Chair of Urban Water Systems Engineering
Technical University of Munich

Writing Guidelines

Brief Guidelines for Writing a Thesis at the Chair of Urban Water Systems Engineering (TUM)

Chair of Urban Water Systems Engineering

School of Engineering and Design

Technical University of Munich

Author: Jonas Aniol, M.Sc. (TUM) / Carolina Feickert Fenske, M.Sc. (TUM)
Version: 1.0
Release: 24. May 2022

Last Updated: 18. May 2022

Preface

These guidelines are a general but not complete support for students preparing a scientific work (thesis) at the Chair of Urban Water Systems Engineering of TUM. The focus and scope of this document is in the writing process. These guidelines are related to theses in the field of environmental engineering and science; please be aware that other research branches/disciplines can have different rules and conventions. Please note that preparing a written report is only a part of the whole scientific work, besides, e.g., practical work, documentation, communication, and/or presentation. There are standards for good scientific working, and students have to follow the Code of Conduct for Safeguarding Good Academic Practice […] (the English version begins at the second half of the linked document). It is the duty of the students to inform themselves about the official boundary conditions of the university and the individual study courses, like the registration forms (available at the examination office of the school), duration of the thesis, deadlines, additional/including achievements (e.g., a presentation/defense), or the grading of related accomplishments. Therefore, students should get familiar with the latest regulations of their university as well as additional and study course-specific regulations. The General Examination and Study Regulations of TUM are available online and study course-specific regulations can be found on the individual course webpages. For demonstration, this document mostly refers to the regulations for the study programs Civil Engineering and Environmental Engineering at TUM. For other study courses, regulations can differ, and only the specific study course regulations are valid.

We will update these guidelines regularly. Please ensure to use the latest version, which is the version published on our chair's website.

Topics

We offer topics for theses, both during the summer and winter semesters. Currently available topics can be found here. External supervised topics or suggestions for own topics are also possible but need to be discussed with a supervisor at the Chair of Urban Water Systems Engineering.

Table of Content

1. Theses: Fundamentals/Requirements/Assessment

The completion of Bachelor's and Master's study programs requires the preparation of a final thesis.

> *"For quality assurance, both Bachelor's and Master's study courses require a dissertation (Bachelor's/Master's dissertation), the purpose of which is to demonstrate the ability to deal independently with a problem in the relevant subject area on the basis of academic methods within a set period of time."* [KMK, 2003].

"The fundamental idea of scientific work is to gain knowledge with the help of systematic and accepted methods and to share that knowledge with others. The prerequisite for scientific work is curiosity. This means to ask questions. It means to start with 'why' but also to analyze the opinion of others and the supposed truth. Writing a thesis should start with a problem and the precise phrasing of a research question. One should separate the components 1) description of facts, 2) the investigation/analysis and 3) the assessment of results" [Sandberg, 2013] – *modified translation*.

Although the most crucial part of a thesis is its content, preparing a scientific report has to follow some basic rules and conventions. The aim of these guidelines is to support students with their task to write a thesis by providing the elementary rules and conventions in the field of engineering and natural sciences.

1.1 Requirements

The subsequent information summarize the most relevant facts out of the official TUM study regulations for enivironmental engineering [TUM, 2022a, 2022b, 2022c, 2016, 2019].

Note that only the latest information given in official TUM study regulations (general regulations and study course-specific regulations) are valid!

Bachelor's Thesis

- A minimum of 120 credits is required for the registration of the Bachelor's thesis.
- To prove the credit threshold, a transcript of records has to be forwarded to the supervisor.
- The Bachelor's thesis consists of a scientific elaboration (writing part) and a presentation (~20 min). The presentation is not counted in the grading.
- The thesis has to be submitted within **five** months after registration.
- The workload is **10 ECTS** or 300 hours (10 x 30 hours per ECTS).
- The scope of the thesis should be between **20 to 30 pages** (max. 40 pages with appendix).

Study Project

- The aim of the study project is to achieve experience in applied environmental engineering, e.g., as part of a research project or practical work.
- The study project has to be submitted within **six** months after registration.
- The study project consists of a project report and a presentation (~20 min). The project report counts 80 % and the presentation 20 % to the grade.
- The workload is **12 ECTS** or 360 hours (12 x 30 hours per ECTS).

Master's Thesis

- A minimum of 75 credits is required for the registration of the Master's thesis.
- To prove the credit threshold, a transcript of records has to be forwarded to the supervisor.
- The thesis should be written in English, but German is also possible if project-related specifics demand it (consider the TUM study regulations and study program specific regulations).
- The Master's thesis consists of a scientific elaboration (writing part) and a presentation (~20 min). The presentation is not counted in the grading.
- The thesis has to be submitted within **six** months after registration.
- The workload is **30 ECTS** or 900 hours (30 x 30 hours per ECTS).
- The scope of the Master's thesis should be **around 60 pages** (max. 100 pages with appendix).

1.2 Assessment

The assessment and grading of the thesis comprise different categories and criteria. The following list shows the principal schematic and most relevant aspects for the evaluation.

Technical Assessment	• Literature research (extent and relevance) • Logical structure and argumentation • Focus on key aspects • Identification of the research gaps/questions • Discussion and interpretation of the results
Formal Assessment	• Written expression and phrasing (clarity/consistency) • Paragraphing • Spelling and grammar • Citation • Layout and formatting
Presentation (if demanded by the FPSO)	• Oral performance • Visual presentation • Discussion / Handling of Questions

2. Content and Structure of a Thesis

The content and structure of a thesis follow a general principle to which students should stick. Briefly, it should include an introduction, material/methods, results/discussion and conclusions. Of course, there is room for individual deviations or modifications if this is beneficial for specific topics or approaches. However, deviations from it should be discussed with the corresponding supervisor beforehand.

2.1 Content

Your work must follow a logical structure, the storyline ("Roter Faden" in German). Think about the aim of your work (research questions) and the message you want to deliver to the reader. Clearly focus on a holistic approach regarding your research question and give it a logical structure instead of writing everything down which is somehow related to your topic. A thesis is not an arbitrary accumulation of information to generate pages. The task is to collect information and decide which information is vital to give the reader the relevant background information and the necessary information to answer the research question. Suppose you are unsure about the relevance of some sections in your report; ask yourself: Is this information really relevant to answer the underlying research questions or to accomplish the research tasks? For example, it happens very often that supervisors read long sections, in which students mainly cites descriptive information from one source, such as the most relevant textbook of the area. This is considered a bad style, as an interested reader lacking the general background can always look into the textbook to get informed on the overall subject matter himself/herself. If you want to start a paragraph like *"The following general description is mostly taken from Example et al. (2021)…",* you are most likely on the wrong track.

Instead, focus on individual pieces of literature that contain specifics that are of greatest importance for your report (research question). For example: "Authors Example et al. (2021) have mainly focused on the removal of compound A, while they largely ignored phenomenon B."

Check your main chapters by answering the following questions:

Introduction	Why is this thesis important/necessary? What is/are your research question(s)? How is the topic/research question embedded in the research field?
Background	Does this chapter deliver all the necessary background information for the reader to understand the following investigations/research?
Methods	Could the reader theoreticall reproduce your results with the information provided?
Results	Are the provided information (results) – descriptions, figures and tables – sufficient to describe what was observed? Have the own results been discussed in conjunction with findings from previous studies?
Conclusion	Have all research questions been addressed and what to conclude? If research hypotheses have been formulated, can these be (partly) accepted or do they need to be rejected?

2.2 Structure

Cover Page

The cover page should state:

- Header: The chair, the university (TUM) and the TUM logo (like the first page of this document). It can also contain the logo of collaborating institutes.
- Title of your thesis
- Type of thesis
- Institute: university, school, chair
- Student's/author's details: Name & degree, name of study program, matriculation number
- Name of the supervisors (internal/external)
- Date of submission

Abstract

The abstract is the most read part of a thesis. An abstract is a very brief, compact and concise repetition of the results, discussion and conclusion. It should tell the reader the (1) TOPIC (research question) and (2) WHY the topic is relevant; (3) HOW was it conducted, what are the main (4) OUTCOMES (results) and what (5) CONCLUSIONS can be drawn from this study including its relevance for the field. The length of an abstract should not exceed one page.

Zusammenfassung

A "Zusammenfassung" (German for summary/abstract) can be added written in German as thesis was prepared at a German University. But it is not absolutely needed.

Table of Content

The table of content lists the names of the main- and subchapters and their page number. It also includes the abstract, list of figures, list of tables, abbreviations, nomenclature, bibliography/reference section, and appendix (if relevant). The *Declaration of Academic Honesty* is not part of the scientific work and therefore does not appear in the table of content.

List of Figures

A list of the used figures giving the numbering of the figure, the corresponding caption, and the page number of the item is optional. It might be moved to the end of the thesis.

List of Tables

There should be a list of the used tables, which gives the numbering of the tables, the corresponding heading, and the page number of the item.

Abbreviations / Acronyms / Nomenclature

There should be a list of all abbreviations and acronyms that are used within the thesis. It is not necessary to include common abbreviations like "e.g." or abbreviations found in the dictionary. Also chemical elements and substances (such as CH_4) do not need to be listed here. In case that the thesis includes a lot of equations, a separate list of mathematical symbols and parameter – a nomenclature – is appropriate.

1. Introduction

This chapter introduces the topic to the reader, describes the relevance of the subject matter and defines the research questions and aim of the work. The introduction should be focused, structured and short (1-3 pages, but not more than five pages).

Try to answer:

- Why is the thesis topic (currently) relevant?
- What is state of the art? / What was recently researched/discovered/developed?
- What is the aim of your work (research questions)?
- How do you approach answering that question?

2. Literature Review/ Theoretical Background

"The literature review is a core element of your thesis and shows that you are capable of working scientifically. As you explain what other researchers have found on your topic, the reader will realize that you know this topic extremely well. This will build trust that you can provide a piece of work yourself that is scientifically relevant" [TUM, 2022d].

"Equally important, you will need to identify a gap in the literature that you intend to fill. This is how you justify your thesis, and it helps the reader to assess the importance of your work" [TUM, 2022d].

3. Hypotheses/ Research questions

This chapter gives an overview of which specific research question(s) you intend to address in your thesis.

It is helpful to number your research questions to (i) enhance the visibility of each aim and (ii) to get a kind of "to-do-list" with which you can track your progress.

4. Materials and Methods

Here you describe which materials and methods (e.g. analytical methods) you used and how you collected the data. The description should be detailed enough that a reader of your research field would be able to reproduce your work [TUM, 2022d]. Provide information on all instruments used in your work, including model, manufacturer and country. List all chemicals used in your work, the manufacturer and level of purity. Describe prepared solutions in such a way that it is reproducible, e.g. "10 mL stock solution of compound X was prepared with a concentration of 5 mmol/L."

5. Results and Discussion

This chapter gives a structured overview of your results. Try to display your results in a meaningful way. Use only significant graphs and tables and always introduce them in the text.

Compare your results with findings from the literature based on the review/theoretical background discussed before. Have all research questions been addressed? Refer to the research questions and evaluate the hypotheses (if formulated).

Tip: Relevant information you found in your literature review fits well into this section as it contextualizes your results. Very often, readers are having a hard time connecting the background section with results sections. Thus, try to keep the background section more general, but concise and discuss specific literature findings in the context of your results!

6. Conclusions and Outlook

This short sectionsummarizes the main outcomes of your study and which conclusions can be drawn from it. Important: The conclusions must not contain any new content that was not already mentioned.

The outlook addresses further research questions or ideas. What was not working? What can be improved? On what ongoing research should focus? “You may also assess if your findings have practical implications” [TUM, 2022d].

References / Bibliography

List all references you used in your report in a consistent way. It does not contain any additional references you read during your time conducting the study. It should be prepared in accordance with the citation rules of the chair (see chapter 6).

Appendix

Provide additional material that is not necessarily needed in the main text body or that is too comprehensive to be included in the main body. Appending files can also be provided as a digital appendix, i.e., on a CD.

Declaration of Academic Honesty

Here the student assures that he/she prepared the submitted thesis by himself/herself and that no other than the mentioned sources and means have been used [TUM, 2020a, §18(9)].

3. Form/Style and Layout/Formatting

An excellent scientific report is characterized by clarity, readability, consistency, and an overall tidy layout. Therefore, exotic font types or color schemes should be avoided. But there is a lot of freedom regarding the choice of style. Nevertheless, consistency is essential. If a particular layout, formatting, or wording is selected, one should use it this way throughout the entire report.

Content vs. Appearance

A scientific text's quality is defined by its content and how concisely it incorporates and structures relevant information. You cannot improve a poorly written text with a propper or even stylish layout or many pictures! So the content, clarity, structure and conciseness should be the top priority for your text. However, an inadequate or inappropriate appearance of a text gives the impression of sloppy work. The appearance of your text should convey clarity and consistency to ease the reading process.

3.1 Layout

TUM offers a template for scientific theses, which can be used and customized if necessary. However, creating your own template provides a better awareness of the layout and formatting. Furthermore, it does not take too much time, and for the commonly used office software applications, plenty of online information exists on how to do layout and formatting. Subsequently, we collected some layout/format settings and rules to which students should stick.

Page Margins

top	bottom	left	right
2.5 cm	1.5 cm	2 cm	2 cm

In case the thesis should be printed, a wider margin is recommended at the inside of the page:

top	bottom	left	right
2.5 cm	1.5 cm	1.5 cm	2.5 cm

Font

standard font	size	line spacing
Arial	11	1.3 – 1.5
Times New Roman	12	1.2 – 1.4

Main Text Alignment

Justify: 

Page Numbers

Page numbers at the bottom of each page (footer line). The page number starts with “1” on the first page of the introduction. Pages before the introduction should be numbered with Greek letters and begin with “II” (the page number on the cover page is not printed).

Header Line/ Footer Line

The header and the footer line can be used to offer additional information, which facilitates navigation through a written report. This can be page numbers as well as the respective chapters (numbering and name), etc. The header and footer line should not be used to deliver unnecessary information. For instance, showing the logo of an/your organization on each individual page does not benefit the reader. It is also unnecessary to state the report's title or the author's name or address on each page; that information is given once on the cover page.

Keep in mind how you intend to print your thesis. If you go for a duplex hard copy, the orientation of the text should alter between even und uneven pages.

3.2 Style and Formatting

Capitalization of Headlines

All words in the title of the thesis are capitalized except articles ("the", "a", "an"), prepositions and *coordinating conjunctions ("but", "and", "or", "for", "nor")* [TUM, 2014]. More information are listed in *The use of English in Thesis Titles at TUM* document.

Abbreviations

Abbreviations are recommended to ease the communication of long technical terms appearing frequently in the text.

General rules:

- Only use abbreviations if they are repetitive and improve the readability of your text. Keep abbreviations to a minimum and only use them if they appear at least two times.
- Do not use abbreviations in the abstract or the title, and avoid abbreviations in figures and tables.
- When using the abbreviation for the first time, write out the full term (e.g., … *the chemical oxygen demand (COD) is* …). Afterward, **only** use the abbreviation.
- List all abbreviations in an alphabetic abbreviation list at the beginning of the thesis to allow the reader a quick identification of an abbreviation.

Lonely Subchapter

There is no such thing as a single subchapter. If a chapter is divided into subchapters, there must be at least two of them. E.g.:

2. Main Chapter
   2.1 Subchapter 1
   2.2 Subchapter 2

Units

Be consistent whether you use units/variables. Allow comparability of results by referring to one unit (e.g., m^3/d or m^3/h) and adapting the values/results to this unit (1 m^3/h → 24 m^3/d).

Abbreviate units when they include numerical information (e.g., 20 L, not 20 liters) and avoid splitting the number and unit.

A space between a value and unit can have a tidy look. If using a space, the utilization of a secured/“non-breaking space” prevents the separation of the number and the unit and keeps the distance always equal. To insert such a secured space, press “Shift”+”Ctrl”+”Space” (the shortcut can differ among software and operating systems). Consider the “%” sign like a unit.

Make consistent use of a thousand separator, like a “,” or a space (non-breaking space). E.g., 5,400 L or 5 400 L instead of 5400 L. Also, consider differences depending on the used language.

Keep in mind that a dot “.” is used in English as a decimal separator and not a comma “,” as in many other languages. Also check your figures for that frequent inconsistency. If your computer has non-English settings (e.g. German), simply go into the system control, set the region to USA and all programs (e.g. Excel) will now appear in the right style.

If a unit should be further specified (mg in the following case), subscript the corresponding information: mg_{COD}/L instead of mg COD / L.

“Non-breaking space”

A “non-breaking space” prevents the separation of the element before and after the space. This can be helpful for, e.g., separating numbers and their corresponding units. To insert such a secured space, press “Shift”+”Ctrl”+”Space”.

Double Spaces

Two consecutive spaces in the written text are a general issue and are often hard to detect. An easy way to get rid of them is to check the document with the help of the office software’s search function.

Declaration of Variation

The declaration of variations has a unit (e.g., mean value and a corresponding standard deviation). It is given in the unit of the corresponding mean value or relative as a percentage of the mean value. Those are correct notations:

123 mg/L ± 8 mg/L
(123 ± 8) mg/L
123 mg/L ± 6.5 %

4. Spelling and grammar

The thesis can be written in German or English (course-specific regulations should be considered). Correct spelling and grammar are prerequisites for a thesis. However, mistake-free writing can be challenging, especially when one has to write in a language other than the mother tongue. There is a lot support that can and should be used by the students – if necessary. The English Writing Center (TUM) offers free one-to-one consulting in English writing. Further, the Language Center of TUM provides many writing resources for scientific and English writing. You can also try grammar-checking software such as Grammarly or other available programs to detect mistakes.

TUM agreed on the usage of American English in general. Therefore, we recommend setting the spelling and grammar checker of your office software to American English right at the beginning of your writing process.

It is impossible and not our goal to give comprehensive grammar and spelling guidelines at this point. However, there are issues that we frequently recognize. Below, there are some tips and a few mistakes that you can avoid easily.

Numbers	Numbers from 0 – 9 (or 12) are written out; higher numbers are given as figures. However, if they are combined with a unit, they can always be written as numbers, e.g., *one kilogram* or *one kg* → *1 kg*. If quantities do not have a mathematical, physical, or chemical unit and are below the mentioned values, then write them out, e.g., *4 plastic containers* → *four plastic containers*.
Technical Terms	Use the appropriate technical terms of your research field. Stick to these technical terms and do not vary your vocabulary to avoid confusion (e.g., nutrient solution, nutrient medium, nutrient stock solution, etc.)
Long Sentences	Some writers repeatedly create very long sentences, which are often hard to follow for the reader. A rule of thumb is that sentences should not exceed three lines. In some cases, it is also possible to split or structure them with the help of bullet points (use this sparingly). Another nice option is the use of numbering within the sentence, like, e.g., *The reason for this outcome can be explained by 1) …, 2) …, 3) ...,*
Articles	A singular countable noun is always introduced by an indefinite (a/an) or definite (the) article [Purdue University, 2022a], e.g., *The reactor is big.* Plural countable nouns are introduced by a definite (the) article if they refer to a specific group or no article if they are used in a general sense [Purdue University, 2022a], (e.g., *Experiments should always be replicable*). Uncountable singular nouns are never introduced by an indefinite article (a/an) (e.g., *Wastewater is a precious resource*). Singular and plural uncountable nouns are only introduced by a definite article (the) to refer to a specific object/group [Purdue University, 2022a], (e.g., *The wastewater quality of Munich is improving*). See more information about articles here.
Comma	Commas are required after introductory elements (e.g., However, …), non-defining relative clauses (e.g., *the water sample, which was collected on the 3rd experimental day, was analyzed.*)

	You can find more rules about commas here.
That vs. Which	If the information in the clause is required to understand the preceding noun, use "that" [Purdue University, 2022b]. E.g., *Biogas that has a methane concentration of over 96 % can be injected into the natural gas grid.* In this case, using gerund is potentially even better: *Biogas having a methane concentration of over 96 % can be injected into the natural gas grid.* If the information in the clause is not required to understand the noun in the sentence, use "which" [Purdue University, 2022b]. E.g., *Biogas, which was generated in biogas digesters, was upgraded by the addition of hydrogen.* More details are described here.
Tenses (Past, Present, Future)	Use the past tense to report what you did or what other researchers reported [Nature Education, 2014] (e.g., *Strübing et al. 2017 reached a methane concentration of over 96 %*). Use the present tense to describe general rules, facts, conclusions (from you or other researchers) [Nature Education, 2014] (e.g., *This graph shows …*). Use the future tense for prospects and perspectives [Nature Education, 2014]. (e.g., *Future studies should focus on …*) More information can be found here.

5. Literature and Sources

There are many different categories or resources, e. g., basic literature, research results, reviews (overviews), datasets, or guidelines and standards, etc. This leads to a wide variety of literature and resource types like textbooks, journal articles, conference proceedings, web pages, guidelines and standards, reports, pamphlets, interviews, and laws and directives – just to mention a few examples. The relevant literature, of course, depends on the topic and type of a thesis. In any case, the used and cited literature should be serious/reliable (peer-reviewed articles, journals with (high) impact factors (IF)) and up-to-date. The following list offers a selection of possible contact points for your literature search in the field of (waste)water science. In addition, the list of references (bibliography) of available literature itself also offers a good starting point for literature search. Please note that this list is neither complete nor should it be seen as compulsory.

TUM Library

The TUM University Library offers numerously printed and electronic media (OPAC). It also provides services like an interlibrary loan (“Fernleihe”), online courses and seminars, access to more than 2 600 databases, as well as access to Perinorm, where some of the below-mentioned guidelines and standards can be acquired via eAccess. The access via the TUM University Library also offers to download many textbooks as an electronic version for free.

Online Databases

- Scopus (Elsevier)
- ScienceDirect (Elsevier)
- Web of Science
- Semantic Scholar
- Google Scholar
- Research Gate
- PubMed
- Royal Society of Chemistry

Publishers

- Elsevier
- Springer
- Wiley

Institutional and Non-Governmental Guidelines

- Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfälle e.V. (DWA)
- Deutscher Verein des Gas- und Wasserfaches e.V. - Technisch-wissenschaftlicher Verein (DVGW)
- Deutsches Institut für Normung e.V. (DIN)
- Verein Deutscher Ingenieure (VDI)
- World Health Organization (WHO)
- United Nations (UN)

Governmental Policy (Laws and Ordinances)	• Laws (Germany) • Umweltbundesamt (UBA) • Landesanstalten • EU Directives
Scientific Institutes	• Universities • eawag • Frauenhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. • Helmholtz-Gemeinschaft • Max-Planck-Gesellschaft
Network Platforms	• Research Gate
Webpages	Webpages can be a valuable source of information. However, you should rather avoid quoting them, but if you need to cite a webpage, pay special attention to reliability/authenticity and transience.

Additional hints for your literature research:

- Track the source of every information you will find already from the beginning. This will save you a lot of time and avoids plagiarism.
- Use one of the many citation programs. These programs are very powerful in managing your references and can save you a lot of time and trouble (see following chapter).
- Search queries in literature databases can show a huge number of results. Take advantage of the specifying search options like keyword appearance, keyword position, or the combination of keywords. Most search engines also offer various filters to limit the received hits (e.g., to only show publications published after 2020).

6. Citation

Working scientifically means making your results verifiable. Any content that is not based on your own work/achievements or is basic/elementary knowledge needs to be acknowledged and referenced. The reader of your work should be able to distinguish your work from the work of other authors clearly. Your citation should allow the reader to access/investigate the same sources you found [TUM, 2020b].

The TUM university library offers courses about citation, reference management programs, and many more topics about scientific writing.

Plagiarism

"When you submit your thesis, you must declare in writing form that you have written it yourself and that no sources or aids other than those listed have been used (§18 (9), APSO)" [TUM, 2020b].

"Plagiarism is a serious offence, and may lead to the disqualification of an academic title […]" [TUM, 2020b].

The library of TUM provides a comprehensive TUM Citation Guide. Students should get familiar with that citation guide and adhere to this. Subsequently, we list an overview of some relevant aspects of citation.

6.1 General Citation Rules

Original Source	Always cite the original source. Secondary citations (citations of citations) should only be used if the original source cannot be accessed without unreasonable difficulty [TUM, 2020b].
General Knowledge	Basic knowledge in your research area, content that is available from many sources and which is not new, does not need to be cited (e.g., the laws of fluid dynamics). As sometimes the boundaries are not clear, ask your supervisor if you are not sure about a citation [TUM, 2020b].
Direct Quotation	Direct quotations are set in quotation marks ("") and should be used only when the exact wording is important. Therefore direct quotations are rarely quoted in the literature of natural science [TUM, 2020b]. Check the rules in the TUM Citation Guide on p.13-14 for direct citation.
Indirect Quotation	Paraphrasing is the rephrasing of a statement/findings/ideas of other authors in your own words. Good scientific practice means distinguishing your ideas from those originating from other authors as best as possible.
Introductory Phrases	To highlight a finding/content from authors, you can include the citation in your text, e.g., *According to KROISS (2006) […]*.
Position of In-Text Citation	"A citation within a sentence (before the full stop) refers only to the sentence in which it is mentioned. A citation after the sentence (after the full stop) refers to the entire paragraph" [TUM, 2020b].

6.2 Citation Style at the Chair of Urban Water Systems Engineering

There are many existing citation styles that might differ between disciplines or be preferred by institutes and publishers. There is no mandatory citation style to be used at the Chair of Urban Water Systems Engineering but discuss with your supervisor which citation style is appropriate for your thesis topic.

Overall Objective

The overall objective of citing is to provide all the necessary information to specify the used source so that the reader can identify and search/find the source(s). Therefore you have to declare at least:

- Author(s)
- (Editor)
- Year (Date)
- Title
- (Journal + Volume and Issue)
- Publisher
- Place
- URL + date of access (in case of an online source)

Further details like the type of work, series and volume, responsible organization, page number(s), URL etc., are helpful and should be given if possible/available. Only stating an ISBN or DOI number for citation is not sufficient! Hence, no one can guarantee that those identifying systems might not change in the future or exist forever. However, for simplified access, readers and your supervisors appreciate it if ISBN and DOI numbers or URLs are provided in the bibliography as well. Add DOIs and URLs, if possible, as hyperlinks so that they can be accessed by a click directly.

Subsequently, we give some examples how citations can look like.

6.2.1 In-text Citation

One Author	([Author last name], [Year of publication]) ➔ e.g. (Kroiss, 2006)
Two Authors	([1st Author´s last name] and [2nd Author´s last name], [Year of publication]) ➔ e.g. (Dupnock and Deshusses, 2017)
More than Two Authors	([1st Author´s last name] et al., [Year of publication]) ➔ e.g. (Strübing et al., 2017)
Sets of Regulations	([Regulation name and number], [Year of publication]) ➔ e.g. (DWA A 281, 2003)

6.2.2 Reference List

Journal Articles	[Author last name], [Author first name(s) abbrebiated] [(Year of publication)]. [Title of article]. [Journal title] [Volume], [Page numbers].
	➔ Strübing, D.; Huber, B.; Lebuhn, M.; Drewes, J. E.; Koch, K. (2017). High performance biological methanation in a thermophilic anaerobic trickle bed reactor. Bioresource Technology 245, 1176–1183.
Book	[Author last name], [Author first name(s) abbrebiated] [(Year of publication)]. [Title]. [Place of pub-lication]: [Publisher].
	➔ Metcalf & Eddy, Inc (2003). Wastewater engineering. Treatment and reuse. Boston: McGraw-Hill.
Internet	[Author last name], [Author first name(s) abbrebiated] [(Year of publication or last update)]. [Title of webpage [type of source, e.g., web page, blog post, etc.]]. Retrieved from [URL], updated on [DD.MM.YYY], checked on [DD.MM.YYY].
	➔ Drewes, J. E. (2022). Inline dosing of powdered activated carbon and coagulant prior to ultrafiltration [web page/online]. Retrieved from https://www.bgu.tum.de/en/sww/research/membrane-filtration/pacuf-hybrid-membrane-processes/, checked on 16.02.2022.
Set of Regulations	[name of regulation and number]. [(Year of publication)]. [Title of regulation]: [Publisher].
	➔ VDI 4630. (2016). Fermentation of organic materials - Characterization of the substrate, sampling, collection of material data, fermentation tests: The Association of German Engineers.

The titles are sorted alphabetically by the first author's surname. If there are multiple publications by the same author (or different authors with the same surname), list them alphabetically by the following author(s) or, if they are all the same, chronologically. Publications with the same author(s) and from the same year, should receive an additional notification for allowing to distinguish between in the text, too (e.g. Chen et al. (2020a) and Chen et al. (2020b)).

More information about citation at the TUM you can find in the TUM Citation Guide and on the Citing website of TUM.

6.3 Citation Software

TUM offers free campus licenses for Endnote and Citavi.

There are many more reference management programs such as Mendeley, Zotero, Overleaf, Jabref, and Bibsonomy. The software comparison guide provides an overview.

7. Figures and Tables

Figures, graphs or tables can deliver vast amounts of information, verify your results and emphasize/promote your conclusions. Thus, they should be applied well-considered and carefully. The design of figures and graphs should be comprehensive and self-explaining. However, they should support the written content and should be well integrated into your text.

Data visualization is a topic by itself and can easily fill a separate guideline. This chapter deals with more basic rules of using figures and tables but also provides a few further aspects and tips that students should consider applying or preparing graphics. However, it is impossible to cover every element in these guidelines. Therefore, interested students are urged to research more specific literature on data visualization and statistics.

7.1 Figures

Numbering, Captions and Citation

Number figures throughout your report (e.g., *Figure 1*, *Figure 2*… or *Fig. 1*, *Fig. 2*…) and describe/explain it with a caption below the image (see Figure 1). The caption of a figure should contain all the necessary information to understand the figure's meaning and presented data without the need to consult the main text body. Clear, informative captions catch the reader's attention and support to self-explain the illustration. To create a comprehensive but also concise caption, one can check if it is possible to understand a figure by only looking at the figure and the related caption without consulting the main text. Yet, graphical elements (figures) should be integrated into the written content and be referenced in the text before they are displayed. The location/placement should be right after/close to where they are mentioned for the first time (on the same page or on the next one in case of limited space). Hence, figures are described with a caption below the graphic, do not add an additional title/headline (a separate headline is often preset in the standard format of MS-Excel diagrams). Spell out used abbreviations in the figure in the caption even though they can be found in the main text or in the list of abbreviations.

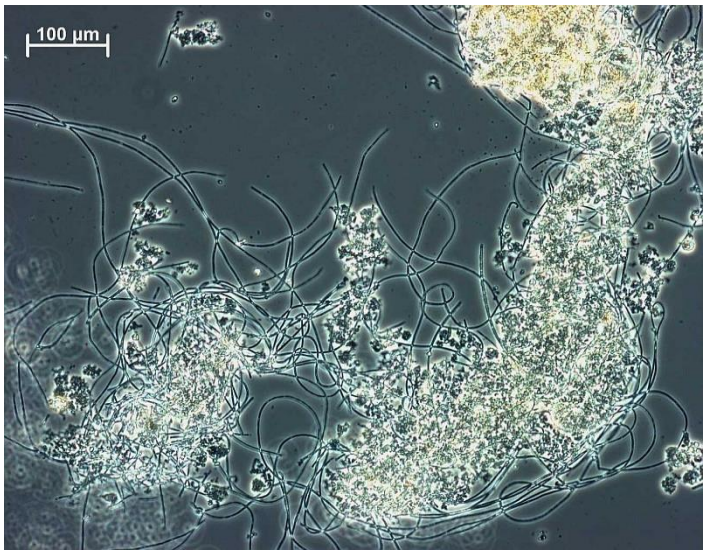

Figure 1: Phase-contrast microscopy image of filamentous bacteria in an activated sludge sample [LfU, n.d.].

Figures, graphs, photographs etc., need to be cited if they originate from someone else. It is necessary to indicate if the original figure was modified (even if the modification is super slightly). Common notations are: *modified from* / *based on* / *inspired by* / *adapted from* / *according to* / *reproduced from.* Own graphics mustnot be cited (e.g., with '*own figure*'), as it is clear that everything that is not cited is from the thesis writer.

Clear and Tidy Diagrams

The purpose of diagrams is to present results and data in a clear and understandable way. Therefore, avoid all effects that are irrelevant, confusing, or draw off the attention of the reader (e.g., 3D, overcoloring or shades etc.). The focus should be set on the information of the figure, graph or table. Make sure that axes are labeled, the units are indicated, and that necessary information is added in the caption. Diagrams, which use different symbols or colors need to have an explaining legend.

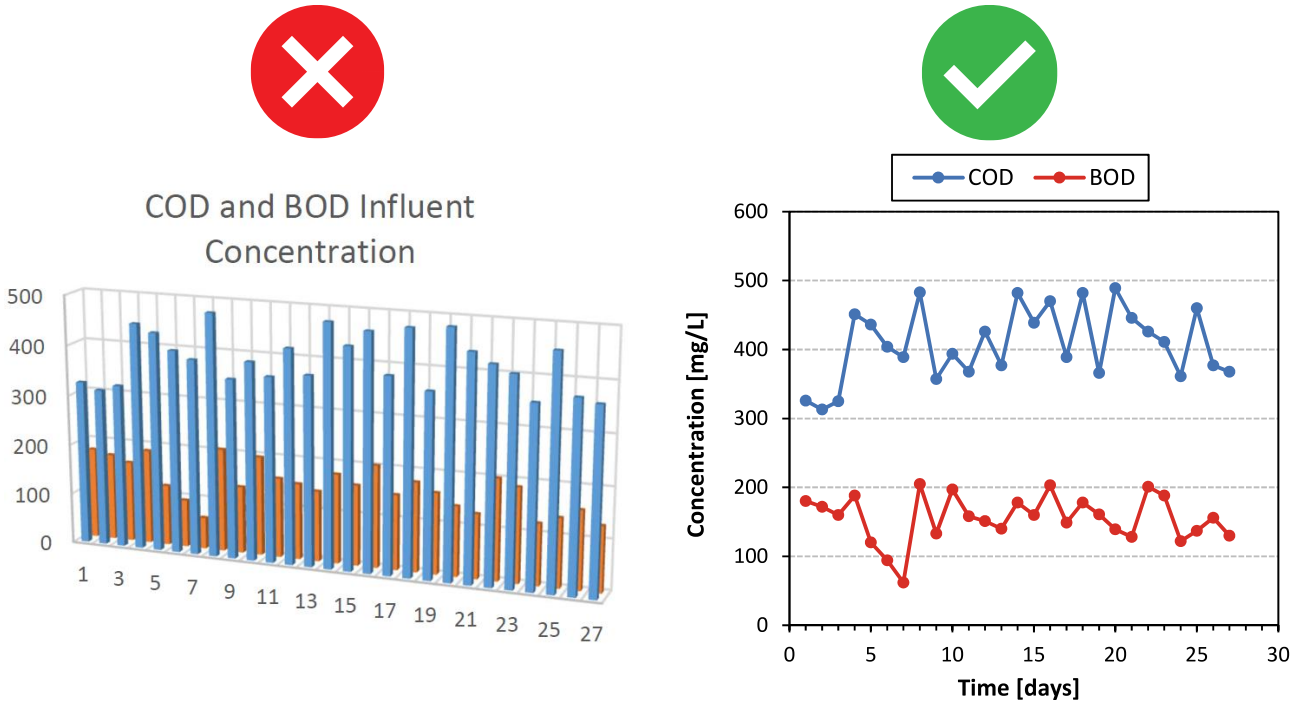

Figure 2: Two examples of showing a time series of data points; left) bad example with a confusing diagram type, unnesessary effects and missing axis labels and legend, right) appropriate depiction with all relevant information.

Presentation, Statistics and Data Manipulation

There are many different types of diagrams to visualize data. The choice of diagram type depends on the underlying data and the main message you want to convey to the reader.

Be critical with your data and do not manipulate or hide data only because they do not fit well to your other results. State and explain all practices of data manipulation (e.g., removed or ignored data). “Outliers” should only be removed from the dataset when they have been clearly identified as such by applying a corresponding statistical test. To eliminate a single outlier from mutiple measurements, the Dixon’s test can be used. An easy-to-use tool to carry out such tests is available at http://contchart.com/outliers.aspx. To assess the quality or how reproducible your results are, include error bars or some indication for variation (e.g., standard deviation) or estimate uncertainties if possible.

Select an appropriate scale to illustrate your findings. You can use a larger scale to cover the full range of data, or you can use a smaller/more zoomed-in scale to emphasize differences, which would not be visible at the full range. However, do not utilize scales to over-emphasize differences/effects or to disguise effects/trends.

Visualization

- Colors can facilitate the differentiation of groups within your data. Nevertheless, colors should be applied carefully/sparingly and only if and where they support the understanding of the presented information. The usage of color also depends on the type of text/publication, e.g., printed versions are generally related to higher costs. If there are just a few different graphs in one figure, such as in Figure 2, ask yourself how a printout in black & white would look like and think about how to improve the readability. Why not using different symbols (filled dots vs. open squares) and line types (full line vs. dashed or dotted line)?
  The selected colors spectrum should contain unique colors, which are easy to distinguish. Colors which are too similar regarding tone and intensity are not helpful for distinction. Another aspect that one should pay attention to is color blindness. A wrong color choice can make it hard or impossible for color-blind people to understand colored graphics correctly. Luckily, there are numerous color-blind-friendly color palettes available or tools to create such. Checkout:
  COLORBREWER 2.0
  Adobe Color
  Chroma Tool

- Do not change the proportions (maintain the original height-length ratio) if you insert or adapt the size of a copied figure.
- When inserting figures and graphs, make sure that the quality and resolution are high. A resolution of at least 100 PPI/DPI is recommended for online publications, and a higher resolution of at least 300 PPI/DPI should be chosen for printed publications.

- The quality of diagrams, drawings, schematics etc., can be improved a lot by inserting the figure as a vector graphic instead of a raster graphic (compare Figure 3 and Figure 4). This helps to maintain sharp and detailed images, even if the image is zoomed. Check out with which formats your office software is compatible and how to insert them. The utilization of vector graphics makes sense if you are preparing your own diagrams, if screenshots of third-party images tend to look blurry or in cases where all details in graphics like, e.g., maps or circuit diagrams, should be pre-served. The difference between vector and raster graphics is briefly explained in this video.
  Tip 1: If you use MS-Excel to prepare diagrams. Do not take a screenshot and insert the image. A better solution is to export the chart as a PDF file, which is a vector graphic. Or copy it and use MS Office Picture Manager to export it to any image type you like.
  Tip 2: Many (not all) online publications come as PDF files with diagrams, drawings, schematics etc., imbedded as vector images. They can be easily extracted by opening the relevant document with vector graphic software like Inkscape (free of charge). See the how-to video and compare Figure 3 and Figure 4. If you have direct access to the publication of interest, you can often directly download a high-resolution image of the figure in the online version (e.g., in publications from Elsevier, simply selected the corresponding figure in the online version of the publication and click on “Download high-res image”).
  Tip 3: If you are using MS Word, the software probably does not accept the import of vector graphics as PDF files (MAC users might have an advantage here). However, there are other vector graphic file types like SVG (recommended) or EMF files which can be created with Inkscape.

Example: comparison of a raster (screenshot; Figure 3) vs. a vector (Figure 4) image of the same graphic. The difference will get even more obvious if you zoom in.

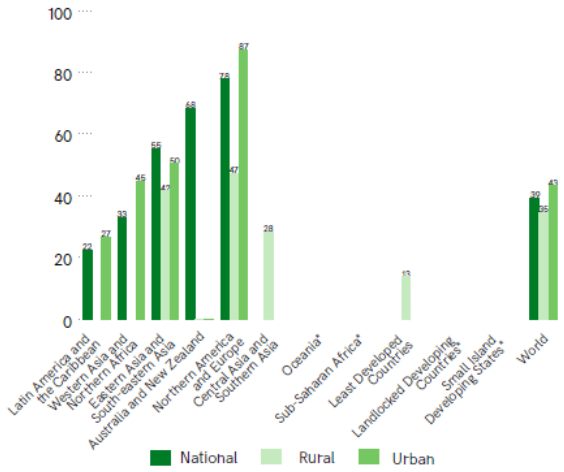

Figure 3: Proportion of population with safely managed sanitation services in 2015 [WHO, 2017].

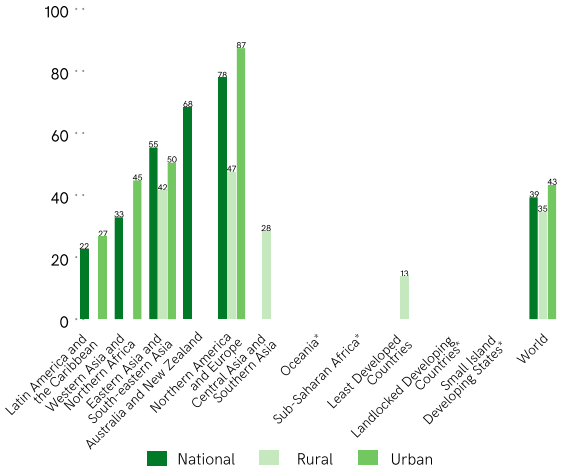

Figure 4: Proportion of population with safely managed sanitation services in 2015 [WHO, 2017].

Example of a circuit diagram with fine structures and many details (see Figure 5d). A raster graphic maintains all those details, and a zoom function (in case of an online view) enables a clearer inspection.

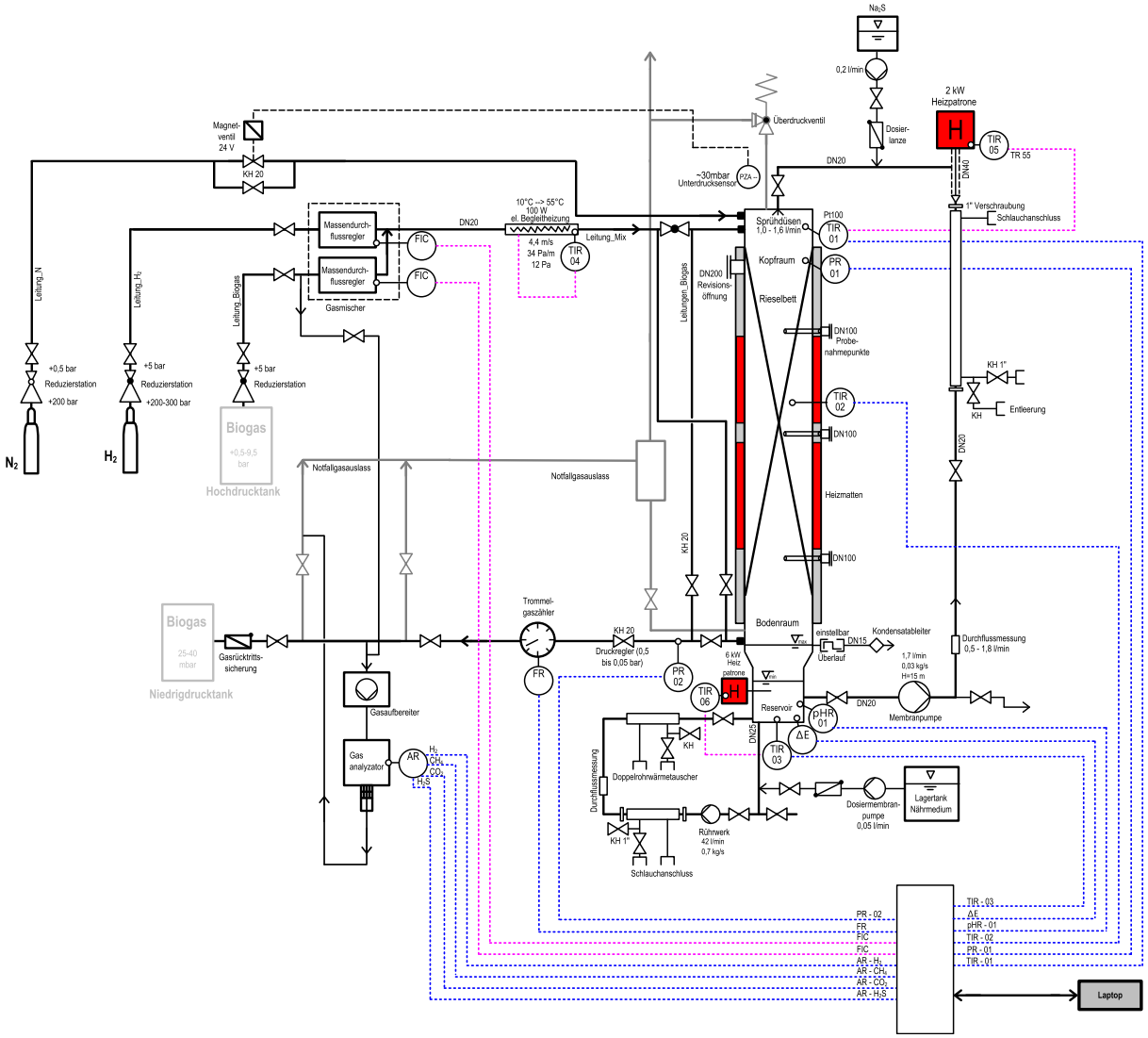

Figure 5: Circuit diagram of the DemoMeth project.

7.2 Tables

On the one hand, tables can be useful to provide small data sets (see Table 1), which might be too small to present them in the form of a diagram. Sometimes, it even does not make sense to present information as a figure (e.g., when few samples are characterized by several parameters). On the other hand, tables are a perfect choice when the author intends to present exact values to the reader. It is also a preferred option for data and information that is hard-to-visualize in the form of graphs or diagrams. This can be the case when information consists of numbers and text or in the case of missing values (see Table 3).

Numbering, Captions and Citation

Tables should be numbered and titled (e.g., *Table 1*, *Table 2*… or *Tab. 1*, *Tab. 2*…) with a headline/description above the table. Focus on clarity, consistency and conciseness for the table's description are the same as for captions of figures (see chapter 7.1). Make sure that there are units for all given values. Units can be given in the headline (e.g., in case all values have the same unit), in the table's header row (e.g., in case units are the same within individual columns) or directly attached to individual values.

The need to cite the source of information presented in a table is obvious.

Table 1: Sewage sludge disposal from public wastewater treatment plants in Germany [Statistisches Bundesamt, 2021] (*translation*).

Year	Total	Material Utilization				Thermal Utilization	Other
		Together	Agricultural	Landscape Construction	Other Material Utilization		
				Dry Mass as 1 000 t			
2019	**1 740.1**	433.7	287.5	58.6	87.6	1 293.2	13.1
2018	**1 747.2**	436.1	280.3	122.6	33.2	1 295.2	15.9
				Ratio as %			
2019	**100**	24.9	16.5	3.4	5.0	74.3	0.8
2018	**100**	25.0	16.0	7.0	1.9	74.1	0.9

Visualization

Good tables are characterized by a reasonable and logical structure, clarity and simplicity. Fancy fonts or colors are often not helpful and disturbing when the table is printed in black and white. If possible, one should apply the same style/layout to all tables in a report.

Do not copy-paste tables from other sources. First, in many cases, your sources use a different style/layout than the one you are using in your report, and, second, tables can easily be reproduced by yourself (see Table 2).

Tabelle 12: Anzahl der Abwasserbehandlungsanlagen in Deutschland und Anschluss an die Kanalisation von 1995 bis 2010; Quelle: Statistisches Bundesamt 2013

	Anzahl der Abwasser-behandlungsanlagen	Anschluss an Kanalisation in %
1995	10.270	92
1998	10.312	93
2001	10.188	95
2004	9.994	96
2007	9.933	96
2010	9.632	97

Screenshot taken from from [Irmer et al., 2013].

Table 2: Number of wastewater treatment plants and the rate of connection to the sewage system from 1995 to 2010 [Satistisches Bundesamt, 2013]. (*translation*)

	Number of Wastewater Treatment Plants	Connection to the sewage system as %
1995	10 273	92
1998	10 312	93
2001	10 188	95
2004	9 994	96
2007	9 933	96
2010	9 632	97

Additional Information/Explanations

Tables showing data with some kind of exception or data that requires additional explanation can be complemented with footnotes under the table. Such an example is given below. Table 3 is written in German but also non-German speakers should understand the idea of utilizing footnotes.

Table 3: Water quality indication for specific substances in surface waters in [µg/L]; grey highlighted values are referred to sediment matrix or biota and are given in [µg/kg] [OGewV. 2016]. (*table in German*)

Stoff	JD-UQN(1) / ZHK-UQN(1) / Biota-UQN *Oberflächengewässer*		Allgemeine Qualitätskomponenten sehr guter(8) ↔ guter ökologischer Zustand(9)
	Ökologischer Zustand	Chemischer Zustand	
Aluminium			
Antimon			
Arsen	40 000(7) / - / -		
Blei		1,2(2) / 14 / -	
Cadmium (je nach Wasserhärteklasse(4); Klasse (K)		K1: ≤ 0,08 / ≤ 0,45 / - K2: 0,08 / 0,45 / - K3: 0,09 / 0,6 / - K4: 0,15 / 0,9 / - K5: 0,25 / 1,5 / -	
Chrom	640 000(7) / - / -		
Chlorid			≤ 50 000 (10) ↔ ≤ 200 000(10)(12)
Eisen			- ↔ (≤ 700 – ≤ 1 800)(10)
Kupfer	160 000(7) / - / -		
Nickel		4(2) / 34 / -	
Quecksilber		- / 0,07 / 20(3)	
Selen	3 / - / -		
Sulfat			≤ 25 000(11) ↔ (≤ 75 000 – ≤ 220 000)(10)(12)
Zink	800 000(7) / - /		

(1) Diese UQN bezieht sich auf die Konzentration der gelösten Phase einer Wasserprobe, die durch Filtration durch ein 0,45 µm Filter oder eine gleichwertige Vorbehandlung gewonnen wird, oder wenn angegeben auf die bioverfügbare Konzentration.
(2) Diese UQN bezieht sich auf bioverfügbare Konzentrationen der Stoffe.
(3) Diese UQN bezieht sich auf die Bezugsmatrix Biota (wenn nicht anders vermerkt auf Fische) und ist in [µg/kg] angegeben.
(4) Abhängig von der Wasserhärte. Einteilung nach Klassen (K): K1: < 40 mg CaCO3/L, K2: ≥ 40 < 50 mg CaCO3/L, K3: ≥ 50 < 100 mg CaCO3/L, K4: ≥ 100 < 200 mg CaCO3/L, K5: ≥ 200 mg CaCO3/L.
(7) Diese UQN bezieht sich auf die Bezugsmatrix Schwebstoff/Sediment und ist in [µg/kg] angegeben.
(8) Allgemeine physikalisch-chemische Qualitätskomponente für Fließgewässer (verschiedene Gewässertypen): Sehr guter ökologischer Zustand bzw. das höchste ökologische Potenzial.
(9) Allgemeine physikalisch-chemische Qualitätskomponente für Fließgewässer (verschiedene Gewässertypen): Guter ökologischer Zustand bzw. gutes ökologisches Potenzial.
(10) Mittelwert als arithmetisches Mittel aus den Jahresmittelwerten von maximal drei aufeinanderfolgenden Kalenderjahren.
(11) 90 Perzentil bezogen auf die Messwerte eines Kalenderjahres
(12) Die Werte für Sulfat und Chlorid gelten ausschließlich dort, wo höhere Sulfat- und Chloridgehalte anthropogen, z. B. durch Einleitungen, bedingt sind

Publication bibliography

Irmer, U.; Huber, D.; Walter, A. (2013). *Wasserwirtschaft in Deutschland – Teil 1: Grundlagen*. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMU).

Kultusministerkonferenz (KMK) (2003). *Common structural guidelines of the Länder for the accreditation of Bachelor's and Master's study courses (online). Retrieved from https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2003/2003_10_10-Accredidation-Bachelors-Masters-study-courses.pdf,* checked on *08.09.2021*.

Nature Education (2014). *English Communication for Scientists. Drafting Your Scientific Paper (online). Retrieved from https://www.nature.com/scitable/ebooks/english-communication-for-scientists-14053993/126083980/,* checked on *07.07.2021*.

OGewV. (2016)*Verordnung zum Schutz der Oberflächengewässer*.

Purdue University (2022a). *Count and Noncount Nouns (with Articles and Adjectives) (online). Retrieved from https://owl.purdue.edu/owl/general_writing/grammar/count_and_noncount_nouns/count_noncount_nouns_with_articles_adjectives.html,* checked on *16.02.2022*.

Purdue University (2022b). *That vs. Which (online). Retrieved from https://owl.purdue.edu/owl/general_writing/grammar/that_vs_which.html,* checked on *16.02.2022*.

Sandberg, B. (2013). *Wisschenschaftlich Arbeiten von Abbildung bis Zitat - Lehr- und Übungsbuch für Bachelor, Master und Promotion*. München: Oldenbourg Wissenschaftsverlag.

Satistisches Bundesamt (2013). *Anzahl der Abwasserbehandlungsanlagen in Deutschland und Anschluss an die Kanalisation von 1995 bis 2010 (online). Retrieved from https://www.destatis.de/DE/Home/_inhalt.html, updated on 16.02.22*.

Statistisches Bundesamt (2021). *Drei Viertel des kommunalen Klärschlamms wurden 2019 verbrannt, ein Viertel stofflich verwertet*. Pressemitteilung Nr. 036 vom 27. Januar 2021 *(online). Retrieved from https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/01/PD21_036_32214.html, updated on 2021,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2014). *The Use of English in Thesis Titles at TUM (online). Retrieved from https://www.tum.de/fileadmin/w00bfo/www/Studium/Dokumente/Pruefungsangelegenheiten/The_Use_of_English_in_Thesis_Titles_at_TUM.pdf, updated on 21.03.14,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2016). *Fachprüfungs- und Studienordnung für den Masterstudiengang Umweltingenieurwesen (Environmental Engineering) an der Technischen Universität München (online). Retrieved from https://www.bgu.tum.de/fileadmin/w00blj/umwelt/2_Studium/2_4_Fachpruefungsordnungen/MScEE_FPSO_20161_lesbar.pdf, updated on 06.2016,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2019). *Fachprüfungs- und Studienordnung für den Bachelorstudiengang Umweltingenieurwesen an der Technischen Universität München (online). Retrieved from ttps://www.bgu.tum.de/fileadmin/w00blj/umwelt/2_Studium/2_4_Fachpruefungsordnungen/BScUI_FPSO20191_lesbar.pdf, updated on 16.02.22,* checked on *09.07.2021*.

Technical University of Munich (TUM) (2020a). *Allgemeine Prüfungs- und Studienordnung für Bachelor- und Masterstudiengänge an der Technischen Universität München, updated on 21.12.22,* checked on *19.02.2022*.

Technical University of Munich (TUM) (2020b). *TUM Citation Guide (online). Retrieved from https://mediatum.ub.tum.de/doc/1236069/1236069.pdf, updated on 20.11.20,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2022a). *Bachelor's Thesis (online). Retrieved from https://www.bgu.tum.de/en/umwelt/studies/bachelor/bsc-thesis/,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2022b). *Guidelines for the Study Project (online). Retrieved from https://www.bgu.tum.de/fileadmin/w00blj/umwelt/6_Downloads/Guidelines_Study_Project.pdf,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2022c). *Tips and Tricks for the final research papers and thesis (online). Retrieved from https://www.tum.de/en/studies/graduation/theses/tips-and-tricks/,* checked on *16.02.2022*.

Technical University of Munich (TUM) (2022d). *Typical Structure of a Master's Thesis (online). Retrieved from https://www.bgu.tum.de/msm/lehre/theses/structure/,* checked on *16.02.2022*.