ENVIRONMENTAL FEDERALISM AND THE SAFE DRINKING WATER ACT:

THE ARIZONA ARSENIC EXPERIENCE

by

Miles H. Kiger

A Thesis Submitted to the Faculty of the

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

2007

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona.

SIGNED: ______________________

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the dates shown below:

______________________ May 9, 2007

Dr. Dennis C. Cory Date

ACKNOWLEDGEMENTS

I would like to thank Dr. Dennis C. Cory, my advisor, for his guidance, patience, and encouragement. His positive attitude helped me reach a major milestone in my academic career. His personality and commentary also made the process an enjoyable one.

I would also like to thank my committee members Dr. Tauhid Rahman and Dr. Sharon Megdal for their guidance and insightful comments.

I would also like to express my gratitude to John Calkins and his staff at the Arizona Department of Environmental Quality for providing me data and fielding an assortment of questions over the past year. Also, thanks go out to the folks at the ArtLab at the University of Arizona for their help with my mapping needs.

I would particularly like to thank the Department of Agricultural and Resource Economics for giving me the opportunity to advance my career in the company of such dedicated and interesting individuals. This truly has been an amazing and rewarding experience.

Ultimately, I would like to dedicate this thesis to my mother and father, Meredith and Vaughn, for their incredible support and quest to show their son the importance of an education.

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ABSTRACT

This thesis examines the effect of the revised arsenic standard on Arizona public water systems (PWSs) in the context of environmental federalism. The thesis begins by briefly describing federalism, environmental federalism, and the revised arsenic standard. It goes on to discuss the benefit and cost estimates of the standard in detail and asserts that it is unclear whether the standard is a potential Pareto improvement for Arizona. The remainder of the thesis examines the distributional consequences of the revised standard with respect to Arizona PWSs. Using statistical and econometric techniques the thesis discovers that large PWSs are disproportionately affected by the standard. In addition, it finds that small PWSs are affected in absolute terms, which raises the issue of small system financing. These policy implications are then discussed in the context of the compliance history of PWSs to date. The thesis concludes by asserting that more reliable health benefits estimates are needed to determine if the uniform national arsenic standard is inefficient in Arizona.

I. Introduction

"Federal-state relations have been a chronic source of political conflict since the founding of our republic,"[1] and contemporary relations reveal no particular advancement toward greater harmony. The recent controversy over the Safe Drinking Water Act (SDWA) amendment that reduced the allowable concentration of arsenic in drinking water from 50 parts per billion (ppb) down to 10 ppb, embodied by the lawsuit filed by the state of Nebraska against the U.S. Environmental Protection Agency (EPA),[2] highlights the popular disagreement over the constitutionality of federal regulatory actions that restrict states' ability to manage their internal affairs.

The theory of federal-state relations, referred to as federalism, is defined as a system of government where power is vertically distributed among a central authority and smaller constituent units. As the above quotation suggests, how to distribute power within a federalist hierarchy has long been the source of much contention within the United States. Original disagreements over how to distribute power within a federalist system were resolved by the U.S. Constitution, which granted states and the central government "dual" authority in public affairs (Inman and Rubinfeld, 1997). Since that

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[1] Percival (1995), p. 1141.

[2] The case is Nebraska v. Environmental Protection Agency. The D.C. Circuit Court of Appeals issued their opinion on the *Nebraska* case on June 20, 2003 (available online at http://pacer.cadc.uscourts.gov/docs/common/opinions/200306/01-1101a.pdf), denying the state any exemption from the mandates of the arsenic regulation. Interestingly, the state of Nebraska lost on procedural grounds (it failed tell EPA about its constitutional objections during the comment period), not because the Court believed the federal government acted within its prescribed authority under the Commerce Clause or the Tenth Amendment. However, the Court did allow Nebraska to challenge the Safe Drinking Water Act itself, though the Court rejected the challenge on the grounds that Nebraska could not show that the SDWA would be constitutional under "no set of circumstances." Despite the Court's decision, Nebraska could once again challenge the SDWA if and when EPA takes an enforcement action against a public water provider deemed in violation of the arsenic rule.

time, the desirable locus of ultimate authority has shifted significantly reflecting the political and social goals, and budgetary considerations of the moment.[3] The most notable, relevant, and controversial development in federalist ideology during federalism's U.S. history is the fairly recent advent of "new federalism", which arose out of the Reagan administration and advocates returning more power to lower levels of government.

Theoretically, "new federalism" gives states greater freedom in executing state-level programs but also achieves its ends with grant assistance from the federal government. Though born out of the ideology of the Reagan administration, "new federalism" failed to produce any substantive policy results until the Rehnquist Court ruled on United States v. Lopez[4] in 1995. This ruling signaled, at least on legal grounds, that growing federal authority over state and local matters would not continue completely unchecked. Rather, the Lopez ruling served to initiate a "flurry of scholarly commentary"[5] over the significance of the Commerce Clause, as well as the Tenth Amendment, and pushed the federalism debate back into the limelight. Moreover, as

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[3] Inman and Rubinfeld (1997) characterize these distinct periods over the past two centuries as "dualism" (1790-1860), with responsibility split between state and central authority; "centralizing federalism" (1860-1933), where federal responsibility increased considerably; "cooperative federalism" (1933-1964), indicated substantial growth in social programs as a result of the Great Depression; and "creative federalism" (1964-present), where "the federal government has taken a direct and active role in the problems of state and local governments," (p. 44).

[4] In United States v. Lopez, 514 U.S. 549 (1995), the Supreme Court broke nearly 60 years of precedent by limiting the powers of Congress to regulate states under the Commerce Clause. The Court, led by Chief Justice William Rehnquist, ruled that the federal government had no authority to regulate firearms in school zones under the Gun-Free School Zone Act of 1990 despite the claims of government prosecutors that such authority fell broadly under the Commerce Clause. The Court held that possession of a firearm in a school zone was not an economic activity that has a "substantial relation to interstate commerce" and provided that the "proper test" for validating this connection is "whether the regulated activity 'substantially affects' interstate commerce," (*Lopez*, 115 S. Ct. at 1629-1630) quoted in Percival (1995), p. 1169. Percival (1995) asserts that, "it is unclear to what extent the *Lopez* 'substantially affects' test will impose new restrictions on federal regulatory authority," (p. 1169).

[5] Klein (2003), p. 1.

Robert Percival declared in 1995, “national environmental policy has surged to the forefront of federalism debates due to the growth of federal environmental regulation,”[6] which focused political and scholarly attention on environmental federalism. In order to evaluate the practical implications of the new federal arsenic standard, which is the goal of this paper, it is essential to understand the dynamics of environmental federalism.

A. Environmental Federalism

Similarly to federalism, environmental federalism is a theory concerned with the appropriate division of authority among federal and state governments, though more specifically in how this division of authority pertains to environmental management and policymaking. The theory of environmental federalism, from an economist’s perspective, is cogently outlined in Wallace E. Oates’ paper “A Reconsideration of Environmental Federalism.” In it, Oates describes different economic models that explain the basis for selecting an appropriate authority for the standard setting and management of environmental quality.[7]

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[6] Percival (1995), p.1141.

[7] Oates (2001) describes three benchmark cases for understanding the dynamics of regulating environmental quality within a federalist system. The first, termed Pure Public Good, is exemplified by global warming, where the level of environmental quality at any given jurisdiction within the nation is variable and depends on the aggregate level of emissions. Because in this case an interjurisdictional externality exists, there is a need for centrally determined emissions standards. In the second case, environmental quality is a Local Public Good, where locally produced emissions only affect the local population. Thus environmental quality is not dependent on aggregate emissions occurring within the whole nation and no interjurisdictional externality exists. In this case, exemplified by local drinking water quality, decentralized standard setting and environmental management is likely to produce more efficient results than a centrally determined uniform national standard. The third case, dubbed Local Spillover Effects, negative external effects of pollution are regional in nature. Acid rain mimics this benchmark case. Here, environmental quality depends on the particular pattern of emissions occurring in all jurisdictions and an interjurisdictional externality exists. According to Oates, both decentralized and central standard setting and management are likely to produce sub-optimal results. However, he contends that, “the efficient

For the case where external effects are local in nature, Oates' model implies that pollution is best managed with decentralized responsibility over standard setting.[8] The environmental federalism literature is rife with criticisms of decentralized environmental standard setting which claim environmental protection will be eroded because of poor local decision-making, arguments referred to as the "race to the bottom". But Oates examines these viewpoints and concludes that, "if there is a race to the bottom, we are left with a choice between two alternatives: suboptimal local decisions on environmental quality or inefficient uniform national standards."[9] Deciding which strategy is better in the event of a race to the bottom is no simple matter, and according to Oates, "[e]mpirical studies of the alternative regimes are needed to shed light on this issue."[10] Because of its potential effect on policy, it is clearly important to develop research that looks at the

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pattern of pollution control will generally imply differing levels of environmental quality across jurisdictions," (p. 5). In addition, Oates offers that a Coasian-style regional cooperation could produce more efficient results in the case of regional spillovers, though, in his view, regional environmental management pacts can be fraught with problems themselves, (p. 19).

[8] It must be noted, however, that Oates still sees an important role for the federal government in instances of decentralized authority, particularly in the areas of environmental science and research, and technical assistance and enforcement, where economies of scale are at work. Also, in the case of drinking water, Dinan et al. (1999) claim, "[g]iven the public good characteristics of research and development, it would probably be most efficient for the federal government to conduct drinking water research," (p. 29).

[9] Oates (2001), p. 9. The race to the bottom argument basically asserts that, in a case of decentralized authority concerning environmental quality, local government officials, in an effort to attract business to their jurisdiction and thus increase employment and expand the tax base, sacrifice environmental quality in the form of lax environmental regulations. Oates examines the theoretical and empirical literature concerning the race to the bottom, and regarding the theoretical literature, results are "inconclusive," (p. 8). Also, Oates offers that measuring the magnitude of distortions resulting from interjurisdictional competition, rather than simply determining the existence of a distortion (as most theoretical models do), is the "important issue," (p. 8). From the empirical literature on the race to the bottom, Oates also finds mixed results and interestingly points out that, Goklany (1999) finds a "race to the top" for some types of air emissions standards prior to federal involvement in air quality regulation.

[10] (ibid). One such study that measures the tradeoffs in social welfare between central and decentralized alternatives is Dinan et al. (1999), "Environmental Federalism: Welfare Losses from Uniform National Drinking Water Standards."

economic outcomes of alternative environmental federalist regimes.[11] However, utilizing the efficient environmental federalist regime to manage environmental quality ostensibly lies not in the hands of economists but largely with lawyers and judges, who have battled fiercely over the federal government's role in a number of environmental issues.

As evidenced by high-profile legal cases, the Clean Air Act (CAA) and the Clean Water Act (CWA) have recently come under fire as compulsory environmental statutes imposed by Washington. One such lawsuit, which challenged the constitutionality of the Environmental Protection Agency (EPA) to regulate air emissions under the CAA, is American Trucking Associations v. EPA.[12] More recent cases challenged CWA prohibitions to the development of wetlands as "takings" of private property.[13] In both

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[11] As Dinan et al. (1999) claim, during the amending process of the Safe Drinking Water Act (SDWA) in 1996, "Congress never deliberated shifting the standard-setting authority under the SDWA from Washington to the 50 state capitals…One [explanation] may be the absence of any evidence on the welfare losses that attend uniform national drinking water standards," (p. 14).

[12] American Trucking Associations v. EPA, 175 F. 3d 1027 (D.C. Cir. 1999). This suit challenged three things: The science of EPA's 1996 proposed revision of the National Ambient Air Quality Standards (NAAQS) on ozone and particulate matter; EPA's lack of consideration of costs when setting the standards; and, most importantly, the constitutionality of EPA's authority to impose tighter standards under the Clean Air Act (CAA). In 1999, the D.C. District Circuit Court of Appeals rejected the first two claims but upheld the third, expressing that the CAA, "effects an unconstitutional delegation of legislative power" to EPA. The decision was appealed to the U.S. Supreme Court and in 2001 the Court confirmed the D.C. Court's rulings on the science and cost considerations, but parted with the D.C. Court by affirming the constitutionality of EPA's authority under the CAA.

[13] The cases are United States v. Rapanos, 126 S. Ct. 2208 (2006), and Carabell v. United States Army Corps of Engineers, 391 F. 3d 704 (6th Cir. 2004). Both cases deal with the filling of wetlands for the purposes of economic development and both cases were consolidated for decision by the Supreme Court. As a basis, "[t]he CWA allows the government to regulate the discharge of any pollutant (including dirt or sand) into "navigable waters," which the Act defines as "the waters of the United States,"" (The OYEZ Project). Based on the language of the CWA, the Court issued a 4-1-4 ruling that remanded the suit back to the Sixth Circuit Court of Appeals and also delivered five separate opinions on the matter. According to Channing J. Martin, the plurality opinion, expressed by Justice Scalia, "held two findings were necessary to establish that the wetlands at issue were covered by the CWA: 'First, that the adjacent water channel [to the wetlands] contains…a relatively permanent body of water connected to traditional interstate navigable waters…and second, that the wetland has a continuous surface connection with that water, making it difficult to determine where the water ends and the wetland begins," (Martin, Trends, p. 14). Justice Kennedy wrote a concurring opinion with the plurality, but disagreed with their assertion that wetlands need a continuous surface connection to 'traditionally navigable waters.' He also provided that mere adjacency does not constitute CWA coverage, though "wetlands that are not adjacent to a traditionally

the CAA and CWA instances, the petitioners sought to limit the effect regulations would have on private conduct. The outcomes, however, were not as favorable to the petitioners as they had likely hoped,[14] and the contentiousness of the CAA and CWA remains no less diminished. Despite the contentiousness of these environmental statutes, environmental federalism theory would predict that interjurisdictional pollution problems should be addressed at the federal level, and locally generated pollution problems at the local level. Thus, theoretical considerations would likely predict that uniform national standards would be appropriate under the CAA, while regional cooperation might best be suited for the CWA.[15] The judicial results of *American Trucking Associations* and *Rapanos* seem logical and predictable from an economist's standpoint. Less logical from an economics standpoint is the new arsenic standard promulgated under the Safe Drinking Water Act (SDWA), where theory predicts that decentralized decision-making would address pollution most efficiently.

B. The New Arsenic Drinking Water Standard

The Safe Drinking Water Act, "was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply," (EPA, SDWA Basic Information, 2006). The "SDWA authorizes [EPA] to set national health-

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navigable water must have a "significant nexus" with one," to imply coverage, (The OYEZ Project). The dissenting opinion, articulated by Justice Stevens, "argued that the Corps's regulations should be upheld as a reasonable interpretation of the Act. The inclusion of all wetlands adjacent to tributaries of navigable waters was most consistent with the CWA's purpose of eliminating pollution in the nation's waters," (The OYEZ Project). At best, wetlands regulation under the CWA is murky, and the recent Supreme Court decision and opinions do little to clarify the intention and scope of the Act.

[14] See notes 12 and 13.

[15] See note 7 for the theory behind this application.

based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water," (EPA, Understanding the SDWA, 2006). These standards are referred to as National Primary Drinking Water Regulations (NPDWRs). Furthermore, the SDWA applies to all public water systems (PWS) in the U.S.[16]

The responsibility for implementing and enforcing the regulations of the SDWA falls to EPA if a state has not applied for and received primacy. State primacy is, "the authority to implement [the] SDWA within their jurisdictions, if [states] can show that they will adopt standards at least as stringent as EPA's and make sure water systems meet these standards," (EPA, Understanding the SDWA, 2006). Only Wyoming and the District of Columbia have not received primacy in the management of the SDWA.

Ensuring safe drinking water is the SDWA's primary objective and it achieves this through source water protection, treatment, distribution system integrity, and public information, (EPA, Understanding the SDWA, 2006). It is tempting to believe that the public would be united behind this simple mandate of ensuring safe drinking water, but the truth is the SDWA is quite controversial. Its most controversial element is the treatment component from the four objectives above, precisely because it relates to the

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[16] A public water system (PWS) is defined as having at least 15 service connections or serving at least 25 people per day for 60 days annually. There are approximately 160,000 PWSs serving customers in the U.S. A PWS can be publicly or privately owned, but the SDWA applies only to systems that satisfy the basic definition of a PWS. In addition to PWSs, there are a number of other classifications of water systems and drinking water standards of SDWA apply to systems differently based on these classifications. A community water system (CWS) is a PWS that serves the public on a year-round basis. There are roughly 54,000 CWSs in the U.S. A non-community water system (NCWS) is a PWS, but does not serve the public on a year-round basis. A non-transient non-community water system (NTNC) is a PWS that serves the public for at least six months of the year, but not year-round. There are roughly 20,000 NTNCs in the U.S. Finally, a transient non-community water system (TNC) has less than 15 service connections or serves fewer than 25 residents for six months or more annually, but not year-round. There are roughly 89,000 TNCs in the U.S. Source: (EPA, Understanding the SDWA, 2006).

standard setting process conducted by EPA for the treatment of contaminants.[17] There are five steps to the setting of an enforceable, health-based standard under the SDWA.[18] The idea of having enforceable, health-based drinking water standards is not controversial in and of itself. What stokes the fire is the benefit-cost considerations that accompany the development of new standards. No other proposed regulation epitomizes this type of controversy over a benefit-cost analysis more than the new arsenic standard.

As part of the 1996 amendments to the Safe Drinking Water Act the Environmental Protection Agency was required to promulgate an updated arsenic standard by January 1, 2001, in order to replace the existing standard of 50 part per billion (ppb) which had been law since 1942, (NRDC, 2000). There were many steps that

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[17] It is essential to note that although 49 of the 50 states have primacy in the implementation and enforcement of SDWA regulations, EPA is given the authority to set the regulatory standards to which states and water systems will be subject.

[18] First, EPA determines whether to regulate a contaminant based on the available science of the health effects of exposure and level of exposure, (EPA, Drinking Water Standards and Health Effects, 2006). Second, EPA sets a maximum contaminant level goal (MCLG), "(the level of a contaminant in drinking water below which there is no known or expected health risk. MCLGs allow for a margin of safety)," which is not enforceable but simply most protective of human health, (ibid). Third, EPA proposes an enforceable maximum contaminant level (MCL), "(the maximum amount of a contaminant allowed in water delivered to a user of any public water system)," which is set as close to the MCLG as feasible, (ibid). Feasible is defined, "as the level that may be achieved with the use of the best technology, treatment techniques, and other means which EPA finds (after examination for efficiency under field conditions) are available, taking cost into consideration, (EPA, Understanding the SDWA, 2006). Following the determination of the MCL, EPA conducts an economic analysis to:

> "determine whether the benefits of that standard justify the costs. If not, EPA may adjust the MCL for a particular class or group of systems to a level that maximizes health risk reduction benefits at a cost that is justified by the benefits. EPA may not adjust the MCL if the benefits justify the costs to large systems and small systems that are unlikely to receive variances," (EPA, Drinking Water Standards and Health Effects, 2006).

Fourth, EPA sets an MCL, considers public comments submitted during the MCL proposal process, and finalizes the new MCL by outlining testing procedures and reporting schedules, (ibid). Last, during the exemption period, states can grant variances and exemptions to small systems (< 3,300 customers) and medium systems (3,301-10,000) can apply for variances or exemptions from EPA, and these systems must install a variance technology prescribed by EPA, (ibid). Variances and exemptions do not apply for microbial MCLs: "After the exemption period expires, the public water system must be in compliance…[and] [t]he terms of variances and exemptions must ensure no unreasonable risk to public health," (ibid).

accompanied this process.[19] Nonetheless, a final rule was issued by EPA that established an enforceable MCL of 10 ppb for all community water systems (CWSs) and non-transient-non-community water systems (NTNCs). Despite being higher than the original MCL proposal of 5 ppb, the new standard of 10 ppb was still met with strong opposition.

Critics attacked the new arsenic standard from all sides. Both EPA benefits and cost estimates for the arsenic rule were sharply criticized.[20] Attacks ranged from faulty science to political agendas. The high compliance costs anticipated by the new standard created such indignation that a lawsuit challenged the constitutionality of EPA's authority to regulate arsenic.[21] Although there appears to be more opposition to the new arsenic standard than not, the stricter standard is not without its defenders.[22] Political agendas aside, the EPA economic analysis for arsenic is less than demonstrative, and an examination of the document demonstrates why its practical implications have frustrated so many.

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[19] EPA originally proposed a new standard of 5 ppb on June 22, 2000 but increased this maximum contaminant level (MCL) to 10 ppb on January 22, 2001, ostensibly due to opposition from water authorities encountered during a requested comment period on alternative MCLs, (EPA, Fact Sheet: Drinking Water Standards for Arsenic, 2001). The effective date for the new standard of 10 ppb was February 22, 2002, and all water systems subject to the final rule (all CWSs and NTNCs) were compelled to comply by January 23, 2006.

[20] See AEI-Brookings Joint Center paper (2001), "EPA's Arsenic Rule: The Benefits of the Standard Do Not Justify the Costs," an American Council on Science and Health position paper (2002), "Arsenic, Drinking Water, and Health," and a National Research Council report (1999), "Arsenic in Drinking Water," for critical analyses of EPA benefits estimates and their application in arsenic rulemaking. For EPA cost critiques, see Frey et al. (1998), "Cost To Utilities of a Lower MCL for Arsenic," and Frey et al. (2000), "Cost Implications of a Lower Arsenic Standard," and Gurian et al. (2001), "Addressing Uncertainty and Conflicting Cost Estimates in Revising the Arsenic MCL." These positions, as well as the EPA economic analysis, are entirely the subject of Chapter 2 of this paper.

[21] Nebraska v. Environmental Protection Agency. The petitioners claimed that the provision of local drinking water was an intrastate matter and thus the arsenic rule and the SDWA are unconstitutional. See note 2 for a more detailed description of the case.

[22] The Natural Resources Defense Council is strongly in favor of the new standard and asserts that a standard lower than 10 ppb is desirable. See NRDC, (2000), "Arsenic and Old Laws," and Richard Wilson, (2001), "Underestimating Arsenic's Risk."

Even though there is considerable concern over the methodologies employed in the estimation of benefits and costs for the arsenic standard,[23] methodologies aside, EPA's final arsenic rule does not pass a quantified benefit-cost test (benefits greater than costs). Even for the alternative MCL scenario of 20 ppb (where compliance costs are lowest) and using the upper bound estimate for benefits, net benefits are still negative. For the MCL scenario of 10 ppb, at which the standard was promulgated, net benefits range from -$66 million to -$7.9 million dollars per year (in 1999 dollars).[24] However, there were substantial "non-quantifiable" benefits of arsenic reduction that EPA believed would make actual benefits exceed costs at the 10 ppb MCL.[25] Hence EPA's decision to finalize the proposal of a new arsenic standard of 10 ppb.

Considering all the debate that has surrounded the arsenic issue it seems appropriate to test the practical implications of the standard. As it turns out, Arizona is the perfect place to conduct a case study analysis of the arsenic issue because of its high incidence and wide geographic distribution of naturally occurring arsenic.

C. Research Objectives

Chapter 1 has laid out the foundations for understanding what is at play in this Arizona arsenic case study analysis: Explaining the ever-changing, controversial federalist legacy in the United States; describing the economic theory of environmental

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[23] These methodological concerns are examined in depth in Chapter 2 of this paper.

[24] U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000.

[25] Quantifiable benefits used in the economic analysis were limited to avoided cases of bladder and lung cancer. Some of the non-quantifiable benefits included avoided cases of skin, kidney, liver, and prostate cancer, and other cardiovascular, pulmonary, neurological, and endocrine effects.

federalism and the court cases that have challenged major environmental statutes; detailing the workings of the Safe Drinking Water Act; and summarizing the EPA benefit-cost analysis for arsenic and underscoring its legal and economic controversy.

Chapter 2 analyzes EPA's benefit-cost analysis for arsenic, focusing mainly on the cost portion, and addresses it in the context of other arsenic cost studies conducted outside EPA. After this in depth examination, the results from these studies will be extrapolated to the Arizona situation to determine whether the new standard is Pareto optimal, or even a potential Pareto improvement (PPI), for Arizona.

Chapter 3 uses statistical tests and econometric techniques to explore the characteristics of Arizona community water systems (CWSs) and non-transient non-community water systems (NTNCs), (herein after simply referred to as public water systems (PWSs) unless otherwise noted). The main objective of this analysis is to verify the presence, or lack thereof, of any statistically significant relationships among affected water systems, non-affected water systems, and between these groups. Furthermore, other descriptive tests are run to get a better sense of the characteristics of Arizona PWSs.

Chapter 4 examines the policy implications that arise from the analyses in chapter 3. These policy implications are discussed in the context of their implementation in Arizona.

Chapter 5 summarizes the findings of the investigation and concludes the research by discussing its contribution to the environmental federalism literature.

II. Arsenic Benefit-Cost Analyses and the Arizona Experience

A. Is the Arsenic Standard a Potential Pareto Improvement for Arizona?

Much of the debate over the new arsenic standard has revolved around the considerable disagreement concerning EPA's benefit-cost analysis used in the establishment of the standard. In order for the new standard to be economically justifiable, it must be a potential Pareto improvement (PPI), which is defined as any positive change in net benefits. Presumably the net benefits of the old standard of 50 ppb were so low that any MCL decrease represented a PPI, considering MCLs of 20, 10, 5 ppb were the only options considered by EPA in its economic analysis.[26] Even though the new arsenic MCL of 10 ppb passed EPA's nationwide benefit-cost test,[27] it is not clear how an MCL of 10 ppb will affect specific states and localities whose water districts have remarkable differences in the cost of treating for arsenic.

While some states, such as Alabama, will have little problem complying with the new standard others, like Arizona and California, will have to spend substantial resources in order to comply. This discrepancy is due not only to the uneven incidence of arsenic occurrence throughout the United States,[28] but also because of the cost variation in

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[26] U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000. As part of the 1996 Safe Drinking Water Act (SDWA) amendments, Congress directed EPA to propose a revised National Primary Drinking Water Regulation (NPDWR) for arsenic. In addition, the 1996 SDWA amendments required EPA to set an MCL, "that is protective of public health while also ensuring that the quantified and non-quantified costs are justified by the quantified and non-quantified benefits of the rule," (ibid). Thus EPA's economic analysis implicitly considered other MCL options as unable to pass a benefit-cost criterion.

[27] The standard did not pass, however, on the quantifiable benefit-cost criterion. Only after non-quantifiable benefits of reducing arsenic were included did it pass a benefit-cost test.

[28] Arsenic is naturally occurring in some geologic formations, though arsenic contamination has anthropomorphic causes as well. The incidence of naturally occurring arsenic is highest in the western

treating drinking water. Table 1 demonstrates the variation in economies of scale at work in the treatment of drinking water. For those households who are part of a large water system with a customer base of greater than 1 million people, the additional cost of receiving drinking water with safer levels of arsenic is less than $1 per year. However, for those households that are served by smaller water systems the additional cost of the new arsenic standard is quite substantial, exceeding $300 per year for the smallest systems. Of the roughly 3,000 community water systems (CWSs) that are likely to have

TABLE 1.

Mean Annual Household Cost of 10 ppb Arsenic MCL

System Size	Cost Per Household
< 100	$326.82
101-500	$162.50
501-1,000	$70.72
1,001-3,300	$58.24
3,301-10,000	$37.31
10,001-50,000	$32.37
50,001-100,000	$24.81
100,001-1,000,000	$20.52
> 1,000,000	$0.86
All Categories	$31.85

Source: EPA “Arsenic in Drinking Water Rule Economic Analysis,” 2000, p. 8-14.

United States. Furthermore, arsenic levels tend to be higher in ground water sources as opposed to surface water. Source: U.S. EPA, 2006. “Arsenic in Drinking Water, Basic Information,” Office of Groundwater and Drinking Water Web Resources. http://www.epa.gov/safewater/arsenic/basicinformation.html (last accessed Feb. 2007).

to take corrective action to lower their arsenic levels,[29] 866 systems serve fewer than 100 customers and 961 serve between 100 and 500 customers.[30] Of the roughly 334 public water systems (PWSs) in Arizona that are expected to take corrective action to lower their arsenic levels, 192 of them serve 500 or fewer customers and 136 of these are CWSs.[31] Furthermore, the 334 Arizona systems expected to take corrective action because of the new arsenic standard represent nearly 10% of nation's total number of systems needing additional treatment, but represent over 30% of all Arizona systems. So, does the new arsenic standard make economic sense from Arizona's perspective?

B. What Does the Theory of Environmental Federalism Predict and What Is the Evidence?

The theory of environmental federalism is concerned with the appropriate division of authority among federal and lower levels of government in environmental management and policymaking. From an economist's standpoint, an appropriate division of authority means maximizing efficiency, or the net benefits of a given environmental policy. Because managing environmental quality is no simple matter, the theory of environmental federalism makes use of economic models to make predictions about how

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[29] U.S. EPA, 2006. "Arsenic in Drinking Water, Basic Information." Office of Groundwater and Drinking Water Web Resources. http://www.epa.gov/safewater/arsenic/basicinformation.html (last accessed Feb. 2007).

[30] U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000, Chapter 8, p. 8, Exhibit 8-3.

[31] Arizona water system data provided by Arizona Department of Environmental Quality, John Calkins, Drinking Water Section Manager.

to efficiently divide responsibility for managing the environment for each of the variety of real world contexts.

Following the benchmark cases set forth by Oates (2001), modeling environmental federalism involves examining the external effects of polluting activities.[32] The first of Oates' three benchmark cases is the Pure Public Good, where the provision of environmental quality is a pure public good. In this case, the level of environmental quality experienced by any given jurisdiction within the larger system is variable and depends on the aggregate level of emissions occurring in the larger system. Because pollution can flow across political boundaries, an interjurisdictional externality exists. Because an interjurisdictional externality exists, there is a need for centrally determined emissions standards because local decision makers have no incentive to bear the added cost of reducing emissions if the health benefits of the reduction accrue largely to the residents outside of its borders. Global warming is a good example of when centrally determined standards would apply.

Oates' second benchmark case is that of a Local Public Good, where locally produced emissions only affect the local population. Here, the level of environmental quality is not dependent on the aggregate level of emissions occurring in the larger system and thus no interjurisdictional externality exists. An efficient solution to local pollution in this case is decentralized standard setting and environmental management. Local drinking water quality is a good example of where decentralized responsibility

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[32] Oates, Wallace E., 2001. "A Reconsideration of Environmental Federalism." *Resources for the Future,* Washington, D.C.

appropriately applies. The Arizona arsenic issue clearly mimics this case and Oates' second benchmark case will be more closely examined in the context of the arsenic standard below.

The third and last benchmark case that Oates sets forth is Local Spillover Effects, where interjurisdictional externality exists but its effects are regional in nature. In this case, the level of environmental quality experienced at a given jurisdiction is not dependent on the aggregate level of emissions occurring in the larger system, but rather on the particular pattern of emissions occurring in all of the jurisdictions. Oates contends that both decentralized and central standard setting and management are likely to produce sub-optimal results, and that "the efficient pattern of pollution control will generally imply differing levels of environmental quality across jurisdictions," (Oates, 5). Rather, Coasian-style regional cooperation could produce more efficient results in the case of regional spillovers, though the record of regional environmental pacts is mixed, (Oates, 19).

Returning to the case of local drinking water quality, which is what the new arsenic standard is addressing, theory would predict that decentralized standard setting is the best candidate for achieving an economically efficient policy result. Two justifications are typically proffered for this proposition. The first reason is that uniform national standards are likely to impose welfare losses on communities with substantial drinking water contamination issues. Because uniform national standards do not reflect the variation in costs of compliance across water districts or the diversity of preferences of consumers for safer drinking water, they generally do not produce the best outcome for cases of environmental pollution where no interjurisdictional externality exists. The second reason decentralized standard setting is likely the most efficient candidate in the case of a local public good is that it allows each jurisdiction to select its own optimal standard thus producing an efficient aggregate result. Indeed jurisdictional standards would vary from one another, but differences in treatment costs and localities' preferences for safe drinking water would be fully reflected in these differentiated standards. A decentralized standard setting approach in the case of the provision of a local public good would minimize the welfare losses that generally attend uniform national standards. Within the economic framework of public goods, the theory of environmental federalism is rather clear on how to deal with different cases of environmental quality, but what about the empirical evidence on the matter?

Currently, there is only one empirical study available in the literature that attempts to measure the welfare losses that attend uniform national standards in the case of the regulation of drinking water. The study, by Dinan et al. (1999), is aptly titled "Environmental Federalism: Welfare Losses for Uniform National Drinking Water Standards."[33] Dinan et al. (1999) "estimate[s] the welfare losses that households might incur under a proposed federal standard for a particular class of pollutant, namely *adjusted gross alpha emitters*."[34] The alpha emitter of interest in the study is polonium-210 and the proposed standard requires that the concentration not exceed 15 picocuries/liter (piC/L). Benefits are measured as cancer cases avoided and the

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[33] Dinan, Terry M., Maureen L. Cropper, and Paul R. Portney. "Environmental Federalism: Welfare Losses from Uniform National Drinking Water Standards." In Environmental and Public Economics: Essays in Honor of Wallace E. Oates, Arvind Panagariya, Paul R. Portney, and Robert M. Schwab eds., pp. 13-31. Cheltenham, U.K.: Edward Elgar, 1999.

[34] ibid. An adjusted gross alpha emitter is an EPA defined class of radioactive isotopes that emit radiation.

conservative assumption of $10 million value of a cancer case avoided is used. Furthermore, the study based per household cost on water system size and the removal efficiency of a reverse osmosis treatment technology. Table 2 summarizes some of the important findings of the Dinan et al. (1999) study.

One major result is that welfare losses (negative net benefits) predominate in the analysis. Only in one case were net benefits actually positive. Moreover, there is considerable variation in the magnitude of welfare losses across system size categories. As you scroll down each column in Table 2 losses become smaller, displaying the vast economies of scale at work in the treatment of drinking water. Concerning the idea of economies of scale, the authors make an important observation, "the SDWA directs the

TABLE 2.

Net Benefits per Household from Remediating polonium- 210 Using the Lowest Removal Efficiency Necessary to Meet the Standard of 15piC/L (dollars/year)					
		Initial Concentration (piC/L)			
	20	25	30	35	50
System Size		Required Removal Efficiency			
Population Served	25%	40%	50%	57%	70%
25-100	-651	-706	-738	-756	-774
101-500	-266	-313	-339	-341	-329
501-1K	-95	-172	-219	-227	-225
1K-3.3K	-85	-128	-153	-156	-147
3.3K-10K	-67	-85	-93	-91	-71
10K-25K	-55	-63	-64	-60	-38
25K-50K	-47	-48	-45	n.a.	n.a.
50K-75K	-45	n.a.	n.a.	n.a.	n.a.
75K-100K	n.a.	n.a.	n.a.	n.a.	n.a.
100K-500K	2	n.a.	n.a.	n.a.	n.a.
500K-1000K	n.a.	n.a.	n.a.	n.a.	n.a.
>1000K	n.a.	n.a.	n.a.	n.a.	n.a.

Notes: Net benefits equal value of household risk reduction minus household cost of treatment.
Source: Dinan et al. (1999), p. 23.

EPA to set standards as close to a zero risk level as is considered affordable to large systems. Given the economies of scale in drinking water treatment, standards that are affordable for large systems are often not affordable for smaller systems," (Dinan et al. 1999, p. 24). This observation is potentially significant in relation to the new arsenic standard because the results of an American Water Works Association Research Foundation (AWWARF) funded case study cost analysis by Frey et al. (2000) was dominated by large system costs, which may render the true national cost of the standard an underestimate.[35]

Based on the theory of environmental federalism and also on some empirical evidence on the welfare losses that can attend uniform national standards for drinking water, before even analyzing data specific to the Arizona arsenic experience, there is certainly some initial skepticism whether the new federal arsenic standard is Pareto optimal or even a potential Pareto improvement (PPI) for Arizona. After briefly referring to some descriptive statistics about the Arizona arsenic experience and examining the health benefits of reducing arsenic in drinking water, the analysis proceeds by taking an in-depth look into EPA's cost analysis, highlighting its differences with the arsenic cost study funded by AWWARF.

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[35] Frey et al. (2000), pp. ES-6 and -7.

C. Review of Benefit and Cost Impacts in Arizona of the Revised Arsenic Standard

The brunt of the impact of the new arsenic standard affects primarily, though not exclusively, small public water systems that serve fewer than 10,000 customers.[36] In addition, western states are hardest hit by the standard with Arizona, Nevada, and California topping the list. In fact, Arizona, the topic of this research, is indeed the hardest hit by the standard in terms of the proportion of state systems expected to have arsenic concentrations exceeding the maximum contaminant level (MCL) of 10 ppb.[37] EPA estimated that roughly 5% of the 54,000 CWSs and roughly 5% of the 20,000 NTNCs would have to take some sort of corrective action to comply with the new standard.[38] In Arizona the impact is more dramatic where roughly 334 Arizona systems need to take corrective action. That number represents roughly 10% of the nation's total number of systems needing to take corrective action and represents one-third of all Arizona PWSs. Furthermore, EPA indicates that nationwide roughly 13 million people served by either a PWS will be affected by the arsenic regulation. In Arizona, almost 4.5 million people will be affected by the new standard. That represents 35% of the national

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[36] U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000

[37] Gurian et al. (2001) lists the top ten states most impacted by the arsenic standard in order of proportion of state systems expected to exceed the 10 ppb MCL as : Arizona, Nevada, Oklahoma, California, Montana, Nebraska, Alaska, New Mexico, North Dakota, and Indiana. Accordingly, these affected systems account for nearly 20% of the total number of CWSs and NTNCs in the U.S. and 62% of the total number of systems expected to exceed the 10 ppb MCL. Note, however, that these percentages reflect the results of the statistical simulations performed by the authors.

[38] U.S. EPA, 2006. "Arsenic in Drinking Water, Basic Information," Office of Groundwater and Drinking Water Web Resources. http://www.epa.gov/safewater/arsenic/basicinformation.html (last accessed Feb. 2007).

population expected to be affected by the standard and 75% of the total Arizona population.[39]

Arizona is clearly hard hit by the standard. Table 3 presents additional descriptive statistics concerning the Arizona experience and Table 4 highlights the distribution of the Arizona impacts according to system size and average arsenic concentration. In Table 3, note the high mean arsenic concentration for the group of Arizona 334 PWSs, as well as the predominance of groundwater as the source water for this group affected systems. Also, in Table 4, note the declining trend in number of systems affected, average arsenic concentration, and maximum arsenic concentration as system size increases.

TABLE 3. Descriptive Statistics of 334 Arizona Public Water Systems (PWSs)

STATISTIC	**MEAN**	**MAX**	**MIN**	**TOTAL**
Arsenic Concentration	21 ppb	144 ppb	9 ppb	NA
Population Served	13,359	1.2 million	25	4,444,826
Source Water Type	NA	NA	NA	Ground = 316 Surface = 18
System Type	NA	NA	NA	CWS = 260 NTNC = 74

Source: ADEQ public water system data. Calculations done by author.
NA: Not applicable.

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[39] Arizona water system data provided by Arizona Department of Environmental Quality, John Calkins, Drinking Water Section Manager. Total Arizona population from U.S. Census Bureau, 2007. “State and County Quick Facts,” http://quickfacts.census.gov/qfd/states/04000.html (last accessed Feb. 2007). National CWS and NTNC system estimates: U.S. EPA, 2006. “Arsenic in Drinking Water, Basic Information,” Office of Groundwater and Drinking Water Web Resources. http://www.epa.gov/safewater/arsenic/basicinformation.html (last accessed Feb. 2007).

TABLE 4. Distribution of System Impacts According to System Size

System Size/ Population Served	25-500	501-3,300	3,301-10,000	10,001-100,000	>100,000
No. of Systems Needing Treatment	192	74	29	31	8
Average Affected EPDS Arsenic Concentration	22.6 ppb	19.5 ppb	17.8 ppb	16.5 ppb	13 ppb
Max Arsenic Concentration	144 ppb	76 ppb	46 ppb	35 ppb	18 ppb

Source: ADEQ public water system data. Calculations done by author.
Note: A system '"needing treatment" does not necessarily mean installing new treatment technology, it simply means that some sort of corrective action will be necessary to reduce arsenic concentrations in their delivered water.

D. Health Benefits of Arsenic Reduction

Generally speaking, the economic benefits of reduced arsenic in drinking water estimated in EPA's economic analysis reflect the health benefits that accrue to society due to fewer non-fatal and fatal cases of cancer that arise due to arsenic exposure.[40] However, "ingestion of inorganic arsenic can result in both cancer and non-cancer health effects," (EPA, 2000 citing NRC (1999)). Though EPA was only able to include the health benefits of avoiding lung and bladder cancer in its quantitative risk assessment of arsenic in drinking water, it did acknowledge that: "it is likely that the estimated benefits

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[40] Specifically, according to EPA, "the value to consumers of a reduction in the risk of adverse health effects [of arsenic exposure] includes the following components: 1) The avoidance of medical costs and productivity loss associated with illness; 2) The avoidance of the pain and suffering associated with illness; 3) The losses associated with risk and uncertainty of morbidity; 4) The reduction in risk of premature mortality." Source: U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000.

associated with avoidance of bladder and lung cancer underestimate the total benefits of a reduction of arsenic in drinking water (EPA, 2000)." This limitation is due to the fact that of all the potential adverse health effects due to arsenic exposure, "current research on arsenic exposure has only been able to define scientifically defensible risks for bladder and lung cancer," (EPA, 2000).

Thus focusing solely on the carcinogenic role of arsenic on the bladder and lungs, EPA conducted a risk assessment for these two forms of cancer. This process involves numerous steps that inevitably must deal with the uncertainty inherent in statistical analysis and the subjectivity with respect to the assumptions employed in the statistical analysis.[41] This uncertainty and subjectivity is addressed more in EPA's sensitivity analysis,[42] but is not the focus of this section. Rather EPA's final estimates for the health benefits of arsenic reduction in drinking water are presented and then compared with the alternative benefits estimates for reducing arsenic in drinking water generated by other authors. Table 5 summarizes EPA's estimated monetized fatal and non-fatal cancer health benefits from reducing arsenic in drinking water.

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[41] First, EPA developed relative exposure factor (REF) distributions based on water consumption surveys. Second, they calculated arsenic occurrence distributions. Third, risk distributions for bladder and lung cancer were selected from Morales et al. (2000). Lastly, EPA combined the first three steps in Monte-Carlo simulations to develop estimates of the projected lung and bladder cancer risks facing consumers. Source: U.S. EPA, "Arsenic in Drinking Water Rule Economic Analysis," Office of Groundwater and Drinking Water, Washington D.C., 2000.

[42] EPA accounts for latency and other adjustments in a sensitivity analysis. See pages 5-26 thru 5-29 of "Arsenic in Drinking Water Rule Economic Analysis," 2000, for these adjustments.

TABLE 5. Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in PWSs ($millions)

Arsenic Level	Annual Bladder Cancer Health Benefits [1,2]	Annual Lung Cancer Health Benefits [1,2]	Total Annual Health Benefits [1,2]	Potential Non-Quantifiable Health Benefits
3	$58.2-$156.4	$155.6-$334.5	$213.8-$490.9	Skin Cancer Liver Cancer Kidney Cancer Prostate Cancer Pulmonary Effects Neuro. Effects Endocrine Effects Reproductive Effects[3]
5	$52.0- $113.3	$139.1-$242.3	$191.1-$355.6	
10	$38.0-$63.0	$101.6-$134.7	$139.6-$197.7	
20	$20.1-$21.5	$46.1-$53.8	$66.2-$75.3	

1 May 1999 dollars.
2 These monetary estimates are based on cancer cases avoided.
3 There are other non-quantifiable benefits that are not included in this list.
Source: EPA "Arsenic in Drinking Water Rule Economic Analysis," 2000.

In addition to the EPA health benefits estimates of reducing arsenic concentrations in drinking water there are alternative benefits estimates that shed a very different light on the economic justification for the arsenic standard. One prominent analysis that presents alternative benefits estimates is a 2001 Joint Center (a collaboration of the American Enterprise Institute and Brookings Institution on regulatory issues) analysis titled, "EPA's Arsenic Rule: The Benefits of the Standard Do Not Justify the Costs," by Jason K. Burnett and Robert W. Hahn, (herein referred to as Burnett and Hahn (2001)). As the title suggests, the authors' analysis leads them to conclude that the arsenic standard is not justifiable on economic grounds. By altering some of the critical assumptions EPA employed in its benefits analysis, Burnett and Hahn (2001) generate quite different estimates of benefits, none of which exceed EPA's cost estimate. Table 6 summarizes their results. The major assumption that Burnett and Hahn (2001) alter in their analysis is the value of a statistical life (VSL).[43] To get a dollar amount for a health benefit, one must first conduct a risk assessment and then multiply the number of expected lives saved by the VSL. In this case, EPA used $6.1 million as their VSL and Burnett and Hahn (2001) altered that estimate because of latency considerations[44] and

<u>TABLE 6.</u> EPA's Arsenic Rule with Different Assumptions

	Lives[1]	**Benefits**	**Costs**	**Net Costs[2]**
EPA's Model without Accounting for Latency	28	\$170 million	\$210 million	\$40 million
EPA's Model Accounting for Latency	28	\$50 million	\$210 million	\$160 million
High Estimate[3]	110	\$200 million	\$210 million	\$10 million
Best Estimate[4]	11	\$23 million	\$210 million	\$190 million
Low Estimate	5.5	\$10 million	\$210 million	\$200 million

1 Statistical lives saved shown here are not discounted for latency.
2 Net costs are costs minus benefits. Numbers may not add owing to rounding.
3 The upper-bound estimate is obtained by taking the EPA's model, including "non-quantifiable" benefits and accounting for latency.
4 Best Estimate includes "non-quantifiable" benefits, accounts for latency, and incorporates a sublinear dose-response function, (i.e. non-linear and convex below the linear function).
Source: Burnett and Hahn (2001), Table 1, pp. 14.

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[43] As EPA and Burnett and Hahn (2001) both note, the value of a statistical life (VSL) is not a measure of the value of a person's life. Rather, it is a willingness-to-pay estimate for a reduction of a health risk.

[44] Latency refers to the lagged health effects due to arsenic exposure. The onset of cancer due to the consumption of carcinogenic substances will be delayed by some amount of time. EPA employed latency periods of 5, 10, and 20 years in their sensitivity analysis, but not in their primary analysis. Burnett and

came up with $1.1 million as their VSL. This alteration accounts for much of the discrepancy between the estimates of Burnett and Hahn (2001) and EPA, though the best estimate in Table 6 employs another change.[45] No matter how you slice it, the salient message of Burnett and Hahn (2001) is that EPA's benefit estimates are too high once latency and the sub-linear does-response relationship between exposure and health effects are realistically taken into account. Further supporting the authors' claim is a position paper by the American Council on Science and Health (ACSH), which thoroughly reviews the recent history of the development of the knowledge of arsenic's health effects. ACSH concludes "that the limitations of the epidemiological data available and the state-of-the-science on the mode-of-action of arsenic toxicity, including cancer, are inadequate to support the conclusion that there are adverse health effects in the United States from arsenic in drinking water at or below the limit of 50 [ppb]," (ACSH, 2002).

Despite such arguments against the existence of a real human health threat due to arsenic exposure in drinking water, one study offers the opposite conclusion, claiming "our analysis suggests that the current standard of 50 [ppb] is associated with a substantial increased risk of cancer and is not sufficiently protective of public health,"

Hahn (2001) addressed the issue of latency in their re-calculation of the VSL by incorporating a 30 year latency period in the estimation of health benefits. This calculation also assumed a 7% discount rate, annual income growth of 1% and an income elasticity of 1%.

[45] Though EPA assumed a linear dose-response relationship between exposure and health effects, a sub-linear relationship has also been cited as a possibility for describing the true relationship (see "Arsenic, Drinking Water, and Health," 2002, an American Council on Science and Health position paper). In the words of Burnett and Hahn (2001), p. 7,

> "We take the EPA's estimate of 28 lives saved, multiply by two to account for "nonquantifiable" benefits, and then divide by five to account for the non-linear dose-response function. Our reasoning is that including "nonquantifiable" risks would increase the lives-saved estimate by some factor between one and four. Conversely, a sublinear risk extrapolation method would reduce the lives-saved estimate by some factor between one and ten."

(Morales, et al. 2000). In addition to the conclusion of Morales et al. (2000), Wilson (2001) argues that, “A number of recent studies have indicated a potential link between low-level arsenic ingestion by humans and cancers of the bladder, kidney, and lung. What is more, Australian researchers have announced that they had induced mice to develop cancer using small doses of arsenic.” Thus the belief that arsenic follows a sub-linear dose-response relationship, as is fundamental to health benefits calculations of Burnett and Hahn (2001), is also being confronted by scientific opposition in the same way Burnett and Hahn (2001) contested the linear relationship.

It appears there is too much scientific uncertainty surrounding this issue to answer the question of what the actual monetized health benefits of reducing arsenic are. So, given the scientific ambiguity concerning the dose-response relationship of arsenic exposure and its carcinogenic health effects, it is hard to support any one side of the argument with any sort of confidence. This lack of confidence concerning the benefits estimates of the arsenic standard leads this research to examine more closely the cost implications of the standard in order to determine if the standard is a potential Pareto improvement (PPI).

E. Analysis of Two Cost Studies and a Critique Study

This portion of the research examines EPA’s cost analysis used in its economic analysis of the arsenic standard and also looks closely at an American Water Works Association Research Foundation (AWWARF) funded project by Frey et al. (1999) titled “Cost Implications of a Lower Arsenic MCL.” First, these two analyses are scrutinized in the context of another arsenic cost study by Gurian et al. (2001), titled "Addressing Uncertainty and Conflicting Cost Estimates in Revising the Arsenic MCL." After looking generally at the discrepancies between the EPA and AWWARF results with the help of Gurian et al. (2001), the two cost studies are then examined in greater detail. Finally, an attempt is made to determine if the arsenic standard qualifies as a PPI, given what we know about monetized health benefits estimates.

Comparison of Cost Studies

When comparing the EPA cost analysis with AWWARF's cost analysis, the most striking difference is the cost estimates themselves, since AWWARF's estimates are several times higher for most of the MCLs targeted in the analysis. Table 7 presents the baseline annual national cost estimates from both EPA and AWWARF for selected target MCLs. Notice the large discrepancies in cost, especially for the 10 ppb MCL at which the final rule was promulgated.

Interestingly, despite producing a cost nearly 2.5 times that of EPA's for the 10 ppb MCL, the AWWARF study asserts that, "the national compliance [baseline] costs estimated in this study for arsenic MCLs at and above 10 [ppb] might be overly conservative," (Frey et al. (2000), pp. ES-6,7). This is due to the very large system case study results that were a component of their analysis.[46] Consequently, Frey et al. (2000)

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[46] Frey et al. (2000) "investigated the feasibility and cost of implementing arsenic control technologies at six very large [serve >100,000 customers] groundwater systems," (p. ES-5). These case studies helped to inform the study's original baseline national compliance cost estimates. One of the "lessons learned" from the case studies was the effect that the Residuals Influenced analysis (fully integrating residual handling and disposal issues into the analysis) had on the national baseline compliance cost estimates. As mentioned above in the body of the text, national baseline cost estimates may be overly conservative for MCLs of 10

include a separate estimate taking residuals handling and disposal issues into account (i.e., assuming residuals cannot be discharged directly into a sewer system and must undergo further costly treatment) and come up with an annual national cost of $605 million for an MCL of 10 ppb. This estimate is nearly three-fold the EPA estimate of $205 million annually (EPA assumes residuals can be discharged directly into a sewer system). As Gurian et al. (2001) notes, "[t]hus, this single factor may contribute greatly to explaining the discrepancies in the EPA and AWWARF studies," (p. B-3). The authors go on to remark, "[t]o resolve these differences one would have to determine the acceptability of the sewer discharge of the [residual] brine," (ibid).

TABLE 7. Comparison of EPA and AWWARF Baseline Annual National Cost Estimates at Selected Maximum Contaminant Levels ($ millions).

MCL (ppb)	EPA	AWWARF
3	$792	$2,645
5	$472	$1,255
10	$205	$495
20	$77	$135

Estimates are in 1999 dollars.
Sources: EPA "Arsenic in Drinking Water Rule Economic Analysis," 2000, Exhibit 6-10, p. 6-28; AWWARF "Cost Implications of a Lower Arsenic MCL," 2000, Table ES.2, p. ES-4.

In addition to their insightful critique of the EPA and AWWARF cost analyses, Gurian et al. (2001) make a unique contribution to the debate on cost by performing their

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ppb and greater. See Frey et al. (2000) "Cost Implications of a Lower Arsenic MCL," American Water Works Research Foundation, Denver, CO, for more on "lessons learned" from the case study evaluations.

own analysis. Their analysis produces a cost estimate of nearly $300 million per year for an MCL of 10 ppb. This estimate represents an intermediate value between the EPA and AWWARF results. Aside from the cost estimate, what is particularly unique about the Gurian et al. (2001) analysis is that the authors modify their costing model to utilize the EPA cost curves, as well as the AWWARF cost curves, in order to assess the relative impact of those cost curves on the national cost estimates. When their model was run using EPA's cost curves their results resembled those of EPA's. Similarly, when the model was run using the AWWARF cost curves, results similar to AWWARF's were obtained. Thus, Gurian et al. (2001) were led to conclude that the differences in the cost curves were likely the primary source of the large discrepancy in national cost estimates published by EPA and AWWARF.

F. Efficiency Implications for Arizona

Given that the results of the three cost analyses differ by orders of magnitude, it is hard to determine which of the three most likely approximates the true national cost of the arsenic standard. The results of all three can seem quite reasonable under their respective sets of assumptions. Consequently, it is nearly impossible to determine if the new arsenic standard is a potential Pareto improvement (PPI) for Arizona given the variation in published benefit and cost estimates for the standard. For example, if we were to use EPA's benefit estimate and apply it to the affected Arizona population we obtain an annual benefit to Arizona of nearly $60 million. Applying a similar logic for cost, since the number of affected systems in Arizona represents roughly 10% of the nation's total and EPA's national cost estimate is $210 million annually, then Arizona would face an annual cost of roughly $21 million. Comparing the benefits with the costs, the new standard would clearly be a PPI for Arizona.

However, if benefits estimates are left unchanged and the case study results from AWWARF's cost study for three principal Arizona cities, (i.e., Phoenix, Tucson, and Scottsdale) are used then the outcome is quite different. Aggregating the systems costs for those three Arizona cities yields an annual cost of roughly $170 million, clearly disqualifying the new standard as a PPI. Another method might be to take the percentage of AWWARF's national cost attributed to Arizona cost ($170/$605 = 28%) and use this percentage to calculate the proportion of EPA national cost due to Arizona cost ($210 x 28% = $59). By this method, the new standard just barely qualifies as a PPI (benefits = $60 million, cost = $59 million). Additional ambiguity is introduced when the benefit estimates of Burnett and Hahn (2000) and those implied by the American Council on Science and Health are incorporated into the net benefit calculations.[47]

The purpose of all these "what-if" scenarios is not to actually determine with precision whether the new arsenic standard is a PPI, but rather to acknowledge the high degree of uncertainty and ambiguity within the arsenic health benefits and cost literature. The true economic efficiency of the new standard may not be known for many years, and even then benefits and cost numbers might still be highly debatable. However, despite the ambiguity in estimates one thing is still clear: Arizona is particularly affected by the

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[47] The American Council on Science and Health implied that health benefits of regulating at an MCL below 50 ppb could be negligible in their conclusion, "that the limitations of the epidemiological data available and the state-of-the-science on the mode-of-action of arsenic toxicity, including cancer, are inadequate to support the conclusion that there are adverse health effects in the United States from arsenic in drinking water at or below the limit of 50 [ppb]," (ACSH, 2002).

new standard because of its high incidence and wide distribution of naturally occurring arsenic. The objective of this research, however, is not to clarify which study’s results are likely closest to the truth. Thus, instead of going into a deeper analysis of the methods and data used in these three cost analyses to make such a determination, the aim is to make a general determination of the impact to Arizona of the new standard. As Gurian et al. (2001) affirm, “[t]he costs of implementing a lower MCL are subject to debate but will clearly be significant,” (p. 4414).

The following chapter of this research will focus on the nature and characteristics of Arizona public water systems (PWSs), particularly those PWSs that are known to have to take some form of corrective action to deal with elevated arsenic levels. This section will attempt to determine if the group of 334 systems known to have average arsenic concentrations of 10 ppb or greater exhibits statistically significant features that set it apart from the larger group of 1006 Arizona PWSs. Furthermore, a group of 24 PWSs that are known to have violated the previous arsenic standard of 50 ppb will be compared with the group of 334 that are currently at or in excess of the 10 ppb MCL to determine any statistically significant characteristics of the systems that contribute to arsenic MCL exceedance.

III. Impacts of the Revised Arsenic Standard on Arizona Public Water Systems

A. Introduction

This chapter evaluates the impacts on Arizona public water systems (PWSs) attributable to the new arsenic maximum contaminant level (MCL) of 10 ppb. Although the arsenic standard only affects roughly five percent of the nation's total number of PWSs, over 30 percent of Arizona PWSs are affected by the new standard. Due to the disproportionate impact of the arsenic standard on Arizona water systems, it seems reasonable to suspect that there may be a disproportionate distribution of impact within Arizona systems relative to their size, ownership, system type (CWS or NTNC), and water source type. By examining affected and non-affected Arizona PWSs in more detail, any systematic bias resulting from the revised arsenic standard can be identified and evaluated.[48] The existence of disproportionate impacts among Arizona systems can, in turn, suggest policy initiatives that can facilitate the implementation of the revised arsenic standard with its concomitant health benefits.

The following chapter is organized into five parts. The first part introduces the entire population of Arizona PWSs (affected and non-affected), as well as the affected group of PWSs, and describes them in terms of their system characteristics. How are size, ownership, system type (CWS or NTNC), and water source type distributed among this group? Is the affected group systematically different from the entire population of

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[48] The term affected PWSs refers to systems with any entry points to the distribution system (EPDS) with arsenic concentrations of 9 ppb or greater.

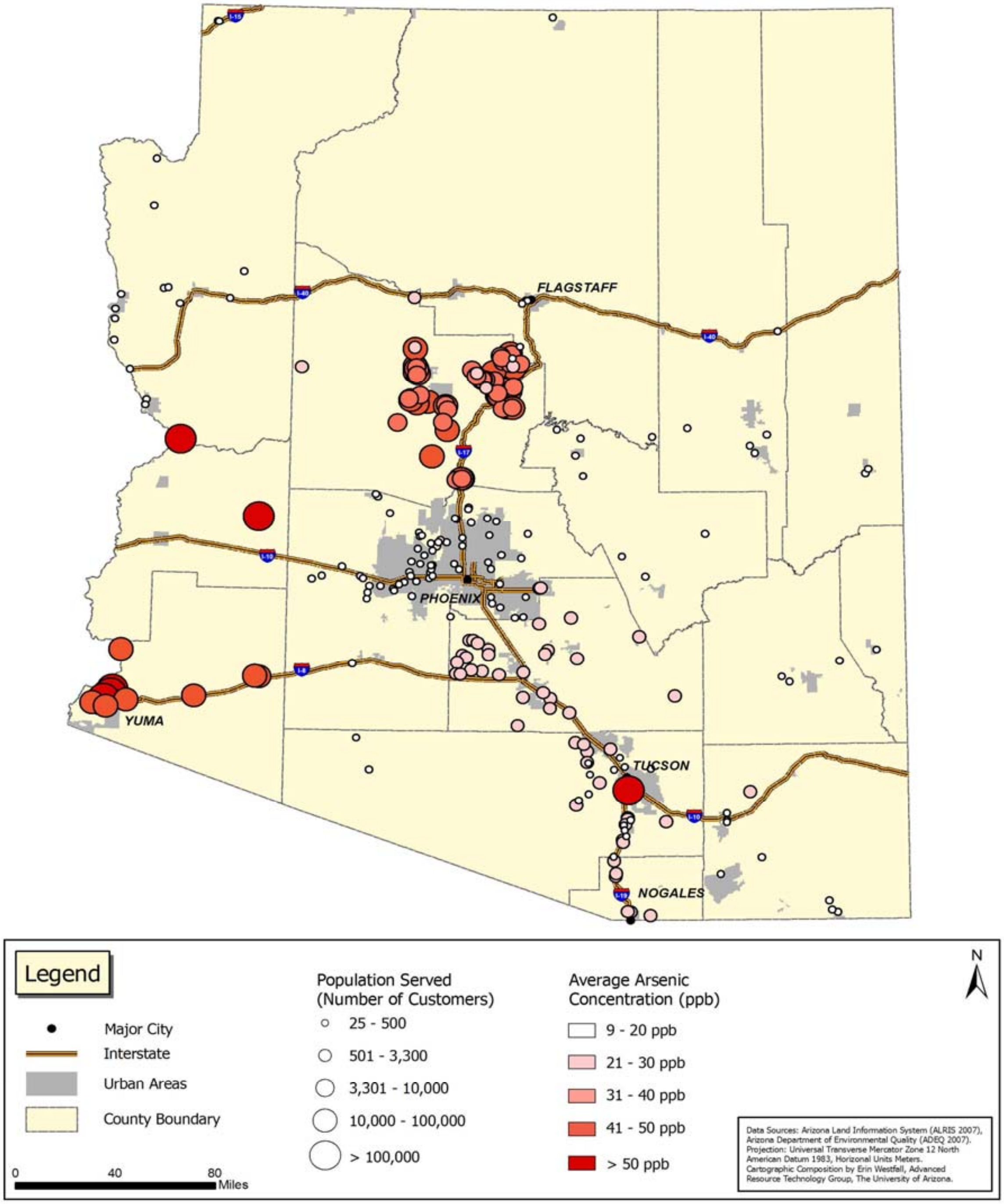
PWSs? What questions arise from this comparison and what testable hypotheses can be generated? Part two tests the hypotheses generated in part one using t-tests and discusses the results. Part three discusses the data, and models and methods used in the econometric analysis of this chapter. Where did the data come from? What form is it in? What models are appropriate for examining PWS characteristics? How will the estimation process occur? Part four presents the regression results from part three. What statistically significant results were found? How should the results be interpreted?

B. General Description of Entire Population of Arizona Public Water Systems and the Group Affected by the Arsenic Standard

There are 1006 active PWSs in Arizona. In order to analyze the impact of the revised arsenic standard in Arizona, it is necessary to distinguish characteristics unique to PWSs. There are a variety of water system characteristics that can be used to distinguish systems and these attributes can also be used to explain phenomena related to PWSs. These attributes are system size (population served), ownership (private, public, mixed), community status (CWS or NTNC), water source type (groundwater or surface water), and arsenic incidence.

Primarily, this research is interested in differentiating PWSs by arsenic incidence. An illustrative and useful way of introducing the affected group of Arizona PWSs is to display a map that shows the geographic distribution of PWSs throughout the state, how many customers they serve (system size), as well as the average EPDS arsenic

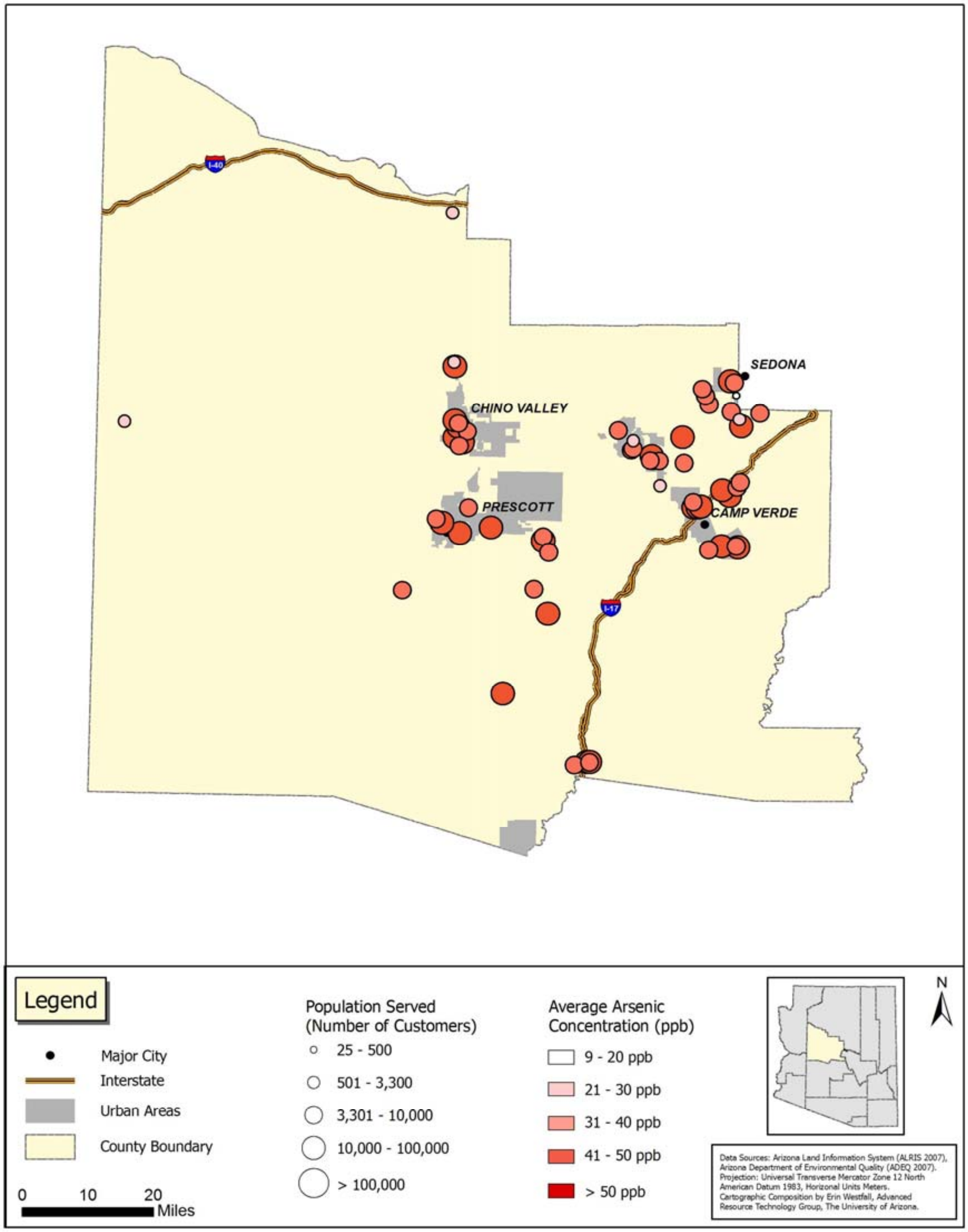
Figure 1. Geographic Distribution of Arizona CWSs, Their Population Served, and Their Average Affected EPDS Arsenic Concentrations in Arizona



Data Sources: Arizona Land Information System (ALRIS 2007), Arizona Department of Environmental Quality (ADEQ 2007). Projection: Universal Transverse Mercator Zone 12 North American Datum 1983, Horizonal Units Meters. Cartographic Composition by Erin Westfall, Advanced Resource Technology Group, The University of Arizona.

Notice the cluster of very small systems (serve 25-500) with average affected EPDS arsenic concentrations between 9-20 ppb in the urban area surrounding Phoenix in Maricopa county. Also notice the clusters of medium (serve 3,301-10,000) and large (10,001-100,000) systems with average affected EPDS arsenic concentrations of 41-50 ppb and >50 ppb in Yavapai county, north of Maricopa county.

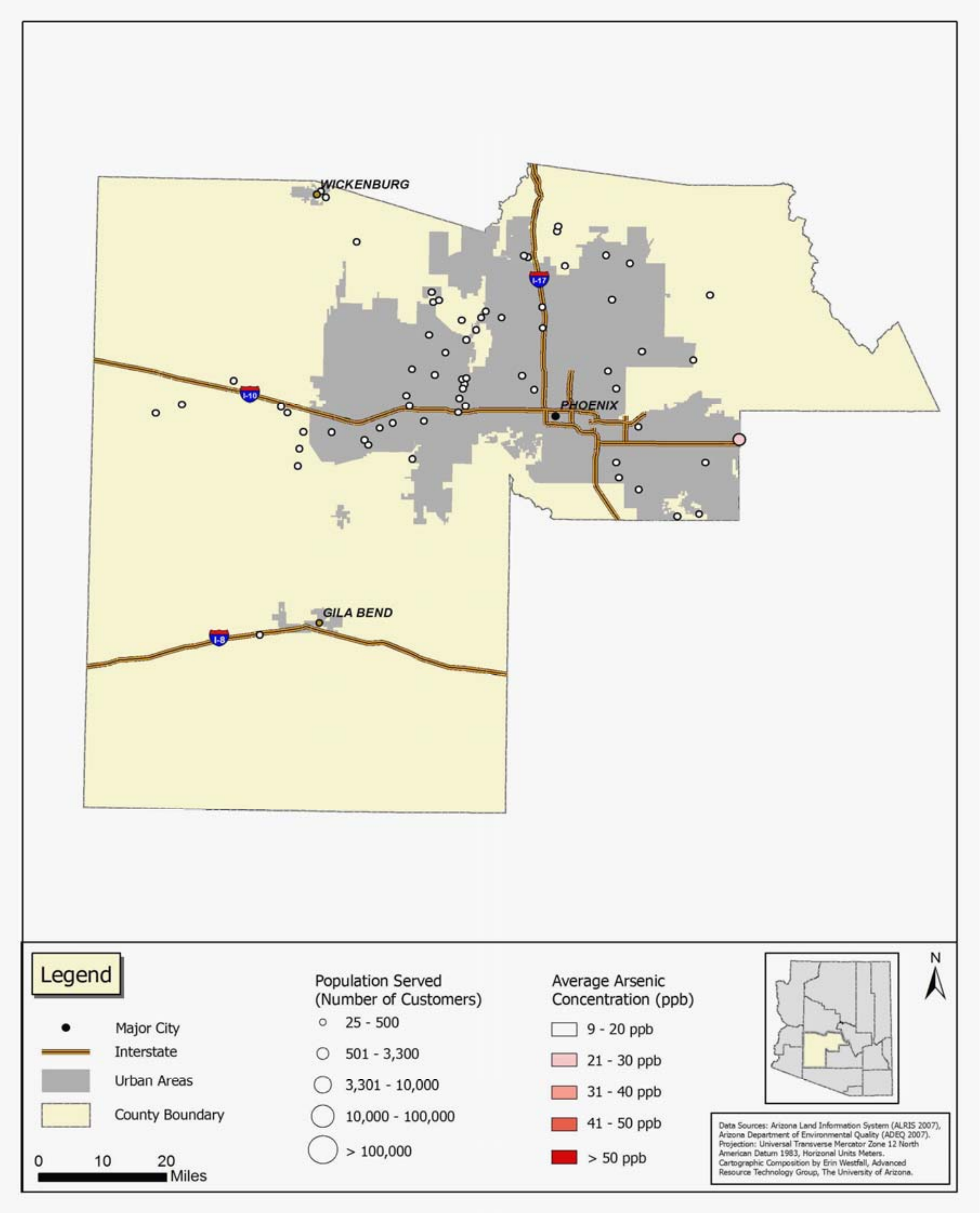
Figure 2. Geographic Distribution of Yavapai County CWSs, Their Population Served, and Their Average Affected EPDS Arsenic Concentrations



Data Sources: Arizona Land Information System (ALRIS 2007), Arizona Department of Environmental Quality (ADEQ 2007). Projection: Universal Transverse Mercator Zone 12 North American Datum 1983, Horizonal Units Meters. Cartographic Composition by Erin Westfall, Advanced Resource Technology Group, The University of Arizona.

There are 59 CWSs with average affected EPDS arsenic concentrations of 9 ppb or greater in Yavapai county. Affected systems are clearly clustered in the five areas with higher population density.

Figure 3. Geographic Distribution of Maricopa County CWSs, Their Population Served, and Their Average Affected EPDS Arsenic Concentrations



Data Sources: Arizona Land Information System (ALRIS 2007), Arizona Department of Environmental Quality (ADEQ 2007). Projection: Universal Transverse Mercator Zone 12 North American Datum 1983, Horizonal Units Meters. Cartographic Composition by Erin Westfall, Advanced Resource Technology Group, The University of Arizona.

There are 67 CWSs in Maricopa county with average affected EPDS arsenic concentrations of 9 ppb or greater. Most all are either located in an urban environment with higher population density or along an interstate highway. Interestingly, despite the large number of affected CWSs Maricopa county, all but one system are very small (serve 25-500) and all but three have average affected EPDS arsenic concentrations between 9-20 ppb.

concentrations of those PWSs. This generates a spatial understanding of the impact of the arsenic standard in Arizona.

Figure 1 shows the distribution of CWSs throughout the state, as well as their average affected EPDS arsenic concentrations (spatial data for NTNCs were not available). Figures 2 and 3 are zoomed portions of Figure 6 representing Yavapai and Maricopa counties respectively. They similarly show the geographic distribution of CWSs, their population served, and average affected EPDS arsenic concentrations.

Examination of Figures 1, 2, and 3 reveals some relationships that raise questions. The most prominent relationship warranting further examination is how the population served (size) of a system relates to its average affected EPDS arsenic concentration. Are smaller systems more likely to exceed the new arsenic standard? Are large systems more likely to exceed?

Also, what is the relationship between geographic location and MCL exceedance? Do systems in Yavapai and Maricopa counties tend to exceed the arsenic MCL more than systems in other counties?

Figures 1, 2, and 3 help give a spatial sense of the incidence of arsenic in Arizona and also help to identify some of the relationships between the average affected EPDS arsenic concentrations and water system attributes that warrant further examination. The following portion of this section evaluates the general characteristics of the affected group of Arizona PWSs.

In addition to knowing how arsenic incidence is distributed among the entire population of Arizona PWSs, it is important to describe this group in terms of general

Table 8. Public Water Systems in Arizona

			Group		
			All PWSs (1,006)	**Affected PWSs (334)**	**Non-Affected PWSs (672)**
System Characteristics	**Avg. EPDS Arsenic Concentration**	**<9**	67% (672)	0% (0)	100% (672)
		≥9	31% (317)	95% (317)	0% (0)
		>50	2% (17)	5% (17)	0% (0)
	System Size	**Very Small (25-500)**	64.3% (647)	57.5% (192)	67.7% (455)
		Small (501-3,300)	23.2% (233)	22.2% (74)	23.6% (159)
		Medium (3,301-10,000)	6.6% (66)	8.7% (29)	5.5% (37)
		Large (10,001-100,000)	5.2% (52)	9.3% (31)	3.1% (21)
		Very Large (>100,000)	0.8% (8)	2.4% (8)	0% (0)
	Ownership Type	**Private**	50% (503)	52% (174)	49% (329)
		Public	19% (191)	20% (67)	18.4% (124)
		Mixed	31% (312)	28% (94)	32.5% (218)
	System Type	**CWS**	79% (795)	78% (261)	79.5% (534)
		NTNC	21% (211)	22% (73)	20.5% (138)
	Water Source	**GW**	93% (936)	95% (317)	92.1% (619)
		SW	7% (70)	5% (17)	7.9% (53)

water system characteristics. By differentiating the entire group of PWSs by system characteristics it will be possible to detect any disproportionate effects of the revised arsenic standard on the group of affected PWSs.

Table 8 shows the percentage of Arizona PWSs from the group of 1006 systems that have an arsenic issue, defined as the average arsenic concentration of systems' EPDSs with arsenic levels of 9 ppb or greater. One-third of all PWSs in the state have an arsenic issue based on this definition.

An important characteristic of water systems is their system size, or the number of customers they serve. Table 8 shows the distribution of system size categories within the entire group of 1006 Arizona PWSs, as well as within the affected and non-affected groups. Notice the predominance of very small and small systems. These two size categories account for 87% of the entire population of PWSs. If it is hypothesized that the revised arsenic standard produces no disproportionate impact on either small or large water systems, then it is expected that a similar proportion of very small and small systems will be impacted among the group of affected systems (i.e., roughly 87%).

Examining the affected PWS column in Table 8 shows that very small and small systems account for about 80% of the total number of affected Arizona systems, and large and very large systems account for about 12% of the total number of affected systems. In order for there to be a disproportionate impact on systems based on their size category, the proportion of systems within a size category must increase in the group of contaminated systems relative to the entire population of systems. Based on this simple criterion, very small and small systems are not disproportionately affected by the revised arsenic standard, but large and very large systems are disproportionately impacted. The proportion of affected systems that are large and very large is twice the proportion of those systems in the entire group (12% to 6%) and all eight very large systems are part of the affected group of PWSs. This is a major result that generates the testable hypothesis of a systematic bias with respect to system size, specifically larger systems (serve > 10,000). This hypothesis will be tested using a t-test to verify its statistical significance.

Another descriptive characteristic of water systems is their ownership type, i.e., whether they are privately or publicly owned and operated. In Arizona, a PWS can either have private, public, or mixed ownership status.[49] Table 8 displays the distribution of ownership among the entire population of Arizona PWSs. Roughly half of all Arizona PWSs are privately owned and operated, one-fifth are publicly owned and operated (i.e., municipal systems), and nearly one-third have a mixed ownership status (unclear ownership). Again, if it is hypothesized that the revised arsenic standard produces no systematic bias, then it is expected that a similar proportion of ownership types will accompany the group of contaminated systems. Examining the affected PWS column of Table 8 shows the distribution of ownership type among the group of affected PWSs, which reveals no disproportionate impact on affected systems with respect to ownership type attributable to the revised arsenic standard. The same proportions of private, public, and mixed ownership hold for the affected group as for the entire group of Arizona

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[49] CWSs and NTNCs are assigned an ownership code of mixed by the Arizona Department of Environmental Quality (ADEQ) if ADEQ has not received information that has clearly defined a system's ownership, (John Calkins, pers. comm.).

PWSs. Despite the anticipation of no disproportionate impact with respect to ownership type, a t-test will be conducted to verify this hypothesis.

The water system characteristic of system type describes PWSs as either a community water system (CWS) or a non-transient non-community system (NTNC). CWSs and NTNCs are the subject of this research because they are the two types of PWSs that are targeted by the revised arsenic standard. Both system types serve at least 25 people or 15 service connections, but CWSs serve their customers on a year-round basis and NTNCs serve their customers for more than six months of the year, but not year-round. Table 8 shows the distribution of system type among the entire population of Arizona PWSs. Roughly 80% of all Arizona PWSs are CWSs and 20% NTNCs. As with the previous characteristics of system size and ownership type, it is expected that there should be a similar proportion of PWSs among the affected group of systems if there no is systematic bias inherent in the revised arsenic standard. Examining Table 8 shows that the distribution of system type among the group of affected Arizona systems is very similar to the distribution among all Arizona PWSs. Roughly four-fifths of affected systems are CWSs and one-fifth NTNCs. This comparison reveals no apparent disproportionate impact. Nonetheless, like the previous ownership case, a t-test will be conducted to verify the hypothesis of no disproportionate impact attributable to the revised arsenic standard with respect to system type.

The last important attribute that can be used to distinguish among water systems is the type of source water they use for their operation. There are two types of source water that a system can use: groundwater or surface water. Specifically, systems that use groundwater are of particular importance to this study because arsenic's occurrence and concentration is much higher in groundwater than in surface water.[50] Table 8 shows the distribution of water source type among the entire population of Arizona PWSs. 93% of all Arizona PWSs are classified as using groundwater with the remaining 7% being surface water systems. Groundwater systems clearly dominate this distribution and it is expected that this proportion would hold for the affected group of systems, otherwise the revised arsenic standard disproportionately affects PWSs based on their water source.

Table 8 shows the distribution of water source type for the group of affected PWSs. Notice the predominance of groundwater as the source type for these affected systems. Comparing this distribution with the distribution for all Arizona PWSs, it is clear that the ratios of groundwater to surface water are very similar between both the contaminated and total group of Arizona CWSs and NTNCs, 95%/5% and 93%/7% respectively. Despite the lack of convincing evidence, a t-test will be conducted for the hypothesis of no disproportionate impact attributable to the revised arsenic standard with respect to source water type.

In summary, this section has compared the group of affected PWSs with the entire group of Arizona PWSs with respect to their system characteristics in order to generally determine if the revised arsenic standard disproportionately impacted the affected group. Preliminarily, it is suspected that there is no disproportionate impact on the affected

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[50] Arsenic levels tend to be higher in ground water sources as opposed to surface water. Source: U.S. EPA, 2006. "Arsenic in Drinking Water, Basic Information," Office of Groundwater and Drinking Water Web Resources. http://www.epa.gov/safewater/arsenic/basicinformation.html (last accessed Feb. 2007).

group with respect to ownership type, system type, or source water type. However, with respect to system size, there is evidence that suggests larger systems are disproportionately impacted by the revised arsenic standard. The following section tests the hypothesis of no systematic bias with respect to each of the four water system characteristics described in this section using t-tests. A summary of the results is reported and important findings are discussed in terms of their policy implications.

C. Results of Tests for Disproportionate Impacts of the Revised Arsenic Standard

This section reports the results of tests of the hypothesis that the revised arsenic standard produces no systematic bias among the contaminated group of Arizona PWSs. If there is no systematic bias produced by the revised standard it means that there is no disproportionate impact on the group of contaminated PWSs.

The first test examines systematic bias with respect to system size (customers served). This is accomplished with a two-sample t-test for equal means. Is the average number of customers of the affected group of systems the same as the average number of customers for the non-affected group? Thus, Hypothesis 1 is: $\mu_1 = \mu_2$, where μ_1= the average number of customers served by the affected group of systems and μ_2= the average number of customers served by the non-affected group of systems.

The second test examines systematic bias with respect to ownership type. This is accomplished with a t-test estimating the difference between proportions. Is the proportion of affected private systems the same as the proportion of affected public systems? Thus, Hypothesis 2 is: $\theta_1 = \theta_2$, where θ_1= the proportion of affected private systems and θ_2= the proportion of affected public systems.

The third test examines systematic bias with respect to system type. This is accomplished with a t-test estimating the difference between proportions. Is the proportion of affected CWSs the same as the proportion of affected NTNCs?
Thus, Hypothesis 3 is: $\delta_1 = \delta_1$, where δ_1= the proportion of affected CWSs and δ_2= the proportion of contaminated NTNCs. Table 9 presents the results of the tests for disproportionate impact.

Because there is such little variation in water source type for both the affected and non-affected groups there is no reason to test for systematic bias with respect to this water systems characteristic. Arsenic contamination is largely a groundwater issue.

Table 9 . Results of Tests for Disproportionate Impact

Hypothesis	Test-Statistic	Decision	Implication
H_1: $\mu_1 = \mu_2$ (System Size)	$t = 3.705$ $t_{(0.05,\ 1004)} = 1.64$	Reject H_1:	Revised Arsenic Standard Disproportionately Impacts Larger Systems
H_2: $\theta_1 = \theta_2$ (Ownership Type)	$z = 0.0926$ $z_{(0.05)} = 1.96$	Fail to reject H_2:	Revised Arsenic Standard Does Not Disproportionately Impact Private or Public Systems
H_3: $\delta_1 = \delta_2$ (System Type)	$z = -.06453$ $z_{(0.05)} = 1.96$	Fail to reject H_3:	Revised Arsenic Standard Does Not Disproportionately Impact CWSs or NTNCs

Examining Table 9 reveals that the tests of disproportionate impact with respect to ownership type and system type are insignificant, which implies that the revised arsenic standard does not disproportionately impact Arizona PWSs based on ownership or system type. However, with respect to system size, the test for systematic bias was significant. It was determined that the average number of customers served by affected systems was larger than the average number of customers served by non-affected systems, which implies that the revised arsenic standard disproportionately affects larger systems. This result may have important policy implications.

Previous research by Rahman et al. (2007) has shown that, in line with the findings of Botelho et al. (2005), larger public water systems (PWSs) have a higher probability of violating MCL regulations, as opposed to smaller PWSs.[51] According to Rahman et al. (2007), a possible explanation for this is that larger systems have larger or greater numbers of wells, which may lead to complexities in the management of wells.[52] Thus with respect to the findings in this analysis, that larger systems are disproportionately impacted by the revised arsenic standard raises legitimate concerns, considering previous research has shown that larger systems are more likely to violate MCL regulations in general. Furthermore, because larger systems serve to greater numbers of people there are greater health consequences of larger systems not meeting MCL standards.[53] Therefore, because larger systems are disproportionately impacted by the revised arsenic standard, there are important policy implications that merit more attention in the policy chapter of this research.

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[51] Rahman et al. (2007), Working Paper.
[52] ibid.
[53] ibid.

D. Econometric Evaluation of System Differences

The results of these tests for systematic bias are suggestive of some things (mainly that larger water systems are disproportionately affected by the new standard) that warrant further investigation. To further explore disproportionate impacts, it is useful to examine the characteristics of Arizona PWSs using an econometric analysis to verify the accuracy of the t-test results and potentially demonstrate other significant relationships between water system characteristics and the revised arsenic standard. The next section discusses the data used in the econometric estimation, followed by the model and methods employed in the estimation.

Data. The data used for the econometric analysis of this research was obtained from the Drinking Water Section of the Arizona Department of Environmental Quality (ADEQ) and closely resembles the data previously introduced in the preceding sections. ADEQ is charged with administering and enforcing the arsenic standard in Arizona and thus compiles data relevant to the compliance of the arsenic standard. The data was received in April 2006.

The data set for this analysis is a cross-sectional dataset of 1006 observations that represent unique Arizona PWSs. Observations in the data set are arranged by ADEQ system identification numbers. Corresponding to each unique system were a set of variables describing the characteristics of water systems, such as ownership type (public, private, mixed), water system type (community, non-transient non-community), service population (number of customers served), water source type (groundwater or otherwise), historical arsenic violation (either affirmative or negative) and average affected EPDS arsenic concentration. Average affected EPDS arsenic concentrations for each unique system were calculated by averaging the samples of affected EPDS arsenic concentrations of 9 ppb or greater for each system.[54] All other variables were given in the data received from ADEQ.

Variables Definitions and Descriptive Statistics. The cross sectional data described in the previous paragraph can be used to distinguish unique PWSs from one another. Each variable is an attribute of a PWS. These attributes can be used to explain phenomena related to PWSs. The explanatory variables used in this research are ownership type, water system type, service population, water source type, historical arsenic violation, and average affected EPDS arsenic concentration. Each variable is described below.

Ownership Type. ADEQ keeps a record of the form of ownership that accompanies a PWS. There are three types of ownership: private, public, and mixed. The most predominant form of ownership among the 1006 PWSs in the state is private ownership, accounting for 50% of systems. A private system is a water system owned and operated by a private entity. Privately owned systems in this study are still subject to the requirements of the Safe Drinking Water Act (SDWA) and thus the arsenic standard. Publicly owned systems account for 19% of the total number of CWSs and NTNCs

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[54] In cases where only one EPDS of a given water system had an arsenic concentration sample of 9 ppb or greater the value of that lone sample was used.

operating in the state. A publicly owned system is one which is owned and operated by the federal, state, or local government. Mixed ownership systems account for 31% of the total and it refers to systems whose ownership, according to ADEQ, is not well defined.[55] By including an ownership variable in our econometric estimation it will be possible to test the hypothesis of whether privately or publicly owned water systems are more likely to exceed the arsenic MCL of 10 ppb.

Water System Type. This study refers to community water systems (CWSs) and non-transient non-community water systems (NTNCs) as simply public water systems (PWSs). Both types of water systems fall under the definitional umbrella of a PWS. A PWS is defined as having at least 15 service connections or serving at least 25 people per day for at least 60 days annually. A CWS is a PWS that serves the public on a year-round basis. Water systems that serve to residential areas are examples of CWSs. An NTNC is also a PWS, but one that serves the public for at least six months of the year, but not year-round. Examples of NTNCs are schools and churches.

For the purpose of this research it is important to test the hypothesis of whether water systems that are community or non-transient non-community are more likely to exceed the arsenic MCL of 10 ppb.

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[55] CWSs and NTNCs are assigned an ownership code of mixed by ADEQ if ADEQ has not received information that has clearly defined a system's ownership, (John Calkins, pers. comm.).

Service Population. The variable service population refers to the number of customers that are served by a water system. This number also refers to the size of a water system. There are five size categories used in this analysis.

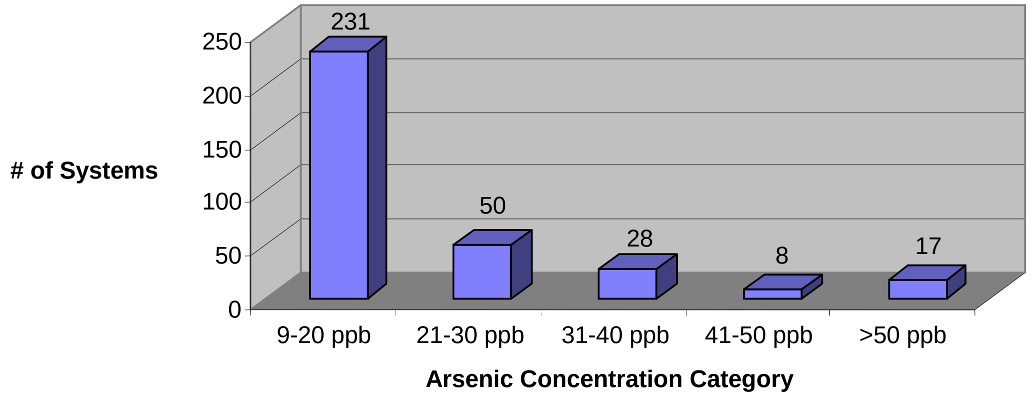
By including a variable for service population it is possible to test the hypothesis of the significance of system size on the exceedance of the arsenic MCL of 10 ppb.

Water Source Type. The raw water that water systems treat and then deliver to customers can be characterized as coming from two sources: groundwater (water that is pumped from a well), or surface water (water that is drawn from rivers, streams, lakes, ponds, etc.). Groundwater is of particular importance to this study because arsenic's occurrence and concentration is much higher in groundwater than in surface water. Thus PWSs that use groundwater as their source of water would be expected to be more likely to exceed the arsenic MCL of 10 ppb.

Average Affected EPDS Arsenic Concentration. Arsenic in water is measured in parts per billion (ppb), which is identical to micrograms/ liter (μg/L). Average affected EPDS arsenic concentration is a measure derived by the author as a proxy for a PWS's arsenic burden. ADEQ receives arsenic concentration samples from each EPDS of a PWS. These samples can then be combined and averaged to determine a system's average affected EPDS arsenic concentration. This process was performed for the group of 334 PWSs known to have at least one EPDS with an arsenic concentration of 9 ppb or greater.

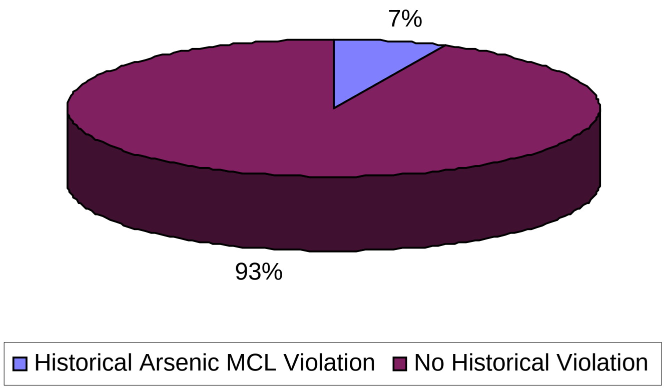
Figure 4 displays the distribution of the group of 334 systems according to five ranges of average affected EPDS arsenic concentration.

Figure 4. Distribution of Group of 334 Systems Within Five Avg. Affected EPDS Arsenic Concentration Categories



Historical Arsenic Violation. Prior to the advent of new arsenic standard arsenic had previously been regulated under the SDWA, but at an MCL of 50 ppb. ADEQ has data on PWSs that violated the historical MCL of 50 ppb and this information was included in one of the regressions performed in this econometric analysis. This information was qualitative in nature and only indicated that a system had received some form of enforcement action, the degree of which is unknown. Nonetheless, if a system had violated the previous arsenic standard then they must have had at least one EPDS in excess of 50 ppb. All systems known to have violated the previous standard were contained in the current group of 334. Figure 5 depicts the percentage of the group 334 systems that had historically violated the arsenic MCL.

Figure 5. Percentage of Group of 334 Systems that Violated Old Arsenic MCL of 50 ppb



Having data on historical arsenic violations produces the testable hypothesis of whether systems that have historically violated are more likely to exceed the current arsenic MCL of 10 ppb.

Table 10 describes the form of the variables as they are used in the regression analysis. Most variables are in binary form and thus take a value of either one or zero. How the ones and zeros are assigned is defined in the description section of the table.

Table 10. Variables and Definitions

VARIABLE NAME	DESCRIPTION	TYPE
Exceedance	={1, if avg. arsenic concentration ≥ 9 ppb ={0, if otherwise	Binary
Hisviolation	={1, if violated old arsenic MCL of 50 ppb ={0, if otherwise	Binary
Popserv	A number representing the number of customers served by a CWS or NTNC	Continuous
Public	={1, if owned by a municipality ={0, if otherwise	Binary
Private	={1, if owned by a private entity ={0, if otherwise	Binary
Watersource	={1, if system uses groundwater ={0, if otherwise	Binary
Commsys	={1, if system is a CWS ={0, if system is an NTNC	Binary

Table 11. Summary Statistics for Group of 1006 Systems

Variable	Mean	Std. Deviation	Min	Max
Exceedance	0.332	0.471	0	1
Popserv	5.444	47.824	0.025	1200.000
Public	0.193	0.395	0	1
Private	0.497	0.500	0	1
Watersource	0.932	0.251	0	1
Commsys	0.792	0.405	0	1
Popserv*Private	1.012	4.581	0	55.451
Popserv*Public	4.170	47.646	0	1200.000
Commsys*Private	0.444	0.497	0	1
Commsys*Public	0.122	0.327	0	1

Table 11 presents the summary statistics (Mean, Standard Deviation, Minimum, and Maximum) for the regression variables and also includes summary statistics for the interaction variables. Variable *Popserv* is reported in units of one thousand (0.025 = 25 customers). The mean of *Exceedance* (0.332) shows that 33% of 1006 total systems are in exceedance of the 9 ppb threshold. Many of the mean values of variables reported in Table 11 are represented graphically earlier in this chapter.

Models and Methods. This section evaluates the impacts to Arizona public water systems (PWSs) attributable to the new arsenic maximum contaminant level (MCL) of 10 ppb using a regressions analysis. Specifically, regressions are performed to determine what characteristics affected Arizona PWSs tend to have. This can be achieved by comparing the group of 334 PWSs known to have average affected EPDS arsenic concentrations of greater than 9 ppb with the group of 772 PWSs that have an average affected EPDS arsenic concentration of less than 9 ppb (i.e., the affected group versus the non-affected group).[56] In addition, to further define typical characteristics of PWSs that are more likely to exceed the 10 ppb MCL, a group of 24 PWSs known to have violated the former arsenic standard of 50 ppb is compared with the group of affected PWSs. Both of these

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[56] 9 ppb is selected as the threshold because the Arizona Department of Environmental Quality (ADEQ) groups these systems with those that have arsenic concentrations of 10 ppb or greater because the natural variation of arsenic levels in groundwater wells could precipitate exceedance of the 10 ppb MCL for systems with concentrations of 9 ppb. Technically, only one entry point to the distribution system (EPDS), (which is defined as any point on a water system's distribution infrastructure where a new water source enters, typically near a well), need be in excess of the 10 ppb MCL for ADEQ to take regulatory action. However, this study uses the average arsenic concentration of a system's affected EPDSs as a proxy for a system's arsenic burden as it relates to the arsenic standard.

regressions utilize a Probability of Exceedance Model. In the following, we discuss the corresponding empirical models and their estimation.

Probability of Exceedance Model I

The first regression undertaken in this econometric analysis utilizes the exceedance of 9 ppb by a PWS as its dependent variable. The relationship of the probability of MCL exceedance by a PWS as a function of their system characteristics must be modeled using a Probit Regression Model (limited dependent variable) because the Linear Probability Model, or Ordinary Least Squares, has a major drawback: “A major weakness of the linear probability model is that it does not constrain the predicted value to lie between 0 and 1,” (Johnston and DiNardo, p. 417). Because the dependent variable for the Probability of Exceedance Model takes a value of either 1 or 0, a Probit Regression Model is used.

In the case of this analysis, the probit model estimates the probability of exceedance by a PWS. Exceedance is defined as having an average contaminate EPDS arsenic concentration of 9 ppb or greater. The probit model assumes there is an unobserved, or latent, variable that determines the observed value of the dependent variable. This latent variable is considered the propensity to exceed an unknown critical value. The latent variable Y_i^* is defined as

$$Y_i^* = X_i\beta + \varepsilon \tag{1}$$

$$\varepsilon \sim N(0,1)$$

where X_i is a matrix of explanatory variables, ε is a random error term that follows a normal distribution, and Y_i* is the unobserved latent variable. Instead Y_i is observed and is defined as

$$Y_i = 1 \textit{ when } Y_i^* > 0 \\ \quad = 0 \textit{ when } Y_i^* = 0 \tag{2}$$

where Y_i is the occurrence or lack thereof of an event, in this case whether a PWS has exceeded. The specification of the Probability of Exceedance Model I is:

$$exceedance(Y=1) = \beta_0 + \beta_1 popserv + \beta_2 public + \beta_3 private + \beta_4 watersource + \beta_5 commsys + \beta_6 popserv*private + \beta_7 popserv*public + \beta_8 commsys*private + \beta_9 commsys*pub \tag{3}$$

where *Popserv* is the number of customers of a PWS, *Public* describes municipal ownership of the water system, *Private* describes private ownership of the water system, *Watersource* indicates whether service water is of groundwater origin or other, *Commsys* indicates whether a water system is a CWS or NTNC, *Popserv*Private* is an interaction term describing the mutual effect *Popserv* and *Private*, and similarly *Popserv*Public*, *Commsys*Private*, and *Commsys*Public* are interaction terms describing mutual effects of the variables interacted.

The probit model in (3) is estimated using the iterative numerical process of the maximum likelihood procedure (MLE). The MLE procedure uses the cumulative density function (CDF) of the standard normal distribution in order to estimate the model, which bounds probabilities between 0 and 1.

Probability of Exceedance Model II

The second regression, as in the Probability of Exceedance Model I, utilizes the exceedance of 9 ppb by a PWS as its dependent variable. In addition, Model II conforms to the assumptions (1) and (2) of Model I. The only difference is that dummy variables representing Arizona counties are included in the model. The resultant Probability of Exceedance Model II is:

$$(4) \quad exceedance(Y=1) = \beta_0 + \beta_1 popserv + \beta_2 public + \beta_3 private + \beta_4 watersource + \beta_5 commsys + \beta_6 popserv*private + \beta_7 popserv*public + \beta_8 commsys*private + \beta_9 commsys*pub + \beta_{10} DCO + \beta_{11} DCOC + \beta_{12} DGI + \beta_{13} DGR + \beta_{14} DGRE + \beta_{15} DMA + \beta_{16} DMO + \beta_{17} DNA + \beta_{18} DPIM + \beta_{19} DPIN + \beta_{20} DSC + \beta_{21} DYV + \beta_{22} DLP$$

where *Popserv*, *Public*, *Private*, *Watersource*, *Commsys*, *Popserv*Private*, *Popserv*Public*, *Commsys*Private*, and *Commsys*Public* are identical to their counterparts in Model I, and *DCO* is a dummy variable for Cochise county, *DCOC* is a dummy for Coconino county, *DGI* is a dummy for Gila county, *DGR* is a dummy for Graham county, *DGRE* is a dummy for Greenlee county, *DMA* is a dummy for Maricopa county, *DMO* is a dummy for Mohave county, *DNA* is a dummy for Navajo county, *DPIM* is a dummy for Pima county, *DPIN* is a dummy for Pinal county, *DSC* is a dummy for Santa Cruz county, *DYV* is a dummy for Yavapai county, and *DLP* is a dummy for La Paz county.

Probability of Exceedance Model III

The third regression for this analysis of Arizona PWSs similarly uses a probit model for its estimation and resembles Model I, though it has fewer explanatory variables.[57] However, Model III utilizes exceedance of 50 ppb as its variable of interest, or dependent variable. Like Models I and II, it conforms to the assumptions described in (1) and (2). Model III also includes a dummy for historical violation of the previous arsenic standard of 50 ppb. The specification for Probability of Exceedance Model III is:

$$(5) \qquad exceedance(Y=1) = \beta_0 + \beta_1 hisviolation + \beta_2 popserv + \beta_3 public + \beta_4 private + \beta_5 commsys$$

where *Popserv*, *Public*, *Private*, and *Commsys* are identical to their counterparts in Models I and II but *Hisviolation* is a dummy for historical violation of the previous arsenic standard of 50 ppb.

E. Results and Findings

Table 12 presents the significant estimated results of the probit Probability of Exceedance Models I, II, and III. The dependent variable for each model is the exceedance of a 9 ppb, average affected EPDS arsenic concentration threshold. The models' significant exogenous variables are presented in column one with their corresponding parameter estimates, standard errors, marginal effects, and the standard

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[57] Some explanatory variables were dropped because the reliability of the maximum likelihood estimates was suspect (standard errors for some coefficients were missing) when all explanatory variables were included.

errors of the marginal effects. Empty cells represent insignificant results for that particular model with respect to the relevant exogenous variable.

Probability of Exceedance Model I. There are many statistically significant results from the Probability of Exceedance Model I. These econometric results have important implications concerning Arizona PWSs. One major result of Probability of Exceedance Model I is that affected water systems tend to be larger and privately owned and operated. This result reinforces the result from the t-test of equal means, where affected systems were shown to tend to be larger systems (serve greater numbers of customers). Also, Model I describes affected water systems as tending to use groundwater as their water source. This result is intuitive since arsenic incidence is largely a groundwater issue. Finally, an interesting but not statistically significant result, is the sign of the parameter estimate for *Commsys*, which is negative. This implies that non-affected systems tend to be CWSs.

Table 12. Significant Results from Probability of Exceedance Models I, II, III.

	Var	*Intercept*	*Water Source*	*Popserv* Private*	*Commsys*	*DMA*	*DYV*	*DPIN*	*Hisviol*
Model I	Coeff	-1.0515*	0.6246*	0.0544*	-0.1262	-	-	-	-
	Std. Error	0.2501	0.2065	0.0211	0.1672	-	-	-	-
	Marginal Effect	-	0.1980*	0.0213*	-0.0754	-	-	-	-
	Std. Error	-	0.0531	0.0054	0.0435	-	-	-	-
Model II	Coeff	-1.2093*	0.5774*	-	-0.0572	0.5398*	0.7491*	0.4133**	-
	Std. Error	0.2916	0.2150	-	0.1722	0.1904	0.1961	0.2143	-
	Marginal Effect	-	0.1798*	-	-0.0229	0.2055*	0.2879*	0.1578***	-
	Std. Error	-	0.0550	-	0.0439	0.0742	0.0753	0.0845	-
Model III	Coeff	-1.8387*	-	-	-0.4173	-	-	-	2.2429*
	Std. Error	0.3490	-	-	0.3346	-	-	-	0.3408
	Marginal Effect	-	-	-	-0.00006	-	-	-	0.02186
	Std. Error	-	-	-	0.0004	-	-	-	0.0777

Note: * Significant at the 1% level, ** Significant at the 5% level, *** Significant at the 10% level.

Probability of Exceedance Model II. The interesting results of Model II are that the groundwater variable remained statistically significant and three counties (Maricopa, Yavapai, and Pinal) have statistically significant results. Thus, affected systems tend to use groundwater as the source of water and are heavily represented in Maricopa, Yavapai, and Pinal counties. Additionally, though still not statistically significant, non-affected systems tend to be CWSs.

Probability of Exceedance Model III. The results for Model III demonstrate that of the current group of affected systems, those that have average contaminated EPDS concentrations of greater than 50 ppb, tend to have violated the historical arsenic MCL of 50 ppb. Model III produced no other significant results to report.

F. Summary

To summarize the results of this chapter, it has been shown that affected PWSs are a representative sample of all Arizona PWSs with respect to: ownership, system type, and water source. This result is interesting, but there are no significant policy implications that arise from its existence.

This chapter has also shown that large and very large PWSs tend to be affected by the revised arsenic standard. For example, two out of three large or very large PWSs are part of the affected group, and every very large PWS is part of the affected group. This may have important policy implications because large and very large PWSs have been shown to have compliance issues in general with SDWA regulations, (Rahman et al., forthcoming).

Lastly, though not disproportionately affected by the new arsenic standard, small PWSs are absolutely affected by the new standard. This could be a major policy implementation issue. For example, four out of five PWSs in Arizona are either small or very small. Moreover, four out of five affected PWSs are either small or very small. In absolute numbers, this means roughly 266 PWSs may face serious financing constraints to comply with the new arsenic standard.

The following chapter will discuss these policy implementation issues that accompany the new arsenic standard in Arizona.

IV. Policy Implementation

A. Introduction

This chapter takes the results from chapter three and examines them in the context of policy implementation in Arizona. The two major policy implications that resulted from the empirical analysis of chapter three, that public water systems (PWSs) affected by the new arsenic standard tend to be larger and that small PWSs will likely face a financing hurdle in order to comply with the standard, are discussed with respect to the current compliance history of affected PWSs. The goal of this chapter is to analyze these policy implications from a general standpoint to determine if they posed a significant implementation issue in Arizona. In general: Have larger affected PWSs had a difficult time complying with the standard thus far? Have small affected PWSs had trouble complying? What forms of treatment options have these affected systems employed in order to comply? How have they financed their treatment? These and other questions are explored in more detail below.

B. Large Systems Analysis

Review of Findings. The major finding of the empirical analysis with respect to larger systems is that they tend to be disproportionately among the affected group of PWSs in Arizona. This is an important result because Rahman et al. (forthcoming) have shown that larger PWSs in Arizona already have trouble complying with Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) regulations, which raises an important public health issue. Because larger systems serve greater numbers of people and those systems are more likely to violate MCL regulations, there are greater health consequences of large systems not meeting MCL standards. This research has shown that Arizona PWSs with an arsenic issue tend to be larger systems, which exacerbates the findings of Rahman et al. (forthcoming). But before any definitive conclusions can be drawn about the added health consequences of large PWSs not meeting the new arsenic standard, the current compliance history of large PWSs must be discussed.

Current Compliance History. The Arizona Department of Environmental Quality (ADEQ) continuously tracks a PWS's compliance with respect to the new arsenic standard. This arsenic compliance history data was obtained in April of 2007. Table 13 shows the current compliance history of the group of large (serve 10,001-100,000) and very large (serve >100,000) PWSs that had an arsenic issue when this research began.

Table 13 . Current Arsenic Compliance History of Large and Very Large PWSs

	System Size	
	Large (10,001-100,000)	**Very Large (>100,000)**
No. of Systems In Affected Group	31	8
No. Currently In Compliance	28	8
No. Currently Not In Compliance	3	0
% Compliance	90%	100%

Source: ADEQ, Drinking Water Section, April 2007.

Notice that all very large PWSs are currently in compliance with the new standard, and that 90% of large PWSs are currently in compliance as well. This is interesting news to report since the empirical results of this research, as well as the results of previous research, showed that larger PWSs tend to have a difficult time complying with MCL standards. There are a few intuitive reasons why the compliance record of these larger PWSs with respect to the arsenic standard is much better than expected.

To begin with, large, and particularly very large, PWSs traditionally have more resources available to them to deal with compliance issues (Brian Popadak, pers. comm.). Larger systems typically have more elaborate water delivery systems, greater technical capabilities, and larger operating budgets to maintain their delivery systems, all of which facilitate meeting a new MCL regulation. Furthermore, obtaining financing for additional treatment installation is generally less difficult for larger systems because their larger customer base enables them to demonstrate that loans can be repaid readily through rate increases.

Furthermore, larger Arizona PWSs typically have a number of wells that they can pump water from, in addition to having access to surface water. So, if only one well is causing the arsenic problem, the water system could simply discontinue the use of that well, or perhaps blend the affected water with less affected water to obtain finished blended water that has an arsenic concentration of 10 ppb or less. Because larger systems typically have raw water coming from a variety of sources they will also have a variety of non-treatment options available for them to address their arsenic issue.

Treatment Options. In order to comply with the new arsenic standard there are a number of treatment options that exist for affected PWSs: disconnection, source rehabilitation, blending, centralized treatment, and point-of-use (POU) treatment. Disconnection refers to the removal of a problematic well that is causing the arsenic exceedance issue. Source rehabilitation includes modifying existing wells or developing new sources with less arsenic. Blending refers to mixing higher arsenic content water with lower arsenic content water to achieve a final content of less than 10 ppb. Centralized treatment involves installing a treatment technology that removes arsenic from the water. Lastly, POU refers to the installation of a treatment technology at the point of consumption, usually a kitchen sink. All of these alternatives, aside from POU, are potentially cost-effective means of complying with the new standard for large PWSs (POU treatment is typically effective only for small PWSs). Table 14 reports the distribution of the types of treatment currently being employed by large and very large PWSs that are presently in compliance with the new arsenic standard.

Centralized treatment alternatives clearly dominate this distribution, which is expected because they are more cost-effective for large scale operations than POU alternatives.[58] A number of centralized treatment alternatives exist and these will be discussed at greater length below.

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[58] ADEQ's Arsenic Master Plan, p. 4-63. Available online at: http://www.azdeq.gov/environ/water/dw/arsenic.html

Table 14 . Current Treatments Employed by Large and Very Large PWSs

	System Size	
	Large (10,001-100,000)	**Very Large (>100,000)**
No. of Systems Reporting Treatment	17	6
Treatment Type:	-	-
Disconnection	1	1
New Source	1	0
Blending	4	0
Centralized Treatment	9	1
Multiple Methods	2	4

Note: Multiple Methods signifies that more than one treatment option is being employed by the PWS. Centralized treatment is likely to be one of these methods.
Source: ADEQ, Drinking Water Section, April 2007.

Centralized Treatment Alternatives. Large PWSs that are affected by the new arsenic standard have little alternative but to use centralized treatment to correct for arsenic MCL exceedance if alternatives like disconnection, blending, or source rehabilitation are infeasible. There are many centralized arsenic removal technologies on the market and they generally employ one of four major methods of arsenic removal: precipitative processes, adsorption processes, ion exchange processes, and filtration processes. Within each of these four general categories of arsenic removal processes exist a variety of specific methods for removing arsenic. This section will briefly describe one technology from each of the four general removal process categories.

Precipitative Process: Coagulation/Filtration (C/F). C/F "is a treatment process by which the physical or chemical properties of dissolved colloidal or suspended matter are altered such that agglomeration is enhanced to an extent that the resulting particles will settle out of solution by gravity or will be removed by filtration," (EPA, Technologies and Costs).

Adsorptive Process: Activated Alumina (AA). AA "is a physical/chemical process by which ions in the feed water are sorbed to the oxidized AA surface," (EPA, Technologies and Costs). In this case the ions are arsenic ions which eventually fill the adsorption sites on the AA surface and then must rinsed by a process called regeneration.

Ion Exchange Process: Anion exchange (IX). IX "is a physical/chemical process by which an ion on the solid phase is exchanged for an ion in the feed water. This solid phase is typically a synthetic resin which has been chosen to preferentially adsorb the [arsenic]," (EPA, Technologies and Costs).

Filtration Process: Reverse Osmosis (RO). RO is a filtration process that uses a membrane as "a selective barrier, allowing some constituents to pass while blocking the passage of others…RO produces nearly pure water by maintaining a pressure gradient across the membrane greater than the osmotic pressure of the feed water," (EPA, Technologies and Costs).

The selection of a given arsenic removal technology by a PWS is a complex process that depends on a variety of factors. For example, a technology's arsenic removal efficiency depends on the flow rate of influent water, the arsenic concentration of influent water, as well as the pH, iron, sulfate, and nitrate concentrations of that influent, in addition to other potential factors. These factors will not only influence the type of technology that will be selected for arsenic removal, but will also affect the operation and maintenance costs of that technology.[59] Also, some treatment technologies have larger land requirements than others, which makes for an additional consideration when determining what technology to employ.

For affected Arizona PWSs, ADEQ provides an online Decision and Costing Tool that aids PWSs in deciding a range of appropriate arsenic removal technologies, as well as their associated capital and operation and maintenance costs.[60] According to ADEQ, coagulation/filtration treatment alternatives are the most predominant centralized treatment option in Arizona, (John Calkins, pers. comm.). Depending on the influent levels of the factors mentioned above, according to ADEQ's Arsenic Master Plan the range of capital cost associated with a C/F technology is anywhere from $1 to $3 million with annual operation and maintenance costs ranging from $100,000 to $300,000.

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[59] See EPA (2000) "Technologies and Costs for Removal of Arsenic from Drinking Water," as well as ADEQ's Arsenic Master Plan for detailed capital and operation and maintenance cost estimates, including sensitivity assessments, for arsenic removal technologies.

[60] Available online at: http://www.azdeq.gov/environ/water/dw/arsenic.html

C. Small Systems Analysis

Review of Findings. A major finding of this paper is that smaller PWSs (those that serve 25-3,300 customers) will be affected by the new arsenic standard in absolute terms, with roughly 266 needing to take some form of corrective action to deal with their arsenic issue. Though the total population of customers that are served by these small systems is minimal (only about 3% of the total number of people served by affected PWSs), these PWSs do face a major financing constraint in order to comply with the new standard.

Unlike large systems who have substantial customer bases with which to spread the treatment cost, small systems have fewer customers which makes arsenic treatment more expensive for those customers on a per household basis. For example EPA estimated that installing centralized treatment could produce average household costs of less than $1 for customers of PWSs that serve more than 100,000 customers, but nearly $330 for customers of PWSs that serve less than 100 customers.[61] Although other treatment options besides centralized treatment exist for small systems, financing is a major issue nonetheless.

Current Compliance History. The current compliance history of small Arizona PWSs with respect to the new arsenic standard is much different than the one for large PWSs. Table 15 shows the current arsenic compliance trend for small and very small Arizona PWSs. Of the 266 total number of small and very small affected PWSs, only 46% of

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[61] Source: EPA "Arsenic in Drinking Water Rule Economic Analysis," 2000, p. 8-14

Table 15 . Current Arsenic Compliance History of Small and Very Small PWSs

	System Size	
	Very Small (25-500)	**Small (501-3,300)**
No. of Systems In Affected Group	192	74
No. Currently In Compliance	108	35
No. Currently Not In Compliance	84	39
% Compliance	56%	53%

Source: ADEQ, Drinking Water Section, April 2007.

them are currently in compliance. Furthermore, only 56% of very small PWSs and just 53% of small PWSs are currently in compliance with the new arsenic standard. This is striking evidence of present small system non-compliance with respect to the 10 ppb arsenic MCL. There are a couple of intuitive explanations for this inability to comply, the most prominent being financing constraints.

Unlike larger PWSs who have more financial resources available to them to deal with compliance issues, small PWSs are financially constrained for a number of reasons. First, they do not have large customer bases from which to generate substantial revenue. Thus small systems have smaller budgets, making the installation and maintenance of costly arsenic removal treatments financially infeasible.

Another reason small PWSs may have trouble complying with the new arsenic standard is that they do not have the broad range of potential non-treatment options that large systems have. For example, some large systems in Arizona have simply disconnected problematic wells, relying on other sources to deliver their customers water. Small systems may only operate small numbers of wells, in some cases just one well. This may make non-treatment options like well disconnection and blending infeasible as alternatives for dealing with an arsenic issue.

For small affected PWSs that must install some form of treatment technology and who also face a financing constraint, there are ways for them to obtain loans in order to comply with the standard. The Water Infrastructure Finance Authority of Arizona (WIFA) “is an independent agency of the state of Arizona and is authorized to finance the construction, rehabilitation and/or improvement of drinking water, wastewater, wastewater reclamation, and other water quality facilities/projects,” (WIFA homepage, last accessed May 2007). According to WIFA, of the 14 arsenic related loans given to PWSs to date, half of those went to small PWSs who serve 3,300 or fewer customers. Although WIFA has disbursed fewer loans for arsenic related activities than it had anticipated, there are other agencies that are a source of loans for affected PWSs.[62]

Treatment Options. The most cost-effective treatment option available for small affected PWSs is the point-of-use (POU) option, which is a small technology installed at a point of consumption, typically a kitchen sink in a residence. POU devices typically remove arsenic by either an activated alumina mechanism or reverse osmosis. Table 16 reports the current treatments employed by small and very small PWS.

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[62] These can be found on the Rural Water Infrastructure Committee website at http://rwic.az.gov/funding.asp.

POU Activated Alumina (AA). For AA, "[c]ontaminant removal occurs as contaminants are exchanged with the hydroxide ions on the alumina surface…Arsenic removal by AA has been shown to be most effective near pH of 5.5 to 6.0," (EPA, Technologies and Costs).

POU Reverse Osmosis (RO). POU RO works in the same fashion as centralized treatment RO does just on a smaller, localized scale.

Table 16 . Current Treatments Employed by Small and Very Small PWSs

	System Size	
	Very Small (25-500)	**Small (501-3,300)**
No. of Systems Reporting Treatment	29	12
Treatment Type:	-	-
Disconnection	0	0
New Source	0	1
Blending	0	2
Centralized Treatment	15	8
Point-of-Use (POU)	14	1

Note: The particular method of arsenic removal used by the POU device was not available.
Source: ADEQ, Drinking Water Section, April 2007.

Examining the data in Table 16 reveals some interesting things. There are very few treatment options being employed other than POU and centralized treatment alternatives. This matches the intuition that smaller systems have fewer options than do larger systems. But more surprisingly, more than half of the treatment options undertaken by very small systems are centralized treatments. Some further investigation reveals why.

According to ADEQ’s Arsenic Master Plan, annualized POU costs range from $8,000 for those systems with 20 service connections to $135,000 for systems with 300 service connections, (ADEQ, 2003). The Master Plan also reports that there is a break-off point where centralized treatment annualized costs are lower than POU annualized costs, and this occurs at 80-90 system service connections (roughly 210-250 customers), (ibid). Beyond this system size centralized treatment alternatives are less costly. This is a likely explanation for why half of very small systems are employing centralized treatment alternatives. Furthermore, some very small systems could be experiencing growth which makes centralized treatment more attractive, (Brian Popadak, pers. comm.).

To summarize, the current compliance history of large PWSs is very good despite the statistical findings of this research. Small PWSs are having more trouble than large systems, probably because of their fewer financial and technical resources, as well as having fewer treatment alternatives. Despite the apparent financing constraints of small PWSs, there have been far fewer arsenic related loans disbursed to small systems by the Water Infrastructure Finance Authority of Arizona. If current compliance numbers of small systems were higher than they are, this would likely indicate some unforeseen resourcefulness of small systems that was unknown prior. However, a better possible explanation is that small systems are likely slower to move on this type of regulation.

V. Summary and Conclusions

A. Summary

Researching how the revised arsenic standard has affected Arizona public water systems has provided a unique case study analysis of an environmental federalism issue with respect to the Safe Drinking Water Act (SDWA). Similar to federalism, environmental federalism wrestles with the pros and cons of distributing environmental regulatory power between states and the federal government. Environmental regulation often highlights political tensions between states and the federal government, and the revised arsenic standard is no exception.[63] However, in order to evaluate the revised arsenic standard from an environmental federalism perspective, this study had to examine the benefits and costs of the standard as they pertained to Arizona.

Determining if the revised arsenic standard is a potential Pareto improvement for Arizona is not as straightforward as one might think. This is because of much ambiguity surrounding the benefits and cost estimates of reducing arsenic in drinking water. Some organizations criticized EPA's health benefits estimates as being overestimates and others criticized them as underestimates. There was also considerable ambiguity concerning EPA's cost estimates for treating arsenic at the new 10 ppb MCL level, with one study coming up with a cost estimate two-and-a-half times EPA's estimate. Because of such considerable disagreement and uncertainty surrounding the health benefits and system

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[63] In fact, a lawsuit challenged EPA's authority to regulate arsenic in drinking water. The case is Nebraska v. Environmental Protection Agency. The D.C. Circuit Court of Appeals issued their opinion on the *Nebraska* case on June 20, 2003 (available online at http://pacer.cadc.uscourts.gov/docs/common/opinions/200306/01-1101a.pdf).

cost estimates of the revised arsenic standard, it is impossible to determine with any degree of surety if the new standard is a potential Pareto improvement for Arizona. But, for certain, Arizona is the state most affected by the new standard.

A greater proportion of public water systems are affected by the new arsenic standard in Arizona than anywhere else in the United States. Only 5% of all public water systems in the nation are affected by the standard, but roughly 30% of Arizona public water systems are affected by the standard. This represents a definitive absolute impact on Arizona systems, but a particular goal of this case study was to determine if the new standard disproportionately affected certain types of Arizona public water systems.

Data exists in Arizona which differentiates PWSs by system characteristics such as: system size (number of customers served), ownership type, system type (community PWS or non-transient non-community PWS), and water source (groundwater or surface water). Using statistical tests, this research found that the affected group of Arizona PWSs was simply a representative sample of the total population of Arizona PWSs with respect to: ownership type, systems type, and water source. However, with respect to system size, a test demonstrated that the average number of customers served by the affected group of PWSs was statistically significant and larger than non-affected PWSs. Furthermore, a regression analysis confirmed the same finding, that PWSs in Arizona affected by the revised arsenic standard tend to be disproportionately larger systems.

The major finding of the statistical tests and regressions highlighted an important policy implication regarding large PWSs. Previous research had shown that large PWSs tended to violate maximum contaminant level (MCL) regulations set under the Safe

Drinking Water Act (SDWA), which meant that, based on the results of this research, the new arsenic standard would exacerbate this already extant condition of larger PWSs violating MCL standards. This policy implication raises a major public health concern, considering larger PWSs serve to larger segments of the population.

Another policy effect of the new arsenic standard is, that because small Arizona PWSs are hard hit in absolute numbers (266 of the 334 affected PWSs), financing small system improvements to treat arsenic at the lower MCL is a major policy implementation hurdle. These small systems typically do not have the resources available to them to readily comply with a new regulation like the arsenic standard.

This research examined the current compliance history of Arizona PWSs with respect to the arsenic standard to determine if practical experience with the standard was actually affirming the policy implications of this research. It turned out that large affected PWSs were not having trouble complying with the arsenic standard as previously expected. Roughly 90% of systems who serve 10,001-100,000 customers, and 100% of systems who serve > 100,000 customers were already compliant as of April 2007. This result is likely due to the fact that larger systems typically have greater resources to comply with MCL standards, and they also have more treatment options available to them.

Unlike larger PWSs, small PWSs have been having trouble complying with the new arsenic standard. Roughly 54% of small affected PWSs have complied with the standard as of April 2007. This is likely due to the fact that small systems do not have substantial financial, or other, resources at their disposal, and also do not have a multitude of treatment options available to them in order to comply with the standard.

B. Conclusions

Although there is considerable theoretical and empirical support for decentralized environmental standard setting with respect to local drinking water quality regulation, through the lens of the Arizona experience it still is not completely clear that the uniform national arsenic standard is woefully inefficient or inefficient at all. The new standard has clearly affected large and small systems alike, but preliminarily, the cost of complying in Arizona does not appear prohibitive. It is impossible to speculate about what the actual cost of complying with the standard will be in Arizona, though it seems as if it will be manageable. However, any argument for decentralization of local drinking water quality standards such as the arsenic standard must examine net benefits, which implies comparing health benefits estimates with cost estimates.

Perhaps the Arizona arsenic experience could be empirical support for decentralization, if only the benefits estimates were unambiguous. Because they are not, it is impossible to assert that the uniform national arsenic standard was inefficient. It is unclear whether the old standard was inadequately protective of human health, what the latency period is for carcinogenic effects of arsenic exposure, or even how long it will take the health benefits of arsenic reduction to fully accrue. For these reasons, any definitive conclusion about the economic efficiency of the federal government imposing the uniform national arsenic standard on Arizona is not forthcoming in this study.

If there was more certainty in the scientific community concerning the health benefits of reducing arsenic in drinking water such a conclusion could potentially be made. More research on the chronic effects of arsenic exposure is needed. Nonetheless, the Arizona arsenic experience is a unique contribution to environmental federalism.

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