

APPENDIX J



CHEMICAL PRETREATMENT

Chemical Pretreatment

This appendix provides a discussion of chemical pretreatment alternatives.

Chemical Dosage, Selection, and Mixing

Chemical pretreatment has a substantial effect on the quality of water produced by rapid rate filtration of water through a bed of granular filtering media. When chemical conditioning, mixing, and flocculation are not performed properly, quality of the filtered water will be impaired. Pretreatment is a performance-limiting factor in many filtration plants. Of ten commonly identified problems encountered in surface water plants, three were directly related to pretreatment. Successful pretreatment is necessary for optimized filter performance, and an investigation of pretreatment may be needed when filtered water quality problems are encountered. Pretreatment issues related to chemical dosage and mixing are discussed below.

1. Pre-oxidation

Pre-oxidation is carried out for a variety of purposes including control of tastes and odors, algae control within the treatment plant, oxidation of iron and manganese, and disinfection. For some source waters, use of pre-oxidation can substantially improve coagulation and filtration performance. For these waters, pre-oxidation becomes an important step in filter performance optimization. Disinfection is another important treatment process for which some of the pre-oxidant chemicals (chlorine, chlorine dioxide, and ozone) play a key role.

1.1 Potassium Permanganate

Potassium permanganate is an oxidant used for control of tastes and odors and oxidation of iron and manganese. Addition of potassium permanganate does not cause formation of trihalomethanes in drinking water. Potassium permanganate should be used with care, as an overdose can cause pink water if some of the permanganate ion does not react in the water and become reduced. Furthermore, water pretreated with permanganate must be filtered carefully so manganese does not pass through the filters and into the distribution system.

1.2 Chlorine Dioxide

Chlorine dioxide is an oxidant that must be produced on-site. If produced so no free chlorine is present in the oxidant solution, chlorinated disinfection by-products are not formed in drinking water. This oxidant is effective for control of tastes and odors, color, and oxidation of iron and manganese; and control of algae in water treatment plant basins. It is also a strong disinfectant.

1.3 Ozone

Ozone is the strongest oxidant in use by the water industry. Like chlorine dioxide, ozone must be produced on site. Ozone is a powerful disinfectant, capable of inactivating *Cryptosporidium parvum* oocysts and other, less resistant, microorganisms. Ozone is a very effective chemical for controlling taste and odor

in water. It readily oxidizes iron and manganese. Ozone is effective for oxidizing and breaking down natural organic matter, but as it breaks down large molecules of natural organic matter, it forms smaller organic molecules and molecular fragments that are readily used as a food source for bacteria. Ozone has been shown to improve coagulation and filtration in numerous source waters.

Ozone is expensive and its use is sometimes justified by having multiple purposes for ozonation, such as taste and odor control, iron or manganese oxidation, pesticide destruction, DBP reduction, reducing chlorine demand, and improving coagulation. Use of ozone for oxidation of iron and manganese can have drawbacks. Other less expensive oxidants are available for oxidation of iron. Also, if excess ozone is used to oxidize manganese, the manganese will be oxidized to permanganate, forming pink water.

When ozone is used to aid coagulation and filtration, it should be employed all of the time. Loss of ozone feed has disrupted filtered water quality at sites where preozonation was beneficial for coagulation and filtration. Frequently when ozone is used ahead of filtration, no other chemical disinfectant is used until after filtration. When chemical disinfectants other than ozone are applied after filtration but not before, water filters operate in a biological mode. To some extent, any filter that is operated without the presence of a disinfectant residual in the water being filtered is operating as a biological filter. Ozone accentuates or maximizes biological activity in the filter bed by breaking down complex organic molecules and forming organics that can be used as food by bacteria in the filter bed. Biological growth in filter beds is a concern for some treatment plant operators and regulatory officials. Biological filters may require a more careful backwashing procedure to avoid long-term problems such as development of mudballs. Growth of pathogenic bacteria in biological filters is highly unlikely, so shedding of bacteria from such filters is very unlikely to result in shedding of pathogens into treated water. Bacteria shed by biological filters should be controlled by post-filtration disinfection. This post-filtration disinfection may produce greater DBP concentrations due to the presence of smaller organic compounds produced during the breakdown of large organic molecules during ozonation.

Ozonation systems are complex, usually involving several pieces of equipment. If air is used for generation of ozone, air compressors, a refrigerant dryer or a desiccant dryer, and a moisture separator and air filter are among the equipment that will need maintenance. Liquid oxygen facilities will also require maintenance if liquid oxygen is used instead of air. The ozone generator, of course, will require periodic maintenance, as will the ozone destruct unit and the ozone contactor.

The surest way to find out if use of ozone as an oxidant is beneficial to filtration performance is to perform a pilot plant study on site. Use of ozone can have detrimental effects as well as benefits. When source water has bromide in

concentrations of about 0.1 mg/L or higher, ozonation can cause formation of bromate, a regulated contaminant. Depending on the level of bromide in the water, the bromate MCL (0.010 mg/L) may be exceeded.

1.4 Free Chlorine

Use of free chlorine to disinfect municipal water supplies began in the United States at Jersey City, NJ in 1908 and has spread across the country. In a survey carried out in 1989 and 1990 by an AWWA committee, about 72 percent of the 267 utilities that responded reported using free chlorine as a disinfectant. For several decades, free chlorine has been a very popular disinfectant. Free chlorine can oxidize iron so it can be subsequently removed by filtration, and its use can also promote removal of manganese. When free chlorine is used as a disinfectant, chlorine substitution reactions occur with natural organic matter, and DBPs are formed.

Pre-oxidation with free chlorine can improve the filterability of water and produce lower filtered water particle counts, as compared to water that has not been treated with a pre-oxidant. This benefit will probably be available, however, only to water utilities having source waters with very low concentrations of TOC, due to the formation of DBPs that occurs when natural organic matter in water is exposed to chlorine.

2 Coagulant Selection, Dosage Determination, and Evaluation of Coagulant Dosage Used

Selection of the right chemical coagulant and determination of the correct dosage are critical steps for optimizing the operation of granular media filters. Effective coagulation is essential. "Chemical pretreatment prior to filtration is more critical to success than the physical facilities at the plant," according to Cleasby et al (1992). "The operating staff must use a well-defined chemical control strategy that has been verified at that particular plant for the varying raw water qualities." What works well at one plant may not be appropriate at another plant that uses a different treatment approach for the same source water. Careful investigation of coagulation control techniques is advisable before large amounts of money are spent on sophisticated equipment for this purpose.

Symptoms of improper coagulation or out-of-control coagulation at a treatment plant may include one or more of the following:

- Hazy or cloudy water in settling basins or on top of filters
- Poor settling related to improper coagulation pH or insufficient coagulant dosage
- Excessively large floc in settling basins and carry over from sedimentation basins, perhaps caused by excessive coagulant dosage
- Weak floc and turbidity breakthrough at low head losses, related to improper coagulation pH or insufficient coagulant dosage

- High filtered turbidity throughout run, related to improper coagulation pH or insufficient coagulant dosage
- High initial turbidity at start of filter run and very long and slow decline of filtered turbidity after startup, possibly related to use of cationic polymer as the sole coagulant
- High rate of head loss increase and short filter runs caused by floc carryover from sedimentation, perhaps caused by excessive coagulant dosage
- Accumulation of mudballs in the filter, caused by excessive dosages of coagulant or polymer

When problems like those noted above are observed, one aspect of plant operations to check is whether the coagulation dosage and pH of coagulation are in the appropriate range for optimum treatment. Other causes for problems like those listed above may exist, but coagulation chemistry is a potential source of these difficulties, so it should not be overlooked.

2.1 Jar tests

Jar tests have been used for decades by water treatment plant operators who develop information on the chemical dosages that should be used to achieve effective coagulation and sedimentation. Many of the water utilities using jar tests have developed modifications or variations to adapt this procedure to the specific conditions encountered at their plants. This is appropriate, but certain common aspects of the jar test procedure should be considered and incorporated by most water utilities.

The jar test is intended to imitate, in a 2-liter jar, the processes of coagulation, flocculation, and sedimentation in a full-scale plant. Jar tests can closely mimic a full-scale plant with regard to order of addition of treatment chemicals to the water, but differences in residence times in pretreatment may be difficult to overcome.

The rapid mixing technique used in a jar test may differ considerably from the rapid mixing technique used in the plant. When in-line mixers or pumped jet mixers are used full-scale, the jar test may be able to approximate the Gt product (the mixing intensity, G per second, multiplied by the mixing time in seconds) although the exact nature of the mixing cannot be reproduced.

Various types of flocculators are used in treatment plants, and an approximation may be the limit of similarity that can be attained in the jar test. For plants using tapered flocculation with greater energy input during the first stage of flocculation and lower energy inputs in later stages, the flocculation process can be performed in stages in the jar test.

Sedimentation is often evaluated in jar tests by determining the overflow rate for the settling basin and evaluating sedimentation at that rate. When the rate of flow and the surface area are known for a settling basin, the overflow rate can be calculated by dividing the flow by the surface area. Typically this calculation will yield an overflow rate expressed in gpm/ft^2 . For jar test work, a 1 gpm/ft^2 overflow rate equals a settling velocity of 4 cm/min. When the overflow rate for a settling basin is known, that rate can be used to calculate the time interval for which settling should take place in the test jars before samples are withdrawn for turbidity measurement.

Jar test procedures may need to be adjusted to account for changes in plant flow. When a plant is operating at its rated capacity, detention times will be half as long as when the plant is operating at 50 percent of its capacity, if all process basins are in use. The jar test procedure adopted for a specific plant can be subject to change. If an extensive jar test program was carried out when the plant operated at half its capacity, later, when flows are close to design capacity, adjustments in detention times for rapid mixing and flocculation as well as adjustments in holding times before sampling in the sedimentation process would be appropriate.

2.2 *Bench-scale procedures for alternative clarification processes*

Bench-scale testing procedures can be used for alternative clarification processes, such as dissolved air flotation and ballasted flocculation. Some specialized equipment is required. Bench-scale testing procedures for dissolved air flotation were described by Plummer, Edzwald, and Kelley (1995) and specialized DAF jar test apparatus is available commercially in the UK. In DAF bench-scale tests, water is coagulated and flocculated, and then a measured amount of water containing supersaturated air is introduced near the bottom of the jar. Floc floats to the top. Typical coagulation variables such as coagulant dosage, coagulant chemical, and coagulation pH can be investigated. In addition, the DAF jar test apparatus can be used to evaluate the effect of air bubble volume on flotation by varying the air pressure used in the saturator and by varying the volume of saturated water added to the test jar. The latter simulates changing the percentage of recycle flow in a full-scale plant. Ballasted flocculation testing (Desjardins et al., 1999) is done by raising jar test jars so the bottom of each paddle is only 3 mm from the jar bottom. The stirrer has to be very close so the ballasted floc that contains sand will not settle to the bottom of the jar and remain there. At treatment plants where these processes are used, the above references can provide useful guidance.

2.3 *pH and alkalinity*

Control of coagulation by use of raw and coagulated water pH and alkalinity data can be very useful at some treatment plants. For example, at plants where pH is about 7 or lower in raw water and alkalinity is quite low, addition of alum or ferric salts lowers the pH and alkalinity and can change coagulation efficacy. It is advisable to track pH and alkalinity and feed chemicals to adjust pH and alkalinity for optimum coagulation. At plants where enhanced coagulation is

practiced, careful tracking of TOC, pH, and alkalinity should be standard practice. Required TOC reductions are related to alkalinity of source water, and pH and alkalinity may be severely depressed by higher dosages of inorganic coagulants needed for enhanced coagulation. Post-filtration adjustment of pH and alkalinity to enhance corrosion control and water quality stability in the distribution system may be needed at some plants practicing enhanced coagulation.