EPA's Arsenic Drinking Water Rule

The purpose of this questionnaire is to collect information and feedback from industry experts on the U.S. Environmental Protection Agency's analysis of compliance costs for the arsenic drinking water rule as undertaken for rule development in 2001. The goal of this project is to assess EPA's analysis and estimates of compliance costs at the time of rule promulgation. We also want to determine whether EPA accurately identified all the process technologies that were available to reduce arsenic levels.

This questionnaire summarizes the assumptions and cost estimation frameworks used by EPA to estimate the costs of treatment technologies that the Agency identified as candidates for compliance with the arsenic rule. We want to assess whether the actual costs of arsenic treatment differed substantially from EPA's estimates at the time of rule development. In addition, we hope to understand the reasons for potential differences in these estimates, including insight into whether new or modified treatment technologies may have been implemented to meet the arsenic standard, which EPA did not account for in its cost analysis.

Section 1. Regulatory Background

On January 22, 2001, EPA published a new national primary drinking water regulation for arsenic (Arsenic Rule), which lowered the maximum contaminant level (MCL) 50 µg/L to 10 µg/L. EPA estimated that the rule would apply to 54,000 community water systems (CWSs) and 20,000 non-transient non-community water systems (NTNCWSs) that serve non-residential communities (e.g. schools, churches). The rule gave water systems until January 23, 2006 to comply with the revised arsenic MCL. EPA had estimated that approximately 3,000 CWSs and 1,100 NTNCWSs would need to reduce arsenic levels in their drinking water for compliance with the 10 µg/L standard.

Section 2. Arsenic Treatment Technologies and Costs

EPA identified the following technologies that would effectively remove arsenic and bring a water system into compliance:

- Modified Coagulation/Filtration;
- Coagulation Assisted Microfiltration;
- Modified Lime Softening;
- Activated Alumina (with and without pH adjustment);
- Ion Exchange (groundwater only);
- Greensand Filtration (groundwater only); and
- Point-of-Use Reverse Osmosis (for small groundwater systems only).

EPA used three models to develop costs for these treatment technologies (except activated alumina and ion exchange): Very Small Systems Best Available Technology Cost Document (VSS model; Malcolm Pirnie, 1993); the Water Model (Culp/Wesner/Culp, 1984); and the W/W Cost Model (Culp/Wesner/Culp, 1994).

All equations for both capital and O&M costs, as well as all monetary figures are presented in 2006 dollars. Equations and monetary figures were converted to 2006 dollars from 1998 dollars using the Engineering News Record Construction Cost Index (ENR CCI).

Q1a: Have treatment technologies changed since the rule was promulgated? For example, have additional or substantially modified treatment technologies or compliance approaches been used to achieve compliance? If so, please explain how.
A1a: >>

Q1b: Based on your professional knowledge and experience, are the treatment technologies that EPA proposed for groundwater and surface water systems for compliance representative of the actual treatment technologies employed for compliance with the Arsenic Rule?
A1b: >>

Q1c: Based on your professional knowledge and experience, please estimate the frequency with which these technology options have been used for compliance? To the extent possible, please identify the principal factors underlying the selection of a particular treatment technology/compliance approach by different categories of drinking water system – e.g., groundwater vs. surface water, small vs. large system.
A1c: >>

2.1 Modified Coagulation/Filtration

EPA assumed that typical coagulation/filtration treatment plants remove 50 percent of the influent arsenic prior to enhancement, and that O&M (operation and maintenance) costs would only include power and materials and not additional labor. EPA used the following design assumptions to develop cost estimates for small and large drinking water systems:

- Small Systems (< 1 mgd): Additional ferric chloride dose, 10 mg/L; Additional feed system for increased ferric chloride dose; Additional lime dose, 10 mg/L for pH adjustment; and Additional feed system for increased lime dose.
- Large Systems (> 1 mgd): Additional ferric chloride dose, 10 mg/L; Additional feed system for increased ferric chloride dose; Additional lime dose, 10 mg/L for pH adjustment; and Additional feed system for increased lime dose.

Table 1a summarizes the capital and O&M cost equations that EPA used to estimate costs for modified/enhanced coagulation/filtration treatment.

Table 1a - Cost Equations for Modified Coagulation/Filtration (2006 dollars)		
Design Flow (x)	**Capital Cost (y) Equation**	**O&M Cost (z) Equation**
Less than 1 mgd	$y = -5095.4x^2 + 19626x + 9516.5$	$z = -402.68x^2 + 9722x + 294.09$
Between 1 mgd and 10 mgd	$y = 125208x - 101161$	$z = 23282x - 4639.8$
Greater than 10 mgd	$y = -8.9397x^2 + 8634.2x + 1065469$	$z = -0.5291x^2 + 19913x + 10531.3$
Source: U.S. EPA (2000) mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost		

Table 1b provides capital costs and O&M costs for different design flow thresholds:

Table 1b - Modified Coagulation/Filtration Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$9,700	$400
0.1	$11,400	$1,300
1	$24,000	$18,600
10	$1,150,900	$228,200
50	$1,474,800	$1,004,900
Notes: Costs are derived from equations found in U.S. EPA (2000), mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.1a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for modified coagulation/filtration.
A2.1a: >>

Q2.1b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.1b: >>

2.2 Coagulation Assisted Microfiltration

EPA used the following design assumptions to develop cost estimates for small and large drinking water systems:

- Very Small Systems (< 0.10 mgd): Coagulant dosage, ferric chloride, 25 mg/L; No polymer addition; Filtration rate, 2.5 gpm/ft2; and Sodium hydroxide dose, 20 mg/L
- Small Systems (< 1 mgd): Package plant for all small systems; filtration rate 5 gpm/ft2; Ferric chloride dose, 25 mg/L; Sodium hydroxide dose, 20 mg/L; and Standard microfilter specifications, provided by vendors.
- Large Systems (> 1 mgd): Ferric chloride dose, 25 mg/L; Rapid mix, 1 minute; Flocculation, 20 minutes; Sedimentation, 1000 gpd/ft2 in rectangular basins; and Standard microfilter specifications, provided by vendors.

Table 2a summarizes the capital and O&M cost equations EPA used to estimate costs for coagulation assisted microfiltration treatment.

Table 2a - Cost Equations for Coagulation Assisted Microfiltration (2006 dollars)	
Design Flow (x)	**Cost Equation**
Capital Costs (y)	
Less than 0.10 mgd	$y = -15898039x^2 + 6500208x + 125640$
Between 0.10 mgd and 0.25 mgd	$y = 3121141x + 304566$
Between 0.25 mgd and 1 mgd	$y = -644143x^2 + 3075576x + 363826$
Between 1 mgd and 10 mgd	$y = 1373039x + 1422220$
Greater than 10 mgd	$y = 426x^2 + 1227399x + 2835987$
O&M Costs (z)	
Less than 0.03 mgd	$z = 262176x + 26992$
Between 0.03 mgd and 0.09 mgd	$z = 181594x + 29489$
Between 0.09 mgd and 0.35 mgd	$z = 106668x + 35933$
Between 0.35 mgd and 4.25 mgd	$z = 17730x + 67951$
Greater than 4.25 mgd	$z = 20294x + 56410$
Source: U.S. EPA (2000) mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost	

Table 2b provides capital costs and O&M costs for different design flow thresholds.

Table 2b - Coagulation Assisted Microfiltration Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$189,100	$29,600
0.1	$616,700	$142,600
1	$2,795,300	$85,700
10	$15,152,600	$259,400
50	$65,271,600	$1,071,100
Notes: Costs are derived from equations found in U.S. EPA (2000), mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.2a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for coagulation assisted microfiltration.
A2.2a: >>

Q2.2b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates
A2.2b: >>

EPA also estimated waste disposal costs, which included mechanical and non-mechanical dewatering with nonhazardous landfill disposal. Table2c summarizes the capital and O&M cost equations that EPA used to estimate costs for coagulation-assisted microfiltration treatment for waste disposal.

Table 3c: Cost Equations for Coagulation Assisted Microfiltration Waste Disposal (2006 dollars)	
Design Flow (x)	**Cost Equation**
Capital Costs (y)	
Less than 0.25 mgd; Mechanical Dewatering	$y = -922800x^2 + 606498x + 35628$
Between 0.25 mgd and 1.75 mgd; Mechanical Dewatering	$y = 281887x + 56001$
Greater than 1.75 mgd; Mechanical Dewatering	$y = -2189.9x^2 + 200335x + 209890$
Less than 0.085 mgd; Non-mechanical Dewatering	$y = 4088388x - 1052$
Between 0.085 mgd and 1.75 mgd; Non-mechanical Dewatering	$y = 2330137x + 143879$
Greater than 1.75 mgd; Non-mechanical Dewatering	$y = 2168456x + 434903$
O&M Costs (z)	
Less than 0.085 mgd; Mechanical Dewatering	$z = -4631178x^2 + 912204x + 7778$
Between 0.085 mgd and 1.75 mgd; Mechanical Dewatering	$z = 33520x + 49094$
Greater than 1.75 mgd; Mechanical Dewatering	$z = 106668x + 35933$
Less than 0.085 mgd; Non-mechanical Dewatering	$z = 25058x^2 + 6242x + 2829$
Between 0.085 mgd and 0.70 mgd; Non-mechanical Dewatering	$z = 148943x - 9257$
Greater than 0.70 mgd; Non-mechanical Dewatering	$z = 22.599x^2 + 80975x + 38308$
Source: U.S. EPA (2000) mgd = million gallons per day, x = design flow, y = capital cost, z = O&M cost	

Table 2d provides capital costs and O&M costs for different design flow thresholds

Table 2d - Coagulation Assisted Microfiltration Waste Disposal Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
Mechanical Dewatering		
0.01	$41,600	$16,400
0.1	$87,100	$52,400
1	$337,900	$82,600
10	$1,994,300	$1,102,600
50	$4,751,800	$5,369,300
Non-Mechanical Dewatering		
0.01	$39,800	$2,900
0.1	$376,900	$5,600
1	$2,474,000	$119,300
10	$22,119,500	$850,300
50	$108,857,700	$4,143,600
Notes: Costs are derived from equations found in U.S. EPA (2000), mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.2c: Please comment on the estimated costs and assumptions EPA used to estimate the costs for coagulation assisted microfiltration waste disposal treatments.
A2.2c: >>

Q2.2d: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.2d: >>

2.3. Modified Lime Softening

EPA assumed that typical lime softening treatment plants remove 50 percent of the influent arsenic prior to enhancement, and that O&M costs would only include power and materials, not additional labor. EPA used the following design assumptions to develop cost estimates for small and large drinking water systems:

- Additional lime dose, 50 mg/L;
- Chemical feed system for increased lime dose;
- Additional carbon dioxide (liquid), 35 mg/L for recarbonation; and
- Chemical feed system for increased carbon dioxide dose.

Table 4a summarizes the capital and O&M cost equations EPA used to estimate costs for modified/enhanced lime softening treatment.

Table 4a - Cost Equations for Modified Lime Softening (2006 dollars)	
Design Flow (x)	**Cost Equation**
Capital Costs (y)	
Less than 1 mgd	$y = -30601x^2 + 64217x + 10519.7$
Between 1 mgd and 10 mgd	$y = 177803x - 133668$
Greater than 10 mgd	$y = -10.042x^2 + 35445x + 1290926$
O&M Costs (z)	
Less than 0.35 mgd	$z = 2986.7x^2 + 40659x + 425.80$
Between 0.35 mgd and 3.5 mgd	$z = 38821x + 1457.6$
Greater than 3.5 mgd	$z = -0.6031x^2 + 34721x + 19921$
Source: U.S. EPA (2000) mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost	

Table 3b provides capital costs and O&M costs for different design flow thresholds

Table 3b - Modified Lime Softening Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$11,200	$800
0.1	$16,600	$4,500
1	$44,100	$40,300
10	$1,644,400	$367,100
50	$3,038,000	$1,754,500
Notes: Costs are derived from equations found in U.S. EPA (2000); mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.3a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for modified lime softening.
A2.3a: >>

Q2.3b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.3b: >>

2.4 Activated Alumina

EPA's design assumptions vary based on whether pH adjustment is necessary. For natural pH (i.e., no pH adjustment), EPA made the following assumptions:

- pH will not need to be adjusted after the activated alumina process;
- Empty Bed Contact Time (EBCT) is 5 minutes per column;
- The density of the activated alumina media is assumed to be 47 lb/ft3;
- The bed depth ranged from 3 to 6 feet, depending on the design flow;
- The maximum diameter per column is 12 feet;
- 50 percent bed expansion during backwash even though backwashing may not be necessary on a routine basis for smaller systems;
- Redundant column necessary to allow the system to operate while the media is being replaced in the old roughing column.

For systems with pH adjustment, EPA used the same assumptions except included cost to adjust pH to the optimal pH of 6. Table 5a summarizes the capital and O&M cost equations EPA used to estimate costs for activated alumina treatment.

Table 5a - Cost Equations for Activated Alumina (2006 dollars)	
Design Flow (x) and Design Parameters	**Cost Equation**
Capital Costs (y)	
Less than 0.10 mgd; natural pH	y = 686392x + 13605
Greater than 0.10 mgd; natural pH	y = 559821x + 13602
Less than 0.10 mgd; pH adjusted to 6.0	y = 740360x + 56081
Greater than 0.10 mgd; pH adjusted to 6.0	y = 613790x + 56079
O&M Costs (z)	
Less than 0.35 mgd; natural pH 7.0 – 8.0	z = 251601x + 5491.4
Greater than 0.35 mgd; natural pH 7.0 – 8.0	z = 254047x + 13051.2
Less than 0.35 mgd; natural pH 8.0 – 8.3	z = 479114x + 5809.6
Greater than 0.35 mgd; natural pH 8.0 – 8.3	z = 485379x + 20999
Less than 0.35 mgd; pH adjusted to 6.0; 23,100 BVs	z = 220201x + 7718.1
Greater than 0.35 mgd; pH adjusted to 6.0; 23,100 BVs	z = 220298x + 15574
Less than 0.35 mgd; pH adjusted to 6.0; 15,400 BVs	z = 273550x + 8425.8
Greater than 0.35 mgd; pH adjusted to 6.0; 15,400 BVs	z = 274543x + 17439
Source: U.S. EPA (2000) BVs = bed volumes; mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost	

Table 4b provides capital costs and O&M costs for different design flow thresholds

Table 4b - Activated Alumina Treatment Costs (2006 dollars)	
Design Flow (mgd)	**Capital Cost ($)**
Natural pH	
0.01	$20,500
0.1	$82,200
1	$573,400
10	$5,611,800
50	$28,004,600
pH Adjusted to 6.0	
0.01	$63,500
0.1	$130,100
1	$669,900
10	$6,194,000
50	$30,745,600
Design Flow (mgd)	**O&M Cost ($)**
Natural pH 7.0 – 8.0	
0.01	$8,000
0.1	$30,700
1	$267,100
10	$2,553,500
50	$12,715,400
Natural pH 8.0 – 8.3	
0.01	$13,300
0.1	$56,400
1	$506,400
10	$4,874,800
50	$24,290,000
pH adjusted to 6.0; 23,100 BVs	

0.01	$9,900
0.1	$29,700
1	$235,900
10	$2,218,600
50	$11,030,500
pH adjusted to 6.0; 15; 400 BVs	
0.01	$11,200
0.1	$35,800
1	$292,000
10	$2,762,900
50	$13,744,600
Notes: Costs are derived from equations found in U.S. EPA (2000) All costs are rounded to the nearest hundred dollars mgd = million gallons per day	

Q2.4a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for activated alumina treatment.
A2.4a: >>

Q2.4b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.4b: >>

EPA also estimated costs for waste disposal which included nonhazardous landfill disposal (for systems operating without regeneration). EPA assumed zero capital cost for nonhazardous landfill disposal. O&M cost vary based on pH and BVs as shown in the following equations.

- Natural pH between 7.0 and 8.0: O&M cost = 10081x
- Natural pH between 8.0 and 8.3: O&M cost = 19387x
- pH adjusted to 6.0; 23,100 BVs: O&M cost = 4364x
- pH adjusted to 6.0; 15,400 BVs: O&M cost = 6547x

Note that the resulting cost estimates from the following equations will be in 2006 U.S. dollars.

Table 4c provides O&M costs for different design flow thresholds for activated alumina waste disposal treatment including nonhazardous landfill.

Table 4c - Activated Alumina Waste Disposal Treatment Costs Including Nonhazardous Landfill (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
Natural pH between 7.0 and 8.0		
0.01	$0	$100
0.1	$0	$1,000
1	$0	$10,100
10	$0	$100,800
50	$0	$504,000
Natural pH between 8.0 and 8.3		
0.01	$0	$200
0.1	$0	$1,900
1	$0	$19,400
10	$0	$193,900
50	$0	$969,400
pH adjusted to 6.0; 23,100 BVs		

0.01	$0	$0
0.1	$0	$400
1	$0	$4,400
10	$0	$43,600
50	$0	$218,200
pH adjusted to 6.0; 15,400 BVs		
0.01	$0	$100
0.1	$0	$700
1	$0	$6,500
10	$0	$65,500
50	$0	$327,300
Notes: Costs are derived from equations found in U.S. EPA (2000) All costs are rounded to the nearest hundred dollars mgd = million gallons per day		

Q2.4c: Please comment on the estimated costs and assumptions EPA used to estimate the costs for activated alumina waste disposal treatment including nonhazardous landfill.
A2.4c: >>

Q2.4d: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.4d:>>

2.5 Ion Exchange

EPA made the following assumptions to estimate costs for ion exchange:

- Empty Bed Contact Time (EBCT) = 2.5 minutes per column
- Bed depth ranged from 3 feet to 6 feet depending on the design flow
- Maximum diameter per column is 12 feet
- Vessel cost has been sized based on 50% bed expansion during backwash
- Capital costs include a redundant column to allow the system to operate while the media is being regenerated in the other column
- The run length when sulfate is at or below 20 mg/L is 1,500 bed volumes (BV); the run length when sulfate is between 20 and 50 mg/L sulfate is 700 BV
- Salt dose for regeneration was 10.2 lb/ft3.
- Incremental labor for the anion exchange is one hour per week plus three hours per regeneration.

Table 6a summarizes the capital and O&M cost equations EPA used to estimate costs for ion exchange treatment.

Table 6a: Cost Equations for Ion Exchange (2006 dollars)	
Design Flow (x) and Design Parameters	**Cost Equation**
Capital Costs (y)	
Less than 0.10 mgd; less than 20 mg/L SO_4	$y = 458982x + 26035$
Greater than 0.10 mgd; less than 20 mg/L SO_4	$y = -8363.2x^2 + 425133x + 48962$
Less than 0.10 mgd; 20 mg/L – 50 mg/L SO_4	$y = 605021x + 26035$
Greater than 0.10 mgd; 20 mg/L – 50 mg/L SO_4	$y = -12995.1x^2 + 497964x + 97662$
O&M Costs (z)	
Less than 0.35 mgd; less than 20 mg/L SO_4	$z = -90359x^2 + 103289x + 6656.5$
Greater than 0.35 mgd; less than 20 mg/L SO_4	$z = -2258.4x^2 + 49750x + 22021$
Less than 0.35 mgd; 20 mg/L – 50 mg/L SO_4	$z = -110306x^2 + 126338x + 11255.3$
Greater than 0.35 mgd; 20 mg/L – 50 mg/L SO_4	$z = -2455x^2 + 64294x + 32786$
Source: U.S. EPA (2000) mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost	

Table 5b provides O&M costs for different design flow thresholds

Table 5b - Ion Exchange Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
Less than 20 mg/L SO_4		
0.01	$30,600	$7,700
0.1	$71,900	$16,100
1	$465,700	$69,500
10	$3,464,000	$293,700
50	$397,500	-$3,136,500
20 mg/L $S0_4$ – 50 mg/L $S0_4$		
0.01	$32,100	$12,500
0.1	$86,500	$22,800
1	$582,600	$94,600
10	$3,777,800	$430,200
50	-$7,491,900	-$2,890,000
Notes: Costs are derived from equations found in U.S. EPA (2000); mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.5a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for ion exchange treatment.
A2.5a: >>

Q2.5b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.5b: >>

EPA also estimated waste disposal costs which included discharge to a wastewater treatment plant for treatment. Table 5c summarizes the capital and O&M cost equations EPA used to estimate costs for ion exchange treatment.

Table 5c: Cost Equations for Ion Exchange Waste Disposal (2006 dollars)	
Design Flow (x) and Design Parameters	**Cost Equation**
Capital Costs (y)	
Less than 0.85 mgd; less than 20 mg/L SO_4	y = 5268
Between 0.85 mgd and 25 mgd; less than 20 mg/L SO_4	y = 6773
Greater than 25 mgd; less than 20 mg/L SO_4	y = 28.6x + 6924
Less than 0.85 mgd; 20 mg/L – 50 mg/L SO_4	y = 5268
Between 0.85 mgd and 2.5 mgd; 20 mg/L – 50 mg/L SO_4	y = 6773
Greater than 2.5 mgd; 20 mg/L – 50 mg/L SO_4	y = 28.6x + 6924
O&M Costs (z)	
All flows; less than 20 mg/L SO_4	z = 4567x + 500
All flows; 20 mg/L – 50 mg/L SO_4	z = 9788x
Source: U.S. EPA (2000) mgd = million gallons per day; x = design flow; y = capital cost; z = O&M cost	

Table 5d provides capital and O&M costs for different design flow thresholds

Table 5d - Ion Exchange Waste Disposal Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
Less than 20 mg/L SO_4		
0.01	$5,300	$500
0.1	$5,300	$1,000
1	$6,800	$5,100
10	$6,800	$46,200
50	$8,400	$228,900
20 mg/L $S0_4$ – 50 mg/L $S0_4$		

0.01	$5,300	$100
0.1	$5,300	$1,000
1	$6,800	$9,800
10	$7,200	$97,900
50	$8,400	$489,400
Notes: Costs are derived from equations found in U.S. EPA (2000) All costs are rounded to the nearest hundred dollars mgd = million gallons per day		

Q2.5c: Please comment on the estimated costs and assumptions EPA used to estimate the costs for ion exchange waste disposal treatment.
A2.5c: >>

Q2.5d: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.5d: >>

2.6 Greensand Filtration

EPA used the following design assumptions to develop cost estimates for greensand filtration:

- Potassium permanganate feed, 10 mg/L;
- The filter medium is contained in a ferrosand continuous regeneration filter tank equipped with an underdrain;
- Filtration rate, 4 gpm/ft2;
- Backwash is sufficient for 40 percent bed expansion; and
- Corrosion control measures are not required because pH is not affected by the process.

EPA used the VSS model to estimate capital and O&M costs because greensand filtration costs are not included in either the Water Model or the W/W Model. Thus, while this technology could be effectively operated in larger size systems, the cost equations below may not provide representative costs for large systems.

$$\text{Capital Costs} = 782662x^{0.838}$$
$$\text{O\&M Costs} = 0.0012x^2 + 78483x + 9847.3$$

Table 6a shows the capital and O&M costs for greensand filtration treatment.

Table 6a - Greensand Filtration Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$16,500	$10,600
0.1	$113,700	$17,700
1	$782,700	$88,300
10	$5,389,800	$794,700
50	$20,764,000	$3,934,000
Notes: Costs are derived from equations found in U.S. EPA (2000); mgd = million gallons per day All costs are rounded to the nearest hundred dollars		

Q2.6a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for greens and filtration treatment.
A2.6a: >>

Q2.6b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.6b: >>

EPA also estimated waste disposal costs which included discharge to a wastewater treatment plant for treatment. EPA assumed capital costs would be $5,300 (in 2006 U.S. dollars), regardless of design flow, and calculated O&M costs based on the following equations:

- Flows less than 0.4 mgd: O&M cost = 10054x + 565
- Flows greater than 0.4 mgd: O&M cost = 10054x + 1505.

Table 6b shows the capital and O&M costs for greensand filtration waste disposal treatment.

Table 6b - Discharge to Wastewater Treatment Plant Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$5,300	$700
0.1	$5,300	$1,600
1	$5,300	$11,600
10	$5,300	$102,000
50	$5,300	$504,200

Notes:
Costs are derived from equations found in U.S. EPA (2000)
All costs are rounded to the nearest hundred dollars
mgd = million gallons per day

Q2.6c: Please comment on the estimated costs and assumptions EPA used to estimate the costs for greens and filtration wastewater treatment.
A2.6c: >>

Q 2.6d: **Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.**
A 2.6d: >>

2.7 Point-of-Use Reverse Osmosis

EPA estimated costs for reverse osmosis (RO) and activated alumina point-of-use (POU) technologies. EPA used "Cost Evaluation of Small System Compliance Options - Point-of Use and Point-of-Entry Treatment Units" (Cadmus Group, 1998) to estimate treatment costs. EPA developed cost curves based on the following assumptions:

- Average household consists of 3 individuals using 1 gallon each per day (1,095 gallons per year)
- Life of unit is 5 years
- Duration of cost study is 10 years (or 2 POU devices per household)
- Cost of water meter and automatic shut-off valve included.
- No shipping and handling costs required.
- Volume discount schedule: retail for single unit, 10 percent discount for 10 or more units, 15 percent discount on more than 100 units.
- Installation time - 1 hour unskilled labor (POU)
- O&M costs include maintenance, replacement of pre-filters and membrane cartridges, laboratory sampling and analysis, and administrative costs.

The capital and O&M cost equations for POU RO are as follows, with x equal to design flow.

$$\text{Capital} = 1151.73x^{0.9261}$$
$$\text{O\&M} = 89.14x^{0.9439}$$

The capital and O&M cost for POU RO treatment are shown in table 7a:

Table 7a - POU RO Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$0	$0
0.1	$100	$0
1	$1,200	$100
10	$9,700	$800
50	$43,100	$3,600
Notes: Costs are derived from equations found in U.S. EPA (2000) All costs are rounded to the nearest hundred dollars mgd = million gallons per day		

Q2.7a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for POU RO treatment.
A2.7a: >>

Q2.7b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.7b: >>

The capital and O&M cost equations for POU activated alumina are as follows, with x equal to design flow.

$$\text{Capital} = 395.46x^{0.9257}$$
$$\text{O\&M} = 549.6x^{0.9376}$$

The capital and O&M cost POU activated alumina treatment are shown in table 7b.

Table 7b - POU Activated Alumina Treatment Costs (2006 dollars)		
Design Flow (mgd)	**Capital Cost ($)**	**O&M Cost ($)**
0.01	$0	$0
0.1	$0	$100
1	$400	$500
10	$3,300	$4,800
50	$14,800	$21,500
Notes: Costs are derived from equations found in U.S. EPA (2000) All costs are rounded to the nearest hundred dollars mgd = million gallons per day		

Q2.7a: Please comment on the estimated costs and assumptions EPA used to estimate the costs for POU activated alumina treatment.
A2.7a: >>

Q2.7b: Have capital and O&M costs for this technology changed significantly from the time facilities complied with the arsenic rule (i.e., since 2006)? If so, what are the principal reasons for these changes? To the extent possible, please indicate the approximate amount of difference from EPA's estimates.
A2.7b: >>

Section 3 Alternative Technologies

Although EPA identified the following alternative treatment technologies at the time of rule development, it did not consider them in its cost analysis because EPA considered them to be emerging technologies. Following are the alternative treatment technologies:

- Sulfur-Modified Iron
- Granular Ferric Hydroxide
- Iron Filings

- Iron Oxide Coated Sand

Q3a: Do you have any knowledge of water systems using these or any other alternative treatment technologies to comply with EPA's arsenic rule? To the extent possible, please characterize the approximate frequency with which these alternative technologies have been used for rule compliance.
A3a: >>

Q3b: Were any of these alternative treatment technologies less costly to install and operate than the treatment technologies on which EPA based its cost analysis at the time the Arsenic Rule was promulgated? To the extent possible, please describe cost differences or other factors that may have favored these alternative technologies compared to the technologies that EPA considered in the rule analysis.
A3b: >>

Section 4 Additional Questions

Q4a: Did technological innovation occur within the treatment systems for which EPA estimated compliance costs? If so, please indicate which technology or technologies were affected and what was the impact on the respective capital and O&M costs.
A4a: >>

Q4b: Did learning-by-doing play a major role in decreasing O&M compliance costs? If so, please indicate which technology or technologies were affected by it.
A4b: >>

Q4c: Were there any factors that may have caused greater implementation difficulty and higher costs with the Arsenic Rule? For example, were there:

- **Any technical challenges to meet compliance requirements?**
- **Issues with financing support for technology installation?**
- **Limitations on compliance in terms of compliance assistance or compliance schedule?**
- **Terms of regulatory requirements, and specific aspects of the rule requirements?**

A4c: >>

Q4d: Did treatment technology used by systems you assisted vary based on existing (pre-rule) arsenic levels (e.g., did systems needing smaller reductions in arsenic concentrations employ different technologies than systems needing greater reductions)? Explain
A4d: >>

Q4e: Did state-level regulations influence the choices treatment technologies that you helped to install? Explain
A4e: >>

Q4e: Do you have any broader knowledge about treatment technologies and their costs installed by facilities in the region where your projects were located? What treatment technologies did the systems typically use? Were there differences: by state, system size, source of water (ground/ surface)?
A4c: >>

Q4f: Please provide any other comments / suggestions that you feel are not covered in this questionnaire, but would be helpful in reaching the goals of this project.
A4f: >>

References

United States Environmental Protection Agency (U.S. EPA). 2000. Technologies and Costs for Removal of Arsenic from Drinking Water. EPA 815-R-00-028. December.