TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

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Water Quality Criteria

This note should be used as a guide line in determining the suitability of water supplies for their intended purpose. This would include ground water developed by wells or obtained from springs as well as diverted surface flows.

Also included in this note is information that can be used to interpret the results obtained using the Water Ecology Field Kits. Each Area Office has a field kit.

Water for Human Consumption and Use

The U.S. Public Health Service (1962) has recommended the following standards for water used for drinking and culinary purposes on interstate carriers:

Constitutuent	Recommended Maximum Concentration (ppm or mg/l)
Iron (Fe)	0.3
Manganese (Mn)	.05
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride	.8-1.7
Dissolved Solids	*500

* 1,000 ppm or mg/l where water of better quality is not available.

Hardness in water is caused principally by calcium and magnesium in solution. It is classified as follows:

Dissolved Solids (ppm or mg/l)	Classification
75 or less	Soft
75 to 150	Moderately Hard
150 to 300	Hard
300 or more	Very Hard

Water for Livestock

Studies at the Wyoming Agricultural Experiment Station have resulted in the following classification of the suitability of water for stock (Beath and others, 1953):

Dissolved Solids (ppm or mg/l)	Classification
1,000 or less	Good
1,000 to 3,000	Fair (usable)
3,000 to 5,000	Poor (usable)
5,000 to 7,000	Very Poor (questionable)
7,000 or more	Not advisable

Water for Irrigation

The most significant properties that affect the suitability of water for irrigation are the dissolved-solids content (salinity hazard), the percent sodium, and the sodium concentration relative to the calcium and magnesium concentrations (sodium-adsorption ratio). The salinity hazard of a water having specific conductance is as follows:

Conductance (µmhos/cm)	Salinity Hazard Classification
250 or less	Low
250 to 750	Medium
750 to 2,250	High
2,250 or more	Very High

(U.S. Salinity Lab. Staff 1954, p. 80)

Water in which the concentration of sodium is appreciably greater than 50 percent of the total cations is of limited suitability for irrigation, and the limitations increase as the sodium percentage increases.

The sodium-adsorption ratio is a refinement of the percent sodium criterion, and is more significant in the evaluation of the suitability of water for irrigation. The following approximate relation between sodium-adsorption ratio (SAR) and the sodium (alkali) hazard in water of high sodium content for irrigation has been established by the U.S. Salinity Laboratory Staff (1954, fig. 25).

SAR (Approximately)	Sodium (Alkali) Hazard
0 - 10	Low
10 - 18	Medium
18 - 26	High
26 or more	Very High

WATER QUALITY

Hach Company Water Ecology Kit Model 36B

One of the important variables to measure in Soil Conservation Service work in the evaluation of the environment is water quality. To assist in this measurement each of the area offices have a small water testing kit.

These kits are the Hach Company Water Ecology Kit Model 36B, and have the capability of making six basic tests. These are acidity, alkalinity, carbon dioxide, dissolved oxygen, hardness, and pH. A thermometer should be added to each kit. Replacement chemicals are available through Ted Gilbert, Hydraulic Engineer and Water Quality Coordinator, Casper. Any questions regarding water quality should also be directed to him.

Following is a discussion of each of the tests the kits are capable of doing.

Acidity: Acidity cannot be a direct or specific pollutant, for it is merely a measure of the effects of a combination of substances and conditions in water. It may be defined as the power of a water to neutralize hydroxyl ions and is expressed in terms of the calcium carbonate equivalent of the hydroxyl ions neutralized.[1/]

The kits measure both free and total acidity as calcium carbonate equivalent.

Free acidity refers to free acids such as HCl or gases like SO_2 that combine with water to form acid. Total acidity is the net effect of hydrolysis of certain cations in solution as well as the free-acid content. The kits use a titration method to determine both free and total acidity. The results are given in grains per gallon (gpg) as calcium carbonate ($CaCO_3$).

Results are commonly referred to as milligrams per liter (mg/l). This is arrived at by multiplying gpg by 17.1. The higher the mg/l the more acidic the water.

Effects Upon Beneficial Uses

a. Irrigation Water - No limiting values for acidity in irrigation water have been established. Generally, moderate acidity in irrigation water is beneficial to alkali soils as it helps to neutralize carbonates and prevent the precipitation of calcium. In some cases, acidification of soils containing certain elements may render these elements soluble. These in turn may be harmful to plant growth and in some cases may even cause death to the plants.

1/ Water Quality Criteria, Publication 3-A, 2nd Edition by McKee and Wolf (1963) (Reprint January, 1973) California State Water Resources Control Board, p. 125.

b. Fish and Other Aquatic Life - Acidities of natural streams vary widely depending upon the soil and vegetation of the watershed. Brook trout have been found to survive comfortably in streams with varying acidities; however, in all cases the acidity was due to organic acids of natural origin. Mineral-acid pollution can be quite detrimental to fish mainly due to higher concentrations of acids.

c. Domestic Water Supplies - The U.S. Public Health Drinking Water Standards do not specify limiting values for acidity. Although there are no limiting values, waters with excessive amounts of acidity promote the solution of zinc from galvanized pipes and other equipment, possibly to a degree harmful to the subsequent uses of the water.

Alkalinity: Like acidity, alkalinity is not a specific polluting substance, but rather a combined effect of several substances and conditions. It is a measure of the power of a solution to neutralize hydrogen ions and it is expressed in terms of an equivalent amount of calcium carbonate. Alkalinity is caused by the presence of carbonates, bicarbonates, hydroxides, and to a lesser extent by borates, silicates, phosphates, and organic substances.[2/]

The kits measure both phenolphthalein and total alkalinity. Phenolphthalein alkalinity is a measure of so-called caustic alkalinity. As in the acidity tests, the kits use a titration method to determine alkalinity. The results are given in gpg as $CaCO_3$ and the conversion to the more commonly used mg/l is the same as described under acidity analysis.

Effects Upon Beneficial Uses

a. Irrigation Water - Excessive alkalinity is detrimental in that it adds to the total salinity and is frequently accompanied by high pH values. In some instances it may indirectly increase the relative proportion of sodium in the soil water. Calcium and magnesium in the proper proportions maintain soil in good condition of tilth and structure, while the opposite is true when sodium predominates. In most normal soils in arid and semiarid regions, calcium and magnesium are the principal cations held by the soil in replaceable or exchangeable form, with sodium making up a small percentage (3 to 7%). Such soils, when not misused, represent a favorable physical condition for root and water penetration. An increase in the exchangeable sodium percentage to as much as 12 to 15 percent causes the granular soil structure to begin to break down when the soil is moistened. Various changes take place resulting in the sealing of the soil pores and a decrease in soil permeability. The increase in exchangeable sodium usually accompanies the use of water containing a high concentration of bicarbonate ions. As an

2/ Ibid., p. 128.

example, when bicarbonate concentrations are high, calcium and magnesium ions that are in solution precipitate as carbonates in the soil water as the water becomes more concentrated through evaporation and transpiration. As the calcium and magnesium ions decrease in concentration, the percentage of sodium increases with the results being soil and plant damage. The action of the sodium with exchangeable ions is known as the sodium hazard. The sodium hazard is best expressed in terms of the Sodium Absorption Ratio or SAR. SAR is a ratio for soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil. The higher the SAR, the greater the sodium hazard.

Alkalinity may also lead to chlorosis in plants because it causes the iron to precipitate as a hydroxide. Hydroxyl ions react with available iron in the soil water and make the iron unavailable to plants. Such deficiencies induce chlorosis and further plant damage.

Usually, alkalinity must exceed 600 mg/l before such effects are noticed.[3/]

b. Stock and Wildlife Watering - High alkalinities in water are reported to have been detrimental to stock. When the caustic (phenolphthalein) alkalinity reaches 50 mg/l, trouble with diarrhea in chickens begins, and at a total alkalinity of 170 mg/l animals were reported to develop diarrhea[4/]

c. Fish and Other Aquatic Life - Alkalinity is important for fish and other aquatic life in fresh water systems because it buffers pH changes that occur naturally as a result of photosynthetic activity of the chlorophyll bearing vegetation. Components of alkalinity such as carbonate and bicarbonate will complex some toxic heavy metals and reduce their toxicity markedly. The limit of 20 mg/l or more as $CaCO_3$ for freshwater aquatic life except where natural concentrations are less has been established as criteria for alkalinity.[5/]

d. Domestic Water Supplies - In itself, alkalinity is not considered to be detrimental to humans, but it is generally associated with high pH values, hardness, and excessive dissolved solids, all of which may be deleterious. Naturally occurring maximum levels up to approximately 400 mg/l as $CaCO_3$ are not considered a problem to human health.[6/]

Carbon Dioxide: This is a colorless, odorless, non-combustible gas that is highly soluble in water. The source of free carbon dioxide (CO_2)

3/ Quality Criteria for Water, U.S. Environmental Protection Agency, Washington, D.C., July 1976, p. 8.
4/ See footnote 1, p. 129.
5/ See footnote 3, p. 7.
6/ Ibid.

in warm, slow moving water is seldom that from air. It usually is the result of aerobic or anaerobic decomposition of organic matter. In colder, more cascading waters much of the free CO_2 could be coming from the air. Dissolved carbon dioxide reacts with water to form carbonic acid.

The kit measures carbon dioxide as mg/l of CO_2.

Effects Upon Beneficial Uses

a. Fish and Other Aquatic Life - The concentrations of dissolved CO_2 and carbonic acid in water have a marked effect on fish. In their migration, fish tend to avoid concentrations of 1.0 to 6.0 mg/l CO_2. It is doubtful if any freshwater fishes can continue to live throughout the year in water with an average CO_2 content as high as 12 mg/l, and concentrations of 20 mg/l will quickly prove fatal to the more sensitive species. Lethal limit for trout has been reported as 45 mg/l.[7] In U.S. waters that support good fish fauna, 95 percent have less than 5.0 mg/l of CO_2.[8]

b. Domestic Water Supplies - Free carbon dioxide in domestic water is of significance only in connection with corrosion and aggressiveness of water. In fact, many soft drinks and beer are highly charged with CO_2. High concentrations in domestic water systems are detrimental in that they accelerate the corrosion of iron and steel, and promote the solution of lead.

Dissolved Oxygen: Dissolved Oxygen (DO) in natural waters cannot rightfully be designated as a primary pollutant. However, it is in the category of a corollary pollutant because excessive dissolved oxygen arising from algal growths may adversely or unreasonably affect such waters for one or more beneficial uses. Inadequate DO in surface waters will contribute to an unfavorable environment for fish and other aquatic life, and the absence of dissolved oxygen may give rise to odoriferous products of anaerobic decomposition.

The kit measures dissolved oxygen as mg/l of DO.

Effects Upon Beneficial Uses

a. Fish and Other Aquatic Life - Water should contain sufficient dissolved oxygen to maintain aerobic conditions. A minimum concentration of DO to maintain good fish population is 5.0 mg/l.[9]

The Wyoming Department of Environmental Quality Water Quality Rules and Regulations, in Chapter 1, states that "in all Class I and II waters, wastes attributable to or influenced by the

7/ See footnote 1, p. 156.
8/ Ibid.
9/ See footnote 3, p. 123.

activities of man shall not be present in amounts which will result in death or injury to existing aquatic life or which will result in a dissolved oxygen content of less than 6 mg/l at any time." The same rules and regulations state that in Class III streams, the DO content cannot be less than 5.0 mg/l at any time.

b. Domestic Water Supplies - The presence of DO is seldom considered to be deleterious, as it has no adverse physiological effect and actually increases the palatability of water. It is detrimental in the corrosion of metal pipes and efforts are sometimes made to eliminate or decrease the DO content of the water to inhibit corrosion.

Hardness: Water hardness is caused by the polyvalent metallic ions dissolved in water. In fresh waters these are principally calcium and magnesium, although other metals such as iron, strontium and manganese contribute to the extent that appreciable concentrations are present. Hardness commonly is reported as an equivalent concentration of $CaCO_3$.

A commonly used classification of hardness in mg/l of $CaCO_3$ is as follows:10/

0 - 75 mg/l -- soft
75 - 150 mg/l -- moderately hard
150 - 300 mg/l -- hard
300 - Up mg/l -- very hard

The kit measures hardness in gpg as $CaCO_3$ and can be converted to mg/l by multiplying by 17.1.

Effects Upon Beneficial Use

a. Irrigation Water - Hardness is not a determination of concern in the use of water for irrigation. The concentrations of the cations, calcium and magnesium, which comprise hardness, are important in determining the exchangeable sodium in a given water. (See Alkalinity for discussion on exchangeable sodium).

b. Fish and Other Aquatic Life - Effects of hardness on freshwater fish and other aquatic life appear to be related to the ions causing the hardness rather than hardness.

c. Domestic Water Supplies - Hardness is a useful parameter to characterize the total dissolved solids present. Because hardness concentrations in water have not been proven health related, the final level achieved principally is a function of economics. However, a negative correlation has been found between hardness in the drinking water of an area and death

10/ Ibid., p. 75.

rates from degenerative cardiovascular disease, i.e., softer water was associated with higher death rates. Generally speaking, hardness over 100 mg/l becomes increasingly inconvenient, for it results in a waste of soap and the incrustation of utensils. Hardness of water of good quality should not exceed 270 mg/l.[11]

pH: pH is a measure of the hydrogen ion activity in a water sample. The principal system regulating pH in natural waters is the carbonate system which is composed of carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ions ($CO_3^=$).

pH is an important factor in the chemical and biological systems of natural waters. The degree of dissociation of weak acids or bases is affected by changes in pH. This effect is important because the toxicity of many compounds is affected by the degree of dissociation; and since the undissociated compounds are frequently more toxic than the ionic forms, pH may be a highly significant factor in determining limiting or threshold concentrations. An example is hydrogen cyanide (HCN). Cyanide toxicity to fish increases as the pH is lowered because the chemical equilibrium is shifted toward an increased concentration of HCN. Conversely, rapid increases in pH can cause increased ammonia (NH_3) concentrations which are also toxic. NH_3 has been shown to be 10 times as toxic at pH 8.0 as at pH 7.0.[12]

The pH of a water does not indicate ability to neutralize additions of acids or bases without appreciable change. The concentration of weakly dissociated acids and bases markedly affects the pH value and the ease with which it can be altered. For this reason, pH should not be confused with acidity and alkalinity. The presence of carbonates, phosphates, borates, and similar ions give water a buffering power so that the addition of an acid or base is less likely to be deleterious.

Effects Upon Beneficial Use

a. Irrigation - The optimum pH for irrigation water depends on the type of crops to be grown and the physical and chemical properties of the soil. In Wyoming where alkaline soils predominate, waters with low pH values are desirable. The range would be from about 5.0 to 9.0.

b. Fish and Other Aquatic Life - The recommended range for freshwater aquatic life is for pH to be between 6.5 and 9.0.[13]

c. Domestic Water Supplies - The pH of a raw-water source for domestic water is important in that it affects taste, corrosivity, efficiency of chlorination, treatment processes such as

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11/ See footnote 1, p. 195.
12/ See footnote 3, p. 178.
13/ Ibid.

coagulation, and industrial applications. The USPHS Drinking Water Standard of 1962 sets no limits for pH in domestic waters. However, it has been recommended by EPA that domestic water supplies have a pH range of from 5.0 to 9.0.[14/]

14/ Ibid.

SUMMARY

TEST	USE CRITERIA			
	DOMESTIC	IRRIGATION	STOCK & WILDLIFE	FISH AND OTHER AQUATIC LIFE
ACIDITY	NE	NE	NE	NE
ALKALINITY	Less than 400 mg/l $CaCO_3$	Less than 600 mg/l $CaCO_3$	Less than 170 mg/l $CaCO_3$	More than 20 mg/l $CaCO_3$
CARBON DIOXIDE	NE	NE	NE	Less than 5 mg/l CO_2
DISSOLVED OXYGEN	NE	NE	NE	More than 5 mg/l DO
HARDNESS	Less than 270 mg/l $CaCO_3$	NE	NE	NE
pH	5.0 to 9.0	5.0 to 9.0	5.0 to 9.0	6.5 to 9.0

NOTE: NE = No Criteria Established

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