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Project Title: **Water Treatment at Household level:**
Testing the Effectiveness of Treatment Methods

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Final Report

Contents:

Construction and Modification of Prototypes

Bucket Filter

Before the start of the project in Hajja, first offers for material needed were sought in Sana'a. For the first prototypes, the equipment was bought there, as well as the first brushes given out with the filters. At this time, it was not sure whether these things were available in Hajja.

Plastic buckets were chosen big enough to provide room for two or three filter candles (volume ~12.5 l). A red one was taken for the top and a blue one for the bottom, to make clear the difference between raw and treated water. Detailed assembling instructions are given in the manual.

Surprisingly, in Hajja bucket filters were found in the suq, but with smaller buckets and only one filter candle. Therefore, both variations were used for the project, the smaller one already known to few people in Hajja and the newly developed bigger one. The bigger buckets and later the large quantities of candles, valves and brushes had to be brought in from Hodeida, but could be purchased through a local salesman.

In the lower plastic buckets wholes had to be drilled for the tap, its lid and the upper bucket had to be prepared with wholes for the filter candles. Different techniques were tried, for large holes cutting with a knife proved to be the easiest and best one. For the small holes burning with a heated metal pipe gave the best results, but the holes had to be smoothened with a knife to prevent leakages.

Different types of filter candles were bought for comparison. Detailed information about these are given in the manual. Some types were left out: The “Better-Fly” filter candle from India was tested before by Mr. Ramon Scoble, an engineer living in Yemen who built first bucket filter prototypes before. It did not give good results. Products of well-known European or North-American companies like Katadyn or British Berkefeld were ignored due to their very high prices. The “Prestige Ceramic Candle” was chosen for all bucket filters. Even though the nut and thread of this type is of low-grade quality and some candles had to be sorted out due to this reason, it was the best solution in that price category.

At first, the prototype filters were operated with water from a cistern in Hajja City. The water was of bad quality as sewerage leaks into that cistern. No filter candle was able to take out all coliforms from that water though all did improve the water quality. When running the filters with cistern water that already is used as drinking water, the results were better, but still no complete removal of all coliforms could be proven. Hence, it can be stated that the Bucket Filter clearly improves the water quality, but does not provide 100% save drinking water. The idea that water presently not taken for consumption due to its obvious contamination might be additionally available after purification must not be promoted.

SoDis

For the SoDis – Solar Water Disinfection, PET-bottles from different mineral waters and soft drinks were taken and painted black halfside. There was no major difference in the performance of different bottles except that the smaller the bottles, the faster the bacteria are reduced. But as the most common and most easily available size is the 0.75l bottle, this type was chosen.

Water analysis proved that – as expected (cf. www.sodis.org) – not necessarily all bacteria were reduced, but all harmful ones. This is true even for very bad raw water quality, though the turbidity must not be too high. Therefore, even more than for the other methods, a pre-filtration through a cloth must be recommended. During times when the sky is completely covered, the bottles had to be exposed to the sun for two consecutive days. Otherwise, an one-day exposure is sufficient to remove coliforms.

Slow Sand Filter

The original design of a slow sand filter for household use was in a 200 l metal drum. This design can be found on SFD teaching material (cf. Manual Slow Sand Filter in Annex IV). These drums are not available in Hajja, except for ones that have been used for oil before and therefore are not acceptable for storing drinking water. Hence, three alternatives were investigated, plastic drums, PVC pipe DN 20 and metal drum handmade in local workshops.

The available plastic drums were too small with a total height of ~60cm. Deducting the gravel at the bottom for collecting water and the storage volume for water at the top, only ~45cm of sand could be filled in. This is only 75% of the suggested minimum height of 60cm.

The PVC pipe was equipped with a funnel at the bottom. To it a hosepipe was connected leading to the tap. Problems occurred when carrying out a watertight connection between the funnel and the pipe. Additionally, the small diameter made it necessary to construct a very high filter to get enough storage volume for water on top of the sand. The small surface results in smaller yields. A higher flowrate would worsen the purification.

A handmade metal drum proved to be the best solution (cf. Manual Slow Sand Filter in Annex IV). As it was constructed only for the purpose of slow sand filtration, a special design could be developed. The result is described in the manual.

In the slow sand filter, for an adequate water purification the right sand must be chosen. The coarse sand (Ø > ~1.6 mm) must be removed, but also the very fine particles and dust. Otherwise not only the flowrate becomes very low as the pores in the sand are closed, but also the water quality gets bad, as canals develop where the water passes the sand without any purification processes. Therefore in the end, the sand was sieved twice to get an adequate particle size.

Teaching, Manufacturing and Distribution

After the prototypes were modified and the final design laid down, the manufacturing started. As all three methods clearly improved the water quality, all of them were chosen for further investigation in a field-survey.

One goal of the project was to support income generating activities. Several shops in Hajja were found already selling bucket filters for several years. This proves that it is possible to earn money by selling water treatment equipment. The filters are produced and sold in the shops. It is not possible to add another step of businesses to the chain for the assembling of the filters. The shopkeepers earn their money through the selling and not through the production. The raw parts of a filter are sold for the same price as a readily prepared one.

Although, after the benefits of water filtration are spread more widely, additional shops might be needed to meet the risen demand. New selling strategies might be helpful, especially those that bring the supply to the new field of demand: e.g. mobile or fixed stores in the rural areas. Thereby, not only existing businesses are improved and strengthened, but also new ones may be created.

The shopkeepers selling bucket filters in Hajja were visited. Teaching material was discussed and handed out to them, namely a poster by which they can explain their customers how to operate and maintain their filter and stickers with the same information to put on the filters. Besides, the shopkeepers demonstrated their technique of cutting the holes in the buckets. Improvements were suggested to them that will help them to produce better quality filters (cf. Annex II: Records Teaching).

Concerning the sand filters, only the metal drum and its equipment with pipes and a valve were manufactured while the filling was done by the beneficiaries. For the construction of the metal drums, welding skills are necessary. For proper installation of the pipes, a plumber was needed. In this case, existing businesses had to be contracted, too. They were strengthened as a new field of work was opened up for them.

Nevertheless, the water treatment equipment will lead to more educational and income generating activities, as the overall health situation will improve. Thereby, time and money will be saved that has been spent on caring for the sick. As women are the key individuals in these fields, in particular they will benefit.

The bucket filter and the SoDis bottles were prepared in the ICS office by unskilled locals that were taught about the basics of water related hygiene and how to do their work. Buckets were cut, filter candles boiled and dried and taps disinfected. The filters were not yet assembled for easier transporting. SoDis bottles were washed and painted black half side.

Distribution started in Herba at the women group gathering three times a week for different educational classes in the sub-district's school. Three female teachers from that group were taught about the importance of drinking water purification and about the functioning of the bucket filter and the SoDis. They were instructed how to use the SoDis and how to assemble the bucket filter, how to operate it and what maintenance is necessary.

After the teaching of teachers, the filters were handed out to the women themselves (cf. Annex II: Records Teaching). 51 households received a bucket filters and a SoDis bottle for comparison which method was more pleasing to them. The women were taught about water related hygiene and about assembling, operating and maintaining the bucket filter and the SoDis. After the teaching, done by the female teachers supported by ICS, the women splitted into four groups. In these groups, every woman received the equipment and – under the assistance of the female teachers and female ICS staff - assembled her own bucket filter to practice what she learnt before. Additionally, a brush was handed out for the maintenance and a paper summarizing the information on bucket filtration and SoDis (as presented in Annex II: Records Teaching).

In other regions, no such women group is existing. Without that frame, it was not possible to mobilize women for the distribution of water filters, as their constraints do not allow such a work. Therefore, the supervisors of the local NGO were brought in. They were assembled for a teaching of teachers (cf. Annex II: Records Teaching). After this, they were able to teach the beneficiaries about the bucket filter and the SoDis. Their teaching skills were tried and repeated when they came to receive additional filters and on the follow up visits.

During this teaching of teachers, a beneficiaries' contribution to the price of the bucket filters was discussed and agreed on:

	Beneficiaries' Contribution	Total Costs
Small Bucket Filter (1 filter candle)	YER 300	YER 850
Large Bucket Filter (2 filter candles)	YER 500	YER 1.390

Table 1: Beneficiaries' Contribution Bucket Filter

The bucket filters that were readily prepared at that time were split among the supervisors who took them to their sub-districts where they distributed the filters and collected the money for the contribution. After returning that money, they received additional filters.

First, together with every bucket filter, SoDis bottles were given out. But soon it became clear that no family would use the SoDis when the have a bucket filter as well. Therefore, for the SoDis an area in Mabian was chosen where the other filters were still unknown, to test the acceptance and the functionality in on-field conditions of that method on its own.

The sand filters were only distributed in certain sub districts where there is enough sand in an acceptable composition. For that reason, not all supervisors were instructed, but only the ones from appropriate regions. These supervisors were accompanied when putting in operation the first sand filters in their region. Together with them the filters were filled after the sand had been sieved and cleaned while the teaching on construction as well as on operation and maintenance was done simultaneously. The beneficiaries' contribution to the costs of the sand filter was lowered to YER 1.000 after the earlier price of YER 1.500 was not affordable. The total costs per filter were about YER 7.100.

Though people seemed to be very much interested in the sand filters and would have liked to get one, the expected contribution prevented the demand from rising. Still the contribution was not further decreased because otherwise it would have been totally out of proportion with the contribution to the bucket filters.

The table below lists the number of filters distributed in the different distribution areas (sub-districts). For comparison the goals defined for each type in the proposal are given. Due to the net costs per unit being lower than expected, more filters could be manufactured and handed out.

distribution area	Bucket filter		Sand Filter	SoDis
	small	large		
Bani Hajar	35	27	23	78
Hajja	2			
Herba		141	4	51
Humlaan	29	36		46
Mabian	70	88	18	486
Shiraqi	30	20		20
Shires Al-Allaa	15	75	15	40
Shires Al-Asphal	25	35		40
Total	**206**	**422**	**60**	**761**
Original goal (cf. proposal)	*100*		*50*	*500*
Price / filter	$4,59	$7,53	$38,82	$0,10
Price / filter	846 YER	1.389 YER	7.159 YER	18 YER
GTZ Contribution	546 YER	889 YER	6.159 YER	18 YER
Beneficiaries' Contribution	300 YER	500 YER	1.000 YER	0 YER
% of total costs	35%	36%	14%	0%

Table 2: Distribution of Filters in the different Subdistricts

Most people favoured the bucket filters, especially the large ones. Although, in some poorer regions the cheaper small filter was preferred, especially in Humlaan. Therefore the money saved with the prototypes, the sand filters and the SoDis was invested in additional bucket filters. Part of the money foreseen for the training of women and artisans in income generating activities also was invested in additional filters as in the manufacturing and the distribution this kind of teaching was included.

In General, people were very excited about the treatment equipment. More people were interested than could be served. The benefits of water purification were sensed and the project gave a reason to get a filter that was even subsidized. The social acceptance was proven by the excitement of the beneficiaries and especially by the fact that they were willing to pay their contribution for the equipment, which was originally not foreseen for the project.

Additional Teaching Material

Common teaching material is created for more or less passive consumption. Similarly, the posters and stickers used were given out to illustrate the teachings and to help the beneficiaries repeat what they have learnt. Posters with all important information about the assembling, operation and maintenance were developed for each of the three methods. They were distributed with each bucket filter and set of SoDis-bottles and sticked on every sand filter. Furthermore, stickers were printed for the bucket filters that can be put on the plastic buckets. (cf. Annex II)

As an additional bridge between theoretical learning and practical application, a ‘memory’ game was developed, which can easily be played, even by illiterates. In this game, a number of pairs of cards is laid upside down. The players, one after another, chose two cards each and turn them around. If the cards show different pictures, they are turned back and the next player can have a try. Goal is, to find the pairs of cards with the same picture and take them.

The pictures chosen for the ‘Memory’ are in relation with hygiene, water treatment and water treatment equipment. Thereby people playing the game learn and repeat important knowledge about this field. Once explained, the game can be played by anyone without needing any supervisor.

The games were printed within the country, in Sana'a. Each set of cards was delivered in a small bag with a written explanation in Arabic. The design of the playing cards is given in Annex II.

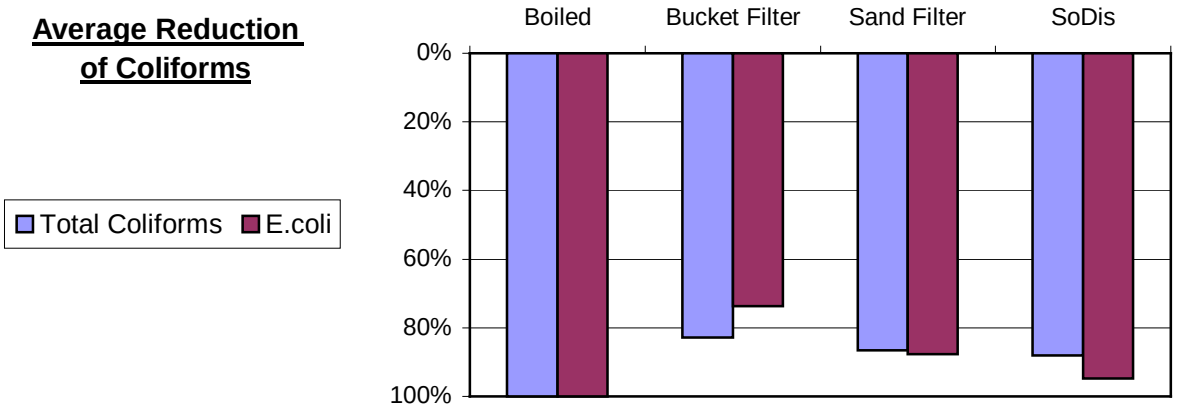
Water Testing

Bacteriological Analysis

According to the WHO 'Guidelines for drinking water quality', Escherichia coli is an indicator for faecal pollution. Together with the coliform organisms (total coliforms), it can be regarded as an indicator for the water quality. As frequent analysis was needed and samples should be tested no more than 6 hours after they were taken, the analysis was done in Hajja. The local branch of the water authorities does not yet have a functioning laboratory. Therefore, a ready made dry culture medium on a foil was used with colour indicators for E.coli and total coliforms (3M™ Petrifilm™ E.coli/Coliform Count Plate).

The plates were filled with 1 ml of water each. After incubation, the colonies were count. Frequently, tap or mineral water was tested for verification. For comparison, boiled water was tested. Though this method is the most effective one, the lack of fuel makes it less attractive. Still the results of these tests were used in the teachings to inform the women that only boiling can provide 100% save drinking water, which is especially to know concerning the nutrition of babies.

The table and the chart below give a general overview on the different treatment methods. The detailed results of the analysis are given in Annex I: Results of Biological and Chemical Analysis.



	Boiled	Bucket Filter	Sand Filter	SoDis
No. of Tests taken into account	2	35	4	19
Average Reduction Total Coliform	100%	83%	87%	88%
Average Reduction Total Coliform [CBU]	53	36	992	85
Average Reduction E.coli	100%	74%	88%	95%
Average Reduction E.coli [CBU]	3	2	344	8

Table 3: Average Coliform Reduction through the different Methods

All methods clearly improve the water quality, though besides the boiling none could guarantee 100% save drinking water.

Chemical Analysis

The water treatment equipment investigated in this project was not designed to change the chemical composition of the water. Although, people from Mabian using the bucket filter reported a testable reduction of salinity. However, the goal of the chemical analysis was to get a possibility to judge the general suitability of the waters in rural parts of Hajja Governorate for consumption.

As in Hajja no laboratory was available, chemical analysis was done in Sana'a at the Laboratory Department of the Sana'a Water and Sanitation Local Corporation. After the SFD laboratory lacked personnel, this was the best alternative. Three exemplary water samples were taken in the sub-district Herba and brought for investigation. The results in comparison to the WHO Guide Line Values are summarized in the table below:

		WHO	Herba		
Parameter	Unit	Guide Line Value	Spring	Roof	Cistern
Electrical Conductivity	**µS/cm**		858	85	220
pH at 25°C	**mg/l**	6,5-8,5	8,40	7,86	8,77
Total Dissolved Solids (Ecx 0.65)	**mg/l**	1000	558	55	143
Total Alkalinity as $CaCO_3$	**mg/l**		88	32	80
Carbonate	**mg/l**		4,8	nil	9,6
Bicarbonate	**mg/l**		98	39	78
Total Hardness as $CaCO_3$	**mg/l**	500	280	32	60
Calcium	**mg/l**	200	74	8	16
Magnesium	**mg/l**		23,4	3,0	5,0
Chloride	**mg/l**	250	108	6	13
Sulfate	**mg/l**	400	160	5	11
Nitrate	**mg/l**	50	12,0	6,2	5,7
Sodium	**mg/l**	200	47,0	2,5	15,3
Potassium	**mg/l**		8,0	36,0	13,8
Turbidity	**NTU**				63,2
Iron	**mg/l**	0,30	0,05	0,08	0,04

Table 4: Results Chemical Analysis

Except for the pH in the cistern water that was a little bit too high, all values are within the WHO Guide Line Values. Though the water quality therefore is acceptable, from a nutritional point of view, supplementation is needed. Especially the demand for minerals needs to be covered additionally by food, e.g. calcium through certain vegetables or wholemeal grain. The calcium/magnesium ratio is about the optimum of 3/1, but at very low values, especially regarding the collected rain water.

Flow Rates

Flow rates have been measured for the filters, while the SoDis production depends on number and size of the bottles used. Normally, per bottle 0.75 l/d can be yielded.

The flow rate of the sand filters mainly depends on the type of sand used. The typical result is about 60 l/h on average. The yield per day depends on how frequently the filling and drawing off is done.

The flow rate of the bucket filters varies not only with the type of water used (turbidity, hardness), but also strongly with the water level in the upper bucket. Keeping that water level high results in a higher yield. The correlation is shown in the chart below. On average, about 20 l can be filtered per candle per day. If the candle is not brushed regularly (suggestion: once a week), the filtration rate goes down.

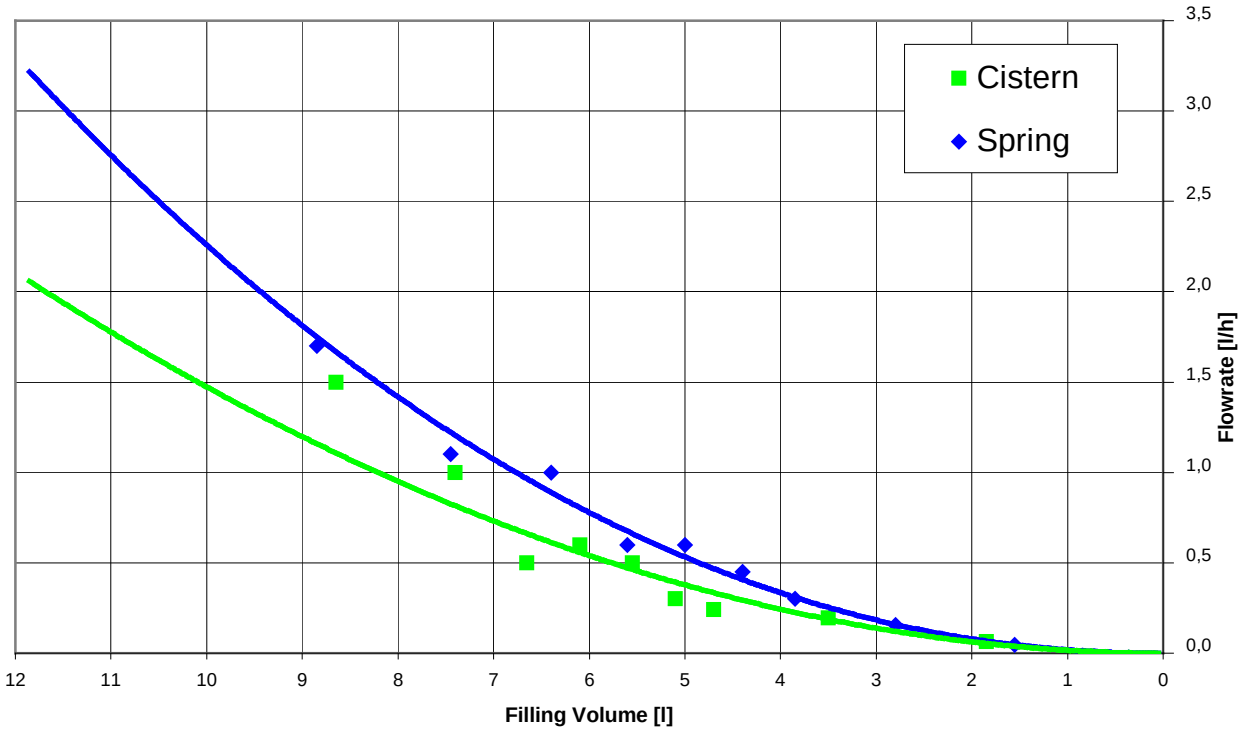


Chart 1: Flow rates per Filter Candle in Bucket Filters

Spot-check visits

Spot check follow-up visits were done in several villages in different sub-districts. For the questioning of the beneficiaries, a paper was used. The questionnaire and the records are collected in Annex III: Records Spot-check Visits.

The most distinct results of the spot-check visits were the following: SoDis may be accepted by poor people, though the filters are preferred. The bucket filters need to be well maintained, but after being rightly instructed, the beneficiaries seem to perform well. The plastic buckets easily broke at the hole for the tap, but can be repaired with wax or by welding with a hot piece of metal. The first time the bucket filter is used, the water gets a strange taste. This disappears at the second or third flush, but people need to know about this since they otherwise might stop using the filter.

The sand filter was liked because of its impressive appearance. It was well accepted, but the high price was a big hindrance. It is essential to sieve the sand twice, to remove the dust and the coarse sand. Otherwise both the flow rate and the water purification worsen. Since nearly no maintenance is needed for the sand filter, operating it did not cause any problems. But in some regions, especially in Shires, people started using the sand filter drum for water storage instead of for water treatment. They believe their water was of sufficient quality and did not need any treatment, even though water analysis proved the contrary. Contributing to this misuse might be the fact that some people are sceptical about sand being able to purify their water.

The acceptance of the treatment equipment should be tested again after a longer time span beyond the project horizon to learn about how people maintain it in the long-term.

Conclusions / Recommendations

During this project it became clear, that none of the three investigated household-level water treatment methods can clearly be marked as the best one. All of them have advantages and disadvantages in different areas. Therefore, the best fitting technique for a certain project must be weighted out. As a help, the following table was developed, summarizing the results. Boiling was originally not part of the project due to its strong disadvantage of high energy consumption. Therefore, it is not considered in the table. Still, it might be an option for water treated for sick people, small children and especially babies, as it provides the safest water of all.

	Bucket Filter ☺/😐/☹ (explanation)	**Sand Filter** ☺/😐/☹ (explanation)	**SoDis** ☺/😐/☹ (explanation)
investment costs	☺😐 (850-1400 YER)	☹ (7400 YER)	☺ (180 YER/set of 10 bottles)
operation costs	☺ (in general none)	☺ (in general none)	☺ (in general none)
maintenance costs	☺😐 (energy for boiling of candles; spare parts might have to be bought)	☺ (in general none)	☺😐 (bottles might have to be exchanged)
work intensity assembling	😐 (drill holes, screw candle(s) and tap)	☹ (prepare pipes, sieve sand, fill sand)	😐 (paint bottles)
work intensity operation	☺ (fill water on top, draw off at bottom)	☺ (fill water on top, draw off at bottom)	☹ (fill bottles ¾, shake, fill rest, lay in sun, let cool down)
work intensity maintenance	😐 (brush candles every week, boil candles once a month)	☺ (renew upper 0.5cm of sand or whole filling very rarely)	☺😐 (renew bottles when scratchy)
robustness	😐 (buckets can break, especially at holes; taps and candles have to be handled carefully)	☺ (very durable if properly constructed and standing on firm ground)	😐 (bottles can break or get scratches)
production capacity	☺😐 (~20 l/d (per candle))	☺ (~60 l/h)	☹ (7.5 l/d (10 bottles))
purification quality	😐 (acceptable results)	☺ (good results)	☺ (best results)
equipment safe against misuse	☺ (cannot be used for other purposes)	😐 (can be misused for storage)	😐 (can be misused for storage)
acceptance	☺ (preferred by beneficiaries)	☺😐 (good, but too expensive)	😐 ('too easy', people did not understand technique, preferred filters)

Table 5: Judgement on the three investigated Treatment Methods

Annexes:

I Results of Biological and Chemical Analysis

II Records Teachings
including Teaching Material: Posters etc.

III Records Spot-check Visits
including questionnaire

IV Manuals
for Assembling, Operation and Maintenance

Biological Analysis (p.1)

Carried out on site with 3M™ Petrifilm™ E.coli/Coliform Count Plate

information on water, filter, sampling and analysis						*raw water*		*treated water*		*reduction*				*Photo-No.*	
Analysis			Sampling		Kind of Filter	Total Coliform	E.coli count	Total Coliform	E.coli count	Total Coliform	E.coli count	Total Coliform	E.coli count	raw	treated
Date	Time	Where	Kind of Water	sample taken...		#	#	#	#	#	#	%	%	water	water
28.03.	15:30	Office	Ramon-Filter, in use since 4 months without maintening, with tap water	directly from bucket	Bucket Filter	0	0	0	0	0	0			01a	01b
28.03.	16:00	Office	White filter, candles not boiled, with tap water	directly from bucket	Bucket Filter	0	0	0	0	0	0			02a	02b
28.03.	16:00	Office	Metal filter, with tap water	directly from bucket	Bucket Filter	0	0	0	0	0	0			02a	03b
30.03.	11:00	Office	Metal filter, with cistern water	directly from bucket	Bucket Filter	83	5	8	1	75	4	90%	80%	04a	04b
30.03.	11:00	Office	Bucket filter 1, with cistern water	directly from bucket	Bucket Filter	92	5	30	3	62	2	67%	40%	05a	05b
30.03.	11:00	Office	Bucket filter 2, with cistern water	directly from bucket	Bucket Filter	82	4	3	0	79	4	96%	100%	06a	06b
30.03.	11:00	Office	Bucket filter 3, with cistern water	directly from bucket	Bucket Filter	100	5	5	1	95	4	95%	80%	07a	07b
31.03.	11:00	Office	White filter, candle not boiled, with cistern water	directly from bucket	Bucket Filter	101	0	0	0	101	0	100%		08a	08b
31.03.	11:00	on site	Filter Leibbrand family	directly from bucket	Bucket Filter	0	0	0	0	0	0			cf. 13a	cf. 13b
31.03.	11:00	Office	Ramon-Filter; after boiling the candles, with tap water	directly from bucket	Bucket Filter	0	0	0	0	0	0			cf. 13a	cf. 13b
3.04.	13:30	on site	Filter from Myrta, candles not boiled since 4 or 5 month	directly from bucket	Bucket Filter	0	0	0	0	0	0			09a	09b
3.04.	17:00	Office	Cistern Water, boiled for 20 min.	directly from pan	Boiled	92	5	0	0	92	5	100%	100%	05a	10b
3.04.	17:00	Office	SoDis (Hadda bottle), with cistern water	directly from bottle	SoDis	92	5	22	0	70	5	76%	100%	05a	11b
3.04.	17:00	Office	SoDis (Canada dry bottle), with cistern water	directly from bottle	SoDis	92	5	14	0	78	5	85%	100%	05a	12b
3.04.	17:00	Office	SoDis, with tap water	directly from bottle	SoDis	0	0	0	0	0	0			13a	13b
3.04.	17:00	Office	SoDis (Shamlan bottle), with cistern water	directly from bottle	SoDis	92	5	24	0	68	5	74%	100%	05a	14b
3.04.	17:00	Office	SoDis (big bottle); with cistern water	directly from bottle	SoDis	92	5	31	0	61	5	66%	100%	05a	15b
3.04.	17:00	Office	SoDis (water from all bottles mixed together in a bucket); with cistern water	directly from bottle	SoDis	92	5	91	0	1	5	1%	100%	05a	16b
4.04.	10:55	Office	Metal filter, lower bucket, cistern water with a tablespoon of clorox in the upper bucket	directly from bucket	Bucket Filter	13	0	0	0	13	0	100%		17a	17b
4.04.	10:55	Office	Bucket filter 1, cistern water with a tablespoon of clorox in the upper bucket	directly from bucket	Bucket Filter	13	0	0	0	13	0	100%		17a	18b
4.04.	15:00	Office	Bucket filter 2, cistern water with a tablespoon of clorox in the upper bucket	directly from bucket	Bucket Filter	13	0	0	0	13	0	100%		17a	19b
4.04.	15:00	Office	Bucket filter 3, cistern water with a tablespoon of clorox in the upper bucket	directly from bucket	Bucket Filter	13	0	0	0	13	0	100%		17a	20b
4.04.	10:50	Office	White bucket, cistern water with a tablespoon of clorox, candles not boiled	directly from bucket	Bucket Filter	13	0	0	0	13	0	100%		17a	21b
4.04.	15:30	Office	Slow Sand filter, with cistern water	through pipe	Sand Filter	1000	180	520	160	480	20	48%	11%	22a	22b
7.04.	15:00	Office	Cistern water just shortly boiled (less then one min.)	directly from pan	Boiled	13	0	0	0	13	0	100%		17a	23b
7.04.	09:00	Office	SoDis (big bottle), with cistern water, 2 days outside, cloudy weather	directly from bottle	SoDis	92	5	0	0	92	5	100%	100%	05a	24b
7.04.	09:00	Office	SoDis (little bottle), with cistern water, 2 days outside, cloudy weather	directly from bottle	SoDis	92	5	0	0	92	5	100%	100%	05a	25b
13.04.	17:00	Office	big Sandfilter	through pipe connected to valve	Sand Filter	63	12	50	11	13	1	21%	8%	26a	26b
19.04.	15:20	Office	Ramon filter, candles not brushed for 3 weeks	directly from bucket	Bucket Filter	0	0	0	0	0	0			cf. 13a	27b
19.04.	15:30	Office	Bucket filter, cistern water from Herba	directly from bucket	Bucket Filter	45	0	0	0	45	0	100%		28a	28b
19.04.	15:30	Office	Bucket filter, spring water from Herba	directly from bucket	Bucket Filter	12	4	2	0	10	4	83%	100%	29a	29b
21.04.	19:20	office	So-Dis spring	directly from bottle	SoDis	12	4	1	0	11	4	92%	100%	29a	30b
21.04.	19:20	office	So-dis cistern	directly from bottle	SoDis	45	0	0	0	45	0	100%		28a	31b
24.04.	18:30	office	cistern Herba filter	directly from bucket	Bucket Filter	111	4	6	0	105	4	95%	100%	32a	32b
24.04.	18:30	office	spring Herba	directly from bucket	Bucket Filter	36	5	3	0	33	5	92%	100%	33a	33b
25.04.	15:30	office	Abdula Ali house	directly from bucket	Bucket Filter	57	23	45	9	12	14	21%	61%	34a	34b
25.04.	16:30	office	Abdul Al-Wadud house	directly from bucket	Bucket Filter	24	7	3	0	21	7	88%	100%	35a	35b
25.04.	16:20	office	Ali Mahdi house	directly from bucket	Bucket Filter	5	1	0	0	5	1	100%	100%	36a	36b
25.04.	16:40	office	Hussin Ali house	directly from bucket	Bucket Filter	270	10	39	4	231	6	86%	60%	37a	37b

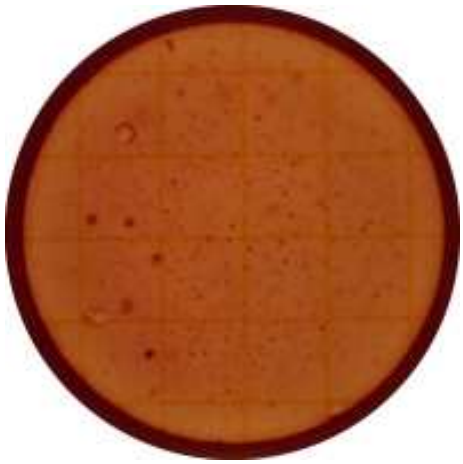
Biological Analysis (p.2)

Carried out on site with 3M™ Petrifilm™ E.coli/Coliform Count Plate

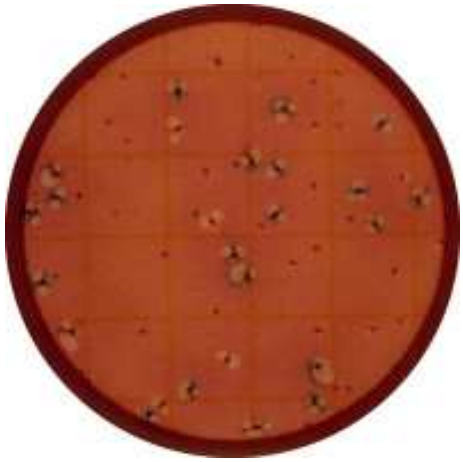
information on water, filter, sampling and analysis						raw water		treated water		reduction				Photo-No.	
Analysis Date	Time	Where	Sampling Kind of Water	sample taken...	Kind of Filter	Total Coliform #	E.coli count #	Total Coliform #	E.coli count #	Total Coliform #	E.coli count #	Total Coliform %	E.coli count %	raw water	treated water
28.04.	12:10	office	Mohammed Abdulah filter	directly from bucket	**Bucket Filter**	35	7	25	4	10	3	29%	43%	38a	38b
28.04.	12:10	office	Hussin house filter	directly from bucket	**Bucket Filter**	30	0	14	0	16	0	53%		39a	39b
28.04.	12:30	office	Azadeen house	directly from bucket	**Bucket Filter**	184	2	4	0	180	2	98%	100%	40a	40b
28.04.	12:45	office	Waled house	directly from bucket	**Bucket Filter**	19	1	15	0	4	1	21%	100%	41a	41b
2.05.	12:00	on site	Shires (1)	directly from bucket	**Bucket Filter**	18	0	11	0	7	0	39%		42a	42b
2.05.	12:15	on site	Shires (2)	directly from bucket	**Bucket Filter**	2	0	1	0	1	0	50%		43a	43b
4.05.	9:00	office	Bani Hajjar spring (sand filter)	directly from filter	**Sand Filter**	2100	1200	39	21	2061	1179	98%	98%	44a	44b
4.05.	9:00	office	Bani Hajjer cistern (sand filter)	directly from filter	**Sand Filter**	1420	180	8	3	1412	177	99%	98%	45a	45b
5.05.	10:30	office	office filter	directly from bucket	**Bucket Filter**	0	0	0	0	0	0			46a	46b
8.05.	12:45	office	SoDis Mabian: Spring Water 1	directly from bottle	**SoDis**	9	0	0	0	9	0	100%		47a	47b
8.05.	12:50	office	SoDis Mabian: Spring Water 2	directly from bottle	**SoDis**	0	0	0	0	0	0			48a	48b
10.05.	11:30	office	bucket filter: Sherres Al Asphal, boiled 1d before	sampling bottle taken to office	**Bucket Filter**	61	0	14	0	47	0	77%		49a	49b
10.05.	12:10	office	bucket filter 2: Sherres Al Asphal	sampling bottle taken to office	**Bucket Filter**	59	2	23	0	36	2	61%	100%	50a	50b
10.05.	12:15	office	bucket filter 1: Sherres Al Asphal	sampling bottle taken to office	**Bucket Filter**	51	6	14	2	37	4	73%	67%	51a	51b
11.05.	15:45	on site	Al Maifri SoDis 7.5h (house 2)	directly from bottle	**SoDis**	195	42	0	0	195	42	100%	100%	52a	52b
11.05.	15:45	on site	Al Maifri SoDis 7.5h (house 1)	directly from bottle	**SoDis**	195	42	0	0	195	42	100%	100%	52a	53b
11.05.	16:20	on site	Al Maifri SoDis 1h (house 3)	directly from bottle	**SoDis**	195	42	28	1	167	41	86%	98%	52a	54b
11.05.	14:50	on site	Bani Soad SoDis 7h (house 1)	directly from bottle	**SoDis**	158	1	0	0	158	1	100%	100%	55a	55b
11.05.	14:35	on site	Bani Soad SoDis 7h (house 2)	directly from bottle	**SoDis**	158	1	0	0	158	1	100%	100%	55a	56b
11.05.	13:25	on site	Bani Shumy SoDis 1.5h	directly from bottle	**SoDis**	44	3	0	0	44	3	100%	100%	57a	57b
11.05.	13:00	on site	Bani Shumy SoDis 5h	directly from bottle	**SoDis**	183	8	8	8	175	0	96%	100%	58a	58b

Biological Analysis: Photographs Count Plates:

(three samples; complete set of photos is handed out digitally)



***Bucket Filter**:* *top (Photo-No. 32a)* *bottom (Photo-No. 32b)*



***Sand Filter**:* *raw water (Photo-No. 44a)* *filtered water (Photo-No. 44b)*

***SoDis**:* *raw water (Photo-No. 52a)* *treated water (Photo-No. 52b)*

Chemical Analysis

Results of Chemical Analysis		WHO	TrinkWV	Herba			Mineral Water		
Parameter	**Unit**	**Guide Line Value**	**Maximum Value**	**Spring**	**Roof**	**Cistern**	**Albaraka**	**Hadda**	**Shamlan**
Electrical Conductivity	**mS/cm**	0	0	858	85	220	0	0	0
pH at 25°C	**mg/l**	6,5-8,5	0	8,4	7,86	8,77	7	7,5	7,6
Total Dissolved Solids (Ecx 0.65)	**mg/l**	1000	0	558	55	143	0	150	180
Total Alkalinity as CaCO3	**mg/l**	0	0	88	32	80	0	0	0
Carbonate	**mg/l**	0	0	4,8	Nil	9,6	0	0	0
Bicarbonate	**mg/l**	0	0	98	39	78	70	50	131
Total Hardness as CaCO3	**mg/l**	500	0	280	32	60	0	0	0
Calcium	**mg/l**	200	400	74	8	16	18	10	25
Magnesium	**mg/l**	0	50	23,4	3	5	6	7	11
Chloride	**mg/l**	250	250	108	6	13	68	40	21
Sulfate	**mg/l**	400	240	160	5	11	18	20	34
Nitrate	**mg/l**	50	50	12	6,2	5,7	4	2	2,5
Sodium	**mg/l**	200	150	47	2,5	15,3	38	40	0
Potassium	**mg/l**	0	12	8	36	13,8	0,5	1,5	0
Turbidity	**NTU**	0	0	0	0	63,2	0	0	0
Iron	**mg/l**	0,3	0,2	0,05	0,08	0,04	0	0	0

Results of Chemical Analysis of Spring, Roof and Cistern Water from Herba
(analysed at the Laboratory Department of the Sana'a Water and Sanitation Local Corporation):
in comparison with International (WHO) and German (Trinkwasserverordnung) guide line values
as well as with values for the most famous mineral waters available in Yemen (as declared on the labels)

Teachings

30.03.2004
ca. 11.00-11.45 Uhr
by Stephan Krämer in cooperation with Myrta von Siebenthal and Miriam Krämer

Teaching of three teachers for Herba (Fatima, Nadja, Suruw)

- Teaching about the importance of water purification: clean water = less diarrhoea and less other deseases!
- Explanations to the Bucket Filter
- Assembling of Bucket Filter
- Explanations to the SoDis
- Demonstration of the SoDis
- Questions answered

6.04.2004
ca. 15.00-17.00 Uhr
by teachers Fatima, Nadja, Suruw
and Stephan Krämer, Miriam Krämer, Charity and Myrta von Siebenthal

Teaching of 51 women in Herba

- Fatima explains in Arabic the importance of water purification in general and in particular the handling of the treatment equipment (bucket filter and SoDis) while Stephan Krämer demonstrates simultaneously the equipment
- The women are split in 4 classrooms where the teachers repeats how to assemble, operate and maintain the filters
- Every woman receives her own filter and assembles it under supervision of the teachers and the female ICS staff
- Special problems are solved with the assistance of Stephan Krämer outside
- In two classrooms a survey was done about household water
- Every woman takes home her assembled filter, a brush for maintaining it, a paper summarizing all information and a SoDis bottle

Feedback:
- The women were anxious about getting their filters, but did not help each other
- The women were shy when assembling the filter, afraid of doing something wrong or being laughed at
- Problems occurred with thread and nut of the filter candles: they often did not fit together and had to be exchanged: though all the same type, the threads differed in diameter

14.04.2004
ca. 10.00-13.00 Uhr

Teaching of nine Supervisors of local NGO

- Explaining of manufacturing, practical exercises
- Explaining of the three water purification methods Sand Filter, SoDis, Bucket Filter, construction, operation and maintenance, practical exercises (Bucket Filter + SoDis)
- Discussion of feasible pricing: 500YR for big filters; 300YR for small ones
- Practical exercise: Sand Filter
- Distribution of Filters and documentation: every region 15 small bucket filters, 5 large ones including one brush each and 1-2 SoDis bottles per household buying a filter; Teaching Material: manual and questionnaire for supervisors, one paper that goes with the filter

08.05.2004
ca. 16.00-18.00 Uhr

Teaching of Shopkeepers that sell Bucket Filters in Hajja

- 6 shops were visited, all located on Hajja's main shopping street between the two roundabouts, between the new football stadium and the old suk:
  1. near the stadium, on the right (selling metal filters)
  2. opposite side, selling household goods and both metal and plastic bucket filters
  3. on the right, selling plastic ware and household goods and bucket filters
  4. directly opposite, selling plastic ware + household goods, no filters but filter candles
  5. at the roundabout near the old suk, on the left, selling household goods and both metal and plastic bucket filters
  6. at the roundabout near the old suk, on the right, selling household goods and both metal and plastic bucket filters
- The shopkeepers were introduced to the project implemented by ICS Hajja and about the importance of maintenance when operating a bucket filter:
  - careful construction (smooth holes, good sealing: so no water can find shortcuts)
  - brushing the candle every week!
  - boiling the candle every month for ½ h
- A shrink-wrapped poster was handed out to the shopkeepers, for repetition and as a tool to teach their customers how to operate their bucket filters
- Stickers with the same pictures as on the posters were promised to the shopkeepers to be put on the filters, they will be handed out later, after their production is finished.

Questionnaire used for Teaching in Herba

The answers should be counted by a show of hands.

1. Where do you catch the water for the household?

    a) cistern
    b) spring
    c) other

2. How do you clean the water?

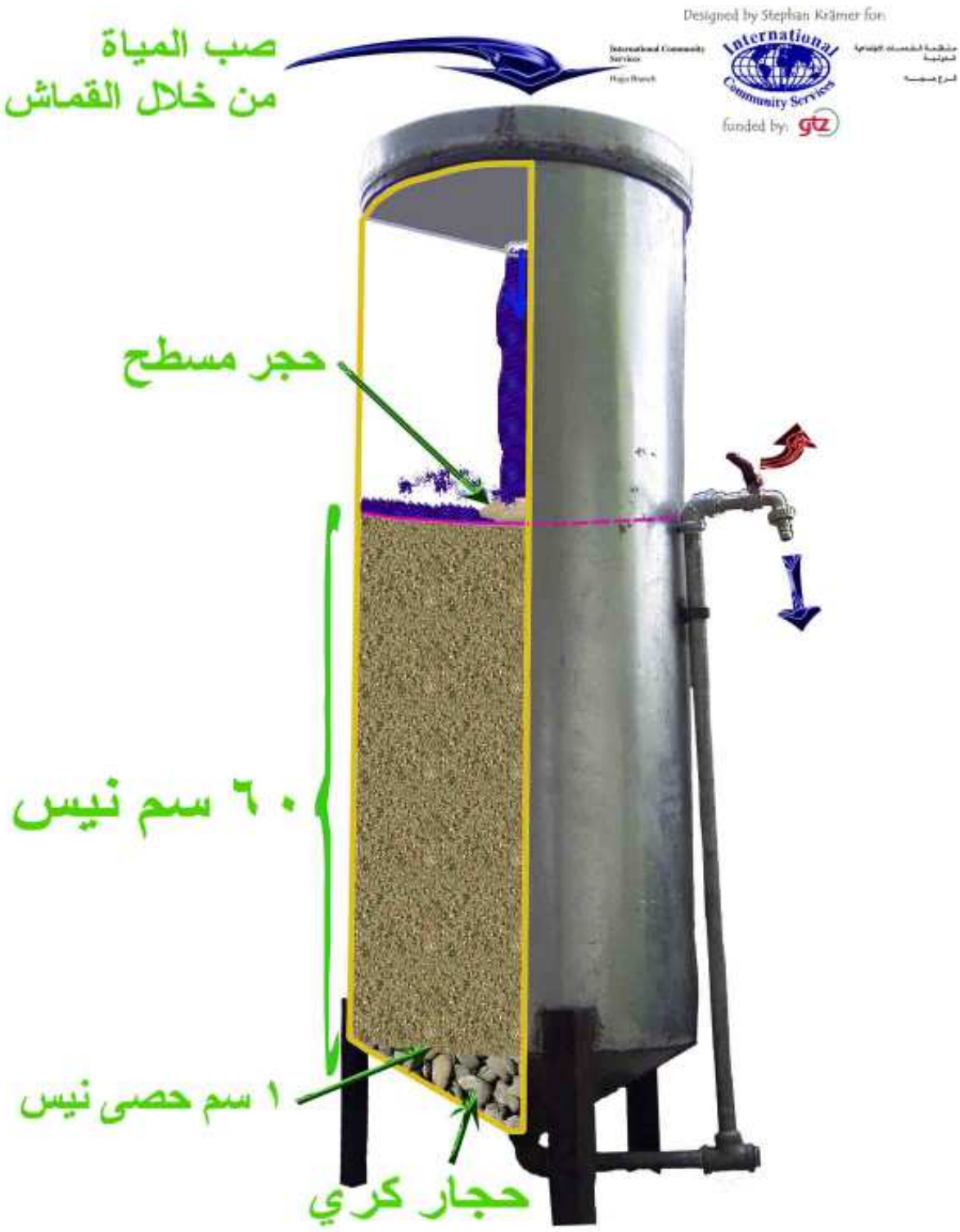
    a) with a towel
    b) with a filter
    c) no treatment
    d) other

3. Where do you store the water?

    a) in an open bucket
    b) in plastic canisters
    c) other

Teaching Material: Poster / Sticker Bucket Filter:

Teaching Material: Poster Sand Filter:



عندما يقل خروج المياه من الحنفية يجب أخذ مقداره٥- سم من أعلى النيس واستبدالها بنيس اخرى وبنفس المقدار .
أما في حالة قلة خروج المياه بعد الاستبدال يفضل تغيير كل النيس الموجودة بالخزان.

Teaching Material: Poster SoDis:

Teaching Material: Memory Game

(designs of 24 pairs of cards; original size: 6 x 6 cm)


Assembling candle inside.jpg


Assembling candle outside.jpg

boiling.jpg

brushing.jpg


bucket dirt.jpg


filling glas.jpg


Logo.jpg


on table.jpg


sandfilter mountains.jpg


sandfilter.jpg


SoDis in glass.jpg


SoDis in Shade.jpg


SoDis in Sun.jpg


Yemen I.jpg


Yemen II.jpg


Yemen IV.jpg


Yemen VII.jpg


Yemen VIII.jpg


Yemen VIIII.jpg


Yemen XI.jpg


Yemen XII.jpg


Yemen XIII.jpg


Yemen XIV.jpg


Yemen XIVb.jpg

Spot-check visits

21.04.2004
ca. 14.30-15.30 Uhr
by Stephan Krämer

Spot-check visits in Bani Hagar

- Saleh's house: large filter brought to mafradsch, said to be used regularly, little dirt under upper bucket -> "don't put filter on the ground!!!"; SoDis not used; old British Berkefeld filter also in the house, but full of dust and not used for long time because of broken valve, two candles inside, one original in good condition, second one exchanged, condition not bad
- Second house, at entrance of village: small filter installed in mafradsch at good position next to window, seems to be in good condition and regularly used, little dirt at bottom of lower bucket! but water clear; SoDis only used once, three new bottles handed out and right handling tested and explained again; problems: bottles not filled till top, too much air inside!
- Third house at other end of village: Filter installed in mafradsch on small table, seems to be constantly in use and in good condition, except for leakage at valve that has been tried to be repaired (problem: glue was used instead of working with the original rubber and tightening it properly; men asked for repair and were told to try by themselves instead of returning the bucket to the office: no major problem!)
  SoDis bottle never used (lost), new bottles handed out and boy who listened before explained it in good way, this boy encouraged to continue teaching others
- ~20 additional SoDis bottles were distributed via the supervisor and the boy who could explain how to handle them, 50 more were kept at the supervisor's house to be given to families not receiving any other filter
- No more houses visited, because supervisor needed to leave for Hajja

25.04.2004
in the morning
by Gertrud Leibbrand and Miriam Krämer

Spot-check visits in Bani Ali

- All filters in good condition, clean and in good place
- No sanitation
- Many people drink out of the same glass
- SoDis was not well accepted (only one bottle per household received which is not enough; filter easier and better)
- Water sampling difficult as no tables available for the count plates
- Taking pictures nearly impossible: too many women everywhere who did not want to be photographed
- Some people didn't like the taste of the first filtered water and stopped using the filter!
  => needs to be taught that the taste gets normal again at the second or third run!

26.04.2004
in the morning
by Myrta von Siebenthal

Spot-check visits in Bait al Siraihy

- Most of the ladies use clean piece of cloth for pre-filtration
- Water is taken from the well, only one lady takes it from a cistern
- SoDis is not used
- One bucket had been leaking, lady repaired it with wax
- The ladies brush the candles at least once a week, often even more often if the candles color from particles in the water
- Treated water is mainly used for drinking; few also take it for boiling
- Ladys have the impression of feeling healthier since they use the filter

28.04.2004
in the morning
by Myrta von Siebenthal and Miriam Krämer

Spot-check visits in Al-Rakab

- All filters in good condition, clean and in good place
- No sanitation
- Many people drink out of the same glass
- SoDis was not well accepted (only one bottle per household received which is not enough; filter easier and better)
- Water sampling difficult as no tables available for the count plates
- Taking pictures nearly impossible: too many women everywhere who did not want to be photographed

10.05.2004
in the morning
by Myrta von Siebenthal and Miriam Krämer

Spot-check visits in Turef

- All filters in good condition, clean and in good place
- Sanitation existent (one toilet for all the three households)
- SoDis was not well accepted (only one bottle per household received which is not enough; filter easier and better)
- Water sampling difficult as no tables available for the count plates
- Taking pictures nearly impossible: too many women everywhere who did not want to be photographed

11.05.2004
all day
by Stephan Krämer

Spot-check visits in Mabian

- Several households in different villages were visited
- In Al Maifri, Bani Soad and Bani Shumy water samples were taken from raw (spring/well) and treated SoDis water
- Some SoDis bottles were cold though people said they had been in the sun or were from the day before; water analysis revealed the truth later
- SoDis bottles were put in the sun, most of the bottles taken for sampling were hot, which is a proof that they had been exposed to the sun for several hours
- SoDis bottles were put on elevated places where no shade can hinder the purification
- For many people it was difficult to understand that the water quality improves through simply putting the water in the sun
- A filter is easier to understand and if available would be preferred

Questionnaire for Spot-check visits

1. How do you deal with the filter? Can you please show me in short time how you handle the filter?
    a) two bucket filter

    b) SoDis bottles

2. Do you prefer the two bucket filter or the SoDis bottles?

3. Are there any problems with the filter?

4. Did you brush the candles? How often did you brush them?
   Please remember, you have to brush them every week and boil them once a month!

5. Where do you collect the water for the filter?

6. For what do you use the cleaned water, just for drinking or also for boiling?

7. Did you notice any improvement since you use the water filter?
   Did you for example feel healthier (less diarrhoea)?

Bucket Filter

Two types of bucket filter: with two filter candles, as developed during the project (left) and with one filter candle, as already available in shops in Hajja (right)

The bucket filter is composed of two plastic buckets with lids that are shaped in a way that the buckets fit well on top of each other, a plastic tap and one or more ceramic filter candles. The buckets should be large enough to provide space for the number of candles wanted. It is recommended to chose different colours for the top and the bottom to make it easy to differ between bad and good water quality.

The buckets need to be prepared with holes for the tap and for each filter candle. The best technique is to use a metal pipe heated in fire to burn the holes. The edges need to be smoothened with a knife, otherwise leakages occur as the sealings do not fit well. The lid of the bottom bucket needs to be equipped with corresponding holes for the candles. If more than one candle is used, one larger hole is better that can be cut with a knife. If only one candle is installed, the hole in the lid can be burnt as well.

In the latter case, the lid may be connected to the upper bucket through the filter candle. This should not be done, as it is more difficult to tighten the nut on the candle's thread leading to inappropriate sealing. Moreover, it has to be considered that the candle is taken out at least every week for maintenance. Therefore it should be as easy as possible to remove it and tighten again.

The tap must have a thread that allows to install it properly in the relatively thin wall of the bucket, otherwise leakages may occur. Concerning the filter candles, different types were tested. Detailed information about these are given in the following table. The Prestige Ceramic Candle was chosen for this project. Even though the nut and thread of this type is of low-grade quality and some candles had to be sorted out due to this reason, it was the best solution in that price category.

The prestige filter candle

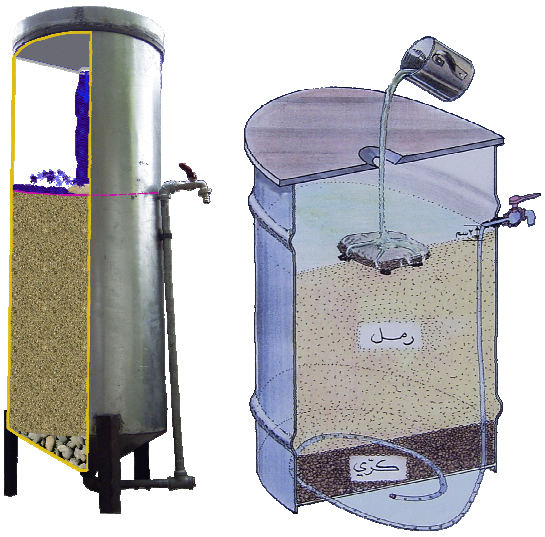
Name	Origin	Height	Price	Comments
Welofil Water Filter Candle	India	19 cm	YER 300-350 ~ US-$ 1.63-1.90	robust plastic screw, but connection to ceramic broke during boiling
Prestige Ceramic Candle	India	18 cm	YER 200-250 ~ US-$ 1.08-1.36	ceramic robust, but metal screws in bad quality: nut and thread in several cases did not fit well
Prestige Water Filter Candle **Super Deluxe**	India	15 cm	YER 350 ~ US-$ 1.90	as other Prestige Candle, bigger diameter => not enough space in bucket for more than 1 candle
The **Heart of Water Filter** Water Filter Candle	India	18 cm	YER 200-250 ~ US-$ 1.08-1.36	same construction and also same problems as with Prestige Ceramic Candle, more difficult to obtain in Hajja
Doulton Ceramic Water Filter Candle, Standard	England	24 cm	YER 1,200 ~ US-$ 6.51	Plastic screw and ceramic robust, but too expensive while reduction of pathogens no better than with other candles

A bucket filter in operation should be based on a clean, elevated place. Filtered water must be drunk out of a clean glass. Crucial for accurate purification is maintenance. Otherwise the filtered water may become worse than the raw water, as bacteria can grow on the filter candle leading to an increased bacteriological pollution in the filter. Every week the filter candles must be brushed. Therefore a bucket filter should not be sold or handed out without a brush. The filter candle(s) is (are) taken out. Under running water, e.g. through the tap from the lower bucket, the surface is brushed to remove particles and bacteria. If the turbidity of the raw water is high, even after pre-filtration through a cloth, the brushing might be desirable more often.

hole at mounting of candle

Once a month, the candles need to be taken out and boiled. The candles are put into a pan filled with cold water in which they are boiled for about 30 min. After removed from the fire, the candles are left in the water until it has cooled down. Otherwise the ceramic might crack. If the candles crack or even small holes at the mounting occur (*cf. photograph on the left*), they must be exchanged as good purification cannot be expected any longer. Accurate sealing is also essential so that no water can directly flow from the upper bucket to the lower one besides through the filter candle.

Slow Sand Filter



Sand Filter:
Modified project design in specially designed metal drum (left) and design for a 200 l metal drum (right; SFD-Teaching material)

Basically, a slow sand filter can be constructed in any kind of vessel. No special design is needed, it just has to be big enough to be filled with a few cm of gravel and 60 cm of sand while still providing a little space to fill water on top. The vessel can be made of wood, metal, masonry or concrete. The vessel is equipped with a water collector. This can either be the funnel-shaped bottom of the vessel that is filled with gravel and connected to a pipe in its centre, or in any other vessel a pipe with holes in a layer of gravel at the bottom. The latter version is found in the literature and is taught e.g. by the SFD. The first one was developed in the project and is preferable if vessels are constructed anyways especially for the purpose of slow sand filtration (*cf. picture on the left*). The design of the metal drum may be imitated with other materials as well, e.g. concrete.

On top of the gravel, a layer of sand of 60 cm thickness is installed. The sand must be sieved twice before being used: with a larger net to remove all particles ~Ø1.6mm and with a small net to remove all dust and smallest particles. The nets can be purchased in goods stores where they are sold e.g. as fly screen. If the larger particles are not removed, the filtering gets inferior. If the dust is left in the sand, the filter closes, the filtration rate runs down, the water builds canals in the sand where it flows through without being purified at all.

On top of the sand a flat stone is put at the place where the water is put on to prevent whirling that may disturb the upper layer of sand where the so-called ‘schmutzschicht’ develops, which is essential for the purification of the water.

The filtered water is drawn off through a tap that is installed higher than the top of the sand. This is important so that the schmutzschicht does not run dry. The tap is connected via a pipe with the water collector at the bottom. If the modified design of this project is chosen, the pipe is installed on the outside. An outlet can be foreseen to empty the filter when the sand needs to be taken out.

Whenever the flow rate of the sand filter decreases significantly, the upper 0.5cm of the sand should be removed. If this does not help, all of the sand must renewed. Both must not be done too often (not more than every half a year), because otherwise the schmutzschicht cannot well develop.

Even though the sand filter is good in removing suspended solids, pre-filtering the raw water with a cloth is suggested. Otherwise the filter may close faster and more maintenance is needed. In the special design of the project, the cloth can be fixed to the lid to make pre-filtration easier.

SoDis

For the SoDis – Solar Water Disinfection, different types of transparent PET-bottles were taken. No special size or form is to be preferred, but the material must be transparent PET (no PVC! – harmful substances might be resolved). The bottles must be without scratches and must not have been used for storing chemicals or oil before. In Hajja and probably in the whole of Yemen, 0.75 l mineral water bottles are most common. The bottles can be purchased via boys collecting them or from hotels. The latter offered cleaner bottles for a better price. Even if the bottles look clean, they should be washed before being used, especially the bottle top that is not exposed to sunlight and therefore not disinfected when the bottle is put in the sun.

SoDis:
painting the PET-bottle (above);
SoDis-bottles in the sun (bottom)

The PET bottles should be painted black on one half to heat up more which results in better purification. Black waterproof paint can be purchased from any goods store, but needs to be tested. Some paints do not stick to PET or get sticky; others are strong and drying fast. The bottles are painted in a way that when laid down, the lower half is black while the upper half is all clear.

Ready SoDis bottles must be filled for 2/3 and shaked to resolve more oxygen in the water, which gives a better taste. Than the bottle is filled completely, as air bubbles may diffuse the UV ratio and by this means reduce the purifying effect. The water should be pre-filtered through a piece of cloth, as particles in the water are also limiting the purification. In the morning, the SoDis bottle should be put on an elevated place where no shade comes to. They should be left in the sun for a whole day, even though a shorter period (up to as little as 3 hours) may be sufficient. The adequate time span depends on the cloudiness, but to prevent confusion, it is better to give only one time that is long enough to purify the water even if the sky is partly covered.