First Edition

# Math for Wastewater Treatment Operators

Practice Problems to Prepare for Wastewater Treatment Operator Certification Exams

## Grades 3 and 4



American Water Works Association

The Authoritative Resource on Safe Water®

Advocacy
Communications
Conferences
Education and Training
Science and Technology

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operat...

# MATH FOR WASTEWATER TREATMENT OPERATORS GRADES 3 AND 4

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# MATH FOR WASTEWATER TREATMENT OPERATORS GRADES 3 AND 4

Practice Problems to Prepare for Wastewater Treatment Operator Certification Exams

**John Giorgi**

FIRST EDITION

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

This work is dedicated to my wife, Flora Zhou Giorgi; my children, Sara, Stephanie, and Steve; my mother, Thelma Giorgi; and my father, Albert Peter Giorgi.

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

*Math for Wastewater Treatment Operators Grades 3 and 4*
Copyright © 2009 American Water Works Association

AWWA Publications Manager: Gay Porter De Nileon
Technical Editor/Project Manager: Martha Ripley Gray
Production: SquareOne Publishing and Cheryl Armstrong

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information or retrieval system, except in the form of brief excerpts or quotations for review purposes, without the written permission of the publisher.

## Disclaimer

The authors, contributors, editors, and publisher do not assume responsibility for the validity of the content or any consequences of their use. In no event will AWWA be liable for direct, indirect, special, incidental, or consequential damages arising out of the use of information presented in this book. In particular, AWWA will not be responsible for any costs, including, but not limited to, those incurred as a result of lost revenue. In no event shall AWWA's liability exceed the amount paid for the purchase of this book.

Although this study guide has been extensively reviewed for accuracy, there may be an occasion to dispute an answer, either factually or in the interpretation of the question. Both AWWA and the author have made every effort to correct or eliminate any questions that may be confusing or ambiguous. If you do find a question that you feel is confusing or incorrect, please contact the AWWA Publishing Group.

Additionally, it is important to understand the purpose of this study guide. It does not guarantee certification. It is intended to provide the operator with an understanding of the types of math questions he or she will be presented with on a certification exam and the areas of knowledge that will be covered. AWWA highly recommends that you make use of the additional resources listed at the end of this study guide and any other resources recommended by your state certification board in preparing for your exam.

Library of Congress Cataloging-in-Publication Data

Giorgi, John.
Math for wastewater treatment operators grades 3 and 4 : practice problems to prepare for wastewater treatment operator certification exams / John Giorgi and prepared by the editors of American Water Works Association. -- 1st ed.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-58321-586-9
1. Sewage--Purification--Mathematics. 2. Sewage--Purification--Problems, exercises, etc. 3. Sewage disposal plants--Employees--Certification. 4. Water--Purification--Mathematics. 5. Water--Purification--Problems, exercises, etc. 6. Water treatment plants--Employees--Certification. 7. Engineering mathematics--Formulae. I. Title. II. Title: Math for wastewater treatment operators grades three and four.

TD745.G56192 2008
628.301'51--dc22
2008016935

Printed on recycled paper.

American Water Works Association

6666 West Quincy Avenue
Denver, Colorado 80235-3098
800.926.7337

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# CONTENTS

**List of Figures** . . . . . xiii
**List of Tables** . . . . . xv
**Acknowledgments** . . . . . xvii
**Preface** . . . . . xix
**Introduction** . . . . . xxi

CHAPTER 1 WASTEWATER TREATMENT GRADE 3 MATH PROBLEMS WITH SOLUTIONS . . . . . 1

Percent Calculations . . . . . 1
Percent Strength by Weight Solution Problems . . . . . 2
Percent Solids by Weight Calculations . . . . . 3
Percent Volatile Solids Reduction and Volatile Solids Destroyed . . . . . 4
Percent Seed Sludge Problems . . . . . 7
Volatile Solids Pumping Calculations . . . . . 8
Solution Mixture Calculations . . . . . 10
Arithmetic Mean, Median, Range, Mode, Geometric Mean, and Standard Deviation . . . 15
Area Problems . . . . . 20
Volume Problems . . . . . 22
Density and Specific Gravity of Liquids and Solids . . . . . 26
Hydraulic Press Calculations . . . . . 27
Screening Material Removal Calculations . . . . . 29
Screening Pit Capacity Calculations . . . . . 30
Grit Removal Calculations . . . . . 31
Detention Time Calculations . . . . . 33
Weir and Surface Overflow Rate Problems . . . . . 35
Flow and Velocity Calculations . . . . . 36
Pump Discharge Problems . . . . . 42

Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Solids and Hydraulic Loading Rate Calculations . . . 45
Sludge Pumping Problems . . . 50
Biosolids Pumping, Production, and Retention Time Problems . . . 53
Waste Activated Sludge Pumping Rate Calculations . . . 58
Pumping Horsepower, Efficiency, and Costing Calculations . . . 61
Dosage Problems . . . 65
Chemical Feed Solution Settings . . . 70
Dry Chemical Feed Settings . . . 71
Sludge Production Calculations . . . 76
Sludge Age (Gould) Calculations . . . 78
Organic Loading Rate Calculations . . . 80
Suspended Solids Loading Calculations . . . 83
Biochemical Oxygen Demand Loading Calculations . . . 86
Soluble and Particulate Biochemical Oxygen Demand Calculations . . . 88
Chemical Oxygen Demand Loading Calculations . . . 90
Hydraulic Digestion Time Calculations . . . 93
Digester Loading Rate Calculations . . . 94
Mean Cell Residence Time (Solids Retention Time) Calculations . . . 96
Digester Volatile Solids Loading Ratio Calculations . . . 100
Digester Gas Production Problems . . . 102
Digester Solids Balance . . . 103
Solids (Mass) Balance Calculations . . . 110
Volatile-Acids-to-Alkalinity Ratio Problems . . . 117
Lime Neutralization Problems . . . 118
Population Loading Calculations . . . 121
Population Equivalent Calculations . . . 122
Solids Under Aeration . . . 124
Suspended Solids Removal . . . 125
Biochemical Oxygen Demand Removal Calculations . . . 128
Food-to-Microorganism Ratio Calculations . . . 130
Waste Rates Using Food/Microorganism Ratio Calculations . . . 132
Seed Sludge Problems . . . 134
Gravity Thickener Solids Loading Problems . . . 135
Dissolved Air Flotation: Thickener Solids Loading Problems . . . 137
Dissolved Air Flotation: Air-To-Solids Ratio Calculations . . . 138
Dissolved Air Flotation: Air Rate Flow Calculations . . . 140
Centrifuge Thickening Problems . . . 141
Sand Drying Bed Problems . . . 142
Dewatering Calculations . . . 144



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Settleable Solids Calculations . . . 145
Composting Calculations . . . 146
Biosolids Disposal Calculations . . . 152
Chemistry and Laboratory Problems . . . 158
Equivalent Weights . . . 160
Basic Electricity Problems . . . 172
Kilowatt Determinations . . . 174
**GRADE 3 TEST . . . 179**
**GRADE 3 TEST SOLUTIONS . . . 185**

CHAPTER 2 WASTEWATER TREATMENT GRADE 4 MATH PROBLEMS WITH SOLUTIONS . . . 241

Percent Calculations . . . 211
Percent Strength by Weight Solution Problems . . . 212
Percent Solids by Weight Calculations . . . 214
Percent Volatile Solids Reduction and Volatile Solids Destroyed . . . 216
Percent Seed Sludge Problems . . . 219
Volatile Solids Pumping Calculations . . . 220
Solution Mixture Calculations . . . 222
Volume Problems . . . 229
Density and Specific Gravity of Liquids and Solids . . . 232
Pressure Problems . . . 233
Screening Material Removal Calculations . . . 236
Screening Pit Capacity Calculations . . . 237
Grit Removal Calculations . . . 238
Detention Time Calculations . . . 240
Weir and Surface Overflow Rate Problems . . . 243
Flow and Velocity Calculations . . . 244
Pumping Calculations . . . 250
Solids and Hydraulic Loading Rate Calculations . . . 256
Sludge Pumping Problems . . . 261
Biosolids Pumping, Production, and Retention Time Problems . . . 265
Waste Activated Sludge Pumping Rate Calculations . . . 271
Pumping Horsepower, Efficiency, and Costing Calculations . . . 275
Dosage Problems . . . 280
Chemical Feed Solution Settings . . . 284
Dry Chemical Feed Settings . . . 289
Sludge Production Calculations . . . 293
Sludge Age (Gould) Calculations . . . 296
Organic Loading Rate Calculations . . . 298



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Suspended Solids Loading Calculations . . . . . 300
Biochemical Oxygen Demand Loading Calculations. . . . . 303
Soluble and Particulate Biochemical Oxygen Demand Calculations . . . . . 306
Chemical Oxygen Demand Loading Calculations . . . . . 309
Hydraulic Digestion Time Calculations. . . . . 310
Digester Loading Rate Calculations. . . . . 311
Mean Cell Residence Time (Solids Retention Time) Calculations. . . . . 314
Digester Volatile Solids Loading Ratio Calculations . . . . . 319
Digester Gas Production Problems . . . . . 320
Digester Solids Balance . . . . . 322
Solids (Mass) Balance Calculations. . . . . 329
Volatile-Acids-to-Alkalinity Ratio Problems. . . . . 337
Lime Neutralization Problems. . . . . 338
Population Loading Calculations . . . . . 340
Population Equivalent Calculations. . . . . 342
Solids Under Aeration. . . . . 344
Suspended Solids Removal . . . . . 346
Biochemical Oxygen Demand Removal Calculations . . . . . 348
Food-to-Microorganism Ratio Calculations . . . . . 351
Waste Rates Using Food/Microorganism Ratio Calculations . . . . . 353
Seed Sludge Problems. . . . . 356
Gravity Thickener Solids Loading Problems . . . . . 357
Dissolved Air Flotation: Thickener Solids Loading Problems . . . . . 358
Dissolved Air Flotation: Air-to-Solids Ratio Calculations . . . . . 360
Dissolved Air Flotation: Air Rate Flow Calculations . . . . . 362
Centrifuge Thickening Problems . . . . . 363
Sand Drying Bed Problems . . . . . 364
Dewatering Calculations . . . . . 367
Settleable Solids Calculations. . . . . 368
Composting Calculations. . . . . 369
Biosolids Disposal Calculations . . . . . 377
Chemistry and Laboratory Problems. . . . . 383
Basic Electricity Problems. . . . . 395
Kilowatt Determinations . . . . . 398
**GRADE 4 TEST . . . . . 401**
**GRADE 4 TEST SOLUTIONS . . . . . 407**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**Appendix A Common Conversion Factors** . . . . . 433
**Appendix B Summary of Wastewater Treatment Equations** . . . . . 437
**Appendix C Chemistry Tables** . . . . . 465
**Appendix D Depth/Diameter (d/D) Table** . . . . . 471
**Appendix E Wastewater Flow Chart Diagrams** . . . . . 473
**Appendix F Abbreviations** . . . . . 487
**Bibliography** . . . . . 489
**Additional Resources** . . . . . 491



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# FIGURES


Figure E-1 Flow Chart of Typical Wastewater Treatment Processes . . . . . 474

Figure E-2 Flow Chart of Conventional Activated Sludge Process . . . . . 475

Figure E-3 Flow Chart of Contact Stabilization Process. . . . . 476

Figure E-4 Flow Chart of Activated Sequencing Batch Reactor . . . . . 477

Figure E-5 Flow Chart of Typical Wastewater Treatment Using Ponds After Secondary Treatment . . . . . 478

Figure E-6 Flow Chart of Typical Wastewater Treatment Using Polishing Ponds in Series Treatment . . . . . 479

Figure E-7 Flow Chart of Wastewater Treatment Using Rotating Biological Contactor Process . . . . . 480

Figure E-8 Flow Chart of Typical Wastewater Treatment Using an Oxidation Ditch. . . . . 481

Figure E-9 Flow Chart of Typical Wastewater Treatment Using Electrodialysis or Nanofiltration . . . . . 482

Figure E-10 Flow Chart of Typical Wastewater Treatment Using a Membrane Bioreactor . . . . . 483

Figure E-11 Flow Chart of Wastewater Treatment Nitrification Process. . . . . 484

Figure E-12 Flow Chart of Wastewater Treatment Plant Processing Sludge . . . . . 485




Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# TABLES


C-1 International Atomic Weights. . . . . 465
C-2 Common Chemicals Used and Encountered in the Water Industry . . . . . 467
C-3 Common Formula Weights . . . . . 469
D-1 Depth/Diameter Table . . . . . 471




Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# ACKNOWLEDGMENTS

I would like to thank the staff and editors of the American Water Works Association, publications manager Gay Porter De Nileon, editor Martha Ripley Gray, and reviewers Radenko Odzakovic and Tim McCandless for their help and guidance in making this book possible. Their assistance is greatly appreciated. Thanks also to Dean Bugher for his assistance with the flow charts.

I am grateful to my wife, Flora, and my children, Steve, Stephanie, and Sara. Their patience and support for my long hours working on this book will always be greatly appreciated.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# PREFACE

The first edition of *Math for Wastewater Treatment Operators Grades 3 and 4* was written to provide students and operators with examples of a variety of different problems that will be encountered both on certification exams and on the job. This book is divided into four main parts: the introduction, which is a review of significant numbers and rounding; two chapters on math followed by practice tests, one after each math chapter; and appendices. The math problems in chapter two are a little more difficult than the math problems in chapter one and also contain a few new types.

Each problem is presented with easily followed steps and comments to facilitate understanding. One possible way to go through the math problems presented in this study guide is for you to cover the page you are working on with a piece of paper or cardboard. Then, slowly move the cover down until you can read the question. Do the problem on a separate piece of paper. Uncover the worked solution and compare your method and result to the book's method and result. If your answer is the same, but your method is different, that's okay. Remember that there may be more than one way to solve a problem. If there is a certain problem that gives you trouble, try to do the problem again on another day until you completely understand it. Do similar problems that may be found in the other grade in the book. The more math problems you do, the more comfortable you will become with them.

Included after each grade level are tests to help you determine where your strengths or weaknesses are. Each test consists of randomly chosen problems from the associated problems in that chapter. The questions in the test are followed immediately by each individual question, procedure, and result. You can complete all the problems in the test on a separate piece of paper. After completing the test, the procedures and answers can be checked against the provided procedures and solutions.

Common conversion factors are included in appendix A for reference purposes and for doing problems in this book. Appendix B is a summary of the wastewater treatment equations. Appendix C consists of chemistry tables that are needed for some of the problems. Appendix D is the depth-to-diameter table for calculating flow in a pipeline that is not full. Appendix E contains flow charts of wastewater treatment processes. and Appendix F lists abbreviations used in this book.

Any suggestions for improving this math book, including additional types of problems, would be appreciated by the author. Please send your suggestions or questions to John Giorgi at aujourney@hotmail.com, or in care of Publications Manager, AWWA, 6666 West Quincy Avenue, Denver, CO 80235-3098.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

# INTRODUCTION

## SIGNIFICANT FIGURES

When you see an answer to a mathematical problem, laboratory test result, or other measured values, do you ever wonder how accurate they are? The accuracy of any answer is based on how accurate the values are in determining the answer, or the accuracy of the laboratory result depends on the precision of the measuring instruments, and even the laboratory analyst.

The following discussion will show how to determine the number of significant figures or digits an answer to any particular problem should have, i.e., how many decimal places, if any, should the answer have.

The number 30.03 has four significant figures, while the number 33,000 has only two. Why is this so? The number 30.03 has been measured to the hundredth place, so the zeroes that are straddled by the threes are significant. In fact, all figures to the left of a decimal point are significant (for example, 2.000 has four significant figures). The second number, 33,000, has only two because the zeroes are only placeholders and are thus not significant. See the exercise below on significant figures.

### "Rounding Off"

"Rounding off" numbers is simply the dropping of figures starting on the right until the appropriate numbers of significant figures remain. Let's look at the three rules and an example for each that governs the process of rounding numbers.

1. When a figure less than five is dropped, the next figure to the left remains unchanged. Thus, the number 11.24 becomes 11.2 when it is required that the four be dropped.
2. When the figure is greater than five that number is dropped and the number to the left is increased by one. Thus 11.26 will become 11.3.
3. When the figure that needs to be dropped is a five, round to the nearest even number. This prevents rounding bias. Thus 11.35 becomes 11.4 and 46.25 becomes 46.2.

### The Significance or Insignificance of Zero

A zero may be a significant figure, if it is a measured value, or be insignificant and serve only as a spacer for locating the decimal point. If a zero or zeroes are used to give position value to the significant figures in the number, then the zero or zeroes are not significant. An example of this would be the following expression: 1.23 mm = 0.123 cm = 0.000123 m = 0.00000123 km. The zeroes are insignificant and only give the significant figures, 123, a position that dictates their value.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

### Addition and Subtraction

In addition and subtraction, only similar units and written to the same number of decimal places may be added or subtracted. Also, the number with the least decimal places, and not necessarily the fewest number of significant figures, places a limit on the number that the sum can justifiably carry, for example, when adding the following numbers: 446 mm + 185.22 cm + 18.9 m.

First, convert the quantities to similar units, which in this case will be the meter (second row below). Next, choose the least accurate number, which is 18.9. It has only one number to the right of the decimal, so the other two values will have to be rounded off (third row below).

| | | | | |
|---|---|---|---|---|
| 446 mm | = | 0.446 m | = | 0.4 m |
| 185.22 cm | = | 1.8522 m | = | 1.8 m |
| 18.9 m | = | 18.9 m | = | 18.9 m |
| | | | | 21.1 m |

When adding numbers (including negative numbers), the rule is that the least accurate number will determine the number reported as the sum. In other words, the number of significant figures reported in the sum cannot be greater than the least significant figure in the group being added. Another example is given below in which the least accurate number, 170, dictates how the other three numbers will have to be changed before addition is done.

| | | |
|---|---|---|
| 1.023 grams (g) | = | 1 g |
| 23.22 g | = | 23 g |
| 170 g | = | 170 g |
| 1.008 g | = | 1 g |
| 195.251 g | = | 195 g |



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

However, you cannot report either of these values. The third value, 170 g, has two significant numbers, while all the others have four. The limiting factor is this third value, 170 g. The number 195 has three significant figures, and thus, cannot be used either. The answer must be reported as 200 g even though this looks wrong because it only has one significant figure!

### Multiplication and Division

In multiplication or division, the number that has the fewest significant figures will dictate how the answer will be written. Suppose we had a problem where we had to multiply two numbers: (23.88)(7.2) = 171.936. The first number has four significant figures, while the second has only two. The answer should only be written with two significant figures, as 170, because one of the numbers, 7.2, has only two significant figures. In both multiplication and division, "rounding off" never should be done before the mathematical exercise. Only the result should be appropriately "rounded off."

However, the above explanation of rounding multiplication and division problems is really an approximation of the exact rule. The exact rule states that the fractional or percentage error of a multiplication or division problem cannot be any less than the fractional or percentage error of any one factor. The exact rule always has to consider the amount of error that would result when rounding and applies to problems that have only one or two significant figures. These problems may require an additional significant number. An example follows: (0.93)(1.23) = 1.14. If this were rounded to 1.1 (two significant figures as is 0.93), as per the generalized or approximate rule, it would result in an error of approximately 3.5%, i.e., from the 1.14 answer. If the least significant number in the problem, 0.93, were written as 0.93 ± 0.01, it would result in an error of just over 1%, i.e., if it were really 0.94 or 0.92.

$$\frac{(0.01)\,(100\%)}{0.93} = 1.075\%, \text{ round to } 1.1\%$$

Thus, the best answer would be 1.14 because it introduces less error than the least significant number, if again it were measured wrong and were a little more or less (0.94 or 0.92).

Because this is much more difficult than what we need in this book, we will use the approximate rounding rule throughout this book, except where indicated. I stated it here so that you would be aware of this rule in case you are not already.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

In the following exercise, give the number of significant figures from each of the values below:

| Value | Answer |
|---|---|
| a. 8.34 lb/gal | 3 |
| b. 0.03 ntu | 1 |
| c. 19.08 mgd | 4 |
| d. 3 1-ton sulfur dioxide containers | 1 or infinite* |
| e. 2.30 mg/L | 3 |
| f. 0.00000254 | 3 |
| g. 80,000 pennies | 1 to 5** |
| h. 0.006700 | 4 |
| i. 43,560 $ft^3$/acre-ft | 4 or 5 or infinite# |
| j. 220 m | 2 or 3 |
| k. 9.02 mg | 3 |
| l. 10,200,050 gal | 7 or 8 |
| m. 1,000,000/mil | 7 or infinite# |
| n. 1,440 min/day | 4 or infinite+ |
| o. 7.481 gal/$ft^3$ | 4 |
| p. 86,400 sec/day | 5 or infinite+ |

* Because one would not divide them up in little pieces.

** Because one could argue that 1 or all of the zeroes could be significant, but not likely.

# By definition, so one could extend the zeros past the decimal point to infinity.

+ By definition, these are the minutes and seconds, respectively, that are in a day; until the earth's rotational speed slows down enough to warrant a change in these times, I will call these as indicated.

See chapter 1, Significant Figures, for more practice.

## ROUNDING IN THIS BOOK

The problems in this book are done in steps so the student can see each operation visually, which facilitates understanding. In so doing, a certain amount of "pre-rounding" has to occur, otherwise the numbers continue in most cases to absurdity. This "pre-rounding" was done as much as possible such that the final answer would not be affected.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

## SET UP OF PROBLEMS IN THIS BOOK

Note that many of the same problem types have the equation written each time and that the units are written throughout each problem. The reason this is done is to help the student form a good habit, because carrying units throughout a calculation will assist in identifying which units require conversion and as a check on the final result. This habit should be carried over during a certification test or on the job. In some cases, partial credit will be given for a correct written equation. When the units are written down, it will not only help the student in setting up the problem correctly by seeing how the units will cancel, but will also make it easier for the person correcting the test to see your intent and also in correcting the problems.

## Pi ($\pi$)

The number used for pi ($\pi$) will be 3.14 throughout this book.

## ppm and mg/L

Since in most cases mg/L = ppm, please note that mg/L will cancel out units that are in millions. For example, mg/L will cancel with the mil (million) in mil gal.

## DERIVATION OF THE NUMBER 0.785

The number 0.785 is used extensively in this book in conjunction with the diameter squared. Examples include the determination of the area of a circular reservoir or the volume of the tank. The same answer can be achieved using $\pi r^2$, where "r" equals the radius. But how is this number, 0.785, derived? The following applies:

$$\mathbf{(0.785)(Diameter)^2 = \pi r^2}$$
$$\mathbf{(Diameter)^2 = 4r^2}$$

**Proof:** Assume $x$ is the number 0.785 but is not yet known. We know some number, $x$, times the diameter squared equals $\pi$ times the radius squared. The equation is:

$$x(\text{Diameter})^2 = \pi r^2$$



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

From 1 above and substituting $x$ for 0.785, substitute $4r^2$ for $(\text{Diameter})^2$ from 2 above.

$$x(4r^2) = \pi r^2$$

Rearrange equation to solve for $x$.

$$x = \frac{\pi r^2}{4r^2} = \frac{\pi}{4} = \frac{3.14}{4} = \mathbf{0.785}$$

Thus, $x$ is equal to 0.785, which is what we wanted to prove. Most water treatment operators like to use $(0.785)(\text{Diameter})^2$, while engineers and scientists like to use $\pi r^2$. Because both will be encountered, it is advisable to know both methods.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

CHAPTER

1

# WASTEWATER TREATMENT
# Grade 3

*Students preparing for Grade 4 wastewater treatment certification tests should also understand these problems.*

## PERCENT CALCULATIONS

Percent calculations are used throughout this book and are thus essential to understand. They are also a good refresher for the student or operator.

**1. A settleability test is performed on a mixed liquor suspended solids sample. If 376 mL of solids settle out of a 2,000 mL sample in a graduated cylinder, what are the percent settleable solids by volume? Give answer to three significant figures.**

Equation: **Percent settleable solids** $= \dfrac{(\text{Settleable solids, mL})\,(100\%)}{\text{Total sample volume, mL}}$

Percent settleable solids $= \dfrac{(376\text{ mL})\,(100\%)}{2{,}000\text{ mL}} =$ **18.8% Settleable solids by volume**

**2. What is the percent removal across a primary clarifier, if the influent biochemical oxygen demand ($BOD_5$) is 365 and the effluent $BOD_5$ is 199?**

Equation: **Percent $BOD_5$ removal** $= \dfrac{(\text{Influent BOD}_5 - \text{Effluent BOD}_5)\,(100\%)}{\text{Influent BOD}_5}$

Percent $BOD_5$ removal $= \dfrac{(365\text{ BOD}_5 - 199\text{ BOD}_5)\,(100\%)}{365\text{ BOD}_5} = \dfrac{(166\text{ BOD}_5)\,(100\%)}{365\text{ BOD}_5} =$ **45.5%**



Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

## PERCENT STRENGTH BY WEIGHT SOLUTION PROBLEMS

The strength of solution calculations are important to determine so that operators can properly mix chemicals in the percentages they need for dosing a particular wastewater process or other application.

**3. If 250 lb of magnesium hydroxide are dissolved in 125 gallons of water, what is the percent strength by weight of the magnesium hydroxide solution?**

Equation: $\textbf{Percent strength} = \dfrac{(\text{Number of lb, chemical})\,(100\%)}{(\text{Number of gal})\,(8.34\ \text{lb/gal}) + \text{Number of lb, chemical}}$

Substitute values and solve.

$$\text{Percent strength} = \frac{(250\ \text{lb})\,(100\%)}{(125\ \text{gal})\,(8.34\ \text{lb/gal}) + 250\ \text{lb}} = \frac{25{,}000\ \text{lb}\,\%}{1{,}042.5\ \text{lb} + 250\ \text{lb}}$$

$$\text{Percent strength} = \frac{25{,}000\ \text{lb}\,\%}{1{,}292.5\ \text{lb}} = 19.34\%, \text{ round to } \textbf{19\% Mg(OH)}_2 \textbf{ solution by weight}$$

**4. If 304 lb of dry alum ($Al_2SO_4$) are dissolved in 75.0 gallons of water, what is the percent strength by weight of the alum solution?**

Another way to solve this problem that differs from the problem above is to first convert the number of gallons of water to pounds.

Number of lb = (75.0 gallons)(8.34 lb/gal) = 625.5 lb of water

Next, find the percent strength of the solution.

Equation: $\textbf{Percent strength} = \dfrac{(\text{Number of lb of chemical})\,(100\%)}{\text{Number of lb, Water} + \text{lb, Chemical}}$

Substitute values and solve.

$$\text{Percent strength} = \frac{(304\ \text{lb}\ Al_2SO_4)\,(100\%)}{625.5\ \text{lb, Water} + 304\ \text{lb Alum}}$$

$$\text{Percent strength} = \frac{(304\ \text{lb}\ Al_2SO_4)\,(100\%)}{929.5\ \text{lb}} = \textbf{32.7\% Alum solution by weight}$$



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**5. If 25.0 grams (g) of magnesium hydroxide are dissolved in 1.000 liters (L) of water, what is the percent strength by weight of the magnesium hydroxide solution?**

Equation: $\textbf{Percent strength} = \dfrac{(\text{Number of grams, chemical})\,(100\%)}{(\text{Number of L})\,(1{,}000\ \text{grams/L}) + \text{grams, Chemical}}$

$$\text{Percent strength} = \frac{(25.0\ \text{g Mg(OH)}_2)\,(100\%)}{(1.000\ \text{L})\,(1{,}000\ \text{g/L}) + 25.0\ \text{g Mg(OH)}_2}$$

$$\text{Percent strength} = \frac{(25.0\ \text{g Mg(OH)}_2)\,(100\%)}{1{,}025\ \text{g}} = \textbf{2.44\% Mg(OH)}_2\ \textbf{solution by weight}$$

## PERCENT SOLIDS BY WEIGHT CALCULATIONS

Operators use percent solids calculations to determine efficiency of different unit processes, as well as to determine how much waste will require disposal.

**6. A wastewater treatment plant pumps an average of 27,480 gpd of sludge. If the percent of solids in the sludge averages 4.59% by weight and the sludge weighs 8.56 lb/gal, what is the lb/day of solids pumped?**

First, calculate the number of lb/day of sludge pumped.

$$\text{Sludge, lb/day} = (27{,}480\ \text{gpd})(8.56\ \text{lb/gal}) = 235{,}228.8\ \text{lb/day}$$

Next, calculate the lb/day of solids pumped.

Equation: $\textbf{Solids, lb/day} = \dfrac{(\text{Sludge, lb/day})\,(\text{Percentage of solids})}{100\%}$

$$\text{Solids, lb/day} = \frac{(235{,}228.8\ \text{lb/day})\,(4.59\%)}{100\%} = 10{,}797\ \text{lb/day, round to } \textbf{10,800 lb/day}$$



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**7. What is the percent of total inorganic solids by weight in a sludge sample, given the following data?**

**Sludge sample wet weight = 513 grams**
**Total solids dry weight = 32.7 grams**
**Inorganic dry weight = 6.81 grams**

Equation: **Percent inorganic solids** $= \dfrac{(\text{Dry sample in grams})\,(100\%)}{\text{Sludge sample in grams}}$

Percent inorganic solids $= \dfrac{(6.81\text{ grams})\,(100\%)}{513\text{ grams}} =$

1.327%, round to **1.33% total inorganic solids by weight**

**8. A total of 3,570 gpd of sludge (primary sludge) with 5.82% solids by weight content and weighing 8.41 lb/gal is pumped to a wastewater thickener tank. Determine the amount of sludge that should flow from the thickener tank in gpd, if the sludge (secondary sludge) is further concentrated to 7.09% solids by weight and weighs 8.49 lb/gal. *Note:* For convenience, primary sludge is abbreviated to 1° sludge and secondary sludge to 2° sludge.**

Equation: **(*x* gpd)(2° sludge lb/gal)(% 2° sludge) =**

**(1° sludge, gpd)(1° sludge lb/gal)(% 1° sludge)**

Substitute values and solve.

($x$ gpd)(8.49 lb/gal)(7.09%/100%) = (3,570 gpd)(8.41 lb/gal)(5.82%/100%)

$x$ gpd $= \dfrac{(3{,}570\text{ gpd})\,(8.41\text{ lb/gal})\,(5.82\%)\,(100\%)}{(8.49\text{ lb/gal})\,(100\%)\,(7.09\%)} = 2{,}902.9$ gpd, round to **2,900 gpd**

## PERCENT VOLATILE SOLIDS REDUCTION AND VOLATILE SOLIDS DESTROYED

The percent volatile solids reduction calculations indicate the effectiveness of the digested sludge process when compared to the volatile solids in the influent. The higher the percent volatile solids reduced or destroyed, the more stable the organic matter in the digester becomes and the more gas that is produced. Volatile solids destroyed are a measure of the effectiveness of the digester process. It tells the operator the number of pounds of volatile solids destroyed per cubic foot of digester



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

volume. See figures E-2, E-4, E-5, and E-6 in Appendix E for four types of wastewater plants using a digester.

**9. Calculate the percent volatile solids (VS) reduction, if the digester influent sludge has a VS content of 58.4% by weight and the digester effluent sludge has a VS content of 38.0% by weight.**

First, convert percentage to decimal form by dividing by 100%.

58.4%/100% = 0.584 and 38.0%/100% = 0.380

Equation: **Percent VS reduction** $= \dfrac{(\text{Influent} - \text{Effluent})(100\%)}{\text{Influent} - (\text{Influent})(\text{Effluent})}$

Percent VS reduction $= \dfrac{(0.584 - 0.380)(100\%)}{0.584 - (0.584)(0.380)} = \dfrac{0.204(100\%)}{0.584 - 0.22192}$

Percent VS reduction $= \dfrac{20.4\%}{0.36208} = 56.34\%$, round to **56.3% VS reduction by weight**

**10. If the sludge entering a digester has a volatile solids (VS) content of 62.9% by weight and the digester effluent sludge has a VS content of 42.8% by weight, calculate the percent VS reduction.**

First, convert percentage to decimal form by dividing by 100%.

62.9%/100% = 0.629 and 42.8%/100% = 0.428

Equation: **Percent VS reduction** $= \dfrac{(\text{Influent} - \text{Effluent})(100\%)}{\text{Influent} - (\text{Influent})(\text{Effluent})}$

Percent VS reduction $= \dfrac{(0.629 - 0.428)(100\%)}{0.629 - (0.629)(0.428)} = \dfrac{0.201(100\%)}{0.629 - 0.269212}$

Percent VS reduction $= \dfrac{20.1\%}{0.359788} = 55.866\%$, round to **55.9% VS reduction by weight**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**11. Given the following data, calculate the amount of volatile solids (VS) destroyed in lb/day/ft$^3$ of digester capacity:**

**Digester radius = 25.4 ft**
**Average sludge height = 17.0 ft**
**Sludge flow (Flow) = 3,485 gpd**
**Sludge solids concentration (SSC) = 6.33% by weight**
**Volatile solids content (VSC) = 68.4% by weight**
**Volatile solids reduction (VSR) = 56.1% by weight**
**Specific gravity of sludge = 1.02**

First, determine the number of lb/gal for the sludge.

Sludge, lb/gal = (8.34 lb/gal)(1.02 sp gr) = 8.507 lb/gal

Next, calculate the digester capacity in ft$^3$.

**Digester capacity, ft$^3$ = $\pi$(radius)$^2$(Height, ft)**

Digester capacity, ft$^3$ = 3.14(25.4 ft)(25.4 ft)(17.0 ft) = 34,438.64 ft$^3$

Next, write the equation.

$$\textbf{VS destroyed, lb/day/ft}^3 = \frac{(\text{Flow, gpd})\,(\text{Sludge, lb/gal})\,(\text{SSC, \%})\,(\text{VSC, \%})\,(\text{VSR, \%})}{\text{Digester capacity, ft}^3}$$

Substitute values and solve.

$$\text{VS destroyed, lb/day/ft}^3 = \frac{(3{,}485\text{ gpd})\,(8.507\text{ lb/gal})\,(6.33\%)\,(68.4\%)\,(56.1\%)}{(34{,}438.64\text{ ft}^3)\,(100\%)\,(100\%)\,(100\%)}$$

VS destroyed, lb/day/ft$^3$ = **0.021 lb/day/ft$^3$ VS destroyed by weight**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

## PERCENT SEED SLUDGE PROBLEMS

These calculations are used by operators when starting up a new digester or one that has been cleaned, and are based on volume. The other method presented later in this chapter is based on volatile solids added per pound of volatile solids contained in the digester.

**12. How many gallons of seed sludge are needed, if the digester is 48.5 ft in diameter, has a maximum side depth of 24.9 ft, has a wastewater depth of 17.2 ft, and requires the seed sludge to be 24.5% of the digester volume?**

First, determine the volume of the digester in gallons.

Number of gallons = $(0.785)(\text{Diameter})^2(\text{Depth, ft})(7.48\ \text{gal/ft}^3)$

Number of gallons = $(0.785)(48.5\ \text{ft})(48.5\ \text{ft})(24.9\ \text{ft})(7.48\ \text{gal/ft}^3) = 343{,}917\ \text{gal}$

Next, calculate the seed sludge required in gallons.

Equation: $\textbf{Percent seed sludge} = \dfrac{(\textbf{Seed sludge, gal})\,(100\%)}{\textbf{Total digester volume, gal}}$

Rearrange the equation to solve for the number of gallons.

$$\text{Seed sludge, gal} = \frac{(\text{Total digester volume, gal})\,(\text{Percent seed sludge})}{100\%}$$

$$\text{Seed sludge, gal} = \frac{(343{,}917\ \text{gal})\,(24.5\%)}{100\%} = 84{,}260\ \text{gal, round to } \textbf{84,300 gal}$$

Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**13. What must have been the percent seed sludge by volume added to a digester, given the following data?**

**Diameter of digester = 44.7 ft**
**Maximum side height = 21.5 ft**
**Seed sludge added to digester = 63,450 gal**

First, determine the volume of the digester in gallons.

Number of gallons = $(0.785)(\text{Diameter})^2(\text{Depth, ft})(7.48\ \text{gal/ft}^3)$

Number of gallons = $(0.785)(44.7\ \text{ft})(44.7\ \text{ft})(21.5\ \text{ft})(7.48\ \text{gal/ft}^3) = 252{,}246\ \text{gal}$

Next, calculate the seed sludge required in gallons.

Equation: $\textbf{Percent seed sludge} = \dfrac{(\text{Seed sludge, gal})\,(100\%)}{\text{Total digester volume, gal}}$

Percent seed sludge = $\dfrac{(63{,}450\ \text{gal})\,(100\%)}{252{,}246\ \text{gal}}$ = **25.2% Seed sludge by volume**

## VOLATILE SOLIDS PUMPING CALCULATIONS

These calculations are used as a planning tool by the operator. By knowing the pumping rate of volatile solids into a digester, an operator can make sure it is not overloaded, which would adversely affect the digester's operation and performance.

**14. Given the following data, how many lb/day of volatile solids (VS) are pumped to a digester?**

**Influent pumping rate = 4,274 gpd**
**Solids content = 5.62%**
**Volatile solids (VS) = 60.5%**
**Specific gravity of sludge = 1.06**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

First, determine the lb/gal for the sludge.

Sludge, lb/gal = (8.34 lb/gal)(1.06 sp gr) = 8.84 lb/gal

Equation: **VS, lb/day =**

$$\textbf{(Number of gpd to digester)}\frac{\text{(Percent solids)}}{100\%}\ \frac{\text{(Percent VS)}}{100\%}\textbf{(Sludge, lb/gal)}$$

$$\text{VS, lb/day} = (4{,}274\text{ gpd Solids})\frac{(5.62\%)}{100\%}\ \frac{(60.5\%\text{ VS})}{100\%}(8.84\text{ lb/gal})$$

VS, lb/day = 1,284.63 lb/day, round to **1,280 lb/day VS**

**15. Given the following data, how many lb/day of volatile solids (VS) are pumped to a digester?**

**Pumping rate = 4.1 gpm**
**Solids content = 4.74%**
**Volatile solids (VS) = 59.3%**
**Specific gravity of sludge = 1.03**

First, determine the lb/gal for the sludge.

Sludge, lb/gal = (8.34 lb/gal)(1.03 sp gr) = 8.59 lb/gal

Next, convert gpm to gpd.

Number of gpd = (4.1 gpm)(1,440 min/day) = 5,904 gpd

Equation: **VS, lb/day =**

$$\textbf{(Number of gpd to digester)}\frac{\text{(Percent solids)}}{100\%}\ \frac{\text{(Percent VS)}}{100\%}\textbf{(Sludge, lb/gal)}$$

$$\text{VS, lb/day} = (5{,}904\text{ gpd Solids})\frac{(4.74\%)}{100\%}\ \frac{(59.3\%\text{ VS})}{100\%}(8.59\text{ lb/gal})$$

VS, lb/day = 1,425.52 lb/day, round to **1,400 lb/day VS**

Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

## SOLUTION MIXTURE CALCULATIONS

These calculations are used when mixing two of the same solutions that have different strengths given a volume target. They are important for the operator to understand because there most probably will be times when solutions will require mixing. There are three ways to solve dilution problems. The dilution triangle is perhaps the easiest, and is shown below for the next two problems. The method scientists and chemists use is $C_1V_1 + C_2V_2 = C_3V_3$.

**16. How many gallons of a 64.5% solution must be mixed with a 30.0% solution to make exactly 250 gallons of a 48.5% solution?**

**How to solve the problem using the dilution triangle:** The two numbers on the left are the existing concentrations of 64.5% and 30.0%. The number in the center, 48.5%, is the desired concentration. The numbers on the right are determined by subtracting diagonally the existing concentrations from the desired concentration.

| | | | |
|---|---|---|---|
| 64.5% | | 18.5*1 | 18.5 parts of the 64.5% solution are required for every 34.5 parts. |
| | 48.5% | | |
| 30.0% | | 16.0*2 | 16.0 parts of the 30.0% solution are required for every 34.5 parts. |
| | | 34.5 total parts | |

***1 18.5 is determined by subtracting diagonally 30.0% from 48.5%.**
***2 16.0 is determined by subtracting diagonally 48.5% from 64.5%.**

$\frac{18.5 \text{ parts}\,(250 \text{ gal})}{34.5 \text{ parts}} = 134.06$ gallons, round to **134 gallons of the 64.5% solution**

$\frac{16.0 \text{ parts}\,(250 \text{ gal})}{34.5 \text{ parts}} = 115.94$ gallons, round to $\frac{116}{250}$ **gallons of the 30.0% solution** gallons—added here to cross check math.

**To make the 250 gallons of the 48.5% solution, mix 134 gallons of the 64.5% solution with 116 gallons of the 30.0% solution.**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**17. A 7.5% hypochlorite solution is required. If exactly 475 gallons are needed, how many gallons of a 12% solution must be mixed with a 2.5% solution to make the required solution? Give answer to nearest gallon.**

Solve the problem using the dilution triangle.

| | | | |
|---|---|---|---|
| 12% | | 5.0 | 5.0 parts of the 12% solution are required for every 9.5 parts. |
| | 7.5% | | |
| 2.5% | | 4.5 | 4.5 parts of the 2.5% solution are required for every 9.5 parts. |
| | | 9.5 total parts | |

$$\frac{5.0 \text{ parts}\,(475 \text{ gal})}{9.5 \text{ parts}} = \textbf{250 gallons of the 12\% solution}$$

$$\frac{4.5 \text{ parts}\,(475 \text{ gal})}{9.5 \text{ parts}} = \frac{\textbf{225 gallons of the 2.5\% solution}}{\textbf{475 gallons}}$$

**Mix 250 gal of the 12% solution with 225 gal of the 2.5% solution to get the final solution of 7.5% hypochlorite.**

Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**18. What percent hypochlorite solution would result, if 325 gallons of a 14% solution were mixed with exactly 170 gallons of a 3.5% solution? Assume both solutions have the same density.**

First, find the total volume that would result from mixing these two solutions.

Total Volume = 325 gal + 170 gal = 495 gal

Then, write the equation.

**(Concentration$_1$)(Volume$_1$) + (Concentration$_2$)(Volume$_2$) = (Concentration$_3$)(Volume$_3$)**

Condensed as $C_1V_1 + C_2V_2 = C_3V_3$, where $C_1$ and $C_2$ = % Concentration of the two solutions before being mixed, $V_1$ and $V_2$ = Volume of the two solutions before being mixed, and $C_3$ and $V_3$ = the resulting % Concentration and Volume, respectively.

Substitute values and solve.

$$\frac{(14\%)\,(325\text{ gal})}{100\%} + \frac{(3.5\%)\,(170\text{ gal})}{100\%} = \frac{C_3\,(495\text{ gal})}{100\%}$$

$$45.5\text{ gal} + 5.95\text{ gal} = \frac{C_3\,(495\text{ gal})}{100\%}$$

Solve for $C_3$.

$$C_3 = \frac{(45.5\text{ gal} + 5.95\text{ gal})\,100\%}{495\text{ gal}} = \frac{(51.45\text{ gal})\,(100\%)}{495\text{ gal}}$$

$C_3$ = 10.39, round to **10% Final solution**

**19. What percent polymer solution would result, if 355 gallons of a 15.5% solution were mixed with 935 gallons of a 2.50% solution? Assume both solutions have the same density.**

First, find the total volume that would result from mixing these two solutions.

Total Volume = 355 gal + 935 gal = 1,290 gal



Documents
Document Sharing Hub

Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

Write the equation.

$\mathbf{C_1V_1 + C_2V_2 = C_3V_3}$, where $C_1$ and $C_2$ = % Concentration of the two solutions before being mixed, $V_1$ and $V_2$ = Volume of the two solutions before being mixed, and $C_3$ and $V_3$ = the resulting % Concentration and Volume, respectively.

Substitute values and solve.

$$\frac{(15.5\%)\,(355\text{ gal})}{100\%} + \frac{(2.50\%)\,(935\text{ gal})}{100\%} = \frac{C_3\,(1,290\text{ gal})}{100\%}$$

Solving for $C_3$

$$C_3 = \frac{(55.025\text{ gal} + 23.375\text{ gal})\,(100\%)}{1,290\text{ gal}} = \frac{(78.4\text{ gal})\,(100\%)}{1,290\text{ gal}}$$

$C_3 = 6.078$, round to **6.08% Final solution**

**20. What percent strength of a solution mixture results, when 45 lb of a 12% solution are mixed with 75 lb of a 5.5% solution?**

Equation: **% Mixture strength** =

$$\frac{(\text{Solution}_1\text{ lb})\,(\text{Available }\%/100\%)\ +(\text{Solution}_2\text{, lb})\,(\text{Available }\%/100\%)\,(100\%)}{\text{Solution}_1\text{, lb} + \text{Solution}_2\text{, lb}}$$

Substitute values and solve.

$$\%\text{ Mixture strength} = \frac{[(45\text{ lb})\,(12\%/100\%) + (75\text{ lb})\,(5.5\,\%/100\%)]\,(100\%)}{45\text{ lb} + 75\text{ lb}}$$

$$\%\text{ Mixture strength} = \frac{[5.4\text{ lb} + 4.125\text{ lb}]\,(100\%)}{120\text{ lb}}$$

$$\%\text{ Mixture strength} = \frac{[9.525\text{ lb}]\,(100\%)}{120\text{ lb}} = 7.9375\%\text{, round to } \mathbf{7.9\%\ Mixture\ strength}$$



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**21. Given the following data, calculate the percent solids content that results when a primary sludge is mixed with a secondary sludge.**

**Average of primary sludge = 2,560 gpd**
**Average of secondary sludge = 2,975 gpd**
**Primary sludge = 6.38% solids**
**Secondary sludge = 3.77% solids**
**Primary sludge = 8.36 lb/gal**
**Secondary sludge = 8.58 lb/gal**

Equation: **Percent sludge mixture =**

$$\frac{[(\text{Sludge}_1\ \text{gal})\,(\text{lb/gal})\,(\text{Avail}\,\%/100\%)\ +\ (\text{Sludge}_2\ \text{gal})\,(\text{lb/gal})\,(\text{Avail}\,\%/100\%)]\,100\%}{(\text{Sludge}_1,\ \text{gal})\,(\text{lb/gal})\ +\ (\text{Sludge}_2,\ \text{gal})\,(\text{lb/gal})}$$

Where Avail = Available

% Mixture strength =

$$\frac{[(2{,}560\ \text{gal})\,(8.36\ \text{lb/gal})\,(6.38\%/100\%)\ +\ (2{,}975\ \text{gal})\,(8.58\ \text{lb/gal})\,(3.77\%/100\%)]\,100\%}{(2{,}560\ \text{gal})\,(8.36\ \text{lb/gal})\ +\ (2{,}975\ \text{gal})\,(8.58\ \text{lb/gal})}$$

$$\%\ \text{Mixture strength} = \frac{(1{,}365.42\ \text{lb} + 962.31\ \text{lb})\,(100\%)}{21{,}401.6\ \text{lb} + 25{,}525.5\ \text{lb}} = \frac{(2{,}327.73\ \text{lb})\,(100\%)}{46{,}927.1\ \text{lb}}$$

% Mixture strength = **4.96% Mixture strength**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**22. What percent strength of a solution mixture results, when 125 gallons of a 19.5% solution that weighs 8.94 lb/gal are mixed with 275 gallons of an 8.25% solution that weighs 9.01 lb/gal?**

Equation: **Percent mixture strength** =

$$\frac{[(\text{Solution}_1\ \text{gal})(\text{lb/gal})(\text{Avail}\ \%/100\%) + (\text{Solution}_2\ \text{gal})(\text{lb/gal})(\text{Avail}\ \%/100\%)]100\%}{(\text{Solution}_1,\ \text{gal})(\text{lb/gal}) + (\text{Solution}_2,\ \text{gal})(\text{lb/gal})}$$

Where Avail = Available

% Mixture strength =

$$\frac{[(125\ \text{gal})(8.94\ \text{lb/gal})(19.5\%/100\%) + (275\ \text{gal})(9.01\ \text{lb/gal})(8.25\%/100\%)]100\%}{(125\ \text{gal})(8.94\ \text{lb/gal}) + (275\ \text{gal})(9.01\ \text{lb/gal})}$$

$$\%\ \text{Mixture strength} = \frac{(217.91\ \text{lb} + 204.41\ \text{lb})(100\%)}{1{,}117.5\ \text{lb} + 2{,}477.75\ \text{lb}} = \frac{(422.32\ \text{lb})(100\%)}{3{,}595.25\ \text{lb}}$$

% Mixture strength = 11.75%, round to **11.8% Mixture strength**

## ARITHMETIC MEAN, MEDIAN, RANGE, MODE, GEOMETRIC MEAN, AND STANDARD DEVIATION

These calculations are good tools for planning and evaluating plant processes.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**23. Given the following data, calculate the unknowns:**

*Note:* A scientific calculator is required for determining the geometric mean and standard deviation.

| Day | Chlorine dose, mg/L | Unknown |
|---|---|---|
| Monday | 11.5 | a. Arithmetic mean, mg/L |
| Tuesday | 11.8 | b. Median, mg/L |
| Wednesday | 12.4 | c. Range, mg/L |
| Thursday | 11.8 | d. Mode, mg/L |
| Friday | 11.4 | e. Geometric mean, mg/L |
| Saturday | 10.9 | f. Standard deviation, mg/L |
| Sunday | 10.7 | |

**a. Calculate the arithmetic mean, mg/L.**

Equation: $\textbf{Arithmetic Mean} = \dfrac{\text{Sum of all measurements}}{\text{Number of measurements}}$

Arithmetic Mean $= \dfrac{11.5 + 11.8 + 12.4 + 11.8 + 11.4 + 10.9 + 10.7}{7} =$ **11.5 mg/L $Cl_2$**

**b. Determine the median, mg/L.**

To determine the median, put the chlorine dosages in ascending order and choose the middle value.

| 1 | 2 | 3 | **4** | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 10.7 | 10.9 | 11.4 | **11.5** | 11.8 | 11.8 | 12.4 |

In this case the middle value is **11.5 mg/L $Cl_2$**

**c. Determine the range, mg/L.**

Equation: **Range = Largest value − Smallest value**

Range, mg/L = 12.4 mg/L − 10.7 mg/L = **1.7 mg/L $Cl_2$**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**d. Determine the mode, mg/L.**

Mode is the measurement that occurs most frequently.

In this case it is **11.8 mg/L $Cl_2$**

**e. Calculate the geometric mean.**

Equation: **Geometric mean = $[(x_1)(x_2)(x_3)(x_4).....(x_n)]^{1/n}$**

Geometric mean, mg/L = $[(10.7)(10.9)(11.4)(11.5)(11.8)(11.8)(12.4)]^{1/7}$

Geometric mean, mg/L = $[26399680.269168]^{1/7}$

Geometric mean, mg/L = **11.5 mg/L $Cl_2$**

**f. Calculate the standard deviation.**

| Dose, mg/L | Frequency(f) | (X − X) | $(X - X)^2$ | $f(X - X)^2$ |
|---|---|---|---|---|
| 10.7 | 1 | 10.7 − 11.5 | 0.64 | 0.64 |
| 10.9 | 1 | 10.9 − 11.5 | 0.36 | 0.36 |
| 11.4 | 1 | 11.4 − 11.5 | 0.01 | 0.01 |
| 11.8 | 2 | 11.8 − 11.5 | 0.09 | 0.18 |
| 12.4 | 1 | 12.4 − 11.5 | 0.81 | 0.81 |
| | | | | $\sum f(X - X)^2 = 2.00$ |

Equation: **Standard deviation = $[\Sigma f(X - \bar{X})^2/n - 1]^{1/2}$**

Substitute values and solve.

Standard deviation = $[\Sigma f(2.00)^2/7 - 1]^{1/2}$

Standard deviation = $(4/6)^{1/2}$ = **0.82 mg/L $Cl_2$**

Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**24. Given the following data, calculate the unknowns. *Note:* A scientific calculator is required for determining the geometric mean and standard deviation.**

| Day | Flow mgd | Unknown |
|---|---|---|
| Monday | 1.25 | a. Arithmetic mean, mg/L |
| Tuesday | 1.19 | b. Median, mg/L |
| Wednesday | 1.24 | c. Range, mg/L |
| Thursday | 1.35 | d. Mode, mg/L |
| Friday | 1.48 | e. Geometric mean, mg/L |
| Saturday | 1.46 | f. Standard deviation, mg/L |
| Sunday | 1.57 | |

**a. Calculate the arithmetic mean, mg/L.**

Equation: **Arithmetic Mean** $= \dfrac{\text{Sum of all measurements}}{\text{Number of measurements}}$

Arithmetic Mean $= \dfrac{1.25 + 1.19 + 1.24 + 1.35 + 1.48 + 1.46 + 1.57}{7} =$ **1.36 mgd**

**b. Determine the median, mg/L.**

To determine the median, put the chlorine dosages in ascending order and choose the middle value.

| 1 | 2 | 3 | **4** | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 1.19 | 1.24 | 1.25 | **1.35** | 1.46 | 1.48 | 1.57 |

In this case the middle value is **1.35 mgd**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**c. Determine the range, mg/L.**

Equation: **Range = Largest value − Smallest value**

Range, mg/L = 1.57 mg/L − 1.19 mg/L = **0.38 mgd**

**d. Determine the mode, mg/L.**

Mode is the measurement that occurs most frequently.

In this case it is all of them because they all occur once. You can think of it as a tie, so they all win first place.

**e. Calculate the geometric mean.**

Equation: **Geometric mean = $[(x_1)(x_2)(x_3)(x_4).....(x_n)]^{1/n}$**

Geometric mean, mg/L = $[(1.19)(1.24)(1.25)(1.35)(1.46)(1.48)(1.57)]^{1/7}$

Geometric mean, mg/L = $[8.447469874]^{1/7}$

Geometric mean, mg/L = **1.36 mgd**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**e. Calculate the standard deviation.**

| mgd | frequency(f) | $(X - \bar{X})$ | $(X - \bar{X})^2$ | $f(X - \bar{X})^2$ |
|---|---|---|---|---|
| 1.19 | 1 | 1.19 − 1.36 | 0.0289 | 0.0289 |
| 1.24 | 1 | 1.24 − 1.36 | 0.0144 | 0.0144 |
| 1.25 | 1 | 1.25 − 1.36 | 0.0121 | 0.0121 |
| 1.35 | 1 | 1.35 − 1.36 | 0.0001 | 0.0001 |
| 1.46 | 1 | 1.46 − 1.36 | 0.01 | 0.01 |
| 1.48 | 1 | 1.48 − 1.36 | 0.0144 | 0.0144 |
| 1.57 | 1 | 1.57 − 1.36 | 0.0441 | 0.0441 |

$\Sigma f(X - \bar{X})^2 = 0.124$

Equation: **Standard deviation** $= [\Sigma f(X - \bar{X})^2/n - 1]^{1/2}$

Substitute values and solve.

Standard deviation $= [\Sigma f(0.124)^2/7 - 1]^{1/2}$

Standard deviation $= (0.002563)^{1/2} =$ **0.0506 mgd**

## AREA PROBLEMS

Areas are important to determine for a number of reasons including knowing the "footprint" of a tank or pond or the area of a particular process to make further calculations in other wastewater problems.

**25. What is the area of a circular pond, if it has a diameter of 194 ft?**

Equation: **Area** $= \pi r^2$ **where** $\pi = 3.14$

First, find the radius. Radius, ft = Diameter/2 = 194/2 = 97 ft

Area of tank = (3.14)(97 ft)(97 ft) = 29,544.26 ft$^2$, round to **29,500 ft$^2$**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**26. Find the area in cm² for a parallelogram, if the base is 48 cm and the height is 16.5 cm.**

Know: **Area = (Base)(Height)**

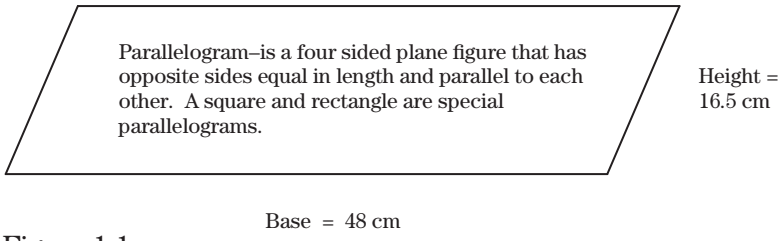



Figure 1-1.

Substitute values and solve.

Area = (48 cm)(16.5 cm) = 792 cm², round to **790 cm²**

**27. Find the area of a water channel that has a trapezoidal shape in square feet, if the altitude is 4.55 ft, the base on the bottom ($Base_1$) is 8.22 ft, and the base on the top ($Base_2$) is 12.03 ft.**

Know: $\textbf{Area} = \textbf{(Altitude)}\dfrac{(\text{Base}_1 + \text{Base}_2)}{2}$

Substitute values and solve.

$$\text{Area} = (4.55\text{ ft})\frac{(8.22\text{ ft} + 12.03\text{ ft})}{2} = (4.55\text{ ft})\frac{(20.25\text{ ft})}{2}$$

Area = (4.55 ft)(10.125 ft) = 46.07 ft², round to **46.1 ft²**

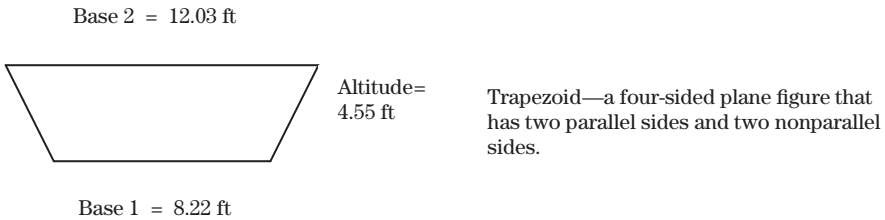



Figure 1-2.



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**28. What is the diameter of a tank, if the surface area is 1,962 ft²?**

Know: **Area = (0.785)(Diameter)²**

Solve for the diameter by rearranging the equation as shown.

$$D^2 = \frac{\text{Area}}{0.785} = \frac{1{,}962\ \text{ft}^2}{0.785} = 2{,}499.36\ \text{ft}^2$$

Then, take the square root of 2,499.36 ft².

D = 49.99 ft, round to **50.0 ft in diameter**

## VOLUME PROBLEMS

Volumes are very important to determine because many problems in the wastewater field require the volume to be known first before the rest of the calculations can be made. Knowing the volume of a particular process can also help the operator plan and make proper decisions in the treatment of wastewater.

**29. Find the capacity of a cylindrical tank in cubic feet and in liters, if it has a diameter of 10.3 ft and has a height of 18.5 ft.**

Equation: **Volume = (0.785)(Diameter)²(Height)**

Volume = (0.785)(10.3 ft)(10.3 ft)(18.5 ft) = 1540.69 ft³, round to **1,540 ft³**

Next, find the number of liters.

(1540.69 ft³)(7.48 gal/ ft³)(3.785 liters/gal) = 43,619.71 liters, round to **43,600 liters**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009

**30. Calculate the volume in cubic feet for a pipeline that is 18.0 in. in diameter and 1,704 ft long, using both formulas in bold, below.**

First, convert the diameter to feet.

$$(18.0 \text{ in.})\frac{(1 \text{ ft})}{12 \text{ in.}} = 1.50 \text{ ft (Diameter)}$$

Then, convert the diameter to the radius.

Radius = Diameter /2 = 1.50 ft/2 = 0.75 ft in radius

Formula for the volume of a pipe in cubic feet is **$\pi r^2$(Length)** or **(0.785)(Diameter)$^2$ (Length)**.

Using the first equation, the Volume, $ft^3$ = (3.14)(0.750 ft)(0.750 ft)(1,704 ft)

Volume, $ft^3$ = 3,009.69 $ft^3$, round to **3,010 $ft^3$**

Using the second equation, the Volume, $ft^3$ = (0.785)(1.50 ft)(1.50 ft)(1,704 ft)

Volume, $ft^3$ = 3,009.69 $ft^3$, round to **3,010 $ft^3$**

**31. How many gallons would be in the pipe for the previous problem?**

(3,009.69 $ft^3$)(7.48 gal/$ft^3$) = 22,512.48 gal, round to **22,500 gal**

**32. What is the volume of a conical tank in cubic feet that has a radius of 10.25 ft and a height of 18.1 ft?**

Equation: **Volume, $ft^3$ = 1/3$\pi r^2$(Height or Depth)**

Volume, $ft^3$ = 1/3(3.14)(10.25 ft)(10.25 ft)(18.1 ft) = 1,990.37 $ft^3$, round to **1,990 $ft^3$**



Documents
Document Sharing Hub
Full document details: AWWA Math for Wastewater Treatment Operators Grades 3 and 4. 2009