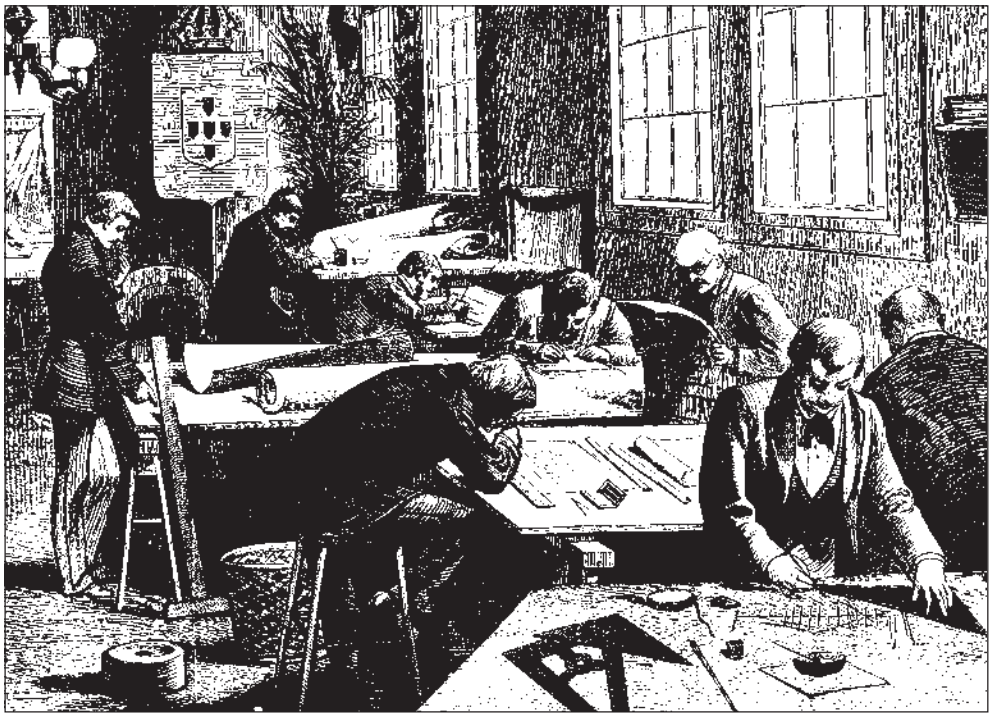
A Beginner's Guide to Water Management —

Symbols, Abbreviations & Conversion Factors

Information Circular 105



Florida LAKEWATCH
UF/IFAS
Department of Fisheries and Aquatic Sciences
Gainesville, Florida

April 2002
2nd Edition

UF IFAS Extension
UNIVERSITY of FLORIDA

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http://lakewatch.ifas.ufl.edu/LWcirc.html

As always, we welcome your questions or comments.

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Before reading this circular, we encourage you to read the four circulars that precede it:

A Beginner's Guide to Water Management – The ABCs (Circular #101)

A Beginner's Guide to Water Management – Nutrients (Circular #102)

A Beginner's Guide to Water Management – Water Clarity (Circular #103)

A Beginner's Guide to Water Management – Lake Morphometry (Circular #104)

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Copies of any of these publications can be obtained by contacting the Florida LAKEWATCH office at 1-800-LAKEWATCH
(1-800-525-3928)

They can also be downloaded for free from the Florida LAKEWATCH web site:

http://lakewatch.ifas.ufl.edu/LWcirc.html

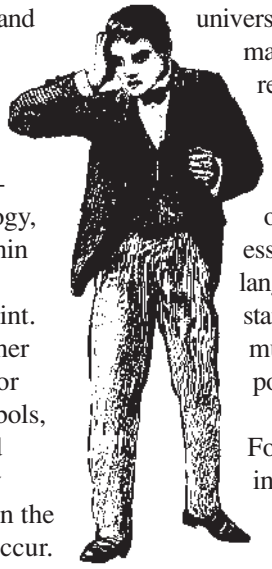
or from the UF/IFAS Electronic Document Information System (EDIS):

http://edis.ifas.ufl.edu

Prologue

Communication is the basis for most human interactions. It could even be said that societies cease to function when they lose the ability to communicate. Because of this need to express ideas and exchange information, people around the world have gone to great lengths to develop languages for use within a common geographic region or culture. Given the diversity of the human race, some of these languages are vastly different. Even within a single language there are dialects or slang expressions that can hinder communication.

Many cultures have tried to solve this dilemma by developing dictionaries, standard abbreviations and symbols — an attempt to share their language with those who are willing to learn. The scientific community is no different as it has attempted to resolve communication difficulties by developing glossaries for its numerous disciplines (e.g., biology, chemistry, physics, zoology, etc.). Such glossaries can usually be found within any textbook or journal relating to a specific discipline and they provide a good starting point. Scientists have also taken things one step further by developing an **International System (SI)** for standardizing scientific and mathematical symbols, abbreviations, and units of measure to be used around the world. While this system has certainly helped reduce communication problems within the general scientific community, problems still occur.



For example, even though the U.S. scientific community adopted the metric system (the basis of the SI system) many years ago, some people still need conversion tables to insure their measurements are properly translated into the metric system. Failure to do this can cause problems. A case in point is the U.S. Mars Climate Orbiter that missed its target in September of 2000 and burned up deep in Mars' atmosphere due to a mistake in measurement units within the engineering process. Contractors building the spacecraft specified the engine's thrust in English units (i.e., pounds), while navigators planning the orbiter's flight path assumed the units were in metric units of newtons. The oversight resulted in the loss of the $125 million orbiter. As they say, "old habits die slowly" and many of the individuals that grew up with the English system are obviously still adjusting to the metric system.

However, aside from the English vs. metric quandary, scientists will probably always continue to face their greatest communications challenge: communicating with non-scientists. For the lay public, language used by scientists remains shrouded in mystery. Unfamiliar words often convey unintended meanings, or in many instances, no meaning at all. Even the most intelligent or well-educated listeners have difficulty understanding scientific jargon, especially when the language is not part of their everyday experience.

Communication is further complicated by the fact that there are a multitude of distinct disciplines within the scientific community itself: some scientists study the universe, some study the human body, while others may study the natural world. Even in closely related subjects such as limnology or oceanography, researchers tend to gravitate toward highly specialized topics such as the biological, chemical or physical aspects of freshwater and/or marine environments. As a result, scientists essentially end up developing their own customized language that only their immediate peers understand. This is unfortunate because in the long run, much of the research being done these days can potentially have an impact on our daily lives.

So what can we do to bridge this gap? For starters, it's imperative that the public not be intimidated by science and to remember that science is, after all, a human endeavor. Although scientists may be highly trained individuals, they make mistakes too and contrary to popular belief, they don't always have the answers. Those of us with LAKEWATCH are of the opinion that the best scientists are those who know how to say "I don't know, but I'll do my best to find out."

Secondly, continue asking questions! This can be a difficult assignment as many people are afraid to ask questions for fear that it will show their ignorance. All of us need to be reminded that (1) there is no such thing as a dumb question, and (2) this problem is not just limited to the lay public; scientists are afraid to ask questions too. Such fears prevent us all from learning something new.

As our LAKEWATCH team continues to help translate the scientific concepts and ideas related to water management, we hope that you'll be patient if any information should happen to get lost in the translation. Even the best translators make mistakes in interpretation — evidence of just how imperfect language can be and how important it is for us all to keep trying.

Joe Richard

Fishery scientists often measure the length and weight of individual fish to assess the "health" of a fish population.

Introduction

Florida LAKEWATCH is committed to helping non-scientists become familiar with the language used by scientists, particularly the terminology related to freshwater and marine sciences. This circular and the four others that precede it are evidence of that commitment.

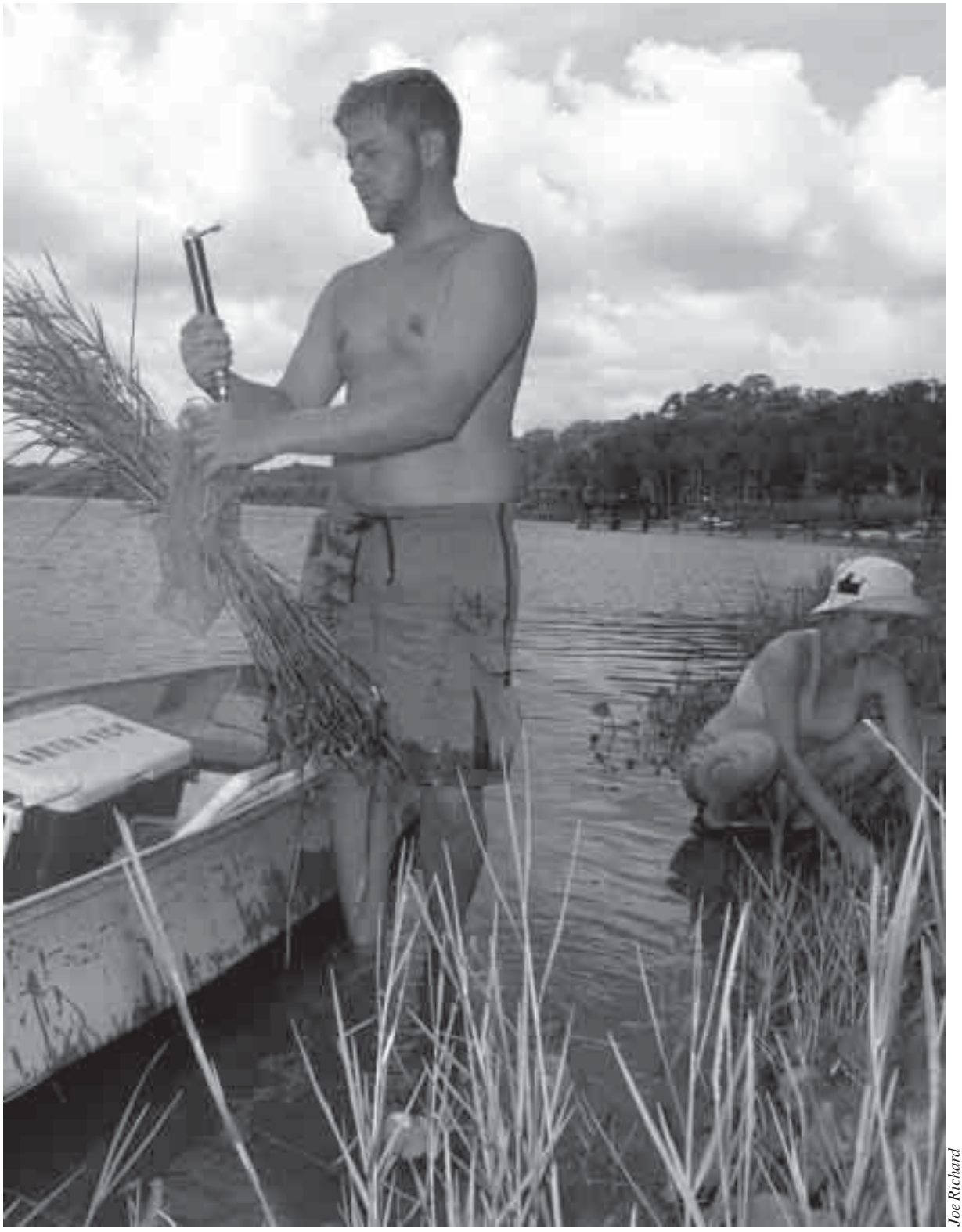
The first in the series, ***A Beginner's Guide to Water Management – The ABCs (Circular 101)***, was designed to help readers become acquainted with terminology and management concepts used by limnologists and water management professionals.

The circular you have in hand, the fifth in our series, is a sequel of sorts to Circular 101 as it provides the tools for interpreting and/or translating units of measure, conversion factors, symbols, and abbreviations used by scientists in the U.S. and on an international basis.

Much of this information is typically only available by searching numerous publications, but we have assembled it here under one cover for quick reference. Emphasis is placed on the International System (SI) so that readers can become familiar with the metric system and perhaps even begin to use it in their everyday activities. It should be noted that, while we tried to make this booklet as comprehensive as possible, the information provided is not totally inclusive. Therefore, if you encounter something you don't understand or if you need more information about any of the material, feel free to contact Florida LAKEWATCH for assistance.

It is hoped that continued use of and exposure to the SI system will ultimately reduce problems related to metric conversions and enhance the communication of scientific ideas and concepts.

Included in this circular:



Joe Richard

UF students Eric Porak and Amber Paxton collect and weigh aquatic plants to determine the aquatic plant biomass (kilogram wet weight/m^2) of emergent plants at Lake Wauberg in Gainesville. Florida LAKEWATCH staff, students, and volunteers work together each summer to collect this information on a number of lakes throughout the state.

Part I
Common SI Prefixes

While reading scientific literature, you may have noticed that many of the words used to indicate the size or quantity of things (i.e, units of measure) are often compound words. Deciphering the meaning of these words is easy if you remember that the first part of the word, the prefix, often denotes a numerical value and the second part indicates the actual unit of measure. For example, the term ***milligram*** can be translated by defining the two parts of the word separately: if the prefix ***milli*** means one-thousandth, then a milligram is one-thousandth of a gram.

Listed below are some of the common prefixes and their corresponding symbols used by scientists. Notice that the multiplying factor[1] for each prefix is also provided along with the appropriate scientific notation. It's important to be familiar with these factors as they are often used in scientific literature and/or mathematical text. For example, if you should see the number "10" depicted with an exponent[2] while reading a scientific journal, graph or chart, you'll be able to translate that number into its numerical equivalent by using the information provided below.

Prefix	Symbol	Multiplying Factor		
giga	G	1,000,000,000	=	10^{9}
mega	M	1,000,000	=	10^{6}
kilo	k	1,000	=	10^{3}
hecto	h	100	=	10^{2}
deca	da	10	=	10^{1}
(no prefix for the number 1)	—	1	=	10^{0}
deci	d	0.1	=	10^{-1}
centi	c	0.01	=	10^{-2}
milli	m	0.001	=	10^{-3}
micro	μ	0.000,001	=	10^{-6}
nano	n	0.000,000,001	=	10^{-9}
pico	p	0.000,000,000,001	=	10^{-12}

1 *The multiplying factor for the prefix "mega" is* ***1,000,000.*** *Therefore, the scientific notation equivalent for 1,000,000 is expressed as* $\mathbf{10^{6}}$.

2 *Exponent – the small number or symbol placed above and to the right of the base number (e.g.,* 10^{1}*).*

Part II
Commonly Used Abbreviations and Symbols

The use of abbreviations and symbols in scientific writing reduces the number of letters and words needed thus making manuscripts less cumbersome for both the writer and the reader. It can also shorten the actual length of an article, saving paper. With this in mind, we've provided the following list of commonly used symbols and abbreviations within both the metric and English systems of measurement. While it's not necessary to learn all of these, familiarity with some of them can certainly help, particularly those related to water management. Consider this a cheat sheet to assist you in your efforts to become better acquainted with the wild and wonderful world of chemistry and water management.

Commonly Used Abbreviations and Symbols

Abbreviation	Definition
a	annum (year)
acre-ft	acre foot
a.i.	active ingredient
atm	atmosphere
avdp	avoirdupois
C	Celsius
cal	calorie
cc	cubic centimeter
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
d	day
diam	diameter
doz	dozen
F	Farenheit
fm	fathom
ft	foot
ft^2	square foot
ft^3	cubic foot
g	gram
gal	gallon (US)
g-cal	gram calorie
gpm	gallons per minute
grains/gal	grains per U.S. gallon
h	hour
ha	hectare
hp	horsepower
in	inch
in^2	square inch
in^3	cubic inch
j	joule
kcal	kilocalorie
kg	kilogram
km	kilometer
km^2	square kilometer
kw	kilowatt
L	liter
lb	pound
log	logarithm (common)
ln	logarithm (natural)
$\log_e$	logarithm (natural)
m	meter

Abbreviation	Definition
m^2	square meter
m^3	cubic meter
mb	millibar
mg	milligram
mi	mile (statute)
mi^2	square mile
min	minute
mm	millimeter
µg	microgram
µg/L	microgram per liter
$\mu g \cdot L^{-1}$	microgram per liter
$\mu mho \cdot cm^{-1}$	micromho per centimeter
µm	micrometer
µM	micromole
$\mu M \cdot L^{-1}$	micromole per liter
µmol/L	micromole per liter
$\mu S \cdot cm^{-1}$	microsiemen per centimeter
mg/m^3	milligram per cubic meter
$mg \cdot m^{-3}$	milligram per cubic meter
mgd	million gallons per day
mg/L	milligram per liter
$mg \cdot L^{-1}$	milligram per liter
ml	milliliter
mol/L	mole per liter
$mol \cdot L^{-1}$	mole per liter
ng	nanogram
oz	ounce
ppb	part per billion
ppm	part per million
ppt	part per thousand
psi	pound per square inch
pt	pint
qt	quart
s	second
t	tonne (metric)
ton	ton (English)
W	watt
yr	year
yd	yard
yd^2	square yard
yd^3	cubic yard

Part III
Commonly Used Metric and English Conversion Factors

As you probably know by now, there are a multitude of ways to measure things and not everyone uses the same unit of measure. That's one reason why the scientific community developed an International System (SI) for standardizing scientific and mathematical symbols, abbreviations and units of measure. While this system has helped reduce confusion within the scientific community and even some portions of the general public, problems still occur as not everyone has universally adopted the SI system. As a result, conversions often need to be done so that measurements are properly translated and interpreted — an important step toward insuring that within the communication process, everyone is "on the same page."

For this reason, conversion factors are provided in the following section so the reader may convert from metric to English or vice versa. We've organized the information under units of measure that are commonly applied within the water management arena (i.e., Area, Concentration, Length, Mass, Power, Pressure, Temperature and Volume). For a more comprehensive listing, see **Part IV A Glossary of Common Metric and English Conversion Factors**.

Joe Richard

Florida LAKEWATCH volunteer Susan Wright carefully measures water volume in a graduated cylinder before pouring it into the filtration system to the right of the cylinder. This water volume measurement must be accurately measured and recorded.

Jeanne Hearn

To convert...

square centimeters (cm^2)	to	multiply by
square centimeters	square feet	0.001076
square centimeters	square inches	0.155
square centimeters	square meters	0.0001

square meters (m^2)	to	multiply by
square meters	acres	0.0002471
square meters	square centimeters	10,000
square meters	square feet	10.76
square meters	square miles	0.0000003861
square meters	square yards	1.196

square kilometers (km^2)	to	multiply by
square kilometers	acres	247.1
square kilometers	square feet	10,760,000
square kilometers	square miles	0.3861

hectares (ha)	to	multiply by
hectares	acres	2.471
hectares	square feet	107,639
hectares	square meters	10,000

Lynda Russell

To convert...

square inches (in^2)	to	multiply by
square inches	square centimeters	6.452
square inches	square meters	0.0006452
square inches	square feet	0.00694

square feet (ft^2)	to	multiply by
square feet	acres	0.00002296
square feet	square centimeters	929
square feet	square meters	0.0929

square yards (yd^2)	to	multiply by
square yards	square meters	0.8361
square yards	hectares	0.00008361
square yards	acres	0.000207

square miles (mi^2)	to	multiply by
square miles	acres	640
square miles	square kilometers	2.59
square miles	hectares	259
square miles	square meters	2,590,000

acres (acre)	to	multiply by
acres	hectares	0.40470
acres	square meters	4,047
acres	square feet	43,560
acres	square yards	4,840

METRIC conversions Units of CONCENTRATION

To convert...

milligrams / liter (mg/L or mg · L^{-1})	**to**	**multiply by**
milligrams/liter	parts/million	1
milligrams/liter	grains/U.S. gallon	0.0584
milligrams/liter	micrograms/liter	1,000
milligrams/liter	milligrams/cubic meter	1,000

milligrams / cubic meter (mg/m^3 or mg · m^{-3})	**to**	**multiply by**
milligrams/cubic meter	micrograms/liter	1
milligrams/cubic meter	milligrams/liter	0.001

micrograms / liter (μg/L or μg · L^{-1})	**to**	**multiply by**
micrograms/liter	parts/billion	1
micrograms/liter	milligrams/cubic meter	1
micrograms/liter	milligrams/liter	0.001
micrograms/liter	ppm	0.001

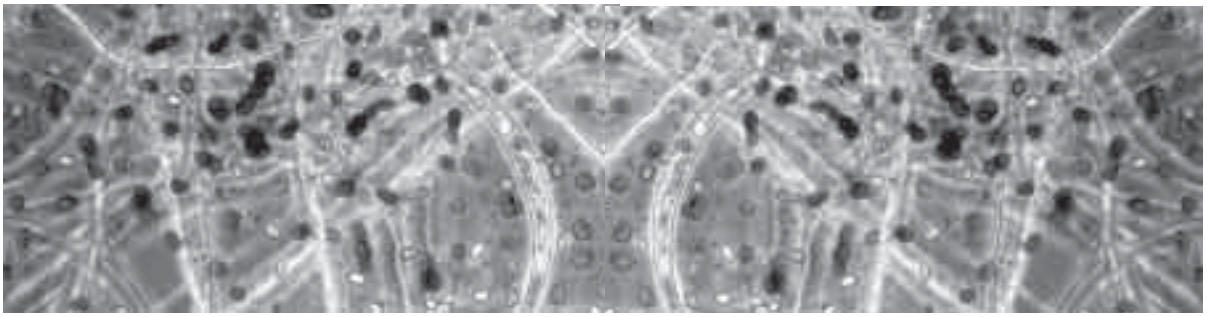
You may notice in our tables (above) that a concentration of **milligrams per liter** can be abbreviated either as **mg/L** or as **mg· L^{-1}**. Both abbreviations are considered to be equivalent because of the algebraic property **L^{-1} = 1/L** .
This means that multiplying by L^{-1} is the same as dividing by L.

$\frac{mg}{L}$ In the first abbreviation, the symbols **mg/L** mean that we are dividing the weight of a substance (**mg**) by the volume in which it is dissolved (one liter or **L**).

$mg \times \frac{1}{L}$ In the second abbreviation, we are multiplying the weight of a substance (**mg**), times one divided by the volume in which it is dissolved (one liter or **L**).

*Note: Following the same rules, **milligrams per cubic meter** could be expressed either as **mg/m^3** or as **mg · m^{-3}**.*

While reading scientific publications, you will most likely see negative exponents used rather than the slashes as this is currently the accepted method of notation. This is done to avoid confusion in calculations when there are multiple divisions in a combined unit of measurement. For example, let's say that we are keeping track of the weight of fish harvested from a lake over several years. If we wanted to compare our fish weight data with the weights of fish harvested from other lakes of different sizes, we would need to calculate all the harvest data in terms of **kilograms of fish per hectare per year**. This could be noted as **kg/ha/yr**. However, the preferred way to abbreviate the unit would be **kg · ha^{-1} · yr^{-1}**.



Mary Cichra

To convert...

parts per billion (ppb)	**to**	**multiply by**
parts/billion	micrograms/liter	1
parts/billion	milligrams/liter	0.001
parts/billion	parts/million	0.001

parts per million (ppm)	**to**	**multiply by**
parts/million	grains/U. S. gallon	0.0584
parts/million	parts/thousand	0.001
parts/million	micrograms/liter	1,000
parts/million	parts/billion	1,000
parts/million	milligrams/liter	1

parts per thousand (ppt)	**to**	**multiply by**
parts/thousand	parts/billion	1,000,000
parts/thousand	parts/million	1,000
parts/thousand	milligrams/liter	1,000
parts/thousand	micrograms/liter	1,000,000

moles per liter (mol/L or mol L^{-1} or M/L)	**to**	**multiply by**
moles/liter	parts/million	(molecular weight) x 1,000
moles/liter	milligrams/liter	(molecular weight) x 1,000

micromoles per liter (µmol/L or µmol L^{-1} or µM/L)	**to**	**multiply by**
micromoles/liter	parts/million	(molecular weight) x 0.001
micromoles/liter	milligrams/liter	(molecular weight) x 0.001
micromoles/liter	micrograms/liter	(molecular weight) x 1

Amy Richard

millimeters (mm)	to	multiply by
millimeters	feet	0.003281
millimeters	inches	0.03937
millimeters	microns	1,000
millimeters	centimeters	0.1
millimeters	meters	0.001

centimeters (cm)	to	multiply by
centimeters	feet	0.03281
centimeters	inches	0.3937
centimeters	meters	0.01

meters (m)	to	multiply by
meters	feet	3.281
meters	inches	39.37
meters	miles *(statute)*[*]	0.0006214
meters	yards	1.094
meters	millimeters	1,000
meters	centimeters	100
meters	kilometers	0.001

kilometers (km)	to	multiply by
kilometers	feet	3,281
kilometers	miles *(statute)*	0.6214
kilometers	centimeters	100,000
kilometers	meters	1,000

[*] ***Statute mile*** *– a unit of distance used on land in the English speaking countries equal to 5,280 feet or 1,760 yards.*

Amy Richard

inches (in)	to	multiply by
inches	centimeters	2.54
inches	meters	0.0254
inches	fathoms	0.01389
inches	yards	0.0278

feet (ft)	to	multiply by
feet	centimeters	30.48
feet	meters	0.3048
feet	kilometers	0.0003048
feet	inches	12
feet	fathoms	0.1667
feet	miles *(statute)*[*]	0.0001893

yards (yd)	to	multiply by
yards	centimeters	91.44
yards	meters	0.9144
yards	kilometers	0.0009144
yards	feet	3
yards	fathoms	0.5

fathoms (fm)	to	multiply by
fathoms	inches	72
fathoms	feet	6
fathoms	yards	2

miles (mi)	to	multiply by
miles (*statute*)[*]	kilometers	1.609
miles (*statute*)	meters	1,609
miles (*statute*)	miles *(nautical)*[**]	0.8684
miles (*statute*)	feet	5,280
miles (*statute*)	yards	1,760

[*] ***Statute mile*** *– a unit of distance used on land in the English speaking countries equal to 5,280 feet or 1,760 yards.*

[**] ***Nautical mile*** *– officially fixed in the United States at 6,080.20 feet and in Great Britain at 6,080 feet.*

To convert...

kilograms (kg)	to	multiply by
kilograms	ounces *(troy)*[*]	32.15
kilograms	pounds *(avoirdupois)*[**]	2.205
kilograms	tons *(short)*[***]	0.0011
kilograms	tons *(long)*[****]	0.000984
kilograms	grams	1,000

grams (g)	to	multiply by
grams	grains	15.43
grams	ounces *(avoirdupois)*	0.03527
grams	ounces *(troy)*	0.03215
grams	pounds *(avoirdupois)*	0.002205
grams	milligrams	1,000
grams	micrograms	1,000,000
grams	kilograms	0.001

milligrams (mg)	to	multiply by
milligrams	grains	0.01543
milligrams	ounces *(avoirdupois)*	0.00003527
milligrams	ounces *(troy)*	0.00003215
milligrams	pounds	0.000002205
milligrams	grams	0.001
milligrams	micrograms	1,000

micrograms (μg)	to	multiply by
micrograms	pounds	0.000000002205
micrograms	milligrams	0.001
micrograms	grams	0.000001

tonnes (t) *(metric)*	to	multiply by
tonnes *(metric)*[*****]	pounds *(avoirdupois)*	2,205
tonnes *(metric)*	tons *(long)*	0.984
tonnes *(metric)*	tons *(short)*	1.102
tonnes *(metric)*	kilograms	1,000

[*] ***Troy weight*** *– a system of weights (i.e., 12 ounces to a pound) used for precious metals, gems, and formerly also for bread, etc.*

[**] ***Avoirdupois weight*** *– a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

[***] ***Short ton*** *refers to avoirdupois weight used for the ton in the U.S. (i.e., 2,000 pounds).*

[****] ***Long ton*** *refers to the avoirdupois weight used for the ton in Great Britain (i.e., 2,240 pounds).*

[*****] ***Metric tonne*** *refers to a unit of 1,000 kilograms, equivalent to 2,205 avoirdupois pounds.*

Joe Richard

To convert...

ounces (oz)	to	multiply by
ounces *(troy)*[*]	pounds *(troy)*	0.0833
ounces *(troy)*	grams	31.103
ounces *(troy)*	milligrams	31,103
ounces *(avoirdupois)*[**]	pounds *(avoirdupois)*	0.0625
ounces *(avoirdupois)*	grams	28.35
ounces *(avoirdupois)*	milligrams	28,350

pounds (lb)	to	multiply by
pounds *(avoirdupois)*	grains	7,000
pounds *(avoirdupois)*	ounces *(avoirdupois)*	16
pounds *(avoirdupois)*	grams	453.5924
pounds *(avoirdupois)*	kilograms	0.4536

tons (ton)	to	multiply by
tons *(short)*[***]	pounds *(avoirdupois)*	2,000
tons *(long)*[****]	pounds *(avoirdupois)*	2,240
tons *(short)*	tonnes *(metric)*[*****]	0.907
tons *(long)*	tonnes *(metric)*	1.016

[*] ***Troy weight*** *refers to a system of weights (i.e., 12 ounces to a pound) used for precious metals, gems, and formerly also for bread, etc.*

[**] ***Avoirdupois weight*** *refers to a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

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[****] ***Long ton*** *refers to the avoirdupois weight used for the ton in Great Britain (i.e., 2,240 pounds).*

[*****] ***Metric tonne*** *refers to a unit of 1000 kilograms which is equivalent to 2,205 avoirdupois pounds.*

METRIC conversions — Units of POWER

To convert...

watts (w)	to	multiply by
watts	kilowatts	0.001
watts	kilocalories/minute	0.01434
watts	joules/sec	1
watts	horsepower *(electric)*	0.00134
watts	ergs/second	10,000,000

watt-hours (whr)	to	multiply by
watt-hours	ergs	36,000,000,000
watt-hours	gram calories	859.18

kilowatts (kw)	to	multiply by
kilowatts	watts *(Int.)*	1,000
kilowatts	joules/sec	1,000
kilowatts	horsepower *(electric)*	1.34

ENGLISH conversions — Units of POWER

To convert...

horsepower (hp)	to	multiply by
horsepower *(electric)*	watts	746
horsepower *(electric)*	kilowatts	0.746
horsepower *(electric)*	joules/sec	746

Florida LAKEWATCH regional coordinators can often be found in the field working with citizens on freshwater lakes or coastal waters. Regional coordinator Dan Willis, pictured here, is involved in various activities such as monitoring fish populations and aquatic plant communities.

David Watson

METRIC conversions — Units of PRESSURE

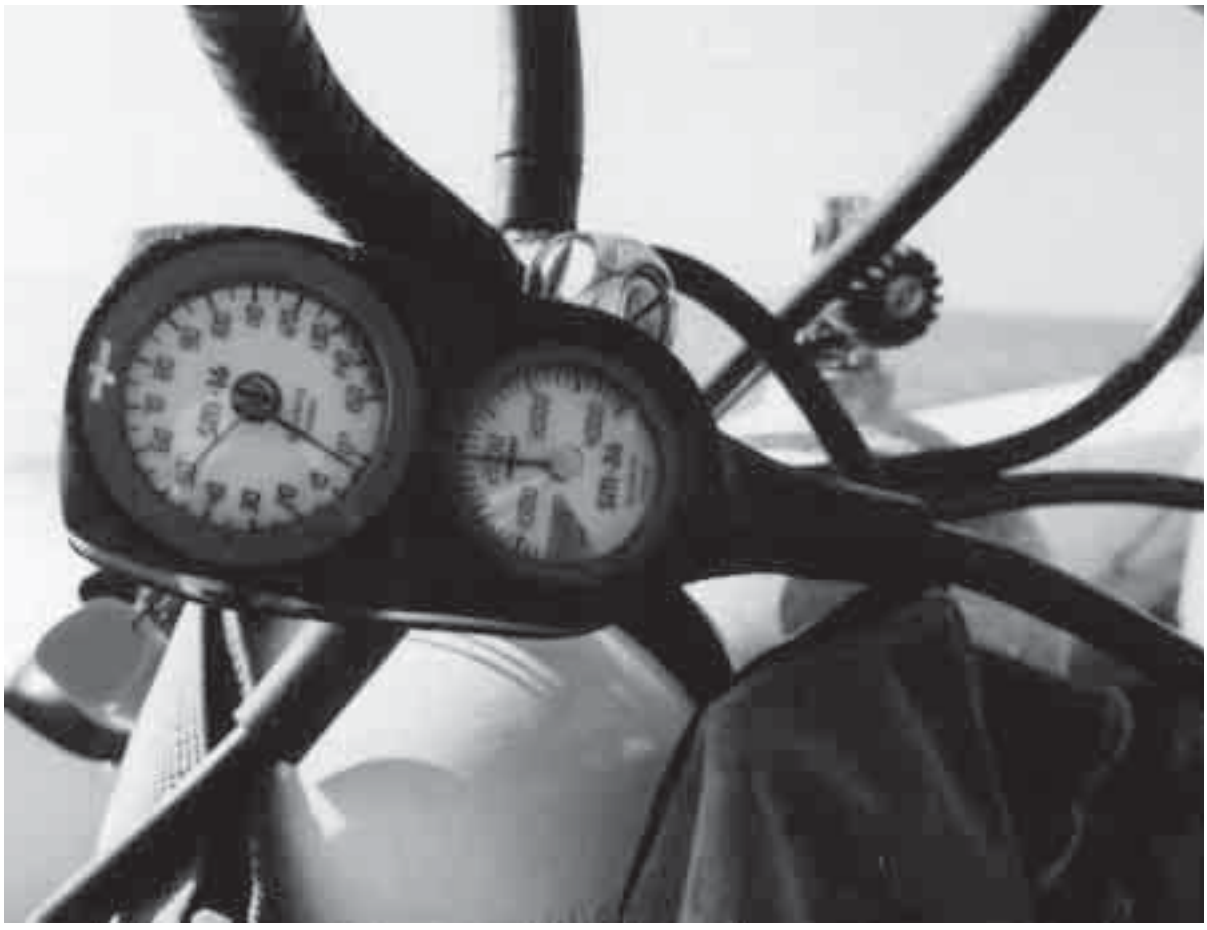
To convert...

millibars (mb)	**to**	**multiply by**
millibars	atmospheres	0.000987
millibars	bars	0.001
millibars	pounds/square inch	0.0145

ENGLISH conversions — Units of PRESSURE

To convert...

pounds per square inch (psi)	**to**	**multiply by**
psi	atmospheres	0.068
psi	bars	0.0689
psi	grams/square cm	70.3
psi	millibars	68.9



Joe Richard

METRIC conversions Units of TEMPERATURE

To convert...

degrees Celsius (°C)	to	multiply by
Celsius	Fahrenheit	(°C x 9/5) + 32

ENGLISH conversions Units of TEMPERATURE

To convert...

degrees Fahrenheit (°F)	to	multiply by
Fahrenheit	Celsius	(°F - 32) x 5/9

Florida LAKEWATCH volunteer Dave Byrd takes a temperature reading from waters adjacent to Sugarloaf Key in the lower Florida Keys.

Joe Richard

METRIC conversions — Units of VOLUME

To convert...

cubic centimeters (cm^3)	to	multiply by
cubic centimeters	cubic feet	0.00003531
cubic centimeters	cubic inches	0.06102
cubic centimeters	gallons	0.0002642
cubic centimeters	milliliters	1
cubic centimeters	liters	0.001
cubic centimeters	cubic meters	0.000001

milliliters (ml or mL)	to	multiply by
milliliters	cubic inches	0.0610
milliliters	ounces	0.0338
milliliters	pints	0.00211
milliliters	liters	0.001
milliliters	cubic centimeters	1

liters (L)	to	multiply by
liters	cubic feet	0.03531
liters	gallons	0.2642
liters	quarts	1.0567
liters	milliliters	1,000
liters	cubic centimeters	1,000
liters	cubic meters	0.001

cubic meters (m^3)	to	multiply by
cubic meters	acre-feet	0.00081
cubic meters	cubic feet	35.31
cubic meters	cubic yards	1.308
cubic meters	gallons	264.2
cubic meters	liters	1,000

Joe Richard

Florida LAKEWATCH volunteers may use a variety of graduated cylinders for measuring water samples for the filtering process. The smaller graduated cylinder allows one to measure and filter smaller amounts of water. This is particularly helpful to volunteers monitoring waterbodies with an abundance of algae in the water, as they won't need to filter as much water to obtain a chlorophyll sample.

To convert...

cubic inches (in^3)	to	multiply by
cubic inches	cubic centimeters	16.39
cubic inches	cubic meters	0.00001639
cubic inches	liters	0.0164
cubic inches	gallons	0.00433
cubic inches	quarts	0.0173
cubic inches	pints	0.0346

cubic feet (ft^3)	to	multiply by
cubic feet	cubic meters	0.02832
cubic feet	liters	28.32
cubic feet	acre-feet	0.0000230
cubic feet	gallons	7.48052
cubic feet	quarts	29.9

cubic feet/second (ft^3/sec)	to	multiply by
cubic feet/second	gallons (U.S.)/minute	448.83117
cubic feet/second	liters/minute	1698.963
cubic feet/second	liters/second	28.31605

gallons (gal)	to	multiply by
gallons	cubic centimeters	3,785
gallons	cubic feet	0.1337
gallons	cubic meters	0.003785
gallons	liters	3.785
gallons of water	pounds of water	8.3452
gallons	quarts	4
gallons	pints	8

quarts (qt)	to	multiply by
quarts	cubic centimeters	946.4
quarts	cubic feet	0.03342
quarts	cubic meters	0.0009465
quarts	liters	0.9463
quarts	gallons	0.25
quarts	pints	2
quarts	ounces	32

To convert...

pints (pt)	to	multiply by
pints	cubic centimeters	473.2
pints	cubic feet	0.0167
pints	cubic meters	0.000473
pints	liters	0.473
pints	gallons	0.125
pints	ounces	16

ounces (oz)	to	multiply by
ounces	cubic centimeters	29.57
ounces	liters	0.02957
ounces	pints	0.0625
ounces	quarts	0.03125
ounces	gallons	0.00781

acre feet (acre-ft)	to	multiply by
acre-feet	cubic feet	43,560
acre-feet	gallons	325,851
acre-feet	cubic yards	1,613.3
acre-feet	cubic meters	1,233.5

cubic yards (yd^3)	to	multiply by
cubic yards	cubic feet	27
cubic yards	gallons	201.97
cubic yards	liters	764.5

Florida LAKEWATCH volunteers collect water samples in two different sized bottles. The larger bottle shown here on the left holds up to 500 milliliters (ml) of water and is used for coastal monitoring. The smaller 250–ml bottle on the right is used for freshwater sampling.

Part IV

A Glossary of Commonly Used Metric and English Conversion Factors

Joe Richard

Florida LAKEWATCH regional coordinators Jeanette Lamb and David Watson collect aquatic plant data in Crystal River. The technique involves throwing a quarter-meter square into the water and letting it sink to the bottom. Plants are then collected from within the quarter-meter square frame, identified, and then weighed to obtain an average plant biomass data.

To convert...	to...	multiply by...
acres	hectares	0.4047
acres	square meters	4,047
acres	square feet	43,560
acres	square yards	4,840
acre-feet	cubic feet	43,560
acre-feet	gallons	325,851
acre-feet	cubic yards	1,613.3
acre-feet	cubic meters	1,233.5
Celcius	Fahrenheit	(°C x 9/5) + 32
centimeters	feet	0.03281
centimeters	inches	0.39370
centimeters	meters	0.01
cubic centimeters	cubic feet	0.00003531
cubic centimeters	cubic inches	0.06102
cubic centimeters	gallons	0.0002642

A Glossary of Common Metric and English Conversion Factors (continued)

To convert...	to...	multiply by...
cubic centimeters	milliliters	1
cubic centimeters	liters	0.001
cubic centimeters	cubic meters	0.000001
cubic feet	cubic meters	0.02832
cubic feet	liters	28.32
cubic feet	acre-feet	0.0000230
cubic feet	gallons	7.48052
cubic feet	quarts	29.92
cubic feet/second	gallons/minute *(U.S.)*	448.83117
cubic feet/second	liters/minute	1698.963
cubic feet/second	liters/second	28.31605
cubic inches	cubic centimeters	16.39
cubic inches	cubic meters	0.00001639
cubic inches	liters	0.0164
cubic inches	gallons	0.00433
cubic inches	quarts	0.0173
cubic inches	pints	0.0346
cubic meters	acre-feet	0.00081
cubic meters	cubic feet	35.31
cubic meters	cubic yards	1.308
cubic meters	gallons	264.2
cubic meters	liters	1000
cubic yards	cubic feet	27
cubic yards	gallons	201.97
cubic yards	liters	764.5
ergs	gram calories	0.00000002389
ergs	kilocalories	0.00000000002389
ergs/second	kilocalories/minute	0.000000001433
Fahrenheit	Celcius	(^{o}F – 32) x 5/9
fathoms	meters	1.8288
fathoms	feet	6
feet	centimeters	30.48
feet	meters	0.3048
feet	kilometers	0.0003048
feet	inches	12
feet	fathoms	0.1667
feet	miles *(statute)*[*]	0.001893

[*] ***Statute mile*** *– a unit of distance used on land in the English speaking countries equal to 5,280 feet or 1,760 yards.*

A Glossary of Common Metric and English Conversion Factors (continued)

To convert...	to...	multiply by...
foot-candles	lumens/square meter	10.764
gallons	cubic centimeters	3,785
gallons	cubic feet	0.1337
gallons	cubic meters	0.003785
gallons	liters	3.785
gallons	quart	4
gallons	pints	8
gallons *(U.S)* of water *(4^0C)*	pounds of water	8.3452
gallons *(U.S.)*/minute	cubic feet/second	0.002228
gallons *(U.S.)*/minute	liters/second	0.06308
grains/gallon *(U.S.)*	parts/million	17.119
grams	milligrams	1,000
grams	micrograms	1,000,000
grams	kilograms	0.001
grams	grains	15.43
grams	ounces *(avoirdupois)*[*]	0.03527
grams	ounces *(troy)*[**]	0.03215
grams	pounds *(avoirdupois)*	0.002205
grams/centimeter	pounds/inch	0.0056
grams/liter	parts/million	1,000
grams/square centimeter	pounds/square foot	2.0481
gram calories	ergs	0.00000041868
hectares	acres	2.471
hectares	square feet	107,639
hectares	square meters	10,000
horsepower *(electric)*	watts	746
horsepower *(electric)*	kilowatts	0.746
horsepower *(electric)*	joules/sec	746
inches	centimeters	2.54
inches	meters	0.0254
inches	fathoms	0.01389
inches	yards	0.0278
joules	ergs	10,000,000
joules	kilocalories	0.0002389

[*] ***Avoirdupois weight*** *– a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

[**] ***Troy weight*** *– a system of weights used for precious metals and gems (formerly also for bread, etc.)*

A Glossary of Common Metric and English Conversion Factors (continued)

To convert...	to...	multiply by...
kilograms	ounces *(troy)*[*]	32.15
kilograms	pounds *(avoirdupois)*[**]	2.205
kilograms	tons *(short)*[***]	0.0011
kilograms	tons *(long)*[****]	0.000984
kilograms	grams	1,000
kilograms/cubic meter	pounds/cubic foot	0.06243
kilograms/meter	pounds/foot	0.6720
kilograms/square meter	pounds/square foot	0.2048
kilometers	feet *(U.S.)*	3,281
kilometers	miles *(statute)*[*****]	0.6214
kilometers	centimeters	100,000
kilometers	meters	1,000
kilometers/hour	feet/second	0.9113
knots	miles *(statute)*/hour	1.151
liters	cubic feet	0.03531
liters	gallons	0.2642
liters	quarts	1.057
liters	milliliters	1,000
liters	cubic meters	0.001
liters/minute	cubic feet/second	0.0005886
lumens/square foot	foot-candles	1
lux	foot-candles	0.0929
meters	feet	3.281
meters	inches	39.37
meters	miles *(statute)*	0.0006214
meters	yards	1.094
meters	millimeters	1,000
meters	centimeters	100
meters	kilometers	0.001
meters/minute	feet/second	0.05468
micrometers	meters	0.000001

[*] ***Troy weight*** *refers to a system of weights used for precious metals and gems (formerly also for bread, etc.).*
[**] ***Avoirdupois weight*** *is a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*
[***] ***Short ton*** *refers to avoirdupois weight used for the ton in the U.S. (i.e., 2,000 pounds).*
[****] ***Long ton*** *refers to the avoirdupois weight used for the ton in Great Britain (i.e., 2,240 pounds).*
[*****] ***Statute mile*** *is a unit of distance used on land in the English speaking countries equal to 5,280 feet or 1,760 yards.*

A Glossary of Common Metric and English Conversion Factors (continued)

To convert...	to...	multiply by...
micrograms	pounds *(avoirdupois)*[*]	0.000000002205
micrograms	milligrams	0.001
micrograms	grams	0.000001
micrograms/liter	milligrams/cubic meter	1
micrograms/liter	milligrams/liter	0.001
micrograms/liter	ppm	0.001
micromoles/liter	parts/million	(molecular weight) x 0.001
micromoles/liter	milligrams/liter	(molecular weight) x 0.001
miles *(statute)*	kilometers	1.609
miles *(statute)*	meters	1,609
miles *(statute)*	miles *(nautical)*[**]	0.8684
miles *(statute)*	feet	5,280
miles *(statute)*	yards	1,760
millibars	atmospheres	0.000987
millibars	bars	0.001
millibars	pounds/square inch	0.0145
milligrams	grains	0.01543
milligrams	ounces *(avoirdupois)*	0.00003527
milligrams	ounces *(troy)*[***]	0.00003215
milligrams	pounds	0.000002205
milligrams	micrograms	1,000
milligrams	grams	0.001

Conversion Factors Used in Water Management

To Convert...	to...	multiply by...
mg/L	µg/L	1,000
µg/L	mg/L	0.001
µM/L	mg/L	(molecular weight) x 0.001
mg/m^3	mg/L	0.001
mg/m^3	µg/L	1
ppm	mg/L	1
ppm	ppb	1,000
ppb	ppm	0.001
pounds/acre	kg/ha	1.12

[*] ***Avoirdupois weight*** *is a system of weights used (i.e., Great Britain, U.S.) for goods other than gems, precious metals, and drugs.*

[**] ***Nautical mile*** *– officially fixed in the United States at 6,080.20 feet and in Great Britain at 6,080 feet.*

[***] ***Troy weight*** *refers to a system of weights used for precious metals and gems (formerly also for bread, etc.)*

A Glossary of Common Metric and English Conversion Factors

To convert...	to...	multiply by...
milligrams/cubic meter	micrograms/liter	1
milligrams/cubic meter	milligrams/liter	0.001
milligrams/liter	parts/billion	1,000
milligrams/liter	parts/million	1
milligrams/liter	grains/gallon *(U.S.)*	0.0584
milligrams/liter	micrograms/liter	1,000
milligrams/liter	milligrams/cubic meter	1,000
milliliters	cubic inches	0.061
milliliters	ounces	0.0338
milliliters	pints	0.00211
milliliters	liters	0.001
milliliters	cubic centimeters	1
millimeters	feet	0.003281
millimeters	inches	0.03937
millimeters	microns	1,000
millimeters	centimeters	0.1
millimeters	meters	0.001
millimicrons	meters	0.000000001
moles/liter	parts/million	(molecular weight) x 1,000
moles/liter	milligrams/liter	(molecular weight) x 1,000
million gallons/day	cubic feet/second	1.54723
ounces *(troy)*[*]	pounds *(troy)*	0.0833
ounces *(troy)*	grams	31.104
ounces *(troy)*	milligrams	31,104
ounces *(avoirdupois)*[**]	pounds *(avoirdupois)*	0.0625
ounces *(avoirdupois)*	grams	28.35
ounces *(avoirdupois)*	milligrams	28,350
parts/billion	micrograms/liter	1
parts/billion	milligrams/liter	0.001
parts/million	grains/gallon *(U.S.)*	0.0584
parts/million	parts/billion	1,000
parts/million	parts/thousand	0.001
parts/million	micrograms/liter	1,000
parts/million	milligrams/liter	1
parts/thousand	parts/billion	1,000,000
parts/thousand	parts/million	1,000
parts/thousand	milligrams/liter	1,000

[*] ***Troy weight*** *refers to a system of weights used for precious metals and gems (formerly also for bread, etc.)*

[**] ***Avoirdupois weight*** *is a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

A Glossary of Common Metric and English Conversion Factors

To convert...	to...	multiply by...
parts/thousand	micrograms/liter	1,000,000
pints	cubic centimeters	473.2
pints	cubic feet	0.0167
pints	cubic meters	0.000473
pints	liters	0.473
pints	gallons	0.125
pints	ounces	16
pounds *(avoirdupois)*[*]	grains	7,000
pounds *(avoirdupois)*	grams	453.5924
pounds *(avoirdupois)*	kilograms	0.4536
pounds *(avoirdupois)*	ounces *(avoirdupois)*	16
pounds of water/minute	cubic feet/minute	0.01602
pounds of water/minute	cubic inches/minute	27.68
pounds of water/minute	gallons *(U.S.)*/minute	0.1198
pounds/foot	kilograms/meter	1.488
pounds/inch	grams/centimeter	178.6
pounds/square foot	inches of mercury	0.01414
pounds/square inch (psi)	atmospheres	0.068
pounds/square inch (psi)	bars	0.0689
pounds/square inch (psi)	grams/square cm	70.3
quarts	cubic centimeters	946.4
quarts	cubic feet	0.03342
quarts	cubic meters	0.0009464
quarts	liters	0.9463
quarts	gallons	0.25
quarts	pints	2
quarts	ounces	32
square centimeters	square feet	0.001076
square centimeters	square inches	0.155
square centimeters	square meters	0.0001
square feet	acres	0.00002296
square feet	square centimeters	929
square feet	square meters	0.0929
square inches	square centimeters	6.452
square inches	square meters	0.0006452
square inches	square feet	0.00694

[*] ***Avoirdupois weight*** *is a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

A Glossary of Common Metric and English Conversion Factors

To convert...	to...	multiply by...
square kilometers	acres	247.1
square kilometers	square feet	10,763,910
square kilometers	square miles	0.3861
square meters	acres	0.0002471
square meters	square centimeters	10,000
square meters	square feet	10.76
square meters	square miles	0.0000003861
square meters	square yards	1.196
square miles	acres	640
square miles	square kilometers	2.59
square miles	hectares	259
square miles	square meters	2,589,988.1
square yards	square meters	0.8361
square yards	hectares	0.00008361
square yards	acres	0.000207
tons *(short)*[*]	pounds *(avoirdupois)*[***]	2,000
tons *(long)*[**]	pounds *(avoirdupois)*	2,240
tons *(short)*	tonnes *(metric)*	0.907
tons *(long)*	tonnes (*metric)*	1.016
tonnes	pounds	2,205
tonnes	tons *(long)*	0.984
tonnes	tons *(short)*	1.102
tonnes	kilograms	1,000
watts	kilowatts	0.001
watts	kilocalories/minute	0.01433
watts	joules/sec	1
watts	horsepower *(electric)*	0.00134
watts	ergs/second	10,000,000
watt-hours	ergs	36,000,000,000
watt-hours	gram calories	859.85
yards	centimeters	91.44
yards	kilometers	0.0009144
yards	meters	0.9144
yards	feet	3
yards	fathoms	0.5

[*] *A **short ton** refers to avoirdupois weight used for the ton in the U.S. (i.e., 2,000 pounds).*
[**] *A **long ton** refers to the avoirdupois weight used for the ton in Great Britain (i.e., 2,240 pounds).*
[***] ***Avoirdupois weight** is a system of weights used in Great Britain and the U.S. for goods other than gems, precious metals, and drugs.*

Part V
Elements and Atomic Weights

Element ~ One dictionary defines it as a substance with "a chemical composition that is in a class unto itself here on earth and even in this universe." Another defines it as a substance containing "atoms of only one kind that singly or in combination constitute all matter."

To put it simply, elements are the basic building blocks of the chemical and physical world, as we know it.

While many of us remember this basic concept from high school chemistry class, details such as the name, abbreviation, and atomic weight[3] of each element are probably a bit fuzzy. This is understandable as there are more than 100 elements recognized by the international scientific community. Fortunately, a list of elements and their international atomic weights can be found in most chemistry books, in some dictionaries, and at a number of on-line web sites.[4] (A good reference source for anyone working in the aquatic sciences is *STANDARD METHODS for the Examination of Water and Wastewater*.) For your convenience however, we've provided a table of international relative atomic weights in this section along with a brief explanation of how relative atomic weights are determined (page 29) and how they are used to calculate the molecular weight of the various chemical compounds found on earth (page 30).

Why do we need to know about elements and their atomic weights?

For starters, many elements, including calcium, magnesium, nitrogen, phosphorus and silicon, are considered to be important nutrients found in aquatic environments. Familiarity with their names and abbreviations is useful from a communications perspective as scientists commonly use abbreviated terminology in their journal articles, graphs, charts, and lectures. For example, when a scientist discusses the effects of "**N**" or "**P**" in a lake system, an educated reader/listener will know that the scientist is referring to the elements nitrogen or phosphorus, respectively.

Secondly, knowledge of an element's atomic weight is required for accuracy when converting from one unit of measure to another. A marine scientist, for instance, might record nutrient concentrations in units of **micromoles per liter** (μM/L) while a freshwater scientist may use **milligrams per liter** (mg/L) or **micrograms per liter** (μg/L). If either scientist wants to combine databases for comparison, conversions would need to be made to standardize the units of measure. To make the conversions, the atomic weight of each element, such as nitrogen or phosphorus, would have to be known. An explanation of how to do these conversions is provided in Section VII on page 35 of this booklet. And remember, if you should encounter any difficulties converting from one unit of measure to another, don't feel bad as this can be a difficult task even for professionals!

3 *An element's atomic weight is approximately equal to the number of protons and neutrons found in an atom.*

4 *Atomic Weights of the Elements. 1999. World Wide Web version prepared by G.P. Moss, originally from a file provided by D.R. Lide.* <http://www.chem.qmw.ac.uk/iupac/AtWt/>

International Relative* Atomic Weights

Element	Symbol	Atomic Weight
Actinium	Ac	227**
Aluminum	Al	26.981538
Americium	Am	243
Antimony	Sb	121.760
Argon	Ar	39.948
Arsenic	As	74.92160
Astatine	At	210
Barium	Ba	137.327
Berkelium	Bk	247
Beryllium	Be	9.012182
Bismuth	Bi	208.98038
Bohrium	Bh	264
Boron	B	10.811
Bromine	Br	79.904
Cadmium	Cd	112.411
Calcium	Ca	40.078
Californium	Cf	251
Carbon	C	12.0107
Cerium	Ce	140.116
Cesium	Cs	132.9054
Chlorine	Cl	35.453
Chromium	Cr	51.9961
Cobalt	Co	58.933200
Copper	Cu	63.546
Curium	Cm	247
Dubnium	Db	262
Dyprosium	Dy	162.50
Einsteinium	Es	252
Erbium	Er	167.259
Europium	Eu	151.964
Fermium	Fm	257
Fluorine	F	18.9984032
Francium	Fr	223
Gadolinium	Gd	157.25
Gallium	Ga	69.723
Germanium	Ge	72.64
Gold	An	196.96655
Hafnium	Hf	178.49
Hassium	Hs	277
Helium	He	4.002602
Holmium	Ho	164.93032
Hydrogen	H	1.00794
Indium	In	114.818
Iodine	I	126.90447
Iridium	Ir	192.217
Iron	Fe	55.845
Krypton	Kr	83.80
Lanthanum	La	138.9055
Lawrencium	Lr	262
Lead	Pb	207.2
Lithium	Li	6.941
Lutetium	Lu	174.967
Magnesium	M	24.3050
Manganese	Mn	54.938049
Meitnerium	Mt	268
Mendelevium	Md	258
Mercury	Hg	200.59
Molybdenum	Mo	95.94
Neodymium	Nd	144.24
Neon	Ne	20.1797
Neptunium	Np	237
Nickel	Ni	58.6934
Niobium	Nb	92.90638
Nitrogen	N	14.0067
Nobelium	No	259
Osmium	O	190.23
Oxygen	Os	15.9994
Palladium	Pd	106.42
Phosphorus	P	30.973761
Platinum	Pt	195.078
Plutonium	Pu	244
Polonium	Po	209
Potassium	K	39.0983
Praseodymium	Pr	140.90765
Promethium	Pm	145
Protactinium	Pa	231.03588
Radium	Ra	226
Radon	Rn	222
Rhenium	Re	186.207
Rhodium	Rh	102.90550
Rubidium	Rb	85.4678
Ruthenium	Ru	101.07
Rutherfordium	Rf	267
Samarium	Sm	150.36
Scandium	Sc	44.955910
Selenium	Se	78.96
Seaborgium	Sg	266
Silicon	Si	28.0855
Silver	Ag	107.8682
Sodium	Na	22.989770
Strontium	Sr	87.62
Sulfur	S	32.065
Tantalum	Ta	180.9479
Technetium	Tc	98
Tellurium	Te	127.60
Terbium	Tb	158.92534

International Relative* Atomic Weights

Element	Symbol	Atomic Weight
Thallium	Tl	204.3833
Thorium	Th	232.0381
Thulium	Tm	168.93421
Tin	Sn	118.710
Titanium	Ti	47.867
Tungsten	W	183.84
Ununilium	Uun	281
Ununquadium	Uuq	289
Uranium	U	238.02891
Vanadium	V	50.9415
Xenon	Xe	131.293
Ytterbium	Yh	173.04
Yttrium	Y	88.90585
Zinc	Zn	65.39
Zirconium	Zr	91.224

** Based on the assigned relative atomic mass of $^{12}C=12$.*

*** Relative weights shown here as whole numbers indicate the mass number of the longest-lived isotope of that element.*

Note: The atomic weights you may see here and in other publications may vary slightly. This is due to each publisher rounding off the numbers differently. It's also important to note that atomic weight values are periodically re-determined; this may also contribute to minor differences in weights shown.

Relative Atomic Weights

Before the age of nuclear technology, scientists were limited to studying chemical reactions that involved large numbers of atoms at once, as there were no methods for isolating a single atom to determine its weight. However, scientists were able to devise a system for assigning weights to the elements by comparing how heavy a given atom was in relation to other atoms. This is known as the system of relative atomic weights. The following is a brief explanation of how it works.

The current practice is to express the weight of a given element as it relates to the weight of some known standard. In recent years, the accepted standard is a carbon isotope known as **carbon-12** with an assigned weight of 12 atomic mass units.* Using only one of these twelve units (i.e., 1/12th), we can assign atomic weights for all the other elements.

In other words, when expressing the atomic weight of an element, we simply need to express the mass of that element relative to the mass of one-twelfth of a carbon-12 atom. These units of weight are referred to as "atomic mass units."

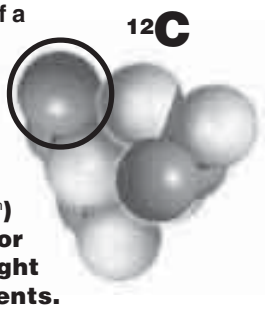
Take hydrogen, for example. The relative atomic weight of hydrogen is expressed as **1.008**. This means that the mass of a hydrogen atom is slightly greater than one-twelfth the mass of a carbon-12 atom.** ***See illustration below.***

We can use the element copper (**Cu**) as a second example. Copper has a relative atomic weight of **63.546**. This means that the mass of a copper atom is nearly 64 times that of one carbon-12 atomic unit (i.e., 1/12th).

** To further visualize this, imagine 12 individual spheres clustered together as seen in the figure below.*

*** The expressed weight of 1.008 is the **average** weight of naturally occurring hydrogen; the reason it is not exactly 1.000 is that a small fraction of naturally occurring hydrogen atoms have a weight of 2, rather than 1.*

A hydrogen atom is assigned an atomic weight of 1 (rounded from 1.008) **because the mass of a hydrogen atom is roughly equal to 1/12th the mass of a carbon-12 atom (depicted on the right).**



This cluster of 12 protons and neutrons represents the total mass of a carbon-12 atom. The sphere that is circled represents one atomic unit (i.e., 1/12th) of that atom. This unit is the basis for determining the relative atomic weight for all other elements.

Part VI
Interpreting Water Chemistry Formulas and Calculating Molecular Weights

Now that we've got a better understanding of relative atomic weights (see page 29), **we can begin to consider chemical compounds and learn how to interpret them.**

It's important to be able to interpret such formulas because elements are rarely found alone in nature. More often than not, they combine with other elements to form chemical substances or compounds. For example, let us consider one of the most commonly known compounds — water. The abbreviation alone tells us that a water molecule ($\mathbf{H_20}$) is comprised of two atoms of hydrogen ($\mathbf{H_2}$) and one atom of oxygen (**O**). When combined with one more atom of oxygen, we end up with a compound known as hydrogen peroxide ($\mathbf{H_2O_2}$).

We can find the molecular weight of a chemical compound by totaling up the weight, in atomic mass units, of all the atoms in that given formula.

We use molecular weights to describe how many grams are in one **mole*** of a substance. When dealing with concentrations of chemicals, it's often helpful to know the molecular weight of a specific compound so that we can evaluate how it is interacting with other substances. While you may not have the opportunity to do this in a laboratory, it is still helpful to be able to interpret the language used by the chemists. Learning to calculate the molecular weight of a substance is the first step toward a better understanding of water chemistry. To help you in this endeavor, we've provided several practice exercises below.

A mole is the standard unit of measure used by chemists for communicating quantities of a chemical compound; a mole is also referred to as a **gram molecule. The term* "mole" *is abbreviated as "mol" or "M."*

Step 1

Before we can calculate the molecular weight of a chemical compound, we need to know how many atoms are present for each element.

For the purposes of this exercise, we've chosen three chemical compounds that are commonly associated with water chemistry.

For **NaCl** *(sodium chloride)* there will be:

- one atom of sodium (**Na**)
- one atom of chlorine (**Cl**)

For **$CaCO_3$** *(calcium carbonate)* there will be:

- one atom of calcium (**Ca**),
- one atom of carbon (**C**)
- three atoms of oxygen (**O**)

For **$Fe(OH)_3$** *(hydrated ferric hydroxide)* there will be:

- one atom of iron (**Fe**),
- three atoms of oxygen (**O**)
- three atoms of hydrogen (**H**)

Note: If a subscript follows an atom abbreviation with no parenthesis, that number tells us how many atoms are present for that element. If parentheses are involved, you must multiply each individual subscript on the inside of the parentheses by the subscript number on the outside.

Step 2

To calculate the molecular weight of a substance or compound, you must first know the atomic weight of each element within the compound.

International Relative Atomic weights can be found in the table on pages 28-29. For your convenience, we've provided atomic weights for the compounds used in this exercise.

NaCl

Na	=	22.989770
Cl	=	35.453

$CaCO_3$

Ca	=	40.078
C	=	12.0107
O	=	15.9994

$Fe(OH)_3$

Fe	=	55.845
O	=	15.9994
H	=	1.00794

Step 3

Once you have a relative atomic weight for each element in a compound, multiply the weight of each atom by the number of atoms that are present in the formula, then add the answers.

NaCl

One atom of sodium (Na) = 1 x 22.989770 = **22.989770**
One atom of chlorine (Cl) = 1 x 35.453 = **35.453**

Add these values for the molecular weight:

22.989770 + 35.453 = **58.44277** atomic mass units (amu)

The answer **58.44277** represents the molecular weight for one mole of **NaCl** in atomic mass units (amu).

$CaCO_3$

One atom of calcium (Ca) = 1 x 40.078 = **40.078**
One atom of carbon (C) = 1 x 12.0107 = **12.0107**
Three atoms of oxygen (O) = 3 x 15.9994 = **47.982**

Add these values for the molecular weight:

40.078 + 12.0107 + 47.982 = **100.0707** atomic mass units (amu)

The answer **100.0707** represents the molecular weight for one mole of **$CaCO_3$**.

$Fe(OH)_3$

One atom of iron (Fe) = 1 x 55.845 = **55.845**
Three atoms of oxygen (O) = 3 x 15.9994 = **47.982**
Three atoms of hydrogen (H) = 3 x 1.00794 = **3.02382**

Add these values for the molecular weight:

55.845 + 47.982 + 3.02382 = **106.85082** atomic mass units (amu)

The answer **106.85082** represents the molecular weight for one mole of **$Fe(OH)_3$**.

Part VII
Different Ways of Expressing a Chemical Compound

Many elements that are important to lakes are found in more than one chemical form. **Nitrogen** (**N**) is a good example. It can combine with two oxygen atoms to form **nitrites** (expressed by the compound formula $\mathbf{NO_2^{-1}}$) or it can combine with three oxygen atoms to form nitrates ($\mathbf{NO_3^{-1}}$). Ammonium ions ($\mathbf{NH_4^{+1}}$) are formed when one nitrogen atom is combined with four hydrogen atoms. Nitrogen can also be found in various organic molecules produced by living organisms in lakes.[5]

The sum of these various nitrogen compounds is known as **total nitrogen**. We often rely on total measurements because some elements, nitrogen included, tend to continually transfer from one form to another through the metabolism of aquatic organisms, making it difficult to track individual chemical compounds. This is true for phosphorus as well. Florida LAKEWATCH measures total phosphorus concentrations for the same reason. These compounds are commonly measured in concentrations of milligrams per liter (mg/L) or micrograms per liter (μg/L).

There are times however, when we may want to isolate and measure a specific chemical compound. A case in point is the standard that has been set for nitrates in drinking water: In most communities in the United States, the maximum amount of nitrates allowed in drinking water is considered to be **45 mg/L $\mathbf{NO_3}$**. (While occurrences have been rare, it's been found that in small babies, higher nitrate levels can interfere with the ability of the blood to carry oxygen, resulting in a phenomenon known as the *blue baby syndrome*.)

Joe Richard

Because nitrogen compounds are constantly changing within an aquatic environment, some water monitoring programs, including Florida LAKEWATCH, prefer to measure total nitrogen concentrations. Such information helps scientists estimate the potential for biological productivity in a waterbody.

If we made a separate measurement of just the nitrogen contained in the **nitrate** formula mentioned above, we would express the concentration as **10.2 mg/L $\mathbf{NO_3}$-N**. This is known as a **nitrate-nitrogen** formula. An interpretation of this particular formula tells us that there are **10.2 mg** of nitrogen contained within the nitrates in a liter of water. The "**-N**" symbol found in the latter portion of the formula tells us that the number value (**10.2 mg/L**) is describing the weight of nitrogen only contained in that compound.

A similar approach would be used if we were to make a

5 *Organic molecules are formed by the actions of living things and/or have a carbon backbone. Methane (CH_4) is an example, although it's important to note that not all methane is formed by living organisms.*

separate measurement of the nitrogen contained in an ammonium compound. The formula would be expressed as **mg/L NH_4 -N** and is known as an **ammonium-nitrogen** formula. And if we wanted to measure the weight of nitrogen only as it combines with organic molecules, we would use an **organic-nitrogen** formula expressed as **mg/L organic-N.**

As you can see from the examples above, a nitrate formula is expressed differently than a nitrate-nitrogen formula, even though they both represent measurements of nitrates found in one liter of water.

To convert units of nitrates to units of nitrate-nitrogen we need to multiply by a conversion factor consisting of the atomic weight of nitrogen divided by the combined atomic weights of one nitrogen and three oxygen atoms. An example of this conversion process is provided below.

Note: The same approach can be used for other chemical compounds found in water. For instance, there may be times when one would want to isolate the weight of phosphorus contained in phosphates or the weight of sulfur contained in sulfates, etc.

Converting from nitrates to nitrate-nitrogen

45 mg/L NO_3 = 45 x (14* ÷ (14 + 48)) = ?**

(original nitrate formula)

45 mg/L NO_3 = 45 x 0.226 = 10.2 mg/L NO_3– N

(nitrate-nitrogen formula)

* ***14*** *is the relative atomic weight for* ***nitrogen*** *(rounded from 14.00674).*

** *The number* ***48*** *was attained by multiplying the relative atomic weight of a single oxygen atom (16) by 3, as there are three oxygen atoms in a nitrate molecule.*

The nitrate formula *(top left)* **tells us that there is a total concentration of 45 mg of nitrates in a liter of water. After doing the conversion, the nitrate-nitrogen formula** *(bottom right)* **tells us that out of the 45 mg/L of nitrates, there are 10.2 mg of actual nitrogen within that same liter of water. It should be noted that the nitrate-nitrogen formula is currently being used by most water chemistry labs as the preferred way to express this relationship.**

Part VIII
Using Atomic Weights to Compare Different Measures of Concentration

Amy Richard

Joe Richard

Kelly Schulz (left) processes total phosphorus samples for the Florida LAKEWATCH program at a UF/IFAS water chemistry laboratory. The freshwater total phosphorus concentrations she records into the LAKEWATCH database are expressed as micrograms per liter (µg/L). Erin Bledsoe (right) prepares a Van Dorn sampler before lowering it into marine offshore waters for a sample. Phosphorus and nitrogen concentrations found in saltwater samples are often expressed as micromoles per liter (µM/L). If the two were to be compared, conversions would be needed.

Although most aquatic scientists have adopted the International System (SI) for standardizing scientific units of measure, it doesn't necessarily mean they will use the same units of measure for the same things. For example, scientists who study saltwater systems (i.e., oceanographers, etc.) and those that study freshwater systems (i.e., limnologists) often express their work differently. Oceanographers tend to use the micromole per liter (µM/L) as a unit of measure in their analyses while limnologists tend to use the milligram per liter (mg/L) or microgram per liter (µg/L) units of measure for their studies.

This isn't a problem unless one scientist decides to compare his or her data with those of another, in which case conversions must be made so that one can compare "apples with apples." See the examples on the next page for an explanation on how atomic weights are used to convert from one unit of measure to another.

Converting micromoles per liter (μM/L) to micrograms per liter (μg/L)

To convert a concentration of an element given as **micromoles per liter** (μM/L) to units of **micrograms per liter** (μg/L), you would simply **multiply** the concentration in **micromoles** times the relative atomic weight of the element. For example, to convert a phosphorus concentration of **10 μM P/L** to units of **μg P/L**, you would multiply **10** times the relative atomic weight for phosphorus (**31**)* to get **310 μg/L** of phosphorus. *Notice how the abbreviation for phosphorus (P) is expressed in the equation below.*

10 μM P/L = 10 (micromoles) X **31** (relative atomic weight for phosphorus) = **310 μg P/L**

** Using the table on page 28 we can see that the relative atomic weight for phosphorus is 31 (rounded from 30.973761).*

Converting micrograms per liter (μg/L) to micromoles per liter (μM/L)

To convert a concentration of an element given as **micrograms per liter** (μg/L) to units of **micromoles per liter** (μM/L), you would **divide** the concentration in micrograms by the relative atomic weight of the element. For example, to convert a nitrogen concentration of **100 μg/L** to units of **μM/L** you would divide **100** by nitrogen's relative atomic weight of **14** to get **7.142 μM/L** of nitrogen. *Notice how the abbreviation for nitrogen (N) is expressed in the equation below.*

100 μg N/L = 100 (micrograms) **÷ 14** (relative atomic weight for nitrogen) = **7.142 μM N/L**

** Using the table on page 28 we can see that the relative atomic weight for nitrogen is 14 (rounded from 14.0067).*

Speaking in Molecular Terms

The following are terms that you are likely to hear within the water chemistry arena:

Atomic weight is approximately equal to the number of protons and neutrons found in an atom.

Gram atomic weight refers to the weight of an element in units of grams. Along those same lines, if one were to express the weight of an element in units of milligrams, you would then refer to it as the milligram atomic weight.

Micromolar solution refers to the molecular weight of a substance expressed as "micrograms contained in one liter of water" (i.e., one-millionth of a gram molecular weight). For example a micromolar solution of phosphorus contains 31 micrograms (μg) of phosphorus in one liter of water.

Molar solution is one mole dissolved in enough water to make one liter.

Mole is the molecular weight of a substance expressed in grams; also known as a gram molecule. Chemists tend to use moles to describe chemical compounds.

Molecular weight refers to the combined (the sum) atomic weight of all the atoms in a molecule.

Relative atomic weight refers to the relative weight of each element, based on the assigned relative atomic mass of $^{12}C = 12$.

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