Is the Arsenic Rule Affordable?

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This article compares different methods—viz., the US Environmental Protection Agency's (USEPA's) current expenditure margin affordability method, its proposed incremental burden method, and other methods based on below-median household income thresholds—that are primarily used to assess affordability of the Arsenic Rule. The authors use the original cost estimates from 2000 and actual cost data reported in 2010 to analyze the affordability of the USEPA's revised Arsenic Rule. We find the Arsenic Rule is affordable for all systems only under the current expenditure margin method; according to all other methods, between 24 and 83% of small US community water systems examined had unaffordable arsenic removal. Analyzing the USEPA's 2010 Arsenic Removal Demonstration Project, zero to 22 of the 40 systems (0–55%) have unaffordable arsenic removal treatment. Further, we find that affordability methods based on a 25th percentile income (with criteria to identify economically disadvantaged communities) most closely match the purpose of drinking water affordability.

Keywords: *affordability, arsenic, income, regulations*

Arsenic has been linked to increased risks of lung, bladder, and skin cancer for many years, and its presence in drinking water was first regulated in the 1940s by the US Public Health Service (Tiemann 2007). In 1975, the US Environmental Protection Agency (USEPA) adopted the US Public Health Service's 50 µg/L limit for arsenic in drinking water on an interim basis and spent nearly three-and-a-half decades collecting data about the risks associated with arsenic-induced cancer before finalizing the 10 µg/L rule in 2001. Though the USEPA determined that the Arsenic Rule would be affordable for all system sizes, many criticized both the conclusion and the method the USEPA used to make its affordability determination. Jones and Joy (2006) found that the cost of imposing the regulation exceeded the expected benefit for some very small drinking water systems (six to 95 households) of 14 tribal communities in Arizona. In a study of 36 treatment sites throughout California, Hilkert Colby et al. (2010) found that 15% of the systems were not "affordable." These criticisms prompted the USEPA to reconsider its affordability methods for drinking water, culminating in the proposal (but not yet finalization) of a new set of affordability methods.

The controversy over drinking water affordability and potentially excessive regulatory burdens placed on small systems has subsided as the Arsenic Rule has reached a decade of enforcement. The underlying economic reason behind why regulations become costlier (and perhaps unaffordable) for a small system is that of "economies of scale," which implies that the average cost of production decreases as output increases. However, in 2014 the USEPA made another round of "regulatory determinations" of the contaminants listed on the third Contaminant Candidate List (USEPA 2014). According to the USEPA website, "the Safe Drinking Water Act (SDWA) requires USEPA to periodically decide whether or not to regulate at least five contaminants on the contaminant list; this action is called regulatory determination" (USEPA 2016a). The increasing cost burden implies that the affordability issues may well reappear as a significant factor in evaluating potential regulations in the near future. In addition, the potential benefits of future regulations could be dwarfed by a host of other factors (e.g., increasing costs associated with replacement of existing infrastructure). These considerations have led the USEPA and others in the water supply community to predict that the cost of water and wastewater services could quadruple in the coming decades (Baird 2010). Clearly, affordability is a timely issue (Pontius 2008).

This article compares the current (expenditure margin method) and proposed (incremental burden method) USEPA methods to critically evaluate the affordability of the Arsenic Rule using data from both 2000 (when the affordability was evaluated for the first time with estimated costs) and 2010 (four years after the implementation of the Arsenic Rule). The primary focus is on whether

small water systems (USEPA classifies a drinking water system as small if it caters to 10,000 or fewer households) can afford to comply with the Arsenic Rule. Both the expenditure margin and the incremental burden methods are based on thresholds derived from the national median household income (MHI). The National Rural Water Association (NRWA) notes that the USEPA's MHI standard "does not consider the quantity, concentration, rural demographics, financial abilities of low-income families or disadvantaged populations to afford the Rule as required by the Agency's Environmental Justice Policy" (NRWA 2016). In addition, this article evaluates the performance of other proposed affordability methods on the basis of regional (as opposed to national) income data and on lower-than-median household income (e.g., the first quartile household income).

A HISTORY OF AFFORDABILITY

Concerns over the affordability of drinking water regulations, particularly for small systems, have been part of the national debate since the SDWA was passed in 1974 (Rosenbaum 2008). As part of the SDWA amendments of 1996, Congress authorized the Drinking Water State Revolving Fund program to help fund drinking water system upgrades and mandated that the USEPA develop a method for assessing affordability. In response, in 1998 the USEPA adopted a method to assess the affordability of drinking water regulations called the expenditure margin method (USEPA 1998). The expenditure margin method uses the ratio of the total cost (the current annual water bill baseline plus the projected cost for the treatment required to meet the proposed standard) for water treatment in each of its small system size classes divided by the national MHI for each small system size class. Furthermore, in the 1996 amendments of the SDWA, Congress authorized the potential use of small-system variances to address small-system affordability challenges. This allowed small systems to use a variance technology that does not reduce a contaminant to the level required by the regulation, is affordable, and is protective of public health (USEPA 2016b). So, if the calculated ratio exceeds 2.5%, the regulation is deemed to be unaffordable for that size class, and permission to use variances—i.e., point-of-entry or point-of-use technologies instead of centralized treatment—can be considered by the states for those systems (method 1 in Table 1). Note that the large systems—those that serve more than 10,000 households—do not qualify for affordability variances. An alternative but equivalent way to calculate affordability under this method is to subtract the baseline median household water bill from 2.5% of the MHI, and the difference is the allowable "expenditure margin." If the cost of the regulation is greater than the expenditure margin, the regulation is considered unaffordable.

For example, in 1998, 2.5% of the US median household income was about $750 annually in 1997 dollars (throughout this article, prices are nominal prices in the year in parenthesis that follows the price), and the median water bill in the small systems was $250 (1997) per year. Therefore, the expenditure margin was $500 (1997) per year, and a rule could not cost more than this without being deemed unaffordable (Gurian et al. 2001, USEPA 2000). However, this method faced scrutiny in 2001 during the revision of the arsenic maximum contaminant

TABLE 1 Affordability methods considered

Method Number	Method Name	Criteria	Reference
1	Expenditure margin approach	Proposed total water costs (baseline plus proposed regulation costs) cannot exceed 2.5% of national MHI (i.e., $750 (1997 dollars)).	USEPA 1998
2	Incremental burden approach	a. Proposed regulatory costs cannot exceed one of three considered limits: 0.25% MHI, 0.50% MHI, and 0.75% MHI. b. If regulatory costs do not exceed the final limit, systems can still qualify if they are located in an economically disadvantaged community (county MHI ≤65% national MHI or poverty or unemployment rate twice the national average).	USEPA 2006
3	Low-income expenditure margin national study	Proposed total water costs (baseline plus proposed regulation costs) cannot exceed 2.5% of national first quartile household income (i.e., $555 (2000 dollars) or $661 (2010 dollars)).	Proposed on the basis of USEPA 1998
4	Low-income incremental burden national study	Proposed regulatory costs cannot exceed one of three considered limits: 0.25, 0.50, or 0.75% first quartile household income. If a system does not exceed the final limit, systems can still qualify if they are located in an economically disadvantaged community.	Proposed on the basis of USEPA 2006
5	Low-income expenditure margin local test	Systems can qualify for an extension if the system's costs to meet the regulation exceed 2.5% of the municipality or county's first quartile household income.	Proposed on the basis of Rubin 2002

MHI—median household income, USEPA—US Environmental Protection Agency

level (MCL). Contrary to the USEPA's finding that the revised arsenic MCL was projected to be affordable for all systems, Hilkert Colby et al. (2010), Jones and Joy (2006), and the Environmental Economics Committee (EEC) (2002) subsequently found that small systems "genuinely struggled with costs" in meeting the USEPA's arsenic MCL.

Within days of the finalization of the Arsenic Rule (and as part of the appropriations process for fiscal year 2002), the USEPA was asked by Congress to reevaluate its affordability methodology (USEPA 2002a). In response, the USEPA sought additional input from its Science Advisory Board (SAB) and the National Drinking Water Advisory Council (NDWAC) (for a concise summary of their concerns and recommendations, see USEPA 2006). The SAB's EEC did have some concerns with the existing method—namely the use of a median household income threshold, the use of national rather than regional income data, and the use of the 2.5% affordability threshold for small systems, among other aspects—and consequently offered alternative proposals to address these concerns (EEC 2002). In particular, the EEC recommended to opt for an alternative lower income threshold, such as 25th or 10th percentile income, and to rely only on the additional cost burden of the new regulation (ignoring the baseline cost). The NDWAC also strongly argued that the USEPA should consider only the additional cost burden on water systems associated with the proposed regulation rather than the total cost for drinking water (original baseline plus the cost of the proposed regulation); this essentially addressed the "adding up" problem, whereby early and expensive regulations use up the entire expenditure margin, leaving all latter regulations to be found unaffordable irrespective of their costs (NDWAC 2003).

On the basis of SAB and NDWAC recommendations (the NRWA also made specific recommendations via the NDWAC working group), in a *Federal Register* notice (USEPA 2006), the USEPA requested comment on two distinct approaches for determining affordability. The first approach critically examines whether "the incremental household cost of treatment" to comply with the new drinking water regulation exceeds an "increment based threshold" (USEPA 2006). In other words, if the incremental burden ratio exceeds the proposed threshold levels (three thresholds—0.25, 0.50, or 0.75% of MHI—are being considered), the regulation would be deemed unaffordable for that size class. In this article, this method is termed the "incremental burden approach" ("incremental approach" in the original). The proposed second approach is essentially a two-part methodology, which stems from the analyses by Rubin (2002, 2001) in which once the USEPA finds a particular compliance technology affordable at the national level using the incremental burden approach, in the next step the USEPA is supposed to identify counties that are economically "at risk" and consequently propose affordable variance technologies for small systems in these counties (USEPA 2006).

In addition to this rule, USEPA sought comments on whether the costs should be evaluated for the 10th percentile- or the 50th percentile-sized system within a given small-system size category (USEPA 2006). As part of its guidance for the states, the USEPA proposed three other supplemental criteria that could additionally determine whether an individual system would likely face undue difficulties in raising funds for necessary capital improvements: (1) an MHI ≤65% of the national MHI, (2) a US Census Bureau (USCB) poverty rate at least twice the national average, or (3) a two-year average unemployment rate of greater than twice the national average (method 2b in Table 1).

Since the Arsenic Rule triggered much of the debate over affordability, it is important to examine and compare the performance of the USEPA's current expenditure margin and proposed incremental burden affordability methodologies in the context of this Arsenic Rule. The USEPA originally projected that the Arsenic Rule would cost $205.6 million (1999) annually nationwide (Abt Associates Inc. 2000). Quantifiable health benefits from lung and bladder cancer reductions came to an upper-end estimate of $197.7 million (1999) annually, with the unquantifiable benefits (from other cancers and non-cancer health effects linked to arsenic consumption, but without those data available for the USEPA analysis) estimated to be sufficient to make up the difference between costs and quantified benefits (Abt Associates Inc. 2000).

In contrast, some researchers, such as Frost et al. (2002) and Burnett and Hahn (2001), disputed the finding of this cost–benefit analysis and found that the costs far outweighed the benefits, especially for small systems and their customers. The average projected cost for arsenic treatment to those in the smallest system size class (systems serving fewer than 100 households) annually was $327 (1999) per household, about 10 times the $33 (1999) average national projected cost per affected household (Abt Associates Inc. 2000). However, despite the projected costs, the USEPA found that this burden was affordable for households in small systems nationwide, since even the maximum cost associated with a small system did not exceed the expenditure margin of $500 (1997) (Abt Associates Inc. 2000).

However, at least two ex-post reviews of the affordability of arsenic have been conducted, indicating that some systems have faced significant affordability challenges. A review of arsenic treatment alternatives for 14 tribal communities in Arizona found that the cheapest treatment alternative was within the expenditure margin but in excess of 2.5% of the community's MHI (Jones & Joy 2006). Hilkert Colby et al. (2010) compared performance and cost data of 36 treatment sites in California with 13 USEPA demonstration sites (in rounds 1 and 2

that use absorptive media) as well as with the affordability metrics; they found that 22% of the surveyed California systems paid more than the predicted additional cost burden as a result of the new Arsenic Rule, 19% of the households "paid more than the USEPA's affordability limit for a new regulation," and "15% paid more than the USEPA's affordability limit of the drinking water." However, the authors argue that the assumption that all water sources in a particular property are treated for arsenic (even though all sources might not contain arsenic) might have overestimated the cost of the Arsenic Rule.

IS THE ARSENIC RULE AFFORDABLE?

This article presents the results of an analysis of the USEPA's expenditure margin and incremental burden affordability methods using both predicted cost estimates from the original economic evaluation (Abt Associates Inc. 2000) and actual cost data from a geographically diverse set of 40 community water systems in the United States that had USEPA-funded arsenic-removal technologies in operation between July 2003 and July 2011 (Wang & Chen 2011). The first time point, 2000, uses the originally estimated costs to examine how the different affordability determination methods would have performed when the arsenic MCL was initially promulgated. The second time point, 2010, uses actual arsenic removal data to examine whether arsenic treatment was indeed affordable for the customers of those systems.

Data sources for affordability determinations. Affordability determinations require information on the costs of arsenic treatment, baseline drinking water treatment costs (i.e., before the Arsenic Rule), and socioeconomic data. Data from the USEPA's evaluation of the economic impact of the proposed 10 µg/L rule is used as the source of arsenic treatment's projected costs in 2000. The USEPA used the 2000 USEPA Community Water System Survey (CWSS) (USEPA 2009, 2002b) to determine national baseline costs for water treatment in its original affordability analysis. This source of baseline water costs is also used for the present analysis (Table 2).

Actual arsenic treatment cost data are taken from the USEPA's Office of Research and Development's Arsenic Removal Technology Demonstration project (ORD project). From July 2003 to July 2011, the ORD (USEPA) performed arsenic removal demonstration projects in 50 (12 in round 1, 28 in round 2, and 10 in round 2(a), respectively) selected water systems in 26 states that required treatment for arsenic in drinking water to comply with the new rule. The main objective of these demonstration projects was to collect cost and performance data and disseminate the findings so that stakeholders such as small water systems, engineering firms, and state agencies could make informed and efficient decisions about their choice of arsenic removal technology. Note that the ORD projects were not designed to minimize cost or make the new Arsenic Rule affordable. Thus, our results, based on the ORD projects' data, should be considered a conservative estimate of the affordability of the new Arsenic Rule.

Arsenic removal technologies used in the ORD projects were adsorptive media, iron removal and coagulation/filtration, ion exchange, reverse osmosis, point of use, and system/process modification. The total costs of the arsenic removal technology were classified into the capital cost (equipment, site engineering, installation) and the operation and maintenance cost (media replacement, chemical

TABLE 2 Annual arsenic and total water treatment cost in 1999, 2000, and 2010[a]

		System Size *number of households*				
Year	**Cost $**	**≤100**	**101–500**	**501–1,000**	**1,001–3,300**	**3,301–10,000**
1999	Estimates of annual arsenic treatment cost	327	163	71	58	38
	Annual average baseline cost of water	223	220	275[b]	275[b]	294
	Annual total cost of water	550	383	346	333	332
2000	Estimates of annual arsenic treatment cost	345	172	75	61	40
	Annual average baseline cost of water	235	232	289[b]	289[b]	253
	Annual total cost of water	580	404	364	350	293
2010	Estimates of annual arsenic treatment cost	437	218	95	77	50
	Annual average baseline cost of water	300	294	366[b]	366[b]	320
	Annual total cost of water	737	512	461	443	370

USEPA—US Environmental Protection Agency

[a]USEPA 2002b, Abt Associates Inc. 2000
[b]The annual average baseline costs are from the USEPA Community Water System Survey (CWSS 2000), which reports these two system sizes under one system size.

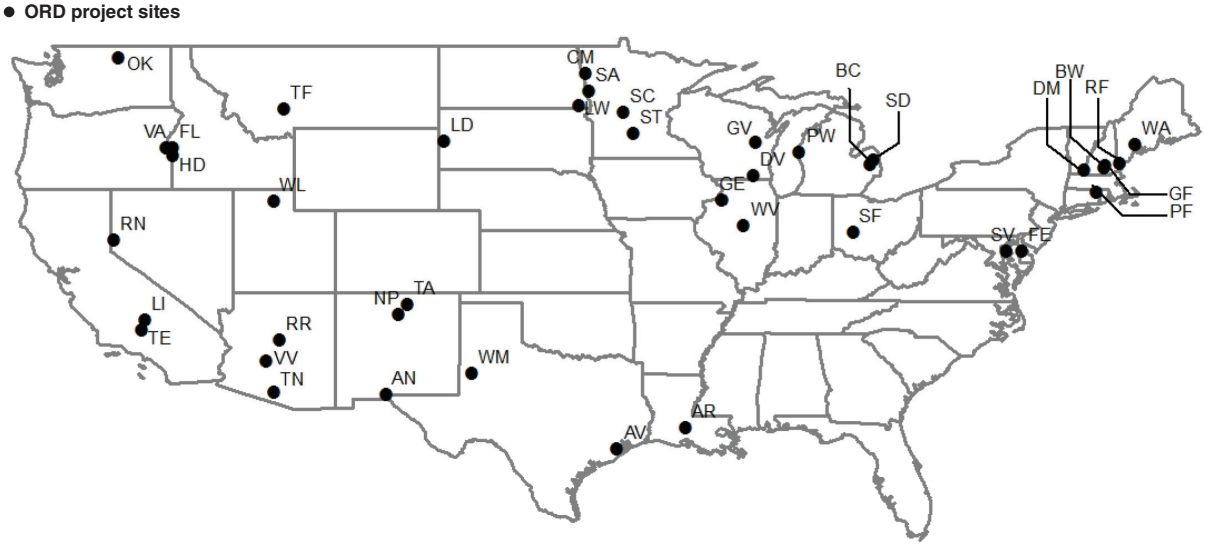
TABLE 3 Annual arsenic treatment and total water cost per household of 40 sites considered

System ID	Municipality	County	State	Annual Arsenic Treatment Cost *$/household*	Annual Total Water Cost *$/household*
AN	Anthony	Dona Ana	NM	155.55	416.39
AR	Arnaudville	St. Landry	LA	42.34	227.55
AV	Alvin	Brazoria	TX	161.35	516.29
BC	Brown City	Sanilac	MI	85.44	349.86
BW	Bow	Merrimack	NH	661.70	906.46
CM	Climax	Polk	MN	350.82	503.93
DM	Dummerston	Windham	VT	584.48	797.68
DV	Delavan	Walworth	WI	134.90	379.66
FE	Felton	Kent	DE	107.90	379.46
FL	Fruitland	Payette	ID	53.77	306.28
GE	Geneseo	Henry	IL	329.56	555.86
GF	Goffstown	Hillsborough	NH	176.78	421.54
GV	Greenville	Outagamie	WI	31.07	277.02
HD	Homedale	Owyhee	ID	554.45	806.96
LD	Lead	Lawrence	SD	145.02	393.95
LI	Lake Isabella	Kern	CA	213.81	456.19
LW	Lidgerwood	Richland	ND	114.69	383.27
NP	Nambe Pueblo	Santa Fe	NM	561.24	855.43
OK	Okanogan	Okanogan	WA	63.15	407.37
PF	Pomfret	Windham	CT	223.73	466.11
PW	Pentwater	Oceana	MI	94.01	303.04
RF	Rollinsford	Strafford	NH	152.14	395.71
RN	Reno	Washoe	NV	47.33	323.66
RR	Rimrock	Yavapai	AZ	16.98	304.03
SA	Sabin	Clay	MN	199.96	425.07
SC	Sauk Centre	Stearns	MN	146.80	346.90
SD	Sandusky	Sanilac	MI	48.38	312.80
SF	Springfield	Clark	OH	162.66	423.50
ST	Stewart	McLeod	MN	165.45	406.04
SV	Stevensville	Queen Anne's	MD	140.44	423.91
TA	Taos	Taos	NM	27.92	272.68
TE	Tehachapi	Kern	CA	17.42	259.80
TF	Three Forks	Gallatin	MT	49.77	287.98
TN	Tohono O'odham Nation	Pima	AZ	359.60	597.81
VA	Vale	Malheur	OR	106.48	373.87
VV	Valley Vista	Yavapai	AZ	82.36	369.41
WA	Wales	Androscoggin	ME	344.13	631.77
WL	Willard	Box Elder	UT	267.94	537.72
WM	Wellman	Terry	TX	498.80	800.73
WV	Waynesville	De Witt	IL	106.53	309.01

ID—identification

consumption, electricity, labor). The USEPA collected and then published the cost and performance data from these demonstration projects in a series of 49 reports (the report for one of the selected sites was not yet available for the analysis in this article). Of the 49 sites with reports, eight of these sites are nontransient, noncommunity systems, and one serves a seasonal resort. These nine are not considered in this study because those systems do not serve households. Therefore, the remaining 40 sites are used for this study (Table 3 and Figure 1). For

FIGURE 1 Sites used in evaluating affordability of the Arsenic Rule



ORD project—US Environmental Protection Agency's Office of Research and Development Arsenic Removal Technology Demonstration project

Refer to Table 3 for individual site details.

a summary of the ORD projects' data considered in this article, see Gingerich (2013).

Costs were recorded over a one-year study period and reported by the USEPA (Wang & Chen 2011). Capital and start-up costs were annualized over a 20-year period, with an interest rate of 7% in keeping with standard government practice. For some adsorption and ion exchange systems, breakthrough was yet to occur by the end of the ORD project study, so costs for media replacement were projected rather than actual. One important reason for examining affordability prospectively (using 2000 cost estimates) and retrospectively (using 2010 cost data) is due to the difference between the treatment technologies envisioned and those actually used. In 2000, the USEPA considered ion exchange and activated alumina the best options for small systems, whereas iron-based removal systems were, in fact, heavily used in the ORD project. According to Abt Associates Inc. (2000), the USEPA found the following best available technologies to be affordable for all system sizes: anion exchange, activated alumina, reverse osmosis, modified coagulation/filtration, modified lime softening, and oxidation/filtration.

There are some limitations and potential biases of the data collected from these demonstration projects (Wang & Chen 2011). For example, the operation and maintenance costs (recorded in the ORD projects) did not include residual disposal nor building construction. Moreover, wage (cost of labor) varies significantly across different states (geographic regions), and labor hours depended on the specific characteristics and circumstances of different demonstration sites. Finally, little to no pilot testing was conducted to optimize the design and installation of the technology at the site before the selection of a technology.

Many of these reports list the number of households or connections served. Reports that do not provide the number of households list the total population served. In such cases, USCB data on community household size (2010a, 2000) are used to estimate the number of households served. The total cost for treatment is divided by the number of households to yield an average cost per household. The average cost per household is adjusted for inflation using US Bureau of Labor Statistics (USBLS) data (2012) to convert into 2010 dollars. The ORD project cost data are paired with Rubin's (2004) regional estimates of water costs (followed by an adjustment for inflation) on the basis of the data collected as part of the 2000 long-form census. Because this estimate includes both water and wastewater bills, the household cost for water treatment alone is isolated on the basis of the data collected as part of the Water and Wastewater Rates 2000 Survey performed by Raftelis Financial Consulting (2000).

Data from the USCB and USBLS are used for the socioeconomic variables needed to make affordability determinations under method 2b. For the year 2000, household size, median income, income distribution, and poverty rate are all taken from the 2000 Decennial Census performed by the USCB (2000). For 2010, total population is taken from the USCB's 2010 Decennial Census (2010a), and household size, median income, income distribution, and poverty rate are taken from the USCB's American Community Survey 2010 Five-Year

Estimates (2010b). All unemployment statistics come from USBLS (2010, 2000).

How affordability is determined. As noted previously, the USEPA's current expenditure margin and proposed incremental burden methods are examined in this article using the original predicted costs from the 2000 *Arsenic in Drinking Water Rule Economic Analysis* (Abt Associates Inc.) and actual cost data developed during the Arsenic Removal Technology Demonstration projects (Wang & Chen 2011). First, we examine the affordability of the new Arsenic Rule following the USEPA's expenditure margin affordability methodology (method 1). The sum of the Abt Associates Inc. (2000) predicted cost for arsenic treatment and the average baseline water cost from the 2000 CWSS is compared with 2.5% of the national MHI in 2000 for systems serving up to 10,000 households (Table 2). Second, the 2006 incremental burden USEPA affordability methodology (method 2a) is applied by considering the incremental cost burden (i.e., the estimated cost for the arsenic treatment per household). The projected cost for arsenic treatment alone for each size class is compared with 0.25, 0.50, and 0.75% of the 2000 national MHI.

These two tests are then repeated using the actual data collected from the Arsenic Removal Technology Demonstration projects (Wang & Chen 2011) and the 2010 national MHI in place of the *Arsenic in Drinking Water Rule Economic Analysis* projected costs (Abt Associates Inc. 2000) and 2000 national MHI, respectively. Since the 2010 analysis uses actual data from specific individual communities, the second criterion of method 2 (method 2b, identifying economically disadvantaged communities that could potentially qualify for variances on the basis of community-specific socioeconomic conditions) is also tested using socioeconomic data collected from the USCB and USBLS from 2010 (2009–2010 for unemployment data). The MHI, poverty rate, and two-year average unemployment rate for the municipalities and counties (where the demonstration sites are located) are divided by the national MHI, poverty rate, and two-year average unemployment rate, respectively. (For the unemployment rate, only Reno, Nev., and the New England sites were analyzed using municipal data because the USBLS does not report unemployment for municipalities with a population of <25,000 outside of New England.) The USEPA has proposed that if the ratios exceeded either 0.65 for MHI, 2 for poverty level, or 2 for unemployment, arsenic removal could be potentially unaffordable because of an inability to raise the necessary capital funds.

Considering below-median income. The USEPA incorporated some of the suggestions made by its EEC in its 2006 proposed affordability criteria, including using regional data after applying the national test as an initial screening procedure. However, some key proposals, most notably the recommendation to use a below-median household income affordability threshold, were not incorporated. The EEC gave many reasons to use an income level lower than the MHI. The most significant reason for this recommendation was within-system income differences. Since all households—not just the median households—within a system pay for drinking water treatment, the EEC recommended that affordability to houses with below-median income be considered. The EEC also noted significant income variation within systems of the same size class. Using the MHI for an entire size class ignores variations within the size class, so poorer systems are held to the same expenditure level as the richer systems, an issue that could be accounted for by using a lower income (EEC 2002).

The EEC (2002) suggested a few alternative household income levels that could be used in place of MHI in affordability determinations, specifically the 25th or 10th percentile and 1, 1.5, or 2 standard deviations below the mean—with the 25th percentile and 1.5 standard deviations below the mean being "reasonable." However, household income is not normally distributed (according to the data collected by the USCB). Most household income distributions have a mode well below the mean and a small number of households with very high incomes. Because of this non-normal distribution, 1.5 standard deviations below the national mean household income is actually below zero, and even with the top 5% of the distribution removed (to reduce the effect of outliers), this level of income would only be a few hundred dollars per household per year for most systems. Therefore, the 25th percentile of household income is selected for this analysis as a below-median income threshold to test three new potential affordability methods:

- Substitute 2.5% of the 25th percentile of national household income for 2.5% of the national MHI in the expenditure margin method (method 3 in Table 1).
- Substitute the 25th percentile of household income for MHI in the incremental burden method (method 4 in Table 1).
- Use 2.5% of the 25th percentile of the local community (as opposed to the national) household income as a threshold limit for a decentralized, system-specific treatment affordability determination (method 5 in Table 1).

The 25th percentile household income values (national and local) are identified from the 2000 USCB and the 2006–2010 American Community Survey (USCB 2010b, 2006) data. These income levels are then applied in the affordability criteria to examine the sensitivity of the outcomes to the income threshold used. Note, however, that the affordability criteria analyzed herein are not exhaustive, and other potentially viable criteria have been developed as well (Christian-Smith et al. 2013).

RESULTS OF THE AFFORDABILITY COMPARISONS

A total of 18 possible affordability scenarios are compared in this study (Table 4). Four possible median household income rules use the national MHI; the total cost

for water treatment cannot exceed 2.5% of national MHI (method 1), and the arsenic cost for water treatment cannot exceed 0.25, 0.50, or 0.75 of national MHI (method 2a). These same four rules can also be applied using the national first quartile household income substituted for the national MHI (methods 3 and 4); this generates an additional four scenarios. These eight rules can be applied both prospectively (using the 2000 predicted costs) and retrospectively (using actual site-specific costs from the ORD reports) for a total of 16 affordability scenarios. Finally, two additional scenarios compare cost data with 2.5% of the town (or municipal) and county first quartile household income (method 5). Note that the rules based on methods 1–4 are performed using both the projected costs in 2000 and the ORD project cost data in 2010, while the two rules from method 5 are performed using only 2010 data because these rules use site-specific income instead of the national-level data.

TABLE 4 Eighteen affordability scenarios

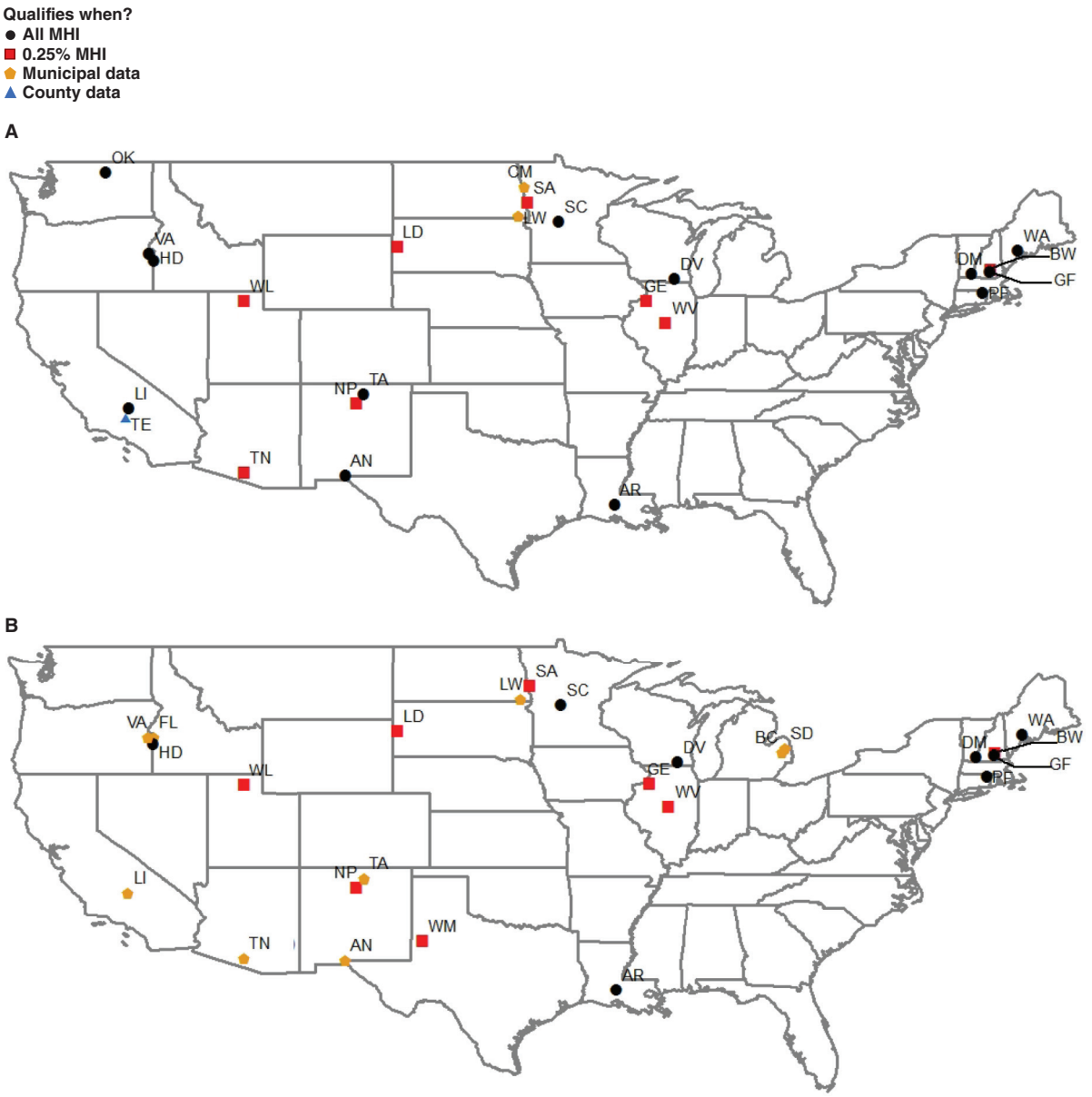
Scenario Number	Scenario
1	Incremental burden method with 0.75% of first quartile household income (2000)
2	Incremental burden method with 0.50% of first quartile household income (2000)
3	Incremental burden method with 0.25% of first quartile household income (2000)
4	Expenditure margin method with 2.5% MHI (2000)
5	Incremental burden method with 0.75% MHI (2000)
6	Incremental burden method with 0.50% MHI (2000)
7	Incremental burden method with 0.25% MHI (2000)
8	Expenditure margin method first quartile household income (2000)
9	Incremental burden method with 0.75% MHI (2010)
10	Incremental burden method with 0.50% MHI (2010)
11	Incremental burden method with 0.25% MHI (2010)
12	Expenditure margin method with 2.5% MHI (2010)
13	Incremental burden method with 0.75% of first quartile household income (2010)
14	Incremental burden method with 0.50% of first quartile household income (2010)
15	Incremental burden method with 0.25% of first quartile household income (2010)
16	Expenditure margin method first quartile household income (national) 2010
17	Expenditure margin method first quartile household income (county) 2010
18	Expenditure margin method first quartile household income (municipal) 2010

MHI—median household income

Figure 2, part A, shows the results associated with the eight scenarios that use the predicted costs for arsenic removal and national-level income data from 2000. Since these are based on national-level data, determinations are made by system size class; we find that all systems within a qualifying size class potentially qualify for affordability variances. The only scenario in which the Arsenic Rule is judged affordable for all system size classes is the one the USEPA used for its original affordability determination—i.e., the expenditure margin approach with an affordability threshold of 2.5% of the national MHI (method 1). However, even though the Arsenic Rule is deemed "affordable" by this measure, some small-system water bills are projected to increase markedly as a result of the rule, increasing almost 150% for the smallest systems serving ≤100 households (Table 2). For the other methods tested in this article, anywhere from 24 to 83% of small systems would qualify for an affordability variance. Under scenarios 1 and 8, all systems serving ≤100 households qualify. For scenarios 2, 3, 5, and 6, systems that serve ≤500 households qualify. The most generous scenario (i.e., the one granting the most variances) is scenario 7 (the incremental burden method with a 0.25% MHI affordability threshold), in which all systems that serve ≤3,300 (83% of small systems) qualify for permission to use affordability variances. Although we do not observe any strong relationships between the site characteristics and the likelihood of a site exceeding a particular affordability criterion, McGavisk et al. (2013) demonstrate that the MHI of noncompliant systems is slightly (~3%) less than the MHI for compliant systems.

Figure 2, part B, shows how many of the 40 ORD systems have "unaffordable" treatment under each of the 10 scenarios that are evaluated with 2010 data. Just as previously, only under the current USEPA affordability methodology (method 1) is the Arsenic Rule judged affordable for all 40 systems. Under the other nine methods, between six (15%) and 22 (55%) of the 40 systems would qualify for variances. The most generous scenarios are with the incremental burden method, using affordability thresholds of 0.25% of national MHI and 0.25 and 0.50% of first quartile income, all of which would qualify 22 of the 40 systems (55%) for variances. The incremental burden rules using 0.75, 0.50, and 0.25% of MHI (scenarios 9, 10, and 11) qualify five (13%), 10 (25%), and 22 (55%) systems, respectively, for affordability variances. Scenarios 13, 14, and 15, incremental burdens with 0.75, 0.50, and 0.25% of first quartile household income, qualify 13 (33%), 22 (55%), and 22 (55%) systems, respectively. Finally, the expenditure margin approaches using national, county, and municipal first quartile household income (scenarios 16, 17, and 18) qualify 13 (33%), seven (18%), and seven (18%) systems, respectively.

FIGURE 2 Systems qualifying for variances based on proposed USEPA criteria in 2000 (A) and 2010 (B)



MHI—median household income, USEPA—US Environmental Protection Agency

Refer to Table 3 for individual system details.

HOW DO THESE EVALUATIONS COMPARE?

Next, we describe the number of potential affordability scenarios (out of 18) in which the systems in the ORD study would qualify for a variance. Only three systems (8%) would not qualify for a potential affordability variance under any of the scenarios. Eleven systems (28%) qualify for a variance under half of the scenarios included. However, only one system qualifies under all scenarios except for the current USEPA affordability methodology (scenarios 4 and 12). There are two different sets of comparisons that evaluate the performance of the affordability determinations: (1) methods that use median household income compared with methods that use below-median household income and (2) methods that use the expenditure margin approach compared with methods that use the incremental burden approach.

Comparing the income levels. As should be expected, using a lower income qualifies more systems for variances when the national-level income data are used. Using the projected costs and 2000 data and the incremental

methods, 16,461 more systems fell in system size classes having unaffordable arsenic treatment for 0.75% of the income level (scenarios 1 and 5); there is no difference in the number of systems for 0.50% of the income level (in both scenarios 2 and 6, all systems serving fewer than 500 qualify); and 14,017 additional systems qualify when 0.25% of the income level is used (scenarios 3 and 7). No system has "unaffordable" arsenic treatment using the median household income (scenario 4), so the 12,658 systems that qualify only do so when the first quartile household income is used in scenario 8.

When the cost data from the 40 ORD sites are used, similar patterns emerge. An additional eight systems qualify when 0.75% of the first quartile household income is used in comparison with the median household income (scenarios 9 and 13); 12 more systems qualify for 0.50% of the income level (scenarios 10 and 14); and no additional ORD system has "unaffordable" arsenic treatment when 0.25% of the income level is used (scenarios 11 and 15). When the cumulative threshold is adjusted from 2.5% of MHI to 2.5% of the first quartile household income, 13 systems potentially qualify for affordability variances (scenarios 12 and 16).

A potential criticism of the use of below-median income thresholds is that their use could reduce the regulatory burden necessary to receive permission to use a variance to a level that is unacceptably low. Comparing the results of the methods that used first quartile income with the results from methods that used MHI shows that this is not necessarily the case. An affordability criterion that considers the expected treatment cost in excess of 2.5% of the 25th percentile of the national MHI is as stringent as the USEPA incremental burden screening criterion of 0.75% of national MHI. A study using 0.75 or 0.50% of the 25th percentile household income is as stringent as the incremental burden screening criteria of 0.25% of MHI. As such, the use of a below-median income threshold does not necessarily qualify more systems for a variance than all other proposed methods based on the MHI.

Comparing the approaches. There is a systematic difference between the outcomes of the two basic methods for determining affordability—the expenditure margin approach and the incremental burden approach. With only one exception, the expenditure margin approach qualifies fewer systems for affordability variances than the incremental burden approach does. For the 2000 and median household income determinations, the expenditure margin would not grant any affordability variances, while the incremental burden approach grants them to over half of the community water systems in the United States (under the 0.50 and 0.25% incremental burden). For the 2000 and first quartile household income, the incremental burden gives permission to use variance technologies to over twice as many systems (0.75 and 0.50% incremental burden) or three times as many systems (0.25% incremental burden).

Similar results are observed for the ORD project sites in 2010. When the median household income methods are compared, five (0.75% MHI), 10 (0.50% MHI), and 22 (0.25% MHI) more systems qualify for affordability variances than the zero systems that qualify under the expenditure margin approach. For the first quartile household income methods, nine additional systems have "unaffordable" treatment under the incremental burden approach at 0.50 and 0.25% first quartile household income (the one exception to the rule is that the incremental burden method qualifies more systems), and no additional systems qualify with the 0.75% of first quartile household income incremental method (although the systems that do qualify are different in the two methods).

If the purpose of revising the affordability criteria is to make it easier to trigger permission to use variances, the incremental burden method proposed by USEPA meets this goal. One can perhaps argue that the selection of 0.25% MHI and the use of municipal data can potentially facilitate decentralized variance decisions (i.e., can make it easier for the state and counties to trigger affordability decisions). Similarly, an affordability rule with 0.75% MHI as the threshold, and that uses county data, might qualify (for variance technology) only the systems that experience a severe economic burden of the new Arsenic Rule.

CONCLUSION

This article critically analyzes the affordability of the new Arsenic Rule comparing the USEPA's expenditure margin affordability method and the incremental burden methodology (proposed in March 2006) with a lower income level in the metric. While the results presented here are consistent with the USEPA's original affordability decision that the Arsenic Rule is affordable for all systems, we show that the 2006 incremental burden criteria would have found arsenic to be unaffordable for some systems. One of the main contributions of this article is an analysis of the effect of using the 25th percentile income, instead of the MHI, for affordability methodologies in order to address concerns of environmental justice (i.e., affordability of the small systems, maintenance of public health standard, especially for the economically backward communities, etc.) (Balazs et al. 2012, USEPA 2011, Cory & Rahman 2009).

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

Ultimately, selection of an affordability methodology is a subjective decision that requires balancing the accuracy of cost estimates (NCEE 2012, Harrington et al. 2000), risk, economics, and political considerations. It is our position that the use of a 2.5% of the county's 25th percentile income threshold with the USEPA's incremental burden criteria for identifying disadvantaged communities (methods 5 and 2b) meets various standards that define an effective affordability methodology (promotes economic efficiency, grants some variances as needed by environmental justice, is not overly generous with the number of variances to protect public health, accounts for overestimation of costs, and maintains affordability practicality).

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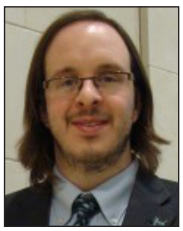

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