PB84-161793

Cost Equations for Small Drinking Water Systems

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

Feb 84

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EPA-600/2-84-059
February 1984

COST EQUATIONS FOR SMALL DRINKING WATER SYSTEMS

by

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-84-059	2.	3. RECIPIENT'S ACCESSION NO. PB84 161793
4. TITLE AND SUBTITLE Cost Equations for Small Drinking Water Systems		5. REPORT DATE February 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Richard G. Eilers		8. PERFORMING ORGANIZATION REPORT NO. N/A
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. EPA/MERL/DWRD 26 West St. Clair Street Cincinnati, OH 45268		10. PROGRAM ELEMENT NO. CBNC1A
		11. CONTRACT/GRANT NO. Inhouse
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final - 12/83
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

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16. ABSTRACT

This report presents capital and operation/maintenance cost equations for 33 drinking water treatment processes as applied to small flows (2,500 gpd to 1 mgd). The equations are based on previous cost data development work performed under contract to EPA. These equations provide a hand calculation method that can be easily used to compute preliminary cost estimates for individual unit processes or for an entire system within the specified size range.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Treatment Cost Estimates Regression Analysis Economic Analysis	Unit Process Costs Construction Costs Operation/Maintenance Costs Cost Curve Data	13B

18. DISTRIBUTION STATEMENT RELEASE UNLIMITED	19. SECURITY CLASS *(This Report)* NONE	21. NO. OF PAGES 27
	20. SECURITY CLASS *(This page)* NONE	22. PRICE

EPA Form 2220-1 (9-73)

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FOREWORD

The U. S. Environmental Protection Agency was created because of public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research - a most vital communications link between the researcher and the user community.

The cost of water treatment processes that may be used for the removal of contaminants included in the National Interim Primary Drinking Water Regulations is of interest to the U.S. Environmental Protection Agency, state and local agencies, and the engineering community in general. The impact of proposed regulations will impact the small system water producers and consumers the most significantly with respect to economics. The cost equations presented in this report will help in analyzing the situation and providing solutions to the rising cost of water supply.

Francis T. Mayo
Director
Municipal Environmental Protection Agency

ABSTRACT

This report presents capital and operation/maintenance cost equations for 33 drinking water treatment unit processes as applied to small flows (2,500 gpd to 1 mgd). The equations are based on previous cost data development work performed under contract to EPA. These equations provide a hand calculation method that can be easily used to compute preliminary cost estimates for individual unit processes or for an entire system within the specified size range.

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INTRODUCTION

The need to consider the cost of drinking water production when regulations are proposed was established with the passage of the Safe Drinking Water Act of 1974. Efficient unit process design and its effect on controlling the escalating costs of water supply need to be considered. This type of analysis is most important in the design of small (less than 1 mgd) water systems for several reasons. Small systems often lack operating revenues and cannot benefit from economies of scale as do large urban systems. Another problem is that of providing high quality drinking water. Studies indicate most waterborn disease outbreaks seem to occur in small systems and are due primarily to inadequancy of treatment technology. Future proposed standards will likely compound these problems for the small utilities when they are forced to install additional technology in order to meet new quality requirements. Substantial or even prohibitive cost increases could result. In order to help measure the economic impact of regulation in advance, the cost information presented in this report can be of value in performing preliminary studies to estimate the cost effectiveness of alternate designs for small systems. Although these cost equations cannot be used for extremely detailed design purposes, they can be a useful tool for the consulting engineer or planner.

PREVIOUS WORK

The Drinking Water Research Division (DWRD) of the USEPA's Municipal Environmental Research Laboratory (MERL) has conducted research to develop cost data associated with unit treatment processes for water supply.

In 1979 a significant piece of work entitled "Estimating Water Treatment Costs"[1] was completed and published. This was an EPA sponsored project that was performed by Culp/Wesner/Culp Consulting Engineers of Santa Ana, California (CWC). The resulting four-volume series of reports presents construction and operation/maintenance costs for 131 unit process modules (98 applicable to large systems greater than 1 mgd, and 33 applicable to small systems less than 1 mgd) which are useful for removing contaminants included in the National Interim Primary Drinking Water Regulations.

Volume 1 of the series is a summary which discusses the cost estimating approaches that were utilized to develop the cost curves, presents the treatment techniques that are applicable to contaminant removal, and gives a series of examples demonstrating the use of the cost curves. Volume 2 presents cost curves applicable to large water supply systems with treatment capabilities between 1 and 200 mgd, and also contains information on virus and asbestos removal. Volume 3 includes cost curves for flows of 2,500 gpd to 1 mgd. Volume 4 is a computer user's manual and contains documentation for a computer program that can be used for retrieving and updating all cost data contained in the reports.

For each unit process, conceptual designs were formulated, and construction costs were then developed using the conceptual designs. The construction costs that were developed are presented in tabular form by eight categories: excavation and sitework; manufactured equipment; concrete; steel; labor; pipe and valves; electrical and instrumentation; and housing. The construction cost curves were checked for accuracy by a second consulting engineering firm, Zurheide-Herrmann, Inc., using cost-estimating techniques similar to those used by general contractors in

preparing their bids. Construction costs are also shown graphically, plotted versus the most appropriate design parameter for the process (such as square feet of surface area for a filter). This type of plot allows the data to be used with varying design criteria and designers' preferences. Operation/maintenance requirements were determined individually for three categories: energy, maintenance material, and labor. Energy requirements for the building and the process are presented separately.

All costs were given in terms of October 1978 dollars, and a discussion is included on cost updating. For construction cost, either of two methods may be used. One is the use of indices that are specific to each of the eight categories used to determine construction cost. The second is use of an all-encompassing index, such as the ENR Construction Cost Index. Operation/maintenance requirements may be readily updated or adjusted to local conditions, since labor requirements are expressed in hours per year, electrical requirements are in kilowatt-hours per year, diesel fuel is in gallons per year, and natural gas is in standard cubic feet per year.

It will be helpful for the user of the small system cost equations presented later in this report to use Volume 3 of the CWC series as a reference source for explaining all of the design and operating assumptions which are associated with the individual unit processes. All costs are a function of a specific design parameter related to a particular unit process. Examples of some design parameters would be flow, area, volume, etc.

The CWC cost data base in its original form was not simple to use for determining costs of specific systems. Calculating costs by hand using the graphical or tabular data is laborious and prone to errors. Use of the computer program requires a medium size computer system with FORTRAN

capability and some knowledge of computer programming. Therefore, an attempt was made to simplify the cost estimating technique through an inhouse EPA project.(2) In order to improve the usefulness of the cost data to a point where cost estimates could be made quicky and accurately using a hand calculator, a series of analytic equations were developed for each of the 98 unit treatment process that were applicable to the large scale systems. Regression estimates were calculated based on the general equation of the form:

$$Y = a\, X_1^b\, X_2^c \ldots X_n^r \qquad (1)$$

where Y = either capital or annual operating cost; a, b, ..., r = constants determined from a regression analysis; and X_1, X_2, ..., X_n = significant variables influencing cost. Capital costs in general were found to be a function of process design parameter, Engineering News Record Construction Cost Index, number of separate units in the process, total dynamic head, sludge hauling distances, and energy gradient. Annual operation/maintenance costs in general were found to be a function of process operating parameter, power cost, Producers Price Index, direct hourly wage rate, cost of natural gas, cost of diesel fuel, number of separate units in the process, total dynamic head, hauling distances, and energy gradient. The equation coefficients and exponents were determined and presented in tabular form for each unit process. At this point the cost engineer has a relatively simple method for estimating the same costs that are normally calculated from the CWC cost data base by means of a computer program or directly from graphs. The need to do the same thing for small systems still remained.

GENERATION OF COST EQUATIONS

With the use of the CWC computer program, a random number generator, and multiple regression analysis, cost estimates based on Equation 1 were computed for the 33 small system unit processes. A capital cost equation of the form:

$$CC = K_1 \ USRT^a \ CCI^b \ MI^c \qquad (2)$$

and an operation/maintenance cost equation of the form:

$$OM = K_2 \ USRT^d \ PPI^e \ PR^f \ DHR^g \ NTG^h \ DSL^i \ MI^j \qquad (3)$$

were generated, where CC = capital cost for construction in dollars; OM = annual operation/maintenance cost in dollars/year; USRT = either design parameter for CC or operating parameter for OM; CCI = Engineering News Record Construction Cost Index; MI = sludge hauling distance in miles; PPI = Producers Price Index; PR = electric power cost in dollars/kilowatt hr; DHR = direct hourly wage rate in dollars/hr; NTG = natural gas cost in dollars/standard cu ft; DSL = dissel fuel cost in dollars/gal; and K_1, K_2, a, b, ..., j = constants estimated from the regression analysis.

Note that CC is capital cost which is defined as the construction cost plus the costs of sitework, subsurface considerations, standby power, general contractor overhead, engineering, land, legal-fiscal-administrative expenses, and interest during construction. Examination of the CWC data base shows that the capital cost obtained from Equation 2 is about 1.35 to 1.40 times the construction cost. Therefore, an estimate of the construction cost for a unit process can be obtained by dividing CC with a factor of 1.35 to 1.40. The annualized capital cost in dollars/year can be easily calculated by multiplying CC with an amortization factor given by:

$$AF = \frac{i(1 + i)^n}{(1 + i)^n - 1} \tag{4}$$

where i is the annual fractional rate of interest and n is the number of years over which the investment is financed.

Equations 2 and 3 are compact and allow a direct analysis of the sensitivity of cost to certain cost influencing variables. Other variables not included in the equations could also influence cost, but only those variables having a significant impact on cost were considered. The CWC computer program was run 100 times with randomly changing values within specified ranges for the variables influencing cost, thereby generating 100 data points for capital cost and annual operation/maintenance cost as a function of the cost factor variables. A multiple regression analysis was then performed on the 100 data sets to evaluate the coefficients and exponents of Equations 2 and 3. This procedure was performed for each of the 33 unit process for small systems.

Table 1 is a listing of the unit processes for small systems along with their respective design/operating parameters. Table 2 gives the capital cost equations, and Table 3 gives the operation/maintenance cost equations. Note that it was necessary to generate two cost curves for some unit processes. The reason for this was to provide a more accurate cost estimate within the specified design parameter range, because some of the cost curves change slope at lower levels of the design paramter. This phenomenon is a reflection of economies of scale, and the limitation is inherent in sizing technological components. Below a given use level, the size of a process component often remains constant; therefore the cost curve no longer changes with the level of the design parameter. When two

cost curves are given for an individual unit process, there will be a discontinuity where the two curves meet, but the difference should be negligible in all cases. The discontinuity from one curve to the next is relatively insignificant in terms of the entire cost but would cause slight inconsistencies at the intersection of the two curves. An important point to remember is that the operation/maintenance cost equations in Table 3 do not include the cost of any chemicals that are to be used. The amount of chemicals (if any) to be used by a unit process must be estimated and their cost added to the operation/maintenance cost calculated from Table 3.

APPLYING THE EQUATIONS

To illustrate the use of the cost equations given in Tables 2 and 3, it would be helpful to look at several examples. Table 4 shows some typical values for the various cost influencing variables based on 1983 levels and approximate costs for various chemicals used for drinking water treatment. Table 5 gives the details of a cost calculation for a .1 mgd (70 gpm) package complete treatment system. Volume 3 of the CWC reports gives the explanation for the design assumptions built into the cost data, such as pumping head, application rate, output pressure, etc. These "fixed" values limit the flexibility of the cost data, but the cost equations can still be used effectively for preliminary design purposes. Table 6 constains the cost analysis for a .5 mgd system. All of the cost calculations are based on the cost influencing parameter values and the chemical costs listed in Table 4.

SUMMARY AND CONCLUSIONS

Preliminary design cost estimates can be used to compare the economics of several treatment systems with similar water treatment goals and to identify the most cost-effective alternative. A series of equations for estimating the capital and operation/maintenance costs of small systems in the range of 2500 gpd to 1.0 mgd has been developed which can be easily used to make a quick cost analysis for a proposed design. These equations could be easily incorporated into a simple computer program that could operate on a microcomputer system, if the user would prefer that approach over the hand calculation procedure outlined in this report.

TABLE 1

UNIT PROCESSES AND DESIGN PARAMETERS

Unit Process	Design Parameter (USRT)
Package Complete Treatment	gpm
Package Gravity Filtration	gpm
Package Pressure Filtration	gpm
Filter Media - Rapid Sand	sq ft
Filter Media - Dual Media	sq ft
Filter Media - Mixed Media	sq ft
Filter Media - Mixed Media/Supervised Installation	sq ft
Package Pressure Diatomite Filtration	gpd
Package Vacuum Diatomite Filtration	gpm
Package Ultrafiltration Plants	gpd
Package Granular Activated Carbon Column	gpd
Potassium Permanganate Feed System	lb/day
Polymer Feed Systems	lb/day
Powdered Activated Carbon Feed System	lb/hr
Direct Feed Gas Chlorination	lb/day
Sodium Hypochlorite Solution Feed System	lb/day
Ozone Generation and Feed System	lb/day
Ozone Contact Chamber	gal
Chlorine Dioxide Generation and Feed System	lb/day
Ultraviolet Light Disinfection	gpm
Reverse Osmosis	gpd
Pressure Ion Exchange - Softening	gpd
Pressure Ion Exchange - Nitrate Removal	gpd
Activated Alumina - Fluoride Removal	gpd
Bone Char - Fluoride Removal	gpd
Package Raw Water Pumping	gpm
Package High Service Pumping	gpm
Steel Backwash/Clearwell Tanks	gal
Liquid Sludge Hauling	gpd
Dewatered Sludge Hauling	cu yd/yr
Sludge Disposal - Sanitary Sewer	gpd
Sludge Dewatering Lagoons	cu ft (capital) cu ft/yr (O&M)
Sand Drying Beds	sq ft

TABLE 2

CAPITAL COST EQUATIONS FOR SMALL SYSTEMS

$$CC = K_1 \ USRT^a \ CCI^b \ MI^c$$

Unit Process	USRT Range	K_1	a	b	c
Package Complete Treatment	4-1000 gpm	170.3	.3359	.9840	0.
	100-1400 gpm	17.59	.7798	1.005	0.
Package Gravity Filtration	80-300 gpm	148.7	.3747	1.001	0.
	300-1400 gpm	1.742	1.116	1.025	0.
Package Pressure Filtration	.7-10 gpm	108.8	.3045	.9801	0.
	10-350 gpm	73.39	.4922	.9844	0.
Filter Media-Rapid Sand	4-280 sq ft	.5529	.7617	.9895	0.
Filter Media-Dual Media	4-280 sq ft	.5584	.8463	.9768	0.
Filter Media-Mixed Media	4-280 sq ft	.7415	.8520	.9928	0.
Filter Media-Mixed Media/SI	4-280 sq ft	1.849	.6892	.9987	0.
Package Pressure Diatomite Filtration	28,000-100,000 gpd	68.39	.1208	1.000	0.
	100,000-1,000,000 gpd	.2668	.5824	1.001	0.
Package Vacuum Diatomite Filtration	30-100 gpm	112.8	.2505	1.001	0.
	100-720 gpm	38.48	.4674	1.002	0.

TABLE 2 (Cont'd)

Unit Process	USRT Range	K_1	a	b	c
Package Ultrafiltration Plants	2,500-10,000 gpd	3.693	.3487	.9988	0.
	10,000-1,000,000 gpd	.0634	.7763	1.001	0.
Package Granular Activated Carbon Columns	2,500-10,000 gpd	12.41	.1783	.9936	0.
	10,000-500,000 gpd	1.158	.4333	.9986	0.
Potassium Permanganate Feed System	.1-10 lb/day	37.50	0.	1.0	0.
Polymer Feed System	.1-10 lb/day	96.80	0.	1.0	0.
Powdered Activated Carbon Feed System	.1-10 lb/hr	18.70	.1639	.9842	0.
Direct Feed Gas Chlorination	.1-100 lb/day	22.00	0.	1.0	0.
Sodium Hypochlorite Solution Feed System	.1-100 lb/day	23.70	0.	1.0	0.
Ozone Generation and Feed System	.5-10 lb/day	113.1	.2684	1.004	0.
Ozone Contact Chamber	850-13,500 gal	.0035	1.047	.9845	0.
Chlorine-Dioxide Generation & Feed System	.1-50 lb/day	49.30	0.	1.0	0.
Ultraviolet Light Disinfection	10-100 gpm	9.685	.2786	.9889	0.
	100-780 gpm	.8958	.7728	.9982	0.
Reverse Osmosis	2,500-10,000 gpd	2.349	.4241	1.004	0.
	10,000-1,000,000 gpd	.1590	.7252	1.005	0.
Pressure Ion Exchange-Softening	70,000-860,000 gpd	7.471	.3247	1.012	0.

TABLE 2 (Cont'd)

Unit Process	USRT Range	K_1	a	b	c
Pressure Ion Exchange-Nitrate Removal	70,000-830,000 gpd	2.618	.4258	1.003	0.
Activated Alumina-Fluoride Removal	12,700-910,000 gpd	9.513	.3035	.9964	0.
Bone Char-Fluoride Removal	16,300-800,000 gpd	5.655	.3656	1.003	0.
Package Raw Water Pumping	20-700 gpm	25.24	.2536	.9996	0.
Package High Service Pumping	30-1,100 gpm	18.97	.2483	.9977	0.
Steel Backwash/Clearwell Tanks	50-30,000 gal	.0684	.7417	.9853	0.
Liquid Sludge Hauling	68-1,000 gpd	1405.	.0716	.9987	.0220
	1,000-41,000 gpd	5.109	.4107	1.050	.2221
Dewatered Sludge Hauling	100-1,000 cu yd/yr	.8196	.1598	.9743	1.257
	1,000-50,000 cu yd/yr	.1438	.4044	.9054	1.366
Sludge Disposal-Sanitary Sewer	50-25,000 gpd	-	-	-	-
Sludge Dewatering Lagoons	1,500-30,000 cu ft	.5418	.3735	1.010	0.
Sand Drying Beds	200-800 sq ft	.3406	.6729	.9772	0.

TABLE 3

OPERATION/MAINTENANCE COST FOR SMALL SYSTEMS

$$OM = K_2\ USRT^d\ PPI^e\ PR^f\ DHR^g\ NTG^h\ DSL^i\ MI^j$$

Unit Process	USRT Range	K_2	d	e	f	g	h	i	j
Package Complete Treatment	4-1,400 gpm	5660.	.3096	.0260	.4449	.4705	-.0972	.2468	0.
Package Gravity Filtration	80-300 gpm	11717.	.1947	-.0016	.3411	.5772	-.0030	-.0591	0.
	300-1,400 gpm	3234.	.5434	.0365	.4414	.4614	.0634	.1864	0.
Package Pressure Filtration	.7-10 gpm	3698.	.0806	-.0149	.3401	.6099	.0093	-.0454	0.
	10-350 gpm	8233.	.3253	.0206	.6273	.2942	.0255	-.1049	0.
Filter-Media-Rapid Sand	4-280 sq ft	-	-	-	-	-	-	-	0.
Filter Media-Dual Media	4-280 sq ft	-	-	-	-	-	-	-	0.
Filter Media-Mixed Media	4-280 sq ft	-	-	-	-	-	-	-	0.
Filter Media-Mixed Media/SI	4-280 sq ft	-	-	-	-	-	-	-	0.
Package Pressure Diatomite Filtration	28,000-100,000 gpd	351.9	.1925	.0237	.2290	.7025	-.0209	-.0049	0.
	100,000-1,000,000 gpd	2.414	.6067	.0050	.2319	.6845	-.0358	-.0987	0.
Package Vacuum Diatomite Filtration	30-100 gpm	2560.	.2180	.0230	.2649	.6593	.0527	-.0542	0.
	100-720 gpm	460.0	.5838	.0401	.2920	.6392	.0609	-.0408	0.
Package Ultrafiltration Plants	2,500-10,000 gpd	301.0	.1359	.1073	.2116	.6338	-.0347	.0369	0.
	10,000-1,000,000 gpd	.0719	.8225	.6008	.2122	.0619	-.0148	-.1143	0.
Package Granular Activated Carbon Columns	2,500-10,000 gpd	154.6	.1635	.1033	.3279	.5544	-.0077	.0224	0.
	10,000-500,000 gpd	2.972	.5594	.3284	.4050	.2581	.0357	-.0714	0.

TABLE 3 (Cont'd)

Unit Process	USRT Range	K_2	d	e	f	g	h	i	j
Potassium Permanganate Feed System	.1-10 lb/day	6.051	0.	1.0	0.	0.	0.	0.	0.
Polymer Feed System	.1-10 lb/day	15.33	0.	1.0	0.	0.	0.	0.	0.
Powered Activated Carbon Feed System	1-10 lb/hr	253.6	.4257	.0284	.0534	.9256	.0083	.0470	0.
Direct Feed Gas Chlorination	.1-100 lb/day	10.26	0.	1.0	0.	0.	0.	0.	0.
Sodium Hypochlorite Solution Feed System	.1-100 lb/day	19.28	0.	1.0	0.	0.	0.	0.	0.
Ozone Generation and Feed System	.5-10 lb/day	1191.	.2573	.0755	.2581	.6790	-.0289	-.0337	0.
Ozone Contact Chamber	850-13,500 gal	-	-	-	-	-	-	-	-
Chlorine Dioxide Generation and Feed System	1-50 lb/day	20.05	0.	1.0	0.	0.	0.	0.	0.
Ultraviolet Light Disinfection	10-100 gpm	741.19	.2324	.1779	.5826	.1744	.0059	.0078	0.
	100-780 gpm	25.17	.6923	.3824	.4520	.1010	.0111	.0134	0.
Reverse Osmosis	2,500-10,000 gpd	411.4	.1922	.0464	.1811	.7075	-.0333	.0299	0.
	10,000-1,000,000 gpd	6.967	.7860	.2231	.4943	.1207	.0693	-.1108	0.
Pressure Ion Exchange - Softening	70,000-860,000 gpd	36.84	.3401	.1284	.1120	.7234	.0272	-.0178	0.

TABLE 3 (Cont'd)

Unit Process	USRT Range	K_2	d	e	f	g	h	i	j
Pressure Ion Exchange - Nitrate Removal	70,000-830,000 gpd	3.546	.4729	.3423	.0933	.5179	-.0181	.0255	0.
Activated Alumina - Fluoride Removal	12,700-910,000 gpd	101.5	.2531	.0645	.0898	.7979	.0011	.0183	0.
Bone Char - Fluoride Removal	16,300-800,000 gpd	59.86	.3337	.1039	.1639	.6778	.0097	.0030	0.
Package Raw Water Pumping	20-700 gpm	246.2	.7528	.0075	.6896	.2227	.0670	.1975	0.
Package High Service Pumping	30-1,100 gpm	142.5	.8767	.0387	.7474	.1293	-.0341	-.0219	0.
Steel Backwash/Clearwell Tanks	500-30,000 gal	-	-	-	-	-	-	-	-
Liquid Sludge Hauling	68-1,000 gpd	2.552	.4336	.2285	.0265	.4922	.0661	.2232	.6813
	1,000-41,100 gpd	0.0204	1.059	.2693	.0145	.4170	-.0192	.1117	.7037
Dewatered Sludge Hauling	100-1,000 cu yd/yr	.4064	.4673	.4413	-.0269	.3224	-.0284	.1547	.7768
	1,000-50,000 cu yd/yr	.1087	.8225	.2748	-.0139	.4131	.0233	.3396	.7190
Sludge Disposal - Sanitary Sewer	50-25,000 gpd	.0002	1.0	1.0	0.	0.	0.	0.	0.
Sludge Dewatering Lagoons	1,500-30,000 cu ft	.1152	.7271	.1717	-.0063	.7617	.0537	.2184	0.
Sand Drying Beds	200-800 sq ft	3.148	.6676	.0338	-.0097	.9601	-.0410	-.0814	0.

TABLE 4

COST INFLUENCING PARAMETERS

Equation Input Variables

Engineering News Record Construction Cost Index	366.00	CCI
Producer Price Index	284.00	PPI
Electric Power Cost, $/kw-hr	.06	PR
Labor Wage Rate, $/hr	10.00	DHR
Cost of Natural Gas, $/std cu ft	.005	NTG
Cost of Diesel Fuel, $/gallon	1.25	DSL
Sludge Hauling Distance - One Way, miles	10.0	MI

Cost of Chemicals

Chlorine, $/ton	300.
Polymer, $/ton	4000.
Alum, $/ton	140.
Sodium Hydroxide, $/ton	200.

TABLE 5

PACKAGE COMPLETE TREATMENT PLANT (.1 MGD)

Cost Analysis
- 1983 Dollars -

Unit Process	Design Parameter	Capital Cost, $	Operating Parameter	Operating Cost, $/yr Excluding Chemicals	Chemical Costs, $/yr
Package Raw Water Pumping (Pumping Head = 50 ft)	105 gpm	30,000	50 gpm	859	0
Package Complete Treatment (2 gpm/sq ft)	70 gpm	236,333	50 gpm	32,891	
Alum - 2.2 tons/yr					308
Polymer - 55 lb/yr					110
Chlorine - .33 tons/yr					100
Steel Backwash/Clearwell Tank	15,000 gal	28,725	-	0.	0
Package High Service Pumping (Output Pressure = 70 psi)	105 gpm	21,753	50 gpm	1,073	0
Sand Drying Beds	500 ft^2	7,135	500 ft^2	2,762	0
TOTALS		323,946		37,585	518

Construction Cost, $ = 323,946/1.35 = 239,960
Amortization Factor (10%, 20 yrs) = .1175 (Equation 4)
Amortized Capital Cost, $/yr = 323,946 (.1175) = 38,063
Total Treatment Cost, $/yr = Amortized Capital Cost + Operating Cost + Chemical Costs
= 38,063 + 37,585 + 518 = 76,166
Total Unit Treatment Cost, $/1000 gal = 76,166/.072 mgd/3650/100 = 2.90 (Based on 50 gpm = .072 mgd)

TABLE 6

PACKAGE COMPLETE TREATMENT PLANT (.5 MGD)

Cost Analysis
- 1983 Dollars -

Unit Process	Design Parameter	Capital Cost, $	Operating Parameter	Operating Cost, $/yr Excluding Chemicals	Chemical Costs, $/yr
Package Raw Water Pumping (Pumping Head = 50 ft)	500 gpm	44,566	245 gpm	2,840	0
Package Complete Treatment (2 gpm/sq ft)	350 gpm	637,025	245 gpm	53,798	
Alum - 11 tons/yr					1,540
Polymer - 264 lb/yr					528
Chlorine - 1.6 tons/yr					480
Steel Backwash/Clearwell Tank (three 30,000 gal tanks)	90,000 gal	144,097	-	0.	0
Package High Service Pumping (Output Pressure = 70 psi)	500 gpm	32,048	245 gpm	4,323	0
Sludge Dewatering Lagoon	15,000 sq ft	7,634	12,000 sq ft	1,305	0
TOTALS		865,370		62,266	2,548

Construction Cost, $ = 865,370/1.35 = 641,015
Amortization Factor (10%, 20 yrs) = .1175 (Equation 4)
Amortized Capital Cost, $/yr = 865,370 (.1175) = 101,681
Total Treatment Cost, $/yr = Amortized Capital Cost + Operating Cost + Chemical Costs
= 101,681 + 62,266 + 2,548 = 166,495
Total Unit Treatment Cost, $/1000 gal = 166,495/.353 mgd/3650/100 = 1.29 (Based on 245 gpm = .353 mgd)

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2. Clark, R. M.; Dorsey, P.; "A Model of Costs for Treating Drinking Water", Management and Operations, Journal AWWA (December 1983), pp. 618-627.