

CLARA Simplified Planning Tool v1.6

User Manual

The screenshot shows the Microsoft Excel interface for the CLARA SPT v1.5 Ethiopia spreadsheet. The window title is "Microsoft Excel - CLARA_SPT_V1.5_Ethiopia.xlsm". The spreadsheet is titled "Project Information" and contains the following fields:

- Project Title: Project title
- Period of Consideration [Years]: 50
- Net Interest Rate [%]: 3
- Expected Annual Growth [%]: 0.5
- Justification/Source: Add argumentation here
- Change in cost since release 2013 [%]: 5
- Alternative Labels/Names: Alternative #1, Alternative #2, Alternative #3, Alternative #4
- Technology Documentation Folder:
- Online Documentation Folder: <http://clara.boku.ac.at/images/spt/>

On the right side of the spreadsheet, the text "CLARA SPT v1.5 Ethiopia" is written vertically. The spreadsheet interface includes a ribbon with "Save", "Save As...", "Remove Toolbars", "Restore Toolbars", and "SPT Manager" buttons. The status bar at the bottom shows "Bereit" and a zoom level of 90%.

Günter Langergraber, BOKU University, Vienna, Austria
Atekelt Abebe Ketema, BOKU University, Vienna, Austria
Rafael Casielles Restoy, BIOAZUL S.L., Malaga, Spain
Markus Lechner, EcoSan Club Consulting OG, Weitra, Austria



Funded within the
EU 7th Framework Programme

© CLARA 2015



DISCLAIMER

This document presents the user manual for the CLARA Simplified Planning Tool (SPT). The user manual was prepared for version 1.6 of the CLARA SPT.

Version 1.6 of the CLARA SPT includes:

- The SPT file itself
- The user manual
- Descriptions of the implemented technologies

All these files can be downloaded as a single zip file.

CLARA SPT is implemented in Microsoft Excel®; MS Excel® 2010 is required for running the CLARA SPT.

This document is not aimed to provide a guide on the planning process of water supply and sanitation systems; it just describes the use of the CLARA SPT.

For the calculation cost in Euro the CLARA SPT uses the following conversion rates:

- Ethiopia: 1 EUR= 23.50 ETB
- Kenya: 1 EUR= 108.50 KES
- Burkina Faso: 1 EUR= 655.96 XOF
- South Africa: 1 EUR= 11.80 ZAR
- Morocco: Costs have been provided in Euro

Compared to version 1.5 (released in February 2014), in version 1.6 of the CLARA SPT cost functions of the following technologies have been updated based on the work of Ketema and Langergraber (2015a,b):

- 1.2 Borehole
- 2.3 Disinfection
- 3.1 Surface water tank
- 3.3 Water pumping station
- 5.1 Cesspit
- 5.2 Collection of (faecal) sludge from cesspits
- 5.2a Collection of primary sludge from septic tanks
- 5.3 Sanitary Sewer
- 5.4 Sewage pumping station
- 5.8 Collection of urine
- 5.9 Collection of faeces
- 6.1 Septic tank

- 6.3 Screen
- 6.11 Struvite production
- 6.14 UASB

References:

Ketema, A.A., Langergraber, G. (2015a): Sensitivity of results from the CLARA Simplified Planning Tool for different input parameters. *Water Sci Technol* 71(2), 234-244, doi: 10.2166/wst.014.497.

Ketema, A.A., Langergraber, G. (2015b): Three supplementary methods for sensitivity analysis of water supply system's life cycle cost using the CLARA Simplified Planning Tool. *Journal of Water Supply: Research and Technology - AQUA*, in press, doi: 10.2166/aqua.2015.126.

ACKNOWLEDGEMENTS

The CLARA SPT was developed and tested within the project CLARA (Capacity-Linked water supply and sanitation improvement for Africa's peri-urban and Rural Areas; Contract # 265676; duration: 1.3.2011 – 28.2.2014, <http://clara.boku.ac.at/>), a Collaborative Project funded within the EU 7th Framework Programme, Theme "Environment (including Climate Change)". The CLARA team is grateful for the support.



TABLE OF CONTENTS

DISCLAIMER.....	2
ACKNOWLEDGEMENTS	3
TABLE OF CONTENTS	4
DEFINITIONS	6
1. INTRODUCTION	8
1.1. BACKGROUND.....	8
1.2. PURPOSE	8
1.3. INNOVATION	8
1.4. THE CLARA SIMPLIFIED PLANNING TOOL IN THE PLANNING PROCESS	9
2. USING THE CLARA SPT	11
2.1. SYSTEM REQUIREMENT	11
2.2. OPENING THE SPT FILE	11
2.3. DOCUMENTATION FILES	12
2.4. STARTING A NEW PROJECT	13
2.5. IMPLEMENTING THE PROJECT INTO THE SPT	13
3. FUNCTIONAL GROUPS AND TECHNOLOGIES	21
4. EXAMPLE	23
5. SUMMARY AND OUTLOOK	27
APPENDIX 1 - DETAILED TECHNOLOGY DESCRIPTIONS	28
1.1 EXTRACTION FROM SPRING.....	29
1.2 GROUNDWATER EXTRACTION (BOREHOLE)	29
1.3 RIVERWATER EXTRACTION	30
2.1 SURFACE WATER TREATMENT	32
2.2 FLOCCULATION AND SEDIMENTATION	33
2.3 CHLORINATION.....	34
3.1 SURFACE WATER TANK (CONCRETE).....	35
3.2 ELEVATED WATER TANK (STEEL).....	35
3.3 WATER PUMPING STATION (CENTRIFUGAL PUMP).....	36
3.4 WATER TRANSPORT MAIN.....	37
3.5 WATER DISTRIBUTION NETWORK.....	38
3.6 HOUSE CONNECTIONS (SUPPLY)	39
5.1 CESSPIT	41
5.2 COLLECTION OF (FAECAL) SLUDGE	41
5.3 SANITARY SEWER.....	43
5.4 SEWAGE PUMPING STATION	44
5.5 HOUSE CONNECTION (SEWER)	45
5.6 UDDT CHAMBER (LARGER URINE STORAGE TANK)	46
5.7 COMPOSTING CHAMBER TOILET	47
5.8 COLLECTION OF URINE	47
5.9 COLLECTION OF FAECES	49
5.10 COLLECTION OF SOLID BIOWASTE.....	50
6.1 SEPTIC TANK.....	52
6.2 IMHOFF TANK	52

6.3 SCREEN.....	53
6.4 BUFFER TANK	54
6.5 SEQUENCING BATCH REACTOR (SBR)	55
6.6 ANAEROBIC BAFFLED REACTOR (ABR)	56
6.7 HORIZONTAL FLOW (HF) CW	57
6.8 VERTICAL FLOW (VF) CW	58
6.9 SLUDGE DRYING REED BED	59
6.10 URINE STORAGE.....	60
6.11 URINE TREATMENT - STRUVITE PRODUCTION	60
6.12 COMPOSTING	61
6.13 WASTE STABILISATION POND.....	63
6.14 UPFLOW ANAEROBIC SLUDGE BLANKET (UASB) REACTOR.....	64
6.15 PHOSPHORUS-PRECIPIATION.....	65
6.16 MECHANICAL SLUDGE DEWATERING (BELT FILTER PRESS).....	65
6.17 SLUDGE THICKENER.....	66
7.1 STRUVITE USE.....	68
7.2 COMPOST USE	68
7.3 IRRIGATION WATER	68
7.4 URINE USE	69

APPENDIX 2 - TECHNOLOGY COMBINATIONS FOR WASTE COLLECTION AND TREATMENT FUNCTIONAL GROUPS..... 70

EXPLANATION ON HOW TO USE.....	70
DRY SANITATION ALTERNATIVES	71
A) WITH UDDTs	71
B) WITH COMPOSTING TOILET.....	72
WATER-BORNE SANITATION ALTERNATIVES	73
C) CESSPITS FOR BLACKWATER, FAECAL SLUDGE TREATED WITH SLUDGE DRYING REED BED AND TREATMENT OF GREYWATER WITH HF CWs.....	73
D) SEWER.....	74
E) WASTEWATER TREATMENT WITH SBR (WITHOUT P-ELIMINATION) AND SLUDGE TREATMENT.....	75
F) WASTEWATER TREATMENT WITH SBR WITH P-ELIMINATION AND SLUDGE TREATMENT	77
G) WASTEWATER TREATMENT WITH WSP AND HF CW FOR C ELIMINATION	78
H) WASTEWATER TREATMENT WITH VF CW FOR NITRIFICATION	79

DEFINITIONS

CLARA Simplified Planning Tool (SPT)

Software tool which allows the comparison of different water and sanitation systems based on their net present value. Simplified means that the software tool is based on numbers of simplifying assumptions, which allow the planner to use the SPT with the limited amount of data available at the pre-planning stage of a project. Due to the resulting error the water and sanitation systems which will be compared using the SPT have to be fundamentally different, as minor differences will not result in a significantly different NPV.

Technology

Technology for the purpose of the CLARA simplified planning tool means civil infrastructures, machinery, devices and operations used in water supply and sanitation systems.

Process

A systematic series of operations that are performed in order to achieve a pre-defined functionality, e.g. pathogen removal, BOD₅ reduction up to a certain standard value and etc.

Functional group

A Functional group is a group of technologies which perform a similar function in the water supply and sanitation system. For the CLARA SPT we use the functional groups as defined in the Sustainable Sanitation and Water Management (SSWM; <http://www.sswm.info>) toolbox. These are:

- Water Source
- Water Purification
- Water Distribution
- Waste Collection
- Waste Treatment
- Water Reuse

System

A set of technologies and/or processes working together as parts of an interconnecting network; a complex whole.

Planner

User of the SPT; with limited access of the SPT only to fill the input data.

Developer

IT and WatSan specialists developing the SPT; with unlimited access to structure and content of the SPT.

Authority

The legal entity which authorizes or requests the use of the tool. Typically the entity which issues permits and/or provides subsidies (local, regional, and central authorities, donors, etc.).

The Authority is responsible for defining “technology screening criteria” (beyond legal requirements) and the updating of cost functions.

Client

The legal entity responsible for water supply and/or sanitation planning in the target area. The client represents the population in the target area. Typically a municipal council, association, institution.

Responsible for defining client specific technologies by setting screening criterion (within the limitations defined by laws and the Authority). The client might adopt multi criteria decision support approach to screen feasible technologies.

Criterion

A standard by which something may be judged or decided.

Technology Screening Criterion

A criterion which a technology has to fulfil in order to be used in the SPT.

Net present value (NPV)

NPV of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows of the same entity. NPV is a central tool in discounted cash flow analysis and is a standard method for using the time value of money to appraise long-term projects.

Each cash inflow/outflow is discounted back to its present value (PV). Then they are summed. The net present value NPV is calculated by:

$$NPV(i, N) = \sum_{t=0}^N \frac{R_t}{(1+i)^t}$$

where

t.... the time of the cash flow

N... the total number of periods

i.... the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.); the opportunity cost of capital

R_t.. the net cash flow, i.e. cash inflow – cash outflow, at time t

Discount rate

The rate used to discount future cash flows to the present value. One approach to choosing the discount rate factor is to decide the rate which the capital needed for the project could return if invested in an alternative venture. The discount rate used to evaluate a project should reflect:

1. The cost of the capital (investors', shareholders' or lender's return on investment)
2. The risk of the project (the benefit of money received now is certain whereas the benefit of money received next year is uncertain. There is, therefore, a risk with any investment and that risk tends to grow with time.).
3. The opportunity cost of that capital (money received now can be 'put to work' to earn a return so that, in a year's time it will have accumulated in value.).

1. INTRODUCTION

1.1. Background

Systemic decisions in water supply and sanitation usually have a long term impact due to the lifespan of the related investments. If therefore investments in one particular water supply and sanitation system (or a combination thereof) have been made it is unlikely that this decision is revoked for a long term, at least the lifespan of the investment. For this reason it makes sense to thoroughly analyse different water supply and sanitation systems at a very early stage of the planning process for water and sanitation infrastructure and select the most appropriate system for future investments. Obviously such a systemic comparison requires the planners to consider a planning area of sufficient size and/or clearly defined interface conditions at the borders of the planning area. Frequently – in particular for sanitation investments mostly due to lack of sufficient funds – planning approaches limit themselves to consider relatively small planning areas, say parts of a town or village, which neglects that certain systems may require a minimum size to become effective and efficient. Or systemic decisions, e.g. centralised or decentralised, water borne or dry, etc., are already decided before the planning process starts and set as a pre-condition for this very planning process. In all cases alternative systems or system combinations may be overlooked which might be more appropriate for a given situation.

1.2. Purpose

Purpose of this simplified planning tool is therefore to avail planners a software tool which not only allows but even encourages the comparison of fundamentally different water and sanitation systems at a very early planning stage, requiring a limited amount of effort from the side of the planner, respectively creating minimal cost for the client. The tool shall, for given framework conditions, identify the most appropriate water and sanitation system, appropriate being defined as legally compliant, fulfilling clients' requirements and having the lowest NPV. This means that the identified solution fulfils all pre-defined criteria in the most cost effective way.

1.3. Innovation

Contrary to other planning approaches the SPT does not value soft criteria but uses such and other criteria as thresholds which every water supply and sanitation technology has to fulfil. Technologies that do not fulfil these thresholds will not be accepted for use in the SPT. As soon as a particular technology has passed one particular criterion (e.g. legal requirements) this very criterion is not used any more for further comparison. If, for example, effluent standards in a country limit the concentration of ammonia to a certain value, all technologies which cannot achieve this value will be discarded while all technologies which can achieve this value will pass as being equal with respect to this criterion. This will increase objectivity by preventing planners or other stakeholders in the planning process to describe one technology as better than another based on personal opinion and not objective criteria. One technology might even be better in one particular field compared to another but if both pass the criteria this difference does not matter.

Furthermore the use of a software tool with limited access for the planner will guarantee objectivity in the sense that different planners will arrive at the same result using the same input parameters. However deviations from the SPT's in-built assumptions are possible but only if clearly justified to guarantee transparency of the entire pre-planning process.

1.4. The CLARA Simplified Planning Tool in the Planning Process

Figure 1 shows the position of the SPT in the planning process. Following project identification and definition it is the immediate next step to help decision making on a systemic level. It is separated into two parts, the first (“Developer”) resulting in the pre-selection of technologies and processes which will then be used in the second part. This first part does not necessarily have to be repeated for different projects for a comparable region, e.g. for one specific country with similar framework conditions.

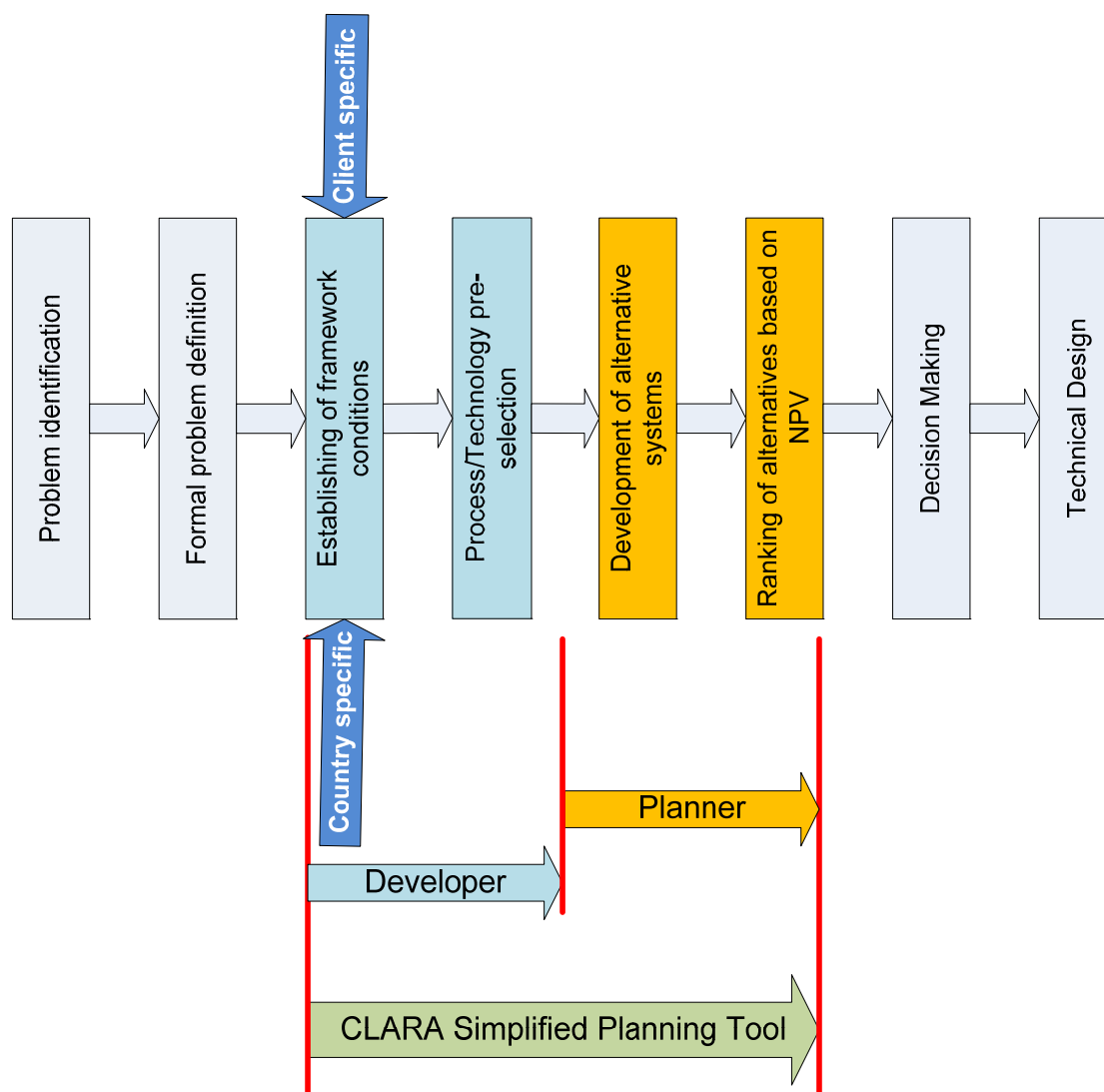


Figure 1: The CLARA Simplified Planning Tool in the pre-planning process

The SPT cannot be used for comparison of technologies in the preliminary and detailed technical design of water supply and sanitation infrastructure. However, obviously, the underlying principles are certainly applicable also at this point in the planning process but require far more detailed and accurate data and information as will be available at the pre-planning stage for which the SPT has been developed.

The Developer's Role

1 Technology Screening

The first step is the decision regarding the technologies which will be used in the water and sanitation systems. Technology screening criteria are used to identify suitable technologies for given framework conditions. These criteria are derived from

- a. country-specific laws, regulations, standards and climatic condition
- b. client requirements (as long as they do not contradict a.)

All technologies which pass all these criteria will be eligible for inclusion in a water and sanitation system. As these criteria are “yes/no criteria”, there will be no further differentiation among technologies based on these criteria – either a criterion is passed or not.

2 Cost functions

The calculation of the NPV in the next steps requires information on cost for investment, lifespan and operation and maintenance for all technologies which have passed the screening step. The most appropriate procedure is to derive this information from technologies already in operation in the country/region since a number of years. However, since the SPT includes a number of innovative technologies which might not happen in the region before. Therefore preparation of detailed technical design documents, country specific Bills of Quantities for each technology has been employed to derive cost functions. The cost functions have been derived with a maximum of 4 critical (cost relevant) input parameters.

The Planner's role

1 Combining Technologies to Systems

A professional planner will combine technologies which are available in the SPT to sensible water supply and sanitation systems. Since this will take place at a very early stage in the planning process the objective is to identify the most appropriate system / system combination for a given problem situation. Therefore the system chosen shall be fundamentally different, e.g. comparing centralised with decentralised systems, water borne with dry systems, etc. The planning tool is not designed to compare different types of technologies e.g. wastewater treatment technologies rather to compare alternative systems designs, which are a set of sequential technologies for defined functionality. These systems have then to be entered into the SPT. Examples for technology combinations are given in Appendix 2.

2 Modifying assumptions

The SPT as mentioned above is based on a number of assumptions; in particular the method for the development of the cost functions is not perfectly accurate. For this reason it is possible for the planner to modify these cost assumptions when using the SPT. However for the sake of objectivity these modifications should have to be justified, otherwise they will not take effect (see also chapter 2.5).

2. USING THE CLARA SPT

2.1. System requirement

The CLARA SPT is implemented in Microsoft Excel® which facilitates its widespread distribution. As long as no technologies are selected in the SPT Excel file, its size is about 8 MB (about 5 MB as zip-file). The SPT was developed with MS Excel® 2010 and should work properly with any later version. Mac OS Excel distributions were not tested yet, thus there is no guarantee for successful operation on this platform.

2.2. Opening the SPT file

The CLARA SPT is basically a “Macro-Enabled Excel Workbook”. As a domain specific language, Microsoft Visual Basic for Application (VBA) Macros can contain a certain security risk and it is necessary to explicitly permit their execution. MS Excel® therefore shows a warning message after opening the CLARA SPT (Figure 2).

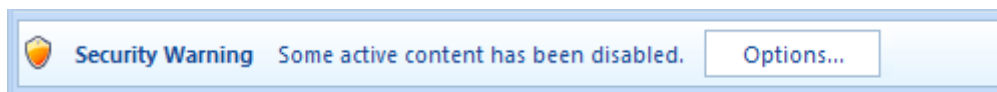


Figure 2: Click on “Options” to enable the macros of the CLARA SPT.

Depending on the system configuration, macros may be disabled by default. In that case, the user has to enable this content directly after opening the Clara SPT.

Since the CLARA SPT depends on VBA (Visual Basic for Applications), a programming language included in MS Office, it is mandatory to enable this content.

To do that, click on the "Options" button next to the warning message (Figure 2). A window dialog opens, providing the option to enable macro's and ActiveX elements (Figure 3). One must select “Enable this content” and confirm this choice with the OK button.

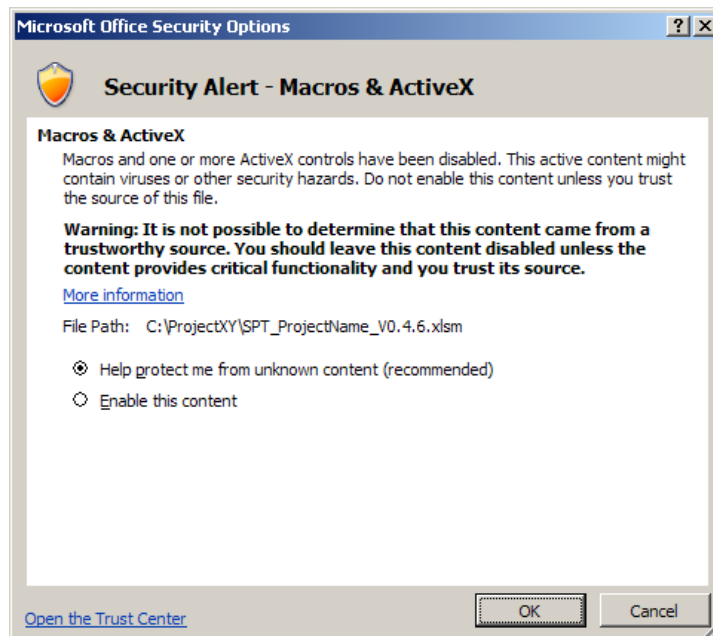


Figure 3: Window showing up after clicking on the "Options" button next in Figure 2. To work with the CLARA SPT, one must select “Enable this content” and confirm this choice with the OK button.

If you want to avoid this step, it is possible to permanently configure Excel® to enable VBA macros. Note that this is only advisable if you work with Excel documents from trustworthy sources only. Follow the steps below in order to configure Excel 2010 (Microsoft, 2012):

1. Click the 'Office Button'
2. Click 'Excel Options' at the bottom
3. Click the 'Trust Center' tab
4. Click 'Trust Center Settings'
5. Click the 'Macro Settings' tab in the new window
6. Click the 'Enable all Macros' button
7. Confirm your choice by clicking OK

2.3. Documentation files

For each technology implemented in the CLARA SPT a "*Technology descriptions*" is provided. The technology descriptions include the assumptions made to develop the costs functions and include:

- A short description of the technology
- Design assumptions
- Input data
- Validity range of cost function
- Assumed lifespan
- Assumptions for O&M costs

The technology descriptions are found in Annex 1 of this document but are also provided on the CLARA website as well as separate pdf-files with the CLARA SPT.

To access the files from the SPT user interface they need to be copied in a user specific folder (Figure 5; the files have been saved in the directory "D:\CLARA\Technologies". The folder name also needs to be selected in the "Project Information" sheet (Figure 5)

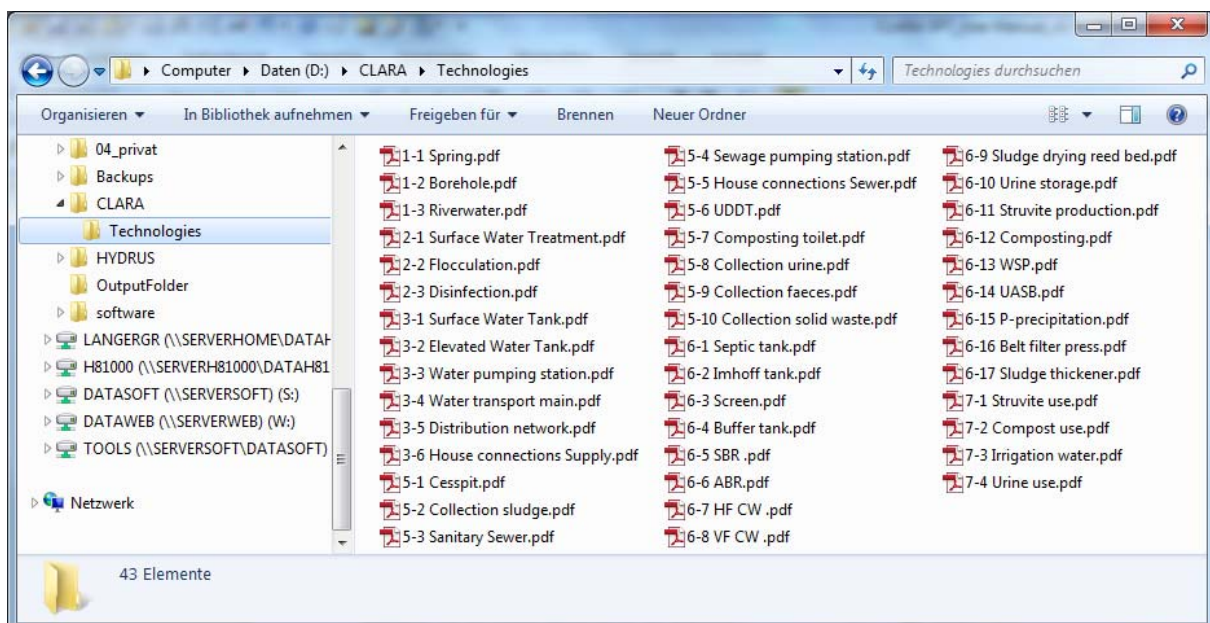


Figure 4: Technology description files.



Figure 5: Selection of folder in which technology descriptions are located: 1. Select "Technology Documentation Folder" and 2. Select folder name by pressing the folder symbol or enter folder name manually.

2.4. Starting a new project

To start a new project, copy a plain SPT-Excel® file to a folder of your choice. It is also possible to open a plain SPT file and save it to a new location and/or under a different filename. To do so, use the "Save As" button located at the top row of the "Project Information" sheet (Figure 6). Subsequent savings of the document can be performed by clicking on "Save" button. Opening the SPT file removes the toolbars of MS Excel® are removed. By clicking the "Restore Toolbars" button the toolbars are restored.

Figure 6: "Project Information" sheet.

2.5. Implementing the project into the SPT

For comparing different system designs data need to be inserted into the different Excel sheets of the SPT (Figure 6). The first sheet, "Project Information", comprises general information of the project. There is one Excel sheet for each alternative system design to be compared. The

tool is limited to four "Alternative" Sheets, named A1, A2, A3 and A4, respectively, are the ones to actually puzzle together as different alternatives. The "Results" sheet illustrates the one time and recurrent costs and benefits of the different alternatives for a defined period of consideration after all the required input information have been supplied.

"Project Information" Sheet

The "Project Information" sheet (Figure 6) contains following input fields related to general information of the water and sanitation infrastructure project:

- **Project Title:** one or a few words describing the project
- **Period of Consideration [Years]:** The number of years for which the comparison of costs is calculated (e.g. 50 years). For this period the SPT calculates the future reinvestment, the operation and maintenance costs as well as the residual value of infrastructure at the end of this period. Since future reinvestments and the corresponding residual values have a discontinuous behaviour over time, one must be aware of the importance of a well-chosen and justifiable period of consideration.
- **Net Interest Rate [%]:** Difference between interest rate and inflation. The user must choose justifiable value of the Net Interest Rate, since the value considerably affects the NPV of reinvestment and other recurrent costs and benefits.
- **Expected Annual Growth [%]:** Population growth in the planning region. Population growth is considered for adjustment of reinvesting costs after the lifetime of a technology. Such value does not influence the initial investment cost of the technology.
- **Justification/Source:** Justifications and resources for the assumptions taken shall be included in this box.
- **Change in cost since release in 2013 [%]:** The costs functions have been developed based on units prices collected in 2013. For considering price increments, the planner can provide information on price changes ("price index") occurred since this date. A planner may obtain information on building cost indexes from local statistical offices or he or she can use industry knowledge.
- **Alternative Labels/Names:** To differentiate and label the different system designs (alternatives) the planner should choose meaningful, short and precise names. An alternative name can already give some superficial information about the system. If there is explicitly no name defined for an alternative, the SPT uses the corresponding labels "Alternative 1" to "Alternative 4".
- **Technology documentation folder:** Folder of your PC where the technology descriptions are stored.
- **Online documentation folder:** Link to general technology information provided at the SSWM toolbox.

Sheets for each system alternative: "A1", "A2", "A3" and "A4"

How to select functional groups and technologies

The planner has to select the functional groups which will be part of the systems he or she wants to compare. On top of each "Alternative" Sheet, the tool shows the 6 functional groups in the form of buttons which can be clicked. Each functional group button is linked to a box including field areas for the different technologies (Figure 7). These **functional group boxes**

can be selected by clicking on the buttons which are at the top of the sheet, or by scrolling down the Alternative Sheet until the functional group is reached.

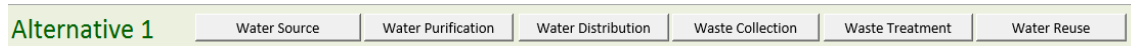


Figure 7: Functional group buttons direct you to functional group boxes

Once a functional group has been selected, it is necessary to select the technologies which will be part of it. Each functional group gives the opportunity to select up to 10 different technologies. On the "Alternative" Sheets, within each functional group box, 10 **technology form areas** are available containing specific **technology form fields** and descriptive text asking for the required input data (Figure 8).

Figure 8: Top of a functional group box comprising 10 technology form areas

Each technology form area contains a combo box field to select a certain technology (Figure 9). There is no limit of how often one technology is part of a functional group. Below the top edge of a functional group box, buttons are available to hide or unhide all or specific technology form areas (i.e. T1, T2, etc.). The user can hide or unhide these fields by clicking the buttons at the top of a functional group box.

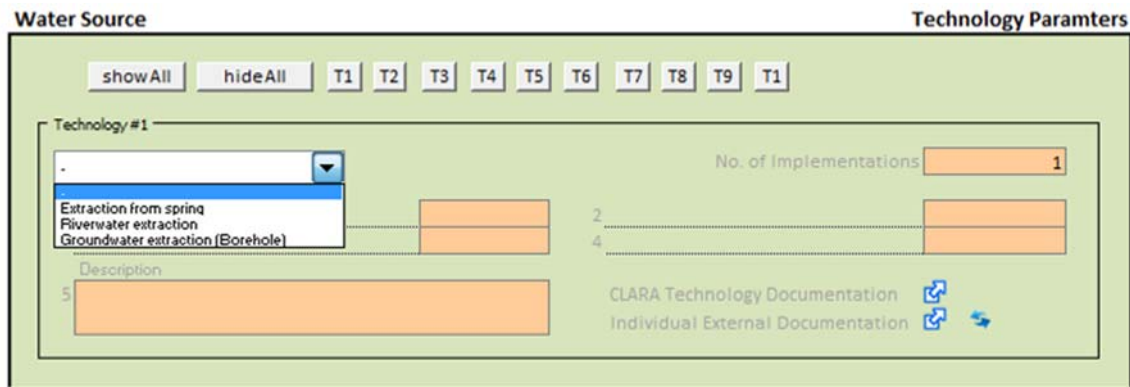


Figure 9: Combo box field used to select a technology within a functional group.

How to insert input data

After the selection of the technologies, the planner needs to input the data required for the selected technologies. In Appendix 1 all implemented technologies are described including the required input data and main design assumptions. Figure 10 shows as an example the input data required for the technology "SBR" in the functional group "Waste treatment". These are the size of the treatment plant in terms of PE and the treatment level. If a technology with the same design size is used more than once in the system this can be easily considered by entering the number of implementations in the upper left corner (Figure 10). In the "Description" field the planner can include site specific descriptions (e.g. "SBR plant for village A").

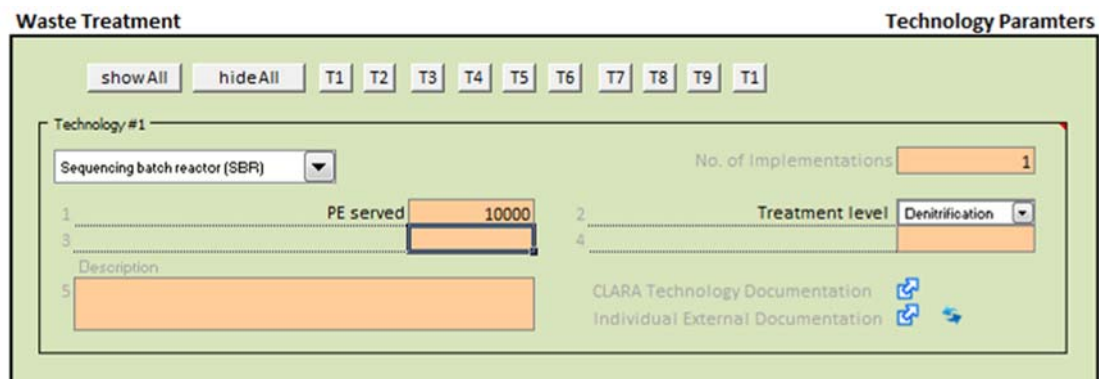


Figure 10: Example of input parameters required for a technology.

When moving the cursor to the upper left corner of the technology input field shown in Figure 10 the user gets information on the validity of the cost function for this specific technology. For the SBR the costs function is valid in the range of 50 to 50'000 PE (Figure 11).

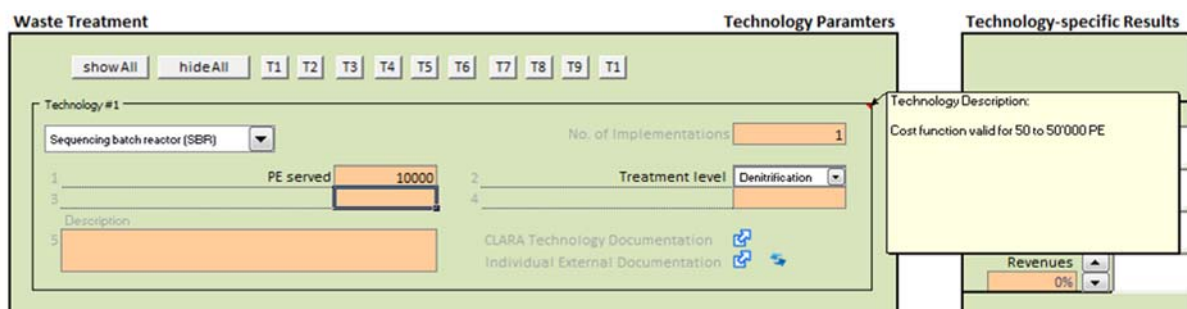


Figure 11: Example of information on validity of cost functions.

As previously described, the top row of each "Alternative" sheet contains buttons to jump from any vertical location on the sheet to the beginning of a certain functional group. A red

background of this row (see Figure 12) indicates that at least one of the technologies of the alternative fails to calculate, i.e. the field(s) of a selected technology has/have not been fully completed and some data is missing. If the background is green no errors occur during the calculation of the alternative.

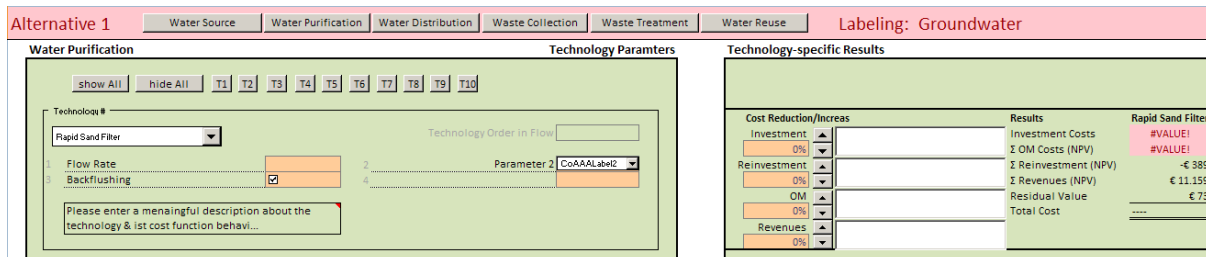


Figure 12: Example in which required input data are not complete and therefore no cost calculation can be carried out.

Technologies are the basic elements of which any functional group is formed. It is possible that a single technology delivers the whole functionality for a functional group, but quite often the target of the water supply or sanitation system will be met through the combination of several different technologies. Additionally, the user of the SPT is responsible for considering all water and mass flows for the design alternatives. Appendix 2 shows examples of combinations of technologies to meet specific requirements in the functional groups Waste collection and Waste treatment with a specific focus on showing interrelations between input parameters of different technologies combined to a system.

Technology-specific results

The technology-specific results (i.e. the Net Present Values related to each individual technology) directly next to the technology form area in a separate box on the right of the "Alternative" Sheets. Figure 13 shows the technology-specific results for a water pumping station.

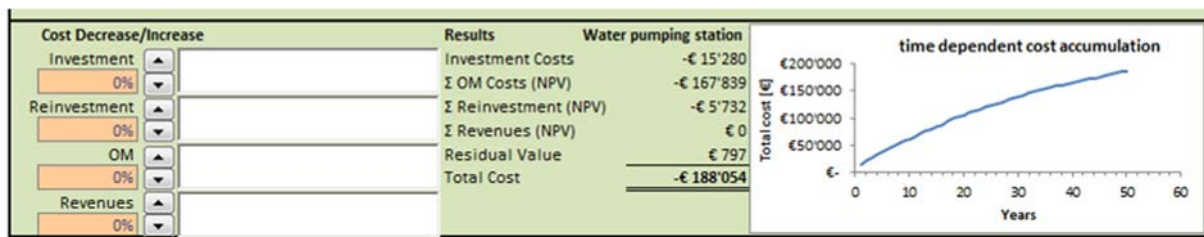


Figure 13: Technology-specific results displayed in the "Alternative" Sheets for each technology

The results of each technology-specific analysis are related to:

- Investment Costs: The initial construction costs of an infrastructure. The CLARA SPT does not consider costs of land
- O&M Costs: Discounted and accumulated annual costs for operating, maintaining and managing the technology
- Reinvestments: Recurrent costs for the renewal of system components, discounted and accumulated over the whole period of consideration
- Revenues: Discounted and accumulated annual net benefits
- Residual Value: The assumption in the CLARA SPT is that it is possible to re-alienate reinvestments since they are modular system components like pumps, filters, etc. If the period of consideration is close to a multiple of the lifetime of a substantial reinvestment,

the neglect of the residual value could lead to an inappropriate preference or discrimination of a technology or system

- Total Cost: The sum of investment, operation and maintenance and reinvestment present costs minus discounted revenues and the residual value.
- Graph of the temporal economic behaviour: In the graph total costs are shown as positive values.

The technology-specific results box also provides the option for the user to modify the costs (in the left part of this box, below the heading "Cost Decrease/Increase" in Figure 13). In particular, it is possible to increase and decrease the result of each cost function by a certain percentage but at the same time it is mandatory to provide an explanation for these changes. If a planner does not provide an explanation, the changes to the cost function results have no influence and a red field indicates that information is missing (Figure 14).

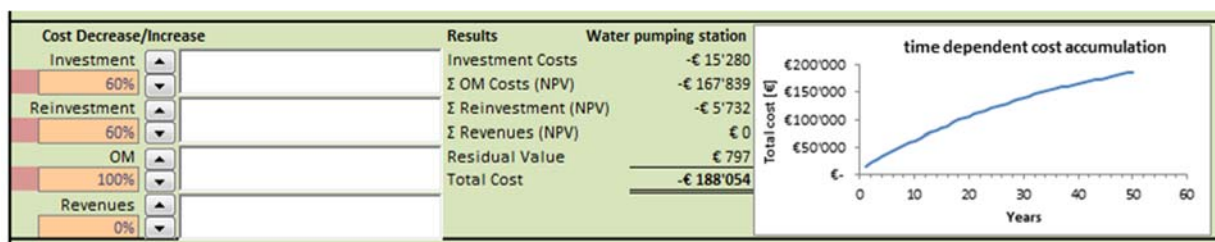


Figure 14: Example in which explanations for modification of costs are not provided.

Example: Use of diesel generators for electricity cuts

The following example shows how to modify the technology-specific results for the case of water pumping stations. For example a pump for a daily flow of 1000 m³ for a pressure head of 100 m is considered (resulting in a required power of ca. 23 kW).

The SPT considers that a pumping station is fully operated with electric power, but in most of developing countries the availability of electric power at 24-7 is uncertain. Therefore a standby diesel generator is commonly installed as a part of pumping station to substitute the conventional electric power source during off time.

Table 1 shows as an example how to calculate the additional investment and annual O&M costs when a diesel generator is used. The data used for this example are from Ethiopia. Figure 15 shows the example with modified costs in the case that the diesel generator is used for an average of 2 hours per day. According to Table 1 the investment and re-investment costs have to be increased by 60% and the O&M costs by 100%.

Table 1: Cost increase by using diesel generator for water pumping station (Assumptions: 1) fuel costs: 0.66 EUR/L and 2) Electrical power: 0.025 EUR/kWh)

Power (kW)	Without diesel generator			With diesel generator				
	Daily working hours (h)	Investment costs (EUR)	Annual O&M costs (EUR)	Additional investment costs (EUR) (%)		Generator working hours (h)	Additional Annual O&M costs (EUR) (%)	
23	24	29'526	6'205	18'498	63%	1	3'213	52%
						2	6'427	104%
						3	9'640	155%
						4	12'853	207%

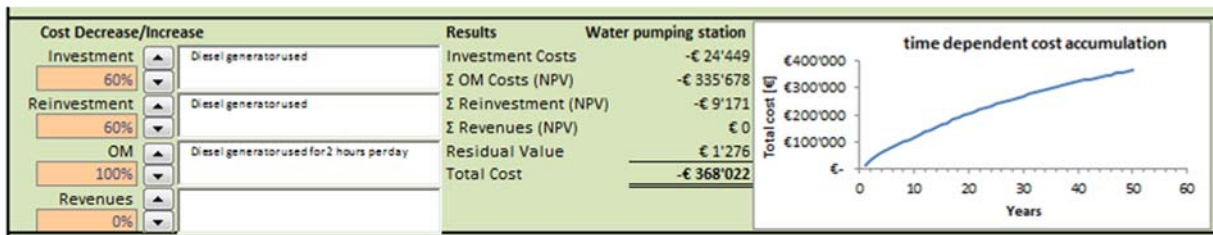


Figure 15: Example in which explanations for modification of costs are provided.

"Results" Sheet

The overall results of the CLARA SPT are presented in a separate sheet called "Results". For the sake of visualization, costs are shown as positive values in the graphs.

The first graph (Figure 16) shows the cost distribution of all alternatives of the project at the end of the considered period. Besides the ratio between investments and all other costs, the graph does not provide information on the temporal distribution of the cash flows.

The second graph (Figure 17) shows on the development of the total costs of alternatives over the period of consideration. It is probably the most important single output of the SPT.

These graphs as well as the technology specific results provide supporting information for the planner and decision maker to refer the economic performance of the proposed systems over the period of consideration.

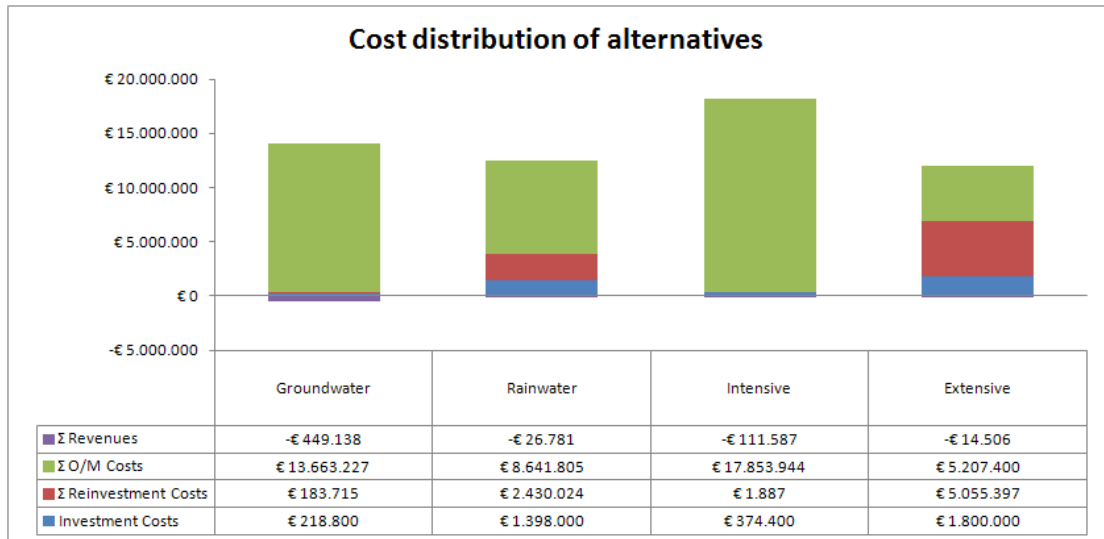


Figure 16: First graph of the "Results" sheet: Accumulated costs over the whole duration of consideration.

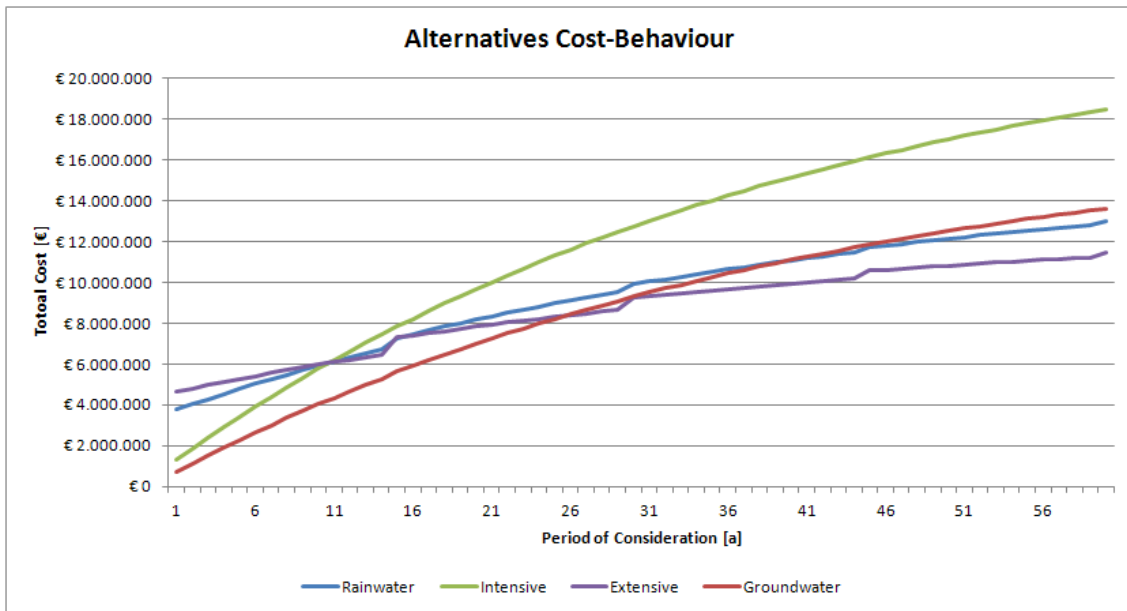


Figure 17: Second graph of the "Results" sheet: Development of total costs over time.

3. FUNCTIONAL GROUPS AND TECHNOLOGIES

The functional groups as defined in the Sustainable Sanitation and Water Management (SSWM) toolbox are used in the CLARA planning tool (Figure 18).

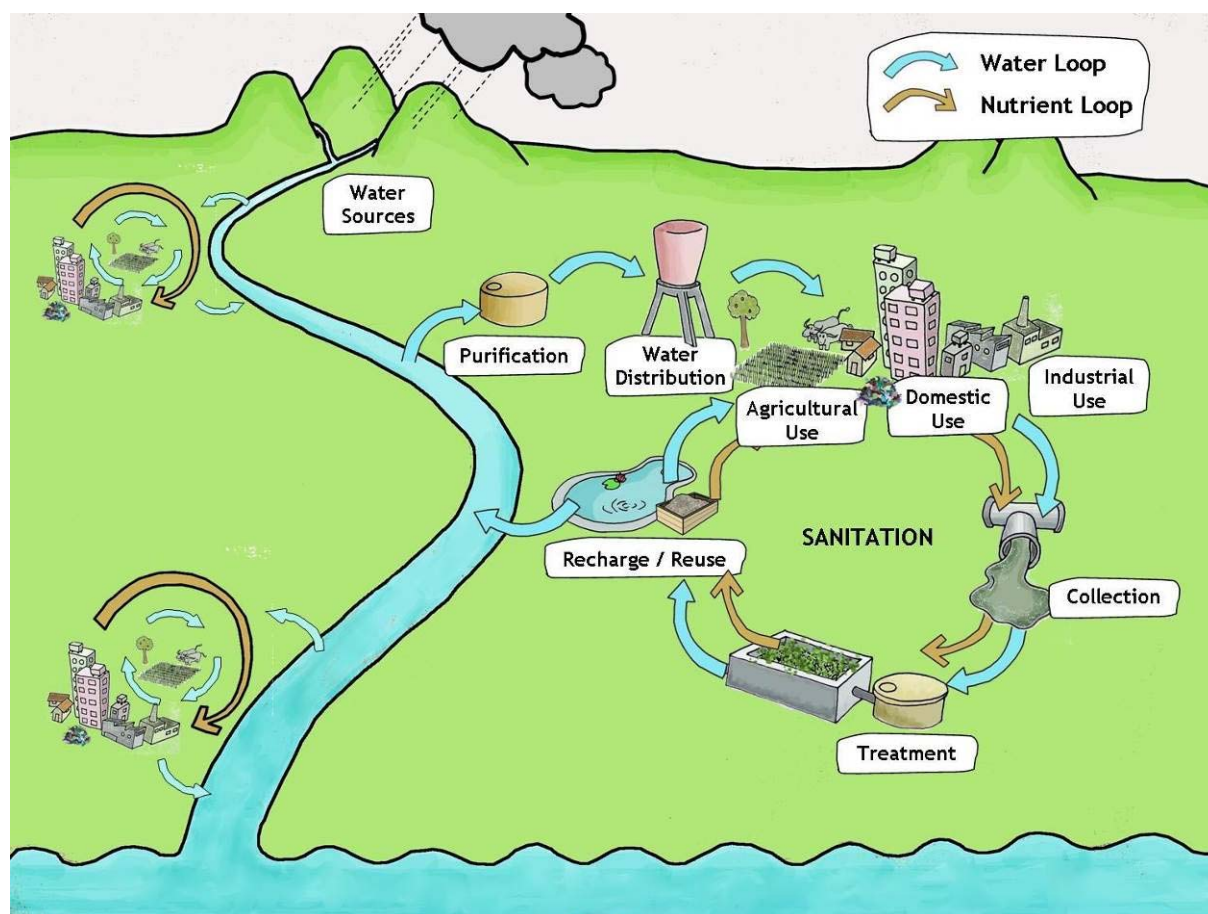


Figure 18: Functional groups for water supply and sanitation systems as defined in the SSWM toolbox (<http://www.sswm.info>).

For the functional groups the following technologies are implemented in the CLARA SPT:

1 Water sources

- 1.1 Extraction from spring
- 1.2 Groundwater extraction (Borehole)
- 1.3 Riverwater extraction

2 Water purification

- 2.1 Surface water treatment
- 2.2 Flocculation and Sedimentation
- 2.3 Chlorination

3 Water distribution

- 3.1 Water tank surface
- 3.2 Water tank elevated
- 3.3 Pumping station
- 3.4 Water transport main
- 3.5 Water distribution network
- 3.6 House connections (Supply)

5 Waste Collection

Water borne system

- 5.1 Cesspit
- 5.2 Collection of (faecal) sludge
- 5.3 Sewer
- 5.4 Sewage pumping station
- 5.5 House Connection (Sewer)

Dry sanitation system

- 5.6 UDDT chamber (larger urine storage tank)
- 5.7 Composting chamber toilet
- 5.8 Collection of urine
- 5.9 Collection of faeces
- 5.10 Collection of Solid Biowaste

6 Waste Treatment

- 6.1 Septic tanks
- 6.2 Imhoff tank
- 6.3 Screen
- 6.4 Buffer tank
- 6.5 Sequencing Batch Reactor (SBR)
- 6.6 Anaerobic baffled reactor (ABR)
- 6.7 Horizontal flow constructed wetland (HF CW)
- 6.8 Vertical flow constructed wetland (VF CW)
- 6.9 Sludge drying reed bed
- 6.10 Urine storage
- 6.11 Struvite production
- 6.12 Composting
- 6.13 Waste stabilisation pond
- 6.14 Upflow anaerobic sludge blanket (UASB) reactor
- 6.15 Phosphorus-Precipitation
- 6.16 Mechanical sludge dewatering (Belt filter press)
- 6.17 Sludge thickener

7 Reuse

- 7.1 Struvite use
- 7.2 Compost use
- 7.3 Irrigation water
- 7.4 Urine use

Descriptions of the technologies are provided in Appendix 1. These technology descriptions include:

- A short description
- Design assumptions
- Input data
- Validity range of cost function
- Assumed lifespan
- Assumptions for O&M costs

4. EXAMPLE

We finally show in a simple example the use of the CLARA SPT. For the example a community with 10'000 persons is considered. In the example a sewer-based and dry sanitation solution shall be compared. The technologies selected for the 2 alternatives are shown in Table 2. In this simplified example potential revenues from using struvite, compost and irrigation water are not considered for the dry sanitation alternative.

Table 2: Selected technologies for the 2 system design alternatives

Functional group	Water-borne sanitation	Dry sanitation
Waste collection	House Connection Sewer	UDDT chamber Collection of urine Collection of faeces
Waste treatment	Treatment plant- SBR Sludge drying reed bed	Struvite production Composting of faeces VF CW (for effluent from struvite production)

Figure 19 shows the "Project information" sheet for this example in which the two alternatives "Water-borne sanitation" and "Dry sanitation" are defined. For the other parameters the default values are not changed.

The screenshot shows the 'Project Information' sheet in Microsoft Excel. The window title is 'Microsoft Excel - CLARA_SPT_V1.5_Ethiopia.xlsm'. The sheet contains various input fields for project parameters. The 'Project Title' is 'Meaningful Project Title'. 'Period of Consideration [Years]' is 50, 'Net Interest Rate [%]' is 3, and 'Expected Annual Growth [%]' is 0.5. A text box for 'Justification/Source:' contains 'Add argumentation here....'. 'Change in cost since release 2013 [%]' is 5. Under 'Alternative Labels/Names', 'Alternative #1' is 'Water-borne sanitation' and 'Alternative #2' is 'Dry sanitation'. 'Alternative #3' and 'Alternative #4' are empty. 'Technology Documentation Folder' is 'D:\CLARA\Technologies' and 'Online Documentation Folder' is 'http://www.sswm.info/category/imp'. The sheet name is 'Project Information' and the status bar shows 'Bereit Berechnen' and '90%' zoom.

Figure 19: Example: "Project information" sheet.

Figure 20 and Figure 21 show for the "Water-borne sanitation" alternative the input parameters for the functional groups Waste collection and Waste treatment, respectively. Based on the design of the SBR plant the daily production of surplus sludge is 66 m³ for nitrifying plants (see also Appendix 1 - Technology descriptions).

Technology #1

House Connection (Sewer) No. of Implementations: 1

1 PE served: 10000
 2 No. of HCs with manhole [%]: 0
 3 Average length [m]: 10
 4 Average trench depth [m]: 1.5

Description: [Empty text box]

CLARA Technology Documentation [Link]
 Individual External Documentation [Link]

Technology #2

Sanitary Sewer No. of Implementations: 1

1 PE served: 10000
 2 Length [m]: 25000
 3 Average trench depth [m]: 1.5
 4 [Empty text box]

Description: [Empty text box]

CLARA Technology Documentation [Link]
 Individual External Documentation [Link]

Figure 20: Input data for technologies for functional group Waste collection (Alternative "Water borne sanitation").

Technology #1

Sequencing batch reactor (SBR) No. of Implementations: 1

1 PE served: 10000
 2 Treatment level: Nitrification
 3 [Empty text box]
 4 [Empty text box]

Description: [Empty text box]

CLARA Technology Documentation [Link]
 Individual External Documentation [Link]

Technology #2

Sludge drying reed bed No. of Implementations: 1

1 Amount of sludge [m3/year]: 24000
 2 TS content [%]: 4
 3 [Empty text box]
 4 [Empty text box]

Description: [Empty text box]

CLARA Technology Documentation [Link]
 Individual External Documentation [Link]

Figure 21: Input data for technologies for functional group Waste treatment (Alternative "Water borne sanitation").

Figure 22 and Figure 23 show for the "Dry sanitation" alternative the input parameters Waste collection and Waste treatment, respectively. Urine is collected every 14 days using a vacuum truck, faeces are collected using a small truck. The average distance to the central treatment site is assumed to be 10 km. A VF CW is considered for treating the remaining water from struvite production. The annual urine volume represents the amount of wastewater from 170 PE, for the VF bed a specific surface area of 1.5 m²/PE is considered.

Technology #1	
Urine-Diversion Dehydration Toilet (UC)	
No. of Implementations: 1	
1 People served: 10000	2 Urine emptying interval: 14 days
3 Description:	4
5	CLARA Technology Documentation
	Individual External Documentation

Technology #2	
Collection of urine	
No. of Implementations: 1	
1 People served: 10000	2 Type of transport: Vacuum truck
3 Distance to treatment site [km]: 10	4 Collection interval: 14 days
5 Description:	
	CLARA Technology Documentation
	Individual External Documentation

Technology #3	
Collection of faeces	
No. of Implementations: 1	
1 People served: 10000	2 Type of transport: Small truck
3 Distance to treatment site [km]: 10	4 Source: UDDT
5 Description:	
	CLARA Technology Documentation
	Individual External Documentation

Figure 22: Input data for technologies for functional group Waste collection (Alternative "Dry sanitation").

Technology #1	
Composting	
No. of Implementations: 1	
1 Faeces from UDDTs [m ³ /year]: 500	2 watered sludge from WWTP [m ³ /year]: 0
3 Other biosolids [m ³ /year]: 0	4 Price of bulking material [EUR/m ³]: 2
5 Description:	
	CLARA Technology Documentation
	Individual External Documentation

Technology #2	
Struvite production	
No. of Implementations: 1	
1 Amount of urine [m ³ /year]: 5000	2 Precipitation agent: Magnesium Sulfi
3 Description:	4
5	CLARA Technology Documentation
	Individual External Documentation

Technology #3	
Vertical flow (VF) CW	
No. of Implementations: 1	
1 PE served: 170	2 Required area [m ² /PE]: 1.5
3 Intermittent loading with: siphon	4
5 Description:	
	CLARA Technology Documentation
	Individual External Documentation

Figure 23: Input data for technologies for functional group Waste treatment (Alternative " Dry sanitation").

Figure 24 and Figure 25 show the results from the cost comparison. Although "Dry sanitation" alternative has lower investment costs compared to the "Water-borne sanitation" alternative the overall costs for 50 years are almost as high due to the higher effort in O&M of the system. The high O&M costs are mainly caused by transport of urine and faeces.

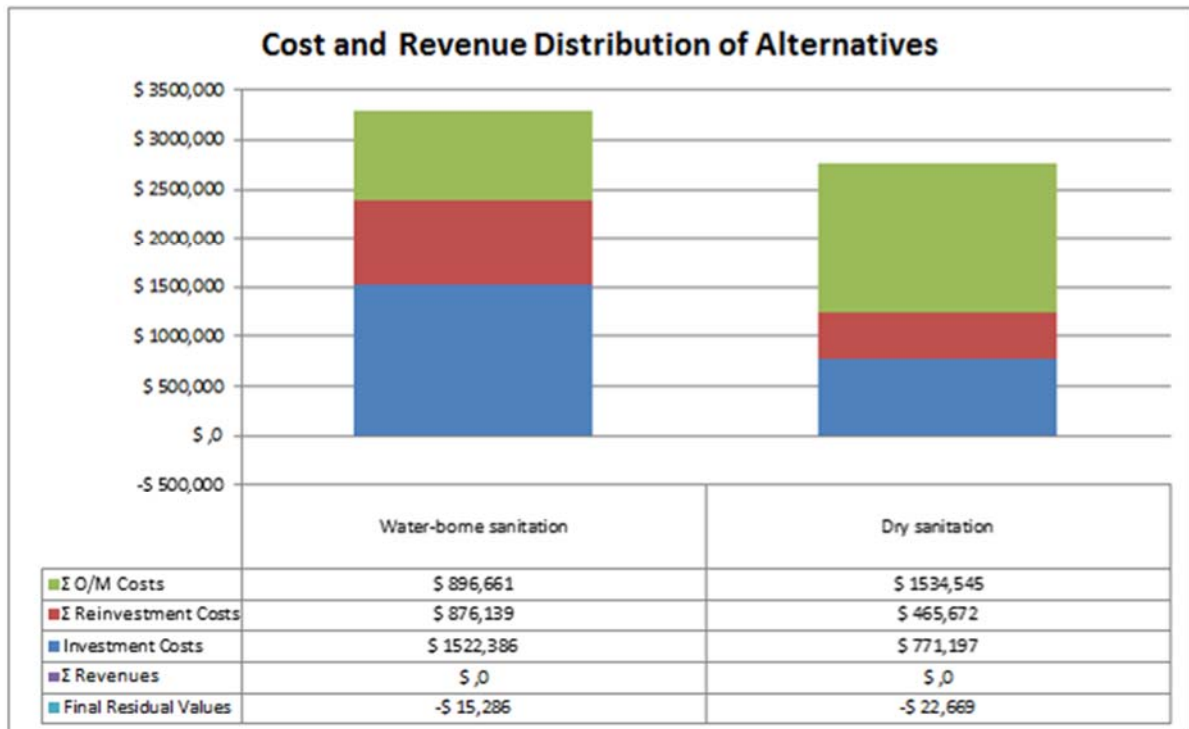


Figure 24: Accumulated costs over the whole duration of consideration.

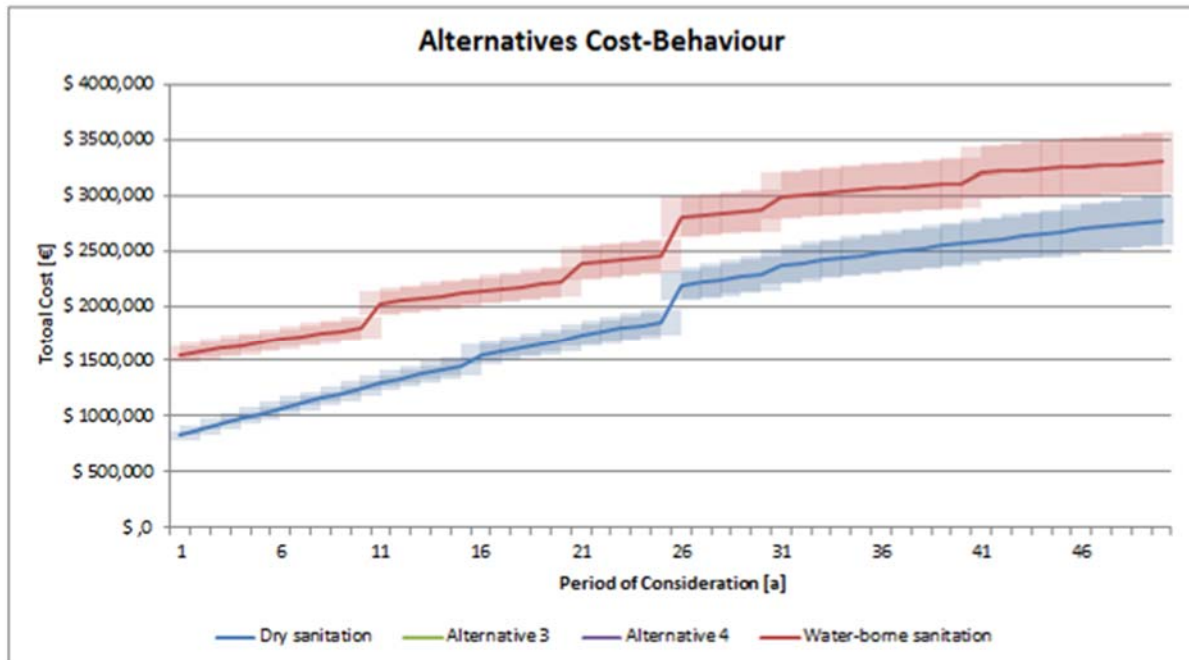


Figure 25: Development of total costs over time.

5. SUMMARY AND OUTLOOK

The CLARA Simplified Planning Tool (SPT) aims to be a tool for comparing **SYSTEM** alternatives during the pre-planning phase. One of the main pre-conditions for using the tool is that only alternatives that provide a service level above a specific threshold (e.g. legal requirements) can be considered thus the comparison can be reduced to the life-time costs.

Version 1.5 of the CLARA SPT presents the final version released in the CLARA project duration and includes:

- The SPT file itself
- The user manual
- Descriptions of the implemented technologies

All files can be downloaded in a single zip-file.

The CLARA SPT is available for download for free from

- the CLARA website (<http://clara.boku.ac.at/>) and
- within the SSWM toolbox (<http://www.sswm.info/home>)

The CLARA SPT has been developed based on cost data for the following countries: Burkina Faso, Ethiopia, Kenya, Morocco and South Africa.

The developers plan to further develop the CLARA SPT by a) including more technologies and b) adapting the cost functions for additional countries. It is planned that new versions of the SPT shall be released at the above mentioned platforms.

If you are interested in the CLARA SPT please contact the CLARA Coordinator Dr. Guenter Langergraber (guenter.langergraber@boku.ac.at).

APPENDIX 1 - DETAILED TECHNOLOGY DESCRIPTIONS

General assumptions

Definitions

Person Equivalent (PE):

- 80 L/d for wastewater
- 20 L/d for blackwater

- *Per person*
- 120 g/d COD
- 60 g/d BOD₅
- 11 g/d N
- 2.5 g/d P

- 500 L/year - Urine
- 50 L/year - Faeces

Water Temperature for water purification

- average 20°C

Wastewater Temperature

- average 20°C

Earthwork / Construction work:

- type of trench: parallel walls
- buildings below topsoil: inward-sloping to pit ground 45°

Cost functions

- Cost functions establish a relationship between input parameters and cost.
- Cost functions have been developed based on actual cost of implemented projects or in the absence of such information on Bills of Quantities for the technologies / process steps in question.

Implemented Projects

- In case cost functions are based on cost of a number of recently implemented projects this is explained in the respective technology description.

Bills of Quantities (BoQ's)

- All cost functions which are based on BoQ's make use of the Clara standardised BoQ which is linked with country specific unit cost for each item.
- Quantities are calculated according to the rules of the Clara standardised BoQ.

Reinvestment

- Σ all reinvestments = initial investment

1.1 Extraction from spring

Description

When groundwater makes its way to the earth's surface and emerges as small water holes or wet spots, this feature is referred to as a spring. The use of springs as the main source for community water supply is applicable whenever a spring occurs and its yield and quality are adequate. Several types of springs can be distinguished: Gravity springs emerging in a **single spot**, springs that have no distinct single outlet and require the installation of a catchment **drainage system**, and finally **artesian** springs.

Design assumptions

- gravity spring with catchment drainage system
- If not given - hydraulic conductivity k_f assumed to be 10^{-5} m/s
- Drains manufactured out of PVC pipes
- Depth of trenches: min 200 cm
- Drain cover: 40x40 cm gravel, rest filled up with excavated soil
- The gravel cover is surrounded by a geotextile
- Collection in a concrete chamber/spring box (for 1 - 200 m³/d a small chamber, from 200 - 3000 m³/d a large chamber is used)
- Fenced protection zone: radius of 15 m around the catchment area

Input data (planner)

- (1) Daily water demand Q_d [m³/d];
- (2) Hydraulic conductivity k_f [m/s]

Cost function valid for (1) $Q_d = 1$ to 2000 m³/d and (2) $k_f = 10^{-3}$ m/s 10^{-6} m/s

Lifespan

PVC pipes _____ 40 years

Concrete spring box _____ 25 years

O&M costs

Periodic (weekly) check-up

Maintenance costs (1% of investment costs/year)

1.2 Groundwater extraction (Borehole)

Description

A borehole is a well or hole which is drilled into the aquifer and partially or fully lined for the abstraction of groundwater. If lined it has a casing consisting of pipes in the non-water bearing formations, and perforated or slotted screen sections in the aquifer. At the bottom of the borehole a pump delivers the extracted groundwater to the top.

Design assumptions

- Hydraulic conductivity k_f assumed to be 10^{-4} m/s
- Borehole lined with PVC pipe
 - a) DN 200 (8 inch diameter)
 - b) DN 500 (20 inch diameter)

First 8 m drilled with bigger diameter to allow installation of surface casing

- Standard method: rotary drilling
- Rate of successful drillings: 70%
- Rate of post-construction failure rate: 30%
- Fenced protection zone: radius of 15 m around the catchment area
- Only one pump per borehole

Input data (planner)

- (1) Daily water demand Q_d [m^3/d]
- (2) Diameter (8 inch, 20 inch)
- (3) Depth of borehole [m]

Cost function valid for (1) $Q_d = 25$ to $1'500$ m^3/d [for 8 inch diameter] and 100 to $5'000$ m^3/d [for 20 inch diameter] and (3) Groundwater level = 5 to 180 m

Lifespan

Mechanical equipment _____ 10 years

Concrete works _____ 25 years

O&M costs

Inspection and cleaning of pump after 2000 operating hours.

Operation is simple, maintenance of pumps requires technician.

Maintenance costs (1% of investment costs/year) Borehole jetting (cleaning) every 5 years

1.3 Riverwater extraction***Description***

Surface water sources for extraction include rivers, canals and lakes. The water usually will be pumped out of the source into the treatment plant. Coarse screening for pump protection is used as first step of surface water treatment and is part of the extraction structure.

Design assumptions

Water extraction: robust construction made of concrete with an inlet-gate which is protected by metal bars, located at the riverbank.

- Electrical submerged pump extracts river water
- Distance pump to treatment plant: 100 m

Screen: consists of metal bars. Removal of screenings is performed manually. For maintenance and as emergency overflow, 2 screens are placed in parallel.

- Coarse screen flat bar 10mm, spacing 25mm
- Sum of spacings = channel width before screen
- $v_{\min} = 0.6$ m/s; $v_{\max} = 1.2$ m/s
- Calculation headloss according to Kirschmer/Mosonyi
- Maximum screen occupation ~ 75%
- channel width >2 x max. headloss
- 2 parallel waterlines
- Cleaning manually

Input data (planner)

(1) Daily water demand Q_d [m^3/d]

(2) Pumping head [m]

Cost function valid for (1) $Q_d = 300$ to $5'000$ m^3/d and (2) 5 – 60 m

Lifespan

Mechanical equipment _____ 10 years

Concrete works _____ 25 years

O&M costs

Inspection and cleaning of pump after 4000 operating hours.

Maintenance costs (1% of investment costs/year)

1h casual labourer/day/500PE

Screener maintenance: check every day, cleaning on demand

2.1 Surface water treatment

Description

The Grit Channel is a construction where the velocity of the incoming water is reduced by widening the cross section to allow the settlement of e.g. sand and grit. These particles are removed because they may damage pumps and other equipment or clog channels or pipes further along the purification plant.

The Slow Sand Filter (SSF) process consists of a number of filtration tanks containing a supernatant water layer, a bed of sand filter medium, a gravel supporting bed and a draining system with filter regulation and control accessories (pipes, valves, fittings and others).

Design assumptions

Grit Channel:

- 2 parallel channels > 3,500 m³/d (in special cases second line is only Bypass-channel)
- Rectangular horizontal flow design
- Manual cleaning
- Ratio: Length/Width 3:1; Length/Depth 15:1
- settling velocity e.g 7 cm/s (sandparticle 0.5 mm)

SSF:

- Min. no. of filters: 2
- Area of each filter : < 250 m²
- a maximum of 40 filters per treatment plant
- Roofed with corrugated iron
- Free board: 0.5 m
- Standing Water depth (supernatant depth) over the filter = 1 m
- Period of operation: 24 hr

Filtration rate: 0,15 m/h Filterbed of SSF

- Initial depth of sand filter bed ($d_{10}= 0.3\text{mm}$ and $U_c=1.5$ to 3): layer thickness 1 m
- 4 layers of gravel filter bottom bed:

Grain size:	0.7-1.4	2-4	6-12	18-36 mm
layer thickness:	5	5	5	10 cm
- Using PVC perforated lateral pipe to collect filtered water

Input data (planner)

(1) Daily water demand Q_d [m³/d]

Cost function valid for (1) $Q_d = 300$ to 35.000 m³/d

Lifespan

Mechanical equipment _____ 10 years

Civil works _____ 25 years

O&M costs

Grit Channel:

- Should be cleaned once a week at least, manual cleaning 2 h/week.

- Maintenance costs (1% of investment costs/year)

-

SSF:

- daily checking 1 h/day/2000PE
- Manual cleaning filter unit every 2 months
- Re-sanding every 5 years or 30 cleaning-steps
- Maintenance costs (1% of investment costs/year)

2.2 Flocculation and Sedimentation

Description

Sedimentation is the process of removing suspended and colloidal particles by settlement. The process can be aided by adding chemicals to create bigger flock size of colloidal particles and raise the density and surface area to enhance their settlement performance.

Design assumptions

- Tanks per waterline: coagulation tank with rapid stirrer, horizontal-shaft paddle flocculator, sedimentation tank
- Surface loading: 1 m/h
- Coagulation detention time: 60 seconds
- Retention time for sedimentation: 3 h
- By using Aluminium sulfate (Alum, $KAl(SO_4)_2 \cdot 12H_2O$): Flocculant demand: 30 mg/l
- By using Aluminium chlorohydrate (ACH, $Al_nCl_{(3n-m)}(OH)_m$): Flocculant demand: 10 mg/l
- By using Ferrous Sulphate ($FeSO_4$): Flocculant demand: 15 mg/l
- Flocculation time (20% of Sedimentation time): 0.6 h
- Sludge treatment and disposal included

Input data (planner)

- (1) Daily water demand Q_d [m^3/d]
- (2) No. of waterlines [-] (one or two)
- (3) Kind of flocculant (Alum, ACH or Ferrous Sulphate)

Cost function valid for (1) $Q_d = 300$ to $35.000 m^3/d$

Lifespan

Mechanical equipment _____ 10 years

Civil works _____ 25 years

O&M costs

- Flocculant/m³_{water}
- Once a week for 2 h and 1h/d/2000PE
- Dewatering and disposal of sludge
- Maintenance costs (1% of investment costs/year)

2.3 Chlorination**Description**

Sodium hypochlorite solution (NaClO) or Calcium hypochlorite solution (Ca(ClO)₂) is chosen to use as disinfectant agent for simplified planning tool. It is injected by a pump directly into the waterpipe. A dosage flow controlled unit is used if >500PE (40m³/d).

Design assumptions

- Concentration after dosage 2mg Cl /L (to achieve a residual chlorine at the furthest user point 0.2-0.5 mg/L)
- 75% solution
- Equipment such as storage tank, injection pump and dosage flow control unit for disinfectant is included

Input data (planner)

(1A) Daily water demand Q_d [m³/d] if pumping in a tank (open system)

OR

(1B) Largest hourly water demand Q_{hmax} [m³/h] if pumping in a water main

(2) Kind of disinfectant (Sodium Hypochlorite, Calcium Hypochlorite or Chlorine Gas)

Cost function valid for (1A) $Q_d = 300$ to 35.000 m³/d and (1B) $Q_h = 13$ to 1.460 m³/h

Remark: (1) If (m³/h*24) > m³/d → basis for calculation is (m³/h*24)

Lifespan

Mechanical equipment _____ 10 years

Civil works _____ 25 years

O&M costs

- energy for pump
- chemicals (disinfectant m³)
- check once a day for 1 h
- labour cost 1h/d/2000PE
- Maintenance costs (1% of investment costs/year)

3.1 Surface water tank (concrete)

Description

The Surface Water Tank stores water from a source or a purification plant to balance the average supply and variable water demands of users.

Design assumptions

Total reservoir volume (m³) = Active reservoir volume (m³) + Storage for fire fighting(m³) + Storage for maintenance (cleaning) (m³)

- Active reservoir volume to balance daily supply and demand = Maximum daily demand/3
- Storage for maintenance, emergency and cleaning = 10% of average daily demand
- Rectangular shape of the tank
- Construction made of concrete is completely buried, coverplate is on topsoil-level
- Maximum tank area 2.500 m², one support column per 25m²

Input data (planner)

(1) Daily water demand Q_d [m³/d]

Cost function valid for (1) Q_d = 10 to 10'000 m³/d

Lifespan

Steel works _____ 25 years

Concrete works _____ 50 years

O&M costs

Inspection every 2 weeks

cleaning once a year

Maintenance costs (2% of investment costs/year)

3.2 Elevated water tank (steel)

Description

Elevated water reservoirs are usually erected at a required height to allow an effective gravity feed and adequate line pressure in the water distribution network. It is supplied with drinking water from a purification plant to balance the average supply of users.

Design assumptions

Total elevated water reservoir volume (m³) = Active reservoir volume (m³) + Storage for fire fighting (m³) + Storage for maintenance (cleaning) (m³)

- Active reservoir volume to balance daily supply and demand = Maximum daily demand/3
- Storage for maintenance, emergency and cleaning = 10% of average daily demand

- Tower and watertank made of steel
- Rectangular shape of watertank-elements joined together
- Constructed on a concrete foundation (4 Baseplates) with steel anchors

Input data (planner)

- (1) Daily water demand Q_d [m^3/d]
- (2) Elevation of the tank [m]

Cost function valid for (1) $Q_d = 10$ to $10.000 m^3/d$ and (2) elevation = 1 to 20 m

Lifespan

Steel works _____ 25 years

Concrete works _____ 50 years

O&M costs

Inspection

cleaning once a year

Maintenance costs (3% of investment costs/year) (mostly painting!)

3.3 Water pumping station (centrifugal pump)

Description

A Pumping station is an integral part of most water supply systems and is used mainly for following purposes:

- To continuously pump water in a tank (open system)
- To increase the water pressure or head (potential energy) in the conveyance system (closed system)
- To increase the flow rate of supply (kinetic energy) to the systems (closed system)

Design assumptions

- Electrical connection available on site
- Energy = $m \cdot g \cdot h \cdot \eta$

m = mass [kg]

g = acceleration of gravity [m/s^2]

h = height [m]

η = pump efficiency = 0.5

- no. of pumps =2 (100% reserve)
- incl. air vessel if pumping into closed system (booster pumps)
- if buried, construction is made of concrete (depth pump foundation 2,0 m), coverplate is on topsoil-level

- if not buried, there is small pumping house on the surface
- maximum pressure head 150 m

Input data (planner)

(1) Daily water demand Q_d [m^3/d] if pumping in an open system (tank)

OR

(1) Largest hourly water demand Q_{hmax} [m^3/h] if pumping in a closed system (e.g. water main)

(2) Pressure head [m]

(3) Pump station at surface / subsurface

Cost function valid for (1) $Q_d = 100$ to $3'600 m^3/d$ and $Q_h = 4$ to $150 m^3/h$, respectively.

Remarks:

- (a) If $Q_d > 0 m^3/d$ this value is used for calculation is (m^3/d), Q_h in (m^3/h) is neglected
- (b) If Q_h in (m^3/h) shall be used, the cell for Q_d in (m^3/d) must be empty!

Lifespan

Pumps _____ 10 years

Concrete works _____ 50 years

O&M costs

Energy requirements for pump

Check pumping station 1h/week

Inspection and cleaning of pump after 4000 operating hours

Maintenance costs (1% of investment costs/year)

3.4 Water transport main***Description***

Water needs to be transported from the source to the purification plant, and onward to the water supply network. Robust pipes are used for this purpose. They are protected by buried in a trench.

Design assumptions

- DN calculated for flow rate $> 0,6 m/s$ and $< 1.2 m/s$; nearest norm diameter
- Peak flow factor 1.8 Pipe material: PVC or HDPE (only < 3 inch)
- type of trench: parallel walls
- Trench depth $< 1.25 m \rightarrow$ no need of formworks in the trench; Trench depth $> 1.25 m \rightarrow$ formworks in the trench is necessary.

- Minimum working width (for both sides) 0.06 m (trench depth < 1.25 m) and 0,07 m (trench depth > 1.25 m and < 4,0 m)
- Pipe bedding with sand (0.1 m)
- Surcharge for fittings (valves, T's, etc.) 10% flat
- Disinfection of pipe and leakage testing after construction
-

Input data (planner)

(1) Average Flowrate Q_d [m^3/d]

OR

(1) Largest Flowrate Q_{hmax} [m^3/h]

(2) Pipe Length [m]

(3) Average depth of pipes [m]

Cost function valid for (1) $Q_d = 100$ to $10'000 m^3/d$ and $Q_h = 4$ to $150 m^3/h$, respectively, and (3) depth = 0.5 to 4.0 m.

Remarks:

- (a) If $Q_d > 0 m^3/d$ this value is used for calculation is (m^3/d), Q_h in (m^3/h) is neglected
- (b) If Q_h in (m^3/h) shall be used, the cell for Q_d in (m^3/d) must be empty!

Lifespan

Pipes and Concrete works _____ 50 years

O&M costs

Inspection every 10 years

Maintenance costs (2% of investment costs/year)

3.5 Water distribution network

Description

Supply networks are a system of pipes, fittings (manholes) and trenches. The aim of a distribution network is to supply a community with the appropriate quantity and quality of water.

Design assumptions

- DN calculated for flow rate > 0,6 m/s and < 1.2 m/s; nearest norm diameter
- Pipe DN in networks considers: 20% of largest, 30% of middle, and 50% of small diameter
-
- Peak flow factor 1.8

- Pipe material: PVC or HDPE (< 3 inch)
- Surcharge for fittings (valves, T's, etc.) 15% flat
- type of trench: parallel walls
- Trench depth < 1.25 m → no need of formworks in the trench; Trench depth > 1.25 m → formworks in the trench is necessary.
- Minimum working width (for both sides) 0.06 m (trench depth < 1.25 m) and 0,07 m (trench depth > 1.25 m and < 4,0 m)
- Pipe bedding with sand (0.1 m)
- Disinfection of pipe and leakage testing after construction

Input data (planner)

(1) Average Flowrate Q_d [m^3/d]

OR

(1) Largest Flowrate Q_{hmax} [m^3/h]

(2) Pipe length [m]

(3) Average depth of pipe [m]

Cost function valid for (1) $Q_d = 100$ to $10'000 m^3/d$ and $Q_h = 4$ to $150 m^3/h$, respectively, and (3) depth = 0.5 to $4.0 m$.

Remarks:

- (a) If $Q_d > 0 m^3/d$ this value is used for calculation is (m^3/d), Q_h in (m^3/h) is neglected
- (b) If Q_h in (m^3/h) shall be used, the cell for Q_d in (m^3/d) must be empty!

Lifespan

Pipes and Concrete works _____ 50 years

O&M costs

Inspection every 10 years

Maintenance costs (2% of investment costs/year)

3.6 House connections (Supply)

Description

House connections are the final pipes linking a single house to the nearest pipe of the supply network. A water meter is installed to measure the amount of water consumption.

Design assumptions

- Average DN/OD 63
- Pipe material: HDPE
- Surcharge for fittings (valves, T's, water meter, etc.) 20% flat
- type of trench: parallel walls

- Excavation depth < 1.25 m → no need of formworks; excavation depth > 1.25 m → formwork is necessary.
- Minimum working width (for both sides) 0.06 m (excavation depth < 1.25 m) and 0,07 m (excavation depth > 1.25 m and < 4,0 m)
- Pipe bedding with sand (0.1 m)
- Manhole buried, manhole cover is on topsoil-level
- Manhole inner diameter: 0.6 to 1,0 m depending on bottom depth
- Disinfection of pipe and leakage testing after construction
-

Input data (planner)

- (1) No. of house connections [-]
- (2) No. of house connections with an installation manhole [-]
- (3) Average length [m]
- (4) Average depth [m]

Cost function valid for (3) length < 50 m and (4) depth = 0.5 to 4.0 m

Lifespan

Water meter _____ 15 years

Concrete works _____ 50 years

O&M costs

Periodic inspection twice a year

Change of water meter every 5 years (for calibration)

Maintenance costs (2% of investment costs/year)

5.1 Cesspit

Description

Cesspit is an underground tank used for temporary collection and storage of wastewater.

Design assumptions

- 20 L/PE/d for blackwater
- 80 L/PE/d for wastewater
- Cesspit emptying interval 45 days
- construction is made of concrete, cover plate is on topsoil-level
- rectangular shape
- excavation depth 2.7 to 3.2 m

Input data (planner)

- (1) PE served
- (2) Wastewater or blackwater
- (3) Volume of 1 cesspit [m³] ... fixed to 10, 20, 50 or 100 m³ per cesspit

Lifespan

Pipes and manhole cover	25 years
Building structure	25 years

O&M costs

Faecal sludge removal – costs are considered in collection of (faecal) sludge

Inspection every month (1h)

Maintenance costs (1% of investment costs/year)

5.2 Collection of (faecal) sludge from cesspits

Description

Collection of faecal sludge from cesspits.

Design assumptions

- Collection interval: 45 days
- Vacuum truck: The vacuum truck consists of 5 m³ tank and a pump assembly installed on a truck.
- Vacutug: tank capacity of 500 litres capacity and a pump assembly on wheels. A small gasoline engine is used to operate the pump and transport the waste at a maximum speed of 2 km/h. The maximum distance to the treatment site for application of the vacutug is limited to 8 km.

	Vacuum truck	Vacutug	Unit
Working hours per day	10		hours
Working days per year	295		days
Average speed	20	2	km/h
Maximum load	5	0.5	m ³
Time spent at costumer	45	30	min
Time for discharge at disposal site	45	30	min

Input data (planner)

- (1) Type of transport (vacuum truck or vacutug)
- (2) No. of pick-up points [-]
- (3) Distance to treatment site [km]
- (4) Volume per pick-up point [m³]

Lifespan

15 years

O&M costs

Truck: Annual fuel costs (25 l/100km) and maintenance costs of 10 % of the investment costs. The truck is operated by one driver and one unskilled labourer per vehicle.

Vacutug: fuel consumption of 3 litres per day and maintenance costs of 10 % of the investment costs. The vacutug is operated by one skilled and one unskilled labourer per vehicle.

5.2a Collection of sludge from septic tanks

Description

Collection of sludge from septic tanks (and Imhoff tanks).

Design assumptions

- Emptying: Twice a year
- Volume of septic tank [m³] = 0.15 * PE; for Imhoff tanks: Volume [m³] = 0.065 * PE
- Emptying interval: 1 year for septic tanks < 20 PE and 1/2 year for ≥ 20 PE (see 6.1)
- Vacuum truck: The vacuum truck consists of 5 m³ tank and a pump assembly installed on a truck.
- Vacutug: tank capacity of 500 litres capacity and a pump assembly on wheels. A small gasoline engine is used to operate the pump and transport the waste at a maximum speed of 2 km/h. The maximum distance to the treatment site for application of the vacutug is limited to 8 km.

	Vacuum truck	Vacutug	Unit
Working hours per day	10		hours
Working days per year	295		days
Average speed	20	2	km/h
Maximum load	5	0.5	m ³
Time spent at costumer	45	30	min
Time for discharge at disposal site	45	30	min

Input data (planner)

- (1) Type of transport (vacuum truck or vacutug)
- (2) No. of septic tanks [-]
- (3) Distance to treatment site [km]
- (4) Volume per septic tank [m³]

Lifespan

15 years

O&M costs

Truck: Annual fuel costs (25 l/100km) and maintenance costs of 10 % of the investment costs. The truck is operated by one driver and one unskilled labourer per vehicle.

Vacutug: fuel consumption of 3 litres per day and maintenance costs of 10 % of the investment costs. The vacutug is operated by one skilled and one unskilled labourer per vehicle.

5.3 Sanitary Sewer

Description

A sanitary sewer is used for transporting the sewage from houses to a treatment plant. For inspection and renewal works manholes are placed at different points in the network. Flow by gravity due to a slope.

Design assumptions

- 80 L/PE/d
- 15 persons per house (connection)
- Minimum design flow rate 0.6 m/s
- Peak flow factor 1.5
- The hydraulic radius (d/D) = 0.5
- Gradient of flow = 0.7%
- Pipe diameter increases over length due to “imaginary house connections”
- Pipe material PVC
- Surcharge for fittings (valves, T’s, water meter, etc.) 15% flat
- type of trench: parallel walls

- Trench depth < 1.25 m → no need of formworks in the trench; Trench depth > 1.25 m → formworks in the trench is necessary.
- Minimum working width (for both sides) 0.06 m (trench depth < 1.25 m) and 0,07 m (trench depth > 1.25 m and < 4,0 m)
- Pipe bedding with sand (0.1 m)
- Manhole buried, manhole cover is on topsoil-level
- Manhole inner diameter: 0.6 to 2,0 m depending on bottom depth and sewer diameter
- Distance between manholes 35m
- leakage testing after construction

Input data (planner)

- (1) PE served (wastewater disposed of via sewer)
- (2) Length [m]
- (3) Average trench depth [m]

Cost function valid for (3) 0.5 to 4.0 m

Lifespan

Civil works _____ 40 years
 PVC pipes _____ 40 years

O&M costs

Leakage control: pressure tests every 5 years

Maintenance costs (2% of investment costs/year)

5.4 Sewage pumping station

Description

A pumping station is an additional component of a sewer system which is necessary if head differentials have to be overcome. The whole construction is beneath the surface. The fixed submerged pumps are controlled via a floating switch.

Design assumptions

- Electricity available on site (no additional cost considered).
- Pumps used for design and calculation are submerged pumps (Grundfos SEG and SEV). Cost for guide shoe, guide pipe, lifting chain, and control system included.
- Control cabinet and cabling is considered in the cost function.
- no. of pumps =2 (100% reserve)
- pumping station buried, cover plate is on topsoil-level
- depth of pump foundation 2.5 m
- rectangular shape, base area 3.0 m²

- maximum pressure head 50 m

Input data (planner)

- (1) Hourly water flow Q_h [m³/h]
- (2) Pressure head [m]

Cost function valid for (1) $Q_h = 4$ to 150 m³/h and (2) max. 50 m

Lifespan

Pumps _____ 10 years
Concrete works _____ 50 years

O&M costs

Electricity for pump

Check pumping station 1h/week

Inspection and cleaning of pump after 4000 operating hours

Cleaning of pump station twice annually

Maintenance costs (2% of investment costs/year)

5.5 House connection (Sewer)

Description

The connection from the household to the sewer network. Flow by gravity.

Design assumptions

- 15 persons per house(connection)
- DN 160mm
- Pipe material PVC
- Surcharge for fittings (valves, T's, water meter, etc.) 20% flat
- type of trench: parallel walls
- Trench depth < 1.25 m → no need of formworks in the trench; Trench depth > 1.25 m → formworks in the trench is necessary.
- Minimum working width (for both sides) 0.06 m (trench depth < 1.25 m) and 0,07 m (trench depth > 1.25 m and < 4,0 m)
- Pipe bedding with sand (0.1 m)
- Manhole buried, manhole cover is on topsoil-level
- Manhole inner diameter: 0.6 to 1,0 m depending on bottom depth
- leakage testing after construction

Input data (planner)

- (1) PE served [-]
- (2) House connections with manhole [%]
- (3) Average length [m]
- (4) Average trench depth [m]

Cost function valid for (4) 0.5 to 4.0 m

Lifespan

PVC pipes and construction work _____ 50 years

O&M costs

Maintenance costs (2% of investment costs/year)

5.6 UDDT chamber (larger urine storage tank)***Description***

The urine-diversion dehydration toilet is a sanitation facility that separates urine and faeces and stores it for collection and further treatment.

There are two types of UDDT units. When using single-vault UDDT the faeces need to be collected for further treatment (composting). When using the double-vault UDDT the faeces are dried or composted on-site.

Design assumptions

Only substructure, superstructure is required for any type of toilet and therefore not relevant for variant analyses.

- Single-vault UDDT is used
- Maximum number of people using one toilet: 15 Persons
- Maximum number of toilets per block: 4 Toilets
- Urine volume per person per year: 500 l/a
- Faeces per person per year: 50 l/a
- Faeces dry mass: 11 kg
- Faeces water content: 80 %
- Addition of bulk material: 100 % of faeces volume

Input data (planner)

- (1) People served
- (2) Urine emptying interval (7 days, 14 days or 30 days)

Lifespan

civil works 25 years

O&M costs

Maintenance costs (2% of investment costs/year)
emptying considered in urine and faeces transport.

5.7 Composting chamber toilet***Description***

Composting chamber toilets are sanitation facilities that collect human excreta in one chamber. If the urine is not divided in an extra storage tank, it is drained out after entering the chamber. The construction of the chamber enables the composting process. Collection of compost will be arranged after a certain time.

Design assumptions

Only substructure, superstructure is required for any type of toilet and therefore not relevant for variant analyses.

- Maximum people using one toilet: 15 Persons
- Maximum number of toilets per block: 6 Toilets
- Faeces per person per year: 50 L/a
- Addition of bulk material: 100 % of faeces volume
- Volume shrinking: 30 %
- Storage time in composting chamber: 6 month
- No seepage
- Urine is not divided

Input data (planner)

(1) People served

Lifespan

Civil works 25 years

O&M costs

Maintenance costs (2% of investment costs/year)
emptying considered in urine and faeces transport.

5.8 Collection of urine***Description***

Collection of urine from urine diversion dry toilets

Design assumptions

- Urine volume per person per year: 500 L/PE/a
- Vacuum truck: The vacuum truck consists of 5 m³ tank and a pump assembly installed on a truck.
- Vacutug: tank capacity of 500 litres capacity and a pump assembly on wheels. A small gasoline engine is used to operate the pump and transport the waste at a maximum speed of 2 km/h. The maximum distance to the treatment site for application of the vacutug is limited 8 km.

	Vacuum truck	Vacutug	Unit
Working hours per day	10		hours
Working days per year	295		days
Average speed	20	2	km/h
Maximum load	5	0.5	m ³
Time spent at costumer	45	30	min
Time for discharge at disposal site	45	30	min

Input data (planner)

- (1) People served
- (2) Type of transport (vacuum truck or vacutug)[-]
- (3) Distance to treatment site [km]
- (4) Collection interval (7 days, 14 days or 30 days) [d]

Lifespan

15 years

O&M costs

Truck: Annual fuel costs (25 l/100km) and maintenance costs of 10 % of the investment costs. The truck is operated by one driver and one unskilled labourer per vehicle.

Vacutug: fuel consumption of 3 litres per day and maintenance costs of 10 % of the investment costs. The vacutug is operated by one skilled and one unskilled labourer per vehicle.

5.9 Collection of faeces

Description

For the collection and transportation of faeces three systems are available: donkey cart, small truck and big truck.

Design assumptions

- Faeces will be collected with storage container (replacement container).
- Parameters for the faeces volume determination

Faeces per person per year	50	L/PE/a
Addition of bulk material	100% of faeces volume	-
Density of faeces	1.3	kg/L
Shrinking of faeces in UDDT	20%	-
Shrinking of faeces in compost chamber	75%	-
Capacity of faeces container	50	L
UDDT emptying interval	14	days
Compost chamber emptying interval	6	months

- Parameters for the design of faeces transport

	Donkey cart	Small truck	Big truck	Unit
Container for faeces collection	50			L
Time required per container	3	3	2.5	min
Time for offload at treatment area	30	60	90	min
Working hours per day	10			hours
Working days per year	295			days
Average speed	3	20	20	km/h
Maximum load	300	1200	10,000	kg
Rate of loading utilisation	90%	90%	90%	-

Input data (planner)

- (1) People served
- (2) Type of transport (Donkey cart, small truck or big truck)
- (3) Source of faeces (UDDT or composting toilet) [-]
- (4) Distance to treatment site [km]

Lifespan

15 years

O&M costs

O&M costs for the donkey cart include costs for food and water which are 7% of the investments costs and maintenance and spare part costs are 7% of the investments cost. Each cart is operated by two unskilled labourers.

O&M costs for the small truck includes a diesel consumption of 20 litres per 100 km and maintenance costs of 7 % of the investment costs. Each truck is operated by one driver and an unskilled labourer.

O&M costs for the big truck includes a diesel consumption of 40 litres per 100 km and maintenance costs of 7% of the investment costs. Each truck is operated by one driver and two unskilled labourers.

5.10 Collection of solid biowaste**Description**

For the collection and transportation of biodegradable solid waste three systems are available: donkey cart, small truck and big truck.

Design assumptions

- Collection interval: 14 days
- Parameters for the design of solid waste transport

	Donkey cart	Small truck	Big truck	Unit
Container for collection	50			l
Time required per container	3	3	2.5	min
Time for offload at treatment area	30	60	90	min
Working hours per day	8			hours
Working days per year	220			days
Average speed	3	15	15	km/h
Maximum load	300	1200	10,000	kg
Rate of loading utilisation	90%	90%	90%	-

Input data (planner)

- (1) Volume of solid biowaste [m³/d]
- (2) Type of transport (Donkey cart, small truck or big truck)
- (3) Number of pick-up points [-]
- (4) Distance to treatment site [km]

Lifespan

15 years

O&M costs

O&M costs for the donkey cart include costs for fodder and water which are 7 % of the investments costs and maintenance and spare part costs are 7 % of the investments cost. Each cart is operated by two unskilled labourers.

O&M costs for the small truck includes a diesel consumption of 20 liters per 100 km and maintenance costs of 7 % of the investment costs. Each truck is operated by one driver and an unskilled laborer.

O&M costs for the big truck includes a diesel consumption of 40 liters per 100 km and maintenance costs of 7 % of the investment costs. Each truck is operated by one driver and two unskilled laborers.

6.1 Septic tank

Description

A two-chamber septic tank is operated as a pre-treatment technology for grey water and black water.

Design assumptions

- Hydraulic Retention time (HRT) = 24h
- De-sludging interval 6 months (20 to 2000 PE) and once a year (< 20 PE)
- Sludge accumulation rate 60 L/PE/a

Input data (planner)

(1) PE served

Cost function valid for (1) 5 to max 2000 PE per unit

Lifespan

civil works 25 years

O&M costs

control 2x/month

sludge removal (1x/a or 2x/a) – cost considered in sludge transport!

Maintenance costs (1% of investment costs/year)

6.2 Imhoff tank

Description

The Imhoff tank is a pre-treatment technology for wastewater. An Imhoff tank consists of a settling compartment, and a conical digestion chamber for anaerobic sludge stabilisation.

The effluent usually requires further treatment, therefore the technology is mainly used as a pre-treatment stage in small treatment plants.

Design assumptions

- COD removal efficiency 30% (based on ESC experiences)
- HRT at periods of peak flow min. 2 hours.
- SS/COD ratio 0.42
- Desludging interval: 6 months.
- incoming sewer pipe at 0.5 m below topsoil level
- Construction made of concrete is completely buried, depth water level below topsoil level 0.6 m
- excavation (earthworks) with sheeting, due to deep tank when PE >

Input data (planner)

- (1) PE served
- (2) cover slab (yes / no)

Cost function valid for (1) 50 to 15'000 PE

Lifespan

civil works 25 years

O&M costs

Daily inspection and removal of material from inlet area

Bi-annual de-sludging (cost included in sludge transport)

Regular cleaning

Maintenance costs (1% of investment costs/year)

6.3 Screen

Description

A coarse and/or a fine screen is used as pre-treatment step to remove solids from raw wastewater to protect subsequent treatment units and avoid blockages. It consists of metal bars placed in an open flow channel. For maintenance works and as emergency overflow two units are placed in parallel, with the second one being cleaned manually.

Design assumptions

- bar width / bar spacing: coarse = 10 / 25 mm, fine = 5 / 8 mm
- channel flow velocity: 0.75 m/s
- screen angle 45°
- Units \leq 3000 PE consist of one channel, where the flow can be directed to two different subdivisions, screens $>$ 3000 PE consist of two different channels with separate screens
- screenings volume: course: 0,022 m³ screenings/1000 m³ wastewater; fine: : 0,120 m³ screenings/1000 m³ wastewater:

Input data (planner)

- (1) PE served
- (2) Screen type (fine or coarse)

Cost function valid for (1) 250 20 000 PE (fine screen) and 100 000 PE (course screen), respectively

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

daily removal of screenings and cleaning

costs for disposal are not considered

Maintenance costs (1% of investment costs/year)

6.4 Buffer tank***Description***

A subsurface buffer tank can be used at a treatment plant for temporary storage and for lifting of wastewater with submerged pumps. This is required for discontinuous processes like sequencing batch reactors. A mixer is included to prevent sedimentation.

Design assumptions

- Electricity available on site (no additional cost considered).
- Pumps used for design and calculation are submerged pumps (Grundfos type SEG and SEV).
- Pumping head 7.5 m
- Mixing unit (jet aerator).
- Rectangular shape.
- Construction made of concrete is completely buried, cover plate is on topsoil-level
- tank depth max 3.0 m

Input data (planner)

(1) Buffer tank volume [m³]

(2) Pump flow [l/s] (for emptying buffer tank)

(3) Jet aerator (yes/no)

(4) Daily pump flow [m³/d] (inflow water)

Cost function valid for (1) max 150 m³ and (2) max 80 l/s

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

Electricity

Cleaning twice annually and maintenance works quarterly

Maintenance costs (1% civil works, 2% mechanical & electrical components)

6.5 Sequencing batch reactor (SBR)

Description

The treatment principle of sequencing batch reactors is the activated sludge process. All processes are incorporated in one single tank but at different times. This requires intermittent flow conditions. The sequence of steps is: filling, reacting, settling and drawing off the treated water. Sludge is removed periodically during the draw-off-phase. Depending on the operational stages included in the treatment process different treatment levels can be achieved with an SBR reactor:

- C-removal and Nitrification
- C-removal and N-removal
- C-removal, N-removal and aerobic sludge stabilisation

Design assumptions

- The design of the reactor size is based on standards ATV A131 (2000) and DWA-M210 (2009).
- Sludge volume index: nitrification and denitrification = 120; denitrification and extended aeration = 100
- Dry substance content at min water level (after decanting) = 5.0 kg/m³
- Cycle time: nitrification = 6 hours; denitrification = 8 hours; denitrification and extended aeration = 8 hours
- A plant consists of 1 – 4 separate SBR reactor tanks, depending on the population size.
- A storage tank for the inflowing wastewater is necessary for small units with just one reactor tank and may be required for bigger plants too.
- Volume of the storage tank = peak inflow * cycle time / no. of SBR units. → The storage tank needs to be selected as a separate technology -> see “Buffer tank (6-4)”

Input data (planner)

- (1) PE served
- (2) Treatment level (1=nitrification, 2=denitrification, 3=denitrification and extended aeration)

Cost function valid for (1) 50 to 50'000 PE

Lifespan

Civil Works 25 years

Mechanical equipment 10 years

O&M costs

energy costs

manpower operation and maintenance

Maintenance costs (1% civil works, 2% mechanical & electrical components)

Price Base

Cost assumptions for mechanical and electrical equipment are based on cost data from SBR plants implemented in Austria. They were implemented in the years 2006 to 2011. The costs are valorised (interest rate 0.03) to the year 2012. It is assumed that equipment of comparable quality will have to be imported into the countries of implementation and therefore the costs will be the same as in Austria plus additional costs for transport (10% of the price).

Equipment costs include:

- pre-treatment (fine screen)
- aeration system
- clear water draw-off
- sludge draw-off
- boarding aid, steel grating
- bringing into service of the plant
- minor laboratory devices

Electrical equipment

- control device SBR tank
- telecontrol system
- plant cabling
- potential equalization
- measurement technique
- bringing into service of electrical equipment

6.6 Anaerobic baffled reactor (ABR)

Description

An anaerobic baffled reactor (ABR) is a primary treatment unit usually applied for wastewater with BOD >150 mg/L. It consists of a settling chamber, similar to a septic tank, followed by up to 6 up-flow chambers. This setup results in a better mixing of the wastewater with the active biomass and increased degradation compared to a septic tank. Removal efficiency for COD is 65-90%.

Design assumptions

- Hydraulic retention time (HRT) = 35 h
- Max. up-flow velocity (at average flow rate) = 1.5 m/h
- Max. organic load = 3 kg BOD/m³/d

- SS/COD ratio 0,42
- No. of up-flow chambers: 5
- water depth 1.5 to 2.2 (depends on PE)
- desludging interval: 1x/year < 100 PE; 2x/year >= 100 PE
- Sludge accumulation rate 60 L/PE/a

Input data (planner)

(1) PE served

Cost function valid for (1) 10-1000 PE

Range of application

max. 1000 PE (80m³/d) per unit

Lifespan

civil works 25 years

O&M costs

control 4x/month

sludge removal: 1x/year or 2x/year – cost to be considered in sludge transport!

Maintenance costs (1% of investment costs/year)

6.7 Horizontal flow (HF) CW

Description

The horizontal flow constructed wetland is a planted filter bed for secondary or tertiary treatment. In order to operate the filter bed properly mechanical treatment of solids will be necessary in advance.

The filter medium is moderate aerated, with many anoxic zones good denitrification results can be achieved.

Design assumptions

- Maximum size for one bed is 225 m² (assuming max. length of 9 m and max. width of 25 m)
- minimal cross sectional area required for flow hydraulics
- Filter depth 0.7 m; $d_{10} = 0.3\text{mm}$; $k_f 10^{-3}$ Pumps are included. Every bed is supplied with a separate pump. This is necessary to ensure equal loading of each bed.

Input data (planner)

(1) PE served

(2) Required area [m²/PE]

Surface area = (1) * (2)

Cost function valid for surface area of 10 to 6'000 m²

Lifespan

civil works 25 years

filter material and lining 25 years

O&M costs

O&M costs consider monthly inspections and cutting of plants once a year.

Maintenance costs (1% civil works)

6.8 Vertical flow (VF) CW

Description

The vertical flow constructed wetland is a planted filter bed for secondary or tertiary treatment. In order to operate the filter bed properly mechanical pre-treatment of solids will be necessary in advance.

The filter medium is due to intermittent flushing well aerated, allowing for nitrification to take place. Systems of 2 stages of VFCW, including an anaerobic zone also achieve good denitrification results (about 70%).

Design assumptions

- Maximum size for one bed is 400 m²
- Bed length/width ratio 4:3
- Filter depth 0.9 m; ; $k_f 10^{-4}$ Feeding interval 4-6 hours; Feeding duration max 15 minutes
- VFCWs are operating intermittently, thus requiring a siphon or pump system Every bed is supplied with a separate pump or syphon.
- No pf siphons = 1; no. of pumps =2 (100% reserve)
- feeding station is made of concrete (depth pump foundation 2,6 m), coverplate is on topsoil-level
-

Input data (planner)

(1) PE served

(2) Required area [m²/PE] (influencing the level of treatment)

(3) Intermittent loading with pump / siphon

Surface area = (1) * (2)

Cost function valid for surface area of 8 to 4'000 m²

Siphon only possible for up to 400 m²

Lifespan

civil works 25 years

filter material and lining 25 years

mechanical equipment (pump, siphon) 10 years

O&M costs

O&M costs consider monthly inspections and cutting of plants once a year.

feeding station: electricity costs (if pump is used), manpower cost

Maintenance costs (1% civil works, 2% mechanical & electrical components)

6.9 Sludge drying reed bed**Description**

Sludge drying reed beds are sealed shallow ponds filled with several drainage layers. They are designed to separate solid from the liquid fraction of sludge from several sources.

Design assumptions

- Surface loading rate per year: 100 kg/m²/a
- Maximum size for one bed: 2500 m²
- Storage time of sludge in bed: 8 years; resting period of bed: 2 years
- Average sludge accumulation per year: 15 cm; height of maximum sludge level 1.2 m
- Bed length/width ratio: 3:2

Design size [m ²]	Bed configuration
5	3 x 5 m ²
20	5 x 5 m ²
50	10 x 5 m ²
100	10 x 10 m ²
250	10 x 25 m ²
500	10 x 50 m ²
1,000	10 x 100 m ²
2,500	10 x 250 m ²
5,000	10 x 500 m ²
10,000	10 x 1,000 m ²
25,000	10 x 2,500 m ²
50,000	20 x 2,500 m ²

Input data (planner)(1) Amount of sludge [m³/year]

(2) Dry substance content [%]

Cost function valid for solids load up to 4'000 tons per year

Lifespan

civil works 25 years

O&M costs

O&M costs consider regular operation and maintenance tasks and removal of stabilised sludge from drying bed every 10 years.

Maintenance costs (1% of investment costs/year)

6.10 Urine storage***Description***

Storage of urine from UDDT's is a buffer and disinfection process before further utilisation.

Design assumptions

- Storage in PE tanks with a max. capacity of 10.000 Liter
- Foundation made of concrete for the tanks
- movable access stairs
-
- suggested storage time for hygienisation: 180 d
- Emptying by vacuum truck - no pump included in design

Input data (planner)

(1) Amount of urine [m³/year]

(2) Storage period [d]

Cost function valid for total storage volume up to 1000m³

Lifespan

Tank: 10 years

civil works 25 years

O&M costs

Caretaker on site

Maintenance costs (1% of investment costs/year)

6.11 Urine treatment - Struvite production***Description***

Struvite production is a precipitation process to create a fertiliser out of urine in a safe and hygienic condition.

The process recovers about 90 % of the P, but the effluent still contains considerable amounts of N and K and can either be used for restricted irrigation or requires further treatment.

Design assumptions

- Volume of struvite is based on the PE using UDDT
- urine 500 L/PE/a
- Precipitation agent: Magnesium sulphate (1.67 kg/m³ urine), Magnesium oxide (0.59 kg/m³ urine), Bittern (2.35 kg/m³ urine)
- Reactor parameters:
 - Batch size: small = 0.23 m³
 - Batch duration: 2 h
 - Daily operation hours: 8 h
 - Maximum daily load: small = 0.92 m³
 - Working days per year: 220 days
 - Replacement filter: 6 filters per reactor per year

Input data (planner)

- (1) Amount of urine [m³/year]
- (2) Precipitation agent (Magnesium sulphate, Magnesium oxide, Bittern)

Cost function valid for (1) max. 25'000 m³/year

Lifespan

Reactors and pumps: 10 years

Baseplate: 25 years

O&M costs

Salary for operational staff

Precipitation agent cost

replacement of the filter every 2 months

Maintenance costs (1% civil works, 2% mechanical & electrical components)

6.12 Composting

Description

The composting plant is designed to process municipal organic waste, faeces of dry toilets and sludge from wastewater treatment plants in order to produce marketable compost.

The composting plant uses a windrow system and includes areas for active composting, curing, storage and required facilities dependent on the plant size. In addition a runoff pond is considered to collect rainfall.

Depending on the capacity of the plant processing machinery and equipment is considered in the design.

Design assumptions

- Addition of bulking material to faeces: 100 %
- TS content of dewatered sewage sludge: 22 %
- Purchase of additional bulking material for sewage sludge: 66 %

Composting windrows

- Active composting phase: 6 weeks
- Windrow width: 2 – 4 m
- Windrow height: 0.9 – 2.4 m

Curing piles:

- Volume shrinkage after composting: 50 %
- Time required for curing: 4 weeks
- Curing pile height: 1.3 – 3 m
- Curing pile width: 3 – 6 m

Compost storage area:

- Storage time: 9 weeks
- Pile height: 1.5 – 3.5 m

Runoff collection pond

- Six month rain in the worst 25 year: 300 mm
- Runoff on hard surface: 85 %
- Runoff on windrows and other piles: 50 %
- Depth of runoff basin: 3 m

Additional facilities

- Size for additional facilities: 10 – 50 % of total area (depending on size)

Needed machinery:

- Weigh bridge, Processing machinery (such as rotary screens with conveyor belts)
Tractor Front end loader for tractor Windrow turner small (up to 1.6 m height),
Windrow turner self propelled (up to 2.1 m height),

Input data (planner)

- (1) Faeces from single-vault UDDTs [m³/year]
- (2) Dewatered sludge from WWTP (TS=20%)[m³/year]
- (3) Other biosolids [m³/year]
- (4) Price of bulking material [EUR/m³]

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

staff dependent of the size of the site

electricity - 5 % of the machinery investment cost

fuel - 5 % of the machinery investment costs

repair costs - 2 % of the machinery investment costs

civil works – 1 % of the investment costs

costs for bulking material to be mixed with dewatered sewage sludge at a volumetric ratio of 2 : 3 and 1 : 1, respectively

6.13 Waste stabilisation pond

Description

Waste stabilisation ponds (WSP's) are constructed ponds for wastewater treatment. In a WSP system different types of ponds are combined. Anaerobic ponds are deep ponds, highly loaded and provide space for sludge storage. Facultative ponds are less deep and receive oxygen input from the surface and from algae photosynthesis. Maturation ponds are shallow and their main function is pathogen reduction (by 3-5 log).

Design assumptions

- COD removal 80%
- sequence of anaerobic ponds, facultative ponds and 2 maturation ponds
- At a population size <9,000 a sequence of 1 anaerobic pond, 1 facultative pond is used, at a population size >9,000 2 anaerobic and 2 facultative ponds are used in parallel. At a population size > 90,000 3 anaerobic ponds are used in parallel.
- For the anaerobic pond the required volume is determined by the maximum organic loading rate (kg BOD₅/m³/d), calculated according to von Sperling (2005).
- For the facultative pond the surface loading rate (kg BOD / ha/d) is the determining factor. It is calculated according to Mara (1997).
- For the maturation pond the maximum surface loading rate is assumed as 75% of the surface loading rate of the facultative pond as a design value (Mara, 1997).
- HRT. 4, 40, and 3 days for anaerobic, facultative and maturation ponds, respectively.
- Sludge production: $2.1 * X_{ss} / 1000$ assuming $X_{ss} = 70 \text{g/pe/d}$
- pond depth (m) 4-5 m

Input data (planner)

- (1) PE served
- (2) Average temperature of coldest month (> 10°C, > 15°C, > 20°C)

Cost function valid for (1) 200 - 100'000 PE

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

- O&M costs include:
 - Daily inspection

- Regular maintenance tasks (cleaning of embankments, scum removal)
- Annual de-sludging of the anaerobic ponds (manpower and energy costs)
- Repair costs of the de-sludging pump
- Sludge is removed by pumping using a raft mounted sludge pump. The sludge has a TS content of about 2 %. Pumping costs are included in the costs calculation, however the treatment of the sludge has to be considered separately, e.g. in sludge drying beds.
- civil works – 1 % of the investment costs

6.14 Upflow anaerobic sludge blanket (UASB) reactor

Description

Upflow anaerobic sludge blanket reactors (UASB) are a treatment technology for wastewater with high organic load. The wastewater enters the reactor at the bottom and flows upwards through a sludge blanket. The flow rate must be regulated according to fluctuations of the organic loading. At the top of the reactor deflectors are installed to separate the rising biogas from solid and liquid phase. The biogas may be used.

Design assumptions

- min. hydraulic retention time (HRT) = 5 h
- min. sludge retention time (SRT) = minimum 50 d
- average upflow velocity = 0.5 m/h
- max. upflow velocity = 1.2 m/h
- max. organic load = 15 kg COD/m³/d
- construction above ground level (max. water level 6 m above ground level)
-

Input data (planner)

(1) PE served

Cost function valid for (1) 200 to 100'000 PE

Lifespan

civil works 25 years

pipes, mechanical equipment 10 years

O&M costs

daily monitoring and operation tasks

regular sludge removal

Maintenance costs (1% of investment costs/year)

6.15 Phosphorus-Precipitation

Description

For phosphorus removal a precipitation agent is mixed with the wastewater prior to the main treatment unit, causing a precipitation of phosphorus. The technology includes a storage tank for the agent, and a dosing station. Total sludge production is increased.

Design assumptions

- Beta-value [mol active agent/mol P]: 1.5
- FeCl₃: content of active substance - 13.7%; density: 1.42 kg/L
- [Al(OH)₃·Cl_x]_n: content of active substance - 8%; density: 1.3 kg/L

Input data (planner)

- (1) PE served
- (2) Effluent concentration [mg PO₄-P/L]
- (3) Precipitation agent (Fe or Al based, i.e. Alum (Al₂O₃) or Fe(III)Cl)

Cost function valid for (1) max 50'000 PE

Lifespan

10 years

O&M costs

electricity cost

cost of dosing agent

regular monitoring of P-level and maintenance tasks

increased sludge production has to be considered in sludge transport

Maintenance costs (1% civil works, 2% mechanical & electrical components)

6.16 Mechanical sludge dewatering (Belt filter press)

Description

The belt filter press is a technology for a continuous mechanical sludge dewatering. It is applied at medium to big treatment plants. The dewatering process can achieve a cake with total solids (TS) content of about 22%. If unstabilised sludge is used as input, the cake has to be further processed before disposal / reuse.

Design assumptions

- The belt filter press setup consists of these components: polymer mixing unit, belt filter press, flush water pump, compressor, polymer dosing station, electronic control station., effluent recirculation pump
- 8 h daily operation time

- The dimensions of the machine are determined by the sludge flow only, not by TS content

Conditioner consumption determined by the sludge type. These assumptions are made:

- 3 kg of polymer / t TS of anaerobically digested primary + activated sludge
- 4 kg of polymer / t TS of raw primary + activated sludge
- 5 kg of polymer / t TS of aerobically stabilised primary + activated sludge

The Belt filter press has to be installed indoors. Costs for a roof structure are not included. If no building is available on site additional costs have to be considered. Space required: approx. 8 m x 6 m.

Input data (planner)

- (1) Sludge volume [m³/d];
- (2) TS content [%];
- (3) Sludge origin ... (unstabilised, aerobically stabilised, anaerobically stabilised)

Cost function valid for (1) 30 to 175 m³/d and (2) TS < 6 %

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

Inspection, cleaning and maintenance - 1 h/d for all design sizes

Electricity cost

Conditioner consumption determined by the sludge type. Water demand for belt washing

Water demand for polymer mixing to achieve 0.1% concentration

Annual spare parts cost is 1.5 % of the initial equipment cost

civil works – 1 % of the investment costs

Price Base

Investment costs include installation cost and 10 % surcharge for transport

6.17 Sludge thickener

Description

A sludge thickener is used for pre-dewatering of mainly secondary sludge coming from an activated sludge plant (SBR) by reducing water content of the sludge. Primary aim of reducing the water content is to operate further sludge dewatering (e.g. belt filter press, sludge drying reed bed) in a feasible and economically way.

The supernatant water has to be treated in an appropriate treatment plant (i.e. usually recycled to the main treatment unit).

Design assumptions

- Circular tank equipped with agitator and sludge scraper
- overflow rate $q_A < 1.5$ m/h (for a daily loading time of 3.6 h)
- sedimentation zone height: 1 m
- consolidation zone height h_s : about 2 m (depending on sludge type)
- TS inflow sludge = 1.1%
- TS dewatered sludge = 4.0 %

Input data (planner)

(1) Sludge volume [m³/d]

Cost function valid for (1) min 20 m³ /d; max. 1000 m³/d

Lifespan

civil works 25 years

mechanical equipment 10 years

O&M costs

Inspection, cleaning and maintenance - 1 h/d for all design sizes

Electricity cost

civil works (1% of investment cost)

7.1 Struvite use

Description

Struvite is produced from urine and can be used as fertilizer.

(Design) Assumptions

- Volume of struvite is based on the PE using UDDT.
- Price of Struvite depends on used precipitation agent: Magnesium sulphate, Magnesium oxide, Bittern.
- The customers are responsible for the transport of the material bought.

Input data (planner)

- (1) Amount of struvite [kg/d]
- (2) Market price struvite [EUR/kg]

Comments

The available amounts of precipitation agent resources (magnesium sulphate, magnesium oxide, and bittern) might vary in different countries.

7.2 Compost use

Description

Composting products can be used as soil amendment and fertilizer source.

(Design) Assumptions

- Volume of composting material is based on collected biowaste and sludge.
- The customers are responsible for the transport of the material bought.

Input data (planner)

- (1) Amount of compost [kg/d]
- (2) Market price compost [EUR/kg]

7.3 Irrigation water

Description

Treated wastewater can be used for irrigation.

(Design) Assumptions

- The volume of water is based on PE connected to different waste water treatment plants.
- Storage is needed if discontinuous irrigation is used.
- Price – ex factory

Input data (planner)

- (1) Amount of irrigation water [m³/d]
- (2) Market price irrigation water [EUR/m³]

7.4 Urine use***Description***

Urine is used after storage as fertilizer.

(Design) Assumptions

- Volume of urine is based on the PE using UDDT.
- The customers are responsible for the transport of the urine to the fields

Input data (planner)

- (1) Amount of urine [m³/d]
- (2) Market price urine [EUR/m³]

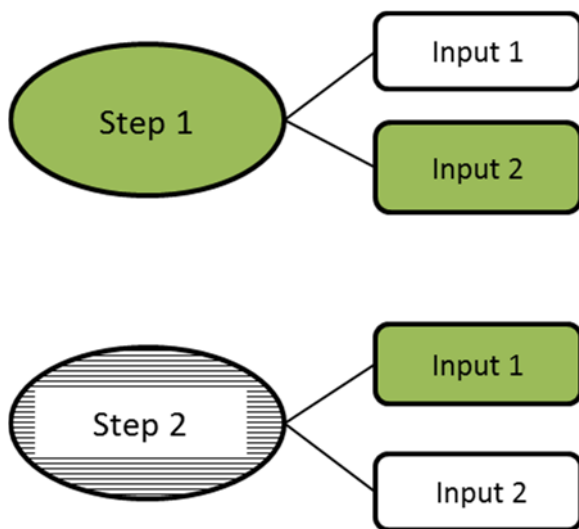
APPENDIX 2 - TECHNOLOGY COMBINATIONS FOR WASTE COLLECTION AND TREATMENT FUNCTIONAL GROUPS

Explanation on how to use

Appendix 2 is meant as a help for the setting of input parameters for the most common system for waste collection and –treatment.

The steps necessary for each system are depicted in ellipsoid shapes and allocated a pattern each. The input parameters for each step are depicted in rectangular shapes. Input parameters are given the same pattern as the step, which parameters determining them, are defined in. Input parameters that have no colour (white) can be chosen independently

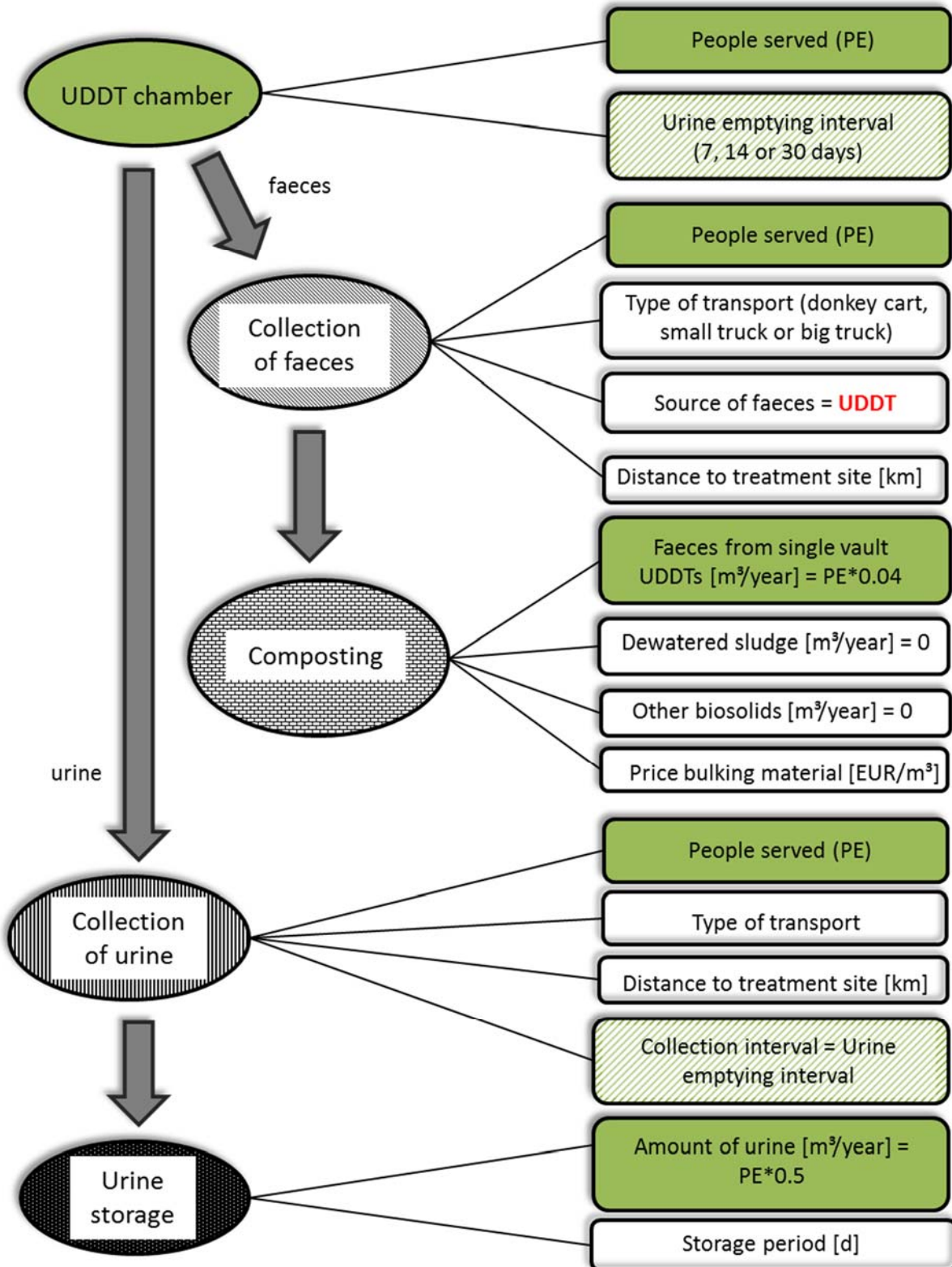
Example:

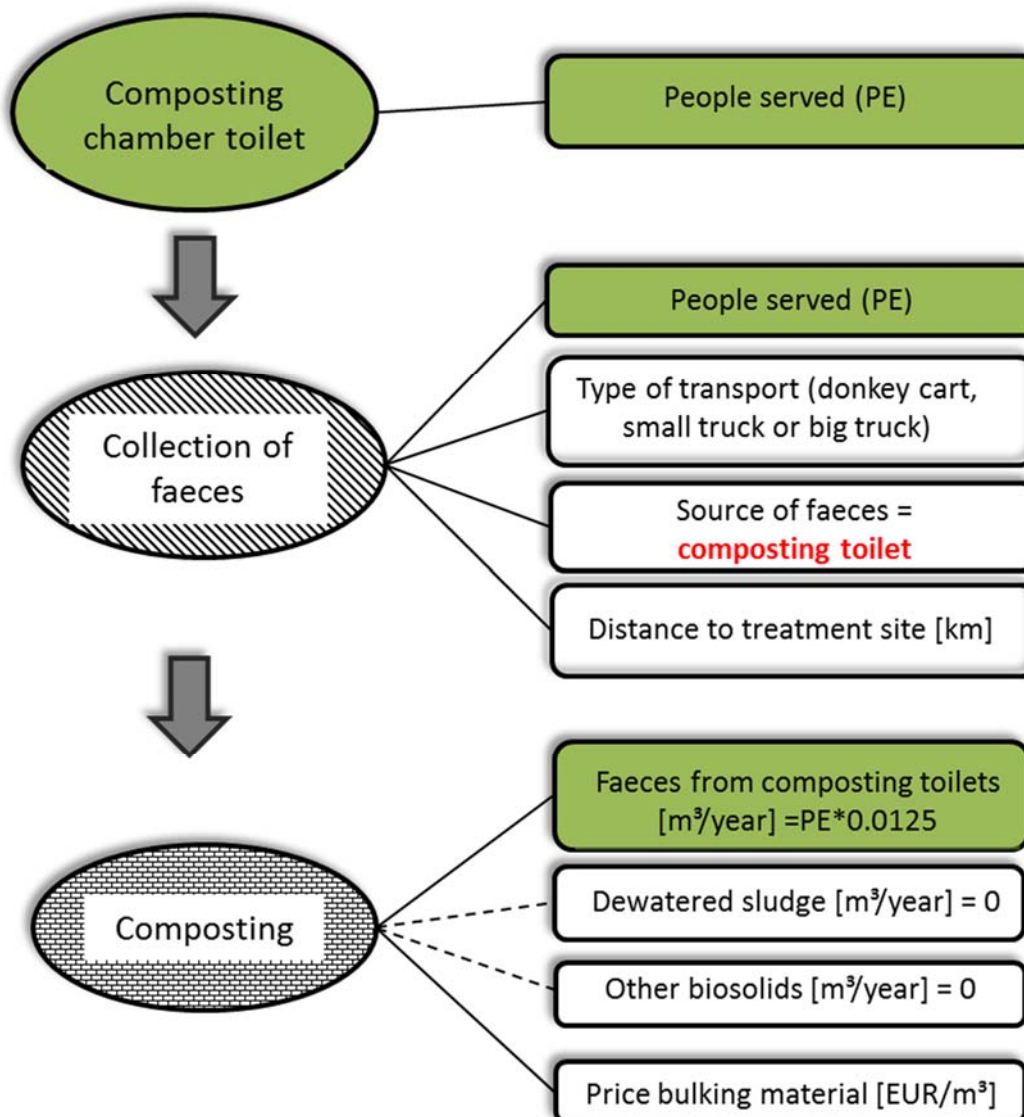


In this example Input 1 of step 2 is dependent on Input 2 of step 1. Input 1 of step 1 and Input 2 of step 2 are independent parameters

Dry sanitation alternatives

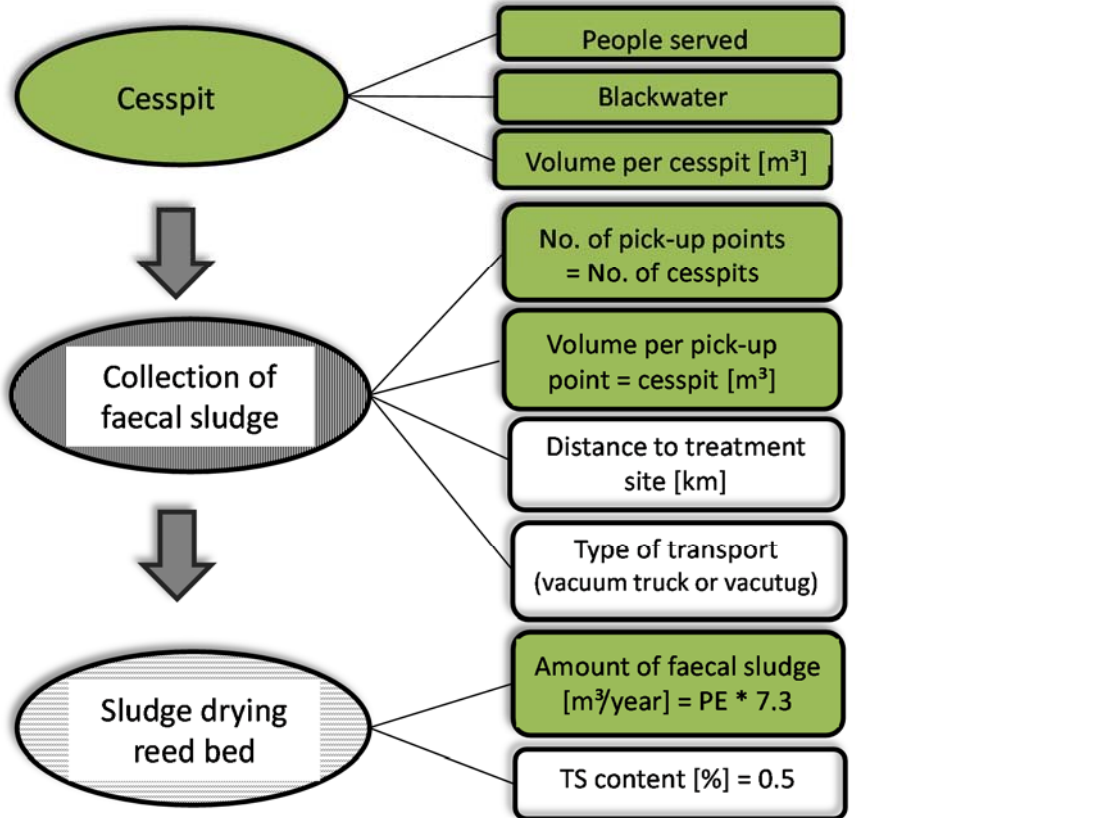
A) with UDDTs



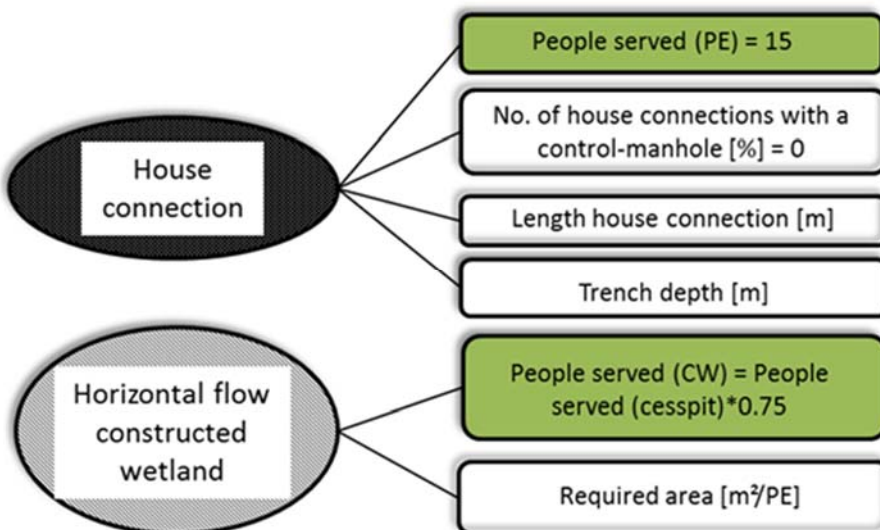
B) with composting toilet

Water-borne sanitation alternatives

C) Cesspits for blackwater, faecal sludge treated with sludge drying reed bed and treatment of greywater with HF CWs



Greywater treatment for 1 cesspit (e.g. for 20 persons)

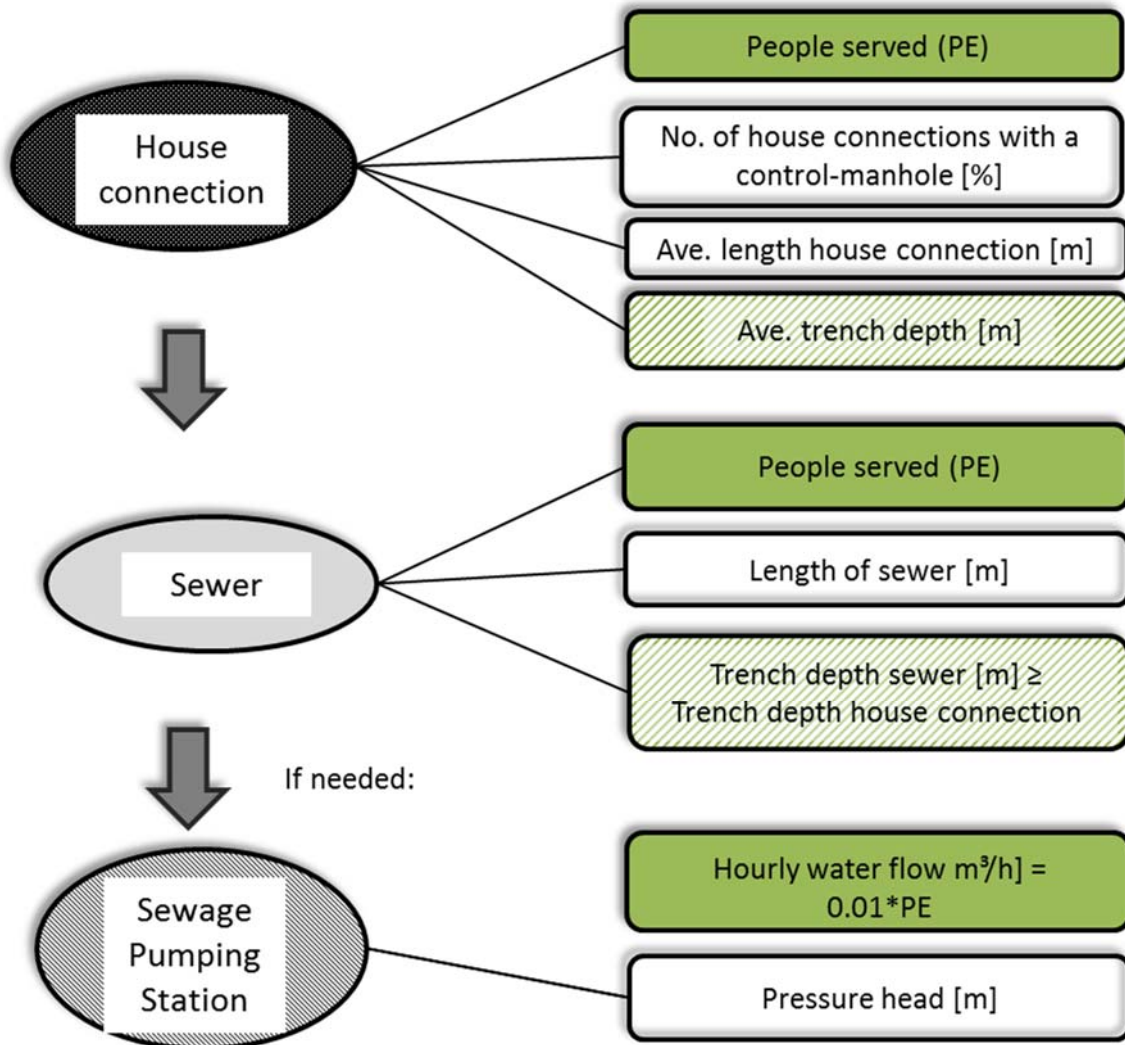


Amount of faecal sludge (cesspit) = PE * 20 L/PE/d * 10⁻³ * 365 = PE * 7.3 m³/year

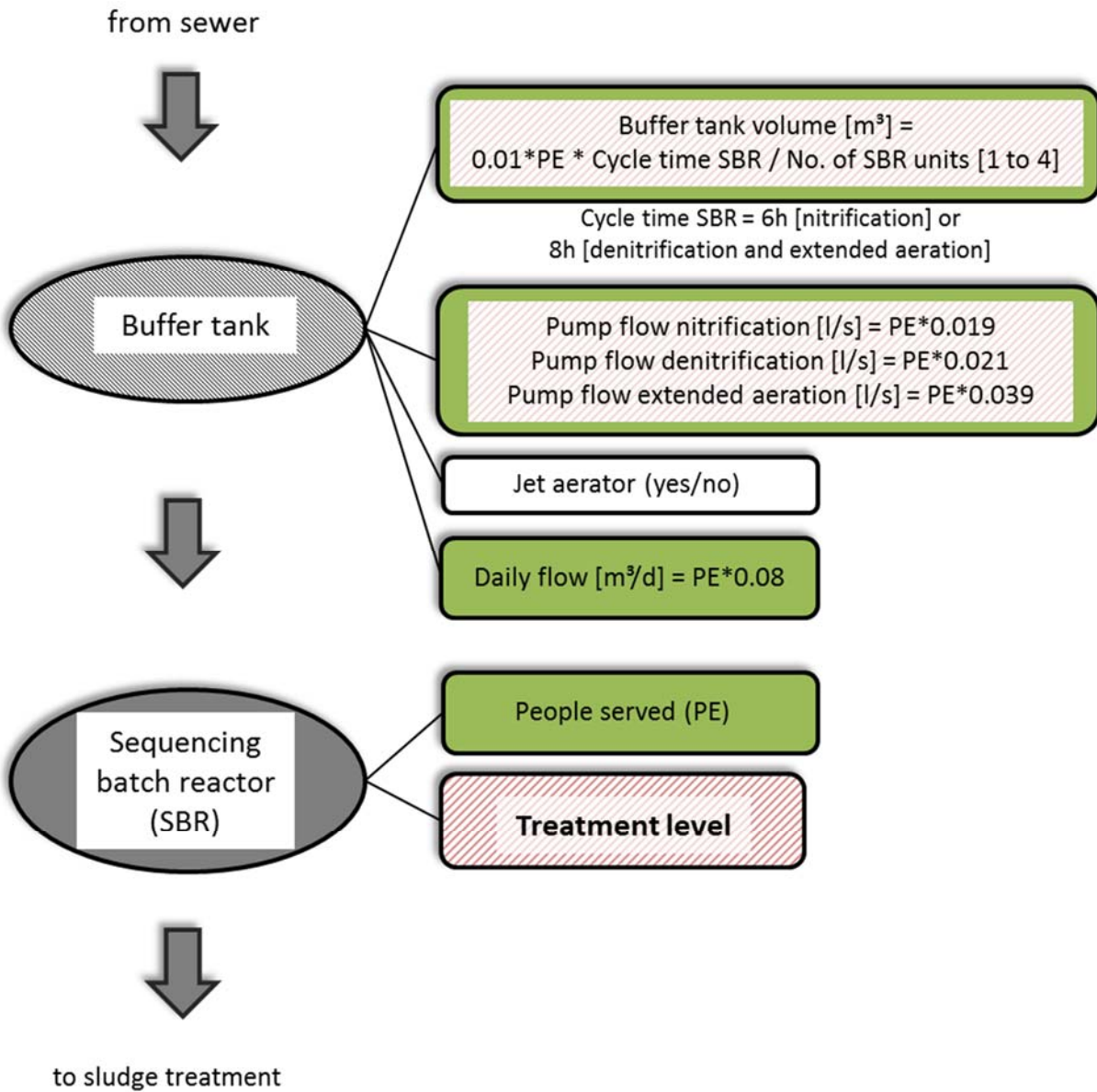
Greywater = Wastewater - Blackwater = 80 L/PE/d - 20 L/PE/d = 60 L/PE/d

PE served (CW) = People served (cesspit) * 60 L/PE/d / 80 L/PE/d

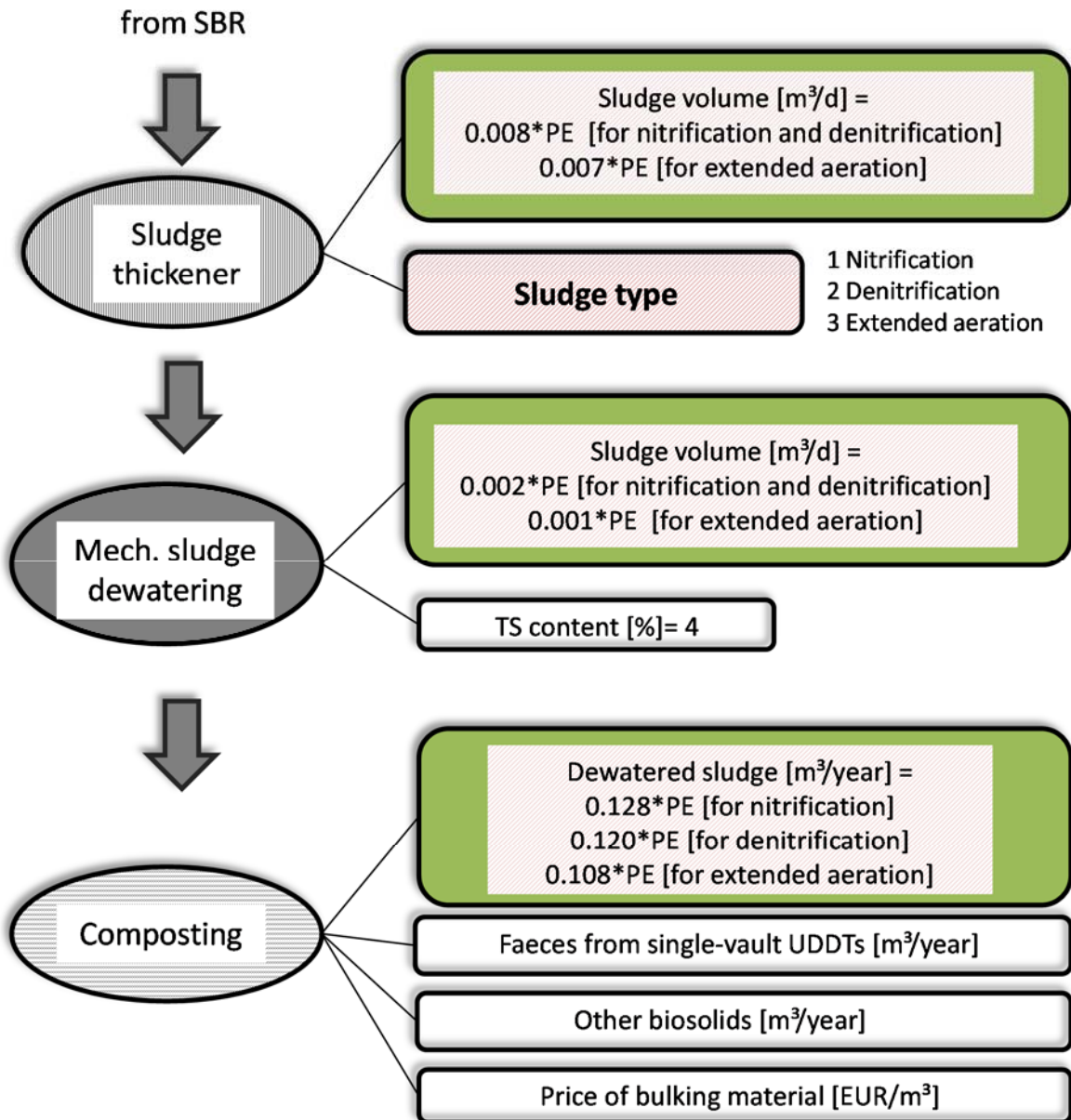
D) Sewer



E) Wastewater treatment with SBR (without P-elimination) and sludge treatment

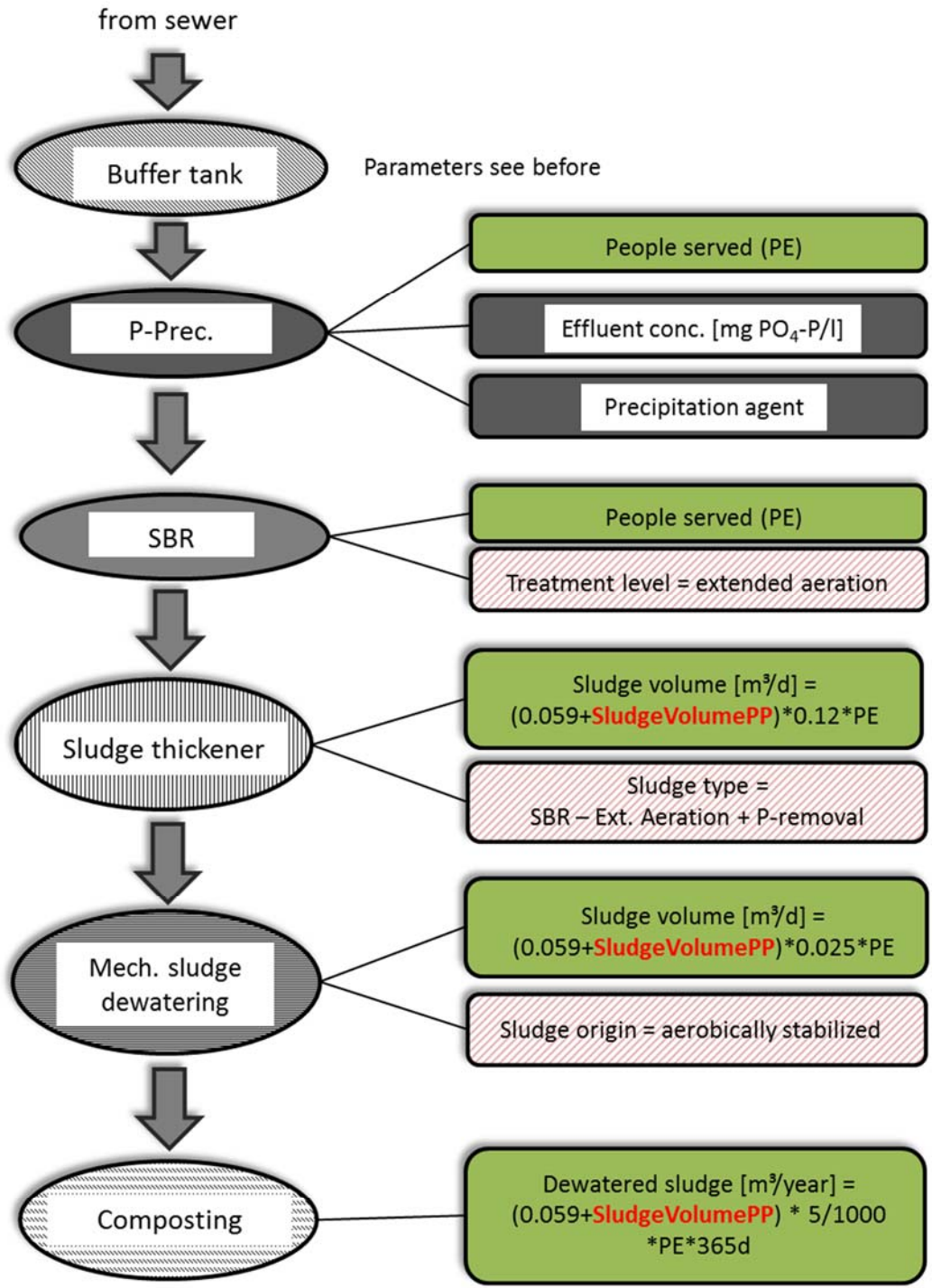


Pump flow [l/s]	Nitrification:	$PE * 100 \text{ L} * 0.4/0.6 \text{ h} * 3600 \text{ s} = PE * 0.019$
	Denitrification:	$PE * 150 \text{ L} * 0.4/0.8 \text{ h} * 3600 \text{ s} = PE * 0.021$
	Extended aeration:	$PE * 280 \text{ L} * 0.4/0.8 \text{ h} * 3600 \text{ s} = PE * 0.039$



Sludge thickener:	volume	sludge	Nitrification:	$0.070 * 120 * 10^{-3} * PE = 0.008 * PE$
			Denitrification:	$0.066 * 120 * 10^{-3} * PE = 0.008 * PE$
			Extended aeration:	$0.059 * 120 * 10^{-3} * PE = 0.008 * PE$
Mechanical sludge dewatering:			Nitrification:	$0.070 * 25 * 10^{-3} * PE$
			Denitrification:	$0.066 * 25 * 10^{-3} * PE$
			Extended aeration:	$0.059 * 25 * 10^{-3} * PE$
Composting:			Nitrification:	$0.070 * 5 * 10^{-3} * PE * 365d$
			Denitrification:	$0.066 * 5 * 10^{-3} * PE * 365d$
			Extended aeration:	$0.059 * 5 * 10^{-3} * PE * 365d$

F) Wastewater treatment with SBR with P-elimination and sludge treatment

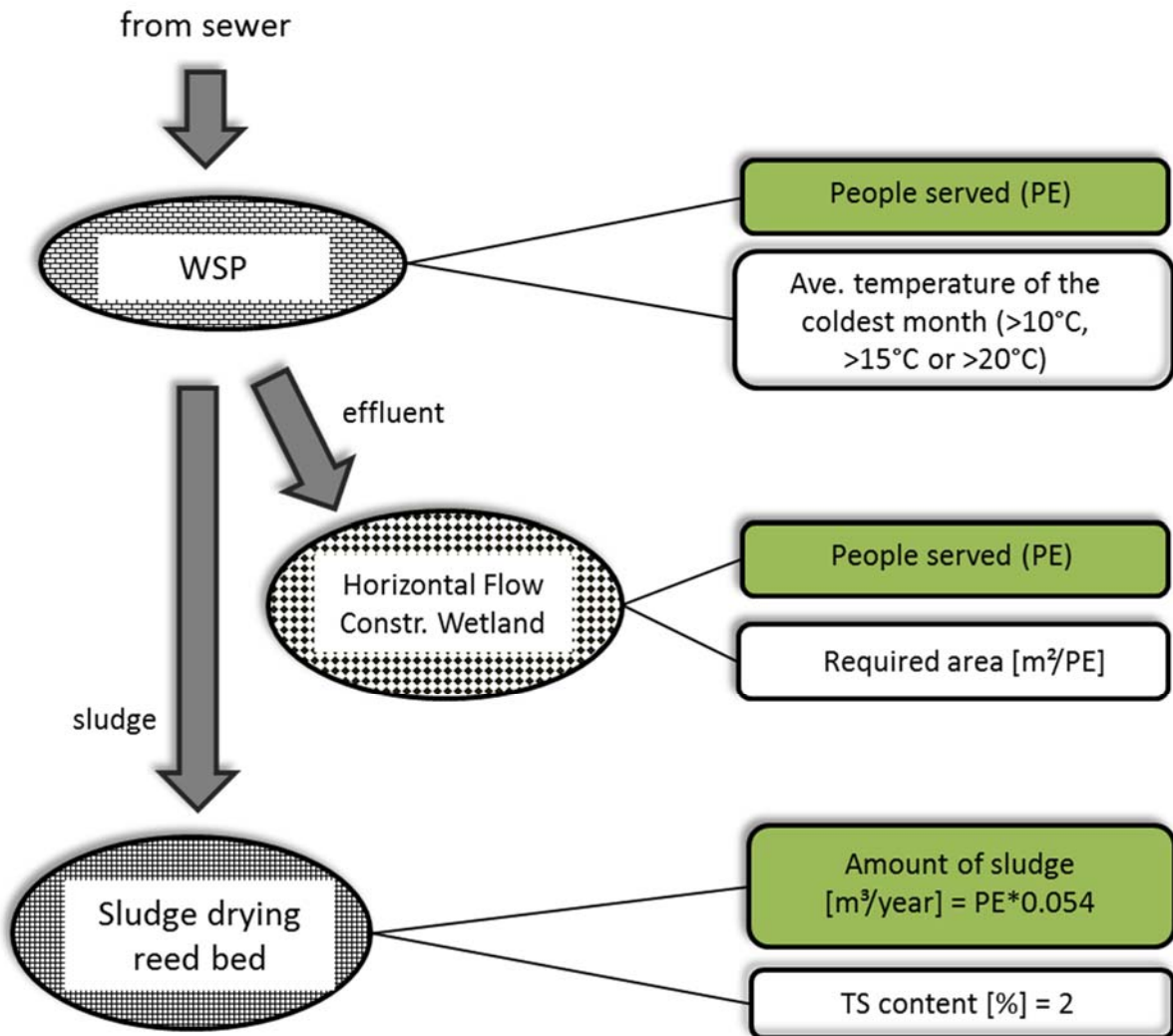


SludgeVolumePP [kg TS/(d.PE)] =

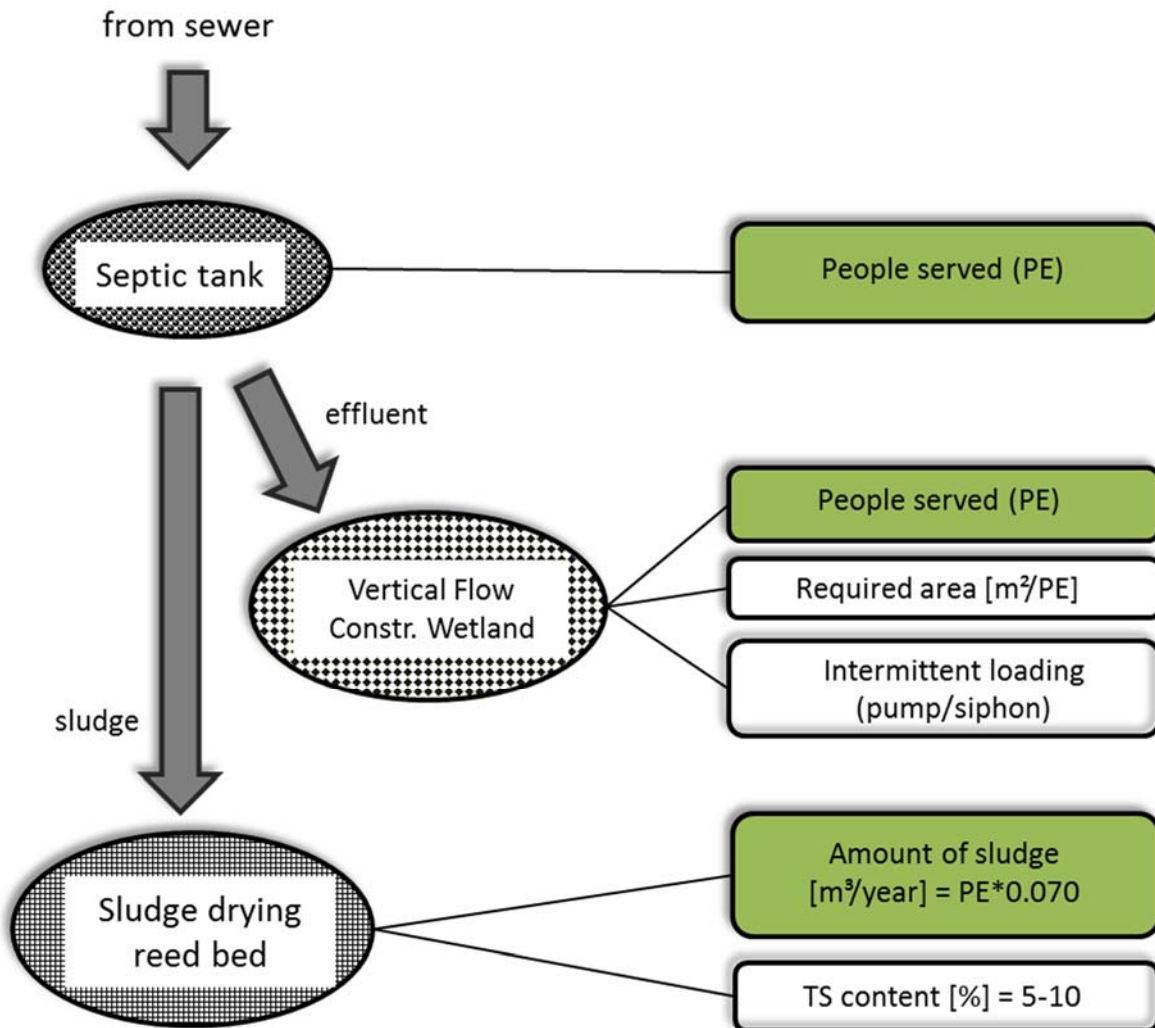
0.08/1000*(0.0025-effl. conc.*0.08)*2.7*2.5 = 0.0005*(0.0025-effl. conc.) [for Fe]

0.08/1000*(0.0025-effl. conc.*0.08)*1.3*4 = 0.0004*(0.0025-effl. conc.) [for Al]

G) Wastewater treatment with WSP and HF CW for C elimination



H) Wastewater treatment with VF CW for nitrification



If primary sludge from septic tanks is collected and treated in a larger Sludge drying reed bed:

Collection of sludge from septic tanks:

Input parameters related to septic tank:

- No. of septic tanks
- Volume per septic tank [m³] = 0.15 * PE (size of septic tank)



Capacity-Linked water and sanitation
for Africa's peri-urban and Rural Areas

More information: <http://clara.boku.ac.at/>