CHAPTER 4
WATER TREATMENT

4-1. General.

The basic requirement, criteria and procedures for water treatment systems for military facilities are covered in TM 5-813-1/AFM 88-10, Vol. 1. This chapter will discuss only those aspects unique to the Arctic and Subarctic. There are three major process concerns: the low temperature of the raw water, removal of glacial silt from surface sources and removal of dissolved minerals and organics from surface or groundwater sources.

4-2. Temperature effects.

The temperature of surface water sources during winter will be at or very near 32 degrees F, while ground-water sources in permafrost regions may be a few degrees warmer and maintain that level year-round. The water must be preheated to at least 40 to 50 degrees F or the unit processes must be designed for low temperature operation. The effect of low temperatures on equipment operations must also be evaluated during facility design.

a. *Preheating.* A number of methods have been successfuly used to heat water in arctic systems. Safeguards are necessary to avoid contamination (and cross connections) during the heating process and the corrosion induced if dissolved oxygen is released from solution. Very cold surface waters may be at or near saturation with respect to dissolved oxygen. Oxygen is then released as a gas as the water is warmed and can cause severe corrosion in iron and steel pipes, pumps, and tanks. Use of non-ferrous metals in the heating stage and controlling the release point for this oxygen will reduce corrosion problems.

(1) *Liquid-liquid heat exchangers.* Hot water is the preferred source of heat for these devices to eliminate problems from tube leakage and contamination. The source of hot water might be a central heating system or cooling water from an engine. Double wall, or double liquid to liquid exchangers are necessary to prevent any possibility of contamination of potable water.

(2) *Blending.* In some cases a source of clean hot water may be available and can be blended directly with the cold water to achieve the desired temperatures. Condenser water from a steam system was successfully used in this way in Fairbanks, Alaska.

(3) *Direct-fired boiler.* These systems use oil, gas or coal furnaces to maintain the contained water at just below boiling temperature. This is then blended with the cold water source or used in a heat exchanger.

4-3. Low temperature treatment.

Almost all of the physical, chemical, and biological processes used in water treatment are sensitive to temperature either through viscosity effects or as an influence on reaction rates. Figure 9-1 illustrates the influence of viscosity, and the multiplier shown must be used to adjust the design of a water treatment process component for temperature.

a. *Mixing.* Mixing is strongly dependent on temperature because of viscosity changes in the water. The power input for mechanical flocculation is directly dependent on fluid viscosity as defined by:

$$P = G^2 V \mu \qquad \text{(eq 4-1)}$$

where P = power input
G^2 = velocity gradient
V = tank volume
μ = absolute fluid viscosity.

To maintain the same velocity gradient in the tank as the liquid temperature decreases, it is necessary to adjust the 68 degree F power requirement by the multiplier from figure 9-1. This relationship will be valid for any kind of mechanical mixing. Detention time for mixing is determined separately. Detention times for flocculation range from 15 to 30 minutes and tend to be arbitrarily based on successful performance. The multiplier from figure 9-1 must be used for this adjustment. Multiple basins are recommended when surface water is the source and warmer temperatures are expected in the summer. In this way some of the units can be taken out of service when not needed.

b. *Sedimentation.* Settling of discrete particulate material is retarded by the increased viscosity in cold waters. As shown in figure 9-2 the effect of low temperature decreases as the solids concentration increases. Plain gravity sedimentation of individual particles would be subject to full viscosity effects and the detention time must be adjusted with the multipliers from figure 9-1.

Upflow and sludge blanket clarifiers are not as sensitive to viscosity effects and the multipliers from figure 9-2 will be used in these cases (solids concentrations >2000 mg/L). Another concern for any type of clarifier is the presence of density currents induced by strong temperature differences between the incoming fluid and the tank contents. These currents will disrupt the settling process and are particularly critical for upflow clarifiers. If possible these units will be maintained at nearly constant temperature and the incoming fluid adjusted to that same level.

c. Filtration. Filtration is influenced by low temperature since the head loss through the filter is proportional to viscosity. Mixed media filters will provide a more efficient use of space in cold regions facilities. The multiplier values from figure 9-1 will be used to adjust filtration efficiency. Backwashing of filters is also affected since power for pumping will vary with temperature, due to the increased water viscosity. The minimum upflow velocities will be reduced because of the increased fluid density at low temperature.

d. Disinfection. TM 5-813-3/AFM 88-10, Vol. 3, should be consulted for basic criteria on disinfection procedures, chlorine dosages and residuals. The solubility rate of chlorine decreases at very low water temperatures, but for practical purposes this will not occur at the dosage rates commonly used. The effectiveness of chlorination is hindered in cold water, and the exposure times must be increased in order to provide adequate disinfection. Contact time of about 1 hour is recommended for cold water below 40 degrees F.

e. Fluoridation. If fluoridation is practiced at remote cold regions facilities, the U.S. Public Health Service (USPHS) recommends that the dosage should be increased since the actual per capita consumption of drinking water tends to be somewhat less than in temperate locations. Fluoride concentrations of about 1.4 mg/L are recommended for the Arctic and Subarctic. Table 4-1 relates the USPHS recommended fluoride limits to the annual average air temperature at the design location. (See TM 5-813-3/AFM 88-10, Vol.3, for specific guidance at military installations.)

Annual Average (5 yr +) Maximum Air Temperature (°F)	Fluoride Limits (mg/L)		
	Lower	Optimum	Upper
54	0.9	1.4	2.4
54-58	0.8	1.1	2.2
58-63	0.8	1.0	2.0
63-70	0.7	0.9	1.8
70-80	0.7	0.8	1.6
80-90	0.6	0.7	1.4

4-4. Removal of minerals and organics.

Ion exchange water softening is commonly used at smaller installations with hard water. Lime-soda softening is frequently used when the water is both turbid and has a high hardness. Dissolved iron is common in cold regions ground waters and can foul zeolite and greensand ion exchange resins so that it must be removed prior to ion exchange processes. Aeration or chemical oxidation with chlorine have been successful for precipitation of elemental iron. However, iron/organic complexes are present in many cold regions groundwaters. Ozone has been shown to be effective in treating such waters. Ozone and carbon adsorption are very effective for color and organics removal.

4-5. Treatment of brackish and saline waters.

Distillation, reverse osmosis and freezing have all been used in the cold regions to reduce salt concentrations to potable levels.

a. Distillation. Distillation is expensive, requiring relatively high skill levels to accomplish, and will be considered only if other alternatives do not exist.

b. Reverse osmosis. Reverse osmosis (RO) is temperature sensitive, with best results obtained when water temperatures are in the range of 68 to 85 degrees F, and the cost is also high. Packaged reverse osmosis units are available from about 1000 to 1,000,000 gallon/day capacity (gpd). Power requirements are approximately one kilowatt-hour of power for each 100 gallons of potable water produced. These RO systems must be protected from freezing at all times, from the point of manufacture, during storage and during use.

c. Freezing. This process takes advantage of natural low temperatures to separate the saline brine from the ice which is then melted (naturally in the spring and summer) and used for water. Trenches have been filled with brackish water, allowed to freeze several feet deep, and then the remaining liquid under the ice pumped out. Spray freezing involves sprinkling brackish water through a nozzle to form a large cone of ice, with the brine draining away continuously during the winter. In a pilot-scale test in Saskatchewan, chloride content was reduced from 2000 mg/L to 500 mg/L in the melted ice. The recovered water represented about 75 percent of the volume sprayed.