Incorporating Consideration for Poor Households into U.S. Environmental Protection Agency Affordability Methodologies for Drinking Water Treatment

by

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Abstract

In the 1996 Amendments to the Safe Drinking Water Act, Congress charged the U.S. Environmental Protection Agency (EPA) with developing affordability methodologies to determine if new drinking water treatment regulations will be affordable to consumers. In 1998, the EPA introduced a methodology based on the median household income (MHI). When the EPA proposed a new method in 2006, it kept the use of the MHI as an appropriate measure of household income but introduced additional criteria for identifying economically disadvantaged communities (EDCs) to also receive variances. However, the EPA's continued use of the MHI ignores that poor households are the most burdened by new drinking water regulations. This thesis examines the use of a lower income threshold, the first quartile household income, and recommends that water treatment be deemed unaffordable if either the costs are predicted to exceed 2.5% of a community's first quartile household income or if the system will be located in an economically disadvantaged community. This proposed rule would potentially qualify 12,000 drinking water systems. The EPA's definition of EDCs is also examined as the current definition fluctuates over the business cycle, producing a situation in which it is harder for systems to receive variances during economic recessions, when they are most needed. Adjustments to the EDC criteria that set fixed thresholds based on MHI, poverty and unemployment rate in periods of economic growth or long-term averages are proposed to correct this. EDC definitions that use consumption measures, i.e. county food stamp program participation rates and share of households spending more than 35% of income, are investigated as well.

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BLS	United States Bureau of Labor Statistics
CB	United States Census Bureau
CWS	Community Water System
EDC	Economically Disadvantaged Community
EEC	Environmental Economics Committee to the Science Advisory Board of the U.S. Environmental Protection Agency
EPA	United States Environmental Protection Agency
MCL	Maximum Contaminant Level
MHI	Median Household Income
NDWAC	National Drinking Water Advisory Council
ORD	U.S. Environmental Protection Agency Office of Research and Development
Q1HI	First Quartile Household Income
SDWA	Safe Drinking Water Act
SNAP	Supplemental Nutrition Assistance Program

CHAPTER 1

INTRODUCTION

BACKGROUND

Arsenic is a naturally occurring chemical that is found in groundwaters worldwide. Well-studied arsenic hotspots include the Southwestern United States, the Western portions of the United States' Rust Belt and Southeast Asia (Amini et al. 2008). Geochemists, stymied in identifying areas with high arsenic concentrations by a lack of field data, also predict hotspots in Central Asia, Eastern Australia, Northern Africa and the Sahara and the Southern tip of South America, based on pH and electrochemical conditions of groundwaters which are favorable to the release of arsenic in drinking water (Amini et al. 2008). These conditions include high pHs and the accompanying oxidizing conditions and low pHs created by mining and industrial activity. The literature reports common arsenic concentrations in groundwaters ranging from 0.5 μg/L to 5000 μg/L, with only a few places reporting levels more than 10 μg/L. Surface waters have values that exceed 1 μg/L only when affected by anthropogenic contaminants or under localized geologic influence (Smedley and Kinniburgh 2002). This translates to arsenic levels in the wells for public drinking water supplies here in the United States ranging from an average of 0.67 μg/L in the Southeast to 6.59 μg/L in the Southwest (Kumar et al. 2010).

Elevated arsenic concentrations in drinking water pose health risks to consumers; second to radon, inorganic arsenic greatest known risk due to a waterborne chemical (Brown 2008). Arsenic's health risk to humans was first noted in German scholar Georgias Agricola's *De re metallica*, published in 1556, which documented that workers who handled arsenical cobalt

(CoAsS) developed skin conditions on their hands (Smith et al. 1992). A 1637 Chinese manuscript called the *Tian Gong Kai Wu* discussed Pee-song, an arsenic based pesticide and fungicide used on the rice fields of China and that workers that were involved in its production couldn't work for more than two years without losing their hair and becoming ill (Wang and Wai 2004). Skin cancer was first linked to arsenic consumption based on studies of patients that had taken Fowler's solution (a 1% arsenate solution used to treat skin conditions) in the late 19th century (Hutchinson 1887). As metal smelting increased during the industrial revolution, more and more workers were exposed to airborne arsenic, and the connection between cancers and arsenic was quickly realized (Wilson 2001). In the twentieth century, research on arsenic's effect on drinking water rapidly increased, with studies in Taiwan, Japan, India, South America (Chile and Argentina), Europe (United Kingdom and Finland) and the United States, all pointing towards a relationship between the consumption of arsenic and increases in various cancer and non-cancer health effects (National Academy of Science 2001). Exposure to arsenic has been linked to increased incidence of skin cancer, bladder cancer, lung cancer, liver cancer, kidney cancer, nasal cancer, prostate cancer and uterine cancer (Kapaj et al. 2006; National Academy of Science 1999, 2001). Non-cancer effects of arsenic exposure include sensory-motor deterioration; behavioral changes; loss of long-term memory; reduced IQ; pregnancy complications in women; increased risk of thrombosis, atherosclerosis and other cardiovascular diseases; chronic respiratory difficulties; disruption of the endocrine system (including diabetes mellitus); a characteristic skin pigmentation change known as Blackfoot Disease; gangrene and spontaneous amputation; and reduced liver function (Kapaj et al. 2006).

In 1942 the United States Public Health Service, responding to the emerging body of evidence linking cancer and arsenic, set a limit for arsenic in drinking water of 50 μg/L. The

U.S. Environmental Protection Agency (EPA) adopted this limit on an interim basis in 1975 when they were given the mandate for drinking water protection as part of the Safe Drinking Water Act (SDWA) (Cho et al. 2007). The EPA faced pressure from the Congress, citizens and the courts to finalize an arsenic rule. When Congress passed the SDWA Amendments of 1996, they mandated that the EPA propose a finalized arsenic rule by January 1, 2000 and a final regulation deadline of January 1, 2001. The EPA proposed a 5 μg/L regulation on June 22, 2000 and a final regulation of 10 μg/L was published in the Federal Register on January 22, 2001.

The arsenic rule was finalized on the last day of the Clinton Administration. On January 20, 2001, following the inauguration of President George W. Bush, his Chief of Staff Andrew Card published a memo entitled "Regulatory Review Plan" which directed government regulatory agencies to temporarily withdraw or suspend regulations proposed in the past two months, including the arsenic rule (66 FR 7702). The EPA complied, and on May 22, 2001 announced a delay of the effective date of the regulation to February 22, 2002 in order to accommodate a review of the risks, benefits and costs associated with the arsenic rule (66 FR 28342). The final rule had an EPA projected cost of $205.6 million annually (Abt Associates Inc. 2000) and other estimates, such as that by the American Water Works Association Research Foundation, projected it would cost over $550 million per year to treat arsenic to 10 μg/L (Frost et al. 2002), Given these high costs, the EPA wanted to ensure that the benefit-cost analysis was correct. In order to accomplish this, the EPA requested that the National Academy of Sciences review the health effects and risks associated with arsenic reduction, and directed that the EPA Science Advisory Board to review the benefits associated with reduction of arsenic in drinking water and the National Drinking Water Advisory Council (NDWAC) to review the costs associated with arsenic treatment (66 FR 28342). The EPA also sought public comment on the regulation, its benefits and costs and if the rule was justified (66 FR 42974). The National Academy of Science (National Academy of Science 2001), the Science Advisory Board (EPA-SAB 2001) and the NDWAC (National Drinking Water Advisory Council 2001) released their reports late in the summer of 2001, generally finding in favor of the 10 μg/L rule. Support from the public was mixed. Many in the water supply industry that commented to the EPA criticized the rule as unjustifiably costly given the lack of solid data to support it and the general public responded in support of the original rule. Polling data showed that a majority (56%) of Americans criticized the May extension of the arsenic rule, journalists questioned the decision and the U.S. House of Representatives voted to reinstate the 10 μg/L limit (Sunstein 2002). In this environment, the director of the EPA, Christine Whitman, announced the EPA's decision to end the delay and to reinstate the 10 μg/L rule on October 31, 2001 (Woods 2001).

Even after this announcement, the costs associated with the arsenic rule remained an issue. The water treatment community, the EPA and Congress focused on the costs that small systems were facing to attain compliance with the arsenic regulation. The regulatory burdens placed on small systems are of particular concern because they have a smaller customer base to defray capital costs when compared to larger systems. The EPA has created funding mechanisms for small systems (e.g. Drinking Water State Revolving Fund), but these funding sources remain under-funded by Congress and are often underutilized by systems (Levine 2012). As part of the 1996 SDWA Amendments, the EPA was specifically directed to establish criteria for assessing the affordability of drinking water treatment. If a treatment was found unaffordable, systems would be granted permission to use approved variances to reduce the costs.

In 1998, the EPA announced it would be using a measure that limits the burdens placed on household incomes for affordability determinations, i.e. that if the total costs of water treatment (including expenditures for the proposed regulation) for the average system within a system size class (e.g. 25-100 customers, 101-500, 501-1,000) more would exceed 2.5% of the MHI for that class, it would be considered unaffordable (63 FR 42032). However, as part of the appropriations process for 2002, on November 8, 2001, Congress charged the EPA with reassessing affordability (Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 2002). The EPA tasked two groups, one of which was the Environmental Economics Committee to the Science Advisory Board (EEC) and the National Drinking Water Advisory Council (NDWAC), with reviewing the 1998 affordability methodology. The EEC returned with a report, that while supportive of the general methodology of the burden measure, found that "significant levels of inequality both within and between systems argued for lower income levels" (the first quartile household income, or Q1HI, and 1.5 standard deviations below the mean household income were both suggested) and demonstrated the need for a more decentralized approach (U.S. Environmental Protection Agency-Environmental Economics Committee (EEC) 2002).

The EPA proposed a new, two-part affordability criterion in March of 2006 that implemented suggestions from both the EEC and NDWAC. The first part was a test using nationwide averages to determine if a regulation would be unaffordable by comparing the compliance costs to the median household income (MHI) within a size class. If compliance costs for a regulation exceeded a set percentage of MHI (0.25%, 0.50% and 0.75% were all considered), then the regulation would be determined unaffordable nationwide. If the test did not qualify all small systems for a variance, then a more decentralized approach could be applied by the states in the second step. This second step would be based on written testimony before Congress by Scott Rubin, an attorney for the National Rural Water Association, in which he proposed five criteria for determining affordability. These five criteria are as follows (Rubin 2002):

1. Community MHI less than 65% of national MHI;
2. Community poverty rate twice the national average;
3. Community two-year average unemployment twice the national average;
4. Total water bills in excess of 2.5% of community MHI; or
5. Total water bills would double as a result.

The EPA proposed the first three be used by the states in making affordability determinations at the local level (71 FR 10671). Since the proposal of these criteria, the call for affordability considerations has quieted, but not completely disappeared, in the EPA and Congress. The EPA hasn't acted on these criteria since their proposal, and it does not seem like they will address it until the next regulation raises concerns about affordability and funding issues. Problems surrounding affordability could arise soon. The EPA's current drinking water policy agenda includes determinations of the contaminants listed in the third candidate contaminant list, small systems compliance with the Stage 2 Disinfection Byproducts Rule and a potential hexavalent chromium rule.

OBJECTIVES

As the EPA addresses contaminants that are easily and cheaply removed from drinking water first, more and more regulations in the future will involve contaminants with costly removal techniques. This poses a problem for the EPA and ensures that it is only a matter of time until it creates the "next arsenic MCL", an expensive regulation that places an immense regulatory burden on small systems. Affordability concerns and funding issues will reappear on the EPA's agenda when this happens. A retrospective study of how the EPA determines if a regulation is affordable, applied to one of the more costly drinking water regulations to date would be useful to the EPA in guiding decisions about affordability going forward. Alternative funding mechanisms will have to be developed that can address the inequity of setting regulations for all systems based on the economic situations of large systems, as was the case for the arsenic MCL (Jones and Joy 2006; Oates 2002).

To study these problems, socioeconomic data and information on the cost of arsenic treatment were compiled and the affordability methods applied to the data. Data about income levels and distribution, poverty rates and community populations was taken from the U.S. Census Bureau's (CB's) 2000 and 2010 decennial censuses and the 2006-2010 American Community Survey. Data about unemployment came from the U.S. Bureau of Labor Statistics (BLS). Cost data utilized the EPA's Arsenic Demonstration Sites Project that included fifty sites that installed a variety of technologies throughout the United States. These compiled data sets were then used to perform an affordability determination using the current and proposed EPA criteria and using the lower income level recommended by the EEC.

Median household income, poverty rate and unemployment data were then converted into a GIS database for use in a sensitivity analysis. First, the number of counties nationwide that could potentially qualify for a variance under the proposed socioeconomic status criteria were calculated, as well as the share of the systems qualifying for each characteristic. Second, the effect of adjusting the various ratios for the three EDC criteria (both making them more lenient and more strict) on the number of counties that qualify were determined. The adjusted criteria were combined together into a few possible combinations to look at alternatives to the EPA's proposed method. Finally, two alternative measures that represent expenditures rather than income were analyzed as potential indicators of the need to grant variances.

The main objective of this thesis is to review and propose policy solutions to the questions of affordability for small systems. The hypotheses of this study are: 1) the EPA's current and proposed methodologies are insufficient because the current methodology is too difficult to trigger and the proposed methodology is not strict enough when it comes to granting variances; 2) using the EEC proposed income level of the first quartile household income (Q1HI) as the income used for affordability determinations can successfully identify systems that deserve variances, without being too lenient; and 3) that other definitions of EDCs will successfully identify these communities. The specific objectives of this research are:

1) Application of the EPA's current and proposed criteria to make a determination about the affordability of the arsenic MCL for small water systems to study performance of EPA affordability methodologies;
2) Use of the EEC's recommendation for a lower income level, the first quartile, as the income for the burden measure for an affordability determination of the arsenic MCL for small water systems to demonstrate the ability of the first quartile household income ; and
3) Performance of a sensitivity analysis on EPA socioeconomic status variance criteria for EDCs and testing of other definitions of EDCs.

OVERVIEW

A review of the current literature on the arsenic MCL, its cost, the burden it imposed and funding problems is presented in Chapter 2 and precedes the results of this thesis, which are found in Chapters 3 and 4. Chapter 3 is written in the format of a draft manuscript currently in preparation for submission to the Journal of the American Water Works Association. This chapter discusses the application of the EPA's current and proposed methods for determining affordability to the arsenic MCL. It also outlines the development and application of an alternative affordability methodology using an income level lower than the MHI used by the EPA. The chapter concludes with a comparison of the two methods in identifying systems of deserving variances for arsenic treatment. Chapter 4 turns to an analysis of the affordability criteria selected by the EPA by determining how many counties qualify for variances and how adjusting these criteria affect the final results. This chapter is also formatted as a draft manuscript, and it is also currently in preparation for submission to a peer-reviewed journal. Chapter 5 concludes with a summary of the results, suggestions for research going forward and implications and suggestions for policy development and analysis when tackling the problems of the high cost of drinking water treatment.

CHAPTER 2

LITERATURE REVIEW

DRINKING WATER AFFORDABILITY AT THE U.S. ENVIRONMENTAL PROTECTION AGENCY

In debate over the initial passage of the SDWA in 1974, a congressman from Ohio asked the following question about a community facing a new drinking water regulation with a water system that had used up all its bonding authority: “How can that community come up with the money to meet the standards that some EPA directive might set forth?” (Cong. Rec. 1974). At the time no one had the answer to his question (Pontius 2008). It would take the EPA a decade to include affordability as part of its considerations for SDWA regulations, and then only in determining best available technologies for meeting new regulations (Beecher and Shanaghan 1998). As part of the SDWA Amendments of 1996, the EPA was explicitly tasked with answering this question by addressing concerns over affordability of drinking water regulations (Beecher and Shanaghan 1998; Pontius 2008; Tiemann 2010).

The concept of affordability was developed by economists working on housing problems and draws heavily on the work of two statisticians in the 19th century, Ernst Engel and Herman Schwabe, studying how household budgets were spent in an attempt to uncover laws about social interactions (Hulchanski 1995). These researchers developed a measure of burden for various items in a household budget, the expenditure-to-household-income ratio. While this work to establish descriptive laws of household expenditures was eventually discredited, it is still influential in determining affordability for housing ("one weeks pay for one month's rent" is taken from the results by Engel and Schwabe), and the expenditure to income ratio is still used. Housing economists have six common uses for this measure: (1) describing expenditures made by households, (2) analysis of these expenditures, (3) for government to help with administering subsidies, (4) defining households in need, (5) criteria for selecting households to receive items at free or reduced prices and (6) predicting the ability of households to pay for expenditures (Hulchanski 1995).

EPA drew on the expenditure to income ratio in developing its own affordability metrics for SDWA regulations. The EPA first looked at affordability in the context of providing guidance to the state primacy agencies, the state-level departments tasked with overseeing the drinking water programs in the individual states under the SDWA. The EPA identified six different characteristics that contribute to affordability for water treatment: 1) household affordability, the impact of rate increases on households; 2) financial capacity, how a water systems has its finances organized; 3) access to private capital, how easily a system can achieve funding through the private market; 4) eligibility for public capital, how easily a system can receive funding from public grants or other programs; 5) fiscal conditions, the stresses the local government faces in funding water systems (amid other infrastructure demands); and 6) general socioeconomic conditions, including income, poverty and unemployment (U.S. Environmental Protection Agency 1998). On August 6, 1998, EPA announced its affordability criteria for small system variances (63 FR 42032). This affordability criteria joined the two dozen other affordability metrics the EPA had implemented for various programs in offices such as the Offices of Water; Solid Waste; Compliance Monitoring; and Policy, Planning, and Evaluation. Most of these other criteria were based on a two-step process. The first step screened out systems where the additional cost of treatment would not be a significant burden and a second step looked at the community's financial capacity, as was recommended by a panel for the EPA Office of Police, Planning and Evaluation (Beecher and Shanaghan 1998; U.S. Environmental Protection Agency 1998).

In contrast to the other methods at the EPA, the SDWA affordability criteria had only the burden screening step, drawing exclusively on the household affordability component of affordability by including only a screening to identify systems that would not be significantly burdened by new regulations. The EPA used an expenditure-to-income ratio and said that if it exceeded 2.5% the new regulation would be unaffordable. The EPA would predict the average household cost for treatment for a series of water system size classes as part of its economic analysis for each new rule and compare these costs with the MHI for the size class (Abt Associates Inc. 2000; Baird 2010; Pontius 2008). This process was simplified by the calculation of what is called an expenditure margin. The EPA calculated that 2.5% of the U.S. MHI to be $750 (1998) and that currently an average of $250 (1998) was spent annually on household water supply. The expenditure margin is $500 ($750-$250) and any new regulation cannot cost the median system in a size class more than this amount without being unaffordable (Abt Associates Inc. 2000; Cooke 2005; Hilkert Colby et al. 2010; Jones and Joy 2006).

. In November 2001, EPA was tasked with revising its affordability criteria as part of Congress's appropriations process for 2002 (71 FR 10671). The EPA turned to two different groups for advice on how to review their rules on affordability: the EPA's Environmental Economics Committee of the Science Advisory Board (EEC) and the National Drinking Water Advisory Council (NDWAC).

The EEC was charged with examining several questions by the EPA including: questions about the basic method, appropriate income limits and shares, the level at which the determination should be made and whether there should be a separate affordability method for groundwater-sourced systems and surface-water-sourced systems. The EEC concluded that the basic method the EPA was using was appropriate as it was practical while still addressing questions over efficiency and equity. The EEC recommended that the EPA consider an income level below the MHI because of inequality between water system customers and between the systems themselves. The EEC also concluded that the 2.5% of MHI threshold was too high and that it should be lowered with the EPA providing clear guidance to the states. Other conclusions the EEC made were to recommend the EPA consider a more regional (or ideally, a local) approach with any national method serving as a screen and that the affordability methodology encourages the consolidation of smaller systems together should be considered during the affordability process (and encouraged by the agency to increase the economic efficiency of water supply) (U.S. Environmental Protection Agency-Science Advisory Board 2002).

The NDWAC Work Group on the National Small Systems Affordability Criteria recommended a much more dramatic departure from the EPA's original methods. The NDWAC recommended dropping the expenditure margin approach the EPA had adopted and implement an incremental approach. Rather than looking at how any new regulations would add to the burden systems and households already face, the NDWAC recommended that the EPA only consider regulations one at a time. If the regulation exceeds 1% of MHI, then it should be determined to be unaffordable and the EPA should allow the granting of variances. An incremental approach was recommended because it could avoid the "adding up" problem, the problem that occurs when later rules are found unaffordable because of earlier, expensive regulations that consumed the expenditure margin. The NDWAC did not completely ignore cumulative cost burdens in their methods, but left these considerations to the state primacy agencies that would have better access to this data. The 1% MHI threshold was selected because it represented a doubling of the water bills in 2003 (based on the 2000 EPA Community Water System Survey). This new method was not unanimously endorsed by the working group's membership; a representative from the National Rural Water Association believed that the new method was still not sufficiently strict enough to identify systems (National Drinking Water Advisory Council 2003).

The EPA considered the EEC and NDWAC proposals in revising its affordability criteria. The NDWAC's recommended incremental approach addressed many of the EPA's significant concerns. Because of this the EPA adopted the NDWAC's approach in March 2006. The EPA then announced that it was seeking feedback on using an incremental burden approach with a threshold of either 0.25%, 0.50% or 0.75% of MHI. The EPA announced that it was also considering adding a second step in the affordability process. The purpose of this second step would be to identify economically disadvantaged communities (EDCs). EDCs were mentioned in Section 1452 of the SDWA as an area "of a public water system that meets affordability criteria established after public review and comment by the State in which the public water system is located". This language was considered too broad to be of use to state primacy agencies and before this 2006 proposal, the EPA had not defined an economically disadvantaged community (EDC) in a regulatory context for the entire nation. In an evaluation of the Drinking Water State Revolving Fund's impact on EDCs, the EPA referred to a general definition in socioeconomic characteristics like MHI, the poverty level and unemployment rates. However, this definition did not impact regulatory enforcement (U.S. Environmental Protection Agency

2000). The EPA identified three potential criteria that could be used for this purpose: i) a county with a MHI of less than 65% of the national average MHI, ii) a county with two-year average unemployment rate that is twice the national average and iii) a county with a poverty rate that is twice the national average. Systems in counties that meet one of these criteria could be granted variances even if the national screen found the regulation affordable (71 FR 10671). These criteria draw on the ability of households within the system to pay for drinking water. Ability to pay depends heavily on the level of a household income and employment, so these proposed measures would at least measure the correct factors that contribute to affordability (U.S. Environmental Protection Agency 1998).

The criteria used by the EPA in identifying EDCs were developed by Scott Rubin at the National Rural Water Association. After the EPA proposed the expenditure margin approach based on MHI, Rubin studied the relationship between the poverty rate in an area, a factor crucial in systems being able to get funding from their customers, and an area's MHI. He found that there is only a moderately strong relationship between the two variables (R^2=0.7609), and that the poverty rate can range anywhere from 0% to over 20% when a community's MHI is equal to $30,000. The correlation between MHI and the percent of households living in poverty areas is even worse with an R^2 of 0.4707 (Rubin 2001). Rubin examined various criteria that states and federal agencies use to identify EDCs. Many states selected criteria that drew on MHI comparisons, and the state of Washington used a criterion based on unemployment rate. The federal agency criteria that Rubin analyzed included the Department of Commerce's Economic Development Administration (average twenty-four months of unemployment greater than 1% above the national average, per capita income that is no more than 80% of national average income), the Treasury (30% of the population live below the poverty line, average unemployment rate 1.5 times the national unemployment rate) and the Department of Agriculture's Rural Utilities Service (MHI of 80% of the state's non-metropolitan MHI, or an MHI below the poverty level) (Rubin 2002).

Even with the EPA's proposed changes to the affordability guidelines, some still have found issue with the EPA incremental criteria. Fred Pontius (2008) argues that the EPA's affordability criteria still need work and that they should remain focused on the issue of household affordability. Pontius also discusses how the Small Business Administration had nominated the EPA's affordability policy for revision under the Regulatory Review and Reform Initiative in 2007 and as a top ten rule for revision in February of 2008. Gregory Baird shows that in 2020 and 2030, due to dramatic increases in water rates to keep up with the need for infrastructure maintenance and upgrades, water and wastewater treatment will take up 5% of household income (Baird 2010). The 2013 Infrastructure Report Card released by the American Society of Civil Engineers in March of 2013 highlighted both the need for water revenues to increase to pay for infrastructure maintenance and increasing regulatory burdens (American Society of Civil Engineers 2013). If this is to be the case there is little reason to believe that affordability will be going away soon.

A second line of criticism the EPA's affordability metrics is subject to is that they do not capture the factors that really affect whether water treatment will be affordable or not. While MHI, poverty and unemployment rate can serve as indicators of a household's income resources, they do not serve as a measure of their actual behavior when it comes to consumption. Households do not always spend in accordance with their income, especially when they experience negative shocks they expect to be temporary (e.g. unemployment) and can tap into other resources like savings or access to credit (Citro and Michael 1995). Furthermore, annual incomes as reported by the Census Bureau (CB) do not match up well with a measure of the total income of the nation produced by the Commerce Department. For example, in 1996 the difference between the CB's total national income and Commerce's was two trillion dollars or about $20,000 per household. A better measure of the resources a household has available to them *and* how they spend their resources can be determined by studying their consumption patterns and behavior (Citro and Michael 1995; Meyer and Sullivan 2003; Rector et al. 1999). Poor households are usually identified by this method as those experiencing material hardships in funding the necessities of life. These material hardships are often categorized into four main classes, food insecurity, housing insecurity, inability to obtain medical care because of cost and inability to pay household bills (Heflin et al. 2009). This option is more advantageous to researchers because it considers hard and fast options that allow researchers to evaluate the actual choices made by consumers who can't afford everything they need (Pilkauskas et al. 2012). The general public and policymakers also appear to favor material hardship measures since officials and the populace concern themselves not with income, but if consumers can afford their necessities (Mayer and Jencks 1989). These advantages make measures of material hardship more desirable than the income definitions of need.

THE ECONOMICS OF ARSENIC

Arsenic was first regulated in the 1940s by the U.S. Public Health Service. The limit was set at 50 μg/L and was designed for arsenic not as a carcinogen, but as a toxin (Scheberle 2004). In the 1960s, the U.S. Public Health Service recommended the standard be set at 10 μg/L, but never acted to adopt this lower standard (Reimann and Banks 2004). It was the 50 μg/L rule that the EPA adopted on an interim basis in 1975 following the passage of the SDWA (Tiemann 2007). It would take evidence that arsenic was a carcinogen, and the accompanying assumption that there is no “safe” amount of arsenic below which there is no observable adverse effects, for regulators to revise the rule downward.

The evidence that arsenic has negative health consequences has existed since the 16^{th} century (Smith et al. 1992). The first link between arsenic exposure and cancer was made by Hutchinson in 1887 as he observed skin tumors developing on patients who had used arsenic-containing medications (Hutchinson 1887). Since the 1960s, epidemiologists have linked arsenic to skin, bladder, lung, kidney, nasal, liver, prostate, urinary tract and uterine cancers (Bates et al. 1995; Chen and Wang 1990; Chen et al. 1985; Chiou et al. 1995; Cuzick et al. 1992; Guo et al. 1997; Hopenhayn-Rich et al. 1996; Mushak and Crucetti. 1995; Tseng et al. 1968; Tseng 1977; Tsuda et al. 1995; Wu et al. 1989). Non-cancer effects of arsenic include damage to the peripheral sensory nervous systems, reduced intellectual functions in children, increased rate of miscarriage, lowered birth weight and increases in other birth defects (if the mother consumes arsenic), enlargement of the liver, blood clots and associated cardiovascular conditions, reduced blood supply to the heart (ischemic heart disease), thickening of the carotid artery, chronic cough and bronchitis, disruption of hormone production, type II diabetes and skin discoloration in the extremities (Blackfoot’s Disease) (Kapaj et al. 2006). For a more in-depth (but out of scope of this thesis) review of studies investigating the health effects of arsenic, the reader can turn to the reviews by the National Research Council conducted during the arsenic regulatory process (National Academy of Science 1999, 2001)).

The EPA took data from epidemiological studies of cancer risks in developing the risk assessment models they used to calculate the benefits of reduced exposure. The data for risk assessment came from a study of the arsenic risk faced by villagers in Taiwan obtaining drinking water from wells with high arsenic concentrations (Morales et al. 2000). This data was paired with EPA data on the exposure faced by American consumers. The EPA was the able to predict the cancer risks faced by American consumers. These predicted risks are presented in Table 2-1 (Abt Associates Inc. 2000). For reference an "acceptable" cancer risk is set by the EPA as

Table 2-1 Estimated cancer risks and avoided cases at or above potential MCLs

MCL (μg/L)	Cancer Risks for U.S. Populations At MCL[1]	Annual Total Cancer Cases Avoided per Year[2]
3	$0.11\text{-}1.25 \times 10^{-4}$	57.2-138.3
5	$0.27\text{-}2.02 \times 10^{-4}$	51.1-100.2
10	$0.63\text{-}2.99 \times 10^{-4}$	37.4-55.7
20	$1.1 – 3.85 \times 10^{-4}$	19.0-19.8

[1]From Exhibit 5-4(c) (Abt Associates, 2000).
[2]From Exhibit 5-9(c) (Abt Associates, 2000).

$1\text{x } 10^{-4}$ (Gurian et al. 2001b). These risks were applied to the exposed populations in order to get the number of cancer cases prevented (Abt Associates Inc. 2000). Other risk estimates show much greater risks associated with arsenic concentrations. The California Office of Environmental Health and Hazard Assessment (COEHHA) determined a unit cancer risk, the risk of developing a cancer per additional unit of carcinogen exposed to, of $2.7\text{x}10^{-4}$ $(\mu g/L)^{-1}$ and the National Research Council (NRC) unit cancer risk was $2.3\text{x}10^{-4}$ $(\mu g/L)^{-1}$, ten times greater than the EPA's unit cancer risk of $2.41\text{x}10^{-5}$ $(\mu g/L)^{-1}$ (Brown 2008).

Putting a monetary value to prevented cancer cases requires another pair of values, willingness to pay and the value of a statistical life. The willingness to pay is the amount a consumer would be willing to pay to avoid having to experience a risk (in this case the risk of cancer). The value of a statistical life is the willingness to pay to avoid a fatal risk, divided by the risk (Kolstad 2000; Viscusi et al. 2000). The EPA obtained a willingness to pay to avoid a non-fatal case of cancer of $607,162 (1999; from Viscusi, Magat and Huber's study of willingness to pay to avoid chronic bronchitis (1991)) and a value of a statistical life of $6.1

million (1999; a meta-analysis performed by the EPA of wage risk-premiums identified that most workers exposed to fatal risks value their life at a median value of $6.1 million) (Abt Associates Inc. 2000).

The EPA identified thirteen different treatment technologies that could be used to remove arsenic from a drinking water supply. The EPA ran a Monte Carlo simulation in order to determine the national costs based on a decision tree that considered the necessary removal efficiency and costs. These costs were summed over all of the systems to develop national treatment costs. State regulatory enforcement costs were also calculated. Treatment and regulatory costs were added together to come up with national costs (Abt Associates Inc. 2000).

THE ACCURACY OF THE COST-BENEFIT ANALYSIS

When establishing the arsenic MCL at 10 μg/L, the EPA used its discretionary authority to establish a MCL higher than the minimum feasible level of 3 μg/L and well above the health protective concentration of 16-40 ng/L (COEHHA estimated a health protective concentration of 4 ng/L and NRC 1.5 ng/L) (Brown 2008). This was done because the EPA found that the benefits of a 3 μg/L MCL did not outweigh the costs, but (when unquantifiable benefits, i.e. not benefits from lung or bladder cancers, were considered) that a 10 μg/L rule would meet this requirement. The costs of implementing the 10 μg/L rule was found to be $205.6 million (1999) annually with an upper-bound estimate of quantifiable benefits of $197.7 billion (1999) annually. The benefit-cost ratio for the 10 μg/L rule was found to be approximately 0.96 (the ratio for the 3 μg/L rule was 0.62; 5 μg/L rule, 0.75; and 20 μg/L rule, 0.98) (Abt Associates Inc. 2000). While the 10 μg/L failed the quantifiable benefit-cost test, many prominent environmental economists have written in support of the idea that agencies should not have their hands tied by failed benefit-cost calculations when other factors can come into play (Arrow et al. 1996).

This finding of arsenic treatment's affordability was highly controversial and received much criticism in the literature. The most prominent critique among these was that of Burnett and Hahn (2001). Burnett and Hahn found several questionable assumptions underpinning the EPA's analysis, including faulty assumptions about risk, using upper-bounds instead median or best estimates, and a failure to take into account that cancers occur in the future, which suggested to Burnett and Hahn that discounting of monetized health benefits should be performed. By correcting for these, Burnett and Hahn adjusted the value of the statistical life to $1.8 million. Using a sublinear dose-response curve and reasonable estimates for non-quantifiable benefits, Burnett and Hahn develop a best estimate of 11 lives saved for a monetized benefit of $20 million and a cost effectiveness per life saved of $65 million per life. Burnett and Hahn concluded that the 10 μg/L rule was unsupported by a cost-benefit analysis. Some have found flaws with the idea of discounting the value of a statistical life, most notably Lisa Heinzerling (2002) who pointed out that the EPA values the reduction in risk (and not the loss of life), and that this reduction in risk occurs when the regulation is promulgated (and not twenty years hence) and Richard Wilson (2001), who argues that if discounting is to take place it should be done not to lives lost but years of life lost.

Another set of authors, Frost et al. (2002), take a different track in analyzing the EPA's cost-benefit analysis. Although the authors criticized the EPA's application of the scientific data on the risks associated with arsenic, their main critique was with the costs associated with bringing water systems up to the arsenic MCL. The authors used the cost data from the American Water Works Association Research Foundation (AWWARF), which was significantly higher than the EPA's data, from $55 million (1999) for a 20 μg/L rule to well over a billion dollars a year for a 3 μg/L rule. With these costs a 10 μg/L rule would cost upwards of between three and ten million dollars for each *year* of life saved, well above the EPA's calculated value of about $370,000 (1999). This led the authors to conclude that the arsenic rule was severely economically inefficient at an MCL of 10 μg/L.

Modeling work by Gurian et al. (2001a) also examined how much the arsenic regulation would cost. The authors used the same cost curves as Frost et al. (2002) and incorporated this into their treatment technology selection algorithm. This algorithm was then used to model if the selection of arsenic removal technology would be necessary, and if necessary, which treatment technique would be used for the systems in the Safe Drinking Water Information System (this universe of systems was the same one used by the EPA in doing their estimates, albeit with a different set of cost curves). In doing so the authors calculated that a 10 μg/L rule would cost nationwide $294 million (1997) per year. The authors also performed an uncertainty analysis on their results by propagating through the errors resulting from the various assumptions and variations in their data. With this uncertainty analysis performed, their low estimates are similar to the EPA's high estimates and their high estimates are similar to the AWWARF's low estimates. Gurian et al. (2001a) predict that in total Americans nationwide would be exposed to 300 g of arsenic less each day, and there would be 55 fewer deaths annually from bladder cancer each year. Considering only fatal bladder cancer, the arsenic rule would save a life at the price of about $17 million each. This is almost three times higher than the value of a statistical life used by the EPA, and so the arsenic rule was inefficient.

An important assumption in these algorithms is that they are based on systems selecting the least-cost method for arsenic removal; however, this may not be the case. First, such an assumption requires perfect knowledge of the true long-term costs faced by water supply systems when they make their decisions related to arsenic removal, which is highly unlikely to be the case. Second, many of the more conventional arsenic removal techniques (e.g. filtration in a traditional water treatment system, coagulation/flocculation, activated alumina adsorption) pose the possibility of assisting systems in meeting not only primary MCLs but also secondary MCLs (for contaminants like iron, manganese, sulfate and nitrate) and other goals like hardness reduction. If this is the case for a particular plant, it may select a more expensive treatment option and just pay a "premium" for the assistance in meeting the optional targets. Source water composition can also drive systems to select more expensive technologies, since waters high in sulfate are unsuitable for arsenate removal by anion exchange due to sulfate's higher selectivity for conventional anion exchange resins. Finally, considerations of residuals management can force utilities to select more expensive treatment techniques in order to avoid the burden of disposing potentially hazardous wastes (Chen et al. 1999).

Cass Sunstein (2002) developed a third argument against the EPA's cost-benefit analysis of the 10 μg/L arsenic rule, an argument that questioned neither the EPA's cost calculations nor benefit estimates. Sunstein criticized cost-benefit analysis as a whole for its creation of an illusion of certainty, when in fact the best that can often be done is creating a range of potential values for the benefits. Sunstein does not believe that this should be used to fundamentally undermine the use of cost benefit analysis by regulators, but kept in mind by policy practitioners, legislators and the judiciary should not view the results of benefit-cost analyses as highly accurate, simply because numerical values are assigned to benefits and costs. For the arsenic rule, Sunstein found that the benefits could range anywhere from \$0-\$560 million (1999) depending on a whole host of assumptions made in interpreting the risk information available.

Because of this wide benefits range, Sunstein said it is incorrect to believe the EPA's 10 μg/L rule was the right or wrong thing to do based on the science it had at the time. There simply was no way to finalize the benefits in a conclusive way.

The biggest factor in explaining the variability of the cost estimates is the treatment technology cost curve utilized by the different studies (EPA, AWWARF and Gurian et al.). When they adjusted their national cost model to use the treatment technology cost curves from the EPA and AWWARF studies, Gurian et al were able to obtain a reasonably close match with the costs predicted by the other studies. The primary reason for the difference in technology cost curves comes from differences in residual management used by the different studies. The EPA study assumes ion exchange brines can be disposed of simply by use of sanitary sewers. The AWWARF study required that arsenic containing brines would have to undergo arsenic removing coagulation, evaporation and then disposal in a landfill. The difference between these two methods can lead to a doubling or even tripling of the costs for the anion exchange process. For activated alumina process, AWWARF included regeneration and residual disposal costs (which contributes to 20-40% of total costs for an activated alumina process) whereas EPA did not. Gurian et al.'s model (based on the National Arsenic Occurrence Survey) had questionable assumptions about acceptable disposal processes, but Gurian et al. (2001b)believed it represented a happy medium as far as costs were concerned. A second (and of smaller importance) explanation for the variability in the cost estimates is a 20-30% variation in the number of systems that will be required to adopt arsenic treatment. In general the EPA predicted the fewest systems would need to install arsenic treatment and AWWARF predicted the most - with Gurian et al. (2001b) striking a middle value

Wilson (2001) argued that the EPA had a history of overpredicting compliance costs and so that their cost estimates were higher than they would be in reality. A report by the EPA in 2012 confirmed that the EPA did overpredict the costs associated with the arsenic rule (National Center for Environmental Economics (NCEE) 2012). This overprediction was due to the innovation in the technology that would become available to remove arsenic from drinking water. Iron adsorption was developed after the Best Available Technologies (BAT) were identified and included in the cost estimates. Iron adsorption was shown to be a cheaper technique than many of the previously identified options, which led the EPA to designate it as a BAT. This designation led to its widespread adoption, which contributed to the development of cheaper adsorbents that followed. The use of iron adsorption for arsenic removal by water systems meant that costs had been overestimated since it was not considered during the cost analysis (NCEE 2012).

EPA has also taken a look at the accuracy of its cost-benefit analysis – with a focus on the costs, not just for the arsenic rule, but for all its rules. In general, the EPA has concluded that it overestimates the costs for its rules (National Center for Environmental Economics 2012). This error is not exclusively due to the regulators making errors as part of their simulations, incomplete information about regulations, or from accurate cost information being withheld by industry, but a mathematical principle known as Jensen's inequality. The ratio of *ex ante* to *ex post* costs for regulations is a convex function when *ex ante* costs are held constant and *ex post* costs allowed to vary. Applying this to the situation of regulatory costs provides an explanation for the overestimation of the costs related to regulations (Simpson 2011).

THE COSTS OF ARSENIC FOR DIFFERENT SYSTEM SIZES

Lost in the focus on the big picture of arsenic's total costs and total benefits to society was the important question of how these costs and benefits would be distributed. The distribution of costs and benefits to society would become a major flash point for critics of the arsenic regulation shortly after its finalization in October of 2001. The EPA's analysis analyzed

Table 2-2 - Projected costs and population served by CWS size

System Size Class	Projected Costs (in millions $, 1999)[1]	Percentage of U.S. Population Served[2]
<500	$18.4	1.4%
501-3,300	$33.2	5.3%
3,301-10,000	$27.9	8.0%
10,001-100,000	$72.9	26.5%
>100,000	$40.8	58.8%

[1] From Abt Associates Inc. (2000).
[2] From U.S. Environmental Protection Agency (2002).

the distribution of costs to community water systems (CWS) of various size classes. Table 2 shows the projected cost for various size classes (Abt Associates Inc. 2000) as well as the share of the U.S. population served by CWSs that are served by a system of that size class (U.S. Environmental Protection Agency 2002a). As can be seen, there is little correlation between total costs for a size class and the number of people served by the size class. This has significant implications for household water bills, as presented in Table 3. A customer in the smallest system pays over ten times the average cost for arsenic treatment and almost 400 times as much as customers in the largest systems (Abt Associates Inc. 2000). The difference between these costs caused significant controversy over whether or not customers in small systems could afford arsenic treatment for their water supplies.

Table 2-3 – Annual household costs per CWS size class

System Size Class	Costs per Household $(1999)/yr.[1]
<100	$326.82
101-500	$162.50
501-1,000	$70.72
1,001-3,300	$58.24
3,301-10,000	$37.71
10,000-50,000	$32.37
50,001-100,000	$24.81
100,001-1,000,000	$20.52
>1,000,000	$0.86
All Systems	$31.85

[1]From Exhibit 6-17 (Abt Associates Inc. 2000).

Oates (2002) interpreted these results to argue for a decentralized regulation process. Given that arsenic treatment is a "local public good", in that the level of the good (protection from arsenic) is the same for all consumers, that all the consumers are relatively concentrated in a single area and that the distribution of costs are wildly divergent, it makes sense for regulations to be established at a local level. For consumers in large systems paying less than a dollar a year for the relatively small risk reduction is relatively rational, but Oates argued that it does not make sense for customers in a small system to pay well over $300 annually to experience the same small risk reduction. As such, Oates recommended that the EPA should have kept the MCL at 50 μg/L and set a recommended limit at 10 μg/L for systems that could afford it.

Analyses of the costs of arsenic treatment conducted even before a 10 μg/L rule was proposed also found that a significant proportion of the national costs would be faced by small systems. Simulations by Frey et al. (1998) concluded that for a 10 μg/L rule, small systems would pay (on an average run of the author's model) 38.5% of the $708 million national annual compliance costs. Small groundwater systems would pay between 30 and 40% of the total national compliance costs for arsenic MCLs between 0.5 and 10 μg/L, with large groundwater systems facing 39-45% of the national compliance costs.

Using their treatment cost model, Gurian et al. (2001b) also analyzed the impact of the arsenic regulation on small water systems and found that about 1.5% of water systems will face total water bills in excess of 2.5% of MHI (serving 0.03% of the US population). If one assumes that a system that cannot afford treatment will not undertake it, the number of systems taking no treatment action rises from 96.4% to 97.8% of systems with a corresponding 34% reduction in aggregate costs and a 4% reduction in aggregate benefits. The authors examine several techniques that could increase compliance. The first is subsidizing treatment costs; however, this method was disregarded as an undesirable disincentive to increasing efficiency in the water supply market. They also examined the potential for point-of-use (POU) technology to assist and found that not only does allowing POU technology reduce national costs by 19%, but that aggregate benefits are increased by a slight 0.2%. This increase in benefits will probably be reduced due to imperfect maintenance on individual POU units.

Even with the passage of the arsenic rule, size differences have continued to play a role in compliance issues. A study of the violations that was conducted in fiscal year 2011 found that no violations of the arsenic MCL were found in very large systems (serving greater than 100,000 people) (Rubin 2013a). A statistical analysis of the remaining systems found that while a larger percentage of very small systems (<100 customers) reported violations of the arsenic MCL, they were statistically no more likely to experience violations than other systems serving less than 100,000. A further analysis of states with elevated concentrations of arsenic also failed to find that very small systems were statistically more likely to have violations of the arsenic MCL (Rubin 2013a).

A 2013 study by McGavisk et al. (2013) analyzed a possible explanation for whether or not a system was in compliance with the arsenic rule by 2011, the MHI of the community. The authors used an ANOVA test procedure to determine if there was a statistical difference in the community's MHI between systems that were in compliance, were not in compliance and systems that closed during the interval between the finalization of the arsenic rule and the study period. They concluded that there was a statistical difference between the compliance statuses: those systems that were compliant had higher incomes per capita than those systems that were not in compliance. Systems that closed and replaced in the study period were in areas with higher incomes per capita than systems that were either compliant or not compliant. These differences were explained by arguing that systems in poorer areas would be unable to raise the funds to install treatment and those in richer areas could close one treatment plant and open another elsewhere that used a different source that would be in compliance. The authors warned against treating MHI as the only factor in compliance and identified several case studies that illuminated MHI as only one factor in system compliance, other factors including operator inability to upgrade systems, the community's resistance to pay for system upgrades and miscommunication between regulators and those designing the systems.

Cho et al. (2007) analyzed the willingness to pay for consumers in several of Minnesota's rural communities in order to bring their water supply into compliance with the arsenic rule. Using survey data from a contingent valuation study, the authors determined that consumers with drinking water contaminated only occasionally containing arsenic in excess of 10 μg/L were willing to pay between $8 and $9 each year, while customers with water that regularly exceeded 10 μg/L of arsenic were willing to pay between $15 and $17 each year to bring their arsenic concentrations down to the MCL. These willingness to pay values were significantly less than how much actually bringing systems into compliance would cost, and as such the authors concluded that the arsenic MCL was not reasonable for small water systems. Cho et al. suggested that POU/POE technologies could be used instead, but should be installed, paid for and maintained by the customers and not the water system as required under SDWA. Instead the system should make homeowners aware of the risks they face from arsenic in their drinking water and subsidize the costs of installation and operation for homeowners that choose to install them.

A 2006 study by Jones and Joy looked at fourteen small systems (6-95 system connections) on New Mexico tribal reservations and the measures they had taken in order to implement the revised arsenic MCL. The authors ran several different scenarios analyzing the usage of different treatment technologies and compared these to the benefits the communities would receive. For 13 of the 14 systems, the benefit-cost ratio is never any greater than 0.29 (for home delivery of bottled water). Jones and Joy (2006) concluded that the arsenic rule was inequitable for these 14 tribal communities and that these cases were similar to the problems faced by small, rural populations nationwide in meeting the arsenic MCL. The lack of adequate financial resources provided by the federal government meant that available funding for risk averting measures would have to be shifted from other non-mandatory health expenditures (e.g. doctor visits, nutrition) to meet the arsenic standard, meaning that in all likelihood small CWS users would face at best no change in their overall health risk level due to the new regulation (if not an increase to their risks).

ENVIRONMENTAL JUSTICE AND ARSENIC

Even before the arsenic regulation was finalized, small water systems were preparing themselves to face extremely high costs for drinking water treatment. For the first two decades of the 2000s, the EPA predicted that per capita water costs would be four times higher for small systems than for large systems due to needs like infrastructure replacement and capital improvements in order to bring systems into compliance with SDWA regulations (including arsenic) (Scheberle 2004). Normative considerations about the inequity of the arsenic MCL (and drinking water regulations in general) for small systems tends to draw on considerations of environmental justice. Environmental justice is defined by EPA as “the fair treatment of all people…with respect to the development, implementation or enforcement of environmental laws, regulations and policies.” Under this definition of environmental justice, those who live in small systems need to be given the same level of consideration that residents in large water systems receive during the regulatory process. Other definitions of environmental justice (such as that of environmental justice theorist, Robert D. Bullard) outline a component of geographical inequality of the burdens. Geographical inequality of the burdens holds that a situation where some areas receive benefits and others receive the costs and negative health impacts is inequitable and should be addressed. This situation applies for the arsenic rule in particular where benefits are equally distributed, but (because of the cost differences) the costs are not remotely equitably distributed between all recipients of the benefits (Rosenbaum 2008). Cory and Rahman (2009) argue that there are two ways SDWA can raise environmental justice issues, unequal enforcement of regulations that increase the risk to minority communities and forcing systems into (often prohibitively) costly compliance in order to obtain the health benefits. Of particular significance for small system operators is the latter.

In order to address environmental justice concerns the EPA is mandated by SDWA to consider affordability of their proposed regulations. For the arsenic rule, the EPA determined that arsenic would not be unaffordable for small systems. The expenditure margin for new drinking water regulations at the time the arsenic regulation was proposed was $500 $(1999)/household/year. Since no system size class had average household costs in excess of this expenditure margin (see Table 2-2), the rule was found to be affordable (Abt Associates Inc. 2000).

As with most of the other facts surrounding the cost of the arsenic regulation, this finding was highly controversial. With small water systems worried about how much the rule would cost the customers they challenged the finding (Hogue 2001). Reviews conducted by the EEC found that systems were indeed having a hard time raising the capital necessary to meet the arsenic rule (EPA-EEC 2002).

The conclusion that obtaining the funding to pay for arsenic treatment could be difficult for some systems was supported by two different studies. The Jones and Joy (2006) study of the benefits and costs on Native American communities located in New Mexico also analyzed whether arsenic treatment was affordable for those on the reservations. One of these systems had water costs following installation of the least-cost treatment alternative in excess of the $500 expenditure margin. All of the systems had water costs in excess of 2.5% of their local MHI. Jones and Joy concluded that arsenic treatment for water was unreasonable for customers on these 14 reservations. The second was a study of the costs faced by 35 water systems in California by Hilkert Colby et al (2010). About a fifth of the systems in the study sample had treatment costs for arsenic removal in excess of the expenditure margin for a regulation, and a seventh of the systems paid more solely for arsenic removal than the EPA allowed for the entire water bill.

A finding that required water treatment is unaffordable for systems is the first step in granting systems variances and other selective enforcement measures. The concern exists that selectively enforcing a regulation like the arsenic rule would raise environmental justice concerns if minority communities were likely to be the ones receiving the variances. Cory and Rahman (2009) set out to examine if selective enforcement of the arsenic rule for systems would cause environmental injustice in the state of Arizona. Analyzing the 1,006 public water systems in the state, the researchers compared the racial make-up and socioeconomic class of the customers in the systems affected by arsenic to those that receive water from systems that do not have a problem with arsenic. The authors found that racial minorities or lower income households are not more likely to be found in areas with arsenic contamination issues. The only racial group that is disproportionately negatively affected by arsenic is whites (African-Americans are actually a significantly smaller share of the population in arsenic-affected communities). All of the measures of wealth (per capita income, per household income and household value) are higher in arsenic affected areas than in non-affected areas. Cory and Rahman conclude therefore that selective enforcement of the arsenic regulation does not appear as if it would produce environmental injustice against minority and poor communities in Arizona.

Cory and Rahman's results may have been a unique feature of the systems in Arizona, as this was not the case for the residents of the San Joaquin Valley of California. A study by Balazas et al. (2012) found that there was a significant environmental injustice posed by arsenic in community drinking water systems for residents in systems with more racial minorities and fewer homeowners. Customers of these utilities were more likely to have higher concentrations of arsenic in their finished water than customers of more affluent systems. Systems with more "persons of color" and fewer homeowners were also more likely to have been found in violation of the arsenic MCL, although a significant number of systems that had average arsenic concentrations above the MCL were not officially found to be in violation. These problems were worse for small systems (defined by the authors as having fewer than 200 connections), where a 10% decrease in the home ownership rate was predicted to correspond to an increase in 4.3 μg/L of arsenic in the water. The authors attribute these trends of smaller systems and systems serving low socioeconomic status customers to the reduced capacity of these systems to finance, install and operate arsenic removal processes. The authors propose that the regulatory burden that gets passed onto these customers could force poorer households to adopt expensive alternatives (like the purchase of bottled water) or adopt treatment only imperfectly which would increase their related risks. The authors conclude that the solution is not variances and exemptions, but for these systems to partner with state and federal agencies to seek financial and technical help in securing affordable arsenic treatment.

CHAPTER 3

EPA'S REVISED METRICS AND LOWER INCOMES FOR DRINKING WATER AFFORDABILITY

Introduction

Arsenic has been linked to increased risks of lung, bladder and skin cancer worldwide for many years now and its presence in drinking water was first regulated in the 1940s by the U.S. Public Health Service. The EPA adopted U.S. Public Health Service's 50 μg/L limit on an interim basis and spent nearly three and a half decades collecting data about the risks associated with arsenic-induced cancer before finalizing the 10 μg/L rule in 2001 (Tiemann 2007). This arsenic rule was set to impose a significant burden on the smallest of drinking water systems. Although the EPA determined that the arsenic rule would be affordable for all system sizes, many criticized both the conclusion and the method the EPA used to make its affordability determination. These criticisms prompted the EPA to reconsider their affordability methods for drinking water, culminating in the proposal (but not yet the finalization) of a new set of affordability methods.

The controversy over drinking water affordability and potentially excessive regulatory burdens placed on small systems has diminished as the arsenic rule nears a decade of enforcement. However, the EPA is currently moving to make another round of regulatory determinations of the contaminants listed on the third contaminant candidate list (Roberson et al. 2009) and other potentially forthcoming rules, such as a hexavalent chromium rule with costs projected at a minimum of $500 million (C. J. Seidel et al. 2013), mean that affordability issues may reappear as a factor in evaluating potential regulations. The potential benefits of future regulations could be dwarfed by a host of other factors that have led the EPA and others in the water supply community to predict that the cost of water and wastewater services could quadruple in the coming decades (Baird 2010). If questions about affordability return, the EPA could find itself unprepared to address these concerns.

Concerns over the affordability of drinking water regulations have been part of the national discussion since the SDWA was first passed in 1974. As part of the SDWA Amendments of 1996, Congress authorized the State Drinking Water Revolving Fund to help with problems of system affordability and mandated that the EPA develop a method for assessing affordability (Pontius 2008). In response, the EPA proposed a method, called the expenditure margin approach, for this purpose in 1998 (63 FR 42032). The EPA took the ratio of the total cost for water treatment (a baseline cost and the projected cost for the treatment required to meet the proposed standard) divided by the MHI in each of its small system size classes (i.e.., <100, 101-500, 500-1,000, 1,000-3,300 and 3,300-10,000 households). If this ratio exceeds 2.5%, the regulation is considered to be unaffordable for that size class, and permission to use variances would be considered by the states for the systems (Method 1 in Table 3-1). An alternative way of conceptualizing this method is by calculating 2.5% of the MHI and subtracting the median household water bill, this difference is termed the expenditure margin. If the cost of the considered regulation is greater than this difference, then the regulation will be unaffordable. For example in 1998, 2.5% of the MHI was $750 (1997, throughout this thesis prices are nominal prices in the year that follows the price) and the median water bill in the small systems was $250 (1997). Therefore the expenditure margin was $500 (1997) and a rule could not cost more than this without being deemed unaffordable. Permission to use variances allows water systems to implement more affordable treatment techniques that provide some protection

Table 3-1 – Affordability methods considered

Method Number	Name	Criteria	Reference
1	Expenditure Margin Approach	Proposed total water costs (baseline plus proposed regulation costs) cannot exceed 2.5% of national MHI (i.e. $750 (1999)) .	(63 FR 42032)
2	Incremental Burden Approach	(2a) Proposed regulatory costs cannot exceed one of three considered limits: 0.25% MHI, 0.50% MHI, 0.75% MHI. (2b) If regulatory costs do not exceed the final limit, systems can still qualify if they are located in an economically disadvantaged community (county MHI less than 65% national MHI or poverty or unemployment rate twice the national average).	(71 FR 10671)
3	Low-Income Expenditure Margin National Screen	Proposed total water costs (baseline plus proposed regulation costs) cannot exceed 2.5% of national first quartile household income (i.e. $555 ($2000) or $661 ($2010)).	Proposed based on (63 FR 42032)
4	Low-Income Incremental Burden National Screen	Proposed regulatory costs cannot exceed one of three considered limits: 0.25%, 0.50% or 0.75% first quartile household income. If a system does not exceed the final limit, systems can still qualify if they are located in an economically disadvantaged community.	Proposed based on (71 FR 10671)
5	Low-Income Expenditure Margin Local Test	Systems can qualify for extension if the system's costs to meet the regulation exceed 2.5% of the municipality or county's first quartile household income.	

to consumers at a more equitable cost. This method, and other affordability methods, does not consider the opportunity costs associated with the increased risk faced by consumers when variance technologies are used when a decision is made on whether or not systems will be given permission to use variance technologies. This method faced a test in 2001 during the revision of the arsenic MCL. Contrary to the EPA's finding that the revised arsenic MCL was affordable for all systems, Hilkert Colby et al (2010), Jones and Joy (2006) and the Environmental Economics

Committee (EEC) (2002) found that small systems "genuinely struggled with costs" in meeting the EPA's arsenic MCL.

Within days of the finalization of the arsenic rule (and as part of the appropriations process for fiscal year 2002), the EPA was asked to reevaluate its affordability methodology by Congress (EPA 2002b). The EPA conducted a review and sought input on its affordability methodology from the water supply community. Among those the EPA requested advice from was the EEC and the NDWAC. The EEC found that the basic method for evaluating affordability was sound and justifiable on the basis of efficiency and equity (2002). However, the EEC found several problems that the EPA should address in their revised criteria, such as the use of a median income and national income data, and offered proposals that would address these concerns. The NDWAC recommended a more dramatic solution, that the EPA only consider the proposed regulation's burden and not the total cost for drinking water treatment on water systems. Using an incremental method addressed the "adding up problem"; the "adding up problem" describes the situation that occurs when early and expensive regulations use up the entire expenditure margin, leaving all later regulations to be found unaffordable no matter their cost (NDWAC 2003).

Based on EEC and NDWAC recommendations, the EPA proposed a new two-part methodology in 2006 that included a screen that used predicted cost for the average system in each size class in the US and guidance for state agencies to make affordability determinations. In the nationwide screen (Method 2a in Table 3-1), the ratio of the cost for installing treatment to meet the proposed regulation to the MHI for the system size classes would be determined, in a method known as the incremental burden approach (71 FR 20671). If the incremental burden ratio exceeds one of three proposed threshold levels (0.25%, 0.50% and 0.75% of MHI), the regulation is unaffordable for that size class. In addition to this rule, and as part of its guidance for the states, the EPA proposed three criteria that would determine if an individual system would likely face undo difficulties in raising funds for necessary capital improvements: (i) a MHI less than or equal to 65% of the national MHI, (ii) CB poverty rate at least twice the national average, (iii) or a two-year average unemployment rate of greater than twice the national average (Method 2b in Table 3-1, this method is examined in greater detail in the next chapter).

Because the arsenic rule is the regulation that triggered the debate over affordability, this chapter discusses the performance of the EPA's expenditure margin and incremental burden affordability methodologies in the context of the arsenic rule. The EPA originally projected the arsenic rule would cost $205.6 million (1999) nationwide annually (Abt Associates Inc. 2000). Quantifiable health benefits from lung and bladder cancer reductions came to an upper-end estimate of $197.7 million (1999) annually, with the unquantifiable benefits (from other cancers and non-cancer health effects linked to arsenic consumption, but without dose-response data available for the EPA analysis) estimated to be sufficient to make up the difference between costs and quantified benefits (Abt Associates Inc. 2000).

Some researchers, such as Frost et al. (2002) and Burnett and Hahn (2001), disputed the finding of this cost-benefit analysis and found that the costs far outweighed the benefits, especially for small systems and their customers. The average cost for arsenic treatment to those in the smallest system size class (systems serving less than 100 households) per year was $327 (1999) per household, about 10 times the average cost per household requiring treatment per year nationwide ($33 (1999)) (Abt Associates Inc. 2000). Despite this cost, the EPA found that this burden was affordable for households in small systems nationwide since small system costs did not exceed the expenditure margin of $500 (1997) (Abt Associates Inc. 2000).

To the author's knowledge, two ex *post* reviews of the affordability of arsenic have been conducted. A review of arsenic treatment alternatives for fourteen tribal communities in Arizona found that the cheapest treatment alternative was within the expenditure margin but in excess of 2.5% of the community's MHI (Jones and Joy 2006). In a study of thirty-six treatment sites throughout California, Hilkert Colby et al. (2010) found that 15% of the systems in the study exceeded the 2.5% MHI affordability criteria.

This chapter sets out to compare the current EPA method for affordability, the expenditure margin approach, and their proposed methodology, an incremental burden approach, in the context of the arsenic rule. It also sets out to evaluate if the ability of these methods to find water treatment unaffordable and thereby enable states to grant systems permission to use variance technologies (i.e. point-of-entry and point-of-use systems that may produce water at lower quality but cheaper cost for consumers) has been compromised by the use of the MHI and whether a lower household income, the first quartile household income (Q1HI), is a better fit with both the purpose and function of affordability determinations.

Data and Methods

An evaluation of the the EPA's expenditure margin and incremental burden affordability criteria using a geographically diverse set of systems in the United States that had EPA installed treatment for arsenic removal between July 2003 and July 2011 is performed and its results discussed in this chapter. The evaluations of affordability were also performed at two different time points. First, using 2000 data to model how affordability determinations would have performed when the arsenic MCL was initially promulgated. Second, this is also performed using 2010 data to see how it would perform under the most recently available census data. While national screens using the projected annual costs (Abt Associates Inc. 2000) with adjustment for inflation using the Consumer Price Index (BLS 2012) were performed, system-by-system tests using system-specific cost data (Wang and Chen 2011) were also done to determine whether a significant number of systems exceed the national screening criteria.

Making affordability determinations requires information on the costs of arsenic treatment, baseline drinking water treatment before the arsenic rule and socioeconomic data. Arsenic treatment cost data came from the EPA Office of Research and Development's Arsenic Removal Technology Demonstration Project (ORD Project). The ORD Project selected fifty sites nationwide that required treatment for arsenic in drinking water. The EPA selected and funded the treatment regime, any associated engineering costs and installation and operation costs in exchange for the ability to collect information on performance and cost to help other systems make decisions about selecting arsenic removal technology. The EPA then published this data in a series of forty-nine reports (one of the selected sites does not have a report prepared as of June 2013). Of the forty-nine sites with reports, eight of these sites are non-transient, non-community systems and one serves a seasonal resort. These nine were not considered in this study since those systems do not serve households. Therefore, the remaining forty sites were used for this study (sites, as well as key system and community properties, can all be found in the Appendix).

Costs for arsenic treatment were recorded during the one-year study period and reported by the EPA (Wang and Chen 2011). Capital and start-up costs were annualized over a 20-year period with an interest rate of 7% in keeping with standard government practice. For some adsorption and ion exchange systems, breakthrough had yet to occur by the end of the ORD Project study, so costs for media replacement were projected as part of the ORD Project reports. Many of these reports list the number of households or connections served. Reports that did not provide the number of households did list the total population served and Census Bureau (CB) data on household size (2010a; 2000) was used to estimate the number of households served. The total cost for treatment was divided by the number of households to come up with average cost per household. The average cost per household was adjusted for inflation using Bureau of Labor Statistics (BLS) data to convert into 2000 and 2010 values (BLS 2012). The EPA used the 2000 EPA CWS survey (CWSS) (EPA 2002b) to determine national costs for water treatment when they performed their original affordability analysis. This same data was used for the national screens in this paper for both 2000 and 2010. System-specific data used for more local analysis utilized regional estimates of water costs based on data collected as part of the 2000 long form census (Rubin 2004). Because this estimate includes both water and wastewater bills, the household cost for water treatment alone was isolated based on data collected as part of the Water and Wastewater Rates 2000 Survey performed by Raftelis Financial Consulting (2000).

Data from the CB and BLS was used for the socioeconomic variables needed in making affordability determinations under Method 2b. For the year 2000, household size, median income, income distribution and poverty rate were all taken from the 2000 Decennial Census performed by the CB (2000). For 2010, total population was taken from the CB's 2010 Decennial Census (2010a) and household size, median income, income distribution and poverty rate were taken from the CB's American Community Survey 2010 5-Year Estimates (2010b). All unemployment statistics came from BLS (2010; 2000).

The EPA's expenditure margin and incremental burden methods were both used in this study as national screens using *ex ante* regulatory cost estimates (from before implementation) and as *ex post* estimate of arsenic's affordability using ORD Project cost data. This analysis was started by conducting a national screen based on the EPA expenditure margin affordability methodology (Method 1). The sum of the Abt Associates Inc. (2000) predicted cost for arsenic treatment and the average baseline water cost from the 2000 CWSS was compared to 2.5% of the MHI in 2000 and 2010 for systems serving up to 10,000 people. Following this calculation, it was determined how many systems in the sample ended up exceeding the affordability rule compared to the expected results from the nationwide screen. The average cost per household per system for arsenic treatment as reported by the ORD Project reports was then added to the average annual water costs per household for the area. This total cost was then divided by the 2000 U.S. MHI at the national level. This process was then repeated with 2010 MHI data and inflation adjusted cost data. Any system producing an expenditure-to-income ratio greater than 2.5% was flagged for having unaffordable water treatment for arsenic removal.

The 2006 incremental burden EPA affordability methodology (Method 2) was applied by performing an incremental burden national screen (Method 2a). The expected cost for arsenic treatment alone for each size class was compared to 0.25%, 0.50% and 0.75% of the national MHI. Following the national screen the average annual cost for arsenic treatment per household at the 40 demonstration sites was divided by the 2000 national MHI to determine how many systems in the set exceeded the affordability threshold. The same was done with the 2010 MHI.

The EPA's guidance for the states on identifying EDCs (Method 2b) that could potentially qualify for variances based on socioeconomic conditions was then applied. To do this the socioeconomic data collected from the CB and BLS from 2000 and 2010 (1999-2000 and 2009-2010 for unemployment data) was utilized. The MHI, poverty rate and two-year average unemployment rate for the municipalities and counties the demonstration sites were located in was divided by the national MHI, poverty rate and two-year average unemployment rate (for the unemployment rate only Reno, NV and the New England sites were analyzed using municipal data as the BLS does not report unemployment for municipalities with a population of less than 25,000 outside of New England). The EPA proposed that if the ratios exceeded any of these limits, 0.65 for MHI, 2 for poverty level, or 2 for unemployment, the arsenic removal treatment for drinking water could be potentially unaffordable due to an inability to raise the funds needed to pay.

As previously discussed, some of the suggestions made by the EEC were incorporated into the EPA's 2006 proposal of new affordability criteria, including using regional data and applying the national test as an initial screening procedure. Many key proposals, most notably the need to use a below median household income, were unincorporated. The EEC gave many reasons to examine a lower income level. The most significant reason for this recommendation was within-system income differences. Because all households within a system pay for the drinking water treatments, not just the median households, the affordability to houses below the median income level should be considered. The EEC also noted significant income variation within systems of the same size-class. Using the MHI for an entire size class ignores variations within the size class and so poorer systems are held to the same expenditure level as the richer systems (EPA-EEC 2002).

The EEC suggested a few alternative household income levels that could potentially be utilized in affordability determinations. They suggested the 25th or 10th percentile and 1, 1.5 or 2 standard deviations below the mean – with the 25th percentile and 1.5 standard deviations below the mean being "reasonable" (EPA-EEC 2002). Household income is not normally distributed. Most household income distributions have a mode well below the mean and a small number of households with very high incomes. Because of this non-normal distribution, 1.5 standard deviations below the mean is below zero and even with the top 5% of the distribution removed (to reduce the effect of outliers) this level of income would only be a few hundred dollars for most systems. The 25th percentile of household income was therefore selected to represent low income in developing the following three new potential methods for affordability determinations:

1. Substitute 2.5% of the 25th percentile of household income for 2.5% of the MHI into the national screen (Method 3 in Table 3-1).
2. Substitute the 25th percentile of household income for MHI in the national screens that look at the incremental burden (Method 4 in Table 3-1).
3. Use of 2.5% of the 25th percentile of household income as a threshold limit for a decentralized decision making processes about treatment affordability (Method 5 in Table 3-1).

The 25th percentile of household income was identified from the 2000 U.S. Census (CB 2000) and the 2006-2010 American Community Survey (CB 2010b) data. These income levels were then applied in the above affordability criteria.

RESULTS OF THE AFFORDABILITY METHODOLOGIES

There are 14 possible rules analyzed in this study. Four possible MHI rules use the projected costs: total cost for water treatment cannot exceed 2.5% of national MHI (Method 1) and arsenic cost for water treatment cannot exceed 0.25%, 0.50%, or 0.75% of national MHI (Method 2a and 2b). These four rules can also be applied using site- specific costs from the ORD reports for a total of eight rules using the national MHI. These same four rules that use MHI and predicted costs can also use Q1HI (Methods 3 and 4), for an additional four rules. A final two rules compare site-specific cost data to 2.5% of the municipal and county Q1HI (Method 5). These 14 rules are used in both 2000 and 2010, for a total of 28 different affordability determination scenarios.

Based on the expenditure margin method, the results of this analysis here confirm the EPA's original evaluation that arsenic removal would be affordable for all system size classes. In neither 2000 nor 2010, did total predicted water treatment costs exceed 2.5% of the MHI (Table 3-2). In 2000, the national MHI was $41,994 with 2.5% of that being $1,050; for 2010, the national MHI was $51,914 with 2.5% equal to $1,298. None of the individual sites exceed these levels either, with total water treatment costs for the 40 sites ranging from $174.94-$709.55 and an average of $346.04 (2000) (in 2010, $221.53-$898.50 with an average of $438.19

Table 3-2 – Arsenic and Total Water Treatment Costs in 2000 and 2010

Table 3-2 – Arsenic and total water treatment costs in 2000 and 2010

	2000			2010		
System Class Size (people served)	Estimates for Arsenic Treatment per Household	Average Cost of Water per Household	Total Cost of Water (Including Arsenic) per Household	Estimates for Arsenic Treatment per Household	Average Cost of Water per Household	Total Cost of Water (Including Arsenic) per Household
≤100	345	235	580	437	300	737
101-500	172	232	404	218	294	512
501-3000	65	289	354	82	366	448
3001-10,000	40	253	293	50	320	370

Arsenic treatment was not affordable for all systems when the EPA incremental burden criteria are applied. Starting with the national screen, the relevant thresholds are $315, $210 and $105 in 2000 and $389, $260 and $130 in 2010 (for 0.75%, 0.50% and 0.25% MHI, respectively). Under these thresholds, the ≤100 size class qualifies for variances under all three thresholds and the 101-500 size class qualifies for variances under the 0.25% MHI threshold only. Figure 3-1 shows the results when using system-specific cost data of the burden imposed by arsenic treatment. Five systems have arsenic treatment costs in excess of 0.75% of the

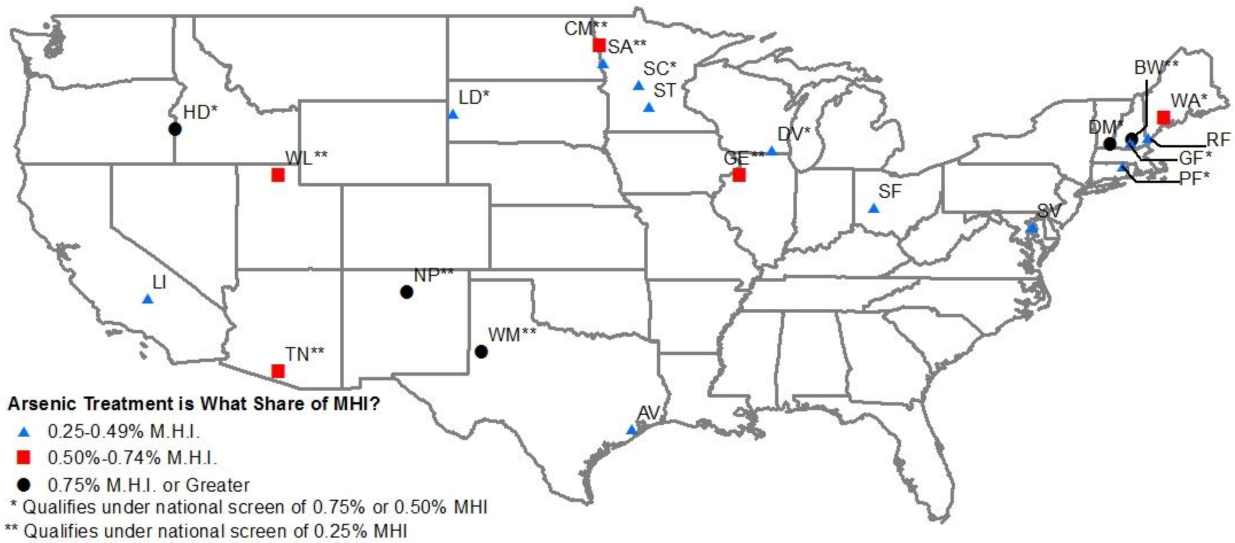


Figure 3-1 - Systems with arsenic treatment cost violating one of the incremental burden standards

national MHI. Of those five, three have populations greater than 100 people and so would not qualify for a variance under the national screen. The cost per household for arsenic removal imposes a burden exceeding 0.50% MHI for ten systems, seven of which do not qualify for a variance under the national screen. Of the forty total systems, over half (22) have costs for arsenic removal in excess of 0.25% of MHI and six of these 22 systems serve a population of greater than 500 people and so would not qualify for variances under the national screen.

Following the national screen, the next step was to examine the ability of the three criteria for identifying disadvantaged communities in Method 2b that qualify for variances. Depending on the year and the geography used (municipal-level or county-level data), between 1-10 systems could potentially qualify for a variance. Of these three criteria, the MHI less than 65% of the national MHI qualifies the most systems for a variance. In total, 15 systems would have qualified using 2000 municipal-level data, 14 using 2000 county-level data, 17 using 2010 municipal-level data and 8 using 2010 county-level data (an additional four systems qualify when the national screening threshold is 0.25% of MHI). Figure 3-2 shows the systems that qualify based on the incremental burden criteria.

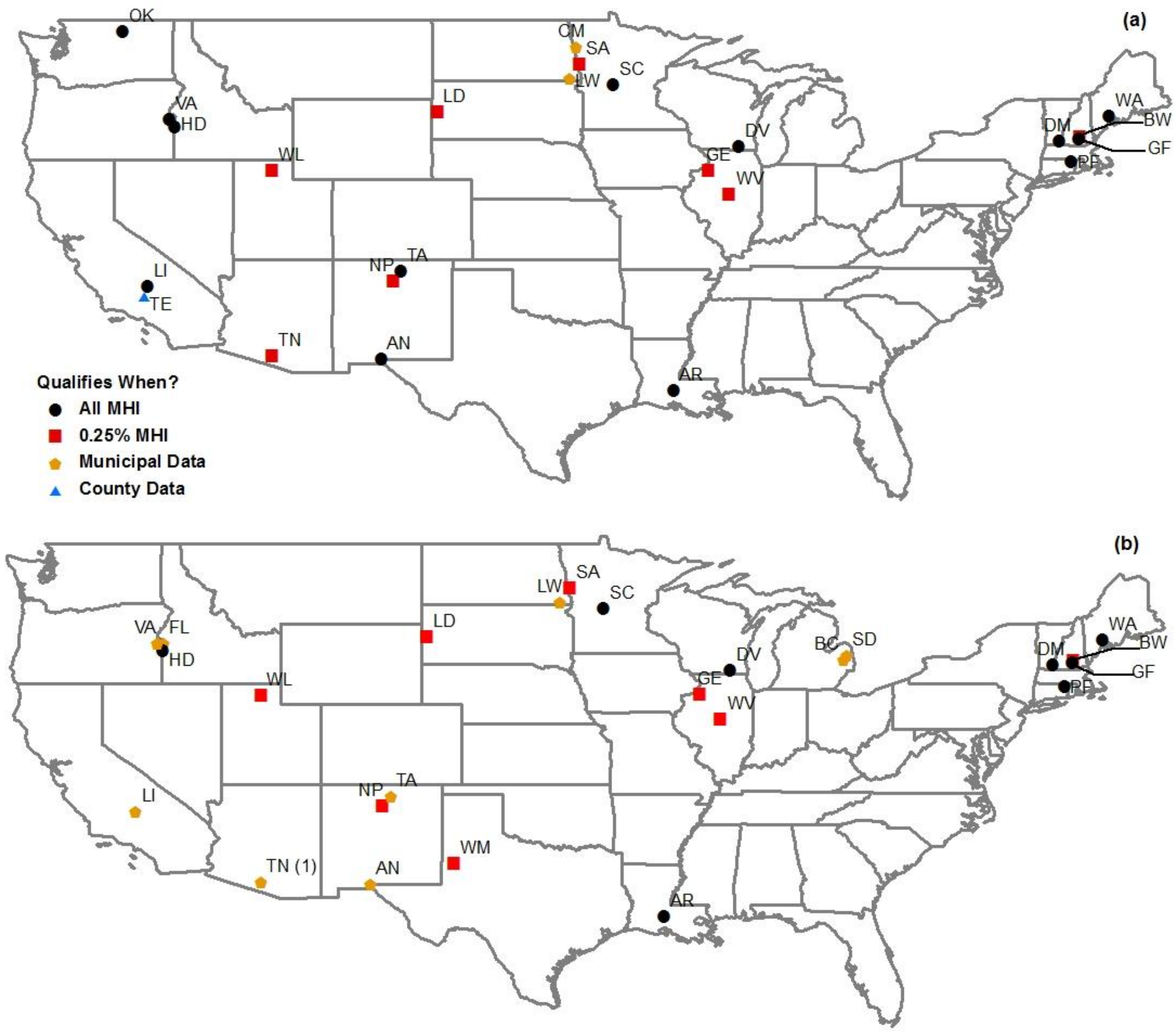


Figure 3-2 - Systems qualifying for variances based upon proposed EPA criteria in (a) 2000 and (b) 2010

The impact of using an income level below the MHI, specifically the 25th percentile of household income, has on affordability determinations was examined next. Starting with the use of the 25th percentile of national household income in a screening procedure (Method 3), the usage of a below median income level significantly altered the results of affordability determinations. The 25th percentile income in 2000 was $22,197 (2000) and 2.5% of that is $555; in 2010 it was $26,428 and $661. Compared to the total cost for water treatment (baseline plus arsenic treatment) found in Table 3-2, the treatment for arsenic removal is unaffordable in systems serving less than 100 people in both 2000 and 2010.

Limiting the incremental burden of arsenic treatment to 0.75%, 0.50% and 0.25% of the national 25th percentile of household income ($166, $111 and $55 in 2000 and $198, $132 and $66 in 2010) to the predicted costs in a national screen (Method 4) leads to the conclusion that arsenic is unaffordable for systems serving 500 people or less no matter the threshold selected and for systems serving between 501 and 3,000 people when the threshold used is 0.25% of the 25th percentile of household income.

This lower income level could also be used in decentralized decision-making processes using system-specific cost data and local income data to determine if the regulation is affordable (Method 5). Figure 3-3 shows the systems that have unaffordable arsenic treatment under this method. In 2000, three systems qualify when municipal income is used and six systems when county income levels are used. In 2010, seven systems qualified when either municipal or county level Q1HI is used. Only one system qualified in both years using either municipal or county incomes.

HOW DO THESE EVALUATIONS COMPARE?

Figure 3-4 shows the number of potential affordability scenarios (of the 28 listed in the beginning of the previous section) in which a system qualifies for a variance or extension. Two systems never have unaffordable treatment under any of the scenarios. A quarter of the systems violate only the 0.25% of the 25th percentile household income national screen rule in 2000 and 2010. One-fifth of the systems qualify for a variance under half of the scenarios included.

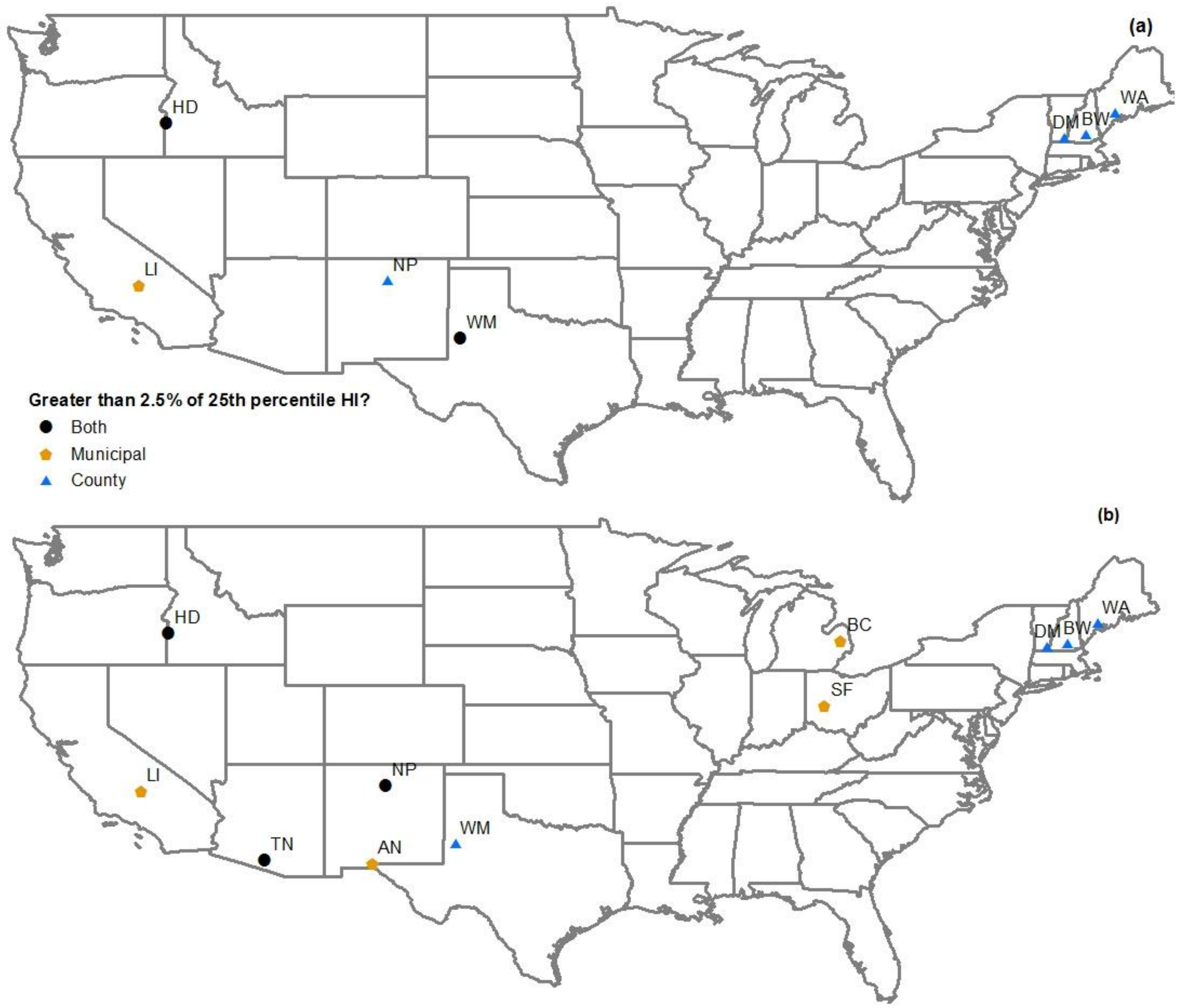


Figure 3-3 - Systems with arsenic treatment in excess of 2.5% of the Q1HI in (a) 2000 and (b) 2010

The above results lead to two general facts. First, as expected, the lower the allowable burden water treatment is allowed to place on communities, the more likely it is that systems will qualify for variances. A second observation is that the more local the data used in the decision, the more likely it is that more systems will qualify for a variance. These should be remembered during the comparison of potential affordability methods.

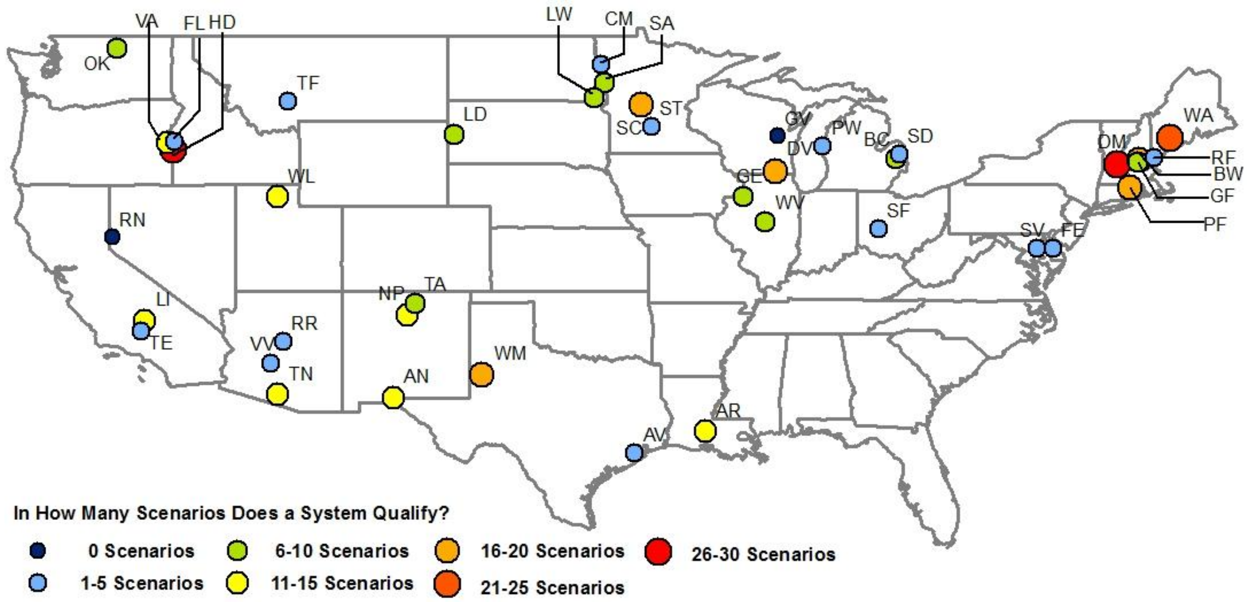


Figure 3-4 - Number of different affordability rule scenarios under which a system qualifies for variances

There is a significant difference between the outcomes of the two EPA methods (Methods 1 and 2). Under the expenditure margin approach no systems qualified for variances between 7-24 systems in the 40 systems (depending on the share of MHI allowed and the geography of the data used) have unaffordable arsenic removal costs according to the incremental burden approach. If the purpose of revising the affordability criteria is to make it easier to trigger permission to use variances, the incremental burden method proposed by EPA meets this goal. If the EPA wants to make it easier to trigger affordability decisions, they should select the 0.25% MHI and recommend the use of municipal data for states and counties trying to make more decentralized variance decisions. If the EPA wants the rule to qualify only those systems experiencing a severe burden, then the EPA should select 0.75% MHI as its threshold and make use of county data as it qualifies fewer systems.

The results of each of the three criteria used by the EPA to identify EDCs were also compared to the other criteria and to the results of the national screens. It is possible that the individual EDC criteria are all qualifying the same communities. It is also possible that these criteria are all identifying systems that may be qualifying under a national screen. In either of these cases, some of the EDC criteria could be unnecessary because they are not identifying different systems for permission to use variances. Observing which rules qualify systems for variances in 2000 and 2010, only a few systems meet the conditions for a variance under multiple economically disadvantaged criteria or one of the EDC criteria and under the national screen. As such, redundancy of the criteria does not seem to be a significant issue and they are capable of identifying different sites.

A potential criticism of the use of low income methods is that their use could reduce the regulatory burden necessary to receive permission to use a variance to a level that is unacceptably low. Comparing the results of the methods that used Q1HI to the results from methods that used national MHI show this is not necessarily the case. A national screen composed of expected treatment cost in excess of 2.5% of the 25th percentile household income is as stringent as the EPA incremental burden screening criteria of 0.75% of MHI. A national screen using 0.75% or 0.50% of the 25th percentile household income is as stringent as the incremental burden screening criteria of 0.25% of MHI.

DISCUSSION

In 2002 the EEC evaluated the EPA's affordability criteria based on two conditions, economic efficiency and equity. Economic efficiency is achieved when marginal benefit (MB) is equal to marginal cost (MC), i.e. when the benefit of producing one more unit is equal to the cost of producing this additional unit. Figure 3-5 illustrates this for water quality. Because of the difference in the economies of scale, the marginal cost for producing improvements in water quality for large systems is less than the marginal cost for small systems. This produces two

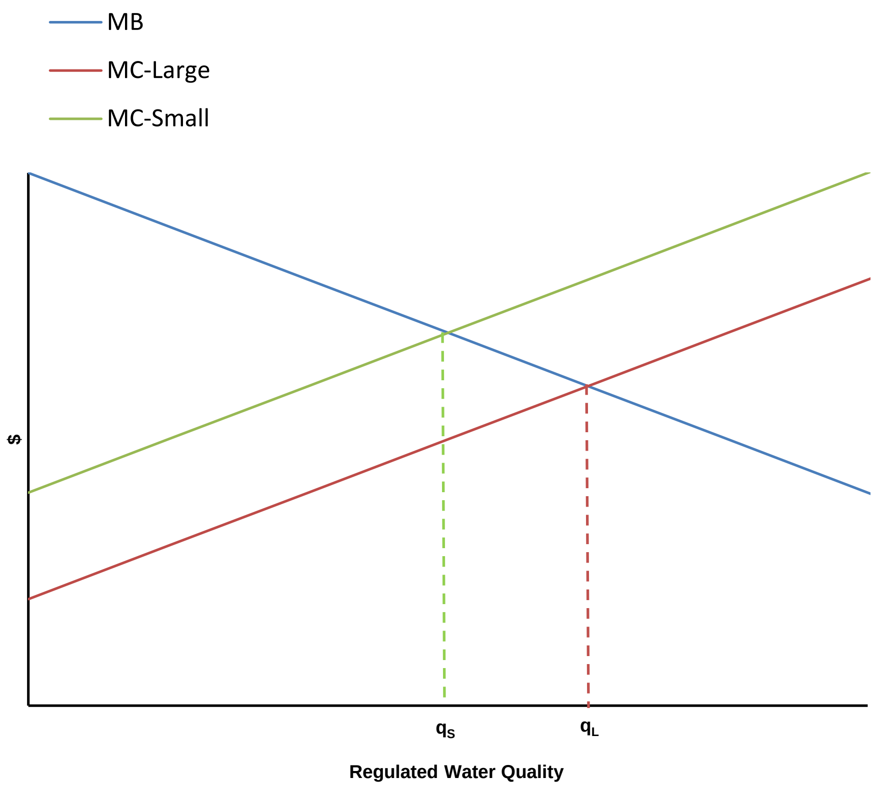


Figure 3-5 - Marginal benefits and costs for increasing regulated water quality

different efficient results, one for large systems (q_L) and one for small systems (q_S). Regulations are designed to be feasible for large systems, but apply to all systems independent of their size. This introduces an economic inefficiency into the small systems water quality market (what economists call a deadweight welfare loss, representing the area between the marginal benefit curve, the marginal cost curve, and q_L). Allowing variances, and making them easier to receive, makes it possible for small systems to approach q_s which would make the market more efficient.

Considerations of equity and environmental justice are normative arguments to allow for variances when the costs of a regulation become excessive. The EPA defines environmental justice as the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies" (EPA 2011). For drinking water and environmental justice, the limited literature draws on two arguments. The first is that drinking water contamination may correspond well to the existing power structure with minority and less affluent groups more likely to use contaminated water sources. The second approach to environmental justice for drinking water argues that forcing systems to meet drinking water rules can force them to forgo cheaper ways to undertake similar risk reduction measures. This second model of environmental justice is more relevant to the question of affordability (Cory and Rahman 2009).

Environmental justice, as a whole, focuses on the elimination of environmental inequity, which includes a component of geographical inequity-the unequal distribution of costs, benefits and resources over different locations (Rosenbaum 2008). Drinking water regulations can fall into this definition of geographical inequity if the costs of meeting the regulation for small systems in rural areas are significantly larger than the costs faced by consumers in large systems. The case that geographic inequity is at play in the determination of drinking water regulations is also demonstrated by the emphasis the EPA places on the economics of drinking water provision for large systems in establishing regulations (EPA 2006, 2002). Providing a way for small water system consumers to obtain treated water without paying an excessive amount for it by granting systems the ability to use variance technologies can serve as a remedy to geographic inequity and to promote environmental justice.

Though geographic inequity makes a case for variances in general, the use of a lower income limit is not a part of geographic inequity. The EPA defines environmental justice in part as consideration of interests of individuals irrespective of income (EPA 2011). Using an income level below the MHI explicitly seeks to promote the fair treatment of people regardless of income. Using a lower income level therefore allows the EPA to promote environmental justice for all persons irrespective of income and socioeconomic class.

The goal of increasing the ease with which systems trigger national affordability criteria is contrasted by the need of water providers to supply their customers with safe water. Variance technologies are required to produce water at a quality that is "protective of public health" which is a different standard and can be of a lower quality than that produced under the MCL. As such, granting a system the right to use variance technology could very well introduce increases in health risk to those in small systems. Because of this added risk, EPA and the states have to be selective in the number of systems that are granted permission to use variances.

An ideal affordability metric therefore needs to balance the two conflicting objectives of promoting environmental justice and protecting health. Therefore, any metric must be able to grant systems variances when necessary. But the metric should not grant too many variances in order to minimize the increase in risk to consumers. Where to strike the balance between these two forces is ultimately a subjective call. The author suggests that the rules at the extremes, the total costs for water greater than 2.5% of MHI (which allowed for no variances) and the national screens for incremental treatment burden greater than 0.25% MHI (which found that all systems serving fewer than 500 people plus all small systems in 492 counties) is undesirable as they are too strict or too generous (respectively).

Another important factor to consider when deciding the right level of balance between the need to grant variances to systems and to protect public health is that the cost estimates made before regulations are implemented typically overestimate the cost (Harrington et al. 2000; NCEE 2012). Taking this into account, affordability metrics should be stricter than desired. Making this adjustment allows for the affordability determination procedure to select systems that deserve variances without selecting systems that have their costs over-predicted. There are two methods that best meet this. Method 2, which compares the cost of a new regulation to 0.75% of the national MHI with the disadvantaged community approach, grants variances to systems serving less than 100 people and all other small systems in 492 counties. Method 5, setting affordability for water treatment at 2.5% of the county's 25^{th} percentile household income paired with the criteria for identifying a disadvantaged community (in Method 2b), grants variances to systems in the economically disadvantaged counties and no more than about 10,000 other systems serving fewer than 100 people.

Both these methods end up qualifying approximately the same number of systems (about 14,000 in all, which is an intermediate value between the extremes of no small systems and all 30,000 small systems) but the 25^{th} percentile household income allows for a more targeted approach opposed to the blanket determination for the 0.75% of national MHI.

Other problems undermine the use of an incremental burden approach. The NDWAC (2003) recommended the incremental burden approach of Method 2 as a way of avoiding the "adding up" problem in which early regulations add up to consume the entire expenditure margin and preclude the implementation of new rules; the EPA is considering an incremental approach because of this. However, Table 3-3 demonstrates that the adding up problem does not occur

Table 3-3 – Expenditure margin

System Size	1998 Expenditure Margin[1] (1998)	1998 Expenditure Margin (2006)	Expenditure Margin Based on 2006 CWSS[2] (2006)
25-100	$537	$664	$899
101-500			$920
501-1,000	$463	$572	$907
1,001-3,300			$871
3,301-10,000	$474	$586	$942

[1]From (63 FR 42032)
[2]Calculated as 2006 MHI (USCB, 2006) less the Annual Residential Revenue per Connection from the 2006 CWSS (EPA, 2009)

and that the expenditure margin has actually increased since its original proposal in 1998.

Furthermore, the incremental burden approach introduces another form of an adding-up problem; a series of regulations could all be found affordable individually whereas their cumulative burden (once added up) could be unaffordable. The NDWAC (2003) did consider this possibility and recommended that cumulative burdens still be examined but the EPA did not mention this in their proposal of this new affordability methodology. Because of this new version of the adding up problem, Method 5 should be further preferred over the incremental burden approach of Method 2 with a limit of 0.75% MHI. An argument can be made that Methods 2 and 5 could both be applied with systems having to meet one of the two criteria in order to qualify for a variance as this would serve to balance out the weaknesses of the two methods. However, it is very likely that over a series of new drinking water rules, affordability determinations would be controlled by just the results of Method 5 (or any cumulative method that is adopted).

Using county-level data runs the risk of granting variances to systems that do not need it based on their municipal conditions. This leads to problems from the perspective of protecting public health by exposing communities to risks they could afford to reduce. However, the actual choice between using the municipal and county data depends on administrative objectives. Whether it is the EPA or the various state primacy agencies in charge of administering determination of affordability, the data should be readily available to them. This lends itself to adopting county-level criteria as the data is more readily available. This leads to the recommendation that a variance be granted to a system located in a county where the cost of treatment is more than 2.5% of the county's 25th percentile income, the county's MHI is less than 65% of the national income, the poverty rate is twice the national average, or the average two-year unemployment is twice the national average. Figure 3-6 shows the systems qualifying under this rule.

Figure 3-6 - Systems qualifying for variances under proposed rule in (a) 2000 and (b) 2010

CONCLUSION

This chapter sought to perform an affordability determination using the EPA's expenditure margin affordability method, the incremental burden methodology they proposed in March of 2006 and using a lower income level in the metric by using the 2001 arsenic MCL as a case study. While the results presented here agree with the EPA's original affordability decision that the arsenic rule was affordable for all systems, the 2006 incremental burden criteria would have found arsenic to be unaffordable for some systems. The main outcome of this chapter was an analysis of the effect of using the 25th percentile income, instead of the MHI, for affordability methodologies in order to address concerns of environmental justice.

The criteria proposed by the EPA in 2006 addressed the biggest concern raised about the 1998 method, namely that the bar had been set too high, by making significant changes to all parts of the method. However, the incremental burden method still leaves much to be desired. For example due to its incremental approach, it fails to place a maximum cap on drinking water costs. A far more important shortcoming is the EPA declining to take into account explicitly the impacts regulatory burden has on low income households. The method put forward in this paper addresses this concern.

Ultimately selecting an affordability methodology is a subjective decision that requires balancing risk, economics and political considerations. It is the author’s position that the usage of a 2.5% of the county's 25th percentile income threshold with the EPA's incremental burden criteria for identifying disadvantaged communities (Methods 5 and 2b) meets various standards that define an ideal affordability methodology (helps meet conditions of economic efficiency, grants some systems variances as needed by environmental justice, not overly generous with the number of variances to protect public health, accounts for overestimating of costs and affordability practicality).

CHAPTER 4

ADJUSTING THE DEFINITION OF AN ECONOMICALLY DISADVANTAGED COMMUNTIY

Introduction

During debate on the SDWA in 1974, Representative Del Latta stated that, "nobody is, of course, against the purpose of this bill, but the real question is that…how can that (referring to a community that had used up its bonding authority) community come up with the money to meet the standards that some EPA directive might set forth?" As Rep. Latta pointed out no one had any answers for him; the SDWA did not contain any provisions relating to the affordability of water service (Congr. Rec. 1974). This question remained unanswered for two decades.

In 1995 the Congressional Budget Office used SDWA regulations as a case study for unfunded mandates (U.S. Environmental Protection Agency 1998), and in the development of the 1996 SDWA amendments Congress became aware that the current regulatory framework posed a significant challenge for small water systems. Congress incorporated the concept of affordability into the amendments and directed the EPA to consider affordability when establishing regulations. For each regulation considered, the EPA would analyze the costs for implementing the possible technologies and determine which treatment technologies would be affordable for each size of system. If they were unable to find a treatment technology that met the standard, systems would be allowed to apply for the use of variance technologies. These variance technologies would provide a level of treatment that was protective of human health (but maybe not to the same level as the MCL) that would still be affordable to water systems. The EPA was left to determine what criteria would be used to determine affordability (Tiemann 2010). Congress also created the Drinking Water State Revolving Fund, whose purpose was to provide states with funding for drinking water projects with special attention to disadvantaged communities (Beecher and Shanaghan 1998; Levine 2012).

The context of drinking water regulations was not the EPA's first time considering affordability as part of the regulatory process. The EPA had already considered and codified criteria for affordability of its regulations in nearly two dozen areas in the Offices of Water; Solid Waste; Compliance Monitoring; and Policy, Planning and Evaluation for regulatory frameworks under the Clean Water Act; the Toxic Substances Control Act; and the Comprehensive Environmental Response, Compensation and Liability Act (Beecher and Shanaghan 1998; U.S. Environmental Protection Agency 1998). In the 1990s, the EPA addressed affordability agency-wide with a panel under the Office of Policy, Planning and Evaluation. The panel established two different, two-step methods for measuring the affordability of EPA regulations. In both methods the first step was a basic burden screen that examined if costs were a significant share of household income. The second step of the first method then screened again the systems that determined if these systems would face a challenge in obtaining the necessary funding for improvements by assessing their access to financial resources if they had an unaffordable burden placed on them as determined in the first screen. In the second method, systems would petition either the EPA or their state for regulatory relief if their costs to finance the project would be too high or if the costs would exceed their capability, which left the systems with the burden of proof (U.S. Environmental Protection Agency 1998).

When the EPA made its affordability criteria for the 1996 Amendments, they included only the burden screen (Method 1 in Table 3-1) (63 FR 42032). They defined that a rule would be unaffordable if it caused the total amount of drinking water costs to exceed 2.5% of MHI per year for the system's size class (Cooke 2005; Hilkert Colby et al. 2010; Pontius 2008). The arsenic rule quickly questioned the validity of this method and in 2001, Congress charged the EPA with reevaluating their affordability methodology both in general and in the case of the arsenic rule (EPA 2002a). As far as evaluating the affordability for the arsenic rule, the debate focused on identifying disadvantaged communities for relief. The most significant contribution to this discussion came from Rubin (2002), who examined definitions for disadvantaged communities from state drinking water programs and federal agencies. Rubin identified three criteria that could be used for this purpose: (1) MHI less than 65% of the national MHI, (2) a poverty rate twice the national average and (3) two-year average unemployment twice the national average. If a community met any of these criteria they would be considered disadvantaged. These criteria represent the socioeconomic status of the community which represents the ability of water systems to fund improvements through their customers (EPA 1998).

When the EPA published their new method in the Federal Register in 2006 they incorporated Scott Rubin's work on identifying EDCs and brought drinking water affordability determinations into the 1990 Office of Policy, Planning and Evaluation format. The first step was a national burden screen. If a new rule would cost an average system in a particular size class greater than one of three (0.25%, 0.50%, or 0.75%) shares of MHI, then the systems in that size class would qualify for variances. For systems that had affordable treatment based on this first screen, a second round would be used to further identify systems located in EDCs meeting the criteria Rubin identified above. These EDCs could then request variances from their states (71 FR 10671).

The purpose of this chapter is two-fold. First, the author will determine how many counties meet the EPA criteria for an EDC using up-to-date socioeconomic data. Second, the author will evaluate how adjusting the multiples (0.65 for MHI, 2 for poverty and unemployment) used in the criteria for defining an EDC affects the number of counties that can qualify for a variance. In identifying their criteria, the EPA did not publish work that looked at other ratios than those that were under consideration. Their criteria were adopted based on recommendations by Rubin (2002) who tried to develop numerical definitions of EDCs based upon review of criteria states had already adopted for their drinking water programs and qualifying conditions for communities to receive assistance grants from various state agencies. However, the states that had implemented affordability criteria tended to be more affluent and so even their most stringent criteria may not have been appropriate for national use. For instance, New Jersey's affordability criteria was 65% of the state's MHI. According to the 2000 census 65% of New Jersey's MHI was $35,845, a value greater than the MHI for the ten poorest states in the US at the time. By performing a sensitivity analysis on these ratios, the author hopes to identify a more appropriate combination of ratio and criteria.

The remainder of this paper proceeds as follows. Next is an evaluation the evolution of the concept of affordability at the EPA over time, followed by a description of the data and methods used in the sensitivity analyses of the criteria, as well as introducing and explaining the justifications for several alternative ratios for the criteria used. The number of counties and an approximate number of small (less than 10,000 people served) CWSs (contained in the Safe Drinking Water Information System) that qualify at the EPA proposed criteria is calculated.

This discussion is followed by a presentation of the results of how many counties and CWSs qualify under other ratios for these three criteria. The sixth section analyzes two different methods of measuring EDCs. Finally, the last section presents conclusions and recommendations for the affordability criteria.

Data and Methods

The socioeconomic data for this work included the MHI, poverty rate for individuals and unemployment rates for the 3,143 counties and county equivalents in the 50 states. MHI and poverty rate for all 3,143 counties and county equivalents were taken from the U.S. CB's 2010 American Community Survey (ACS) 5-year estimates (CB 2010). Local, seasonally-unadjusted, monthly unemployment rates from November 2011-December 2012 for all but one of the counties and county equivalents were taken from the BLS (BLS 2013).

The number of small (10,000 or fewer customers) systems and the population served by these systems in these counties was taken from the EPA's Safe Drinking Water Information System-Federal Version (SDWIS/FED) (EPA 2013). The SDWIS/FED serves as a clearinghouse for the general public and provides information on systems, their characteristics and violations. It is not a complete inventory of all drinking water systems in the country because it relies on states and systems to submit the required information, but it is the most exhaustive catalog for the entire U.S. that is available to the general public. The number of systems and population are accurate as of October 2011.

This socioeconomic data and drinking water system counts were combined into a GIS database for identifying and displaying counties that met the various affordability criteria. Initially, the current number of counties, systems and population served by these systems that could qualify for variances using the proposed economically disadvantaged criteria were identified. For the entire United States, the MHI and poverty rate from the 2010 American Community Survey 5-year estimates were $52,762 and 14.3% and average unemployment at 8.7% from November 2011-December 2012. The thresholds therefore were $34,295 (0.65 x 52,762) for MHI, 28.6% (2 x 14.3%) for poverty, 17.4% (2 x 8.7%) for unemployment.

To determine the impact that altering the ratios for the various factors has on selecting counties that qualify for variances, the author adjusted the various ratios over a wide range. For income, the author selected a strict, yet reasonable, condition of 50% of national MHI to a generous 100% MHI ($26,381-$52,762). The author also examined the impact of using the national nonmetropolitan area median household income (non-MA MHI), since many federal agencies use this as their income level for determining program eligibility (for 2010, this value was $41,440 (CB 2010b)). The range for the national non-MA MHI is between 50-100% ($20,720-$41,440). For the poverty criteria, the range over which it will be considered was between the national average and three times the national average (14.3%-42.9%). Unemployment was studied over the range from the national average to three times the national average (8.7%-26.1%).

There are several ratios deserving of special attention because they are used by state drinking water agencies or federal programs that provide assistance to counties in need. Income values include: incomes below the poverty level ($22,113 (CB 2010b)), Department of Agriculture’s Rural Utilities Service grants for water and wastewater treatment; MHI less than $17,000 in 1989 (corresponding to $29,895 in 2010 dollars), EPA’s “Road to Financing”; and MHI below 80% of nonmetropolitan area MHI ($33,152), Department of Agriculture’s Rural Utilities Service grants for water and wastewater treatment, grant eligibility for the Rural Development Administration and the Small Business Administration’s Historically Underutilized

Business Zones program. For poverty rate, the only other definition that uses poverty rate is the Department of the Treasury's community development program, which defines EDCs as having a poverty rate of at least 30%. For unemployment these ratios are: the average (8.7%), based on the EPA's "The Road to Financing"; 1 percentage point above the average (9.7%), based on the

Table 4-1 - Definitions of EDCs considered

Category	Source	Level
Median Household Income Thresholds		
65% MHI	EPA's Drinking Water Affordability	$34,295
	Sensitivity Analysis Range (MHI)	$26,381 - $52,762
	Sensitivity Analysis Range (non-MA MHI)	$20,720 - $41,440
Poverty Level	Agriculture Dept.'s Rural Utilities Service	$22,113
$17,000 (in 1989)	EPA's "Road to Financing"	$29,985
80% non-MA MHI	Agriculture Dept.'s Rural Utilities Service	$33,152
	Rural Development Administration	
	Small Business Administration's HUBZones	
Poverty Rate Thresholds		
200% Poverty Rate	EPA's Drinking Water Affordability	28.6%
	Sensitivity Analysis Range	14.3% - 42.9%
30%	Treasury Department	30%
Unemployment Rate Thresholds		
200% Unemployment	EPA's Drinking Water Affordability	17.4%
	Sensitivity Analysis Range	8.7% - 26.1%
Avg. Unemployment	EPA's "Road to Financing"	8.7%
Avg. + 1%	Commerce Dept.'s Economic Dev. Admin.	9.7%
120% Unemployment	State of Washington	10.4%
125% Unemployment	EPA's CSO Financial Capacity Review	10.9%
140% Unemployment	Small Business Administration's HUBZones	12.2%
150% Unemployment	Treasury Department	13.1%

Department of Commerce's Economic Development Administration; 20% greater than average (10.4%), based on Washington state's definition of a distressed county; 25% greater than average (10.9%), based on the EPA's Combined Sewer Overflow Financial Capacity Review; 140% of the average (12.2%), the Small Business Administration's Historically Underutilized Business Zones program; and 1.5 times the average (13.1%), based on the Treasury Department's community development programs (Rubin 2002; EPA 1998; U.S. Small Business Administration 2013). All these definitions of EDCs, including the EPA drinking water criteria and the range over which the sensitivity analysis was performed over can be found in Table 4-1.

Results and Discussion Using Proposed EPA Criteria

Table 4-2 shows the number of counties that could qualify under the 2006 EPA proposed criteria, the number of small systems in those counties and customers served by these systems. Of the 3,143 counties and county equivalents in the United States, 511 meet at least one of the three socioeconomic criteria the EPA has proposed to identify counties that qualify for variances. According to the SDWIS/FED database, in these 511 counties there are 3,812 small water systems serving a population of 5,629,431 customers. Most of these counties qualify because of the MHI < 65% MHI criteria; a total of 383 counties meet only this criteria. Nine counties meet only the poverty rate criteria and six counties meet only the unemployment criteria.

Table 4-2 - Counties and systems qualifying for variances under proposed EPA criteria

Criterion	Number of Counties	Number of Small Systems	Population Served
MHI ≤ 0.65 National MHI	495	3,630	5,527,726
Poverty Rate ≥ Twice National Average	122	832	1,480,165
Unemployment Rate ≥ Twice National Average	10	111	94,247
One or More of the Above	511	3,812	5,629,431

Figure 4-1 shows the counties that qualify for a variance based upon the EPA's criteria. Many states do not have any counties qualifying while several states have a multitude. Regions that have many counties qualifying for variances include the Sun Belt stretching from North Carolina to southern California and the southern portions of the Appalachian Mountains (primarily in Western Virginia and Kentucky).

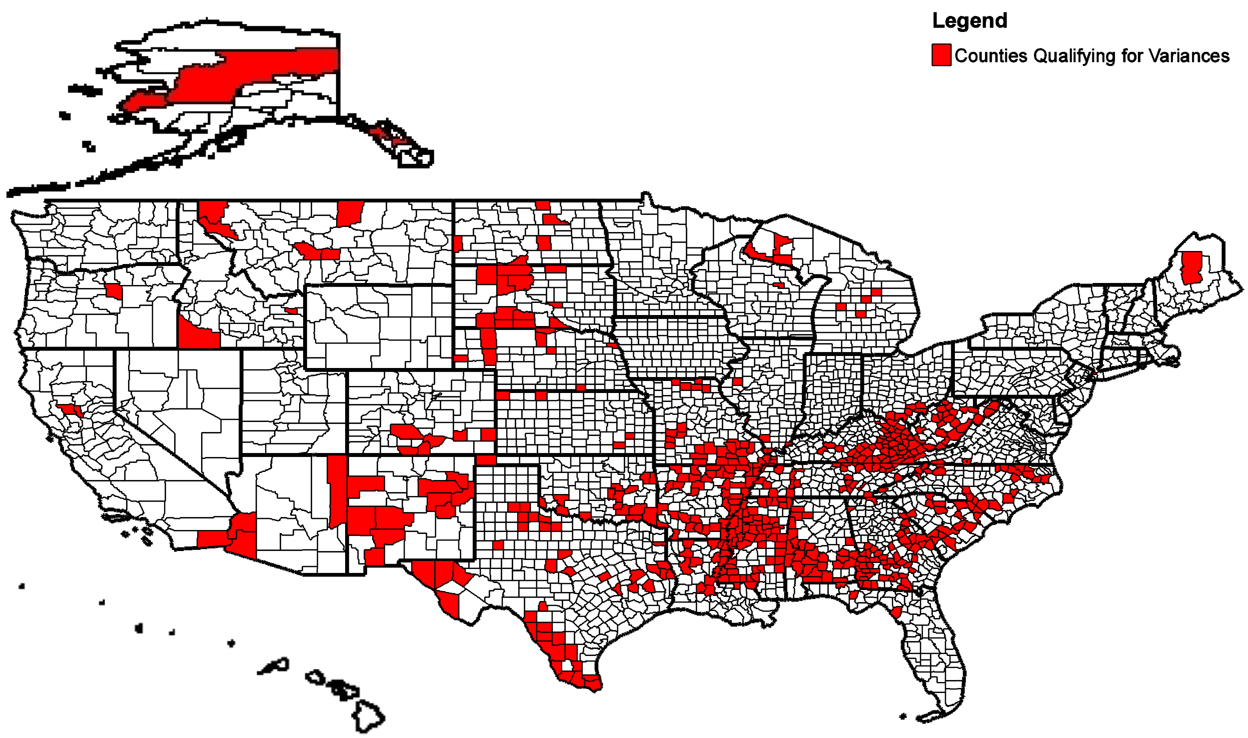


Figure 4-1 - Counties potentially qualifying for variances at different EDC ratios

While the number of systems that qualified when the EPA originally proposed these variance criteria and the application of these criteria to today's socioeconomics situation has decreased, both the number of counties that qualify and the number of small system customers affected increased. For counties, an additional 101 total counties (up from 410 in the original estimate) qualified using the most recent data. The EPA estimated that the total number of systems in these counties was 4,249 and the counties identified in this present analysis contain

437 fewer systems. The total number of customers potentially affected by these criteria increased in this latest analysis by 144,273 people after 5,485,158 customers were served by systems that qualified in the 2006 EPA analysis. There is some indication that system consolidation has occurred with 1,275 fewer small systems in the October 2011 SDWIS/FED database. In the decade between 2001 and 2011, a net 480 systems (in SDWIS/FED databases in both years) moved from serving fewer 10,000 customers to serving greater than 10,000 customers (Rubin 2013b).

The individual criteria also showed a mixed response. The income criteria showed the most dramatic increase between the original analysis and the results here, an additional 139 counties, 145 systems and 1,155,049 customers qualified because of income. The poverty criteria also increased the number of counties, systems and customers potentially qualifying for variances, 41, 300 and 529,960, respectively. Finally, the unemployment criteria showed a significant decrease in the numbers qualifying: 70 fewer counties, 809 fewer systems and 1,296,979 fewer people.

The unemployment criteria qualified fewer systems is most likely because that while the MHI and the national poverty rate increased in between the EPA's analysis and this, they did not increase as significantly as unemployment did. The MHI increased just a little more than $1000 (in real dollars) and the poverty rate increased by a percentage point. Unemployment showed a much more significant increase of nearly two points in the period between the EPA's proposal of these criteria and the period used in this analysis. This increase set the bar much higher for systems trying to qualify for variances based on their unemployment than was set for qualifying based on MHI and poverty rate.

This demonstrates a potential problem with the EPA's method. In a recession, unemployment tends to increase and lost income due to this unemployment drives poverty rates up. This has been true for the Great Recession (starting in December 2007 and ending in June 2009 from which the recovery is still ongoing) and recessions in general (Pilkauskas et al. 2012). This means that if a regulation passes the first step of an EPA affordability determination, the incremental burden, whether a system passes the second step, the identification of disadvantaged communities, could very well depend on when in the business cycle affordability is being evaluated. If the economy is expanding (and with it MHI increasing and poverty and unemployment rates decreasing), the levels of need that will have to be met will be less stringent. In a recession, however, the levels of poverty and unemployment will be higher making it harder for communities to qualify for variances. This is unfortunate, because when poverty and unemployment rates are high is exactly when systems will have trouble affording treatment. A few alternative arrangements that can alleviate these problems exist and will be considered in a following section.

Sensitivity Analysis

Figures 4-2, 4-3 and 4-4 show the number of counties, the number of systems in those counties that could qualify and customers of these small systems that could be affected under various ratios for the MHI, the non-MA MHI, the poverty rate and the unemployment rate. Half of the MHI qualifies 63 counties and 373 systems while the most generous 100% of MHI potentially affects 2,602 counties and 32,685 small systems. For half of non-MA MHI, five counties and ten systems are potentially affected with the entire non-MA MHI qualifying 1,422 counties and 13,597 small systems. The toughest poverty rate criteria, three times the national rate, qualifies 51 systems in ten counties and the most generous, the national average, finds

1,642 counties with 21,210 small systems potentially qualifying for variances. Finally, three times the unemployment rate qualifies two counties and 55 small systems and 1,044 counties and 15,751 small systems have unemployment greater than the national average.

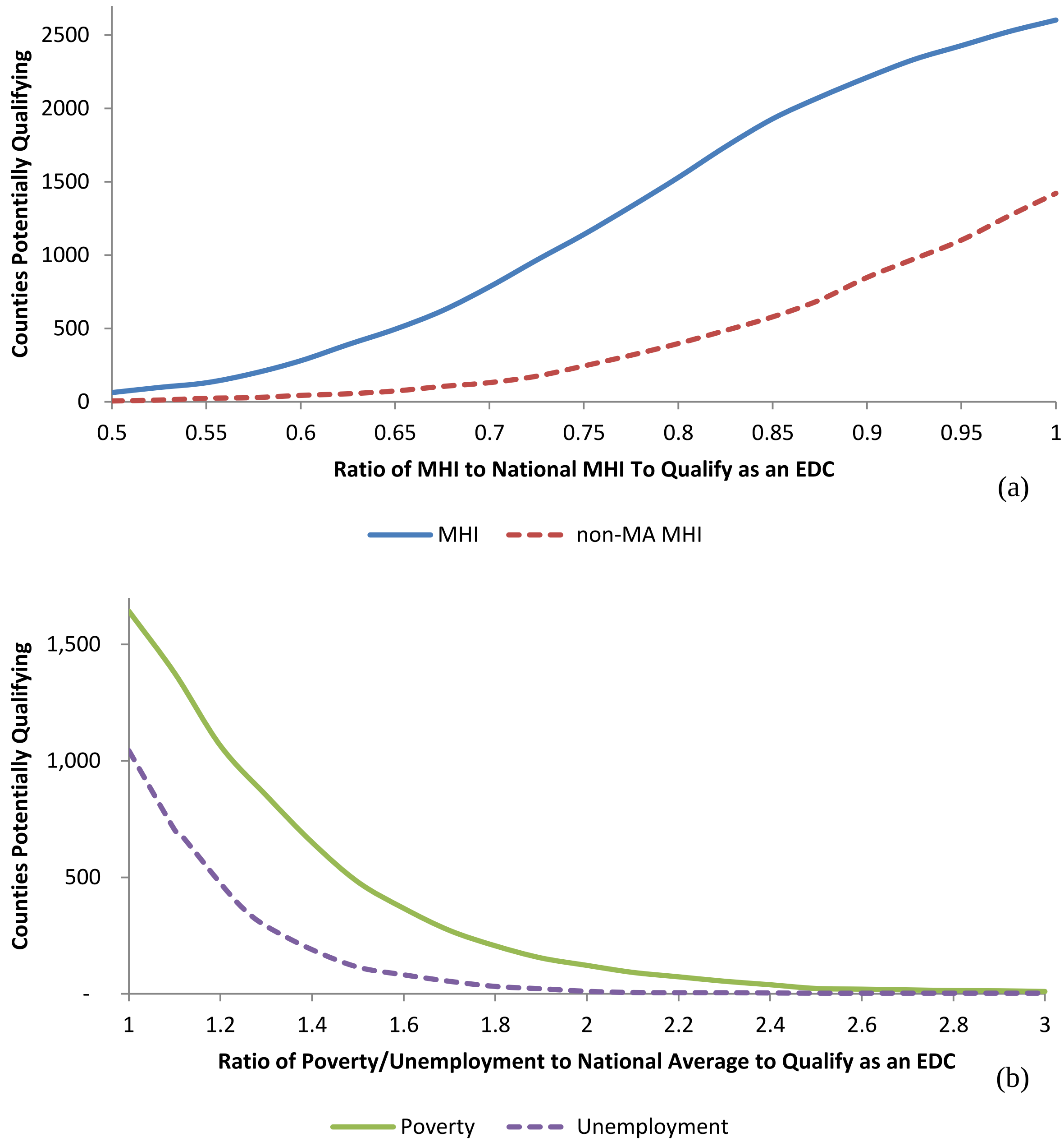


Figure 4-2 – Counties qualifying at various ratios of (a) MHI and non-MA MHI and (b) poverty and unemployment rates for the EDC criteria during the sensitivity analysis

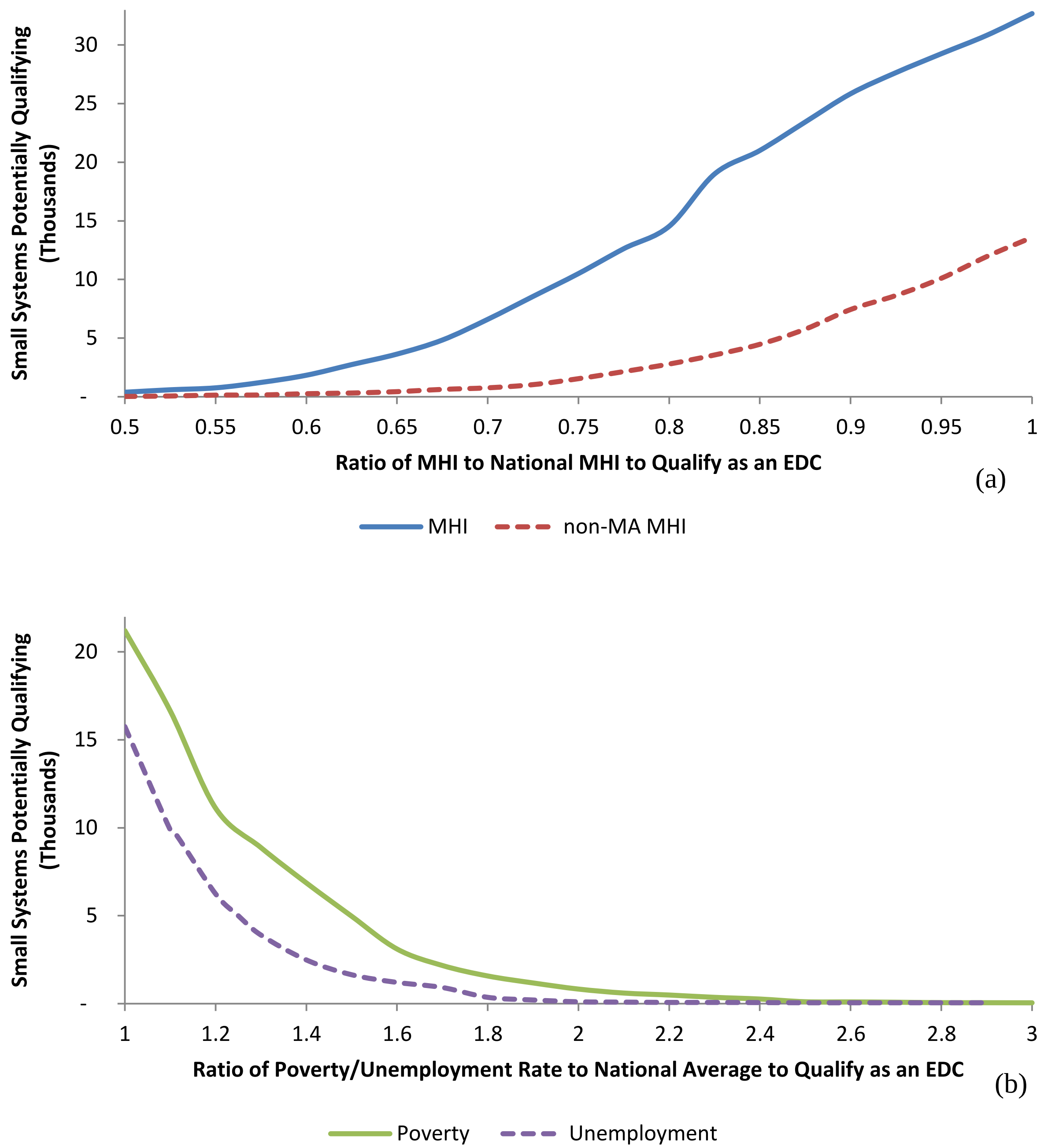
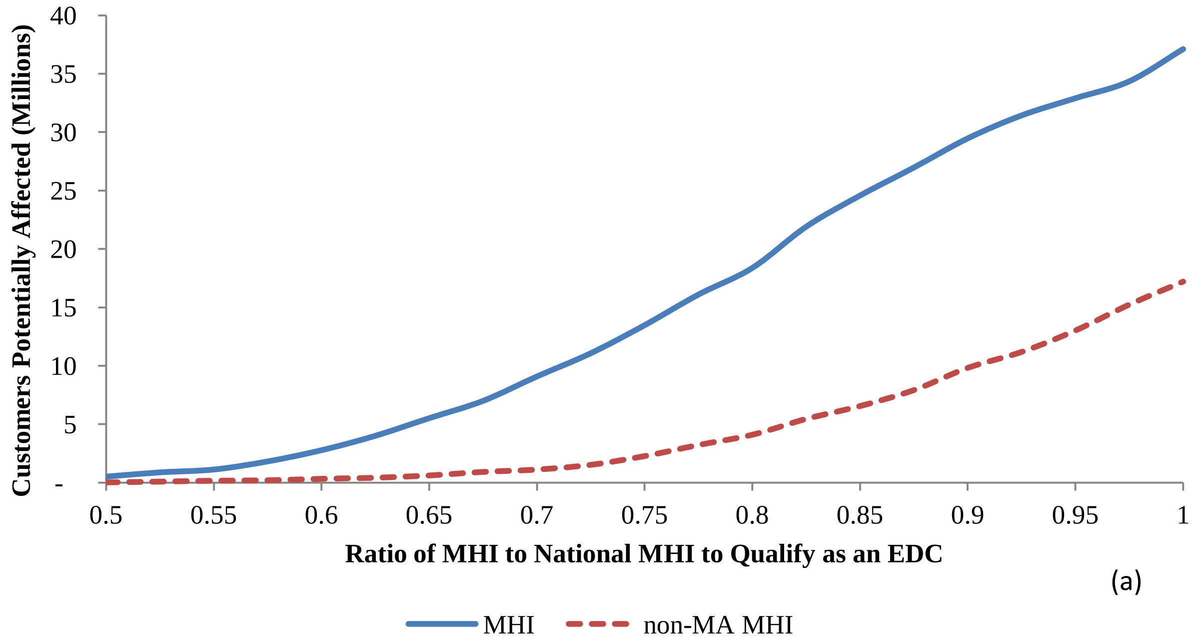


Figure 4-3 – Small systems qualifying at various ratios of (a) MHI and non-MA MHI and (b) poverty and unemployment rates for the EDC criteria during the sensitivity analysis



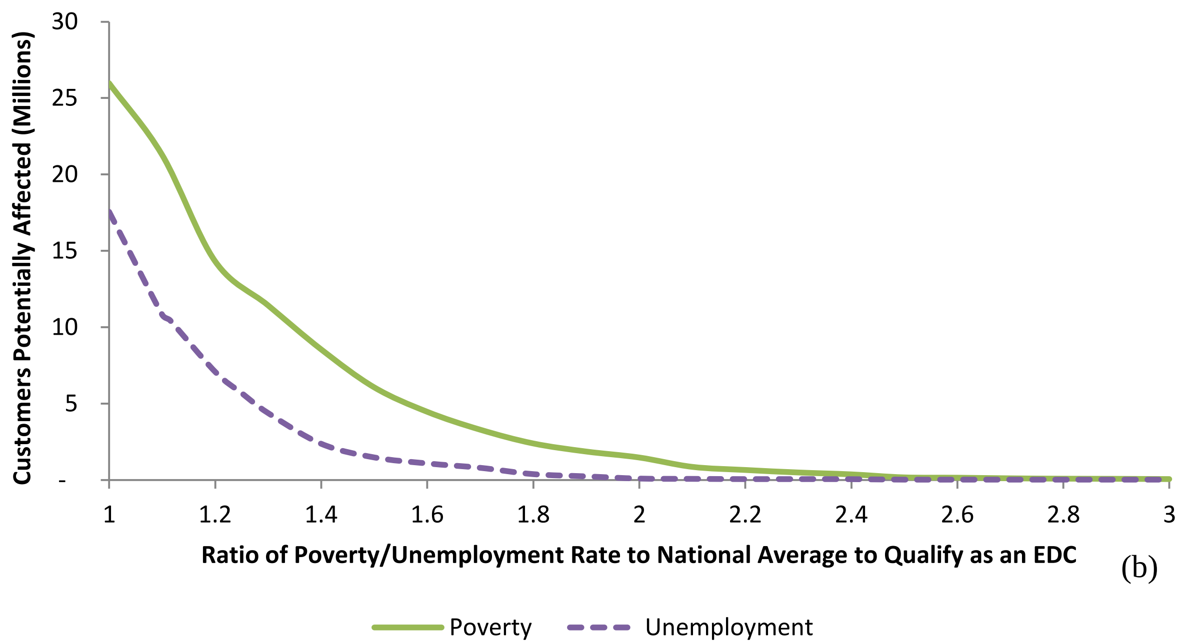


Figure 4-4 – Customers potentially affected at various ratios of (a) MHI and non-MA MHI and (b) poverty and unemployment rates for the EDC criteria during the sensitivity analysis

The criteria used by other systems showed significant variability in the amount of systems they would qualify for permission to use variances as can be seen from Table 4-3. From the toughest standard, MHI below the poverty line (granting permission to 14 counties and 68 small systems), to the most generous, unemployment above the national average (1,044 counties and 15,751 systems), there is a large variability in other definitions that could be applied to the EPA's affordability determination. In general, the EPA's proposed criteria are more stringent than these proposed criteria: unemployment is the strictest of all of them and poverty only less strict than the other standard. The MHI is of middle difficulty compared to the other standards.

Table 4-3 – Other regulatory definitions of EDCs

Category	Source	Level	Counties	Systems
MHI Thresholds				
Poverty Level	Ag. Dept.'s Rural Utilities Service	$22,113	14	68
$17,000 ($1989)	EPA's "Road to Financing"	$29,985	172	1017
80% non-MA MHI	Ag. Dept's Rural Utilities Service, Rural Development Admin., Small Business Admin.'s HUBZones	$33,152	397	2,779
Poverty Rate Thresholds				
Poverty Rate<30%	Treasury Department	30%	92	606
Unemployment Thresholds				
Avg. Unemployment	EPA's "Road to Financing"	8.7%	1,044	15,751
Avg. + 1%	Commerce Dept.'s Econ. Dev. Admin.	9.7%	680	9,544
120% Unemployment	State of Washington	10.4%	474	6,244
125% Unemployment	EPA's CSO Financial Capacity Rev.	10.9%	365	5,004
140% Unemployment	Small Business Admin.'s HUBZones	12.2%	189	2,491
150% Unemployment	Treasury Department	13.1%	114	1,648

The results of the sensitivity analysis can be used to develop a set of alternative ratios that produce similar results to the original determinations by the EPA, assuming that the number of systems that would be granted variances in 2006 was acceptable. To do this, the ratios will be adjusted until they identify a percentage of all small systems that is similar to the ones identified by the EPA in 2006. The ratios that meet these conditions are 0.646 for MHI (3,445 small systems), 2.16 for poverty (518 small systems) and 1.71 for unemployment (920 small systems). These three criteria identify 4,190 systems as potentially qualifying for variances or approximately 8.9% of all small systems (the EPA originally found that 8.8% of all small systems in 2006 would qualify). As should have been expected MHI multiple (which qualified about the same number of systems in both 2006 and today) remained relatively unchanged, the poverty multiple was made significantly higher and the unemployment factor significantly decreased.

An alternative way of assessing the ratios to determine appropriate levels would be to base them on the criteria least likely to grant variances used by other agencies and comparing the difficulty in the EPA's affordability criteria. Table 4-2 shows the number of counties qualifying and systems affected by the other measures used by various programs and states in determining EDCs. The strictest standards are the Department of Agriculture's for household income (county MHI below the poverty level) and the Treasury Department's for poverty (above 30%) and unemployment (above 150% the national average which is 13.1%) rates. Under these conditions 2,077 small systems in 178 counties could potentially qualify for permission to use variance technology. This is significantly fewer systems than under the EPA's proposed method, mostly because of the severe tightening of the threshold required for systems to meet and qualify based on MHI. The Department of Agriculture's standard is a significant drop as the poverty level is $2/3^{rds}$ of 65% of the MHI.

Alternatives to the Current Ratios and Measures

The current methods run into problems when used during a recession or before the economy fully recovers from a recession. As highlighted above, when the economy is in recession, poverty and unemployment rates are high, which makes the thresholds that must be met in order to qualify for variances even higher at a time when flexibility is most needed in granting permission to use variance technology. There are two other alternative ways of handling these ratios, setting fixed thresholds that do not change to reflect the general health of the economy or setting the threshold as a certain number of percentage points above the current level of a socioeconomic indicator. It is important to note that finding an appropriate level for these thresholds is fundamentally a political question. In the methods outlined below, the author makes two assumptions to address potential political concerns. First, the author assumes systems can demonstrate the need for variances if it is located in a county that has a poverty or unemployment rate that is twice a recent national average rate. Second, the author assumed that the amount that the poverty or unemployment rate had to be in excess of in 2006 in order to qualify for variances (i.e. the poverty and unemployment rates in 2005) were acceptable amounts to set the threshold by.

For the first method, thresholds could be identified that would stay the same at all times and would therefore be independent of the fluctuations of the business cycle. There are two possible ways of doing that. First, the EPA could adopt the thresholds used in the original analysis as permanent thresholds. For the first method, the thresholds are $30,935 (65% of MHI in 2005 adjusted only for inflation to 2010), average poverty rate of 26.6% (13.3% of the population was in poverty in 2005) and average unemployment of 10.6% (for the period from Jan 2004-Dec 2005, average unemployment was 5.3%). Using the 2010 American Community Survey data and the fixed ratio based on EPA's 2006 criteria, 6,797 systems in 573 counties potentially qualify for variances (1,491 systems in 235 counties for income, 1,341 systems in 178 counties for poverty and 5,687 systems in 428 counties for unemployment). Table 4-4 shows the results for this method and the methods considered in the remainder of this section.

Table 4-4 – Alternative criteria for EDC definitions

Method Description	Criteria Applied	Counties Affected (Systems in Parentheses)
Thresholds Are Fixed Over Time		
Original poverty and unemployment thresholds from 2006 proposal are adopted permanently.	Poverty Rate (26.6%)	178 (1,341)
	Unemployment (10.6%)	428 (5,687)
	Total	*573 (6,797)*
Twice the long term average poverty and unemployment rates are adopted permanently.	Poverty Rate (28.1%)	133 (1,023)
	Unemployment (14.0%)	91 (1,486)
	Total	*481 (4,517)*
Thresholds Vary Over Time		
2006 poverty and unemployment rates added to current rates to develop thresholds.	Poverty Rate (27.6%)	147 (1,130)
	Unemployment (14.0%)	79 (1,195)
	Total	*545 (4,787)*
Average poverty and unemployment rates added to current rates to develop thresholds.	Poverty Rate (28.3%)	128 (999)
	Unemployment (15.5%)	34 (450)
	Total	*521 (4,173)*
Consumption Measures		
Twice the SNAP participation rate	SNAP Rate (18.5%)	316 (2,448)
15% + Households with rent greater than 35% of income	Rent Expenditure (44.4%)	132 (2,967)

Alternatively, longer term averages for MHI, poverty rate and unemployment rate could be used to account for variability in these metrics over the business cycle. Using the 1-year estimates of the American Community Survey from 2005-2011 and BLS unemployment data over the same period, 65% of the MHI (adjusted for inflation to 2010) was $33,441, twice the average poverty rate of 28.1% (the average poverty rate over the period was 14.0%) and twice the average unemployment of 13.7% (average unemployment was 6.8% over the period). Using the 2010 census data and the average ratio method, 4,517 systems in 481 counties potentially qualify for variances (3,060 systems in 420 counties for income, 1,023 systems in 133 counties for poverty and 1,486 systems in 91 counties for unemployment).

Under the second method the threshold will be set as a certain amount of percentage points above the current poverty and unemployment measures. There are two different ways to do this. First, we can use the poverty and unemployment rates the EPA used in proposing this EDC definition (13.3% and 5.3%, respectively) and add this to the current poverty and unemployment rates to develop the thresholds. This would lead to the adoption of an EDC definition of counties that have poverty rates greater than 27.6% or unemployment rates greater than 14.0%. In 2010, 147 counties with 1,130 small systems exceeded the poverty threshold and 1,195 small systems in 79 counties met the unemployment threshold. With the addition of the 65% of MHI criteria, 4,787 small systems in 545 counties could potentially qualify for variances.

The second technique uses long-term average poverty and unemployment rates (14.0% and 6.8%) instead of the rates from the original EPA analysis. Doing so sets a poverty threshold of 28.3% and an unemployment threshold of 15.5%. Using the most recent data, 999 systems in 128 counties exceed the poverty rate threshold and 450 small systems in 34 counties meet the unemployment threshold. If these two criteria are used in conjunction with the MHI criteria, 4,173 small systems in 521 counties could potentially qualify for variances.

There exists another source of measures for whether a system could potentially need permission to use variance technologies. The purpose of variance technologies is to prevent environmental injustices to consumers by allowing those whose incomes could be strained by mandating centralized treatment technologies to have cheaper point-of-use and point-of-entry technologies (Cory and Rahman 2009). The money that is saved can then be spent on other risk-reducing technologies or on other household necessities (Balazs et al. 2012; Beecher and Shanaghan 1998; Cory and Rahman 2009; Jones and Joy 2006; EPA 1998). A new drinking water regulation that forces households to make a trade-off between paying for water and paying for another necessary expenditure should be found unaffordable. This is a question not of income resources, but of consumption decisions faced by the consumers and the economics literature identifies several metrics that capture these decisions better.

There is evidence in the literature that suggests that poverty is better measured by looking for concrete examples of economic hardship (Citro and Michael 1995; Pilauskus et al., 2012). Consumption measures offer several advantages over using income as a measure of poverty and affordability. The biggest such advantage is that consumption measures for the same household are more stable over time than income measures. Families consume based not entirely on current income, but on expected streams of income. In essence, households that experience temporary household income shocks (often from unemployment or changes in the family structure) do not necessarily adjust their consumption patterns, often by tapping into savings, borrowing from friends or family, or using credit to make up the difference between income and expenses and thereby maintain a constant standard of living. Consumption taps into (predictions of) a household's longer term income and therefore the ability of households to afford their basic needs (Citro and Michael 1995; Meyer and Sullivan 2003).

Consumption measures and (more importantly) ways of identifying households that are poor based on consumption measures can be found in the literature. Identifying households based on being consumption poor is typically done by analyzing material hardship in four domains: food security, housing security, access to medical treatment and ability to pay bills (Pilkauskas et al. 2012). While many studies and surveys by academics and government agencies (most notably the Survey of Income and Program Participation sponsored by the CB) capture various measures of material hardships, none of them have significant data that is organized on a county-by-county basis and so these studies are of little use in affordability determinations. Fortunately there exist three potential characteristics measured by the CB as part of the American Community Survey that are presented on a county level and could potentially allow for operationalization of three of the four categories of material hardship. The lack of health insurance can serve as a proxy measure of ability to obtain medical care; however, because not everyone decides to purchase insurance, it is a poor measure of material hardship on the medical care dimension. The second, rent as a share of income above 35% of income, can serve as an indicator that a household is spending a large amount of income on housing and expenses on other items or rises in utility costs could pose a potential problem for the household budget. Finally, participation rates in the Supplemental Nutrition Assistance Program (SNAP, also known more colloquially as the Food Stamps program) can serve as measures of a lack of food security on the justification that SNAP participants have income that is insufficient to cover their food expenses. These last two measures of hardship populations will serve as indicators that a community could potentially not afford water treatment.

The criteria studied for these two measures will be if food stamps participation in a county is greater than twice the national average or if the share of population with rent in excess of 35% of their income is 15% higher than the national average. For this first measure, the national SNAP participation rate is 9.3% and the county threshold is 18.5%. Using 2010 ACS 5-year estimates, 316 counties with 2,448 small systems could qualify for variances with this threshold. In the rent as a share of income measure, 38.6% of the U.S. population has rent that exceeds 35% of their income and so if a county has 44.4% of its population paying more than 35% of their income in rent it can qualify for a variance. Nationwide, 132 counties and 2,967 systems could potentially qualify for permission to use variances under this criteria. These two measures identify approximately the same number of counties and systems as the definitions considered currently under consideration by the EPA, but since they more accurately represent the consumption choices faced by consumers that are the heart of affordability determinations, that these consumption measures are desirable alternatives to the EPA measures.

Conclusions

This study demonstrates that, using recent data from the CB and BLS, at least 3,812 systems serving less than 10,000 customers located in 511 counties could potentially qualify according to EPA's 2006 proposed affordability criteria for permission to use variance technologies to treat drinking water to the levels mandated by the EPA under the SDWA. This is about five hundred less systems than when this methodology was initially proposed in 2006, despite more counties qualifying for variances. While some of this reduction may be due to consolidation of small systems, fewer counties qualified because of their unemployment level than did in 2006. The high national level of unemployment in the study period demonstrate a potentially significant weakness for the EPA methodology, namely that it is likely to grant fewer variances when the health of the economy is poor and systems and customers most in need of them.

In order to address this problem two different methods of establishing threshold criteria were considered, setting permanent threshold levels or using material hardship measures that are less likely to be affected by short term income shocks like unemployment. The results of these methods are reported in Table 4-4. These alternative methods either do not change during the business cycle or fluctuate significantly less. These criteria therefore can help alleviate the risk that systems qualifying for variances depend on the health of the whole United States' economy (instead of just the health of the local economy). Furthermore, with the consumption indicators of household levels of income, EDC definitions can consider a potentially more methodologically sound consideration of poverty (Citro and Michael 1995). These proposed revisions should be taken into consideration to the EPA and state drinking water primacy agencies in developing affordability criteria for their drinking water programs.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Statistical data was used to study the implications of various methods for determining whether treatment to meet drinking water standards set by the EPA is affordable. There were three hypotheses of this study:

1) The EPA's current and proposed methodologies are insufficient because the current methodology is too difficult to trigger and the proposed methodology is not strict enough when it comes to granting variances;
2) Using the EEC proposed income level of the first quartile household income (Q1HI) as the income used for affordability determinations can successfully identify systems that deserve variances, without being too lenient; and
3) That other definitions of EDCs will successfully identify these communities.

These three hypotheses gave rise to three objectives:

1) Application of the EPA's current and proposed criteria to make a determination about the affordability of the arsenic MCL for small water systems to study performance of EPA affordability methodologies;
2) Use of the EEC's recommendation for a lower income level, the first quartile, as the income for the burden measure for an affordability determination of the arsenic MCL for small water systems to demonstrate the ability of the first quartile household income ; and

3) Performance of a sensitivity analysis on EPA socioeconomic status variance criteria for EDCs and testing of other definitions of EDCs.

These three objectives were completed by the use of statistical analysis of treatment costs and socioeconomic data. The conclusions of these studies are outlined below followed by recommendations for future research and policy makers.

CONCLUSIONS

The results of a study of the costs and burdens associated with the removal of arsenic in drinking water in dozens of sites located across the United States were detailed in Chapter 3. In doing so it addressed Hypotheses 1 and 2 and Objectives 1 and 2. Arsenic removal was selected as the regulatory burden studied for two reasons. First, the arsenic rule was the first rule under the SDWA to have its affordability significantly challenged. This challenge was used to critique the expenditure margin approach to drinking water affordability. Furthermore, the discussion over affordability of the arsenic rule is still ongoing, with the rule being questioned on the grounds of affordability in the published literature more than a decade after its finalization in 2001. Second, a large set of readily available cost data has been compiled and released by the EPA that represents a wide array of arsenic treatment costs and socioeconomic conditions. This cost data was used to compute the annual costs for arsenic removal in forty CWSs located throughout the United States. Socioeconomic data from these forty sites (MHI, Q1HI, poverty rate and unemployment rate) was compiled from the CB and BLS. This data was used to run the EPA's expenditure margin and incremental burden/disadvantaged community approaches to affordability determinations. The Q1HI was then substituted for MHI in the affordability determination methodologies.

The results of this study confirm the EPA's original affordability determination, that the arsenic regulation was affordable for all systems based on the predicted average costs. Even when affordability determinations were made on a system-by-system basis using the actual costs, the arsenic rule was affordable and none of the costs exceeded 2.5% of the system's customer-base's MHI. The incremental burden/disadvantaged community approach is more generous with granting variances. Systems serving 500 or fewer people qualify for variances based on the incremental burden criteria when an acceptable burden for treatment is set at 0.25% of national MHI. Under the most likely scenario for identifying EDCs (analysis done at the county level), only one additional system qualifies for variances. In total 18 of the 40 systems in the sample would qualify for variances based on this approach. When the arsenic removal costs are compared to the Q1HI, seven systems have treatment costs in excess of 2.5% of their Q1HI.

An analysis of the metrics used by the EPA to identify the EDCs that qualify for variances was carried out in Chapter 4. This analysis addressed Hypothesis and Objective 3. The MHI, poverty rate and unemployment rate were collected for the 3,143 counties and county equivalents in the U.S. states and Washington, D.C. and analyzed using a geographic information system. This data was first used to update the total number of counties, small systems and population potentially affected by the EPA's definition of an EDC using 2010 data. Following the updated count of affected systems, a sensitivity analysis was performed by adjusting the ratios and several specific definitions of EDC used by other agencies and programs. Lastly, a few other measures, the population with rent in excess of 35% of their income and participation in the Supplemental Nutrition Assistance Program (food stamps) were used to capture consumption choices faced by consumers.

In this analysis, 3,812 small systems located in 511 counties qualified using the EPA's definition of an EDC with the most recent socioeconomic data. While fewer systems qualified with this data compared to the EPA's original analysis, more counties and more people were in these potentially affected systems. The results of the sensitivity analysis were used to identify a new set of ratios (0.646 for MHI, 2.16 for poverty and 1.71 for unemployment) that found the same proportion of systems potentially qualifying for variances as in the original analysis based on the assumption that the percentage of systems qualifying was politically acceptable. Finally, alternative indicators that households and therefore systems may not be able to afford water treatment, SNAP participation and share of households paying more than 35% of income in rent, were examined and identified 316 counties with 2,448 systems and 132 counties with 2,967 systems respectively potentially qualifying for variances under those two criteria.

Together these two chapters examined the EPA's affordability methodology and found both the method the EPA has implemented and has considered and found them lacking. The methods themselves ignore those who are most impacted by a higher cost of drinking water treatment regulatory burdens, the poor. This thesis sought to better develop the environmental justice literature on drinking water regulations by studying different ways to bring the situations of the poor directly into the affordability determination process. Chapter 3 introduced the usage of a below MHI, the 25th percentile household income, to explicitly address the incomes of the poor in using expenditure-to-income ratios as part of the determination process. Chapter 4 addressed the inadequacy of the ratios during economic downturns and proposed two alternative criteria to be used in classifying a community as economically disadvantaged that better identify houses that have a true need for relief from drinking water regulations.

RECCOMEDATIONS

The impact of price and household income on the quantity of water demanded is well documented in the literature (Agthe and Billings 1987; Espey et al. 1997; Fenrick and Getachew 2012). However there is significantly less (i.e. to the knowledge of the author, none) to be found that discusses how households make the trade-off between water and other essential needs. This lack of research will hamper decision making and development of the tools necessary to analyze the question of affordability. Fundamental research, probably in the form of detailed case studies or targeted survey research, on when households face the decisions to make these trade-offs, how they decide what to give up, what is essential for their needs and how these decisions impact their quality of life need to be completed. By answering those questions, policy makers can better understand what the signs are that households are about to make these tough decisions and how to assist those who are already making them.

Only after research has been completed on households that face affordability problems can policy makers and those that seek to provide them with decision support tools decide what signs indicate that the a non-negligible number of households in a system's customer base could be pushed over the edge into unaffordable water bills. The current indicators (low MHI in a county, high poverty rate in a county, high unemployment rate in a county) and those proposed in this thesis (low Q1HI in a county, high participation rate in SNAP programs in a county, high proportion of a county's population that spends more than 35% of household income on housing) have theoretical justifications and may serve as valid indicators. However, there is little empirical evidence to demonstrate that if a county has a low median or Q1HI or high poverty, unemployment, SNAP participation or household expenditures on housing, that they have a need to grant variances to their water systems. Once research has identified what the signs are that water will be unaffordable to households, the above indicators can be verified or new ones with stronger empirical foundations can be developed. However, any indicator that can be empirically verified will need to be further evaluated for suitability in use. Is the indicator selective enough to highlight counties where there is a need for variances as opposed to being too generous? Is the indicator easily available by use of data that is aggregated at a county-level or will the EPA, state agencies, counties or systems themselves (the worst option) be responsible for collecting and analyzing the data? Those questions also will need to be answered if policy makers are to use the appropriate affordability criteria in their decision making.

Once indicators have been identified, it will be up to analysts to develop the tools that collect, compile and make the data useful to policy makers and regulators. While the exact nature of the decision support tool and its content depends on the nature of the affordability methodology adopted, there are several features that will most certainly need to be included, and in several cases the information may need to be updated. The decision tool will need to include any socioeconomic variables that are used in the methodology. If a method that incorporates household expenditures on drinking water is used, this data will need to be included and updated since the last data set on cost of drinking water was done in 2006 (U.S. Environmental Protection Agency 2009) and ignores regional variations (the last study that took regional variations into account was performed using 2000 census data (Rubin 2004, 2005)). Because the number of individuals and systems granted variances is a crucial factor in understanding their impact on consumers, any decision tool should incorporate the total number of systems and individuals affected by variances so that increases in health risks can be better predicted. This data is readily available from the EPA in the form of the SDWIS/FED database. The decision support tool developed from this data would be useful to policy makers in informing them about the impacts on public health when making decisions about drinking water affordability.

A further complication that policy researchers will need to tackle and incorporate into affordability metrics is the rising cost of distribution system maintenance. Maintenance and replacement costs are expected to cost the American public a trillion dollars in the coming decades (American Society of Civil Engineers 2013), and this will most certainly impact the cost and affordability of drinking water provision outside of the regulatory framework. Finding a way to properly incorporate maintenance expenditures in addition to regulatory changes into an affordability framework will be crucial to account for the costs consumers face for water and will have major ramifications on policy outcomes. A related issue is how external funding (e.g. the Drinking Water State Revolving Fund) for drinking water treatment and distribution systems affects the costs faced by consumers and the affordability of water treatment. Finding ways to incorporate the availability of external funding sources into affordability metrics will also need to be done as well to ensure that systems that receive permission to use variance technologies truly have no way to fund the upgrades they need

In developing their affordability criteria, the EPA decided to focus on the "typical or average situation, rather than a worst case scenario" (U.S. Environmental Protection Agency 2002b). The purpose of providing small systems with permission to use variances is to ensure that customers in those systems are protected from excessive treatment – associated expenses so that the money can be spent on other household essentials and risk-reducing measures. Affordability criteria should be designed with that purpose in mind.

This research addresses how a concern for the poor and those unable to pay for water services can be inserted into the regulatory framework for drinking water standards.

Incorporating a below MHI allows the EPA to take explicitly address the needs of these groups. The results outlined in Chapter 3 showed that using a lower income, while most certainly incorporating a concern for those who would struggle to support increases in water charges, is not quite the “worst-case scenario” it sounds like it has the potential to be. Because using the first quartile household income is not a worst-case scenario, and given its advantage of being a more accurate representation of the burden on households that are most affected by new drinking water rules, the EPA and state primacy agencies should adopt the method outlined in Chapter 3. This method of granting variances to communities where drinking water expenses per household to 2.5% of the Q1HI (or located in EDCs), is therefore strongly recommended.

Chapter 4 also illustrates the effects of how the EPA’s definition of an EDC in finding in favor of granting systems permission to use variance technology. It demonstrated how the measures used to indicate need could be altered to give them a better methodological justification without dramatically adjusting the number of systems that could potentially qualify. It also pointed out a serious flaw in the current EPA definition of an EDC, that it depends on business cycles in a way that makes it harder to be called an EDC when the general economy is in a recession. The recommended definitions of an EDC outlined in this chapter (fixed definitions that do not vary over time; definitions that fluctuate over the business cycle, but less than the current method; and definitions that tap into measures of longer-term, consumption measures of income resources and predictions – food stamp participation and expenditures on housing) reduce the effects of the business cycle on drinking water affordability. Because of this reduced effect, they should also be considered by the EPA and state primacy agencies for their definitions of EDCs.

While the regulatory burden studied for this thesis was the arsenic rule, it's not hard to imagine other regulations running into questions of affordability. Under the 1996 SDWA Amendments every potential drinking water rule (except for microbial contaminants and indicators of microbial contamination rules) is evaluated by the EPA for affordability to small systems. While most rules won't be classified as unaffordable (unless the EPA fails to adopt any changes to its affordability measures), it is not unforeseeable that a few rules will. Affordability therefore needs to be something that can be determined reasonably easily and consistently going forward. As a result of this, readily available data is crucial to any useful affordability methodology. All the data used in the methods are already collected by the Census Bureau and the Bureau of Labor Statistics, and most are currently reported as summary statistics. This data reporting makes it easier to use them in an affordability methodology adopted by the EPA or state primacy agencies based on these results.

Affordability and EDCs are not unique concepts to EPA drinking water regulations. Affordability is a central concept in nearly two dozen environmental regulations at the EPA (Beecher and Shanaghan 1998; U.S. Environmental Protection Agency 1998). State primacy agencies are also compelled to adopt affordability methods for making determinations for making decisions on which systems to provide money to as part of the Safe Drinking Water Revolving Fund. Several federal agencies target grant money to EDCs, each with their own definition of an EDC. Many of these definitions could be updated to reflect the research undertaken here.

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APPENDIX A

LIST OF SITES

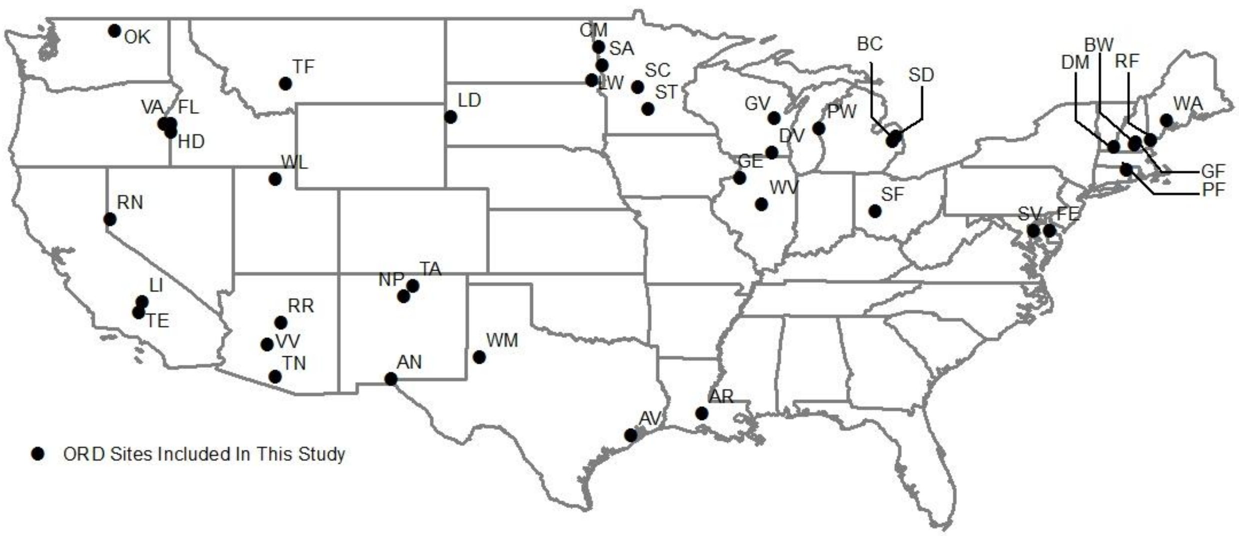

Figure A-1 – ORD Sites included in Chapter 3 study

AN	Desert Sands Mutual Domestic Water Consumers Association		
Anthony		Dona Ana	NM
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	40,395
Arsenic Treatment Costs (per household):	$155.55	Baseline Water Costs (per household):	$260.84
Total Water Costs (per household):	$416.39	Number of Households in Systems:	437

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$22,547	Median Household Income (2000):	$29,808
(2010):	$22,258	(2010):	$36, 657
25th Percentile Income (2000):	$12,540	25th Percentile Income (2000):	$14,859
(2010):	$14,927	(2010):	$18,333
Unemployment (2000):		Unemployment (2000):	7.00%
(2010):		(2010):	7.20%
Poverty (2000):	38.0%	Poverty (2000):	25.4%

AR	United Water Systems		
Arnaudville		St. Landry	LA
In a Metropolitan Area?			No

What Technology is Used?	IR	Annual Production (kgal):	101,152
Arsenic Treatment Costs (per household):	$42.34	Baseline Water Costs (per household):	$185.21
Total Water Costs (per household):	$227.55	Number of Households in Systems:	1200

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$21,600	Median Household Income (2000):	$22,855
(2010):	$23,083	(2010):	$31,813
25th Percentile Income (2000):	$11,895	25th Percentile Income (2000):	$9,766
(2010):	$11,190	(2010):	$13,601
Unemployment (2000):		Unemployment (2000):	6.45%
(2010):		(2010):	7.55%
Poverty (2000):	25.6%	Poverty (2000):	29.3%
(2010):	27.3%	(2010):	28.3%

AV	Oak Manor Municipal Utility District		
Alvin		Brazoria	TX
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	18,928
Arsenic Treatment Costs (per household):	$161.35	Baseline Water Costs (per household):	$354.94
Total Water Costs (per household):	$516.29	Number of Households in Systems:	189

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$38,576	Median Household Income (2000):	$48,632
(2010):	$46,110	(2010):	$65,607
25^{th} Percentile Income (2000):	$21,323	25^{th} Percentile Income (2000):	$26,120
(2010):	$22,443	(2010):	$33,953
Unemployment (2000):		Unemployment (2000):	5.95%
(2010):		(2010):	8.45%
Poverty (2000):	13.3%	Poverty (2000):	10.2%
(2010):	14.9%	(2010):	10.6%

BC	City of Brown City		
Brown City		Sanilac	MI
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	51,334
Arsenic Treatment Costs (per household):	$85.44	Baseline Water Costs (per household):	$264.42
Total Water Costs (per household):	$349.86	Number of Households in Systems:	450

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$33,906	Median Household Income (2000):	$36,870
(2010):	$28,889	(2010):	$40,818
25^{th} Percentile Income (2000):	$21,214	25^{th} Percentile Income (2000):	$29,581
(2010):	$11,443	(2010):	$21,979
Unemployment (2000):		Unemployment (2000):	5.20%
(2010):		(2010):	16.15%
Poverty (2000):	11.7%	Poverty (2000):	10.4%
(2010):	25.6%	(2010):	14.8%

BW	White Rock Water Company		
Bow		Merrimack	NH
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	8,530
Arsenic Treatment Costs (per household):	$661.70	Baseline Water Costs (per household):	$244.76
Total Water Costs (per household):	$906.46	Number of Households in Systems:	96

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$79,329	Median Household Income (2000):	$56,842
(2010):	$101,731	(2010):	$63,012
25th Percentile Income (2000):	$54,750	25th Percentile Income (2000):	$28,017
(2010):	$58,048	(2010):	$34,120
Unemployment (2000):	1.85%	Unemployment (2000):	2.25%
(2010):	4.10%	(2010):	5.60%
Poverty (2000):	1.8%	Poverty (2000):	5.9%
(2010):	13.8%	(2010):	8.1%

CM	City of Climax		
Climax		Polk	MN
In a Metropolitan Area?			Yes

What Technology is Used?	IR/IA	Annual Production (kgal):	13,800
Arsenic Treatment Costs (per household):	$305.82	Baseline Water Costs (per household):	$225.11
Total Water Costs (per household):	$530.93	Number of Households in Systems:	111

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$24,688	Median Household Income (2000):	$35,105
(2010):	$45,938	(2010):	$47,233
25th Percentile Income (2000):	$17,083	25th Percentile Income (2000):	$18,881
(2010):	$31,560	(2010):	$23,559
Unemployment (2000):		Unemployment (2000):	4.25%
(2010):		(2010):	5.90%
Poverty (2000):	11.8%	Poverty (2000):	10.9%
(2010):	3.7%	(2010):	13.0%

DM	Charette Mobile Home Park		
Dummerston		Windham	CT
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	571
Arsenic Treatment Costs (per household):	$584.48	Baseline Water Costs (per household):	$213.20
Total Water Costs (per household):	$797.68	Number of Households in Systems:	14

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$46,121	Median Household Income (2000):	$38,204
(2010):	$62,591	(2010):	$46,714
25th Percentile Income (2000):	$27,019	25th Percentile Income (2000):	$20,800
(2010):	$41,250	(2010):	$24,473
Unemployment (2000):	1.80%	Unemployment (2000):	2.75%
(2010):	4.15%	(2010):	6.50%
Poverty (2000):	2.4%	Poverty (2000):	9.4%
(2010):	5.0%	(2010):	11.1%

DV	Vintage on the Ponds		
Delavan		Walworth	WI
In a Metropolitan Area?			No

What Technology is Used?	IR	Annual Production (kgal):	2,200
Arsenic Treatment Costs (per household):	$134.90	Baseline Water Costs (per household):	$244.76
Total Water Costs (per household):	$379.66	Number of Households in Systems:	52

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$42,551	Median Household Income (2000):	$46,274
(2010):	$45,218	(2010):	$54,487
25th Percentile Income (2000):	$24,296	25th Percentile Income (2000):	$26,393
(2010):	$22,678	(2010):	$29,411
Unemployment (2000):		Unemployment (2000):	2.65%
(2010):		(2010):	9.05%
Poverty (2000):	7.6%	Poverty (2000):	8.4%
(2010):	20.7%	(2010):	11.7%

FE	Town of Felton		
Felton		Kent	DE
In a Metropolitan Area?			Yes

What Technology is Used?	CF	Annual Production (kgal):	38,200
Arsenic Treatment Costs (per household):	$107.90	Baseline Water Costs (per household):	$271.56
Total Water Costs (per household):	$379.46	Number of Households in Systems:	428

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$42,589	Median Household Income (2000):	$40,950
(2010):	$44,533	(2010):	$53,183
25th Percentile Income (2000):	$27,642	25th Percentile Income (2000):	$27,573
(2010):	$22,439	(2010):	$28,725
Unemployment (2000):		Unemployment (2000):	3.55%
(2010):		(2010):	7.85%
Poverty (2000):	10.4%	Poverty (2000):	10.7%
(2010):	11.8%	(2010):	12.5%

FL	City of Fruitland		
Fruitland		Payette	ID
In a Metropolitan Area?			Yes

What Technology is Used?	IX	Annual Production (kgal):	65,400
Arsenic Treatment Costs (per household):	$53.77	Baseline Water Costs (per household):	$252.51
Total Water Costs (per household):	$306.28	Number of Households in Systems:	1377

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$32,469	Median Household Income (2000):	$33,046
(2010):	$32.855	(2010):	$43,559
25th Percentile Income (2000):	$18,345	25th Percentile Income (2000):	$18,352
(2010):	$24.758	(2010):	$22,793
Unemployment (2000):		Unemployment (2000):	6.80%
(2010):		(2010):	8.80%
Poverty (2000):	11.9%	Poverty (2000):	13.2%
(2010):	18.2%	(2010):	15.7%

GE	Geneseo Hills Subdivision		
Geneseo		Henry	IL
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	14,868
Arsenic Treatment Costs (per household):	$329.56	Baseline Water Costs (per household):	$226.30
Total Water Costs (per household):	$555.86	Number of Households in Systems:	155

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$40,760	Median Household Income (2000):	$39,854
(2010):	$58,830	(2010):	$49,164
25th Percentile Income (2000):	$25,208	25th Percentile Income (2000):	$22,466
(2010):	$30,377	(2010):	$26,935
Unemployment (2000):		Unemployment (2000):	4.95%
(2010):		(2010):	9.05%
Poverty (2000):	5.3%	Poverty (2000):	8.0%
(2010):	5.0%	(2010):	10.4%

GF	Orchard Highlands Subdivision		
Goffstown		Hilsborough	NH
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	1,509
Arsenic Treatment Costs (per household):	$176.78	Baseline Water Costs (per household):	$244.76
Total Water Costs (per household):	$421.54	Number of Households in Systems:	42

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$55,833	Median Household Income (2000):	$53,384
(2010):	$76,171	(2010):	$69,321
25th Percentile Income (2000):	$34,210	25th Percentile Income (2000):	$30,377
(2010):	$39,513	(2010):	$37,459
Unemployment (2000):	2.45%	Unemployment (2000):	2.70%
(2010):	5.15%	(2010):	6.40%
Poverty (2000):	4.2%	Poverty (2000):	6.3%
(2010):	3.4%	(2010):	7.2%

GV	Town of Greenville		
Greenville		Outagamie	WI
In a Metropolitan Area?			Yes

What Technology is Used?	IR	Annual Production (kgal):	24,051
Arsenic Treatment Costs (per household):	$31.07	Baseline Water Costs (per household):	$245.95
Total Water Costs (per household):	$277.02	Number of Households in Systems:	1502

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$61,381	Median Household Income (2000):	$49,613
(2010):	$81,405	(2010):	$55,914
25th Percentile Income (2000):	$44,545	25th Percentile Income (2000):	$29,824
(2010):	$54,418	(2010):	$30,980
Unemployment (2000):		Unemployment (2000):	4.7%
(2010):		(2010):	8.30%
Poverty (2000):	2.0%	Poverty (2000):	2.70%
(2010):	4.5%	(2010):	8.5%

HD	Sunset Ranch Development		
Homedale		Owyhee	ID
In a Metropolitan Area?			No

What Technology is Used?	POU-RO	Annual Production (kgal):	n/a
Arsenic Treatment Costs (per household):	$554.45	Baseline Water Costs (per household):	$252.51
Total Water Costs (per household):	$806.96	Number of Households in Systems:	10

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$24,196	Median Household Income (2000):	$28,339
(2010):	$36,370	(2010):	$33,441
25th Percentile Income (2000):	$13,840	25th Percentile Income (2000):	$16,404
(2010):	$17,526	(2010):	$20,544
Unemployment (2000):		Unemployment (2000):	16.9%
(2010):		(2010):	4.25%
Poverty (2000):	20.3%	Poverty (2000):	3.95%
(2010):	18.5%	(2010):	22.2%

LD	Terry Trojan Water District		
Lead		Lawrence	SD
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	18,790
Arsenic Treatment Costs (per household):	$145.02	Baseline Water Costs (per household):	$248.93
Total Water Costs (per household):	$393.95	Number of Households in Systems:	187

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$29,485	Median Household Income (2000):	$31,755
(2010):	$38,845	(2010):	$42,356
25th Percentile Income (2000):	$17,241	25th Percentile Income (2000):	$16,453
(2010):	$22,380	(2010):	$21,323
Unemployment (2000):		Unemployment (2000):	14.8%
(2010):		(2010):	4.60%
Poverty (2000):	12.9%	Poverty (2000):	3.40%
(2010):	12.4%	(2010):	15.3%

LI	Upper Bodfish Well CH2-A		
Lake Isabella		Kern	CA
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	9,318
Arsenic Treatment Costs (per household):	$213.81	Baseline Water Costs (per household):	$242.38
Total Water Costs (per household):	$456.19	Number of Households in Systems:	200

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$19,813	Median Household Income (2000):	$35,446
(2010):	$19,627	(2010):	$47,089
25th Percentile Income (2000):	$10,478	25th Percentile Income (2000):	$18,204
(2010):	$12,863	(2010):	$23,934
Unemployment (2000):		Unemployment (2000):	9.85%
(2010):		(2010):	15.15%
Poverty (2000):	20.5%	Poverty (2000):	20.8%
(2010):	21.3%	(2010):	20.6%

LW	City of Lidgerwood		
Lidgerwood		Richaland	ND
In a Metropolitan Area?			No

What Technology is Used?	SM	Annual Production (kgal):	65,7000
Arsenic Treatment Costs (per household):	$114.69	Baseline Water Costs (per household):	$268.58
Total Water Costs (per household):	$383.27	Number of Households in Systems:	385

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$25,887	Median Household Income (2000):	$36,098
(2010):	$31,731	(2010):	$47,131
25th Percentile Income (2000):	$14,403	25th Percentile Income (2000):	$19,461
(2010):	$21,891	(2010):	$26,406
Unemployment (2000):		Unemployment (2000):	2.70%
(2010):		(2010):	4.65%
Poverty (2000):	13.7%	Poverty (2000):	10.4%
(2010):	11.0%	(2010):	10.7%

NP	Nambe Pueblo Tribe		
Nambe Pueblo		Santa Fe	NM
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	30,709
Arsenic Treatment Costs (per household):	$561.24	Baseline Water Costs (per household):	$294.19
Total Water Costs (per household):	$855.43	Number of Households in Systems:	150

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$30,452	Median Household Income (2000):	$42,207
(2010):	$41,343	(2010):	$52,696
25th Percentile Income (2000):		25th Percentile Income (2000):	$23,071
(2010):	$19,565	(2010):	$25,808
Unemployment (2000):		Unemployment (2000):	3.20%
(2010):		(2010):	6.25%
Poverty (2000):	14.2%	Poverty (2000):	12.0%
(2010):	14.3%	(2010):	14.4%

OK	City of Okanogan		
Okanogan		Okanogan	WA
In a Metropolitan Area?			No

What Technology is Used?	CF	Annual Production (kgal):	139,400
Arsenic Treatment Costs (per household):	$63.15	Baseline Water Costs (per household):	$344.22
Total Water Costs (per household):	$407.37	Number of Households in Systems:	1047

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$26,994	Median Household Income (2000):	$29,726
(2010):	$36,394	(2010):	$38,551
25th Percentile Income (2000):	$13,079	25th Percentile Income (2000):	$15,393
(2010):	$16,493	(2010):	$18,404
Unemployment (2000):		Unemployment (2000):	8.65%
(2010):		(2010):	10.15%
Poverty (2000):	24.3%	Poverty (2000):	21.3%
(2010):	22.7%	(2010):	19.5%

PF	Seely-Brown Village		
Pomfret		Windham	CT
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	706
Arsenic Treatment Costs (per household):	$223.73	Baseline Water Costs (per household):	$242.38
Total Water Costs (per household):	$466.11	Number of Households in Systems:	32

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$57,938	Median Household Income (2000):	$45,115
(2010):	$68,278	(2010):	$59,370
25th Percentile Income (2000):	$34,244	25th Percentile Income (2000):	$23,905
(2010):	$41,128	(2010):	$30,340
Unemployment (2000):	2.05%	Unemployment (2000):	2.80%
(2010):	4.60%	(2010):	10.9%
Poverty (2000):	4.1%	Poverty (2000):	8.5%
(2010):	6.0%	(2010):	11.4%

PW	Village of Pentwaer		
Pentwater		Oceana	MI
In a Metropolitan Area?			No

What Technology is Used?	IR/IA	Annual Production (kgal):	38,300
Arsenic Treatment Costs (per household):	$94.01	Baseline Water Costs (per household):	$209.03
Total Water Costs (per household):	$303.04	Number of Households in Systems:	450

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$38,542	Median Household Income (2000):	$35,307
(2010):	$44,524	(2010):	$39,543
25th Percentile Income (2000):	$21,311	25th Percentile Income (2000):	$19,582
(2010):	$27,766	(2010):	$22,098
Unemployment (2000):		Unemployment (2000):	6.25%
(2010):		(2010):	15.35%
Poverty (2000):	8.4%	Poverty (2000):	14.7%
(2010):	5.4%	(2010):	19.2%

RF	Rollinsford Water/Sewer District		
Rollinsford		Strafford	NH
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	21,243
Arsenic Treatment Costs (per household):	$152.14	Baseline Water Costs (per household):	$243.57
Total Water Costs (per household):	$395.71	Number of Households in Systems:	654

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$48,588	Median Household Income (2000):	$44,803
(2010):	$66,161	(2010):	$57,809
25th Percentile Income (2000):	$30,106	25th Percentile Income (2000):	$25,873
(2010):	$33,268	(2010):	$30,463
Unemployment (2000):	1.05%	Unemployment (2000):	2.60%
(2010):	4.60%	(2010):	6.05%
Poverty (2000):	3.7%	Poverty (2000):	9.2%
(2010):	7.9%	(2010):	11.3%

RN	South Truckee Meadow General Improvement District		
Reno		Washoe	NV
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	22,885
Arsenic Treatment Costs (per household):	$47.33	Baseline Water Costs (per household):	$276.33
Total Water Costs (per household):	$323.66	Number of Households in Systems:	3410

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$40,530	Median Household Income (2000):	$45,815
(2010):	$48,895	(2010):	$55,658
25th Percentile Income (2000):	$22,368	25th Percentile Income (2000):	$25,692
(2010):	$25,259	(2010):	$29,571
Unemployment (2000):	4.05%	Unemployment (2000):	3.65%
(2010):	12.05%	(2010):	12.25%
Poverty (2000):	12.6%	Poverty (2000):	10.0%
(2010):	16.3%	(2010):	12.6%

RR	Arizona Water Company		
Rimrock		Yavapai	Arizona
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	8,508
Arsenic Treatment Costs (per household):	$16.98	Baseline Water Costs (per household):	$287.05
Total Water Costs (per household):	$304.03	Number of Households in Systems:	1048

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$33,750	Median Household Income (2000):	$34,901
(2010):	$40,476	(2010):	$43,290
25th Percentile Income (2000):	$20,286	25th Percentile Income (2000):	$24,080
(2010):	$24,894	(2010):	$24,031
Unemployment (2000):		Unemployment (2000):	3.80%
(2010):		(2010):	10.70%
Poverty (2000):	9.1%	Poverty (2000):	11.9%
(2010):	11.4%	(2010):	13.7%

SA	City of Sabin		
Sabin		Clay	MN
In a Metropolitan Area?			Yes

What Technology is Used?	IR	Annual Production (kgal):	12,200
Arsenic Treatment Costs (per household):	$199.96	Baseline Water Costs (per household):	$225.11
Total Water Costs (per household):	425.07	Number of Households in Systems:	175

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$43,523	Median Household Income (2000):	$37,889
(2010):	$62,292	(2010):	$50,057
25^{th} Percentile Income (2000):	$28,146	25^{th} Percentile Income (2000):	$19,999
(2010):	$39,481	(2010):	$25,345
Unemployment (2000):		Unemployment (2000):	2.85%
(2010):		(2010):	4.90%
Poverty (2000):	6.4%	Poverty (2000):	13.2%
(2010):	4.1%	(2010):	12.0%

SC	Big Sauk Lake Mobile Home Park		
Sauk Centre		Stearns	MN
In a Metropolitan Area?			Yes

What Technology is Used?	IR	Annual Production (kgal):	1,650
Arsenic Treatment Costs (per household):	$146.80	Baseline Water Costs (per household):	$200.10
Total Water Costs (per household):	$346.90	Number of Households in Systems:	50

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$37,644	Median Household Income (2000):	$42,426
(2010):	$47,061	(2010):	$51,779
25^{th} Percentile Income (2000):	$20,215	25^{th} Percentile Income (2000):	$19,029
(2010):	$25,649	(2010):	$27,752
Unemployment (2000):		Unemployment (2000):	3.00%
(2010):		(2010):	7.60%
Poverty (2000):	5.2%	Poverty (2000):	8.7%
(2010):	13.8%	(2010):	12.9%

SD	City of Sandusky		
Sandusky		Sanilac	MI
In a Metropolitan Area?			No

What Technology is Used?	IR	Annual Production (kgal):	60,300
Arsenic Treatment Costs (per household):	$48.38	Baseline Water Costs (per household):	$264.42
Total Water Costs (per household):	$312.80	Number of Households in Systems:	1124

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$33,667	Median Household Income (2000):	$36,870
(2010):	$29,250	(2010):	$40,818
25th Percentile Income (2000):	$14,564	25th Percentile Income (2000):	$20,581
(2010):	$13,350	(2010):	$21,979
Unemployment (2000):		Unemployment (2000):	5.20%
(2010):		(2010):	16.15%
Poverty (2000):	11.0%	Poverty (2000):	10.4%
(2010):	28.6%	(2010):	14.8%

SF	Chateau Estates Mobile Home Park		
Springfield		Clark	OH
In a Metropolitan Area?			Yes

What Technology is Used?	IR & AM	Annual Production (kgal):	16,700
Arsenic Treatment Costs (per household):	$162.66	Baseline Water Costs (per household):	$260.84
Total Water Costs (per household):	$423.50	Number of Households in Systems:	226

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$32,193	Median Household Income (2000):	$40,340
(2010):	$34,045	(2010):	$44,141
25th Percentile Income (2000):	$17,102	25th Percentile Income (2000):	$22,191
(2010):	$16,274	(2010):	$22,968
Unemployment (2000):		Unemployment (2000):	4.40%
(2010):		(2010):	10.35%
Poverty (2000):	16.9%	Poverty (2000):	10.7%
(2010):	25.8%	(2010):	15.9%

ST	City of Stewart		
Stewart		McLeod	MN
In a Metropolitan Area?			No

What Technology is Used?	IR & AM	Annual Production (kgal):	19,133
Arsenic Treatment Costs (per household):	$165.45	Baseline Water Costs (per household):	$240.59
Total Water Costs (per household):	$406.04	Number of Households in Systems:	247

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$38,542	Median Household Income (2000):	$45,953
(2010):	$48,646	(2010):	$58,544
25th Percentile Income (2000):	$21,781	25th Percentile Income (2000):	$22,778
(2010):	$24,507	(2010):	$32,326
Unemployment (2000):		Unemployment (2000):	3.25%
(2010):		(2010):	9.35%
Poverty (2000):	7.1%	Poverty (2000):	4.8%
(2010):	18.3%	(2010):	6.6%

SV	Queen Anne's County		
Stevensville		Queen Anne's	MD
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	28,106
Arsenic Treatment Costs (per household):	$140.44	Baseline Water Costs (per household):	$283.47
Total Water Costs (per household):	$423.91	Number of Households in Systems:	300

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$63,962	Median Household Income (2000):	$57,037
(2010):	$86,932	(2010):	$81,096
25th Percentile Income (2000):	$46,299	25th Percentile Income (2000):	$31,915
(2010):	$53,293	(2010):	$67,289
Unemployment (2000):		Unemployment (2000):	3.00%
(2010):		(2010):	6.90%
Poverty (2000):	2.5%	Poverty (2000):	6.3%
(2010):	3.5%	(2010):	5.5%

TA	Town of Taos		
Taos		Taos	NM
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	42,961
Arsenic Treatment Costs (per household):	$27.92	Baseline Water Costs (per household):	$244.76
Total Water Costs (per household):	$272.68	Number of Households in Systems:	2416

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$25,016	Median Household Income (2000):	$26,762
(2010):	$36,389	(2010):	$35,441
25th Percentile Income (2000):	$11,556	25th Percentile Income (2000):	$12,981
(2010):	$13,161	(2010):	$18,167
Unemployment (2000):		Unemployment (2000):	9.15%
(2010):		(2010):	8.70%
Poverty (2000):	23.1%	Poverty (2000):	20.9%
(2010):	30.8%	(2010):	17.0%

TE	Golden Hills Community Service District		
Tehachapi		Kern	CA
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	34,039
Arsenic Treatment Costs (per household):	$17.42	Baseline Water Costs (per household):	$242.38
Total Water Costs (per household):	$259.80	Number of Households in Systems:	2917

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$29,208	Median Household Income (2000):	$35,446
(2010):	$46,067	(2010):	$47,089
25th Percentile Income (2000):	$13,737	25th Percentile Income (2000):	$18,204
(2010):	$20,374	(2010):	$23,394
Unemployment (2000):		Unemployment (2000):	9.85%
(2010):		(2010):	15.15%
Poverty (2000):	20.4%	Poverty (2000):	20.8%
(2010):	14.3%	(2010):	20.6%

TF	City of Three Forks		
Three Forks		Gallatin	MT
In a Metropolitan Area?			No

What Technology is Used?	IX	Annual Production (kgal):	111,100
Arsenic Treatment Costs (per household):	$49.77	Baseline Water Costs (per household):	$238.21
Total Water Costs (per household):	$287.98	Number of Households in Systems:	730

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$34,212	Median Household Income (2000):	$38,120
(2010):	$43,058	(2010):	$50,136
25th Percentile Income (2000):	$21,235	25th Percentile Income (2000):	$21,739
(2010):	$27,133	(2010):	$28,361
Unemployment (2000):		Unemployment (2000):	3.25%
(2010):		(2010):	6.45%
Poverty (2000):	22.2%	Poverty (2000):	12.8%
(2010):	8.3%	(2010):	13.5%

TN	Tohono O'Odlham Utility Authority		
Tohono O'Odlham Nation		Pima	AZ
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	5,755
Arsenic Treatment Costs (per household):	$359.60	Baseline Water Costs (per household):	$238.21
Total Water Costs (per household):	$597.81	Number of Households in Systems:	64

Municipality Characteristics		County Characteristics	
Median Household Income (2000):		Median Household Income (2000):	$36,758
(2010):	$24,496	(2010):	$45,521
25th Percentile Income (2000):		25th Percentile Income (2000):	$20,062
(2010):	$7,961	(2010):	$23,842
Unemployment (2000):		Unemployment (2000):	3.45%
(2010):		(2010):	9.20%
Poverty (2000):		Poverty (2000):	14.7%
(2010):	45.2%	(2010):	16.4%

WA	Springbrook Mobile Home Park		
Wales		Androscoggin	ME
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	955
Arsenic Treatment Costs (per household):	$344.13	Baseline Water Costs (per household):	$287.64
Total Water Costs (per household):	$631.77	Number of Households in Systems:	14

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$44,444	Median Household Income (2000):	$35,793
(2010):	$51,111	(2010):	$44,470
25th Percentile Income (2000):	$28,252	25th Percentile Income (2000):	$19,332
(2010):	$36,966	(2010):	$23,243
Unemployment (2000):	2.20%	Unemployment (2000):	3.60%
(2010):	7.50%	(2010):	8.45%
Poverty (2000):	8.0%	Poverty (2000):	10.0%
(2010):	4.1%	(2010):	14.3%

WL	Hot Springs Mobile Home Park		
Willard		Box Elder	UT
In a Metropolitan Area?			No

What Technology is Used?	IR & AM	Annual Production (kgal):	3,049
Arsenic Treatment Costs (per household):	$267.94	Baseline Water Costs (per household):	$269.78
Total Water Costs (per household):	$537.72	Number of Households in Systems:	46

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$52,150	Median Household Income (2000):	$44,630
(2010):	$57,202	(2010):	$55,135
25th Percentile Income (2000):	$31,901	25th Percentile Income (2000):	$27,583
(2010):	$37,514	(2010):	$23,103
Unemployment (2000):		Unemployment (2000):	4.15%
(2010):		(2010):	8.85%
Poverty (2000):	7.2%	Poverty (2000):	7.1%
(2010):	6.2%	(2010):	8.6%

WM	City of Wellman		
Wellman		Terry	TX
In a Metropolitan Area?			No

What Technology is Used?	AM	Annual Production (kgal):	11,758
Arsenic Treatment Costs (per household):	$498.80	Baseline Water Costs (per household):	$301.93
Total Water Costs (per household):	$800.73	Number of Households in Systems:	95

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$50,833	Median Household Income (2000):	$28,090
(2010):	$51,250	(2010):	$39,498
25th Percentile Income (2000):	$21,250	25th Percentile Income (2000):	$14,291
(2010):	$32,484	(2010):	$17,932
Unemployment (2000):		Unemployment (2000):	6.05%
(2010):		(2010):	7.10%
Poverty (2000):	22.0%	Poverty (2000):	23.3%
(2010):	7.1%	(2010):	16.6%

WV	Village of Waynesville		
Waynesville		De Witt	IL
In a Metropolitan Area?			No

What Technology is Used?	IR	Annual Production (kgal):	10,731
Arsenic Treatment Costs (per household):	$106.53	Baseline Water Costs (per household):	$202.48
Total Water Costs (per household):	$309.01	Number of Households in Systems:	214

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$40,588	Median Household Income (2000):	$41,256
(2010):	$48,438	(2010):	$45,347
25th Percentile Income (2000):	$22,727	25th Percentile Income (2000):	$22,835
(2010):	$27,782	(2010):	$26,021
Unemployment (2000):		Unemployment (2000):	5.65%
(2010):		(2010):	9.5%
Poverty (2000):	7.8%	Poverty (2000):	8.2%
(2010):	4.5%	(2010):	8.6%

VA	City of Vale		
Vale		Malheur	OR
In a Metropolitan Area?			No

What Technology is Used?	IX	Annual Production (kgal):	111,100
Arsenic Treatment Costs (per household):	$106.48	Baseline Water Costs (per household):	$267.39
Total Water Costs (per household):	$373.87	Number of Households in Systems:	749

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$27,065	Median Household Income (2000):	$30,241
(2010):	$31,307	(2010):	$39,114
25th Percentile Income (2000):	$15,714	25th Percentile Income (2000):	$16,739
(2010):	$16,183	(2010):	$19,037
Unemployment (2000):		Unemployment (2000):	8.40%
(2010):		(2010):	10.60%
Poverty (2000):	20.0%	Poverty (2000):	18.6%
(2010):	24.3%	(2010):	22.7%

VV	Arizona Water Company		
Valley Vista		Yavapai	AZ
In a Metropolitan Area?			Yes

What Technology is Used?	AM	Annual Production (kgal):	18,750
Arsenic Treatment Costs (per household):	$82.36	Baseline Water Costs (per household):	$287.05
Total Water Costs (per household):	$369.41	Number of Households in Systems:	757

Municipality Characteristics		County Characteristics	
Median Household Income (2000):	$44,042	Median Household Income (2000):	$34,901
(2010):	$49,749	(2010):	$43,290
25th Percentile Income (2000):	$23,602	25th Percentile Income (2000):	$24,080
(2010):	$28,797	(2010):	$24,031
Unemployment (2000):		Unemployment (2000):	3.80%
(2010):		(2010):	10.70%
Poverty (2000):	9.7%	Poverty (2000):	11.9%
(2010):	10.8%	(2010):	13.7%

Notes: All costs per household in 2010 prices. All incomes in 2000 and 2010 are reported in nominal values.

Technology Key: AM-Adsorptive Media
CF-Coagulation/Filtration
IR-Iron Removal
IR/IA-Iron Removal with Iron Addition
IX-Ion Exchange
POU-RO-Point of Use-Reverse Osmosis System
SM-System Modification

APPENDIX B

COST EFFECTIVENESS OF ARSENIC TREATMENT FOR EACH SYSTEM SIZE CLASS

Tables B-1 and B-2 show the cost effectiveness of the 10 μg/L rule for each of the nine size classes plus overall effectiveness based on the Abt Assoicates, Inc. (2000) estimates of cost and avoided cancer cases. Table B-1 shows the effectiveness for the low estimate of avoided cancer cases (37.4 cancers each year) and B-2 shows the effectiveness for the high estimates (55.7 cancers each year). The number of cancer cases each year was assigned to system size classes on the basis of the number of households in each system size class. The cost for the entire system size class was divided by the number of avoided cancer cases to find cost effectiveness for each system size class. The cost for the average household in each system size class was then divided by cancer cases to determine how much each household was paying to avoid a case of cancer within its size class. Overall there is a difference of several orders of magnitude between the smallest systems and the largest systems or averages for all systems in the effectiveness of avoiding cancer cases.

Table B-1 - Cost effectiveness for arsenic treatment under low cancer occurrence estimates

	System Size Class									
	<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	All Systems
Households Served (thousands)	26.4	104.4	101.9	289.0	475.6	997.9	469.2	936.6	1,185.0	4,585.8
Share of Households (%)	0.58	2.28	2.22	6.30	10.37	21.76	10.23	30.42	25.84	100.0
Cancer Cases Avoided (cases/yr)	0.215	0.851	0.831	2.357	3.879	8.138	3.826	7.638	9.664	37.4
How much does the entire system size class pay to avoid a cancer case in its size class?										
Costs for the Size Class ($mil/yr)	5.90	12.50	7.60	25.60	27.90	53.90	19.00	36.50	4.30	193.00
Cost per Avoided Cancer Case ($mil/cancer)	27.44	14.68	9.15	10.86	7.19	6.62	4.97	4.78	0.44	5.16
How much does each household pay to avoid a cancer case in its size class?										
Costs for Each Household ($/yr)	326.82	162.50	70.72	58.24	37.31	32.37	24.81	20.52	0.86	31.85
Costs per Avoided Cancer Case ($/cancer)	1,519.72	190.90	85.13	24.71	9.72	3.98	6.48	2.69	0.09	0.85

Table B-2 - Cost effectiveness for arsenic treatment under high cancer occurrence estimates

	System Size Class									
	<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	All Systems
Households Served (thousands)	26.4	104.4	101.9	289.0	475.6	997.9	469.2	936.6	1,185.0	4,585.8
Share of Households (%)	0.58	2.28	2.22	6.30	10.37	21.76	10.23	30.42	25.84	100.0
Cancer Cases Avoided (cases/yr)	0.320	1.268	1.237	3.510	5.777	12.120	5.698	11.376	14.393	55.7
How much does the entire system size class pay to avoid a cancer case in its size class?										
Costs for the Size Class ($mil/yr)	5.90	12.50	7.60	25.60	27.90	53.90	19.00	36.50	4.30	193.00
Cost per Avoided Cancer Case ($mil/cancer)	18.42	9.86	6.14	7.29	4.83	4.45	3.33	3.21	0.30	3.46
How much does each household pay to avoid a cancer case in its size class?										
Costs for Each Household ($/yr)	326.82	162.50	70.72	58.24	37.31	32.37	24.81	20.52	0.86	31.85
Costs per Avoided Cancer Case ($/cancer)	1,020.42	128.18	57.16	16.59	6.53	2.67	4.35	1.80	0.06	0.57