

# Cost Estimating Program for Arsenic Removal from Drinking Water Supplies by Adsorptive Media and Anion Exchange Processes

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View Schematic Diagrams

**Adsorptive Media  
Throwaway System**

**Adsorptive Media  
Regeneration System**

**Anion Exchange System**

**Input General Design  
Parameters**

Prepared for:  
U.S. EPA  
National Risk Management Research  
Laboratory (NRMRL)



Prepared by:  
**Battelle**  
... Putting Technology To Work



Questions or comments?

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## Cost Summary

Category	Cost Component	Adsorptive Media Throwaway System	Adsorptive Media Regeneration System	Anion Exchange System
Capital Cost	Total capital cost	\$26,629	\$29,990	\$22,185
	Annualized capital cost (\$/yr)	\$3,122	\$3,516	\$2,601
	Unit annualized capital cost (\$/1000 gal)	\$0.57	\$0.64	\$0.48
Operating and Maintenance Cost	Total annual O&M cost (\$/yr)	\$24,522	\$5,166	\$12,536
	Unit annual O&M cost (\$/1000 gal)	\$4.48	\$0.94	\$2.29
Total Cost	Annualized total cost (\$/yr)	\$27,644	\$8,682	\$15,136
	Unit total cost (\$/1000 gal)	\$5.05	\$1.59	\$2.76
Waste Production	Volume of spent media (cf/yr)	236.18	0.72	2.88
	Daily wastewater stream (gal/day)	Not applicable	1.14	112.50
	Daily spent regenerant stream (gal/day)	Not applicable	1.24	19.30

## Major Design Parameters

Category	Design Parameter	Adsorptive Media Throwaway System	Adsorptive Media Regeneration System	Anion Exchange System
General Design Input	Average Water Usage (gal/day)	15,000	15,000	15,000
	Treatment Duration (hr/day)	8	8	8
	Design Flow Rate (gal/min)	36	36	36
Raw Water Quality	pH	8	8	8
	Alkalinity (mg/L as CaCO <sub>3</sub> )	100	100	100
	Arsenic (ug/L)	50	50	50
	Sulfate (mg/L)	100	100	100
Media Vessel Design	Empty bed contact time per vessel (min)	5	5	3
	Media volume, total (cf)	24	24	14
	Number of treatment trains	1	1	1
	Bed depth (ft)	4	4	4
	Media vessel volume (cf/vessel)	36	36	22
	Target treatment pH	No pH adjustment	6	Not applicable
	Media run length (#BVs)	3,090	95,520	600
	Media run length (gal)	557,028	17,219,199	64,627
Annualization Factors	Replacement/Regeneration frequency (yr)	9.8	0.3	84.5
	Net interest rate (%)	3	3	3
	Years of investment	10	10	10

Notes:

1. Detailed design parameters and cost factors can be found on detailed cost sheets.
2. Changes to design parameters shall not be made on this page. Use buttons on the top to make changes.

**Adsorption Media Throwaway System Design Parameters**

Category	Design Parameter	Value
General Design Parameters	Average water usage (gal/day)	15,000
	Treatment duration (hr/day)	8
	Design flowrate (gal/min)	36
	Inlet pH	8
	Inlet alkalinity (mg/L as CaCO <sub>3</sub> )	100
	Inlet arsenic (µg/L)	50
	Inlet sulfate (mg/L)	100
Media Vessel Design	Empty bed contact time (min)	5
	Media volume (cf)	24.1
	Number of treatment trains	1
	Bed depth (ft)	4
	Media run length (#BVs)	3090
	Media run length (gal)	557028
	Fractional media expansion	0.5
	Media unit price (\$/cf)	75.00
	Media vessel volume (cf)	36.15
	Replacement frequency (1/yr)	9.80
	Target pH	No pH adjustment
Operating and Maintenance	Replacement item (% of equipment and material cost)	5
	System pressure loss (psi)	20
	Acid unit price (\$/ton)	49
	Base unit price (\$/ton)	371
	Electricity unit price (\$/kwh)	0.08
	Electricity consumption (kwh/day)	25
	Routine inspection (hr/wk)	1
	Media replacement (hr/event)	10
	Plant supervision (hr/mon)	1
	Operator labor rate (\$/hr)	30
	Supervisory labor rate (\$/hr)	80
Direct Capital Cost Factors	Piping (% of equipment cost)	10
	Electrical (% of equipment cost)	2
	Instrumentation (% of equipment cost)	3
	Shipping and installation (% of equipment and material cost)	10
Indirect Capital Cost Factors	Contractor/Engineering (% of direct capital cost)	30
	Permitting (% of direct capital cost)	15
	Contingency (% of direct capital cost)	25
	Working capital (% of direct capital cost)	15
	Startup (% of direct capital cost)	15
Annualization Factors	Net interest rate (%)	3
	Years of investment (yr)	10

Note:

Changes to design parameters shall not be made on this page. Use buttons on top of Cost Summary Sheet to make changes.

**Detailed Cost Sheets for Adsorption Media Throwaway System**

Category	Sub-Category	Cost Components	Total
Capital Cost	System direct capital cost	Adsorption media cost	\$3,615
		Tank cost	\$7,382
		Equipment cost	\$7,382
		Material cost	\$4,722
		System installation cost	\$1,210
		System direct capital cost	\$13,314
		Acid feed system direct capital cost	Acid day tank cost
	Acid metering pump cost		Not applicable
	Acid feed system equipment cost		Not applicable
	Acid feed system material cost		Not applicable
	Acid feed system installation cost		Not applicable
	Base feed system direct capital cost	Acid feed system direct capital cost	Not applicable
		Base day tank cost	Not applicable
		Base neutralization pump cost	Not applicable
		Base feed system equipment cost	Not applicable
		Base feed system material cost	Not applicable
		Base feed system installation cost	Not applicable
	Capital cost summary	Base feed system direct capital cost	Not applicable
		Total equipment cost	\$7,382
		Total material cost	\$4,722
		Total installation cost	\$1,210
		Total direct capital cost	\$13,314
		Contractor/engineering	\$3,994
		Permitting	\$1,997
		Contingency	\$3,329
		Working capital	\$1,997
		Startup	\$1,997
		Total indirect cost	\$13,314
		Total capital cost	\$26,629
	O & M Cost	Chemical and material cost	Annualized capital cost (\$/yr)
Unit annualized capital cost (\$/1000 gal)			\$0.57
Replacement item cost, \$/yr			\$605
Electrical cost		Adsorption media replaced (cf/yr)	236.18
		Media replacement cost (\$/yr)	\$17,714
		Total chemical and material cost (\$/yr)	\$18,319
		System pressure loss electrical usage (kwh/yr)	529.16
		Misc. power usage (kwh/yr)	8,760.00
Labor cost		Total annual electrical cost (\$/yr)	\$743
		Routine inspection labor hours (hr/yr)	52.00
		Media replacement labor hours (hr/yr)	98.00
		Operator labor cost (\$/yr)	\$4,500
	Supervisory labor cost (\$/yr)	\$960	
	Total annual labor cost (\$/yr)	\$5,460	
	Total annual O&M cost	\$24,522	
Total Cost	Total annual O&M cost (\$/yr)	\$24,522	
	Unit annual O&M cost (\$/1000 gal)	\$4.48	
	Annualized total cost (\$/yr)	\$27,644	
Waste Production	Unit total cost (\$/1000 gal)	\$5.05	
	Volume of spent media (cf/yr)	236.18	
	Daily wastewater stream (gal/day)	Not applicable	
	Daily spent regenerant stream (gal/day)	Not applicable	

### Adsorption Media Regeneration System Design Parameters

Category	Design Parameter	Value
General Design Parameters	Average water usage (gal/day)	15,000
	Treatment duration (hr/day)	8
	Design flowrate (gal/min)	36
	Inlet pH	8
	Inlet alkalinity (mg/L as CaCO <sub>3</sub> )	100
	Inlet arsenic (µg/L)	50
	Inlet sulfate (mg/L)	100
Media Vessel Design	Empty bed contact time (min)	5
	Media volume (cf)	24.1
	Number of treatment trains	1
	Bed depth (ft)	4
	Media run length (#BVs)	95520
	Media run length (gal)	17219199
	Fractional media expansion	0.5
	Media unit price (\$/cf)	75.00
	Media vessel volume (cf)	36.15
	Replacement frequency (1/yr)	0.30
	Target pH value for treatment	6
Media Regeneration	Backwash flowrate (gpm/sq ft)	8
	Backwash duration (min)	10
	Caustic rinse flowrate (gpm/sq ft)	2.5
	Caustic rinse duration (min)	70
	Flushing flowrate (gpm/sq ft)	5
	Flushing duration (min)	30
	Neutralization flowrate (gpm/sq ft)	2.5
	Neutralization duration (min)	30
Operating and Maintenance	Replacement item (% of equipment and material cost)	5
	Media life (number of regenerations)	10
	Acid unit price (\$/ton)	49
	Base unit price (\$/ton)	371
	System pressure loss (psi)	20
	Electricity unit price (\$/kwh)	0.08
	Electricity consumption (kwh/day)	37
	Routine inspection (hr/wk)	1
	Media regeneration (hr/event)	8
	Plant supervision (hr/mon)	1
	Operator labor rate (\$/hr)	30
Supervisory labor rate (\$/hr)	80	
Direct Capital Cost Factors	Piping (% of equipment cost)	10
	Electrical (% of equipment cost)	2
	Instrumentation (% of equipment cost)	3
	Shipping and installation (% of equipment and material cost)	10
Indirect Capital Cost Factors	Contractor/Engineering (% of direct capital cost)	30
	Permitting (% of direct capital cost)	15
	Contingency (% of direct capital cost)	25
	Working capital (% of direct capital cost)	15
	Startup (% of direct capital cost)	15
Annualization Factors	Net interest rate (%)	3
	Years of investment (yr)	10

Note:

Changes to design parameters shall not be made on this page. Use buttons on top of Cost Summary Sheet to make changes.

**Detailed Cost Sheets for Adsorption Media Regeneration System**

Category	Sub-Category	Cost Components	Total	
Capital Cost	Adsorption media system direct capital cost	Adsorption media cost	\$3,615	
		Tank cost	\$7,382	
		Equipment cost	\$7,382	
		Material cost	\$4,722	
		System installation cost	\$1,210	
		System direct capital cost	\$13,314	
	Acid feed system direct capital cost	Acid storage tank cost	\$0	
		Acid day tank cost	\$0	
		Acid metering pump cost	\$273	
		Acid feed system equipment cost	\$273	
		Acid feed system material cost	\$41	
		Acid feed system installation cost	\$31	
		Acid feed system direct capital cost	\$345	
	Base feed system direct capital cost	Base storage tank cost	\$0	
		Base storage tank heating and insulating cost	\$0	
		Base day tank cost	\$160	
		Base neutralization pump cost	\$273	
		Base regeneration pump cost	\$623	
		Base feed system equipment cost	\$1,056	
		Base feed system material cost	\$158	
		Base feed system installation cost	\$121	
		Base feed system direct capital cost	\$1,335	
	Capital cost summary	Total equipment cost	\$8,710	
		Total material cost	\$4,922	
		Total installation cost	\$1,363	
		Total direct capital cost	\$14,995	
		Contractor/engineering	\$4,499	
		Permitting	\$2,249	
		Contingency	\$3,749	
		Working capital	\$2,249	
		Startup	\$2,249	
		Total indirect cost	\$14,995	
		Total capital cost	\$29,990	
Annualized capital cost (\$/yr)		\$3,516		
Unit annualized capital cost (\$/1000 gal)		\$0.64		
O & M Cost	Chemical and material cost	Replacement item cost (\$/yr)	\$682	
		Media replaced (cf/yr)	0.72	
		Media replacement cost (\$/yr)	\$54	
		Acid consumption (gal/yr)	219	
		Acid cost (\$/yr)	\$73	
		Base consumption (gal/yr)	320	
		Base cost (\$/yr)	\$673	
		Total chemical and material cost (\$/yr)	\$1,483	
		Electrical cost	System pressure loss electrical usage (kwh/yr)	529
			Pump electrical usage (kwh/yr)	4,355
	Immersion heater electrical usage (kwh/yr)		0	
	Misc. power usage (kwh/yr)		8,760	
	Total annual electrical cost (\$/yr)		\$1,092	
	Labor cost	Routine inspection labor hours (hr/yr)	52.00	
		Media regeneration labor hours (hr/yr)	2.40	

		Operator labor cost (\$/yr)	\$1,632
		Supervisory labor cost (\$/yr)	\$960
		Total annual labor cost (\$/yr)	\$2,592
	Total annual O&M cost	Total annual O&M cost (\$/yr)	\$5,166
		Unit annual O&M cost (\$/1000 gal)	\$0.94
Total Cost		Annualized total cost (\$/yr)	\$8,682
		Unit total cost (\$/1000 gal)	\$1.59
Waste Production		Volume of spent media (cf/yr)	0.72
		Daily wastewater stream (gal/day)	1.14
		Daily spent regenerant stream (gal/day)	1.24

### Anion Exchange System Design Parameters

Category	Design Parameter	Value
General Design Parameters	Average water usage (gal/day)	15,000
	Treatment duration (hr/day)	8
	Design flowrate (gal/min)	36
	Inlet pH	8
	Inlet alkalinity (mg/L as CaCO <sub>3</sub> )	100
	Inlet arsenic (µg/L)	50
	Inlet sulfate (mg/L)	100
AIX Vessel Design	Empty bed contact time (min)	3
	Resin volume (cf)	14.4
	Number of AIX trains	1
	Resin bed depth (ft)	4
	Resin run length (#BVs)	600
	Resin run length (gal)	64627
	Fractional media expansion	0.5
	Resin unit price (\$/cf)	120.00
	Resin bed volume (cf)	21.60
	Regeneration frequency (1/yr)	84.49
AIX Regeneration	Salt dosage (lb/sq ft)	15
	Backwash flowrate (gpm/sq ft)	2.5
	Backwash duration (min)	10
	Brine regeneration flowrate (gpm/cf)	0.5
	Brine regeneration duration (min)	12
	Slow rinse flowrate (gpm/cf)	0.5
	Slow rinse duration (min)	15
	Fast rinse flowrate (gpm/cf)	2
	Fast rinse duration (min)	10
Operating and Maintenance	cost)	5
	Media life (number of regenerations)	5
	Salt unit price (\$/ton)	99
	System pressure loss (psi)	20
	Electricity unit price (\$/kwh)	0.08
	Routine inspection (hr/wk)	1
	Media regeneration (hr/event)	3
	Plant supervision (hr/mon)	1
	Operator labor rate (\$/hr)	30
	Supervisory labor rate (\$/hr)	80
Direct Capital Cost Factors	Piping (% of equipment cost)	10
	Electrical (% of equipment cost)	2
	Instrumentation (% of equipment cost)	3
	material cost)	10
Indirect Capital Cost Factors	Contractor/Engineering (% of direct capital cost)	30
	Permitting (% of direct capital cost)	15
	Contingency (% of direct capital cost)	25
	Working capital (% of direct capital cost)	15
	Startup (% of direct capital cost)	15
Annualization Factors	Net interest rate (%)	3
	Years of investment (yr)	10

Note:

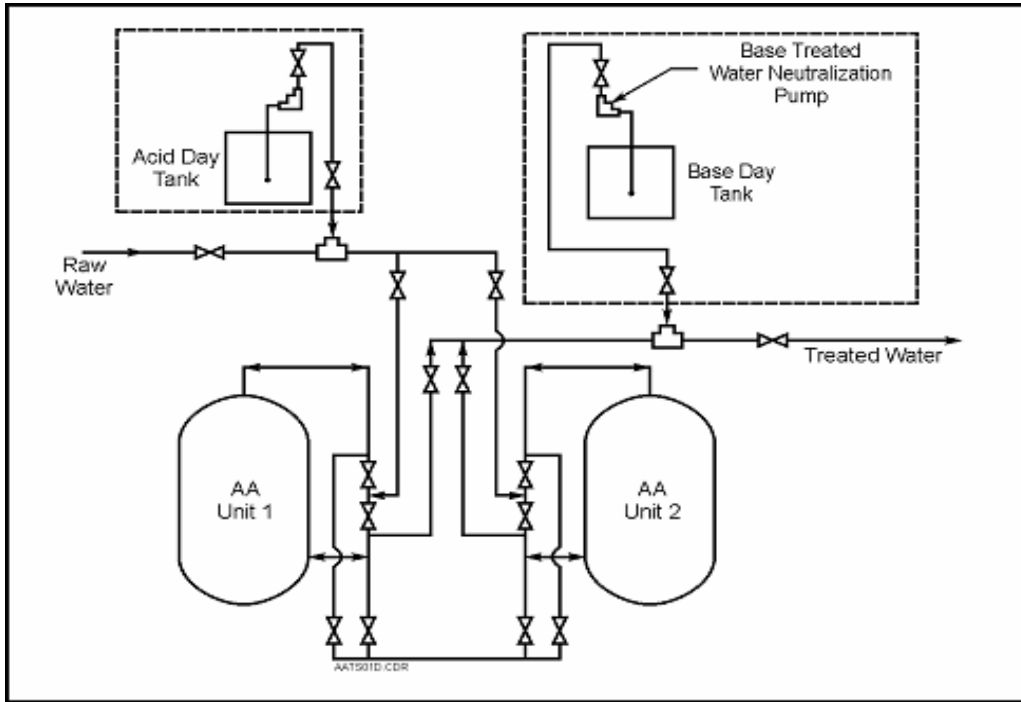
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**Detailed Cost Sheets for Anion Exchange System**

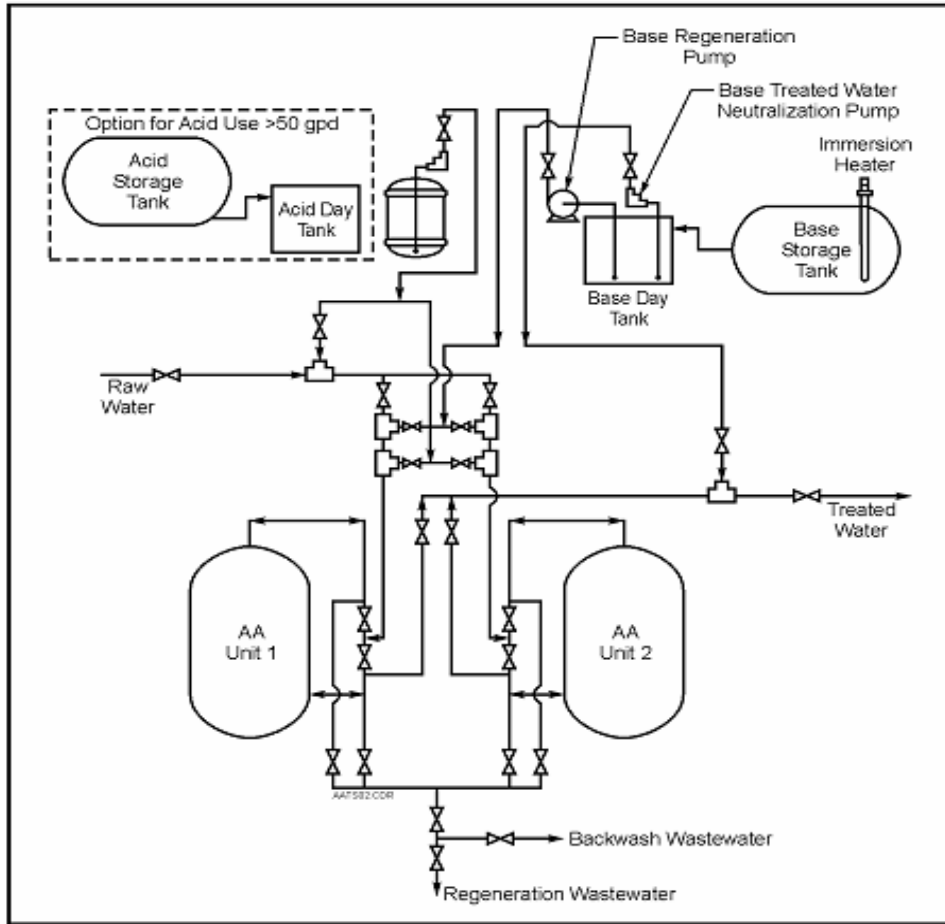
Category	Sub-Category	Cost Components	Total
Capital Cost	AIX system direct capital cost	AIX resin cost	\$3,456
		AIX tank cost	\$4,884
		AIX system equipment cost	\$4,884
		AIX system material cost	\$4,189
		AIX system installation cost	\$907
		AIX system direct capital cost	\$9,980
	Brine system direct capital cost	Brine tank cost	\$205
		Brine pump cost	\$675
		Brine system equipment cost	\$880
		Brine system material cost	\$132
		Brine system installation cost	\$101
		Brine system direct capital cost	\$1,113
	Capital cost summary	Total equipment cost	\$5,764
		Total material cost	\$4,321
		Total installation cost	\$1,008
		Total direct capital cost	\$11,093
		Contractor/engineering	\$3,328
		Permitting	\$1,664
		Contingency	\$2,773
		Working capital	\$1,664
Startup		\$1,664	
Total indirect cost		\$11,093	
Total capital cost		\$22,185	
Annualized capital cost (\$/yr)		\$2,601	
Unit annualized capital cost (\$/1000 gal)		\$0.48	
O & M Cost	Chemical and material cost	Replacement item cost (\$/yr)	\$504
		Resin replaced (cf/yr)	2.88
		Resin replacement cost (\$/yr)	\$346
		Salt consumption (lb/yr)	18,250
		Salt cost (\$/yr)	\$807
		Total chemical and material cost (\$/yr)	\$1,656
	Electrical cost	System pressure loss electrical usage (kwh/yr)	529
		Pump electrical usage (kwh/yr)	148
		Misc. power usage (kwh/yr)	8,760
		Total annual electrical cost (\$/yr)	\$755
	Labor cost	Routine inspection labor hours (hr/yr)	52.00
		Media regeneration labor hours (hr/yr)	253
		Operator labor cost (\$/yr)	\$9,164
		Supervisory labor cost (\$/yr)	\$960
		Total annual labor cost (\$/yr)	\$10,124
	Total annual O&M cost	Total annual O&M cost (\$/yr)	\$12,536
		Unit annual O&M cost (\$/1000 gal)	\$2.29
	Total Cost	Annualized total cost (\$/yr)	\$15,136
		Unit total cost (\$/1000 gal)	\$2.76
	Waste Production	Volume of spent media (cf/yr)	2.88
Daily wastewater stream (gal/day)		112.50	
Daily spent regenerant stream (gal/day)		19.30	

### Schematic Diagram for Dual Vessel Series Downflow Adsorptive Media Throwaway System



[Back to Main Menu](#)

### Schematic Diagram for Dual Vessel Series Downflow Adsorptive Media Regeneration System



[Back to Main Menu](#)

### Schematic Diagram for Dual Vessel Series Downflow Anion Exchange System

Back to Main Menu

