A Model-Based Tool to Quantify and Characterise Wastewater in Small Nile Delta Settlements

User Manual

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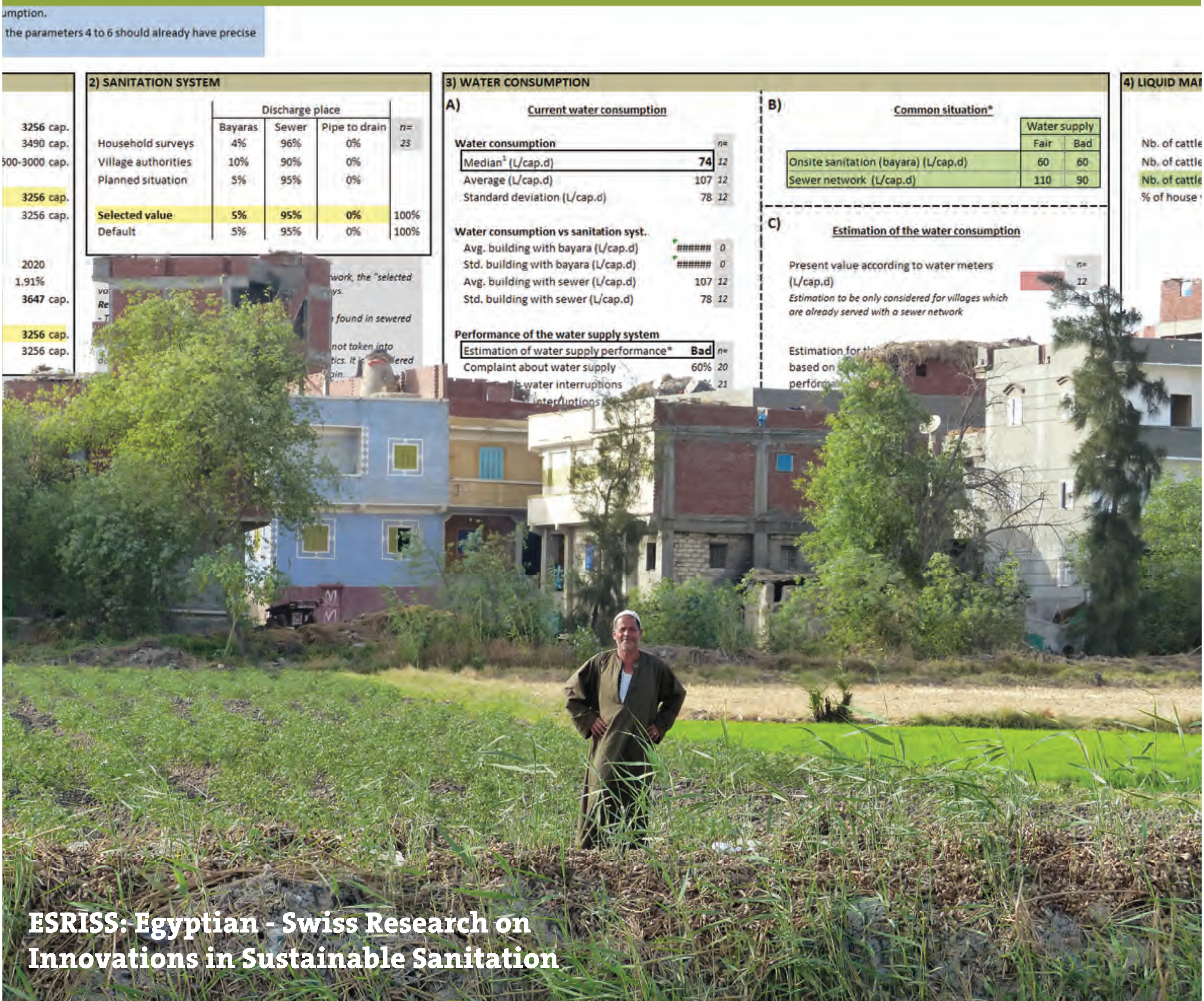

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Picture on the cover page: Household survey in Beheira Governorate (©Colin Demars)

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TABLE OF CONTENTS

1 Introduction to the tool

1.1 Rationale behind the tool

Lack of baseline data and design parameters characterising rural wastewater in the Nile delta is seen as a major gap in the development of sound sanitation strategies for settlements under 5,000 inhabitants. Such data is usually made up of the characteristics and quantities of the wastewater to treat, be it in the form of sewage or septage. However, Nile delta ezbas and villages are very heterogeneous, which prevents the definition of values applicable to all settlements; instead, developing a baseline data in this context means understanding current sanitation practices, the factors influencing the quantities and characteristics, and the extent of this influence. For this reason, the ESRISS project decided to undertake a thorough analysis of the sanitation-related flows (blackwater, greywater, animal manure) within Nile delta settlements, with the following objectives:

1. Identify, quantify and characterise the sanitation-related flows
2. Understand the factors influencing wastewater quantities and characteristics
3. Develop a model of the sanitation-related flows in Nile Delta small settlements in order to be able to compare sanitation system scenarios, based on the *Material Flow Analysis* approach (MFA)
4. Estimate the nutrient flows (nitrogen and phosphorus) in the perspective of an optimal nutrient reuse in agriculture.
5. Develop a tool which will help designers and consultants to estimate quickly the quantity and characteristics of the raw wastewater to be treated, on a site-specific basis

Points 1 and 2 are developed in the ESRISS Report "*Small-Scale Sanitation in the Nile Delta: Baseline Data and Current Practices*", whereas Points 3 and 4 are developed in the ESRISS Report "*Modelling Small-Scale Sanitation in the Nile delta: A Material Flow Analysis with Nutrient Reuse Perspective*", both to be downloaded at www.sandec.ch/esriss.

The tool presented here is the result of the combination and simplification of the materials developed by the ESRISS team during the four-year project in Egypt. Its purpose is to help designers and consultants to estimate quickly (max. 3 days) the quantity and characteristics of the raw wastewater to be treated, on a site-specific basis, in settlements of up to 5,000 inhabitants, without industry, served or to be served by a sewer network. It is a planning tool which permits to estimate the wastewater quantity and characteristics both in the existing situation and in future scenarios, for example in order to anticipate the sewage characteristics in villages not yet served by sewer networks.

The tool allows to predict village-specific design parameters without taking any samples. Sewage sampling was recognised as a bottleneck as it is very difficult, often even impossible, to be able to get representative samples; in all case, it is time-consuming and expensive. Instead, the tool relies on the extensive data baseline developed by the project (cf. ESRISS *Baseline Data Report*) and requires the input of a minimal number of qualitative data to estimate values corresponding to the village under investigation.

This tool is a result of the Egyptian-Swiss Research on Innovations in Sustainable Sanitation (ESRISS - www.sandec.ch/esriss), a parallel research component of the World-Bank funded Integrated Sanitation and Sewerage Infrastructure Project (ISSIP); the ESRISS Project is led by the Swiss Federal Institute of Aquatic Science and Technology (Eawag) in partnership with the Egyptian Holding Company for Water and Wastewater (HCWW) and financed by the Swiss State Secretariat for Economic Affairs (Seco).

1.2 Components of the tool

The tool consists of the following components:

- A **step-by-step procedure** on how to carry out the assessment of the initial situation in the field *(in Appendix)*
- Clear guidance on which stakeholder to meet, and which relevant data to get, with the support of ready-made **interview guidelines and survey questionnaires** *(in Appendix)*
- An **Excel-sheet based model**, which, upon entering the site-specific data, provides automatically the range of wastewater quantity and characteristics to be expected, including the flow, BOD, COD, TS, TSS, TN and TP. It also delivers a factsheet for the village under investigation and an estimation of the residual flows which do not enter the sewer network (septage, greywater and liquid animal manure).

The tool is based both on the baseline data gathered within the ESRISS project and the *Material Flow Analysis* model. In the two first steps, the site-specific data collected from the Village Council, village authorities, households, sanitation stakeholders and personal observation are entered in the model, which treats the data automatically. The model then helps the user to cross-check the different data for each sensitive parameter in order to predict the more realistic value when the village will be served with a sewer network; thus, it is not a black box, but a decision-making support. Based on that, it calculates the range of values to be expected for the main design parameters.

1.3 Application

The model has been applied and calibrated in four villages with existing “informal” sewer networks in Beheira Governorate (cf. ESRISS *MFA Report*). Further application is recommended in order to strengthen it further and to adapt it to other contexts, for example Upper Egyptian villages.

This model does not allow to estimate the quantity and characteristics of septage, in case of non-sewered village. It only provides an estimation of the quantity of residual septage to be treated and give the average septage characteristics measured by the ESRISS team. The factors influencing septage characteristics are numerous and difficult to measure, and result in high variations (cf. ESRISS *Baseline Data Report*). Thus, septage could not be included in this tool within the timeframe of this project; it would be however a very useful further development, if the concept of septage treatment plant is validated by the authorities.

THIS MODEL IS AN OPEN-SOURCE ENTERPRISE. ANY FURTHER DEVELOPMENT, IMPROVEMENT OR APPLICATION IS WELCOME AND ENCOURAGED. FEEDBACK IS HIGHLY APPRECIATED. FOR ANY FEEDBACK OR QUESTIONS, PLEASE CONTACT:

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Kawm Abu Khalifa, a small settlement in Beheira Governorate (picture: Ph. Reymond)

2 Model description

The model consists of an Excel file, to be downloaded at www.sandec.ch/esriss, which:

- Treats automatically the field data.
- Eases the crosschecking of the sensitive parameters, leading to realistic estimations of these parameters in the future when the village under investigation will be served by a functioning sewer network.
- Estimates the future wastewater quantity and characteristics by processing the parameters computed/selected in the previous steps through a material flow analysis model.

The procedure on how to make the assessment of the initial situation, how to collect the data and how to enter it in the Excel model is described in the *Step-by-Step Procedure* provided in the Appendix and the Excel file itself. The following sections describe the different components of the model and how it works.

2.1 Structure of the model

The model consists of nine Excel sheets, as shown in Figure 1. The *Introduction* sheet explains briefly the rationales of this model, such as described in this manual. *Step 1* and *Step 2* are the two sheets where the field data is entered. *Step 3* is where the data from various sources are crosschecked, in order to define the most realistic value for each key parameter. The sheet *RESULT* delivers the main result of the model: the expected wastewater quantity and characteristics. The sheets *FACTSHEET-Village* and *Non-Sewered Flows* deliver secondary results of the model: a factsheet gathering the relevant information for the village under investigation and an estimation of the quantities and characteristics of the septage, greywater and animal manure which do not enter the sewer network, thus ending up directly in the environment.

CompSheet1 and *CompSheet2* are the two calculation sheets behind the model. CompSheet1 is where the field data is treated, whereas CompSheet2 hosts the simplified Material Flow Analysis (MFA) model. These two sheets should not be touched, except if the user wants to adapt the model to his/her own conditions.

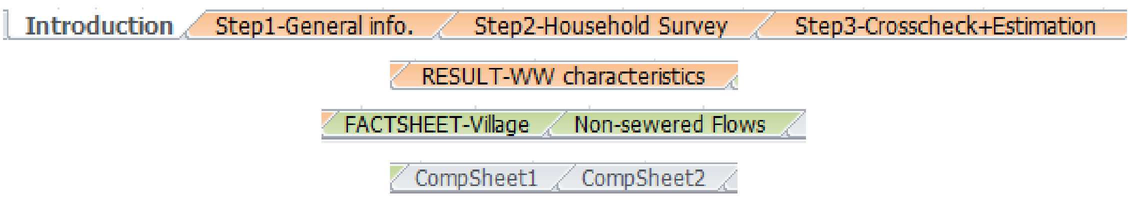


Figure 1: Excel sheets forming the model

2.2 Treatment of the field data

The information collected on the field has to be entered in the model through two Excel sheets (*Step 1* and *Step 2*): the first one for the information collected from the Village Council, the village authorities and the personal observations; the second for the results of the household surveys. The format in which to enter the data is always indicated in the Excel sheets; it has to be taken with care as the model ignores the data in the wrong format.

All the entered information are treated in the first computation sheet (*CompSheet1*), which consists in:

- Computation of the different parameters based on the answers of the Village Council, village authorities, responsible of sewer maintenance and personal observations.
- Statistical analysis of household survey results and computation of valid answers, e.g. proportion of farmers in the village, water consumption, average number of cow per people.

2.3 Crosscheck and estimation of the most sensitive parameters

While data is collected from different sources, it is probable that different values are given for the same parameter by different stakeholders (a most common example being the number of inhabitants). A crucial step in order to get accurate values is to crosscheck the data for the most sensitive parameters, which have been computed in *CompSheet1* and delivered side-by-side in the Excel sheet *Step 3* for comparison.

The most sensitive parameters are: the number of inhabitants, the water consumption, the type of sanitation system(s), the interaction with groundwater, the liquid manure production and discharge location and the discharge point(s) of greywater.

Step 3 allows to easily compare the different values and choose the most suitable one for each of these parameters. In what follows, further guidance and explanations are provided for each of the sensitive parameters. When the crosschecking process does not allow to get consistent results, further interviews need to be carried out in order to get more precise data. These can be done during the second visit in the village, dedicated to the second water meter readings.

2.3.1 Number of inhabitants

Three different sources of information are used to estimate the number of inhabitants in the selected villages:

- The official data: a census was done in all villages, mainly in 2006; the actual number of inhabitants is computed with the growth rate entered in Box 4 "*Personal observations*"; the default value is set at 1.91%, as in the

Code of Practice. NB: it appears that the official data often do not match reality.

- The estimation from the village authorities (Sheikh el Balad or Omda)
- The estimation based on the number of houses counted on satellite images (e.g. Google Earth) and the average number of inhabitants per house as obtained through the household survey.

Figure 2 features the corresponding box in the Excel model. The default value for the current population is the personal estimation. Most of the time, the data coming from the personal estimation are more accurate than from the two other methods.

The model also computes the population at the planning horizon according to the selected value for the current population and the planning horizon and growth rate entered under "*Personal observations*" in *Step 1*.

1) NUMBER OF INHABITANTS		
Current situation		
Personal estimation	**3256**	cap.
Official (based on census and growth rate)	3490	cap.
According to village authorities	2500-3000	cap.
Current population	**3256**	cap.
Default	3256	cap.
Population at planning horizon		
Planning horizon	2020	
Estimated growth rate	1.91%	
Estimated population at planning horizon	**3647**	cap.
Selected value	**3256**	cap.
Default	3256	cap.

Figure 2: Box featuring the different sources of demographic information

2.3.2 Sanitation system

The percentage of buildings connected to bayaras, to a sewer network or directly connected to a drain through a pipe is computed based on the results of the household survey and the estimation from the village authorities. The model considers that the houses discharging wastewater directly into the drain (pipe to drain) are not sewered.

Figure 3 features the corresponding box in the Excel model. The default value corresponds to the typical situation found in sewered villages. If the studied village is already served with a sewer network, the "selected value" should be the results from the HH surveys; otherwise, it will be the values of the planned situation.

2) SANITATION SYSTEM				
	Discharge place			
	Bayaras	Sewer	Pipe to drain	*n=*
Household surveys	4%	96%	0%	*23*
Village authorities	10%	90%	0%	
Planned situation	5%	95%	0%	
Selected value	**5%**	**95%**	**0%**	100%
Default	5%	95%	0%	100%

Figure 3: Box featuring the different sanitation systems

2.3.3 Water consumption

Two different perspectives are used for the estimation of the drinking water consumption, as shown in Figure 4: (i) the consumption based on two water meter readings done with a minimum interval of one week, and (b) an estimation based the common situation, based on the choice of the sanitation system selected in the previous box and the performance of the water supply system.

3) WATER CONSUMPTION

A) **Current water consumption**

Water consumption		*n=*
Median[1] (L/cap.d)	**74**	*12*
Average (L/cap.d)	107	*12*
Standard deviation (L/cap.d)	78	*12*
Water consumption vs sanitation syst.		
Avg. building with bayara (L/cap.d)	#######	*0*
Std. building with bayara (L/cap.d)	#######	*0*
Avg. building with sewer (L/cap.d)	107	*12*
Std. building with sewer (L/cap.d)	78	*12*
Performance of the water supply system		
Estimation of water supply performance*	**Bad**	*n=*
Complaint about water supply	60%	*20*
House with water interruptions	52%	*21*
Frequency of interruptions (#/week)	5.7	*11*
Duration of interruptions (hours)	8.0	*8*

B) **Common situation***

	Water supply	
	Fair	Bad
Onsite sanitation (bayara) (L/cap.d)	60	60
Sewer network (L/cap.d)	110	90

C) **Estimation of the water consumption**

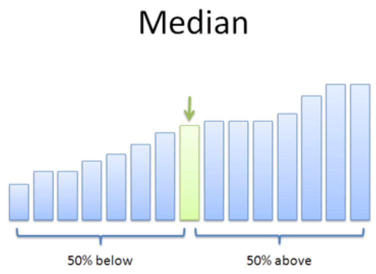
		n=
Present value according to water meters (L/cap.d) *Estimation to be only considered for villages which are already served with a sewer network*	**74**	*12*
Estimation for the selected sanitation system based on the common situation and the performance of the water supply (L/cap.d)* *Estimation to be considered for villages which currently rely on bayaras, or for sewered villages with a low reliability of water meter readings*	**89**	

Selected value	**89**	**L/cap.day**
Default	89	L/cap.day

Figure 4: Box featuring the different water consumption information

The estimation of the **current water consumption** is based on two water meter readings done with a minimum interval of one week. The sheet *CompSheet1* computes the water consumption per capita for each building. It should be noted that malfunctioning of a high proportion of water meters, as well as intentional by-passing of the water meter through a second pipe system, may lead to aberrant results. The aberrant values (<20 L/cap.d and >800 L/cap.day) are not taken into account. Field work shows that there is high variation of water consumption within the same village; therefore, the default value of the water consumption is the median of the sample and not the average. The median is the "middle number" in a sorted list of numbers, as shown in **Figure 5**.

Figure 5: Illustration of the median



The validity of the current water consumption is checked by observing the standard deviation of the results and comparing the median with the average. A distinction is made in the Excel sheet between the water consumption computed for houses with on-site sanitation system and the one connected to a sewer network.

In the case of a village which is currently served by on-site sanitation systems or dysfunctional sewer network(s), the current water consumption will increase if the village get connected to a proper sewer network. In order to estimate the **water consumption after the construction of a proper sewer network**, the model relies on the data baseline ("common situation") and the performance of the water supply system in the village. Table 1 synthesises the data baseline. It shows that, in households with an onsite sanitation system (bayara), the tap water consumption is lower, as people tend to reduce the amount of water consumed in order to decrease the bayara emptying frequency (cf. ESRISS *Baseline Data Report*). On the contrary, in villages with sewer networks, the water consumption is higher, but can be limited by a poor water supply.

In the model, the water supply is considered as "bad" if more than 50% of surveyed people are complaining about interruptions and if there are on average more than two water supply interruptions per week.

Table 1: Estimation of daily water consumption

	Fair water supply	Bad water supply
Onsite sanitation	60 L/cap.d	60 L/cap.d
Sewer network	110 L/cap.d	90 L/cap.d

2.3.4 Liquid animal manure

The material flow analysis shows that the number of cattle per inhabitant and the discharge location of liquid manure can have a big influence on the amount of nitrogen, COD and TSS in the wastewater (cf. ESRISS *MFA Report*). It varies from one village to the other and needs to be deduced on a site-specific basis.

The model synthesises the information regarding cattle and manure in the box feature in Figure 6. The number of cattle usually varies between 0.05 to 0.5 animals per inhabitants. Regarding the discharge location, the study shows that when a village is sewered, most of the liquid manure ends up in the network. In villages with a person responsible for the sewer maintenance, this amount can be lowered (to an average of 10% in certain villages) due to the establishment and enforcement of a rule forbidding this practice. Disposal in the street is less than 20% in villages equipped either by onsite sanitation or with a sewer network. On average an animal spends 27% of its time in the field; therefore, we assume that about this percentage of liquid manure always ends up in the fields (cf. *Baseline Data Report*).

4) LIQUID MANURE

Nb of Cattle

		n=
Nb. of cattle per cap (HH surveys)	0.29	23
Nb. of cattle per cap (Vil. auth.)	0.15	
Nb. of cattle per cap (Common situation)	0.05-0.5	
% of house with cattle	91%	23
Selected value	**0.29**	cow/cap
Default value	0.29	cow/cap

Discharge location of liquid manure

Forbidding rule of discharging liquid manure in the sewer network? NO

	Bayara	Sewer	Other	n=
HH surveys	0%	65%	35%	20
Common situation:				
Village with sewer network	0%	**10-70%**	30-90%	
Village with sewer network[1]	0%	**10%**	90%	
Village with bayara	**~20%**	0%	~80%	
Selected value	**0%**	**65%**	**35%**	100%
Default value	0%	65%	35%	100%

[1] With a forbidding rule to discharge liquid manure in the sewer network

Figure 6: Box featuring the different information related to cattle and liquid manure disposal

When the liquid manure collection hole in the stable is not directly connected to the sanitation system, it can contribute to higher concentrations of COD and nutrients during the morning peak flow, as most of the women empty these holes manually at more or less the same time. On the contrary, if a stable is connected to the sewer network, the liquid manure discharge into the sewer system will be better distributed in time, thus reducing the peak. The effect related to manual emptying is taken into account by displaying a remark next to the daily peak flow results in the *Result* Excel-sheet :

- When less than 50% of the liquid manure is manually emptied, the remark indicates that the peak concentration should be lower.
- When more than 50% of the liquid manure is manually emptied, the remark indicates that the peak concentration should be higher.

2.3.5 Groundwater interaction

The depth of the ground water level can be considerably high in certain villages (up to a few dozen centimetres below surface), leading to a significant groundwater infiltration into the sewer network if it is not watertight (which is common), thus resulting in the dilution of wastewater with groundwater. In case of a really high depth of the groundwater table, some exfiltration of sewage into the soil could occur; however, this process has been considered non-existent in the model.

The estimation of the infiltration (groundwater to sewer) phenomenon is difficult. The model proposes an estimation based on the difference between the groundwater level and the depth of the sewer network outlet as shown in Table 2. The infiltration rate should not be higher than 30% of the flow.

Table 2 Estimation of infiltration

Proportion of the sewer network below groundwater	Infiltration (% of total sewage)
25%	10%
50%	20%
75%	30%

In an ideal case, where the outlet of a functioning sewer network can be observed, the amount of groundwater infiltration can be deducted from the residual flow in the middle of the night (from 2 to 5 am).

Figure 7 features the corresponding box in the Excel model.

5) GROUNDWATER INTERACTION		
Estimated infiltration		
Infiltration rate	0%	
Depth of the sewer network and groundwater table		
Depth of groundwater table [m]	8	
Depth of the outlet of the sewer network [m]	2	
Exfiltration rate (sewer network)- Selected value	**0%**	*[0-30%]*
Default value	0%	
Infiltration rate (sewer network) - Selected value	**0%**	*[0-30%]*
Default value	0%	

Figure 7: Box featuring the estimation of in-/exfiltration rates in the Excel-based model

2.3.6 Discharge location of greywater

The type of sanitation system has an influence on where greywater is disposed of. People who rely on an onsite sanitation system tend to decrease the load of wastewater ending up into the bayara in order to reduce the emptying frequency and thus tend to discharge greywater on the street or into a drain. Laundry and dishwashing often occur outside, keeping a big part of greywater out of the sanitation system.

The model estimates the percentage of greywater ending in the sanitation system based on these observations, as shown in Figure 8. The default values are those estimated by the model.

6) GREYWATER			
Discharge location of greywater	Bayara	Sewer	Other
Estimation based on the percentage of sewer network coverage and the baseline data:	**3%**	**83%**	14%
Common situation:			
Village with bayaras	**45-60%**	0%	40-55%
Village with sewer network	0%	**75-100%**	0-25%
Selected value	**3%**	**83%**	**14%**
Default value	3%	83%	14%

Figure 8: Box featuring the estimation of the proportion of the greywater ending up in the different discharge locations

2.4 Result: estimation of wastewater quantity and characteristics through a simplified MFA model

Once the selected values for each sensitive parameter are entered, the tool calculates the expected wastewater quantity and characteristics through a simplified material flow analysis (MFA), adapted from the more extensive MFA model of Nile Delta villages (cf. ESRISS *MFA Model* Report). The computed fluxes are: the flow volume, the COD, the total suspended solid (TSS), the total nitrogen (TN) and the total phosphorus (TP). In addition the BOD and TS are calculated based on the BOD:COD, respectively TSS:TS ratios from the data baseline.

The amount of greywater, liquid manure and household wastewater disposed of outside of the sewer network is also computed.

2.4.1 The MFA model

The material flow analysis (MFA) consists in measuring all the sanitation flows (i.e. all the inputs to the sanitation system, the outputs and what happens in between) within a defined system boundary, here a Nile Delta village; the model is illustrated in Figure 9. The model entails 9 processes and 27 flows. Processes within the system boundary are the household wastewater collection, the non-domestic wastewater collection, the onsite sanitation storage system (cesspits, bayara, “trenches”), the liquid manure collection and the sewer network(s). The processes outside the system are: the agriculture, the surface waters (canals/drains), the soil/groundwater and the atmosphere.

The MFA model equations can be found in the hidden column in *CompSheet2* and details can be found in the MFA report. The original model was simplified by identifying which parameters were constant in all villages. The constant parameters are further described below.

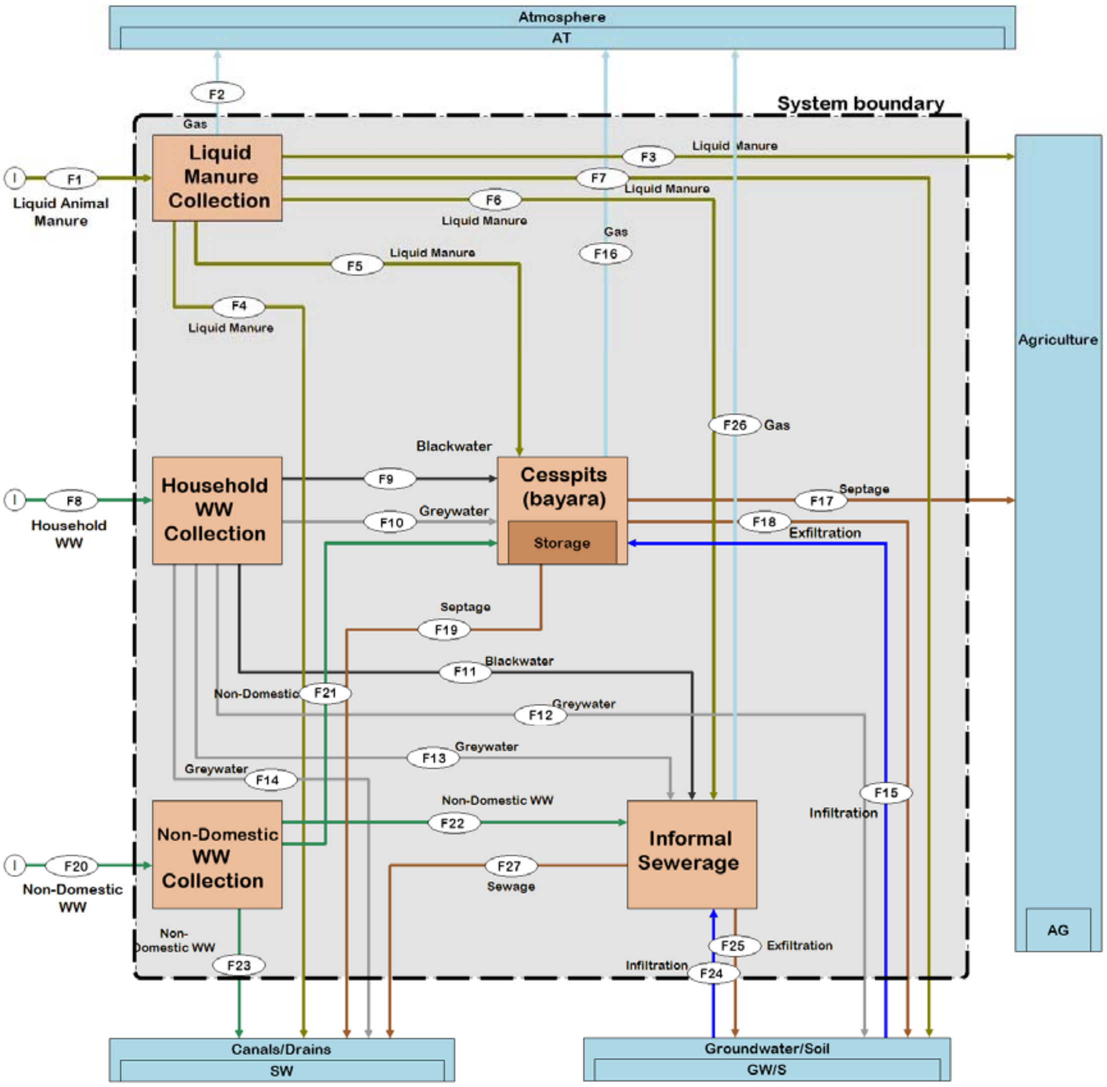


Figure 9: MFA model of sanitation flows in Nile Delta *ezbas*

2.4.2 Simplification of the model: identification of the constant parameters

A good way to simplify a model is to identify which parameters are constant from one village to the other and which ones vary from place to place. Parameters which can be considered as constant were identified based on literature review, results from the field surveys, interviews, observation, sampling campaigns and a sensitivity analysis, as described in the *MFA Report*. The complete list can be found in *CompSheet2* of the model. The most important constant parameters are:

- The concentrations of nutrients, COD and TSS in the flows entering the system, i.e. blackwater, greywater and liquid manure.
- The volume of blackwater

- The proportion of greywater produced in the bathrooms in comparison to the total amount of greywater.
- Quantity of liquid manure produced per cow and the time that cattle spend in the fields.

The constant parameters do not need to be measured again and they are directly derived from the baseline data (cf. *Baseline Data* Report). The most sensitive of the variable parameters are those which need to be studied on a site-specific basis, as shown in this manual, and whose assessment is described and supported in this tool.

2.4.3 Precision of the estimation

The precision of the model is computed based on its application to the four studied villages. Two different types of sampling were made: morning samples in two villages and full-day sampling in two others. The results of the full day sampling were directly compared to what was predicted by the model. The results from the morning sampling were adjusted with factors computed based on the ratio between the average concentrations during the morning and the average daily concentrations.

Table 3 and Figure 10 show that the model matches the measured values with a difference lower than 30% and even less than 20% for the flow. The sampling campaign shows that the variation of concentration from one to another day from the same outlet is also around 30%.

Table 3: Comparison between sewage characteristics estimated by the model and the measurements

		M.Nassar	K.Nuss	K.a. Khalifa	Fishah
FLOW [m^3/y]	MFA		236		249
	Sampling		257		276
	Diff.		**-8%**		**-10%**
TN [mg/L]	MFA	131	119	268	176
	Sampling	112	111	272	216
	Diff.	**17%**	**7%**	**-1%**	**-18%**
TP [mg/L]	MFA	10	10	15	11
	Sampling	8	10	17	12
	Diff.	**27%**	**0%**	**-11%**	**-9%**
COD [mg/L]	MFA	833	757	1'629	1'083
	Sampling	823	605	1'499	1'366
	Diff.	**1%**	**25%**	**9%**	**-21%**
TSS [mg/L]	MFA	251	231	474	318
	Sampling	172		467	405
	Diff.	**46%**		**1%**	**-21%**

The concentration of TP and TSS measured by the MFA are reduced by a factor of 0.7 in order to fit the sampling results. Indeed, these estimated concentrations were systematically higher than the one from the sampling results (see MFA report).

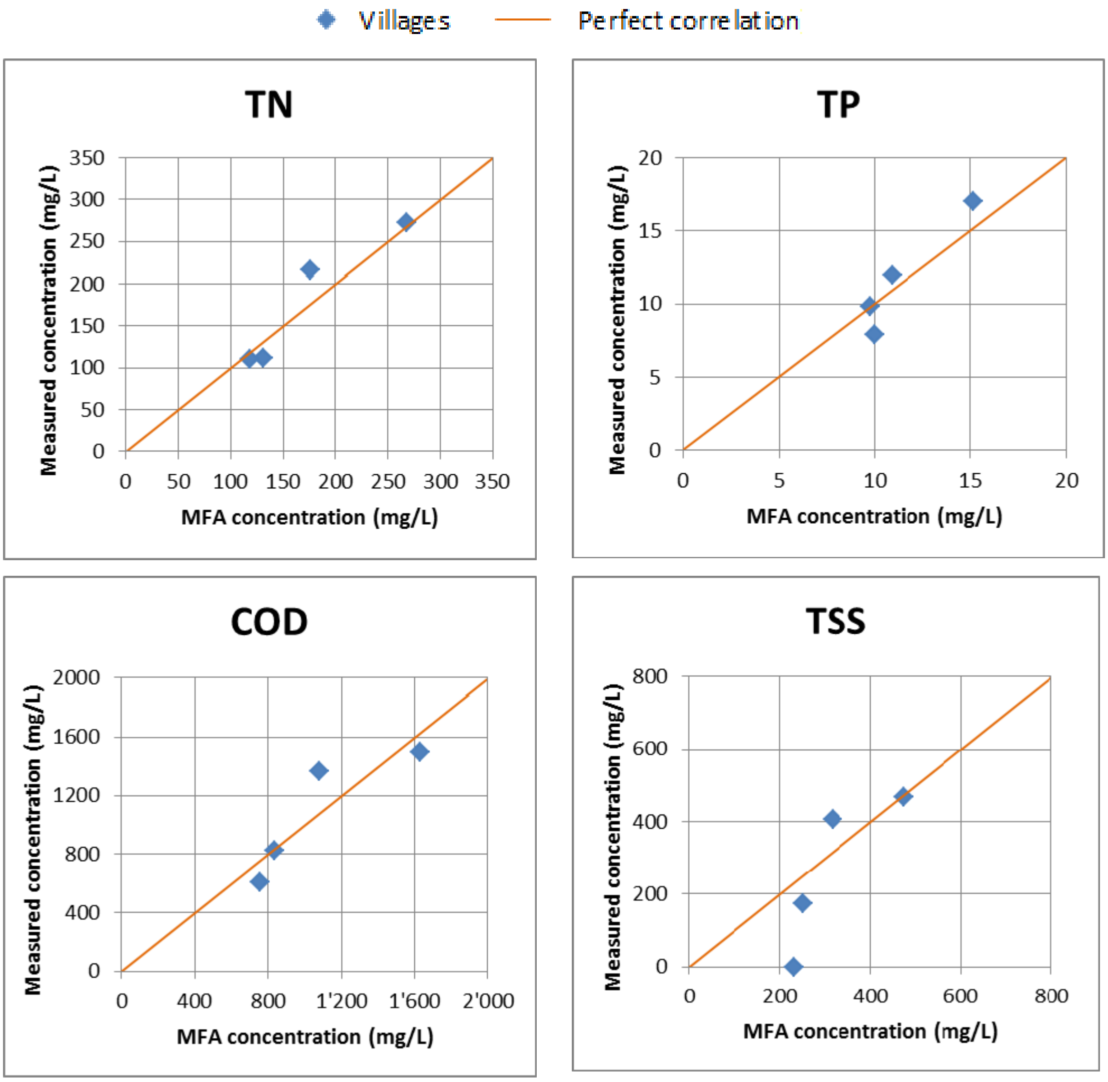


Figure 10: Comparison of the concentrations of TN, TP, COD and TSS measured with those estimated by the MFA model

2.4.4 Calculation of the peaks

Two types of peak concentrations were identified in sewage: (i) the morning peak and (ii) the "unclogging peaks".

The morning peak reflects the higher domestic water consumption at the beginning of the day, as well as the discharge into the sewer system of liquid manure manually emptied from the stables (see also section 2.3.4). The characteristics of this peak were estimated by using the peak factor measured in Fisha el Safra during a full day sampling campaign on a sewer network collecting wastewater from around 250 inhabitants (Table 4). The sampling consisted of composite samples for each 1h30. The main peak occurs in the morning and a lower peak occurs in the afternoon or beginning of evening.

Table 4: Morning peak factors measured during the sampling campaign

	COD	BOD	TS	TSS	TN	TP
Morning peak factors	1.3	1.2	1.5	1.4	1.4	1.4

Beside the morning peaks, unclogging peaks occur at any moment of the day or night. They are caused by the sudden unclogging of a blockage in the network. All the accumulated sludge of the past days reaches the outlet in a short time. This leads to sudden high concentrations, which could not be computed by the model. Table 5 provides the factors calculated based on two sets of three samples which were taken during unclogging events.

Table 5: Unclogging factors measured during the sampling campaign

– Based on measurements during two different unclogging events

	COD	BOD	TS	TSS	TN	TP
Unclogging peak factors	3.0	3.1	2.8	-	2.3	1.7

3 Potential developments

Above all, the model needs to be applied to more villages in the Nile Delta in order to provide more evidence of its validity and further calibrate it if needed. Ideal cases for validation are (i) villages where a sewer network is existing and where it is possible to take representative samples at the outlet in order to validate the model estimations, or (ii) villages that are about to be served by a sanitation project so that the estimated design parameters can be quickly verified after implementation.

Then, it is recommended to validate it for the other regions of Egypt, starting with Upper Egypt, where conditions are slightly different than in the Nile Delta. The model can also be used in other countries, in the MENA region and beyond. The ambition is that it can be adapted to help planners and engineers working on small-scale sanitation systems in any region worldwide.

This model is the result of the combination and simplification of the materials developed by the ESRISS team during the four-year project in Egypt. Simplification of such a complex system as rural sanitation is complicated and the estimation methods presented here intend to generalise as well as possible with the limited amount of baseline data available. Further studies could target the optimisation of these methods. In particular, the estimation of the water consumption based on the quality of the water supply (frequency and length of the interruptions, pressure) could be refined. This is a key-aspect, as it is the most sensitive parameter and water meters are not always available. It goes along with a clearer definition of what is a bad/fair water supply, i.e., in which conditions it can be assumed that people are able to use as much water as they want to. Besides, it would be relevant to make more investigation on peak flows, with a focus on 24-hour sampling campaigns.

Another further development concerns the estimation of septage/faecal sludge characteristics. Due to the high variability of septage and the limited data baseline, it could not be integrated within this model. However, with the rise of the concept of septage/faecal sludge treatment plant, which would contribute significantly to pollution reduction with a lower investment from the government, the estimation of design parameters for such plants could become a crucial issue in a near future.

Further work on the user interface could be done. The model allows to estimate the wastewater quantity and characteristics both in the current situation and in future scenarios. The differentiation between the present and future situation could be improved. Currently, this is done by letting the user selecting present or future values in Step 3.

Entering data in the model is quite straightforward. However, the user needs to be systematic and stick to the defined data formats. The comments in the Excel sheet are here to help the user. However, the development of a system which indicates to the user which data is in a wrong format would be an added value. So far, the model discard such values without the user being warned.

This model is an open-source enterprise. Any further development, improvement or application is welcome and encouraged. Feedback is highly appreciated. For any feedback or questions, please contact:

- **philippe.reymond@eawag.ch**
- **demars.colin@gmail.com**

4 References

- Reymond, Ph., Demars, C., Papangelou, A., Hassan Tawfik, M., Hassan, K., Abdel Wahaab, R., Moussa, M. (2014), *Small-Scale Sanitation in the Nile Delta: Baseline Data and Current Practices*. 2nd edition. Eawag, Seco, HCWW. Switzerland-Egypt.
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These reports, as well as the model Excel file, can be downloaded at www.sandec.ch/esriss .

APPENDIX

A Model-Based Tool to Quantify and Characterise Wastewater in Small Nile Delta Settlements

STEP-BY-STEP PROCEDURE

STEP-BY-STEP PROCEDURE

1. **Field work**
   a. Meeting at the Village Council (1 hour)
   b. Interviews with village authorities and person responsible for the sewer maintenance (1 hour)
   c. Household surveys and first water meter readings (4 hours)
   d. Personal observations (1 hour)
   e. Second reading of water meters (2 hours)
2. **Computer work**
   a. Entering data in the model (3 hours)
   b. Crosschecking the sensitive parameters (1 hour)
3. **Results**
   ⇨ Wastewater quantity and characteristics
   ⇨ Village characteristics

1 Field work

The field work allows to get first-hand information about the village and get support from influent people. It consists of: meeting at the Village Council, interviews of the village authorities (Omda or Sheikh el Balad) and the person responsible of sewer maintenance (if existing) and surveys with a representative number of households. Personal observations are also needed for crosschecking purposes.

The field work has to be done in two steps: the first step lasts about a full day and the second one (second reading of water meters) about one hour and has to be carried out at least a week after the first step.

a. Meeting at the Village Council (1 hour)

- Meet the Village Council of the selected village
- Explain the project
- Ask for the official number of inhabitants (census data) in the village and the date of the last census.
- Take the contact information of the village authority (Sheikh el Balad or Omda). It is recommended to ask someone from the Village Council to come along, which eases the first contact in the village.

b. **Interview with village authorities and the person responsible for sewer maintenance** (1 hour)

- Meet the local authority (Sheikh el Balad, Omda). If the village does not have any of them, find an influent and helpful villager.
- Interview him using the semi-structured interview guidelines for Village Authorities and Representatives (in the Appendix of the Manual and at www.sandec.ch/esriss).
- In case of a village already served by a sewer network and if existing, meet the person responsible for sewer maintenance, who can provide more precise information about the sewer network.

c. Household surveys (4 hours)

- The household survey questionnaire is provided in the Appendix of the Manual and at www.sandec.ch/esriss.
- Ask the local authority (Sheikh el Balad, Omda or influent villager) to identify and propose a set of households where to start the survey. These households should represent different main occupations, levels of income and social status. After 5 to 10 surveys, when villagers are more familiar with the procedure and the members of the study team, select houses randomly, making sure that the buildings are located in different parts of the village. Try to have someone from the village to accompany you during the surveys; this will be helpful to gain the trust of villagers.
- At least 25 interviews are needed to have a representative overview of the situation. A questionnaire should take less than 10 minutes, which allows to realise all of them in about 4 hours.
- Advice to carry out the surveys:
    - Always ask the question without giving a possible answer in the question.
    - Take only the answer from the man/woman you are interviewing. The answers from other villagers have to be ignored.
    - No answer is better than a wrong answer; when there is a doubt concerning the accuracy or honesty of the interviewee, leave the case blank and go to another question.

  - Do not hesitate to ask a question again in other words and sentence structure in order to confirm the answer.
  - In case that a family leaves in several buildings (e.g., courtyard), make sure to consider the data for one building only.
- Identify each house on a satellite map (e.g. on Google Earth) in order to be able to locate them during the second visit, when the second water meter readings are taken.

d. Personal observations (1 hour)

- Personal observations are to be made while walking in the village, during the household surveys. It consists in observing:
  - The existing infrastructure and practices.
  - Hotspots and problems related to wastewater management.
  - Sewer outlets and septage discharge points
  - Confirmation of the information collected during the interviews, surveys and localisation on the map.

e. Second reading of water meters (1 hours)

- At least one week after the household surveys, the village has to be visited a second time in order to read the water meters again. This is necessary for computing the drinking water consumption.
- This field trip is also the opportunity to get clarifications, if needed, about incoherent information and/or do complementary household surveys.

2 Computer work

An Excel-based model is provided, in which the collected data can be easily entered. The model helps to crosscheck the data collected and estimate the future situation. The model is sequenced in three steps, corresponding to three sheets to be successively filled in, as shown below; the yellow cells signal where data should be entered.

The model is based both on the existing data baseline and on the *Material Flow Analysis* model (MFA) developed by the ESRISS Project (cf. *MFA Report*). It is described further in the *User Manual*, to be downloaded at www.sandec.ch/esriss .

The procedure is the following:

Step1-General info.

a. Entering data in the model (3 hours)

- **Sheet STEP 1 – General information:** Enter the information collected from:
  - The meeting at the Village Council

- The interview with the village authority (Omda, Sheikh el Balad or influent villager) and the person responsible for sewer maintenance
- The personal observations
- The planned system

Step2-Household Survey

- **Sheet STEP 2 – Household survey:** Enter the results of the household survey while taking care of the following:
  - Pay attention to units (e.g. frequency needs to be given in #/week)
  - Put the results in the requested formats. (e.g. Y/N means that you should put a “Y” or “N” in the case, # means that you have to put a number)
  - If there is no answer in a question (e.g. people did not know the answer, did not want to answer) leave the case empty.
  - Do not leave the case blank when an answer is zero, instead put 0 (e.g. no children, no cattle)
  - If the answer is approximate then write the average value (e.g. “10-12 cows” becomes “11 cows”)
  - When a house has more than one water meter put the sum of both readings; the details can be written in a comment.

b. Crosschecking the sensitive parameters (1 hour)

Step3-Crosscheck+Estimation

- **Sheet STEP 3 – Crosscheck and Estimation:** look at each box (one for each sensitive parameter) and compare the different data displayed in order to determine the most realistic value for the future situation:
  - Instructions are given below each box in order to help checking the consistency of the different data and estimate the most suitable value for each parameter
  - For each parameter a default value is given, which consists of an estimation after construction of a sewer network. In case a village is already served by a sewer network, most of the values can be derived from the household survey results.
  - If the information is not sufficient to choose consistent values, clarifications may be requested or additional household survey can be done during the second reading of water meters.
  - It is possible to estimate a future situation by changing the "selected values", e.g. by entering the future population number or the future water consumption.

3 Results

3.1 Wastewater quantity and characteristics

Once that all values are selected in Step 3, the model calculates the wastewater quantity and characteristics, including the precision range of the estimations.

Sheet RESULT - Wastewater characteristics provides:

a) The estimation of the *daily average concentrations*.

b) The precision of these estimations, i.e. a *realistic range* in which the real values will be comprised

c) An estimation of the wastewater characteristics during the daily peak (in the morning). This peak flow is caused by a higher domestic water consumption in the morning.

These concentrations are calculated through the MFA model (**Compsheet2**) which take the parameters computed in **Compsheet1** and crosschecked in **Sheet STEP 3**.

3.2 Village factsheet and non-sewered flow characteristics

The model provides extra information in two separate sheets: (a) a factsheet about the village and (b) an estimation of the sanitation-related flows (septage, greywater and liquid manure) which do not end up into the sewer network.

a) **Sheet FACTSHEET – Village:** synthesises all the information about the village which has been computed from the field work results; the factsheet consists of four different categories: i) General characteristics, ii) Inhabitants, iii) Water supply and iv) Sanitation system. This sheet mainly features the results from the calculations in **Compsheet1**.

b) **Sheet Non-sewered Flows:** provides information about:

- Septage: the quantity is roughly estimated based on the frequency of emptying of bayaras and the number of trips per emptying event.
- Greywater which is not discharged in sanitation system: consists of the greywater still ending in a drain/canal and on the streets.
- Liquid animal manure not discharged in sanitation system: consists of the liquid manure discharged on fields, in a drain/canal and on the streets.

The characteristics of the septage and liquid manure are taken from the baseline data, whereas the characteristics of the greywater are calculated through the MFA model.

Interview Guide for Village Authorities and Representatives

دليل المقابلة مع المسؤلين فى القرية

- First Contact Visit أول زيارة–

Contact: Philippe Reymond, ESRISS project coordinator, 0106 483 43 14 - philippe.reymond@eawag.ch

Materials: this semi-structured interview guide and detailed satellite images of the village (from Google Earth).

Questionnaire for village authorities (Omda / Sheikh el Balad) أسئلة للعمدة

1. How many inhabitants, how many households, how many buildings? ماعدد الاسر الموجودة؟ عدد السكان
2. **General sanitation situation:** الوضع الصحى العام
   a. Bayaras and/or sewer system(s)? يستخدم بيارة أم شبكة صرف
   b. Any problems linked to sanitation? هل هناك أى معوقات
3. Groundwater table منسوب المياة الجوفية
4. Location of **drains and canals** on the map تحديد الترع والمصارف على الخريطة
5. If there is a **sewer:** اذا كان هناك مجارى
   a. How many systems? كم عدد الخطوط
   b. Identify the locations of the main lines and exit points on the map تحديدها على الخريطة
   c. How many households are connected? If not, why? كم عدد ألاسر الموصلة أليها ؟ اذا كان لا فلماذا ؟
   d. When was this system built and by whom? متى تم الأنشاء
   e. Cost per household – construction & maintenance? تكلفة كل أسرة بالنسبة للأنشاء و الصيانة
   f. Problems with the network(s)? هل هناك مشاكل مع الشبكة
   g. Which material for the pipe? ما الخامات المستخدمة فى ألانشاء
   h. Who is responsible for the maintenance (take the contact) ? من المسؤل عن الحفاظ علية (الصيانة)

If there are bayaras: اذا كان لايوجد مجارى

a. Bayara emptiers: how many trucks, public/private, origin? كم عدد عربات الكسح, وتابعة لأى جهة؟
b. Contacts of the bayara emptiers أرقام التليفون
c. Location of disposal points (map) ماقع التخلص من مياة الصرف على الخريطة
d. Frequency of emptying عدد مرات الكسح
e. Cost for desludging (cost per trip; is there any difference in the price according to the season?) ماهى تكلفة أزالة مياة المجارى وهل هناك أختلاف على حسب الموسم؟
f. Price difference between public and private truck(s)? فرق السعر بين العربات الخاصة و الحكومية؟
g. What happens if someone cannot afford emptying? ماذا يحدث لو هناك شخص لا يستطيع الدفع
h. Is there someone in the village who builds bayaras? هل هناك شخص يبنى البارات فى القرية

i. Cost to build a bayara? ما هى تكلفة بناء بيارة

j. How are bayaras constructed (watertight or not, lining, bottom, measures to improve infiltration)? كيف يتم أنشاء البيارات؟ (ألارضية,القاع,..)

k. Do farmers use wastewater from the bayaras in their fields? هل يستخدم الفلاحون مياة الصرف من البيارات فى الحقول؟

6. Quality of drinking water supply network: pressure, quantity, quality; everybody connected?

هل كل ألاسر موصلة لشبكة مياةالشرب ؟هل هى جيدة من حيث (ضغط المياة ,الكمية ,نوعية المياة)

7. What are the main professional occupations of the inhabitants? ماهى الوظائف الاساسية لمعظم السكان

8. Are there significant differences in the inhabitants' income and social status?

هل هناك فرق واضح فى الدخل والمستوى المعيشى بين أهالى القرية؟

If yes: what are the different categories? أذا كان الجزاب بـ "نعم" , ما هى الفئات المختلفة؟

9. Are there any community members who play a special role in this village?

(Examples: leading an association, organising special activities, religious leaders, etc.)

هل هناك أىً من الافراد الذين يلعبون دورا خاصا فى القرية؟ (على سبيل المثال:تأسيس جمعيات,تنظيم أنشطة أجتماعية)

10. Are there NGOs in the village? A Water User Association?

هل هناك منظمات غير حكومية فى القرية؟ او جمعية لمستخدمى المياة ؟

11. What type of non-domestic building(s) are there in the village? Where do they discharge wastewater? ما هي أنواع الأبنية الغير منزلية الموجودة بالقرية ؟ وأين تصرف مياه الصرف الصحي؟

	Number & discharge place العدد واماكن التفريغ		
	Bayara بيارة	Sewer شبكة	Pipe to drain وصلة للترعة
Health centre وحدة صحية			
School مدرسة			
Mosque جامع			

12. Are there small industrial activities (e.g. milk factories, cattle or poultry farms)?

هل يوجد انشطة صناعية صغيرة (البان؟)

13. How many cattle does one household have on average? Do they live in the house, a separate building or outside? كم عدد الحيوانات التى تملكها الاسرة الواحدة (المتوسط) ؟هل تعيش هذة الحيوانات فى نفس المنزل أم فى مبنى منفصل؟

14. Do farmers use manure and animal urine in their fields? هل يتم استخدام روث الحيوانات فى الحقول؟

Ask for contact number *رقم تليفون العمدة أو أى شخص أخر يمكن الاتصال بةفى القرية*

ESRISS Project
www.sandec.ch/esriss

Household survey questionnaire

نموذج استبيان المنازل

Contact: Philippe Reymond, ESRISS project coordinator, 0106 483 43 14 - philippe.reymond@eawag.ch

للتواصل: فيليب رايموند منسق المشروع البحثي المصري- السويسري لتطوير أنظمة الصرف الصحي المستدامة ESRISS.

Team members: ____ أعضاء فريق الاستبيان:

Person interviewed الشخص الذي تمت مقابلته		Questionnaire no رقم الاستبيان	
Surname القب		**Date** التاريخ	
Family Name اسم العائلة		**Start time** وقت البدء	
Household head? المسؤل عن الاسرة (كبير العائلة)		**End time** وقت الانتهاء	
Coordinates احداثيات		**Duration** المدة	
Latitude خط العرض	**Longitude** خط الطول	**Interview completed?** هل تم استكمال المقابلة؟	

A	**HOUSEHOLD CHARACTERISTICS** **خصائص المنزل**	
1	**How many households are there in <u>your</u> building?** كم عدد الأسر فى المنزل؟	
2	**How many people live in <u>your</u> building?** كم عدد افراد فى هذا البيت ؟	
	Total اجمالى العدد	
	Adults (18 and older) – men رجال	
	Adults (18 and older) – women سيدات	
	Children (Boys / girls) اطفال	
3	**What is the main occupation / source of income?** مصدر الدخل الرئيسي, الوظيفة ؟	
	Farmers فلاح/مزارع	
	Shop owners مالك محل	
	Workers (builders, plumbers…) عامل (أعمال بناء, سباكة ... الخ)	
	Civil servants موظف خدمة مدنية	
4	**To what type of sanitation system are you connected to?** ما نوع الصرف الموصل اليه ؟	
	Sewer network شبكة صرف صحى	
	Bayara / Trench بيارة	
	Pipe directly to drain انابيب مباشرة الى المصرف	
	If only sewer: go to section B1 *لو فقط شبكة صرف صحي: اذهب الى* C1 *If only bayaras: go to section B2* *لو فقط بيارة: اذهب الى* C2	

B1	**BLACKWATER – SEWERS** **المجارى**	
5	**For how long have you had a sewer connection?** منذ متى لديك وصلة الصرف الصحي؟	
6	**Do you face any problem with the network?** هل تواجة اى مشكلات مع شبكة الصرف ؟	
	How often does clogging occur (#/week)? كم مرة في الاسبوع تحدث هذة المشكلات ؟	
7	**How much do you pay per month for the maintenance of the network?** كم تدفع في الشهر مقابل صيانة شبكة الصرف ؟	

B2	BLACKWATER – BAYARAS البيارات		
8	**Do you face any problem with the bayara?** هل تواجة مشكلات مع البيارة		
	If yes: **What kind of problems? (open ended)** ما نوع هذة المشكلات		
9	**Does infiltration or exfiltration take place?** هل هناك تسريب من او الى البيارة ؟		
10	**How often the bayara is emptied (every x day)? What is the difference between winter and summer?** كم مرة يتم افراغ البيارة في الشهر؟ هل هناك اختلاف على حسب الموسم؟	**Winter** الشتاء	**Summer** الصيف
11	**How many trucks are filled on average each time?** كم عدد العربات التى تمتلىء فى كل مرة ؟ وما هو حجمها ؟		
12	**How much do you pay per month for the emptying?** كم تدفع كل شهر مقابل تفريغ البيارة؟		

C	ANIMALS – MANURE [Explain relation to wastewater management] المخلفات السائلة للحيوانات (لتوضيح علاقتها بإدارة مياه الصرف)	
13	**How many cows do you have?** كم عدد المواشي التي تملكها ؟	
14	**Is there a collection tank (or hole) for the liquid manure (manual emptying) or is it directly evacuated through a pipe?** هل هناك وعاء لتجميع السوائل ومنها الى لشبكة, أم يتم تصريفها في الشبكة مباشرة ؟	
	If presence of a tank: **How often are you emptying the tank?** كم مرة يتم تفريغ الوعاء ؟	
15	**What is the final destination of the liquid manure?** اين تصر هذه السوائل ؟	
	Bayara / Trench بيارة	
	Sewer network شبكة صرف صحى	
	Canal / Drain *(including pipe to drain)* الترعة أو المصرف	
	Street الشارع	
	Fields الحقل	

D	DRINKING WATER SUPPLY مياة الشرب	
16	**How many water meters for the house?** كم عدد عدادات المياه بالمنزل ؟	
17	**Is there any kind of problem with the water supply?** هل هناك مشاكل خاصة بمياه الشرب ؟	
18	**What kind of problems?** ما هى المشكلات ؟	
	Interruptions: frequency (time/week) and duration (hour) هل هناك إنقطاع في المياه؟ وكم عدد مرات الإنقطاع في الاسبوع ؟ وكم ساعة انقطاع في المرة الواحدة ؟	
	Pressure: good/bad كيف ضغط المياه ؟ سيء أم جيد ؟ Do use an engine to pump the water? هل تستخدم مضخة (موتور) مياه ؟	
	Bad taste, smell رائحة او طعم سيء	

	FIRST READING OF THE WATER METER: قراءة عداد المياة	
	Number of people connected to this water meter? قراءة عداد المياة	
	SECOND READING: القراءة الثانية للعداد	
	Number of people connected to this water meter? (crosscheck during second water meter reading) عدد السكان المستخدم لعداد المياة	
	MOBILE NUMBER: رقم الموبايل	

The ESRISS project deals with the sanitation planning gap in Nile Delta villages which cannot be connected to large centralised treatment plants. Led by the Swiss Federal Institute of Aquatic Science and Technology (Eawag-Sandec) in partnership with the Egyptian Holding Company for Water and Wastewater (HCWW) and funded by the Swiss State Secretariat for Economic Affairs (SECO), it aims to provide baseline data, policy recommendations and planning tools for the scaling-up of small-scale sanitation in Egypt.

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