

MADFORWATER
**Development AND application of integrated technological and management solutions FOR
wasteWATER treatment and efficient reuse in agriculture tailored to the needs of
Mediterranean African Countries**

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Contents

1	Introduction	5
2	Decision Support Tools (DST) from Madforwater Project.....	5
2.1	- Decision Support Tool for Water Reuse- Poseidon 2.0	5
2.1.1	<i>Where to find it?.....</i>	5
2.1.2	<i>DST Description</i>	5
2.1.3	<i>Specific aspects to be considered in the application of the DST to a new MENA country.....</i>	9
2.2	DST for water reuse and water & land management in agriculture	10
2.2.1	<i>Where to find it?.....</i>	10
2.2.2	<i>DST Description</i>	11
2.2.3	<i>Specific aspects to be considered in the application of the DST to a new MENA country.....</i>	14
3	References	14
3.1	Poseidon 2.0.....	14
3.2	DST for water reuse and water & land management in agriculture	15
4	Appendix I – Handbook: Poseidon 2.0 – A tool to Promote and Assess Water Reuse	17
4.1	Preface.....	1
4.2	Introduction.....	1
4.3	Basic mode	2
4.3.1	<i>Welcome.....</i>	3
4.3.2	<i>Learn.....</i>	4
4.3.3	<i>Water quality – Inflow.....</i>	5
4.3.4	<i>Water treatment cost entry.....</i>	5
4.3.5	<i>Water quality – Outflow.....</i>	6
4.3.6	<i>Distribution and storage costs.....</i>	7
4.3.7	<i>Calculation and Assessment Algorithm (Informative).....</i>	7
4.3.8	<i>Elimination, Ranking and Assessment Process.....</i>	9
1.1	Understanding the Results	11
4.3.9	<i>Summary</i>	13
4.4	Typical Example – Two Potential Water Reuse Scenarios for Untreated Wastewater from a City	15
4.4.1	<i>Suggested Procedure.....</i>	15
4.4.2	<i>Suggested Procedure – Analyze the Results</i>	18
4.4.3	<i>Questions & Answers.....</i>	20
4.5	Conclusions.....	21
4.6	Glossary	22

4.7	References of this Appendix.....	23
5	Appendix II – Handbook: DST for water reuse and water & land management in agriculture	24
5.1	DST components.....	24
5.2	Model	26

List of Figures

Figure 1: Principle of Poseidon 2.0.....	6
Figure 2: Main objectives of Poseidon 2.0.....	7
Figure 1: Excel Macro Security Warning Message.	1
Figure 2: Principle of Poseidon 2.0.....	2
Figure 3: Main objectives.....	3
Figure 4: Welcome.	4
Figure 5: Learn	4
Figure 6: Water quality - Inflow	5
Figure 7: Water treatment cost entry.	6
Figure 8: Water quality - Outflow.	6
Figure 9: Distribution and storage costs.	7
Figure 10: Soil treatment USA: example of a treatment train composed of 7 unit processes.....	8
Figure 11: Weight the relative importance of different parameters in order to calculate an overall treatment train score.	9
Figure 12: Assessment algorithm proposed by the stage II assessment.....	9
Figure 13: Analyze solutions.	10
Figure 14: Example 1 of results sheet.	11
Figure 15: Example 2 of results sheet.	12
Figure 16: Results for all treatment trains displayed in a table.	13
Figure 17: Summary of all scenarios considered.....	14
Figure 18: Visualization of example task.....	15
Figure 19: Starting point.	16
Figure 20: Water quality and quantity input.....	16
Figure 21: Cost entry.....	16
Figure 22: Water quality outflow entry.....	17
Figure 23: Distribution and storage cost entry.	18
Figure 24: Analyze solutions.	18
Figure 25: Table with results.....	19
Figure 26: PESTLE analysis simplified results.	19

List of Tables

Table 1: Input parameters required in Poseidon 2.0	8
Table 2: Output parameter specification in Poseidon 2.0	8
Table 3: Integrated agro-economic model: Initial parameters	30
Table 4: Integrated agro-economic model: results.....	31

1 Introduction

This deliverable provides the description and the user guides for two Decision Support Tools (DSTs) relative to wastewater management and water & land management in agriculture, developed in the MADFORWATER project. The actual software and codes relative to these two DSTs have been deposited in open access repositories, and the corresponding links are reported in this deliverable.

The first DST (Poseidon 2.0) compares different water-reuse options and it shows decision makers implementable solutions for wastewater treatment which comply with local requirements. It was developed in the framework of Task 5.2 of MADFORWATER - Strategies and economic instruments for WW management. Section 2.1 describes the DST and provides the links where it can be downloaded. A dedicated handbook explaining how to use the DST is included in [Appendix I](#).

The second DST is an integrated agro-economic model developed in Tasks 3.3 and 5.3, aimed at integrating water reuse and irrigation technologies (developed, tested and implemented in the MADFORWATER project) with economic instruments into basin-scale strategies to enhance the use of treated wastewater. Section 2.2 describes this DST and provides the links where it can be downloaded. A dedicated handbook explaining how to use the DST is included in [Appendix II](#).

2 Decision Support Tools (DST) from Madforwater Project

2.1 - Decision Support Tool for Water Reuse- Poseidon 2.0

This sections present the first DST (i.e., Poseidon 2.0), which compares different water-reuse options and shows decision makers implementable solutions which comply with local requirements. It was developed in task 5.2 - Strategies and economic instruments for WW management. In addition, a dedicated handbook explaining how to use the DST is included in [Appendix I](#).

2.1.1 Where to find it?

The open access DST “Poseidon 2.0” and its corresponding handbook is freely available to any interested stakeholder on the [Zenodo Repository](#):

Oertlé, Emmanuel. (2020). Poseidon 2.0 - Decision Support Tool for Water Reuse (Microsoft Excel) and Handbook (Version 2.0) [Data set]. Zenodo. <http://doi.org/10.5281/zenodo.3755380>

2.1.2 DST Description

Poseidon 2.0 itself is a user-oriented, simple and efficient Excel-Tool. It compares different wastewater treatment techniques, considering their removal efficiencies, their lifecycle treatment costs, and additional assessment criteria. From the different wastewater treatment techniques, the background of the different technologies related to water reuse and the underlying theory are explained. The additional assessment criteria include national thematic subjects related to water reuse in the form of a multi-criteria analysis called PESTLE (political, economic, social, technological, legal and environmental). These indicators collectively

provide an indicative general understanding of the current situation of water reuse in selected countries.

Poseidon 2.0's scope is a pre- feasibility study before more detailed investigation in order to assess possible water-reuse options. The results show decision makers and other stakeholders that implementable solutions are available which comply with local requirements, as shown in Figure 1.

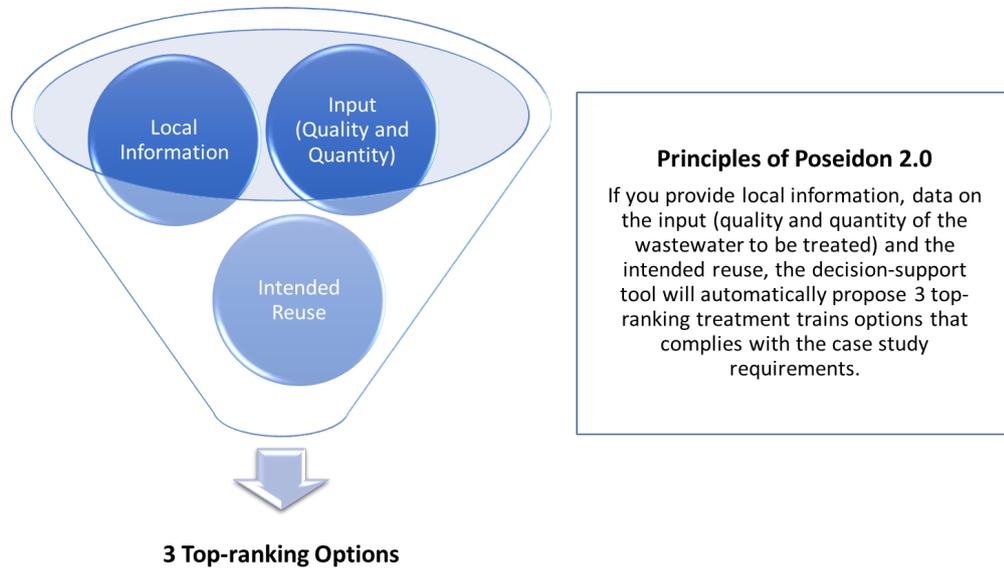


Figure 1: Principle of Poseidon 2.0

In Poseidon 2.0, the user is guided through all necessary steps to obtain first indicative results for a case-specific water treatment strategy. Figure 2 describes the main objectives and steps of Poseidon 2.0 to analyse which treatment trains would comply with the user's own situation.

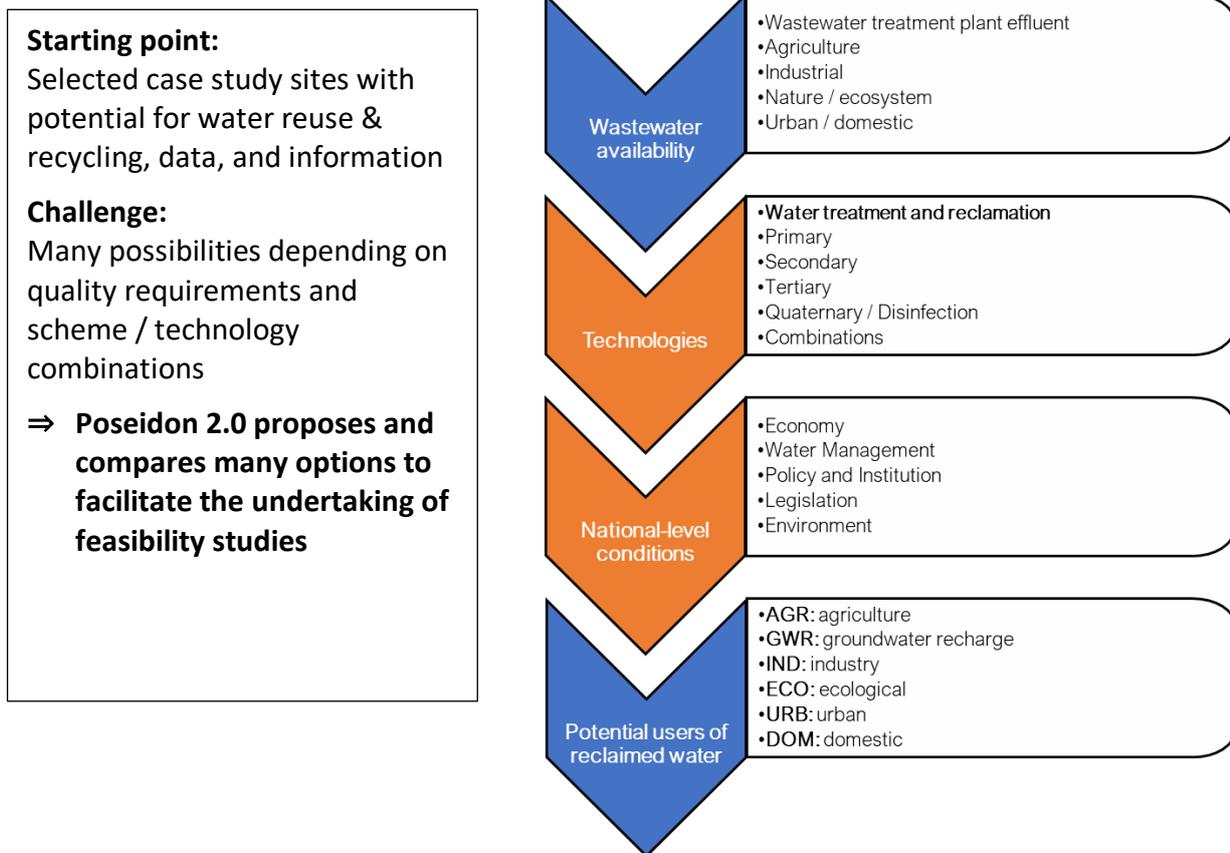


Figure 2: Main objectives of Poseidon 2.0

The tool's general steps are shortly described in the following section:

- (1) *“Welcome”* is the first sheet of the Excel-Tool, where you can find a first structural timeline overview. There are two fields to be filled out, (a) your country of origin and (b) the currency to be applied for cost purposes.
- (2) *“Learn”* about Poseidon 2.0 by using a dropdown list. The essential definitions and terms about wastewater treatment and reuse are provided in this section. You will find a selection of different questions about the tool and some abbreviations you might not be

familiar with. By selecting one of the questions, the tool will automatically give you the answer in form of a picture or chart, together with a short description.

- (3) “*Input parameters*” The Excel Tool consists of two data input sheets, where the user can enter case-specific relevant data. Table 1 summarizes the input data that can be entered.

Table 1: Input parameters required in Poseidon 2.0

Entry data sheet	Data entry / selection
WQ – Inflow	Selection of a water inflow quality according to Poseidon 2.0 proposed water quality class catalogue from several references (USEPA, WHO, national regulations, etc.). Alternatively, the user can also enter own water inflow parameter to adapt them to local conditions.
WQ – Inflow	Selection of the wastewater inflow quantity . The user has to choose one of the following three wastewater inflow quantity options: (a) Peak flow [m ³ /h] (b) Average flow [m ³ /d] (c) Serviced population [people]
Water treatment cost entry	The cost data used were compiled from various sources. These only represent country-specific average values. You are therefore given the opportunity to personalize the costs, since local costs can vary greatly depending on the site.

- (4) The Excel-Tool is versatile and can be used for up to three different end-uses. The only required data regarding the water quality outflow are as follows (see Table 2).

Table 2: Output parameter specification in Poseidon 2.0

Entry data sheet	Data entry / selection
WQ – Outflow	Model personalization: The user can specify up to three different end-uses.
WQ – Outflow	Selection of the water outflow quality for each end-user and the corresponding water quality class (regulation) to be applied.
WQ – Outflow	Specifying the price at which the reused water can be sold to the intended end-user (water tariff).
D&S costs (distribution and storage)	The user can define the specific quantity to be delivered to each end-user.
D&S costs	The user can specify the length of the pipes required and the elevation to calculate the pumping costs.
D&S costs	Additionally, the user can specify the need of a water or wastewater storage facility .
Weighting parameters	This sheet is intended to give the users the opportunity to not only include treatment trains identified only based on meeting quality requirements of available reuse applications. The user has the possibility to add qualitative options adapted to local environmental, economic, and social conditions by assigning weights to predefined evaluation parameters.

Based on the input data in point 3, the Excel-Tool will calculate the performance, cost, and other assessment criteria for all the treatment trains included in the system and

proposes three top-ranked options according to a varied selection and assessment methods.

(5) Finally, the user either selects the three top-ranked solutions based on the treatment costs or the three top-ranked solutions based on the weights assigned in the “*weighting parameters*” sheet. The displayed “*result sheets*” are then divided in two sections. The first section on the left side covers the following:

1. The data input is recapitulated (input quality and quantity, output quality, and distribution).
2. The three top-ranked wastewater treatment technology options that comply with the desired outflow quality are displayed in three colors (red, blue, green). For each option, the name of the treatment train is displayed. The additional information on the treatment trains and the process units included can be accessed through the two grey buttons below the three options.
3. If a user wants to compare the three top-ranked options, it can be done right next to the three top-ranked options. A treatment train can be selected from the dropdown list to see the cost figures attributed to the selected treatment train.
4. In addition, some results are presented in an additional sheet that can be accessed by selecting the red bottom below the three options.
5. The overall score results of the three best-ranked options are presented in a table form at the bottom of the sheet. The user can access them by selecting the grey button.

The second section on the right side covers the PESTLE results. The following results are displayed:

1. In this step the user sees the results from the PESTLE analysis (political, economic, social, water management, legislation, and environment) that covered national thematic subjects related to water reuse. They were developed for the MADFORWATER project countries: Egypt, Tunisia, and Morocco. Therefore, the results are an indication of national-level conditions if the user’s case is from a similar country. On the left side the thematic subjects are depicted, followed by key questions. These are underpinned by (semi)quantitative indicators. On the very right side are the results displayed, which were normalized to a scoring between 1 (orange; lower ranked), 2 (yellow; moderate ranked), and 3 (green; higher ranked). The detailed results were aggregated to provide an overall statement of each thematic subject. For knowing more about the methodology used to derive these results, please see the MADFORWATER project report D5.2.
 2. In addition, a red button at the very right top takes the users to the detailed calculations of the PESTLE analysis.
- (6) The very last sheet of the Excel-Tool figures as a “*summary*” sheet of all scenarios considered, including the treatment trains suggested, the costs attributed to the proposed treatment trains, and suggested measures according to the PESTLE analysis.

2.1.3 Specific aspects to be considered in the application of the DST to a new MENA country

The first version of Poseidon has been developed for the Latin-American context. Poseidon 2.0 has been adapted to the national cases of Egypt, Morocco and Tunisia by adding

local information and specific analysis, especially for the second section covering the PESTLE analysis. This shows that the tools can be adapted to another region or to another country of the same region.

Regarding Poseidon 2.0, that can be openly accessed, it can be noted that the first section of the tool (technology selection) could directly be applied to a new MENA country if some local and national data are collected beforehand. For the second section (PESTLE analysis), more data would be required, and a new version of the tool should be developed.

If one would like to make use of the first section of the tool (technology selection), the following data would be necessary:

1. Wastewater quality parameters
2. Quality parameters to comply with for the intended reuse (from a national regulation)
3. Local data regarding electricity cost, labor cost, land cost and discount rate.

The experience showed that the tool is user-friendly and can easily be understood by a wide range of potential users. Nevertheless, for a vast replication in the MENA region, it would be advisable to offer a multi-lingual version including the Arabic language. Possible training packages, illustrated in Deliverable 6.4, would also complement a smooth regional dissemination.

2.2 DST for water reuse and water & land management in agriculture

This section presents the second DST, an integrated agro-economic model developed in Tasks 3.3 and 5.3 aimed at integrating water reuse and irrigation technologies (developed, tested and implemented in MadforWater project) with economic instruments into basin-scale strategies to enhance the use of treated wastewater. In addition, a dedicated handbook explaining how to use the DST is included in [Appendix II](#).

2.2.1 Where to find it?

The hydro-agro-economic DST consists of statements that define the data first, followed by the model and the solution statements. The DST is contained in a computer code constructed with the text editor GAMS IDE. The file has the file extension .gsm and can be read using any text editor. To run the DST, it is necessary to install the GAMS IDE software. The code has been written in order to be usable also with the demo license of GAMS, that can be freely obtained at the following link: <https://www.gams.com/download/>. At the same link, it is possible to freely download the GAMS software, for Windows, Linux or MAC operating systems.

The GAMS computer code containing the hydro-agro-economic DST, together with the User Manual, have been deposited in the AMS Acta repository of the University of Bologna (Scardigno et al., 2020), where they can be freely downloaded through the following link: <http://doi.org/10.6092/unibo/amsacta/6444>.

An extremely wide documentation on the use of GAMS, including a relevant library of GAMS codes, is available at this link: <https://www.gams.com/31/docs/>.

Three additional datasets developed by UPM have been deposited in the AMS Acta repository, containing a large information base that has been developed to frame the research into the MENA region food and water issues. These datasets include (1) information on food security (effects of water stress on food security and socio-economic development across the MENA region), (2) water management in the case study countries, Morocco, Egypt and Tunisia, and (3) current cooperation agreements and implications on water related goals in the case study countries. These datasets refer to tasks 1.1, 1.3, 5.1 of MADFORWATER and can be found as follows:

- <http://amsacta.unibo.it/id/eprint/6370> (task 1.1)
- <http://amsacta.unibo.it/id/eprint/6371> (task 1.3)
- <http://amsacta.unibo.it/id/eprint/6372> (task 5.1)

The complete citations of the datasets, including the DOIs, are included in Section 3, References.

Also, several data sets, specific to the DST developed for the Tunisia case study (UPM), are deposited in the referred Repository of UNIBO under an embargo period (due to PhD thesis confidentiality). The data sets are related to the overall description of the case study, (based on three rounds of field work), to the specificities of all agronomic parameters of the study region (crops, yields, input use, water use, tillage operations etc.), interviews to different types of stakeholders (farmers, policy makers, water management agencies, irrigation firms), and all the scenario definition parameters.

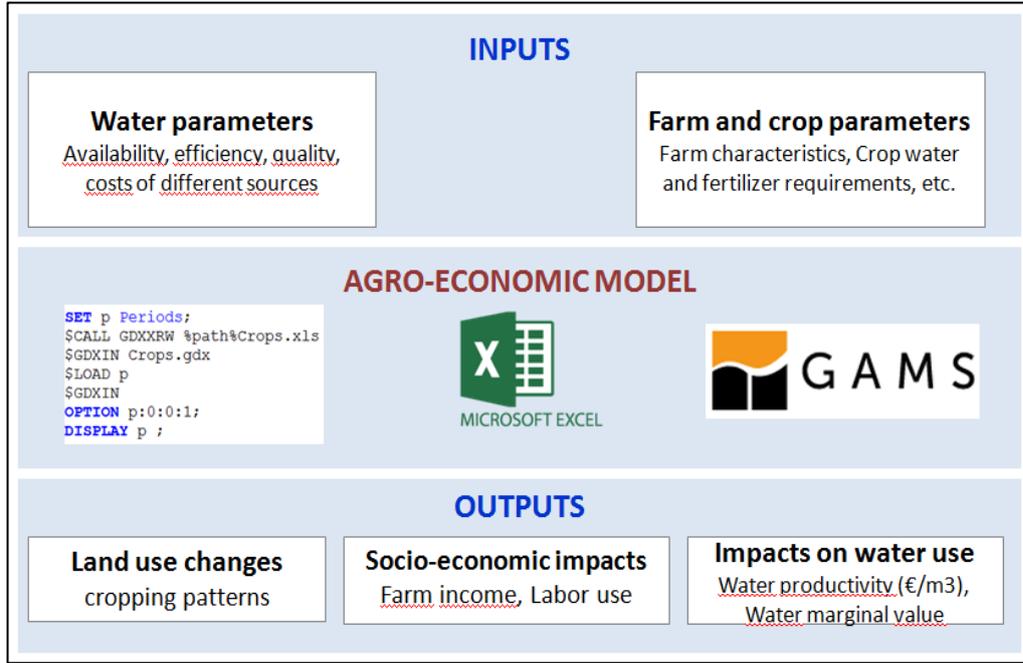
2.2.2 DST Description

The DST is an integrated agro-economic model useful to basin authorities, water planning and management agencies, water users' associations and farmers and environmental organizations, to develop strategies for water reuse and water & land management in agriculture.

The general objective of the DST (agro-economic model) is to develop water and land management strategies as a response to different technological and socioeconomic scenarios defined in the project. The aim is to achieve an optimal exploitation of the irrigation technologies and to assess the impact of economic instruments for improving irrigation efficiency and for enhancing treated WW reuse in agriculture.

A common structure of the DST has been framed to be comprehensive and flexible in order to include different types of crops, intensification levels, use of fertilizers, as well as different types of water sources and different water delivery periods.

The general structure of the agro-economic model can be illustrated as follows:



The agro-economic model is written in GAMS (General Algebraic Modeling System) language and it is based on a mathematical programming of a farm model.

The objective of this model is to guide the farmers' choices under different scenarios and risk situations.

The agro-economic model maximizes farmers' utility defined as the expected revenue minus its standard deviation due to risk adverse towards price/yield variation.

$$MaxU = Z_p - \phi * \sigma(Z_p) \quad (1)$$

Where: **U**: Utility to be maximized, **Z_p**: Average (expected) farm revenue (€); ϕ : Risk aversion coefficient; σ : Standard deviation of the expected income (€); **p**: farming type/position

and

$$Z_p = \sum_{c,i,q} Pr_c * Y_{c,q} * X_{c,i,q,p} - Vcost_c * X_{c,i,q,p} - Fcost - (Fertreq_{c,q,f} * Fertpr_f) - PrWat_q * QWat_{q,p} - TarWat_q * Irrland_q \quad (2)$$

Where: **c**: crops, **q**: type of water, **i**: irrigation technique, **f**: type of fertilizer, **X_{c,i,q,p}**: the crop activity level (ha), **Pr_c**: average crop price (€/ql), **Y_{c,q,t}**: crop yield (ql/ha), **Vcost_{c,t}**: variable costs (€/ha), **Fcost**: fixed costs (€), **Fertreq_{c,q,f}**: amount of fertilizer (kg), **Fertpr_f**: fertilizer price (€/kg), **PrWat_q**: water tariff per m3 or per type of water, **QWAT_{q,p}**: annual used water (m3) per type of water, **TarWat_q**: water tariff per ha and per type of water, **Irrland_{q,p}**: irrigated land (ha) by type of water.

HOW TO CHANGE THE OBJECTIVE

The DST can be changed in order to achieve different objectives, such as the maximization of food production or of the amount of treated wastewater reuse. This change, that requires a deep modification of Equation 1 and of other sections of the code, goes beyond the scope of this deliverable and of the MADFORWATER project.

The agro-economic model maximizes farmers' utility subject to a set of resources constraints (land and water), agronomic and economic conditions, and offers the possibility to simulate and analyze different scenarios.

HOW TO CHANGE THE CONDITIONS AND CONSTRAINTS

- Agronomic and economic conditions can be changed by changing the related parameters: yields, prices, cost of cultivation, cost of technologies, level of subsidies, cost and amount of fertilisers, efficiency of irrigation methods.

- Constraints can be changed by changing the availability of the inputs such as land and water

Scenario simulations can combine in different ways technological and policy scenarios, such as an increased amount of water availability (obtained from improved water reuse and the implementation of more efficient irrigation technologies) as well as the decrease in fertilizer requirement (due to high levels of organic matter in treated WW).

HOW TO CHANGE THE SCENARIOS

The water availability scenario

Availability of the fresh and treated wastewater can be changed in the 'TABLE watsup(p,q,s)'.

Given the characteristics of the TWW and their nutrient content, crops fertilizer requirements and crops yields could be changed in the 'TABLE fertreq(c,q,f)' and 'TABLE y (c,q,t)'.

The policy scenarios

Different water pricing policies can be simulated by changing the price for freshwater and for treated wastewater in the parameter 'WATPR (q)'.

Also, in combination with the 'technology scenarios', a public subsidy to the farmer to cover the cost of the innovative irrigation technologies can be also simulated in the parameter 'sub_lev(q)'.

The technology scenario

The cost of the innovative irrigation technologies can be also simulated in 'TABLE tech_cost(c,q)'.

The effect of the new technology could appear in the efficiency of the irrigation system through the parameter 'eff(i,q)'.

For each possible scenario, the proposed DST allows to identify the most efficient scenario for farmers and water managers: the optimal allocation of land and of different quality irrigation waters among crops is identified and, ultimately, the level of adoption of the different water reuse and irrigation technologies developed in MADFORWATER will be estimated. By identifying the optimal choices of farmers in relation to cultivation and agro-technical systems, the model allows to estimate the impacts of the adoption of technological innovations and economic and regulatory tools that can be put in place to encourage the practice of water reuse. The model provides also the impacts of different key parameters for irrigated farms, such as farm income, labor use, water consumption, marginal value of water etc. in each of the selected MADFORWATER scenarios.

Input data of the DST include: cultivated and irrigated surface, crop surface, crops irrigation requirements and schedules, water availability and price, variable costs of inputs for crop production, crop prices, crop yields, performance indicator of irrigation technologies and crop intensification levels.

Main output include: land allocation changes, farmers' income, water use per crop and per quality of water, water productivity and water marginal value.

2.2.3 Specific aspects to be considered in the application of the DST to a new MENA country

The proposed DST is very flexible and can be used to simulate and/or optimize the agricultural production processes at farm and at basin scale level where the optimal allocation of land and different water quality represents a choice for the decision –makers.

As explained also in Del. 6.4, the main lesson learnt from the experience made during the MADFORWATER project is related to the crucial task of data collection: a deep knowledge of economic, social and institutional characteristics of the farming systems to be modelled is strongly recommended for the credibility of the obtained results. Both formal and informal sources of information should be considered given the high level of informality of agricultural system.

In particular, knowledge of the economic and social characteristics of farmers is useful for adequately defining the goals and the objective to be maximized, while from the knowledge of the policy and environmental contexts one can obtain the information required to establish the constraints within which the farmers in each type of agricultural system make decisions regarding the management of land and water. In this respect, the experience made in MADFORWATER has underlined the importance to carry out specific field work in selected areas of study in which different types of stakeholders were interviewed, such as farmers, water users' associations, water management agencies, environmental agencies and ministerial departments. In addition, an important aspect of the model development is the validation of the model results among the concerned stakeholders, which will give added credibility to the model outputs.

3 References

3.1 Poseidon 2.0

Oertlé, Emmanuel. (2020). Poseidon 2.0 - Decision Support Tool for Water Reuse (Microsoft Excel) and Handbook (Version 2.0) [Data set]. Zenodo. <http://doi.org/10.5281/zenodo.3755380>

Oertlé E, Hugi C, Wintgens T, Karavitis C, Oertlé E, Hugi C, Wintgens T, Karavitis CA. 2019. Poseidon—Decision Support Tool for Water Reuse. *Water*. 11(1):153. doi:10.3390/w11010153. [accessed 2019 Jan 22]. <http://www.mdpi.com/2073-4441/11/1/153>.

Oertlé, Emmanuel. (2018, December 5). Poseidon - Decision Support Tool for Water Reuse (Microsoft Excel) and Handbook (Version 1.1.1). Zenodo. <http://doi.org/10.5281/zenodo.3341573>

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Oertlé, Emmanuel. (2018). Treatment Trains for Water Reclamation (Dataset) (Version 1.0.0) [Data set]. Zenodo. <http://doi.org/10.5281/zenodo.1972627>

Oertlé, Emmanuel. (2018). Water Quality Classes - Recommended Water Quality Based on Guideline and Typical Wastewater Qualities (Version 1.0.2) [Data set]. Zenodo. <http://doi.org/10.5281/zenodo.3341570>

3.2 DST for water reuse and water & land management in agriculture

Scardigno, Alessandra; Varela-Ortega, Consuelo ; Boubakri, Najib ; Blanco-Gutiérrez, Irene (2020) *MADFORWATER. Decision Support Tool for wastewater management and for water & land management in agriculture*. University of Bologna. <http://doi.org/10.6092/unibo/amsacta/6444> [Software]

Varela-Ortega, Consuelo ; Esteve, Paloma ; Blanco-Gutiérrez, Irene ; Suárez-Varela Maciá, Marta ; Jaouani, Atef ; Gafrej, Raoudha ; Souissi, Yasmine ; Abdel-Motaleb, Alaa ; Chenini, Faycel ; Choukr-Allah, Redouane ; Ker Rault, Philippe (2020) *MADFORWATER. WP5 Strategies and economic instruments for basin-scale water resources management. Task5.1 Review and assessment of the use of economic instruments and policies in water management in Egypt, Morocco and Tunisia*. <http://doi.org/10.6092/unibo/amsacta/6370> [Dataset]

Varela-Ortega, Consuelo ; Esteve, Paloma ; Blanco-Gutiérrez, Irene ; Suárez-Varela Maciá, Marta ; Boubakri, Najib (2020) *MADFORWATER. WP1 Water and water-related vulnerabilities in Egypt, Morocco and Tunisia. Task1.3 Analysis and mapping of water stress effects on food security and socio-economic development in Egypt, Morocco and Tunisia*. <http://doi.org/10.6092/unibo/amsacta/6371> [Dataset]

Varela-Ortega, Consuelo ; Esteve, Paloma ; Blanco-Gutiérrez, Irene ; Suárez-Varela Maciá, Marta ; Jaouani, Atef ; Gafrej, Raoudha ; Souissi, Yasmine ; Abdel-Motaleb, Alaa ; Chenini, Faycel ; Choukr-Allah, Redouane ; Ker Rault, Philippe (2020) *MADFORWATER. WP5 Strategies and economic instruments for basin-scale water resources management. Task5.1 Review and assessment of the use of economic instruments and policies in water management in Egypt, Morocco and Tunisia*. <http://doi.org/10.6092/unibo/amsacta/6372> [Dataset]

Varela-Ortega, Consuelo; Boubakri, Najib ; Blanco, Irene ; Sangro, Sebastián ; Scardigno, Alessandra; Lamaddalena, Nicola; Oertlé, Emmanuel; Müller, Sandra; Dietziker, Andrin (2020) WW management strategies and water & land management strategies in agriculture. p. 150. DOI 10.6092/unibo/amsacta/6323.



4 Appendix I – Handbook: Poseidon 2.0 – A tool to Promote and Assess Water Reuse



University of Applied Sciences Northwestern Switzerland
School of Life Sciences

Handbook

Poseidon 2.0 – A tool to Promote and Assess Water Reuse



European
Commission

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European Union funding
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4.1 Preface

This developed Excel-Tool is an Excel file which contains macros. You can open this file type like usual Excel files. However, the following Security Warning message appears:

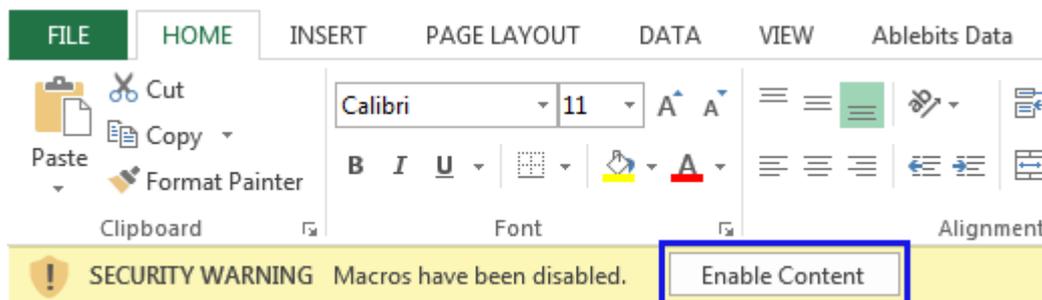


Figure 3: Excel Macro Security Warning Message.

Click the “Enable Content” button for the developed Excel-Tool to work. These are simple macros, which give a better overview while simplifying the usage.

4.2 Introduction

Poseidon 2.0 has been developed in the frame of the EU Horizon 2020 project MADFORWATER¹, which aims to develop an integrated set of technological and management instruments for the enhancement of wastewater treatment, treated wastewater reuse for irrigation and water efficiency in agriculture, with the final aim to reduce water vulnerability in selected basins in Egypt, Morocco and Tunisia. The challenge of reuse and recycling technology projects is not the lack of treatment techniques and technologies but rather lies in how such schemes may be implemented in the local context.

Poseidon 2.0 itself is a user-oriented, simple, and efficient Excel-Tool, which aims to compare different wastewater treatment techniques based on their removal efficiencies, their costs, and additional assessment criteria. The background of the different technologies related to water reuse and the underlying theory are explained. Furthermore, national thematic subjects related to water reuse are included in form of a multi-criteria analysis called PESTLE (political, economic, sociological, technological, legal and environmental). These indicators collectively aim to provide an indicative general understanding of the current situation of water reuse in Egypt, Tunisia, and Morocco and are selected on the basis of existing indicators, which were scanned from major water reuse studies and recognized databases (Esteve et al., 2017; FAO - UN Food and Agriculture Organisation, 2016; Snethlage et al., 2018). The analysis was also applied to Australia. The reason for integrating Australia is its function as a benchmark country with well-established water reuse practices (Asian Development Bank, 2017).

Poseidon 2.0 can be applied prior to a more detailed feasibility study in order to assess possible water-reuse options and it shows decision makers and other stakeholders that

¹ <https://www.madforwater.eu>, This project has received funding from the European Horizon 2020 WATER-5c-2015 Program for the development of water supply and sanitation technology, systems and tools, and/or methodologies

implementable solutions are available which comply with local requirements, as shown in Figure 2.

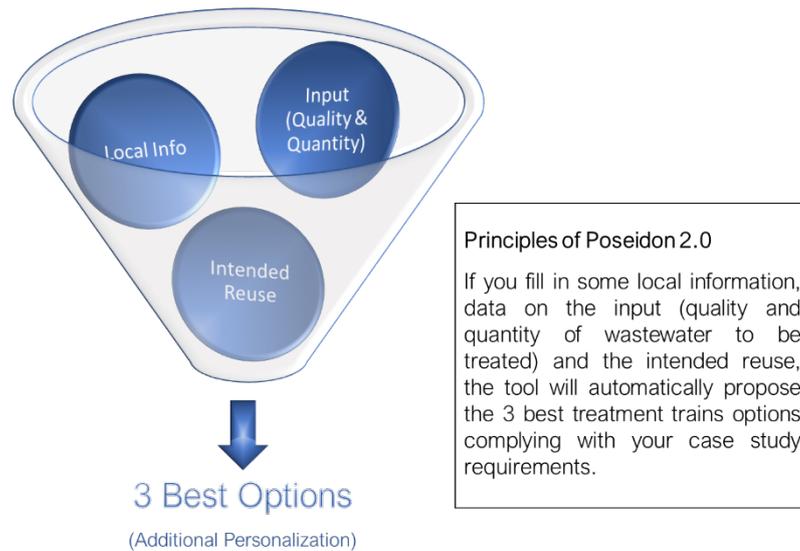


Figure 4: Principle of Poseidon 2.0

4.3 Basic mode

Typical users: Users not used to this tool and non-experts of wastewater treatment technologies.

Typical use: The typical intended use of this basic mode is to learn about water-reuse treatment technologies and to analyze which treatment trains would comply with your own situation, as shown in Figure 3.

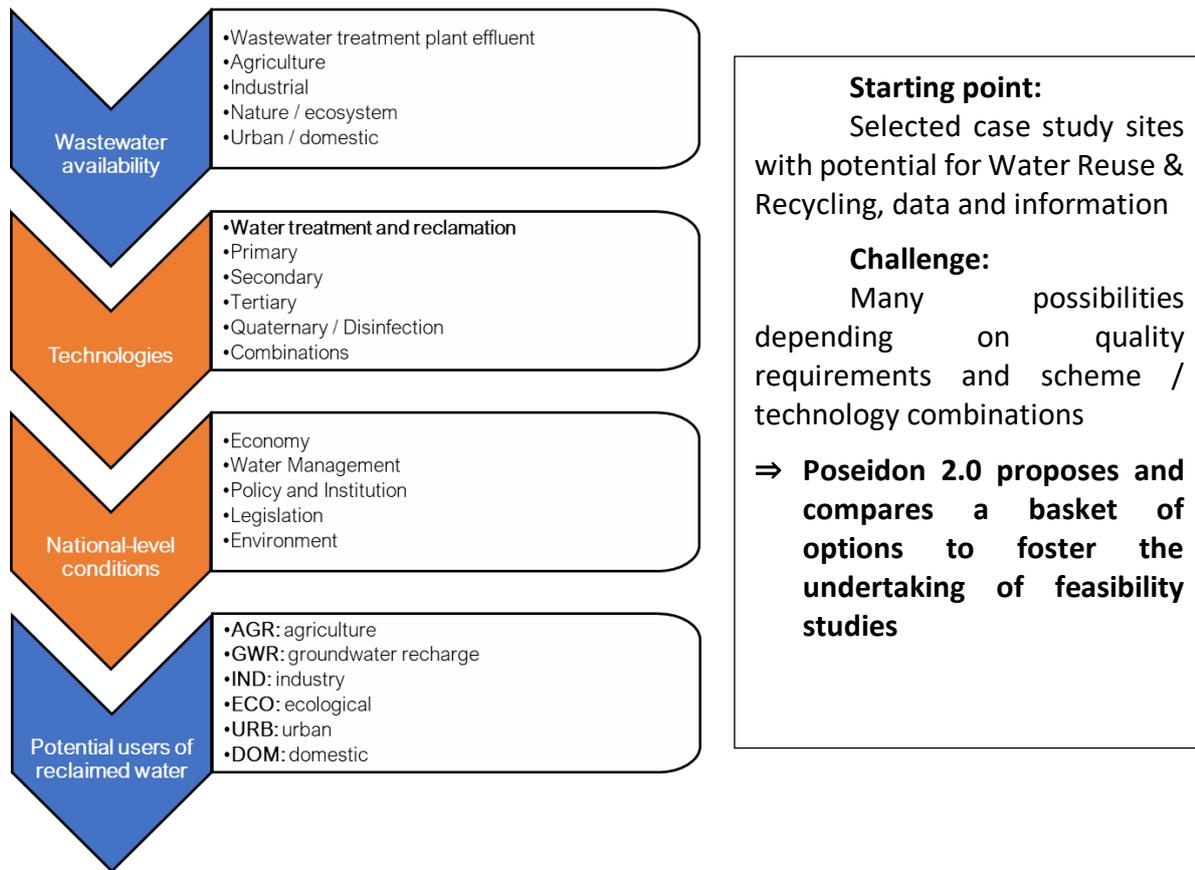


Figure 5: Main objectives

The next sections will provide you with all the necessary steps to take in order to reach a basket of three top-ranked options for wastewater treatment.

4.3.1 Welcome

“Welcome” is the first sheet of the Excel-Tool where you can find a first structural timeline overview. There are two fields to be filled out, (a) your country of origin and (b) the currency to be applied for cost purposes.

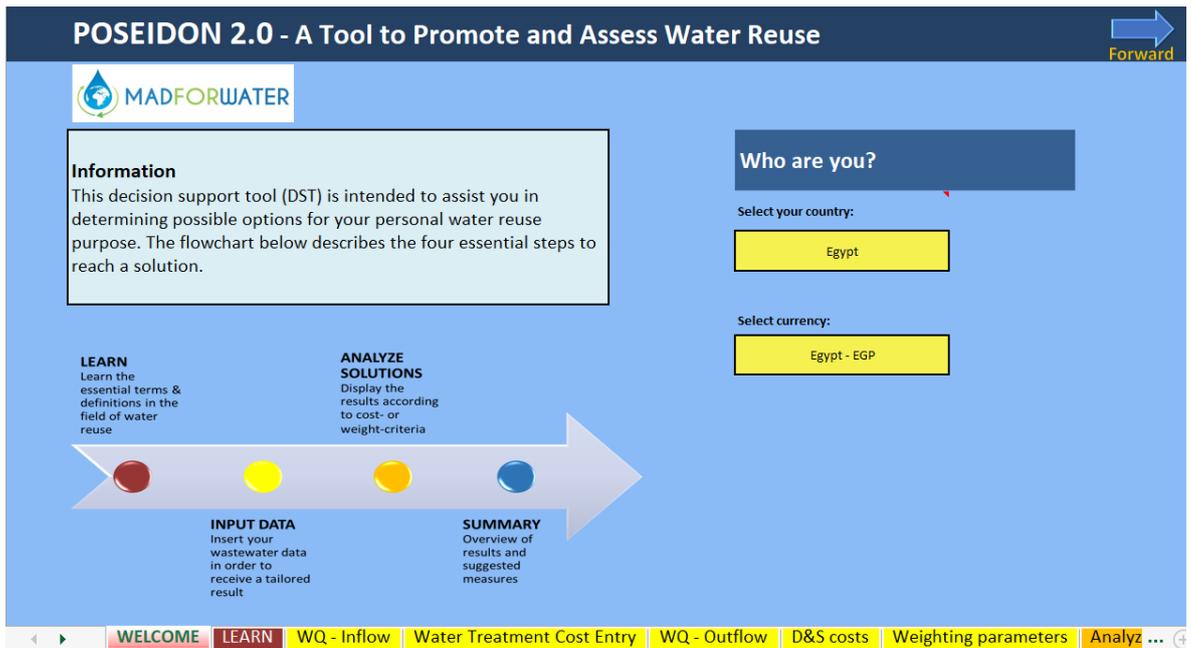


Figure 6: Welcome.

4.3.2 Learn

Learn about Poseidon 2.0 by using the dropdown list. The essential definitions and terms about wastewater treatment and reuse are provided in this section. You will find a selection of different questions about the tool and some abbreviations you might not be familiar with. By selecting one of the questions, the tool will automatically give you the answer in form of a picture or chart, together with a short description.

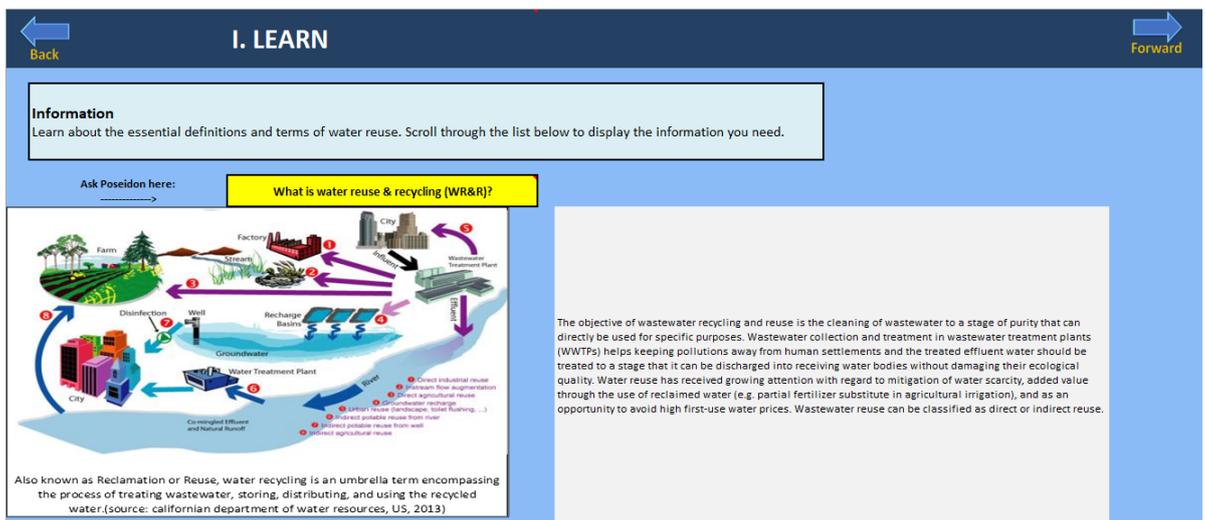
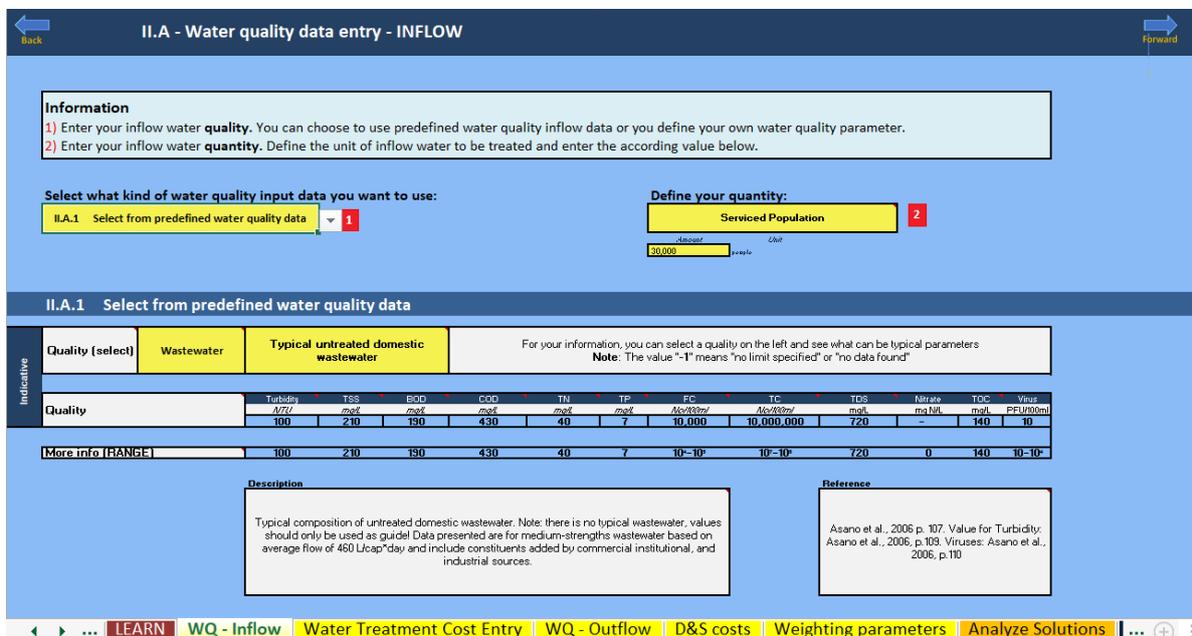


Figure 7: Learn

4.3.3 Water quality – Inflow

You will find all the details about different water quality classes included in Poseidon 2.0. There is a short description and references as well. Water quality regulations, recommendations and requirements are a very broad topic and sometimes remain undefined. In addition, compliance with requirements is a separate topic. For this reason, the tool proposes a catalogue of quality classes from several references (USEPA, WHO, national regulations, etc.) as an indication, and the user can either select one of those classes or adapt it to its own local conditions by using the dropdown list under point 1. Some references propose a range of values for selected parameters, and this section allows the user to see what is used for the calculation and where those numbers come from, along with some additional information. Furthermore, the quantity of the wastewater inflow has also to be defined under point 2. You can choose between three different units, (a) Peak flow, (b) Average flow, and (c) Serviced population.



Information

- 1) Enter your inflow water **quality**. You can choose to use predefined water quality inflow data or you define your own water quality parameter.
- 2) Enter your inflow water **quantity**. Define the unit of inflow water to be treated and enter the according value below.

Select what kind of water quality input data you want to use:

II.A.1 Select from predefined water quality data 1

Define your quantity:

Serviced Population 2

30,000 people

II.A.1 Select from predefined water quality data

Quality (select)	Wastewater	Typical untreated domestic wastewater											
		Turbidity	TSS	BOD	COD	TN	TP	FC	TC	TDS	Nitrate	TOC	Viruses
		NTU	mg/L	mg/L	mg/L	mg/L	mg/L	10 ³ /100ml	10 ³ /100ml	mg/L	mg/L	mg/L	PFU/100ml
Quality		100	210	190	430	40	7	10,000	10,000,000	720	-	140	10
More info [CHANGE]		100	210	190	430	40	7	10 ³ -10 ⁶	10 ³ -10 ⁶	720	0	140	10 ³ -10 ⁶

Description

Typical composition of untreated domestic wastewater. Note: there is no typical wastewater, values should only be used as guide! Data presented are for medium-strengths wastewater based on average flow of 460 L/cap/day and include constituents added by commercial institutional, and industrial sources.

Reference

Asano et al., 2006 p. 107. Value for Turbidity.
Asano et al., 2006, p.109. Viruses: Asano et al., 2006, p.110

Figure 8: Water quality - Inflow

4.3.4 Water treatment cost entry

The cost data used were compiled from various sources. These only represent country-specific average values. You are therefore given the opportunity to personalize the costs, since local costs can vary greatly depending on the site. In order to enter personal costs, you must first select "Your case" under currency in "Welcome". Otherwise the calculation will be based on the average costs.

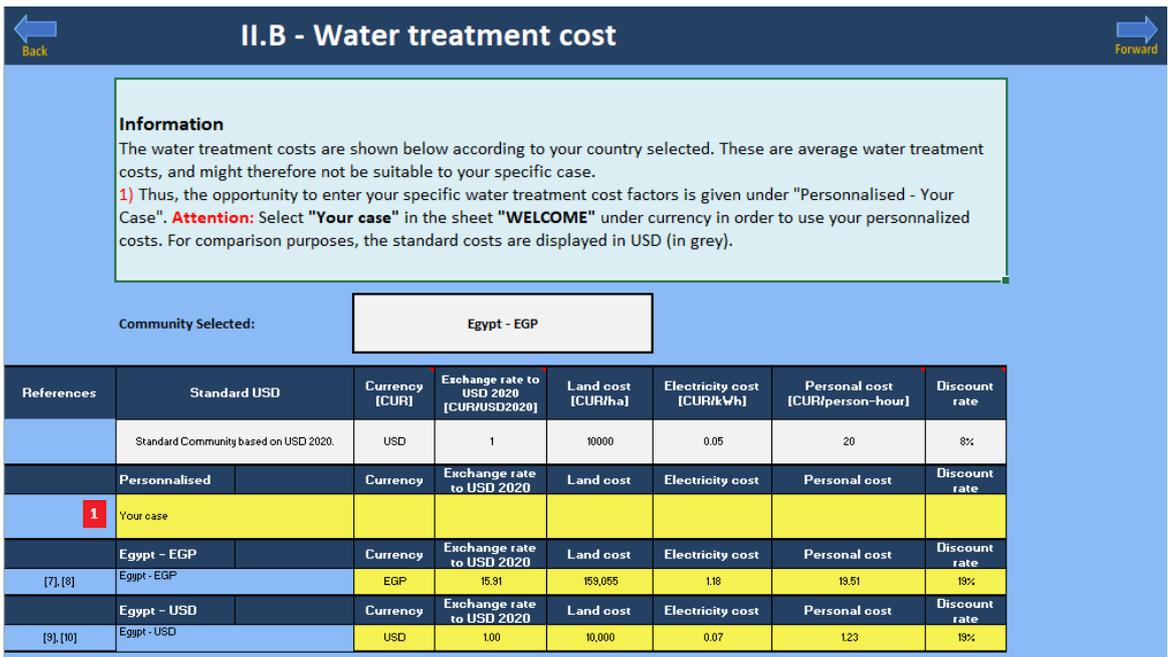


Figure 9: Water treatment cost entry.

4.3.5 Water quality – Outflow

The Excel-Tool is versatile and can be used for up to three different end-uses. The only required data regarding the water quality outflow are as follows (see Figure 8):

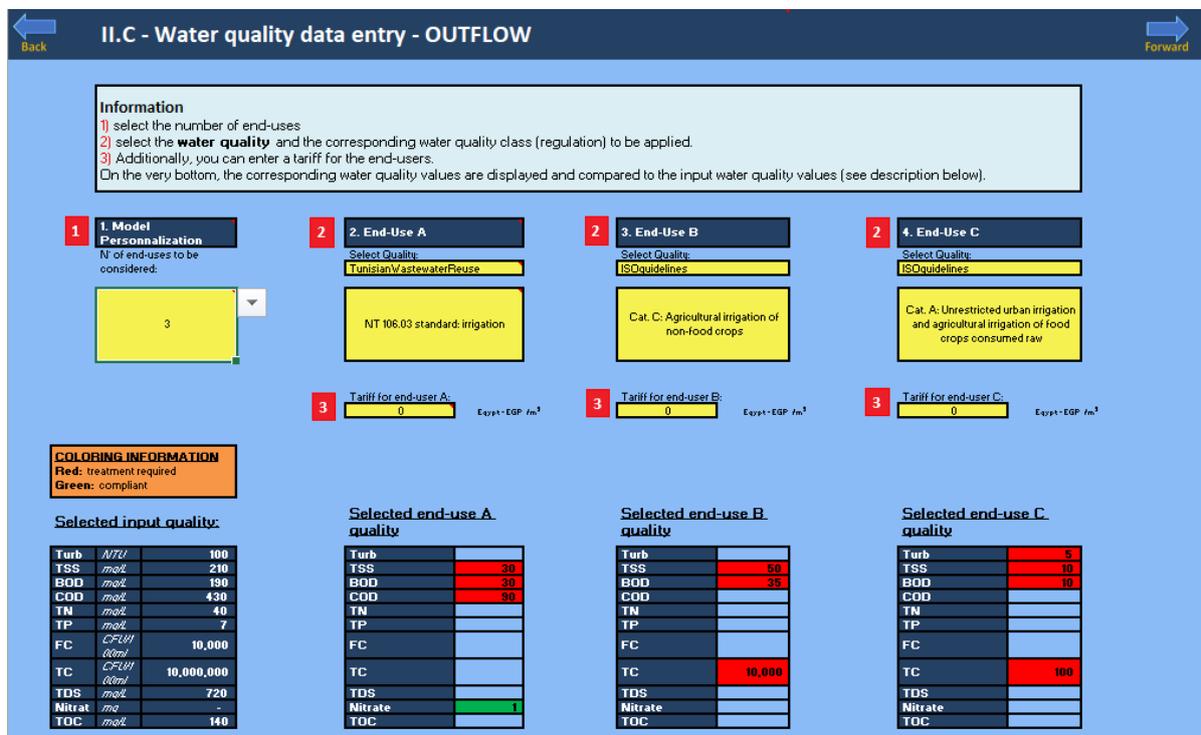


Figure 10: Water quality - Outflow.

1. **Model personalization:** You have the option to personalize the end-use purpose up to three different cases.
2. **End-use quality:** What is the quality requirement for your intended end-use of the water after treatment? You can choose from a list of pre-defined quality categories and specify in a second step the water quality class.
3. **Tariff for end-user:** Specify the price at which the reused water can be sold to the intended end-user.

4.3.6 Distribution and storage costs

First, define the specific quantity you will deliver to each end-user. Second, specify the length of the pipes required and the elevation to calculate the pumping costs. You can also specify whether you need a water or wastewater storage facility.

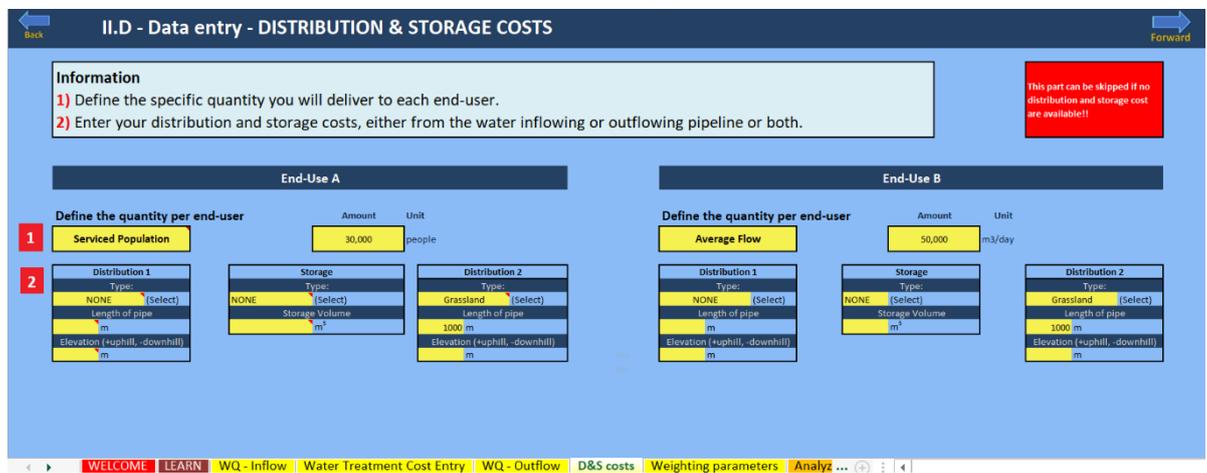


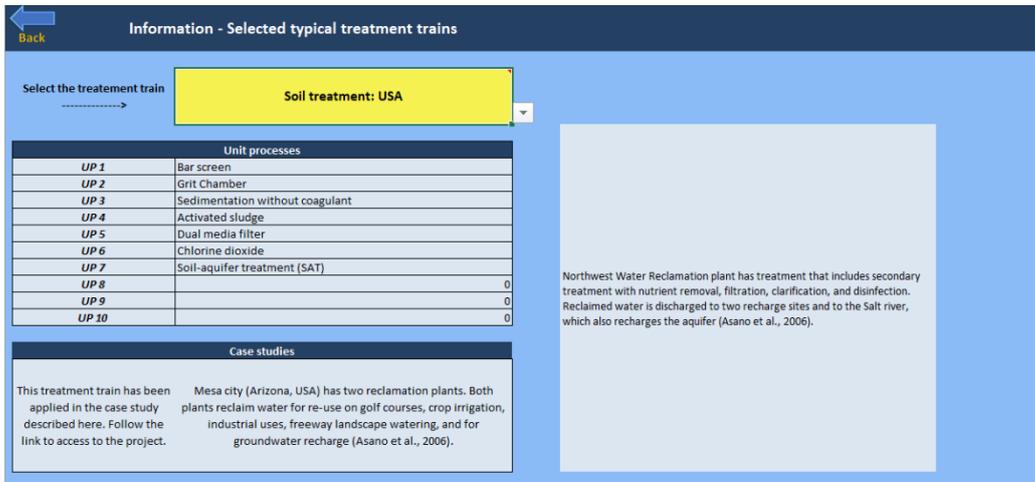
Figure 11: Distribution and storage costs.

Based on the input data in the preceding sections, the Excel-Tool will calculate the performance, cost, and other assessment criteria for all the treatment trains included in the system and propose to you three top-ranked options according to a varied selection and assessment methods as explained in Sections 2.7 and 2.8.

4.3.7 Calculation and Assessment Algorithm (Informative)

In order to understand the results, the user should have a basic understanding on how the tool performs the calculations before being able to analyze the results (All those calculations are performed automatically, and the user does not see the details while using the tool). Poseidon contains a catalogue of unit processes (technologies) assembled into a catalogue of treatment trains (i.e., a combination a series of technologies). The treatment trains are based on case studies and contain main benchmarks treatment trains and several

additional examples worldwide. One example of treatment train is shown in Figure 10. Poseidon 2.0 contains around 40 unit processes and around 50 treatment trains.



Information - Selected typical treatment trains

Back

Select the treatment train

Soil treatment: USA

Unit processes		
UP 1	Bar screen	
UP 2	Grit Chamber	
UP 3	Sedimentation without coagulant	
UP 4	Activated sludge	
UP 5	Dual media filter	
UP 6	Chlorine dioxide	
UP 7	Soil-aquifer treatment (SAT)	
UP 8		0
UP 9		0
UP 10		0

Case studies

This treatment train has been applied in the case study described here. Follow the link to access to the project.

Mesa city (Arizona, USA) has two reclamation plants. Both plants reclaim water for re-use on golf courses, crop irrigation, industrial uses, freeway landscape watering, and for groundwater recharge (Asano et al., 2006).

Northwest Water Reclamation plant has treatment that includes secondary treatment with nutrient removal, filtration, clarification, and disinfection. Reclaimed water is discharged to two recharge sites and to the Salt river, which also recharges the aquifer (Asano et al., 2006).

Figure 12: Soil treatment USA: example of a treatment train composed of 7 unit processes.

Each unit process, and therefore each treatment train, contains following information:

1. General description of unit process, treatment trains that can be found in the additional information sheet "L3" of the Excel-Tool (also accessible from the "results" sheets)
2. Pollutant removal percentage for each water quality parameter under minimum, average, and maximum performance
3. Quantitative lifecycle costs information in order to calculate the important cost components for each case
4. Additional assessment criteria for the technical assessment, requirements, impacts, cost, and resources, where the values are between 0 and 3 (0 = nil, 1 = low, 2 = medium and 3 = high)
5. A normalized and aggregated single treatment train score that is calculated based on the weights defined by the user (Figure 11). The values are between 0 (worst) and 3 (best).

II.E - Entry data - WEIGHTING PARAMETER

Information
This information can be added in order to not only include treatment trains identified only based on meeting quality requirements of available reuse applications.
Here you have the possibility to add **qualitative options** adapted to local environmental, economic, and social conditions. Define here your "Evaluation Profile" by assigning weights. You can select only one parameter or all of them. Be careful not to include twice the same parameter (e.g. for cost of treatment).

1. Select a weighting profile: Manual entry

Reset the weights:

Technical evaluation		Requirements and impacts		Costs and resources	
Reliability	Regular	Power demand	Not important (not considered)	Annualised capital costs	Important
Ease to upgrade	Not important (not considered)	Chemical demand	Very important	Land cost	Not important (not considered)
Adaptability to varying flow	Very important	Odor generation	Not important (not considered)	Energy cost	Not important (not considered)
Adaptability to varying quality	Not important (not considered)	Impact on ground water	Not important (not considered)	Labour	Not important (not considered)
Ease of O & M	Not important (not considered)	Land requirement	Important	Operation and maintenance others	Not important (not considered)
Ease of construction	Regular	Cost of treatment	Not important (not considered)	Total annualised costs	Not important (not considered)
Ease of demonstration	Not important (not considered)	Quantity of sludge production	Not important (not considered)		

Figure 13: Weight the relative importance of different parameters in order to calculate an overall treatment train score.

4.3.8 Elimination, Ranking and Assessment Process

As described in the previous section, each parameter is calculated for each treatment train included in Poseidon 2.0. Those parameters can be divided into three categories:

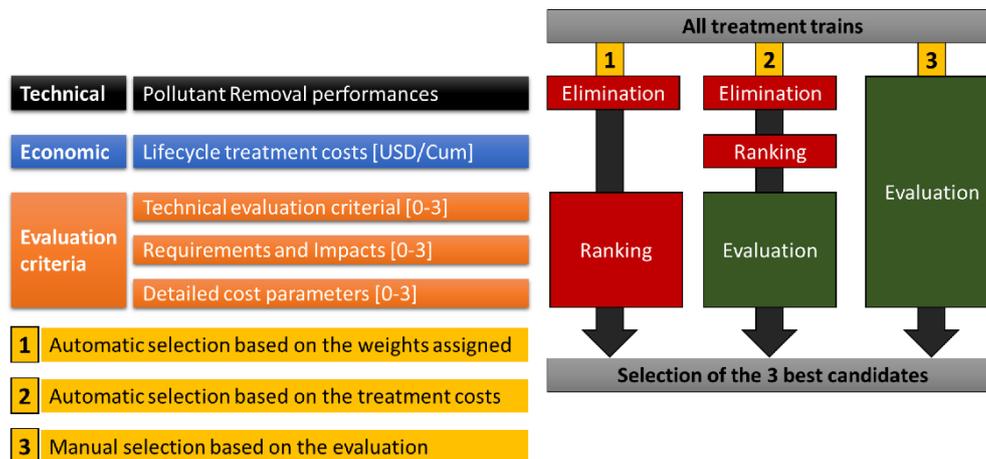


Figure 14: Assessment algorithm proposed by the stage II assessment.

- 1. Technical:** This is the calculation of the pollutant-removal performance for the considered quality parameters. If a given treatment train complies with all the water quality parameters specified for a given end-use, the treatment train is considered compliant.²

² Note that for each parameter, three performances are calculated (minimum, average and maximum performance), depending on the operation conditions and external factors. In the selection process, the maximum performance is considered, and the user should be aware that under less well-operating treatment trains, the quality might not comply with the water quality required for the end-use.

2. **Economic:** These are the lifecycle treatment costs calculated quantitatively in the selected currency per cubic meter. Such a cost is calculated for each treatment train.
3. **Assessment criteria:** These are all the additional assessment criteria that are normalized, and their values are between 0 and 3 (0 = nil, 1 = low, 2 = medium, and 3 = high). Out of those assessment criteria, another aggregated score is calculated for every treatment train based on the assigned weights by the user, as explained in the previous section.

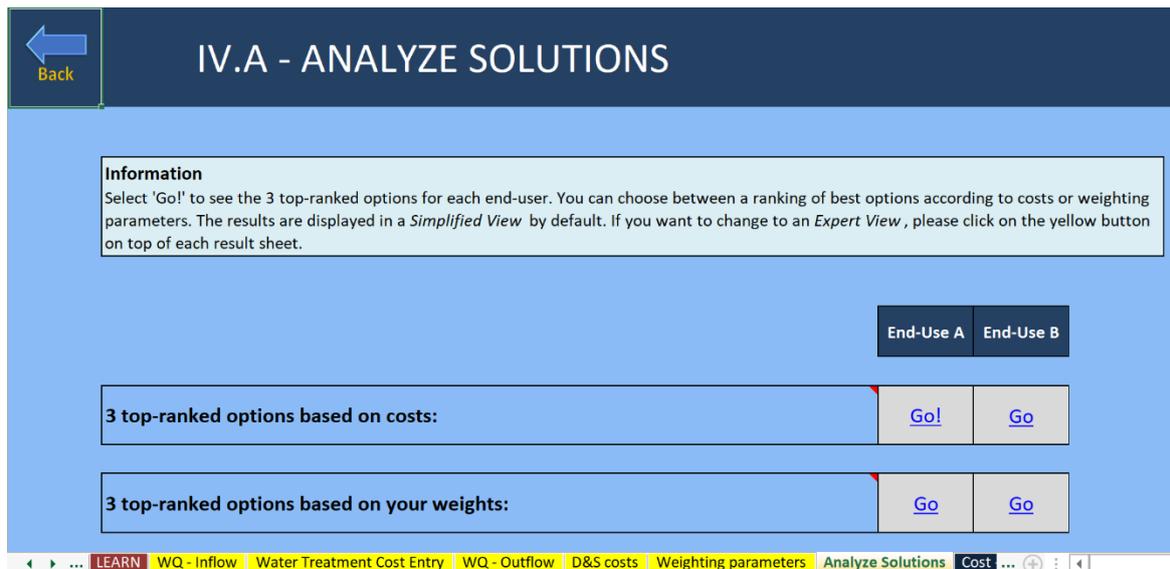


Figure 15: Analyze solutions.

Based on those three categories of parameters (technical, economic, and assessment criteria), the user can proceed to three main elimination, ranking, and assessment selections, as represented in Figure 12 and Figure 13.

The results are displayed in a simplified view of the PESTLE results by default. The simplified results are designed to give an initial overview of the national-level conditions regarding the various subjects of wastewater treatment. If you want to have a more detailed analysis of the national-level conditions, please select “*Expert Results*” in each result sheet. Next, you can display the results according to the following two criteria:

1. **Automatic selection based on the treatment costs:** In this mode, all treatment trains not complying with the water quality required are eliminated (under maximum performance). The treatment trains complying with the quality required by the foreseen end-use are ranked according to the lifecycle treatment costs, and the three top-ranked treatment trains are presented. In addition, the assessment criteria are displayed but do not affect the ranking.
2. **Automatic selection based on the weights assigned:** In this mode, all treatment trains not complying with the water quality required are eliminated (under maximum performance). The treatment trains complying with the quality required by the

foreseen end-use are ranked according to the aggregated treatment trains' single score, based on the weights assigned by the user. The best three candidates are presented automatically.

1.1 Understanding the Results



Figure 16: Example 1 of results sheet.

When looking at the results, you can see that the results are divided in two sections, as you can see in Figure 14 and Figure 15. The first section on the left side covers the following:

1. The data input is recapitulated (input quality and quantity, output quality, and distribution)
2. The three top-ranked wastewater treatment technology options that comply with your desired outflow quality are displayed in three colors (red, blue, green). For each option, the name of the treatment train is displayed. The additional information on the treatment trains and the process units included can be accessed through the two grey buttons below the three options.
3. If you want to compare the three top-ranked options, you can do this here. Select a treatment train from the dropdown list to see the cost figures attributed to the selected treatment train.
4. In addition, some results are presented in an additional sheet that can be accessed by selecting the red bottom below the three options, as shown in Figure 16.

5. The overall score results of the three best-ranked options are presented in a table form at the bottom of the sheet. You can access them by selecting the grey button.

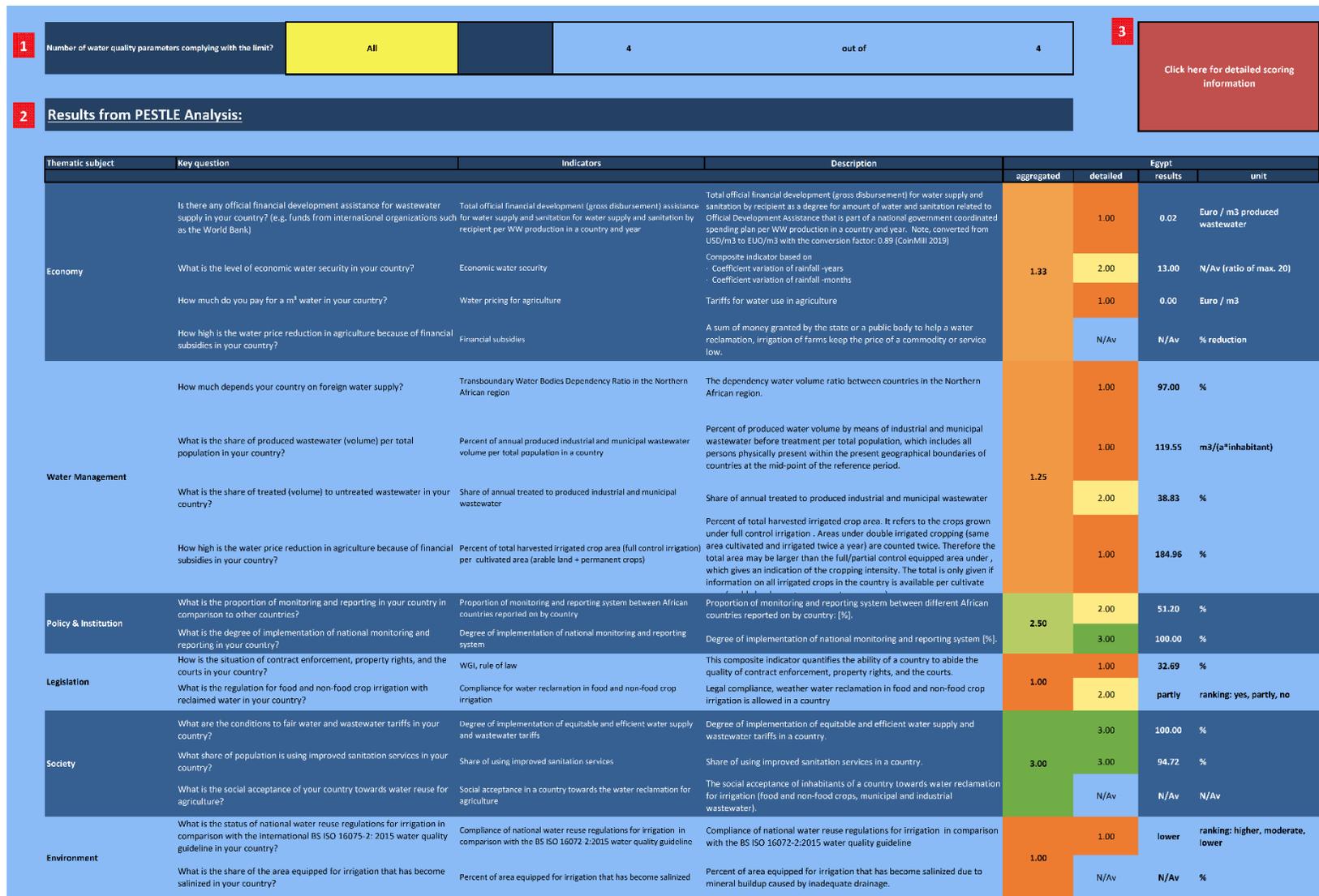


Figure 17: Example 2 of results sheet.

The second section on the right side covers the PESTLE result. The following results are displayed:

1. This still belongs to the first section explained above. In case no treatment train complies with the water quality required, you can choose how many water quality parameters should comply with the requirements (e.g. two out of three).
2. Here you see results from the PESTLE analysis (political, economic, social, water management, legislation, and environment) that covered national thematic subjects related to water reuse. On the left side you see the thematic subjects, followed by key questions. These are underpinned by (semi-)quantitative indicators. On the very right side you see the results, which were normalized to a scoring between 1 (orange; lower ranked), 2 (yellow; moderate ranked), and 3 (green; higher ranked). The detailed results were aggregated to provide an overall statement of each thematic subject. If you want to know more about the methodology used to derive these results, please see the MADFORWATER project report D5.2.
3. This button takes you to the detailed calculations of the PESTLE analysis.

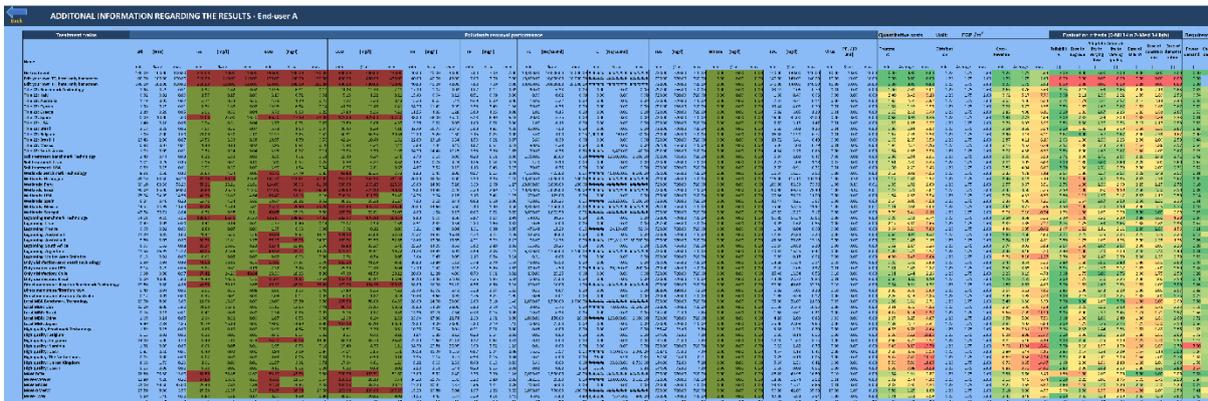


Figure 18: Results for all treatment trains displayed in a table.

4.3.9 Summary

The very last sheet of the Excel-Tool figures as a summary of all scenarios considered, including the treatment trains suggested, the costs attributed to the proposed treatment trains, and suggested measures according to the PESTLE analysis.



Figure 19: Summary of all scenarios considered.

This last sheets purpose is to give a short and concise overview of all cases analyzed. Firstly, the user should select one out of the three proposed top-ranked options (cost and weighted results). By making a selection, the user is simultaneously shown the associated costs under the second section "Costs in CUR/m³". Furthermore, the user is shown the water tariffs paid for treated wastewater in the selected country. This provides the user with an overview of the costs and revenues. Finally, the user is shown possible measuers based on the PESTLE analysis. The color coding of the analysis is used. Meaning that in those categories that are colored red or orange, it is more likely that action is needed.

4.4 Typical Example – Two Potential Water Reuse Scenarios for Untreated Wastewater from a City

A village in Egypt with typical domestic untreated wastewater from 30,000 inhabitants is considered. You would like to analyze how to treat this water for two scenarios and find the 3 top-ranked options based on costs of treatment as described in Figure 18.

Scenario 1: Reuse for aquaculture.

Scenario 2: Reuse for landscape irrigation in urban areas according to Egyptian wastewater reuse regulations

The foreseen wastewater treatment plant (WWTP) will be at an altitude of 1,000 m above sea level. The foreseen agriculture area is 1 km away in a rural area and has an altitude of 500 m above sea level. The landscape area is 100 m away from the foreseen WWTP.

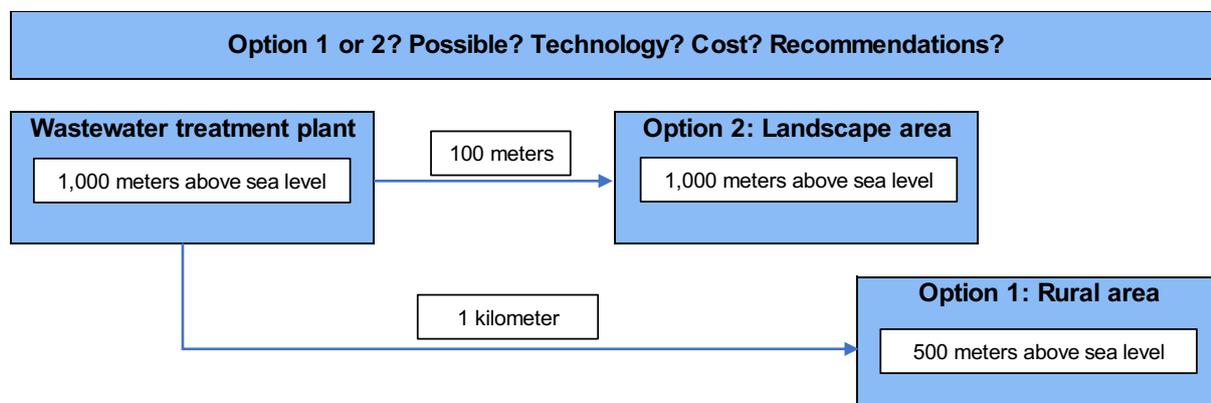


Figure 20: Visualization of example task.

Answer the following questions:

- Are there suitable treatment trains for reuses 1 or 2, or both?
- Which are the best three options based on the costs?
- What are the costs of treatment for those options?
- What are the costs of distribution?
- What are possible measures to tackle national-level barriers?

4.4.1 Suggested Procedure

Figure 19 shows how the tool looks at the beginning of an assessment.

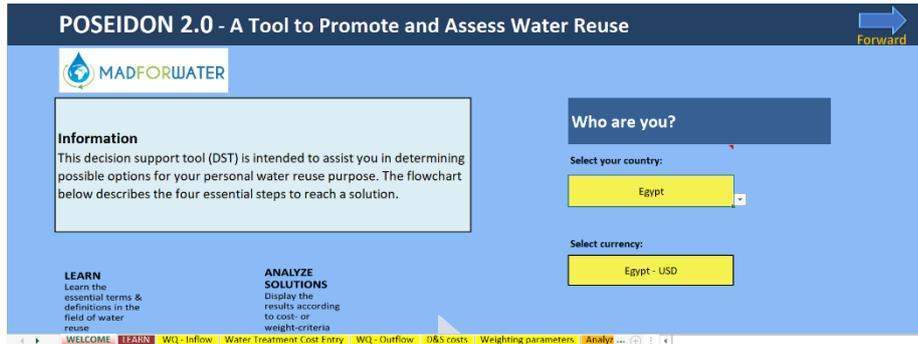


Figure 21: Starting point.

First select your country of origin “Egypt” and the currency you want to apply, in this case “Egypt – USD”.

Let’s start to fill in information

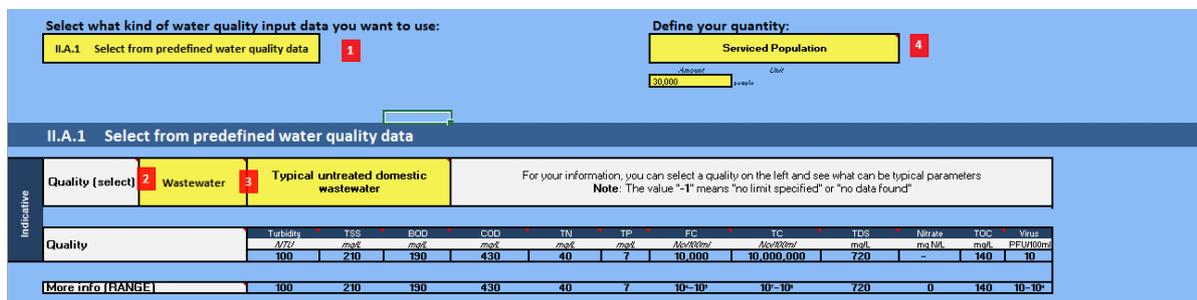


Figure 22: Water quality and quantity input.

1. First, select “II.A.1 Select from predefined water quality data”.
2. Select “Wastewater” from the water categories available.
3. Select “Typical untreated domestic wastewater” from the water quality classes available.
4. Select “Serviced Population” as the unit for the water quantity inflow, and subsequently enter “30,000” in the yellow field below.

References	Standard USD	Currency [CUR]	Exchange rate to USD 2020 [CUR/USD2020]	Land cost [CUR/ha]	Electricity cost [CUR/kWh]	Personal cost [CUR/person-hour]	Discount rate
	Standard Community based on USD 2020.	USD	1	10000	0.05	20	8%
	Personnalised	Currency	Exchange rate to USD 2020	Land cost	Electricity cost	Personal cost	Discount rate
1	Your case						
	Egypt - EGP	Currency	Exchange rate to USD 2020	Land cost	Electricity cost	Personal cost	Discount rate
[7], [8]	Egypt - EGP	EGP	15.91	159,055	1.18	19.51	19%
	Egypt - USD	Currency	Exchange rate to USD 2020	Land cost	Electricity cost	Personal cost	Discount rate
[9], [10]	Egypt - USD	USD	1.00	10,000	0.07	1.23	19%

Figure 23: Cost entry.

The average costs proposed by the Excel-Tool can be accepted (as done in this example) or otherwise can be adapted under “Your Case”. However, if you want to adapt the costs, you have to go back to the very first sheet to change the selected currency in Figure 19 to “Your Case”.

1. Model Personalization
N° of end-uses to be considered:

1 2

2. End-Use A
Select Quality:
AQUAREC

2 AQUAREC: Environmental and aquaculture Category 2

Tariff for end-user A: 0 Egypt - USD /m³

3. End-Use B
Select Quality:
EgyptianWWReuse

3 Level A: landscape irrigation in urban areas

Tariff for end-user B: 0 Egypt - USD /m³

COLORING INFORMATION
Red: treatment required
Green: compliant

Selected input quality:

Turb	NTU	100
TSS	mg/L	210
BOD	mg/L	190
COD	mg/L	430
TN	mg/L	40
TP	mg/L	7
FC	CFU/100 ml	10,000
TC	CFU/100 ml	10,000,000
TDS	mg/L	720
Nitrate	mg N/L	-
TOC	mg/L	140

4

Selected end-use A quality

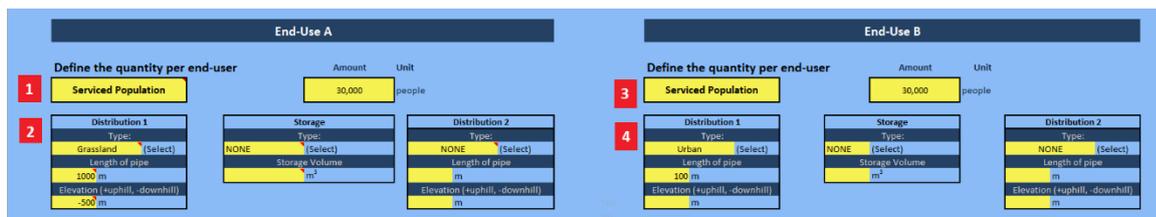
Turb		
TSS		10
BOD		10
COD		70
TN		
TP		0
FC		-
TC		
TDS		1,650
Nitrate		
TOC		70

Selected end-use B quality

Turb		
TSS		20
BOD		20
COD		
TN		
TP		
FC		
TC		1,000
TDS		
Nitrate		
TOC		

Figure 24: Water quality outflow entry.

1. In N° of end-uses to be considered, enter a value of “2”, because we have 2 different scenarios in this task.
2. Here, choose “AQUAREC” on the top, and just below, choose “AQUAREC: Environmental and aquaculture Category 2”. Since we do not consider an end-user tariff, you can leave this value at 0.
3. Here, choose “EgyptianWWReuse” on the top, and just below, choose “Level A: landscape irrigation in urban areas”. Since we do not consider an end-user tariff, you can leave this value at 0.
4. This is only an informative part of this sheet. It shows if the water inflow quality parameters are already complying with the desired water outflow qualities without any treatment. If all parameter values would be colored green, no additional treatment would be necessary.



The screenshot shows two side-by-side panels for 'End-Use A' and 'End-Use B'. Each panel has a 'Define the quantity per end-user' section with a 'Serviced Population' field set to 30,000 people. Below this are 'Distribution 1' and 'Distribution 2' sections. In 'End-Use A', Distribution 1 is set to 'Grassland' with a length of 1,000 m and elevation of -500 m. In 'End-Use B', Distribution 1 is set to 'Urban' with a length of 100 m and elevation of 0 m. A 'Storage' section is also present in both, with 'Type' set to 'NONE' and 'Storage Volume' set to 0 m³.

Figure 25: Distribution and storage cost entry.

1. Here you can further specify the water outflow quantity per end-user. We assume that the landscape area and the rural area are equally receiving the water from the WWTP. Therefore, the “Serviced Population” has not to be changed.
2. Here you enter the distribution distances. Since the treated wastewater will not be stored anywhere, we only need to enter the distance data in the “Distribution 1” section. Select “Grassland” as the type of land and enter “1,000” right below as the length of pipe. Finally, you enter “-500” as the elevation.
3. This is the same as under point 1.
4. Here you choose “Urban” as the type of land and “100” as the length of pipe.

We skip the “Weighting parameters” part in this example because we only consider the three top-ranked options according to cost. However, if you also want to consider the three top-ranked options according to the weighting parameters, please consider entering your preferences in this sheet.

4.4.2 Suggested Procedure – Analyze the Results



The screenshot shows a control panel with a dropdown menu set to 'Simplified Results'. To the right are 'End-Use A' and 'End-Use B' buttons. Below the dropdown are two rows of results, each starting with '3 top-ranked options based on costs:' and '3 top-ranked options based on your weights:'. Each row has two 'Go' buttons, one highlighted in red.

Figure 26: Analyze solutions.

After you entered all necessary input data, you can now select one of the two buttons under “3 top-ranked options based on costs”. For example, if you click the leftmost “Go!” (see Figure 24), you will see the three top-ranked options based on costs for the 1st scenario. If you click the “Go!” on the right side, you will see the same, but adapted to the 2nd scenario.

1	Input Quality	Typical untreated domestic wastewater	Input Quantity	30,000	people	Dist. pipes:	1000	[m]
	Output Quality	AQUAREC: Environmental and aquaculture Category 2						
2	3 top-ranked results according to the cost criteria:							
	Option 1		Option 2		Option 3		3 Select your own option	
	Soil treatment: Israel		Title 22: USA I		Title 22: Brazil II		M4W-TWW	
	Treatment costs [CUR/m3]	1.36	Treatment costs [CUR/m3]	1.43	Treatment costs [CUR/m3]	1.48	Treatment costs [CUR/m3]	1.11
	Distribution costs [CUR/m3]	0.01	Distribution costs [CUR/m3]	0.01	Distribution costs [CUR/m3]	0.01	Distribution costs [CUR/m3]	0.01
	Cost-Revenue [CUR/m3]	1.38	Cost-Revenue [CUR/m3]	1.45	Cost-Revenue [CUR/m3]	1.50	Cost-Revenue [CUR/m3]	1.13

Figure 27: Table with results.

- Here you can see the input data for the 1st scenario.
- The three top-ranked options are displayed here. These are examples of projects in other countries which are already in service. The associated costs are shown below the options. The cost-revenue is calculated based on the entered costs and the foreseeable tariff. Since we have not specified any end-use tariff, the cost-revenue is only the rounded sum of the treatment and distribution costs.
- Here you can select any other treatment train available in this Excel-Tool. This serves as a comparison option.

Thematic subject	Key question	Indicators	Description	Egypt		unit
				aggregated	detailed	
1 Economy	How much do you pay for a m ³ water in your country?	Water pricing for agriculture	Tariffs for water use in agriculture	1.00	1.00	0.00 Euro / m ³
	How high is the water price reduction in agriculture because of financial subsidies in your country?	Financial subsidies	A sum of money granted by the state or a public body to help a water reclamation, irrigation of farms keep the price of a commodity or service low		N/A	N/A % reduction
2 Water Management	What is the share of treated (volume) to untreated wastewater in your country?	Share of annual treated to produced industrial and municipal wastewater	Share of annual treated to produced industrial and municipal wastewater	2.00	2.00	38.83 %
3 Policy & Institution	What is the degree of implementation of national monitoring and reporting in your country?	Degree of implementation of national monitoring and reporting system	Degree of implementation of national monitoring and reporting system [%]	3.00	3.00	51.20 %
4 Legislation	What is the regulation for food and non-food crop irrigation with reclaimed water in your country?	Compliance for water reclamation in food and non-food crop irrigation	Legal compliance, whether water reclamation in food and non-food crop irrigation is allowed in a country	2.00	2.00	partly ranking: yes, partly, no
5 Society	What is the social acceptance of your country towards water reuse for agriculture?	Social acceptance in a country towards the water reclamation for agriculture	The social acceptance of inhabitants of a country towards water reclamation for irrigation (food and non-food crops, municipal and industrial wastewater)	#DIV/0!	N/A	N/A N/A
6 Environment	What is the status of national water reuse regulations for irrigation in comparison with the international BS ISO 14075-2:2015 water quality guideline in your country?	Compliance of national water reuse regulations for irrigation in comparison with the BS ISO 14075-2:2015 water quality guideline	Compliance of national water reuse regulations for irrigation in comparison with the BS ISO 14075-2:2015 water quality guideline	1.00	1.00	lower ranking: higher, moderate, lower

Figure 28: PESTLE analysis simplified results.

We selected the “simplified results” for the PESTLE analysis in order to have a concise overview of the national-level conditions.

- The economic results indicate rather low water tariffs to be paid for the water use in agriculture. It can therefore be concluded that as a WWTP no direct income can be generated from treated wastewater sale. However, it should be noted that at the time of the PESTLE analysis no data were available on the subsidies paid. It can be assumed, that this is the case in Egypt and that the WWTP therefore does generate indirect revenue through subsidies.

2. The water management results indicate a moderate share of treated to untreated wastewater volume in Egypt (around 39%). Consequently, an entry into the wastewater treatment market still seems worthwhile from this perspective, as there is no market saturation yet.
3. The policy and institution results indicate a high degree of national monitoring and reporting implementation. Consequently, as a WWTP operator it can be assumed that the required quality can and must be maintained.
4. The legislation results indicate a partial compliance for water reclamation in food and non-food crop irrigation. Meaning that the irrigation of food and non-food crop with reclaimed water might be allowed in certain circumstances and in others not.
5. The social results could apparently not be measured at the time of the PESTLE analysis. Consequently, no statement can be made on the social acceptance of the use of treated wastewater in agriculture.
6. The environmental results indicate a lower compliance of national water reuse regulations for irrigation in comparison with the BS ISO 16072-2:2015 water quality guideline. This means that there is still room for improvement in terms of the environment. In concrete terms, this means that potentially stricter regulations would have to be introduced to protect the environment more effectively.

4.4.3 Questions & Answers

1. Are there suitable treatment trains for reuses 1 and/or 2?	Yes, there are a lot of suitable treatments for reuses for both the scenarios.	
2. Which are the three top-ranked options based on the costs?	1 st scenario (reuse for aquaculture)	
	Option 1:	Soil treatment: Israel
	Option 2:	Title 22: USA I
	Option 3:	Title 22: Brazil II
	2 nd scenario (reuse for landscape irrigation in urban areas)	
	Option 1:	Lagooning: Australia I
Option 2:	Wetlands: USA	
Option 3:	Title 22: Belgium	
3. What are the costs of treatment for those options?	1 st scenario	
	Soil treatment: Israel	1.36 [USD/m ³]
	Title 22: USA I	1.43 [USD/m ³]
	Title 22: Brazil II	1.48 [USD/m ³]

	2 nd scenario
	Lagooning: Australia I 0.47 [USD/m ³]
	Wetlands: USA 0.97 [USD/m ³]
	Title 22: Belgium 1.16 [USD/m ³]

4. What are the costs of distribution?	1 st scenario: 0.01 [USD/m ³]
	2 nd scenario: 0.01 [USD/m ³]

Remarks and analysis: For this case, it appears that it is necessary to treat the wastewater separately in order to comply with the water quality requirements. Consequently, it is likely that only one strategy will be followed. This Excel-Tool therefore gives a first impression on the feasibility of these two scenarios in combination. This conclusion can now be used to re-evaluate the foreseen water reuse. For example, further scenarios can be evaluated with the Excel-Tool, which might have more similar reuse purposes. Furthermore, from the a WWTP operator perspective, it might be advisable to keep an eye on the economic and environmental results of the PESTLE analysis, as these two thematic subjects are most likely to require measures.

4.5 Conclusions

Poseidon 2.0 is a tool to promote and asses water reuse. Different parameters can be personalized and adapted in this tool per user. The values calculated by Poseidon 2.0 should not be considered absolute values but only as indicators. The accuracy is not guaranteed. The given results show different possibilities to adapt or enhance the treatment of wastewater, but only the implementation in “real life” with adapted monitoring of the treatment can produce accurate values for a given treatment plant.

4.6 Glossary

Term	Definition (<i>applied to the use and understanding of Poseidon 2.0</i>)
Input	The wastewater that has to be treated before being reused
Unit Processes	Single water treatment technologies (primary, secondary, tertiary treatment and disinfection technologies)
Treatment Trains	Series of unit processes combined in a so-called treatment train or treatment chain
End-use	The intended reuse of reclaimed water after its treatment with an adequate treatment train (e.g. agricultural, industrial, potable reuse or environmental recharge)
Quality class	Defined by several quality parameters included in the tool (e.g. turbidity, biological oxygen demand, etc.); those included in Poseidon 2.0 either represent typical water quality of wastewaters or limits based on guidelines and recommendations for reuse
Weighting	Can be assigned to the different assessment criteria in order to calculate an overall treatment train score (single indicator) that consider the relative importance of different criteria based on specific cases
Distribution	Transport of wastewater and water in pipes or open channels; depending on elevation, distribution involves pumping
Wastewater	Water which has been polluted by human activities
Water reuse	Beneficial use of reclaimed water
Greywater	Wastewater from households or office buildings (bathing, cleaning, laundry, etc.) without faecal contamination, i.e. all streams except for the wastewater from toilets
Blackwater	Wastewater and sewage from toilets
Primary treatment	Usually first step in cleaning process involving removal of solids, oils, and greases by flotation, sedimentation, and screening

Term	Definition (applied to the use and understanding of Poseidon 2.0)
Secondary treatment	Removal of dissolved suspended biological matter, which typically involves biological processes by microorganisms (activated sludge, membrane bioreactors, etc.)
Tertiary treatment	Cleaning to a high level of purity or removal of specific contaminants (e.g. heavy metals); can include disinfection
Water reclamation	Cleaning of wastewater to a purity that can be used for specific purposes
Direct reuse	Direct use of reclaimed water for a specific purpose
Indirect reuse	Reuse of wastewater which has been previously mixed and diluted with fresh water by discharge into receiving water bodies

4.7 References of this Appendix

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5 Appendix II – Handbook: DST for water reuse and water & land management in agriculture

The hydro-agro-economic DST consists of statements that define the data first, followed by the model and the solution statements. The DST is contained in a computer code constructed with the text editor GAMS IDE. The file has the file extension .gsm and can be read using any text editor. To run the DST, it is necessary to install the GAMS IDE software. The code has been written in order to be usable also with the **demo version of GAMS**, that can be freely obtained at the following link: <https://www.gams.com/download/>. At the same link, it is possible to freely download the GAMS software, for Windows, Linux or MAC operating systems.

An extremely wide documentation on the use of GAMS, including a relevant library of GAMS codes, is available at this link: <https://www.gams.com/31/docs/>

When GAMS is 'run', the file containing the program (the input file) is submitted to be processed. After this processing has finished, the results, which are in the output file(s), can be inspected. By default the GAMS log appears on the screen while GAMS runs, keeping the user informed about progress and error detection. The output from GAMS contains many components in support for checking and comprehending the model.

In order to use the DST the following steps are needed :

1. Install GAMS and the IDE on your computer making an icon 
2. Open the IDE through the icon
3. Go to the file selection in the upper left corner to Create a project.
4. Define a project name and location. Put it in the directory you want to use.
5. Create or open an existing .gms file with GAMS instructions
7. Run the file with GAMS by pushing the 'run' button
8. Open and navigate around the output

5.1 DST components

Data

SET declarations and definitions to be included in the DST are the following:

C crops

CS(c) summer crops

CW(c) winter crops

T irrigation methods

P field sections

Q water quality

F fertiliser

I irrigation techniques

M month

S season

SM(m) summer months

WM(m) winter months

Kp random prices

Ky random yields

PARAMETERS to be entered as scalar are the following:

phi risk aversion_coefficient

el_pr price elasticity

landf(p) available land

PARAMETERS to be entered as list are the following:

eff(i,q) application efficiency of irrigation methods

WATPR (q) price of water (euro per cubic meter)

fertpr (f) price of the fertilisers (euro per kg)

pr (c) price of the crop (euro per 1000kg)

pr_dev (c) Coefficient of variation of crops price

sub_lev(q) percentage of technology cost subsidized

VC (c,q) Crops variable costs (euro per ha) ;

PARAMETERS to be entered as tables of two or more dimensions are the following:

TABLE L_use (c,m) Land use (yes or no)

TABLE Combi1 (c,i,t,p) Possible combination of crop/irrigation methods/field sections/ irrigation techniques

TABLE nir (c,t,m) Net irrigation requirements (m3 per ha)

TABLE fertreq(c,q,f) Fertiliser requirements (kg per ha)

TABLE y (c,q,t) (yields ton per ha)

TABLE y_dev (c,q,t) (% of variation of random yields)

TABLE vc(c,q) variable cost (euro per ha)

TABLE tech_cost(c,q) cost of technology (euro per ha)

TABLE iniarea(c,p) observed cropping pattern (ha)

TABLE watsup(p,q,s) water availability (m3 per ha)

Data entered using assignment statements are the following:

GIR (c,i,t,m,q) Gross irrigation requirements (m3 per ha) ;

$GIR(c,i,t,m,q) = (NIR(c,t,m)/eff(i,q));$

Pr_k (c,kp) Random prices ;

$pr_k(c,kp) = normal(pr(c),pr_dev(c)) ;$

Y_k (c,q,t,ky) Random yields ;

$y_k(c,q,t,ky) = normal(y(c,q,t),y_dev(c,q,t)) ;$

5.2 Model

VARIABLES are declared and positive variables are specified as follows:

VARIABLE

U Utility function (euro)

ZK(ky,kp,p) Random Income (euro)

sigma (p) Standard deviation (euro)

GRMARG Gross margin (euro)

GRMARG_k Random gross margin (euro)

fertused Amount of fertiliser applied (kg)

diff Difference between observed and actual cropping pattern (ha)

techamount Area with the new technology (ha)

POSITIVE VARIABLE

X(c,i,q,t,p) Crop activity level (ha)

Z Expected income (euro)

watreqc Water demand (m3)

pricewat Price of water (euro/m3)

varcosts Variable cost (euro)

tot_cost_wat Cost of water (euro)

EQUATION declarations and EQUATION definitions

Equations included in the model can be distinguished in two main blocks.

The first one is related to the objective function and to all its nested components.

objective.. $U = e = Z('c_land') - phi * SIGMA('c_land') ;$

differ(c).. $diff(c) = e = ((sum((i,q,t,p), X(c,i,q,t,p) * Combi1(c,i,t,p))) - (sum((p),(Iniarea(c,p)))))/(sum((p),(Iniarea(c,p)))));$

GM(c,t,q,p).. (Y(c,q,t) *(Pr(c)-Pr(c)*0.957*diff(c))) - tech_cost(c,q)*sub_lev(q) - vc(c,q) -sum (f, fertreq(c,q,f)*fertpr(f)) =e= GRMARG(c,q,t,p);

GM_k(c,q,t,p,ky,kp).. (Y_k(c,q,t,ky)*(Pr_k(c,kp)-Pr_k(c,kp)*0.957*diff(c))) - tech_cost(c,q)*sub_lev (q)- vc(c,q) -sum (f, fertreq(c,q,f)*fertpr(f)) =e= GRMARG_k(c,q,t,p,ky, kp) ;

income_e(p).. Z(p) =e= (sum((c,q,t,i),GRMARG(c,q,t,p) *X(c,i,q,t,p))-tot_cost_wat(p));

income_k(ky,kp,p).. Zk(ky,kp,p)=e= (sum((c,q,t,i), GRMARG_k(c,q,t,p,ky,kp)*X(c,i,q,t,p)) -tot_cost_wat(p));

std_dev(p).. SIGMA (p) =e= sqrt(sum ((ky,kp), sqrt(ZK(ky, kp,p)-Z(p)))/(card (Kp)*card (ky)));

fert_tot(f,q).. sum ((c,i,t,p), fertreq(c,q,f)*X(c,i,q,t,p)) =e= fertused(f, q) ;

tech_amount(q).. sum ((c,i,t,p), tech_cost(c,q)*X(c,i,q,t,p)) =e= techamount(q) ;

var_costs(c,q).. sum ((i,t,p), vc(c,q)*X(c,i,q,t,p)) =e= varcosts (c, q) ;

swater_tot_tot_c(p).. tot_cost_wat(p)=e= sum ((c,q),pricewat(p,q,c));

swater_totc(p,q,c).. watreqc(p,q,c)*watpr(q)=e= pricewat(p,q,c);

The second one is related to the constraints of the optimization, mainly, land and water availability. As for water, four equations are included one for each season, summer and winter, and each water quality, q1 and q2.

fland(p,m).. sum((c,i,t,q),X(c,i,q,t,p)) =e= landf(p) ;

water_totcs1(p,'q1',cs).. sum((i,t,m), gir(cs,i,t,m,'q1') * X(cs,i,'q1',t,p)\$Combi1(cs,i,t,p)*L_use(cs,m))=e=watreqc(p,'q1',cs);

water_totcs2(p,'q2',cs).. sum((i,t,m), gir(cs,i,t,m,'q2') * X(cs,i,'q2',t,p)\$Combi1(cs,i,t,p)*L_use(cs,m))=e=watreqc(p,'q2',cs);

water_totcw1(p,'q1',cw).. sum((i,t,m), gir(cw,i,t,m,'q1')*X(cw,i,'q1',t,p)\$Combi1(cw,i,t,p)*L_use(cw,m))=e=watreqc(p,'q1',cw);

water_totcw2(p,'q2',cw).. sum((i,t,m), gir(cw,i,t,m,'q2')*X(cw,i,'q2',t,p)\$Combi1(cw,i,t,p)*L_use(cw,m))=e=watreqc(p,'q2',cw);

suwatfs1(p,'q1',sm).. sum(cs,watreqc(p,'q1',cs)) =e= watsup(p,'q1',sm)*landf (p) ;

suwatfs2(p,'q2',sm).. sum(cs,watreqc(p,'q2',cs)) =e= watsup(p,'q2',sm)*landf (p) ;

suwatfw1(p,'q1','wm').. sum(cw,watreqc(p,'q1',cw)) =e= watsup(p,'q1','wm')*landf (p) ;

suwatfw2(p,'q2','wm').. sum(cw,watreqc(p,'q2',cw)) =e= watsup(p,'q2','wm')*landf (p) ;

MODEL DEFINITION

The model statement is used to collect equations into groups and to label them so that they can be solved. The simplest form of the model statement uses the keyword all: the model consists of all equations declared before the model statement is entered.

SOLVE

Once a model has been defined using the model statement, the solve statement prompts GAMS to call one of the available solvers for the particular model type.

The proposed model is a Non Linear Programming (NLP) model and the chosen solver is CONOPT.

DISPLAY of results

The display statement in GAMS is a quick way to write data into the listing file user to control the layout and appearance of the output.

While there is no fixed order in which statements have to be arranged, the order in which data modifications are carried out is important. Symbols must be declared as to type before they are used, and must have values assigned before they can be referenced in assignment statements. Each statement is followed by a semicolon except the last statement, where a semicolon is optional.

The output file generated from a GAMS run is called listing file. The listing file has the file extension .lst and can be read using any text editor. By default the listing file has the same file name as the input file, but this can be changed using the command line parameter Output. The main components in the listing file are:

Compilation. The compilation output contains an echo print of the input file, possibly error messages, along with lists of GAMS objects and cross reference maps.

Execution. The execution output contains the results of display statements and possibly execution error messages.

Model Generation. The output generated during model generation contains listings of equations and variable listings as well as model statistics and possibly generation execution error messages.

Solution. The output generated when an external solver program processes the model is the solution report including the solve summary, the solver report, the solution listing and the report summary.

Post-Solution. The final components added to the listing file are the final execution summary and the file summary.

A selection of the most important outputs of the model is shown here below, using the gams screen output following the sequence that appears in the original model:

- **Utility** (objective function) as defined in the model equation in the precedent section

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR U	-INF	4.2196E+8	+INF	.
U Utility function				
---- VAR Z Expected income (euro)				
	LOWER	LEVEL	UPPER	MARGINAL
c_land	.	4.2196E+8	+INF	.
---- VAR ZK Random Income				
	LOWER	LEVEL	UPPER	MARGINAL

- **Fertilizer use:** as defined in the model equation in the precedent section:

VAR	LOWER	LEVEL	UPPER	MARGINAL
pepper_ext.q2.t1.c_land.ky5.kp5	-INF	3637.753	+INF	.
pepper_ext.q2.t1.c_land.ky5.kp4	-INF	4059.780	+INF	.
pepper_ext.q2.t1.c_land.ky5.kp5	-INF	3442.259	+INF	.
---- VAR fertused Amount of fertiliser applied				
	LOWER	LEVEL	UPPER	MARGINAL
1.q1	-INF	1.9374E+7	+INF	.
1.q2	-INF	1.6642E+6	+INF	.
2.q1	-INF	2.6212E+6	+INF	.
2.q2	-INF	7.4978E+5	+INF	.
---- VAR diff Difference between observed and actual cropping pattern				
	LOWER	LEVEL	UPPER	MARGINAL

Note: q1, q2 are water types, defined in the model constraints (see equation definitions above) as:

- q1: freshwater
- q2: treated wastewater

- **Crop distribution**

VAR	LOWER	LEVEL	UPPER	MARGINAL
LANDT .tot .tot				47592
LAND .tot .q1				33873
LAND .tot .q2				13719
crop .Clementine.q1				12472
crop .Navel .q2				4754
crop .Maroc_Late.q2				8965
crop .Nour .q1				4856
crop .Nadorcott .q1				1195
crop .tomato_int.q1				4996
crop .tomato_ext.q1				3274
crop .pepper_int.q1				5040
crop .pepper_ext.q1				2040
WATq1 .c_land .Clementine				7588422
WATq1 .c_land .Nour				2811094
WATq1 .c_land .Nadorcott				1323391
WATq1 .c_land .tomato_int				3444452

The colors indicate:

- Total land
- Area irrigated with freshwater
- Area irrigated with treated wastewater
- Crop distribution

- **Water requirement**

		---- VAR watreqc			
		LOWER	LEVEL	UPPER	MARGINAL
Compilation					
Equation Listing	SOLVE general Using NLP F				
Equation					
Column Listing	SOLVE general Using NLP F				
Column					
Model Statistics	SOLVE general Using NLP F				
Solution Report	SOLVE general Using NLP F				
SolEQU					
SolVAR					
U					
Z					
ZK					
sigma					
GRMARG					
GRMARG_k					
fertused					
diff					
techamount					
X					
watreqc					
pricewat					
varcosts					
tot_cost_wat					
Execution					
Display					
RES_RES					

	LOWER	LEVEL	UPPER	MARGINAL
c_land.q1.Clementine	.	7.5884E+6	+INF	.
c_land.q1.Navel	.	.	+INF	.
c_land.q1.Maroc_Late	.	.	+INF	-0.003
c_land.q1.Nour	.	2.8111E+6	+INF	.
c_land.q1.Nadorcott	.	1.3234E+6	+INF	.
c_land.q1.tomato_int	.	3.4445E+6	+INF	.
c_land.q1.tomato_ext	.	1.9645E+6	+INF	.
c_land.q1.pepper_int	.	3.1301E+6	+INF	.
c_land.q1.pepper_ext	.	1.2092E+6	+INF	.
c_land.q2.Clementine	.	.	+INF	.
c_land.q2.Navel	.	3.2626E+6	+INF	.
c_land.q2.Maroc_Late	.	6.8228E+6	+INF	.
c_land.q2.Nour	.	.	+INF	.
c_land.q2.Nadorcott	.	.	+INF	-0.011
c_land.q2.tomato_int	.	.	+INF	.
c_land.q2.tomato_ext	.	.	+INF	-0.003
c_land.q2.pepper_int	.	.	+INF	.
c_land.q2.pepper_ext	.	.	+INF	-0.264

The colors indicate:

- Amount of freshwater
- Amount of treated wastewater

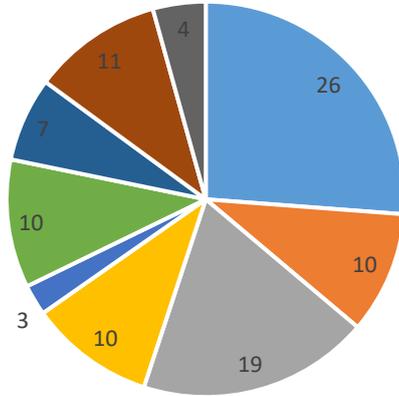
As an example, the summary of the initial parameters and main outputs of the model are shown in Tables 3 and 4, relatively to the application of the model to an integrated farm that represents two of the MADFORWATER case studies, the permanent citrus farming system in the region of Souss Massa in Morocco and the annual horticulture farming system in the region of Nabeul in Tunisia

Table 3: Integrated agro-economic model: Initial parameters

	Variables				
	Crop distribution (ha)	Yield (ton/ha)	Price (€/ton)	Variable costs (€/ha)	Cost of technology (€/ha)
Clementine	12527	30	280	3042.2	350
Navel	4750	40	380	3105.6	350
Maroc_late	8981	45	365	3105.6	350
Nour	4840	40	304	3105.6	350
Nadorcott	1194	65	404	3042.2	350
Tomato_int	5000	50	350	3200	350
Tomato_ext	3300	30	300	3100	350
Pepper_int	5000	40	380	3000	350
Pepper_ext	2000	28	360	2800	350

Total area (ha)	47592
------------------------	-------

Table 4: Integrated agro-economic model: results

Crops	Variables	
	Area (ha)	Water req (m3/ha)
Clementine	12472	608
Navel	4754	686
Moroc_late	8965	761
Nour	4856	578
Nador_cott	1195	1107
Tomato_int	4996	689
Tomato_ext	3274	600
Pepper_int	5040	621
Pepper_ext	2040	593
Total area (ha)	47592	
Total income (euro)	421958614	
Income (euro/ha)	8866	
Crop distribution (%)	 <p> ■ Clementine ■ Navel ■ Moroc_late ■ Nour ■ Nador_cott ■ Tomato_int ■ Tomato_ext ■ Pepper_int ■ Pepper_ext </p>	