New England Water Treatment Technology Assistance Center
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NE-WTTAC

PROJECT SUMMARY

Background

Common filtration methods applicable for small water systems to remove particulate matter, destabilize precursor material, and microbial contaminants from surface waters include the following options (Hansen 1987):

- package chemical clarification treatment plants,
- ultrafiltration (membrane or cartridge),
- diatomaceous earth (precoat) filtration, and
- slow sand filtration.

Package plants are defined as factory-assembled, skid-mounted units incorporating individual processes similar to conventional or direct clarification treatment plants (Hansen 1987). Their compact size, minimal installation requirements, and ability to operate with little supervision make them attractive to small communities. However, the necessity for controlling chemical coagulant dosage is an inherent disadvantage to small communities with limited resources for hiring and keeping skilled water treatment plant operators. Large chemical dosages can also increase the cost of providing drinking water because of increased chemical usage and sludge volumes requiring proper handling and disposal. Consequently, membrane, diatomaceous earth and slow sand filtration are receiving renewed interest as viable treatment options for many communities, primarily because of their lack of operational dependence on chemical coagulant reactions.

Raw Water Quality Limitations

Except for conventional treatment, a major limitation to any filtration option is the severe restrictions imposed upon filter run length should the turbidity or particulate content of the raw water exceed relatively low levels. It is believed that high turbidity in surface waters caused by suspended clay particles was the original reason that slow sand filtration had to be rejected in many parts of the United States and led to the development of rapid sand filtration (Ellis 1985; Montgomery 1985; Steel and McGhee 1979). Most design considerations limit the slow sand filtration process to low turbidity raw waters ranging from <5 ntu (Cleasby et al. 1984) to <50 ntu (Montgomery 1985) with <10 ntu (Hendricks et al. 1991) considered as a compromise. Diatomaceous earth and direct filtration have similar restrictions with raw water turbidities <5-10 ntu (AWWA 1995; Hansen 1987) and <10-15 ntu (Hansen 1987; Kawamura 1975; McCormick and King 1982), respectively, in order for these filtration systems to be cost effective. Cost effectiveness in this sense means that filter run lengths between filter clearings are long enough to offset the cost of filter downtimes and increasing filter backwash volumes.

However, raw water turbidity alone is not considered an adequate predictor of filter-run length. Quantification of raw water algal content to include enumeration of algae species is essential for judging the acceptability of the raw water (Cleasby et al. 1984). Algae blooms can result in early filter clogging and have been reported as reducing slow sand filter runs to as little as one-sixth of normal operation (Ellis 1985). *Standard Methods* (APHA, AWWA, and WPCF 1989) lists the following as filter-clogging algae: Dinobryon, Anacystis, Chlorella, Gymbella, Closterium, Synedra, Rivularia, Cyclotella, Navicula, Tabellaria, Asterionella, Palmella, Spirogyra, Oscillatoria, Trachelomonas, Fragilaria, and Anabaena. Other deleterious effects of algae include production of taste and odor in the water, development of anoxic conditions, increased concentration of soluble and biodegradable organics in the water, and increased difficulties associated with filter cleaning (Ellis 1985). Algae may also be a source of trihalomethanes (THMs) after chlorination (Hoehn et al. 1980). Consequently, considerable efforts are recommended to prevent algae blooms or to remove algae prior to the filtration processes. Raw water algae concentration (clump count) of less than 1,000 units/mL has been recommended as acceptable for treatment by direct filtration (McCormick and King 1982). Chlorophyll-a concentrations of <5 mg/m^3 are suggested as upper limits for slow sand filtration (Cleasby 1991). Upper raw water algal content for diatomaceous earth and membrane filters have not been reported in literature but are assumed to be similar to slow sand filters.

Another water quality parameter that may be a deciding factor in selecting a filtration option is the concentration and characteristics of natural organic matter in the raw water source. The concerns with disinfection by-products, e.g. trihalomethanes, have required treatment processes to remove significant fractions of organic precursor material. In many instances the coagulant dosage required for clarification is dictated by the organic carbon content of the raw water (Edzwald 1986). This is not surprising since many of the colloidal particles in natural waters may be coated with organic material (Lyklema and Fleer 1987; O'Melia 1991). Because of filter storage constraints, the direct filtration process is usually limited to raw water sources with color content <40 cu (Hansen 1987). Membrane processes may be readily plugged by excessive long chain organic molecules, e.g. humic substances, thus requiring pretreatment to reduce the dissolved organic carbon content to low levels. Conventional diatomaceous earth and slow sand filtration are relatively ineffective in removing dissolved organic carbon with average removals frequently below 10 percent (Spencer and Collins 1990) and 20 percent (Collins et al. 1989; Fox et al. 1984), respectively.

A summary of raw water constraints for economical operation of various filtration options is shown in Table 1. Although direct filtration package plants may be capable of handling significantly higher turbidity, algae, and color loadings, a skilled operator is required to maintain optimum treatment performance, especially if these loadings fluctuate. Membrane, diatomaceous earth, and slow sand filters are treatment options that rely on physical or biological removal mechanisms and generally do not require as highly skilled operators as direct filtration; however, they do require a higher raw water quality to be economically feasible. In general, some type of pretreatment process is required if the raw water exceeds 10 ntu, 5 mg/m^3 chlorophyll-a, and 5-10 Pt-Co units true color in order for these filtration systems to be viable treatment options for small communities.

Table 1. Recommended raw water quality constraints for various filtration systems (combined from several sources)

Treatment system	Turbidity ntu	Color units (Pt-Co Cu)	Algal content (as shown)
Direct filtration	<10-15	<7-14	<1000 counts/ml
Diatomaceous earth filtration	<10	<5	-
Slow sand filtration	<10	<5-10	<5 mg/m^3a

Pretreatment Techniques

A number of techniques can be employed for reducing high turbidities in the source water down to levels considered acceptable for diatomaceous earth and slow sand filtration. Some have been applied for centuries while others are quite new or even in a developmental stage (IRC 1989). These techniques can be listed as:

- Riverbank filtration
- River bed filtration
- Plain sedimentation
- Tilted plate settling
- Roughing filtration

A number of techniques can be employed to reduce natural organic precursor material in the source water prior to the primary filtration process. These pretreatment techniques include the following:

- Preozonation + biological filtration
- Activated Carbon (powdered or granular)
- Coagulant Addition (e.g. alum) + Contact Flocculation
- Riverbank filtration

The selection of any of these pretreatment options will be based on several factors including costs, operator skill level, ease of operation and maintenance, and reliability. One of the most important factors to consider in the selection process is the overall treatment objective, e,g, microorganism reductions, particulate removals, organic precursor removals, and/or minimization of exposures to source water shock loadings.

Project Objective

The principal goal of this proposed study is to investigate source water pretreatment needs for small water systems. Special emphasis will be given to those source water qualities that are considered to be the most problematic for selected filtration systems satisfying EPA drinking Water regulations (e.g. Enhanced Surface Water Treatment Rule (SWTR), Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and Disinfectants and Disinfection Byproducts Rule (D/DBP)).

Methodology

The basic approach in this study is to investigate as many states as possible to determine what violations, besides administrative or non-reporting violations, are most prevalent for their small surface water filtration systems. Assistance from regional EPA offices and waterworks associations will be utilized. State and Federal water system databases will be used where available. This information will then be used to survey individual treatment plants. Our goal is to receive responses back from 20-30 states.

The heart of this project will be a survey questionnaire available from the Water Treatment and Technology Assistance Center (WTTAC) website link shown below. The survey questionnaire will be geared toward collecting information regarding the overall physical characteristics of a targeted treatment facility including age, capacity, population served; the characteristics of quality of influent and effluent water; the basic design of the filtration system; the operating practices; the costs of treatment; and the treatment violations(s) or source water quality concerns most frequently noted for the facility.

The questionnaire will be organized simply and require only straightforward responses to ensure a reasonably high percentage of return. Follow-up phone call and/or site visits are planned. Lessons learned from previously successful small surveys will be utilized as much as possible (Slezak and Sims, 1984).

Enough completed questionnaires will be sought (30-60) to make the results statistically viable and defensible. The questionnaire may also be modified to reflect regional drinking water treatment concerns.

Deliverables

Many small surface water treatment systems do not operate as efficiently as desired primarily due to marginal quality source waters high in particles and organic precursor material. Pretreatment options including roughing filters, settling basins, and riverbank filtration have been used to improve the quality of the source water before the primary treatment system. The extent and effectiveness of these pretreatment options are unknown. The overall goal of this project is to ascertain source water pretreatment practices that have been used for marginal quality surface waters in order to enhance the performance of subsequent treatment processes. This resulting information will assist in the promotion of sustainable drinking water treatment infrastructure. This project is linked to EPA's Strategic Plan under Goal 2 Clean and Safe Water, Objective 2.1 Protecting Human Health, Sub-objective 2.1.1 Water Safe to Drink.

The results of this study will be made available on the WTTAC website, in at least one conference proceeding, and in a journal.

WTTAC website: http://www.unh.edu/erg/wttac/