; 100,001-90,000). The resulting stratification of the 1997 SDWIS freeze used in SafeWaterXL is described in Exhibits C-1 and C-2 below for ground and surface water systems, respectively.

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[2]U.S. EPA. 1999. *Geometries and Characteristics of Public Water Systems.* Prepared for Office of Ground Water and Drinking Water by Science Applications International Corporation. EPA Contract No. 69-C6-0059.

[3]Note that public-purchased systems are analyzed as publicly-owned systems and similarly, private-purchased systems are analyzed as privately-owned system.

**Exhibit C-1.**
**Stratification of Community Ground Water Systems**

| System Size Category | Publicly-Owned | | Privately-Owned | | All GW Systems |
|---|---|---|---|---|---|
| | Non-Purchased | Purchased | Non-Purchased | Purchased | |
| **25-100** | 1,217 | 125 | 12,893 | 197 | 14,432 |
| **101-501** | 4,141 | 480 | 10,242 | 385 | 15,248 |
| **501-1,000** | 2,574 | 300 | 1,798 | 115 | 4,787 |
| **1,001-3,300** | 3,847 | 347 | 1,599 | 100 | 5,893 |
| **3,301-10,000** | 2,027 | 229 | 493 | 35 | 2,784 |
| **10,001-50,000** | 1,078 | 207 | 259 | 17 | 1,561 |
| **50,001-100,000** | 126 | 26 | 27 | 1 | 180 |
| **100,001-900,000** | 74 | 15 | 18 | -- | 107 |
| **Total** | 15,084 | 1,729 | 27,329 | 850 | 44,992 |

**Exhibit C-2.**
**Stratification of Community Surface Water Systems**

| System Size Category | Publicly-Owned | | Privately-Owned | | All SW Systems |
|---|---|---|---|---|---|
| | Non-Purchased | Purchased | Non-Purchased | Purchased | |
| **25-100** | 150 | 209 | 404 | 293 | 1,056 |
| **101-501** | 348 | 634 | 396 | 490 | 1,868 |
| **501-1,000** | 331 | 476 | 131 | 212 | 1,150 |
| **1,001-3,300** | 873 | 930 | 225 | 280 | 2,308 |
| **3,301-10,000** | 771 | 567 | 102 | 104 | 1,544 |
| **10,001-50,000** | 724 | 387 | 114 | 35 | 1,260 |
| **50,001-100,000** | 133 | 61 | 31 | 3 | 228 |
| **100,001-900,000** | 136 | 33 | 33 | 3 | 205 |
| **Total** | 3,466 | 3,297 | 1,436 | 1,420 | 9,619 |

Systems in each worksheet are further defined by their ownership type and an exact number of people served. A separate decision tree also exists for each size category, such that there are sixteen in total available for analysis in SafeWaterXL, as presented in Appendix A.

For example in this step, a system is selected from one of the data files. Recall that when a model "run" is performed, only one source type may be analyzed at a time. The selection made by the user triggers which data file is utilized. Once designated, assuming all size categories are being analyzed, the model begins with the smallest size category (<100 people served).

- Each system is assigned a random concentration from an occurrence distribution.

The system selected in Step 1 has various associated system characteristics. Each system is also associated with an arsenic occurrence distribution based on the source water. However, these distributions define the universe of systems with the same type of source water using a mean and log standard deviation. To model a single system chosen from the data files, a random system occurrence is selected from this distribution.

In this manner, contaminant occurrence information determines the average system concentration given various system size and source water combinations. Exhibit 6-6 shows the estimated finished water arsenic occurrence distribution for ground and surface water systems. For use in the SafeWaterXL model, EPA performed a regression analysis that weighted actual occurrence data by National Arsenic Occurrence Survey region. On the basis of this, EPA replicated the estimated finished water distribution of ground and surface water systems through a log-normal fit using two sets of distribution parameters. The analysis resulted in the following distribution of systems exceeding various arsenic concentration levels:

**Exhibit C-3**
**Arsenic Occurrence Distribution, Log-Normal Regression Results**

| | 3 µg/L | 5 µg/L | 10 µg/L | 20 µg/L |
|---|---|---|---|---|
| **Ground water** | 19.7% | 12.0% | 5.3% | 2.0% |
| **Surface water** | 5.6% | 3.0% | 1.12% | 0.37% |

*Percentages represent systems exceeding the arsenic concentration

For ground water systems, the percentages displayed in Exhibit C-3 above were based on a lognormal distribution with a mean of -0.2507 and a log standard deviation of 1.5828. Among surface water systems, the percentages were based on a lognormal distribution of -1.6781 and a log standard deviation of 1.7425.

- The selected arsenic concentration for the system is distributed across the number of sites (entry points) of possible contamination for that system based on the relative intra-system standard deviation (RSD).

Once the system arsenic concentration is determined, the number of entry points, or sites of the system, are determined. The number of sites a system has is another important system characteristic to consider in the analysis because entry points are used as a proxy for the potential or actual points of treatment. Since not all sites in the system are equally likely to exceed the MCL standard, the likelihood of contamination is determined on a site-by-site basis. That is, each system may have more than a single site treating independently.

The average number of sites per system is determined based on the distribution of system intake sites for the size category as estimated from the CWSS. The range of number of sites per system is described in Exhibit C-4 for ground water systems, where a maximum of 37 possible sites was modeled. Linear extrapolation was used to estimate values for the number of sites in cases where survey data was not available.

**Exhibit C-4**
**Distribution of Entry Points by Size Category Among Ground Water Systems**

| System Size Category | Mean | 5th Percentile | 50th Percentile (Median) | 75th Percentile | 95th Percentile | Maximum |
|---|---|---|---|---|---|---|
| <-100 | 1 | 1 | 1 | 1 | 2 | 4 |
| 101-500 | 1 | 1 | 1 | 1 | 3 | 10 |
| 501-1,000 | 2 | 1 | 1 | 2 | 3 | 4 |
| 1,001-5,000 | 2 | 1 | 1 | 2 | 5 | 6 |
| 5,001-10,000 | 2 | 1 | 2 | 3 | 5 | 15 |
| 10,001-50,000 | 4 | 1 | 3 | 5 | 12 | 19 |
| 50,001-100,000 | 6 | 1 | 4 | 8 | 22 | 37 |
| 100,001-900,000 | 9 | 1 | 5 | 15 | 28 | 30 |

Source: U.S. EPA. 1999. *Geometries and Characteristics of Public Water Systems*. Prepared for Office of Ground Water and Drinking Water by Science Applications International Corporation. EPA Contract No. 68-C6-0059.

Among surface water systems, fewer sites per system exist. About 95 percent of the systems that serve fewer than 50,000 people have only a single entry point. Of the remaining surface water systems that serve greater than 50,0001 people, the majority of the systems had fewer than three entry points, although some in the 50,001-100,000 and 100,001-900,000 service size categories were observed to have as many as six and four sites per system, respectively.

The SafeWaterXL model calculates potential costs of compliance at the entry point level, allowing for a maximum of 37, but modeling only the estimated number attributable to each system, based on the distribution described in Exhibit C-4. Once the number of sites within the system is determined from the distribution, the concentration of the contaminant at the site is calculated by applying the assumed relative intra-system standard deviation (RSD) around the mean system concentration. The average concentration of arsenic for that system (from Step 2) is assigned between all the system's sites using a log-normal distribution with the system concentration as the mean, and the intra-system deviation as the standard deviation, which is derived by multiplying the RSD by the system concentration. The RSD is an input ultimately used to distribute the system occurrence between the various entry points of the site. The RSD is a model input provided by the user that feeds into the calculation of the intra-system deviation based on the relationship expressed in Equation 1.

$$RSD = \frac{Intra\text{-}System\ Standard\ Deviation}{System\ Concentration} \qquad \text{(Eq. 1)}$$

This distribution used to assign site concentration is bound by zero at the lower limit and by the maximum site concentration (Eq. 2) at the upper limit. Note however, that the sum of the mean arsenic concentration of all sites within a system must still equal the mean arsenic concentration of the system.

$$Max\ Site\ Conc. = (SysConc) \times (\#\ of\ sites) \qquad \text{(Eq. 2)}$$

where: SysConc = arsenic concentration for system

The maximum is set using the assumption that despite the number of entry points, if only one entry is contaminated, its individual concentration cannot exceed a limit such that when averaged across the number of possible sites, the overall concentration would exceed the original concentration determined for that system.

For any given system that has more than a single site, the average system concentration of arsenic for that system is assigned between all the system's sites using this method. Otherwise, if the system has only a single site, then the site concentration must equal the system concentration.

- The concentration at each site is compared to the revised MCL standard to determine if the site is in violation of the standard.

Although the system concentration could itself fall below the MCL, once the system concentration has been distributed between the possible number of entry points, one site may significantly exceed the MCL while the other falls below the MCL such that their average still equals the system concentration. For example, in a system with three sites, there may have two sites whose individual site concentrations are well below the MCL and one site whose concentration exceeds the MCL. In this example, only costs to the third site are calculated. However, if a system has only one site, then that single site is assigned the entire system concentration of arsenic.

For this reason, the concentration of each site of the system is individually compared to the MCL. No costs are incurred for those sites whose concentrations fall below the specified MCL, as no treatment is required. However, if the site is determined to be in violation of the MCL, then treatment costs for regulatory compliance will be calculated and the model must record the data and output information. To do so with the best approximation of the true costs of compliance, only the portion of the system's flow that must be treated to achieve the target MCL level is assigned a cost, as described in Step 5.

- If the site is in violation of the revised MCL, the percentage removal required in order to reach the treatment target is calculated.

If the site is determined to be in violation of the MCL, then SafeWaterXL calculates the percent reduction in the site's arsenic concentration required to reduce the site concentration to 80 percent of the MCL standard. This is a safety factor which includes a 20 percent excess removal to account for system over-design. The percent of contamination reduction required can be expressed as:

$$\% \ removal = \frac{(SiteConc - TrtTarget)}{SiteConc.} \qquad \text{(Eq. 3)}$$

where: % removal = percent removal required to meet treatment target
SiteConc = arsenic concentration at the treating site
TrtTarget = 80 percent of revised MCL

The magnitude of reduction required determines which treatment decision tree is used. A technology is chosen depending on the percentage removal required and treatment train removal efficiencies that will meet the target MCL. The model recognizes three categories of required reduction: <50 percent, 50-90 percent, and >90 percent. Each category is represented by a distinct decision tree of feasible technologies for the amount of removal required. For example, if a site has an influent arsenic level of 50 µg/L, and the target MCL is 2 µg/L, then 96 percent removal is required. Research indicates that lime softening is only capable of achieving approximately 80 percent removal, therefore lime softening would not be a viable treatment option for that site. Therefore, with information about the appropriate amount of removal required for the site to achieve compliance, the model is directed to the corresponding decision tree for a distribution of treatment trains from which to make a selection.

- Based on the percentage of removal required to meet the treatment target and on the decision tree for the size and type of the system, a treatment train is then assigned to the site.

Since entry points may have different site concentrations, it is likely that different treatment technologies would be applied at different sites to meet the target MCL depending on the percentage of removal required to meet the treatment target, and on the removal efficiency of the treatment train selected. The variability of treatment train selection among sites is based on probabilities defined in a decision tree, which contains a range of compliance responses for different system types and sizes, and represent EPA's best estimate of the treatment train technologies that system operators will choose to achieve a particular percentage reduction in arsenic concentration. Specifically, the compliance decision trees are distributions that identify the percentage of systems in different categories that will choose specific compliance options. For example, the decision tree specifies the probability of different compliance choices for systems with different removal percentages required, baseline influent concentrations, different sizes (e.g., population served), and different sources (groundwater and surface water).

The decision trees are specific to the system's size categories and source water, and vary according to the contaminant under consideration. SafeWaterXL uses sixteen distinct decision trees in total: one for each of the eight system size categories with ground water and surface water sources. Each decision tree contains a list of treatment trains with three sets of probabilities that would apply to the site, depending on which of three required treatment scenarios the site belongs (<50 percent, 50-90 percent, or >90 percent removal required as described in Step 5). The actual decision tree is illustrated as a flowchart, and is often summarized as a decision matrix, for a particular source water and size category. The matrices used in this analysis were developed for the Revised Arsenic Rule and may be found in Appendix A.

Appendix A describes the treatment technologies, their effectiveness, and the major factors that affected the composition of a particular decision tree. Among some of the centralized treatment options presented include: lime softening, anion exchange, activated alumina, reverse osmosis, and coagulation assisted microfiltration. Some associated waste disposal technologies are also described. Waste disposal technologies are specific to the treatment technology, although their availability does vary between size categories. In addition to these centralized treatment options, small systems may also elect to use point-of-entry (POE) devices to achieve compliance with the MCLs, identified as affordable technologies by the SDWA. The available POE technologies for arsenic removal are essentially smaller versions of reverse osmosis and activated alumina.

- Using the removal efficiency of the treatment train chosen, the percentage of flow that must be treated in order for the entry point to meet the treatment target, is calculated.

Once a treatment train is selected from the decision tree, the associated removal efficiency of the technology is used with information on system flow to determine the amount of flow at the site that must be treated in order to meet the treatment target. System flow is calculated as a power law function of the population served. EPA derived these functions, the derivation of which can be found in the *Geometries and Characteristics of Public Water Systems* report (U.S. EPA, May 1999). Both the equations, and the regression parameters employed in the SafeWaterXL cost model are presented in the following two equations and Exhibit C-5, respectively.

$$Average\ Flow \quad a_A \cdot (Population)^{b_A} \qquad \text{(Eq. 4)}$$

$$Design\ Flow = max\begin{cases} 2 \cdot Average\ Flow \\ a_D \cdot (Population)^{b_D} \end{cases} \qquad \text{(Eq. 5)}$$

where: $a_A$, $b_A$, $a_D$, $b_D$ = regression parameters derived for flow vs. population
Population = population served by the system type and source

**Exhibit C-5.**
**Flow Regression Parameters by System Source and Ownership Type**

| System Source and Ownership Type | Average Flow | | Design Flow | |
|---|---|---|---|---|
| | $a_A$ | $b_A$ | $a_D$ | $b_D$ |
| *Ground Water* | | | | |
| Public | 0.08558 | 1.05840 | 0.54992 | 0.95538 |
| Private | 0.06670 | 1.06280 | 0.41682 | 0.96078 |
| Public-Purchased | 0.04692 | 1.10190 | 0.31910 | 0.99460 |
| Private-Purchased | 0.05004 | 1.08340 | 0.32150 | 0.97940 |
| *Surface Water* | | | | |
| Public | 0.14004 | 0.99703 | 0.59028 | 0.94573 |
| Private | 0.09036 | 1.03340 | 0.35674 | 0.96188 |
| Public-Purchased | 0.04692 | 1.11020 | 0.20920 | 1.04520 |
| Private-Purchased | 0.05004 | 1.08340 | 0.20580 | 1.00840 |

Source: U.S. EPA. 1999. *Geometries and Characteristics of Public Water Systems*. Prepared for Office of Ground Water and Drinking Water by Science Applications International Corporation. EPA Contract No. 68-C6-0059.

Based on these data, the system flow is determined in thousands of gallons per day (KGPD). The system flow is then divided equally among the possible sites of contamination, regardless of whether they are treating (i.e., violation of the revised MCL standard) or not. For example, a system with four potential sites of contamination is modeled to have four sites, each with 25 percent of the total system flow. However, even with this distribution of system flow between the number of sites, the resulting flow assumed at each site is further adjusted for treating sites, such that only the portion of flow that must be treated to lower the arsenic concentration is accounted for in the subsequent cost estimate.

SafeWaterXL employs a "blending" principle to determine the amount of flow that requires treatment in order for the entry point to meet the treatment target established by the MCL. The treatment target is considered 80 percent of the MCL and represents the contaminant level to which the design of systems will perform, to ensure adequate compliance with the MCL. To reach this target, data on the removal efficiencies of the chosen treatment trains, the contaminant occurrence at the site, and the percent of flow apportioned to that entry point are used to determine the fraction of flow needed to be treated, as expressed by the following relationship:

$$Fraction\ of\ Flow\ Treated = \frac{\left(\frac{TrtTarget}{SiteConc} - 1\right)}{-\ \%\ RE} \times (\%SiteFlow) \qquad \text{(Eq. 6)}$$

| where: | TrtTarget | = | 80 percent of revised MCL |
|---|---|---|---|
| | SiteConc | = | arsenic concentration at the site |
| | % RE | = | % removal efficiency of treatment train chosen |
| | % Site Flow | = | % of total system flow attributable to that site |

Notice that the blending technique is applied at the entry point level, but it is not used for systems selecting POU devices, as those options treat water at the tap rather than for the entire house. Since treatment costs to reduce such high levels of contamination can be significant, blending is an approach SafeWaterXL takes to best characterize the expected cost of compliance. In this manner, treatment costs are tallied only among the sites that are expected to treat, for the portion of the overall system flow that actually gets treated.

- The percentage of flow that needs to treated is applied to the design flow, which is then used to derive the capital costs of the components of the treatment train (the sum of: treatment capital, waste disposal capital, and any pre-treatment capital costs).

Each treatment train is defined by a treatment technology and (where relevant in order to be effective) a waste disposal option, and/or pre-treatment technology. Therefore, the cost of the treatment trains is related to its constituent capital and O&M cost components. Capital costs are estimated as a function of design flow. When the treatment train has been selected, the overall capital costs of these various components are aggregated to derive an overall capital cost estimate. This is expressed in the following general treatment train cost functions at each site:

$$TrC_{cap} = T_{cap} + WD_{cap} + \left[ \left( P_{PO} \right) \left( PO_{cap} \right) \right] \quad \text{(Eq. 7)}$$

| where: | $TrC_{cap}$ | = | Treatment train capital cost at treating site |
|---|---|---|---|
| | $T_{cap}$ | = | Treatment technology capital cost at treating site |
| | $WD_{cap}$ | = | Waste disposal technology capital cost at treating site |
| | $P_{PO}$ | = | Probability of using pre-oxidation at treating site |
| | $PO_{cap}$ | = | Pre-oxidation technology capital cost at treating site |

Depending on the source water conditions and on the treatment technologies involved, EPA determined that some systems would require additional pre-oxidation. EPA developed a separate decision tree to approximate the number of systems that would implement pre-oxidation technologies when selecting a treatment train. The need for this separate decision tree was based in part on the distribution of systems with and without treatment-in-place. For technology trains in which pre-treatment is required, Exhibit C-6 summarizes the decision tree of probabilities by system size that a system would require these technologies.

Each of the treatment technologies considered in the decision tree remove As(V) more readily than As(III) and as a result, pre-oxidation may be necessary depending upon source water conditions. Systems without treatment in-place may already be chlorinating which may meet pre-oxidation requirements. For those systems, pre-oxidation may or may not need to be installed. Similarly, systems with treatment in-place may have pre-oxidation in-place, which could meet the pre-oxidation requirements.

**Exhibit C-6.**
**Probability of a System Requiring Pre-Oxidation**

| System Size Category | Pre-Oxidation (GW systems) | Pre-Oxidation (SW systems) |
|---|---|---|
| 25-100 | 0.54 | 0.09 |
| 101-500 | 0.30 | 0.04 |
| 501-1,000 | 0.24 | 0 |
| 1,001-3,300 | 0.24 | 0 |
| 3,301-10,000 | 0.27 | 0.03 |
| 10,001-50,001 | 0.13 | 0.01 |
| 50,001-100,000 | 0.41 | 0.02 |
| 100,001-1,000,000 | 0.16 | 0 |

Source: Facsimile from Amit Kapadia, EPA OGWDW, July 27, 1999.

Similarly, the percentage of flow that needs to treated is also applied to the average flow, which is then used to derive the operation and maintenance costs of the components of the treatment train (the sum of: treatment O&M, waste disposal O&M, and any pre-treatment O&M costs).

Unlike capital costs, which are expressed as a total cost, operation and maintenance costs are expressed as a cost per year, and are calculated as a function of average flow. The total O/M costs for each treating site are aggregated to derive an annual system O/M cost for the treatment technology. Treatment O&M cost, waste disposal O&M, and any pre-treatment O&M costs are tallied. These conditions are expressed in the following general treatment train cost functions at each site:

$$TrC_{O\&M} = T_{O\&M} + WD_{O\&M} + \left[\left(P_{PO}\right)\left(PO_{O\&M}\right)\right] \qquad \text{(Eq. 8)}$$

where:

- $TrC_{O\&M}$ = Treatment train O&M cost at treating site
- $T_{O\&M}$ = Treatment technology O&M cost at treating site
- $WD_{O\&M}$ = Waste disposal technology O&M cost at treating site
- $PO_{O\&M}$ = Pre-oxidation technology O&M cost at treating site

Since the treatment technologies produce residuals that may contain various levels of arsenic, the O&M costs associated with the treatment train are an important consideration in the overall cost of the technology chosen. The handing and disposal costs associated with these residuals can be significant, and depend on a number of factors, such as the size and flow of the water system. The amount of waste that is generated will affect which technology is implemented by a water system. For example, some methods may be impractical for larger systems due to land requirements. Alternatively, more expensive processes may be inappropriate for smaller system due to the cost. Process oversight, transportation, and labor are all factors affecting the overall cost of the process. In general, the more complex the handling and the disposal methods, the more significant the maintenance requirements, and therefore the more costly.

- The system's total annual treatment costs are calculated for the selected treatment train at various discount rates, by summing the treatment costs (annualized capital plus annual O&M cost components) across all treating sites.

Since operation and maintenance costs are annual, applying the amortization formula on the capital cost component (Step 8) over a specified period of repayment, results in an overall annual cost of treatment at a site:

$$TrC_{tot} = \left(TrC_{cap}\right)\left(\frac{r}{1-(r+1)^{-rp}}\right) + TrC_{O\&M} \qquad \text{(Eq. 9)}$$

where:

| | | | |
|---|---|---|---|
| | $TrC_{tot}$ | = | Annual total treatment train cost at treating site |
| | $TrC_{cap}$ | = | Treatment train capital cost at treating site |
| | r | = | Discount rate |
| | rp | = | Repayment period |
| | $TrC_{O\&M}$ | = | Treatment train O&M cost at treating site |

For the purposes of estimating the national cost of compliance, public water system and implementation costs are tracked over a 20-year period. This time frame is used because many public water systems often finance their capital improvements over 20 years. This may, however, result in an overestimate of annualized costs because many types of equipment last longer than 20 years. Capital and operational and maintenance (O&M) costs may be incurred at different points throughout the time period. For this reason, two adjustments were made to the estimated costs forecasted by SafeWaterXL in order to render future costs comparable with current costs, reflecting the fact that a cost outlay today is a greater burden than an equivalent cost outlay sometime in the future.

In the first instance, compliance costs that are subsequently used in cost-benefit analyses are annualized using a social discount rate so that regulatory option costs (e.g. costs for an MCL of 5 µg/L vs. an MCL of 10 µg/L) may be directly compared to the annual benefits of the corresponding regulatory option. Annualization is similar to the process involved in calculating a mortgage payment; the result is a constant annual cost as expressed in Equation 9. The Agency performs cost-benefit analyses using two social discount rates. As required by the Office of Management and Budget (OMB), a seven percent discount rate is used in estimating the national cost of compliance in a rulemaking. A three percent discount rate is also used to estimate the costs of compliance, as the Agency believes this rate more closely approximates the true social discount rate.

In the second instance, compliance costs that are subsequently used in various economic impact analyses as required by the SDWA and its Amendments, such as in affordability analyses, are annualized using an actual cost-of-capital discount rate rather than a social discount rate. Affordability analyses examine the costs of compliance to systems and individual households, rather than on a national level. Costs to households are considered a good proxy for determining the affordability of regulatory compliance, as described in the discussion on maximum allowable household cost in Step 11 below.

They are dependent on system costs to the extent that system costs are recovered through increased water rates. The cost-of-capital rate is used to reflect the true after-tax cost-of-capital that water systems face, net of any government grants or subsidies. The recommended cost-of-capital rates stratified by ownership, system type and size, as reported in *Development of Cost of Capital Estimates for Public Water Systems* (U.S. EPA, 1998), were used in SafeWaterXL. These were presented in Exhibit 6-7.

Together, the annualized capital and O&M cost components equal the annual cost of treatment. When these costs are summed across all the treating sites in a system, the annual system cost is calculated. In other words, the system's cost of compliance is determined by summing across the treating sites. For each system in which a violation of the revised MCL is expected, this overall cost is calculated:

$$SC_{ir} = \sum_{n=1}^{n} \left( TrC_{tot,n} \right) \qquad \text{(Eq. 10)}$$

where:

| | | | |
|---|---|---|---|
| | i | = | System/model iteration |
| | n | = | Number of treating sites in the system |
| | $SC_{ir}$ | = | Annual cost for system i at discount rate r |
| | $TrC_{tot}$ | = | Annual total treatment train cost at treating site |

- The annual system cost is used to derive the cost per thousand gallons (cost/kgal) delivered by the water system.

Once the annual cost per system is determined by summing the costs of all the treating sites of the system, this cost is used to determine the unit cost of delivery (cost per thousand gallons delivered) for the system as a result of the new treatment technology. The system cost annualized at the cost-of-capital discount rate is used in this calculation as it best represents the true cost impact on the system. The cost per thousand gallons delivered is calculated as:

$$Cost_{kgal} = SC_{i,coc} \div \left( AF_i \cdot \frac{365\text{ days}}{1\text{ yr}} \cdot \frac{1000\text{ kgal}}{1\text{ Mgal}} \right) \qquad \text{(Eq. 11)}$$

where:

| | | | |
|---|---|---|---|
| | $Cost_{kgal}$ | = | Cost per thousand gallons for the system |
| | $AF_i$ | = | Average flow (MGD) of system i |
| | SC i, coc | = | Annual cost for system i at the cost-of-capital discount rate |

- Annual household costs are then calculated based on the system's unit cost of delivery (cost per thousand gallons) and the average annual household consumption per year.

The system's cost per thousand gallons delivered is used to calculate household costs according to Equation 12. The values used as estimates of the average annual tap water consumption per year are presented in Exhibit 7. More detail was given in Chapter 4.

$$Cost_{HHi} = Cost_{kgal} \cdot C_{HH} \quad \text{(Eq. 12)}$$

where: $Cost_{HHi}$ = Household cost per year for system i
$C_{HH}$ = Household consumption per year (kgal)

**Exhibit 7.**
**Water Consumption per Residential Connection**

| System Size Category | System Ownership Type | |
|---|---|---|
| | Public | Private |
| <100 | 81 | 92 |
| 101-500 | 93 | 110 |
| 501-1,000 | 97 | 88 |
| 1,001-3,300 | 82 | 102 |
| 3,301-10,000 | 87 | 124 |
| 10,001-50,000 | 108 | 110 |
| 50,001-100,000 | 122 | 96 |
| 100,001-1,000,000 | 127 | 114 |

Source: EPA. 1997. *CWSS, Vol. II: Detailed Summary Result Tables and Methodology Report*, Table 1-14.

- If household costs are determined to exceed an affordability threshold of $500, a less expensive treatment technology (POU device) is chosen and new costs are calculated (Steps 7-12 above are repeated using data for POU devices).

SafeWaterXL employs a maximum allowable household cost of $500, which forces systems who initially choose a treatment train with annual household costs in excess of $500, to default to a POE device, thereby seeking a less expensive method of compliance. In general, the results of the model simulation showed that only the smallest systems (serving 25-500 people) are affected by this threshold. Based on the overall number of systems in these two size categories (see Exhibits 1 and 2), the number of systems affected is relatively small. SafeWaterXL does record the number of systems exceeding this affordability threshold.

- The system results are maintained in a database for further analysis.

### C.2.1 Example Calculation (Single Iteration)

In this section, we demonstrate the process by which SafeWaterXL calculates the annual cost of compliance for a single system assuming a target MCL of 5 µg/L. Each step in the procedure described in the previous section is addressed to exemplify how the many assumptions and data inputs are pooled together in a single iteration.

Given the following SafeWaterXL model setting selections by the user:

- Source water = ground water;
- Ownership type = public;
- MCL = 10 µg/L;

Then, a single iteration of the model proceeds as follows:

1. A system is selected from data files.

A publicly-owned community ground water system with three entry points serving 10,000 people is selected from the data files.

2. Each system is assigned a random concentration from an occurrence distribution.

Based on accompanying information in the data file for ground water systems, an average system concentration of 11.03 µg/L is selected from an occurrence distribution bound by a lognormal mean of
-0.2507 and a log standard deviation of 1.5826.

3. The selected arsenic concentration for the system is distributed across the number of sites (entry points) of possible contamination for that system based on the relative intra-system standard deviation (RSD).

Since the system has three entry points, based on the average system concentration of 11.03 µg/L, the maximum site concentration is determined to be 33.10 µg/L (= 11.03 * 3). Using the default RSD of 0.64 and this limitation on the maximum site concentration, the three sites are assigned concentrations of 8.89, 9.69, and 14.52 µg/L, respectively. These three concentrations keep the average system concentration at 11.03 µg/L.

4. The concentration at each site is compared to the revised MCL standard to determine if the site is in violation of the revised standard.

The first two sites are determined to have concentrations of 8.89µg/L and 9.69µg/L, both of which are below the user selected MCL of 10 µg/L. The final site of the system, however, exceeds the MCL with a concentration of 14.52 µg/L, and is the only site for which the remainder of the calculations are conducted.

5. If the site is in violation of the revised MCL, the percentage of removal required in order to reach the treatment target is calculated.

From Equation 3 above, the percent of removal required for a site with an influent concentration of 14.52 µg/L to reach the treatment target of 8 µg/L (80 percent of MCL 10 µg/L) equals 45 percent:

$$\%\ removal = \frac{(SiteConc - \text{TrtTarget})}{\text{SiteConc.}} = \frac{(14.52 - 8)}{14.52} = 0.4490$$

6. Based on the percentage of removal required to meet the treatment target and on the decision tree for the size and type of the system, a treatment train is then assigned to the site.

Using the decision tree for ground water systems for the size category serving 3,301-10,000 people, a treatment train is selected based on the probabilities from the “<50%” removal column since this site requires 45 percent removal.

For this iteration, Treatment Train #6 (Coagulation/Microfiltration, Nonmechanical Dewatering, Non-Hazardous Landfill) is selected. This treatment rain has a removal efficiency of 90 percent.

7. Using the removal efficiency of the treatment train chosen, the percentage of flow that must be treated in order for the entry point to meet the treatment target is calculated.

The system flow must now be determined. Since the system in this iteration of the model is a public groundwater system, using the flow equations (Equations 4 and 5) and the regression parameters from Exhibit C-5, the design flow equals 3.646 MGD:

$$Design\ \text{Flow} = a_D \cdot (population)^{b_D} = (0.54992)\cdot(10{,}000)^{0.95538} = 3646.02393 \times \frac{1Mgal}{1000kgal} = 3.646$$

and the average flow equals 1.465 MGD:

$$Average\ Flow = a_A \cdot (population)^{b_A} = (0.08558)\cdot(10{,}000)^{1.05840} = 1465.454309 kgal \times \frac{1Mgal}{1000kgal} = 1.465$$

As described in Step 7 above, the system’s total flow is evenly distributed among all the possible sites. In this case, since there are three sites, each receives 33.3 percent of the total system flow. Using the principle of blending, the fraction of the system’s total flow that must be treated in order for the site to meet the treatment target equals 16.6 percent:

$$\text{Fraction of Flow} = \frac{\left(\frac{\text{TrtTarget}}{\text{SiteConc}} - 1\right)}{\text{- \% RE}} \times (\%SiteFlow) = \frac{\left(\frac{8}{14.52} - 1\right)}{-0.90} \times \left(0.33\bar{3}\right) = 0.1663$$

8. The percentage of flow that needs to treated is applied to the design flow, which is then used to derive the capital costs of the components of the treatment train (the sum of: treatment capital, waste disposal capital, and any pre-treatment capital costs).

Applying the fraction of the system's total flow (16.6 percent) to the system's total design flow (3.646 MGD) from Step 7 above, the design flow at the treating site can be calculated:

$$(3.646\,MGD) \times (0.166) = 0.606\,MGD$$

This adjusted flow is then used to determine the capital costs of the treatment train using the various cost equations for the treatment capital and waste disposal capital. For this treatment train, the treatment capital cost is $1,495,716 and the waste disposal capital cost is $1,169,055, for a total capital cost of $2,664,771.[4] For design flow (x), the cost (y) can be calculated:

| | | |
|---|---|---|
| Treatment capital: | $x<0.1$ | $y = -11935465x^2 + 48800366x + 94324$ |
| | $0.1<x<0.27$ | $y = 2343199x + 228653$ |
| | $0.27<x<1$ | $y = -483591x^2 + 2308991x + 273143$ |
| | $<1x<10$ | $y = 1030810x + 1067733$ |
| | $x>10$ | $y = 320x^2 + 921471x + 2129119$ |

Based on a site design flow of 0.606 mgd, the third segment of the cost equation is used:

$$y = -483591(0.606)^2 + 2308991(0.606) - 273143$$

Similarly, for design flow (x) = the waste disposal capital cost (y) can be calculated from these equations:

| | | |
|---|---|---|
| Waste Disposal capital: | $x<0.085$ | $y = 3069360x - 790$ |
| | $0.085<x<1.8$ | $y = 1749352x - 108017$ |
| | $x>1.8$ | $y = 1627970x + 326504$ |

For the waste disposal capital cost, the second cost segment is used:

$$y = 1749352(0.606) - 108017$$

In this example, based on the probability distribution listed in Exhibit 6, pre-oxidation was not selected, therefore the pre-oxidation capital costs are not calculated and included in the capital cost component of the treatment train.

[4]Costs presented in this example are in April 1998$, although post-processing of SafeWaterXL results updated these costs to May 1999$ in the Regulatory Impact Analysis. Totals may not equal sample calculation provided due to rounding of input variables.

9. Similarly, the percentage of flow that needs to treated is also applied to the average flow, which is then used to derive the operation and maintenance costs of the components of the treatment train (the sum of: treatment O&M, waste disposal O&M, and any pre-treatment O&M costs).

Similarly, by applying the fraction of the system's total flow (16.6 percent) to the system's total average flow (1.465 MGD) from Step 7 above, the average flow at the treating site can be calculated as follows:

$$(1.465\,MGD) \times (0.1663) = 0.244\,MGD$$

This flow is then used to determine the operation and maintenance costs of this treatment train using the various cost equations for treatment O&M and waste disposal O&M. The treatment O&M cost is $46,500 and the waste disposal O&M cost is $20,309, for a total annual O&M cost of $66,809. For average flow (x), the O&M cost (y) is:

| | | |
|---|---|---|
| Treatment O&M: | $x<0.03$ | $y = 196829x + 20264$ |
| | $0.03<x<0.09$ | $y = 136332x + 22139$ |
| | $0.09<x<0.36$ | $y = 80081x + 26977$ |
| | $0.36<x<4.3$ | $y = 13311x + 51014$ |
| | $x>4.3$ | $y = 15236x + 42350$ |

Based on a site average flow of 0.244 MGD, the third segment of the cost equation is used:

$$y = 80081(0.244) + 26977$$

Similarly, for average flow (x), the waste disposal cost (y) is:

| | | |
|---|---|---|
| Waste Disposal O&M: | $x<0.085$ | $y = -18812x^2 + 4686.1x + 2123.8$ |
| | $0.085<x<0.72$ | $y = 111819x - 6950.5$ |
| | $x>0.72$ | $y = 16.966x^2 + 60792x + 28760$ |

For the waste disposal O&M cost, the second cost segment is used:

$$y = 111819(0.244) - 6950.5$$

Again, since pre-oxidation was not selected, no pre-oxidation O&M costs are calculated or included in the O&M cost component of the treatment train.

10. The system's total annual treatment costs are calculated for the selected treatment train at various discount rates, by summing the treatment costs (annualized capital plus annual O&M cost components) across all treating sites.

From Step 8, the total capital costs for this treatment train equal \$2,664,771. From Step 9, the total O&M costs for the treatment train equal \$66,809. Using a capital cost amortized at 5.26 percent[5] over 20 years, the annual cost to the system equals \$284,278:

$$= \left(TrC_{cap}\right)\left(\frac{r}{1-(r+1)^{-rp}}\right) + TrC_{O\&M} = (\$2{,}664{,}771)\left(\frac{0.0526}{1-(0.0526+1)^{(-20)}}\right) + \$66{,}809 = \$284{,}278$$

The example displayed here uses the commercial rate, which is a closer approximation to the cost of capital to water systems. Annual costs are also calculated at 3 and 7 percent, respectively, as \$245,923 and \$318,344.

11. This annual system cost is used to derive the cost per thousand gallons (cost/kgal) delivered by the water system.

The unit cost of water delivered by this system (cost per kgal per year) as a result of installing treatment is determined by dividing the system cost by the system average flow. The system cost that was derived using the commercial discount rate is used to arrive at a unit cost of \$0.53:

$$= SC_{ir} \div \left( AF_i \cdot \frac{365\ days}{1yr} \cdot \frac{1000\ kgal}{1\ Mgal} \right) = (\$284{,}278) \div \left( (1.465) \cdot \frac{365}{1} \cdot \frac{1000}{1} \right) = \$0.53$$

12. Annual household costs are then calculated based on the system's unit cost of delivery (cost per thousand gallons) and the average annual household consumption per year.

The cost per thousand gallons to the water system calculated in Step 11 is used to estimate the annual cost to households as a result of regulatory compliance, by multiplying it with the average annual household consumption of tap water for a system in that size category:

$$= Cost_{kgal,i} \cdot C_{HH} = (\$0.53) \cdot (108 kgal) = \$46.24$$

The annual water consumption per household is presented in Chapter 4 and stratified by size category and ownership type.

13. If household costs are determined to exceed an affordability threshold of \$500, a less expensive treatment technology (POU device) is chosen and new costs are calculated (Steps 7-12 above are repeated using data for POE devices).

[5]Commercial discount rates are presented in Exhibit 6-7 of Chapter 6 of the Regulatory Impact Analysis, and determined by size category and ownership type.

Since the estimated annual household cost for this system is $46.24, this step does not affect the calculations already discussed. As described earlier, this affordability threshold affects only the smaller system size categories (<100 and 101-500). Therefore, the results of this iteration are recorded and the next iteration is triggered in Step 14.

14. The results are maintained in a database.

## C.3 Model Run

### C.3.1 Number of Iterations

Once a single iteration is completed, the calculated system data is recorded. Among the cost data forecasted for each iteration are the following:

- annual system cost (calculated at three discount rates: three percent, seven percent, cost-of capital);
- system capital cost (calculated at one discount rate: cost-of capital);
- system O&M cost (calculated at three discount rate: cost-of capital);
- cost per thousand gallons (calculated at one discount rate: cost-of capital); and
- household cost (calculated at one discount rate: cost-of capital).

Once complete, another iteration is started. This is repeated N times, until the total number of iterations (the total number of systems) for that size category is met, at which point the total annual national cost estimate for that size category is determined.

Next, once each size category is finished, the first iteration of the next size category begins. The cycles continue until all iterations of all eight size categories have been completed. The total annual national cost across all systems is therefore the sum of the annual national costs for each size category of systems, both publicly- and privately-owned.

If graphed against the estimated mean, the average system cost would generally fluctuate greatly between iterations at the beginning of a model run. However, as the number of data points increases, these fluctuations will dampen and should eventually converge on the estimated mean. The number of iterations must be a multiple of the number of systems that belong to each size category. This setting will avoid any systematic bias as the model cycles through all the systems within each size category from smallest to largest.

Each cycle therefore represents the universe of systems in that category as pulled from SDWIS (as summarized in Exhibits C-1 and C-2). Using this method, approximately the same number of non-zero data points should be generated when the same iteration settings are selected.

The anticipated number of non-zero data points is a function of the MCL, the occurrence distribution, and the number of systems in the size category, where a non-zero data point is a system that is required to treat and incurs treatment costs. For example, approximately eight cycles of the universe of ground water systems serving less than 100 people (14,432 systems, as shown in Exhibit 1) are required to achieve 20,000 data points given an MCL of 3 µg/L, and an occurrence distribution where 19.7 percent of the systems are expected to exceed the MCL. For the purposes of regulatory analysis of arsenic in drinking water, a goal of 20,000 data points was used in SafeWaterXL.

### C.3.2 Model Outputs

The primary outputs of the SafeWaterXL model are national-level estimates of costs of compliance, as well as distributions of cost to systems or households, across various water system service size categories. To achieve these results, the output generated for each iteration, as striated by water source, ownership, and service size category, are combined by SafeWaterXL at the conclusion of the model run.

<u>Average Annual System Cost</u> (Calculated at the Cost-of Capital Discount Rate)

Each iteration of the model describes the treatment and cost profile for a single system in a single size category. System cost is essentially equal to treatment cost, which is based on the treatment train technology chosen and the capital and operating and maintenance (O&M) costs of that selected treatment train. These costs are in turn a function of the amount of flow processed by the water system: capital costs are estimated as a function of design flow, while O&M costs are based on average flow. In addition to these treatment cost components, associated waste disposal capital and O&M costs are also included. A portion of these systems are then estimated to require pre-oxidation, which would add incremental costs to the total treatment cost.

In the case of calculating an average system cost, a commercial discount rate that is closer to the actual cost of capital that systems might face is used:

$$Avg.SC_{jr} = \frac{\sum_{i=1}^{m_j}(SC_{ir})}{m_j} \qquad \text{(Eq. 13)}$$

where:

| | | | |
|---|---|---|---|
| | $SC_{jr}$ | = | Annual system cost for size category j at discount rate r |
| | $SC_{ir}$ | = | Annual cost for system i at discount rate r |
| | j | = | Size category |
| | $m_j$ | = | Number of systems in size category j |

Although the equation above is used to calculated the average system cost for a particular size category, the result represents one ownership and source type (e.g. average system cost for public ground water systems serving <100). In order to combine the results for the two ownership types for a single run, each system cost must be weighted by its respective number of treating systems over the universe of systems in that size category:

$$Avg.SC_{j(total)} = \frac{\left(Avg.SC_{j(pub)}\right)\left(n_{j(pub)}\right) + \left(Avg.SC_{j(prv)}\right)\left(n_{j(prv)}\right)}{\left(n_{j(pub)} + n_{j(prv)}\right)} \qquad \text{(Eq. 14)}$$

where: $SC_{j(tot)}$ = Total annual system cost for size category j
$SC_{i(pub)}$ = Annual system cost for publicly-owned systems of size category j
$SC_{i(prv)}$ = Annual system cost privately-owned systems of size category j
$n_{j(pub)}$ = Number of publicly-owned treating systems in size category j
$n_{j(prv)}$ = Number of privately-owned treating systems in size category j

<u>Average Annual Household Cost</u> (Calculated at the Cost-of Capital Discount Rate)

Since household costs are also calculated for each system, a similar distribution of the cost of compliance at the system level are also calculated at the household level:.

$$Avg.Cost_{HHj} = \frac{\sum_{i=1}^{mj}\left(Cost_{HHi}\right)}{m_j} \qquad \text{(Eq. 15)}$$

where: $Cost_{HHj}$ = Annual household cost for size category j
$Cost_{HHi}$ = Household cost for system i
$m_j$ = Number of systems in size category j

Similarly, just as the average system cost was weighted across ownership types (Equation 14) the average household cost for a single size category must be a weighted average taking into consideration the number of households affected for each ownership type within the size category.

<u>Annual National Cost</u> (Calculated at Two Discount Rates , 3 percent and 7 percent)

Annual cost for a system size category is determined by adding the total cost of compliance across each treating system within that size category (e.g. the sum of all the system costs for each iteration in that size category). This is a function of the individual system cost not the average system cost, calculated at three and seven percent discount rates:

$$AC_{jr} = \sum_{i=1}^{mj}\left(SC_{ir}\right) \qquad \text{(Eq. 16)}$$

where: $AC_{jr}$ = Annual cost for size category j at discount rate r
$SC_{ir}$ = Annual cost for system i at discount rate r

Similarly, the annual national cost is total determined by adding the annual cost of compliance across all the size categories (e.g. the sum of all the system costs for all the iterations in the run):

$$ANC_r = \sum_{j=1}^{8}\left(AC_{jr}\right) \qquad \text{(Eq. 17)}$$

where: $ANC_r$ = Annual national cost at discount rate r

# Appendix D. *What-If* Cost Sensitivity Analysis

Chapter 6 of this report discusses the uncertainty associated with the National cost estimate. Lacking information on exactly which systems will need to undertake activities to achieve compliance, or what portion of those systems would require treatment, there will always be some uncertainty associated with the actual costs likely to be incurred. The Agency conducted a Monte Carlo simulation to provide a best estimate of probable costs and a sense of the relative precision of the estimate. None of that analysis addresses potential bias in Agency estimates.

A number of commenters asserted that there were factors in the Agency analysis that could significantly bias its estimate. The Agency disagrees with the issues raised for the reasons detailed in the response to comment document. This Appendix will not attempt to address all of those concerns. Rather, it describes a SafewaterXL simulation conducted to assess the sensitivity of the National cost estimate to changes in factors involving professional judgment and where there is uncertainty with respect to the status quo of the water supply industry. The factors considered relate to unit treatment costs and the compliance forecast (decision tree). Modeling was not conducted relating to water system entry point configurations since the Agency and commenters are in agreement that the entry point is the appropriate point for consideration of compliance costs and commenters have demonstrated that changes in such assumptions have minimal impact on national estimates. Likewise, factors, which could bias the Agency's cost estimates downward, are not evaluated.[1]. These factors are not evaluated to give the clearest picture of the absolute magnitude of the potential for underestimation. The data discussed in this section are from a single Monte Carlo run of the Safewater XL model.

**Unit treatment costs-** The response to comment document contains a thorough critique of commenter unit cost estimates. There are four areas, however, where anecdotal evidence suggests costs beyond those evaluated by the Agency could be experienced by individual water systems in their compliance efforts. In an effort to provide some context on the significance of these concerns, modifications were made to the Agency's best estimate equations to incorporate these factors. The following changes were incorporated into this analysis:

**Accessory costs-** Some commenters asserted that the costs for installing clearwells or storage to achieve flow equalization after treatment, repiping around new treatment devices, and additional pumping needed after pressure breaks for treatment would be incurred by water systems, aside from the piping and pumping costs considered by the Agency. These commenters estimated that such costs could add up to 76 percent to the capital costs of compliance.

Technologies costed by the Agency do include ancillary piping costs. Further, technologies, which break pressure, like coagulation, included re-pumping costs. What neither the commenters, nor the Agency have information on, however, is the extent to which additional storage might be

[1]A recently completed Agency report (Abt, 2000) suggests that many water systems achieve compliance with some rules without major treatment reconstruction. In some cases, as many as a third of all systems were able to achieve compliance without major reconstruction. Less capital intensive options than were costed in the Agency's decision trees could include drilling a new well, reconfiguring intakes to blend to the MCL level, or closing one, or more, wells and purchasing from a larger system can appreciably reduce costs.

required post treatment by water systems undertaking construction as part of their compliance effort. This impact was evaluated by increasing treatment capital costs by 76 percent for those systems that did not presently have disinfection (per EPA, 1999b). The Agency considered it highly improbable that a system which presently conducted disinfection would not have adequate storage or mixing zone capacity

**Land costs-** Some water systems undoubtedly will need to relocate entry points or acquire land for the building of new treatment facilities. Commenters agree with the Agency that there is no source of information for preparing a sound estimate of this impact. The issue is most likely to arise with currently untreated entry points. One commenter estimated that land acquisition could add five percent to compliance capital costs for ground water systems. While the Agency believes land acquisition will not be a common occurrence, the what-if analysis included a five percent increase in capital costs for land acquisition by ground water systems.

**Permitting and pilot testing-** The Agency has taken various approaches to the consideration of permitting and pilot testing requirements in past cost analyses. While such costs are not expected to be appreciable for most water systems, it is plausible that they could cause engineering costs to exceed the fifty percent of direct costs currently costed. For the purposes of the what-if analysis, the Agency is including three percent increases to direct capital costs for each factor per the recommendations of the Technology Design Panel (EPA, 1997).

**Compliance forecast/decision tree-** In developing its compliance decision trees, the Agency considers water quality factors, water availability, and cost. It is presumed that a water system will adopt the lowest cost technology it can feasibly use. Admittedly, systems sometimes select more expensive technologies, but do so to accomplish multiple treatment objectives. Lacking comprehensive information on co-occurrence, the Agency is unable to consider the benefits or costs of such actions. Regardless, they are not costs attributable to arsenic compliance.

The Agency made numerous modifications to the proposal decision tree in response to public comment. The use of ion exchange, for instance, was greatly reduced in response to residuals management concerns. To assess the impact of the decision tree upon National cost estimates, the what-if analysis eliminated ion exchange (a relatively inexpensive technology) and greatly increased the projected use of coagulation and microfiltration (the most expensive option for many strata). Tables D-1 through D-8 present the decision trees used in the analysis and can be compared to the primary analysis decision trees in Appendix A.

**Results-** Table D-9 depicts the results of the model run in comparison to those generated by the best estimate. It is interesting to note that, at the MCL option of 10, the 95 percent confidence interval on the best estimate is $215 million dollars. The What-If estimate is less than ten percent greater than the Agency's original estimate. At the MCL option of five, however, the what-if assumptions generate a twenty-five percent increase in the National cost estimate. These results are consistent with those observed in the AWWARF Cost Implications Report (AWWARF, 2000) wherein lower options were much more volatile in the face of varying assumptions. While the Agency remains unpersuaded by many of the commenters arguments, this analysis does support their concern relating to uncertainty at options beneath the selected MCL.

## Exhibit D-1
## Probability Decision Tree: “What-If” Sensitivity Analysis
## Ground Water Systems Serving #100 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 1.0 | 1.0 | 1.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backwash stream and pre-oxidation | 12.9 | 12.4 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 60.3 | 57.3 | 72.2 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 20.5 | 19.1 | 23.7 |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 12 | POU Activated Alumina and pre-oxidation | 2.2 | 4.6 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 2.2 | 4.6 | 2.1 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-2
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 101-500 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 12.9 | 12.5 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 60.4 | 57.2 | 66.1 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 20.5 | 19.1 | 22.7 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 1.8 | 3.1 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 3.1 |
| 12 | POU Activated Alumina and pre-oxidation | 1.1 | 2.7 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 1.1 | 2.7 | 1.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-3
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 501-1,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backwash stream and pre-oxidation | 12.9 | 12.5 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 27.0 | 27.2 | 32.0 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 2.2 | 1.8 | 2.1 |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 27.0 | 27.2 | 31.0 |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 27.0 | 27.2 | 31.0 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-4
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 1,001-3,300 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 3 | Anion Exchange (<20 mg/L $SO_4$) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L $SO_4$) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 5.4 | 4.5 | 5.2 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 5.4 | 4.5 | 5.2 |
| 7 | Oxidation Filtration (Greensand) and POTW for backwash stream and pre-oxidation | 12.9 | 12.5 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 18.3 | 14.5 | 17.5 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 27.0 | 30.0 | 34.1 |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 27.0 | 30.0 | 34.1 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-5
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 3,301-10,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 3.0 | 3.0 | 3.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW waste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 8.7 | 7.2 | 8.3 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal and pre-oxidation | 2.2 | 1.8 | 2.1 |
| 7 | Oxidation Filtration (Greensand) and POTW for backwash stream and pre-oxidation | 0.0 | 12.5 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 26.0 | 22.6 | 26.9 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 28.1 | 24.4 | 27.9 |
| 11 | Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 28.1 | 24.4 | 27.9 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-6
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 10,001-50,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 63.0 | 63.0 | 63.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 4.1 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 4.0 | 3.3 | 3.8 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 11.5 | 9.8 | 11.8 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 11.5 | 9.8 | 11.4 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-7
## Probability Decision Tree: “What-If” Sensitivity Analysis
## Ground Water Systems Serving 50,001-100,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 63.0 | 63.0 | 63.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 4.1 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 2.5 | 2.1 | 2.4 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 12.2 | 10.4 | 12.5 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 12.2 | 10.4 | 12.1 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

## Exhibit D-8
## Probability Decision Tree: "What-If" Sensitivity Analysis
## Ground Water Systems Serving 100,001-1,000,000 People

| No. | Treatment Technology Train | Percent of Treatment Required to Achieve MCL | | |
|---|---|---|---|---|
| | | <50% | 50-90% | >90% |
| 1 | Modify Lime Softening and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 2 | Modify Coagulation/Filtration and pre-oxidation | 4.0 | 4.0 | 4.0 |
| 3 | Anion Exchange (<20 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 4 | Anion Exchange (20-50 mg/L SO4) and POTW w aste disposal and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 5 | Coagulation Assisted Microfiltration and mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 63.0 | 63.0 | 63.0 |
| 6 | Coagulation Assisted Microfiltration and non-mechanical dew atering/non-hazardous landfill w aste disposal and pre-oxidation | 2.0 | 2.0 | 2.0 |
| 7 | Oxidation Filtration (Greensand) and POTW for backw ash stream and pre-oxidation | 0.0 | 4.1 | 0.0 |
| 8 | Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media) and pre-oxidation | 1.4 | 1.2 | 1.4 |
| 9 | Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media) and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 10 | Activated Alumina (23,100 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 12.8 | 10.9 | 12.8 |
| 11 | Activated Alumina (15,400 BV) w ith pH adjustment (pH 6)/corrosion control and non-hazardous landfill (for spent media) and pre-oxidation | 12.8 | 10.9 | 12.8 |
| 12 | POU Activated Alumina and pre-oxidation | 0.0 | 0.0 | 0.0 |
| 13 | POU Reverse Osmosis and pre-oxidation | 0.0 | 0.0 | 0.0 |
| | **Sum of Probabilities:** | **100.00** | **100.00** | **100.00** |

**Exhibit D-9**
**What-If Analysis Results**

| MCL Option | Best Estimate | What-If Estimate |
|---|---|---|
| 5 | $411 Million | $515 Million |
| 10 | $177 Million | $192 Million |

# Appendix E: Benefits and Costs by System Size Category

The drinking water supply industry is subject to considerable economies of scale with respect to the costs of treatment technologies. Per capita treatment costs steeply increase in inverse proportion to system size. This is illustrated earlier in this report by Exhibit 6-17 wherein a hundred-fold increase in household costs over the range of public water supplies can be observed at the chosen MCL. Because there is such a large increase in relative costs, benefit-cost ratios also show appreciable variation with system size. In response to comments received on the proposal, the Agency is providing a subcategorization of the benefits and costs associated with the various regulatory alternatives by system size.

Cost values for strata specific costs were taken from the National cost modeling effort and reflect use of a three percent interest rate for annualizing capital costs. Benefits were calculated as a product of the mean risk reductions (see Exhibit 5-4(c) and calculated as described in Appendix B ), populations served by impacted sites (shown in Exhibit E-1 and calculated per cost methodology described in Appendix C), and costs per case avoided (as described in Chapter 8 and Appendix B). For the latter element, \$6.1 million was assumed per cancer fatality and \$607,000 for non-fatal cancers. Exhibit E-1 depicts the benefits by system size category and Exhibit E-2 displays benefit cost ratios.

**Exhibit E-1**

**Benefits by System Size**

| | | Population Stratum | | | |
|---|---|---|---|---|---|
| **Type** | **MCL** | **25-500** | **500-3300** | **3300-10,000** | **10K-1000K** |
| **Upper** | 20 | 2.41 | 7.90 | 9.09 | 45.18 |
| **Upper** | 10 | 7.13 | 23.34 | 26.85 | 133.50 |
| **Upper** | 5 | 12.45 | 40.75 | 46.89 | 233.11 |
| **Upper** | 3 | 16.67 | 54.57 | 62.80 | 312.18 |
| **Lower** | 20 | 2.72 | 8.91 | 10.25 | 50.97 |
| **Lower** | 10 | 5.15 | 16.85 | 19.39 | 96.40 |
| **Lower** | 5 | 7.01 | 22.94 | 26.39 | 131.20 |

**Exhibit E-2**

**Benefit/Cost Ratios by System Size**

| | | Population Stratum | | | |
|---|---|---|---|---|---|
| **Bound** | **MCL** | **25-500** | **500-3300** | **3300-10,000** | **10K-1000K** |
| **Impacted Population (thousands)** | | **961** | **315** | **3,622** | **18,005** |
| **upper** | 20 | 0.38 | 0.74 | 1.01 | 1.32 |
| **upper** | 10 | 0.42 | 0.81 | 1.11 | 1.39 |
| **upper** | 5 | 0.33 | 0.62 | 0.84 | 1.05 |
| **upper** | 3 | 0.27 | 0.50 | 0.66 | 0.85 |
| **lower** | 20 | 0.43 | 0.84 | 1.14 | 1.49 |
| **lower** | 10 | 0.30 | 0.59 | 0.80 | 1.00 |
| **lower** | 5 | 0.18 | 0.35 | 0.47 | 0.59 |