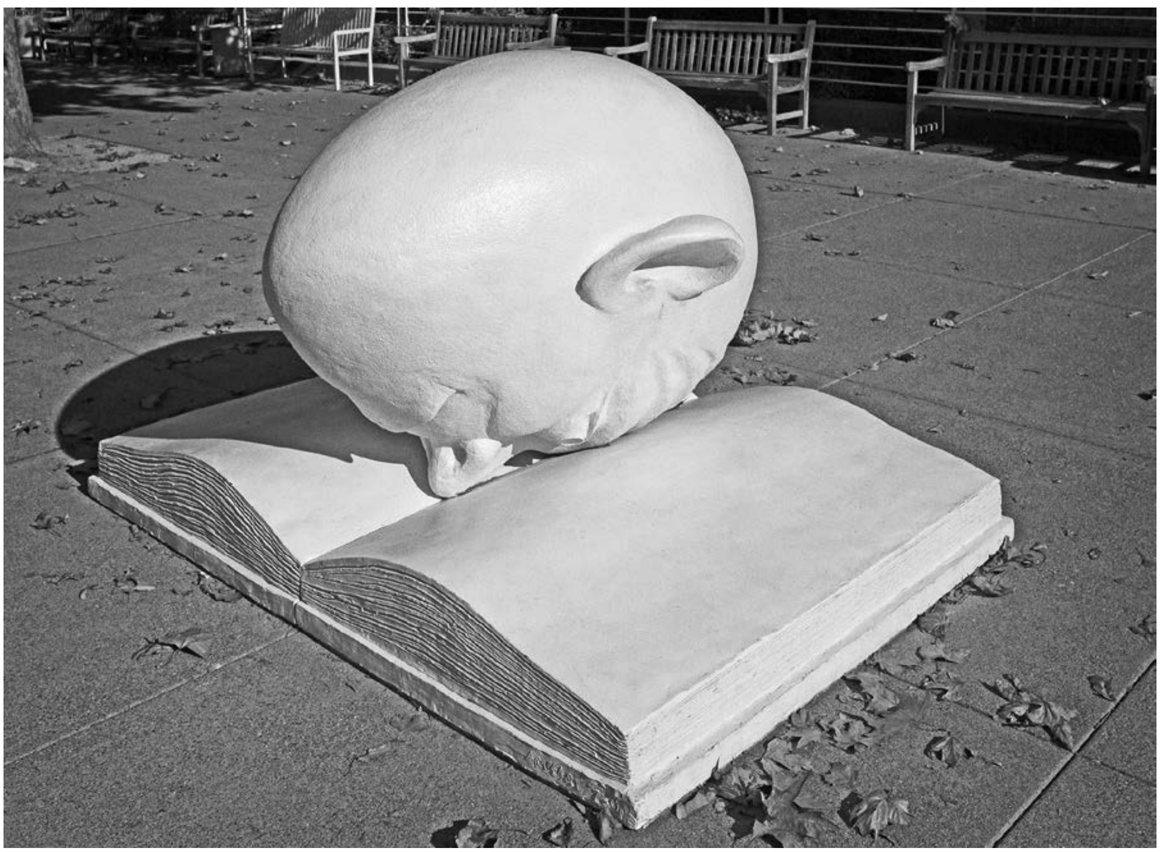
A GUIDANCE MANUAL ON THE PREPARATION OF

TECHNICAL REPORTS, PAPERS, AND PRESENTATIONS

Revised 2nd Edition



Prepared by

GEORGE TCHOBANOGLOUS and HAROLD LEVERENZ

Department of Civil and Environmental Engineering
University of California, Davis
Davis, CA

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ACRONYMS AND ABBREVIATIONS

AWWA	American Water Works Association
BF	Biodegradable fraction
ES	Executive Summary
LDO	Low dissolved oxygen
MS	Microsoft
SI	International System of Units
TSS	Total suspended solids
U.S. EPA	U.S. Environmental Protection Agency
UV	Ultraviolet light

dpi	Dots per inch
ft	Feet
gal/d	Gallons per day
in.	Inch
kPa	Kilo Pascal
L/capita•d	Liters per capita per day
m	Meter
m/d	Meter per day
m^3/m^2•min	Cubic meter per square meter per minute
mg/L	Milligram per liter
Mgal/d	Million gallons per day
pt	Point

μm	Micrometer

PREFACE

Effective writing involves hard work, consideration of technical writing as a subject worthy of inquiry and study, developing writing skills through practice, willingness to review and rewrite as many times as necessary, and the motivation and enthusiasm to persist. The best way to become an effective writer is to write, write, and continue to write at every opportunity. Some suggestions on how to become a better technical writer, along with a review of the key mechanical elements of effective writing, are presented in this second edition of the guidance manual. To enhance the usability of this edition of the guidance manual for self-study, a number of writing exercises have been included, along with suggested answers.

George Tchobanoglous
Harold Leverenz

1
INTRODUCTION

The preparation of reports, papers, and oral presentations on the results of studies is a fundamental part of the modern engineering profession. Effective communication is the engineer's stock in trade. To be competitive, an engineer must develop a proficiency in the preparation of all types of engineering communication. While the clarity of the content is dependent on continual practice, the mechanical features of report preparation, as presented in this writing guidance manual are easy to learn and master. Good form leads to the preparation of better reports. In 1927, C. W. Park in his text, *English Applied In Technical Writing*, noted that:

> Even though a reader's interest is wholly in the subject matter his [*sic*]* first impression of a piece of writing is necessarily based on its general appearance. If the manuscript is neat and well arranged, and if it has a clean-cut, finished look, any one who picks it up is predisposed in favor of the writer and his work. The content, upon being closely examined, may prove to be disappointing; but it will need to be strikingly poor in order to [*sic*] wipe out entirely the favorable impression which was created at the start by its good mechanical form. On the other hand [*sic*], if a manuscript is illegible, untidy, scrappy, or incomplete, the reader's reaction is certain to be unfavorable. The subject matter will need to be exceptionally good in order to [*sic*] overcome the reader's adverse opinion.

1-1   PURPOSE

The purpose of this guidance manual is to serve as a reference for self-study, on the art and mechanics of technical writing, by students and practicing engineers involved in the preparation of engineering literature and presentations.

1-2   ORGANIZATION OF THE GUIDANCE MANUAL

To enhance the use of the guidance manual, individual sections are devoted to specific topics such as organization and formatting; and the preparation of tables, figures, and equations; some notes on writing; and punctuation and word usage.

*The expression "*sic"* italicized (Latin meaning “thus”), enclosed in brackets, is inserted in the quoted material to highlight what is considered to be an error in grammar (the use of the term "in order to" instead of the word "to", for example).

The specific sections included in the guidance manual are:

2. An Overview of Technical Writing
3. Organization and Formatting
4. Preparation of Tables
5. Preparation of Figures
6. Preparation of Equations
7. Citation of References
8. Some Notes on Writing
9. Punctuation and Word Usage
10. Evaluate Your Writing
11. Technical Memorandums
12. Oral Presentations
13. References

The overview of engineering writing, presented in Sec. 2, is included to provide a perspective on what is involved in preparing engineering documents. In addition to the preparation of formal engineering reports and journal articles, the preparation of technical memoranda and the development of materials for oral presentations are addressed in Secs. 11 and 12, respectively. Conversion factors and abbreviations for units are given in Appendix A. Physical constants are presented in Appendix B. Exercises for self-study are provided in Appendix C, and suggested answers to the self-study exercises are given in Appendix D.

1-3 ACKNOWLEDGEMENTS FOR FIRST EDITION

The completion of the first edition of this writing guidance manual was made possible by the cooperation and assistance of numerous individuals–past and present. For all of the students, engineers, writers, and editors who have helped and struggled with the senior author in the past, my heartfelt thanks. The authors are indebted to their colleagues Jeannie Darby and Edward Schroeder, who encouraged and supported the development of this guidance manual and to the Department of Civil and Environmental Engineering at the University of California, Davis for allowing the senior author to teach a course on report writing.

1-4 ACKNOWLEDGEMENTS FOR SECOND EDITION

Since the 2010 draft of this guidance manual has been circulated, a number of individuals have reviewed it and have offered both editorial and structural comments and/or suggestions for additions that have contributed significantly to this revised version of the guidance manual. Arranged alphabetically, they are: Michael Anderson, Consulting Engineer; Jeannie Darby, Professor, University of California at Davis; Steve Dentel, Professor, University of Delaware; Amelia Holmes, Graduate Student, University of California at Davis; Frances Kambour, Business Specialist, U.S. AID; Perry McCarty, Professor Emeritus, Stanford; Hari Seshan, Graduate Student, University of California at Davis; Stephen McCord, Senior Engineer, Larry Walker and Associates, Davis, CA; Doreen Salazar, Health Specialist, U.S. AID; and Edward Schroeder, Professor Emeritus, University of California at Davis. Finally, we owe a debt of gratitude to Lynn Tchobanoglous who edited and coordinated the final version of this revised guidance manual.

1-5 RECOMMENDATIONS FOR FUTURE EDITIONS OF GUIDANCE MANUAL

To improve the guidance manual for subsequent users, it would be helpful if current users of the manual would be kind enough to send corrections, suggested modifications, and possible additions to the authors.

George Tchobanoglous at <gtchobanoglous@ucdavis.edu>
Harold Leverenz at <hlleverenz@ucdavis.edu>

2
AN OVERVIEW OF TECHNICAL WRITING

Technical writing involves the communication of engineering and scientific concepts, ideas, and information to a variety of different audiences. The purpose of this section is: (1) to provide a brief introduction to the various types of engineering writing, (2) to discuss the importance of knowing your audience, (3) to review what should be done before beginning the writing process, (4) to discuss the basic steps involved in engineering writing, and (5) to present some thoughts on becoming a better writer. The detailed mechanics of report preparation are considered in the subsequent sections.

2-1 TYPES OF ENGINEERING WRITING

The types of engineering writing used for the communication of technical concepts, ideas, and information include:

- **Technical memorandums**–used to describe a segment of a large project, for example, observations from site visits, and assessments of new equipment.
- **Letter reports**–used to convey the results or findings for a project of limited scope.
- **Formal reports**–used for presenting the results of extensive engineering studies, such as a master plan.
- **Papers and articles for journals**–used to present the results of research, process and equipment testing, and operational experiences.
- **Proposals–** used to respond to request for qualifications and/or request for proposals. Often the required format is specified by the agency issuing the request for proposals.

2-2 THE AUDIENCE

The most important consideration in engineering writing is the audience. The intended audience will affect the style and form of the memo, article, or report. The style of an engineering report for a technical review panel will be different than that for a city council. If there are multiple audiences, the writing should be geared to the level of understanding of the least knowledgeable audience. As it works out, if your parents (assuming they are not engineers) understand the report, chances are good that others will also understand it.

Engineers often ask about style. The answer is not to worry about style, but to write as **clearly as you can**. It is not a question of whether to be technical or not technical, it is a question of considering the audience and directing the writing to them. Write as though you are explaining the subject to a friend. If you continue to strive to write clearly, **your style will evolve naturally**.

2-3 BEFORE BEGINNING THE WRITING PROCESS

Regardless of the type engineering writing, one way to begin is to ask a series of questions, such as (adapted from Sanks, 1979):

1. Who is the audience? (discussed above)
2. What is the specific purpose of the report, article, or memo (to inform, persuade, propose work)?
3. Is there a standard organizational format that must or should be followed?
4. How much explanation and documentation is required?
5. Is a survey of the literature required, and if so, specific or exhaustive?
6. Should all of the data be analyzed and included and, if not, what should be excluded?
7. What general conclusions can be drawn?
8. To streamline the writing, what material can be removed or placed in an appendix, if any? (will depend on the type document)

As the number of questions increases, sufficient material will be developed to complete the writing.

2-4 STEPS IN THE WRITING PROCESS

The writing process involves (1) the development of a detailed report or article topic outline - essentially the report organization or article format, (2) preparing figures and tables, (3) writing the first draft, (4) revising and editing, and (5) completing the final report.

Outline Development

The first step in the writing process should be the development of a detailed report or article outline. The principal purpose of an outline is to develop a logical approach to present the material, eliminate repetition, reduce unnecessary verbiage, and include the pertinent information and data. With a good outline, the writing is easier, quicker, and better. An outline can take a variety of forms from a simple list of words to a complete outline with headings, subheadings, and topic sentences (Hine, 1975). Some experienced writers simply form a mental image of the outline (Sanks, 1979).

It should be noted that most engineering firms have standard outlines for engineering reports, memos, and interoffice correspondence. Similarly, most journals also have prescribed formats for both text and references for the submission of articles. In such situations, the outlining task is to organize the material to be presented within the style and format constraints. The organization of engineering reports and technical papers is considered in Sec. 3.

Preparing Figures, Tables, and Equations

There are two schools of thought on whether the tables, figures, and equations should be prepared before beginning to write the report. One school of thought is that if these elements are prepared beforehand, it will be easier to write the report because they will help to clarify and amplify the text. The other school of thought maintains that it is best to start writing and when you come to a spot where a table, figure, or equation is needed stop and prepare it. While both approaches are valid, the former is generally more effective. In any case, even if the tables, figures, and equations have been prepared before the writing begins, inevitably revisions or additions will need to be prepared. The specifics of preparing effective tables, figures, and equations are discussed in Secs. 4, 5, and 6, respectively.

Writing the First Draft

Writing the first draft involves fleshing out the detailed outline. Strive to be clear, concise, logical, not repeat yourself, have good organization, use common everyday words, be positive, and not be negative or apologetic. One way of writing the report is to imagine explaining the subject to a colleague. Never take for granted anything the reader should know. Present information that is needed, so the reader does not have to guess at what you had intended. It is recommended to have sources of information and other reference material organized for use during the writing process. Insert citation where needed and prepare the citation list as you write, as described in Sec. 7. Review Secs. 8 and 9 for some useful notes on writing and grammar.

Vary Sentence Length In writing an article, paper, or report, it is desirable to vary the length of your sentences and pace (the rate at which new idea and thoughts are introduced). Start with a leisurely pace that can be increased as the reader becomes more familiar with the material. Selection of the most appropriate word is not necessary in the preparation of a draft. Word usage is refined in the revising and editing process.

Proper Placement of Text Material Review the body of the report to make sure that the statements that belong in other parts of the report are moved or eliminated. Statements and ideas should not be repeated in the body of the report. An exception is their repetition in the abstract, executive summary, and/or conclusions (Sanks, 1979).

The Summary Reports may include an abstract, executive summary, and / or conclusions section. Making statements in a summary and conclusions section that are inconsistent with the material presented in the body of the report is a common error made in engineering reports. To avoid this error, prepare the summary and conclusions sections after the body of the report is completed and recheck these sections for consistency. If a summary is used, it is generally presented in narrative form. Where conclusions are used, they are presented typically as short numbered statements. It must be perfectly clear whether the conclusion is based on the data, on a personal opinion, or on the literature.

Revising and Editing

Once the first draft of an article or report is prepared, the process of revising and editing is needed to elevate ordinary writing to effective, interesting, and award-winning writing. Use the evaluation tools presented in Sec. 10 to identify sections that should be revised or recast. During the revising and editing process it is possible to focus the report to meet various purposes and intended audiences. Asking a colleague to review all or a portion of the manuscript is helpful. Before beginning the revising and editing process, put the report away for a day or two. When revising and editing the report, scan each page and ask if (a) the material presented helps to further the purpose and objectives of the report, (b) should some material be moved to another section for a more logical flow, and (c) can some material be discarded for clarity and brevity.

Completing the Final Report

The process of completing the final article or report involves cross checking to make sure there are no inconsistencies between chapters or sections; making sure the table of contents, list of tables, and list of figures are up to date and complete; and that all the references cited in the text have been included in the reference list. In addition, any necessary acknowledgements should be checked and added. Finally, proofread the final report one more time before releasing it.

2-5 HOW TO BECOME A BETTER TECHNICAL WRITER

Effective writing involves hard work, a willingness to review and rewrite as many times as necessary, and the motivation and enthusiasm to persist. Some suggestions on how to become a better technical writer are (adapted in part from M&E, 1965):

1. Recognize and embrace the importance of writing. Success as an engineer or manager will depend, in part, on one's ability to write.
2. Study writing as a subject of inquiry. Analyze, study, and understand writing as one would a technical subject.
3. Develop writing skills. Practice writing within a prescribed time limit. Writing that is labored is cumbersome to read and understand.
4. Ask colleagues to review what has been written and make constructive use of their feedback. If someone is willing to take the time to review what has been written, consider their comments seriously. Peer review is the order of the day with most professional journals.

3
ORGANIZATION AND FORMATTING

Although each case is unique, most successful reports and articles adhere to some recognized organization and style; include tables and figures to enhance the presentation of information; contain literature references for background material and the support of findings; present findings and conclusions; and often include raw data and other reference materials in one or more appendixes for documentation. The purpose of this section is to consider (1) the general organization of engineering reports, (2) the general organization of technical papers, (3) the mechanics of report and article formatting, and (4) the mechanics of report and article preparation.

3-1 GENERAL ORGANIZATION OF FORMAL ENGINEERING REPORTS

While an infinite number of report formats are possible, a generalized format for successful technical reports is presented in this section. Technical papers are considered in the following section.

Organization of Reports

Engineering reports are organized into three major parts: (1) front matter, (2) report body, and (3) end matter. The individual items typically included in each of the three major parts of an engineering report are presented and described in Table 3-1. Because of its importance, an expanded discussion of what constitutes an effective executive summary is included.

Table 3-1
Items included in the front matter, report body, and end matter of formal engineering reports

Item	Description
Front Matter Front matter is used to provide an overview of the information contained in the report, including where the information is located. Depending on the scope of the report, not all sections listed below may be necessary. The following items typically constitute the front matter of reports.	
Front Cover	Layout of the front cover may be defined by the agency that the report is prepared for. Items on the front cover may include report title, date, number, client or funding agency, and authorship.

Continued on following page

Table 3-1 Continued

Item	Description
Title Sheet	Located inside front cover. Title sheet includes full report title; names of author(s), principal investigator(s), project committee member(s), and/or company affiliation for the author(s); report date; applicable copyright notice; and client or funding agency.
Letter of Transmittal	Sometimes placed in front of the title sheet. Should be presented on company letterhead and contains a letter submitting the report, references the report authorization, and a general statement of the report contents. The letter should be addressed to the client and signed by the principal investigator or person in charge.
Executive Summary	The executive summary is a stand-alone summary of the project or study. Elements of the executive summary include a description of the task, the work done, key findings or results, and future actions (see separate discussion in this section). Sometimes placed in front of report body
Contents	Often listed as Table of Contents. Contains a listing of all major report sections in the order presented in the report and the corresponding report page numbers.
List of Figures	All figures (illustrations, photographs, maps, data plots, etc.) contained in the report should be numbered consecutively and listed along with their corresponding page number on a separate report page titled "Figures." If there are only a few figures, the list of figures may not be necessary.
List of Tables	All tables contained in the report should be numbered consecutively along with their corresponding page number on a separate sheet titled "Tables." If there are only a few tables, the list of tables may not be necessary.
Abbreviations or Acronyms	A listing of all abbreviations and symbols used in the report presented with the corresponding phrase or symbol description. May not be required if limited abbreviations are used or if the intended audience is familiar with the abbreviations.
Working Terminology	Sometimes included as an appendix. Working terminology includes the terms used in the report that may be unfamiliar to the intended audience.
Units	List of all units used in the report along with the symbols used for their representation in the report body.
Preface	An introductory commentary on the scope, background, and intent of the report written by the author(s).
Foreword	A short statement about the report and/or author(s), usually written by someone other than the author(s). Not common in engineering reports.
Acknowledgements	Used to identify the people or entities that contributed to the work.

Continued on following page

Table 3-1 Continued

Report Body The report body contains details of the problem that was being investigated, how the study was conducted, results from the study, an analysis of the results, and conclusions. Tables and figures are used throughout the report body to enhance the presentation of information. The following materials typically constitute the report body.		
1.	Introduction	General description of the study, including the purpose, objectives, and scope, as needed to understand the detailed description of the study presented subsequently in the report.
2.	Project Description and Background	Presentation of information needed to explain the context of the report subject, including reference to previous related work.
3.	Review of Existing Facilities or Systems	Description of the facility or system that is the focus of the study. Explanation of the specific issues encountered that have brought about the study.
4.	Review of Alternatives	Presentation of alternative facilities or systems and development of procedures to evaluate the alternative scenarios.
5.	Technical Feasibility Assessment	Assessment of the selected scenarios based on the design specifications, suitability for the proposed application, or other criteria as appropriate. The technical feasibility assessment results provide the basis for selecting the alternative scenarios that should be subjected to an economic and/or life cycle analysis.
6.	Economic Analysis	Assessment of the expected economic impacts of the project, including capital and operating expenses, and project revenue sources.
7.	Life-Cycle Analysis	Evaluation of the overall environmental impact of the project or proposed alternative(s). This type of analysis has become a standard requirement for most engineering studies.
8.	Comparison of Alternatives	Interpretation of the study findings, including important conclusions and discussion of the engineering implications of the technical, economic, and life cycle analysis.
9.	Conclusions or Findings	Brief restatement of all important findings identified in the study. Always review the project objectives to ensure that the report is complete. No new material or discussion can be introduced.
10.	Recommendations	Presentation of a proposed course of action based on the conclusions developed previously. This section may also include suggestions for necessary or recommended future studies.
	References	Citations to all external sources of information used in the study.
End Matter Appendixes and index (only used for larger reports) typically constitute the end matter of reports.		
Appendixes		Used to present information relevant to the report but not appropriate for inclusion in the report body, including basic or raw data, exhibits, samples of data sheets, etc.
Blank Sheet		Put before the report back cover.
Back Cover		Should be of same paper stock as cover; text is sometimes added to the outside, but may also be left blank.

Importance of the Executive Summary

Perhaps the most important item in the front matter listed in Table 3-1 is the *Executive Summary* (ES), which is what most people read, even those who are not interested in the subject. The ES is the "story" of the project or study; the details are in the body of the report. The most significant feature of an ES is that it must be able to ***stand on its own***. In preparing the ES do not cut and paste random sentences or thoughts from the body of the report (unfortunately, a common practice). The ES should be written anew, restating and summarizing material from the body of the report in a concise and readable manner. Avoid obscure technical terms and jargon, and pay attention to grammar and logic. The key elements of an ES are:

- What was the task or project?
- What was done and by whom?
- What are the key findings, results, or main points?
- What are future or necessary actions?

3-2 GENERAL ORGANIZATION OF TECHNICAL PAPERS

Because some organizations and journals specify rigid formats, practice in conformity is educational. "Such conformity need not throttle creativity any more than the sonnet form inhibits a poet. Instead, a fixed format makes writing easier" (Sanks, 1979). Although each technical journal has its own style, it is possible to generalize the format used by most journals for technical articles as presented in Table 3-2. Always refer to the specifications and requirements for the journal to which the technical paper and article will be submitted.

Table 3-2
Items included in the front matter, paper body, and end matter of technical papers

Item	Description
Title and Authors	The study title or research topic is identified. The author(s), their affiliation(s), and contact information for the corresponding author are included under the title.
Abstract	The abstract in a technical paper corresponds to the ES in the technical report, as noted previously. The abstract, as with the ES, is a chance to "tell the story" of the research study or project. Project details are presented in the paper.

Continued on following page

Table 3-2 Continued

Item	Description
Key Words	Selected words, terms, and phrases used to identify the topics or subjects considered in the paper (also used for database searches).
1. Introduction	General description of the study, including the purpose, objectives, and scope, as needed to understand the detailed description of the study presented subsequently in the report.
2. Background or Literature Review	Presentation of information needed to explain the context of the report subject. Generally, the background contains a summary, along with reference citations, obtained through an extensive review of the literature.
3. Hypothesis	A clear statement of the proposed explanation for an observed phenomenon. The purpose of the study is to test the hypothesis.
4. Experimental Facilities	Description of the type of facility used to conduct the study, if applicable. Field studies may include a description of the site, including coordinates and other relevant information.
5. Methods and Procedures	Explanation of the experimental protocols, experimental design, analytical techniques, statistical evaluations, models or other software platforms used, and other measures relevant to the study. The methods section should contain enough information for another person to replicate the study and obtain the equivalent results.
6. Results	Can also be titled "Experimental Results." Detailed presentation of the study findings, such as measurements that were made or output from modeling.
7. Discussion	Interpretation of the study findings, including important conclusions from the study, a description of how the results support or disprove the hypothesis, discussion of how the present results compare to previous results, analysis of the implications of the results. In some cases, future studies and/or recommendations that can be made as a result of the study may also be presented.
8. Conclusions or findings	A brief restatement of important findings identified in the "Discussion." Always review the study objectives to ensure that the study and report are complete.
References	A list of citations for other sources of information used in the study.
Acknowledgements	Used to identify the people, funding sources, and other entities that contributed to the work.

3-3 REPORT FORMATTING

The format elements of report writing deal primarily with the layout of the report pages including the chapter or section titles, the headings used, the placement of figures and tables, whether justification is used, the citation format for references, and myriad other details that are taken into consideration in the preparation of a successful report.

Headings

Headings are used to introduce the general content of the presentation that follows. Headings should be clear, descriptive, and concise, with a maximum of four to eight words. Make maximum use of each heading by including some introductory text. Do not begin the text with a second level heading.

Hierarchical Number of Heading Levels Although any number of headings can be used, limit the number of hierarchical levels used in a technical report to three, not counting the chapter or section title. If more headings are required, the material should be recast. Examples of two different heading styles are presented on the following pages.

Number of Second and Third Level Headings When second and third level headings are used, a minimum of two consecutive second or third level headings must be used. A single second or third level heading should not be used.

Justification of Text

In engineering reports, the text is often set with margins that are justified (also referred to as flush-left, flush-right). Text that is not justified is referred to as flush-left, ragged-right. Based on numerous tests, reading comprehension is improved by about 20 percent when text is set flush-left, ragged-right as compared to justified text. Uneven spacing used between words eventually tires the eyes and limits the length of time text can be read without straining. The deleterious effect that justification has on comprehension can be appreciated by reading the following two paragraphs: the first is set with justification and the second with flush-left, ragged-right.

Paragraph Set With Flush-Left, Flush-Right Justification

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludges can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Paragraph Set With Flush-Left, Ragged-Right

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludges can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Using White Space (for readability and comprehension)

More white space in the page layout can also effect both readability and comprehension, especially in email transmissions (Chaparro et al., 2004). In their study, Chaparro and her co-authors found that it took longer to read text with large margins (more white space), but comprehension was improved as compared to the use of full margins.

Text With Relatively Large Margins

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludges can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Text With Full Margins

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludges can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

3-4 MECHANICS OF REPORT PREPARATION

The mechanics of report layout include placement of headings, spacing and margins, use of headers and footers, and page numbering conventions.

Placement of Headings

There are many acceptable arrangements for the placement of headings (e.g., flush-left, indented, centered). Two examples of heading placement are presented below.

Report Outline Style – 1: With Section Numbering

First, second, and third level headings flush-left. Third level heading cut in (text follows on same line as heading). First level headings are all capitalized. Lead capitals are used for the second and third level headings.

In Outline Form

CHAPTER 2 SETTING OF MASTER PLAN (Chapter title, text below)

2.1. SERVICE AREA (1st level heading, text below)

Physical Characteristics (2nd level heading, text below)

Surrounding Waters (2nd level heading, text below)

Beneficial Uses (3rd level heading, text follows on same line)

Water Quality (3rd level heading, text follows on same line)

Land use (2nd level heading, text below)

2.2 THE CURRENT SEWER SYSTEM (1st level heading, text below)

In Written Form

2

THE SETTING OF THE MASTER PLAN

To assess the development of the Sewer System Master Plan, it is important to understand the nature of the service area and the sewerage system including the . . .

2.1 THE SERVICE AREA

The service area can be characterized by its climate, land use, surrounding waters (including beneficial uses and water quality), and air quality. . .

Physical Characteristics

San Francisco is situated on the northern end of a narrow peninsula between the Pacific Ocean on the west and the San Francisco Bay estuary on the north . . .

Surrounding Waters

San Francisco Bay bounds the eastern and northern margins of the city. Approximately 40% of the land area of California drains through the bay.

Beneficial Uses. San Francisco Bay provides a wide variety of beneficial uses. These include swimming, boating, fishing, duck hunting, tourism . . .

Water Quality. Many San Francisco Bay species are contaminated and in decline. Factors contributing to this situation may include increasing . . .

Land Use

Of the total city land area, 82% is developed. Somewhat less than half of this developed area is residential (Association of Bay Area Governments, 2004).

2.2 THE CURRENT SEWERAGE SYSTEM

The current San Francisco sewerage system effectively collects, conveys and treats all of the dry-weather domestic wastewater and urban runoff flows . . .

(Report continues)

2-1

Report Outline Style – 2: With Decimal Numbering

First, second, and third level headings flush-left with decimal numbering. Third level heading cut in (text follows on same line as heading). First level headings are all capitalized. Lead capitals are used for the second and third level headings.

In Outline Form

CHAPTER 2 SETTING OF MASTER PLAN (Chapter title, text below)

2.1. SERVICE AREA (1st level heading, text below)

- 2.1.1 Physical Characteristics (2nd level heading, text below)
- 2.1.2 Surrounding Waters (2nd level heading, text below)
  - 2.1.2.1 Beneficial Uses (3rd level heading, text follows on same line)
  - 2.1.2.2 Water Quality (3rd level heading, text follows on same line)
- 2.1.3 Land use (2nd level heading, text below)

2.2. THE CURRENT SEWER SYSTEM (1st level heading, text below)

In Written Form

2

THE SETTING OF THE MASTER PLAN

To assess the development of the Sewer System Master Plan, it is important to understand the nature of the service area and the sewerage system including the . . .

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San Francisco Bay, bounds the eastern and northern margins of the city. Approximately 40% of the land area of California drains through the bay.

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Of the total city land area, 82% is developed. Somewhat less than half of this developed area is residential (Association of Bay Area Governments, 2004).

2.2 THE CURRENT SEWERAGE SYSTEM

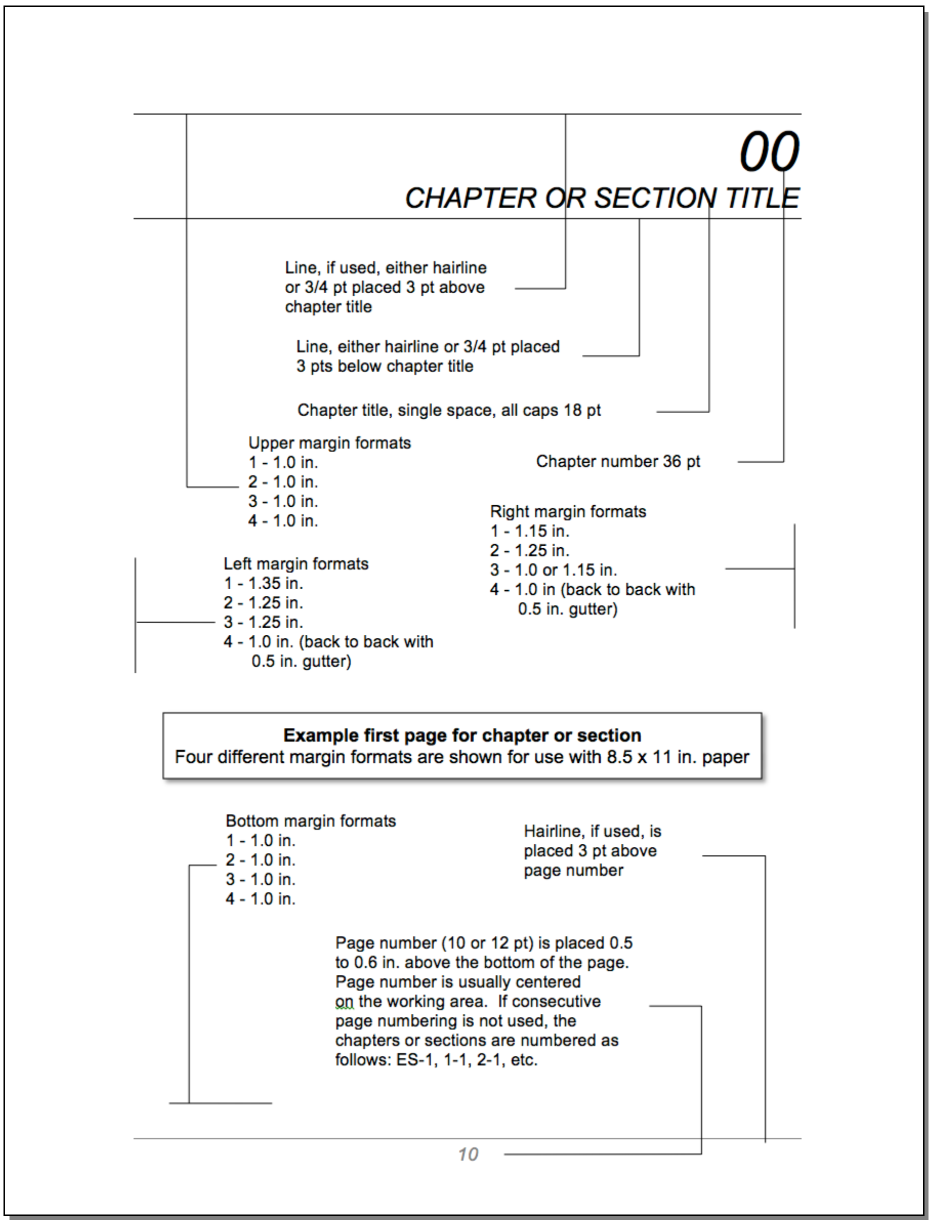
The current San Francisco sewerage system effectively collects, conveys and treats all of the dry-weather domestic wastewater and urban runoff flows . . .

(Report continues)

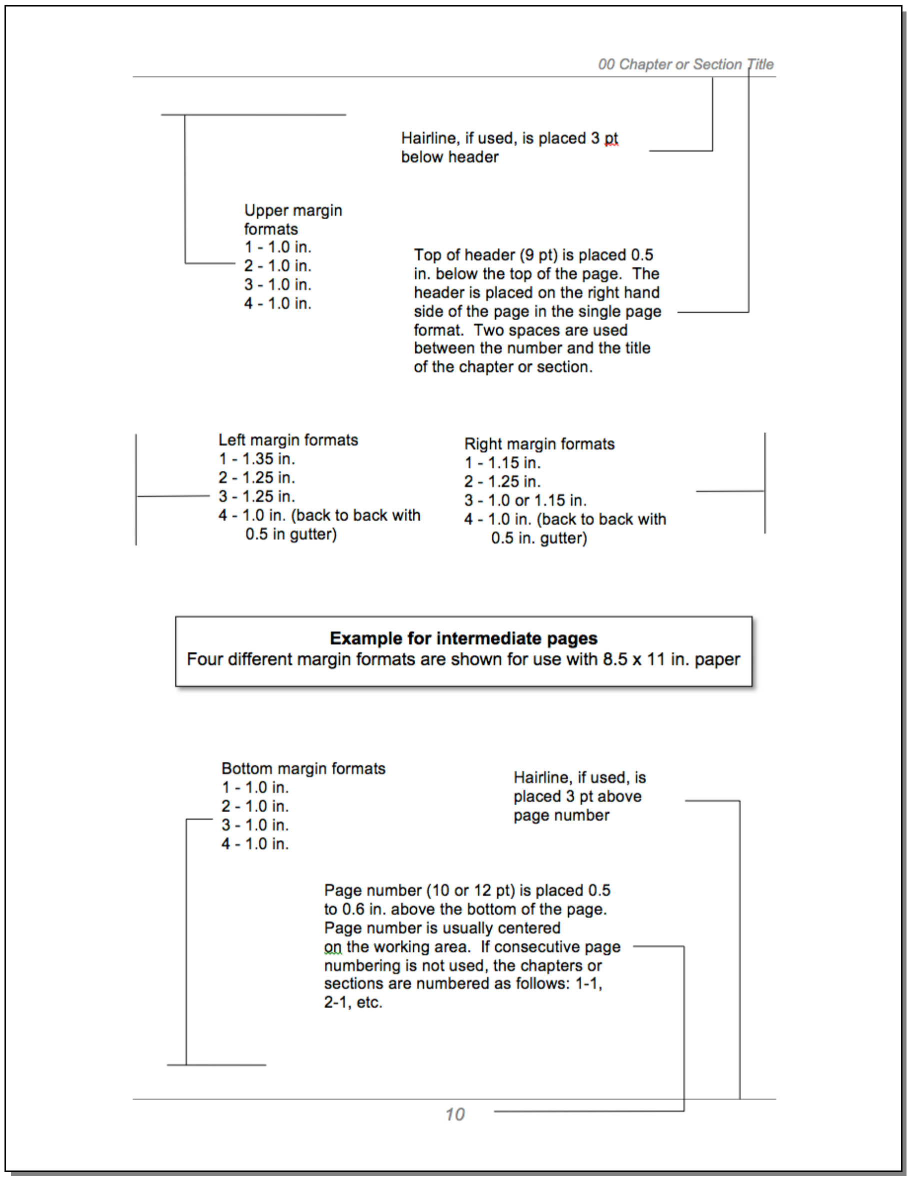
2-1

Spacing and Margins The spacing used in report text should not be too crowded. Examples of spacing and margins for title and intermediate pages are considered in the following paragraphs.

Format for first page of chapter or section. Four different page margin formats, numbered 1 through 4, are shown below for use with 8.5 by 11 in. paper for the first page of a chapter or section. Most organizations will have their own formats.



Format for intermediate pages of chapter or section. Four different page margin formats, numbered 1 through 4, are shown below for use with 8.5 by 11 in. paper for the intermediate pages of a chapter or section. Most organizations will have their own formats.



Use of Headers

A header is used to identify chapters or sections. In textbooks, the left header is used to identify the book or chapter title and the right header is used to identify the chapter or the section within a chapter. The same format is also used in formal reports. Often the header is placed above a fine line as used in this guidance manual (see top of page). A header is not used on the opening page of a chapter or section.

Use of Footers

A footer can be used for items such as the page number and organizational or corporate logo and/or information. For draft reports, the date is sometimes included in the footer to identify the version of the draft.

Page Numbering and Placement Conventions

The following conventions are commonly used for engineering reports.

1. Use lower case roman numerals for the front matter, starting with the report cover. Do not number the report cover and title page even though they are counted in the numbering sequence. For example, the page number of the contents page in this guidance manual is roman numeral iii, following the cover and title page.

2. Two conventions are used for the body of the report. The body of the report is either numbered consecutively starting with page 1 or each chapter or section is numbered separately with the chapter or section number placed in front of the page number. In the case where the chapter or section number precedes the page number, the page numbering starts at 1 for each new section or chapter. Either a dash or period is used between the chapter or section number and the page number (e.g., 2-1 or 2.1). The ES may be numbered as ES-1, etc., before the first section.

3. Two conventions are also used for the end matter of the report. Where consecutive page numbering has been used for the body of the report, the

consecutive numbering is continued through the end matter or each appendix is numbered separately (e.g., A-1, A.1).

4. Page numbers are usually placed in the footer, either centered or right justified and often below a fine ruled line as used in this manual (see bottom of page). Placing page numbers in the header or at the side of each page is not common in engineering reports.

4

PREPARATION OF TABLES

In reports and papers, tables are used frequently to present experimental, computational, and operational data; project information; and summaries of literature search findings. Often tables are used instead of figures and vice versa; the choice to present information in a table and figure will depend on the nature of the report or paper. Table development, citation, and preparation are considered in this section.

4-1 DEVELOPMENT OF TABLES

Consider the following questions when developing and referring to a table in the text:

1. Why is the table being presented?
2. What are the reasons for the design of the table?
3. What data or information does the table contain?
4. Source of original data or information?
5. How have the data been manipulated?
6. Why are some data missing?
7. What exceptions are there to the normal meaning of rows and columns?
8. What is the accuracy of the data?
9. What is the statistical variation of the data?
10. How should the rows and columns of the table be described?
11. How do related or comparable data in the table correlate among themselves?
12. How do the data correlate with other data in the same report?
13. How do the data correlate with data from other publications?
14. What is the meaning of the data?
15. What conclusions can be drawn from the data presented in the table?

4-2 CITATION AND PLACEMENT OF TABLES

Tables must be cited in the text at least once. Place the table immediately after its first mention, either on the bottom half of the same page or on the top of the next page. If tables are placed several pages after first being cited, the reader will find it more difficult to follow the discussion of the table in the text or may fail to consider the table appropriately.

4-3 MECHANICS OF TABLE PREPARATION

Effective table development involves understanding the parts of the table and the alternative methods of formatting.

Parts of a Table

Tables usually have the following parts (see Table 4-1):

1. Table number and title
2. Boxhead for stub
3. Stub (used to identify the horizontal entries in the table)
4. Boxhead for the data field
5. Date field (the area of the table where the data are presented)

Table Formatting

The mechanics of table formatting involve the arrangement of the columns and rows, and spacing within the columns and rows as shown in Table 4-2. The proper format for tables is illustrated in Tables 4-3 through 4-6. All the tables shown are of the open type, meaning that they are not boxed in with borders on all sides. In presenting data values in tables the units should be placed in a separate column or included in the boxhead title, as appropriate. The inclusion of a separate column for units is illustrated in Table 4-3; units are included in the column headings in Table 4-4. A table with multi-level or hierarchical entries is presented in Table 4-5. The presentation of figures in a table is illustrated in Table 4-6. When footnotes are included with tables, they are usually lettered with a superscript and arranged left to right and from top to bottom. Specific journal conventions should be used for publications.

Boxhead for stub

Table number and title

Boxhead for column titles

Table 4-1 (Parts of a table)
Summary of filtration runs for Fuzzy Filter

Run no.	Filtration rate		Compression ratio, %	Medium depth		Estimated porosity, %
	L/m^2•min	gal/ft^2•min		mm	in.	
1	205	5	0	760	30	92
2	205	5	15	650	26	91
3	205	5	30	530	21	88
4	205	5	40	460	18	87
5	410	10	0	760	30	92
6	410	10	15	650	26	91
7	410	10	30	530	21	89
8	410	10	40	460	18	87
9	820	20	0	760	30	92
10	820	20	15	650	25	90
11	820	20	30	530	21	89
12	820	20	40	460	18	87
13	1230	30	0	760	30	92
14	1230	30	15	650	25	91
15	1230	30	30	530	21	89
16	1230	30	40	460	18	87

Stub

Field containing data

Table title can be flush left or centered. Lead cap only for table title

Single entries are placed on bottom line of table heading

Lead cap only followed by comma before unit

3 pt space

Table 4-2 (Mechanics of table formatting)
Data on the biodegradable fraction of selected organic waste components based on lignin content[a]

3 pt space

3 pt space

Component	Volatile solids, VS, % of total solids, TS	Lignin content, LC, % of VS	Biodegradable fraction, BF[a]
Food wastes	7 - 15	0.4	0.82
Paper			
Newsprint	94	21.9	0.22
Office paper	96	0.4	0.82
Cardboard	94	12.9	0.47
Yard wastes	50 - 90	4.1	0.72

1 or 2 pt space

3 pt space

[a]Computed using Eq. 4-11.

3 pt space

Presentation of Tables

Tables are visually more pleasing in appearance when smaller than the full width of the page, but may occupy the full width of the page within the margins. Tables are usually centered, but may be placed on the left margin. When tables are presented in landscape mode, in either a single page or back-to-back format, the bottom of the table should face the right side of the page.

Table 4-3 (Separate column for units)
Typical design information for surface filtration of secondary settled effluent using a Discfilter[a]

Item	Unit	Typical value	Remarks
Size of opening in screen material	µm	20 – 35	Stainless steel or polyester screen cloths are available in sizes ranging from 10 to 60 µm.
Hydraulic loading rate	$m^3/m^2 \cdot min$	0.25 – 0.83	Depends on characteristics of suspended solids that must be removed.
Headloss through screen	mm	75 – 150	Based on submerged surface area of drum.
Disc submergence	% height	70 – 75	Bypass should be provided when head loss exceeds 200 mm.
	% area	60 – 70	
Disc diameter	m	1.75 – 3.0	Varies depending on screen design; 3 m is most commonly used size. Smaller sizes increase backwash requirements.
Backwash requirements	% throughput	2 at 350 kPa	
		5 at 100 kPa	

[a] Adapted in part from Tchobanoglous et al. (2003, 2013)

Table 4-4 (Units listed in column header)
Typical single-family home water use, with and without water conservation[a]

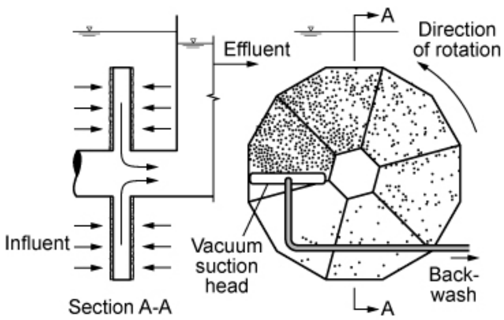
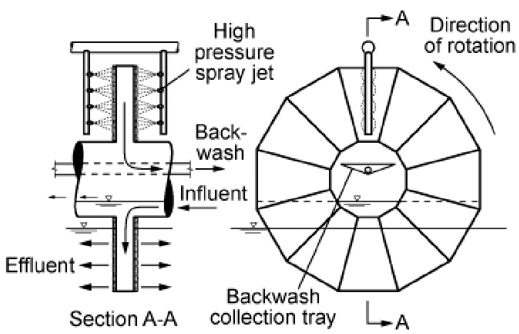
	Typical single-family home water use			
	Without water conservation		With water conservation	
Water uses	L/capita·d[b]	Percent	L/capita·d[b]	Percent
Toilets	76.1	27.7	36.3	19.3
Clothes washers	57.2	20.9	40.1	21.4
Showers	47.7	17.3	37.9	20.1
Faucets	42.0	15.3	40.9	21.9
Leaks	37.9	13.8	18.9	13.8
Other domestic	5.7	2.1	5.7	3.1
Baths	4.5	1.6	4.5	2.4
Dishwashers	3.8	1.3	3.8	2.0
Total:	274.4	100	187.8	100

[a]Adapted from AWWA Research Foundation (1999).
[b]L/capita·d, liters per capita per day

Table 4-5 [Table with multilevel (or hierarchical) entries]
Modifications to physical facilities made to improve plant operation

Date	Improvements
	Inlet works
8/8/06 to 1/8/07	• Rebuilt/replaced all isolation gate hydraulic cylinders. Ground-out gate channels. Installed new rubber seals on gate bottoms. Grouted in new stainless steel gate seats. • Installed new bar screen rakes, wear shoes, repined chains, reset to proper length. • Replaced worn grit collector steel rails with a modified design to improve reliability. • Replaced grit collector chain, sprockets, and tension arms. Installed grease line for submerged bearings.
	Secondary aeration
8/1/05 to 11/28/06	• Installed LDO probes and meters for better dissolved oxygen control. • Installed in-process solids meters in aeration basins. • Purchased two new aeration blower motor-upgrades over existing units. Grease lubricated bearings instead oil bath-Babbitt design.
	South secondary clarifiers
10/18/06 to 1/8/07	• Repaired corner sweeps. • Repaired isolation gate to allow for repairs to clarifiers without taking basins off-line. • Replaced bent gate shaft with custom made shaft. • Removed scale from gate channels to allow freer movement. • Repaired scum pumps.
	Sodium hypochlorite system
9/1/06 to 12/15/06	• Rebuilt all three residual chlorine analyzers • Programmed in a negative residual compensator. • Programmed in a residual trim to subtract from flow-proportioned hypochlorite dosage.

Table 4-6 (Figures incorporated in table)
Description of surface filters used in water reclamation applications

Type	Description
Cloth Media Filter (CMF) 	The CMF, marketed under the trademark AquaDisk by Aqua-Aerobic Systems, also consists of several disks mounted vertically in a tank. Each disk is comprised of six-equal segments. The CMF differs from the DF in that water flows by gravity from the exterior of the disks through the filter medium to an internal collection system. Two types of filter cloth can be used: (1) a needle felt cloth made of polyester or (2) synthetic pile fabric cloth.
Discfilter (DF) 	The DF, developed by Hydrotech and marketed in the U.S. by Veolia Water Systems, consists of a series of disks comprised of two vertically mounted parallel disks that are used to support the filter cloth Each disk is connected to a central feed tube. The cloth screen material used can be of either polyester or Type 304 or 316 stainless steel. The filter mechanism can be furnished with a self-contained tank or for installation in a concrete tank. In cold climates or where odor control is a consideration, an enclosure can be provided for the disks.

5
PREPARATION OF FIGURES

The effective development and use of figures in technical reports is critical. In many cases, a quality figure can convey information that would be laborious to describe in text. The figures used in technical reports are of three general types: (1) pictorial illustrations such as process-flow diagrams, schematics, portions of engineering plans, CAD (computer aided drafting), organization charts, and work-flow diagrams; (2) plots of experimental, computational, and operational data; and (3) photographs and renderings of equipment and facilities. Figure development, citation of figures, and mechanics of pictorial illustrations are considered in this section.

5-1 DEVELOPMENT OF FIGURES

A number of factors need to be considered when developing figures for an engineering report, for example, if the report is ever to be reproduced in black and white or viewed by those with color blindness, the use of color figures must be considered.

Development of Pictorial Illustrations

When referring to a pictorial illustration, consider the following questions:

1. Why is the illustration being presented?
2. What are the reasons for the design or layout of the illustration?
3. What does the illustration contain, e.g., treatment process flow diagrams, organization charts, work flow diagrams?
4. Are there specific parts or elements of the illustration that should be highlighted for the reader?
5. Is the illustration related to any of the data plots or photographs and or renderings presented in the paper?
6. Is the illustration original or adapted from elsewhere?
7. Will it reproduce correctly in black and white?

Development of Data Plots

When developing and referring to a figure containing data, consider the following:

1. Why is the figure being presented?
2. What are the reasons for the design of the figure?
3. What does the figure contain (e.g., axis labels)?
4. Where do the original data come from?
5. How have the data been manipulated?
6. Why are some data missing?
7. What is the accuracy of the data?
8. What is their statistical variation?
9. Is a mathematical equation or model involved?
9. How do related or comparable data in the figure(s) correlate?
10. How do the data in the figure correlate with other data in the same report?
11. How do the data and/or plots correlate with data and plots from other publications?
12. What is the meaning of the plotted data?
13. What conclusions can be drawn from the data presented in the figure?

Development of Photographs and Renderings

When referring to a photograph or rendering, consider the following:

1. Why is the photograph or rendering being presented?
2. What are the reasons for the orientation of the photograph or rendering?
3. Are there specific parts of the photograph that should be highlighted for the reader?
4. Is the photograph related to any of the data plots or pictorial illustrations?
5. Is the photograph or rendering original or provided by someone else?
6. Would providing geographic coordinates help the reader understand the setting for the photograph or the extent of the facility being described?
7. Is the quality of the photograph consistent with the final image size?

5-2 CITATION AND PLACEMENT OF FIGURES

Figures must be cited in the text at least once. Place the figure immediately after its first mention, and depending on the size, either on the bottom half of the same page, the top half of the next page, or on a full page following the first mention of the figure.

5-3 MECHANICS OF PICTORIAL ILLUSTRATIONS

Pictorial illustrations can encompass line drawings of process schematics, flow diagrams, and organizational charts. In addition to the main focus of the illustration, the components for illustrations include callout lines, arrows indicating direction of flow or movement, descriptive text, and standard details. The mechanics of data plots and photographs are presented in subsequent sections.

Size and Layout

Illustrations should not be larger than required to effectively convey the message. In some cases, use breaking symbols () to identify that a portion of an illustration has been omitted or to reduce the overall size of an illustration. The composition of the illustration should only include information required to convey the message. Some illustrations may require supplemental details, such as a directional compass, scale information, or related notes.

Lettering

For most purposes, the font size used in illustrations should be 8 or 10 pt (point). In some cases, a smaller font size may be used where the figure is larger and the font size is therefore reduced to fit. Use san serif fonts, such as Arial, Helvetica, or Tahoma for illustrations. When a font size of 10 pt is used for the regular text, superscripts and subscripts should be 8 pt, and raised or lowered by 2 pt, respectively. Where a font size other than 10 pt is used, the superscript and subscript should remain proportional.

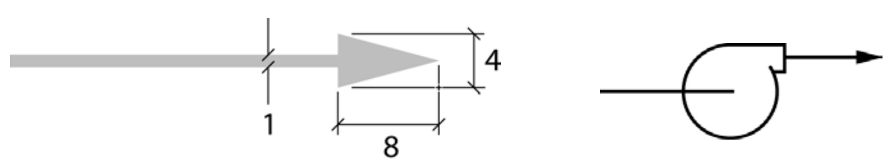
Use of Callouts and Arrows

A callout is descriptive text used to clarify or highlight a particular feature or detail in an illustration with leader line directed to a specific part of the illustration. The leader line should be a hairline, or 0.5 pt, as a heavier line will distract from the diagram and may be confused for a line in the illustration. When possible, set supporting callout text slightly away from the actual illustration to focus the readers eye on the diagram. The callout line should approach the supporting text in a balanced manner. Placing running callout lines in parallel will result in a more organized look.

Arrowheads should not be used with callout leader lines, although it was common practice to do so in the past. Use arrowheads to show the direction of flow or movement. It is important to select an arrow shape and size that is balanced and consistent with all figures in the report. An example arrowhead detail including the proportions for the arrowhead and the connecting line are shown on Fig. 5-1a.

Standard Details

Process-flow diagrams typically include features such as pumps, flow meters, gauges, and valves. Use of a standard set of details for these features for consistency and effectiveness in conveying information to the reader. A sample pump detail used in process-flow diagrams is shown on Fig. 5-1b. Most organizations have a catalogue of standard details.



(a) (b)

Figure 5-1
Standard details used in engineering illustrations (a) proportions of arrowhead used to represent flow direction or movement and (b) pump detail

Software Recommendations

Illustrations can be prepared using various commercially available software packages, however, not all illustration software packages are equal. For example, the drawing software that accompanies MS Word can only be used for preparing simple diagrams, unless significant time is invested. The preferred software, when preparing high-quality technical illustrations, is Adobe Illustrator. AutoCAD is useful for the preparation of precision to-scale drawings. Technical illustrations prepared using AutoCAD can be difficult to import into a technical report due to inconsistencies with other illustrations. In many cases, the illustrations placed in technical reports will not need to be drawn to scale.

Sample Illustrations

The following technical illustrations are presented to illustrate some of the techniques described in this section. Using standard uniform features helps the reader focus on the substance of the figure instead of being distracted by non-uniformity. Lines with arrows are used to represent the UV light emitted during UV disinfection on Fig. 5-2. The plan view of an MBR (membrane bioreactor) facility with standard arroehead and pump details is shown on Fig. 5-3. An informational process-flow diagram with inserts is shown on Fig. 5-4. Two examples of three-dimensional illustrations are presented on Figs. 5-5 and 5-6. An integrated wastewater management scheme employing centralized, satellite, and decentralized facilities is shown on Fig. 5-5. Figure 5-6 is a three-dimensional depiction of the two-dimensional membrane bioreactor shown on Fig. 5-3. Two process-flow diagrams are shown on Figs. 5-7 and 5-8.

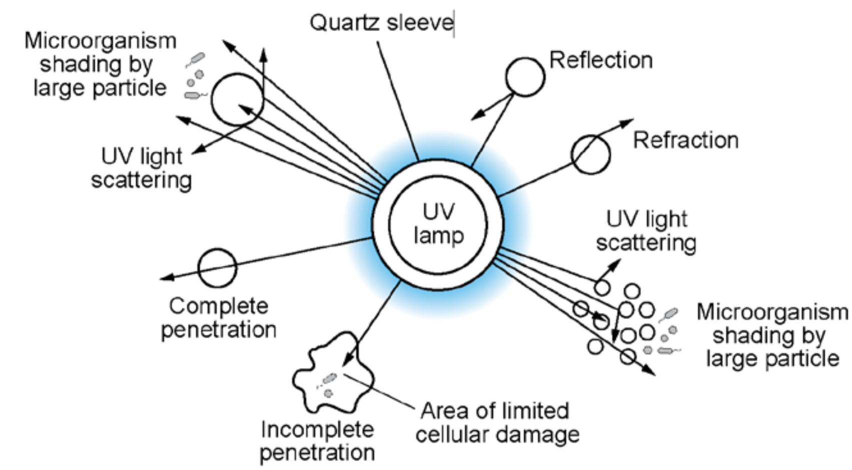


Figure 5-2
Particle interactions that affect the effectiveness of ultraviolet (UV) disinfection including microorganism shading; light scattering, reflection, and refraction; and incomplete penetration (Tchobanoglous et al., 2014)

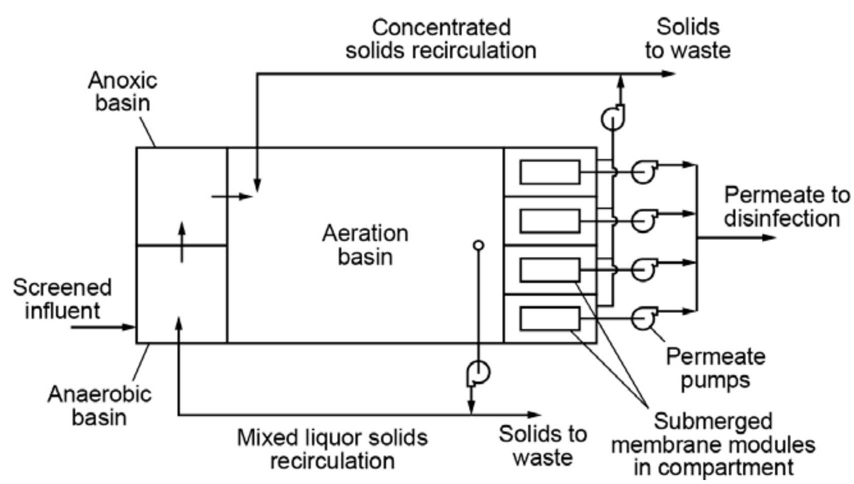


Figure 5-3
Plan view of membrane bioreactor with anaerobic and anoxic zones for nutrient removal

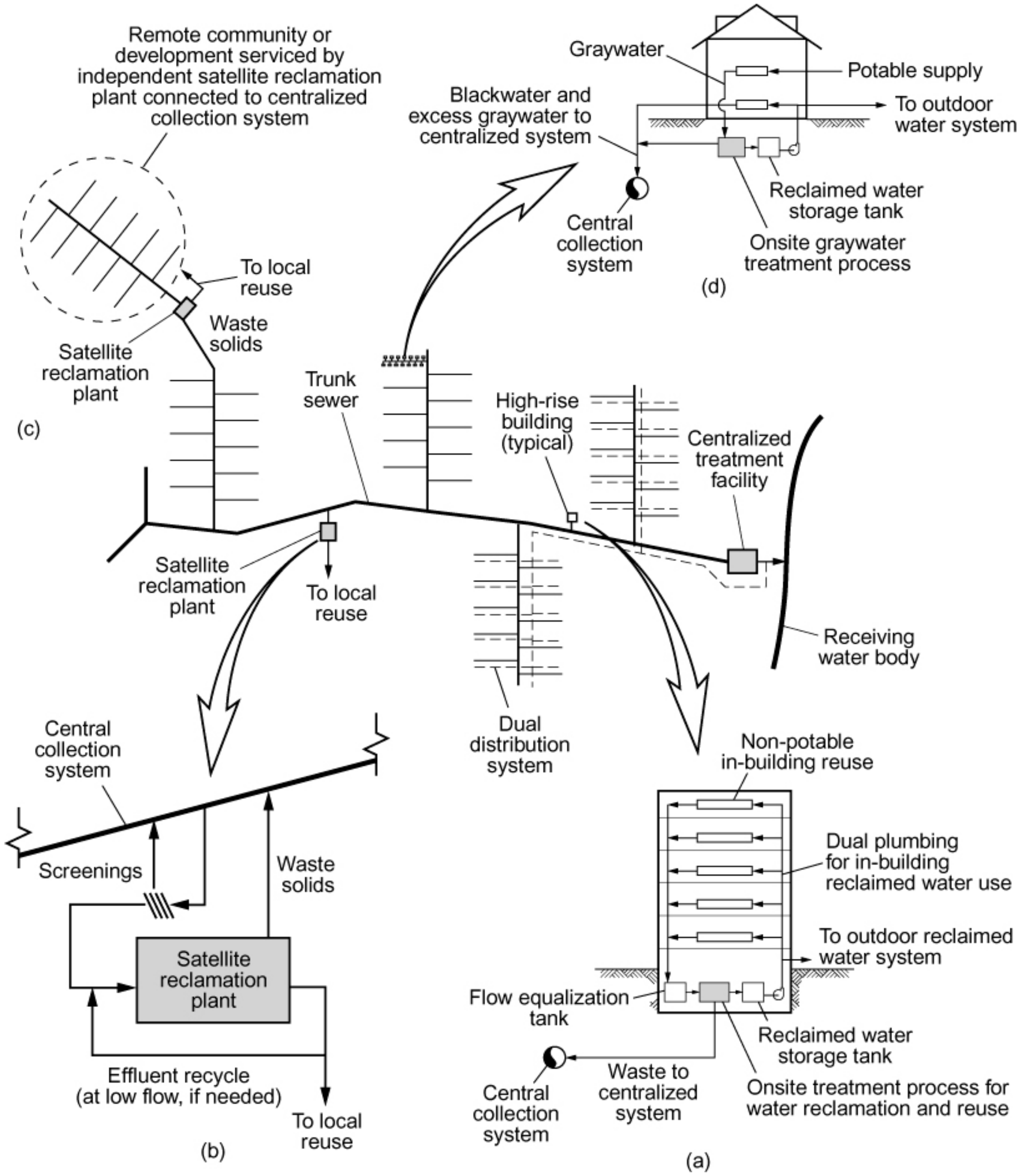


Figure 5-4
Diagram of centralized wastewater collection system with (a) commercial building interception type, (b) extraction type, (c) upstream type, and (d) individual home with greywater interception type satellite facilities (Tchobanoglous et al., 2014)

(Note: flush-left placement of figure number and title)

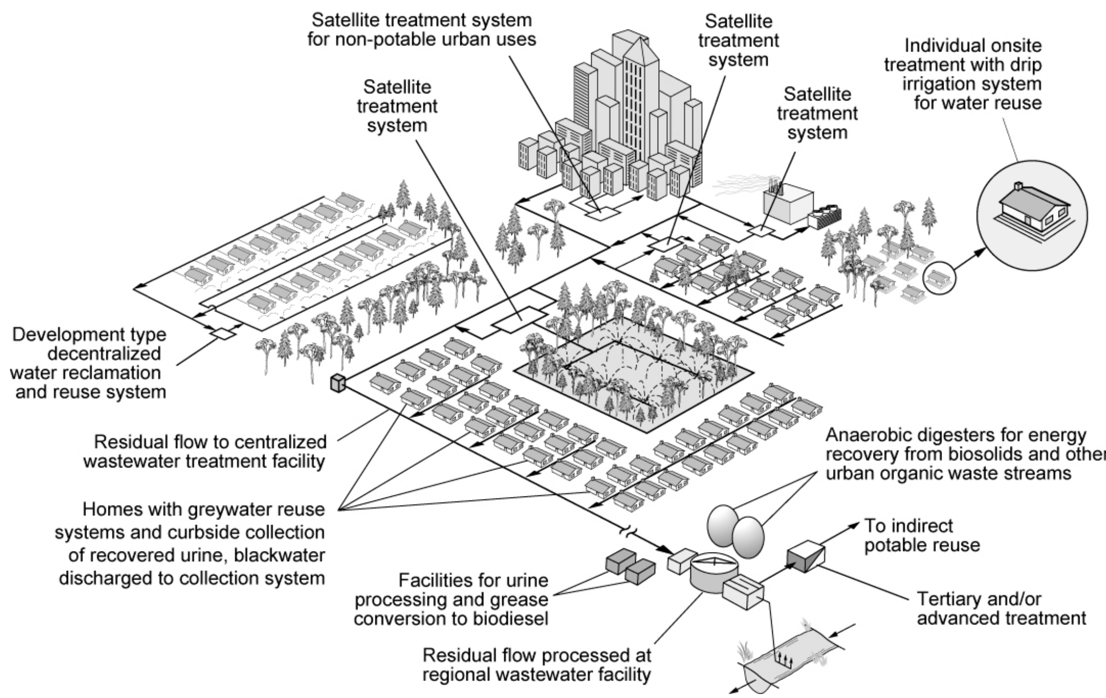


Figure 5-5
Diagram of future hybrid wastewater management system incorporating both decentralized, satellite, and centralized facilities

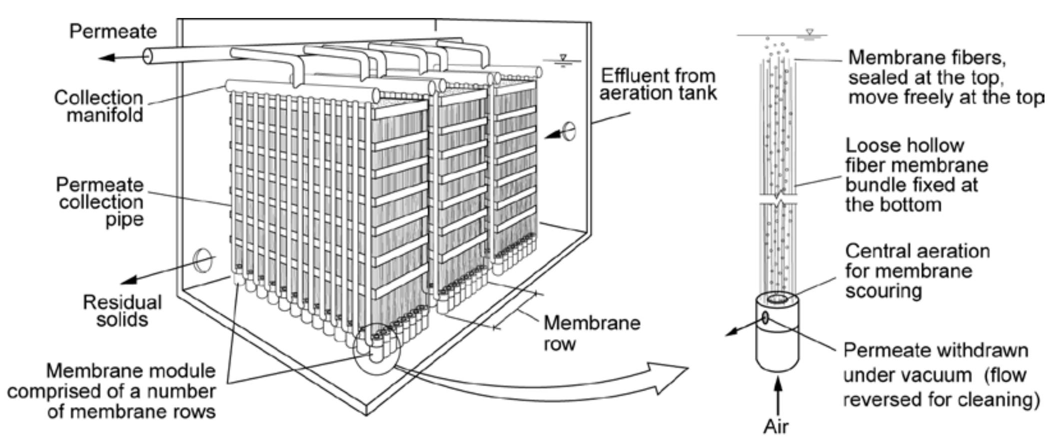


Figure 5-6
Koch Puron submerged hollow-fiber membrane bioreactor

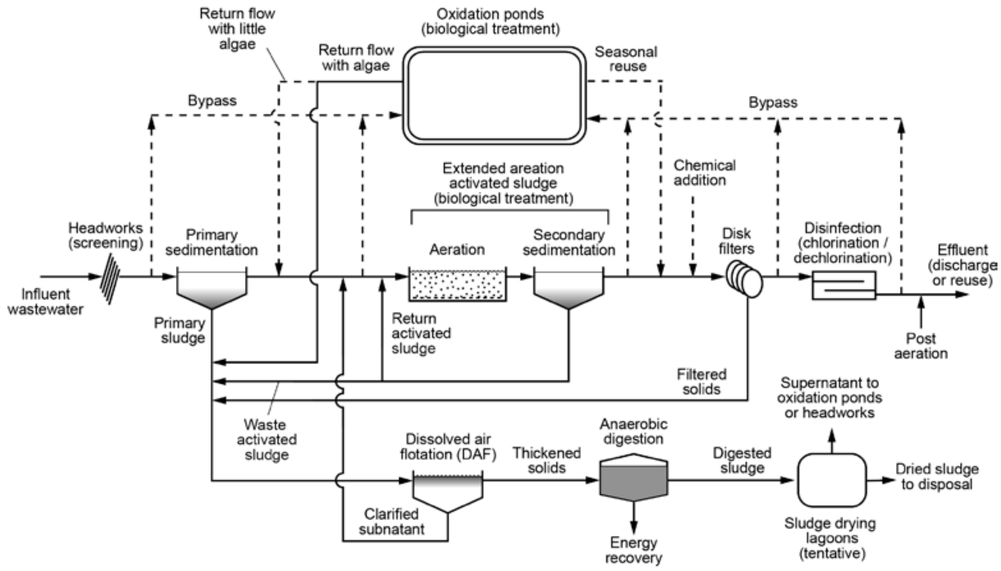


Figure 5-7
Proposed process flow diagram for the City of Davis Wastewater Treatment Plant.
Dashed lines indicate alternative flow pathways or intermittent flows.

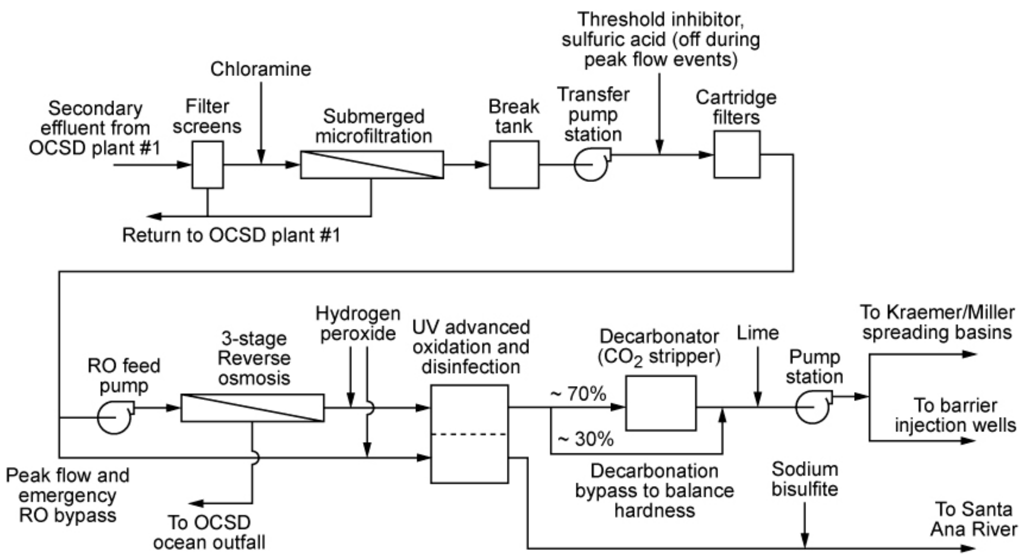


Figure 5-8

Schematic flow diagram for 2.65 x 10^4 m^3/d (70 Mgal/d) advanced water treatment facility (currently under construction, 2006) at the Orange County Water District, Fountain Valley, CA (Coordinates: 33.692 N. 117.942 W) (Tchobanoglous et al., 2014).

(Note: flush-left placement of figure number and title)

5-4 MECHANICS OF DATA PLOTS

It is important to be familiar with the available types of plots. The specific type of plot used for presenting the data can impact the reader's understanding. It is important to be familiar with the available types of plots.

Types of Data Plots

Though different types of plots can be used to present the same data set, some alternatives are more effective than others. Plot types used for most data can be divided into scatter and line plots, bar charts, pie charts, and statistical plots. Scatter and line plots are used commonly for presenting data on an x-y plane. Line plots are used when there is continuity between data points, such as with the output from computer models or theoretical curves. Scatter plots are used when the values between data points are not known, as with experimental measurements. Bar charts can be horizontal or vertical and are most useful for comparing two sets of values for limited data sets.

When plotting a large data set, bar charts can be cumbersome. Use line, scatter, and bar charts for plotting three-dimensional data when a z-axis is included. Use pie charts for comparing percentages of a whole, however, because of their high space to information content ratio, pie charts have limited application in technical reports. Statistical plots may include features such as error bars, confidence intervals, and other information about the distribution. Consult statistics textbooks or reference guides when preparing statistical plots. Probability distributions are another type of statistical plot used commonly when working with environmental data sets. Information on construction and interpretation of probability distributions can be found in Asano et al. (2007).

Plot Size and Line Weights

Plot size and aspect ratio are important considerations when optimizing the visual presentation of a data set for the reader. Common plot sizes used in technical reports are 3 in. (inch) by 3 in. and 2.75 in. by 4 in. for the y- and x-axis lengths, respectively.

Line weights should be selected for a balanced look. Typical line weights used for data plots are 1 pt for the border, 0.75 pt for tick marks, 0.5 pt for internal gridlines. Select the size of the markers used for the data points so that they are not too small to be obscured by lines or curve fits, and not so large that they overlap or obscure other information on the plot. For most purposes a 9 or 12 pt data marker is adequate. Select data marker characters to ensure that they will be unique even when reproduced in black and white. Lines connecting data point markers and curve fits should be 0.75 to 1 pt.

Set axis labels slightly away from the axis values. As a starting point, both axis labels and values should be 10 pt. Internal text can be smaller than the text used for axis labels, usually 8 pt. If callout lines are used in the data plot, a line weight of 0.5 pt should be used, with lines drawn parallel where feasible to give an orderly appearance. When using a legend, place it in a corner of the plot window where sufficient space is available.

Software Recommendations

Software for preparing data plots include MS Excel, Kaliedagraph, and Deltagraph, among others. In some cases, it may be easier to manipulate data in one program (e.g., Excel), while another (e.g., Kaliedagraph) is used for development of the final data plot. When other features need to be added, the data plots can be exported to illustration software for further editing.

Sample Plots

The sample plots shown below are presented to demonstrate different techniques for presenting data. A simple scatter plot with a linear curve fit is shown on Fig. 5-9. Important features to note on Fig. 5-9 include the faded gridlines that do not interfere with the presentation of the data, sufficient tick marks to permit the reader to determine the value of individual data points, and text inserts rather than a legend to identify the data sets.

A hybrid line-bar plot is shown on Fig. 5-10. The hybrid plot is used to display several different data sets simultaneously. The probability distribution shown on Fig. 5-11 is plotted over a set of typical values. Construction of Fig. 5-11 required several steps: extraction of the original data set from an MS Excel database, plotting the data set in Kaliedagraph, and importing the plot into Adobe Illustrator, where the typical values were inserted into the background for reference. Another example of a hybrid plot involving a process schematic, a three-dimensional illustration, and a data plot are shown on Fig. 5-12. The lettering size has been reduced to incorporate the necessary descriptions of the process steps.

5-5 MECHANICS OF PHOTOGRAPHS

Photographs and/or renderings included in technical reports provide the reader visual information about the report topic. In the age of digital image it is important to become familiar with the process of selecting and editing high-quality images for use in technical reports. A wide range of alternatives exist for acquiring digital images, including cell phone camera, still frame capture from video, digital cameras, and flat-bed scanning. Similarly, a variety of computer programs are available for creating renderings. It is important to become familiar with the process of selecting and editing images for use in technical reports. The following discussion is focused on photographs; the same recommendations apply to renderings.

Selection of and Manipulation of Photographs

Select photographs based on their content and quality. Ideally, limit the content of the image to the topic under consideration. Photographs taken haphazardly may contain distracting items such as passers-by and tree branches. Do not use photographs that are blurred or have exposure problems in technical reports. A photograph is often more effective if manipulated by cropping, adjusting the brightness/contrast, removing distortions, rotating, and resizing. Currently, there are numerous commercially available software bundles for photo editing including products by Adobe and Corel.

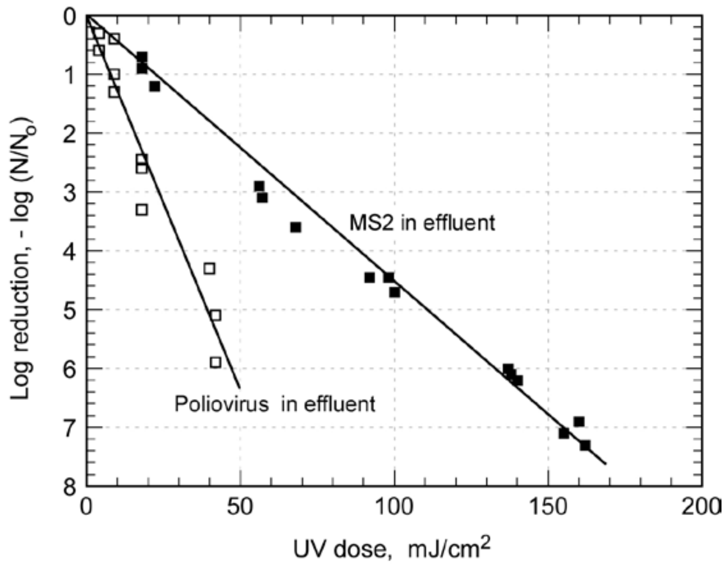


Figure 5-9
Typical dose response curves for UV disinfection developed from data obtained using a collimated beam device for dispersed microorganisms (Courtesy BioVir Laboratories, 2001)

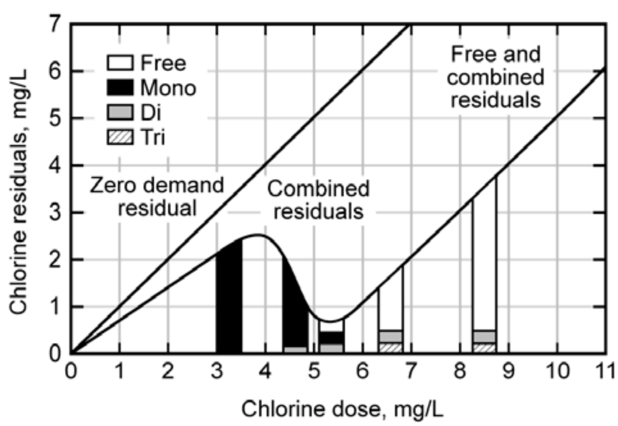


Figure 5-10
Curves of chlorine residual versus chlorine dosage for wastewater containing ammonium nitrogen (Adapted from White, 1999)

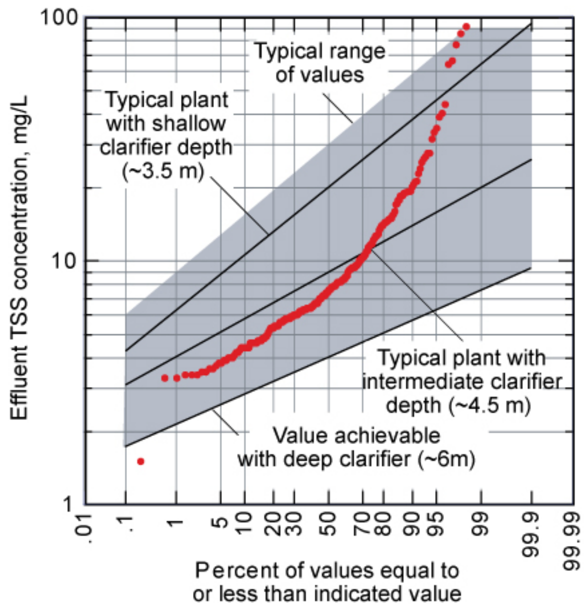


Figure 5-11
Comparison of New Haven WWTP 2007 effluent probability distribution for TSS with range of effluent probability values reported for conventional activated sludge processes (Asano et al., 2007).

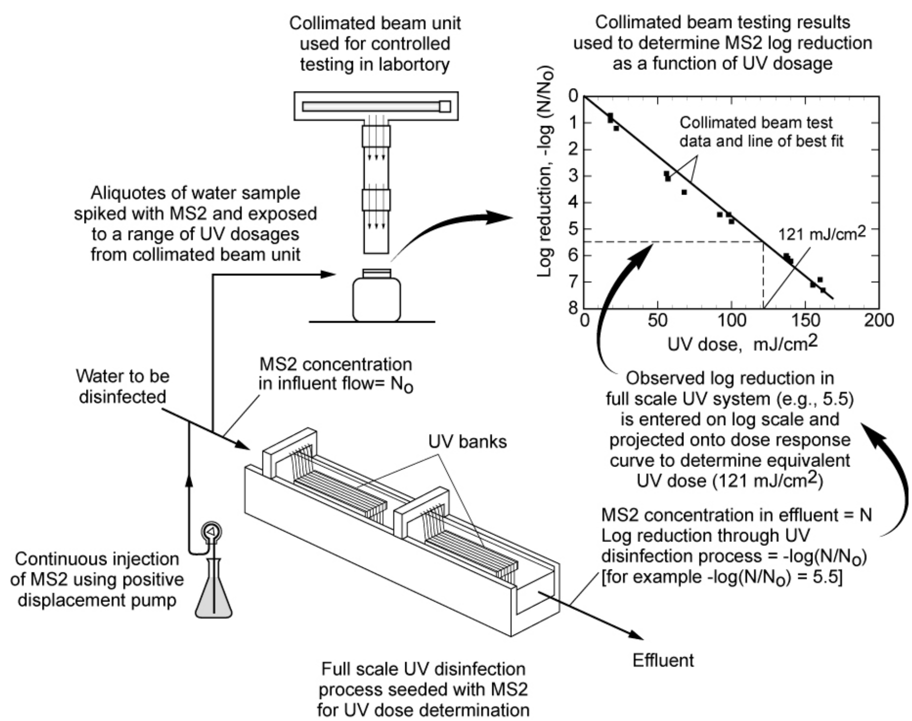


Figure 5-12
Schematic illustration of the application of biodosimetry as used to determine the performance of a test or full scale UV reactor (Adapted in part from Crittenden et al., 2005)

File Type and Resolution

The file type used for acquiring photographic images, manipulating photographs within software, and importing image files into technical reports depends on the equipment and software available as well as the required quality of the finished image. File types used when capturing images include RAW and JPG. The resolution used depends on the final use of the technical report. For example, images used for display on a computer screen at a zoom level of 100 percent may have a resolution of 100 dpi (dots per inch). Images used for printed reports are of higher resolution, typically in the range of 300 to 360 dpi. When there is insufficient resolution, photographs will appear out of focus or pixelated. Options for dealing with low-resolution images include recapturing the image when possible, reducing the size of the image in the document, and manipulating in photo-editing software.

Software Recommendations

There are numerous commercially available software bundles for photo editing including products by Adobe and Corel. Regardless of the software selected for image editing, instructional material should be obtained and used to ensure user proficiency.

Sample Photographs

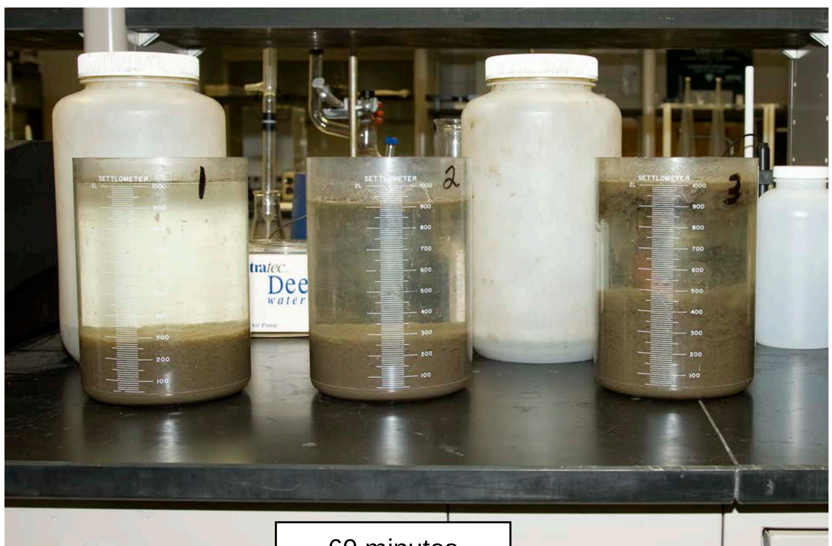
The sample images, presented below, have been selected to demonstrate different approaches for presenting photographic images in technical reports. Images of treatment processes are shown on Fig. 5-13, while close-up detail photographs of a laboratory procedure are shown on Fig. 5-14. A hybrid satellite photo with text callouts is shown on Fig. 5-15. White lines have been added to the callout lines to make them easier to follow. Geographic coordinates are given in the title for Fig. 5-16 to allow the reader to gain additional insight on what is depicted in the photograph by locating the specific site using software such as Google Earth.

(a)

(b)

FIGURE 5-13 (10 pt figure title)
Views of primary sedimentation basins: (a) grit and grease accumulation that has been floated to the surface by gases (CO_2 and CH_4) produced under anaerobic conditions and (b) grit remaining in primary sedimentation tank after dewatering (Note: grit must be removed from basins with a vacuum truck).

(a) 30 minutes



60 minutes

(b)

Figure 5-14 (10 pt figure title)
Photos of activated sludge mixed liquor samples in settlometers after (a) 30 min and (b) 60 min.

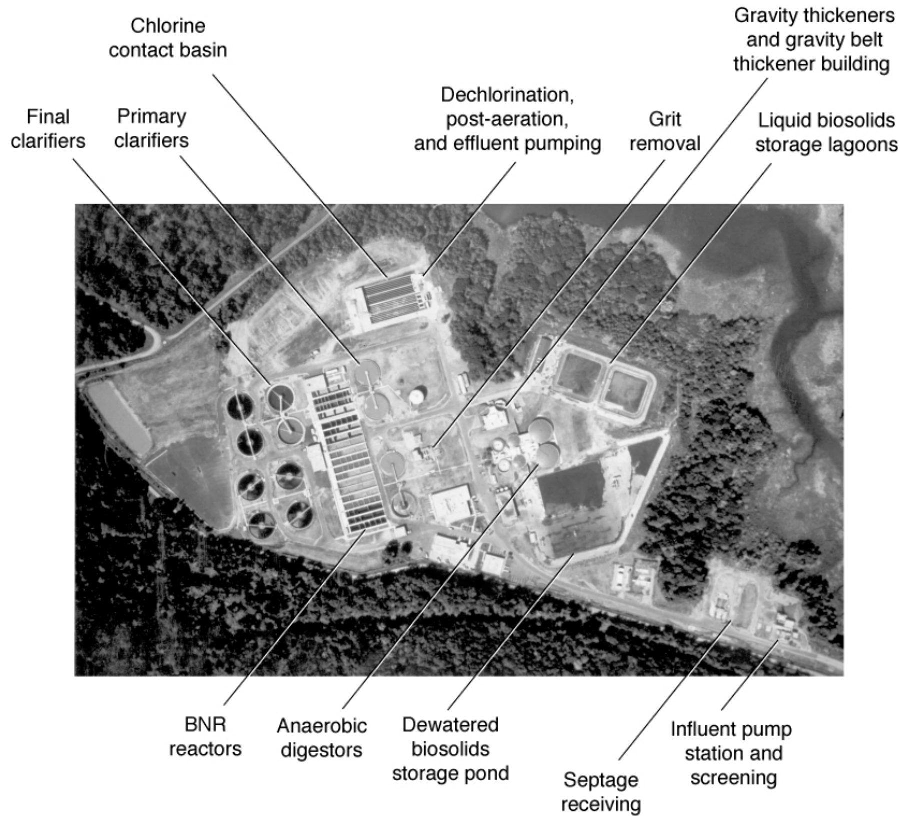


Figure 5-15 (10 pt figure title)
Areal view of modern wastewater treatment plant. Note biological nutrient removal (BNR) and dechlorination and post-aeration features of the plant (Tchobanoglous et al., 2003)

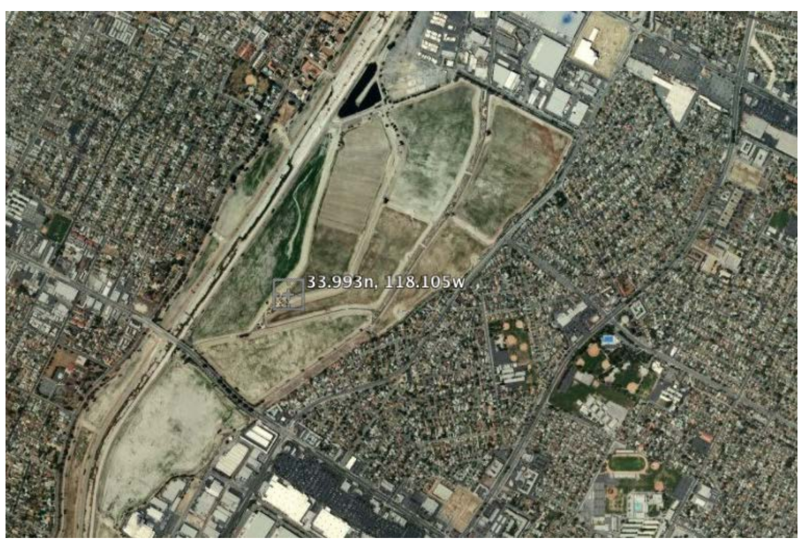


Figure 5-16
Rio Hondo Spreading Grounds operated by the County Sanitation Districts of Los Angeles County. Note: These basins and the unlined portions of the rivers and creeks permit large volumes of reclaimed water to percolate into the aquifer (Coordinates: 33.993 N, 118.105 W, view at altitude 4 km)

6
PREPARATION OF EQUATIONS

In reports and papers, equations are used to define symbolically the relationship between two or more variables. The mechanics, format, and placement of equations in text is considered in what follows.

6-1 MECHANICS OF WRITING EQUATIONS

The mechanics of equation formation are considered below. Formatting options are considered in Sec. 6-2.

Order of Mathematical Structures Called Fences

The most common types of fences used in mathematical expressions are parentheses ( ), brackets [ ], and braces { }. In equations, the order of usage is parentheses first, then brackets followed by braces, as shown below.

$$\text{Order of fences} = \{\ [\ (\quad)\ ]\ \}$$

Use of a Single Open Slash

In metric (SI) units there can only be one open slash (major dividing line). Entries above and below or on either side of the dividing line that contain slashes in units must be enclosed in appropriate fences as illustrated below.

For example, the following equation is written incorrectly:

$$\frac{V}{Q} = \frac{3.00\ \text{m}^3/\text{s}}{0.100\ \text{m}^3/\text{s}} \tag{1}$$

The correct way to write the equation (with only one open slash) is:

$$\frac{V}{Q} = \frac{(3.00\,\text{m}^3/\text{s})}{(0.100\,\text{m}^3/\text{s})} \tag{2}$$

Forms of Equations

1. The preferred general form of equations is as written below.

$$\rho_{a,20^\circ\text{C}} = \frac{(1.01325\times10^5\,\text{N/m}^2)(28.97\,\text{kg/kg}-\text{mole air})}{(8314\,\text{N}\bullet\text{m/kg}-\text{mole air}\bullet\text{K})(293.15\,\text{K})} = 1.204\,\text{kg/m}^3 \tag{3a}$$

2. An alternate form of the above equation is as follows. While not preferred, this form may be used for clarity in certain cases . There is, however, a big space penalty. When the equation moves to two lines, the advantage is less clear.

$$\rho_{a,20^{\circ}C} = \left(\frac{1\ \text{kg}-\text{mole air}\bullet\text{K}}{8314\,\text{N}\bullet\text{m}}\right)\left(\frac{1.01325\times10^{5}\,\text{N}}{\text{m}^{2}}\right)\left(\frac{28.97\,\text{kg}}{\text{kg}-\text{mole air}}\right)\left(\frac{1}{293.15\,\text{K}}\right) \quad (3b)$$

$$= 1.204\,\text{kg}/\text{m}^{3}$$

3. If possible, avoid spanning equations across multiple lines

$$\rho_{a,20^{\circ}C} = \left(\frac{\text{kg}-\text{mole air}\bullet\text{K}}{8314\,\text{N}\bullet\text{m}}\right)\left(\frac{1.01325\times10^{5}\,\text{N}}{\text{m}^{2}}\right)\times$$

$$\left(\frac{28.97\,\text{kg}}{\text{kg}-\text{mole air}}\right)\left(\frac{1}{293.15\,\text{K}}\right) \quad (3c)$$

$$= 1.204\,\text{kg}/\text{m}^{3}$$

6-2 GENERAL FORMAT FOR EQUATIONS

Simple equations are often expressed with a forward slash (/), also known as a shilling symbol or solidus. For example, simple fractions may be expressed as 1/2 or a/b. While the use of the forward slash is acceptable for simple fractions, equations presented in engineering reports should be expressed using a horizontal line for clarity. Several examples of equations expressed with a horizontal line are shown below. In some cases, a forward slash is used within an equation [see Eq. (10)].

$$k = \frac{k_{apparent}}{(1+r\,t)^{n}} \quad (4)$$

$$C = C_o \exp\left\{-\frac{k_o}{r\,(n-1)}\left[1-\frac{1}{(1+r\,t)^{n-1}}\right]\right\} \quad \text{(for } n \neq 1\text{)} \quad (5)$$

$$C = C_o \exp\left[-\frac{k_o}{r}\ln\left(1+r\,t\right)\right] \quad \text{(for } n = 1\text{)} \quad (6)$$

$$\text{COR} = (V_x^2+1)^{1/2}\, e^{\left\{-Z_{1-a}\left[\ln(V_x^2+1)\right]^{1/2}\right\}} \tag{7}$$

$$\text{COR} = (V_x^2+1)^{1/2}\, \exp\left\{-Z_{1-a}\left[\ln(V_x^2+1)\right]^{1/2}\right\} \tag{8}$$

Note order of parentheses ( ), brackets [ ], and braces { } in Eqs. (7) and (8).

$$\frac{TSS_4}{TSS_0} = \frac{1}{\left[1+\frac{k_o}{(1+rt)}\ \frac{V}{4Q}\right]^4} = \frac{1}{\left[1+\frac{0.25k_o t}{(1+rt)}\right]^4} \tag{9}$$

$$t = \frac{V}{Q} = \left[\frac{1}{(C_n/C_o)^{1/n}} - 1\right]\frac{n}{k_o} \tag{10}$$

6-3 PLACEMENT OF EQUATIONS IN TEXT

Equations are placed within text centered or left aligned, with the equation number in parenthesis and right justified, as illustrated below. Note that each equation should be placed on its own line, not embedded in the text. Each variable should be defined immediately following the equation at the location where it is first used, and can be repeated subsequently if needed for clarity. The variable definition should include the variable symbol, definition, and units as used in the equation.

With the first method, the quantity of sludge produced daily (and thus wasted daily) can be estimated using Eq. (7-26) (Tchobanoglous et al., 2003):

$$P_{X,VSS} = Y_{obs}(Q)(S_o - S)(1\,\text{kg}/10^3\,\text{g}) \tag{7-26}$$

where $P_{X,VSS}$ = net waste activated sludge produced each day, kg VSS/d
Y_{obs} = observed yield, g VSS/g substrate removed
Q = influent flow, m^3/d
S_o = influent substrate concentration, g/m^3 (mg/L)
S = effluent substrate concentration, g/m^3

Note: Equal signs are aligned

6-4 EQUATIONS IN EXAMPLES OR SAMPLE CALCULATIONS

Units should always be inserted in equations used in example or sample calculations to allow confirmation that the computation is correct.

1. The concentration is determined as follows:

$$C = \frac{(30\ \text{ng} / \text{L})}{(74.09\ \text{g} / \text{mole})}(1\text{g} / 10^9 \text{ng}) = 4.05 \times 10^{-10}\ \text{mole} / \text{L}$$

2. The absorptivity, $k(\lambda)$, of NDMA is:

$$k(\lambda) = \varepsilon(254)C = (1974\ \text{L} / \text{mole} \bullet \text{cm})(4.05 \times 10^{-10}\ \text{mole} / \text{L})$$
$$= 8.0 \times 10^{-7}\ \text{cm}^{-1}$$

7
CITATION OF REFERENCES

In preparing reports and papers, sources from the literature are commonly referenced to corroborate information and data in support of a specific point or thesis. Whenever mention is made of material derived from another source (e.g., concepts, data, figures), the source of the material must be identified so that the reader knows whom to credit. Strategies for selecting reference sources, techniques used for proper citation of references, and formatting styles for reference lists are discussed in this section.

7-1 EVALUATION OF REFERENCE SOURCES

When the work of other people is referenced, consider the reliability of the reference sources. Was the work cited performed by the cited author or is the "citation a citation of a citation." Too often citations refer to an unfounded opinion by the cited author (particularly when said opinion supports the opinion of the citer). For accuracy, source(s) of information should be scrutinized carefully in their original form (Cooper, 2008). Important questions to ask about research articles, review articles, and theoretical articles or position papers are presented below.

Research Articles

1. Is a meaningful, testable question presented in the introduction?
2. Is the study design appropriate for the research question?
3. Were adequate sampling techniques, controls, and procedures used to ensure the validity of the results?
4. Are the data and results presented in a clear and unambiguous manner?
5. Was enough data collected to justify the analysis?
5. Are the conclusions logical and supported by the results?
6. Were alternative explanations or conclusions considered?
7. Were the limitations of the results discussed?

Review Articles

1. Is the focus of the review on a specific research question or issue?
2. What types and kinds of sources were used in preparing the review? How up-to-date are these sources? Are the sources cited original, or are they secondary citations?
3. Is it clear how each of the sources cited in the review was used to contribute to an understanding of the research question or issue?
4. Are the major sources discussed in the review evaluated critically or are they merely summarized?

Theoretical Articles or Position Papers

1. Is a clear statement presented of the position taken?
2. Are the author's assumptions valid?
3. Are the reasons the author holds this position convincing?
4. Is the experimental, statistical, and observational evidence presented in support of the position taken accurate, representative, and sufficient?
5. Are alternative theories or explanations considered in the paper?
6. Are opposing views presented fairly?
7. Are opposing positions conceded or refuted effectively?

7-2 CITATION METHODS FOR REFERENCE SOURCES

The origin of reference material must be identified so that the readers can review the original sources to ascertain if the interpretation presented is correct. In this section, the format for references and two methods commonly used to cite materials from other sources are presented: the parenthetical reference (also known as an “in text citation”) and the footnote.

Parenthetical Citation

In parenthetical citation, either the author and date or a number are included in the text (typically within parentheses) to identify material taken from another source. The reference listing should contain the following: (1) full authorship, (2) the full title of the work, and (3) the publication information. When the cited work is by two authors, both are included in the citation. When three or more authors are involved, the et al. format is adopted [e.g., (White et al., 1996)].

Citation by Author and Date In the author and date method of citation, the name(s) and date are included in parentheses:

One author: (Jones, 2000)

Two authors: (Jones and Jones, 2000)

Three or more authors: (Jones et al., 2000)

Sort by year when there are multiple citations:

(Author, 2000; Author, 2001; Author, 2002)

(White, 1996; White and White, 1997; White et al., 1998)

(Burton et al., 1995; Crites and Tchobanoglous, 1998; Asano, 2000)

If the author is mentioned by name in the text, then only the date is included:

Jones et al. (2000) reported on the...

… used in Standard Methods (2003).

Note: Do <u>not</u> use *italic* for “et al.” and do not capitalize "et al."

Citation By Number In older engineering reports and in a number of technical journals, it is common practice to identify the source of the material with a number enclosed in parentheses or brackets. The number is keyed to the reference list that contains: (1) full authorship, (2) the full title of the work, and (3) the publication information.

Two types of numbering schemes are used for the reference list: citations in sequence and citations in alphabetical sequence. In the first case, citation numbers are presented in sequence [e.g., (1), (2), (3), . . .] and the references are identified sequentially and not alphabetically. In the second case, the references are arranged alphabetically and numbered sequentially. When reference is made to a specific reference the number of that reference is cited in the text without regard to order of numbering.

The difficulty with the use of the numbering scheme for references is that if a reference is skipped, then all the reference numbers in the text must be changed to accommodate the added reference. By comparison, in the author/date citation format discussed above, an additional reference can be accommodated easily. If numbered references are used, use the author/date citation format. When the manuscript is complete, number the references and then insert the appropriate numbers in the text in place of the author/date citation.

Footnote Citation

In the footnote citation style, superscripted numbers are used to identify material taken from another source. The source of the material corresponding to a given number in the text is identified at the bottom of the page. If the number of citations is lengthy, the footnotes may run to the second page. The footnote citation style is seldom used in engineering reports. A footnote was used to explain the usage of the term [sic] in Sec. 1 of this guidance manual.

7-3 AVOID PLAGIARISM

Plagiarism is the use of material from another source, presented as your own, without proper acknowledgement of the original source. Original ideas and writings are considered intellectual property, and are protected by copyright laws. Examples of plagiarism include (1) changing words but retaining the form and structure of the original work, (2) when the bulk of the report is derived largely from another source, even though acknowledged, and (3) not using quotation marks around another author's words or phrases. The best way to avoid plagiarism is to cite all sources of information used. The citation of the source should be clear so that the original source can be accessed.

7-4 STYLES FOR REFERENCE LISTS

At present, more than 100 reference styles are in use. Regardless of the citation style adopted, the reference list should contain: (1) full authorship, (2) the full title of the work, and (3) the publication information. Two general citation styles are in common use. In the first, the date is included after the author(s) name(s). In the second, the date is included at the end of the reference citation.

Author and Date Citation Format

The format for articles in journals, books, federal agencies, and professional organizations where the date is included at the end of the citation is as follows. All of the references presented below would be arranged alphabetically in an actual paper or article. The initials of subsequent authors following the first author are placed in front of the surname. In some journals, the initials of subsequent authors are placed after the surname.

General guidelines for the format style used for journal citations are as follows:

- First author: Last Name, First and Middle initials.
- Other authors: First and Middle initials, Last Name.
- For more than one author, insert "and" before the last author.
- No period or comma between the last author and (year).
- Journal article title is in quotation marks, comma inside of the quotation mark.
- Use Title Case, except for "a" "of" "the" "from," etc.
- Journal name or standard abbreviation is in *italics*, followed by a comma (see list of standardized journal abbreviations given in Table 6-1).
- Journal volume = number in **bold** followed by a comma.
- Journal issue number = number not bold followed by a comma.
- Journal pages = number-number (e.g., 872-895) followed by period.
- Use a period at the very end.

Examples of the formatting of reference lists are presented below for citations to journal articles, books, works with editors, government agencies and professional organizations, conference proceedings, and Websites.

Table 7-1
Summary of journal abbreviations used commonly in environmental engineering

Journal title	Abbreviation
Agricultural Water Management	*Agr. Water Mgnt.*
American Institute of Chemical Engineers Journal	*AIChE J.*
Applied and Environmental Microbiology	*Appl. Environ. Microbiol.*
American Journal of Public Health	*Am. J. Public Health*
Biosystems Engineering	*Biosyst. Eng.*
Chemical Engineering Science	*Chem. Eng. Sci.*
Corrosion Science	*Corros. Sci.*
Environmental Progress	*Environ. Prog.*
Environmental Science & Technology	*Environ. Sci. Technol.*
Industrial and Engineering Chemistry Research	*Ind. Eng. Chem. Res.*
Irrigation Science	*Irrig. Sci.*
Journal American Chemical Society	*J. Am. Chem. Soc.*
Journal Environmental Engineering Division, American Society of Civil Engineering	*J. Environ. Eng. Div. ASCE*
Journal of Membrane Science	*J. Membr. Sci.*
Journal American Water Works Association	*J. AWWA*
Journal Water Pollution Control Federation	*J. WPCF*
Journal Water Environment Federation	*J. WEF*
Ozone Science & Engineering	*Ozone Sci. Eng.*
Proceedings of Water Environment Federation Technical Exhibition and Conference 2007	*Proceedings of WEFTEC 2007*
Transactions American Society of Agricultural Engineers	*Trans. ASAE*
Water Research	*Water Res.*
Water Environment Research	*Water Environ. Res.*
Water Science and Technology	*Water Sci. Technol.*

Articles in journals

Angelakis, A.N., M.H.F. Marecos do Monte, L. Bontoux, and T. Asano (1999) “The Status of Wastewater Reuse Practice in the Mediterranean Basin: Need for Guidelines,” *Water Res.,* **33**, 10, 2201-2217.

Benjamin, M.M., G.V. Korshin, and C.W. Li (1997) "The Decrease of UV Absorbance as an Indicator of TOX Formation," *Water Res.*, **31**, 6, 946-949.

(Note: Alternate placement of initials)

Benjamin, M.M., Korshin, G.V., and Li, C.W. (1997) "The Decrease of UV Absorbance as an Indicator of TOX Formation," *Water Res.*, **31**, 6, 946-949.

Edwards, M., and T. Meyer (1996) "Lead versus Alkalinity and pH," *J. AWWA,* **88**, 3, 81-90.

Tchobanoglous, G., F. Maitski, K. Thomson, and T.H. Chadwick (1989) "Evolution and Performance of City of San Diego Pilot Scale Aquatic Wastewater Treatment System Using Water Hyacinths," *J. WPCF*, **61**, 11/12, 1245-1257. (or vol. 61, no.11/12, pp. 1245-1257)

Books

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Number Citation Format

The format for articles in journals, books, federal agencies documents, and professional organizations, where the date is included at the end of the citation, is as follows. Also, the initials of subsequent authors following the first author are placed in front of the surname. In many journals, the initials of subsequent authors are placed after the surname.

1. Benjamin, M.M., G.V. Korshin, and C.W. Li: "The Decrease of UV Absorbance as an Indicator of TOX Formation," *Water Res.*, **31**, 6, 946-949, 1997.

(Note: Alternate placement of initials)

1. Benjamin, M.M., Korshin, G.V., and Li, C.W.: "The Decrease of UV Absorbance as an Indicator of TOX Formation," *Water Res.*, **31**, 6, 946-949, 1997.
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Citation Software

Most people now use integrated citation software, such as EndNote to compile and format reference lists. The advantage of citation software is that reference lists for technical articles and reports can be generated instantly from citation libraries or databases. Citation libraries can be assembled manually by entering data, or downloaded from online research databases. Inserting the citation into the document automatically adds the full citation to the reference list, which is updated automatically as changes are made. While citation software can be used to generate a reference list quickly, extra care must be taken to ensure correct formatting and to check for redundancy. Writers are encouraged to first become familiar with reference citation styles before depending on the output of citation software.

8
SOME NOTES ON WRITING

When writing reports, it is common to fall into bad habits with respect to word and term usage, the use of unnecessary expressions, inappropriate reference to elements of the text, and the proper use of numbers. The purpose of this section is four-fold: (1) to identify some of the more common writing problems and to offer alternative approaches to avoid the use of a few terms and words that reduce the effectiveness of the presentation; (2) to identify phases that should be avoided; (3) to review how figures, tables, equations, and other parts of the text should be referred to within a document; and (4) to review the general rules for the use of numbers in text.

8-1 WORDS AND TERMS TO AVOID IN ENGINEERING WRITING

The words and terms in the following listing should be identified using the search function present in all word processing programs and weeded-out systematically.

1. In general, write reports in third person. The terms "I," "we," or "our" should never appear anywhere in the text. If these terms are found, rewrite the sentence to eliminate them. Search for "I," "we," or "our" and edit them out.

2. Avoid the use of the word "this," especially in sentences such as:
   This shows what can be done.
   This indicates good performance.
   Use of the word "this" may be acceptable in sentences such as:
   This situation is deplorable. Only if the "situation" is unambiguous.
   This mechanism is too complex. Only if the "mechanism" is unambiguous.

3. Avoid the following references to tables or figures. In general, inanimate objects should not indicate, show, depict, etc.
   ~~Figure 1-1 shows that~~.
   The engine was warm as shown on Fig. 1
   ~~Figure 1-3 also presents the results of~~ the regression analysis.

The regression analysis results are presented on Fig. 1-3.

~~Table 1-1 shows how complex the situation is.~~

The complexity of the situation is described in Table 1-1.

~~Table 1-2 describes the best approach.~~

The best approach is described in Table 1-2.

4. When referring to tables and figures, use the following style:

   Design information is shown in Table 1. (<u>shown</u> <u>in</u>)

   Typical designs are illustrated on Fig. 12-2. (<u>illustrated</u> <u>on</u>)

5. Use of the words "from" and "between"

   The range is from 10 to 15 m/d. (<u>from</u> with <u>to</u>)

   The range is between 10 and 15 m/d (<u>between</u> with <u>and</u>)

6. Use of the words "which" and that." In general, "which" informs and "that" defines.

   Use "which" with unrestrictive clauses. Unrestrictive clauses inform, but do not change the meaning of the sentence. If the sentence works without the clause, use "which" with commas before and after the clause.

   When David retired from UC Berkeley, which is one of the schools in the region, he started his own consulting firm.

   Use "that" with restrictive clauses. Restrictive clauses limit or define the preceding noun. "That" is used in sentences that do not work without the clause.

   Organizations that fund charitable works are exempt.

7 Avoid using the phrase “in order to.” Replace “in order to” with the word “to.”

8. Avoid misuse of the word "since."

   "Since" is used in a time sense (e.g., since 1900), and not as a substitute for "because" or "as."

9. Avoid split infinitives.

   In the modern language, a split infinitive involves the placement of an adverb (usually an -ly adverb) between the word to and its corresponding

infinitive verb. Avoid the use of split infinitives in engineering reports. In rare cases, a split infinitive can be used for emphasis.
to emphatically inquire; use: to inquire emphatically
to consistently overdose; use: to overdose consistently

10. Avoid excessive use of adverbs, especially adverbs such as very, significantly, drastically, etc.
    The digesters were in ~~drastic~~ need of repair.
    Change was needed ~~drastically~~.

11. Avoid overusing favorite words or expressions.
    For example words such as "existing," "major," "significant," "typical," and word phrases such as "in order to" and "in the manner of"

12. Avoid *hyperbole* (excessive exaggeration) in engineering writing. For example:
    The plant was operated <u>stupendously</u> well.
    The sentence should be written as:
    The plant was operated well.

13. Do not use *arcane* data or information known or understood by only a selected few.

14. Avoid the use of *clichés* such as

    "fit as a fiddle," "dumb as a stump," and "works like a champ."

15. If a foreign term is used, it is "*de rigor*" to use it correctly. (replace "*de rigor*" with "*de rigueur*")

16. Avoid the use of *mixed metaphors*. Mixed metaphors are two words or expressions that are quite different in meaning, but are used together as though they were similar or identical in an implied comparison. For example:
    The proposed plan has as much vision as a stump.
    Because mixed metaphors are difficult to use effectively, and may be difficult for some readers to understand the intended meaning, they should not be used in engineering reports.

17. Do not be vague or repeat the same information a number of times in a single sentence (M&E, 1965). For example:

    "It appears that the estimated cost is about $2,500."

    The reader has been told three times that the cost figure is not exact.

    Replace with:

    "The estimated cost is $2,500."

18. Introduction of abbreviations in text.

    There are two accepted ways to introduce abbreviations in written text.

    - The total suspended solids (TSS) was 25 mg/L
    - The TSS (total suspended solids) was 25 mg/L

    The first method is used commonly in engineering reports. In either case, once introduced, the abbreviation is used thereafter if there are three or more uses.

19. Percent versus %

    Percent should be written out in the text. In tables, use of the symbol, %, is acceptable. In figure captions and table titles, "percent" should be written out. The term "percentage" is not used with numbers, as it is a relative term (e.g., a large percentage)

20. Proper use of parentheses, brackets, and braces in text and equations: parentheses ( ) first, then brackets [ ], followed by braces { }.

    Order of fences = {[( )]}

    At the present time, the California Department of Health requires a Ct [the product of the residual chlorine concentration, C (mg/L) and contact time, t (min)] value of 450 mg-min/L.

21. Use of flush-right justification

    In general, do not use flush-right justification in engineering reports where the objective is the communication of ideas and concepts (see more complete discussion in Sec 3-3).

8-2 PHRASES TO AVOID IN ENGINEERING WRITING

Phrases to avoid in engineering writing with suggested substitutions are presented below.

Empty phrases	Use, substitute
as early as	before
at this point in time / at that point in time	now / then
by means (reason) of	by
draw attention to	show
due to the fact that	because
during the time that	while, when
fewer in number	Few, fewer
filled to capacity	full
for the purpose of	for
for the reason that	because
for the sake of	for
goes under the name of	called
if conditions are such that	under
in accordance with	with, about
in as much as	because
in spite of the fact that	although
in connection with	with, about, concerning
In favor of	for
in order to (should never be used)	to
in the event that	if
in this day and age	today
it is evident that	evidently
It is interesting to note that	note that
In the event of (that)	if
it is often the case that	often
in the final analysis	finally
in view of/in view of the fact that	because
it would appear that	is
on the other hand	delete altogether
on the part of	by
prior to	before
put in an appearance	appear
serves the function of being / serves to function as	is
subsequent to	after
the fact that	that
with reference to	about, concerning
with respect to	compared
with a view to	to

8-3 REFERRING TO FIGURES, TABLES, EQUATIONS, AND OTHER TEXT

The various elements of the report, including figures, tables, and equations, need to be keyed to the text. The recommended formatting guidelines for in-text references to these elements are shown below. The convention for referring to other parts of the text, such as sections and chapters are also discussed below.

Guidelines for Figures

Figure is "Fig." or "Figs." Examples: Fig. 6-2 or Figs. 6-2a and 6-2b or Figs. 6-2a,b. No parentheses around the "a" or "b." First word of sentence: "Figure 6-2a" or "Figures 6-2 and 6-3."

Guidelines for Tables

Table or Tables is not abbreviated. Examples: Table 1-1 or Tables 1-1 and 1-2.

Guidelines for Equations

Equation is "Eq." or "Eqs." The word "Equation" or "Equations" is spelled out if either is the first word in the sentence. Use parentheses "()" around the equation numbers that are referred to in the text. Parentheses should appear around the equation number on the equation line. Examples: "… as defined previously in Eq. (5-1)" or "… defined in Eqs. (5-1) and (5-2)." First word of sentence: "Equation (5-1)" or "Equations (5-1) and (5-2)"

Guidelines for Chapters

Chapter is "Chap." or "Chaps." unless it is the first word in a sentence. Examples: "see Chap. 3" or "see Chaps. 3 and 4." First word of sentence: "Chapter 3" or "Chapters 3 and 4"

Guidelines for Section Numbers

Section is "Sec." or "Secs." unless it is the first word in a sentence. Examples: "see Sec. 6-2" or "see Secs. 7-5 and 7-6." First word of sentence: "Section 6-2" or "Sections 6-2 and 6-3."

8-4 USE OF NUMBERS IN ENGINEERING WRITING

Because numbers, derived from experimental studies and engineering analyses, are used extensively in most reports and papers, the general rules on the use of numeric values in text are discussed below, including: (1) formatting of numbers used in text, (2) the use of the exponential form for numbers, (3) the use of significant figures when adding, subtracting, multiplying, or dividing numbers, and (4) the rules for rounding numbers.

Formatting of Numbers Used in Text

There are a few simple rules that apply to numbers used in text, including the use of commas to separate groups of digits in large numbers and when to spell out numbers.

1. In the United States, it is customary to use commas to separate groups of three digits in large numbers to improve comprehension. For example, the number 1000000 is written as 1,000,000. In the SI system, commas are only used for values of 10,000 or greater. It should be noted that in some countries, periods are used in the place of commas as described above, and commas are used in place of decimal points.

2. Spell out numbers used in text that are integers and less than 10, unless the value is with units. Numbers 10 and greater should be written as numerals. If a sentence begins with an integer number it should be spelled out. For example: Two million gallons per day is the rated capacity of the plant. When not at the beginning of a sentence, two million gallons per day is written as 2-Mgal/d, 2-mgd, or 2-MGD (often, the dash used to form a compound adjective is omitted, e.g., 2 Mgal/d). Decimal values in the text should be reported with numerals and therefore cannot be used at the beginning of a sentence.

Use of Exponential Form for Numbers

Although there is no hard and fast rule, in engineering reports it is common practice to use the exponential form for numbers beyond about 10,000. A useful rule is that exponents should be in factors of three (e.g., 10^3, 10^6). For example:

The flowrate was 150,000 m^3/d. Use: The flowrate was 150 x 10^3 m^3/d

The cost is $2,650,000. Use: The cost is $2.65 x 10^6.

General Rules for Significant Figures

General rules regarding the significance of figures in engineering writing are as follows:

1. All nonzero digits are significant (62.4, three significant figures)
2. All zeroes between nonzero digits are significant (7075, four significant figures)
3. All zeroes to the right of a decimal point in a number are significant (67.0, three significant figures)
4. Zeros used to fix the decimal point are not significant (150,000, two significant figures)

Significant Figures when Adding or Subtracting Numbers

When adding or subtracting numbers, the number of decimal places is counted to determine the number of significant figures. The rule is that the answer cannot contain more places after the decimal point than the smallest number of decimal places in the numbers being added or subtracted.

1. For example, in addition:
   16.5555 (six significant figures) + 12.25 (four significant figures) = 28.81 (four significant figures)
2. For example, in subtraction:
   16.5555 (six significant figures) - 12.25 (four significant figures) = 4.305 (four significant figures)

Significant Figures when Multiplying or Dividing Numbers

When multiplying or dividing numbers, the answer cannot contain more significant figures than the number being multiplied or divided with the least number of significant figures.

1. For example, in multiplication:
   16.5555 (six significant figures) x 12.25 (four significant figures) = 202.8 (four significant figures, see rounding below)

16.5555 (six significant figures) x 12.5 (three significant figures) = 207 (three significant figures)

2. For example, in division:

   16.5555 (six significant figures) / 12.25 (four significant figures) = 1.351 (four significant figures, see rounding below)

   16.5555 (six significant figures) / 12.5 (three significant figures) = 1.32 (three significant figures)

Rounding Numbers

The general rules for rounding numbers are as follows.

1. A number is not rounded up (underestimated) when the following number is between 0 and 4 (19.334 = 19.33, rounded to four significant figures)
2. A number is rounded up (overestimated) when the following number is between 6 and 9 (19.336 = 19.34, rounded to four significant figures)
3. If the following number is 5 the preceding number is rounded up if the number formed when rounding up is odd (13.355 = 13.35 and 13.345 = 13.35, both rounded to four significant figures)

It should be noted that in some fields the number to be rounded is always rounded up regardless of whether the number formed is even or odd (13.345 = 13.35 and 13.355 = 13.56, both rounded to four significant figures)

9
PUNCTUATION AND WORD USAGE

The focus of this chapter is with the important mechanical elements that are fundamental to report preparation including: (1) punctuation, (2) use of numbered and bulleted lists, (3) formation of compound words, (4) abbreviations and units, (5) using words correctly, (6) words misspelled commonly, and (7) a working vocabulary. The intent here to present a quick reference to these subjects, not to replace the many books that have been written on these subjects. For a more in-depth study of these elements and other writing issues, *The Economist Style Guide* (economist.com/styleguide), *Plain English for Lawyers* (Wydick, 2005), and the *Handbook of Technical Writing* (Alred et al., 2006) are recommended.

9-1 PUNCTUATION

The principal punctuation marks used in engineering reports are: the apostrophe, brackets, colon, comma, dash, ellipses, exclamation, hyphen, parentheses, period, question mark, quotation marks, semicolon, and slash. Each of these elements of punctuation is considered in the following discussion, developed, in part, from: Houp and Pearsall (1980), Park (1927), Rosen and Behrens (1997), Shaw (1993), and Alred et al. (2006).

Apostrophes

The apostrophe is used to:

1. **Form the possessive of all nouns.**

Singular		Plural	
Normal	Possessive	Normal	Possessive
man	man’s	men	men’s
woman	woman’s	women	women’s
individual	individual’s	individuals	individuals’
children	children’s	doctors	doctors’

2. **Form the possessive indefinite pronouns.**

   everyone's other's someone's

3. **Stand for missing letters (contractions) and numbers.**

aren't (are not)	can't (can not)	it's (it is)
couldn't (could not)	wasn't (was not)	won't (will not)

   For example:

   The '60s were a wonderful period.

   The class of '53 donated a piano.

Brackets

The bracket is used to:

1. **Enclose comments, alterations, or corrections in quoted material.**

   "The subject matter will need to be exceptionally good in order to [*sic*] overcome the reader's adverse opinion."

   In the above sentence, the expression "*sic"* italicized (Latin meaning "thus"), enclosed in brackets, is inserted in the quoted material to highlight what the authors believe is an error in grammar (the use of the term "in order to" instead of the word "to").

   "He [the superintendent] was preoccupied with the failure of the pumps."

   The words enclosed in brackets "the superintendent," were added by the authors for clarity.

2. **Enclose reference citation numbers instead of parentheses.**

   It has been observed that bacterial populations in natural systems can acclimate to colder temperatures and maintain their mass in spite of slower activity rates [24].

3. **Enclose words or comments enclosed in parentheses.**

   However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Colons

The colon is used to:

1. **Introduce an enumeration or listing.**

   The TRR concept is comprised of a number of key elements: (1) production of water suitable for potable use from wastewater, (2) assessment of the relative health risk of the potable water produced versus the existing potable supply, (3) assessment of an innovative and alternative aquatic plant based secondary wastewater treatment system . . .

The material to be presented is organized into a number of sections: (1) types and application of wetland and aquatic systems, (2) treatment kinetics in constructed wetlands and aquatic systems, (3) free water surface constructed wetlands, (4) subsurface flow constructed wetlands.

Rule: A colon is not used between a verb and its object and a preposition and its object. For example:

With some minor modifications those groups are (1) baffled channels,(2) hydraulic-jet flocculators, and (3) coarse-media flocculators.

Rule: A colon may be used following a verb or preposition when followed by a stacked numbered or bulleted list (see Sec. 9-2).

Rule: A colon should not be used for simple lists with the following words or phrases: *include, such as,* and *for example*.

Regulatory considerations for reuse of water in industrial applications include (1) generation of aerosols and (2) safety of manufactured products

2. Introduce a numbered or bulleted list (see also Sec.9-2).

A colon is used to introduce a numbered or bulleted list. A colon can be used following a verb or preposition with stacked lists.

3. Introduce a long quotation.

In his 1927 text, *English Applied In Technical Writing*, C. W. Park noted that:

> "Even though a reader's interest is wholly in the subject matter his first impression of a piece of writing is necessarily based on its general appearance. If . . . ."

4. Follow a salutation in formal letters.

Dear Professor Fudd: or Dear Elmer:

5. Separate titles from subtitles.

Water Reuse: Issues, Technologies, and Applications

6. Separate the hour and minute and the hour, minute, and second.

9:27 a.m., 10:15:23 p.m.

Commas

The comma is used to:

1. Separate independent clauses in a compound sentence.

If numbered references are used, it is suggested that the manuscript be written using the author/date citation format.

2. Separate a transitional word, a phrase, or a clause at the beginning of a sentence.

Unfortunately, the data did not warrant such a detailed analysis.

Clearly, the equation is in error.

3. **Separate three or more items in a series.**

   Reuse Alternatives 1A, 2B, 3A, and 3B are considered in the following analysis.

   The principal elements of punctuation used in engineering reports, arranged in alphabetical order, are: the apostrophe, brackets, colon, comma, dash, ellipses exclamation, hyphen, parentheses, period, quotation marks, semicolon, and slash.

4. **Set off parenthetical expressions.**

   Nitrite nitrogen, determined colorimetrically, is relatively unstable and is oxidized easily to the nitrate form.

5. **Set off a nonrestrictive appositive clause.**

   Constructed free-water-surface wetlands, shallow basins with emergent plants, will be used for wastewater treatment.

   An appositive is a word, phrase, or clause that repeats the thought of the previous word, phrase, or clause.

6. **Set off a date, geographical expression, proper names, and a title after a proper name.**

   After November 25, 1996, the new routing program should be used.

   The program was developed in Davis, CA, during the ‘60s.

Dashes

Two types of dashes, em (—) and en (–), are in common use. An em dash is the width of the letter m; the en dash is the width of the letter n. The en dash is one-half the length of the em dash. These dashes should not be confused with hyphens. The en dash is longer than a hyphen.

The em dash is used to:

1. **Set off parenthetical comments and statements.**

   Nitrite nitrogen—determined colorimetrically—is relatively unstable and is oxidized easily to the nitrate form.

   Note: Although commas and parentheses can be used for the same purpose, dashes are more emphatic. The em dash is used without spaces.

2. **Set off an abrupt change in thought.**
3. **Highlight an incomplete thought or unfinished statement.**

The en dash is used to:

1. **Set off parenthetical comments and statements in place of an em dash.**

   Nitrite nitrogen – determined colorimetrically – is relatively unstable and is oxidized easily to the nitrate form.

   The en dash is used with spaces.

2. **Form compound adjectives in place of a hyphen.**
3. **Form ranges in place of to and between.**

The range is 10–15.

Ellipses

The ellipsis is used to note a break in continuity to:

1. **Indicate that words have been omitted from the end of a sentence.**

   The material to be presented is organized into sections dealing with: (1) types and application of wetland and aquatic systems, (2) treatment kinetics in constructed wetlands and aquatic systems, (3) free water surface constructed wetlands, (4) subsurface flow constructed wetlands. . . .

   Note: Fuse four spaced periods when material is omitted at the end of a sentence

2. **Indicate that words have been omitted from the middle of a sentence.**

   "The subject matter will need to be exceptionally good . . . to overcome the reader's adverse opinion."

   Note: Three spaced periods are used to indicate words omitted within a quoted sentence:

Exclamation Marks

The exclamation mark is used:

1. **After an exclamatory phrase, clause, or sentence.**

   The activated sludge process is a mess!

   No, the pumps failed!

2. **To highlight strong feelings such as elation or surprise.**

   The failure of the pumps was distressing!

   Wow! The treatment plant worked as designed.

3. **To highlight caution or danger.**

   Danger! do not go into a collection system access port without proper training.

   Placement

   When exclamation marks apply to the material within a quote they are placed within the quote marks. When exclamation marks apply to the entire sentence they are applied outside of the quotation marks.

   Note: Exclamation marks are seldom used in engineering reports.

Hyphens

The hyphen is used to:

1. **Join certain words for clarity (e.g., compound adjectives-see Section 7-3).**

   The six-inch (6-in.) diameter pipe had failed.

   A long-needed overhaul was necessary.

A water-tight septic tank was used.

2. **Write out compound numbers.**

   Fifty-one to fifty-five

3. **Form prefixes with certain words avoid confusion.**

   self-hypnosis, un-American, anti-American de-emphasize re-sign a contract

4. **Divide a word at the end of a line.**

Parentheses

Parentheses are used to:

1. **Enclose numbers and letters in lists.**

   The material to be presented is organized into sections dealing with (1) types and application of wetland and aquatic systems, (2) treatment kinetics in constructed wetlands and aquatic systems, (3) free water surface constructed wetlands, (4) subsurface flow constructed wetlands, ...

2. **Enclose reference citations (author and date or number) within the text.**

   It has been observed that bacterial populations in natural systems can acclimate to colder temperatures and maintain their mass in spite of slower activity rates (Vela, 1974).

   It has been observed that bacterial populations in natural systems can acclimate to colder temperatures and maintain their mass in spite of slower activity rates (24).

3. **Enclose explanatory words, phrases, or reference material.**

   Decisions about treated wastewater dispersal options (e.g., discharge to Willow Slough Bypass for beneficial reuse) will not be constrained.

4. **Enclose either US customary or metric units where dual units are used in the text.**

   It has been found that a paddle-tip speed of approximately 2 to 3 ft/s (0.6 to 0.9 m/s) achieves sufficient turbulence without breaking up the floc.

   ρ = mass density of liquid, slug/ft^3 (kg/m^3)

   μ = dynamic viscosity, lb•s/ft^2 (N•s/m^2)

Periods

The period is used:

1. **At the end of a sentence.**

   The project report is complete.

   What is done is done.

2. **As a full stop, after most abbreviations and contractions.**

   B.S., Ph.D., U.S. EPA, etc.

Dr., Mr., Mrs., etc.

Question Marks

The question mark is used:

1. **At the end of a direct question.**

   Is Eq.12-3 correct?

2. **After a series of questions in the same sentence.**

   Which pump will be used? the 4 in.? 6 in.? or 8 in.?

3. **To express uncertainty when enclosed in parentheses.**

   A value of 425 lb/yd^3 (?) was used in the computations.

Quotation Marks

Quotation marks are used in engineering writing:

1. **To set off short quotes.**

   In his 1927 text, *English Applied In Technical Writing*, C. W. Park noted that: “Even though a reader's interest is wholly in the subject matter his first impression of a piece of writing is necessarily based on its general appearance.”

2. **For titles of articles in reference lists.**

   Tchobanoglous, G., F. Maitski, K. Thomson, and T.H. Chadwick (1989) "Evolution and Performance of City of San Diego Pilot Scale Aquatic Wastewater Treatment System Using Water Hyacinths," *J. WPCF*, **61**, 11/12, 1245-1257. (see also Sec. 6)

Placement of other punctuation marks when used with quotation marks.

1. **Commas and periods.**

   Commas and periods ***are always*** placed inside quotation marks.

2. **Semicolons and colons.**

   Semicolons and colons ***are always*** placed outside of the quotation marks.

3. **Question marks, exclamation marks, and dashes.**

   When question marks, exclamation marks, and dashes apply the material within the quote they are placed within the quote marks. When the question marks, exclamation marks, and dashes apply to the entire sentence they are applied outside of the quotation marks.

Semicolon

The semicolon is used to:

1. **Set off independent clauses in a compound sentence.**

   The work effort was planned for Monday; however, the contractor was busy on anotherproject.

2. **Set off long or subdivided units in a series or when one or more of the items in series contains commas.**

   Some of the reasons for the observed differences are as follows (1) many organic substances that are difficult to oxidize biologically, such as lignin, can be oxidized chemically; (2) inorganic substances that are oxidized by the dichromate increase the apparent organic content of the sample; (3) certain organic substances may be toxic to the microorganisms used in the BOD test; and (4) high COD values may occur because of the presence of interfering substances.

Slash (also known as a forward slash, virgule, etc.)

The slash is used:

1. **To denote alternatives.**

   either/or, and/or, on/off

   (530) 576-5000/5220

2. **In place of omitted words.**

   g/m^3 (gram per cubic meter)

   mi/hr (miles per hour)

3. **To separate the numerator from the denominator in mathematical expressions.**

   a/b, (a + b)/(c + d)

   Note: Although often used with dates (e.g., 5/24/10), the use of slashes in dates should be avoided in technical reports, especially in reports that will be distributed internationally.

9-2 USE OF NUMBERED AND BULLETED LISTS

The use of numbered and bulleted lists is becoming increasingly common in engineering writing. Numbered and bulleted lists can be made up of individual words, phrases and/or sentences. In general, a list should be introduced by a complete sentence or a complete independent clause. For example:

The report has been organized into the following sections:

1. Introduction
2. The Recommended Wastewater Management Plan
3. The Rationale for the Recommended Plan
4. Discussion of Related Issues

Each numbered and bulleted item should start with a capital. No punctuation is used when the list does not contain a complete sentence. If the list contains a complete sentence, a period is placed at the end of each item in the list.

9-3 FORMATION OF COMPOUND WORDS

Typically used as an adjective, compound words are formed by the union of two or more words to represent a single concept. The principal compound words used in engineering reports are compound nouns and adjectives.

Rules For Writing Compound Words

1. Write compound nouns without a hyphen
2. Write compound adjectives with a hyphen
3. Omit the hyphen when the meaning is clear without it

Compound Adjectives

Although the use of compound adjectives has diminished, the examples given below are chosen to illustrate the principal ways in which compound adjectives are formed (Park, 1927).

1. **Noun + noun compounds.**

   tool-room (practice)   motor-generator (set)
   machine-tool (operation)   railway-accident (problem)

2. **Numeral + noun compounds.**

   two-cycle   three-ply
   four-inch (4-in.)   2200-volt
   six-cylinder   seven-candlepower
   40-horsepower   third-class

3. **Descriptive adjective + noun.**

   high-speed (engine)   high-potential (insulator)
   open-hearth (process)   cast-iron (frame)
   heavy-duty (engine)   high-pressure (system)

4. **Compound participial adjectives.**

   wedge-shaped   cold-rolled
   nickel-plated   water-jacketed
   motor-driven   high-priced
   shunt-wound   wood-working (machinery)
   direct-connected   wire-drawing (machine)
   home-made   cost-keeping (methods)

5. **Phrase compounds.**

   make-or-break (analysis)
   state-of-the-art (review)
   filter-to-waste (percent)
   area-to-volume (ratio)

9-4 UNITS AND ABBREVIATIONS

Units are used routinely in engineering reports and papers to standardize reported values. To avoiding the repetition of long phrases and to enhance readability, abbreviations of names and terms, geographic names, latin words, and common abbreviations are considered in this section.

Units

Each engineering discipline has its own set of units and corresponding abbreviations. In the United States, U.S. customary units are used for certain applications, while SI (system international, i.e., metric) are used more commonly in engineering report and papers (see also use of numbers in Sec. 8-4). The units and abbreviations used most commonly in the field of environmental engineering are given in Appendix A-3 in both in SI and US customary units. It is accepted practice when writing an engineering report in US customary units not to put periods after measurement abbreviations with the exception of inches (e.g., ft, min, s, and yd for feet, minute, second, and yard). The abbreviated form of inches is typically written with a period (in.) to differentiate it from the word "in."

Common Names and Terms Used in Environmental Engineering

Name	Abbreviation
Average daily wastewater flow	ADWWF (ADWF is also used)
Biochemical oxygen demand, 5-day	BOD_5
Calcium carbonate	$CaCO_3$
Chemical oxygen demand	COD
Food to microorganisms ratio	F/M
Mixed liquor volatile suspended solids	MLVSS
Ammonia nitrogen as nitrogen	NH_3-N
Nitrate nitrogen as nitrogen	NO_3-N
Oxygen	O_2
Phosphate	PO_4
Total dissolved solids	TDS
Total Kjeldahl nitrogen	TKN
Total organic carbon	TOC
Total suspended solids	TSS

Geographic Names

The abbreviations used by the U.S. Postal Service for states are given below.

State	Abbrev.	State	Abbrev.
Alabama	AL	Idaho	ID
Alaska	AK	Illinois	IL
Arizona	AZ	Indiana	IN
Arkansas	AR	Iowa	IA
California	CA	Kansas	KS
Colorado	CO	Kentucky	KY
Connecticut	CT	Louisiana	LA
Delaware	DE	Maine	ME
Florida	FL	Maryland	MD
Georgia	GA	Massachusetts	MA
Hawaii	HI	Michigan	MI
Minnesota	MN	Oregon	OR
Mississippi	MS	Pennsylvania	PA
Missouri	MO	Rhode Island	RI
Montana	MT	South Carolina	SC
Nebraska	NE	South Dakota	SD
Nevada	NV	Tennessee	TN
New Hampshire	NH	Texas	TX
New Jersey	NJ	Utah	UT
New Mexico	NM	Vermont	VT
New York	NY	Virginia	VA
North Carolina	NC	Washington	WA
North Dakota	ND	West Virginia	WV
Ohio	OH	Wisconsin	WI
Oklahoma	OK	Wyoming	WY

Latin Abbreviations

Latin abbreviations often used in engineering reports include:

ad lib.,	*ad libitum* (at will)
c., ca.,	*circa* (about, around)
e.g.,	*exempli gratia* (for example)
et al.,	*et alia* (and others)
etc.,	*et cetera* (and other things; and so on)
et seq.,	*et sequentes* (and the following)
i.e.,	*id est* (that is)
N.B.,	Nota Bene (note well)
op	opus (work of music, art)
[*sic*]	Bracketed and set in italics. The term is inserted in quoted material to indicate that the writer being quoted is responsible for the grammatical error or poor word usage.
v., vs.,	versus (against, in the direction of)
viz.,	*videlicet* (namely)

9-5 USING WORDS CORRECTLY

Words such as “principal” and “principle;” “stationary and stationery;” and “cite,” “site,” and “sight” are frequently misused in engineering reports. These and other misused words are given in the following list.

Word	Definition or usage
Accept / except	Accept is a verb meaning to receive.
	Except is usually a preposition meaning excluding.
Affect / effect	Affect is usually a verb meaning to have an influence on.
	Effect is usually a noun meaning a result, or the power to produce a result. Note that effect can also be a verb meaning to bring about or execute.
Alternately / alternatively	Alternately is an adverb that means in turn; one after the other.
	Alternatively is an adverb that means another option; one or the other.
Capital / capitol	Capital refers to a city or town that is the seat of government, the accumulation of wealth, purchase cost of equipment or facilities, or to an upper case letter.
	Capitol to a building where lawmakers meet.
Cite / site / sight	Cite is a verb that means to quote as an authority or to recognize as a source.
	Site is a noun meaning location.
	Sight is something that is seen.
Complement / compliment	Complement is a noun or verb that means something that completes or makes up a whole.
	Compliment is a noun or verb that means an expression of praise or admiration.
Comprise / compose	The whole comprises the parts.
	The parts compose the whole.
Concurrent / consecutive	Concurrent is an adjective that means simultaneous or happening at the same time as something else.
	Consecutive means successive or following one after the other.
Council / counsel	Council is an assembly called together for discussion or deliberation.
	Counsel is advice or guidance.
Dependant / dependent	Dependant is a person who depends on another entity for support.
	Dependent is relying on something else, such as relying on or requiring a person or thing for support, supply, or what is needed.

Word	Definition or usage
Discreet / discrete	Discreet is an adjective that means prudent, circumspect, or modest. Discrete is an adjective that means separate or individually distinct.
Farther / further	Farther is used for physical distance. Further means to a greater degree, or an extension of time or degree.
Its /it’s	Its is the possessive pronoun form of it. It’s is a contraction of it is. If it’s can be replaced with “it is” or “it has,” it’s is the correct word.
Past / passed	Past refers to events that have previously occurred. Passed is the past tense of to pass.
Principal / principle	Principal, used as a noun, refers to the head of a school or an organization or a sum of money. Principal, used as an adjective (e.g., the principal ingredient), means the most important. Principle is a noun meaning a basic truth, law, rule, or standard.
Stationary / stationery	Stationary is an adjective that means fixed or unmoving. Stationery is a noun that means paper materials used for writing or printing.
Than / then	Than is a comparison of unequal components. Then refers to another time, next in order, or in that case.
To / too / two	To is a preposition. Too is an adverb usually used as 'also' when adding or including some additional information. Two is a number.
Which / that	Which informs; use which with unrestrictive clauses. That defines; use that with restrictive clauses.

9-6 OFTEN MISSPELLED WORDS

Although misspelled words are often unavoidable, even with the advent of spell checkers embedded with standard writing programs, make a point to learn the correct spelling and usage of words. Following is a listing of words that are commonly misspelled (adapted from Park, 1927).

accessible
accommodate
accurate
affect (effect)
alignment
aluminum
analysis
applied
article
automatically
auxiliary
business
caisson
capacity
chute
column
compressor
condenser
control
controlled
conveyor
coarse (course)
eliminate
cupola
cylinder
definite
description
desirable
detached
dimensions
disappear
disintegrate
distillation
eccentric
efficiency
equipped
exhaust
facilitate
filtration
foundry
gauge
gases
governor
gravitation
graywater (U.S.)
greywater
guard
height
horizontal
hydraulic
ignition
indispensable
inflammable
insoluble
insulation
interchangeable
laboratory
laid
liquefy
lose
maintenance
making
malleable
manufacture
mathematics
movable
necessary
operation
original
piece
parallel
percent
personnel
phosphorus
planning
preceding
precipitate
preventive
principal
(principle)
procedure
propeller
quantity
receptacle
recommend
referred
remedy
reservoir
resources
riveted
scraper
sediment
superintendent
temporary
tendency
too (to)
transmission
triple
trolley
until
vacuum
ventilate
vertical

9-7 A WORKING VOCABULARY

As with the spelling of words, make an effort to learn and use words effectively. The following is a listing of words that should be in the working vocabulary of any practicing engineer (adapted from Park, 1927).

acrid
ameliorate
amenable
cogent
communal
comprise
compose
consummate
contingency
crucial
database
delete
deplete
dereliction
dilemma
disparity
dogma
delete
drastic
deplete
empirical
enjoin
epigram
exotic
extenuate

fortuitous
futility
heterogeneous
homogeneous
implacable
importunity
impunity
increment
indigenous
infrastructure
inhibit
innate
innovation
intrinsic
introspection
inveterate
inviolate
latent
layman
millennium
mural
naive
ostensibly.
parlance
pathological

peremptory
pertinent
plastic
potential
relevant
sheer
smug
solecism
sporadic
static
stigma
subversive
supine
talisman
tautology
transcendental
transient
transitory
ubiquitous
unobtrusive
untenable
untrammeled
utopian
vacillate
vitiate

10
EVALUATE YOUR WRITING

Once a report has been prepared in draft form, and the process of rewriting has begun, evaluate your writing for readability, conciseness, and excessive use of non-essential words. A number of different methods have been devised to assess a written work. For the purpose of this guidance manual, two methods are used to evaluate written material. The first, known as the "Gunning Fog Index" (or "Fog Index"), is used to assess the readability of a written text (Gunning, 1968). The second method deals with "working words" and "glue words," to improve the conciseness and precision of written text and to reduce the use of non-essential words (Wydick, 2005).

10-1 THE FOG INDEX

The Fog Index is computed with the following formula:

Reading level (grade) = (Average number of words in sentences + percentage of complex words of three or more syllables) x 0.4

The value of the Fog Index can vary from about 5 to more than 20. For example, a value of 12 corresponds to the reading level of a high school senior. Technical writing with a Fog Index greater than 12 is difficult for most people to read. As a frame of reference, the Fog Index for the New York Times is about 11 to 12. The Fog Index for technical writing is typically between 14 and 22 and seldom exceeds a value of 24. The higher Fog Index values are a consequence of the fact that so many of the words used in environmental and civil engineering practice contain three or more syllables.

To apply the Fog Index (Gunning, 1968):

1. Take a paragraph of about 100 words in length.
2. Determine the average number of words in a sentence by dividing the total word count by the number of sentences.

3. Count the number of complex words with three or more syllables (not including proper nouns, compound words, common suffixes, and –ing as a syllable) and divide by the total number of words and express as a percentage.
4. Add the average number of words in a sentence and the percentage of complex words and multiply the sum by 0.4

Consider the following passage from an engineering report.

> "The challenges and planning recommendations for (1) sewers including tunnels, transport/storage (T/S) structures, combined sewer discharge (CSD) structures, pump stations and force mains and (2) for treatment facilities, biosolids management, and energy utilization and production were discussed previously in Chapters 3 and 4, respectively. The purpose of this chapter is to discuss the means and methods for the implementation of the aforementioned recommendations. Implementation of such an ambitious program of recommendations will involve a number of changes from past practices. The most comprehensive change is the adoption of integrated urban watershed management as the principal tool for planning and decision making. Other changes involve the use of asset management techniques, revisions of the capital improvement program, changes in the enterprise management, and policy and code revisions. Each of these subjects is considered in this chapter. In addition, responses to regulatory changes and technological developments are also discussed."

Total number of words = 147

Number of sentences = 7

Average number of words in a sentence = 21.0 (147/7)

Words with three or more syllables = 29

Reading level = [21.0 + (29/147) x 100](0.4) = 16.3

10-2 WORKING WORDS AND GLUE WORDS

In the writing of engineering reports, the written text consists of two types of words: "working words" and "glue words" (Wydick, 2005). Working words carry the meaning of the sentence. Nouns, verbs, adjectives, adverbs, and some pronouns are working words. Glue words are used to hold the working words together to form coherent grammatical sentences. Conjunctions, prepositions, interjections, and some pronouns are glue words. Articles, often classified as adjectives, also serve as glue words. Some examples of glue words are as follows:

Conjunctions: and, but, or, for, nor, so, yet

Prepositions:

Direction: across, into, to, toward

Location: at, between, from, in, on, over, under, where

Time: after, before, during, since, until, when, whenever, while

Cause or reason: because, to, into, toward, across

Interjections: indeed, hey, oh, ouch, well

Pronouns: that, these, this, those

Articles: a, an, the

When the percentage ratio of glue words to working words exceeds 75 to 80 percent, the sentence should be recast. Consider the following examples:

From the Textbook "Water Reuse"

"The potential transmission of infectious disease by pathogenic microorganisms is the most common concern associated with nonpotable reuse of treated municipal wastewater. "

Glue words = 8

Working words = 14

Percent glue words to working words [(8/14) x 100] = 57 percent

From the "Pomona Virus Study"

"Concurrent with the development of a virus sampling technique, various unit processes were evaluated to optimize performance."

Glue words = 6

Working words = 11

Percent glue words to working words [(6/11) x 100] = 55 percent

From a Recent Engineering Report

"The conduct of a pilot plant study was requested by the client."

Glue words = 6

Working words = 6

Percent glue words to working words [(6/6) x 100] = 100 percent

Rewritten

The client requested a pilot plant study be conducted

Glue words = 3

Working words = 6

Percent glue words to working words [(3/6) x 100] = 50 percent

Rewritten again

A <u>pilot</u> <u>plant</u> <u>study</u> was <u>requested</u>

Glue words = 2

Working words = 4

Percent glue words to working words [(2/4) x 100] = 50 percent

In addition to a detailed presentation of the concept of working words and glue words, the book *Plain English for Lawyers* by Wydick (2005) is recommended as a guide for improving writing.

10-3 FOG INDEX VERSUS WORKING WORDS AND GLUE WORDS

In evaluating the readability of written material with the Fog Index and the conciseness and precision using the ratio of Glue Words to Working Words, a dichotomy will be observed. That is, as the ratio of glue words to working words is reduced, the Fog Index will increase because, as noted previously, so many of the words used in environmental and civil engineering practice contain three or more syllables. What is needed is to strike a balance between the two measures, especially when writing an executive summary and for the general public. Every effort should be made to reduce the ratio of glue words to working words to below 70 to 75 percent and the Fog Index reading level in the range from 12 to 18.

11
TECHNICAL MEMORANDUMS

The use of technical memorandums has become increasingly popular in the engineering community. Engineers use technical memorandums to describe the progress on a segment of a large job as well as to describe the assessment of new equipment or site visits to existing facilities. On some large planning projects technical memorandums are designed to become individual chapters, sections, or appendixes of the final report.

11-1 FORMATTING

A variety of formats are used for technical memorandums. Following are typical formats for the reporting of engineering findings and visits to new facilities.

11-2 MECHANICS

Most organizations have their own format(s) for technical memorandums. Some suggested margins are as follows.
Margins:

Top = 1 in., bottom = 1 in., left side = 1.25 in., and right side = 1 in.

or

Top = 1 in., bottom = 1 in., left side = 1 in., and right side = 1 in.

Memorandum for Review of Technical Process

Organization Name and Address and Logo, if one is used

TECHNICAL MEMORANDUM NO. 1

Date:	mm:dd:yyyy
To:	Engineering staff
From:	G. Tchobanoglous
Subject:	High-Energy Flocculation Process (for example)

The purpose of this memorandum is to is to present a brief description of a new high-energy flocculation process, information on its application, and a summary of process design criteria. The material presented in this memorandum has been obtained from a review of the manufacturers published literature, research reports, and information obtained during a site visit to an operating facility. The site visit was conducted on mm:dd:yyyy.

Process Description

Description of the key features of the new high-energy flocculation process.

Process Application

Based on the available information and data, suggest potential applications.

Process Design Criteria

Based on the available information and data, list (or prepare a table of applicable design criteria.

Observations and Comments or Action

Observations and impressions of the new technology.

Attachments

Manufacturers literature, field notes from site visit.

Margins:

Top = 1 in., bottom = 1 in., left side = 1.25 in., and right side = 1 in.

or

Top = 1 in., bottom = 1 in., left side = 1 in., and right side = 1 in.

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Memorandum for Site Visit

Organization Name and Address and Logo, if one is used

TECHNICAL MEMORANDUM NO. 2

To:	Engineering staff
From	H. Leverenz
Date:	mm:dd:yyyy
Subject:	Site visit to T & L composting facilities

Purpose

The purpose of this memorandum is to present a brief description of a mixed-waste composting facility visited in Clemson, SC, on mm:dd:yyyy. The facility, built in yyyy, has been in operation since mm:yyyy.

Summary of Findings

Brief synopsis of the findings contained in the memo.

Process Description and Operational Features

Description of facility including dimensions, throughput tonnage, capital and operating costs. Information on key operational features including degree of automation.

Assessment of Process

Summary of pertinent data and information on the design and operations obtained from talking to the operators.

Observations and Comments or Action

Observations and impressions of the facilities visited.

References

See suggested citation format in Sec. 6.

Attachments

Data sheets, photographs, field notes.

Margins:

Top = 1 in., bottom = 1 in., left side = 1.25 in., and right side = 1 in.

or

Top = 1 in., bottom = 1 in., left side = 1 in., and right side = 1 in.

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12
ORAL PRESENTATIONS

Civil and environmental engineers are responsible for the technical aspects of a community infrastructure comprising the basic installations and facilities on which the growth and well-being of a community depend. To be effective in meeting a community's needs, engineers must be able to communicate in a variety of mediums including written, oral, and visual. The ability to communicate effectively plays an important role in career advancement and professional recognition. Suggestions for improving the text of oral presentations are presented in this section. Improvements on delivery involve practice, practice, and more practice. The most important advice for successful oral presentations is to **not read** your presentation material verbatim–**it's a sure way to loose your audience**. Your presentation materials should reflect the main ideas and add clarity to what you are saying.

12-1 TYPES OF ORAL COMMUNICATIONS

The principal types of oral communications are:

- Informal: to exchange ideas, information, and feelings
- Technical presentations: to share information, to inform
- Technical proposal: to gain support for ideas or projects

While the primary focus of this guidance manual is on written communications, principally reports and articles, the visual aids used for oral presentations are the focus of this section.

12-2 PRELIMINARY PREPARATION

When gathering information and data for a presentation, it is useful to answer these questions: who, what, when, where, why, and how (Bolmer, 1981).

12-3 FORMATTING

As noted above, presentation materials must convey the main ideas and reinforce the spoken word. The principal elements of presentation materials are:

- Ideas, concepts, and themes
- Lists of items
- Illustrations
- Tables–general information and data
- Graphs–one and two dimensional
- Figures–line drawings, pictorial graphics
- Figures–photographs
- Equations

With the advent of modern presentation packages, such as PowerPoint, the formatting of presentations has become much simpler. In fact, most organizations have their own style guide for general layout of PowerPoint slides that typically includes the name and logo of the organization.

Identifying Key Ideas and Concepts

The most serious mistake made by presenters is cramming too many ideas and concepts into one presentation. Ask yourself the question: if I could leave the viewers with one or two messages or ideas, what would they be? One effective approach is to **first identify the conclusions** of the presentation. Identifying the conclusions first helps focus the development of the presentation outline and its final form.

Length of Presentation

As a general rule, allow one minute per slide. Thus, for a 30-minute presentation that includes a ten minute question and answer period, the number of slides should be about 20, with 22 as a maximum for the 20-minute presentation period. If more than 25 slides are used, a thoughtful presentation has not been prepared and there may not be any time for questions and answers: an injustice to you and your audience. Take the time to edit and to cut, cut, and cut. The amount of information per slide is considered in the discussion on mechanics.

12-4 MECHANICS

The mechanics of presentations involve the placement of the principal elements in an easy-to-follow logical manner.

Amount of Information Per Slide

For maximum presentation effectiveness and impact, limit the number of words or data bits to ***36 or less per slide,*** excluding short prepositions (e.g., in, of, for) and the slide title. The six by six rule is another standard for slides (e.g., ***six lines with a limit of six words per line*** (original source unknown). Limiting the number of data bits or words is difficult, but will reflect positively on you. How many times have you been to a presentation where the presenter says "I know you can't read the numbers on this slide, I can hardly see them from the podium" (a carryover from the use of overhead projectors). Even if the speaker is well known, he or she has wasted your time. The slide should not have been included in the presentation.

Do the Lights Need to be Dimmed?

If the lights in the presentation venue are to be dimmed, slides with dark colored backgrounds should be avoided, as they are difficult to read. Where the lights will be dimmed, a white background should be used for the slides. Also, when the lights are dimmed, the slides become the focal point for the audience. Thus, the slides must convey the key ideas and concepts you are trying to present as clearly and directly as possible.

Examples

Examples of unacceptable and acceptable slides are presented below.

Unacceptable: Too many words (~ 42 words, not counting slide title)

Challenges for Distributed Systems

1. Provide for the protection of public health and the environment
2. Overcome the stigma associated with past poor performance of onsite systems
3. Play a vital role in water resources management and sustainability
4. Allow for the implementation of new concepts for wastewater management (e.g. different uses of soil, not conventional treatment)
5. Help to create a paradigm shift from effluent disposal to water reuse

Revised: 22 words

Challenges for Distributed Systems

1. Protect public health and the environment
2. Poor past performance
3. Water resources management and sustainability
4. Implement new concepts
5. Effluent disposal versus water reuse

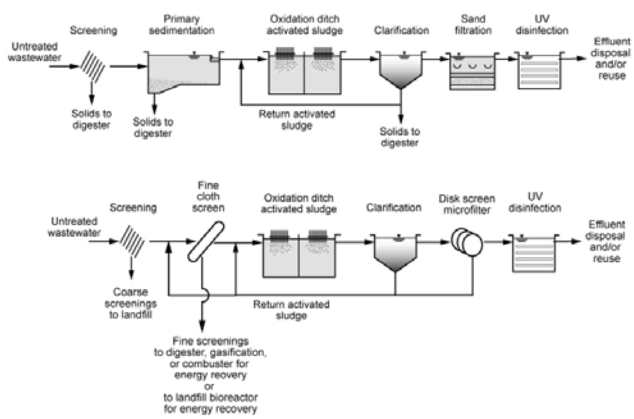
Sample slide with data table

Energy Content of Wastewater

Constituent	Unit	Value
Wastewater, heat basis	MJ/10°C•10^3 m^3	41,900
Wastewater, COD basis	MJ/kg COD	12 - 15
Primary sludge, dry	MJ/kg TSS	15 - 15.9
Secondary biosolids, dry	MJ/kg TSS	12.4 - 13.5

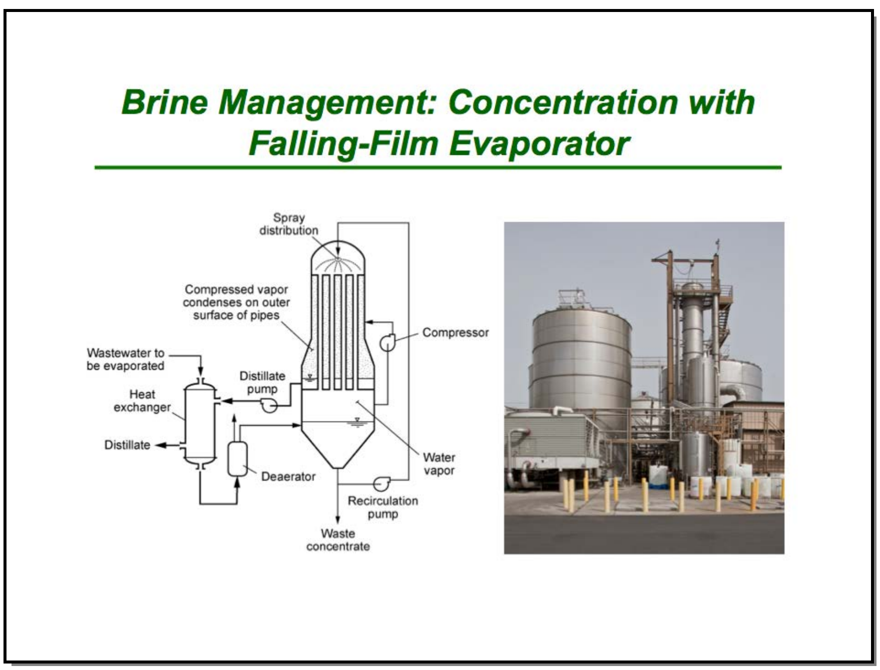
Sample slide with process flow diagram

Wastewater Treatment Process Flow Diagrams Without and With Influent and Effluent Screens



Sample slide with photos and text

Sample slide with line drawing and photo



13
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13-2 USEFUL OLDER REFERENCES

Hundreds of books have been written on report writing. Recent books on the subject may be found by going to amazon.com and typing "engineering writing" or "scientific writing." What follows is a selection of older books that are quite good that can often be found in used book stores. Although there is a 2005 illustrated edition of the famous Strunk book, the older edition is more direct and preferred. In any case, a copy of the Strunk book **should** be in your engineering library.

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Appendix A
CONVERSION FACTORS AND ABBREVIATIONS FOR UNITS

Table A-1
Unit conversion factors, SI units to U.S. customary units and U.S. customary units to SI units

To convert, multiply in direction shown by arrows					
SI unit name	Symbol	→	←	Symbol	U.S. customary unit name
Acceleration					
meters per second squared	m/s^2	3.2808	0.3048	ft/s^2	feet per second squared
meters per second squared	m/s^2	39.3701	0.0254	$in/.s^2$	inches per second squared
Area					
hectare (10,000 m^2)	ha	2.4711	0.4047	ac	acre
square centimeter	cm^2	0.1550	6.4516	$In.^2$	square inch
square kilometer	km^2	0.3861	2.5900	mi^2	square mile
square kilometer	km^2	247.1054	4.047×10^{-2}	ac	acre
square meter	m^2	10.7639	9.2903×10^{-2}	ft^2	square foot
square meter	m^2	1.1960	0.8361	yd^2	square yard
Energy					
kilojoule	kJ	0.9478	1.0551	Btu	British thermal unit
joule	J	2.7778×10^{-7}	3.6×10^6	kW•h	kilowatt-hour
joule	J	0.7376	1.356	$ft \cdot lb_f$	foot-pound (force)
joule	J	1.0000	1.0000	W•s	watt-second
joule	J	0.2388	4.1876	cal	calorie
kilojoule	kJ	2.7778×10^{-4}	3600	kW•h	kilowatt-hour
kilojoule	kJ	0.2778	3.600	W•h	watt-hour
megajoule	MJ	0.3725	2.6845	hp•h	horsepower-hour
Force					
newton	N	0.2248	4.4482	lb_f	pound force
Flowrate					
cubic meters per day	m^3/d	264.1720	3.785×10^{-3}	gal/d	gallons per day
cubic meters per day	m^3/d	2.6417×10^{-4}	3.7854×10^3	Mgal/d	million gallons per day
cubic meters per second	m^3/s	35.3147	2.8317×10^{-2}	ft^3/s	cubic feet per second
cubic meters per second	m^3/s	22.8245	4.3813×10^{-2}	Mgal/d	million gallons per day
cubic meters per second	m^3/s	15850.3	6.3090×10^{-5}	gal/min	gallons per minute
liters per second	L/s	22,824.5	4.3813×10^{-2}	gal/d	gallons per day
liters per second	L/s	2.2825×10^{-2}	43.8126	Mgal/d	million gallons per day
liters per second	L/s	15.8508	6.3090×10^{-2}	gal/min	gallons per minute

Continued on following page

Table A-1 Continued from previous page

To convert, multiply in direction shown by arrows					
SI unit name	Symbol	➔	🡐	Symbol	U.S. customary unit name
Length					
centimeter	cm	0.3937	2.540	in.	inch
kilometer	km	0.6214	1.6093	mi	mile
meter	m	39.3701	2.54×10^{-2}	in.	inch
meter	m	3.2808	0.3048	ft	foot
meter	m	1.0936	0.9144	yd	yard
millimeter	mm	0.03937	25.4	In.	inch
Mass					
gram	g	0.0353	28.3495	oz	ounce
gram	g	0.0022	4.5359×10^{2}	lb	pound
kilogram	kg	2.2046	0.45359	lb	pound
megagram (10^3 kg)	Mg	1.1023	0.9072	ton	ton (short: 2000 lb)
megagram (10^3 kg)	Mg	0.9842	1.0160	ton	ton (long: 2240)
Power					
kilowatt	kW	0.9478	1.0551	Btu/s	British thermal units per second
kilowatt	kW	1.3410	0.7457	hp	horsepower
watt	W	0.7376	1.3558	ft-lb_f/s	foot-pounds (force) per second
Pressure (force/area)					
Pascal (newtons per square meter)	Pa (N/m^2)	1.4504×10^{-4}	6.8948×10^{3}	lb_f/in.^{2}	pounds (force) per square inch
Pascal (newtons per square meter)	Pa (N/m^2)	2.0885×10^{-2}	47.8803	lb_f/ft^2	pounds (force) per square foot
Pascal (newtons per square meter)	Pa (N/m^2)	2.9613×10^{-4}	3.3768×10^{3}	in. Hg	inches of mercury (60°F)
Pascal (newtons per square meter)	Pa (N/m^2)	4.0187×10^{-3}	2.4884×10^{2}	in. H_2O	inches of water (60°F)
kilopascal (kilonewtons per square meter)	kPa (kN/m^2)	0.1450	6.8948	lb/in.^{2}	pounds (force) per square inch
kilopascal (kilonewtons per square meter)	kPa (kN/m^2)	0.0099	1.0133×10^{2}	atm	atmosphere (standard)
Temperature					
degree Celsius (centigrade)	°C	1.8 (°C) + 32	0.555(°F – 32)	°F	degree Fahrenheit
degree Kelvin	K	1.8 (K) – 459.67	0.555(°F + 459.67)	°F	degree Fahrenheit

Continued on following page

Table A-1 Continued from previous page

To convert, multiply in direction shown by arrows					
SI unit name	Symbol	→	←	Symbol	U.S. customary unit name
Velocity					
kilometers per second	km/s	2.2369	0.44704	mi/h	miles per hour
meters per second	m/s	3.2808	0.3048	ft/s	feet per second
Volume					
cubic centimeter	cm^3	0.0610	16.3781	in^3	cubic inch
cubic meter	m^3	35.3147	2.8317×10^{-2}	in^3	cubic foot
cubic meter	m^3	1.3079	0.7646	yd^3	cubic yard
cubic meter	m^3	264.1720	3.7854×10^{-3}	gal	gallon
cubic meter	m^3	8.1071×10^{-4}	1.2335×10^{3}	ac•ft	acre•foot
liter	L	0.2642	3.7854	gal	gallon
liter	L	0.0353	28.3168	ft^3	cubic foot
liter	L	33.8150	2.9573×10^{-2}	oz	ounce (U.S. fluid)

Source: Adapted from Tchobanoglous et al. (2014)

Table A-2
Conversion factors for commonly used wastewater treatment plant design parameters

To convert, multiply in direction shown by arrows			
SI units	→	←	U.S. units
g/m^3	8.3454	0.1198	lb/Mgal
ha	2.4711	0.4047	ac
hm^3	264.1720	3.785×10^3	Mgal
kg	2.2046	0.4536	lb
kg/ha	0.8922	1.1209	lb/ac
kg/kW•h	1.6440	0.6083	lb/hp•h
kg/m^2	0.2048	4.8824	lb/ft^2
kg/m^3	8345.4	1.1983×10^{-4}	lb/Mgal
kg/m^3•d	62.4280	0.0160	$lb/10^3\ ft^3$•d
kg/m^3•h	0.0624	16.0185	lb/ft^3•h
kJ	0.9478	1.0551	Btu
kJ/kg	0.4303	2.3241	Btu/lb
kPa (gage)	0.1450	6.8948	lb_f/in^2 (gage)
kPa Hg (60 °F)	0.2961	3.3768	in Hg (60 °F)
kW/m^3	5.0763	0.197	$hp/10^3$ gal
$kW/10^3\ m^3$	0.0380	26.3342	$hp/10^3\ ft^3$
L	0.2642	3.7854	gal
L	0.0353	28.3168	ft^3
L/m^2•d	2.4542×10^{-2}	40.7458	gal/ft^2•d
L/m^2•min	0.0245	40.7458	gal/ft^2•min
m^3/m^2•min	24.5424	4.0746×19^{-2}	gal/ft^2•min
L/m^2•min	35.3420	0.0283	gal/ft^2•d
m	3.2808	0.3048	ft
m/h	3.2808	0.3048	ft/h

Continued on following page

Table A-2 Continued from previous page

To convert, multiply in direction shown by arrows			
SI units	→	←	U.S. units
m/h	0.0547	18.2880	ft/min
m/h	0.4090	2.4448	gal/ft^2•min
m^2/10^{3}m^3•d	0.0025	407.4611	ft^2/Mgal•d
m^3	1.3079	0.7646	yd^3
m^3/capita	35.3147	0.0283	ft^3/capita
m^3/d	264.1720	3.785 x 10^{-3}	gal/d
m^3/d	2.6417 x 10^{-4}	3.7854 x 10^3	Mgal/d
m^3/h	0.5886	1.6990	ft^3/min
m^3/ha•d	106.9064	0.0094	gal/ac•d
m^3/kg	16.0185	0.0624	ft^3/lb
m^3/m•d	80.5196	0.0124	gal/ft•d
m^3/m•min	10.7639	0.0929	ft^3/ft•min
m^3/m^2•d	24.5424	0.0407	gal/ft^2•d
m^3/m^2•d	0.0170	58.6740	gal/ft^2•min
m^3/m^2•d	1.0691	0.9354	Mgal/ac•d
m^3/m^2•h	3.2808	0.3048	ft^3/ft^2•h
m^3/m^2•h	589.0173	0.0017	gal/ft^2•d
m^3/m^3	0.1337	7.4805	ft^3/gal
m^3/10^3 m^3	133.6805	7.4805 x 10^{-3}	ft^3/Mgal
m^3/m^3•min	133.6805	7.4805 x 10^{-3}	ft^3/10^3 gal•min
m^3/m^3•min	1,000.0	0.001	ft^3/10^3 ft^3•min
Mg/ha	0.4461	2.2417	ton/ac
mm	3.9370 x 10^{-2}	25.4	in
ML/d	0.2642	3.785	Mgal/d
ML/d	0.4087	2.4466	ft^3/s

Source: Adapted from Tchobanoglous et al. (2014).

Table A-3
Abbreviations for units

Name	Abbrev.	Name	Abbrev.
		SI units	
centimeter	cm	kilojoules per kilogram	kJ/kg
cubic meter	m^3	kilojoules per kilowatt-hour	kJ/kW
cubic meter	m^3	kilometer	km
cubic meters per second	m^3/s	kilometers per hour	km/h
degree Celsius	°C	kilometers per liter	km/L
gram	g	kilowatt	kW
grams per square meter	g/m^2	liter	L
hectare	ha	liters per second	L/s
joules per second per square meter	$J/s \bullet m^2$	megajoule	MJ
Kelvin	K	meter	
kilogram	kg	meters per second	m/s
kilograms per capita per day	kg/capita•d	milligram	mg
kilograms per cubic meter	kg/m^3	milligrams per liter	mg/L
kilograms per hectare	kg/ha	Newton	N
kilonewtons per square meter	kN/m^2	Newtons per square meter	N/m^2
kilosecond	ks	square kilometer	km^2
kilojoule	kJ	square meter	m^2
kilojoules per cubic meter	kJ/m^3		
		U.S. customary units	
acre	ac	kilowatt	kW
British thermaL unit	Btu	kilowatt -hour	kWh
British thermal units per cubic foot	Btu/ft^3	pound (force)	lb_f
British thermal units per hour per	Btu/hft	pound (mass)	lb_m
British thermal units per kilowatt-hour	Btu/kWh	pounds per acre	lb/acre
British thermal units per pound	Btu/lb	pounds per acre	lb/acre
British thermal units per ton	Btu/ton	pounds per capita per day	lb/capita•d
degree Celsius	°C	pounds per cubic foot	lb/ft^3
cubic foot	ft^3	pounds per cubic yard	lb/yd^3
cubic feet per minute	ft^3/min	million gallons per day	Mgal/d
cubic feet per second	ft^3/s	miles	mi
cubic yard	yd^3	miles per hour	mi/h
day	d	miles per gallon	mi/gal
degree Fahrenheit	°F	parts per million	ppm
foot	ft	ounce	oz
feet per minute	ft/min	pounds per square foot	lb/ft^2
feet per second	ft/s	pounds per square in	lb/in^2
gallon	gal	square foot	ft^2
gallons per minute	gal/min	square mile	mi^2
grain	gr	square yard	yd^2
horsepower	hp	ton	ton
horsepower-hour	hp-h	watt-hour	W-h
hour	hr	yard	yd
inch	in.		

Source: Adapted from Tchobanoglous et al. (2014)

Appendix B
PHYSICAL CONSTANTS

Acceleration due to gravity (standard),

g = 9.8066 m/s^2 (32.174 ft/s^2) (value varies with latitude)

Avogadro's number, N_A = 6.0221 x 10^{23} molecules/mole

Boltzmann's constant, k = 1.3807 x 10^{-23} J/K

Faraday's constant, F = 96,485 C (abs)/g-eq

Latent heat of fusion of water (0° C and 1 atm) = 333.6 J/g (144 Btu/lb)

Latent heat of vaporization of water (100° C and 1 atm) = 2258 J/g (971 Btu/lb)

Molecular mass of dry air = 28.97 g/mole (lb/lb-mole)

One angstrom, A = 10^{-10} m

One bar = 10^5 N/m^2 (14.504 lb_f/in.^{2})

One hectare, ha = 10,000 m^2 (0.4047 ac)

One meter head of water (20°C and 1 atm) = 9.789 kN/m^2

One torr (0°C) = 1 mm Hg = 133.322 N/m^2(1/760 standard atmosphere)

Plank's constant, h = 6.6261 x 10^{-34} J•s

Specific heat of water,

c_p (0°C) = 4.2174 J/g•°C

c_p (10°C) = 4.1919 J/g•°C

c_p (20°C) = 4.1816 J/g•°C

Standard atmosphere = 101.325 kPa (kN/m^2) (14.7 lb/in.^{2})

= 10.333 m (33.899 ft) of water

= 760 mm Hg

Standard conditions

General scientific = 0°C and I atm (32 °F and 14.7 lb/in.^{2})

Compressors and blowers = 70 °F and 14.7 lb/in.^{2}

Natural gas industry = 60 °F and 14.7 lb/in.^{2}

Stephen-Boltzman constant, σ = 5.6704 x 10^{-8} W/m^2•K^4 (0.1713 x 10^{-8} Btu/ft^2•h•R^4)

Temperature (absolute)

Kelvin, K = 273.15 + °C

Rankine, °R = 459.67 + °F

Universal gas law constant

R = 1.9872 cal/mole•K

= 8.3144 J(abs)/mole•K

= 8.3130 J(int)/mole•K

R = 0.000082057 atm•m^3/mole•K

= 0.082057 atm•L/mole•K

= 62.63 mm Hg•L/mole•K

R= 1543 ft • lb_f/lb-mole•°R (Universal)

R = 53.3 ft • lb/lb-air•°R (Engineering gas constant for air)

R = 0.729 ft^3 • atm/lb-mole•°R

Velocity of light, c = 2.99792 x 10^8 m/s

Volume occupied by an ideal gas [0°C (32°F) and 1 atm] = 22.4140 L/mole

= 359 ft^3/lb-mole

Source: From Tchobanoglous et al. (2014).

Appendix C
EXERCISES FOR SELF STUDY

The following self-study exercises were developed for use in conjunction with a writing workshop presented over a six to seven hour time period. With the exception of "Exercise 6 Descriptive Writing," about 20 minutes should be allocated for each exercise. Thirty minutes was allocated for Exercise 6. Do not worry if the exercises cannot be completed in the allotted time. An important aspect of developing writing skills is to write within a prescribed time limit. As writing skills develop, these and similar exercises will become easier to complete within the allotted time. Suggested answers to the exercises are presented in Appendix D.

Self-Study Exercise No. 1
EMPTY WORD PHRASES

Empty word phrases to avoid in engineering reports

Empty phrases	Use, substitute
at this point in time	
at that point in time	
by means (reason) of	
due to the fact that	
during the time that	
fewer in number	
for the purpose of	
for the reason that	
for the sake of	
goes under the name of	
if conditions are such that	
in accordance with	
inasmuch as	
In favor of	
in order to	
in the event that	
In this day and age	
it is evident that	
It is interesting to note that	
it is often the case that	
in view of the fact that	
it would appear that	
on the other hand	
prior to	
serves the function of being	
serves to function as	
subsequent to	
with reference to	
with respect to	
with a view to	

Self-Study Exercise No. 2
TABLES AND GRAPHS

The following data were derived from a food science experiment. The purpose of the study was to determine the influence of temperature on the respiration rate of vegetables in storage. The results are expressed in milliliters of carbon dioxide produced per kilogram of vegetable per hour. Measurements were made at 0, 10, 20, and 30°C.

Tomato:	at 0° - 5 mL/kg•hr, at 10° - 8 mL/kq•hr, at 20° - 20 mL/kg•hr, at 30° - 37 mL/kg•hr.
Broccoli:	at 0° - 11 mL/kg•hr, at 10° - 22 mL/kg•hr, at 20° - 89 mL/kg•hr, at 30° - 136 mL/kg•hr.
Onion:	at 0° - 4 mL/kg•hr, at 10° - 5 mL/kg•hr, at 20° - 6 mL/kg•hr, at 30° - 9 mL/kg•hr.
Lettuce:	at 0° - 4 mL/kg•hr, at 10° - 12 mL/kg•hr, at 20° 23 mL/kg•hr, at 30° - 42 mL/kg•hr.
Potatoe:	at 0° - 4 mL/kg•hr, at 10° - 5 mL/kg•hr, at 20° - 6 mL/kg•hr, at 30° - 29 mL/kg•hr.

Summarize the given data in a table, and prepare two different types of plots of the data. Construct each graphic in complete form, including legends and axis label.

Data source: Monroe J, C. Meredith, and K, Fisher (1977) *The Science Of Scientific Writing,* Kendall/Hunt Publishing Company, Dubuque, IA

Self-Study Exercise No. 3
FORMATTING EQUATIONS

Set up equations in proper metric form to answer the questions posed below.

1. Determine the mass of mixed liquor suspended solids (MLSS) in an aeration tank in kilograms (kg) using the following information.

   Volume of aeration tank = 4500 m^3

   MLSS = 3,000 mg/L

   Note: Mass = concentration x volume

2. Determine the depth of the sludge zone in a primary sedimentation tank in meters (m) using the following information.

   Area of sedimentation tank = 2,500 m^2

   Mass of sludge in sedimentation tank = 6,000 kg

   Average sludge concentration = 7,000 mg/L = 7,000 g/m^3

   Note: depth = mass in aeration tank/concentration x area

3. Determine the efficiency of removal of soluble BOD in percent for the following conditions.

   Influent BOD = 250 mg/L

   Effluent BOD = 6.2 mg/L

   Note: Efficiency= [(influent – effluent)/influent] x 100

Self-Study Exercise No. 4
FORMATTING CITATIONS

Using the publication information given below, prepare appropriate reference citations.

Damkohler number design method to avoid clogging of subsurface flow constructed wetlands by heterotrophic biofilms

D. Austin, D. Maciolek, B. Davis and S. Wallace

Water Science & Technology Vol. 56 No. 3 pp. 7–14 *Q* IWA Publishing 2007

Chapter 6, Flotation Process Used For Calcium Carbonate Recovery From Water Treatment Sludges, pages 105 through 130

By Harmel A. Dawson

From Water Treatment Plant Design For The Practicing Engineer, Copyright 1978

Edited by Robert L. Sanks

Ann Arbor Science Publishers, Inc.

P.O. Box 1425. Ann Arbor, Mich. 48106

Survey of High-Recovery and Zero Liquid Discharge Technologies for Water Utilities, Copyright 2008

By Michael Mickley

WateReuse Foundation Product Number: 02-006a-O 1

WateReuse Foundation Alexandria, VA.

Self-Study Exercise No. 5
RECASTING SENTENCES

Although Figure 2 shows the required information for both BOD and nutrient removal processes, this study considered only carbon-based emissions and so only BOD removal processes are examined.

Any plant designated as a lagoon was treated as a standard facultative lagoon, and, hence, not included in the evaluation. This is not to imply that facultative lagoons do not have GHG (greenhouse gases) emissions.

Equation 4 defines the total increase in the mass of solids in the reactor as YV_r.

Equation 7 predicts that, for every mole of oxygen consumed, 0.8 moles of CO_2 are released.

Self-Study Exercise No. 6
DESCRIPTIVE WRITING

Write a short paragraph description (about five or six sentences long) one of the following four figures with which you are familiar

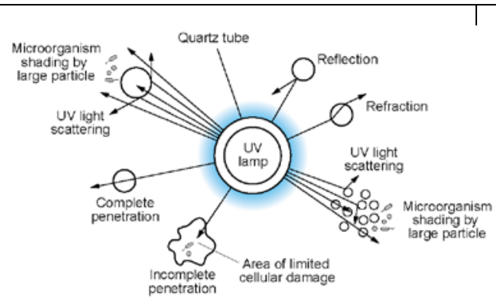


Figure E6-1

Particle interactions that affect the effectiveness of ultraviolet (UV) disinfection including microorganism shading; light scattering, reflection, and refraction; and incomplete penetration.

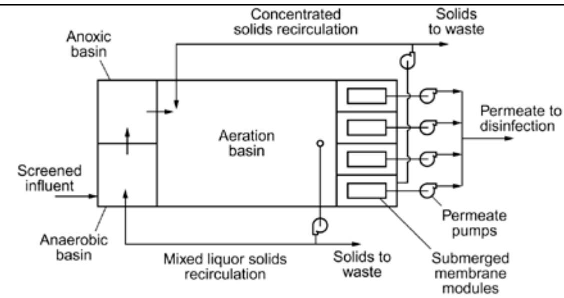


Figure E6-2

Plan view of membrane bioreactor with an anaerobic section for nitrogen removal.

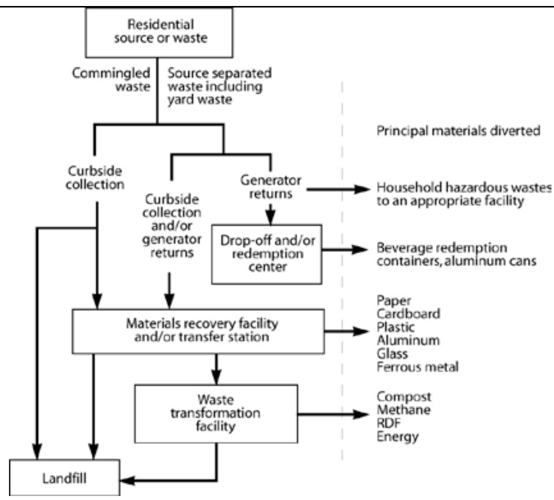


Figure E6-3

Simplified flow diagram for an integrated waste management system.

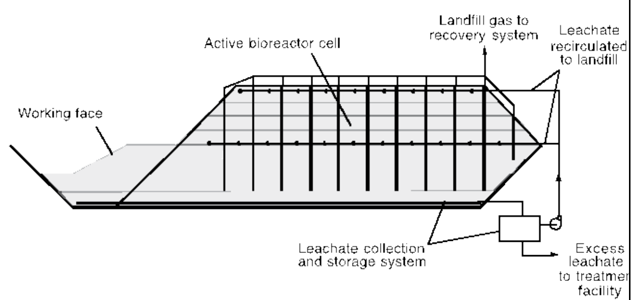


Figure E6-4

Cross section through bioreactor landfill showing elements of gas collection and leachate management systems.

Self-Study Exercise No. 7
THE FOG INDEX

Determine the "Fog Index" of the following two excerpts from two different engineering reports

1. San Diego Health Effects Study

The most important risk consideration for non-potable reuse of recycled water is pathogen exposure. In recent years, most attention in the U.S. has been focused on managing potential risks associated with the ingestion of potable water supply from sources recharged (groundwater) or augmented (surface water) with recycled water. Exposure to potentially harmful microbiological agents through irrigation with recycled water, especially when consumption of agricultural products is considered, has been studied in the past. With respect to irrigation, a high level of recycled water treatment and controlling opportunities for incidental contact with recycled water are the most important risk management factors limiting exposure and hence, risk.

Total number of words (TW) =

Number of sentences (NS) =

Average number of words in a sentence (AWS) =(TW/NS) =

Words with three or more syllables (TS) =

Reading level [AWS + (TS/TW) x 100](0.4) =

2. City of Davis Wastewater Planning Charrette

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludge can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Total number of words (TW) =

Number of sentences (NS) =

Average number of words in a sentence (AWS) =(TW/NS) =

Words with three or more syllables (TS) =

Reading level [AWS + (TS/TW) x 100](0.4) =

Self-Study Exercise No. 8
RATIO OF GLUE WORDS TO WORDKING WORDS

Determine the "Ratio of glue words to working words" for the following two excerpts from two different engineering reports

1. San Diego Health Effects Study

The most important risk consideration for non-potable reuse of recycled water is pathogen exposure. In recent years, most attention in the U.S. has been focused on managing potential risks associated with the ingestion of potable water supply from sources recharged (groundwater) or augmented (surface water) with recycled water. Exposure to potentially harmful microbiological agents through irrigation with recycled water, especially when consumption of agricultural products is considered, has been studied in the past. With respect to irrigation, a high level of recycled water treatment and controlling opportunities for incidental contact with recycled water are the most important risk management factors limiting exposure and hence, risk.

Total number of words (TW) = 104

Glue words (GW) = 43

Working words (WW) = 61

Ratio of glue words to working words = (GW/WW) x 100 =

2. City of Davis Wastewater Planning Charrette

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludge can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Total number of words (TW) =

Glue words (GW) =

Working words (WW) =

Ratio of glue words to working words = (GW/WW) x 100 =

Self-Study Exercise No. 9
WORKING WORDS AND GLUE WORDS

Determine the number of glue words, working words, and the percentage of glue to working words. If the percentage of glue to working words is greater than 70 percent, rewrite the sentence

1. From a US Public Health Service Report

In order to check the effectiveness of the disinfection treatments, bacterial plate counts were made at intervals to get an index of the relative levels of bacterial populations both in the effluents and in the soils.

Glue words (GW) =
Working words (WW) =
Percent glue words to working words [(GW/WW) x 100] =

2. From a US Public Health Service Report

On the first day of the run there seemed to be no difference in the soil population levels.

Glue words (GW) =
Working words (WW) =
Percent glue words to working words [(GW/WW) x 100] =

3. From a US Public Health Service Report

Since the disinfected effluents seem to clog the soils faster and to a greater degree than the normal effluents, it may be inferred that the solids added to the cores have a greater effect on clogging that does the biological activity after the effluent is added to the soil.

Glue words (GW) =
Working words (WW) =
Percent glue words to working words [(GW/WW) x 100] =

Self-Study Exercise No. 10
PREPARING SLIDES FOR PRESENTATIONS

Unacceptable: Too many words (~ 65 words, not counting slide title)

Impact of Sustainability Considerations on the Future of Solid Waste Management

1. Must institute changes in product packaging
2. Must modify consumer behavior with respect to waste generation and source separation
3. Development of new strategies and concepts for control of greenhouse gas emissions
4. Need improved waste management strategies
5. New product and waste generation regulations
6. Must deal with reduced waste volumes to landfills and reduced demand for recycled materials
7. Must develop new strategies to deal with market constraints and variations

Revised: ___ words

Impact of Sustainability Considerations on the Future of Solid Waste Management

1.
2.
3.
4.
5.
6.
7.
8.

Unacceptable: Too many words (~ 71 words, not counting slide title)

Energy Usage In Wastewater Treatment

- Energy required for treatment could be reduced by improved process designs (e.g., both hydraulic and treatment process)
- Energy required could also be offset by a fractional increase in fleet gas mileage
- Carbon emissions can be mitigated through use of renewable energy sources
- New technologies being developed to recover energy from wastewater (biodiesel, fuel cells, green plastics from wastewater biomass)
- Energy choices have to be made to protect the environment for a sustainable future

Revised: ___ words

Energy Usage In Wastewater Treatment

•
•
•
•
•

Unacceptable: Too many words (~ 55 words, not counting slide title)

Challenges For The Implementation Of DWM in the 21st Century

- Protection of public health and the environment
- Must development robust DWM systems and new system concepts and conduct research
- Must create a paradigm shift from effluent Disposal (Dispersal) to water Use (Reuse)
- Must resolve inconsistencies (disconnects) now exist between research (applied) and regulations
- Integration of DWM systems in water resources management plans for sustainable development

Revised: ___ words

Challenges For The Implementation Of DWM in the 21st Century

Appendix D
SUGGESTED ANSWERS TO SELF-STUDY EXERCISES

Suggested answers to the self-study exercises given in Appendix C are given in this appendix. Because there are no right or wrong answers, the answers are suggested as there may be more appropriate or refined answers. As your writing skills develop, the answers to these exercises will become more direct and concise.

Suggested Answers to Self-Study Exercise No. 1
EMPTY WORD PHRASES

Empty word phrases to avoid in engineering reports

Empty phrases	Use, substitute
at this point in time	now
at that point in time	then
by means (reason) of	by
due to the fact that	because
during the time that	while, when
fewer in number	few
for the purpose of	for
for the reason that	because
for the sake of	for
goes under the name of	called
if conditions are such that	under
in accordance with	with, about, concerning
inasmuch as	because
In favor of	for
in order to	to
in the event that	if
In this day and age	today
it is evident that	evidently
It is interesting to note that	note that
it is often the case that	often
in view of the fact that	because
it would appear that	is
on the other hand	delete altogether
prior to	before
serves the function of being	is
serves to function as	is
subsequent to	after
with reference to	about, concerning
with respect to	compared
with a view to	to

Suggested Answers to Self-Study Exercise No. 2
TABLES AND GRAPHS

Table 1
Respiration rates of common vegetables from 0 to 30°C

Vegetable	Gas produced, mL CO_2/kg•hr at indicated temperature, °C			
	0	10	20	30
Broccoli	11	22	89	136
Lettuce	4	12	23	42
Onion	4	5	30	9
Potato	4	5	6	29
Tomato	5	8	20	37

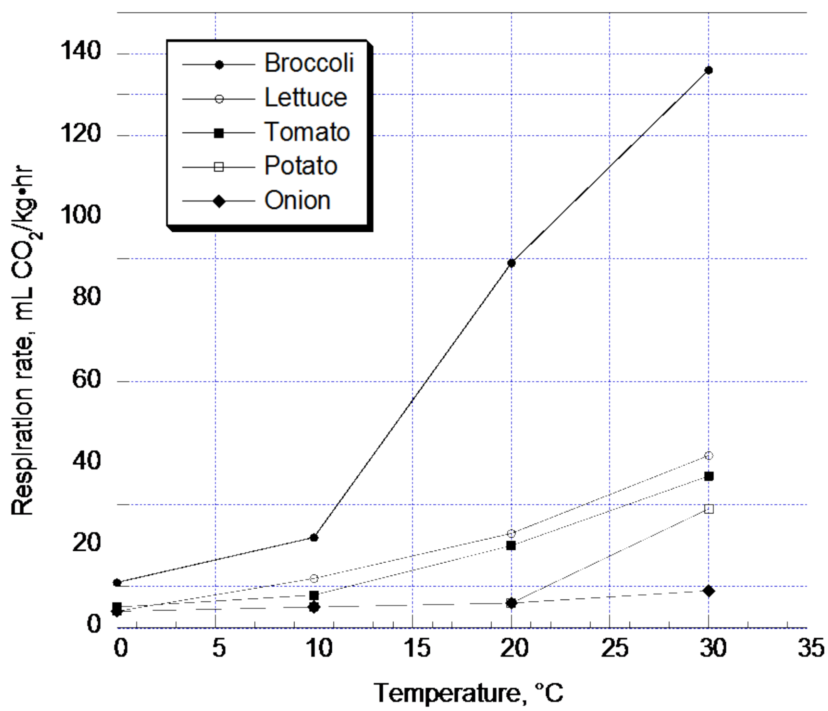


Figure 1
Respiration rate of several vegetables as a function of temperature

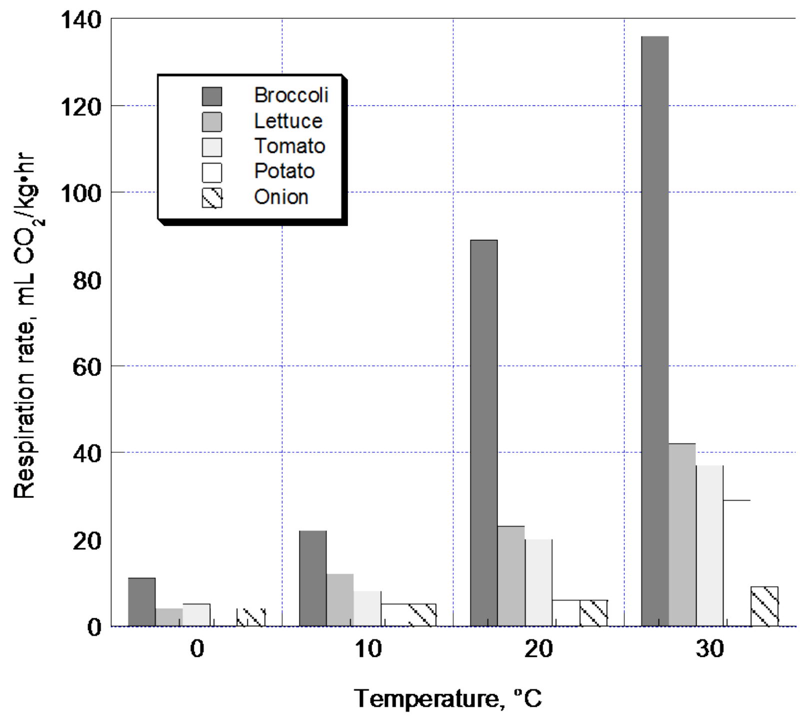


Figure 2
Respiration rate of several vegetables as a function of temperature

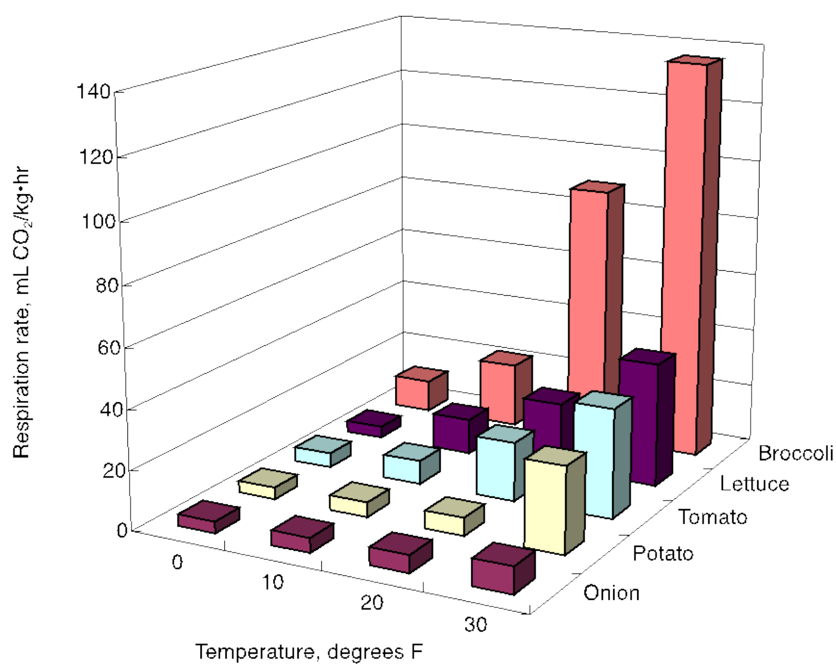


Figure 3
Respiration rate of several vegetables as a function of temperature

Suggested Answers to Self-Study Exercise No. 3
FORMATTING EQUATIONS

1. Determine the mass of mixed liquor suspended solids (MLSS) in an aeration tank in kilograms (kg) using the following information.

   Volume of aeration tank = 4500 m^3

   MLSS = 3,000 mg/L

   Note: Mass = concentration x volume

$$\text{MLSS, kg} = \frac{(4{,}500\ \text{m}^3)(3{,}000\ \text{mg/L})(10^3\ \text{L/m}^3)}{(10^3\ \text{mg/g})(10^3\ \text{g/kg})} = 13{,}500\ \text{kg}$$

   Noting that: 1 mg/L = 1 g/m^3, the above expression can be written as:

$$\text{MLSS, kg} = \frac{(4{,}500\ \text{m}^3)(3{,}000\ \text{g/m}^3)}{(10^3\ \text{g/kg})} = 13{,}500\ \text{kg}$$

   Alternatively,
   MLSS, kg = (4500 m^3)(3,000 g/m^3)(1 kg/10^{-3} g) = 13,500 kg

2. Determine the depth of the sludge zone in a primary sedimentation tank in meters (m) using the following information.

   Area of sedimentation tank = 2,500 m^2

   Mass of sludge in sedimentation tank = 6,000 kg

   Average sludge concentration = 7,000 mg/L = 7,000 g/m^3

   Note: depth = mass in aeration tank/concentration x area

$$\text{Depth, d, m} = \frac{(6{,}000\ \text{kg})(10^3\ \text{g/kg})}{(7{,}000\ \text{g/m}^3)(2{,}500\ \text{m}^2)} = 0.34\ \text{m}$$

3. Determine the efficiency of removal of soluble BOD in percent for the following conditions.

   Influent BOD = 250 mg/L

   Effluent BOD = 6.2 mg/L

   Note: Efficiency= [(influent – effluent)/influent] x 100

$$\text{Efficiency, E, \%} = \frac{[(250 - 6.2)\ \text{mg/L}]}{(250\ \text{mg/L})}\ \text{x}\ 100 = 97.5\%$$

   Alternatively,

$$\text{Efficiency, E,\%} = \frac{[(250 - 6.2)\ \text{mg/L}](100)}{(250\ \text{mg/L})} = 97.5\%$$

   Note use of parentheses and brackets (see Section 5)

Suggested Answer to Self-Study Exercise No. 4
FORMATTING CITATIONS

Using the publication information given below, prepare appropriate reference citations.

D. Austin, D. Maciolek, B. Davis and S. Wallace

Water Science & Technology Vol. 56 No. 3 pp. 7–14 *Q* IWA Publishing 2007

> Austin, D., D. Maciolek, B. Davis, and S. Wallace (2007) "Damkohler Number Design Method to Avoid Clogging of Subsurface Flow Constructed Wetlands by Heterotrophic Biofilms," *Water Sci. Technol*., **56**, 3, 7-14.

Chapter 6, Flotation Process Used For Calcium Carbonate Recovery From Water Treatment Sludges, pages 105 through 130

By Harmel A. Dawson

From Water Treatment Plant Design For The Practicing Engineer, Copyright 1978

Edited by Robert L. Sanks

Ann Arbor Science Publishers, Inc.

P.O. Box 1425. Ann Arbor, Mich. 48106

> Dawson, H.A. (1978) "Flotation Process Used For Calcium Carbonate Recovery From Water Treatment Sludges," 105-130, in R.L. Sanks (ed.), *Water Treatment Plant Design For The Practicing Engineer,* Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

Survey of High-Recovery and Zero Liquid Discharge Technologies for Water Utilities, Copyright 2008

By Michael Mickley

WateReuse Foundation Product Number: 02-006a-01

WateReuse Foundation Alexandria, VA.

> Mickley, M. (2008) *Survey of High-Recovery and Zero Liquid Discharge Technologies for Water Utilities,* Product Number: 02-006a-01, WateReuse Foundation, Alexandria, VA.

Suggested Answers to Self-Study Exercise No. 5
RECASTING SENTENCES

Although Figure 2 shows the required information for both BOD and nutrient removal processes, this study considered only carbon-based emissions.

- *While both BOD and nutrient removal processes are shown on Figure 2, only carbon-based emissions were considered in this study.*
- *The removal of BOD and nutrients are shown on Figure 2, however, only carbon-based emissions were considered in this study.*
- *Although both BOD and nutrients are shown on Figure 2, only carbon-based emissions were considered in this study.*

Any plant designated as a lagoon was treated as a standard facultative lagoon, and, hence, not included in the evaluation. This is not to imply that facultative lagoons do not have GHG (greenhouse gases) emissions.

- *Any plant designated as a lagoon was treated as a standard facultative lagoon, and, hence, not included in the evaluation. This grouping does mean that facultative lagoons do not have GHG (greenhouse gases) emissions.*
- *While lagoon systems generate GHG (greenhouse gas) emissions, these facilities were not included in the study.*
- *Greenhouse gas (GHG) emissions from lagoon systems were not considered in the study.*

Equation 4 defines the total increase in the mass of solids in the reactor as YV_r.

- *As shown in Eq. 4, the term YV_r is used to represent the increase in he mass of solids*

Equation 7 predicts that, for every mole of oxygen consumed, 0.8 moles of CO_2 are released.

- *From Equation 7, for each mole of oxygen consumed 0.8 moles of CO_2 are released.*
- *For one mole of oxygen consumed, 0.8 moles of CO_2 are released (see Eq. 7).*

Suggested Answers to Self-Study Exercise No. 6
DESCRIPTIVE WRITING

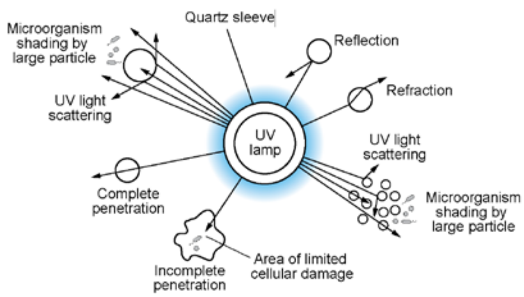


Figure 6-1

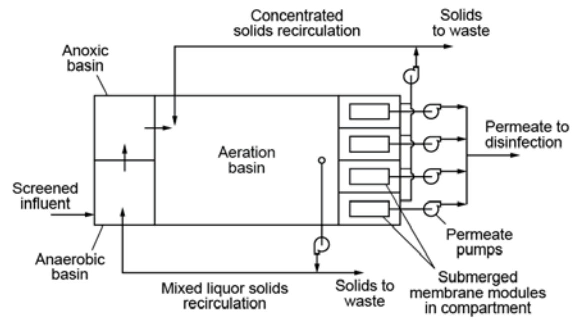


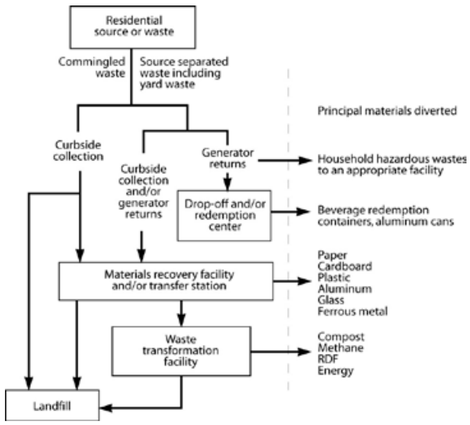
Figure 6-2

Figure 6-1

In recent times, the use of UV disinfection has become more popular in both water and wastewater treatment. A number of factors related to suspended particulate matter can have a negative impact on the performance of ultraviolet (UV) disinfection processes. For example, as illustrated on Fig E6-1, microorganisms in suspension may be shaded from the UV light by a large particle or many small particles. Similarly, microorganisms that are embedded in particles will not receive the design UV dose. Suspended particles can also reduce the overall effectiveness of UV disinfection processes by UV light scattering, refraction, reflection, and by accumulation on the quartz sleeve surrounding the UV lamp. To optimize the performance of the UV disinfection process the liquid to be disinfected is filtered to remove particulate matter and mechanical wipers are used to clean the quartz sleeve.

Figure 6-2

The membrane bioreactor process (MBR), a relatively new process designed to accomplish wastewater treatment, nutrient removal, and effluent filtration on a small footprint, is shown schematically on Fig E6-2. As shown, submerged membranes are used in place of a sedimentation tank found in conventional activated sludge processes. Permeate pumps draw treated water through the membrane modules while rejecting biomass and other particulate matter. Nitrogen is removed by recirculating the mixed liquor containing nitrate to the anaerobic basin where it is denitrified (i.e., converted to nitrogen gas) using the organic matter in the influent wastewater as a carbon source. Bacteria are conditioned to accumulate phosphorus in the anoxic basin. Wasting a portion of the mixed liquor solids that have accumulated phosphorus results in a net removal of phosphorus from the system.



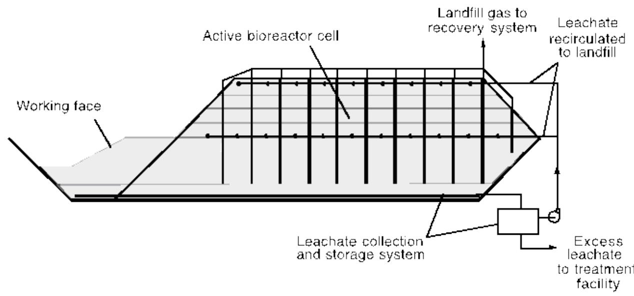


Figure 6-3 **Figure 6-4**

Figure 6-3

The functional elements that comprise an integrated solid waste management system are identified on Fig. E6-3. The first functional element involves the source of the waste, where waste materials may be commingled or source separated. Commingled materials are collected at curbside typically and hauled to a materials recovery facility (MRF) or landfill. Source separated materials can also be collected at curbside, using multiple trucks or multi-bin trucks, or hauled to a management facility by the waste generator. Various materials, including metals, glass, plastics, and paper products can be recovered at the MRF for recycling. Following processing at the MRF, residuals may be sent to a transformation facility for energy or organics recovery, or hauled directly to a landfill. It should be noted that it is always the waste generators responsibility to manage hazardous materials appropriately.

Figure 6-4

The bioreactor landfill is a relatively new process designed to both reduce the volume of waste and increase the recovery of biogas. A synthetic liner is placed at the base and on the top of the landfill to contain all liquid and gas emissions, and exclude oxygen from the anaerobic process. Leachate recovered from the bottom of the landfill is recirculated as needed to maintain the optimal moisture content in the waste material for anaerobic decomposition. Excess leachate is sent to an appropriate treatment facility. Landfill gas recovered using vertical extraction wells can be used for energy production to offset natural gas use. Placement of the leachate recirculation and gas collection systems is of critical importance in the design of bioreactor landfills. When the digestion process is complete, the top liner can be removed and the digested waste can be composted further for use as cover material

Suggested Answers to Self-Study Exercise No. 7
RATIO OF GLUE WORDS TO WORDKING WORDS

1 San Diego Health Effects Study

The most important risk consideration for non-potable reuse of recycled water is pathogen exposure. In recent years, most attention in the U.S. has been focused on managing potential risks associated with the ingestion of potable water supply from sources recharged (groundwater) or augmented (surface water) with recycled water. Exposure to potentially harmful microbiological agents through irrigation with recycled water, especially when consumption of agricultural products is considered, has been studied in the past. With respect to irrigation, a high level of recycled water treatment and controlling opportunities for incidental contact with recycled water are the most important risk management factors limiting exposure and hence, risk.

Total number of words (TW) = 104

Glue words (GW) = 43

Working words (WW) = 61

Ratio of glue words to working words = (7/9) x 100 = 70 percent

2. City of Davis Wastewater Planning Charrette

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludge's can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Total number of words (TW) = 115

Glue words (GW) = 43

Working words (WW) = 61

Ratio of glue words to working words = (7/9) x 100 = 70 percent

Suggested Answers to Self-Study Exercise No. 8
THE FOG INDEX

1 San Diego Health Effects Study

The most important risk consideration for non-potable reuse of recycled water is pathogen exposure. In recent years, most attention in the U.S. has been focused on managing potential risks associated with the ingestion of potable water supply from sources recharged (groundwater) or augmented (surface water) with recycled water. Exposure to potentially harmful microbiological agents through irrigation with recycled water, especially when consumption of agricultural products is considered, has been studied in the past. With respect to irrigation, a high level of recycled water treatment and controlling opportunities for incidental contact with recycled water are the most important risk management factors limiting exposure and hence, risk.

Total number of words (TW) = 104

Number of sentences (NS) = 4

Average number of words in a sentence (AWS) = (TW/NS) = 26

Words with more than three syllables (TS) = 32

Reading level [AWS + (TS/TW) x 100]](0.4) = [26 + (32/104) x 100](0.4) = 22.7

2. City of Davis Wastewater Planning Charrette

Municipal wastewater contains a wide range of particulate and dissolved constituents. Most of the particulate matter is organic and biodegradable. Separation of the larger particulate matter from the wastewater, using screens and sedimentation, is inexpensive and the resulting sludge's can be stabilized, concurrent with energy recovery, using anaerobic digestion. Material remaining in the wastewater after primary sedimentation includes fine and colloidal particles and dissolved organic and inorganic material. The organic matter is mostly biodegradable and is usually treated using an aerobic biological process. The dissolved inorganic material is typically non-reactive and can be discharged to the environment. However, a few inorganic constituents [e.g., ammonia nitrogen (NH_3)] are toxic to aquatic organisms and will need to be removed.

Total number of words (TW) = 115

Number of sentences (NS) = 7

Average number of words in a sentence (AWS) = (TW/NS) = 115/7 = 16.4

Words with more than three syllables (TS) = 42

Reading level [AWS + (TS/TW) x 100]](0.4) = [16.4 + (42/115) x 100](0.4) = 21.2

Suggested Answers to Self-Study Exercise No. 9
WORKING WORDS AND GLUE WORDS

1. From a US Public Health Service Report

In order to check the effectiveness of the disinfection treatments, bacterial plate counts were made at intervals to get an index of the relative levels of bacterial populations both in the effluents and in the soils.

Glue words = 20
Working words = 16
Percent glue words to working words = 125% [(20/16) x 100]

The relative effectiveness of the disinfection treatments were evaluated over time, using effluent and soil bacterial plate counts .

Glue words (GW) = 7
Working words (WW) = 11
Percent glue words to working words = 64% [(7/11) x 100]

The (relative) effectiveness of the disinfection treatments were evaluated using bacterial plate counts in effluents and soils.

Glue words = 7
Working words = 9 or 10
Percent glue words to working words = 78% [(7/9) x 100]
Percent glue words to working words = 70% [(7/10) x 100]

2. From a US Public Health Service Report

On the first day of the run there seemed to be no difference in the soil population levels.

Glue words (GW) = 10
Working words (WW) = 8
Percent glue words to working words = 125% [(10/8) x 100]

Rewritten
No difference in soil population levels were observed on the first run.

Glue words (GW) = 4
Working words (WW) = 8
Percent glue words to working words = 50% [(4/8) x 100]

Rewritten again
No difference was observed in soil population levels on the first run.

Glue words (GW) = 4
Working words (WW) = 8
Percent glue words to working words = 50% [(4/8) x 100]

3. **From a US Public Health Service Report**

Since the disinfected effluents seem to clog the soils faster and to a greater degree than the normal effluents, it may be inferred that the solids added to the cores have a greater effect on clogging that does the biological activity after the effluent is added to the soil.

Glue words (GW) = 28
Working words (WW) = 21
Percent glue words to working words = 133% [(28/25) x 100]

Rewritten

Because clogging occurred faster in soil cores loaded with disinfected effluent, as compared to normal effluent, it is hypothesized that solids have a greater effect on clogging than does biological activity.

Glue words (GW) = 13
Working words (WW) = 18
Percent glue words to working words = 72% [(13/18) x 100]

Suggested Answers to Self-Study Exercise No. 10
PREPARING SLIDES FOR PRESENTATIONS

Unacceptable: Too many words (~ 65 words, not counting slide title)

Impact of Sustainability Considerations on the Future of Solid Waste Management

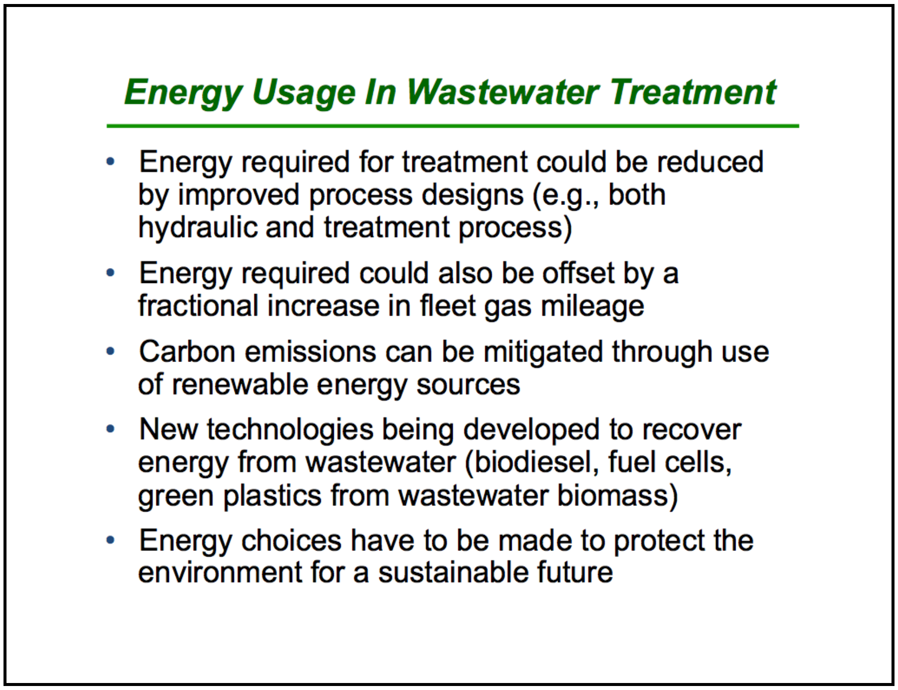
1. Must institute changes in product packaging
2. Must modify consumer behavior with respect to waste generation and source separation
3. Development of new strategies and concepts for control of greenhouse gas emissions
4. Need improved waste management strategies
5. New product and waste generation regulations
6. Must deal with reduced waste volumes to landfills and reduced demand for recycled materials
7. Must develop new strategies to deal with market constraints and variations

Revised: 26 words

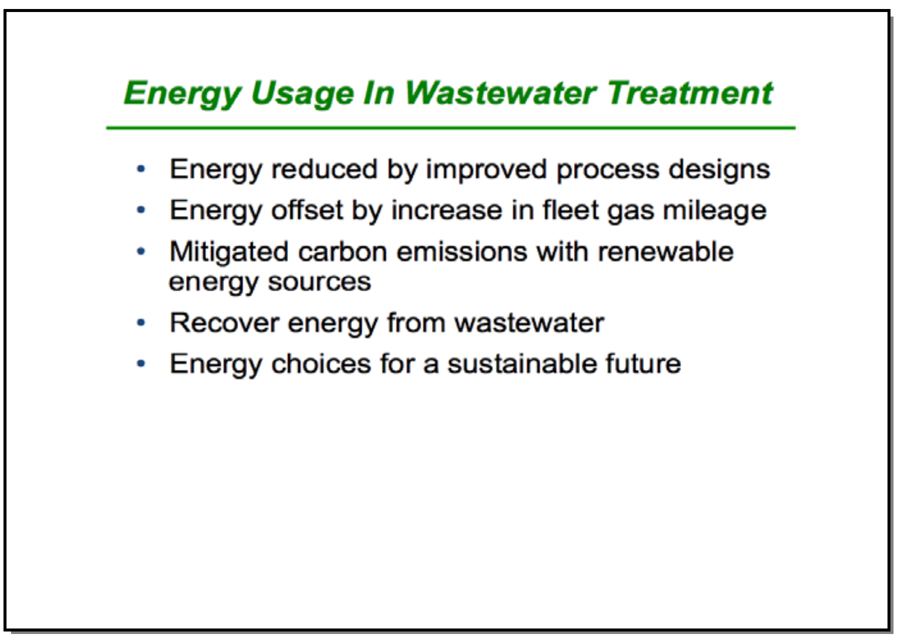
Impact of Sustainability Considerations on the Future of Solid Waste Management

1. Product packaging
2. Consumer behavior
3. Control greenhouse gases
4. Waste management strategies
5. Product and generation regulations
6. Reduced waste to landfills
7. Demand for recycled materials
8. Market constraints and variations

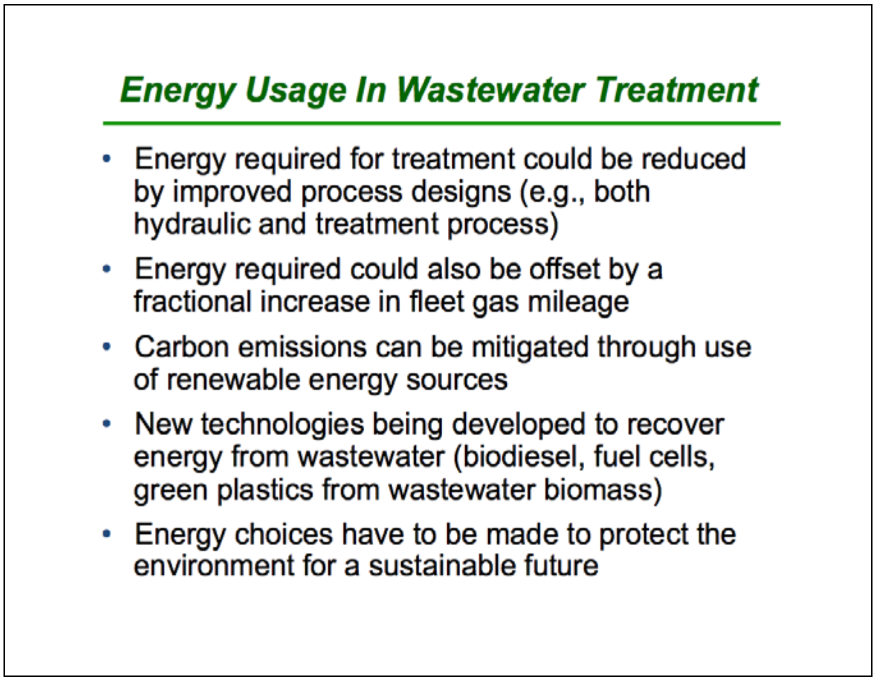
Unacceptable: Too many words (~ 71 words, not counting slide title)



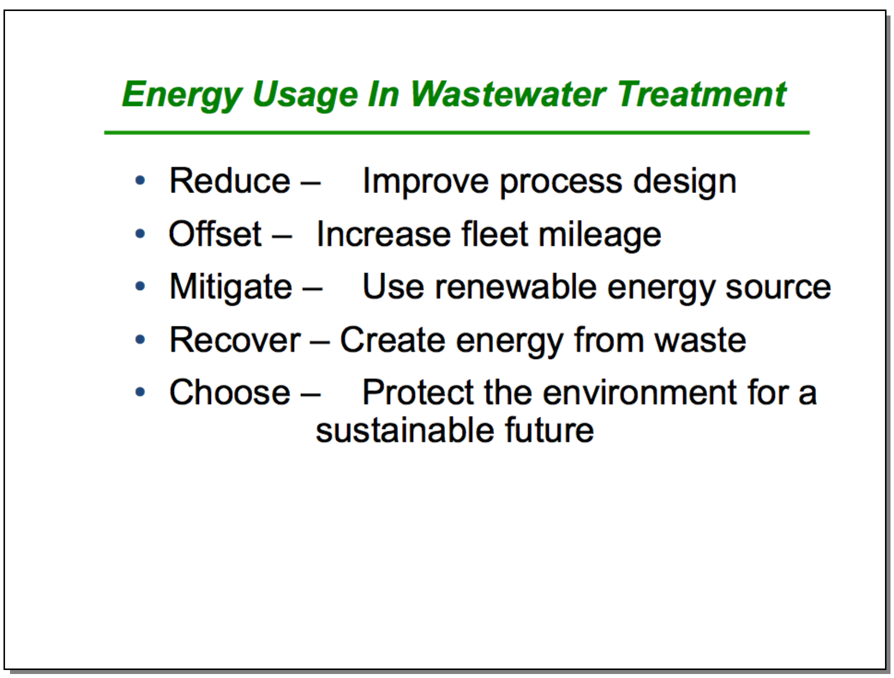
Revised: 31 words



Unacceptable: Too many words (~ 71 words, not counting slide title)



Revised: 26 words The revised slide is courtesy of one of the attendees in Sacramento on March 9, 2010



Unacceptable: Too many words (~ 55 words, not counting slide title)

Challenges For The Implementation Of DWM in the 21st Century

- Protection of public health and the environment
- Must development robust DWM systems and new system concepts and conduct research
- Must create a paradigm shift from effluent Disposal (Dispersal) to water Use (Reuse)
- Must resolve inconsistencies (disconnects) now exist between research (applied) and regulations
- Integration of DWM systems in water resources management plans for sustainable development

Revised: 30 words

Challenges For The Implementation Of DWM in the 21st Century

- Protect public health and environment
- Robust DWM systems, concepts, and research
- Paradigm shift effluent disposal to water reuse
- Disconnects between research and regulations
- Integration of DWM systems in sustainable development