Dutchess County Health Department

Water System Operator Certification - Grade C

Introduction

Registration and Opening remarks

- Handout Rural water supply, Part 5, Grade C manual.
- Passing grade is 70%. HW is 10%, quiz 10%, final 80%.

Water operator certification

- **Explanation of the Grade C category**
- **How to become certified; recertification**
- **Part 5-4 classification of Community water system operators.**

Safe Drinking Water Act (SDWA) / 10NYCRR5 (New York State Sanitary Code) (Part 5)

The SDWA was passed by the Senate in mid 1973, by the House on November 19, 1974 and signed into law on December 16, 1974 by President Ford.

Need for the regulations

The Congress had been debating national drinking water standards for several years. The need for national requirements became evident when it was foud that out of 446 water systems studied only 60 met existing federal standards for bacteria content and testing frequency. Moreover, the existing standards applied only to contaminants which could cause communicable diseases and not to chemical toxins. Concurrently, organic chemicals were discovered in New Orleans' drinking water. In 1975 a follow up study found organic contamination in 80 cities' water.

- **Water supplies not in compliance with standards**
- **Uneven supervision by states**

Goals of the regulations

The SDWA directed EPA to set up national primary drinking water regulations applicable to public water systems throught the country.

Safe water

The primary regulations concern matters directly affecting the health of the consumer.

Pleasing water

In addition, secondary regulations dealing with the aesthetic qualities of drinking water (color, taste, odor, etc.) were created as guidelines.

Scope of the regulations

SDWA (1974) and 1986 amendments

primary standards

safety

secondary standards

aesthetics

Part 5

Responsibilities of State

Part 5 of the New York State Sanitary Code was enacted by New York in order to provide a legal framework for the state to enforce the provisions of the SDWA. In some cases Part 5 is more stringent than the SDWA. As the SDWA, or the regulations promulgated under SDWA by the US EPA, is modified and expanded, Part 5 is updated by New York, so that the state may continue to comply with and enforce the provisions of the SDWA.

Responsibilities of operators

Overview

5-1 Public Water Supplies	5-4 Water Operators	5-1.1 Definitions
5-2 Wells	5-5 Special Improvement Districts	
5-3 repealed	5-6 Bottled Water	

Public Water Supply

Service Connection

Community PWS

Non Community PWS

Non Transient Non Community

5-1.22 Approvals

Professionally engineered

plans approved by state

Additional standards

Ten states

Rural Water Supply

5-1.52 tables 1-7 Maximum Contaminant Levels

Levels	Inorganics	Organics	UOCs	Radiological
Units	Nitrates	SOCs	Turbidity	
Violations	As N	POCs	Coliforms	

The state will test small systems

Mathematics for Water Supply Operators

A knowledge of addition, subtraction, multiplication, division, and basic algebra is necessary. The algebra consists of rearranging formulas or solving for unknowns.

Units

Describe what parameter the numerical value represents (lbs, feet, inches, etc.). Give dimensions to values.

Include units on all numerical values.

Include units in calculations and intermediate values. Units can be multiplied (ft x ft = sq. ft or ft2) and divided. Dividing a unit by itself yields 1 (the unit cancels itself - 4 sq. ft / 2 ft = 2 feet). Check units in answer to ensure that the calculation has been done properly.

Common

Metric/English

Metric units are often composed of a prefix which determines how many and a root which explains what is being measured.

Prefix	**abbreviation**	**meaning**	**Root**	**abbreviation**	**meaning**
Mega	M	million	gram	g	weight
Kilo	K	thousand	litre	L or l	volume
milli	m	1/1000	volt	V	electrical potential
micro	or u or mc	one millionth	meters	m	length

Dimensional analysis
Length, mass, time

Typical units used in water systems

Temperature

Scale Freezing Boiling Groundwater Surface water

Celsius 0 100 10 0-24

Fahrenheit 32 212 50 32-75

F=Cx1.8+32

C=(F-32)/1.8

Length

Linear distance; one dimension.

inches " 1" diameter pipe

feet ' 60' high tank

Area

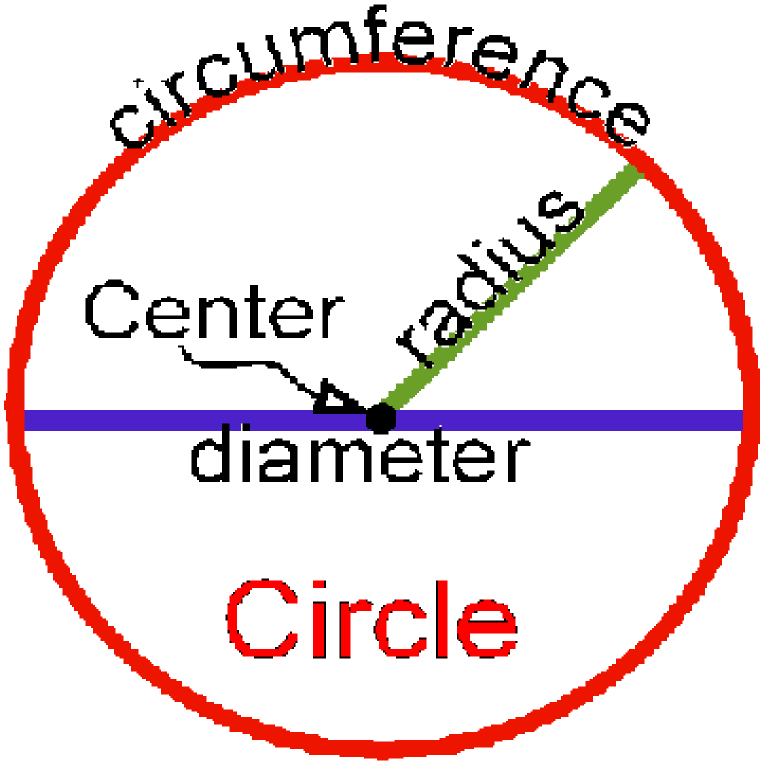
Two dimensions

"square" units square inches, sq. ft.

Rectangular area is calculated by multiplying the length by the width

Triangular area = 1/2 x base x height

Circles



The radius, r, is the length from the center of a circle to the edge of the circle. The diameter, d, is the length across the circle through the center. The diameter is thus twice the radius. The circumference is the length of the circle perimeter. The circumference is equal to d or 2r. (pi or) is a constant equal to about 3.14. Pi is often found in circle formulas.

The area of a circle is equal to r2. Substituting d/2 for r, A=d2/4. Substituting 3.14 for , A=0.785d2.

Volume

Volumes are measured in three dimensions of length. Often the units will be "cubic" such as cubic feet (ft3) or cubic inches (cu. in., in3). Other volume units just describe a certain space: gallons, liters.

Volume = length x width x height. Since Area = length x width, volumes can also be expressed as area x height. This is very useful for shapes that do not have a rectangular cross section, such as cylinders.

Volume shape names

Name	Shape	Example
cuboid, box	Box, cube	rectangular tanks, buildings
cylinder	circular cross section	pipe, can, bucket, tank, well
sphere	ball	some water towers

Flow

Flow is the measure of volume over time.

Examples are:

Gallons per minute	gpm
Gallons per day	GPD
cubic feet per second	cfs

Weight/Mass

Mass is a measure of how forces affect matter. Primarily, this means the force of gravity. When the gravity at the surface of the earth attracts a gallon of water, it pulls with 8.34 pounds.

Weight can be measured in pounds, ounces, grams, kilograms, tons, etc.

Concentration

The strength of a solution is often refereed to as its concentration. More concentrated solutions have more "stuff" dissolved in them. "Weaker" solutions have less "stuff" dissolved.

Concentration is normally expressed as the mass (or weight) of the dissolved substance divided by the volume of the total solution. For example, 3 milligrams per liter of chlorine (in water). Concentrations are also expressed as "per cents", meaning what per cent of the total solution is the dissolved "stuff". E.g. 5% chlorine (which is therefore 95 percent water). Percents are usually expressed as a weight to weight ratio rather than weight to volume, as in the first example.

Conversion

Similar units

Units which measure the same property can be readily converted from one to another. Inches and feet both measure distance. There are 12 inches in a foot. To obtain feet from inches, divide by 12.

A convenient way to remember whether to divide or multiply is to set up the conversion as a fraction with one unit on the top and an equal quantity on the bottom: 12 inches/foot. Because 12 inches = one foot, the fraction's value is one. You may then multiply this fraction by feet to obtain inches since any quantity multiplied by one will yield the same quantity: 3 feet x (12 inches/foot) = 36 inches.

It is also useful to remember which unit is bigger. Since feet are bigger (longer) than inches, you will always expect that a pipe will have more inches than feet. A 6 foot pipe is 72 inches. Knowing what answer to expect makes picking the right conversion factor easier.

Conversion factors:

12 inches = 1 foot

7.48 gallons = 1 cubic foot

1440 minutes = 1 day

1000000 gallons = 1 million gallons

Physical constants

Physical substances have many properties. Often there are constant relations between these properties. A given volume of water usually has a fixed weight. This constant (normally) relation allows us to express a quantity of water in weight or in volume and to convert from one method of expression to another.

Conversion factors

1 gallon of water = 8.34 pounds

1 vertical foot of water = .433 pounds/square inch

Significant figures

The result of a calculation can be no more precise than the least precise input. Round off answers as necessary.

6.2 feet x 5.1 feet = 31.62 ft2 which should be rounded to 32 ft2 since the lengths have only 2 significant figures.

11.078 5 significant figures

21,000 2 significant figures. The zeros just take up space.

0.00325 3 significant figures

87.62 4 significant figures.

Other

Algebra

Identities

X*1=X, X*0=0, X+0=X, X/X=1

Use the above identities to simplify equations.

Equations

You may multiply or divide both sides of an equation by the same non-zero value.

Know how to "solve for X" by rearranging equations.

Statistics

Averages

arithmetic mean

geometric mean

Rounding

Percentiles

Precision

Precision is the exactness of a number. Accuracy is the "rightness" of the answer. 49783 is more precise than 50000. 50000 is more accurate if the actual value is 51225. A quartz watch may be very precise in its display of the time, but is only as accurate as the time it was set with. Be careful calibrating instruments.

Calculators often are capable of displaying 8 digits. Calculated results may contain many digits, for example 12.56398 feet. Not all of the digits in an answer will be meaningful. 0.00098 feet is thinner than most hair. The result of a calculation can be no more accurate than the numbers originally entered in. Such numbers come from the real world; from pressure gauges, from tape measures, from scales. Just as you can not measure the width of a hair with a tape measure, any calculated result must match the precision of the device that generated the original numbers. See significant figures, above

Problem solving

Balance units

Make sure that the units on one side of an equation equal those on the other side. Know which units can be converted into which others. Look at the different units in the question and in the answer for clues as to how to proceed. For example if you are given gallons and minutes, and asked to figure out gallons per minute, you may want to be dividing the gallons by the minutes.

Operating on units

Only add like units. Never add two numbers with different units. Always convert one number to the units of the other.

When multiplying or dividing, always multiply or divide the units.

Look for ways to simplify the units. Cancel units which appear on both the top and bottom of a fraction.

Look for language clues

Many common verbs and prepositions correspond to mathematical operations. Also look at units to give clues as to types of information.

Multiply words: at, by. 12 apples AT $.35 each. 4 BY 4

Divide words: per, in, of. miles PER hour; 4 out OF 5 dentists

Add words: and, plus

Subtract words: difference, from, minus

Distance words: length, width, depth, height, far

Circumference words: girth, around

Area words: circular, round, square, rectangular, cross section

Volume words: tank, gallons

Time words: how long, duration, when

Mass/weight words: heavy, amount

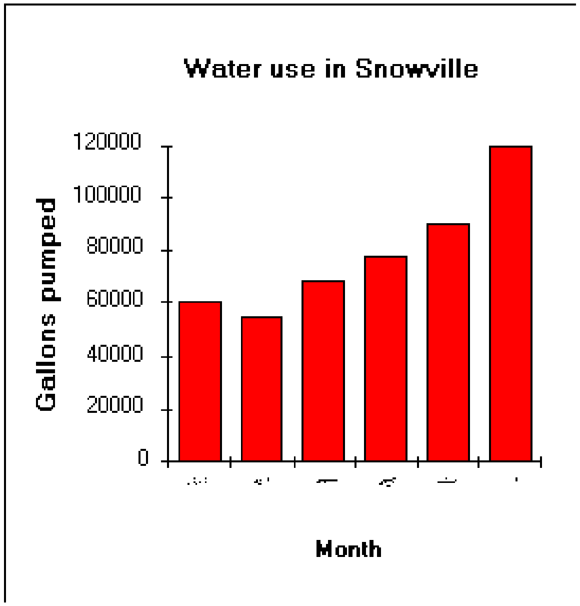
Concentration words: strength

Find a system you are comfortable with

There are always several ways to solve a problem. Notice the three equations for the area of a circle (above). Find a formula, or approach, that makes sense to you and don't worry about the others. Don't be upset if your system is different from mine or your neighbors.

Graphs

Graphs are useful for showing the relationships between parameters (variables, sets of numbers, things). Often a graph will convey information (trends, correspondences) that a list of numbers will not. Graphs can be very useful when explaning technical details to the public or to managment.



The axes of a graph represent the variable being shown. They should be labeled with descriptions and units. The vertical axis might show gallons pumped, the horizontal might show months:

Sources

Where is water

Oceans

97.2% of all water. Too salty for human consumption

Atmosphere

Expensive to extract.

Polar Ice caps

2.14%. Expensive to transport.

Lakes, Streams, Rivers

.009%. Easy to get (if you are close)

Underground

.61% Generally available.

Hydrologic Cycle

Describes how water moves from one place to another.

Evaporation	vaporization of water from the ocean, streams, lakes, ground. May include transpiration from plants. Liquid water becomes a gas (and enters the atmosphere)
Precipitation	Rain, snow. Atmospheric water becomes liquid or solid and hits the earth's surface
Runoff	Precipitation which flows along the surface rather than soaking in
Infiltration	Precipitation which seeps into the ground

Water is constantly moving from one of the above places to another. Among these movements are Rain, Evaporation, Transpiration, Runoff, Flow, etc.

Surface water

Types

Streams, lakes, swamps, rivers

Surface supplies are preferred for large users (cities) because of the large volume of available water and the ease of access to the water.

Reservoirs

Stratification due to temperature. Mixing (turnover).

Intakes

Structures

Intakes at various levels to allow use of top, middle, or lower layers of water.

Galleries

Dams

Quality and Contamination

Surface water quality is dependent upon the characteristics of the watershed which collects it. Surface water quality changes much more quickly and varies more widely than ground water. Surface water is prone to contamination from actions taken in the watershed and from accidents.

Ground water (Aquifers, Wells)

Definition

The water-saturated subsurface geologic formations which are now or may be developed to supply water in usable quantities to public or individual wells.

Any geologic formation containing water, especially one that supplies water for wells, springs, etc.

Structure of Aquifers

how water is stored

Gravel

Rock

Fractured

Solution channels

where the water enters an aquifer

recharge area

types of aquifers

confined

ground water which is overlain by impermeable deposits. Often, this water will be under pressure.

unconfined (water table)

ground water not confined. The upper surface of this type of aquifer is the water table.

Quality and Contamination

Because ground water travels for long periods of time through rock and soil, its quality varies little and slowly. Groundwater is usually well filtered but may be very hard because it has dissolved minerals from the rocks and soil. Ground water is also susceptible to contamination, however, the area of recharge is much harder to delineate.

Removal of water

Springs

Can be surface or ground water depending on development. Best to eliminate surface water with properly constructed enclosures.

Wells

AWWA specification A100-90

dug

Dug wells are shallow (20-30 feet) with little penetration of the water table. Their output is usually variable because of water table fluctuations. Water quality may also be variable. Contamination may be caused by surface water seepage. The well curbing should extend above the ground surface at least one foot. There should be a watertight cover, penetrated only by the water withdrawal pipe and or vent, to prevent contamination.

driven

drilled

hole

rotary

Rotary bit grinds rock. Water or air drilling fluid cools bit and carries spoil back to surface. The drilling fluid is often called 'mud'.

Most common well drilling method. Quick. Capable of great depths. Rotary bit tends to force rock dust into water seams.

percussion

Heavy bit is dropped onto rock. Bit is exchanged for bucket which draws up rock fragments.

Slow. Only capable of moderate depths (~200'). Tends to suck crushed rock out of seems.

casing

grout

Grout is used to fill the space between the casing and the drill hole. Grout prevents surface water from gaining access, prevents mixing of different aquifers along the outside of the casing. Grout also supports the casing.

Nonshrinkable

Bentonite clay

neat cement

concrete

Tremmied

Grout should be placed in one continuous operation.

screen

The screen prevents loose sandy deposits from collapsing into the bore hole. Screens can be made by winding steel or by cutting slots in casing.

The screen slots must be sized to allow enough water into the well without creating excessive water velocity at the slots. Changing the velocity changes the pressure in the water (see Bernoulli) altering the chemical balance and depositing minerals in the screen.

Screens may be cleaned chemically by use of acids (usually muriatic or acetic). Acetic is less likely to also dissolve the screen). Mechanical means such as water jets are also available.

cap

The cap should provide a sanitary seal to prevent any contaminants from entering the well.

pitless unit

pump

drop pipe

If the drop pipe supports a submersible pump, brackets called torque arrestors will often be installed along the drop pipe to transmit torque from the pump to the casing, rather than allowing the drop pipe to absorb the torque.

vent

Vents should be free from flooding. Generally a U tube with a screen is installed. The screen prevents insects or animals from getting into the well.

development

AWWA Specification A100-90

Washing

Disinfecting

Cone of depression

Zone of influence

yield testing

Sustained well yield

Step test

monitoring wells

testing considerations

test length

water disposal

Quality of water

natural

dissolved minerals

unnatural

spills, fills, discharges, non point pollution

DNAPLs, LNAPLs, mixers, soil adsorbers

POCs, SOCs, UOCs

microbiological

protozoa

bacteria

viruses

Protection

Well head

Fixed radius

Calculated radius

Groundwater flow modeled

Hydrologically tested

Water shed

prevention

Good housekeeping

Be careful using chemicals onsite.

ownership

easement

Rules and regulations

inspection

Approval requirements for sources

WSA from DEC

DCHD well permit

State approval of engineering 5-1.22

Previously covered in Part 5 intro. above

Part 5

Source protection 5-1.12

Biology

Common Waterborne Diseases

Vector	**Disease**

Bacteria

Vibrio cholera	Cholera
Shigella sonnei	Bacterial Dysentery
Salmonella typhi	Typhoid Fever
Salmonella paratyphi	Paratyphoid Fever
Salmonella enteritidis	Gastroenteritis
Legionella pneumophila	Legionnaire's disease
Yersinia enterocolitica	
Campylobacter jejuni	
Viruses	
	Infectious Hepatitis
	Myocarditis (heart disease)
Numerous forms isolated from human feces	Poliomyelitis (suspected)
	Viral Gastroenteritis
	Viral Diarrhea
Parasitic Protozoans	
Amoeba histolytica (Entamoeba)	Amoebic Dysentery
Giardia Lamblia	Giardiasis
Cryptosporidium Parvum	Cryptosporidiosis
Cyclospora Treat with Bactrim. Attacks small intestine. Disinfect water by boiling. First seen 1979. - from 1/3/95 NYT	

Importance of Water

Drinking

Washing

Cleaning

Diseases

Agents

Bacteria

Bacterial diseases were among the first to be discovered and, thus, the most is known about bacteria, including types, symptoms, treatments, and how they work. Bacteria are one celled "animals" which can live and reproduce, sometimes in humans. Some bacteria directly cause infection, others produce byproducts which are toxic.

Viruses

These are the smallest biological agents. They require a host organism in order to reproduce. They do not eat or move by themselves. For these reasons they are difficult to test for.

Protozoans

Protozoans are larger than bacteria. Some form a cyst (or oocyst) with a hard protective coat. Giardia cysts range from 6-10 micrometers. Cryptosporidium cysts are 2-6 micrometers. Cryptosporidium is present in roughly 75% of surface waters tested in the United States. Cyclospora is twice as big as cryptosporidium.

Cycle

Although there has been a sharp decline in the incidence of waterborne diseases in the United States in the last century, there has been a leveling off of the decrease and even an increase in outbreaks since the 1950's.

The major cause of outbreaks in public water supplies is through contamination of the distribution system, but contamination of the source or a breakdown in disinfection, though responsible for fewer outbreaks, results in a far greater number of illnesses.

Cycles are popular in nature. Just as water evaporates from the sea to the air, rains into the rivers, which flow back to the sea, so too do diseases cycle. A typical waterborne disease cycle may start with a contaminated drinking water source. Customers drink the water and become infected, their waste (feces) then recontaminate the well.

One goal of the water operator is to break this cycle. Every link in the cycle is an opportunity. Protecting the well and distribution system from sewage and other contaminants; disinfecting the water to eliminate pathogens, and preventing users from drinking contaminated water are possible strategies.

Transmission modes

The portal of entry is the route by which a pathogen obtains access to the body. The skin protects us from all manner of hazards, in addition to keeping our insides in. Some organisms attack the skin itself (worms, mosquito borne diseases), most exploit holes in the skin (the mouth, ears, nose, eyes, or wounds).

Airborne

Legionnaire's disease spends part of its life cycle in water, such as in air conditioner cooling towers. The disease is spread when mists of the water are inhaled.

Contact

Waterborne

Ingestion

Water operators are primarily interested in this pathway. The stomach and intestines are the usual targets.

Contact

Schistosomiasis

Symptoms

Microbiological

Diarrhea

Fever

Anorexia

Aches and Pains

Nausea

Cramps

Vomiting

Death

Non water bourne

Symptom	**Cold**	**Flu**
Fever	None or low grade	Often high
Chills	Rare	Common
Headache	Rare	Common
Body aches	None or slight	Often severe
Fatigue	Mild	Can be extreme
Cough	Mild/moderate	Dry, hacking
Runny/stuffy nose	Common	Sometimes
Sore throat	Common	Sometimes
Sneezing	Common	Rare

Indicators

Epidemiological

Your customers becoming sick may be an indicator of a problem with the water supply. This is a poor indicator, since major damage will have been done before you receive notification.

Doctors are required to report to the Health Department a wide range of communicable diseases, including giardiasis. The health department will attempt to isolate a common cause (perhaps a food, restaurant, pool, or the water) so that the problem can be addressed.

Direct

Difficult

Expensive

Indirect

Good indicator attributes

Are present when contaminant is

Easy to test for

Plentiful

Behave similarly to actual contaminant

Microbiological Testing

Standard Plate Counts

Coliform Testing

Three different tests are available for coliform bacteria. All of them grow the bacteria on special media (nutrients).

Most Probable Number

The Most Probable Number test (MPN) uses several test tubes with differing dilutions of sample water. It yields an estimate of the number of bacteria in the sample (the most probable number of bacteria). MPN is more difficult for laboratories to perform, but is less susceptible to interference from turbidity.

Membrane Filter Test

The Membrane Filter Test (MFT) catches the bacteria in the sample on a filter (the pores of which are smaller than a bacterium but larger than water). The bacteria are then counted. Naturally, turbid water will clog the filter, making the test unuseable.

Presence/Absence

The Presence/Absence test (P/A) uses one tube and just tells if coliform bacteria are present. It does not tell how many were found. This is the easiest test.

E. Coli

In most cases, your lab should automatically check for E. coli if any coliform is found.

Chemical diseases

Symptoms

Cancer

Death

Brain Damage

Agents

Trihalomethanes

Lead

Lead is the worst of many metals which cause health problems. Mercury, cadmium, and arsenic also have long histories as poisons. Cyanide will be regulated soon.

Nitrate

From septic systems (the breakdown of ammonia in sewage) or fertilizers.

Mercury

Organics

Sodium

Testing

When the contaminant is known, direct testing is available and practical. Because there is a limited number of metals direct testing can be practical. Like the biological agents, organic chemicals are inumerable. Certain classes can be tested for, but indirect or indicator type tests may be necessary.

Total Dissolved Solids

Total Organic Carbon

Total Organic Halides

Total Trihalomethane Potential

Taste and Odor

The human body has very sensitive chemical analysers (the nose and mouth). Humans are better at detecting types of molecules rather than identifying specific ones. Human sensitivity varies from person to person and from hour to hour.

Disinfection

Disinfection is the process by which water and water systems are made free from pathogens

Sterilization is the destruction of all bacteria, virus, etc.

Code requirements 5-1.30

Chlorine

Safety

Elemental

Gas

heavier than air

forms acids upon contact with moisture

Oxidizer

Chlorine can act as an oxidizer, one of the three necessary components for fire. If fuel and spark are also present with chlorine, fire will result, even without oxygen. Starving such a fire of oxygen will not help.

Respirators

Monitors

Liquid

Cold or compressed

Tank repair kits

Standard kits are available for common problems with standard size tanks. Always be familiar with use of safety equipment prior to needing it. You will not have time to read the directions while your tank is leaking.

Separate room

Ventilated

Designed to Standards

Special entry procedures

Aqueous

Sodium Hypochlorite

Bleach

Gloves, boots, aprons, goggles, respirators

Solid

Calcium Hypochlorite

70% available chlorine

Powder

Tablets

Keep dry

Keep from oils/organics

Chemistry

Formula

Chemical Symbols

Water H2O

Hydrogen ion (or proton) H+

Hydroxyl ion OH-

Chlorine Cl2

Sodium Hypochlorite NaOCl

Calcium Hypochlorite Ca(OCl)2

Hypochlorous Acid HOCl

Hydrochloric Acid HCl

Chloride ion Cl-

Decomposition

Hypochlorites are unstable and decay.

Make sure solutions are fresh

Test older solutions. Half life may be as short as 60 days.

Avoid heat and sun.

Reaction Mechanics Review

Equilibrium

Reactions favor some distribution of chemicals. Some reactions favor one side strongly, others are more even.

Le Châtelier's Principle

If some stress is brought to bear on a system in equilibrium, a change occurs, such that the equilibrium is displaced in a direction which tends to undo the effect of the stress. In other words, a reaction will compensate increases in concentration of constituents on one side of the equation by forming more of the constituents on the other side.

Kinetics (rates)

The speed at which a reaction proceeds. This is independent on the equilibrium point (or constant) of the equation. A reaction which is very favorable may or may not proceed quickly. The speed of reactions is important in designing treatment processes. The reaction of chlorine and hydrogen sulfide is quick, so a detention tank may not be necessary. The reaction of chlorine and bacteria is slower (and dependent on temperature, pH, and the type of bacteria) so a detention tank is necessary to provide time for the bacteria to be killed prior to entering the distribution system.

pH and water

Water is composed of two hydrogen atoms bonded to one oxygen atom. When water splits up (dissociates) two ions are produced, the positively charge hydrogen ion and the negatively charged hydroxyl ion. The hydrogen ion is what pH measures. In pure water enough of the water dissociates to produce hydrogen ions in an amount which measures 7 on the pH scale.

Although pH is a measure of the concentration of hydrogen ions, its units are not typical concentration units, like mg/l. A mathematical formula is applied to the concentration to yield a scale which ranges from 0 to 14. On this scale 7 is neutral; lower numbers represent acids; higher numbers represent bases.

Bases are also called alkalis or caustics.

Acids are chemicals which produce hydrogen ions (H^+). A solution which is acid has more hydrogen ions than a basic solution. Remember that the pH will be lower.

Aqueous Reactions

Dissociation

H2O «H^++OH-

Water dissociates to the hydrogen ion and the hydroxyl ion. The equilibrium point of this reaction is to have 10 quadrillion times more water than ions. Notice that equal numbers of H^+ and OH- ions are produced in this reaction.

The H^+ ion, or hydrogen ion (also called a proton) is the chemical measured by pH.

HCl « H^++Cl-

Hydrochloric acid dissociates into the hydrogen ion and a chloride ion. This reaction strongly favors the right side. This is why hydrochloric acid is a **strong** acid.

HOCl « H^++OCl-

Hypochlorous acid dissociates into a hydrogen ion and hypochlorite ion. The balance point of this equation is determined by the pH (the concentration of hydrogen ions.)

Acid Formation

Cl2 +H2O « HCl+HOCl

Chlorine gas mixed with water forms hydrochloric acid and hypochlorous acid. The hydrochloric then dissociates (see above) **lowering** the pH. Hypochlorous acid (and the hypochlorite ion) are known as free chlorine, free residual or **free chlorine residual**.

NaOCl « Na^++OCl-

Sodium hypochlorite added to water forms the sodium ion and the hypochlorite ion.

OCl-+H2O « HOCl+OH-

The hypochlorite ion from the previous equation can take a proton (hydrogen ion) from water to form hypochlorous acid and the hydroxyl ion. In an acid environment the hypochlorite ion consumes a free hydrogen ion. This raises pH since hydroxyls are created or hydrogen ions are used up.

Ca(OCl)2 + 2H2O « Ca(OH)2+2HOCl

Calcium scale CaCO3

Premix and decant Calcium Hypochlorite

pH dependence

HOCl is a much better disinfectant than OCl-

Chlorine works much better at low pHs.

temperature dependence

Chlorine is more effective at higher (warmer) temperatures, however, it also breaks down faster so should be stored at low temperatures. Light also hastens the destruction of chlorine.

Chloramines

Chlorine can combine with ammonia or organic nitrogen to form chloramines. This is known as combined chlorine or combined residual. Combined chlorine retains some disinfection potential but is not as effective as hypochlorous acid.

Monochloramine NH_2Cl

Dichloramine $NHCl_2$

Trichloramine NCl_3

$HOCl + NH_3$ « $NH_2Cl + H_2O$

Don't produce THMs

Cause Taste and Odor problems

Demand

Chlorine added - Chlorine remaining

Chlorine reacts with bacteria (to kill them) and with many other chemicals or contaminants in the water. You must use enough chlorine so that some is left over (the residual) even after the chlorine has reacted with impurities. Because chloramines are less effective disinfection agents always measure free chlorine residual.

Chlorine also breaks down of its own accord (see temperature dependence, above). The time that the water takes to reach the end of the distribution system will thus exert a sort of chlorine demand. Long distribution systems or poor quality water may require intermediate chlorinators to be installed in the distribution system

Ammonia: 5.91

Iron: .63

Manganese: 1.29

Hydrogen Sulfide: 8.34

Total Organic Carbon: 1

Nitrite: ?

Breakpoint

Residual vs. applied Chlorine

Demand vs. applied Chlorine

Stoichiometry

Dilution

CV=CV

If you dilute a volume of solution, the product of the concentration and volume of the undiluted solution will equal the product of the concentration and volume of the diluted solution.

Be sure to clearly designate the two solutions you are equating. One might be in the crock, the other in the commercial strength bottle. One might be in a tank. One might be in a pipe. Use subscripts to help you: $C_{bottle}V_{bottle} = C_{tank}V_{tank}$.

One way to look at dilution is to think separately about the chlorine and the water. A volume of liquid with a concentration of chlorine has a fixed amount of chlorine equal to the volume times the concentration: CV=mass. Adding more water will not change the mass of chlorine. Thus we can use the known mass and the new volume to figure out the new concentration: mass / $V_{new} = C_{new}$.

Rearranging C1V1=C2V2 to V2/V1=C1/C2 reveals the dilution factor (C1/C2). To obtain a solution one tenth the strength of the original solution you would dilute by a factor of ten. For example, to obtain 1% solution from 15% solution you would dilute by a factor of 15 or one gallon of 15% in each 15 gallons of total solution (to fill a 50 gallon crock you would use 3 gallons of 15% solution and 42 gallons of pure water.)

Feed rate calculation

The feed rate calculation is just a dilution equation with time factored in. Therefore, instead of volume, we use flow (which is volume/time).

Again, keep track of each side of the equation. Instead of using the subscripts $_1$ and $_2$, use letters or words to describe each place. E.g. $C_{crock}V_{crock} = C_{pipe}V_{pipe}$.

R=(D/C)*Q

Units: be careful to match these up.

Non Aqueous forms of chlorine

Use the CV=mass form of the dilution equation for solid (calcium hypochlorites) or pure chlorine (either gas or liquid). Use CV=CV when the chlorine is already dissolved in water (bleach, aqueous hypochlorite solutions).

Example: To chlorinate a 20,000 gallon tank to 50 ppm requires

(0.02 million gal x 50 ppm x 8.34 lbs/gal) = 8.34 lbs of chlorine.

Notice that the conversion factor 8.34 lbs per gallon is used to convert from volume to weight. Notice that the parts per milllion cancels with the million in the million gallons. Remember that ppm and mg/l are equal (for dilute solutions).

Same problem, conversion factors split up:

20,000 gal x 50 mg/l x g/1000mg x kg/1000g x 2.2kg/lbs x 3.78 litres/gal = 8.34 lbs of chlorine.

lbs=mg/l*8.34*MGD

For calcium hypochlorite remember that only 70% of the weight is from chlorine, the other 30% is calcium. In the above example 1.42 lbs of calcium hypochlorite would be necessary (since 70% of 1.42 lbs is 1 pound.)

Disinfection review

Concentration and Contact Time

Part 5-1.52 table 14

Mixing

Feed to Center of pipe

Several pipe diameters for turbulent mixing

Inline mixers

Contact tanks

Volume/Flow=Time

Plug flow

Baffled

Hydropneumatic

Chlorinators

Gas

Liquid

Parts and Setup

Covered crock

Dilution equation

CV=CV

chemical mixing

estimating service time

T = V/Q

Weighted intake

Positive displacement pump

Antisiphon valve

Adjustments

stroke

frequency

Maintenance

Always make sure that the chlorinator is actually primed and is pumping chlorine solution.

Always have spare parts or a spare chlorinator available.

Cleaning

Acid wash

Some have found acetic acid (vinegar) effective. Hydrochloric acid (muriatic) is stronger and more dangerous to use.

Lubrication

Be sure to use only food grade oils where there is the possibility that oil will enter the water system.

Spare parts

Control

linked to pump circuit

linked to flow sensor

Disinfection of Plumbing

AWWA Standard

Pipes (C651)

Tablet method not acceptable in New York

Continuous

Feed 25 mg/l solution

Must maintain 10 mg/l residual after 24 hours

Operate all valves

Use pressure rated feed equipment

Slug

100 mg/l for 3 hours

Test for bacteria

Estimating flow for chlorine dose setting

Tanks (C652)

Water Plants (C653)

Recalcitrant Slime

boost chlorine

shock, possibly several times

Warn customers before using large doses

flush

Wells (C654) also See Rural Water Supply

Ultraviolet (UV)

Theory

Mutations in DNA

Configuration

Quartz tubes

Water jacket

Sensors

Power supply

Arrangement

Series

Parallel

Maintenance

Ozone

Ozone or $O_3$is a colorless gas formed from three oxygen atoms. The molecule is unstable and a powerful oxidizer.

Safety

The same characteristics that make ozone (and all disinfectants) toxic to microorganisms also make ozone toxic to humans.

Ozone Exposure

Detectable odor	0.01 to 0.05 ppm by volume
Coughing & irritation in 8 min	1.0
Coughing & irritation in 1 min	4.0
Fatal in < 1 min	10,000
OSHA 8 hour limit	0.10
OSHA 15 minute limit	0.30

Chemistry

O_3 + contaminant « O_2 +oxidized material

Operation

Generation

Measurement

Byproducts

Aldehydes, bromate

Other Treatment

		Treatment									
Contaminant		Ion Exchange		Air Stripping	Greensand	Chlorine	GAC	RO (membrane)	Filtration	Chemical addition	UV
	Common names	Cation	Anion								

Radium		10 percent Anion resin added. Regenerate with KCl preferred.						v. good			
Radon				BAT			good (can't dispose?)	maybe			
Fe	rust	fair			V.Good	follow with settling/filtration	bad	should pre treat	with pre oxidation	polyphosphates/oxidants	
Mn	black stains/flecks				BAT	too slow	bad	should pre treat	with pre oxidation	polyphosphates/oxidants	
Other metals		maybe						yes			
Pathogens	bacteria, viruses					BAT, turbidity interferes		maybe not viruses	for protozoans/cysts	chlorine	fair
Hardness	Calcium, Magnesium	BAT						good		polyphosphates	
Nitrate	fertilizer, sewage		fair					good			
Chloride	salt							only choice			
Color					$KMnO_4$ may oxidize colors	may oxidize color	good	maybe		oxidants	
Odor				maybe	$KMnO_4$ may oxidize odors	may oxidize odor	maybe	maybe		oxidants	
Organic	gasoline, solvents, pesticides			smaller, lighter, more volatile POCs		makes problem worse	BAT	check contaminant/membrane compatibility.			
Turbidity	dirt						maybe	overkill	good		
Sulfide	rotten eggs			good	good	good	poor			oxidants	
Corrosivity	dissolved pipes, lead & copper, asbestos					makes worse				alkalinity, orthophosphates, silicates, pH adjusters	

BAT = Best Available Technology

By process

GAC

Applicability

Theory

principle

reaction chemistry/mechanics

Process control

indicators

adjustment

Waste disposal

Air Stripping

Applicability

Theory

principle

reaction chemistry/mechanics

Process control

indicators

adjustment

Waste disposal

Ion Exchange

Applicability

Theory

principle

reaction chemistry/mechanics

Process control

indicators

adjustment

Waste disposal

Make sure that this is away from any water sources. Chloride is not attracted to soil particles so will not be removed.

Reverse Osmosis

Applicability

Reverse osmosis is effective in removing most contaminants, including ions, organics, and bacteria. It is, however, expensive and complicated. RO is not effective in removing small uncharged molecules. Certain contaminants may deteriorate the RO membrane.

Theory

principle

reaction chemistry/mechanics

Process control

indicators

Assessing Membrane Integrity

Most important for low pressure applications

If a membrane is being used to remove biological agents then holes or tears in the membrane or gaskets will destroy the effectiveness of the membrane.

Holes or tears will also degrade removal efficiency of other compounds.

Direct monitoring

Air pressure hold testing

sonic testing

Bubble point testing

Indirect testing

Particle counting

turbidity

adjustment

troubleshooting

Waste disposal

Green sand

Applicability

Greensand is used to remove oxidizable ions, particularly iron and manganese.

Theory

principle

reaction chemistry/mechanics

Process control

indicators

adjustment

Waste disposal

Chemical addition

Applicability

Disinfection

See above

Corrosion control

Fluoridation

Theory

principle

reaction chemistry/mechanics

Process control

indicators

adjustment

Waste disposal

Adding chemicals to the water generally doesn't create waste at the water treatment facility, but may cause problems for the end users of the water. A common problem arises when zinc compounds are used for corrosion control. The extra zinc in the water can raise the level of zinc in the sludge produced by downstream sewer treatment plants, increasing sludge disposal costs.

By contaminant

Iron and Manganese

Importance

Health effects

There are no adverse health effects from iron or manganese

The amount of iron present in water is too little to provide nutritional value

Aesthetic and Practical operational effects

Staining

Iron stains fixtures and laundry reddish brown. Manganese produces black stains. Bleach "fixes" these stains. Fabric life is reduced.

Fouling

Rust or manganese precipitate deposits in boilers, mains, valves, and other tanks. The deposits can prevent proper valve closure, reduce pipe and tank volume, and otherwise prevent proper operation of equipment.

Chemistry

Iron and manganese exert a chlorine demand, i.e. they will be oxidized by chlorine. This uses up chlorine which might otherwise be disinfecting.

Iron can be an energy source for bacteria. The so called "iron bacteria" are colorful, produce tastes, odors, sheens, and slimes, and are very difficult to kill.

Forms

Metal

Soluble ions

Fe^{2+} and Mn^{2+} are soluble. Iron has two oxidation states, +2 and +3. Manganese has many.

Insoluble precipitates

In general, the higher oxidation states are less soluble.

Identifying problems

Complaints

Visually

Are there stains? Is the water brown? Are there black flecks? How does the water look when you flush a hydrant?

Quick test

Add a few drops of chlorine to oxidize dissolved Fe/Mn. Watch for rust or black flecks of Manganese to form and settle to bottom. Look for brown color.

Chemical testing

Be careful when sampling to use properly preserved bottles to prevent Fe/Mn from precipitating out on walls of container.

Be careful when sampling to note particles. Particles of iron or manganese which get into the sample will greatly increase the result. Clays also contain substantial amounts of Fe/Mn. As with all sampling, your Fe/Mn sample should be representative of the water you wish to test. Do you want to be testing the particulate matter?

You can filter the water prior to testing to determine whether the iron/manganese is soluble or insoluble

Colorimetric

Need Spectrophotometer, filter, or Nessler tubes to compare color of reacted sample.

Atomic Absorption (AA)

Large expensive delicate laboratory machine.

Produces most accurate results.

Eliminating

Source changes

New source

Survey other wells in area. Upper aquifers may be better if they are aerated enough to precipitate out iron

Select aquifer

Block off iron/manganese rich vein of water. Call your well driller.

Sequestering

Prevents oxidation (and precipitation) of Fe/Mn. Does not remove Fe/Mn. Requires addition of chemicals (Pyrophosphate, metaphosphate, tripolyphosphate). These can be nutrients and promote bacterial growth. Check phosphate limits at the local sewer plant. Break down to orthophosphate. Bench test to approximate amount. Observe color. Should stay clear for 4 days.

Add phosphate before or with chlorine. Best right below well pump.

Ion exchange

Softening

Must keep oxygen out of resin (or Fe/Mn will plate out on resin beads. Use sulfites during backwash. Pump to waste when starting feed pumps.

removes about 60-80%

requires little attention

record filter volumes

Oxidation

Aeration

Chlorination

Permanganate

Filtering

Greensand

Microbiological

Turbidity

Turbidity is caused by materials in suspension that interfere with the passage of light. Turbid water appears cloudy. Turbidity itself does not necessary cause disease, but can create real problems

Problems caused by turbidity

Consumer seek other sources

Rather than drink turbid water, consumers may choose untested or unsafe supplies.

Your reputation is tarnished

Interferes with treatment

Particulates shield microorganisms from disinfection

Particulates clog filters

Interferes with testing

Clogs the membrane used in certain coliform tests.

Changes apparent color in chlorine and other color change tests.

Exerts a chlorine demand

Removal of turbidity

See surface water treatment, below.

Organic chemicals

Use Granular Activated Carbon

Air strip

Hydrogen sulfide

Nitrates

Use RO

Anion Exchange

Anion exchangers replace nitrate with chloride. Be careful that your chloride limits are not exceeded since other anions (carbonate) will also be exchanged.

Hardness

Softening

By problem

Colored water

Cloudiness

Air

Odors

Tastes

Bitter, Astringent

Check iron and manganese

Particles

Turbidity

Flecks

Rust

Sand and Grit

Feel

pH

High pH (alkaline) water can feel slimy. Check pH. Check chemical feeders.

Hardness

Soaps do not lather well in hard water. Soaps are hard to remove with soft water.

Bacteria outbreaks

Illnesses

Corrosion Control

Background

Pb/Cu rule 5-1.4

Treatment

Operation

Fluoridation

Theory

optimum level: 1 mg/l

equipment

operation

By source

Surface water

SWTR / Part 5

The US EPA has promulgated and the NYS Health Department, Bureau of Public Water Supply Protection has included into Part 5 of the State Sanitary Code, requirements for filtering of all surface water supplies, unless those systems are able to meet certain avoidance criteria. This rule is known as the Surface Water Treatment Rule (SWTR). Due to the financial burden this rule would impose on small water systems if conventional filtering methods were installed alternative filtering methods have been developed. These field tested alternative methods are available to small water systems for use in complying with the SWTR.

Part 5 of the State Sanitary Code states that any addition or deletion of a treatment process must be approved by the State. Therefore, those Grade C systems which must filter will need treatment system plans prepared by an engineer, and submitted to the health department for approval. This must be done before any changes can be made.

Multiple barriers

Should any bacteria or cysts remain after filtration, a disinfection system will act as a second barrier to distribution system contamination.

Filters can be excellent places for bacteria to colonize, therefore, disinfection is required after all filtration systems.

CT

Raw water quality

The purpose of filtering surface water is to provide a potable water free from turbidity, color, and which is biologically safe to drink. Surface waters sometimes contain a parasite known as Giardia Lamblia. The Giardia Lamblia cysts enter the water from the feces of animals such as beaver, deer, dogs, and even humans who may be infected with the parasite. Drinking water that contains the cyst can transmit a waterborne disease to consumers. When the cyst enters the body, the disease that develops is know as giardiasis. Giardiasis is not usually life threatening, but can be incapacitating. These parasites attach themselves to the wall of the small intestine, grow and reproduce there. Disease symptoms include diarrhea, flatulence, abdominal cramps and loss of appetite.

Protozoans

Giardia

Cryptosporidium

Particulates

Humic acids / organic carbon

taste, color, odor

variability

accidents

Filters

Conventional

Large water systems using surface waters normally can remove the Giardia cysts with a series of treatment steps called conventional filtration. In conventional filtration the water and a coagulant, such as aluminum sulfate, are mixed together in a rapid mix chamber. The water is then slowed down for flocculation, where the coagulant and "dirt" particles combine to form larger particles called floc. After flocculation, the water's velocity is decreased further in a clarifier or settling basin where the floc settles out. The water then goes through large filtering systems such as rapid or slow sand, diatomaceous earth (DE), or multimedia filters to remove remaining particulate matter, including the giardia cyst. Disinfection is then performed using chlorine, ozone or U-V to kill any micro-organisms that may have penetrated through the filters. Upon clogging, the filters used in conventional filtration require complicated backwashing cycles to regenerate their capacity.

Cartridge/Bag

Conventional filtration is complicated, so requires expert knowledge to operate. The size and number of processes also make it very expensive. Cartridge or bag type filters are a simpler and affordable alternative for smaller systems. In cartridge filtration, the water is applied directly to the filter. No chemical addition, coagulation, flocculation or settling is performed. The filter element is self contained and is replaced rather than backwashed.

Filtering principles

Strainers

Some cartridge filters work on the principle of straining. The filter has tiny holes. Particles bigger than the holes can't pass through. Smaller particles fit through the holes and are not trapped. The particles passing through the filter show up as **turbidity** in the filtered water.

All bag filters are of this type.

Depth

Some filters work on the principle of adsorption, or sticking. The filter is filled with a media in which particles can become trapped. These medias include sands and wools.

Activated carbon

Activated carbon traps molecules in small crevices in the carbon. Carbon is useful for removing tastes and odors. Carbon comes as a powder or as granules, so will also function as a depth filter (albeit an expensive one). Do not confuse activated carbon with other carbons (coals or anthracites) used as media for depth filters. Only activated carbon can remove the extremely small agents causing taste and odor.

Efficiency

Filters are rated by the nominal size of the particles they can remove. Straining type filters usually remove most particles bigger than their pore size. Depth type filters remove some particles which are smaller than their rated size and also allow some bigger particles to pass through.

The removal efficiency is related to the size of the filter opening, usually listed in microns, and the type of filter media.

Any filter you purchase should be rated for efficiency. Efficiency is the percentage of particles of the rated size that the filter removes. Some filters are tested for efficiency by using a silica test dust in water at 4 gpm; others by using Arizona sand in water. In both tests, efficiencies are calculated using particle counts, not mass weight. The test is conducted using a fresh filter that has been operated for 10 minutes. The efficiencies are specific to the particle size tested, and do not include those of other sizes. If a filter is not rated for efficiency it should either be used only as a pre-filter, or not purchased at all.

Since all cartridge and bag filters are rated in MICRONS, let's take a look at what microns are; The dictionary defines micron as a "unit of length one/one millionth of a meter." A better example would be the period at the end of this sentence is approximately 400 microns. Now reduce this to a 1, 5, 10 micron size, which is normal for these types of filters. Micron size is also related to flow rate, the smaller the micron size, the slower the flow rate through the filter. The smallest pore size available is one micron. Smaller sizes are usually regarded as membrane filtration.

Construction

A cartridge filter consists of a filter module which fits into a (usually) cylindrical housing.

Filter

Cartridge filters are usually made from the following materials: Cellulose, cellulose/polyester, polypropylene, cotton fiber, granular activated carbon, powered activated carbon, phosphate crystal and ceramic. The micron rating will vary from 100 down to 1 micron. Granular activated carbon filters do not have a micron rating. The powdered activated carbon may have a nominal rating of 1-5 microns.

Housing

Filter housings are made of stainless steel, or high density plastic. They are manufactured in single or multiple cartridge models. On those models that have a bottom discharge, an automatic air relief valve is required to vent air that may become trapped in the filter housing. This air may accumulate from degassing of the raw water.

Multiple units (trains)

Often several cartridge filters are arranged in a series of filters set in descending order of filtration sizes, e.g., 10 micron first, 5 micron and last a 1 micron. The first filter traps the largest particles; the next filter has only to filter the remaining smaller particles. This allows each filter to remove the particles for which it is best suited, resulting in longer filter runs.

All filters should have good end seals. This is especially critical with the final filter. If the end seals do not seat tightly against each end of the filter canister, "short circuiting" will occur. This phenomenon occurs when the water flows over the top and bottom of the filter, and not through it.

Selection

When choosing a system for filtration, it is necessary to select a system that offers cost effective benefits. The following economies can be gained by selecting the most effective and efficient system.

Long Runs Low labor

Disposable Quick changes

Reusable minimize purchases

Low pressure drop Smaller pumps, lower power costs

Small size cheaper building

Approved or else

System Arrangement

Intake/Pretreatment

Some pretreatment is going to be required just prior to the filtration process. Poor pretreatment can result in extremely short filter runs and frequent filter replacement. This pretreatment can be one of four types:

1. An infiltration gallery which would be located underwater approximately 20 feet off shore;

2. A well point driven into the lake bottom, approximately 20 feet off shore;

3. A shallow on-shore well, where possible and practical, could be used;

4. A "simple" slow sand filter, measuring approximately 4 X 8 feet, could be built using a good exterior or marine grade plywood. The filter when complete would have an under drain system, a layer of graded gravel and topped with a layer of sand. Topping this off would be a layer of solids and biological growth called **schmutzdecke** which forms on top of slow sand filter after it has been in use for a while.

Prime mover

Since filters require medium to high pressures to operate, gravity is generally insufficient to move water through the treatment plant. Pumps must be used. It is critical to the successful treatment scheme, that all the pumps be properly sized. Improperly sized pumps cause some or all of the following: energy waste, extra pump wear, inability to maintain system flow or pressure, or filter damage.

Disinfection

Should any bacteria or cysts remain after filtration, a disinfection system will act as a second barrier to distribution system contamination.

Filters can be excellent places for bacteria to colonize, therefore, disinfection is required after all filtration systems.

Operation

Replacement

A pressure drop or an increase in turbidity in the finished water will tell the operator that the filter needs replacing. Make sure that your water system has appropriate gauges and that they are functioning. The water operator is cautioned to pay particular attention to their raw water turbidity meter readings, since a turbidity spike could blanket out and clog a filter. Also, since the source is a surface source, the cartridge filter performance will be influenced by algae. Algae are microscopic plants, observed as "green scum" growing on rocks and docks, etc. Algae can clog the filter system, thus preventing a ready supply of raw water from entering the filters. Algae may suddenly "bloom" when weather conditions are favorable. A properly operating and maintained pretreatment system will reduce loading on the cartridge filters from high turbidity or algae in the raw water.

Beware of changing cartridge brands or types. The cartridge must exactly fit the housing in order to prevent short circuiting or bypassing.

A good ceramic cartridge filter will cost in the neighborhood of $40. The danger here is that if the filter ever has to be replaced, it is usually replaced with a cheaper filter. The cheaper filter may result in "short circuiting," because it will be less efficient and require more frequent replacement.

Reuse

Of all the filters named above, the only one which is reusable is the ceramic filter. This filter when clogged may be cleaned with a stiff nylon bristle brush or by blowing the dirt from the openings using an air compressor. Cleaning with air will probably do a better job.

Spare parts

Spare filter cartridges should always be available.

Disinfection

When using cartridge filters or bags, the chlorination system MUST be continuously adjusted. This is because the flow through the filters decreases as the filter become clogged. The best type of chlorinator would be the "flow sensing" chlorinator. Flow sensing (or flow paced) chlorinators automatically adjust the chlorination rate based on information from the system flow meter.

Reporting

Surface water supplies are required to fill out and submit additional forms beyond the standard Operation Report. Please note that water supplies using filtration are required to meet strict finished water turbidity requirements. See Part 5.

Future

The filtration system may in the future have to filter for cryptosporidium. If so, an additional filtration system will be necessary, since cryptosporidium is too small to be removed by standard cartridge filters.

Outbreaks of cryptosporidiosis resulting have occured at supplies using surface water when the finished water turbidity was in the .9-2.0 NTU range. The peak turbidity during the 1993 Milwaukee outbreak was 1.7 NTU. AWWA recommends that finished water turbidity be kept below .2 NTU.

Filter waste

media

backwash

Cross connections

permits

Operation

EquipmentThe following visual aids should be available: Chlorinator, submersible pump, jet pump, hydropneumatic tank, pressure gauges, pressure recorder, centrifugal pumps (big and small). Also: lead pipe, pvc, copper, asbestos?. Bring Goulds catalog. Get pipe company lit for handouts.

Pumps

Types

Positive Displacement

parts

piston or cavity

diaphragms

vanes

check valves

hydraulics

A cavity is enlarged, sucking fluid in. The cavity's volume is then decreased, forcing the water out.

What happens if a positive displacement pump is pumping into a closed container (or the valve on the outlet is off)?

Gear

Tubing

Diaphragm

Piston

Centrifugal

parts

impeller

casing (volute)

seals

packing

lantern rings

glands

wear rings

bearings

hydraulics

theory of operation

The impeller of a centrifugal pump slings the water out away from the center of the pump. The casing collects and channels this water toward the outlet. New water is sucked into the center of the pump to replace the water which was pushed outward.

What happens if a centrifugal pump is pumping into a closed container (or the valve on the outlet is off)?

priming

priming water 5-1.29

head vs. flow

pump curve

efficiency

appurtenances

gauges

valves

checks

transfer

jet

turbine

submersible

Submersible pumps use oil cooled motors. The oil must be food grade. Certain old pumps may have PCBs in their oil.

Tanks

types

storage

elevated

ground

pressure

plain

bladder

contact

materials

Tanks have been made from wood, fiberglass, concrete, steel (sometimes with a glass lining).

pressure ratings

coatings

approved

plumbing

valves

gauges

sight glasses

level sensors

vents

overflows

maintenance

Meters

Pressure

Bourdon tube

Manometer

Piezometer

Flow

Positive Displacement

Known volume

Low flow applications

piston

nutating disk

Under register when worn

Don't operate above rated capacity

Current/Velocity

Turbine

Size to flow

Multijet

Propeller

Pressure Differential

Measured with electronic or hydraulic sensors

Known area

Orifice

high head loss

can plug

Venturi

Pitot

Rotameter

Magnetic

Doppler

Sensors - flow or no flow

can stick

Compound

A large and small flow meter piped in parallel and chosen by automatic valves.

Selection

Head loss

Flow range

5-35% positive displacement

0-100% compound

50-100% turbine

Pipes

Materials

Joints

Bedding

Valves

Ball

Globe

Gate

control

Check

Swing

Ball

Altitude

Pressure reducing

Pressure relief

Hydrants

dry barrel

weep hole

System

Hydraulic

gravity

Elevated water (in a tank) provides pressure. Used mostly in large systems.

hydropneumatic

Most common. Compressed air provides system pressure. May use air compressor to provide the air.

transfer

General

Distribution system

Trench dewatering 5-1.26

Minimum pressure 5-1.27

Blowoffs 5-1.28

Testing

Sampling technique

Strainers

Always remove strainers to prevent contaminants stuck or growing on the strainer from dislodging and entering the sample bottle thus producing a sample which is not representative of the actual water conditions.

Flushing

If a sample of the aquifer water is required, then all the water in the well and plumbing system must first be flushed out. Always know which water you are sampling (from the tank, the pipe, the well, or the ground) and which water you want to be sampling.

filling bottles

preserved

Bottles containing preservative must not be rinsed. The preservative would be rinsed out.

volatiles

Bottles for volatile chemicals must have no air bubbles after filling. The contaminant would partition into the air bubble and be lost when the bottle was opened.

streams

When sampling streams, open bottles beneath the surface to avoid floating debris not representative of the stream water quality.

sampling points

avoiding extra treatment

Make sure samples are representative of the water you want to test. Don't sample treated (softened, filtered, chlorinated, etc.) water if you want to know the quality of the groundwater.

Laboratory data interpretation

reading reports

chain of custody

ELAP considerations

holding times

detection limits

collection requirements

bottle type

preservation

chemical

temperature

Monitoring 5-1.52 tables 8-12

Notifications 5-1.52 table 13, 5-1.78

Public Health Hazards 5-1.77

5-1.71 Due care and diligence

Operation Reports and Records 5-1.72

Records, records, records

Anything and everything

System mapping

Preventative maintenance

Housekeeping

Clean

Paint

Oil

Routine

Adjust service interval

Frequent maintenance for an item may indicate system problem

Valves

locate

exercise

turns

direction

Motors

temperature

current draw

bearings

Pumps

Sound

vibration

seals/packs

wear rings

flow

bearings

Mains

flushing

hydrants

mechanical cleaning

Loss of Head test

Keep coupons from tappings, note appearance when repairing.

Emergencies

Reporting 5-1.23

Emergency plan 5-1.33

This section applies to larger systems (over $125,000 revenue) and includes specific requirements for the plan. Small systems are well advised to create their own emergency plans in order to minimize distractions during an emergency. The operator's memory, although excellent normally, may not be clear when stressed by a natural or man made disaster.

A simple plan should include an inventory of all equipment so that spare parts can be ordered or emergency equipment can be properly interfaced to existing equipment. Provisions for emergency power hook up and emergency tank filling should be provided. A list of public officials, suppliers, repairmen, media, and consumers to contact should be made. The plan must be updated as names and phone numbers change.

Cross Connection Control

Background

gory examples

Strategies

containment

internal plumbing control

Code requirements 5-1.31

Water system responsibility

user responsibility

certification of testers

Surveys

Planning

Degree of hazard

dangerous

aesthetically objectionable

benign

Units

Appropriate control unit

for hazards

for internal plumbing control

Air gap

Reduced Pressure Zone Device (RPZD)

Double Check Valve (DCV)

Other

Approval

state list

test cocks

plan

location

Testing

Yearly

Certified tester

Documentation

Safety

Basic requirements

Attitude

Awareness

OSHA

Clothing

eye protection

goggles

face shields

safety glasses

aprons

coats/suits

gloves

boots

Liquid Chlorine

chemical handling (MSDS)

Must be available to workers

information

active and inert ingredients

types of hazards

symptoms

precautions

personal protective equipment

handling procedures

first aid

clean up

spills

absorbants

Besides safety considerations, check the speed and capacity of your absorbant on the target chemical.

shouldn't react with chemical

Clays react with strong acids (<2.5 pH) and strong bases (> 12 pH).

compatible with disposal method

Don't landfill biodegradable absorbants (newsprint, rice hulls, cord cobs, peat). Incinerate them.

storage

confined spaces

Any area not designed for human habitation.

Examples of confined spaces include manholes, pump pits, tanks, equipment closets, trenches.

Hazards

Atmosphere

Enough oxygen

Normal air is 21% oxygen. The minimum oxygen concentration for entering a confined space is 19%. 16% O_2 impairs judgment and breathing. 14% causes confusion.

Too much oxygen is also dangerous. More oxygen means fires burn faster and are easier to start. Excess oxygen may interfere with normal breathing regulation in humans. Do not enter areas with more than 23.5% oxygen.

Explosive mixtures

vapors

dusts

Poisonous gases

Mechanical or structural

equipment or processes

Confined spaces may house moving equipment such as cutters, stirrers, chain drives, and valve actuators. Clearance for workers may not exist. Many tanks and other confined spaces are supplied by pipes with various liquids. Other spaces may include high voltages.

Lock out all equipment and all sources of power or product.

Do not allow confined spaces to be filled with water or other fluids. Prevent high voltages from being turned on while employees are in confined spaces. Make sure that pumps, motors, actuators, and other moving equipment can not move while employees are present.

The employee in the space should keep the key to the lock out devices. Where many workers are inside, each should have his or her own lockout kit.

Hazards created during access

The work to be performed in the confined space may cause the space to become dangerous. Examples include painting and welding which, among other hazards, may cause toxic, explosive, or oxygen deficient atmospheres.

restricted access

Confined spaces are often arranged such that entering and exiting, or even just moving about within them, is difficult. It may not be possible for an injured person to leave. Rescuers may not be able to remove an injured person.

limited visibility and communication

This may restrict the employee's ability to request help.

entrapment potential

Narrow or converging architectures may trap workers.

OSHA rules

For municipalities or larger (>10 employees) companies. Check current regulations for exact details.

Identify spaces

Permit system

Atmosphere testing and monitoring

Ventilation

Rescue capability

Equipment

Special equipment is available to make confined space entry safer. Much of the following is mandated by good sense or OSHA regulations. Also check with your facility's safety plan.

Air testers

Canaries

Oxygen meters

Lower explosive limit (LEL)

Know the limitations of your equipment. Almost all LEL meters are calibrated based on methane. If your particular atmosphere contains a different flammable gas, you may be misled by your meter. Most LEL meters are incapable of distinguishing between conditions above and below the explosive limits. Once the LEL has been reached, the meter must be returned to a known safe atmosphere. Otherwise, you will not know whether the meter is reading a low level of explosive gas or a mixture too rich to burn.

Organic Vapor Analyzers

These also are calibrated based on a known gas.

Blowers

Tripods/slings

Air packs

Motion sensors

Clipped to a worker, these units send an alarm if the employee is motionless for a preset time.

Protocol

Written plan

Extra personnel

trenches

Being buried in a trench is a serious threat to life. The weight of soil on the chest prevents breathing. Burial victims suffocate. Unconsciousness occurs in about 1 minute; death in 4. Victims must be dug out by hand - nearly impossible to do given the time constraint. The best course of action is prevention.

soils

Different soils have different strengths. Sands and gravels are usually strong but loose. Clays are weaker. Soils have different properties depending on their current moisture content. Wetter soils are usually weaker.

depth

Trenches over 5 feet deep require shoring.

sides

Stepping or sloping the trench sides will reduce the potential for collapse.

loads by edge

trucks, vehicles

spoil, dirt

vibration

wetness condition

Weather, rain

Sump pump discharge

warning signals

Often, there **will be no warning**.

cracks by the edge of the trench running the same direction as the trench.

bulges or partial collapses

miscellaneous

Use the right tool for the job! Don't hurry.

tripping

electrical

labeling

fatigue

Laboratory

Microbiology demosNo fresh bacteria available Monday. Better later in week.

Membrane Filter

MPN

pH

Chlorine residual

Turbidity

Conclusion

Review

certification requirements

Course evaluation

Exam