which will combine with the sulphate and chloride ions, is called permanent or non-carbonate hardness.

Inhibitor. A chemical substance added to an environment to reduce corrosion.

Ion. An electrically charged atom or group of atoms.

Passivity. The tendency of a metal to become abnormally inactive in a certain environment.

pH. The logarithm of the reciprocal of the hydrogen ion concentration of a solution. The *pH* value denotes the degree of acidity or alkalinity of a solution. The value of a neutral solution, such as pure water, is 7. Values below 7 are increasingly acid, while values above 7 are increasingly alkaline.

Polarization. An effect produced on the electrode of an electrolytic cell by products formed by the passage of current through the cell. Hydrogen is the product generally formed, although other corrosion products may also cause polarization. Polarization reduces corrosive activity by offering a resistance to current flow and developing an opposing electromotive force.

Scale. Scale[1] is a deposit formed from solution directly in place upon a confining surface. It is a deposit which will retain its physical shape when mechanical means

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
Sulphate	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 Waters—Public Supply—Dayton, Ohio—30–60 ft.
(6) Well Water—Maywood, Illinois—2090 ft.
(7) Well Water—Smithfield, Va.—330 ft.
(8) Well Water—Rosewell, N. Mexico
(9) Ocean Water—Average

are used to remove it from the surface on which it is deposited. Scale, which may or may not adhere to the underlying surface, is usually crystalline and dense, frequently laminated, and occasionally columnar in structure.

Sludge. Sludge[1] is a water-formed sedimentary deposit. It usually does not cohere sufficiently to retain its physical shape when mechanical means are used to remove it from the surface upon which it deposits. Sludge is not always found at the place where it is formed. It may be hard and adherent, and baked to the surface on which it has been deposited.

Water-Formed Deposits. A water-formed deposit[1] is any accumulation of insoluble material derived from water or formed by the reaction of water upon surfaces in contact with water.

Deposits formed from or by water in all of its phases may be further classified as scale, sludge, corrosion products, or biological deposits.

CLASSIFICATION AND CHARACTERISTICS OF WATER

Due to the many conditions of water encountered in industry,[4] it is frequently necessary to obtain expert advice and a prescribed treatment to make the water suitable for use in a given process. The heating and air

conditioning engineer is concerned chiefly with two broad classifications of water: (1) those waters containing various amounts of mineral impurities and (2) condensates that are relatively free from mineral impurities but contain various amounts of dissolved gases such as carbon dioxide, oxygen, and sulphur 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.

TABLE 2. CONVERSION FACTORS FOR WATER ANALYSES

TO CONVERT	INTO	MULTIPLY BY
Grains per U. S. gallon	ppm	17
Grains per Imperial gallon	ppm	14¼
Grams per liter	ppm	1000
Mg per liter	ppm	1

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.[5]

All values recorded are in terms of parts per million.* This is the approved standard terminology for reporting the results of mineral analyses.[6] 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* CO_2 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.

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