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WHEN IS ARSENIC POISONING PREVENTION UNAFFORDABLE?

DETERMINING THE EPA 'AFFORDABILITY CRITERIA' FOR SMALL WATER
SYSTEMS UNDER THE 1996 CLEAN DRINKING WATER ACT

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24 May 2005

Selected Paper prepared for presentation at the American Agricultural Economics Association
Annual Meeting, Providence, Rhode Island, July 24-27, 2005

PROLOGUE

The 1996 Safe Drinking Water Act (SDWA) amendments include a number of provisions specifically intended to help minimize the impact that new regulations will have on small systems. The major ones include exemptions (compliance extensions); affordability, variance technologies, and small system variances; and small system technical, managerial, and financial capacity. Small system variances were included in the statute to address the concern that small systems may experience high per household treatment costs to meet a regulatory standard, compared to larger systems, due to the quality of the source water and the poorer economies of scale associated with small water systems.

For small systems with a service population of less than 10,000, Section 1415 authorizes a State or primary agency to grant a variance from compliance with a maximum contaminant level (MCL) or treatment technique for the useful life of a variance technology. Section 1412(b)(4)(e) requires EPA to include a list of affordable small system compliance technologies with each rule that the Agency promulgates, and where EPA is unable to identify a compliance technology that is affordable for small systems in a particular size category or with a particular source water quality, the Agency is required under Section 1412(b)(15) to identify a small system variance technology. The three size categories EPA must consider are 25-500 people, 501- 3,300 people, and 3,301- 10,000 people. SDWA provides that, although a “variance technology” may not assure compliance with a MCL or treatment technique requirement, it must “achieve the maximum reduction or inactivation that is affordable considering the size of the system and the quality of the source water.” Section 1412(b)(15) specifies that EPA may not list a variance technology unless the Agency determines that it is “protective of public health.”

A small system may receive such a variance under a particular national primary drinking water regulation only if EPA has determined that there are no nationally affordable compliance technologies for small systems in the corresponding system size/source water quality combination. In order for a system to obtain a variance, EPA must have identified an applicable variance technology, and the system must actually install, operate and maintain that specified technology. In granting this variance, a State or primary agency must provide public notice and an opportunity for public hearing. It must also make two additional determinations: first, that the system cannot otherwise afford to comply through treatment, an alternative source of water supply or restructuring or consolidation and , second that the terms of the variance will ensure “adequate protection of human health.”

... SDWA requires EPA to make national-level, rather than system level, affordability determinations. ... Under the Act, the State has the prerogative to make its own affordability finding on a system-level basis (White Paper, 2002, pp. 2-3).

RATIONALE FOR LESS THAN THE BEST

Why would anyone want lower quality drinking water?

The SDWA allows an “affordability, variance technology, small system variance” exemption to the drinking water standards based on a supply side argument.¹ It assumes small drinking water systems have significant diseconomies of scale in meeting the maximum contaminant levels. We can test this assumption by examining the cost of compliance technologies by system size developed by the EPA to meet the mcl for arsenic. See table 1 and Figure 1. These data show that the least costly arsenic reduction technology to meet the current mcl of 10 parts per billion (ppb) is “modify coagulation/filtration.” This technology is also six to seven times more expensive to implement for very small systems than for the small and medium size systems. At least for very small drinking water systems the arsenic case supports the assumption of diseconomies of small scale production.

On the demand side, Albert Hirschman provides a theory that allows us to look at the tradeoff between the prices and the varieties of quality, e.g., mcl, for two types of consumers for a given quantity of drinking water (pp. 141-143). See Figure 2. Quality demand curves D_0 and D_0' represent the price – quality combinations for quality-conscious consumers who willingly accept big increases in price for small increases in quality. Demand curves D_1 and D_1' reflect the set of price - quality combinations for price-conscious consumers who require big increases in quality for small increases in price.² Assume that there are three levels of drinking water quality available associated with decreasing maximum contaminant levels. Let P_0 equals the average annual cost per household of the status quo level of quality; P_1 is the cost of the compliance technology to meet the national mcl regulation, and P_2 is the quality level provided by a variance technology in which the consumer “pays less for less.” Finally assume that there are two types of consumers in about equal proportions with

different preferences for water quality who make up the total demand for drinking water in a small system.

Welfare for all consumers improves with shifts in the utility function toward the southeast quadrant in figure 2 as more quality becomes available at lower prices. Line segments $D_0P_2D_1$ sketch out the community's maximum composite utility function for quality drinking water that happens to include the option of a variance technology. On the other hand, by connecting the points associated with levels of drinking water quality available from the three technology options results in curve $P_0P_2P_1$ that we can call the community's quality transformation function. This community can maximize welfare by selecting the water quality technology P_2 - the "tangent" between the utility and transformation curves. In this case, a variance technology at P_2 would provide the highest water quality and lowest price combination given the preferences and technology option available in this community. This discrete choice is preferred by both its quality- and price-conscious consumers because it improves their welfare even though it provides neither the quality of the compliance technology at P_1 nor the low price of the status quo at P_0 .³

Now we can synthesize the supply and demand arguments made on behalf of small drinking water systems for less than the best quality. Assume we have two system sizes – large (L) and small (S) and two types of consumers – quality conscious (Q) and price conscious (P). From the arsenic case we know that the average costs and therefore the marginal costs to meet the quality requirements for small systems (MC_S) are much greater than for the larger ones (MC_L). We also know from Hirshman's analysis that the quality conscious consumers receive greater marginal benefits from increases in quality (MB_Q) than the price conscious consumers (MB_P). The intersections of these two sets of marginal costs and benefits curves indicate the optimum price-quality combinations by system size and consumer preference. See figure 3.

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If the national level of water quality is set at Q_R regardless of system size, then it is possible for the large water systems to be in price-quality equilibrium at P_{LR} while small systems are in disequilibrium at P_{SR} . Small water systems come into equilibrium at a higher mcl (Q_1 or Q_2) and lower cost (P_{SQ} or P_{SP}). This is the dilemma facing the EPA as they developed a national affordability criterion that would allow small water systems to pay less for less: the compliance costs of water quality for small systems may sometimes be too high relative to their benefits. At what point does a drinking water regulation become unaffordable? How wide does the gap between P_{SR} and P_{LR} have to be before it is consider too wide? How do you measure it?

Below we describe the EPA affordability criterion. Then we analyze it in terms of changes in consumer surplus and economic rent from welfare theory. Finally we suggest an alternative criterion that we believe is more consistent with economic theory.

EPA'S AFFORDABILITY CRITERION

The EPA has developed an affordability criterion to determine when to begin the process to allow variance technologies to substitute for compliance technologies for small systems. The elements of the criterion are as follows.

Let

i = set of water systems from 1 to 3, where 1 is a very small system serving 25 to 500 people, 2 is a small system serving 501 to 3,300 people, and 3 is a medium system serving 3,301 to 10,000 people

CR_i = cost of regulation (dollars/household/year) for the very small (vs), small (s) and medium (m) system sizes

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AEM_i = available expenditure margin (dollars/household/year) “difference between the affordability threshold and the baseline annual household water bill; calculated for the three size categories” ([Overview](#), 2002, slide 17)

AT_i = affordability threshold = (dollars/household/year) “upper limit on the percentage of median household income directed to drinking water” for each system size category ([Overview](#), 2002, slide 17)

EB_i = current annual water bills for the three system sizes (dollars/household/year) (data: vs, \$211; s, \$184; m, 181) (1995=100) ([Overview](#), 2002, slides 17, 19 and 25)

MHI_i = median household income by system size (dollars/household/year) (data: vs, \$30,785, s, \$27,058; m, \$27,641) (1995=100) ([Overview](#), 2002, slide 19).

s = a parameter equal to the share of household income spend on water quality technology and close substitutes (percent/household/year) (EPA set this parameter at 2.5%) ([Overview](#), 2002, slides 20 and 35).

Let equations

1) $AT_i = sMHI_i$ (result: vs, \$770; s, \$676; m, \$691)

2) $AEM_i = (AT_i - EB_i)$ (result: vs, \$559; s, \$492; m, \$510)

3) If $CR_i > AEM_i = sMHI_i - EB_i$ then there is an EPA “finding” in favor of a variance technology for small water systems (result of CR_i for arsenic using least cost compliance technology 2: vs, \$45; s, \$7; m, \$8)

Equation 3 is the EPA criterion to determine affordability for small water systems. Equations 1 and 2 are the definitions of the components of this criterion.

BACKGROUND

The EPA asked the National Drinking Water Advisory Council (NDWAC) for advice on its national-level affordability criteria as well as on the methodology used to establish these criteria. Taking into consideration the structure of the Safe Drinking Water Act and the limitations of readily available data and information sources, what is the Council's opinion of the Agency's national level affordability criteria, methodology for deriving the criteria, and approach to applying those criteria to national primary drinking water regulations? (White Paper, 2002, p.1).

The purpose of the National Drinking Water Advisory Committee Workgroup on National Small System Affordability Criteria is to: Provide advice to the NDWAC as it develops recommendations for the U.S. Environmental Protection Agency (EPA) on National Small Systems Affordability Criteria as required under the Safe Drinking Water Act. In particular the work group will make recommendations on:

The Agency's national level affordability criteria, the methodology used to derive the criteria and the approach to applying these criteria to national primary drinking water regulations;

Alternative approaches to those used to-date by the Agency; and

The role of alternate strategies – including funding mechanisms and possible legislative actions –that would enable small systems to achieve compliance. (NDWAC Work Group, 2002).

Six Charge questions:

- 1) What is the NDWAC's view of the Agency's basic approach of comparing average compliance costs for a national public drinking water regulation with an expenditure margin, which is derived as the difference between an affordability threshold and an expenditure baseline.*
- 2) If the approach is retained, should a measure other than the median household income be used as the basis for the affordability threshold to capture the impact on more disadvantaged households? If so, what alternative measures should the Agency consider and why? What would be the likely effect of such alternatives on existing and future national level affordability technology determinations?*
- 3) What alternatives should the Agency consider to 2.5% as the income percentage for the national level affordability threshold and what would be the likely effect of such alternatives on existing and future national level affordable technology determinations? What basis should the Agency use to select from among such alternative? Should the Agency use costs of other household goods and services or risk reduction activities as the basis for setting the affordability threshold as was done in the development of the current criteria?*
- 4) Does the Council believe the Agency should consider other approaches to calculating the national "expenditure baseline" than those used by the Agency heretofore?*

- 5) *Does the Council believe that separate national level affordability criteria should be developed for ground water and surface water systems?*
- 6) *Should the Agency include an evaluation of the potential availability of financial assistance in its national level affordability criteria? If so, how could the potential availability of such financial assistance that reduces household burden be taken into consideration? (White Paper, 2002, pp. 4-13).*

AN ANALYSIS OF EPA'S AFFORDABILITY CRITERION

In this section we will examine the components of the affordability criterion (sMHI, EB_p, and CR_i) and determine their relation to economic theory. It is possible to measure the effectiveness of a regulation using benefits and costs analysis measured as changes in economic surplus. Economic surplus is defined as the sum of consumer surplus and economic rent. Consumers receive a cost saving surplus or benefit from quality drinking water equal to the difference between what a household is willingness to pay and what they actually pay for each unit of water of a given quality. Total consumer surplus is measured as the area below the demand curve and above the equilibrium price line. See figure 4. Resources owners also receive a return to fixed factors used to produce each unit of water equal to the difference the price they are actually paid and a lower price at which they would be willing to sell the resource. Total economic rent is measured as the area between the equilibrium price line and the supply curve.

To measure the costs and benefits from a change in water quality as economic surplus we must translate our definition of the problem from a relationship between price and quality to that of price and quantity. To do this we assume that an increase in quality for a given level of quantity can be expressed as its converse. For example, we can translate Hirschman's analysis of two types of consumer demand of water quality into consumer surplus using the conversion

formula that a change in quantity implies a change in quality. See figure 5. The quality-conscious consumers' demand is represented by D_1 and is ironically more "price" elastic than the price-conscious consumers' demand of D_0 . The quality-conscious consumers have a consumer surplus equal to area B because they are not receiving the level of quality they desire implied by lower levels of quantity. However an improvement in water quality from regulation would be expressed as a big shift in demand to the right for this group of consumers. The price-conscious consumers have a consumer surplus equal to area A+B because they are less concerned with quality and receive less disutility from each unit of water of lower quality. An improvement in water quality would result in only a modest shift to the right for them. Willingness to pay is accurately measured as consumer surplus for both types of consumers. For simplicity in our subsequent analysis we will assume a single demand function for water quality that expresses in equal parts the utility of quality- and price-conscious consumers.

It is easier to translate water quality into measures of economic rent than consumer surplus. Water quality improvement represents an increase in the costs of production that are embedded in the firms' marginal cost curves, the sum of which cause a decrease or shift to the left in an industry's supply function. This is true for both large and small systems. However the higher average and marginal costs for small system result in proportionately greater shift than for large systems. As supply decreases, so does economic rent. Again for simplicity we will concern ourselves in subsequent analysis with the supply functions for the industry comprised of small drinking water systems. This supply function is assumed to reflect the composite experience of the very small, small, and medium size operations.

Now we are ready to interpret the EPA's small system affordability criterion in term of economic surplus. EPA's affordability threshold concept ($AT_i = sMHI_i$) is a combination of a

household's willingness (s) and ability to pay (MHI_i). The percent of household income spent on water quality technologies or close substitutes(s) is a proxy for the willingness to pay for clean drinking water. The EPA considered basing this parameter on the portion of median household income (MHI_i) spent on such items as bottled water, point-of-use and point-of-entry devices to purify water, other household utilities, and alcohol and tobacco (Overview, 2002, slide 20). They decided to set s at 2.5% of MHI_i , the portion of a household's budget typically spent on either bottle water or point of entry devices. This percentage is about 3.5 times more than the percent of MHI_i spent on drinking water. The median household income (MHI_i) is a measure of ability to pay based on the level of readily available economic resources available to half of the households in the community.

The affordability threshold (AT_i) relates to willingness to pay for quality drinking water in general. Consumer surplus is also based on willingness to pay. Therefore the affordability threshold relates to consumer surplus. What is the connection? We know that consumer surplus equals area A+B in figure 6. It can be shown that there exists an all-or-none demand curve ($D_{a/n}$) associated with any normal demand curve (D_0). The defining characteristic of an all-or-none demand curve is that the area delimited by any of its price – quantity combinations above the equilibrium price line equals the consumer surplus for that quantity. For example the area under the all-or-non price ($P_{a/n}$) and above the equilibrium price (P_0) equals area A+B, which by definition equals area A+B, the consumer surplus associated with Q_0 . An all-or-none price ($P_{a/n}$) reflects the way for a perfectly discriminating monopolist can extract all consumer surplus using a single discriminating price across all units instead of price discriminating on each unit. We argue that the affordability threshold is a proxy for the “all-or-none” equilibrium price multiplied

by the average annual household drinking water consumption expressed as a percentage of median household income ($AT_i \sim P_{a/n}Q_0$).

If AT_i is approximately equal to the all-or-none price $P_{a/n}$, then we still need the equilibrium price (P_0) to measure consumer surplus. Here we make the case that the expenditure baseline (EB_i) equals the equilibrium price (P_0) multiplied by average annual household drinking water consumption (Q_0). The expenditure baseline is defined as the measure of the actual annual cost of drinking water currently paid per household. We know from microeconomic theory that in equilibrium the price of the output equals its average total costs.⁴ Therefore if we assume the drinking water market is in equilibrium, then the expenditure baseline is a measure its equilibrium price-quantity combination ($EB_i = P_{a/n}Q_0$). By subtracting the expenditure baseline measure from the affordability threshold ($AT_i \sim P_{a/n}Q_0$), the result is the available expenditure margin ($AEM_i \sim P_{a/n}Q_0 - P_{a/n}Q_0 = \text{area } A' + B = \text{area } A + B$), which is approximately equal to the total consumer surplus for drinking water. This is a measure of the total benefits of clean drinking water.

Finally we need to demonstrate that the cost of regulation (CR_i) can also be incorporated into the economic surplus framework. Here we show that the cost of regulation as used in the EPA criterion is a measure of the decrease in economic rent from the introduction of one regulation.

An increase in drinking water quality increases the cost of production and shifts the supply curve to the left. For now we consider the unrealistic case in which the regulation affects supply only. (This case is unrealistic because we believe than an improvement in drinking water quality could result in an increase in demand for water at least by the quality-conscious consumers.) See Figure 7. The shift in the supply curve to the left represents the decrease in productivity from a

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rule change without an offsetting increase in demand from an improvement in quality. Now we measure the change in economic surplus as the sum of the change in both consumer surplus and economic rent.

The change in economic surplus as follows.

The net change in consumer surplus is

$$\Delta CS = CS_1 - CS_0 = -(B+F+G)$$

The net change in economic rent is

$$\Delta ER = ER_1 - ER_0 = B - (E+H+I)$$

The change in economic surplus is

$$\Delta ES = \Delta CS + \Delta ER = -(E+F+G+H+I)$$

The area $E+F+G+H+I$ equals the economic cost of regulation from the lower returns to fixed factors for resource owners and the higher price of drinking water for consumers. There is also a transfer of income from consumers to resource owners equal to area B . It can be shown that this loss in economic surplus is also equal to area $B+F+G+C+H+I$ for a parallel shift in supply such that area $E = \text{area } B+C$.

The cost of regulation (CR_i) equals the increase in the price of drinking water based on projected average compliance costs. The vertical distance between P_1 and P_2 is equal to the change in total factor productivity. Since the EPA measures the effect of regulation on costs is a way to measure productivity, then they are approximately measuring the distance between P_1 and P_2 relative to average annual household consumption (Q_0). The cost of regulation approximately measures the loss in economic surplus ($CR_i = P_1Q_0 - P_2Q_0 \sim \Delta ES$). The measure of the cost of regulation use by the EPA in the affordability criterion approximately equals the change in economic surplus from the change in one regulation.

We know that the affordability criterion is whether $CR_i > AEM_i$. We established above that the AEM_i is approximately equal to the initial total consumer surplus. In figure 7, initial total consumer surplus equals area $A+B+F+G$. Therefore the EPA affordability criterion will trigger a finding for a variance technology if area $A+B+F+G < \text{area } B+F+G+C+H+I$. Since area $B+F+G$ is common to both measures, then the critical components are whether area $A < \text{area } C+H+I$. Area A is the measure of the subsequent total consumer surplus and area $C+H+I$ is the change in economic rent from one regulation. Therefore we conclude that the current EPA affordability criteria will trigger a finding for a small system variance technology if and only if the subsequent total consumer surplus for quality drinking water (from all regulations) is less than the change in economic rent from one regulation. It is difficult for us to conceive of a situation when this would ever be the case. Perhaps only in the case of an extremely expensive and ill-advised water quality regulation would this criterion trigger a variance technology finding. We would also argue that it violates the logic of benefit-cost analysis to compare total benefits to marginal costs since they lack a common denominator for their causation. Total benefits are the result of all previous implemented water quality regulations. Marginal costs, on the other hand, are the result of a single proposed regulation. To construct a measure of affordability for a single drinking water regulation, we believe it is only defensible to compare the marginal benefits of the regulation with its marginal costs.

EPA is aware of a problem with this criterion. In fact, they refer to it as the 'adding up' problem. It is called the adding up problem because it is viewed as one in which subsequent EPA rules will be added to previous rule costs until no expenditure margin exist. In which case, all subsequent rules will trigger a variance technology finding. This is because each additional rule would not be affordable since the EPA would add the cost of each rule to the expenditure baseline. They will add a rule increment to the actual cost of production data collected by a survey of drinking water

systems. The approach assumes that the cost of regulation is not already factored into the survey data. The EPA sees the adding up problem as a data and measurement issue. They believe it is a problem of accounting for costs of regulation with in the expenditure baseline.

Another view of the adding up problem is that it is based on a conceptual error. If the marginal cost of regulation were compared to the marginal benefits then the adding up problem disappears. Then the problem becomes one of how to measure marginal benefits of a single rule. Below we provide an explanation of why that is true and then how marginal benefits of a single rule could be measured using the value of statistical life concept.

TOWARD A MORE CONSISTENT MEASURE OF AFFORDABILITY

Assume that a safe drinking water regulation represents a shift in supply to the left from S_0 to S_1 as production costs increase. See Figure 7. Also assume that the regulation represent a shift in demand to the right from D_0 to D_1 as the demand for drinking water of improved quality increases from quality-conscious consumers. Finally assume that the price of drinking water increases from P_0 to P_1 and the quantity consumed remains constant at $Q_0=Q_1$.

Now let's measure the change in economic surplus (ES) as the sum of the change in consumer surplus (CS) and economic rent (ER).

The net change in consumer surplus is:

$$?CS = CS_1 - CS_0 = A - CE$$

The net change in economic rent is:

$$?ER = ER_1 - ER_0 = CD - G$$

The net change in economic surplus is:

$$?ES = ?CS + ?ER = A + D - (E + G)$$

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Area A+ D is the marginal gain in economic surplus associated with a shift in demand for water with an increase in regulation. Since area A+D is the marginal change in benefits from one regulation, we believe it is the conceptually correct measure of AEM_i .

Area E+G is the marginal loss in economic surplus associated with a shift in supply of water with an increase in regulation. This is the same measure of the cost of regulation as before, so we would keep the current EPA measure of CR_i .

The conceptual correct EPA affordability criterion should be:

If area E+G > area A+D, then a finding for a variance technology would be triggered. Conceptually, a comparison of the marginal costs of a single regulation with its marginal benefits would be the new affordability criterion.

This approach would measure the marginal change in benefits from a regulation (area A+D) using the proxy of value of statistical lives saved associated with the level of the proposed regulation. The measure cost of regulation would remain unchanged. Besides being conceptually accurate, this alternative approach is also simpler, more accurately measured, and resolves the adding up problem. It also avoids the political temptation of ‘just making up the number.’

WILLINGNESS TO PAY — THE VALUE OF A STATISTICAL LIFE

An important observation helps to define how to address the thorny ethical, conceptual, and empirical issues associated with “valuing good health” or “placing a dollar value on lives saved.” The key is to recall that MCLs reduce risks, they do not “save lives” or “improve health” per se. Therefore, the key to valuation is to examine how people respond to and reveal their values (or preferences) about risks.

Every day, people face a wide range of risks to their health and safety. Some of these risks are borne involuntarily (e.g., exposure to pollutants, or a genetic predisposition to certain types of disease); some risks are confronted by choice (e.g., choosing whether to use tobacco, install smoke detectors, wear a seat belt, ride a motorcycle, or accept a job in a risky occupation). By observing how individuals make choices about the level and types of risks they bear, and the level of cost they incur to reduce risks (or the rewards they receive when accepting increased risks), economists have been able to make clear inferences about the monetary worth people place on risk reductions.

There are over 26 published research papers in which economists have developed estimates of the “value of a statistical life” (VSL) by looking how people state or reveal their willingness to pay (or to accept compensation) for lower (or elevated) risks. Typical studies examine wage rate premiums in risky professions, or consumer behavior in purchasing risk-reducing items. Willingness to pay estimates represent monetary measures of the value individuals place on the change in quality of life achieved as a result of a risk reduction. The WTP-based measures are the conceptually appropriate approach, in accordance with well-established and broadly accepted principles of welfare economics.

USEPA has reviewed the WTP literature and found a midrange value for VSL of \$6.1 million (in 1999 dollars), and the range spans roughly from \$1 million to \$20 million (USEPA, 1997). This USEPA finding is generally accepted as a reasonable interpretation of the literature, although there are important controversial issues how the VSL estimate should be adjusted when applied to drinking water standards (as discussed in several sections below).

The VSL concept is suitable for application to MCLs (or other environmental, public health, or safety programs) because the value concept corresponds to the risk reduction context —MCLs reduce low level risks across a large population, and the VSL estimates reflect how people value small changes in low level risks that also are spread across a large population.

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For example, a VSL estimate may be based on a \$610 per year wage premium per worker in an occupation where the risk of fatal accident is 1 in 10,000 per year. This means that for every 10,000 exposed workers, one statistical premature fatality is expected each year. Collectively, these workers enjoy a combined wage premium of \$6.1 million annually (\$610 times 10,000). Thus, the VSL estimate would be \$6.1 million. This is directly parallel to the risk reduction benefits of an MCL in the sense that the number of fatalities, and the overall dollar value, reflect risk-based “statistical lives” over a large population, and not identifiable individuals. However, other issues are important in how VSL estimates should be applied in the MCL context, such as the timing of the risks, the amount of life extension generated per case, and other attributes of the risks and the impacted populations. (Raucher, Benefit-Cost Analysis, 2002?)

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TABLES

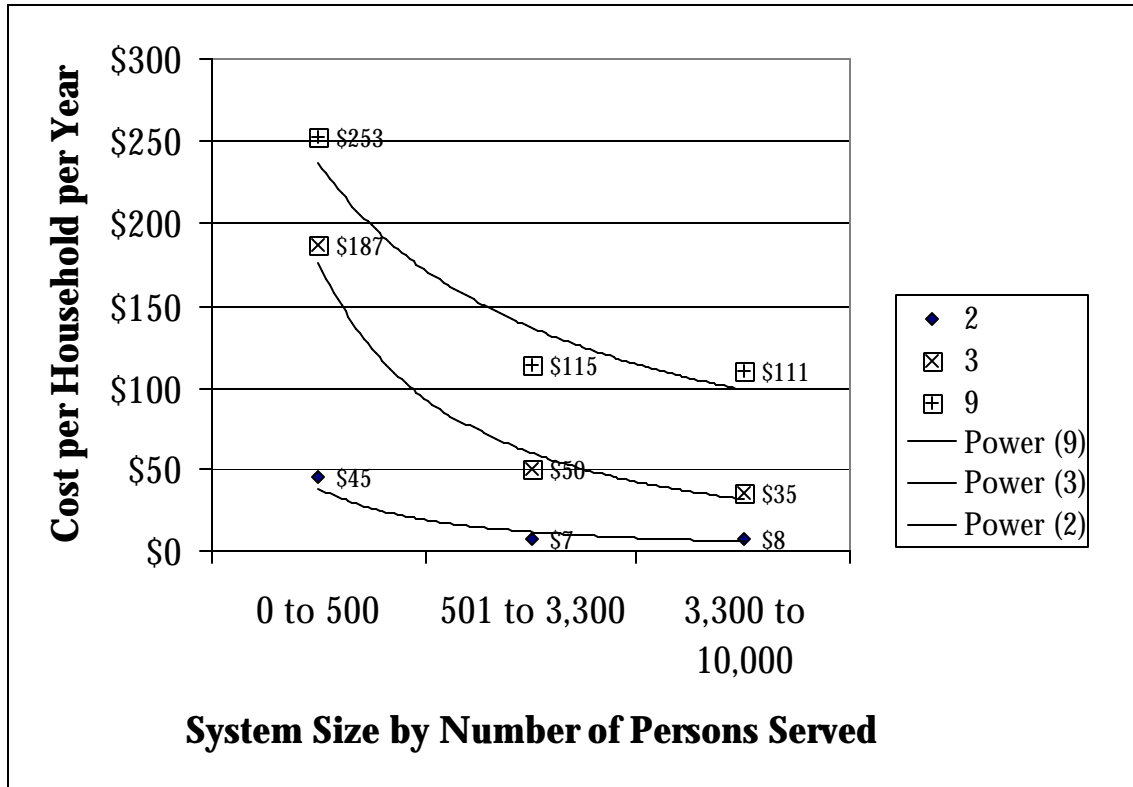
Table 1 Costs of Compliance Technology to Remove Arsenic from Three Sizes of Drinking Water Systems (Dollars/Household/Year)

Costs per household per year			Treatment Train	
System size by population			No.	Description
0-500	501-3300	3300-10000		
\$45	\$7	\$8	2	Modify Coagulation/Filtration
\$56	\$14	\$14	1	Modify Lime Softening
\$183	\$75	\$70	8	Activated Alumina (pH 7 - pH 8) and non-hazardous landfill (for spent media)
\$187	\$50	\$35	3	Anion Exchange (<20 mg/L SO4) and POTW waste disposal with corrosion control sometimes
\$245	\$73	\$52	7	Oxidation Filtration (Greensand) and POTW for backwash stream
\$251	\$78	\$67	10	Activated Alumina (23,100 BV) with pH adjustment (pH 6)/corrosion control already included in cost eq. and non-hazardous landfill (for spent media)
\$252	\$67	\$45	4	Anion Exchange (20-50 mg/L SO4) and POTW waste disposal with corrosion control sometimes
\$253	\$115	\$111	9	Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media)
\$261	\$160	\$166	13	POU Reverse Osmosis and pre-oxidation already always included in cost eq.
\$267	\$87	\$77	11	Activated Alumina (15,400 BV) with pH adjustment (pH 6)/corrosion control already included in cost eq. and non-hazardous landfill (for spent media)
\$297	\$184	\$190	12	POU Activated Alumina and pre-oxidation already always included in cost eq.
\$1,108	\$353	\$237	6	Coagulation Assisted Microfiltration and non-mechanical dewatering/non-hazardous landfill waste disposal
\$1,132	\$293	\$145	5	Coagulation Assisted Microfiltration and mechanical dewatering/non-hazardous landfill waste disposal

Source: [Jeff Kempic](#), EPA

FIGURES

FIGURE 1 SIZE ECONOMIES OF THREE ARSENIC COMPLIANCE TECHNOLOGIES FOR DRINKING WATER



Description of technologies

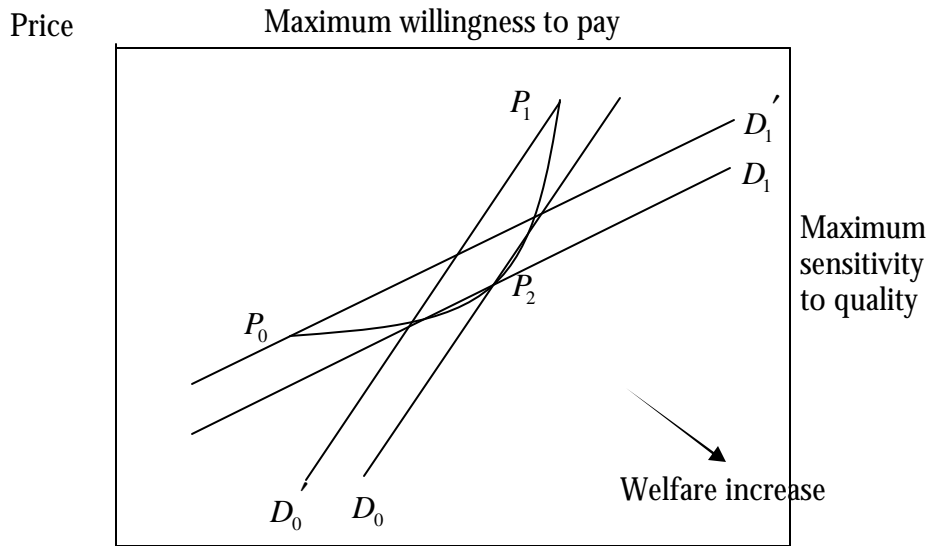
2 Modify Coagulation/Filtration

3 Anion Exchange (<20 mg/L SO₄) and POTW waste disposal with corrosion control sometimes

9 Activated Alumina (pH 8 - pH 8.3) and non-hazardous landfill (for spent media)

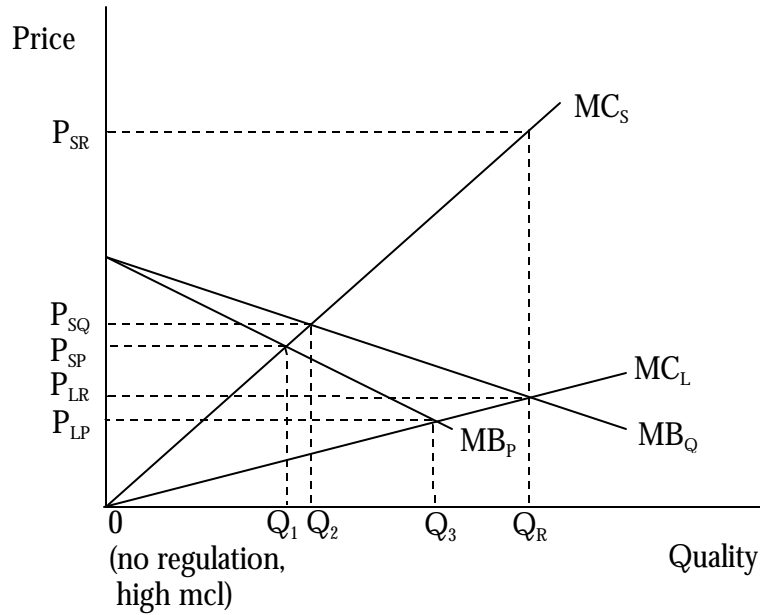
Source: Jeff Kempic, EPA [as-affordable-treatment-tech.xls](#)

FIGURE 2 PRICE ELASTICITY OF DEMAND FOR QUALITY



Source: A. Hirschman, *Exit, Voice, and Loyalty*, p. 142.

FIGURE 3 SUPPLY AND DEMAND FOR DRINKING WATER QUALITY



Source: U.S. EPA, EPA Science Advisory Board, Environmental Economics Advisory Committee, 2002, pp. 6-7).

FIGURE 4 AFFORDABILITY AS CONSUMER SURPLUS

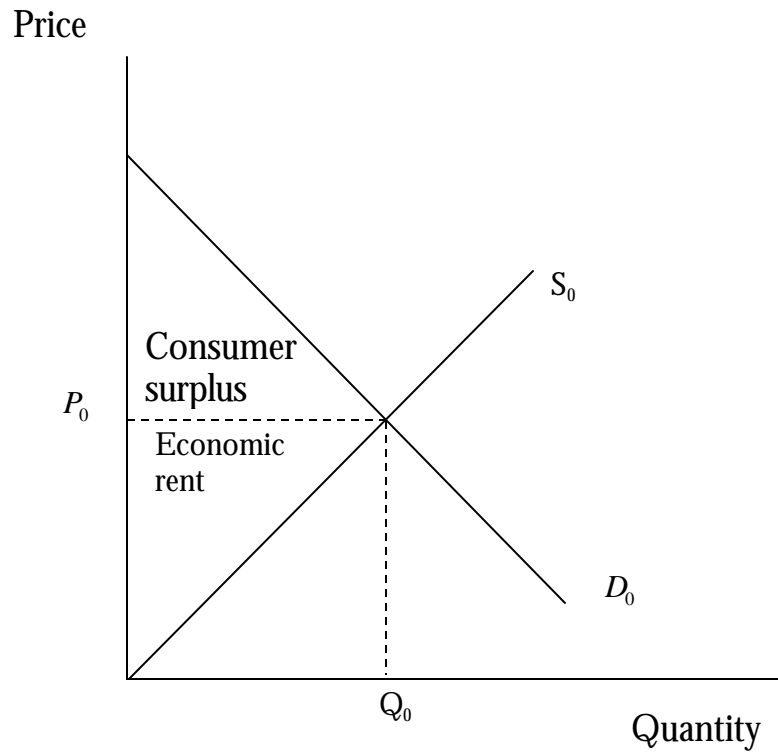


FIGURE 5 HIRSCHMAN'S QUALITY ELASTICITY AND CONSUMER SURPLUS

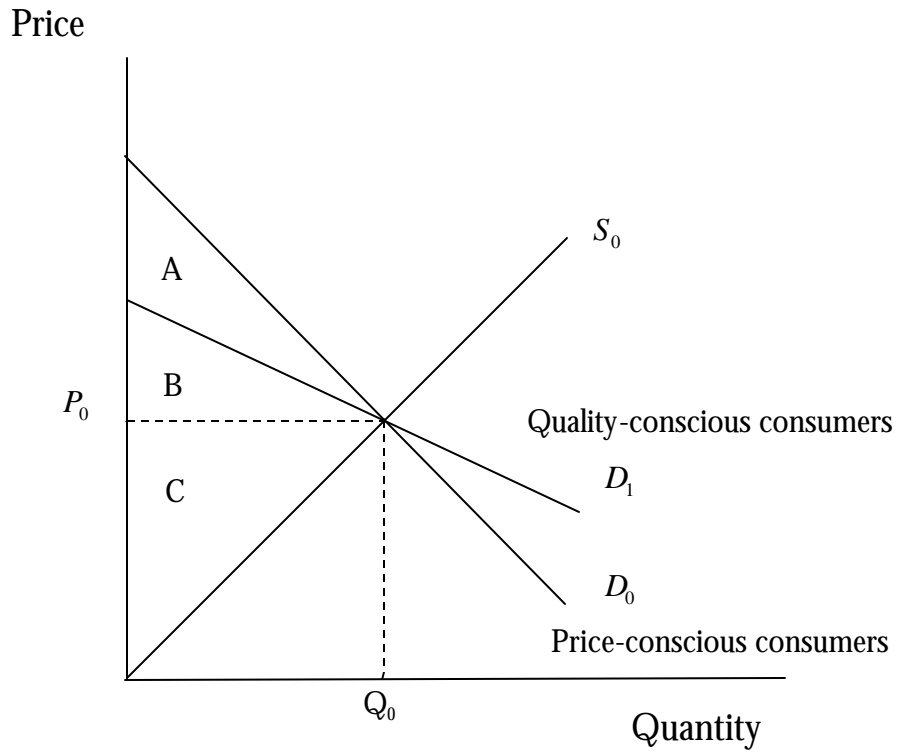


FIGURE 6 EXPENDITURE MARGIN AND THE ALL-OR-NONE DEMAND CURVE

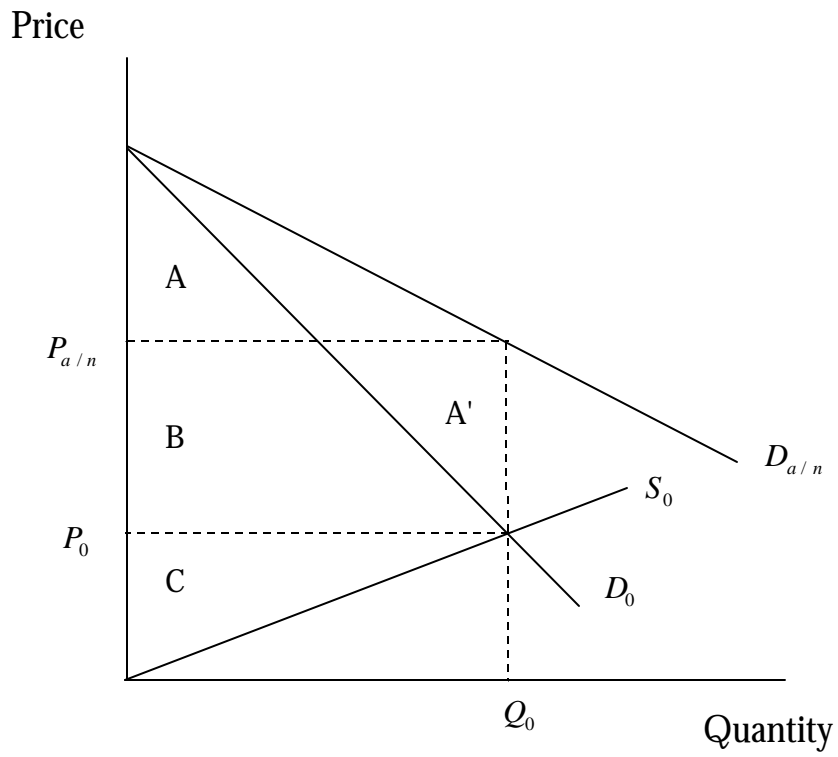


FIGURE 7 REGULATIONS AS A DECREASE IN SUPPLY

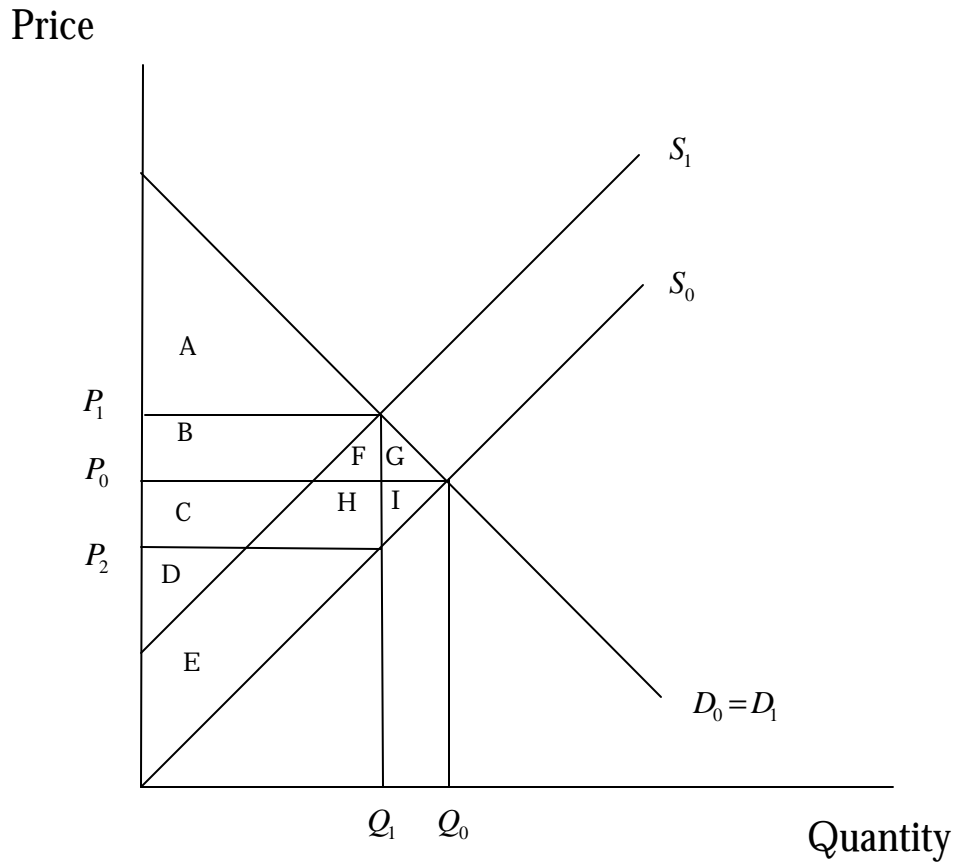
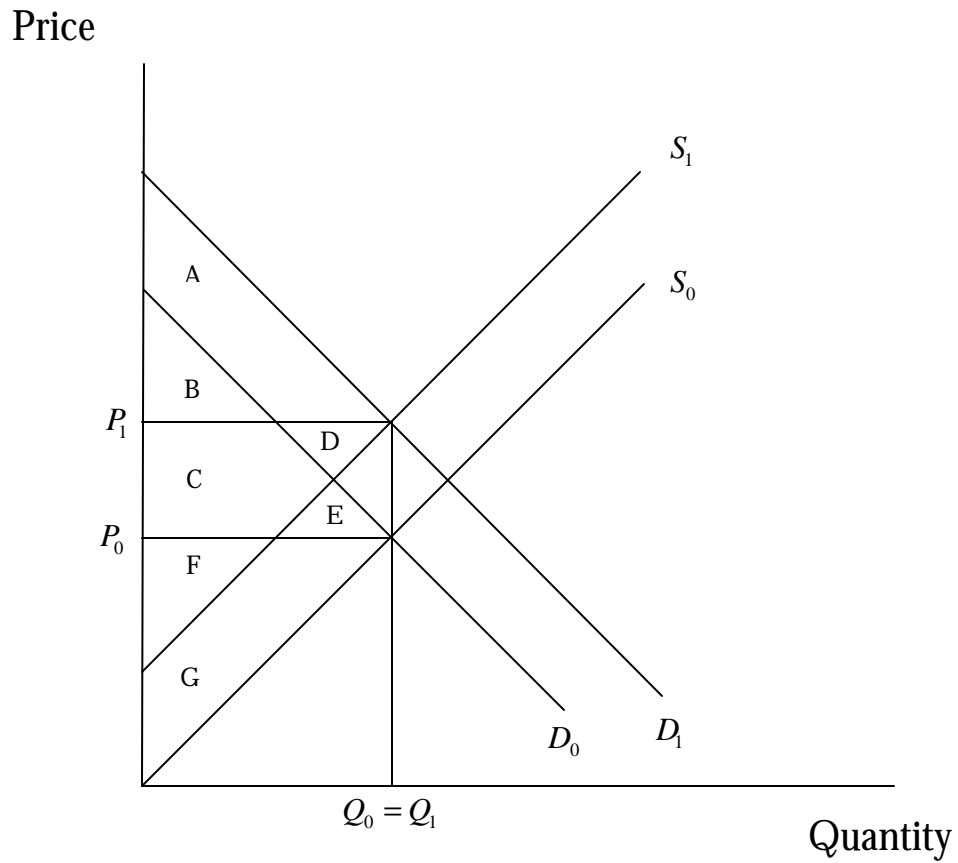


FIGURE 8 REGULATION AS A SHIFT IN SUPPLY AND DEMAND



¹ Variance technologies could include 1) central treatment operated at less efficiently to reduce costs, 2) central treatment with higher degree of blending utilized to reduce costs, 3) point-of-use devices, and 4) central treatment that is less effective in removing the contaminant(s) than compliance technologies (Kempic, Overview, 2002, slide 10).

² The price elasticity of demand for quality is the ratio of the percentage change in quality to the percentage change in price. If the absolute value of the price elasticity of demand for quality is one then the percentage change in quality equals the percentage change in price. For the quality conscious consumer, their elasticity of demand for quality is less than one.

³ If the quality choices were continuous then the price-conscious consumer would prefer somewhat less quality at a somewhat lower price and conversely for the quality-conscious consumer. The discrete choice P_2 is a compromise between these two preferences that assume continuous quality options. (Hirschman, p. 143, fn 3).

⁴ The expenditure baseline is essential in determining consumer surplus through the affordability threshold calculation. The expenditure baseline should reflect the average total cost per household for the three system sizes under consideration. The average total costs of the system include both variable costs (maintenance and operation) and fixed costs (returns to capital necessary to paid the opportunity cost of investment). Price usually reflects costs. Unfortunately, water systems are associated with extraordinary economies of scale in treatment. The economies of scale in transmission depend on the population density. As a result, the marginal cost may be lower than average costs such that margin cost pricing will not cover the total cost of operations.