Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies

SMART

Work package 7, Deliverables D701 and D704

Cost Benefit Analysis of decentralised wastewater treatment and re-use in Jordan: An application in Maghareeb and Ma'addi

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1 INTRODUCTION

This report describes a cost-benefit-analysis of decentralised wastewater treatment technologies and re-use according to project task 7.4 within work package 7 “Socio-economic analysis”. Several project tasks contributed to the cost-benefit analysis: 3.1. “Cost analysis of wastewater treatment technologies”, 7.1 “Valuing the benefits of decentralised wastewater treatment”, and 7.3: “Assessing the impacts of different water qualities/quantities on farmer income and their economic situation”.

The project under investigation is an investment in the field of wastewater treatment and re-use in Jordan. The construction of decentralised treatment plants is planned to serve rural communities in the Lower Jordan River Basin (LJRB) that are currently not connected to wastewater treatment infrastructure and require additional water resources for irrigation (MWI, 2010). In this study we concentrate on villages where sewage systems for wastewater collection in shared cesspits are in place, as the existence of sewage systems is a prerequisite for the installation of pilot plants within SMART II. Thus, the focus is placed on the costs and benefits associated with wastewater treatment and re-use. The project options investigated in the cost benefit analysis (CBA) are:

Option 1) wastewater treatment and re-use through Sequencing Batch Reactors (SBR)

Option 2) wastewater treatment and re-use through Constructed Wetlands (CW)

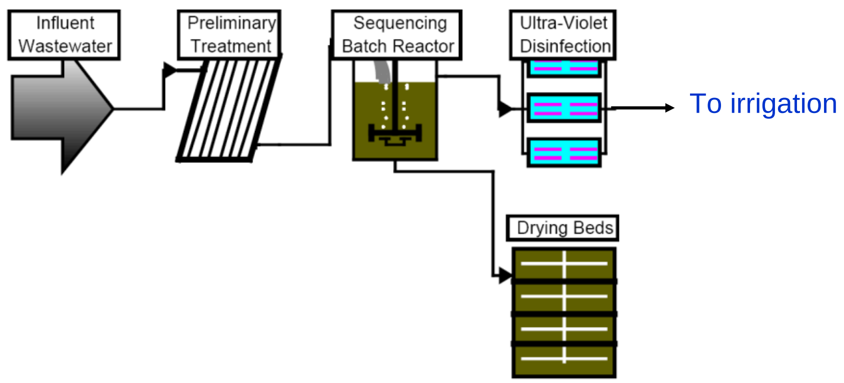
Option 3) do nothing, Business as Usual (BAU).

The do nothing option represents the existing wastewater services and re-use in the villages. The do nothing option is implicit in the analysis because the costs and benefits will be measured as the difference between the do nothing option and the two technology options.

BOX 1: Description of two decentralised wastewater treatment technologies
(Jaime Cardona)

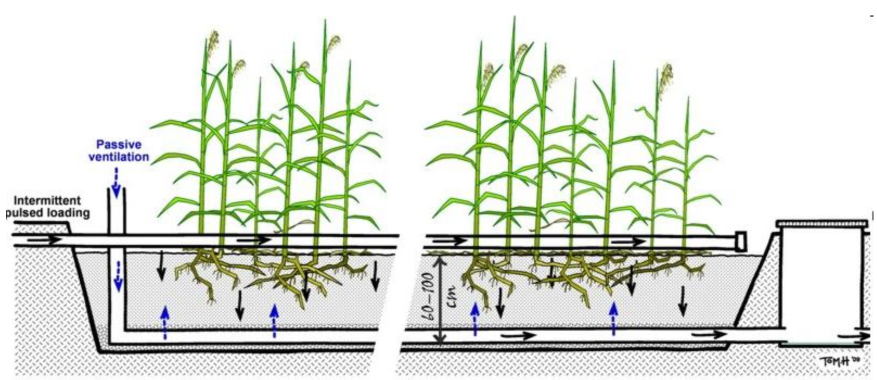
Option 1: Sequencing Batch Reactor

The term Sequencing Batch Reactor (SBR) stands for a discontinuously operated activated sludge process. In discontinuous or batch operation, the five phases, which are spatially separated in conventional activated sludge processes, here all occur in sequence in the same reactor. SBR plants are available in different types. They can be designed as plants with one tank and integrated pre-treatment, or as plants with two or more tanks and external pre-treatment. Furthermore, add-on kits exist such as aerators and programmable pumps which can be fitted as a component in already existing septic tanks.



Option 2: Constructed Wetland

Constructed wetlands are planted or unplanted soil filters. The soil body consists of a sand and gravel mixture, which must guarantee a sufficient permeability for the water, and is isolated from the natural subsoil. The biological purification of the wastewater is accomplished by microorganisms living in the soil, which form a biofilm in the soil body. In vertical flow constructed wetlands, the pre-treated wastewater flows vertically through the filter. The passive oxygen supply of the bacteria proceeds through the pore structure of the filter bed and the manner in which the wastewater is fed to the filter. Commonly wastewater is fed as pulses with frequencies of approximately 10/h to 1/h. The soil filters normally are planted with helophytes, such as reeds. The roots of the plants break up the soil structure and thereby support oxygen supply.



The main reason for the use of cost-benefit analysis in the water sector is to justify the investment needs for improvements to water provision or sanitation, as it provides a methodology to compare the costs and benefits of different options for water resources management.

The key elements of CBA in the water sector include:

- Identifying possible alternatives for intervention, including the alternative of maintaining the status quo (Business-as-usual or failure to take any action).
- Determining the scope of the analysis, which involves identifying key stakeholders and the costs and benefits associated with each of identified individuals and/or groups, compared to the status quo.
- Applying CBA provides the opportunity to make a comparison between different alternatives, which means the need to assess the benefits and costs in a systematic way, based on a common unit of measurement, namely money.
- Identify all tangible and intangible benefits and costs associated with each alternative, including the costs and benefits from a societal perspective, meaning incorporating private as well as external costs and benefits, such as treatment costs borne by the members of the community in case of sickness caused by untreated wastewater.
- Measuring external costs and benefits, including environmental costs and benefits, using appropriate valuation methods.
- Identifying the distribution of benefits and costs over the live span of the project and applying appropriate discount rates on future values of benefits and costs.
- Applying decision criteria to reach a decision: the most common standard criteria utilised in CBA are the net present value (NPV) and the benefit-cost ratio (Turner et al., 2004, Chong et al., 2008, Mitchell et al., 2007, Pearce et al., 2006).

The underlying principle as to whether projects should go ahead is the Kaldor-Hicks criterion. This criterion assumes that beneficiaries from projects should be able to hypothetically compensate losers and have some net gains left over. The overall CBA equation is as follows. If the equation is positive, that is if present values of benefits exceed costs the project can be considered to generate social well-being.

$$\text{NPV} = \sum_{t,i}^{T,N} \frac{B_{i,t} - C_{i,t}}{(1+s)^t}$$

where T is the time horizon, i is the ith household affected and N is the number of households who are affected by the project.

The most economically efficient option is that with the highest present value of net benefits, i.e. net present value (NPV), calculated as

NPV = Sum of Discounted Benefits - Sum of Discounted Costs

The necessary condition for the adoption of the technology options is that the discounted present benefits should be larger than discounted present costs. A project is economically feasible when it has a positive NPV. This decision rules can be stated as:
NPV > 0, and

The cost benefit analysis is carried out for two villages that are in particular need for wastewater treatment and re-use: 1) the Eastern part of Ma'addi, an agricultural village in the Middle Jordan Valley and 2) Maghareeb (phase 1), a suburb of the city Al-Salt (see Figure 1). Both villages have a sewage system in place and wastewater is collected in several shared cesspits that are owned and emptied by the respective municipalities. Both villages face problems with overflowing cesspits causing odour, groundwater contamination and diseases. Treated wastewater is intended to be used for agricultural irrigation. Agricultural production in Ma'addi takes primarily place in greenhouses where a range of vegetables are grown. Agricultural activities in Maghareeb are dominated by olive tree plantations that do not require irrigation and fruit trees.

Figure 1: Location of the two project sites in LJRB.

Since the benefits generated by wastewater treatment technologies are to a large extent not measurable through markets, the following assumptions are made:

- Preferences of individuals are taken as the source of value
- Preferences are measured by willingness to pay (WTP) for a benefit
- Preferences can be aggregated to obtain social benefit.

The analysis looks at the costs and benefits arising from the two technology options in comparison to the status quo (business as usual). We assume that costs for the two technologies do not vary between the two villages, but that health and environmental improvements (benefits) vary according to the situation in the villages. Costs and benefits are estimated for both treatment technologies assuming 500 person equivalents. The time horizon of the analysis is 30 years and corresponds with the lifetime of the technologies. Constant prices were computed to net out the annual inflation rate of 5% (CIA, 2011). Constant prices were discounted using a financial rate of discount of 3, 5 and 7% (see also Section 5).

Overall benefits of decentralised wastewater treatment plants and re-use are 1) benefits from selling treated wastewater, 2) increased productivity in farming, and 3) reduction in odour, poor health and environmental problems in the villages. The costs are mainly construction and operation and maintenance costs of the plants.

2 PROJECT COSTS AND BENEFITS

Costs and benefits arise from two facets of the project, since sewage networks already exist at the project sites:

- The treatment plant
- The irrigation system for re-use

The analysis of costs and benefits goes beyond a pure financial analysis, as the installation of the treatment plants and re-use opportunities in agricultural irrigation also have positive external effects on the environment and society. The main positive externalities are environmental and health benefits, that is the avoided environmental and health costs currently occurring due to overflowing cesspits, as well as the increase in agricultural productivity due to the availability of additional irrigation water.

The contribution of sanitation infrastructure to improved livelihoods, particularly with respect to health, are a widely discussed benefit of wastewater treatment. Recent research has confirmed a link between positive and beneficial health effects and improvement in the quality of sanitation services. This is because there are many varied water-borne diseases, that can affect households with insufficient sanitation provision (Hutton and Haller, 2004). According to WHO (2010), improved sanitation for example reduce diarrheal diseases by about 37%. Health improvements of decentralised wastewater treatment can be summarised as:

- less sick days and so more productive days
- less expenditure on hospital/doctors' visits and medicine; and
- better education and career future because less sick days at school (Borba et al., 2007)

All cost and benefit categories relevant to the analysis as well as the standing of each cost and benefit category (i.e. who receives benefits and who bears costs) are listed in Table 1.

Table 1: Costs and benefits arising at the two project sites in LJRB

COSTS	Standing
TREATMENT PLANT	
Construction costs (construction period 1 year)	Investor
Land purchase	
Labour costs	
Materials for civil works (machinery, building materials)	
Sludge dry bed (for sludge treatment)	
Contingency (10% of construction costs)	
Recurrent costs: Operation & Maintenance	Investor
Labour costs	
Electricity	
Sludge treatment	
Laboratory costs (external quality control)	
Other costs	
Tariff paid for wastewater disposal*	Locals
IRRIGATION SYSTEM FOR RE-USE	
Construction costs	Investor
Irrigation tank, pumps	
Recurrent costs: Operation & Maintenance	Investor
Irrigaiton tank	
Electricity costs (pumping stations)	
Other costs	
Tariff paid for treated wastewater*	Farmers
BENEFITS	**Standing**
TREATMENT PLANT	
Health benefits (avoidance of infections)	Health sector/Locals
Avoided treatment expenditure	
Avoided treatment expenditure	
Avoided income loss	
Avoided loss of leisure time	
Environmental benefits	Locals/Society
Avoided costs of odour from cesspits	
Avoided costs of GW infiltration	
Avoided costs of mosquitoes, insects	
Market benefits	
Revenue gained from tariff collection for wastewater treatment*	Investor
Avoided damage to property due to overflow	Locals
Avoided expenditures on cesspit pumping	Locals
IRRIGATION SYSTEM FOR RE-USE	
Environmental benefits	Locals/Society
Saving GW resources (or is the water supplied additional)	
Market benefits (agriculture)	
Revenue gained from sale of treated wastewater to farmers*	Investor
Added value from additional agricultural production	Farmers

*the tariff categories are omitted from the analysis: costs due to tariffs paid by households and farmers are neutralised because they are a benefit to the investor.

The analysis excludes some costs and benefits which are either very difficult to measure due to lack of data or negligible. Costs and benefits that were excluded are:

- *Increase in property value*: Difficult to evaluate without database. If an entire area receives wastewater treatment the market may not be able to support price increases.
- *Savings in the health sector*: The health sector might save subsidies for doctoral consultations.
- *Negative externalities* (impact from the treatment plant, e.g. noise, odours, aesthetic and landscape impact): These are considered to be negligible.

3 PREDICT AND QUANTIFY IMPACTS

During the first year of the project (year 0), there will be solely investment cost. From year 1 till year 30 operation and maintenance costs and benefits will occur. Overall there is little knowledge about the status quo, e.g. impact of overflowing cesspits on groundwater quality in the villages, and it is therefore difficult to accurately predict the biophysical benefits arising from the treatment plants compared to the status quo. Furthermore, there are no official health statistics available on diseases related to wastewater, hence it is difficult to judge the current health situation in the villages.

- Environmental and health impacts:

A household survey undertaken in Ma'addi and Maghareeb gives some insights into the status quo. According to the survey residents currently face the following environmental problems: odour, groundwater contamination, insects, risk for children and visual impact. With respect to health problems, 19% of the surveyed households in Maghareeb and 13% in Ma'addi state that household members sometimes face health problems associated with wastewater. The most common diseases are: skin problems (increase in mosquito bites), diarrhoea and asthma (as a result of odours). Most of the environmental and health benefits are absolute in a sense that environmental damages/annoyances occurring now will be reduced to zero after the treatment plant has been constructed. The survey undertaken in the villages revealed that there is no income loss associated with illness. It was not possible to obtain information about discomfort and loss in leisure time faced by residents with health problems,

- Revenue from wastewater collection:

The available wastewater from 500 p.e. is estimated to be 13360 m^3 per year. Hence, revenue gained from tariff collection for wastewater treatment can be exactly estimated.

- Agricultural benefits:

The amount of treated wastewater made available for irrigation is 13360 m³/year (SBR technology) and 10979 m³/year (Constructed Wetland)[1]. With this amount of additional irrigation water it would be possible to grow fruit on 13-16 additional dunums in Maghareeb (based on average crop water requirement of 838,9 m³/year for typical crops in the region) and to grow greenhouse crops on 25-30 additional dunums in Ma'addi (based on average crop water requirement of 442 m³/year for greenhouse crops).

- Other impacts:

There was some limited evidence that the overflowing cesspits damage property, i.e. carpets. It was therefore regarded to negligible.

4 MONETISE PROJECT IMPACTS

The underlying principle is that all project costs and benefits are marginal costs and benefits, that is the difference in costs/benefits between the status quo and the project situation. As far as possible, all impacts were quantified in monetary terms to enable the comparison of costs and benefits. While all financial aspects are measured in money units, for other impacts money values are not readily available, because they have no or poorly functioning markets. Hence, for impacts such as environmental or health impacts, non-market valuation methods were applied. Table 2 lists the economic valuation methods used to obtain monetary values for the different impacts of decentralised wastewater treatment and re-use.

Table 2: Valuation methods for monetisation of all project impacts

. PROJECT IMPACT	VALUATION METHODS
Construction and recurrent costs	Market data
Environmental benefits	Contingent valuation
Health benefits	Cost of illness approach
Benefits in agriculture	Market data: gross marginal values

4.1 Estimation of construction and recurrent costs

4.1.1. Data collection, data sources

The sizing of the treatment units is based on engineering models for the dimensioning of the components of the treatment trains. For the conception of the constructed wetlands, calculations

[1] The smaller amount of treated wastewater in constructed wetland is a result of evaporation.

were based on models for intermittent sand filtration of (Crites and Tchobanoglous 1998). In the case of SBR systems, cost data was obtained from ATP company. Every component was multiplied by the local unit prices in Jordan collected on several field visits between 2007 and 2009 in Jordan.

4.1.1. Results

The cost data collected for both SBR and constructed wetland technologies is presented in Table 3 and 4.

Table 3: Cost data for SBR and constructed wetland technologies, water quality A (in Jordanian Dinar*)

SBR TECHNOLOGY	
Population	500
Flow Rate m3/d	37
Land Requirement m2	694
TREATMENT PLANT: Construction and O&M costs	
Preliminary Treat	4396
Primary Sep Tank	6277
Buffer Tank	7604
SBR System	54006
Total CC SBR	72283
O&M Treatment Plant (JOD/year)	28947
UV MODULE	
Construction Cost UV Module	10574
O&M UV Module (JOD/Year)	48
SLUDGE TREATMENT	
Construction cost Sludge Dry Bed	6972
Sludge Treatment O&M	7369
Total construction costs	99805
OTHER COSTS	
Land Costs	13886
Fence	1054
Installation costs 40 % of Construction Costs	39922
Office & Laboratory (1438*Q0.567)	11141
Construction Management (10% of Construction Costs)	9980
Contingency (10% of Construction Costs)	9980
Total other costs	85964
Total Capital Costs	*185768*
Total Operation Costs	*36521*
IRRIGATION SYSTEM: Construction and O&M costs	
CC Irrigation Tank	9976
O&M Irrigation Tank (JOD/Year)	157

CONSTRUCTED WETLAND	
Population	500
Flow Rate m3/d	37
Land Requirement m2	1111
TREATMENT PLANT: Construction and O&M costs	
Preliminary Treat	4396
Primary Sep Tank	6277
Pumping well 1	5332
UASB Reactor	16312
Pumping well2	4589
Vertical Flow Wetland	22249
Recirculating Tank	8169
Total CC CW	59155

O&M Treatment Plant (JOD/year)	17622
UV MODULE	
CC UV Module	10574
O&M UV Module (JOD/Year)	24
SLUDGE TREATMENT	
CC Sludge Dry Bed	7687
Sludge Treatment O&M	2188
Total construction costs	82570
OTHER COSTS	
Land Costs	22221
Fence	1054
Installation costs 40 % of Construction Costs	33028
Office & Laboratory (1438*Q0.567)	11141
Construction Management (10% of Construction Costs)	8257
Contingency (10% of Construction Costs)	8257
Total other costs	83958
Total Capital Costs	*161374*
Total Operation Costs	*19834*
IRRIGATION SYSTEM: Construction and O&M costs	
CC Irrigation Tank	5154
O&M Irrigation Tank (JOD/Year)	24

Table 4: Summary of construction and operational costs

COST ITEMS	SBR TECHNOLOGY	CW TECHNOLOGY
TREATMENT PLANT		
Construction Cost	185768	161374
Annual Operational Costs	36521	19834
IRRIGATION SYSTEM		
Construction Cost	9976	5154
Annual Operational Costs	157	24
TOTAL COST		
Construction Cost	195744	166528
Annual Operational Costs	36678	19858

4.2 Estimation of environmental and health benefits

4.2.1. Valuation methods

The *environmental benefits* associated with decentralised treatment arise from the improvement of the current state of the environment, which is characterised with overflowing cesspits. These include: reductions in odour, reductions in groundwater contamination, reduction of insects and rodents, reduction in visual impact of overflowing cesspit. All of these improvements are public goods and hence have no market that signals the price for obtaining these benefits. In order to value these benefits in monetary terms the Contingent Valuation (CV) method was applied. CV is a survey-based approach that elicits people's preferences for environmental changes in terms of their willingness to pay (WTP) to obtain an environmental improvement or to accept and environmental deterioration in a constructed, or hypothetical, market. The hypothetical market describes the environmental change resulting from a project and explains how it can be obtained. In a representative survey affected individuals are directly asked for their maximum WTP for hypothetical change in the provision of an environmental good (Mitchell and Carson, 1989). In this survey, households were asked for their maximum increase in their water/wastewater bill they could afford to pay for the modernisation of wastewater collection and treatment. The WTP question was formulated as an open-ended question (see questionnaire in Appendix 1). Total benefits are obtained by calculating a mean value and aggregating this value to the affected number of households. CV is the most popular valuation method as it enables both *ex post* and *ex ante* valuation of environmental changes, and it is the only method capable of measuring non-use values (OECD, 1995, Pearce et al., 2006).

The *health benefits* of a decentralised wastewater treatment plant are equivalent to costs of health problems occurring to citizens at the status quo. The costs of illness approach (COI) is a survey-based approach to assess the costs of health impacts in terms of citizens' expenditure on medical services, including consultation with the doctor, medicine, travel cost, and loss in income due to days off work (Pearce et al., 2006). Further health benefits would be the reduction in the number of deaths and the avoided opportunity cost of lost time due to illness (loss in income that could have been earned). However, a household questionnaire in Maghareeb and Ma'addi revealed that no deaths can be associated to wastewater and that almost nobody misses work due to wastewater related diseases. Survey questions used to identify the current expenditure for wastewater related health impacts are presented in Appendix 1.

4.2.2. Data collection

Both CV and COI approaches were applied and integrated in one survey with citizens of Ma'addi and Maghareeb. The survey took place between March 1st and 20th 2011. Data was collected in face-to-face interviews, and each interview took about 30 minutes. All 123 households in Maghareeb (Phase 1) and 38 households the eastern part of Ma'addi were approached. In Maghareeb it was not possible to conduct interviews with every household, because not all families were at home due to work, had no time to participate in the survey or had abandoned their house. 53 interviews were conducted in Maghareeb (response rate: 43%) and 38 interviews in Ma'addi (response rate: 100%). Mainly women (74%) were interviewed because men were at work. Data on the socio-economic characteristics of respondents are presented in Table 5.

Table 5: Socio-economic characteristics of the two samples

	Maghareeb (n=53)	**Ma'addi (n= 38)**
Gender (female)	77%	68%
Household size (average, persons)	5.6	5.3
Household income (average in JD)	451	311
No. of persons at work (average)	1.4	1.4

4.2.3. Results: health and environmental benefits

82% of all households stated a WTP bid larger than zero for improved wastewater services. Table 6 presents mean WTP per household per month to avoid the environmental problems associated with the current wastewater situation in the villages. WTP reflects the benefits of improving the wastewater situation with a treatment plant and sewage system. Based on this data, annual WTP per household is 47.8 JD in Maghareeb and 42.6 JD in Ma'addi. Aggregated environmental benefits for 500 PE were estimated to be 4251 JD per year in Maghareeb and 4004 JD per year in the Eastern part of Ma'addi.

Table 6: Environmental benefits represented by mean WTP per household/month in JD

	Maghareeb (n=52)	**Ma'addi (n= 36)**
Mean	3.98	3.55
Median	2.00	2.50
Standard error	0.59	0.58
Std. deviation	4.23	3.46
Min-Max	0-20	0-10

With respect to health problems, 33% of the surveyed households in Maghareeb and 24% in Ma'addi state that household members sometimes face health problems associated with wastewater. Overall, 19% of the households in Maghareeb and 13% in Ma'addi need to see the doctor as a result of diseases associated with wastewater. The most common diseases are diarrhoea and skin problems as a result of mosquito bites. Households facing wastewater related diseases stated that their families need to consult the doctor 13 times per year in Maghareeb and 5 times per year in Ma'addi. Transport costs and spending on consultation and medicine vary according to where patients seek consultation (e.g. consultation at health centres are cheaper than visits to the hospital or private doctor). There was no incident that household members miss work and thus lose income. Children turned out to be most prone to wastewater related diseases and tend to miss school. Table 7 provides a detailed list of household expenditures associated with wastewater related diseases for Maghareeb[2]. The overall average costs per visit and person were estimated to be 17 JD. The average annual costs per household would amount to 221 JD per year in Maghareeb, as households visit the doctor on average 13 times per year. Since 19% (N=17) of households consult the doctor, the aggregated health costs amount to 3757 JD per year. Although the survey reveals that households in Ma'addi also face considerable health problems, the sample size was too small to provide valid estimates of health costs. We therefore decided to assume equal annual costs per household (221 JD) and multiply these with 12 households (13% of households in Ma'addi need to see the doctor as a result of wastewater related diseases). Hence, the aggregated health costs in Ma'addi amount to 2652 JD per year.

[2] Avoided health costs were not calculated for Ma'addi due to the small sample size and the small proportion of households facing health problems.

Table 7: Current health costs in Maghareeb (mean costs in JD)

Visits to the doctor per HH/year	13
Visits to the doctor per person/year	2.3
Expenditure per visit	
Transport to health centre	1.7
Transport to hospital	2.8
Transport to private doctor	6.1
*Average transport cost per person/visit**	*3.5*
Consultation/medicine health centre (JD)	2.6
Consultation/medicine hospital (JD)	1.9
Consultation/medicine private doctor (JD)	36.2
*Average expenditure on consultation/medicine per person/visit**	*13.5*
Average expenditure per person/visit	*17*

*Visits to the health centre, hospital and private doctor were about evenly distributed and no weighting was necessary for the estimation of average expenditure for transport and consultation/medicine.

4.3 Estimation of benefits in agriculture

4.3.1. Method

The residual imputation method (RIM) is a common approach to estimate the value of treated water for irrigation and industry. The method identifies the contribution of all resources (inputs) used in the production process in the generation of total output value. If appropriate prices can be assigned to all resources but one (i.e. treated wastewater), the remainder of total value of output is imputed to the remaining (or "residual") input (Young, 2005, Ashfaq et al., 2005, Lange and Hassan, 2007, Speelman et al., 2008, Hellegers and Davidson, 2010). Box 2 gives a detailed description of how the benefits of the provision of treated wastewater to agriculture were calculated.

BOX 2: Calculating the gross marginal value of treated wastewater in agriculture

(Amer Salman, Emad Karablieh)

The residual imputation method (RIM) is most suitable where the residual claimant (water in our case) contributes the largest fraction of the value of output. The total value of product can be divided into shares, such that each resource is paid according to its marginal productivity and the total product is completely exhausted. (This is satisfied when the total value function is a linear homogeneous production function'. There is a standard mathematical result, called Ruler's theorem, which shows that if a production function involves constant returns to scale, the sum of the marginal products will actually add up to the total product [Baumol, 1984]).

Assume production and prices are known (no uncertainty and the production function is not stochastic) Py is the price of output, Px price of input under perfect information (Heathfield and Wibe,1987). Assume we have a producer whose objective is to maximize profits with single input X. Then the profit equation is:

$$\pi = Py.Y - Px.X - FC \qquad \text{Equation 1}$$

where FC is the fixed cost of the predetermined inputs. To find the conditions for optimal profits, take the first derivative of π with respect to x and set that equal to zero

$$d\pi/dx = Py.df(X)/dx - Px = 0, \qquad \text{Equation 2}$$

$$WMPx = Px \qquad \text{Equation 3}$$

Which is the value of the marginal product (VMP) inputs, the value of marginal product is defined as output price multiplied by the marginal physical productivity of the input. Notice that as the price of the input (Px) decreases, more input will be used and more output will be produced. The same will occur if the output price increases. If competitive product and factor markets are assumed to exist, then prices may be treated as constants. By the second postulate, it can be written (Chambers, 1988):

This method requires the subtraction of the economic cost of all the other production inputs except water from the sales revenue. The difference becomes the value of water in the production of commodity. In the case where just one commodity is produced, the use of the residual imputation method is based on the theory that the sales revenue exactly equals the total cost of production. This implies that the sales revenue (TV= price multiplied by the quantity sold) exactly equals the sum of the inputs used, multiplied by their respective prices. This relationship is expressed below as:

$$P_y.Y = \sum_{i=1}^{n} Px_i.X_i + P_w.Q_w \qquad \text{Equation 4}$$

Where 'P' is the competitively determined commodity prices, 'Y' represents the quantity of the commodity produced and sold, while 'Px_i' is a vector of competitively determined prices (equal to the marginal value product) of non-water factors, and 'X_i' is a vector of non-water inputs employed in the production process and 'Q_W and 'P_w' are the quantity and price of water respectively. If all the inputs, including water are exchanged in a competitive market and employed in the production process, the value of water (price multiplied by its volume used) will be;

$$P_w.Q_w = P_y.Y - \sum_{i=1}^{n} Px_i.X_i \qquad \text{Equation 5}$$

The RIM determines the incremental contribution of each input in a production process. If appropriate prices can be assigned to all inputs but one, the remainder of total value of product is attributed to the remaining or residual input, which in this specific case is water (Young, 2005, Ashfaq et al., 2005, Lange and Hassan, 2007, Speelman et al., 2008, Hellegers and Davidson, 2010). Residual valuation thus assumes that if all markets are competitive, except the one for water, the total value of production (TV= $P_y.Y$) equals exactly the opportunity costs of all the inputs

$$TV = \sum_{i=1}^{n} VMP_i X_i + VMP_w X_w \qquad \text{Equation 6}$$

Where:

TV =total value of the commodity produced;

VMPi = value of marginal product of input i;

Qi = quantity of input i used in production, w for water.

It is assumed that the opportunity costs of non-water inputs are given by their market prices (or their estimated shadow prices). Therefore, the shadow price of water can be calculated as the difference (the residual) between the total value of output (TVP) and the costs of all non-water inputs to production. The residual, obtained by subtracting the non-water input costs from total annual crop revenue equals the gross margin (Water Related Contribution equal gross margin minus the water costs) and can be interpreted as the maximum amount the farmer could pay for water and still cover costs of production. It represents the at-site value of water: The monetary amount, divided by the total quantity of water used on the crop, determines the marginal value for water (VMPw), corresponding to the irrigator's maximum willingness to pay per unit of water for that crop (Agudelo, 2001). Average values were used in this study as a proxy of the marginal ones.

$$VMP_w = (TV - \sum_{i=1}^{n} P_i X_i)/Q_w$$ Equation 7

The Value of Marginal products in this case is equal to the Gross margin without water divided by the water quantities consumed by crop in a given areas. The above equation will be used to estimate the economic value of water for each product..

The benefits of treated wastewater for agricultural irrigation entering the CBA were estimated on the basis of gross margin calculations in two basins in the Jordan valley. The two basins were compared in terms of the following indicators:

- Crop Yield (kg/du)
- Gross margins (JD/du)
- The average Value of Water per crop (JD/m3)

Basin 10 is irrigated by King Abdullah Canal using fresh water and Basin 22 is irrigated with TWW from King Talal Dam and blended with fresh water from KAC. More details will be discussed in subproject D 703.

4.3.2. Data collection

A survey was conducted among farmers to collect data about the gross margins of different crops in the two basins under investigation (Basin 10 & 22). All farmers growing vegetables in the two basins were interviewed personally with a sample size of 50 farms in each basin. In addition, secondary data was collected from the Department of Statistics in Jordan to update the prices of all crops grown in the area. The data collection was validated by experts who have long experience in the field of agriculture in the Jordan Valley.

The results of the Gross margin analyses carried out in the Jordan Valley were used as a basis to judge the agricultural benefits arising from wastewater treatment and re-use in Ma'addi. In Maghareeb, secondary data from the Department of Statistics were collected to estimate the gross margins for crops that can be grown in the mountain area of Balqa Govenorate[3].

4.3.3. Results: Gross marginal values of benefits in agriculture

Since it is not possible to compare gross margins between freshwater and treated wastewater in Maghareeb, we cannot calculate agricultural benefits from substituting current water sources

[3] These include all crops that are anticipated to have positive gross margins, namely, olives, grapes, figs, almonds, plums, apples and pears.

used for irrigation with treated wastewater. We thus assume that the treated wastewater is made available in addition to currently available irrigation water, and that benefits arise from the extension of cultivated land. Table 8 shows the parameters used for calculating the annual added value of additional treated wastewater for irrigation: amount of treated wastewater, crop water requirements (CWR), gross margins and the number of dunums that can be irrigated.

Table 8: Estimates of additional agricultural benefits per year

<table>
<tr><td>MAGHAREEB - FRUIT</td><td>SBR</td><td>CONSTRUCTED WETLAND</td></tr>
<tr><td>CWR (m3/du/year)</td><td colspan="2">839</td></tr>
<tr><td>Gross margin (JD/dunum)</td><td colspan="2">173</td></tr>
<tr><td>Treated WW (m³/year)</td><td>13359</td><td>10979</td></tr>
<tr><td>No. of dunums irrigated*</td><td>15,9</td><td>13,1</td></tr>
<tr><td>Added value (per year)</td><td>2758</td><td>2266</td></tr>
<tr><td>MA'ADDI – GREENHOUSE CROPS</td><td>SBR</td><td>CONSTRUCTED WETLAND</td></tr>
<tr><td>CWR (m3/du/year)</td><td colspan="2">442</td></tr>
<tr><td>Gross margin (JD/dunum)</td><td colspan="2">679</td></tr>
<tr><td>No. of dunums irrigated</td><td>30</td><td>25</td></tr>
<tr><td>Added value (per year)</td><td>20370</td><td>16975</td></tr>
</table>

* with the amount of treated WW made available

4.4: Estimation of other benefits

According Abu-Madi (2004) and Sorge et al. (2007) the costs of cleaning cesspits ranges between 1-2 JD per m³. This expenditure would be avoided if a wastewater treatment plant was installed and enters the CBA as a benefit. The overall avoided expenditure for a village with 500 inhabitants generating 13359 m³ wastewater would amount to 20039 JD per year, if we consider an average cost of 1.5 JD per m³.

5 ESTIMATE NET PRESENT VALUE

The annual costs and benefits presented in Section 5 were aggregated to 500 person equivalents in order to obtain aggregated annual values for each cost and benefit category that can then be used to estimate present value. Prior to estimating present values the effect of inflation (5%) is netted out and expressed in constant prices. These magnitudes are discounted at 3, 5 and 7%. Three discount rates were chosen to take different credit terms into consideration. The discount rates were selected in accordance to interest rates KfW-investment credits for communal infrastructure projects (KfW, 2011). Table 9 depicts the present values as well as net present value for the three project options using a 3% discount rate. Table 10 shows net present value estimates under the other two discount rates.

Table 9: Net present value of the three project options in m JD (discount rate 3%)

	PV COSTS	**PV BENEFITS**		**NPV**	
		Maghareeb	Ma'addi	Maghareeb	Ma'addi
OPTION 1: SBR	***1.68***	***1.26***	***1.93***	***-0.42***	***0.25***
Min.	1.35	1.22	1.90	-0.13	0.56
Max.	2.02	1.33	1.99	-0.68	-0.03
OPTION 2: CW	***0.98***	***1.24***	***1.78***	***0.26***	***0.80***
Min.	0.78	1.20	1.76	0.41	0.97
Max.	1.18	1.31	1.84	0.14	0.67

Table 10: Net present value discounted at 3, 5 and 7%

	NPV (3%)		**NPV (5%)**		**NPV (7%)**	
	Maghareeb	Ma'addi	Maghareeb	Ma'addi	Maghareeb	Ma'addi
OPTION 1: SBR	***-0.42***	***0.25***	***-0.36***	***0.13***	***-0.32***	***0.06***
Min.	-0.13	0.56	-0.13	0.37	-0.14	0.24
Max.	-0.68	-0.03	-0.56	-0.08	-0.48	-0.11
OPTION 2: CONSTR. WETLAND	***0.26***	***0.80***	***0.15***	***0.54***	***0.07***	***0.37***
Min.	0.41	0.97	0.27	0.67	0.17	0.48
Max.	0.14	0.67	0.05	0.43	-0.01	0.28

6 SENSITIVITY ANALYSIS

A sensitivity analysis was performed due to uncertainty in some parameter values. Since we do not have information about the distribution of uncertainty, we make assumptions about the end-points of the uncertainty range:

- the *discount rate*: given that there is uncertainty regarding the credit terms for the treatment plant, we selected a 5 and 7% discount rate in addition to the 3% discount rate. If the sign of net benefits is unaffected by these different discount rates, the CBA can be considered to be robust with respect to these assumptions.
- *Construction and operation and maintenance costs*: the exact costs cannot be fully anticipated, and there is an uncertainty that costs may go up or down by 20%. The analysis was therefore run with reduced costs (-20%) and with increased costs (+20%)
- *Environmental benefits*: Since environmental benefits were estimated using the contingent valuation method. There are some uncertainty issues with Willingness-to-pay mainly concerning hypothetical bias. Given the realistic context in this study, we assume that respondents stated fairly realistic WTP-values. However, other issues, such as free-riding or lack of affordability may lead to underestimates of WTP estimates, although we did not find any evidence of this. Since there is no guidance with respect to end points of these biases, we assume that the environmental benefits might be 15% higher if free-riding and affordability issues do not occur.
- *Health benefits:* there is considerable uncertainty about the relation of health problems to wastewater. In all households health problems also occur due to poor drinking water quality. The survey revealed that respondents were uncertain about the source of certain illnesses. Hence, we compute health benefits with a relatively high uncertainty range (+30%, -30%)

The results of the sensitivity analysis are shown by the min. and max. values in Tables 8 and 9. Since neither the uncertainty values nor the discount rates affect the sign of the NPV, our estimates can be considered to be robust (Pearce et al., 2006)

7 DISCUSSION

Our results show that the net present value of wastewater treatment is larger than zero for both treatment technologies in Ma'addi. This means that constructed wetlands and SBR technology are welfare increasing projects and should go ahead. Furthermore, the net present value of the SBR technology is negative in Maghareeb. This can be explained by the added value in agricultural production, which is far lower in Maghareeb compared to Ma'addi.

One of the most critical points in our study are the cost estimates of the treatment technologies. At first sight, the costs seem unusually high. Our response to this is that the proposed technologies aim to achieve water quality A in accordance with the Jordanian standard of reclaimed domestic wastewater. This high level of water quality introduces considerable complexity to the treatment process, including recirculation tanks, additional pumps and UV filters. This not only leads to high construction costs, but also to high O&M costs due to qualified staff necessary to operate the complex treatment process and high energy demand. Clearly, the costs used in this analysis are estimates of treatment technologies that are not yet being operated, hence there is some uncertainty associated to the numbers and we therefore introduced an uncertainty range of 20% to the analysis (see Section 6).

As common for projects that affect the environment and welfare of a variety of stakeholders, there are a number of costs and benefits that cannot be estimated in quantitative terms at all or only with considerable uncertainty. In our view there are several indications that suggest that benefits might be higher and costs might be lower. This shall be briefly discussed as follows. We believe that the real benefits are higher than the quantified estimates entered to our analysis.

- the reduction of groundwater contamination was elicited in form of willingness to pay (WTP) from residents in the villages Ma'addi and Maghareeb. Benefits from better groundwater quality (e.g. reduction in ecola and nitrogen) accrue to people beyond the borders of the villages and can be considered to be a benefit to society in general. Our survey was only implemented inside the villages due to limited time and financial resources and is likely to be an underestimate of 'real' benefits arising from improved groundwater quality.
- The cost of illness approach used to estimate the current health costs accruing to residents in terms of consultation and travel to the doctor does not capture the discomfort caused by illness. Furthermore the method is not capable of recording spendings to avoid illnesses. This means, that peoples' WTP to avoid health problems is likely to be higher. According to US EPA (2000, p. 71) the ratio between COI estimates and WTP estimates is 8.1. Health benefits estimated on the basis of COI are thus likely to be underestimated.
- The application of the Contingent Valuation method to value environmental benefits is critical in low-income countries because WTP is restricted by income. Hence, we assume that environmental benefits are underestimated, because of lacking affordability.
- In Jordan, charges for irrigation water are not cost-covering and are highly subsidised. In this study we calculated on the basis of fictitious prices that are not applied in reality but

include operation and maintenance costs. We suspect that the prices used are still too low given that they are not reflecting water scarcity.

- The construction and operation and maintenance costs are relatively high when looking at individual treatment plants. In the implementation phase of the project, treatment plants will be built and operated in regional clusters (Afferden et al., 2011). This means that overall costs will be somewhat lower due to economies of scale.

8 CONCLUSION

Decentralised wastewater treatment and re-use are needed to improve sanitation and agricultural production in rural areas and small communities in Jordan. The net present value calculations in this study include all major costs and benefits associated with wastewater treatment and re-use. The CBA used here differs from traditional CBA in that is not only accounts for market benefits, but also for non-market benefits that have no monetary value and are thus more difficult to value. We elaborated on a range of valuation methods to monetise the benefits associated with the environment, health and irrigation in agriculture. In this way, we can offer estimates of the total benefit from wastewater treatment and re-use and thus enable a sound comparison of benefits with the costs paid for the construction, operation and maintenance of the project options. The models and methods discussed in this paper are principally applicable to any decentralised wastewater treatment projects.

However, the usefulness of CBA is limited by certain limitations, particularly in Arab countries. In addition to the traditional difficulties related to the nature of externalities and to the valuation of non-market cost and benefits, the severe water shortages and poor sanitation facilities in the region practically leave decision-makers with little alternatives to choose from. Given the indisputable need for solutions to improve the current situation and the need for low cost technologies means that cost effectiveness aspects are also of high relevance. Furthermore, decision on wastewater treatment and re-use in rural Jordan entails prerequisites beyond positive CBA results. For example, an important requirement is that residents, mayors and tribes accept and support such a project. Hence, a participatory approach that involves all affected parties in the planning process is essential.

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APPENDIX 1: Extract from household survey in Maghareeb and Ma'addi

Improvements to wastewater disposal (quantification of environmental benefits)

The goal of the new Jordanian Water Strategy is to provide all towns with adequate wastewater collection and treatment facilities within the next 10 years. This would mean, that the wastewater from your household would be disposed by pipe and diverted into a treatment plant. Cesspits would not be used anymore. This would have the following advantages for you, your neighbourhood and the environment:

- there would be no odour from leaking pipes or overflowing cesspits.
- groundwater contamination from wastewater would be reduced.
- children would not be longer at risk when playing.
- no flies.

The modernisation of wastewater collection and treatment means that the water and wastewater tariff might rise.

D 1) We would like to know how much your <u>household</u> would be able to pay in addition to your current water bill to obtain improved wastewater services?

Before you answer this question, please consider

- how important it is to you to improve the current wastewater situation
- that improvements are only possible if enough money can be raised through the wastewater tariff.

_____ JD/month

D2) Please explain why you decided on this figure:

____

____

Health problems (Quantification of health costs associated to wastewater)

We would like to find out more about health problems associated with untreated wastewater in your household.

C 1) Do you or one of your household members sometimes get ill from contact with untreated wastewater?

☐ (1) yes -> continue with next question ☐ (0) no -> move to PART D

C 2) Which diseases are most common?

____

____

____

C 3) How many times per year is someone in your household getting ill due to the wastewater situation?

____ times per year

C 4) How often do you or other household members need to see the doctor when being infected from contact with untreated wastewater?

____ times per year

C 5) What does it cost you to see the doctor (one visit)?

Health Center	Hospital	Private Doctor
Transport: _____ JD Treatment (consultation and medication): _____ JD	Transport: _____ JD Treatment (consultation and medication): _____ JD	Transport: _____ JD Treatment (consultation and medication): _____ JD

C 6) Can you tell us the total number of days per year that members of your household cannot attend work due to an illness caused by untreated wastewater?

Approximately ____ days per year per working individual

C 7) How much income is lost per day if one of your household members cannot attend work due to illness?

_____ JD per day (household member 1)

_____ JD per day (household member 2)

_____ JD per day (household member 3)