

Table 1....Mineral Analyses Typifying Composition of Waters Available and Used Industrially in the USA

Substance	Unit	Location or Area ^{a,b}								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Silica.....	SiO ₂	2	6	12	37	10	9	22	14	.....
Iron.....	Fe	0	0	0	1	0	0	0	2	.....
Calcium.....	Ca	6	5	36	62	92	96	3,155	400	.....
Magnesium.....	Mg	1	2	8	18	34	27	2	46	1,300
Sodium.....	Na	2	6	7	44	8,183	215	78	11,000	.....
Potassium.....	K	1	1	1	1	18	10	3	400	.....
Bicarbonate.....	HCO ₃	14	13	119	202	339	334	549	210	150
Sulfate.....	SO ₄	10	2	22	135	84	121	11,389	2,700	.....
Chloride.....	Cl	2	10	13	13	10,280	22	117	19,000	.....
Nitrate.....	NO ₃	1	.....	0	2	13	0	1	3	.....
Dissolved Solids.....		31	66	165	426	434	983	564	948	35,000
Carbonate Hardness.....	CaCO ₃	12	11	98	165	287	274	8,172	125	.....
Non-Carbonate Hardness.....	CaSO ₄	5	7	18	40	58	54	0.295	5,900	.....

^a All values are parts per million of the unit cited to nearest whole number (see Reference 5).

^b Numbers indicate location or area as follows:

- (1) Catskill supply—New York City
- (2) Swamp Water (Colored) Black Creek, Middleburg, Florida
- (3) Niagara River (Filtered) Niagara Falls, New York
- (4) Missouri River (Untreated) Average
- (5) Well Water—Public Supply—Dayton, Ohio—30-60 ft
- (6) Well Water—Maywood, Illinois—2000 ft
- (7) Well Water—Smithfield, Va.—320 ft
- (8) Well Water—Rosenwell, N. Mexico
- (9) Ocean Water—Average

of dissolved gases such as carbon dioxide, oxygen, and sulfur dioxide, that tend to make them corrosive.

Dissolved gases are the main factors affecting condensate corrosiveness, but they may also be present in water containing mineral impurities to an extent that will make the water corrosive.

Mineralized Waters

All the waters found in streams, wells, lakes, and the ocean are mineralized. The same is true of all municipal supplies even though they may have been treated. For a given area, ground waters are likely to be more highly mineralized than are surface waters. Conversely, surface waters are more likely to be contaminated with municipal sewage and trade wastes. Virtually all mineralized waters also contain biological organisms.

Mineralogical Characteristics. The character and amount of extraneous inorganic materials—including deleterious gases—dissolved and suspended therein, describe the mineralogical characteristics of any water. Revealing such information is the function of a mineralogical chemical analysis.

The analyses in Table 1 disclose the composition of the public water supplies used by about 45 percent of the total population of the cities in the United States, having more than 20,000 inhabitants.^a

All values recorded are in terms of parts per million.^a

^a Parts per million are hereinafter abbreviated ppm. A part per million signifies a unit weight of material per million unit weights of the solution.

Table 2....Conversion Factors for Water Analyses

To Convert	Into	Multiply by
Grains per U. S. gallon.....	ppm	17
Grains per Imperial gallon.....	ppm	14½
Grams per liter.....	ppm	1000
Mg per liter.....	ppm	1

This is the approved standard terminology for reporting the results of mineral analyses.^a Values reported in the other terms commonly used may be converted into the standard form by using the factors listed in Table 2.

Data for dissolved gases or pH values have been omitted in Table 1 because even waters of the same mineral contents may vary widely in these respects. Unpolluted natural waters usually have pH values within the range 5 to 8, depending upon their free CO₂ contents. Polluted waters, which include those derived from wells or swamps in marshy ground, may have pH values well below 5.

Biological Characteristics. The slime-forming organisms are mostly lower plants, grouped by botanists into the phylum thallophyta. This group is distinguished by the absence of leaves, roots, or stems from the mosses, ferns, and seed plants which comprise the three other phyla of the plant kingdom.

The thallophyta (see Table 3) are divided into algae, which can synthesize chlorophyll for the production of sugar, and the fungi which lack chlorophyll, and must therefore secure already synthesized carbohydrates.

All thallophyta are of universal distribution and many of them are slime-forming. Of the five divisions of algae, only three (the green, the blue-green, and the diatoms) are found in fresh water. Of the five divisions of fungi, all may occur in fresh water, the principal slime formers being indicated in Table 3.

The methods of analysis commonly used in the sanitary examination of a water have, as their principal object, to identify and count pathogens.

Most slime-forming organisms are not pathogens. When a water is subjected to a biochemical analysis for the purpose of evaluating its slime producing characteristics, tests, widely different from sanitary bacteriological tests, must be made. Tests upon the water itself are seldom satisfactory, and true indications of the sliming characteristics of a water can

Table 3....Principal Slime Formers

Phyla	Rough Division of Phyla
Algae	Single celled, sometimes forming slimy sheets. Many celled in either sheets or froids.
Fungi	<i>Bacteria</i> (Schizomycetes) frequently forming slimy surface coatings. <i>Slime Molds</i> (Myxomycetes) forming slimy sheets as one stage of their life history. <i>Sac fungi</i> (Ascomycetes) of which one division, the yeasts, occasionally form slimy aggregates. The alga-like fungi (<i>Phycomycetes</i>) and the stalked fungi (<i>Basidiomycetes</i>) rarely form slimes but their filaments may hold together the slimes of other organisms.

only be determined by the analysis of deposits on surfaces having a temperature that approximates the operating temperature range of the final design equipment. The results of such tests are commonly used for selecting proper preventive measures.

Slime and algae micro-organisms are capable of rapid multiplication and, if not controlled, can cause shut-down or permanent damage to equipment. They can be controlled by chemical treatment of the water or in certain cases by mechanical cleaning of the surfaces affected. The chemicals used are usually toxic, and should therefore be handled only by trained personnel having a full understanding of the quantity required and their effect on operators as well as surfaces.

Chemical treatment is usually preferred to mechanical cleaning particularly where surfaces are inaccessible for cleaning or where a shut-down of the operation is necessary for mechanical cleaning.

Condensates

All condensates are caused by the cooling of vapor. Condensates resulting from the cooling of water vapor in air are *dews*, *sweats*, *rain*, and *snow*, while those formed in steam-condensing apparatus are termed condensates or return water.

In the heating and ventilating field, the biological characteristics of condensates are likely to be of concern only where the condensate is used as cooling water in recirculating systems. The deleterious gas contents of condensates, however, very often create serious corrosion troubles.

The data in Table 4 typify the chemical composition of

Table 4....Data Typifying the Deleterious Gas Content of Different Atmospheres

Name of Gas	Chemical Formula	Air			
		Rural		Metropolitan	
		% by Volume	Partial pressure psia	% by Volume	Partial Pressure psia
Oxygen.....	O ₂	21	3.143	21	3.143
Carbon Dioxide....	CO ₂	0.03	0.004	0.06	0.009
Sulfur Dioxide....	SO ₂	None	None	0.003	0.004

Name of Gas	Chemical Formula	Five Gases					
		Bitum. Coal		Fuel Oils		Natural Gas	
		% by Volume	Partial pressure psia	% by Volume	Partial pressure psia	% by Volume	Partial pressure psia
Oxygen.....	O ₂	2	0.299	7	1.043	10	1.497
Carbon Dioxide....	CO ₂	15	2.245	13	1.946	10	1.497
Sulfur Dioxide....	SO ₂	0.07	0.010	0.03	0.004	0.0001	0.0015

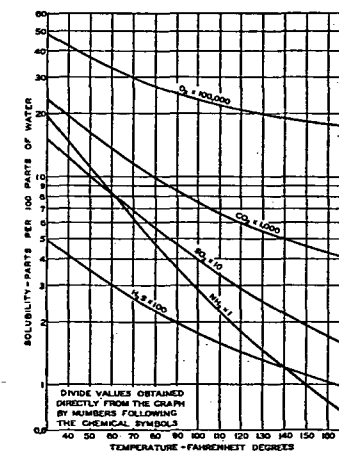


Fig. 1....Solubility of Gases at Partial Pressure of 1 Psi

the atmosphere in rural and metropolitan areas, and of stack gases when various types of common fuels are used. The curves in Fig. 1 disclose the solubility of the major deleterious gases present in such atmospheres in otherwise pure water, when the partial pressure of the gas is one psia.

The most common deleterious gases entrained by steam are oxygen and carbon dioxide. In rare instances, hydrogen sulfide, sulfur dioxide, or ammonia are present.

In most steam-condensing equipment,^{a,b} the non-condensable gases entrained with steam accumulate so that the amount present in the vapor space is several hundred times higher than in the incoming steam and the amount dissolved in the condensate may therefore approach, or even exceed for short periods, the amount entrained by the steam.

CAUSES AND PREVENTION OF SCALES AND SLUDGES

Scales may be formed on surfaces of equipment in contact with water, and sludges in the body of the water, by the separation from the water of dissolved or suspended solids. According to the nature of a particular piece of equipment and the method of its operation, such separation may be promoted by one or more than one, of several factors:

- a. The concentration of solids may be increased by the evaporation of water.
- b. The dissolved solids may be rendered less soluble in the water by changes in temperature.
- c. Conditions may favor the decomposition of unstable compounds with the formation of less soluble compounds.

Figs. 2 and 3 show that the solubilities of both calcium carbonate and calcium sulfate decrease with the rising temperature within a moderate range of temperatures. Surfaces transferring heat into water, such as condensers and