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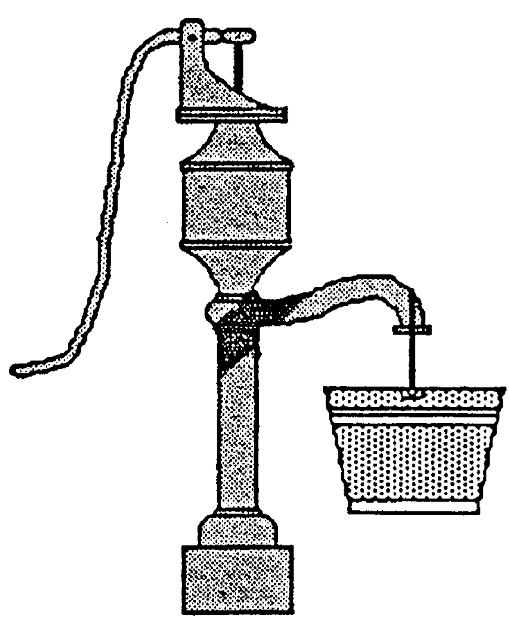
Hygienic Laboratory

The University of Iowa

Well Water Quality and Home Treatment Systems



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Additional copies of this booklet are available through
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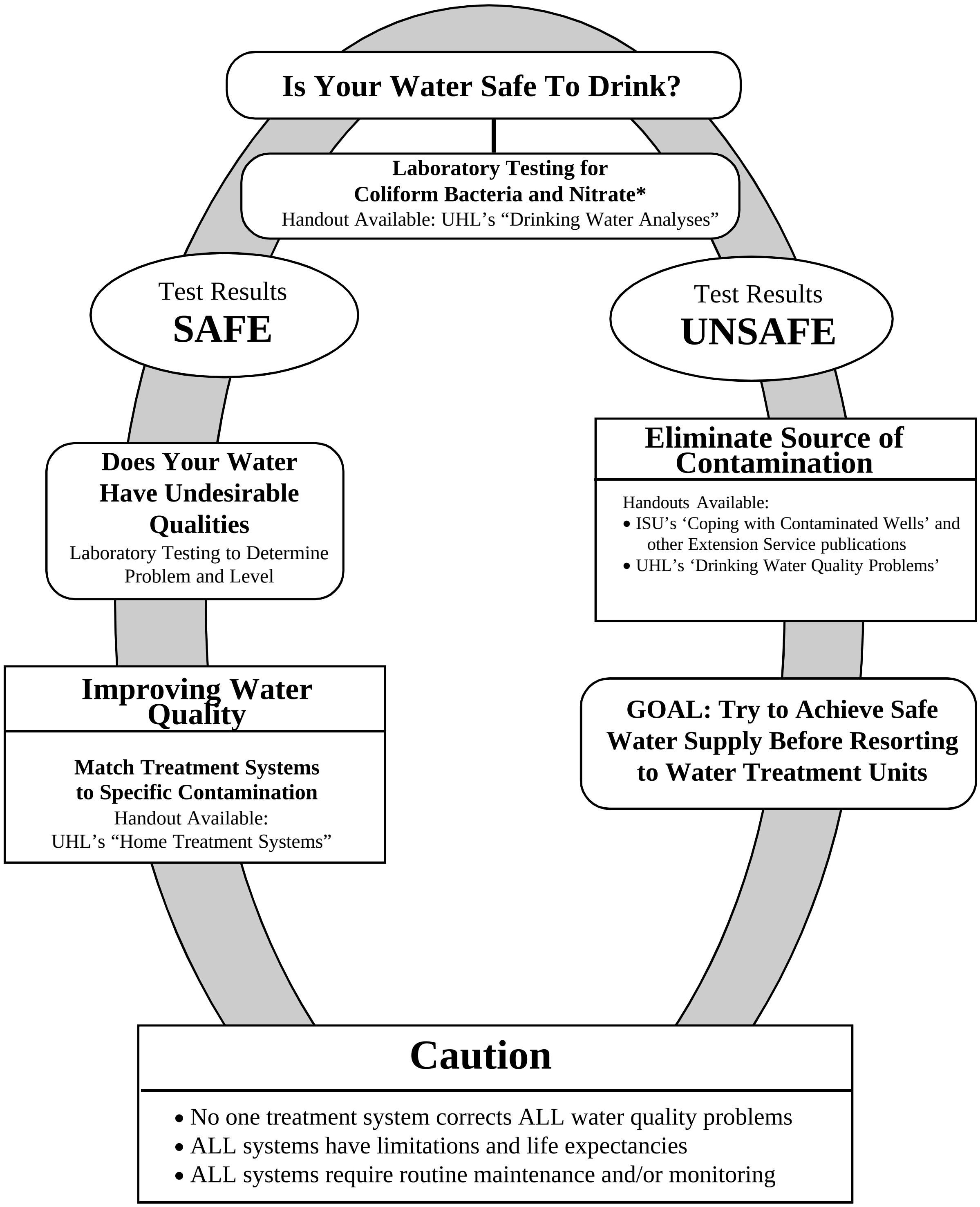
Introduction

This publication is a brief overview of systems commonly used to treat water quality problems. It is preferable to provide a safe source of water rather than to depend upon treatment devices to correct water problems which may threaten your health. If water treatment appears to be your only option, you must match the treatment system to the specific contaminant(s) to be removed. No system treats all water quality problems, and all systems have limitations. Before buying a treatment system, get an accurate analysis of your water and then, if necessary, select the system which would best solve your water quality problem.

Become knowledgeable about the units under consideration, especially regarding system limitations, removal efficiencies, life expectancies, routine maintenance and monitoring. Remember that the claims of manufacturers and dealers may not always accurately describe what the system will do for YOUR water. You may want to lease a unit initially to determine whether it performs properly in your situation.

Drinking Water Quality Flowchart



*Under normal circumstances we recommend testing for the presence of coliform bacteria and nitrates which will provide a good indication of your drinking water safety. If a specific contamination problem is suspected (e.g. from a nearby chemical spill), contact the laboratory, as other tests may be required to determine water quality.

Home Treatment Systems and Drinking Water Quality

Drinking Water Quality Problems in Iowa

I. Problems That May Threaten Health

Contaminant	Possible Health Effects*	Possible Source	Suggested Treatment
A. Coliform bacteria	Intestinal illnesses; taste or odor	Surface or shallow subsurface water or waste water	Eliminate source: correct defects of well or supply; shock chlorinate; then recheck for safety
B. Nitrate	Methemoglobinemia (blue baby disease)	Fertilizer, manure, septic system, etc.	Eliminate source: correct defects of well or supply; anion exchange; reverse osmosis; distillation
C. Pesticide	Acute: vomiting, weakness, etc. Chronic: cancer, genetic or birth defect risks	Improper use, disposal, spills, or back-siphoning accident	Eliminate source: purge system; depending on type of pesticide, treatment units may be available (consult manufacturer)
D. Lead	Chronic: adverse effects on blood, nervous and kidney systems	Corrosion of lead pipes or lead solder	Reduce corrosion (see below), lead pipe/solder replacement, reverse osmosis, distillation
E. Gasoline/ Organic Solvents	Chronic: cancer risks; taste or odor	Leaking storage tanks, spills, improper use or disposal	Eliminate source: purge system; activated carbon filter in series; vented distillation

*varies with exposure, compound, and susceptibility

II. Problems That Usually Do Not Threaten Health

Contaminant	Complaint	Possible Source	Suggested Treatment
F. Iron and Manganese	Rusty water, rust stains on sink or clothes, deposition inside pipes	Corrosion or naturally present in aquifer	Water softners for soluble (ferrous) iron; iron removal units (green sand); reverse osmosis; distillation
G. Hardness	Scale, soap scums, deposition inside pipes	Dissolved calcium and magnesium from soil and/or aquifer	Water softener (ion exchange; reverse osmosis; distillation
H. Iron Bacteria	Oily film on water, slime growth in water tanks or toilets	Present in iron-rich aquifer; contaminated drilling equipment	Shock chlorination; continuous chlorination to retard growth
I. Corrosion	Metallic taste, greenish stains on faucets, sinks, leaking pipes	Corrosive water present in aquifer; "softened" water; incompatible metals in plumbing; aggressive water	Add corrosion control chemicals or sacrificial metal
J. Taste/Odor	Rotten egg odor	Hydrogen sulfide gives water this odor; corrosion; sulfur bacteria NOTE: make sure odor is not due to coliform bacteria problem (see I. A.)	Shock chlorination; green sand iron filter; activated charcoal filters

Iowa Regulations Governing the Sale and Marketing of Residential Water Treatment Systems

(Iowa Administrative Code Chapter 714)

The purpose of the regulations is to protect the consumer from false or deceptive claims regarding the reduction of health-related contaminants in drinking water by sellers of residential water treatment devices in Iowa. The legislation applies to sellers or manufacturers of *any* residential water treatment device offered for sale, lease, or rent for which claims of reducing health-related contaminants are made.

Manufacturer's Performance Data Sheet

Before purchasing such a water treatment device a consumer should read the Manufacturer's Performance Data Sheet. By law, this document *must* be given to the buyer by the seller and signed ant dated by both parties *prior* to the consummation of the sale. The Performance Data Sheet *must* contain but is not limited to the following information.

1. The name, address and telephone number of the seller.

2. The name, brand or trademark under which the water treatment device is sold, and its model number.

3. Performance and test data including but not limited to:

   a. a list of contaminants found to be reduced by the device.

   b. the test influent concentration of each contaminant.

   c. the percent reduction or effluent concentration of each contaminant.

   d. the maximum contaminant level (MCL) specified in the U.S. EPA's National Primary Drinking Water Regulations for each contaminant.

   e. the approximate capacity in gallons or the period of time during which the treatment device is effective in reducing the contaminants based on the contaminant influent concentration used for the performance test. The gallon capacity of the device need only be based on the claimed contaminant most likely to break through into the effluent during the performance test period.

   f. if applicable the flow rate, pressure and temperature of the water during the performance tests.

Home Treatment Systems and Drinking Water Quality

The following information must also be on the Performance Data Sheet or be referenced to the owner's manual.

1. Installation instructions.

2. Procedure and requirements necessary for proper operation of the treatment device including but not limited to electrical requirements, maximum and minimum pressure, flow rate, temperature limitations, maintenance requirements, and expected replacement frequencies.

3. The seller's warranty limitations.

4. Non-health-related substances may be listed on the Performance Data Sheet but may *not* be referred to as contaminants.

Consumer Information Pamphlet

In addition to the Performance Data Sheet, a Consumer Information Pamphlet prepared by the Iowa Department of Public Health (IDPH) *must* also be given to the buyer by the seller again *prior* to the consummation of the sale

Registration

All treatment devices covered by this legislation *must* be registered by the seller with the IDPH. Before registration is approved, the device must be performance tested in accordance with approved protocols by a third-party testing agency. This registration will certify that the system has been thoroughly tested for structural integrity and assure effective performance.

For more information contact:

Health Engineering & Consumer Safety
Division of Disease Prevention
Iowa Department of Public Health
Lucas State Office Building, Des Moines, IA 50319-0072
Telephone: (515) 281-5787

Activated Carbon Filters

Activated carbon is created by the destructive distillation of wood, nut shells, animal bones or other carbonaceous material, and “activated” by heating to 800 - 900 C with steam or carbon dioxide. In the activated state, carbon has a high absorptivity for many gases, vapors and colloidal solids. As water passes through these filters, particles are trapped and some types of contaminants adsorb onto the carbon thus removing them from the water.

Strengths

- removes many organics such as petroleum hydrocarbons, trihalomethanes and possibly some organic solvents and pesticides
- removes humic substances
- removes taste and odor-causing agents such as hydrogen sulfide (“rotten eggs”)
- removes chlorine and ozone
- removes radon

Limitations

- activated carbon has a finite life span and needs to be replaced frequently because it can not be regenerated in line
- there is no reliable way to determine if the carbon is saturated with contaminants and needs replacing
- activated carbon will NOT effectively remove bacteria, nitrates or most metals
- carbon provides an excellent medium for bacterial growth, resulting in potential health problems and therefore should not be used on supplies whose bacterial quality is unknown

CAUTION

- No one treatment system corrects ALL water quality problems
- ALL systems have limitations and life expectancies
- ALL systems require routine maintenance and/or monitoring
- Match the treatment system to the specific contaminant to be removed—laboratory testing may be necessary to determine the problem(s)

Anion Exchange Units

Anion exchange is a demineralization process by which negatively charged ions (non-metal) are removed by passing water through an anionic resin bed.

Strengths

- removes negatively-charged inorganic ions such as nitrates, fluorides, sulfates and bicarbonates
- removes organics such as naturally-occurring humic substances (humic acid, fulvic acid and humin)

Limitations

- a pH adjustment may have to be made to the raw water to facilitate the efficiency of the exchange process
- since the chloride concentration will increase during the process, the water may taste salty
- removal of the bicarbonates may result in more corrosive water
- positively-charged ions such as metals and some radionuclides will not be removed
- nitrate removal efficiency may be significantly lower with water having high levels of sulfates

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Chlorinators

Chlorination is a procedure by which a chlorine-releasing chemical such as calcium hypochlorite, sodium hypochlorite (bleach) or chlorine gas, is added or injected into the water.

Strengths

- destroys microorganisms (bacteria and viruses)
- breaks down bacterial slimes
- facilitates the removal of iron
- destroys algae
- helps control iron and sulfur bacteria
- eliminates odors such as hydrogen sulfide (“rotten eggs”)

Limitations

- hazardous, chlorinated organic chemicals may be formed
- nitrates, fluoride, sodium, heavy metals, pesticides and radionuclides are not removed
- a threshold level of chlorine must be reached and maintained to achieve the desired treatment results

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Distillation Units

Distillation is a separation process by which water is vaporized by heating and then cooled (condensed) back into a liquid.

Strengths

- removes inorganics such as sodium, calcium, magnesium, iron, manganese, heavy metals, nitrates, sulfates, chlorides and fluorides
- removes non-volatile organics such as humic substances and some pesticides
- removes microorganisms such as bacteria, viruses and parasites

Limitations

- most units have small capacities
- contaminants with a lower boiling point than water such as some pesticides and volatile solvents will distill over with the water
- mineral build-up in the distilling chamber will decrease the unit's efficiency
- distilled water can be corrosive
- water may have a "bland" taste

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Ozonators

Ozonation is a process by which ozone (O_3) is injected into the water.

Strengths

- destroys microorganisms (bacteria and viruses)
- controls taste and odor from organic compounds
- breaks down organically bound iron and manganese to facilitate their removal
- removes color by breaking down humic substances
- controls algae
- controls hydrogen sulfide (“rotten egg”) odor
- breaks up some pesticides such as aldrin
- reduces colloidal turbidity thus facilitating filtration

Limitations

- ozone does not provide a disinfecting residual, therefore bacterial regrowth is possible
- some pesticides, such as malathion and parathion are broken down into more toxic components
- ozone must be generated on site with comparatively elaborate equipment
- a threshold level of ozone must be reached and maintained to achieve the desired treatment results
- ventilation may be necessary to eliminate residual ozone in the air

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Reverse Osmosis Units

Reverse osmosis (RO) is a purifying process by which water is forced by pressure through a membrane, effectively "screening" soluble and insoluble material from water. The efficiency of the process can reach 100% depending on temperature, pressure, chemical characteristics of the impurities present and their concentrations.

Strengths

- removes inorganics such as sodium, calcium, iron, manganese, magnesium, heavy metals, nitrates, sulfates, fluorides and chlorides
- removes some organics such as most pesticides, petroleum hydrocarbons, and humic substances
- removes particulates such as rust flakes, sand, grit and clay particles
- removes colloidal suspensions causing turbidity
- removes some radionuclides (with limited effectiveness)

Limitations

- large amounts of water are needed—only about 10 to 30% of the water is recovered as treated water
- some organics are not removed such as chloroform
- RO units are usually more expensive than other types of treatment units
- plugging of the membrane may require pre-treatment measures especially with hard water
- bio-film fouling will decrease membrane efficiency
- not intended for microbe removal
- membranes must be made of the appropriate material for proper application

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Water Softeners

Water softening is a demineralization process by which positively-charged ions (metals) are removed by passing water through a cationic resin bed.

Strengths

- removes hardness chemicals such as calcium and magnesium
- removes other inorganics such as soluble iron and manganese
- removes some radionuclides

Limitations

- will remove calcium and magnesium which are beneficial to your health
- water may become corrosive
- sodium concentrations will increase
- resin bed must be periodically recharged

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Iron and Manganese Removal

Iron is present in many minerals and is a major constituent of clay soils. Because of its prevalence and chemical characteristics, iron is responsible for many aesthetic problems in domestic water systems, thus making its removal desirable.

Manganese, an element similar to iron, but considerably less prevalent, causes similar problems at even lower concentrations, making its removal also desirable.

Suggested Levels for Iron and Manganese

- · Iron 0.3 mg/1
- · Manganese 0.05 mg/1

These limits are secondary Safe Drinking Water Act standards and as such are not legally enforceable. These limits are intended only as guidelines since iron and manganese are related to the aesthetic quality of drinking water but have no direct health impact.

Problems Associated with Iron and Manganese

Iron concentrations above 0.3 mg/L and manganese concentrations above 0.05 mg/L may result in any of the following:

- Plumbing fixtures, porcelain, dishes and laundry may become stained.
- Water may taste bitter or metallic.
- Teas and certain alcoholic beverages may darken in color.
- Efficiency and life expectancy of hot water heaters may decrease with iron build-up.
- Pipes may need to be replaced due to iron build-up and subsequent constriction and impeding of water flow.
- Iron build-up may reduce the efficiency of other water treatment units.

Iron and Manganese Removal Methods

Zeolite Ion Exchange (Water Softener)

- Iron and manganese must be in the soluble form (ferrous and manganous).
- Most efficient if the concentration of iron and manganese is no greater than 0.5 mg/L.
- Care must be taken to avoid aeration prior to softening, otherwise iron and manganese will precipitate, cloning the softener.

Oxidation - Filtration

- Possible oxidants
  - Chlorine, chlorine dioxide, potassium permanganate, atmospheric oxygen, hydrogen peroxide, or ozone.
- Rates of oxidation are pH dependent.
  - Iron oxidation can be accomplished within 10 minutes at pH 7.2 but may require 1 hour at pH 6.9.
  - Manganese oxidation is slower, requiring less than one hour only at a pH of 9.5 or above.
- A detention tank may be necessary to provide adequate time for iron and manganese precipitation.

Green Sand Filtration

- Manganese dioxide in the green sand oxidizes and then filters the precipitated iron and manganese.
- Useful if water softening is not desired.
- Effective for high iron and manganese concentrations of 3 to 10 mg/L.
- Rapid and complete oxidation and removal.
- Optimum pH of 7.5 - 9.0

Distillation

- Very efficient in removing iron and manganese since pH and ion concentrations are not limiting factors in the process.
- Proper maintenance is required to maintain efficiency.
- Stills may not produce sufficient water to meet needs.

Reverse Osmosis

- Removes soluble as well as particulate iron and manganese.
- Membrane plugging may make reverse osmosis unsuitable for some applications.
- Usually more expensive than other treatment methods.
- May not provide an adequate amount of water to meet needs.

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UV (Ultraviolet) Disinfection

UV disinfection is a physical process by which water is exposed to UV radiation generated by a mercury vapor lamp. The UV wavelength is approximately 258 nm and disrupts bacterial activity at the molecular level.

Strengths

- disinfects without using chemicals
- does not introduce objectionable tastes or odors into the water
- immediate treatment effect without the need for holding tanks
- low power consumption
- low capital and operating costs
- compatible with other treatments such as activated carbon, softeners or reverse osmosis
- minimal space requirement

Limitations

- particulates in the water (greater than 5 µm in size) may reduce the UV's disinfection ability by shielding bacteria from the UV light
- large numbers of bacteria (greater than 1,000 coliforms per 100 mL) may reduce the UV's disinfection ability by shielding some bacteria from the UV light
- some naturally occurring compounds in water such as humic acids, tannins, hardness, iron and manganese may reduce UV's disinfection ability by either absorbing W light or by coating the inside sleeve of the UV chamber
- cyst-forming microorganisms such as *Giardia sp.* and *Cryptosporidium* require a larger UV dose than produced by most home treatment units. In these waters where cysts are likely to be present, a 5 µm particulate filter may also be required for cyst removal
- the UV output will gradually decrease through use with corresponding decrease in disinfection ability. Most units do NOT have a mechanism to alert consumer when UV light is not providing adequate dosage

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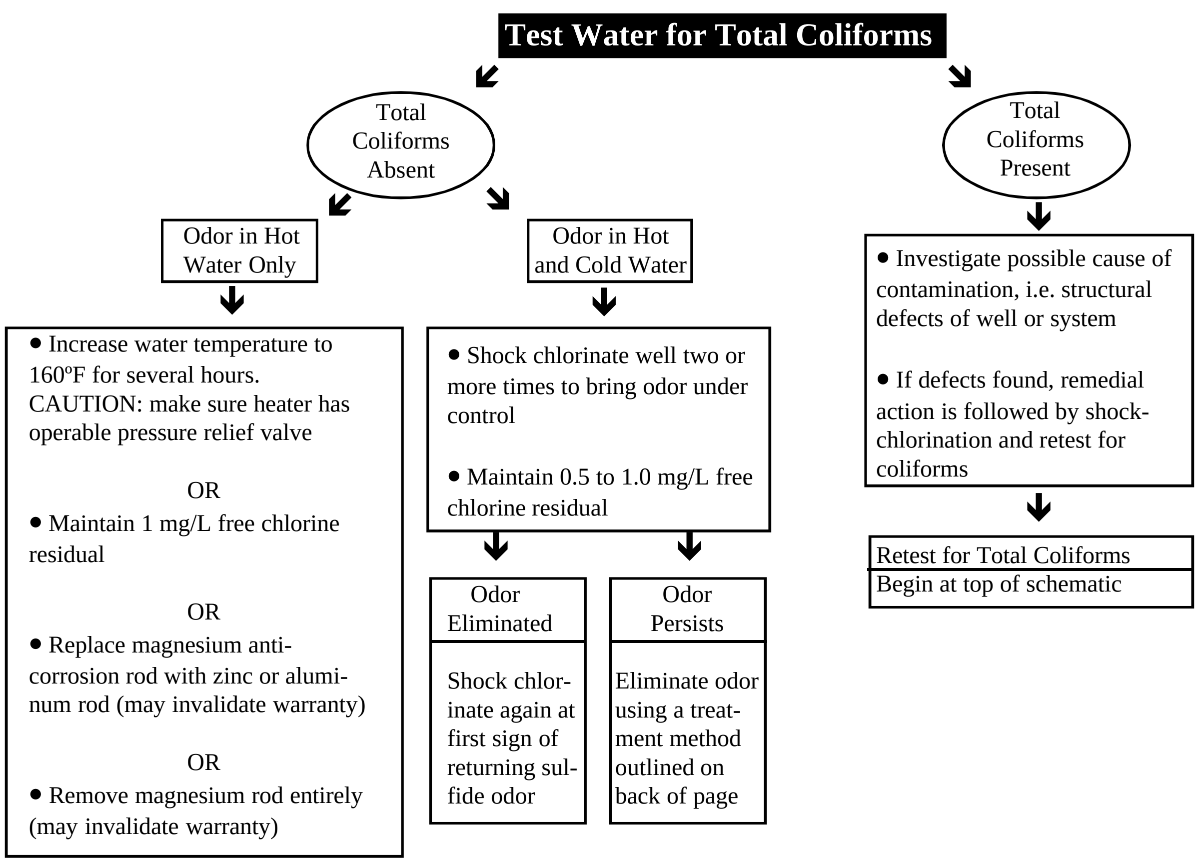
Rotten Egg Odor in Drinking Water

Sulfur and its many compounds are present in gaseous, liquid and solid states. The sulfur form that is responsible for the rotten egg odor in water is hydrogen sulfide, most commonly produced by sulfate-reducing bacteria residing in aquifers or distribution systems. Hydrogen sulfide is not a health hazard in the concentrations found in drinking water.

Schematic for Isolation and Elimination of the Sulfide Odor in Drinking Water



Treatment Methods

Aeration

- effective for reducing up to 2 mg/L hydrogen sulfide; for higher concentrations, choose another treatment method (see below).
- a detention or storage tank may be required to provide adequate contact time.
- filtration may be needed to remove resulting elemental sulfur precipitate.

Chemical Oxidation

1. Chlorine ($C1_2$)
   - 8.7 mg/L chlorine is needed to oxidize 1 mg/L hydrogen sulfide.
   - filtration may be needed to remove resulting elemental sulfur precipitate.
   - activated carbon filter may be needed to remove residual chlorine or sulfide odor.
2. Potassium permanganate ($KMnO_4$)
   - filtration may be needed to remove resulting manganese dioxide (MnO_2) and elemental sulfur precipitate.
   - better oxidant for sulfide odor removal than chlorine.
3. Hydrogen peroxide (H_2O_2)
   - 1 mg/L of H_2O_2 is needed to oxidize 1 mg/L of hydrogen sulfide.
   - filtration may be needed to remove resulting elemental sulfur precipitate.
4. 0zone (O_3)
   - best oxidant for sulfide odor removal ($O_3 > H_2O_2 > KMnO_4 > C1_2$).
   - expensive and sophisticated equipment required.

Manganese Green Sand Filler

- used primarily for iron removal but will also oxidize up to 6 mg/L of hydrogen sulfide.
- regenerated with potassium permanganate.
- adequate backwashing of filter is required to remove elemental sulfur precipitate which may eventually clog filter.

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