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Feasibility study on "tailor-made" SWMED solutions for the project target areas in Palestine

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1. Analysis and selection of the target areas

1.1 Summary

This document aims to present the feasibility study developed by PHG, partner of the project SWMED - Sustainable Domestic Water Use in Mediterranean Region, in order to support the integration of ad-hoc sustainable strategies into the Mediterranean local/regional policies.

During the elaboration of this survey, many aspects have been taken in account, by a deep research and analysis phase that allowed to identify the water supply and wastewater management system, treatment and waste water disposal (sewer network, wastewater treatment system, drains).

The aim of the survey was firstly to evaluate and select the cases of different typologies of settlements that can represent as more as possible the various scenarios where to plan appropriate and sustainable water management interventions; the three selected typologies are:
- a small municipality with partial existent facilities;
- a refugee camp;
- a rural region with diffused villages.

The information about water supply networks and drainage systems characteristics were gained by PWA and by several stakeholders active on the territory.

The last part of the document aims to illustrate the possible scenarios applicable to the three cases studies and the results of the related feasibility evaluation.

1.2 Criteria of Selection of the target area

The main criteria used for the selection of the target areas can be summarized as follows:

- Geographic location of communities (North, Middle or South West Bank).
- Population density (high, average and low density).
- Nature of the community - village - urban - refugee camp.
- Connectivity to a water network and percentage of coverage.
- Connectivity to wastewater collection and treatment system and percentage of coverage.
- Percentage of water losses or non revenue water.
- Water management patterns: Local council, collective management system, i.e. Joint Water Service Councils or local committee.
- To be in line with national priorities and plans

1.3 Description of the sites

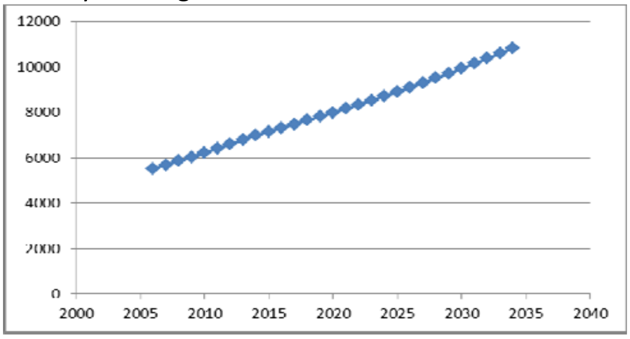
1.3.1 Bani Zaid

The name of the municipality is Bani Zaid, a small town in the Ramallah and al-Bireh Governorate in the north-central West Bank, located 27 kilometers northwest of Ramallah, about 45 kilometers northwest of Jerusalem and about 6 kilometers southwest of Salfit.

The stakeholders and beneficiaries involved in the research are PWA, MoLG, Bani Zaid Municipality, Bani Zaid Women Organization, Deir Ghassaneh Agricultural Society.

Picture 1 Panoramic view of Bani zaid

The type of settlements is rural. According to the PCBS census of 2007, Bani Zeid had a population of 5,515, of which 49% were males and 51% females. There were 1,176 housing units and the average size of a household was five family members. Currently there are approximately 850 houses, that corresponds to a n° of inhabitants of approximately 7000. A growth factor of the population has to be taken in account in the feasibility study; according to PCBS data, the Consultant assumes a population Growth Rate of 2.3% (up to 2016) and 2.2% (from 2016 up to 2031), which respects the Palestinian expectations. It means that the population could reach a total of 8700 inhabitants in a 10 year medium term scenario and 10800 in a 20 year long term scenario.



Picture 2 estimated population growth in Bani zaid

In the village there is the presence of small commercial activities and shops, but any relevant industrial activity. The only industrial activity is related to agro-food industry and oil production: five olive press are present but they are not connected to the sewer.
The average water pro-capita consumption for domestic purposes: 70 l/c/d

The existing facilities are:

- a partial sewage system 2000 m length, where up to now 100 households are connected
- a small wastewater treatment plant designed for 1400 persons.
- several percolation pits that permit the disposal of most part of the wastewater under the ground for the household not connected to the sewer
- rainwater harvesting, a practice well diffused in the site.

The WWTP is constituted by:

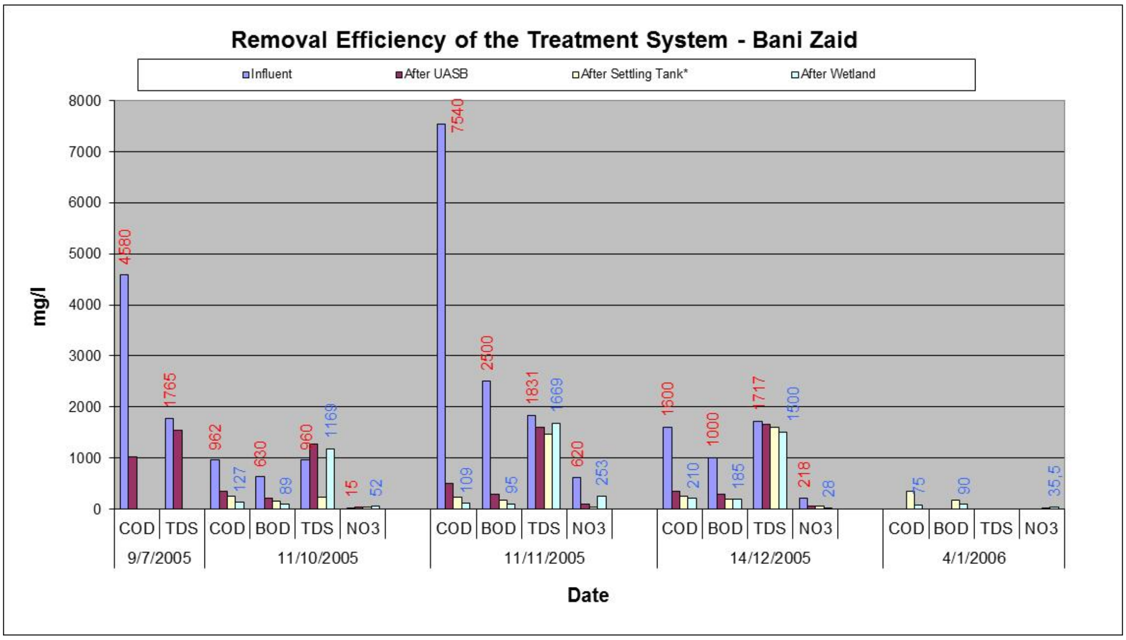
- a manual screen for grit removal;
- a UASB primary treatment of 145 m^2
- a multi-chamber septic tank
- a Constructed Wetland (horizontal flow type) developed on 4 stages in series; each stage is constituted by two beds in parallel. The overall system is about 1800 m^2.
- a final small reservoir of 16 m^3
- a little sludge drying bed of 4 m^3 for the management of primary treatment sludge.



Picture 3 Bani zaid WWTP: screen and UASB (on the left), Horizontal CW (on the right)

Picture 4 Bani zaid WWTP location

The system is designed for 100 m^3/day (1430 p.e. considering a average consumption of 70 l/c/d); the concentration at the inlet of organics and solids are very high, probably due to a low water consumption that lead to high concentrations of each parameter. In the figure below, the performance of the treatment plant are showed.

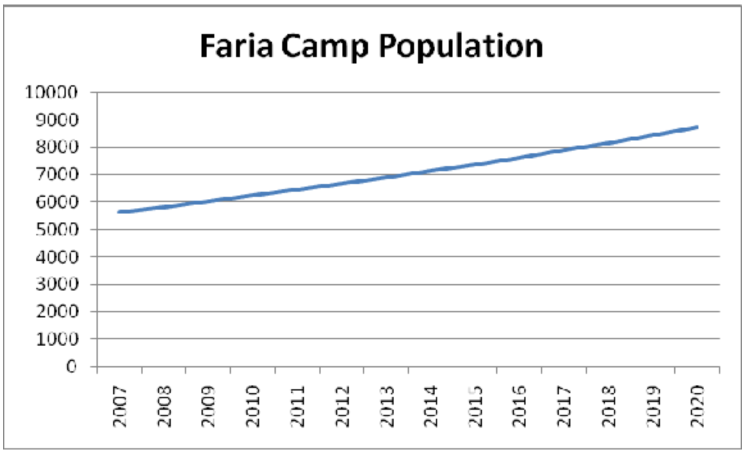


Picture 5 Bani zaid WWTP monitoring

The removal capacity is good, especially in the primary section that permit to reduce strongly the organic and solids load to the wetland. The removal in the horizontal flow constructed wetland is instead quite poor due probably two some hydraulic short-circuits observed during the visit and the need of better feeding systems at the inlet in order to distribute better the flow on the transversal section, and a better management of the flow levels at the outlet thought the installation of a drainage system connected to a regulation device. Moreover the plant used in the plant are Arundo donax and not Phragmites Australis or another kind emergent aquatic macrophyte generally used in Constructed Wetland technology. These are however simple and low cost interventions that could be done to improve the performance. It has also to be considered that 3 of the 4 lines in series are not in function and unplanted, therefore the 700 person are treated only in ¼ of the constructed wetland and the outlet concentrations are generally acceptable.

1.3.2 Faria Refugee Camp (Tubas)

Faria Refugee Camp is considered the main refugee camp in Tubas governorate. It is located nearly 15 kilometers south of Jenin city and nearly 3 kilometers south of Tubas town. The camp was established in 1948 for the Palestinian Refugees after the Israeli Arab war in 1948. It is constructed on area of 2.5 km^2. According to PCBS (2007), Tubas governorate has nearly 15.7% of its population as refugees mostly concentrated in Faria Refugee camp. The camp has a population of nearly 6500 inhabitants. Population density in the camp is 2600 person per km^2. The average number of household is nearly 1148 house and average family size is nearly 5.5 persons.
It is expected that population in the camp will reach nearly 9000 people in the year 2020 as shown in figure 7.



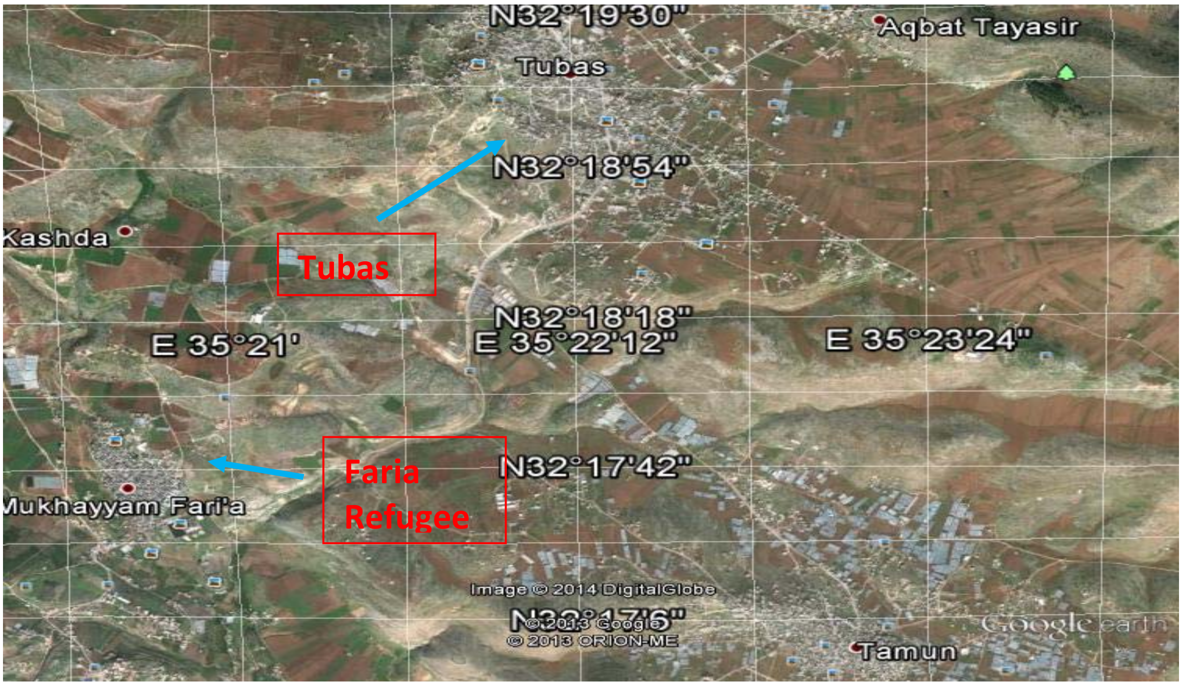
Picture 6 estimated population growth in Faria

The camp has sewage system but has no wastewater treatment plant and collected wastewater from the camp is flowing freely downstream causing some pollution to local water sources and agricultural land. It also has potable water network supplied from local Tubas Municipality well which produces nearly 0.6 MCM / year used mainly for drinking purposes. Average water per-capita consumption for domestic purposes is estimated at nearly 60 l/c/d.

There is no industrial activities in the site but small commercial shops. The percent of urbanization in the site is 100%. Connection to water supply and wastewater collection is 100%. However, some households in the vicinity of the camp uses Percolation pits. These percolation pits or Cesspits are emptied by private tankers and trucks which are disposed nearby the wadies or near the sides of the roads. The average size of the cesspits ranges between 10-50m3. The total cost for construction a new cesspits is between 1000-2000 $US. The average cost for evacuating one tank 6m3 volume from the cesspit and disposing is nearly about 20$. Evacuation cost may vary depending on the location of disposal.

The main Stakeholders and beneficiaries involved include: PWA , MoLG, Tubas Municipality, Faria Refugee Camp Committee, UNRWA, Agricultural Society, Civil Society Organizations.

The location of Tubas and Faria Camp are shown in the following figure.



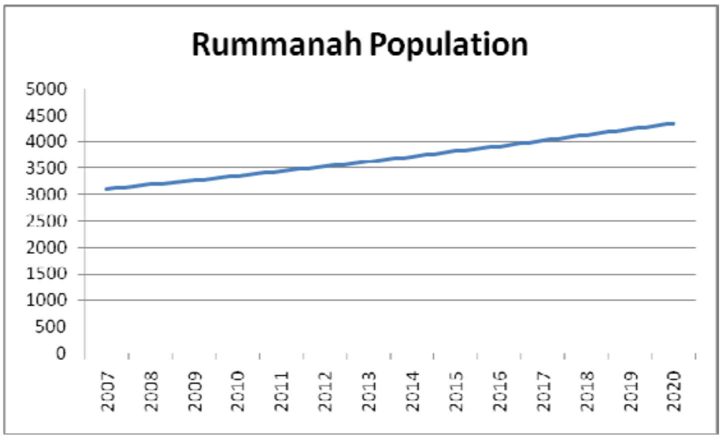
Picture 7 Google-earth satellite view of Tubas and Faria

1.3.3 Jenin rural area - Rummana

Rummanah village is located nearly 17 km northwest of Jenin city. According to PCBS (2007) the total population of Rummanah was 3140 people living in 642 household with average family size of 5.3 persons.

Picture 8 Panoramic view of Rummanah

Average population growth in the village is estimated at 2.6% and population is expected to reach nearly 4500 people in the year 2020 as shown in figure 8.

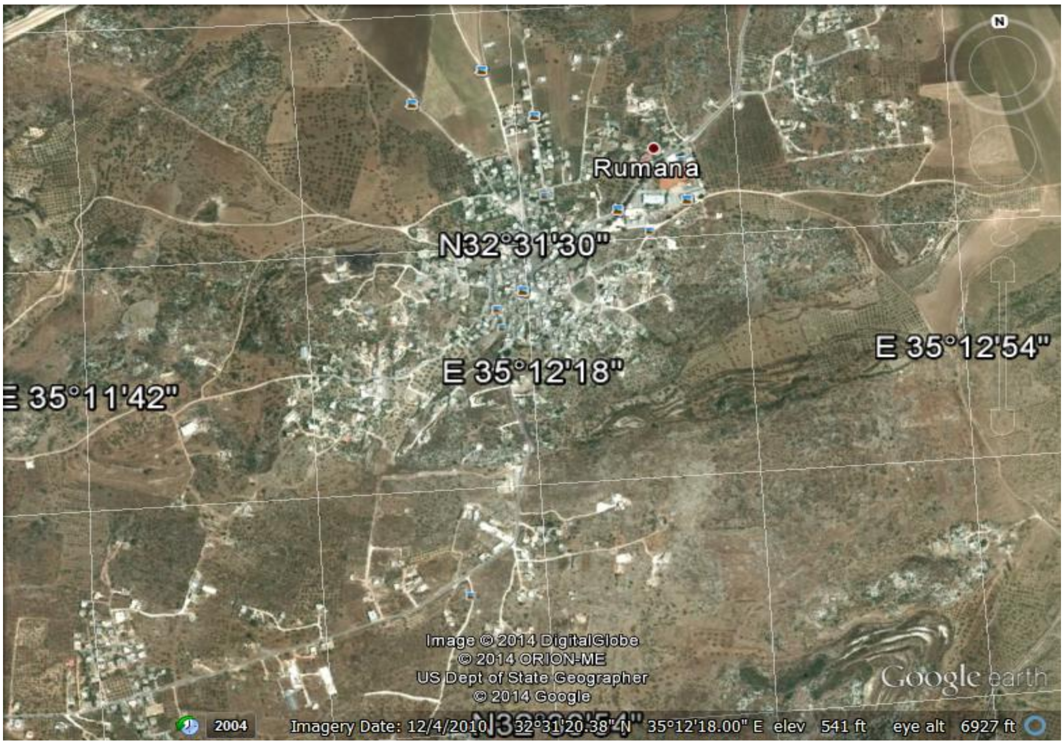


Picture 9 estimated population growth in Rummanah

Together with 11 adjacent villages, Rummanah have unified their water services under one joint water service council. They purchase water from the Israeli company through West Bank Water Department in bulk and distribute it to the customers in the 12 villages. They have no sewage system and all households uses percolation pits as the mean to dispose of sewage. The site has potable water network and they use rainwater harvesting at household level used for drinking as well as other uses.

Rummanah is located in area where groundwater table is more than 50 m deep. There is no surface water bodies and no environmentally sensitive areas or wetlands. There are some agricultural wells in some of the adjacent villages such as Kufur Dan serving irrigated agriculture in the village.

There is no industrial activities in the site but small commercial shops. The percent of urbanization in Rummanah is 100%. Connection to water supply is 100% while connection to sewage system is 0% and 100% of households uses percolation pits. Average water per-capita consumption for domestic purposes: 43 l/c/d and Consumption for other sector (agriculture, industrial): 33 l/c/d (no industry but irrigated agriculture in one community - Kufur Dan).
Stakeholders and beneficiaries involved can be summarized as follows:
PWA , MoLG, Village councils of the 12 communities, Joint Water Service Council, Well Owners, Civil Society Organizations.



Picture 10 Google-earth satellite view of Rummanah

2. Draft feasibility evaluations

Analyzing the data collected during the survey on the three case studies, all the sites face many infrastructural problems related both to the drainage system and to the treatment of wastewater, both to the availability of water for irrigation purposes.

In the Tubas and Jenin areas has already planned the promotion of the water saving kits.
The practice of rainwater harvesting is quite diffused, but we have also to consider that during the dry season the quantity of rainfall are very limited.
Water supply system should be enhanced by the grey water separation and treatment; this approach is well accepted by the population and there are several examples of successful installation both at a household level than at a small village level.
Also the reuse of treated wastewater is quite diffused in Palestine at a municipality level, but the successful of the practice and the acceptance by agriculture depends by the real availability of water in the area and by its cost; where water is distributed at acceptable costs and in sufficient quantity, the farms are not interested in use treated water. Instead treated water could be a good opportunity for public area irrigation.
Adequate drainage of runoff water during storm events is also an issue to be considered, considering the geological and hydrogeological characteristics of many area; therefore the implementation of sustainable urban drainage system could be recommended in order to reduce erosion issues.
Here below a brief list of the possible tools suitable for the Palestinian territory and related cases studies, with some essential explanation and clarifications in order to understand better the selection of the various tools in the proposed alternatives.

Tool	Scale of application	Applicability in the region	Diffusion in the region	Remarks/comments
Water saving devices	Single household			
Rain water harvesting	Single or group of households			
UASB and CW for mixed (black and grey) sewage treatment	Village or portion of village	Applied in Palestine	Applied in Palestine	Low Cost
Grey water Treatment - UFGF	Single or Multi Household	Applied in Palestine	Possible	More Socially Acceptable
Treated Grey water Reuse	Household, Public area	Applied in Palestine	Possible	More Socially Acceptable
Wastewater reuse	For public green area	Applicable		

Water Saving devices

A wide range of fittings and equipment able to reduce water consumption is available on the market. Most effective products are taps aerators and low flow shower-heads. Among the different tap types are lever taps, taps with timers with electronic shutoff, etc. There are also devices which can be adapted for different tap systems like reduced flow, and Tap aerator. Many models of new taps have these devices already incorporated. In addition, these devices are almost always compatible with each other. You can find mixer taps that have a built-in aerator.

	Savings for supply point
Flow restrictors	30-40%
Tap aerator	30-70%
Water pressure limiter	10-40%
Water saving showers	50%
Mixer taps	30-40%
Automatic taps	30-40%
Electronic taps	40-50%
Thermostatic taps	50%

The flush toilet can be adapted in order to use significantly less water than a full-flush toilet. Low-flush toilets use a special design of the cistern and the siphon in order to allow the removal of faeces and excreta with less water. Most often, they also include a dual flush system, with one flush being designed for urine only, using even less water than the other designed for faeces. Today, there exist many suppliers of different models of low-flush toilets all over the world.

Rainwater Harvesting

Rooftop harvesting is the most common technique of rainwater harvesting (RWH) for domestic consumption. It can be done easily, doesn't cost much and is applicable at small-scale with a minimum of specific expertise or knowledge; or in more sophisticated systems at large-scale (e.g. a whole housing area). Rainwater is collected on the roof and transported with gutters to a storage reservoir, where it is either used for groundwater recharge or provides water at the point of consumption. Rainwater harvesting can supplement water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. However, rainwater quality may be affected by air pollution, animal or bird droppings, insects, dirt and organic matter. Therefore regular maintenance (cleaning, repairs, etc.) as well as a filtration treatment before water consumption are very important.

The main components of a system for rainwater harvesting are:

• The collecting surface: only connect suitable roof surfaces if the system does not include a treatment. Take into consideration possible erosion of hazardous matter from the roof. With an appropriate treatment water from pavements can also be used.

• Gutters and downspouts (gullies and rainwater drains)

• Filter – mechanical or natural (as raingarden); the mechanical one are enough for the use in Palestine considering the absence of big cities and industrial areas and that roofs are relatively low polluted.

• Tank below ground or over ground (considering the morphology of the area, several times is possible to maintain the tank partially overground)

• A distribution system for reuse in irrigation or for WC flush; considering the morphology of the area, several times is possible to load by gravity the irrigation system instead of using a pump.

Picture 11 Rainwater harvesting covered and open cisternes in Palestine (source: PHG)

Grey water reuse

Any water that has been used in the household, excluding faecal water from toilets (black water), is called greywater. Shower, sink, laundry, and dishwashing effluents represent up to 70 % -80% of residential and touristic wastewater and as it is relatively clean, it is easier to treat. As drinking water is constantly used, domestic greywater is available in a constant quality and quantity. This is an important advantage for the reuse of greywater for toilet flushing, indoor and outdoor irrigation of plants and cleaning purposes. Major benefits of greywater reuse are the reduction of need for fresh water supply and sewage treatment. Especially in areas with low precipitation rates and water supply deficiencies, reuse for landscaping also has a benefit in reducing demands on high quality water supply.

Grey water are collected by a separate sewer, pre-treated by simple static degreaser, piped into a treatment system to reach the reuse limits and then stocked in a reservoir from which come out depurated water that can be inserted again into house pipes.

In Palestine the practice is quite diffused at household level, especially using enhanced primary treatment and several type of filtration system; the most diffused seems a primary treatment (degreaser) followed by a upflow gravel filter (UFGF) (in some case vegetated with ornamental plants) and a final polishing stage with carbon filter and/or sand filter. Treated water is reused for irrigation.

Picture 12 unplanted and planted upflow gravel filter at household level near Ramallah (source: PHG)


Picture 13 final filtration stage by carbon and gravel filter and reuse for drip irrigation at household level near Ramallah (source: PHG)

There are also several example of constructed wetland (vertical and horizontal flow type), adopted to treat the greywater of rural Bedouin villages of about 50-150 persons; the greywater is collected by a simplified separate sewer, whereas blackwater are disposed by percolating pits.

Constructed wetland and compact precast plant (most of them based on SBR technology, but in some case also simplified MBR (membrane bio reactor) and MBBR (mobile bed biological reactor) are the most diffused as treatment tools.

Picture 14 a Vertical flow system for greywater treatment in a Bedouin village of 70 persons near Hebron (source: IRIDRA-Oxfam Italia)

Other compact systems as SBR and MBR are not used to reuse greywater.

Constructed Wetland

Constructed Wetland are nowadays one of the most worldwide diffused technology for the wastewater treatment; their functioning principles are based on the biological, physical and chemical processes that occur in natural wetland, even if the CWs (especially subsurface types) are engineered systems studied and monitored since the end of ‘70.

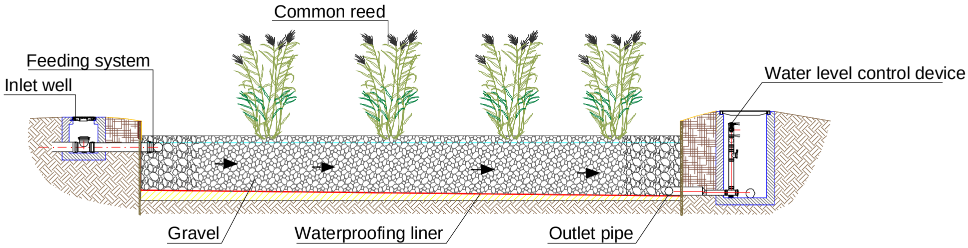
The most diffused are the submerged filters (horizontal and vertical flow type) where the wastewater is filtered by a medium (composed by gravel and/or sand) planted with aquatic macrophyte plants (generally Phragmites Australis or Typha latifolia); these systems require less area than free water systems (more similar to natural wetland) and permit both secondary and tertiary treatment of wastewater (e.g. greywater or blackwater). Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Generally they require a primary treatment for coarse solids (a manual or automatic grid) and suspended solids removal (a septic tank or imhoff tank). The water is treated by a combination of biological and physical processes. The effluent of a well-functioning constructed wetland can be used for irrigation and aquaculture (in these cases a combination of horizontal flow and vertical flow could be suggested for blackwater and mixed water, considering the low capacity of ammonia reduction of HF) or safely been discharged to receiving water bodies.

If the design requires expert knowledge, the implementation is very easy because it requires only a basic knowledge of simple hydraulic and civil works (earthmoving, waterproofing, hydraulic connection, small concrete structures); for the littler plants sometimes it is possible also the self-construction. Moreover CWs are relatively inexpensive to build where land is affordable and can be maintained by the local community as no high-tech spare parts, electrical energy or chemicals are required.

Horizontal Flow Constructed Wetland

HF constructed wetlands consist of waterproofed beds planted with hydrofite vegetation tipical of swamps and marshes (generally common reed - Phragmites Australis - is the most used, but to improve aesthetic amenity we could use together also other ornamental essence as Iris pseudacorus) and filled with gravel. The wastewater is fed by a simple inlet device and flows slowly in and around the root and the rhizomes of the plant and through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone. The filling material (coarse gravel, fine gravel and coarse sand) has to offer an appropriate hydraulic conductivity but also a large surface for the biofilm growing. Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Properly designed HF beds do not provide suitable habitat for mosquitoes or other vector organism and permit public access in wetland area.

HF beds are typically comprised of inlet feeding system, a synthetic liner, filter media, emergent vegetation, berms, and outlet piping with water level control.



Picture 15 – HF wetland schematic longitudinal section

Advantages/Benefits
• High treatment efficiency;
• Excellent environmental integration;
• Low investment cost and low maintenance requirements;
• No Energy consumption;
• The final effluent can be reused;
• High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
• Land requirement;
• High evapotranspiration at high temperatures
• Constrains on geometry (rectangular, ratio between Length and Width)

Operation and maintenance
• Management of primary sludge (periodic emptying of primary treatment)
• Annual mowing of emerging saprophytes.

The performance of HF systems are influenced by the wastewater temperature and the hydraulic retention time (HRT): HRT must be minimal 1 day for greywater (3 days for black water) to permit removal performances of organic matter over 60-70%. High temperatures positively influence the natural purification processes.

Typical removal of a well designed HF system

BOD_5	85-95%
Suspended Solids	70-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	50-70%
Phosphorus	50-90%
Pathogen micro-organisms	97-99,999%

Picture 16 – HF system for greywater reuse in Palestine

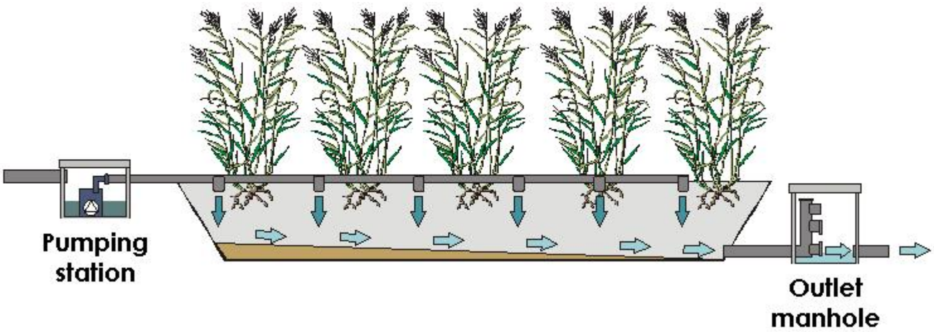
The horizontal flow system is well suitable to treat greywater that contain low content of ammonia and bacteria compared to mixed wastewater and a fast biodegradable organic content; usually 2-3 days of HRT are enough to ensure a safe reuse of greywater.

Vertical Flow Constructed Wetland

In the vertical flow systems (VF) the wastewater is applied through a distribution system on the whole surface area and passes the filter in a more or less vertical path. The pre-treated wastewater is dosed on the bed in large batches (intermittent feeding), thus flooding the surface. During the time between the feedings the pores within the filter media can fill up with air which is trapped by the next dose of liquid. Thus oxygen requiring nitrifying bacteria are favored and full nitrification can be achieved, but only a small part of the formed nitrate is denitrified under aerobic conditions. The treated water is collected in a bottom drainage system to be discharged.

The loading of VFs normally happens intermittently by pumps, or by gravity using special self-priming siphon devices if there is enough difference of level between the primary treatment and the wetland basin.

This kind of CW is particularly efficient in nitrification, carbon and suspended solids removal. Due to its prevalently aerobic conditions de-nitrification is poor.



Picture 17 – VF wetland schematic longitudinal section

Advantages/Benefits
- High treatment efficiency;
- Excellent environmental integration;
- Low investment cost and low maintenance requirements;
- Low Energy consumption;
- The final effluent can be reused
- High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
- Land requirement (generally a little bit less than HF);
- Constrains on geometry (to permit uniform distribution on the surface)

Operation and maintenance
- Management of primary sludge
- Annual mowing of emerging macrophytes;
- Periodic inspection of the feeding system (usually centrifugal submerged pumps).

The performance of VF systems are influenced by the Hydraulic Loading Rate (m^3/m^2 per day) and the Organic Loading Rate (grCOD/m^2 per day). The typical removal efficiency are listed below:

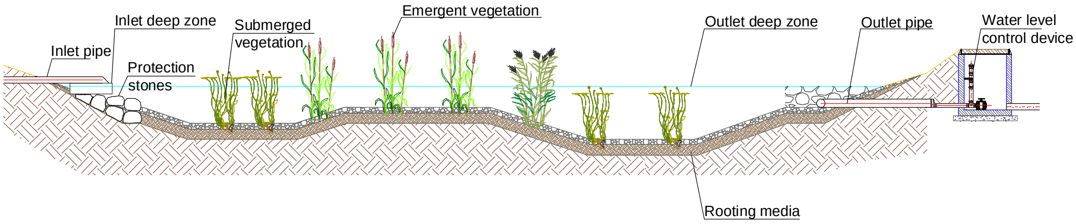
Typical removal of a well designed VF system

BOD_5	85-95%
Suspended Solids	80-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	80-90%
Phosphorus	50-90%
Pathogen micro-organisms	2-3 log

Also the vertical flow system is well suitable to treat greywater that contain low content of ammonia and bacteria compared to mixed wastewater and a fast biodegradable organic content; moreover these systems permit to reduce evapotranspiration losses and the required surface compared to horizontal flow systems. On the other side more attention has to be addressed to the correct and uniform distribution of the water on the filter, ensuring proper hydraulic and organic loading per surface unit and enough resting periods between each load; therefore the use of an equalization tank and a pump (or a self-priming siphon) is required.

Free Water System (FWS)
Generally surface flow wetlands are densely vegetated basins that contains open water, floating vegetation and emergent plants. They need of soil or another suitable medium to support the emergent vegetation. When the FW systems are applied for the control of diffusion pollution, they don't need of waterproofing with plastic liner, due to the low risk of groundwater contamination.
The main components of a FW wetland are:
- An inlet distribution system, followed by an inlet deep zone to allow the removal of heavier sediments;
- Shallow marsh areas with varying depths (0,4 - 0,6 m) with wetlands vegetation;
- An outlet deep zone to clarify the final effluent;
- An outlet device to control the water level.

The most common application of these systems is the tertiary treatment due to their power of de-nitrification and pathogens removal (due to the high exposure of the wastewater to the UV component of the sunlight). FW systems are also largely used to control diffuse pollutions: these systems are one of better choice for the treatment of agricultural, urban and industrial storm water, because of their ability to deal with intermittent flows and low concentrations



Picture 18 – FWS wetland schematic longitudinal section

Advantages/Benefits
• Environmental restoration;
• Provides aesthetic amenity and increases biodiversity;
• Buffer effect when used as tertiary treatment;
• No energy consumption.
Disadvantages/Limitations
• High land requirements.
• Risk of mosquitoes diffusion.
• High evapotranspiration rates
• not indicated for secondary treatment (large area and bad odor diffusion)

Operation and maintenance
• Examine the functioning of the system;
• Annually mow emergent vegetations.

MBR:
A technological and compact sewage treatment systems that permit to clean the sewage water permitting to discharge the outflow in a water body or to reuse the treated water. In the Membrane Bio Reactors (SBR) the process is the same of classic activated sludge plants: oxygen is bubbled through the waste water to reduce pollutants by oxidation processes. The difference is in the final part, where secondary gravity sedimentation is substitute by a ultrafiltration membrane. The quality of the outfall is very high thanks to ultrafiltration technology and for this reason this particular process is well indicated for reuse. However the system requires skilled labor for its management and maintenance; energy costs remain high, as well sludge production. Moreover the maintenance operations on the membrane are very costly and require a specific assistance from the vendor.

Advantages/Benefits
• High treatment efficiency;
• low space required;
• affordable investment cost
• The final effluent can be reused with an additional disinfection unit
• High tolerance to seasonal and daily variation of fluxes and dry periods.
Disadvantages/Limitations
• high energy consumption;
• High maintenance cost for membrane cleaning and substitution
• high surplus sludge production
• skilled labor maintenance required
• higher maintenance cost compared to natural and other low-tech treatment
• Spare parts difficultly available in Palestine

Operation and maintenance
• Management of surplus sludge
• cleaning and regeneration or substitution of membrane
• weekly analytical control of sludge and wastewater characteristics
• Periodic inspection and maintenance of E&M equipment

3. Elaboration of alternative options

Bani Zaid

1. Water Saving devices to reduce water consumption at home: as above explained tools for regulating the water flow, shower diffusers, WC "Water Saving" that drains with 3 l instead of 9 l like the traditional WC and low flush toilet.
   We consider to invest 10 €/household for shower diffusers and flow regulators, in order to achieve a global saving of 15-25%.

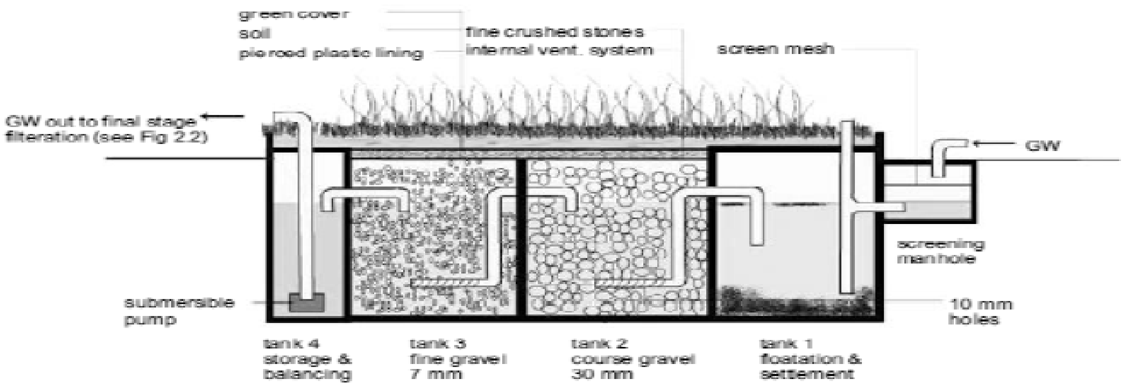
2. Roof rainwater harvesting and reuse for irrigation and domestic purposes

The reuse of wastewater presents an opportunity to save water and to reduce water consumption. This practice is well diffused in Palestine; due to the several problems related to water access, often the rainwater represent one of the main source of water supply for household, that use it for irrigation and domestic purpose as i.e. clothes washing or cooking.
The practice is already well diffused also in Bani Zaid municipality, therefore we consider it in all the alternatives, including alternative 0; the specific water consumption of 70 l/c/d takes already in account the water saving from rainwater harvesting.

3. Greywater reuse for irrigation at household level

Considering that the greywater reuse is a well-accepted and economic practice in the region, we have consider to improve the number of this systems at household level, in order also to increase the income of poor household giving them the possibility to cultivate some agriculture products.
Considering that the irrigation is possible almost along all the year, and that the treated greywater will not discharge in any case in the sewer, this will lead to a significant reduction of the water volume to be treated.
The selected technology is UFGF for single household (or max 2-3), considering that are very simple systems already adopted by several households in the region successfully. Where it could be possible to join a greater number of households, it could be interesting to evaluate also the hypothesis of a simplified sewer connected to a common treatment facility based on constructed wetland technology (horizontal or vertical flow type).

We have considered to apply the greywater reuse for 25% of households.



Picture 19 Burnat's septic gravel up-flow system (source: Burnat & Eshtayah 2010)

According to Abu-Madi's comparative analysis, the average capital cost for the system was $1,212 per household (Abu-Madi, et al., 2010). Considering also the final polishing stage, the cost of the treatment per household could be about 1500 €, that means a cost per person of about **250 €/c**.

4. Up-grading of wastewater treatment capacity

In the several alternatives, we considered to enhance and upgrade the wastewater treatment, considering the progressive increase of connections to the sewer; in the evaluation of the possible solutions, we have also considered the benefits of water saving devices and greywater reuse in terms of hydraulic and organic reduction.

Considering that the greywater production could be considered about 60-70% of the total pro-capita consumption, it means to reduce the wastewater to be treated in the WWTP of about 15%.

For the current scenario, we adopt a consumption of 70 l per capita x day: we consider a progressively increasing of the specific hydraulic consumption until 90 l per capita x day in 10 year medium term scenario (according with the study "Prospects of Efficient Wastewater Management and Water Reuse in Palestine" – Year 2004, Institute for Water Studies, Birzeit University, West Bank-Palestine, Adelphi Research, Berlin, Germany, ENEA, Bologna, Italy), that will be increased to 120 l per capita x day for the long term scenario (20 years).

The expected BOD5 load per each person is assumed to be 45g/c/d in the year 2015 and 55g/c/d in 2025, with a final value of 60 gr in the long-term scenario.

Also the % of greywater is assumed to change during the years.

	n°person	specific hydraulic load	% of greywater	specific organic load	% of BOD in greywater
		l/c/d	%	grBOD/c/day	%
2014	7000	70	60	45	40
2024	8700	90	65	50	40
2034	10800	120	70	55	40

Considering the application of water saving device, a reduction of 15-25% can be considered in a conservative way; the obtained consumption pro-capita will be then 60-70-90 l/c/d in the 3 scenarios.

	n°person	wastewater production	greywater reuse	WW to be treated	
		m3/day	m3/day	m3/day	
2014	7000	420	74	347	
2024	8700	609	91	518	
2034	10800	972	113	859	

	n°person	organic load	organic gw content	organic load to WWTP	C BOD
		KgrBOD/day	KgrBOD/day	KgrBOD/day	mg/l
2014	7000	315	32	284	818
2024	8700	479	48	431	832
2034	10800	648	65	583	679

On the basis of these data, we can provide several alternatives.

4.1 Connect to the existing treatment as more as possible households

Up to now, the existing facilities permits the treatment of about 700 person with a quite acceptable removal capacity of organic load and suspended solids.

According to the memorandum of Understanding (MoU) on Guidelines and Technical Criteria for Sewage projects, which was signed between the Israeli- Palestinian Joint Water Committee, effluent quality should not exceed, in the first phase the following values: BOD max=20 mg/L, TSS max=30mg/L, TN max=25mg/L

The preliminary and primary system (UASB and settler) are designed for 100 m^3, i.e. about 1500 person. Considering the positive effects of water saving devices and of the greywater treatment at household level for the 25% of the population connected to the sewer, the constructed wetland, with some adjustments, could be capable to reach the limit for the discharge for a total number of about **2300 persons** in the current scenario.

In this way the treatment system can ensure the reduction of the BOD concentration below 25 mg/l and a reduction of 40-50% of ammonia and total nitrogen; considering that the discharge is in a not sensitive area, this level of treatment can be acceptable.

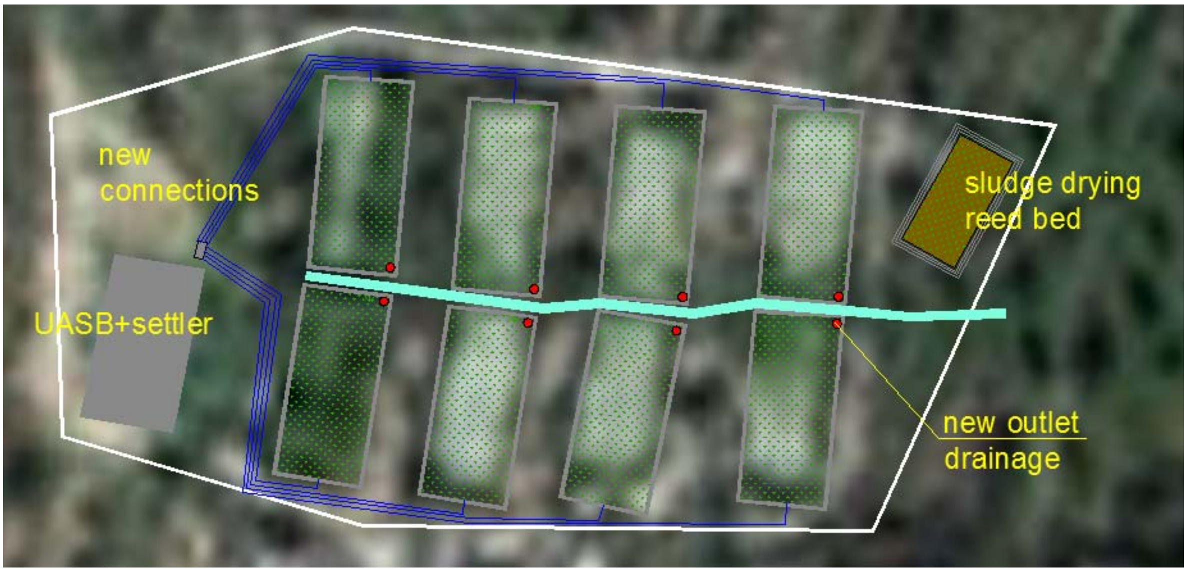
Upgrading cost should consist in:

- Repartition of the flow on each line, transforming the system in 8 basins in parallel, in order to limit any clogging issue and ensure a better distribution of the flux on the inlet section of the horizontal flow systems;
- New pipeline for in parallel configuration;
- Realization of regulation manholes and a more effective drainage system for each bed;
- Realization of a more efficient distribution system at the inlet in each bed;
- Plantation of Phragmites Australis in the unplanted bed, and substitution of Arundo Donax with Phragmites in the first tow beds;
- Sludge drying reed bed for the management of the sludge extracted from the UASB and from the septic tank of 100 m^2

The overall cost of these interventions is about **40.000,00 €.**

Maintenance costs are low and remain approximately the same, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed bed. It is possible to consider a cost of 3,00 €/person, with an annual maintenance cost of **6.900 €/year**.

In this alternatives, great part of the sewage remain untreated (67% in the current scenario, 78% in the long term scenario).



Picture 20 Rehabilitation of the existing treatment possible layout

4.2 Expand the existing treatment realizing new parallel lines with a similar concept, using the nearby areas

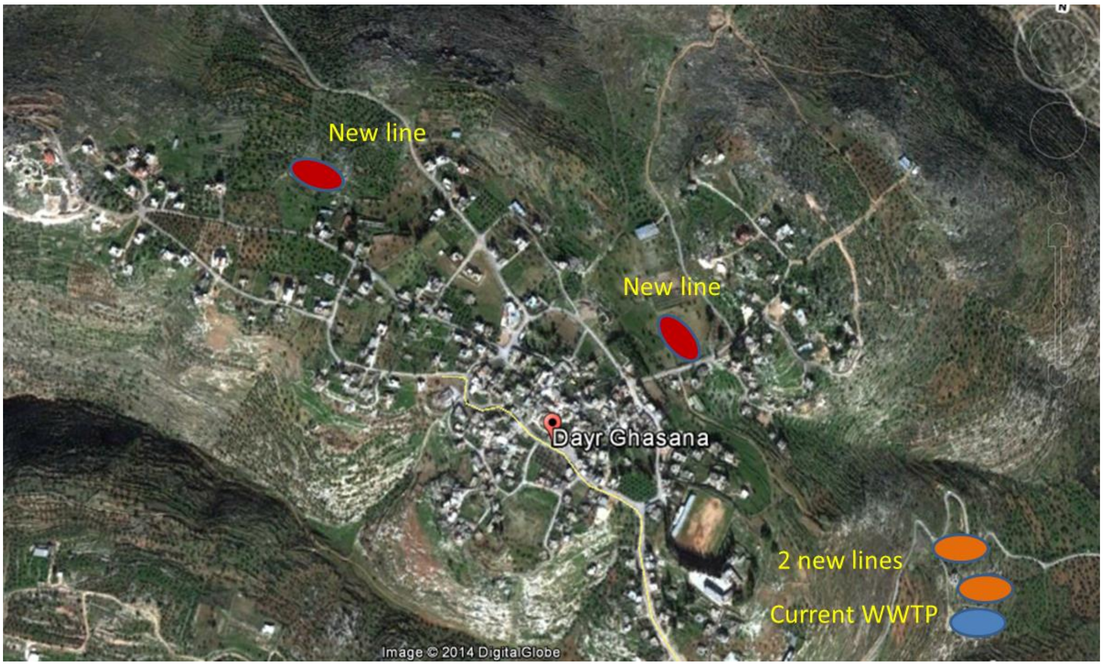
To cover the long term scenario (10.800 persons), if we follow the current treatment scheme (UASB+settler+HF 1800 m^2) other 4 lines could be needed; to cover the current scenario, 2 more lines could be enough. In the following table the cost are showed; the estimation is based on the parametric costs of similar installation in Palestine. The cost don't include the completion of the sewer network and the connection of the remained households.

treatment cost per line	
anaerobic treatment	€ 40.000,00
screen channel	€ 4.000,00
horizontal flow beds	€ 144.000,00
sludge drying reed bed	€ 10.000,00
pipelines	€ 9.400,00
accessorios and landscaping	€ 10.370,00
Cost per line	**€ 217.770,00**
upgrading of the existing one	**€ 40.000,00**
Total cost in the current scenario (+2 lines)	**€ 475.540,00**
Total cost in the medium term scenario (+3 lines)	**€ 693.310,00**
Total cost in the long term scenario (+4 lines)	**€ 911.080,00**

The available space could be the main concern. In the current area, it is possible only to double the plant in the nearby area and probably also to realize a third line with several terraces and retaining walls; the other 2 lines could be realized only downstream, where there are olive tree plantations, therefore the real availability of the total area has to be investigate.

Picture 21 Increase the capacity of the existing treatment adding other similar parallel lines

Another alternative could be to realize different sewer networks and decentralized the other lines in other area, considering that the village is on the top of an hill; the evaluation of decentralized solutions could lead also to a reduction of the cost for the sewer network.



Picture 22 Possible locations for other decentralized system to cover totally the wastewater treatment demand

Another possible solution to limit the required space is to design the wetland treatment as an hybrid system, combining vertical and horizontal flow system. In this case it is possible to reduce the overall net surface of approximately 2000 m^2 and reduce the cost of about 100.000 €.

Two new line could be added to the existing one to cover the long term scenario, whereas 1 line can be enough to the current one (7000 persons). The treatment scheme of each line is the following:

- Grit removal by manual screen;
- UASB and settler 350 m^3;
- Siphon battery to load vertical flow systems by gravity;
- Vertical flow CW 1500 m^2 (net area) divided in several basins;
- Horizontal flow CW 1500 m^2 (net area) divided in several basins
- Sludge drying reed bed of 200 m^2 (net area).

Picture 23 Increase the capacity of the existing treatment adding other lines with the combination of vertical and horizontal flow systems

treatment cost per line	
anaerobic treatment	€ 80.000,00
screen channel	€ 6.000,00
syphon for vertical flow loading	€ 14.000,00
horizontal and vertical flow beds	€ 225.000,00
sludge drying reed bed	€ 20.000,00
pipelines	€ 16.250,00
accessorios and landscaping	€ 18.062,50
Cost per line	**€ 379.312,50**
upgrading of the existing one	**€ 40.000,00**
Total cost current scenario (+ 1 line VF+HF)	**€ 419.312,50**
Total cost long term scenario (+2 lines VF+HF)	**€ 798.625,00**

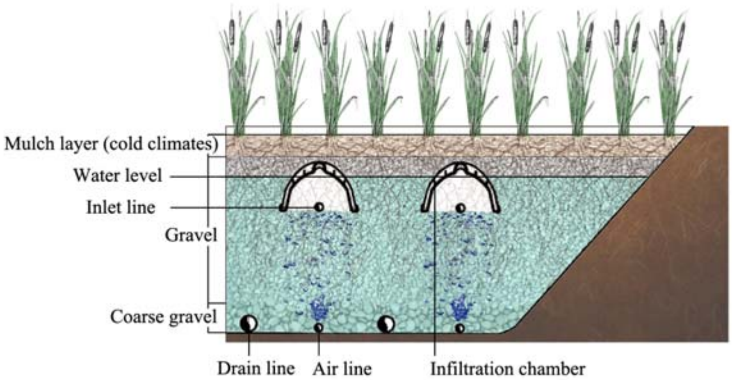
Maintenance cost are low, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. It is possible to consider a cost of 3,00 €/person, with an annual maintenance cost of **31.000 €/year**.

4.3 Enhance the capacity of the existing treatment transforming the current wetland in Aerated Engineered Wetland (AEW)

In order to minimize the required space, to enhance the capacity of the existing plant to cope the long term scenario and to reach the 100% of sewer connection, a possible solution could be the recourse to a particular kind of constructed wetland, namely aerated engineered wetlands (AEW).

AEW are an advanced type of CWs which allow more efficient removals of contaminants from wastewaters, due to the higher availability of oxygen. The wastewater being treated flows subsurface beneath an aggregate substrate which is aerated mechanically from below, with an appropriate distribution system of air. This permits to strongly minimize the footprint. Flux can be through the medium both horizontal than vertical and in both cases the medium is completely saturated by water to permit the optimal oxygen transfer; vertical type are preferred due to the better distribution on the upper surface in order to reduce clogging issues, but also horizontal flow system can work well.
In AEW a coarse bubble aeration network, realized by special drip lines (also used in drip irrigation application) is placed under the gravel substrate, and air is supplied to it by special blower characterized by low energy consumption. Aerated SSF EWs generally have much smaller surface area, even 5 times less size of the equivalent passive sub-surface CWs. Aeration was found to profoundly affect treatment performances. The power consumption depends by the type of wastewater and the oxygen demand: to treat the urban wastewater of a municipality in Eastern Ontario, an external energy input of only 0.16 kWh/m^3 is required and this energy input is considerably less than activated sludge processes, (0.7-2 kWh/m^3).

Despite the higher level of engineering compared to a traditional subsurface wetland, O&M requirements for AEW are relatively simple and conducted for the great part by unskilled labour as the other type of CWs treatment schemes, which may allow to a community organisation or a private to manage the system; a skilled labour is required only to maintain the blowers. The maintenance operations are similar to a traditional wetland (periodical sludge, scum control and emptying in primary treatment, plant harvesting, check the perfect functioning of the distribution system and of the aeration system, regulating the air flow according to inlet wastewater characteristics, ensuring clogging does not occur in the bed, sampling of the discharged water). The maintenance cost is in the range of **15 €/p.e.**



Picture 24 AEW section (source: Nawatech EU project, 2014)

Picture 25 Construction details of the aeration system (source: Scott D. Wallace)

An interesting opportunity offered by this kind of technology is the refurbishment of existing wetland, both vertical than horizontal flow type; the intervention is quite simple and it consists in placing the driplines on the bottom of the basin using a modified plow.

Picture 26 aeration tubing plow (source: Scott D. Wallace)

Therefore we have elaborated an alternative that consists in the transformation of the existing constructed wetland system in a Aerated Engineered Wetland, loaded vertically to reduce the probability of clogging. To reach the same water quality target of the previous hypothesis in the long term scenario, 450.000 grO_2 per day are needed, considering a 70% of organic removal in anaerobic treatment. The existing basins are in total 1800 m^2, therefore we need to transfer to the basins about 260 grO_2/m^2, that is possible with this kind of technology using a dripline net with an interax of about 5 cm between each pipe. In case of plowing installation of the aeration tubing, it is very difficult to ensure this high distribution; moreover the risk of clogging could be high.
If we consider to install aeration driplines with an interax of 10 cm in the current wetland, we can guarantee approximately 230.000 grO_2/day, that is enough to ensure a BOD concentration below 25 mg/l and an ammonia reduction of about 50%.
To cope the long term scenario an additional line has been provided, with total surface of 1800 m^2 (net area).

Picture 27 Upgrade the capacity of the existing treatment with forced aeration technology.

The following cost has been estimated.

Refurbishment of existing WWTP	
blowers	€ 20.000,00
aeration main lines	€ 4.800,00
plow installation of aeration driplines	€ 54.000,00
sludge drying reed bed	€ 20.000,00

syphon for vertical flow loading	€ 10.000,00
additional anaerobic treatment	€ 40.000,00
new pipelines	€ 20.000,00
new feeding systems	€ 16.000,00
modification of drainage systems	€ 16.000,00
Electrical works and PLC	€ 50.000,00
accessorios and landscaping	€ 10.040,00
Total cost	**€ 260.840,00**
treatment cost of new AEW line	
anaerobic treatment	€ 80.000,00
screen channel	€ 6.000,00
syphon for vertical flow loading	€ 10.000,00
AEW beds	€ 198.000,00
sludge drying reed bed	€ 20.000,00
pipelines	€ 20.000,00
blowers	€ 20.000,00
aeration main lines	€ 4.800,00
Electrical works and PLC	€ 50.000,00
accessorios and landscaping	€ 16.700,00
Total cost	**€ 425.500,00**
Total cost current scenario	**€ 260.840,00**
Total cost long term scenario (+1 AEW line)	**€ 686.340,00**

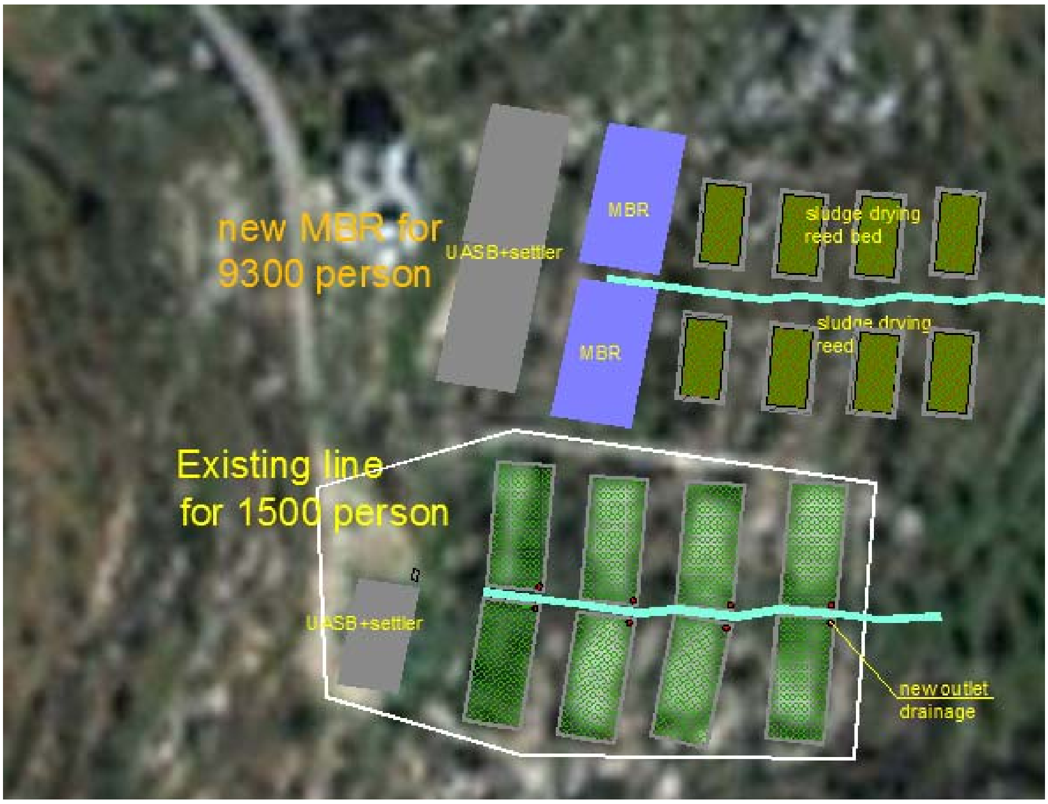
Maintenance cost remain low, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. The only energy consumption is for the aeration: considering a consumption of 0.2 kWh/m^3, we obtain 100 KWh/d kn the current scenario and about 170 KWh/d in the long term scenario. Considering a cost of 0.1 €/KWh, it means 3700 €/year in the current scenario and 6300 €/year in the long term scenario. Therefore, considering also the maintenance of E&M work, it is possible to consider a cost of **50.000 €/year**.

4.4 Enhance the capacity of the existing treatment with the introduction of MBR, in order also to reuse the treated water for public areas irrigation

In order to consider also the reuse of the treated water, we have considered also an additional alternative that provides the installation of a MBR treatment after the anaerobic treatment.

MBR treatment is ah high-technology system that requires continue monitoring and maintenance activities in order to achieve the expected results and to contain the energy and operational cost. The anaerobic treatment permits however to reduce strongly solids and organic load at the inlet of the MBR, reducing power consumption for oxidation processes, decreasing the number of interventions and replacements of the membrane and reducing the amount of surplus sludge to be extracted periodically; these have to be considered the three main cost during operation. The sludge disposal cost can be strongly reduced providing the installation of several sludge drying reed beds.

The existing system can be left in place to treat a maximum of 1500 p.e. in order to consent the reuse.



Picture 28 Upgrade the capacity of the existing treatment adding an MBR

The following cost has been estimated; for MBR we have considered installation cost of similar compact systems supplied by European company, considering also the cost of shipping to Palestine of the equipments. We have considered only the realization of the plant for the long term scenario.

Upgrading with MBR technology for reuse	
anaerobic treatment	€ 120.000,00
MBR compact system for 9300 person	€ 630.000,00
civil works	€ 80.000,00
Electrical works	€ 40.000,00
chlorine disinfection	€ 25.000,00
sludge drying reed bed	€ 80.000,00
upgrading of the existing CW	€ 40.000,00
accessorios and landscaping	€ 20.300,00
Total cost	**€ 1.035.300,00**

According to EPA, **operating costs** are 0.47 dollars/m^3 for systems that treat 4000-8000 m^3/d, including electrical fees, membrane replacements, sludge extraction and chemicals. Considering a reduction of 15-20% due to the presence of sludge drying reed bed, we can consider for the treatment of around 750 m^3/d, an operational cost of 0,5 €/m^3. This lead, considering also the cost of the existing treatment plant, the skilled labour to its operation, and the ordinary and extraordinary maintenance works of civil structures, electrical installations, pipelines and of the other additional facilities, to a yearly cost of **200.000 €/y**. The maintenance cost is however strongly influenced by the frequency of cleaning and substitution of the membrane, that is not foreseeable because it depends by many variables, such the concentration of solids and organics in the sewer, the efficiency of anaerobic treatment, the effectiveness of the ordinary maintenance activities.

MBR membrane price dropped to around US$ 50-100/ m^2 from US$400/$m^2$ in the past decade. The typical flux of MBR is 25 LMH, so each m^3/d treatment capacity needs 1.67 m^2 membrane which costs US$ 83.5. In our case membrane replacement could cost at least about 50-100.000,00 €. Membrane replacement can occur every 2-4 year.

5. Summary of the alternatives in the Bani Zaid

	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Water saving devices	No	Yes	Yes	Yes	Yes
Rain water harvesting	Yes	Yes	Yes	Yes	Yes
WWTP capacity increasing	Yes	connection to the existing WWTP of total 2300 p.e.	Expand Existing WWTP – Same UASB and CW - VF-HF - to 7000 p.e. (10.800 in 2035)	Expand Existing WWTP – Same UASB and AEW CW - to 7000 p.e. (10.800 in 2035)	Introduce Membrane Based Treatment and upgrading to 7000 p.e. (10.800 in 2035)
Grey Water Treatment	No	Yes (25% of connected household)	Yes (25% of connected household)	Yes (25% of connected household)	Yes (25% of connected household)
Grey water reuse	No	Yes	Yes	Yes	Yes
Wastewater reuse	No	No	No	No	Yes

Investment cost (€)	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Water saving devices	-	€ 14.000,00	€ 14.000,00	€ 14.000,00	€ 14.000,00
Rain water harvesting	-	-	-	-	-
WWTP capacity increasing	0	€ 40.000,00	€ 800.000,00	€ 686.000,00	€ 1.035.000,00
Grey Water Treatment and reuse	0	€ 143.750,00	€ 675.000,00	€ 675.000,00	€ 675.000,00
Total	0	€ 197.750,00	€ 1.489.000,00	€ 1.375.000,00	€ 1.724.000,00

P.S. cost not include sewer expansion

Operational cost (€/year)	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Water saving devices	-	-	-	-	-
Grey Water Treatment and reuse	0	€ 9.583,33	€ 45.000,00	€ 45.000,00	€ 45.000,00
WWTP capacity increasing	€ 5.000,00	€ 6.900,00	€ 31.000,00	€ 50.000,00	€ 200.000,00
Total	€ 5.000,00	€ 16.483,33	€ 76.000,00	€ 95.000,00	€ 245.000,00

Treated water (m^3x1000/year) (*)	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
WWTP capacity increasing	18,25	41,56	209,60	209,60	209,60
Grey Water Treatment and reuse	0	8,81	33,85	33,85	33,85
Total	18,25	50,37	243,455	243,455	243,455
% of total	5%	14%	69%	69%	69%

(*) average value in 2014-2034

	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4 (**)
Cost per reused water €/m^3 (20 years payback time)	–	€ 1,90	€ 2,33	€ 2,33	€ 0,99

(**) cost of investment and operation for reuse in MBR has been calculated on the additional cost compared to no reuse option

	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Cost per treated water €/m^3 (20 years payback time)	€ 0,27	€ 0,52	€ 0,62	€ 0,67	€ 1,36

Faria Refugees Camp

1. Water Saving devices to reduce water consumption at home: as above explained tools for regulating the water flow, shower diffusers, WC "Water Saving" that drains with 3 l instead of 9 l like the traditional WC and low flush toilet.

   We consider to invest 10 €/household for shower diffusers and flow regulators, in order to achieve a global saving of 15-25%.

2. Roof rainwater harvesting and reuse for irrigation and domestic purposes

The reuse of wastewater presents an opportunity to save water and to reduce water consumption. This practice is well diffused in Palestine; due to the several problems related to water access, often the rainwater represent one of the main source of water supply for household, that use it for irrigation and domestic purpose as i.e. clothes washing or cooking.
The practice is already well diffused also in this area, therefore we consider it in all the alternatives, including alternative 0; the specific hydraulic consumption takes already in account the water saving from rainwater harvesting.

3. Upgrading of treatment capacity

Currently no WWTP are present in the area, both for the Refugee Camp than for Tubas city. Farias has a sewer network that cover approximately the 80% of the population. The total n° of inhabitants is 24,594, of which 25% are in the refugees camp, i.e. 6149 distributed in 1148 households (5,35 person/household).

For the current scenario, we adopt a consumption of 60 l per capita x day. Also in this case, a grow-factor has to be applied to the number of persons: according to PCBS data, the Consultant assumes a population Growth Rate of 2.3% (up to 2016) and 2.2% (from 2016 up to 2031).

The expected BOD5 load per each person is assumed to be 45g/c/d in the year 2015 and 55g/c/d in 2025-2035 scenarios.

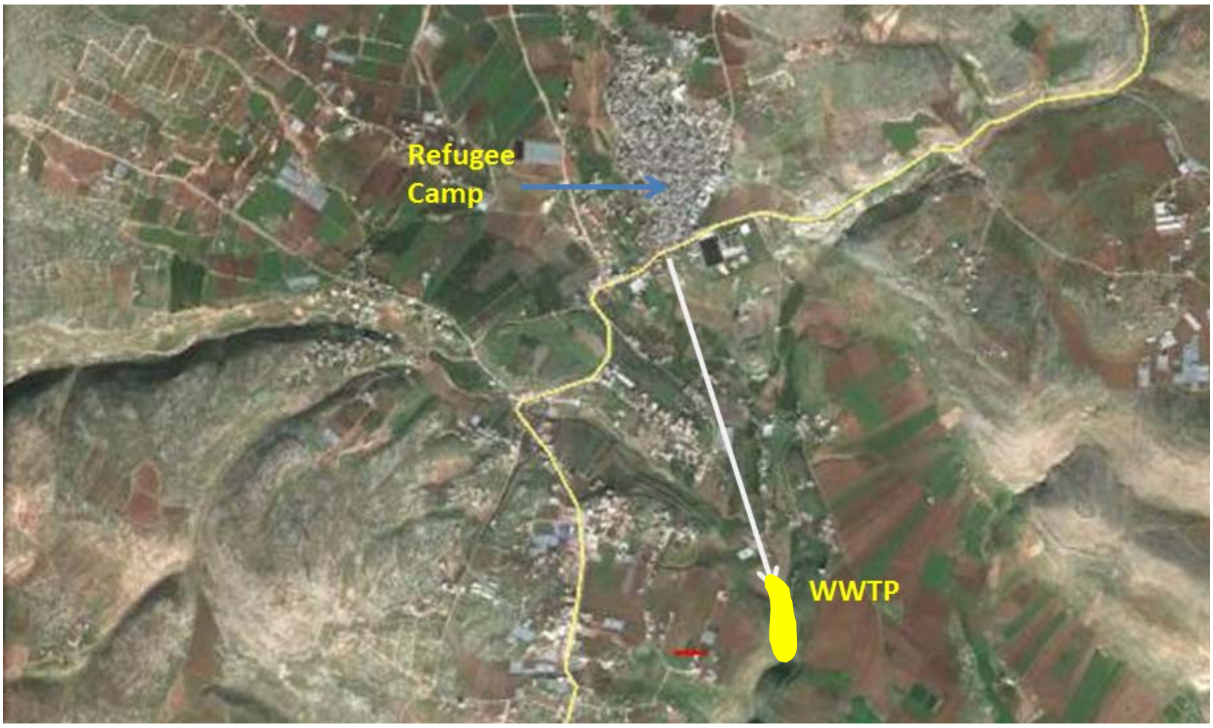
Considering the application of water saving device, a reduction of 10-20% can be considered in a conservative way; the obtained consumption pro-capita will be then 55-60-70 l/c/d in the 3 scenarios.

refugee camp	n°person	wastewater production	organic load to WWTP	C BOD
		m^3/day	KgrBOD/day	mg/l
2014	6147	307	277	900
2024	7658	459	421	917
2034	9520	666	524	786

On the basis of these data, we can provide several alternatives.

3.1 WWTP for Faria refugee camp

An area for the realization of the WWTP has been already selected in the socioeconomic survey conducted within this project.



Picture 29 possible location for the WWTP

We consider to reach 100% of connection in Farias refugee camp; to cover a long term scenario (**9.520 persons**), providing a low technology treatment system, we have considered the obtained results of the Bani Zaid study, where for the final discharge of treated water an anaerobic treatment (UASB + settler) followed by an hybrid constructed wetland has been considered the best option in terms of investment and operational costs with a cost per treated m^3 of 0.42 €. In case of not sufficient available area however also the solution with Aerated Engineerd Wetland should be considered, even if the engineering level of the installation is a little higher.

Thus the treatment scheme could be the following:

- Grit removal by automatic mechanical screw screen;
- UASB and settler 800 m^3;
- Siphon battery to load vertical flow systems by gravity;
- Vertical flow CW 5000 m^2 (net area) divided in several basins;
- Horizontal flow CW 5000 m^2 (net area) divided in several basins
- Sludge drying reed bed of 600 m^2(net area).
- Discharge in the Al-Fari'a Wadi

Picture 30 Constructed wetland alternative for the Faria WWTP

The quality of treated water is according to river discharge, with BOD_5 < 20 mg/l and a nitrogen reduction of 40-50%. The nitrogen reduction can be higher during summer, where the wadi's water is used for agriculture irrigation. It has to be noted that CWs are very effective also in disinfection, with an expected reduction in this case of 3-4 log of Escherichia Coli.

UASB+CW treatment cost	
anaerobic treatment	€ 160.000,00
Automatic screwscreen	€ 16.000,00
syphon for vertical flow loading	€ 25.000,00
horizontal and vertical flow beds	€ 650.000,00
sludge drying reed bed	€ 60.000,00
pipelines	€ 42.000,00
accessorios and landscaping	€ 47.000,00
Cost	**€ 1.000.000,00**

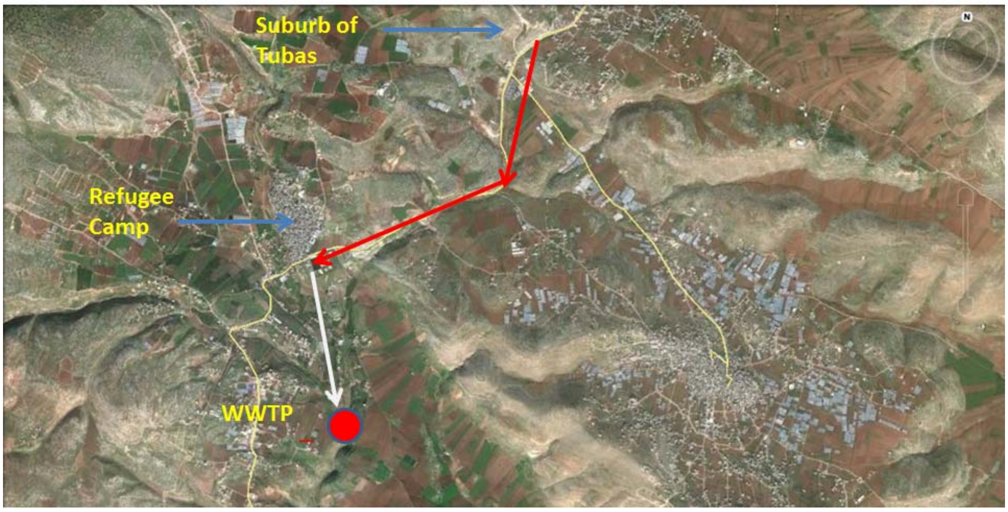
Maintenance cost are low, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. It is possible to consider a cost of 3,00 €/person, with an annual maintenance cost of **28.500 €/year**.

3.2 WWTP for Faria refugee camp and a suburb of Tubas

In this second alternative, we consider to connect to the same treatment system 3000 inhabitants of a suburb of Tubas; considering the grow factor, in the long term scenario they will be around 4800 persons. Considering to adopt the same treatment scheme for **14.300 persons**:

- Grit removal by automatic screw screen;
- UASB and settler 1200 m^3;
- Siphon battery to load vertical flow systems by gravity;
- Vertical flow CW 7500 m^2 (net area) divided in several basins;
- Horizontal flow CW 7500 m^2 (net area) divided in several basins
- Sludge drying reed bed of 900 m^2 (net area).
- Discharge in the Al-Fari'a Wadi

A sewer collector of 4 Km is necessary to reach, from the southern suburb of Tubas, the Farias final collector that connects the camp to the WWTP.



Picture 31 possible connection of a Tubas suburb to the WWTP

treatment cost	
suburb sewer main collector (4 Km)	€ 400.000,00
anaerobic treatment	€ 228.000,00
screen channel	€ 18.000,00
syphon for vertical flow loading	€ 25.000,00
horizontal and vertical flow beds	€ 945.000,00
sludge drying reed bed	€ 72.000,00
pipelines	€ 60.000,00
accessorios and landscaping	€ 54.000,00
Cost	**€ 1.802.000,00**

Maintenance cost are low, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. It is possible to consider a cost of 2,80 €/person, with an annual maintenance cost of **40.000 €/year**.

Compared to the previous hypothesis, it means to increase the WWTP extension of 50% or more; the suitability of the selected area has to be better investigate by topographical and hydrogeological preliminary surveys. The realization of a such big system (15.000 m^2 of sub-surface wetland) could lead to a significant impact on the territory and it needs of important earthmovings in order to create the terraces for the basins.

To reduce the required area, an aerated engineered wetland (as the one introduced in the previous case study of Bani Zaid) could be preferable: only 5000 m^2 could be enough in this case even if it will require a constant power supply to work well and this constraint has to be considered.

treatment cost for AEW alternative	
suburb sewer main collector (4 Km)	€ 400.000,00
anaerobic treatment	€ 228.000,00
screen channel	€ 18.000,00
syphon for vertical flow loading	€ 25.000,00
blowers	€ 80.000,00
main air lines	€ 15.000,00
AEW beds	€ 550.000,00
sludge drying reed bed	€ 72.000,00
electrical works and PLC for automation	€ 80.000,00
diesel generator for emergency power supply	€ 40.000,00
operational building and other civil works	€ 30.000,00
pipelines	€ 46.000,00
accessorios and landscaping	€ 47.000,00
Cost	**€ 1.631.000,00**

Maintenance cost remain low, considering that the whole system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. The only energy consumption is for the aeration: considering a consumption of 0.2 kWh/m^3, we obtain 200 KWh/d in the long term scenario. Considering a cost of 0.1 €/KWh, it means 7300 €/year in the long term scenario. Therefore, considering also the maintenance of E&M and civil works, it is possible to consider a cost of **60.000 €/year**.

4. Summary of the alternatives

	ALT 0	ALT 1	ALT 2
Water saving devices	No	Yes	Yes
Rain water harvesting	No	Yes	Yes
WWTP capacity increasing	No	new WWTP for Faria	new WWTP for Faria and Tubas suburb
Wastewater reuse	No	No	Yes

Investment cost (€)	**ALT 0**	**ALT 1**	**ALT 2**
Water saving devices	-	€ 12.300,00	€ 18.300,00
Rain water harvesting	-	-	-
WWTP capacity increasing	0	€ 1.000.000,00	€ 1.802.000,00
Total	0	€ 1.012.300,00	€ 1.820.300,00

P.S. cost not include sewer expansion or rehanilitation in Faria, neither sewer realization in Tubas suburb (only the main collector is included)

Operational cost (€/year)	**ALT 0**	**ALT 1**	**ALT 2**
Water saving devices	-	-	-
WWTP capacity increasing	€ 0,00	€ 28.500,00	€ 40.000,00
Total	€ 0,00	€ 28.500,00	€ 40.000,00

Treated water (m^3x1000/year) (*)	**ALT 0**	**ALT 1**	**ALT 2**
WWTP capacity increasing	0	174,38	260,98
Total	0	174,38	260,98
% of total	0%	100%	150%

(*) average value in 2014-2034

	ALT 0	**ALT 1**	**ALT 2 (**)**
Cost per treated water €/m^3 (20 years payback time)	€ 0,00	€ 0,45	€ 0,50

(**) in the AEW hypothesis, the cost is 0,55 €

Jenin rural area

1. Water Saving devices to reduce water consumption at home: as above explained, tools for regulating the water flow, shower diffusers, WC "Water Saving" that drains with 3 l instead of 9 l like the traditional WC and low flush toilet.
In the area, SWMED provides the distribution of simple water saving devices.

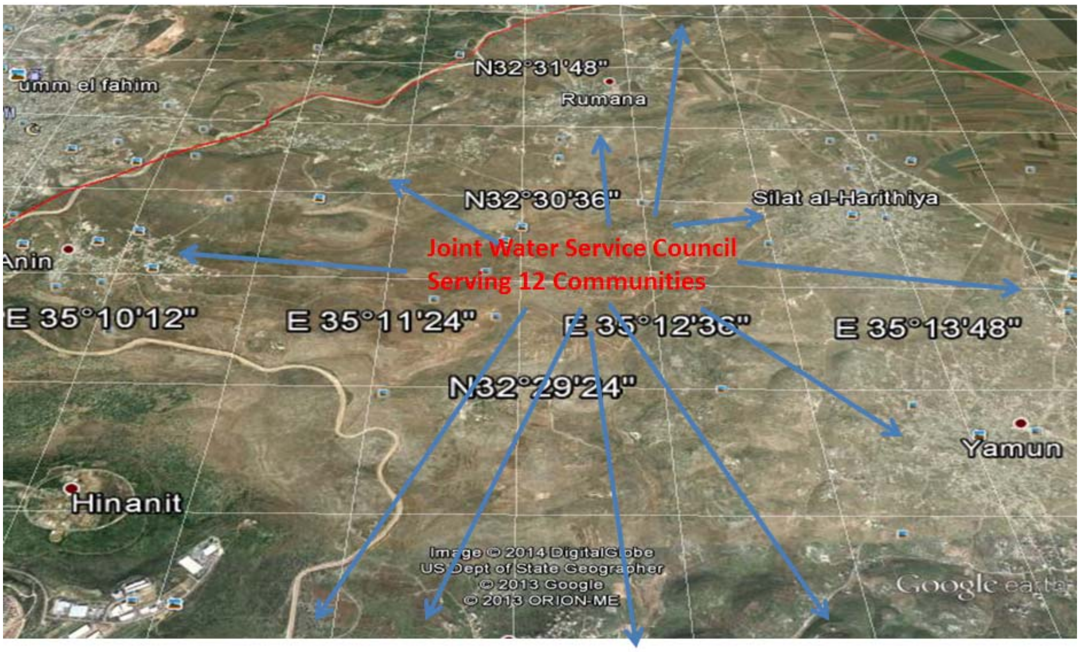
2. Roof rainwater harvesting and reuse for irrigation and domestic purposes

The reuse of wastewater presents an opportunity to save water and to reduce water consumption. This practice is well diffused in Palestine; due to the several problems related to water access, often the rainwater represent one of the main source of water supply for household, that use it for irrigation and domestic purpose as i.e. clothes washing or cooking.
The practice is already well diffused also in this area, therefore we consider it in all the alternatives, including alternative 0; the specific hydraulic consumption takes already in account the water saving from rainwater harvesting.

3. Upgrading of treatment capacity: decentralized or semi-centralized systems?

Currently the water network of the Joint Water Service Council joins 12 communities placed around Jenin. The over population is distributed in 10.000 households, with a total number of person of 50.500. Each village has a population in the range of 3000-5000 persons: currently Rumana village counts 3500 persons.

No WWTP are present in the area; moreover in all the village the sewer is absent.



Picture 32 Area served by the Joint Water Service Council

The pro-capita consumption is very low, about 43 l per capita x day; it is sincerely difficult to consider, in the sizing of WWTPs, a real effectiveness of the application of the water saving device. The scope of their distribution is in fact principally educational, considering the low availability of water in the area and looking forwards also to future increase of water consumptions

Also in this case, a grow-factor has to be applied to the number of persons: according to PCBS data, the Consultant assumes a population Growth Rate of 2.2%, with potentially the possibility to reach in 10 years a total number of 63400 persons, and almost 80.000 n 20 years.

The expected BOD5 load per each person is assumed to be 45g/c/d.

Considering the potential diffusion of water saving device, and considering at the same time the rainwater reuse in the area for domestic purpose, we assume a consumption pro-capita of 45-50-60 l/c/d in the scenarios.

On the basis of these data, we can provide several alternatives.

3.1 WWTP decentralized plants: the case of Rumana

Considering the results in the case study of Bani Zaid, the better solution in case of wastewater with high organic concentration seems to be an anaerobic treatment, with the aim to strongly reduce organic and solid load, followed by a wetland, preferably with an hybrid scheme in order to save space and money.

In the case of Rumana, currently 3500 inhabitants with a perspective of 5500 in the long term scenario, the treatment scheme is the following:

- Grit removal by automatic screw screen if power connection is available (otherwise a manual screen installed on a channel can work as well);
- UASB and settler 450 m^3;
- Siphon battery to load vertical flow systems by gravity;
- Vertical flow CW 2500 m^2 (net area) divided in several basins;
- Horizontal flow CW 2500 m^2(net area) divided in several basins
- Sludge drying reed bed of 300 m^2 (net area).

The estimated cost of this WWTP are the following.

treatment cost per Rumana	
anaerobic treatment	€ 99.000,00
Mechanical automatic screw screen	€ 15.000,00
syphon for vertical flow loading	€ 16.000,00
horizontal and vertical flow beds	€ 380.000,00
sludge drying reed bed	€ 30.000,00
pipelines and main collector	€ 50.000,00
accessorios and landscaping	€ 27.000,00
Total Cost	**€ 617.000,00**

Therefore, considering to cover all the villages in the region with decentralized treatments, the total cost could be about **7.400.000 €.**

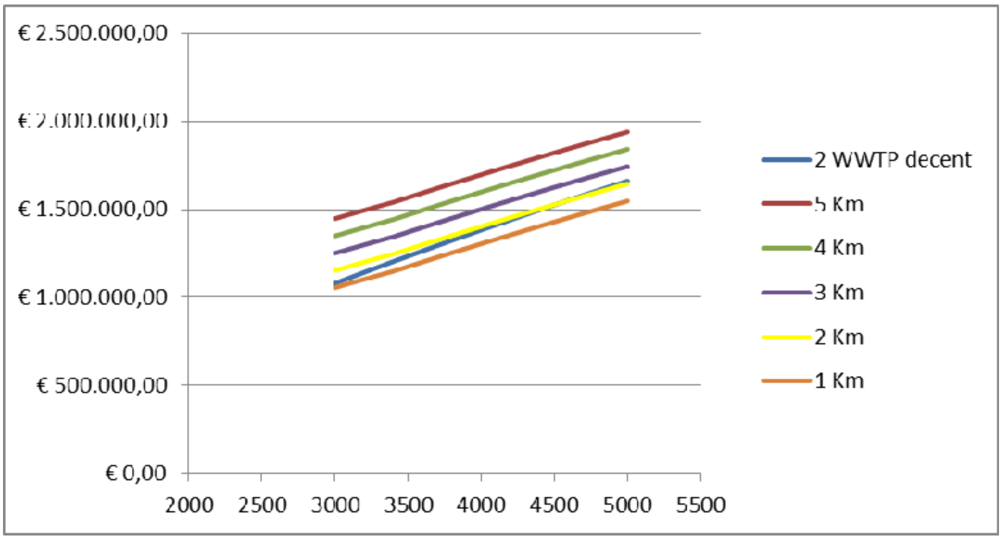
Maintenance cost are low, considering that the system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. It is possible to consider a cost of 3,00 €/person, with an annual maintenance cost of **16.500 €/year**. Thus the overall maintenance cost for the 12 plants will be **198.000 €/year**

In case of reuse, we have considered an additional investment equal to 30% of the cost of the hypothesis with no reuse, and an additional operation cost of 15%.

3.2 WWTP semi-decentralized plants

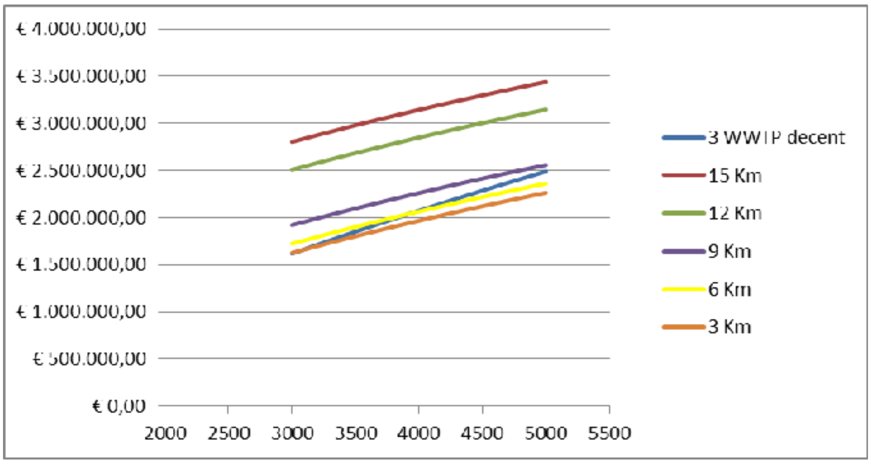
To have a first indication on how many villages could be economically sustainable to be connected to the same WWTP, some preliminary calculations have been done. The opportunity to connect several villages to the same WWTP, in a semi-decentralized approach, depends also by other considerations related to the morphology, the geology and hydrogeology of the area, to the real availability of suitable areas, to the economic and social context; in this phase we have only considered what kind of solution could be more convenient, without individuate any area of intervention. Almost all the village are on the top of hills in a rural and undeveloped areas, overlooking the most low-lying areas down valley.

In the following graphs a comparison of a decentralized alternative (one plant per village) with the opportunity to connect 2 and 3 village is reported. We have considered parametric cost per person of a WWTP with the same treatment process chosen for the decentralized approach (UASB + wetland) and considering a reduction of BOD concentration below 20 mg/l and a nitrogen reduction of approximately 50%.
Considering the distance between two village, the collector to treat their sewage could be about 40% more; we have considered a cost of 70 € per m of sewer.



Picture 33 Economical feasibility of 2 decentralized WWTP compared with centralized approach

In this first case (two villages), it is more convenient to connect 2 villages for a distance of 1 Km in any case, whereas it is more convenient to connect two village only if the total population is more than 8000; for a distance of 3-4-5 Km the cost is always higher.



Picture 34 Economical feasibility of 3 decentralized WWTP compared with centralized approach

In the second case (three villages), it is more convenient to connect 3 villages until a max distance between the first and the third of 4 Km, whereas for higher distances the cost is always higher.

On the basis of this observation, and considering that the 12 villages can be divided in group of 3 with distances not higher than 4 Km in every group, we consider in the semi-decentralzied approach to provide 4 treatment plant, averagely 12.600 person each in the current scenario and about 20.000 in the long term scenario.

For each plant, we have considered to use the scheme with anaerobic treatment followed by aerated engineered wetland in order to reduce the footprint of the plants.

The treatment scheme is the following:

- Grit removal by automatic screw screen if power connection is available (otherwise a manual screen installed on a channel can work as well);
- UASB and settler 1500 m^3;
- Siphon battery to load vertical flow systems by gravity;
- Vertical Aerated CW 7200 m^2 (net area) divided in several basins;
- Sludge drying reed bed of 1100 m^2 (net area).

treatment cost for AEW plant 20.000 persons (long term scenario)	
sewer main collectors	€ 300.000,00
anaerobic treatment	€ 255.000,00
automatic screen	€ 18.000,00
syphon for vertical flow loading	€ 35.000,00

blowers	€ 90.000,00
main air lines	€ 25.000,00
AEW beds	€ 684.000,00
sludge drying reed bed	€ 77.000,00
electrical works and PLC for automation	€ 80.000,00
diesel generator for emergency power supply	€ 40.000,00
operational building and other civil works	€ 30.000,00
pipelines	€ 55.350,00
accessorios and landscaping	€ 41.680,50
Cost	**€ 1.731.030,50**
Total cost (4 plants)	**€ 6.924.122,00**

Maintenance cost remain low, considering that each system will operate by gravity and that the sludge will be managed on site with the sludge drying reed beds. The only energy consumption is for the aeration: considering a consumption of 0.2 kWh/m^3, we obtain 400 KWh/d. Considering a cost of 0.1 €/KWh, it means 15.000 €/year. Therefore, considering also the maintenance of E&M and civil work, it is possible to consider a cost of **80.000 €/year** per each plant, for a total of 320.000 €/year.

In case of reuse, we have considered an additional investment equal to 30% of the cost of the hypothesis with no reuse, and an additional operation cost of 15%.

4. Summary of the alternatives

	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Water saving devices	No	Yes	Yes	Yes	Yes
Rain water harvesting	Yes	Yes	Yes	Yes	Yes
WWTP	No	Semi-centralized WWTP	Decentralized WWTPs	Semi-centralized WWTP	Decentralized WWTPs
Wastewater reuse	No	No	No	Yes	Yes

Investment cost (€)	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices	-	€ 101.000,00	€ 101.000,00	€ 101.000,00	€ 101.000,00
Rain water harvesting	-	-	-	-	-
WWTP	0	€ 7.400.000,00	€ 6.924.000,00	€ 9.620.000,00	€ 9.001.200,00
Total	0	€ 7.501.000,00	€ 7.025.000,00	€ 9.721.000,00	€ 9.102.200,00

P.S. cost not include sewer realization in the village (only the main collectors are included)

Operational cost (€/year)	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Water saving devices	-	-	-	-	-
WWTP capacity increasing	€ 0,00	€ 198.000,00	€ 320.000,00	€ 227.700,00	€ 368.000,00
Total	€ 0,00	€ 198.000,00	€ 320.000,00	€ 227.700,00	€ 368.000,00

Treated water (m^3x1000/year) (*)	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
WWTP capacity increasing	0	1429	1429	1429	1429
Total	0	1429	1429	1429	1429
% of total	0%	100%	100%	100%	100%

(*) average value in 2014-2034

	ALT 0	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Cost per reused water €/m^3 (20	_			€ 0,10	€ 0,11

(**) cost of investment and operation for reuse has been calculated on the additional cost compared to no reuse option

	ALT 0	**ALT 1**	**ALT 2**	**ALT 3**	**ALT 4**
Cost per treated water €/m^3 (20	€ 0,00	€ 0,40	€ 0,47	€ 0,50	€ 0,58

4. Definition of sustainability criteria for evaluation

BANI ZAID

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	5
	illness	5
Reduced exposure to pathogens	of users	5
	of waste workers	2
	of resource recoverers /reusers	4
	of "downstream" population	3
Impact to environment / nature		
use of natural resources	Minimize water use	5
	Low land requirements	5
	Low energy requirements	5
	Uses mostly local Construction material	4
low emissions and impact to the environment	Surface water	3
	Ground water	3
	soil/ land	3
	Air	2
	Noise and vibration	1
	aesthetic	4
	odours	4
good possibilities for nutrients recovering resources	energy	1
	Organic matter	1
	Water	5
	Landscape integration	3
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		5
Purification capacity (wastewater depurated/soil used by the plant)		5
has high robustness and long lifetime/high durability		3
enables simple and low operational procedures		5
Low maintenance and low skills required		5
not reliant on a continuous supply of a resource (such as water or energy)		5
adaptable to unexpected future changes (adaptability)		2
Good quality of effluent (according to the receiving environment)		5
Amount and quality of generated sludge		1
reduction of the imbalance water at the basin level		3
Economical and financial issues		
Provides benefits to the local economy (business opportunities, local employment, etc.)		3
provides benefits or income generation from reuse		4
Social, cultural and gender		
Improves quality of life		5
requires low level of awareness and information to assure success of technology		4
requires low operation & maintenance and little involvement by the user/workers		5

high level of satisfaction of the local people regarding the implemented technology	5
requires low policy reforms at local, regional or national level.	5
educational impacts	1
Costs	
Investment cost (€)	4
Maintenance cost (€/year)	4

Weight definition: number from 1 to 5, 5 is the max score, 1 is the minimum score

FARIAS REFUGEE CAMP

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	3
	illness	3
Reduced exposure to pathogens	of users	2
	of waste workers	2
	of resource recoverers /reusers	2
	of "downstream" population	2
Impact to environment / nature		
use of natural resources	Minimize water use	3
	Low land requirements	3
	Low energy requirements	3
	Uses mostly local Construction material	3
low emissions and impact to the environment	Surface water	5
	Ground water	5
	soil/ land	5
	Air	5
	Noise and vibration	5
	aesthetic	4
	odours	4
good possibilities for nutrients recovering resources	energy	3
	Organic matter	1
	Water	4
	Landscape integration	3
Technical issues		
allows simple construction		4
low level of technical skills required for construction		4
High level of efficiency (wastewater input/depurated/timing)		4
Purification capacity (wastewater depurated/soil used by the plant)		5
has high robustness and long lifetime/high durability		4
enables simple and low operational procedures		4
Low maintenance and low skills required		4
not reliant on a continuous supply of a resource (such as water or energy)		5
adaptable to unexpected future changes (adaptability)		4
Good quality of effluent (according to the receiving environment)		3
Amount and quality of generated sludge		3
reduction of the imbalance water at the basin level		3

Economical and financial issues	
Provides benefits to the local economy (business opportunities, local employment, etc.)	3
provides benefits or income generation from reuse	3
Social, cultural and gender	
Improves quality of life	3
requires low level of awareness and information to assure success of technology	4
requires low operation & maintenance and little involvement by the users	4
high level of satisfaction of the local people regarding the implemented technology	4
requires low policy reforms at local, regional or national level	5
educational impacts	5
Costs	
Investment cost (€)	2
Maintenance cost (€/year)	1

JENIN RURAL AREA

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	4
	illness	4
Reduced exposure to pathogens	of users	4
	of waste workers	4
	of resource recoverers /reusers	4
	of "downstream" population	4
Impact to environment / nature		
use of natural resources	Minimize water use	4
	Low land requirements	3
	Low energy requirements	2
	Uses mostly local Construction material	1
low emissions and impact to the environment	Surface water	4
	Ground water	4
	soil/ land	4
	Air	5
	Noise and vibration	5
	aesthetic	5
	odours	4
good possibilities for nutrients recovering resources	energy	1
	Organic matter	2
	Water	4
	Landscape integration	1
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		4
Purification capacity (wastewater depurated/soil used by the plant)		5
has high robustness and long lifetime/high durability		3
enables simple and low operational procedures		4

Low maintenance and low skills required	3
not reliant on a continuous supply of a resource (such as water or energy)	5
adaptable to unexpected future changes (adaptability)	3
Good quality of effluent (according to the receiving environment)	3
Amount and quality of generated sludge	4
reduction of the imbalance water at the basin level	4
Economical and financial issues	
Provides benefits to the local economy (business opportunities, local employment, etc.)	3
provides benefits or income generation from reuse	3
Social, cultural and gender	
Improves quality of life	3
requires low level of awareness and information to assure success of technology	3
requires low operation & maintenance and little involvement by the users	3
high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level	3
educational impacts	3
Costs	
Investment cost (€)	3
Maintenance cost (€/year)	2

The “weights” will be multiplied for the specific indicator “measures” in order to obtain a final value that will contribute to the calculation of an aggregated and normalised index for each macro-indicator.

5. Evaluation of the proposed scenarios based on a multi-criteria analysis

The kind of procedure to be applied is essentially the same used for a cost-benefit analysis and an environmental risks assessment (like in a EIA), considering not only the direct effects but also the most important indirect effects; the effects/impacts can be both material or immaterial, and so some of them can be measured while some others will need to be quantified by indicators. At the end of every evaluation of possible alternatives, simple and objective indicators should be the results of the multi-criteria analyses, so to provide the stakeholders with proper and "easy to understand" instruments for choosing the most appropriate alternative considering all the environmental, economical and social contexts for every case.

The economic evaluations will have to include the O&M costs for all the lifespan of the realizations and some recommendations in each feasibility study about the locally available fund raising options could be highly welcome from the stakeholders and considered as a very important contribution for the future application in real scale of the proposed solutions

BANI ZAID

Health issues		alternative 0	alternative 1	Alternative 2	Alternative 3	Alternative 4
Causes any risk of	additional mosquitoes (or other insects) growth	2	2	4	4	5
	illness	2	2	4	4	5
Reduced exposure to pathogens	of users	2	2	4	4	4
	of waste workers	3	3	3	3	3
	of resource recoverers /reusers	3	4	4	4	4
	of “downstream” population	3	3	3	3	3
Impact to environment / nature						
use of natural resources	Low land requirements	3	4	4	4	4
	Low energy requirements	4	4	2	2	4
	Uses mostly local Construction material	5	5	5	5	2
	Low water amounts required for construction	5	5	5	5	2
low emissions and impact to the environment	Surface water	3	3	3	3	3
	Ground water	2	2	3	3	3
	soil/ land	2	2	2	2	4
	Air	3	3	3	3	3
	Noise and vibration	3	3	3	3	3
	aesthetic	4	4	4	4	4
	odours	2	2	4	4	5
good possibilities for nutrients recovering resources	energy	3	3	3	3	3
	Organic matter	3	3	5	5	5
	Water	3	4	4	4	4
	Landscape integration	3	3	3	3	3
Technical issues						
allows simple construction		3	3	2	2	2
low level of technical skills required for construction		3	5	4	4	2
High level of efficiency (wastewater input/depurated/timing)		4	4	4	4	5

Purification capcity (wastewater depurated/soil used by the plant)	3	3	4	4	5
has high robustness and long lifetime/high durability	4	4	4	4	4
enables simple and low operational procedures	4	4	4	4	2
Low maintenance and low skills required	4	4	4	4	2
not reliant on a continuous supply of a resource (such as water or energy)	4	4	4	4	2
adaptable to unexpected future changes (adaptability)	4	4	4	4	2
Good quality of effluent (according to the receiving environment)	4	4	4	4	5
Amount and quality of generated sludge	3	3	3	3	3
Economical and financial issues					
Provides benefits to the local economy (business opportunities, local employment, etc.)	2	4	4	4	4
provides benefits or income generation from reuse	2	4	4	4	4
Social, cultural and gender					
Improves quality of life	3	4	4	4	4
requires low level of awareness and information to assure success of technology	4	4	4	4	4
requires low operation & maintenance and little involvement by the users	4	4	4	4	4
high level of satisfaction of the local people regarding the implemented technology	4	4	4	4	4
requires low policy reforms at local, regional or national level.	4	4	4	4	4
Educational impacts	3	3	3	3	4
Costs					
Investment cost (€)	0	€ 197.750,00	€ 1.489.000,00	€ 1.375.000,00	€ 1.724.000,00
Maintenance cost (€/year)	€ 5.000,00	€ 16.483,33	€ 76.000,00	€ 95.000,00	€ 245.000,00

FARIAS REFUGEE CAMP

Health issues		alternative 0	alternative 1	Alternative 2
Causes any risk of	additional mosquitoes (or other insects) growth	3	4	4
	illness	3	4	4
Reduced exposure to pathogens	of users	3	3	3
	of waste workers	3	4	4
	of resource recoverers /reusers	1	4	4
	of “downstream” population	1	4	4
Impact to environment / nature				
use of natural resources	Low land requirements	3	4	4
	Low energy requirements	3	2	2
	Uses mostly local Construction material	3	5	5
	Low water amounts required for construction	3	5	5
low emissions and impact to the environment	Surface water	2	4	4
	Ground water	2	4	4
	soil/ land	2	4	4
	Air	3	3	3
	Noise and vibration	3	3	3
	aesthetic	2	4	4
	odours	2	3	3
good possibilities for nutrients recovering resources	energy	3	3	3
	Organic matter	3	3	3
	Water	2	4	4
	Landscape integration	2	4	4
Technical issues				
allows simple construction		3	4	4
low level of technical skills required for construction		3	4	4
High level of efficiency (wastewater input/depurated/timing)		3	4	4
Purification capcity (wastewater depurated/soil used by the plant)		3	4	4

has high robustness and long lifetime/high durability	3	4	4
enables simple and low operational procedures	3	4	4
Low maintenance and low skills required	3	4	4
not reliant on a continuous supply of a resource (such as water or energy)	3	4	4
adaptable to unexpected future changes (adaptability)	3	4	4
Good quality of effluent (according to the receiving environment)	3	4	4
Amount and quality of generated sludge	3	3	3
Economical and financial issues			
Provides benefits to the local economy (business opportunities, local employment, etc.)	3	3	4
provides benefits or income generation from reuse	3	3	4
Social, cultural and gender			
Improves quality of life	3	4	4
requires low level of awareness and information to assure success of technology	3	4	4
requires low operation & maintenance and little involvement by the users	3	4	4
high level of satisfaction of the local people regarding the implemented technology	3	4	4
requires low policy reforms at local, regional or national level.	3	4	4
Educational impacts	3	3	3
Costs			
Investment cost (€)	0	€ 1.012.300,00	€ 1.820.300,00
Maintenance cost (€/year)	0	€ 28.500,00	€ 40.000,00

JENIN AREA

Health issues		alternative 0	alternative 1	Alternative 2	Alternative 3	Alternative 4
Causes any risk of	additional mosquitoes (or other insects) growth	3	4	4	4	5
	illness	3	4	4	4	5
Reduced exposure to pathogens	of users	3	3	3	3	4
	of waste workers	3	3	3	3	3
	of resource recoverers /reusers	3	3	3	4	4
	of “downstream” population	3	2	2	3	3
Impact to environment / nature						
use of natural resources	Low land requirements	3	4	4	4	4
	Low energy requirements	3	2	2	2	4
	Uses mostly local Construction material	3	5	5	5	2
	Low water amounts required for construction	3	5	5	5	2
low emissions and impact to the environment	Surface water	3	3	3	3	3
	Ground water	2	3	3	3	3
	soil/ land	2	2	2	2	4
	Air	3	3	3	3	3
	Noise and vibration	3	3	3	3	3
	aesthetic	3	4	4	4	4
	odours	3	2	2	2	4
good possibilities for nutrients recovering resources	energy	2	2	2	2	3
	Organic matter	3	3	3	3	3
	Water	3	4	4	4	4
	Landscape integration	3	3	3	3	3
Technical issues						
allows simple construction		3	3	2	3	2
low level of technical skills required for construction		3	4	2	3	2
High level of efficiency (wastewater input/depurated/timing)		3	4	4	4	5
Purification capcity (wastewater depurated/soil used by the plant)		3	3	4	4	5

has high robustness and long lifetime/high durability	3	4	4	4	4
enables simple and low operational procedures	3	4	4	4	2
Low maintenance and low skills required	3	4	4	4	2
not reliant on a continuous supply of a resource (such as water or energy)	3	4	4	4	2
adaptable to unexpected future changes (adaptability)	3	4	4	4	2
Good quality of effluent (according to the receiving environment)	3	4	4	4	5
Amount and quality of generated sludge	3	3	3	3	3
Economical and financial issues					
Provides benefits to the local economy (business opportunities, local employment, etc.)	3	2	2	4	4
provides benefits or income generation from reuse	3	2	2	4	4
Social, cultural and gender					
Improves quality of life	3	4	4	4	4
requires low level of awareness and information to assure success of technology	3	4	4	4	4
requires low operation & maintenance and little involvement by the users	3	4	4	4	4
high level of satisfaction of the local people regarding the implemented technology	3	4	4	4	4
requires low policy reforms at local, regional or national level.	3	4	4	4	4
Educational impacts	3	3	3	3	4
Costs					
Investment cost (€)	€ 0,00	€ 7.501.000,00	€ 7.025.000,00	€ 9.721.000,00	€ 9.102.200,00
Maintenance cost (€/year)	€ 0,00	€ 198.000,00	€ 320.000,00	€ 227.700,00	€ 368.000,00

Altenative 0 = no intervention
++ or 5 the criterion is very fulfilled by this alternative
+ or 4 the criterion is fulfilled by this alternative
0 or 3 the criterion is neutral to this alternative
- or 2 the criterion does not fulfilled well by this alternative
-- or 1 the criterion does not at all fulfilled by this alternative

(the + and – can be substituted by numbers in the range 1-5 as specified above)

6. Conclusions

In the following section we report the results of the multi-criteria analysis, based on the scores and weights previously assigned for each case study, accompanied by some technical comments.

6.1 Definition of the optimal "tailormade" alternative

Legenda

5	the criterion is very fulfilled by this alternative
4	the criterion is fulfilled by this alternative
3	the criterion is neutral to this alternative
2	the criterion does not fulfilled well by this alternative
1	the criterion does not at all fulfilled by this alternative

Bani Zaid

		ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Health issues		2,4	2,5	3,8	3,8	4,2
Impact to environment / nature		3,3	3,6	3,6	3,6	3,5
Technical issues		3,5	3,6	3,6	3,6	3,0
Economical and financial issues		2,0	4,0	4,0	4,0	4,0
Social, cultural and gender		3,8	4,0	4,0	4,0	4,0
Investment cost (€)		0	€ 197.750,00	€ 1.489.000,00	€ 1.375.000,00	€ 1.724.000,00
Maintanance cost (€/year)		0	€ 16.483,33	€ 76.000,00	€ 95.000,00	€ 245.000,00
	WEIGHT	ALT 0	ALT 1a	ALT 2	ALT 3	ALT 4
Investment cost (€)	4	3,0	5,0	4,5	5,0	3,5
Maintenance cost (€/year)	4	3,0	5,0	5,0	4,0	2,0
COST		3,0	5,0	4,8	4,5	2,8
TOTAL SUM		**17,9**	**22,7**	**23,7**	**23,4**	**21,4**

The best alternative is the Alternative 2, although it should be noted that the difference with the alternatives 3 is very limited; therefore the final choice should depends by the real availability of the land and by an accurate survey. Alternative 1 reach a high ranking, mainly due to the low investment cost, but it also to be considered that in this alternative the wastewater treatment coverage remains very low.

MBR solution should be considered only in case of very limited available land, due mainly to the higher cost of maintenance, to the need of spare parts and to the high power consumption; sludge drying reed be could consent in this way to reduce at least the quantity of surplus sludge to manage and to recover nutrients for agriculture.

Faria

		ALT 0	ALT 1	ALT 2
Health issues		2,4	3,9	3,9
Impact to environment / nature		2,5	3,7	3,7
Technical issues		3,0	3,9	3,9
Economical and financial issues		3,0	3,0	4,0
Social, cultural and gender		3,0	3,8	3,8
Investment cost (€)		0	€ 1.012.300,00	€ 1.820.300,00
Maintanance cost (€/year)		0	€ 28.500,00	€ 40.000,00
	WEIGHT	ALT 0	ALT 1	ALT 2
Investment cost (€)	4	3,0	5,0	4,0
Maintenance cost (€/year)	4	3,0	5,0	4,0
COST		3,0	5,0	4,0
TOTAL SUM		**16,9**	**23,2**	**23,2**

In this case both alternatives permit to reach a good overall ranking. In fact the only issue could be the real availability of land which can pursue to realize a decentralized treatment for the Tubas suburb instead to collect it on the same CW.

Jenin villages

		ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Health issues		3,0	3,2	3,2	3,5	4,0
Impact to environment / nature		2,8	3,1	3,1	3,1	3,4
Technical issues		2,7	3,4	3,3	3,4	2,9
Economical and financial issues		3,0	2,0	2,0	4,0	4,0
Social, cultural and gender		3,0	3,8	3,8	3,8	4,0
Investment cost (€)		0	€ 7.501.000,00	€ 7.025.000,00	€ 9.721.000,00	€ 9.102.200,00
Maintanance cost (€/year)		0	€ 198.000,00	€ 320.000,00	€ 227.700,00	€ 368.000,00
	WEIGHT	ALT 0	ALT 1a	ALT 2	ALT 3	ALT 4
Investment cost (€)	4	3,0	4,5	5,0	3,5	4,0
Maintenance cost (€/year)	4	3,0	5,0	4,0	4,5	3,5
COST		3,0	4,8	4,5	4,0	3,8
TOTAL SUM		**17,5**	**20,3**	**19,9**	**21,9**	**22,0**

In this case the "wastewater reuse oriented" solutions seems to be more effective than the "discharge oriented" solutions, due to the particular characteristics of the territory and to the high cost of the water for agricultural purposes. In this sense a semi-centralized option, connecting as more as possible near villages, could probably consent to manage better the treatment plant and the reused wastewater (even if the difference between alternative 3 and 4 is almost insignificant).