



**Work package Nr. 3-3:
Technologies - Brackish Water Usage**

Deliverable D 325:

Demonstration of brackish water desalination

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1 Introduction

The main goal of the SMART II project is to increase the total amount of water for domestic and agricultural usages in the area of the Lower Jordan Rift Valley (LJRV). The major and most important local water sources are fresh water from shallow and deep aquifers. However, due to lack of fresh water resources in the region, secondary origins of brackish and saline water have been taken into consideration for local usage. These potential water reservoirs are found in relatively large amounts in the shallow and deep aquifers, mostly coexisting with fresh water.

This report gives a general overview about the selection of water sources suited for desalination and on the necessities and the emerging difficulties for the start-up of the desalination plant which was constructed in the framework of the SMART II project. Details are given for the demonstration site in Karameh, Jordan.

2 Raw water analysis

Originally the experiments with the pilot plant were supposed to be carried out in different sites in the LRJV to set a small but meaningful scene. In order to select the best suitable sites for desalination, different sampling campaigns were done and the samples were characterized at Engler-Bunte-Institut (EBI). The sites were selected by the German and Jordan partners according to their different site specific characteristics. Figure 1 shows the different sampling sites (Deir Alla, Jordan River, Sweima, Karameh) in Jordan. Table 1 summarizes the main results of the water characterization.

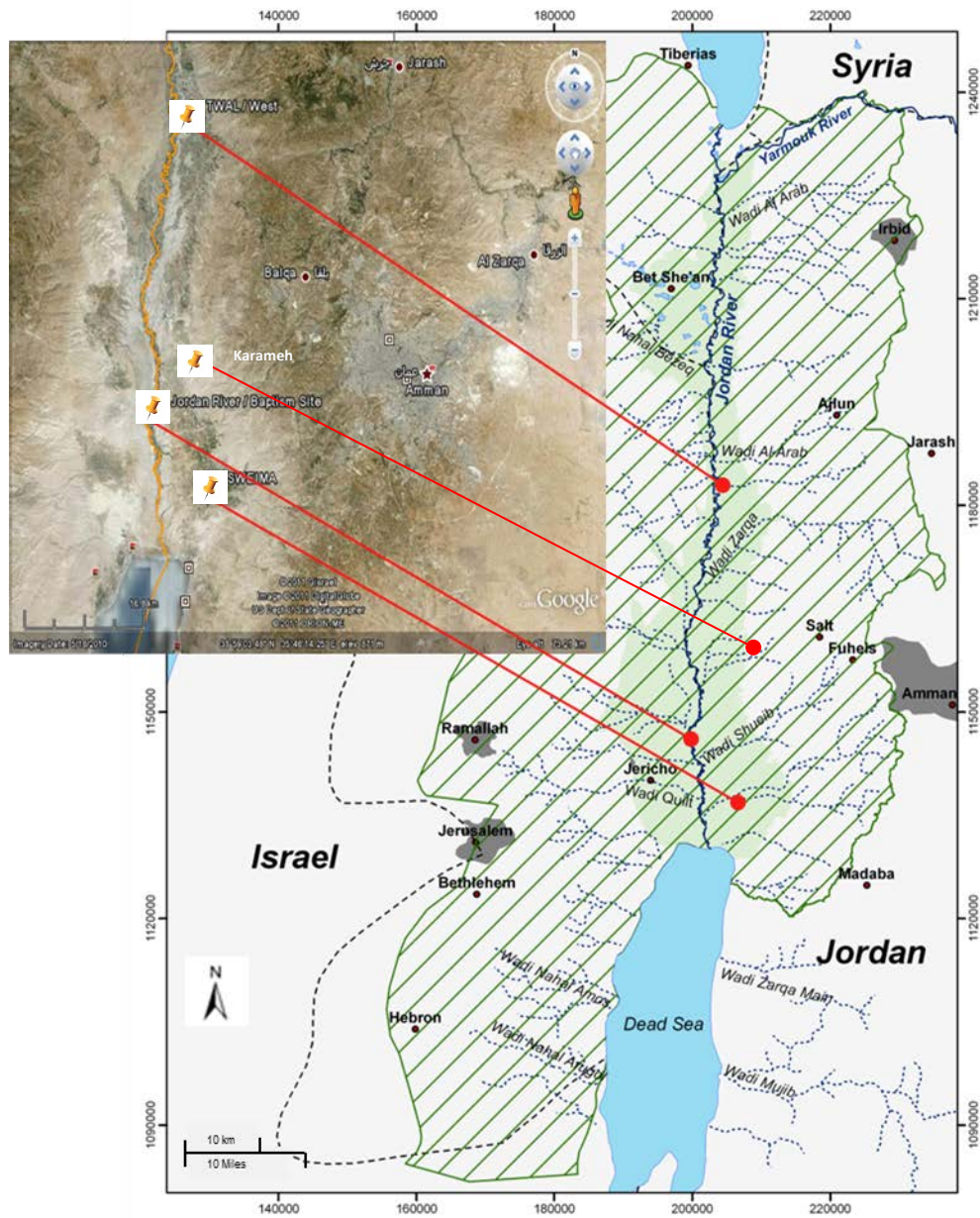


Figure 1: Sampling sites in Jordan.

Table 1: Water characteristics of the pre-selected sites for brackish water treatment.

		Jordan river	Deir Alla	Sweimeh	Karameh
El. conductivity	mS/cm	2.3 - 18.3	3.9 - 8.0	3.9 - 13.8	6.5
pH value	at 25 °C	7.0 - 8.2	6.8 - 7.9	7.2 - 8.2	7.0
Barium	[mg/L]	0.10 - 0.17	0.04 – 0.07	0.10	0.05
Calcium	[mg/L]	82 - 330	98 - 344	117 - 440	287
Potassium	[mg/L]	25 - 167	61 - 94	51 - 220	78
Magnesium	[mg/L]	79 - 490	157 - 229	78 - 444	200
Sodium	[mg/L]	345 - 1380	456 - 1058	475 - 1593	767
Silicon	[mg/L]	10.9 - 13.8	20.5 - 16.0	12.1 - 13.0	7.8
Strontium	[mg/L]	2.5 - 8.6	9.2 - 25	3.6 - 5.7	3.7
Cl ⁻	[mg/L]	345 - 4904	739 - 1598	825 - 4689	1757
NO ₃ ⁻	[mg/L]	12 - 40.5	136 - 244	0.1 - 15.5	4.5
SO ₄ ²⁻	[mg/L]	254 - 2085	399 - 1388	108 - 678	336
HCO ₃ ⁻	[mg/L]	240 - 334	382 - 465	243 - 395	494
CO ₃ ²⁻	[mg/L]	0.1 - 3	0.7 - 1.9	0.5 - 1.7	0.3
Br ⁻	[mg/L]	20 - 48	0.5 - 4.6	2.8 - 30	24
F ⁻	[mg/L]	0.29 - 1.9	0.75 - 1.8	1.1 - 1.3	2.9
DOC	[mg/L]	5 - 7	0.9 - 1.6	0.6 - 1.1	0.7
TOC	[mg/L]	6 - 37	1.6 - 1.8	0.7 - 1.3	-

2.1 Deir Alla

The brackish water from the sampling site “Deir Alla” represents a typical shallow aquifer water corresponding to the Tawal-area region. Electrical conductivity reaches values between 5 and 8 mS/cm, principally because of the high NaCl-concentration present in the samples. The brackish water samples showed fairly high silicon-, strontium- and sulfate-concentrations (Table 1). Deduced from the analytical data severe scaling problems can be expected for the membrane filtration of this water. Additionally the seasonal variation of the water quality is an important aspect to be considered for the desalination plant design.

2.2 Karameh

The brackish water from Karameh represents an anoxic shallow aquifer water, which can be expected to be influenced by (infiltrated) surface water (e.g. water used for irrigation) and non or poorly treated waste water. The site was sampled only once (in January 2012, see paragraph 3. Site selection). The sample showed high iron and manganese content and low amounts of gases (e.g. radon, H₂S). H₂S levels as low as 0.1 mg/L can adversely affect the performance of desalination systems (Dow Liquid 2005). The best pretreatment for filtration of “anoxic” brackish waters with high H₂S, iron and manganese content is keeping the system under anaerobic conditions. For this the water must not be exposed to oxidizing agents, such as air or NaOCl. An alternative pretreatment process is the elimination of H₂S, iron and

manganese by means of aeration or oxidizing chemicals. The iron and manganese hydroxides formed can then be removed with filtration.

In addition, the water in Karameh is high in divalent earth alkaline ions which are known to form scaling with carbonate, sulfate and fluoride, depending on the recovery of the system.

2.3 Jordan River (baptism site of Jesus)

The water from the Jordan River represents the saline surface water in the Jordan Valley. The water composition shows an extremely high seasonal variation. The electrical conductivity (EC) values are in the range between 2 and 20 mS/cm. The samples from the Jordan River also showed had, as expected, high DOC (Dissolved Organic Carbon) concentrations (Table 1). An advanced characterization of the DOC was done by means of size exclusion chromatography coupled with online organic carbon and UV detection (LC-OCD/UV). The LC-OCD/UV measurements (Figure 2) of the sample showed the high molecular weight fraction, also called biopolymer fraction, containing polysaccharides and polysaccharide like substances (elution volume between 25 and 32 mL), and the humic fraction and low molecular weight organics (from 32 mL) (Lankes et al. 2008). The detailed interpretation of the LC-OCD chromatogram with more than 55 mL retention volume was not possible, due to the interference of the highly concentrated chloride in the brackish water sample with the oxidation process and thus the LC-OCD measurement. NaCl breakthrough can be observed in the progression of the EC-signal.

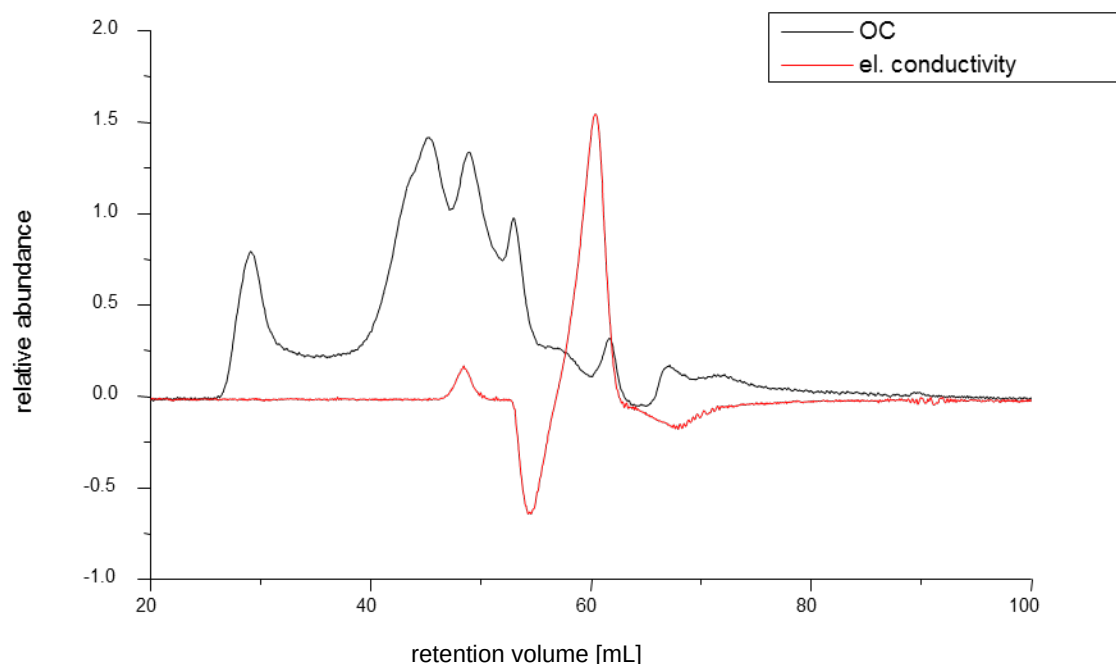


Figure 2: LC-OCD (OC and EC Signals) of the Jordan River sample.

The treatment of Jordan River water presents a high level of complexity. Main challenges are: the seasonal variation of the water quality, the anthropogenic contamination, the suspended solids and the DOC-concentration.

2.4 Sweimeh Area (north-eastern shoreline of the Dead Sea)

The water in the „Sweimeh“-site represents the deep aquifer water with iron and manganese and the gases H₂S, CO₂ and radon. For membrane filtration an extensive pre-treatment (oxidation/ aeration and flocculation) due to reductive conditions, must be considered. An advantage of Sweimeh as potential site for the pilot plant constitutes its location near to the Dead Sea. The Dead Sea can be considered as an environmentally-friendly alternative for high saline brine disposal.

3 Site selection

For the selection of potential sites for the brackish water treatment experiment the following criteria were considered (Papadakis 2007):

- Fresh water scarcity (drinking water, irrigation, groundwater recharge) of the region
- Availability and quality of brackish water sources (availability of data)
- (Basic) water infrastructure (wells, water distribution systems)
- Building/space infrastructure (accessibility)
- Electricity infrastructure (availability)
- Environmental aspects (brine treatment/discharge)
- Accessibility to the site
- Existence of renewable energy potential

After several discussions, the Ministry for Water and Irrigation in Amman (MWI) together with the Institute of Applied Geosciences (KIT) chose a well in Karamah in the lower Jordan Valley in December 2011. In consequence, the final concept differs from the idea presented in our original project application: i.e. only one instead of three test fields had to be tested for desalination. Due to pragmatic political considerations which outruled scientific reasons the plant had to remain only at the test field Karamah for the rest of the project and probably beyond. The selection of only one site should allow a long term study to optimize the operating conditions of the plant. In addition, the produced permeate water can be used best, mainly for drinking water purposes, and the concentrate can be discharged into a Wadi.

The raw water for the pilot plant consists of groundwater (see 2.2 Karamah) and, during rainy seasons, it is a mix of groundwater, well water and surface water. Raw water quality which shows low seasonal variations would be best for operating the plant. Figure 3 and 4 show the facilities for pump test and the surrounding of the well.



Figure 3: Pump experiments, Karameh well, Jordan (photo: MWI).



Figure 4: View from Wadi to well (photo: SPA).

4 Planning, design and concept for the water treatment plant

An innovative plant, which uses elaborated cutting-edge techniques to treat the challenging groundwater from the test site in Jordan, was designed and built by STULZ-PLANQUA (SPA) in cooperation with the Engler-Bunte-Institute (EBI) (Figure 5). The plant can generate about 10 m³/h of treated water – enough to irrigate a large area or to supply a small village with raw water for domestic use. The input of well water was expected to be 16 m³/h. Hence, the plant was designed for a yield of over 60%.



Figure 5: Water treatment plant (test run in Bremen, photo: SPA).

As described in the previous chapter, the water from the well in Karameh requires special treatment. It contains comparatively high concentrations of iron and manganese as well as calcium and has therefore a high scaling potential. In addition, it contains radon and hydrogen sulfide in rather low amounts, but which are still too high for a safe and comfortable usage of the water. In addition, the bacterial load is fairly high for groundwater, which has to be taken into account regarding biofouling. The concept of the water treatment plant takes care of these issues and is therefore much more elaborated than a simple desalination device. It was designed especially for the conditions at Karameh.

Apart from technical issues regarding the water treatment, the additional challenge of the layout design was the limited space of the container-based plant and of course also the limited budget. This is not only due to the restricted budget of the SMART II project, but surely the goal is to show that desalination is also economically attractive.

As energy shortage and climate change are vital issues today, special attention was turned to the energy balance of plant. According to reports from the MWI, cost for energy is one of the main obstacles for farmers who plan to desalinate water. The components of the plant were chosen with regard to their energy consumption and a special energy recovery system as well as a solar plant was installed. The solar plant (Figure 6) has an area of 42 sqm and an output of 10 kWp. The expected maximum output of the energy recovery system is 3.0 kW. The average energy consumption of the plant is estimated as 44 kW. The overall energy consumption is therefore very low for a plant of this size using input water which needs a complex treatment.



Figure 6: Container-based water treatment plant with solar plant (photo: SPA).

4.1 The technical concept

The core of the desalination plant is a reverse osmosis unit. It reduces the content of dissolved salts in the water and it is also a barrier for microorganisms and even viruses. However, the water from the well in Karameh needs ingenious pretreatment to guarantee the quality of the output and to reduce scaling in the reverse osmosis step. Figure 7 gives an overview over the plant layout design. The important steps will be discussed in more detail below. Figure 8 gives an impression of the container-based plant.

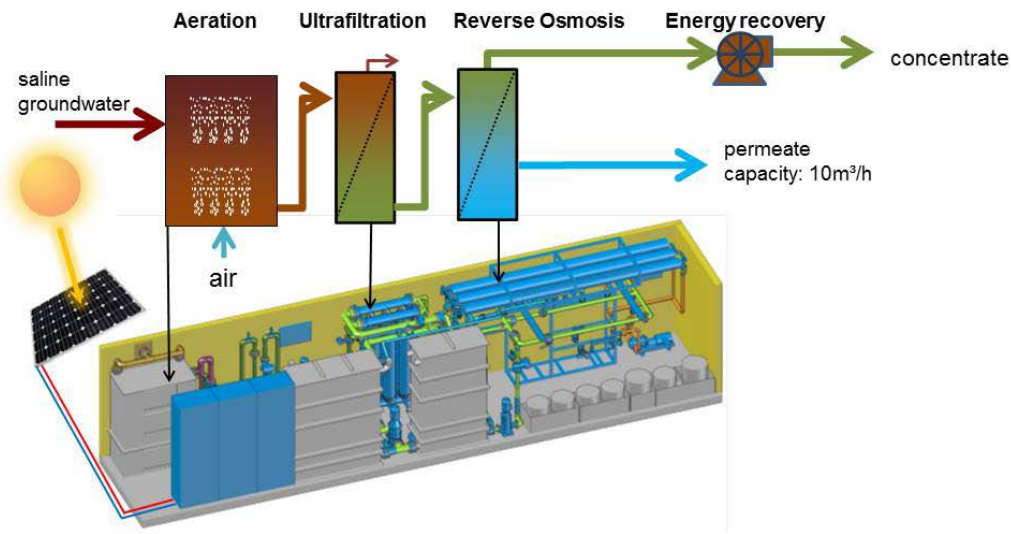


Figure 7: Layout design of the water treatment plant and 3D scheme (SPA).



Figure 8: A view into the container. The reverse osmosis unit can be seen in the right-hand place in front, the ultrafiltration modules behind it. In the back is the aerator. Left hand, the dosing stations for chemicals and the backwash tanks are placed (photo: SPA).

The first step includes the elimination of radon (poisonous and radioactive) and hydrogen sulfide (poisonous). Both radon and hydrogen sulfide are gaseous at room temperature, have higher density than air and are a danger to human health. Hydrogen sulfide can also cause scaling problems. The concentrations in the raw water are low and the gases will be eliminated by aeration. The flat bed aerator was designed and built specially for the requirements at Karameh. To take the limited space of the container into account, it was constructed with three layers. The first two are for aeration and the last one is a settling chamber. It has a through-put of 16 m³/h of raw water and 170 m³/h of air.

The high concentrations of iron (14 mg/L) and manganese (0.4 mg/L) are mainly problematic regarding scaling. In order to flocculate iron and manganese, the ions have to be oxidized. The classical way to do this is to filter the water over large aerated filters filled with gravel, sand and activated carbon. However, the space requirement is large. Plus, in order to fit these filters into a container with a limited height, customized, expensive filters would have been the only choice. For the SMART II water treatment plant, a different and modern way was chosen: the iron and manganese are partly oxidized in the aerator, which is needed anyway for the reasons named above. Additional oxidization is carried out in a chemical way with sodium hypochlorite. After this oxidation, the iron and manganese will mostly be precipitated. More of these ions will be flocculated with a flocculant (aluminium hydroxide solution). The remaining iron and manganese ions will be kept in solution by an antiscalant. This innovative technique with a sophisticated combination of oxidation, ultrafiltration and antiscalant is competitive both regarding costs and space requirements.

The precipitated ions as well as particles contained in the raw water are eliminated by an ultrafiltration step (UF). This modern technique is much more efficient and space saving than classical sand filters. It also solves the problem of high biological contamination as bacteria cannot pass the UF. The UF consists of five Multibore Dizzer Modules with 40 m² membrane each, with a pore size of 20 nm. The filtration mode is in-out. Expected recovery is approximately 92%.

The core of the water treatment plant is the reverse osmosis (RO, Figure 9) unit for the desalination. It contains 12 membrane modules in 3 pressure vessels with a total membrane area of 444 m². The feed pressure is 13 bar and the expected recovery is 60%. To fit the RO into the container, the pressure vessels are installed under the ceiling, while pump, valves and measurement devices are installed on a rack at the wall.



Figure 9: Reverse Osmosis unit (photo: SPA).

5 Desalination in Karameh

5.1 Delivery of the pilot plant in Karameh and challenges regarding Karameh 2 well

In May 2013, after a test run in Bremen, the container based water treatment plant was shipped to Jordan together with a second container with additional equipment. Both containers were set up in Karameh 16th June 2013 (Figure 10). As the infrastructure was not finished then, the plant could not be taken into operation directly.



Figure 10: Set up of pilot plant in Karameh (photo: SPA).

In June and July, 2013, the Jordanian company NAW continued to build the infrastructure with support from SPA. In July, also the solar plant was installed, which had been taken down for transport after a test run in Bremen (Figure 11). The commissioning of the desalination plant, planned for July 2013, had to be postponed as electricity and well pump had not been installed onsite.

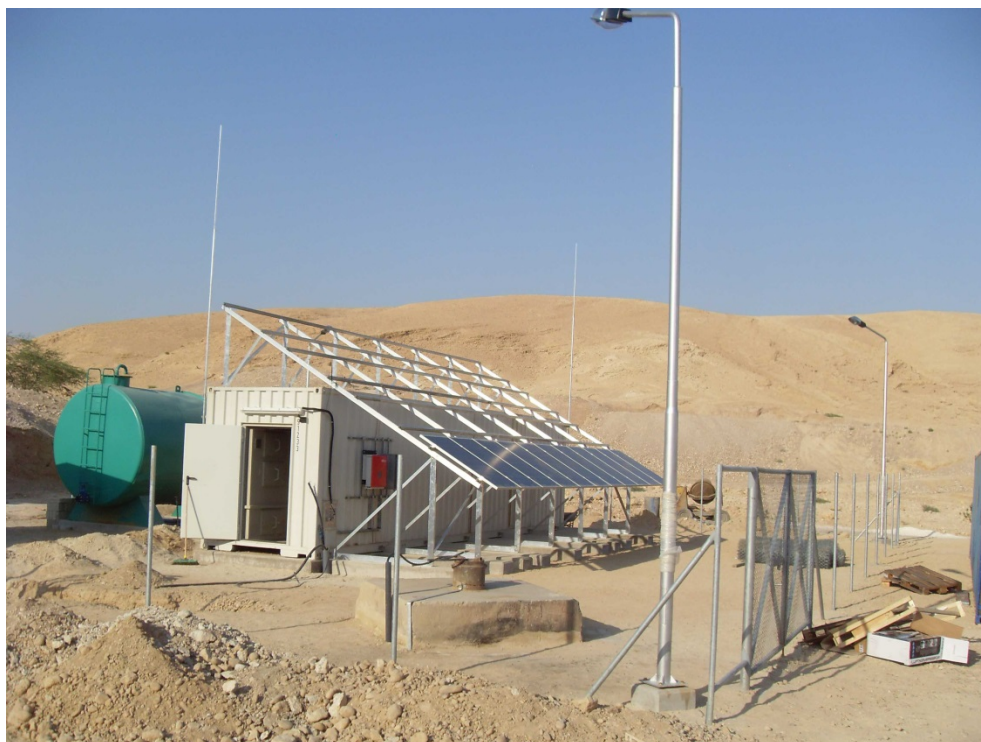


Figure 11: Installation of solar plant in Karameh (photos: SPA).

In July, the well pump was delivered and at the end of August 2013, the connection to power supply was finished. Hence, a new attempt to take the plant into operation was made end of August.

However, it turned out that in spite of the delivery of the well pump several weeks earlier, it had not been installed. It took one week for the WAJ to install the well pump. It was installed at a depth of 180 m, as this was considered to be hydrogeologically the optimal depth. However, once it was in operation, it turned out that the quality of the well water differed significantly from the water analysis from the pump test from January 2012, which was used for the layout design of the water treatment plant (Table 2). The water contained salt concentrations, which were up to 5 times higher than expected according to the analytical data before. The conductivity was much higher than expected, as were the iron and manganese and the chloride concentrations. Water of this quality could not be treated with the pilot plant in Karameh, which was built to work with brackish water of a significantly different quality.

In addition to the bad general water quality, the problems increased if the well pump was stopped for some time. This incident happened fairly often due to unexpected power blackout and it might also be necessary for regular cleaning of the desalination plant elements. The well water, which appears clear otherwise, was silty and brownish after such a stop (Figure 12). It took typically about 30-60 minutes until the water was clear again.



Figure 12: Well water after stop and restart of well pump (photo: SPA).

At the same time, the performance of the well pump decreased. After several weeks of troubleshooting, the WAJ brought the pump up and inspected it. It turned out that the pump was broken and blocked by material (sand, stones, silt) from the bottom of the well. The pump was cleaned and repaired.

In the following months, the main issue was to find the cause for the striking difference in water quality compared to the pump test in 2012. Only the main steps and conclusions will be mentioned in this report.

5.2 Pump tests

5.2.1 Depth

The pump test in January 2012 was carried out at a depth of 147 m while the pump was set at 180 m in September 2013. Hydrogeologists from the SMART II project were consulted and on the 17th of September 2013, the MWI provided a profile of the well. This shows a ferreous layer at 180 m and several layers of clay above.

According to several experts, the water quality at 150 m might be much closer to the originally measured quality. Hence, the repaired pump was placed 150 m the 24th September 2013. A new pump test showed that the water quality had improved a little, but not sufficiently for the commissioning of the desalination plant. The water was still highly saline (see Table 2). Especially the manganese-concentration differs by more than one magnitude. Iron concentration and EC also vary significantly.

5.2.2 Pump rate

Another notable observation was that the conductivity (a rough guide value for the salt concentration) decreased with increasing pump rate. Figure 13 shows the results of a pump test at 126 m depth. The well showed a similar behavior independent on the pump depth. The electrical conductivity (EC) was highest (max. 54.3 mS/cm, measurement Nr.9) at the beginning of the test. Afterward the EC value decreased continuously to approx. 12.4 mS/cm (pump rate of 17.1 m³/h). An increase in the pump rate (from 17.1 m³/h to 29.2 m³/h) led to a further reduction on the EC-Value (about 9.5 mS/cm).

The pump test was carried out for 5720 min. Thus it can be assumed that the measured EC-values will stay without significant variations over the course of several months and therefore during the desalination plant operation months.

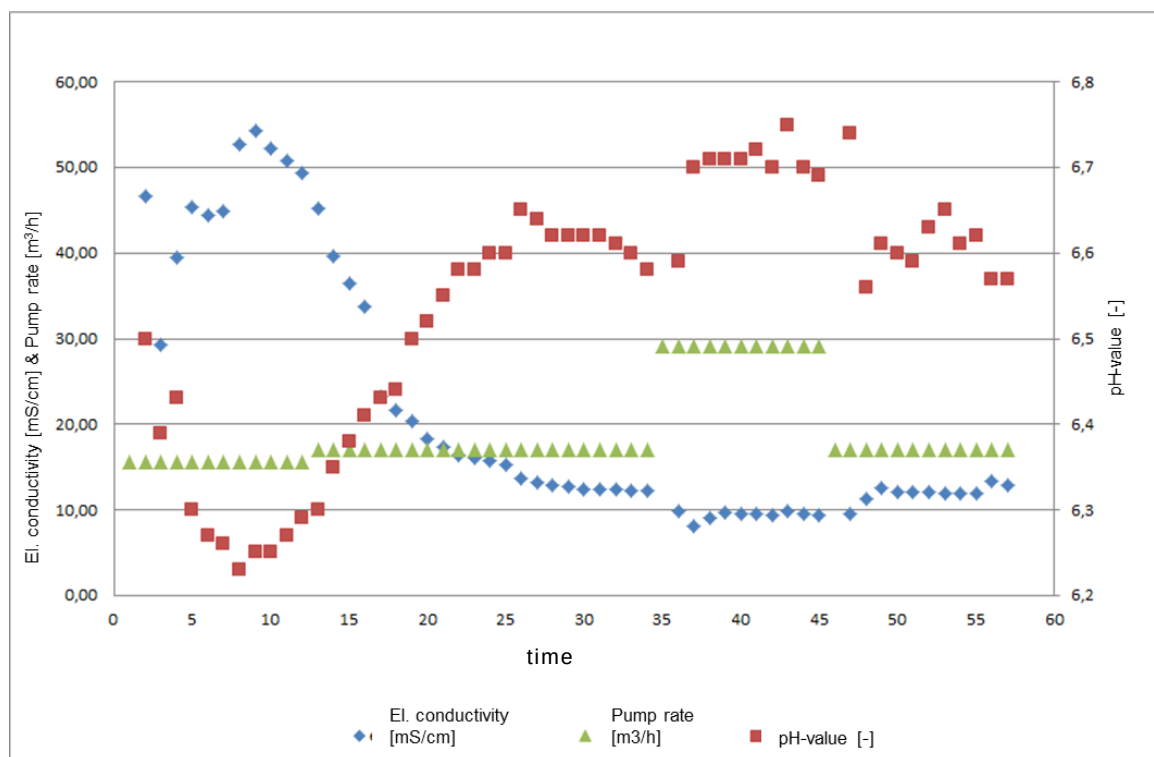


Figure 13: Results corresponding to the pump-tests at a pump depth of 126 m. Selected parameters: pH-value, el. Conductivity [mS/cm], and pump rate [m³/h].

5.2.3 General conclusion from the pump tests

According to hydrogeologists from the SMART II project and further consulted experts, the results indicate that there are possibly two aquifers one upon the other, which are separated by impermeable layers of clay but connected by the borehole of the well.

Additionally, the pump test showed that the EC values are lower at 126 m depth than at 150 m depth. It can be suggested that the upper aquifer has the lower salinity and therefore the greatest potential for operation of the desalination plant.

5.3 EC-Log and Video Scan

For further insights an EC-Log of the well and a video scan were carried out in November 2013. The video scan showed that the well casing was partly broken and that the well was fallen in at a depth of 180 m.

Table 2: Selected parameters of water quality derived from the different pump tests.

Parameter	Date	Jan 12	28.08.13	19.09.13	09.10.13	20.11.13	21.11.13
	Unit						
Measured by		EBI, MWI, JUA	EBI	EBI	EBI	EBI	EBI
Pump depth	m	143	180	180	150	126	126
Pump rate	m³/h	47	17	4,6	17	25	17
Elec. conductivity (EC)	mS/cm	6.4	20.0	50.6	17.3	12.0	16.2
pH-value		7-7.6	6.7	6.2	6.7	6.9	6.8
Mn ²⁺ (original sample)	mg/L	0.4	0.07	0.24	0.05	0.03	0.06
Fe ²⁺ (original sample)	mg/L	14.0	0.02	7.0	0.27	0.07	0.16
Ba ²⁺	mg/L	0.05	0.09	0.13	0.07	0.08	0.07
Boron	mg/L	1.0	2.2	5.8	1.8	1.4	1.9
Ca ²⁺	mg/L	290	809	2161	737	485	664
K ⁺	mg/L	78	203	528	159	124	173
Mg ²⁺	mg/L	200	568	1463	549	353	459
Na ⁺	mg/L	767	2562	7628	2397	1506	2083
SiO ₂	mg/L	16.7	13.5	13.1	12.0	15.0	15.0
Sr ²⁺	mg/L	3.7	9.2	25.1	5.0	4.6	6.3
Chloride	mg/L	1757	7027	20600	5672	3704	5223
Nitrate	mg/L	4.5	15.4	236.1	14.1	15.1	13.9
Nitrite	mg/L	6.0	<0.5	<5	<5	<5	<5
Sulfate	mg/L	336	336	579	300	253	287
HCO ₃ ⁻	mg/L	494	401	590	408	374	398
Bromide	mg/L	24.0	<1	<5	84.3	<5	<5
DOC	mg/L	0.7	1	2	1	0,5	0,6
TC	mg/L	98	79	118	85	75	81

According to the EC log, the well pump should be placed as high as possible in order to suck mainly water from the upper, less saline aquifer. On the other hand, a certain distance must be kept to the water surface at 120 m. Thus, the pump was placed at 126 in the next attempt. The resulting water quality is presented in Table 2.

The data in Table 2 demonstrate the strong variations of the water quality with depth and pump rate. This includes the overall salt concentration as well as the concentrations of ions which might cause scaling (for example iron, manganese, calcium, sulfate, barium and strontium). Chloride concentrations of this magnitude are a danger to the functioning of the desalination plant with regard to corrosion. The requirements regarding the treatment of the water therefore differ strongly from the expected demand.

The data show that the influence of the lower aquifer is still considerable at a depth of 126 m and that the water quality and its stability is not really suited for the treatment with the pilot plant as it was designed.

The results from the pump test in November 2013 also demonstrate the strong influence of the pump rate. Theoretically, a better water quality could be achieved by enhancing the pump rate but the desalination plant can treat 16 m³/h maximum. The additional water is much beyond the actual demand of the region. In a land with a water shortage like Jordan, this solution is not desirable and would contradict to the aims of SMART II.

5.4 Cementation of the well at 147 m

To stop the flux from the lower, highly saline aquifer, the well was cemented at a depth of 147 m by the MWI in December 2013. Additional video scans were carried out. After the cementation, new pump tests were done by the MWI with pump rates of 30 m³/h and 18 m³/h.

The results still show an influence of the pump rate, which probably means that the two aquifers are still not completely separated and the pump still may suck water also from the deeper aquifer.

However, the water quality improved a little at a lower pump rate (Table 3). With this water, it was considered that the plant could get into operation, although the yield of the desalination plant would be reduced to approximately 50%. As the chloride concentration is still very high, the risk of corrosion remains. After discussion with all partners and the project office, it was decided to take this risk and try the commissioning.

Table 3: Water analysis after cementation (Analysis by MWI).

Parameter (unit)	Pump test 06.01.2014, depth 126 m, Pump rate 18 m ³ /h
EC (ms/cm)	11.6
Temperature [°C]	30
pH	6,5
Bicarbonate (mg/L)	350
Chloride (mg/L)	3807
Nitrate as NO ₃ ⁻ (mg/L)	< 0.2
Sulfate (mg/L)	216
Sodium (mg/L)	1478
Potassium (mg/L)	119
Magnesia (mg/L)	382
Calcium (mg/L)	505
Hardness as CaCO ₃ (mg/L)	2829
Iron (mg/L)	1.4
Manganese(mg/L)	0.05
Aluminum (mg/L)	0.01
Barium (mg/L)	0.08
Strontium (mg/L)	9.71
Boron (mg/L)	1.06
Siliciumdioxide (mg/L)	16
Bromide (mg/L)	61.4
Fluoride (mg/L)	1.1

5.5 Commissioning

In March 2014, the plant went successfully into operation (Figure 14).

The yield was approximately 50%. The iron and manganese content after ultrafiltration was below the detection limit of the field tests. So far, all treatment steps worked very well.

The quality of the well water still varied strongly, especially after pump stops. This issue needs to be solved for a stable operation of the plant.

The staff of the WAJ was extensively trained and was shown how to run the plant and how to do trouble-shooting.



Figure 14: Pilot plant producing water in Karamah.

So far, no major hints of corrosion could be seen. Of course, the plant was only in operation for a short time and most of the water-swept parts in danger of corrosion could not be examined during operation.

The plant was handed over to the WAJ officially on April 6th, 2014. The WAJ is now officially in charge of the operation of the desalination plant.

5.6 Remarks

Although the plant was designed for 24 hours operation and there is usually no need for a full time operator. As we understood the WAJ wants to operate the plant only during day time (8 hours) and wants to stop operation at night and during weekends. Reverse osmosis plants similar to the plant in Karameh are not made to be turned on/off frequently. If the plant is turned off for several hours or longer, it must be rinsed with fresh water or treated water. Otherwise, the brine remains in the membrane modules and in the pipes. Salt crystals and fouling layers will be formed and will block the plant components. For this reason, it can be highly recommended to operate the plant on a 24 h per day basis and only switch off for maintenance etc.

One of the most important environmental issues of desalination is the generation of the saline “by product” brine. The concentrate has not only a high content of salts but also residual chemicals (such as antiscalants and cleaning chemicals). The treatment or disposal of brine is one of the drawbacks for the application of membranes in in-land desalination but it was not in the aims of the project. This topic has to be investigated in further research activities to reach environmentally acceptable solutions.

6 Conclusions

The Low Jordan Rift Valley has relatively high quantities of non-exploited brackish water sources which can be treated to generate fresh water. They can be found in the shallow and deep aquifers, mostly coexisting with fresh water.

Membrane filtration is a promising option for brackish water treatment for fresh water supply. Technology of reverse osmosis systems has been improving during the last decade, resulting in the development of high performance membranes which require less pressure and thus less energy, have better rejection properties and larger fluxes, have longer lifetime, and lower cost. Additionally the application of energy recovery systems (e.g. Francis Turbines or Pelton wheels) and the use of renewable energy sources (e.g. Wind and photovoltaic) contribute to the propagation of membrane technologies in countries with non-fossil energy sources.

As part of the SMART II project an innovative water treatment plant, which uses elaborated cutting-edge techniques to treat the challenging ground water from the test site (Karameh) in Jordan, was designed and built by STULZ-PLANQUA (SPA) in cooperation with the Engler-Bunte-Institute (EBI). The plant can generate about 10 m³/h of treated water – enough to irrigate a fairly large area and to supply a small village. The input of well water will be 16 m³/h. The applicability of this advanced technology under the given framework conditions had to be investigated.

The start-up of the desalination plant was no easy. First attempts to take the plant into operation failed. Main issues were: a) some communication problems including essential data and b) severe constraints on the provision of the necessary infrastructure for a technically sustainable operation of a desalination plant.

An important drawback for the commissioning of the desalination plant was the change on the water quality according to the water analysis provided for the design of the plant in comparison with the actual obtainable “real” water quality. After several months of testing and with the enormous concerted efforts of many partners (WAJ, SPA, KIT, EBI, JUA), in January 2014, raw water as obtained from the well Karameh 2 which still was high in salinity, but the quality was good enough to try a promising start-up of the plant.

In March 2014, the water treatment plant went successfully into operation and after the training of the WAJ staff in Jordan, the plant and its responsibility was handed over to the WAJ.

7 References

Dow Liquid, S. (2005) FILMTEC Reverse Osmosis Membranes - Technical Manual.

Lankes, U., Lüdemann, H.-D., Frimmel, F. H. (2008) Search for basic relationships between “molecular size” and “chemical structure” of aquatic natural organic matter – answers from ¹³C and ¹⁵N CPMAS NMR spectroscopy. Water Research 42, 1051-1060.

Papadakis, G. (2007) Adira Handbook. A guide to autonomous desalination concepts