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Microfiltration Cost Benchmarking for Large Facilities

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ABSTRACT

A number of models of the cost of microfiltration treatment exist, but these models generally do not address, or are not validated for, larger facilities (facilities with design flow of 5 mgd or greater). In the past, microfiltration was not cost-competitive for larger facilities, but it is now being adopted at plants with design flows as large as 20 mgd. Accordingly, there is a need to extend these cost models to include larger facilities. Data for the larger facilities is still somewhat sparse, as only a few have yet been constructed. Nevertheless, the information that is available on these facilities can provide a valuable guide as to the economies of scale that may be available to larger treatment plants. In this study a survey of costs at large microfiltration plants was conducted. Data was obtained for 10 facilities, including 3 facilities with design flows greater than 9 mgd. The results indicate that large systems can achieve economies of scale, despite the modular nature of most microfiltration units. The three largest facilities (design flows of 9 to 20 mgd) have costs of less than 50 cents/thousand gallons. The cost estimates for facilities with flows of less than 5 mgd closely match a previous survey of small microfiltration plants. In addition, this study provides a basis for extending the predictions of existing cost models up to design flows of 20 mgd. Results indicate that costs vary among systems of the same capacity with 95% of all systems being within roughly a factor of two of the mean cost.

Keywords: cost benchmarking, cost model, survey, economics

INTRODUCTION

Microfiltration is an effective means of complying with surface water treatment requirements and can be used in conjunction with coagulation to remove arsenic from drinking water. Information about microfiltration construction and operating costs is needed to make decisions about future investments in drinking water treatment infrastructure. A previous study was conducted by Adham et al. [1], but this previous study did not address costs for large facilities. In the past, microfiltration was not cost-competitive for larger facilities, but it is now being adopted at plants with design flows as large as 20 mgd.

An additional issue is that most cost estimates for drinking water treatment processes focus on the average cost of a facility of a given size. In reality the costs of drinking water vary greatly even among systems of the same size, although the extent of this variability has not been well characterized.

This paper describes a survey membrane filtration costs. This study is intended to 1) confirm and update the results of previous work [1], 2) extend the cost model to larger systems (>5 mgd) not considered previously [1], and 3) to assess the magnitude of variability in cost among treatment systems of the same size.

METHODS

Data were collected in late 2000 and early 2001 as part of an effort to develop a national drinking water regulatory compliance benefit-cost model [2]. Information was gathered by a review of the literature and through a small telephone survey. The telephone survey consisted of five recently (post-1994) constructed microfiltration plants, one recently completed ultrafiltration plant, and two microfiltration plants in the process of being constructed. The literature survey identified published cost information for two recently constructed microfiltration plants [3,4,5]. Capital costs were adjusted to 2000 dollars using the construction cost index [6] and operating costs were adjusted using the producer price index [7].

Data were compared with an earlier survey of membrane filtration costs [1]. The total unit cost curves from the previous study were not used as they were based on full capacity operation. Instead capital cost estimates based on design flow and operating costs based on average flow were summed to develop total treatment cost estimates. Design and average daily flow were related by:

$$\text{Log (Design Flow)} = 0.91 * \text{Log (Average Flow)} + 0.41 \qquad \text{(Eq. 1)}$$

where log is the base 10 logarithm, and both design flow and average flow are given in mgd. This equation was based on a log-log regression of standard combinations of average flow and design flow for the EPA’s 12 size categories [9]. A similar relationship can be derived by a regression of average and design flows using information from the Community Water Systems Survey [9].

RESULTS

Figure 1 shows the unit treatment costs for the ten plants as a function of average daily flow. The least squares regression of log cost on log average daily flow is plotted in black. This regression line is given by:

$$\text{Log (cost)} = 2.19 - 0.47 * \text{Log (average daily flow)}$$

where log is the base 10 logarithm, average daily flow has units of mgd, and cost has units of cents per thousand gallons. The r-squared value for this regression is 0.89, an indication of good fit between the data and the regression model. The estimate derived from the survey results of Adham et al. [1] is shown in gray in Figure 1. Agreement between the two studies is excellent. The Adham et al. study results are shown only for facilities of 5 mgd or smaller, since no larger facilities were included in that study.

This study shows decreasing units costs for larger facilities, indicating that economies of scale are achieved by larger facilities. A key question is whether such economies of scale continue to be present at the larger facilities. This study suggests that economies of scale continue to be present even for the largest facilities. The three largest facilities (design flows of 9 to 20 mgd) have costs of less than 50 cents/thousand gallons, which is substantially lower than the smaller facilities and matches well with the regression model predictions for large facilities.

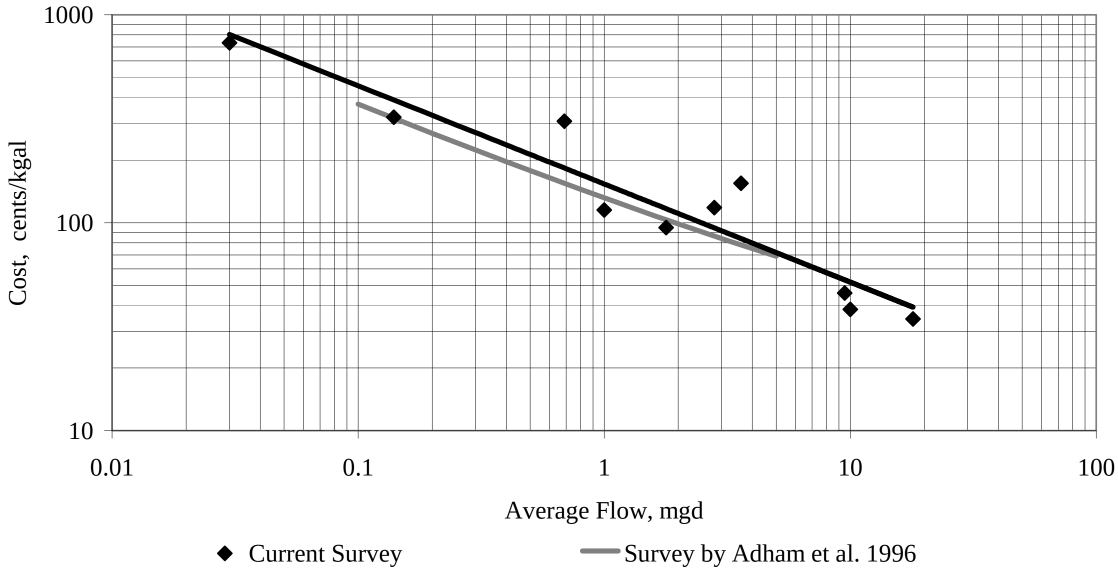

Figure 1. Log-log plot of unit cost and facility size

One quantity estimated by this study which is not usually reported for cost models is the extent of variability in costs among facilities of the same size. This is measured by the residual variance of the regression. In log space the variance of the residuals is 0.13. This value can be used in national compliance cost simulations, such as the work of Gurian et al. (2004) to describe variability in costs between different CWSs. Assuming known regression coefficients, 95% confidence of costs would fall within a factor of two of the nominal estimate.

DISCUSSION

Overall this study indicates that a number of large systems have been able to implement microfiltration in an economical fashion. Several large systems have been able to achieve economies of scale resulting in lower unit costs than smaller systems have achieved. Economies of scale may be limited for capital costs, since the modular nature of most microfiltration units means that large systems are simply purchasing more of a standard sized module. However, economies of scale may continue to be present on the operational side as advanced process control systems typically do not require more operators for larger systems. Operator time is a substantial fraction of overall treatment costs at smaller plants, and further reductions in costs for smaller systems may require greater process automation.

Membrane treatment costs have become much more economical over the past several decades. However, the excellent agreement of this study (conducted in late 2000 and early 2001) with previous work [1] suggests that significant cost reductions were not achieved for microfiltration during the late 1990s. It is possible that costs have reached a plateau as the technology becomes relatively mature. However, ongoing regulatory drivers, such as the Long Term 2 Enhanced Surface Water Treatment rule, may drive wider adoption of membrane treatment technologies and increased adoption has the potential to decrease production costs through both innovation and economies of scale.

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