

Precoat Filtration

MANUAL OF WATER SUPPLY PRACTICES

M30

Second Edition



**American Water Works
Association**

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MANUAL OF WATER SUPPLY PRACTICES — M30, Second Edition

Precoat Filtration

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Contents

Foreword, v

Chapter 1 Introduction 1

History, 1
Description, 1

Chapter 2 Applications and Economic Considerations 7

Source Water Quality Considerations, 7
Economic Considerations, 11

Chapter 3 Filter Design 15

Filter Vessel Design, 15
Filter Element Design, 19
Filter Septum Design, 20
Hydraulics, 22
Filtration Rate, 22
Design Capacity, 23

Chapter 4 Filter Media 25

Media Types and Grades, 25
Precoating, 26
Body-feed, 28
Filter Media Storage, 30

Chapter 5 Spent Cake Removal and Residuals Handling 31

Spent Cake Removal and Cleaning Methods, 31
Sludge and Waste Handling, 32

Chapter 6 Operation, Process Control, and Monitoring 35

Operating Adjustments, 35
Process Control, 36
Monitoring, 37
Emergency Controls, 38
Maintenance, 38
Record Keeping, 39

Chapter 7 Auxiliary Equipment and Safety 41

Auxiliary Equipment, 41
Safety, 42

Glossary, 45

Sources of Information, 47

Index, 49

Foreword

The first edition of AWWA Manual M30, *Precoat Filtration*, published in 1988, was prepared by the Precoat Filtration Subcommittee of the Coagulation & Filtration Committee, AWWA Water Quality Division. The subcommittee consisted of Ray W. McIndoe, Chair; Gary S. Logsdon; James L. Ris; and Alan Wirsig.

Regulations stemming from the 1986 amendments to the Safe Drinking Water Act, specifically the Surface Water Treatment Rule, sparked a renewed interest in filtration techniques, including precoat filtration. The Coagulation & Filtration Committee was asked to review and update M30 in light of both the new regulations and recent experience with this process. A new Precoat Filtration Subcommittee was formed to accomplish this task. This subcommittee consisted of

C. Michael Elliott, Chair, Stearns & Wheler, Cazenovia, N.Y.

Catherine M. Spencer, Wright-Pierce Engineers, Topsham, Maine

Ray W. McIndoe, Plymouth, Mass.

Stephen G. Vanderbrook, Larsen Engineers, Rochester, N.Y.

George Attenboro, Village of Newark, N.Y.

The first task of the subcommittee was to review M30 and solicit input from experts in the precoat filtration area. The subcommittee distributed more than 40 copies of M30 for comments to

- Coagulation & Filtration Committee members
- water suppliers
- engineering firms
- regulatory agencies
- equipment manufacturers
- media suppliers
- universities

Though the names are far too numerous to mention here, the subcommittee's thanks and appreciation go to each person who spent time and effort reviewing the manual and providing comments and suggestions. Based on review results, the subcommittee elected to maintain the established format of M30, revising where appropriate.

The consensus is that precoat filtration is a viable and appropriate filtration technique where source waters are low in turbidity and color. This is true for smaller systems because of the ease of operation and the reduced complexity of residual disposal. Precoat filtration has also been demonstrated appropriate for larger systems, especially where recycling precoat media is applicable.

Based on our review, further research is required for precoat filtration to continue to economically meet regulations. Areas requiring additional research include

- media reuse for small systems
- pretreatment with microscreens, coagulant, powdered activated carbon, or anionic resins
- particle characteristics versus process efficiency
- organics removal and disinfection by-product regulations

* * *

The second edition of *Precoat Filtration* was reviewed and approved by the Coagulation & Filtration Committee (808) of AWWA's Water Quality Division. Members of the committee at the time of approval were

R.W. Bailey, Chair, CH2M Hill, Orlando, Fla.
C.F. Anderson Jr., City of Arlington, Arlington, Texas
H.H. Bryant, Black & Veatch Engineers, Aurora, Colo.
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Chapter 1

Introduction

Precoat filtration is a US Environmental Protection Agency (USEPA) accepted filtration technique for potable water treatment. When the Surface Water Treatment Rule (SWTR) went into effect in 1989, it provoked a renewed interest in this filtration process as well as other accepted filtration methods. This manual provides general guidelines for the use of precoat filtration, commonly called diatomaceous earth (DE or diatomite) filtration, in potable water treatment. It includes an evaluation of appropriate applications for precoat filtration, discusses the design of economical filtration units, and presents an overview of operating practices.

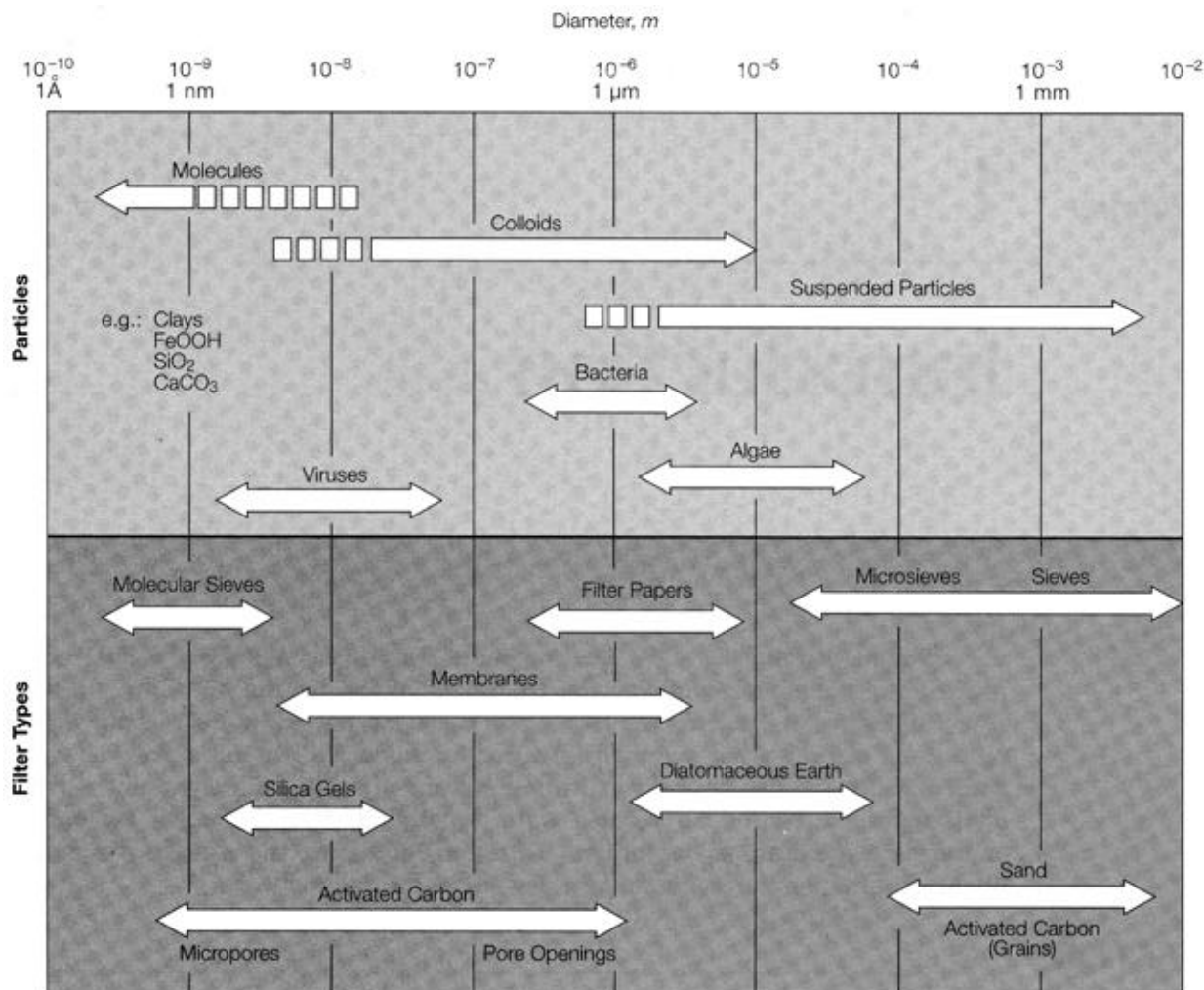
HISTORY

During World War II, the US Army needed a portable, efficient filter to remove *Entamoeba histolytica*, a protozoan parasite prevalent in the Pacific war zone, from drinking water. The army developed precoat filtration, which successfully removed the cysts. Since 1949, precoat filtration has been used in the filtration of sugar syrups, fruit juices, wine, beer, and water. More than 170 potable water treatment plants using precoat filtration have been constructed. New precoat filtration plants are anticipated as a result of the SWTR, including a 300-mgd plant for the treatment of New York City's Croton Reservoir supply.

DESCRIPTION

In precoat filtration, unclarified water containing foreign particles is forced, under pressure or by vacuum, through a uniform layer of filtering material (media) that has been deposited (precoated) on a septum. The septum is a permeable support for the media and is sustained by the rigid structure of the filter element. As the water passes through the filter media and septum, suspended particles about 2 μm and larger are captured and removed. Figure 1-1 presents a size spectrum of waterborne contaminants and various filter pores used in water treatment. The average pore sizes for DE are much smaller than the pore sizes of conventional filter media, such as sand.

2 PRECOAT FILTRATION



Source: Stumm, W. 1977. *Chemical Interaction in Particle Separation*. Environmental Science & Technology, 11:1066.

Figure 1-1 Size spectrum of waterborne particles and pore sizes of filter media

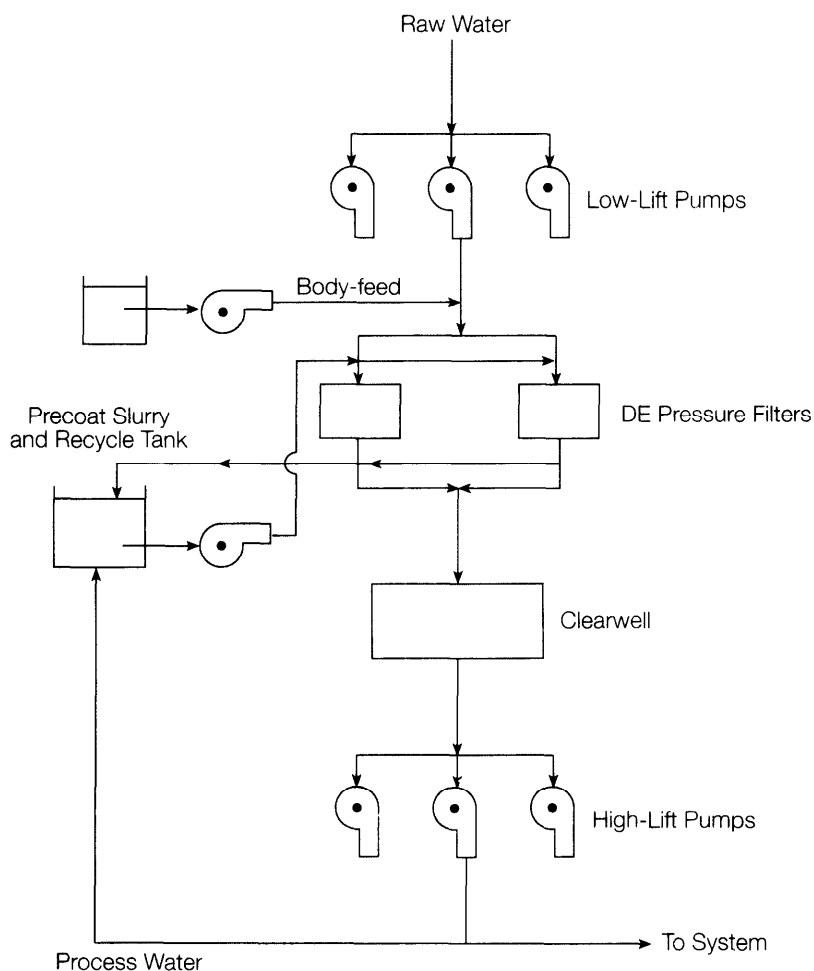
The basic function performed by all water filters is to remove particulate matter from the water. Precoat filters accomplish this by physically straining the solids out of the water. Normally, there is no chemical reaction unless a soluble contaminant must be precipitated prior to filtration. The thickness of the initial layer of precoat filter media is normally 1/8–1/4 in., and the water passageways through this layer are so small and numerous that even very fine particles are trapped.

The majority of particles removed by the filter are trapped at the surface of the filter media layer, although some are retained within the filter layer. As water continues flowing through the filter, additional filter media, called body-feed, is regularly added to the incoming water flow in proportion to the particles being removed. The suspended particles intermingle with the body-feed particles to maintain flow through the filter. This mixture allows water to continue to flow through the filter as the accumulation of particles gradually grows thicker. The

body-feed retards the head loss that might occur if foreign particles clogged the filter. Because the permeability of the filter cake (the mixture of precoat filter media, particles, and body-feed) is maintained, the length of the filter cycle is extended. However, as the filter grows thicker, a gradually increasing pressure drop through the filter system makes filtration impractical. When this stage is reached, the processes stopped, and the filter media and collected particulate are washed off the septum. A new precoat of filter media is then applied, and filtration resumes. A typical flow schematic for a pressure filter is shown in Figure 1-2, and Figure 1-3 shows a flow schematic for vacuum filters.

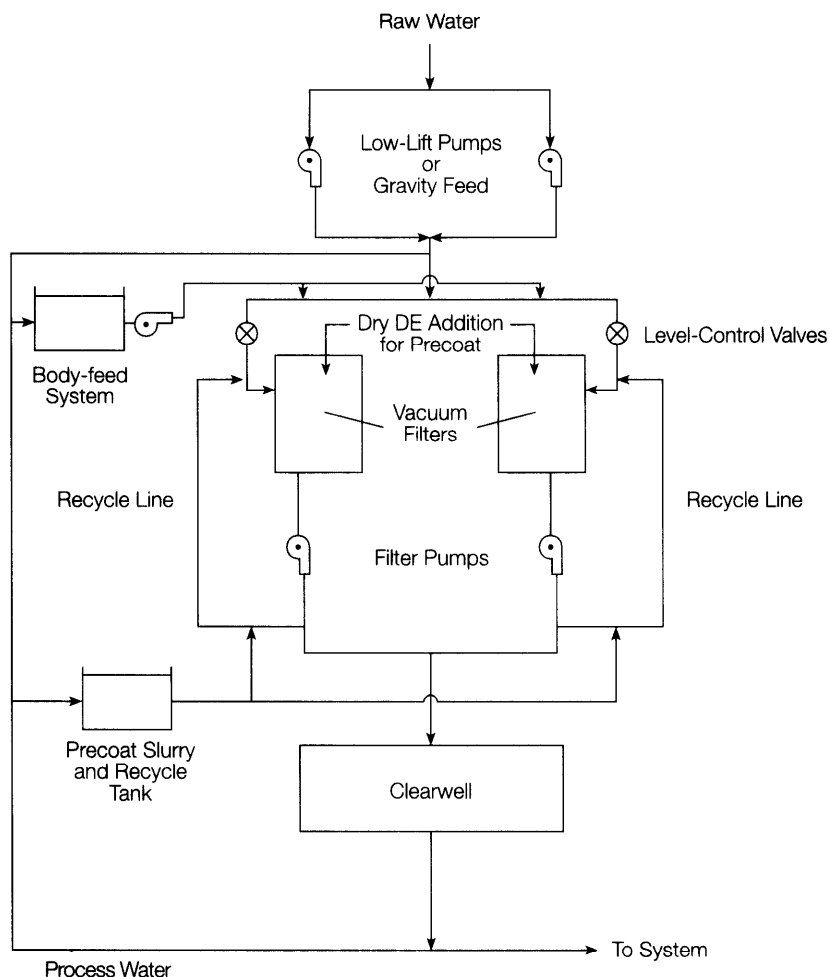
For small installations, the precoat tank functions for both slurry makeup and precoat recycle. Figure 1-2 illustrates the following procedure to precoat the septa:

1. Begin with a clean filter. Fill the associated piping between the precoat tank and the filter, as well as the precoat tank, with clean, filtered water.
2. Start the mixer on the precoat tank to create movement in the water. Add a batch of filter media that is sufficient to cover the septa in the filters, and mix to make the slurry.



Courtesy of Stearns & Wheeler.

Figure 1-2 Schematic of a precoat pressure filter system



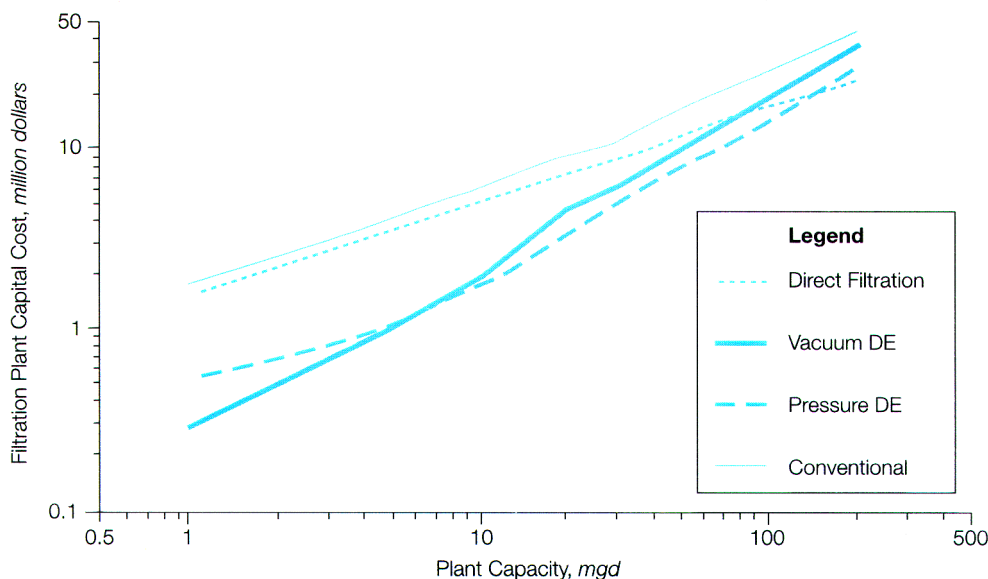
Courtesy of Ray W. McIndoe.

Figure 1-3 Schematic of a precoat vacuum filter system

3. Turn on the precoat pump to bring the slurry to the filter and to recycle the slurry and carrier water from the filter to the tank and back to the filter.
4. When all the filter media is on the filters, change the valving to bring raw water and body-feed to the filter. The filter septa have been covered with all the filter media when the turbidity of the carrier water is as low as the normal, clean filtered water. The filter is then ready for use.

There are five or six commonly used grades of filter media (sometimes called filter aid) available. Various grades of filter media perform differently in the way they remove particles and in flow characteristics. With an appropriate selection from among these grades, a large number of particles as small as 1 μm can be removed by the filter cake. This includes most surface water impurities. However, where small to mid-size particles (10^{-4} to 10^{-6} m) are present, filtration alone may not be adequate to reduce turbidity (particles suspended in the water) below the 1 ntu required by current regulations.

Generally speaking, precoat filtration is most effective when source water turbidity is moderate to low (10 ntu or less). However, higher turbidity levels may be



Courtesy of C.M. Spencer, Wright-Pierce Engineers.

Figure 1-4 Filtration capital costs versus plant capacity for various filtration systems

handled economically, depending on the concentration of the solids to be removed and on their physical characteristics.

Economic Benefits

Where the source water and other conditions are suitable, precoat filtration offers a number of economic benefits to the user, including the following:

- Capital cost savings may be possible because of smaller land and building requirements and lower installed costs (see Figure 1-4).
- Treatment costs may be slightly less than for conventional coagulation, sedimentation, and granular media filtration when filterable solids are low.
- The use of chemicals associated with granular media filtration, such as aluminum sulfate, iron salts, and polymers, is not necessary. The process is entirely physical and does not require operator expertise in water chemistry relating to coagulation.
- The volume of filtered water used for cleaning the filter is less than the volume used to clean granular media filters. Normally, less than 1 percent of the total filtered water is required.
- Diatomaceous earth filter residuals are easily dewatered, and in some cases, the media may be reclaimed for other uses, including soil conditioning and land reclamation. Research is under way to determine the feasibility of reusing filter media as body-feed.

Chapter 2

Applications and Economic Considerations

A number of factors must be considered when selecting effective, economical treatment and filtration processes. The most important factors are the quality of the source water coming into the filter and the desired quality of finished water. Source water quality can vary widely, depending on the source and type of water. Finished water quality may also vary, depending on its intended use and on local contaminants that must be removed.

Selecting a filtration process involves the following steps:

- Each proposed application should be examined to determine whether it produces a satisfactorily treated water, with or without other treatment steps.
- The process should then be compared with alternative types of treatments to see whether it is economically advantageous.

SOURCE WATER QUALITY CONSIDERATIONS

As a general rule, relatively clean source waters are good candidates for precoat filtration. Groundwaters and large impoundments of surface water from which only small amounts of suspended solids must be removed may be more economical to treat by precoat filtration than by conventional treatment. Designers should review historical water quality parameters before selecting or designing precoat filtration facilities. Some of the most important water quality parameters are discussed below.

Turbidity

Diatomaceous earth (DE or diatomite) filtration can be defined as a filtration technique for relatively low turbidity waters, generally below 10 turbidity units (ntu). A survey of direct filtration practice, including precoat filtration plants, indicated that 80 percent of the plants had an average source water turbidity of 5 ntu or less. The maximum turbidity at 80 percent of the plants was 40 ntu or less.

Table 2-1 Effect of pore size on flow rate and clarity

Precoat Media Grades	Average Particle Size,* µm	Median Pore Size,* µm	Flow Rate	Clarity
Fine	15	3.5	Lowest	Highest
↑	16	5.0	↑	↑
	22	7.0		
↓	24	10.0	↓	↓
	34	13.0		
Coarse	36	17.0	Highest	Lowest

Source: Stearns and Wheler and Ray W. McIndoe.

NOTE: Grades most commonly used for water filtration produce precoat cakes with pore sizes ranging from 5.0 to 17.0 µm.

*Typical sizes may vary slightly from one manufacturer to another.

Engineers should evaluate the efficiency and economics of pretreating source waters with turbidity levels higher than 10 ntu to obtain an influent with less than 10 ntu. Because turbidity is an indirect measure of the number and nature of the particulate in a source water, identification of the specific particulate present in a source water is recommended. Figure 1-1 portrays the size spectrum of waterborne particles of interest in contrast with the pore sizes of various filter media.

Both the number and physical nature of the solids present in source water affect the ability of a filter process to remove those solids. Some particulate, such as sand grains, some clays, and protozoan cysts, are nondeformable, discrete particles and do not pose problems. Deformable particles, however, tend to clog the media. In addition, some bacteria and viruses may pass through the filter. Turbidity readings, weight measurements of suspended solids, and particle counts and size distribution analyses are helpful techniques for determining precoat filtration's feasibility. However, those techniques alone may not be sufficient indicators of whether the process can be applied successfully and economically. Study of the types and number of algae present throughout the year and detection of the presence of organic colloids or fine clays in a water source proposed for precoat filtration are important in the evaluation process and in identifying the need for pretreatment.

Surface Water

Surface water sources must be evaluated on the basis of normal conditions that may prevail for most of the year. High-flow and runoff periods should also be examined for increased suspended material and its effect on the filtration process. Facilities for source water or finished water storage to provide adequate potable water supply during periods of adverse source water quality may be needed. Presetting of source water at the plant site may diminish some of the benefits of precoat filtration because of the increased capital and operating costs of the presetting facilities.

Many surface water supplies, such as lakes or ponds, may have algae, color, or taste and odor problems that require additional treatment in conjunction with precoat filtration. A microstrainer used before the precoat filter has been effective in removing microscopic material, including planktonic organisms and amorphous matter. This form of pretreatment has resulted in increased filtration run length.

Research has shown that precoat filtration with DE is capable of removing virtually all *Giardia* cysts normally encountered in low turbidity (<10 ntu) natural waters provided that the appropriate filter media is used and filters are properly

Table 2-2 Effect of DE particle and pore size on particle removal

Median Diatomite Size, μm	Median Diatomite Pore Size, μm	Particle Size, μm	Removal Rates, %
14	2.5	1	99.9
16.4	5	1	85
24	9	3	99.9
36	17	8	99.9

Source: C.M. Spencer, Wright-Pierce Engineers.

maintained and operated. To date, the removal efficiency of *Cryptosporidium* has not been well documented. However, recent experience with removal of particles and viruses from the New York City Croton Reservoir supply indicate the potential for good removal exists with this filtration technique. The following table indicates relative sizes of *Giardia*, *Cryptosporidium*, and coliform microorganisms.

Microorganism	Size, μm
<i>Giardia</i>	6–15
<i>Cryptosporidium</i>	3–6
Coliform	0.5–1

Although filtration generally is more effective with organisms larger than *Giardia*, the resistance of *Giardia* and *Cryptosporidium* to chlorine disinfection makes these organisms of particular concern. Table 2-2 indicates the relative removal rates of DE used in precoat filtration for particles in the size range 1–8 μm (Spencer 1991).

In a study by Schuler and Ghosh (1990), when filter influent between 0.1 and 1.0 ntu was spiked with 2,000 *Cryptosporidium* and *Giardia* organisms per litre at a DE precoat of 1 kg/m^2 , the removal of *Cryptosporidium* oocysts exceeded 99.9 percent, with the addition of alum further improving removal. Conditioning the DE with a coating of aluminum hydroxide, producing a filter media sometimes called coated DE, may also enhance removal of 1- μm particles. When *Giardia* cysts are to be removed by precoat filters, a precoat layer of at least 1/8-in. depth or 1 kg/m^2 plus body-feed is recommended (Logsdon et al. 1981). Media particle and pore sizes, feed and flow rates, depth of precoat layer, and influent turbidity are some of the factors influencing particle removal. See chapter 4 for more information on filter media.

Groundwater

Groundwater supplies may require filtration to remove suspended material. In some cases, mineral impurities, such as soluble iron or manganese, require pretreatment to precipitate them from the source water. The resulting precipitate can then be removed by the precoat filter. (See the section on supplementary treatment practices, page 10.)

Pilot Testing

Where there is no prior practical experience, pilot testing of the water to be filtered is recommended before making a final process selection. Pilot testing the precoat filtration process involves using small-scale equipment similar in function and operation to the proposed full-size units. Pilot filters and ancillary supporting equipment are usually available from equipment manufacturers and producers of

filter media. A pilot operation simulating the operating conditions required of a full-scale plant will help determine process applicability, design criteria, and operating economics. Pilot testing also familiarizes everyone involved with the workings of the filter system being studied. An involved and interested staff is critical to the success of a filtration plant.

Design engineers should check with state regulatory agencies having jurisdiction over public water supplies to identify operational and treatment efficiency parameters of concern for pilot test studies. States generally require a measure of the precoat filter's capability to remove *Giardia lamblia* cysts or particles in the size range of such cysts. The Surface Water Treatment Rule requires filtration processes to remove 99 percent (2 log) of *Giardia* cysts.

Supplementary Treatment

Additional treatment techniques can be used in conjunction with precoat filtration to ensure disinfection and to handle special problems, such as soluble iron and manganese, softening, color, taste, and odor.

Disinfection. Precoat filtration generally provides excellent clarification, and tests with the finest grades of filter media have shown good to excellent removal of turbidity and coliform bacteria. However, final disinfection with chlorine or other acceptable disinfectants must be provided, consistent with the multiple-barrier concept of public health protection.

Iron. Iron can be precipitated or separated from solution by mixing magnesite (MgO) with the source water, as well as with the body-feed, in a 10- to 15-min contact tank to provide sufficient reaction time. The resulting particulate matter is easily removed by the precoat filter. Also, iron could be separated by preaeration or other oxidation methods that make use of detention. Then the iron particles can be removed by the precoat filter. Tests have shown that solids remaining from the magnesite process are much easier to remove by precoat filtration than are the ferric oxide particles from the preaeration process. However, there may be cases in which a combination of aeration and the magnesite process may be more cost-effective.

Manganese. When manganese alone is the principal contaminant to be removed, potassium permanganate may be used to oxidize and separate the manganese. A detention time of up to 30 min at pH >7.5 may be required ahead of filtration, although there are plants that remove manganese by filtration after a 10-min detention period.

Iron and Manganese. Where iron and manganese are both present, there are several treatment options possible. Iron oxidizes more easily than manganese, so potassium permanganate will precipitate the iron first and then react with manganese. Stronger oxidants can be used.

Hardness. Where reduction of total hardness by lime and soda ash is required, residual calcium carbonate and magnesium hydroxide particles in the overflow effluent from the clarifiers have been removed with diatomite media.

Taste and Odor. Where taste and odor are problems, they may be handled by activated carbon in conjunction with precoat filtration. Preceding granular carbon columns with precoat filters will reduce the particulate load on the carbon beds, prevent the carbon media from clogging, and lengthen bed life. Also, the precoat filters may be evaluated to incorporate powdered activated carbon, along with the filter media, as precoat and body-feed, to achieve clarification and taste and odor removal within the filter.

ECONOMIC CONSIDERATIONS

After precoat filtration and appropriate supplementary processes have been shown to produce an acceptable finished water, several design factors must be considered in preparing design and specification documents. Because all these factors will influence the total capital and operating costs of the system, it is important to evaluate them individually and in relation to one another so that the final design will provide water most economically.

The following general economic considerations should be kept in mind when applying the more detailed design and operating guidelines that form the remainder of this manual.

Filtration Rate

The design filtration rate is expressed as gallons per minute per square foot (gpm/ft²) of septum area and is sometimes called the surface loading rate. The higher the design filtration rate allowed, the smaller the required filter surface area to produce the total volume of water needed to satisfy demand. Decreasing the filter area will lower the initial capital costs. With less filter area, less precoat material is required for each filter cycle. On the other hand, higher filtration rates generally result in more rapid filter pressure loss during a filter cycle. This will result in shorter cycles with more frequent precoating. Some states have guidelines for filtration rates and other operational factors that affect design. Demonstration of filtration effectiveness and economy outside of the recommended filtration rates is usually required before state regulatory agencies will approve the design. A minimum suggested filtration rate is 0.1 gpm/ft² to keep the precoat on the septum. Filtration rates of up to 4 gpm/ft² have proven acceptable for certain installations. Most DE filtration plants presently operate within the range of 1–3 gpm/ft². Demonstration of successful operation at flow rates greater than 1 gpm/ft² may justify the use of smaller filter vessels, which afford greater economic benefit to the utility. These higher flow rates may also extend the permissible operating range of an existing plant so that the need for future expansion is delayed.

Terminal Pressure Differential

The terminal pressure differential is the maximum difference in pressure between the inlet to the filter and the outlet of the filter. Higher terminal pressure differential extends both the length of the filter cycle and the useful life of the precoat media. In other words, the longer the filter cycle, the more finished water that is produced per pound of precoat material used. However, inlet feed pumps used to provide the additional pumping pressure needed for the higher terminal pressure differential will increase power costs.

If variable-speed drives are to be used, pumping costs will vary throughout the filter cycle. This variation could affect operating cost estimates. Early in the design phase, the potential use of variable-speed drives on inlet feed pumps should be evaluated with regard to the overall filter run length and terminal pressure differential.

Grade of Filter Media

A coarser grade of media can be used to obtain longer filter cycles, as long as the process still produces acceptable finished water quality. Using a coarser grade of media results in a greater volume of water produced per pound of filter media. This gain may be offset by the added cost (20–30 percent) of the coarser grades of media