Journal of Benefit-Cost Analysis

Volume 2, *Issue* 1 2011 *Article* 4

Benefit-Cost Analysis for Drinking Water Standards: Efficiency, Equity, and Affordability Considerations in Small Communities

Robert S. Raucher, *Stratus Consulting Inc.*
Scott J. Rubin, *Public Utility Consultant*
Douglas Crawford-Brown, *University of North Carolina at Chapel Hill*
Megan M. Lawson, *Stratus Consulting*

Recommended Citation:

Raucher, Robert S.; Rubin, Scott J.; Crawford-Brown, Douglas; and Lawson, Megan M. (2011) "Benefit-Cost Analysis for Drinking Water Standards: Efficiency, Equity, and Affordability Considerations in Small Communities," *Journal of Benefit-Cost Analysis*: Vol. 2: Iss. 1, Article 4.
DOI: 10.2202/2152-2812.1004

Benefit-Cost Analysis for Drinking Water Standards: Efficiency, Equity, and Affordability Considerations in Small Communities

Robert S. Raucher, Scott J. Rubin, Douglas Crawford-Brown, and Megan M. Lawson

Abstract

The federal Safe Drinking Water Act (SDWA), as amended in 1996, enables benefit-cost analysis (BCA) to be used in setting federal drinking water standards, known as MCLs. While BCAs are typically conceived of as a tool to inform efficiency considerations by helping to identify MCL options that maximize net social benefits, in this paper we also illustrate how important equity and affordability considerations can be brought to light by suitably applying BCAs to drinking water regulations, especially in the context of communities served by relatively small water systems. We examine the applicability and relevance of health-health analysis (HHA), and provide an empirical evaluation of the risk tradeoffs that may be associated with the MCL established for arsenic. We find that the cost-associated risks may offset a nontrivial portion of the cancer risk reduction benefits attributed to the MCL (e.g., the additional adverse health impacts from the costs may be roughly half as large as the number of cancer cases avoided). This reveals the relevance of using the HHA approach for examining net benefits of MCLs in small drinking water utilities, and raises issues related to whether and how these cost-associated health risks should be considered in BCAs for drinking water standards.

KEYWORDS: drinking water regulation, BCA, risk assessment, affordability, health-health analysis, uncertainty

Author Notes: The authors thank Dr. John Regnier and the National Rural Water Association for their support in developing the empirical analyses presented in this paper. We also recognize the highly detailed and very constructive review comments provided by Dr. Robert Haveman (University of Wisconsin) and Dr. Paul Portney (University of Arizona) on an earlier version of this material (Rubin et al., 2008). All errors and omissions remain those of the authors.

Introduction

The federal Safe Drinking Water Act (SDWA), as amended in 1996, became the first major national environmental statute to mandate benefit-cost analysis (BCA) be performed for proposed and final rulemakings. More important, the Act enables the Administrator of the U.S. Environmental Protection Agency (EPA) to use the BCA results to establish its enforceable drinking water standards at levels less stringent than what is considered technically feasible. This latitude in standard setting can be used if the EPA Administrator determines that the benefits of the technically feasible option do not "justify" the costs. Thus, BCA has a somewhat unique and important role in how stringently the enforceable federal drinking water standards, known as Maximum Contaminant Limits (MCLs), are set.[1]

Given the important and somewhat unique role that BCA now plays in setting federal drinking water standards, it is critically important to consider the manner in which these BCAs are conducted, presented, interpreted, and applied. While BCAs are typically conceived of as a tool to inform efficiency considerations by helping to identify MCL options that maximize net social benefits (i.e., the health risk reduction benefits, minus regulatory compliance costs), in this paper we also illustrate how important equity considerations can be brought to light by suitably applying BCAs to drinking water regulations, especially in the context of communities served by relatively small water systems. We also examine the applicability and relevance and risk tradeoffs that may be associated with these standards when high compliance costs are borne by economically disadvantaged households.[2]

In exploring the equity implications, this paper discusses the "affordability" of federal drinking water regulations in the United States (U.S.), and the implications for net health benefit. Affordability, especially in the context of households served by small water utilities, has been a challenging policy issue for many years, yet it remains unresolved. This paper examines the efficiency and equity issues associated with the problem, and outlines potential solutions. We then explore the relevance and potential magnitude of risk tradeoffs inherent when significantly increased water costs are borne by economically vulnerable

1. The MCL established for arsenic, in 2001, was the first time this new authority to use BCA was deployed, resulting in an MCL of 10 micrograms per liter (μg/L) rather than the more stringent but technically feasible alternatives of 5 μg/L or less (U.S. EPA, 2001). Prior to the 1996 Amendments, MCLs were required under the statute to be set as close to zero risk health goals as technically feasible, regardless of any benefit-cost considerations.

2. Another critical BCA issue that arises in the SDWA context is the manner in which the uncertainties and variabilities in the underlying health risk assessments are embodied and portrayed in the health risk reduction benefits component of the BCAs. This issue is touched on briefly later in this paper, but requires a separate paper to furnish a more complete discussion.

https://doi.org/10.2202/2152-2812.1004 Published online by Cambridge University Press

households served by small water systems. We also discuss issues related to whether and how these cost-associated health risks should be considered in SDWA BCAs.

Defining the Problem

In the U.S., federal drinking water quality standards are established by the EPA, under the mandate of the SDWA (PL 93-523), originally signed into law in 1974. Enforceable federal drinking water standards, MCLs, apply uniformly to all Community Water Systems (CWS). CWS are defined by the Act as all water utilities serving 25 or more persons year-round.

Under the provisions of the 1996 Amendments to the SDWA, the stringency of an MCL is established based on the risks, costs, and benefits that accrue to people served by relatively large CWS (e.g., urban or suburban water utilities serving more than 10,000 people). In this large system setting, MCLs are often a good public health investment because applicable water treatment processes typically exhibit economies of scale, resulting in an increased water supply cost per-household that is relatively low (e.g., less than $40 per-household per year). Regulatory compliance costs are easily justified when the per-household expense is moderate and generally expected to be outweighed by the risk reduction benefits realized by the people served by these relatively large utilities.

The situation in smaller communities (e.g., where CWS serve between 25 and 1,000 people) is quite different. Most applicable water treatment processes generally do not exhibit economies of scale within the small system size range, which typically results in relatively high MCL compliance costs per household in smaller systems. This often results in relatively large increases in household water bills (e.g., increased costs of $400 per-household per year, or considerably more) to cover the cost of complying with a single MCL. As an example, Table 1 reveals how the EPA-estimated per-household compliance costs for the 2001 arsenic rule are impacted by system size (U.S. EPA, 2000, 2001; Sunstein, 2001). For small systems, such compliance costs may outweigh the health risk reduction benefit that small system households obtain from a standard. Or, viewed from another perspective, the same expenditure may provide a greater public health benefit for the community if applied to another risk. When this type of outcome occurs, it could indicate the MCL is an inefficient public health investment in these small communities.

DOI: 10.2202/2152-2812.1004

Table 1. Mean annual costs per-household of the arsenic MCL (10 ppb) (updated to 2007 dollars)

CWS size category (population served)	EPA-estimated annual cost per-household
25–100	$407
101–500	$202
501–1,000	$88
1,001–3,300	$72
3,301–10,000	$47
10,001–50,000	$40
50,001–100,000	$31
100,001–1 million	$25
More than 1 million	$1
Weighted average across all size categories	$39

ppb = parts per billion.

CWS serving 3,300 or fewer people constitute 83% of the nation's CWS, and serve 9% of the nation's CWS-served population. CWS serving 3,301 to 10,000 people account for 9% of the nation's CWS, and serve 10% of the population. The balance are in the larger categories.

Sources: U.S. EPA, 2000, 2008; Sunstein, 2001.

As a simplified example, consider two communities with pre-compliance arsenic concentrations 50% above the MCL of 10 μg/L, where one community is supplied by a "large" CWS serving 500,000 people, and the other is served by a "very small" CWS supplying 50 people. As noted later in the paper, the EPA risk assessment for reducing these arsenic exposures to the MCL would yield an estimated reduction of 4.45 cancer cases per 1,000 people exposed, of which 53% would be fatal, over a 70-year period (NRC, 1999, 2001). The residents of both communities obtain the same health risk reduction benefits from complying with the MCL, but based on the EPA cost estimates (Table 1), the people in the smaller community pay more than 16 times as much for the same benefit ($407 per household contrasted to $25 per household per year). From a BCA perspective using the EPA recommended Value of a Statistical Life benchmark of roughly $7 million, the present value cost per fatal cancer avoided in the large CWS appears very reasonable at approximately $650,000; however, in the smaller CWS, the cost per fatal cancer avoided is over $10 million and thus does not pass the positive net benefit criterion.[3]

3. The simplified BCA illustration developed here applies EPA's stated risk factors and cost of compliance estimates, uses a 7% real discount rate per the Office of Management and Budget (OMB) guidelines, and assumes a 15-year latency (cessation lag) period with the total risk reduction distributed equally over years 16 through 70. Morbidity benefits are omitted here, for simplicity.

Applying an expensive MCL to small systems may be considered inequitable, because it forces households in small CWS systems to pay considerably more than their big system counterparts, to obtain a comparable risk reduction benefit. Perhaps more important, the high costs imposed on lower income households in small systems may also be counterproductive from a public health standpoint, to the degree that reducing their effective disposable incomes may elevate some risks by curtailing household spending on preventive or other medical care (i.e., the MCL's cost may impose risk tradeoffs on impacted households, as discussed below). These potential cost-associated risk tradeoffs elevate efficiency concerns.

The efficiency and equity problem associated with small water systems is not trivial. There are many more small CWS than large ones in the U.S. Very small (25 to 100 persons served) and small systems (101 to 3,300 served) collectively account for 83% of the nation's approximately 52,000 CWS, but supply only 9% of the U.S. population served by CWS (U.S. EPA, 2008). In contrast, large CWS (serving 10,001 to 100,000 persons) and very large systems (serving more than 100,000 persons) combine to comprise only 8% of the nation's CWS, and they collectively supply roughly 82% of the national population of 292 million served by CWS (U.S. EPA, 2008). Many small systems are located in rural areas with limited resources and median household community incomes below the national level (Rubin, 2001; Ottem et al., 2003), exacerbating the problem.

The small water system challenge has been largely debated within the context of "affordability." These discussions stem from the observation that the cost of compliance with some MCLs is so high as a percentage of income for some households—largely moderate or low-income households in smaller systems, and also the urban poor—that the expense may be unfairly burdensome, perhaps unjustified by the benefit, and conceivably counterproductive from a public health standpoint. This paper extends that discussion to consideration of risk-risk trade-offs that result from this burden.

Small System Solutions Remain Elusive

The efficiency and equity problems posed when some MCLs are applied to small CWS have received considerable attention. The small system compliance/affordability challenge was recognized when the SDWA was first passed into law (e.g., Clark and Stevie, 1978), and then received a great deal of fresh attention following the 2001 promulgation of the MCL for arsenic. More than 35 years after the SDWA was first signed, and nine years following promulgation of the arsenic MCL, a workable solution remains elusive. The problem persists despite serious consideration over the past decade by Congress, EPA, and its Science Advisory Board (U.S. EPA, 2002), the National Drinking Water Advisory Council (NDWAC, 2003), the federal OMB, and various other organizations and researchers.

For example, the 1996 Amendments to the SDWA included a provision wherein EPA could issue "small system technology variances" whenever it determined an MCL was unaffordable for small systems. According to the statute and EPA (U.S. EPA, 2006), a small system variance technology would enable a system to utilize a treatment technology that achieves the maximum removal of the contaminant that is both "affordable" and "protective of public health," but does not remove the contaminant to the degree specified by the drinking water regulation (i.e., it would not meet the MCL). States may then opt to grant small system variances, but only for those drinking water standards that EPA has determined are unaffordable, and only where the Agency has also identified variance treatment technologies that achieve the maximum reduction in the contaminant level that is affordable, and determines that the variance technologies are protective of public health. EPA developed "affordability" criteria for the variance technology provision, and based on its application of these criteria, the Agency has yet to determine that one of its MCLs is unaffordable for small systems. Thus, to date these variances are, in effect, unavailable to small systems.

Potential Solutions

There are four fundamental types of potential solutions to the small CWS affordability challenge. One option is to establish less stringent MCLs for smaller, economically challenged communities, so that the household-borne costs of compliance can be reduced to a point that is sufficiently less burdensome, and such that a more suitable risk-cost balancing can be attained for small system customers. This "dual standard" approach is typically considered only for contaminants that pose a risk from long-term, chronic exposures, and not to pathogens that pose acute risks. This "dual standard" concept was envisioned in the "small system variance technology" provision of the 1996 SDWA Amendments. It was also proposed in a somewhat modified form by EPA, a decade later, with its 2006 affordability proposal that considered a concentration level of up to three times the MCL could be accepted as protective of human health (Federal Register, 2006). The dual standard approach has been opposed, however, when characterized as unfairly providing lesser health protection to people served by small CWS.

A second type of option is to provide federal financial relief to small water systems (or low-income households), to defray a suitable portion of MCL compliance costs. The logic is that if society deems it inequitable and inappropriate to have dual standards that allow less stringent MCLs for small systems, then society as a whole should pay to offset the financial burden that uniform standards impose on small communities, and the poor in general. This funding might take the form of grants or other subsidies to small CWS, or might be targeted directly to low-income households adversely impacted by MCL-related costs. The problem with this approach—even in relatively prosperous times—is that neither the executive nor legislative branches of the federal government have been inclined to allocate sufficient funds for such a program (beyond what is already allocated via existing programs such as the State Revolving Fund, which offers a limited amount of federal funds for state-allocated subsidized loans for water system improvements).

A third option is to significantly reduce the number of small systems, by facilitating or mandating some form of regional or other consolidation into larger utilities where economies of scale in treatment may be realized. There are many types of regional solutions that can be highly beneficial under suitable circumstances (Raucher et al., 2006; Cromwell and Rubin, 2008). However, there are also many technical, economic, and other physical and institutional barriers that make consolidation-based solutions untenable in many small system contexts (Ottem et al.; Raucher et al.).

Each of the three general alternatives described above have their advantages, disadvantages, limitations, and detractors. Due to these conflicts, U.S. policy-makers have not implemented any of these generic choices. As a consequence, the small system affordability issue is governed by the status quo (i.e., the fourth option), which (1) applies uniform standards, where the standards are based on the economics of a large CWS context, (2) does not provide sufficient federal funding to small systems (or highly burdened households) to address the problem, (3) results in high levels of observed small system noncompliance and enforcement issues (which are themselves difficult to resolve due to the high costs of compliance and limited resources in small communities), and (4) impose economic hardships on many households served by those small systems that make significant efforts to comply.

Thus, by default, the national status quo policy includes some MCLs that are inefficient and inequitable. One question that has remained unanswered, however, is whether the status quo is harmful on a net risk basis for many households served by small CWS. The balance of this paper explores the health and risk implications of the status quo, using a BCA perspective. The arsenic rule is used as the basis for illustrating several of the issues, but similar observations can be derived from other proposed or promulgated MCLs.

Defining Affordability

For our purpose, we define affordability for drinking water regulations as household monthly water bills that do not impose "undue economic hardship" (also referred to as "financial distress") on low-income households in the utility's service area. In other words, affordable water rates are those that are inexpensive enough that low- or moderate-income households do not need to displace other essential services (e.g., medical care, food, or energy) to pay their water bills.

There is not an objective, quantitative measure for this definition. Affordability is by nature a subjective construct, requiring gradations and judgment rather than an empirical bright line to differentiate what level of cost and associated tradeoffs constitute an economic hardship for a household. Further, tradeoffs in spending choices are inevitable for any limited income household, so the fact that some tradeoffs occur in spending is not, in and of itself, an indication of economic hardship or increased risk. There may come a point, however, where a household experiences a reduction in effective disposable income (e.g., due to higher water bills) that begins to crowd out expenditures for health care, food, energy, or other essential services. Recognizing that such a threshold exists, and trying to account for it in BCA, provides a useful basis for considering the adverse impact that expensive MCLs may have on lower-income households in small communities.

As noted by Sunstein, the EPA regulatory analysis for the arsenic MCL lacks any discussion or consideration of distributional impacts, and it would be a useful and important part of the policy deliberation to "match the assessment of the range of costs of the rule with an account of the income and wealth of those who will be subject to these costs" (2001: 49). He further notes that data from several states reveal that the substantial increases in water bills (which he denotes as $300 or more per-household annually) would be borne by people whose median income is significantly below the state average. Sunstein concludes that "if safer water is very expensive, then poor people are better off without it than with it…. If the consequence of decreasing (small) risks is significantly to decrease family income for poor people… [who would otherwise] use that money on food, or medical care, or shelter… then it is perfectly legitimate for the government to refuse to act" (p. 49) (i.e., to not impose the regulation).

Potential Risk Tradeoffs in Small Communities

The concept is not new that regulatory-imposed costs might reach a high enough level that they may impose negative impacts on the health of households bearing these costs. There is a considerable body of published peer-reviewed literature on this topic, which has been labeled Health-Health Analysis (HHA) to reflect the context where a regulation intended to protect health may, in effect, also elevate other health risks as a consequence of the costs it imposes.

The logical premise of HHA is that if there are cost-imposed risks to health, then these need to be deducted from the health risk reduction benefits of the policy to obtain an estimate of the *net* risk reduction. If the costs are high enough relative to the primary risk reduction attained, it is conceivable that the cost-induced risk could even outweigh the regulation's expected risk reduction gains, yielding a net increase in health risk.

The extensive literature on HHA has been reviewed elsewhere (Rubin et al., 2008). Briefly, the origins of HHA in the federal regulatory policy context dates back to 1992, when the Occupational Safety and Health Administration (OSHA) considered the effect of compliance costs on workers' disposable incomes and then looked at the health effects associated with lowering those disposable incomes (OSHA, 1992). OSHA concluded that compliance costs could reach a point at which it was likely that the adverse health consequences of the income loss to workers would exceed the health benefits from the regulation.

A 1994 edition of the *Journal of Risk and Uncertainty* was dedicated entirely to HHA. In that edition, Keeney (one of the pioneers of HHA) explained that the central purpose of the analysis is to determine "whether the cost of a proposed regulation, which *de facto* reduces the disposable income of individuals available for other purposes, would increase mortality risks…" (Keeney, 1994).

Lutter et al. (1999) examined the concept of a break-even cost, defined as the amount spent for regulatory compliance where the health benefits of the regulation equaled the health detriments on those who pay for the regulation through reduced disposable income. They estimated a net risk break-even point as occurring when a regulation reaches a cost of roughly $19 million per premature fatality avoided (updated to 2007 dollars) (Lutter et al.).

HHA proved to be very controversial for a variety of conceptual and empirical reasons. One detailed technical critique, by Portney and Stavins (1994), concluded that there were at least two fundamental problems with HHA. First, it treats small costs incurred by many people (as would arise in many regulatory contexts, where compliance costs are dispersed across a large population through marginally higher product prices) as being equivalent to large costs incurred by a few people. Second, they also discuss the need for HHA to consider both the positive and negative economic impacts of a regulation (e.g., where regulations lead to higher incomes for those providing compliance-related goods and services).

Despite these criticisms of HHA, Portney and Stavins acknowledge that the analysis can serve an important purpose by focusing attention on the net health impacts of a regulation. Thus, they posit this question: "Could the economic burden associated with a proposed regulation so adversely affect some individuals or families that the health losses they might suffer as a consequence could actually offset the improvements in health enjoyed by the beneficiaries of the regulation?” The HHA debate continued for nearly a decade, but the analysis itself appears to have fallen into disuse. Coming out of the debate, however, are two important lessons acknowledged by both sides:

- If a regulation significantly decreases the disposable incomes of those affected by the regulation, it could wholly or partially offset the health benefits of the regulation itself.
- Changes in the disposable incomes of low-income households will result in much greater health impacts than similar changes in the incomes of high-income households. For example, Chapman and Hariharan (1996) found that imposing a cost on low-income households would result in a break-even cost that is roughly one-half of the break-even cost if the same regulation applied only to high-income households.

Conceptual Suitability of Considering Risk Tradeoffs for Households in Small CWS

Given the extensive HHA literature, a fair question to ask is, “In a BCA, is it conceptually appropriate to look at how the cost of compliance can adversely impact health in low-income households, and thus reduce the net health benefits associated with drinking water regulations in small rural communities?” We believe the answer to this question is “yes.” The concern over health-health tradeoffs arising from regulatory costs is fully relevant for drinking water standards applied to households served by small rural CWS, because the same individuals who receive the benefits also bear the costs.

One of the valid critiques of HHA is that, in most other regulatory actions, compliance costs are borne by different individuals than receive the benefits, and the costs often are highly dispersed and thus quite low on a per-household basis. For example, an occupational safety standard provides benefits to a well defined set of workers, and the costs usually are widely dispersed throughout the economy as small impacts on prices and profits (thus, the costs only marginally impact a very broad mix of consumers and corporate shareholders).

In contrast, for drinking water regulations, the same households that benefit from the regulation will typically bear the full brunt of compliance costs. Further, health risk reduction benefits from a drinking water regulation may be overstated due to an array of conservative assumptions embodied in regulatory agency risk assessments (although, of course, there may also be benefits that are

https://doi.org/10.2202/2152-2812.1004 Published online by Cambridge University Press

not included in quantified estimates and these too would need to be considered).[4] Thus, the potential exists that the negative health impacts arising from the regulatory costs may appreciably reduce the net risk reduction (and perhaps even exceed the health benefits) offered by some drinking water regulations. This is especially likely in small rural communities, where household incomes tend to be relatively low compared to national averages (Ottem et al.), and per-household compliance costs tend to be high.

On the other side of the ledger is the potential that expenditures made to comply with a regulation would provide added income and associated health gains for those who furnish compliance-related treatment technologies and related services. However, in the context of drinking water regulations, the spending by small utilities is likely to yield a very highly dispersed and very modest level of financial gain to others.[5] This implies that any compliance-related increases in income for any household will be so marginal that the health impact will be inconsequential.

The Magnitude of Potential Risk Tradeoffs

Given that HHA appears to be conceptually appropriate for consideration in BCAs in the small CWS regulatory context, the next question is whether there are reliable empirical measures of the magnitude of the cost-associated risks. This question is particularly pertinent because of the inherent challenges in developing credible statistical associations between health status and income (or other measures of household financial distress or wellbeing).

For more than two decades, researchers have been studying the relationship between income and health at the household level. This literature is reviewed in detail elsewhere (Rubin et al.; Lawson et al., 2009). In general, health researchers and statisticians have concluded that there is a strong correlation between income and mortality, regardless of race, gender, or other factors (Rogot and Sorlie, 1992; Lin et al., 2003). Further studies found that this correlation was much stronger at lower-income levels than it was at higher-income levels

---

4. There are numerous conservative (precautionary) assumptions embedded as a matter of policy in risk assessments developed by EPA for drinking water contaminants (and other compounds associated with environmental exposures). These are intended to provide a “margin of safety” in identifying levels of exposures that are “safe” for even sensitive and highly exposed individuals. Such assumptions include the presumption of a linear no-threshold dose-response function for carcinogens (even when the best scientific understanding suggests that nonlinear functions are more biologically plausible) and use of 95% upper confidence limits rather than central tendency values.

5. Expenditures for water system compliance are likely to be widely dispersed across many energy and chemical suppliers and treatment equipment manufacturers (and hence their employees, owners, and suppliers), engineering consulting and installation firms, and so forth.

(Backlund et al., 1999) and there also was a strong correlation between income and the incidence of various diseases including diabetes, heart disease, stroke, tuberculosis, influenza, and lung cancer (Rubin et al.).

While there has been some debate over how to use this information in the process of setting health and safety regulations (e.g., where regulations adversely impact the effective disposable incomes of low- and fixed-income households), there is little dispute that the relationship exists over a broad range of diseases, health prevention activities, and death itself; and that income is an important determinant of health at the household level.

Relying on income alone as a measure of financial distress, however, can be problematic. First, income is an imperfect measure of financial distress. It does not account for significant differences in expenditures on necessities due to household size or health status (such as food or medical care) and it does not measure household wealth which can affect a household's available resources for current expenditures. Moreover, survey respondents can be reluctant to provide income information, skewing the results of any analysis.

Some potential alternative measures of financial distress are evident from research conducted by Bauman (1998, 1999), Boushey et al. (2001), and others (e.g., Energy CENTS Coalition, 1999). Their studies develop a hierarchy of expenditures on household necessities. From their work, we can answer questions such as: "What will a household give up first if it doesn't have enough money for all necessities?" and "What will a household do to try to keep food on the table?" Combining the work of these researchers yields the hierarchy shown in Figure 1. Households that have trouble paying for all of their necessities will tend to do without health insurance first. Distressed households will effectively work their way down this list, on average, trying to avoid the last item on the list: the loss of their home. These distress indicators may provide a good complementary measure of household ability to pay to consider along with more traditional measures of income. For example, while income measures may show a consistent correlation with health outcomes, the hierarchy described in Figure 1 provides an indication of causation (i.e., foregone medical care and meals) that is lacking from reliance strictly on income measures.

https://doi.org/10.2202/2152-2812.1004 Published online by Cambridge University Press

First to be eliminated →	Do not have health insurance
	Do not pay utility bills in full
	Do not see dentist when needed
	Do not pay rent or mortgage in full
	Do not see doctor when needed
	Do not get enough to eat
	Telephone service disconnected
	Child cares for self
	Utilities disconnected
Last to be eliminated →	Eviction / foreclosure

Figure 1. Hierarchy of household necessities.
Sources: Authors' construct derived from Bauman (1998, 1999), Energy CENTS Coalition (1999), and Boushey et al. (2001).

Our empirical analysis of the association between income or financial distress and health status or preventive care is based on data from the Behavioral Risk Factor Surveillance System (BRFSS) from 2002 through 2006. BRFSS is a database maintained by the U.S. Centers for Disease Control and Prevention. For this analysis, the focus is on using risk factors and sociodemographic variables to predict the probability of obtaining health care and or experiencing negative health outcomes. Importantly, the BRFSS also contains data on the household's income and two additional financial distress indicators: whether the person failed to see a doctor because of the cost, and whether the household lost telephone service for at least one week during the previous 12 months (CDC, 2005). We combined these two fields to create an "economic distress" variable (i.e., reflecting any household that had either foregone medical care due to costs, or lost telephone service, or both). Respondents who did not see a doctor because of the cost or did not have telephone service within the past year tend to have lower incomes, with significant negative correlations between each variable and income: $\rho = -0.246$ for doctor visits and $\rho = -0.106$ for telephone service.[6] The financial distress indicators noted here also have some deficiencies that are important to note. For example, loss of telephone service could be a short-term situation.

The BRFSS under-represents low-income and financially distressed households because the survey is conducted by telephone, thus excluding some households that cannot consistently afford telephone service. As discussed below, the Federal Communications Commission (FCC) reports that nationally 12% of

6. BRFSS reports income in categories; we used the mid-point of these categories in our estimation. We assigned a value of $10,000 for the lowest income category (less than $10,000) and a value of $75,000 to the highest income category ($75,000 or greater).

households with incomes less than $18,000 per year did not have telephone service in March 2004; in some states the figure exceeded 20% (FCC, 2005). However, we incorporate the probability sampling weights provided by BRFSS, which are designed to mitigate under-sampling of these households.

Results from a relevant portion of our statistical modeling of the BRFSS data are summarized in Table 2.[7] The statistical model includes a set of sociodemographic control variables (such as age, gender, and smoking status), but to simplify the table we do not report the coefficients here [more complete details, including a full range of reported coefficients, can be found elsewhere (Rubin et al.; Lawson et al.)]. Bold entries indicate marginal effects that were statistically significant at 10% or better level. Table 2 reports marginal effects for two sets of regressions using either the log of income or the distressed indicator as the policy variable of interest.

The results shown here reflect the relationship between the adverse health outcomes provided in the database and household income or our measure of economic distress. The results summarized in Table 2 indicate a strong correlation between both income or our financial distress measure and the several illnesses and other adverse health outcomes (such as diabetes and cardiovascular disease) included in BRFSS. Additional detail on the data, methods, and results of alternative model and variable specifications can be found in Rubin et al. and Lawson et al.

These results all support the hypothesized relationship between health outcomes and financial distress. We expect higher income to be associated with lower incidence of each health endpoint, evident in negative marginal effects for outcomes like asthma and diabetes and total days in poor health, and positively related to the four variables rating general health. Interpreting the coefficients for the model results, a $10,000 increase in annual income (at the mean) is associated with 1.1% lower likelihood of having asthma (and respondents experiencing some type of financial distress are 3.6% more likely to have asthma).

---

7. We estimated these models using a logit specification, enabling us to estimate the probability of having a health outcome given a respondent's income or financial distress, plus additional explanatory sociodemographic variables. The logit specification is the most commonly-used approach to modeling binary outcomes. In addition, robustness checks using probit and linear probability models yielded very similar results. Each outcome was modeled separately as the dependent variable, so each line in Table 2 represents a separate model. The other explanatory variables included are age, smoking status, marital status, educational attainment, and gender.

Table 2. Health outcomes, regressed on income or distress indicators, from logit models of BRFSS data (bolded results indicate statistical significance at the 10% level)

		Distressed	Income
Asthma	1 = yes, 0 = no	**0.0357**	**-0.0107**
High blood pressure	1 = yes, 0 = no	**0.0654**	**-0.0322**
Angina	1 = yes, 0 = no	**0.0140**	**-0.0085**
Myocardial infarction	1 = yes, 0 = no	**0.0150**	**-0.0092**
Stroke	1 = yes, 0 = no	**0.0095**	**-0.0083**
Diabetes	1 = yes, 0 = no	**0.0242**	**-0.0199**
High cholesterol	1 = yes, 0 = no	**0.0644**	-0.0011
Any health outcome	1 = yes, 0 = no	**0.0934**	**-0.0497**

Additionally, we estimated the change in the probability of having any of the seven negative health outcomes considered here when income or financial distress changes. We did this by creating an indicator variable equal to one if a respondent reported having at least one of the health outcomes and zero otherwise. Eighty-one percent of the respondents in this sample had at least one of the seven health outcomes. The final row in Table 2 reports the marginal effect of changes in income and financial distress: for a $10,000 increase in annual income, respondents' probability of having any one of the health outcomes decreases by approximately 5% (4.96%). An individual who becomes financially distressed (i.e., failing to see a doctor because of cost, or losing telephone service due to inability to pay) has a 9.3% higher probability of having one of the health outcomes.

These risk levels would be higher for individuals at lower-income levels, because the estimates reflect correlation at mean income levels. Further, the elevated percentages of adverse medical outcomes also may be understated for lower income households to the extent that the financially distressed are less likely to have a medical condition diagnosed.

While the results of this analysis do indicate a strong relationship between financial status and health status, they do not necessarily mean that reduced financial security causes greater illness and reduced health status. For example, it is possible that for some households the causality is reversed, with poor health leading to diminished income. While we would like to understand the mechanisms by which health and income are linked, due to the limitations of the data, one can simply confirm that there is a strong association between the two.

Not reported here are similar results obtained on the statistical correlation between income or financial distress and the preventive health care variables contained in the BRFSS database. They show, to a lesser but still significant extent, that people experiencing financial distress are less likely to engage in important disease prevention activities (e.g., receiving a flu vaccination or taking prescribed blood pressure medication) (Rubin et al.; Lawson et al.).

Examining the effect of financial distress indicators on public health provides an important indication of the likely impact on low-income households of increasing water costs. Utility costs – particularly water and wastewater which have no substitutes – are likely to be among the last necessities to be eliminated by financially distressed households. If water costs increase, then a distressed household will need to eliminate other necessities that have a lower priority than water service. That is, increasing the cost of water service to a distressed household will increase the likelihood that the household will forego some other necessity.

For example, in the 2005 BRFSS dataset, one out of every four households that reported an income less than $15,000 per year was forced to make such tradeoffs. Moreover, households that experience this type of hardship (e.g., lack of telephone service) are also less likely to engage in important disease prevention activities, and are more likely to experience poor health and various adverse health outcomes, such as cardiovascular disease, diabetes, and asthma.

The implications for BCA are that significant increases in the cost of water service are likely to force additional households into financial distress. That, in turn, is likely to lead to less preventive health care and a higher incidence of adverse health outcomes. This is an increase in health risk (or, viewed another way, an increase in social costs) associated with high-cost water regulations, and the countervailing risk (or added cost) needs to be considered in a BCA context.

The Size and Relevance of Empirical Risk Tradeoff Estimates

The next question to address is whether the cost-associated health risks for drinking water regulations are potentially large enough—relative to the health risk reductions associated with MCLs—to warrant HHA consideration within a BCA. To address this question, we developed empirical estimates of cost-associated risks to households based on EPA's prediction of compliance costs associated with the arsenic standard. Even in the case of arsenic—a contaminant that is associated with relatively high health risk—and using EPA cost of compliance estimates that many water professionals believe to be understated, we found that the cost-associated health risks may be within the same order of magnitude as the EPA-estimated arsenic risk reductions.

For example, for small communities with an arsenic influent of 15 µg/L, which is 50% above the MCL, the EPA-based estimate of the health risks avoided by moving down to the arsenic MCL of 10 µg/L indicates a reduction of approximately 4,450 cases of bladder and lung cancer per 1 million people exposed, over a 70-year "lifetime" period. EPA estimates that roughly half of these cancers (53%) would result in premature fatality, while the remaining half would be survivable illnesses.

This estimate of 4,450 cases avoided per 1 million people exposed to a 5 µg/L lifetime reduction in arsenic exposure is derived by applying the cancer exposure-response model provided by the National Academy of Science (NRC, 1999, 2001), which performed their analysis at the request of the EPA. Their report suggests a linear model with a cancer slope factor of approximately 8.9×10^{-4} per µg/L of arsenic in water.

Using EPA's estimated cost of compliance estimates of $407 per year (2007 dollars) for households in communities of 25 to 100 persons served (U.S. EPA, 2000), our assessment of the adverse health impacts associated with the reduction in household disposable income is 2,036 added cases of a range of health effects (including diabetes, high blood pressure, heart attack, and stroke) per million persons exposed. This estimate is based on the combined probability of 5.0×10^{-6} of at least one of the BRFSS-tracked adverse effects in one person per dollar spent, as described in the preceding section.[8] Some of these adverse health outcomes would likely result in premature mortality (e.g., fatal heart attacks and strokes).

In small rural communities with a presumed 5 μg/L exposure reduction to meet the arsenic MCL and a $407 per-household annual cost to do so, the results show that the *net* health benefits of the arsenic MCL might be roughly half of the arsenic-associated risk reduction (i.e., 4.45 cases of arsenic-related health effects avoided over 70 years per 1,000 individuals, but 2.04 cases of other adverse effects added per 1,000 persons due to the cost impacts). If a small rural community has a relatively large proportion of low-income households compared to the national average, then the cost-associated health impacts are expected to be even larger, and would result in an even lower *net* benefit from the MCL (because the projected cost-associated risk is estimated at the mean national income and would be higher for lower-income levels).

This empirical exercise reveals that both sides of the health-health tradeoff from a drinking water regulation may be of the same order of magnitude.[9] The estimated cost-associated health risk appears to be large enough—relative to the estimated regulatory health benefit—to make consideration of HHA-type risk-risk tradeoffs a policy-relevant factor that should be included in a BCA of drinking water regulations.[10]

The Role and Relative Scale of Uncertainty

There are considerable uncertainties associated with the estimated risk reductions described above—both for the reduced exposure to arsenic due to the MCL, and for the risks associated with bearing the cost of compliance with that MCL. Given these uncertainties, how confident can we be that the cost-associated risk estimates are as reliable as the health risk reduction estimates for lowering exposure to regulated contaminants?

---

8. The estimate of 2036 cases is derived from $407 × ($5.0 \times 10^{-6}$), and does not precisely compute here due to rounding.
9. I.e., the difference between risk levels of 4.45 per 1,000, and 2.04 per 1,000, is roughly 2, which is well within the factor of 10 associated with order of magnitude estimates.
10. Another approach to reflecting equity considerations within a benefit-cost analysis is to apply distributional weights (e.g., Harberger, 1980). Distributionally weighted benefit-cost analysis is most relevant where the benefits accrue largely to different individuals than those who bear the costs, and where one of these groups is economically disadvantaged relative to the other. In the case of the arsenic MCL, however, the same people who bear the cost also receive the benefits. Hence, distributionally weighted BCA does not provide any real advantage or information. In this circumstance, HHA is more relevant and informative.

While there is clearly uncertainty with the risk estimates for cost impacts, the uncertainty in health risk estimates for contaminant exposures in drinking water may be at least as large (and may be much greater). To demonstrate this, we developed confidence limits for key aspects of the uncertainty for both sides of the risk tradeoff. The 95% confidence limit for health benefits (i.e., cancer risk reduction) from the arsenic rule is 4.4×10^{-6} to 2.7×10^{-3} per µg/L of arsenic (based on Chu and Crawford-Brown, 2006). This translates to a 95% confidence limit of arsenic-related cases avoided of 2.2 per 1,000 to 13.5 per 1,000. A similar analysis for income effects results in a risk range of 3.5×10^{-6} to 1.4×10^{-5} per dollar of disposable income lost, which translates into a 95% confidence limit on cost-imposed health effect cases of 1.4 per 1,000 to 5.7 per 1,000.

The influence of uncertainty in the risk estimates can be assessed using the two uncertainty distributions described above within a Monte Carlo analysis. From each Monte Carlo run, the cumulative distribution function was examined and the probability calculated that the adverse health effects from rising costs equal or exceed the reduction in cancer cases (i.e., the probability that the net effect is adverse rather than an improvement in health). For the scenario of a reduction in arsenic concentrations from 15 to 10 µg/L in CWS serving 25 to 100 persons at a per-household annual cost of $407, the results indicate a 23% probability that the cost-associated risks would equal or outweigh the risk reduction derived from the MCL's reduction in arsenic exposure for the same population.

This result does not necessarily imply that the compliance costs of the arsenic rule outweigh the net risk reduction benefits (although this indeed may be the case in some very small communities). Rather, the main point is that the cost-associated risks are of sufficient magnitude that they will appreciably reduce the net benefit of an MCL applied in a small water system setting. This suggests that the suitable application of HHA, within a BCA framework, to the issue of uniform national MCLs in small CWS will likely show that those regulations are appreciably less likely to have net risk reduction benefits that outweigh the compliance costs. This elevates the urgency of adequately addressing the small system affordability problem.

Policy Implications and Conclusions

The affordability of federal drinking water regulations in the U.S., especially in the context of households served by small water utilities, has been a serious and challenging policy issue for many years. Despite the magnitude of the problem, and despite considerable recognition and discussion by EPA, Congress, and many other entities, the problem remains unresolved.

Ultimately, affordability pertains to the impact that regulations have on the households that bear the costs. Defining an affordability threshold is a subjective exercise, but it can be focused on the degree to which compliance costs force households to make difficult choices that may adversely impact their well-being in terms of requiring people to give up essential goods and services (e.g., skip meals, forgo medical care and preventive health practices).

There is an extensive body of literature on the health tradeoffs associated with reduced incomes, and on the need to consider these HHA implications within the regulatory policy context, under suitable circumstances. The imposition of federal drinking water regulations in small communities is one such suitable HHA application, because the same households that benefit from the rules also bear the costs.

We have provided new empirical evidence of the association between income and health risks, and applied these results to the context of the arsenic MCL. This illustration shows that the cost-associated elevation in health risk in households served by very small water systems is large enough that it may reduce the net risk reduction of the standard by a notable degree (e.g., the net risk reduction in the small CWS scenario may be about half of the cancer risk reduction projected from the reduced exposures to arsenic). Factoring uncertainty into the assessment, we find that there is a nearly 25% probability that the cost-associated risk would outweigh the risk reduction from reduced arsenic levels. This reveals the relevance and potential magnitude of risk tradeoffs inherent when significantly increased water costs are borne by economically vulnerable households served by small water systems.

This additional empirical evidence provides further indication of the extent to which the application of federal drinking water standards to small CWS can create inefficiencies and inequities. The use of suitable BCAs that explicitly examine the impacts of MCLs on small CWS (rather than aggregating results across all water system size categories) —and including risk tradeoffs arising from the cost-associated impacts borne by economically disadvantaged households facing high SDWA compliance cost—will enable BCAs to provide a more complete and informative perspective on the efficiency and equity problem that SDWA rules can impose on small system customers. Further, the risk tradeoff aspect of the affordability issue elevates the need to move forward with a better alternative to the status quo policy of uniform but unfunded drinking water standards being applied to small utilities.

References

Backlund, E., P.D. Sorlie, and N.J. Johnson. 1999. A comparison of the relationships of education and income with mortality: The national longitudinal mortality study, social science and medicine. *Social Science & Medicine* 49:1373–1384.

Bauman, K. 1998. Direct Measures of Poverty as Indicators of Economic Need: Evidence from the Survey of Income and Program Participation. U.S. Census Bureau Population Division Technical Paper No. 30.

Bauman, K. 1999. *Extended Measures of Well-Being: Meeting Basic Needs*, U.S. Census Bureau Current Population Reports No. P70-67.

Boushey, H., B. Gundersen, C. Brocht, and J. Bernstein. 2001. *Hardships in America: The Real Story of Working Families.* Economic Policy Institute.

CDC. 2005. Behavioral Risk Factor Surveillance System. U.S. Centers for Disease Control and Prevention. Available: http://www.cdc.gov/BRFSS/technical_infodata/surveydata/2005.htm.

Chapman, K.S. and G. Hariharan. 1996. Do poor people have a stronger relationship between income and mortality than the rich? Implications of panel data for health-health analysis. *Journal of Risk and Uncertainty* 12:51–63.

Chu, H. and D. Crawford-Brown. 2006. Inorganic arsenic in drinking water and bladder cancer: A meta-analysis for dose-response assessment. *International Journal of Environmental Research and Public Health* 3(4):316–322.

Clark, R.M. and R.G. Stevie. 1978. Meeting the drinking water standards: The price of regulation. In *Safe Drinking Water: Current and Future Problems,* C.S. Russell (ed.). ISBN 0-8018-2181-9. Resources for the Future, Washington, D.C., pp 271–317.

Cromwell, J. and S. Rubin. 2008. Development and Demonstration of Practical Methods for Examining Feasibility of Regional Solutions for Provision of Water and Wastewater Service. AwwaRF Project #4075. A Tailored Collaboration Research Project sponsored by Renew Lehigh Valley and the Awwa Research Foundation. Denver, CO.

Energy CENTS Coalition. 1999. *Minnesota's Energy Gap: Unaffordable Energy and Low Income Minnesotans*.

FCC. 2005. *Telephone Penetration by Income by State.* Federal Communications Commission, Washington, DC.

Federal Register. 2006. Small Drinking Water Systems Variances – Revision of Existing National-Level Affordability Methodology and Methodology to Identify Variance Technologies that are Protective of Public Health. 71(41). March 2.

Harberger, A.C. 1980. On the use of distributional weights in social cost-benefit analysis: Reply to Layard and Squire. *The Journal of Political Economy* 88(5):1050–1052.

Keeney, R.L. 1994. Mortality risks induced by the costs of regulations. *Journal of Risk and Uncertainty* 8:95–110.

Lawson, M., D. Crawford-Brown, S. Rubin, and R. Raucher. 2009. Health status, income, and measures of household financial distress: New empirical evidence.

Lin, C.C., E. Rogot, N.J. Johnson, P.D. Sorlie, and E. Arias. 2003. A further study of life expectancy by socioeconomic factors in the national longitudinal mortality study. *Ethnicity & Disease* 13:240–247.

Lutter, R., J.F. Morrall III, and W.K. Viscusi. 1999. The cost-per-life-saved cutoff for safety-enhancing regulations. *Economic Inquiry* 37(4):599–608.

NDWAC. 2003. Recommendations of the National Drinking Water Advisory Council to U.S. EPA on Its National Small Systems Affordability Criteria. Available: http://www.epa.gov/safewater/ndwac/pdfs/report_ndwac_affordabilitywg_final_08-08-03.pdf.

NRC. 1999. *Arsenic in Drinking Water.* National Research Council. National Academy Press, Washington, D.C.

NRC. 2001. *Arsenic in Drinking Water: 2001 Update.* National Research Council. National Academy Press, Washington, D.C.

OSHA. 1992. Air Contaminants Proposed Rule. *Federal Register* 57:26002 Occupational Safety and Health Administration. June 12.

Ottem, T., R. Jones, and R. Raucher. 2003. Consolidation Potential for Small Water Systems – Differences Between Urban and Rural Systems. White Paper for National Rural Water Association. Stratus Consulting Inc., Boulder, CO. Available: http://www.nrwa.org/whitepapers/TOC.htm.

Portney, P.R. and R.N. Stavins. 1994. Regulatory review of environmental policy: The potential role of health-health analysis. *Journal of Risk and Uncertainty* 8:111–122.

Raucher, R., J. Cromwell, J. Henderson, C. Wagner, S. Rubin, J. Goldstein, A. Hubber-Lee, C. Young, G. Characklis, and B. Kirsch. 2006. Regional Solutions to Water Supply Provision. AwwaRF Project #2950. Denver, CO.

Rogot, E. and P.D. Sorlie. 1992. *A Mortality Study of 1.3 Million Persons by Demographic, Social, and Economic Factors: 1979–1985 Follow-Up.* National Institutes of Health. July.

Rubin, S. 2001. Criteria to Assess the Affordability of Water Service. White Paper for National Rural Water Association. Available: http://www.nrwa.org/whitepapers/TOC.htm.

Rubin, S., R. Raucher, and M. Lawson. 2008. The Relationship between Household Financial Distress and Health: Implications for Drinking Water Regulations. White Paper for National Rural Water Association. Available: http://www.nrwa.org/whitepapers/TOC.htm.

Sunstein, C.R. 2001. The Arithmetic of Arsenic. Chicago John M. Olin Law and Economics, Working Paper No. 135, and AEI-Brookings Joint Center for Regulatory Studies, Working Paper 01-10. August 31.

U.S. EPA. 2000. *Arsenic in Drinking Water Rule Economic Analysis*. EPA 815-R-00-026. U.S. Environmental Protection Agency. Developed by Abt Associates, Bethesda, MD. December.

U.S. EPA. 2001. 40 CFR Parts 141 and 142, National Primary Drinking Water Regulations, Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring, Final Rule, Federal Register. U.S. Environmental Protection Agency.

U.S. EPA. 2002. *Affordability Criteria for Small Drinking Water Systems: An EPA Science Advisory Board Report.* EPA-SAB-EEAC-03-004. U.S. Environmental Protection Agency. Environmental Economics Advisory Committee of the SAB. December. Available: http://www.epa.gov/safewater/pws/affordability.html.

U.S. EPA. 2006. Office of Ground Water and Drinking Water Website on Affordability. U.S. Environmental Protection Agency. Available: http://www.epa.gov/safewater/pws/affordability.html.

U.S. EPA. 2008. *Factoids: Drinking Water and Ground Water Statistics for 2008*. Office of Water, EPA 816-K-08-004. U.S. Environmental Protection Agency. November. Available: www.epa.gov/safewater/data.