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CLEAN WATER FOR WASHINGTON

Defining Water Quality

By Edward B. Adams

An abundant supply of good, clean water must support a variety of beneficial uses. These include drinking water for domestic use and stock watering; industrial, commercial, agricultural, irrigation, and mining use; fish and wildlife maintenance and enhancement; recreation; generation of electrical power; and preservation of environmental and aesthetic values. Drinking water is the beneficial use that usually requires the highest quality water to protect human health.

The quality of water required for each beneficial use often differs. Yet the quality of any body of surface or groundwater is a function of natural influences and human activities. What should the quality of water be? What standards and criteria should apply or be accepted? Further, how can a community rank the set of social or economic needs and uses with the need for a good water quality program? For example, temperature is a physical characteristic of water. Fish such as bass, and most people prefer warm water to swim in. However, warm water is not very tasty to drink. And, cool water fish species such as trout may not reproduce and thrive in warm water.

The Clean Water Act (The Federal Water Pollution Control Act of 1972 as ammended in 1977) grants the Environmental Protection Agency (EPA) authority to regulate surface and groundwater quality. The EPA is responsible for developing national standards for clean water. In Washington, the Washington Department of Ecology (Ecology) carries out the federal and state regulations to protect water quality. Ecology issues permits and develops plans for controlling pollution. Washington is one of the few states where the same state agency protects both water quality and water quantity. Ecology's goal is to ensure a clean supply of water for the citizens of Washington. The antidegradation policy embodied within the state laws and regulations is a three-level approach to water quality protection.

- The first level of protection prevents discharges of contaminants to any water body. Exceptions are granted only when a) an operation can show that the discharging activity is using all known and reasonable technology for cleaning up the discharge (AKART), and b) that the discharge is in the overriding interest of the public.

- The second level of protection allows no degradation of a body of water that would eliminate an existing beneficial use.

- The third level provides additional protection for waters designated as Outstanding Resource Waters. In these waters no degradation may take place even if the existing water quality is not particularly good.

Several beneficial uses may exist for one body of water. Washington's surface and groundwater standards protect water supplies for the beneficial use that requires the highest quality water. These standards are consistent with public health and public enjoyment of Washington's waters. The standards also ensure the propagation and protection of fish, shellfish and wildlife.

Why Does Water Quality Vary?

Water has unique characteristics that can determine its quality.

Physically, water exists in three forms: solid ice, liquid water and gaseous water vapor. Liquid water put under pressure does not compress significantly. However, as it expands when frozen, it may cause water supply pipes to break. Water always flows downhill, from a high point to a lower point. This applies to surface and groundwater. Water molecules evaporate into water vapor from liquid water. This process is called vaporization. Water also may change directly from solid ice to a vapor. This is a unique process called sublimation. As water changes into vapor, it leaves behind any dissolved or suspended solids. These materials then concentrate in the remaining water. This is only a concern if too much dissolved or solid material becomes concentrated in the water left behind. That water then may become degraded to a point where it cannot support the necessary beneficial uses.

Chemically, water is a deceptively simple substance. Two atoms of hydrogen and one of oxygen combine to form the molecule H_20. In its pure form water is a colorless, tasteless liquid. It is neither acidic nor alkaline. Water molecules do not split to form charged particles called ions. Yet water behaves as if it were an ion. Water has a positive charge on one end or pole of the molecule and a negative charge on the other. Because of this dipolar behavior, water is the universal solvent.

Water gathers a little of everything it contacts. Sea water contains nearly every substance known. Fresh water also may contain many substances, but in smaller amounts. In addition to dissolved material, water also carries many suspended particles. Naturally occurring dissolved chemicals and suspended particles make pure water a rare commodity in nature.

Pure water, though safe, is not very good for drinking. It does not taste good to most people. Many of the naturally dissolved minerals and salts give water its flavor and are necessary for life and health. In fact good drinking water has about 200 ppm of these minerals and salts. However, not everything dissolved in water is healthful for people. For example, water also can carry heavy metals like lead and cadmium, or other chemicals. These may be natural or manufactured contaminants.

Biologically, water is the cornerstone of life. Each person is made up of about two-thirds water. Adults require at least two quarts of water in some form each day to sustain life. Losing just 10% of the body's water would be fatal. Nearly all the water in the body is exchanged for new about every four months. However, not all contaminants swallowed with the daily intake of water are excreted, and some may accumulate in the body.

Wherever water occurs, except in the deepest aquifers, life exists. Most living organisms are harmless. However, harmful organisms such as typhoid and cholera disease organisms and viruses can exist in water. These pathogens, whether naturally occurring or the result of human activities, are also contaminants. While "pure" water is unnatural, clean water is cherished. The news media emphasizes water quality, and most people now regard water quality as important in their own minds, However, disagreements often occur over what constitutes good quality water. The following information will help you sort out what is safe and useful water.

Regulatory Definitions of Water Quality

Drinking Water. Drinking water is the most stringent classification for water. Ecology regulates all groundwater, except when naturally contaminated, as if it were drinking water. Groundwater is the source of drinking water for nearly two-thirds of Washington's residents.

Drinking Water

Good drinking water has none of the following characteristics:

- astringent taste caused by sulfate
- metallic taste caused by iron
- salty taste caused by impurities or softener
- soda taste caused by dissolved salts
- medicinal taste caused by chlorination
- foul/putrid odor caused by organic matter
- rotten egg odor caused by hydrogen sulfide
- rotten egg odor in hot water caused by a Magnesium rod in water heater

(From OSU Bulletin No. FG 77)

Good drinking water is virtually colorless and odorless. It should taste good (see insert). Good drinking water also is low in dissolved solids, metals, and salts. It should be low in suspended solids and microorganisms. And last, but not least, drinking water should be safe from pesticides, organic toxins and radioactive contaminants.

Standards or criteria define the maximum allowable level of any contaminant. Table 1 lists the primary contaminant standards for drinking water except for carcinogens. Carcinogen standards are listed in Table 2. These primary standards, which regulate contaminants that pose serious health risks, are enforceable by EPA and Ecology. The limits for carcinogens are based on the 1:1,000,000 rule. That rule assigns an estimated risk factor of no more than one additional cancer in one million people who drank the maximum contaminant level for a lifetime. Table 3 lists secondary standards for drinking water. Secondary standards set desirable levels for nuisance contaminants that affect the aesthetics (taste, smell, etc.) of water. These standards are not enforceable.

Table 1. Primary contaminant standards for groundwater and drinking water. (Adapted from Chapters 248-54-175 and 173-200-040 WAC and WSU bulletin SP 53-414)

Primary Contaminant	Criterion		Primary Contaminant	Criterion
Inorganics			**Microbiological**	
Arsenic	0.05	mg/l	Total Coliform Bacteria	1.0 bacteria/100ml
Barium	1.0	mg/l		
Cadmium	0.01	mg/l	**Radionuclides**	

Chromium	0.05	mg/l	Gross Alpha Particle Activity	15 pCi/l
Lead	0.05	mg/l	Gross Beta Particle Activity	
Mercury	0.002	mg/l	Gross Beta Activity	50 pCi/l
Selenium	0.01	mg/l	Tritium	20,000 pCi/l
Silver	0.05	mg/l	Strontium-90	8 pCi/l
Fluoride	4.0	mg/l	Radium 226 & 228	5 pCi/l
Nitrate (as Nitrogen)	10.0	mg/l	Radium -226	3 pCi/l
Organic			**Turbidity**	1 turbidity unit
Endrin	0.0002	mg/l		
Methoxychlor	0.1	mg/l		
1,1,1-Trichloroethane	0.2	mg/l		
2-4 D	0.1	mg/l		
2,4,5-TP Silvex	0.01	mg/l		
mg/l = milligrams per liter which is equivalent to parts per milliion pCi/l = picocuries per liter which is equivalent to 1 trillionth of a curie per liter of water.				

Table 2. Carcinogenic contaminant standards for groundwater and drinking water.
(Adapted from Chapter 173-200-040 WAC)

Contaminant	Criterion	Contaminant	Criterion
	micrograms/ liter (µg/l)		micrograms/ liter (µg/l)
Acrylamide	0.02	Ethyl acrylate	2.0
Acrylonitrile	0.07	Ethylene dibromide	0.001
Aldrin	0.005	Ethylene thiourea	2.0
Aniline	14.0	Folpet	20.0
Aramite	3.0	Furazolidone	0.02
Arsenic	0.05	Furium	0.002
Azobenzene	0.7	Furmecyclox	3.0
Benzene	1.0	Heptachlor	0.02
Benzidine	0.0004	Heptachlor Epoxide	0.009
Benzo(a)pyrene	0.008	Hexachlorobenzene	0.05

Benzotrichloride	0.007	Hexachlorocyclohexane (alpha)	0.001
Benzyl chloride	0.5	Hexachlorocyclohexane (technical)	0.05
Bis (chloroethyl) enter	0.07	Hexachlorodibenzo-p-dioxin, mix	0.00001
Bis (chloromethyl) ether	0.0004	Hydrazine/Hydrazine sulfate	0.03
Bis (2-ethylhexyl) phthalate	6.0	Lindane	0.06
Bromodichloromethane	0.3	2 Methoxy-5-nitroaniline	2.0
Bromoform	5.0	2 Methylaniline	0.2
Carbazole	5.0	2 Methylaniline hydrochloride	0.5
Carbon tetrachloride	0.3	4,4' Methylene bis (N,N'-dimethyl) aniline	2.0
Chlordane	0.06	Methylene chloride (dichloromethane)	5.0
Chlorodibromomethane	0.5	Mirex	0.05
Chloroform	7.0	Nitrofurazone	0.06
4 Chloro-2-methyl aniline	0.1	N-Nitrosodiethanolamine	0.03
4 Chloro-2-methyl analine hydrochloride	0.2	N-Nitrosodiethylamine	0.0005
o-Chloronitrobenzene	3.0	N-Nitrosodimethylamine	0.002
p-Chloronitrobenzene	5.0	N-Nitrosodiphenylamine	17.0
Chlorthalonil	30.0	N-Nitroso-di-n-propylamine	0.01
Diallate	1.0	N-Nitrosopyrrolidine	0.04
DDT (includes DDE and DDD	0.3	N-Nitroso-di-n-butylamine	0.02
1,2 Dibromoethane	0.001	N-Nitroso-N-methylethylamine	0.004
1,4 Dichlorobenzene	4.0	PAH	0.01
3,3' Dichlorobenzidine	0.2	PBBs	0.01
1,1 Dichloroethane	1.0	PCBs	0.01
1,2 Dichloroethane (ethylene chloride)	0.5	o-Phenylenediamine	0.005
1,2 Dichloropropane	0.6	Propylene oxide	0.01

1,3 Dichloropropene	0.2	2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.0000006
Dichlorvos	0.3	Tetrachloroethylene (perchloroethylene)	0.8
Dieldrin	0.005	para, alpha, alpha, alpha-Tetrachlorotoluene	0.004
3,3' Dimethoxybenzidine	6.0	2,4 Toluenediamine	0.002
3,3 Dimethylbenzidine	0.007	o-Toluidine	0.2
1,2 Dimethylhydrazine	60.0	Toxaphene	0.08
2,4 Dinitrotoluene	0.1	Trichloroethylene	3.0
2,6 Dinitrotoluene	0.1	2,4,6-Trichlorophenol	4.0
1,4 Dioxane	7.0	Trimethyl phosphate	2.0
1,2 Diphenylhydrazine	0.09	Vinyl chloride	0.02
Direct Black 38	0.009		
Direct Blue 6	0.009		
Direct Brown 95	0.009		
Epichlorohydrin	8.0		
µg/l = micrograms per liter, which is equivalent to parts per billion.			

Table 3. Secondary standards for drinking water. (Adapted from Chapters 248-54-175 WAC and 173-200-040 WAC and WSU bulletin SP 53-414).

Secondary Contaminants	Criterion		Secondary Contaminants	Criterion	
Copper	1.0	mg/l	Total Dissolved Solids	500.0	mg/l
Iron	0.3	mg/l	Foaming Agents	0.5	mg/l
Manganese	0.05	mg/l	pH	6.5-8.5	
Zinc	5.0	mg/l	Corrosivity	noncorrosive	
Chloride	250.0	mg/l	Color	15 color units	
Sulfate	250.0	mg/l	Odor	3 threshold odor units	

Swimmable Water is clean enough for humans to swim in safely. The primary measure of swimming water quality is numbers of fecal coliform bacteria. Fecal coliform bacteria occur naturally in the intestines of mammals. The bacteria are easily detected in water tests. High numbers of fecal coliform bacteria also indicate that pathogens may be present. Presence of any fecal coliform bacteria offer some risk to those swimming in or accidentally swallowing the water. However, if the water body contains fewer than 100 fecal coliform bacteria per 100 ml of water, it provides an appropriate level of protection (reduced risk).

Water For Fish and Wildlife. Surface waters in Washington are classified into six classes. These are Class AA, A and B marine waters and freshwater streams, Class C marine waters, wetlands, and lakes. Class AA waters are pristine waters that may be fresh or marine water. While class AA waters are possible throughout Washington, most occur in areas less affected by civilization. Class A, B and C waters each support fewer beneficial uses, in order. Class B waters no longer support recreational uses such as swimming, or spawning of fish. Fish or shellfish must be harvestable without having adverse effects on human health. This includes fresh and marine waters. (Table 4).

Table 4. Water quality requirements for surface waters in Washington. (Adapted from Chapter 173-201 WAC)

Class & Type of Water	Bacteria	D.O.	Maximum Temp.	pH	Turbidity
	organisms/100ml	mg/l	°C		NTU[a]
AA - Fresh	50	9.5	16	6.5-8.5	5(10%)
AA - Marine	14	7.0	13	7.0-8.5	5(10%)
A - Fresh	100	8.0	18	6.5-8.5	5(10%)
A - Marine	14	6.0	16	7.0-8.5	5(10%)
B - Fresh	200	6.5	21	6.5-8.5	10(20%)
B - Marine	100	5.0	19	7.0-8.5	10(20%)
C - Marine	200	4.0	22	6.5-9.0	10(20%)
Lake - Fresh	50	b	b	b	5

a. Nephelometric Turbidity Units (NTU). Allowable number over background if turbidity is 50 NTU or less and percent (in parens) over background if 50 NTU or more.
b. No change or decrease from natural conditions.

Class C waters are polluted marine bays. Class C marine waters need only support the passage of salmon and other fishes and aquatic species.

Nonregulatory Definitions of Water Quality

Water has other uses besides drinking, swimming and fishing. Home water uses include cooking, bathing and laundry. Outside the home, water uses include watering home and garden plants, irrigating crops, food processing, industry, fish rearing and power generation. Some beneficial uses may require certain water quality measures to be purer than drinking water standards.

Bathing and Laundry. The primary water quality problem for bathing and laundry is hardness. Dissolved salts of calcium and magnesium cause hard water. Usually bicarbonate salts, these may be chloride, sulfate or nitrate salts.

Water hardness is measured in grains. One grain of calcium bicarbonate equals 17.1 ppm by weight. The American Society of Agricultural Engineer's water hardness classification system has four classes:

Class	Grains per gallon
Soft	0 to 3.5
Moderate	3.5 to 7
Hard	7 to 10.5
Very Hard	more than 10.5

Hard water reduces the cleaning efficiency of both soap and detergents. It reacts with soap to form curds and soap scum on bathroom fixtures. Hard water reacts with detergent in laundry or dishwashing to form solids that precipitate out of solution. These solids collect between the fibers in clothing, making them stiff. Collected solids can wear clothes out faster. Hard water also may discolor clothes. Hard water solids also collect in washing machines and water heaters, causing excessive wear.

The addition of phosphate to detergents prevents solids from forming. Unfortunately, phosphate returning to surface water through sewers and septic systems may degrade lake and stream quality.

Phosphate is the limiting factor in plant growth in most lakes. Enough nitrogen usually is present in lakes for plant growth. Excess phosphate in lakes promotes algal blooms. One pound of phosphate may promote the growth of half a ton of algae. Algal blooms make the water murky. When light cannot reach plants at the bottom of the lake, the plants die. Bacteria in the lake digest the dead plants, but use up oxygen in the water in the process. Without oxygen, flsh die because they cannot breathe. More bacteria consume more oxygen and the lake dies. This process is known as eutrophication.

Phosphates are difflcult to remove at waste treatment plants. Use nonphosphate detergents whenever possible.

Water softeners treat hard water. Water softeners exchange sodium for the salts of calcium and magnesium. Home softened water prevents many of the household problems mentioned earlier. However, people who have sodium restricted diets should use unsoftened water for drinking and cooking.

Irrigated Agriculture. Water is one of the most limiting factors in crop production in Washington. Most precipitation falls in the period from October through April. Even on the normally wet, west side of Washington some crops need irrigation in the summer. In eastern Washington growers irrigate nearly 2,000,000 acres of cropland. Crops have different requirements for the quality of irrigation water applied (Table 5).

Table 5. Water quality guidelines for Irrigation water. (adapted from Pettygrove and Asaro,1985. "Irrigation With Reclaimed Municipal Wastewater - A Guidance Manual.
Lewis Publishers, Chelsea, MI)

		Degree of Restriction on Use		
Potential Irrigation Problem	**Units**	**Slight to None**	**Moderate**	**Severe**
Salinity (affects crop water availability)				
EG_w[a]	dS/m or mmho/cm	<0.7	0.7 - 3.0	>3.0
TDS	mg/L	<450	450-2000	>2000

Permeability (affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)[b,c]				
SAR = 0-3	and EC_w =	>0.7	0.7 - 0.2	<0.2
= 3-6	=	>1.2	1.2 - 0.3	<0.3
= 6-12	=	>1.9	1.9 - 0.5	<0.5
= 12-20	=	>2.9	2.9 - 1.3	<1.3
= 20-40	=	>5.0	5.0 - 2.9	<2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na)[d,e]				
surface irrigation	SAR	<3	3 - 9	>9
sprinkler irrigation	mg/L	<70	>70	
Chloride (Cl)[d,e]				
surface irrigation	mg/L	<140	140 - 350	>350
sprinkler. irrigation	mg/L	<100	>100	
Boron (B)	mg/L	<0.7	0.7 - 3.0	>3.0
Miscellaneous effects (afftects susceptible crops)				
Nitrogen (Total-N)[f]	mg/L	<5	5 - 30	>30
Bicarbonate (HCO_3) (overhead sprinkling only)	mg/L	<90	90-500	>500
pH		Normal range 6.5 - 8.4		
Residual chlorine (overhead sprinkling only)	mg/L	<1.0	1.0 - 5.0	>5.0

a. EC_w means electrical conductivity of the irrigation water, reported in mmho/cm or dS/m. TDS means total dissolved solids, reported in mg/L.
b. SAR means sodium adsorption ration. At a given SAR, infiltration rate increases as salinity (EC_w) increases. Evaluate the potential permeablility problem by SAR and EC_w in combination.
c. For wastewaters, it is recommended that the SAR be adjusted to include a more correct estimate of calcium in the soil water following an irrigation.
d. Most tree crops and woody ornamentals are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive.
e. With overhead sprinkler irrigation and low humidity (<30%), sodium or chloride greater than 70 or 100 mg/L, respectively, have resulted in excessive leaf absorption and crop damage to sensitive crops.
f. Total nitrogen should include nitrate-nitrogen, ammonia-nitrogen, and organic-nitrogen. Although forms of nitrogen in wastewater vary, the plant responds to the total nitrogen.

Salinity is the most important factor in irrigation water. Fortunately, most surface water and ground water in Washington used for irrigation is low in salt. However, evaporation causes even the low levels of salts applied with the water to concentrate in the root zone. When this occurs crop damage may result.

It takes extra water to flush excess salts through the soil profile and maintain a favorable salt balance in the crop root zone. Excess salts, nutrients and even pesticides may collect in shallow, unprotected aquifers as well as in irrigation return flows to surface water. Test these water sources before using them on crops. Carefully manage contaminated supplies to prevent further accumulation of salts and agricultural chemicals.

Food Processing. The minimum water quality for food processors is the same as that for drinking water. Food processors, however, may require stricter standards for certain elements to prevent discoloring, or an off-taste. For example, chlorine and metals may cause problems in the processing of some products. Food processors look for water supplies that contain even less of these chemicals than drinking standards allow.

Balancing Water Quality Concerns

To begin balancing water quality needs, determine what is known about the water body or aquifer. Ecology maintains the largest data base of water quality information in Washington. Even so, some information is not readily available. Bay Watchers and Beach Watchers, WSU Cooperative Extension programs, along with Stream Watch, an EPA program, and Adopt-a-Stream are citizen monitoring efforts that can help you learn how to gather water quality information. All public water supply systems test their water regularly. Any water system that supplies water to two or more hookups in Washington is a public system. Information on public water supply is available directly from your local water supplier or from the Department of Health.

The next step is to define the beneficial uses of the water body. For example, will the water body supply drinking water, swimming or irrigation water? Compare the water quality information available to the standards and criteria for those uses. Is the water quality acceptable?

Whether the water quality is acceptable or not, local organizations can often lead the way in protecting or restoring the water resource. Your community may have a lake association or other group already organized. Or you may want to organize a group. Obtain additional help from Ecology and your local Cooperative Extension, Conservation District, or Soil Conservation District office. County and city engineers, public health officers and elected officials can also help you protect or restore the quality of your water body or aquifer.

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