Soil Aquifer Treatment

Basic aspects, operability, troubleshooting and new improvements

Prepared by:

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Dr. Joseph Guttman, Avi Aharoni

SWITCH

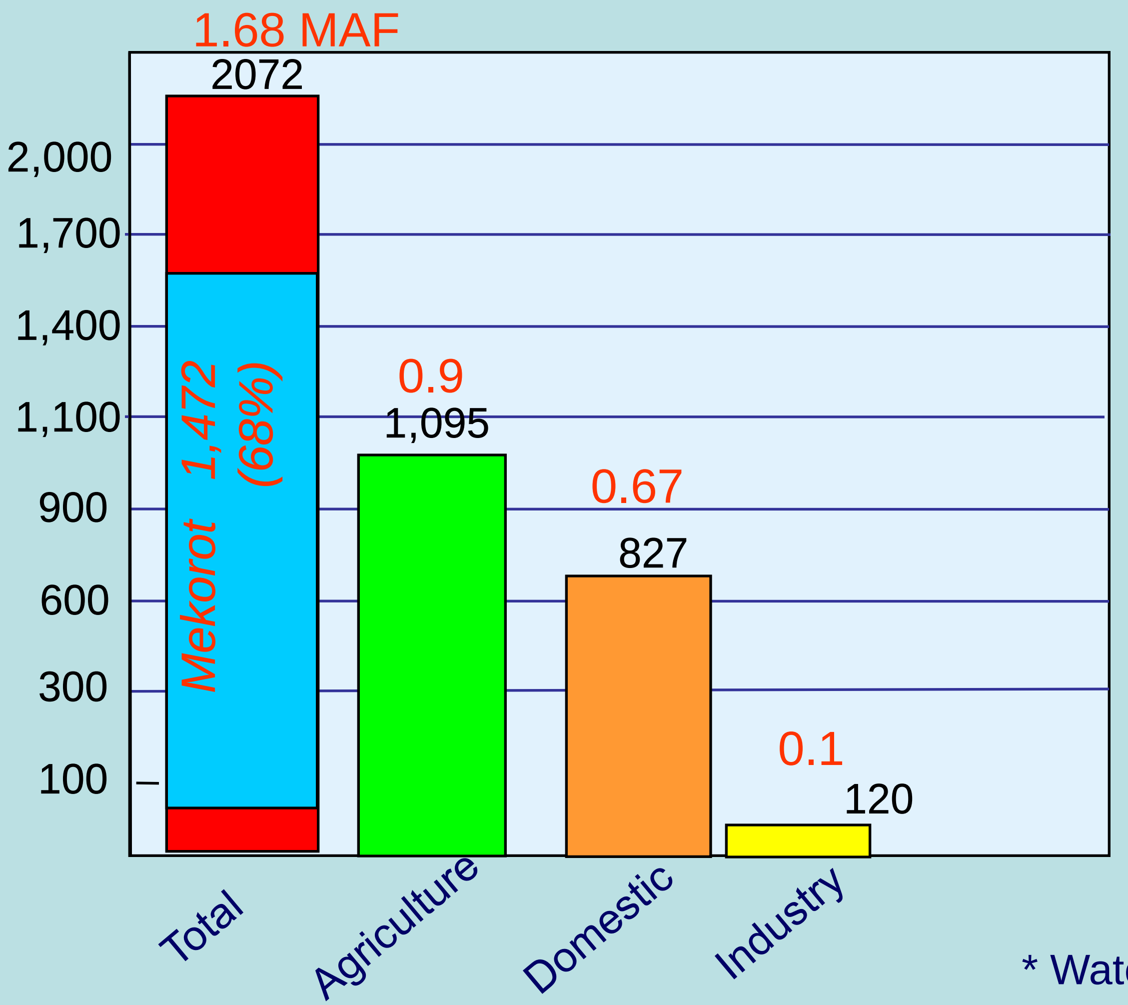
Sixth Framework Programme (2002-2006)

MEKOROT
ISRAEL NATIONAL WATER CO.

GENERAL:
ISRAEL WASTEWATER AND EFFLUENT REUSE

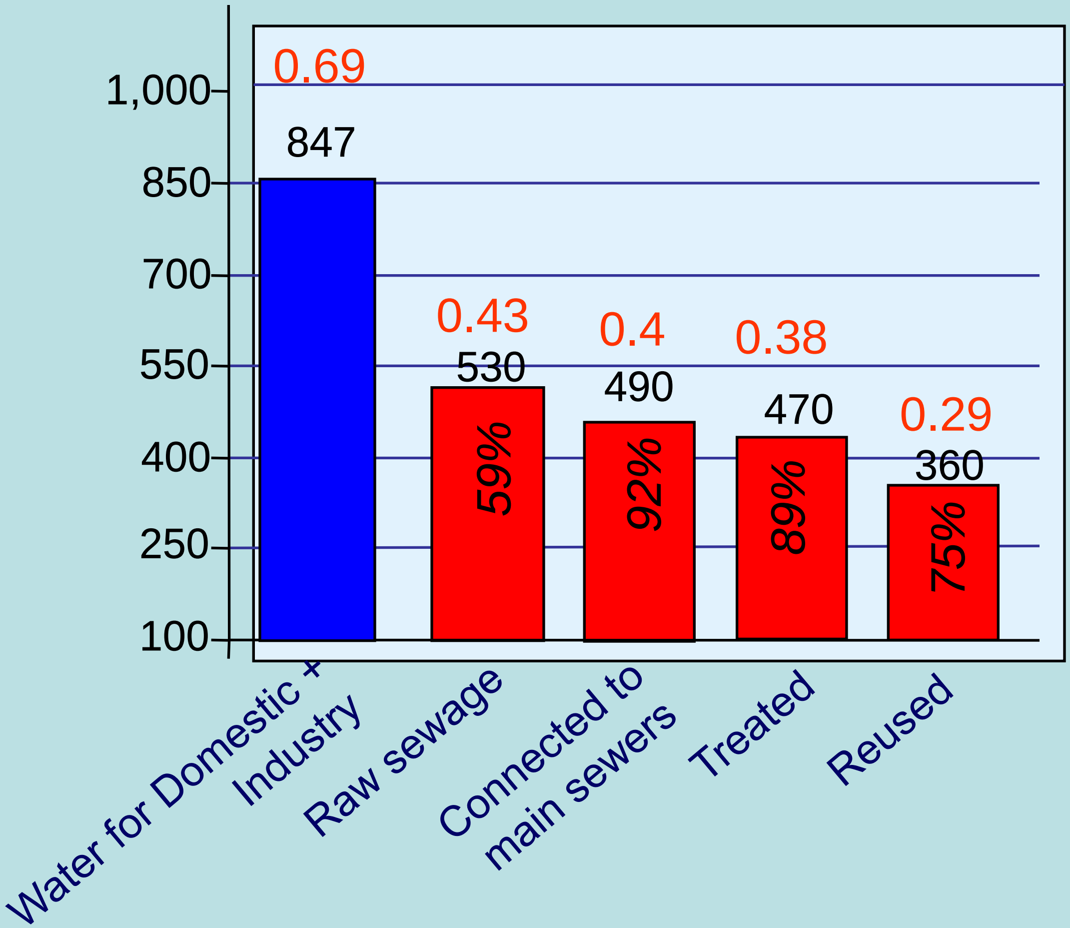
Water consumption in Israel (Mm3/Year)

(100 Mm3/Year to Jordan and Palestine)



* Water data – 2008

Wastewater production in Israel (Mm^3/Year)



* Sewage data - 2006

National Water Carrier and Shafdan irrigation project

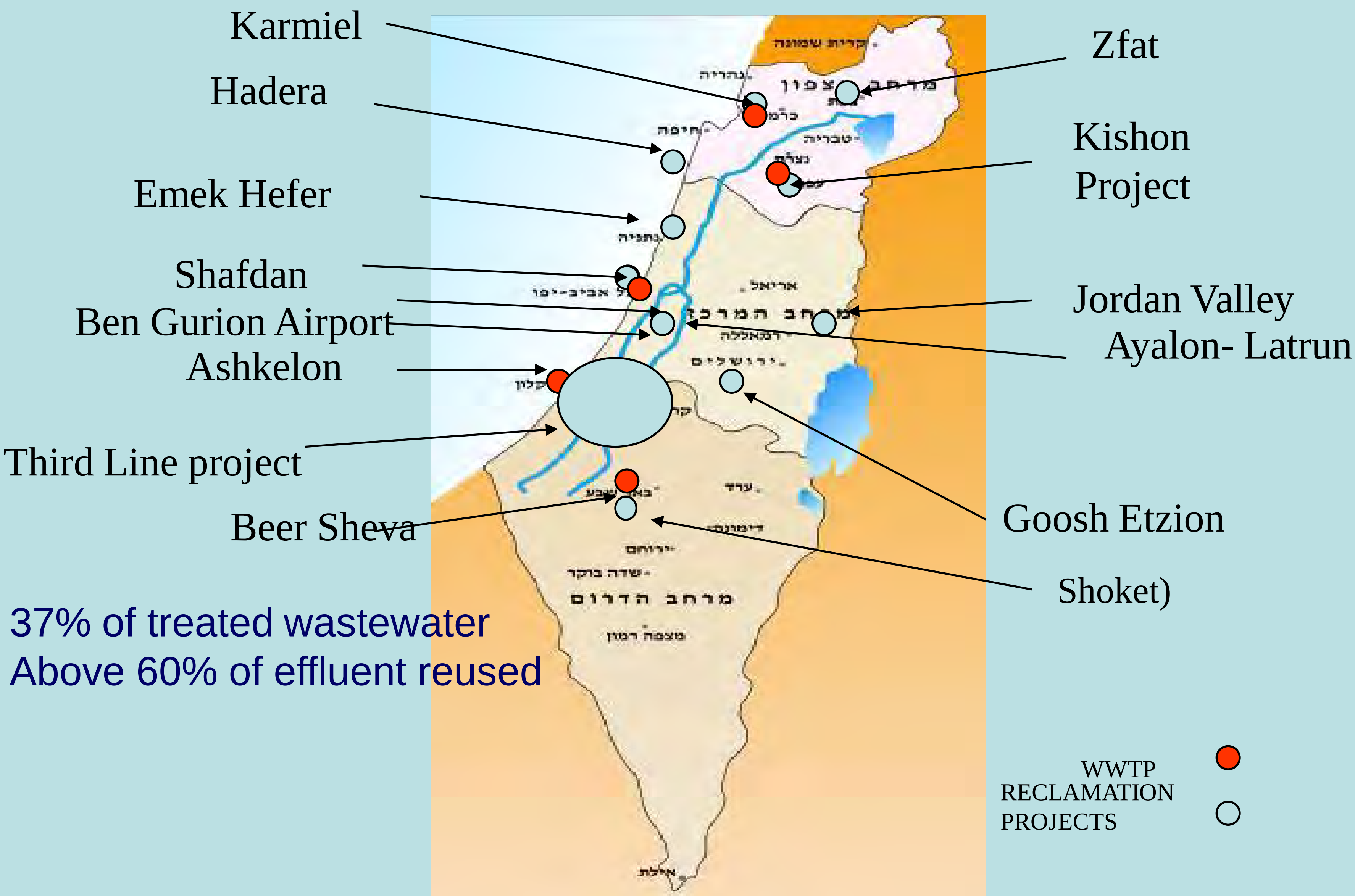
National Water Carrier

Tel Aviv Metropolitan City

Irrigation Area of Reclaimed Water

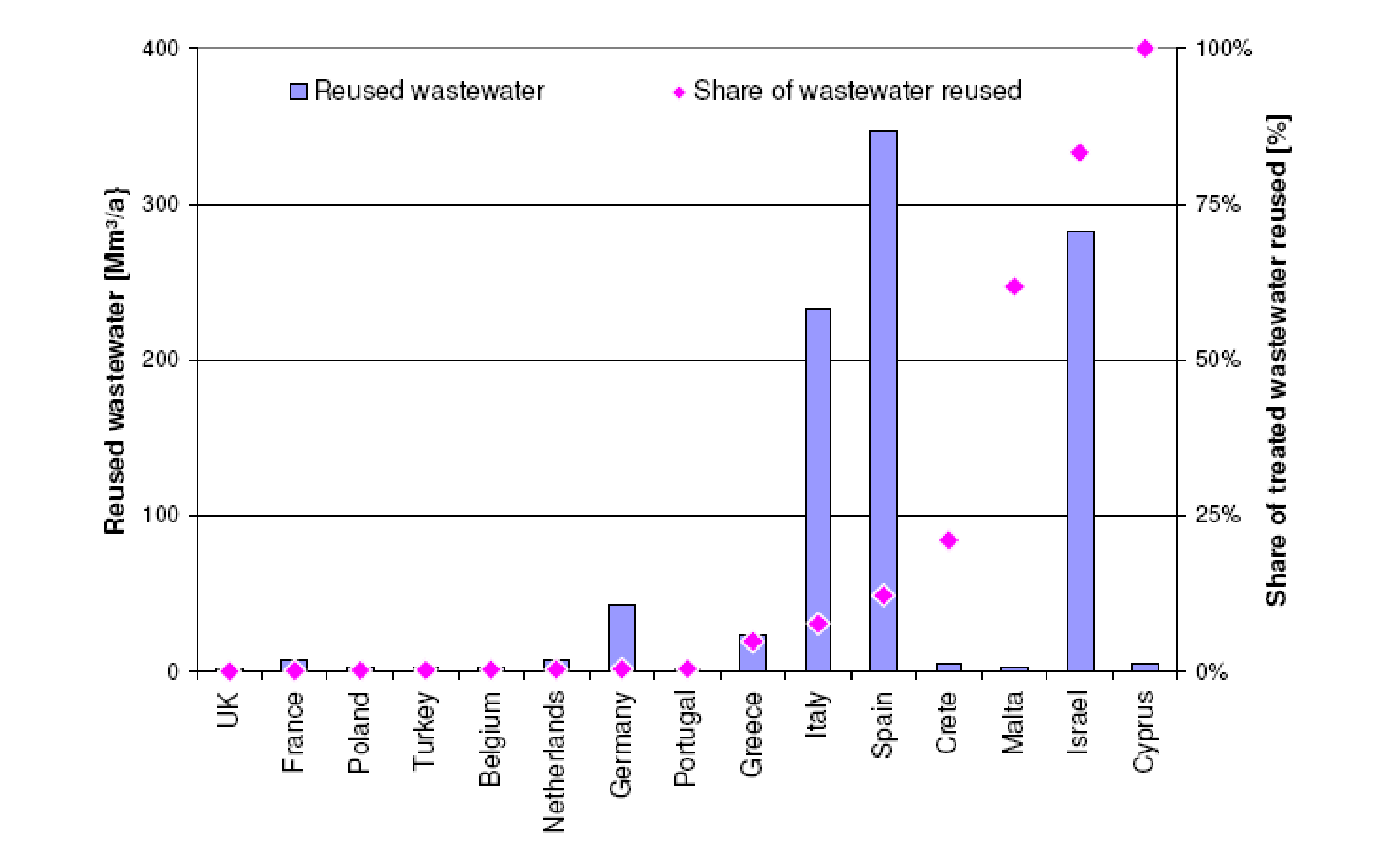
Galil Lake

WWTP's and eff Reuse Projects in Israel operated by Mekorot



37% of treated wastewater
Above 60% of effluent reused

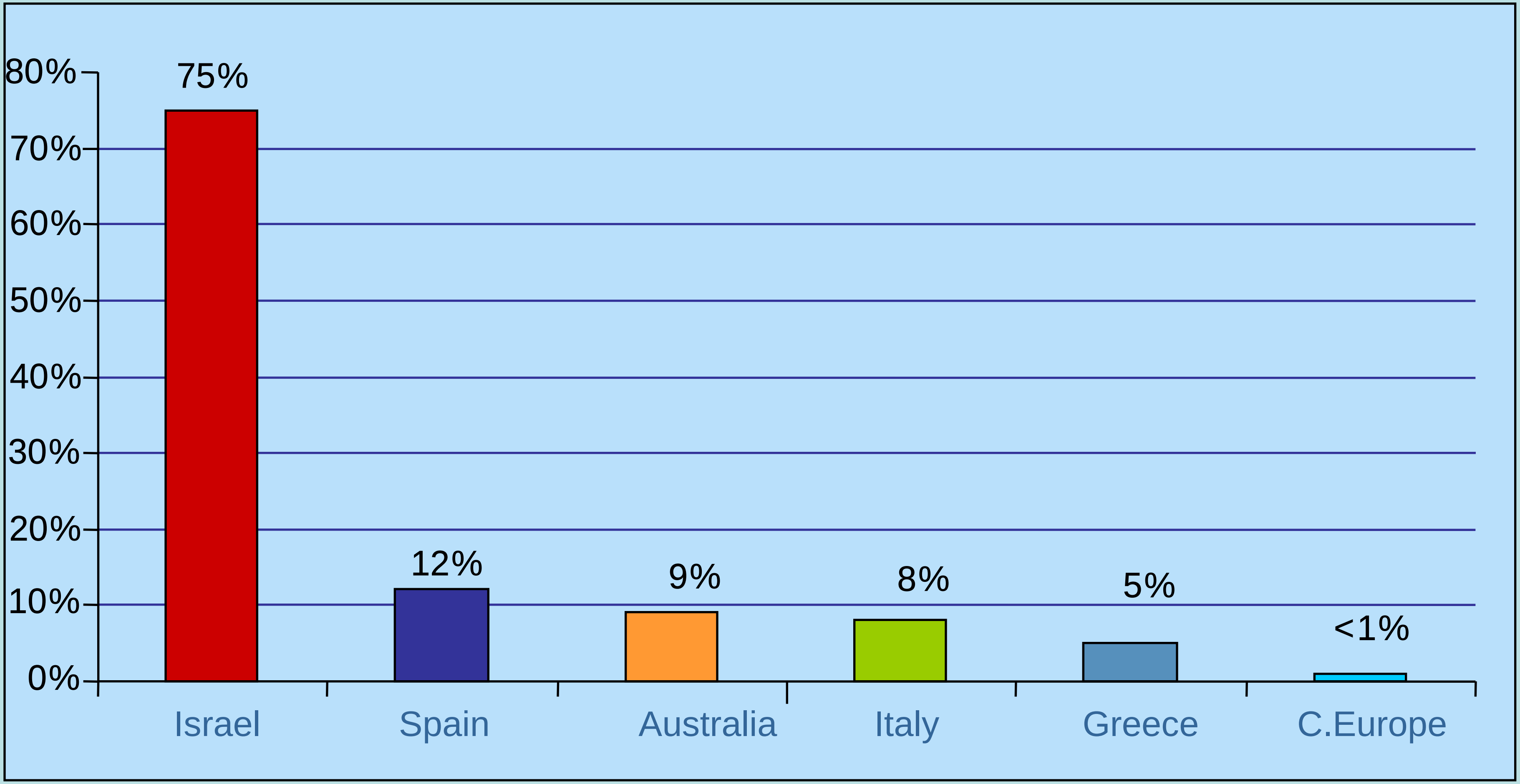
Status of wastewater reuse in selected European countries and Israel



Source: WSSTP – UPT3 “Alternative Water Resources”

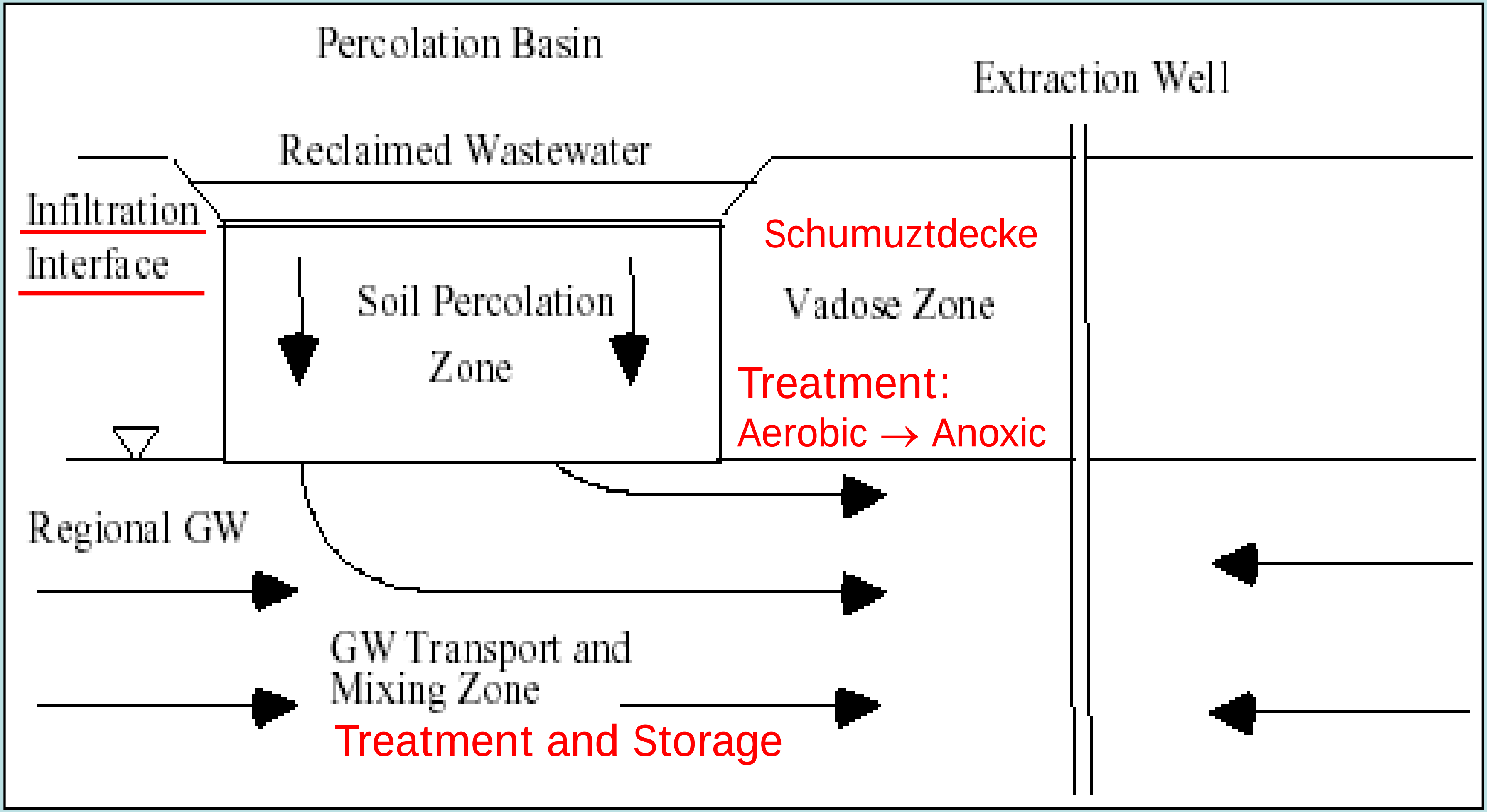
Reused effluent in agriculture

The target-Raising the Eff Reuse in Israel to 90% - 95%



SAT PROCESS

Soil Aquifer Treatment (SAT)



Capabilities of SAT process

- Removal of: suspended matter and DOC, UV_{abs} by Slow sand filtration
- Biodegradation of bacteria, viruses, parasites - die off during the prolonged time , or by Adsorption or absence of food
- Chemical precipitation and Immobilization by Ion exchange of Phosphate,, Cu, (>70%)
- Continuous removal of nitrogen by Nitrification and Denitrification
- Effective removal of most micropollutants
- Residence time needed in the aquifer:
  - For unrestricted irrigation quality > 2 weeks (mostly bacterial decay)
  - For accidental drinking water Quality > 6 months (total microbial, chemical removal and removal of most micropollutants)

USE OF THE SAT INFILTRATION AREA AS SEASONAL RESERVOIR

Comparison of Typical SAT Zones

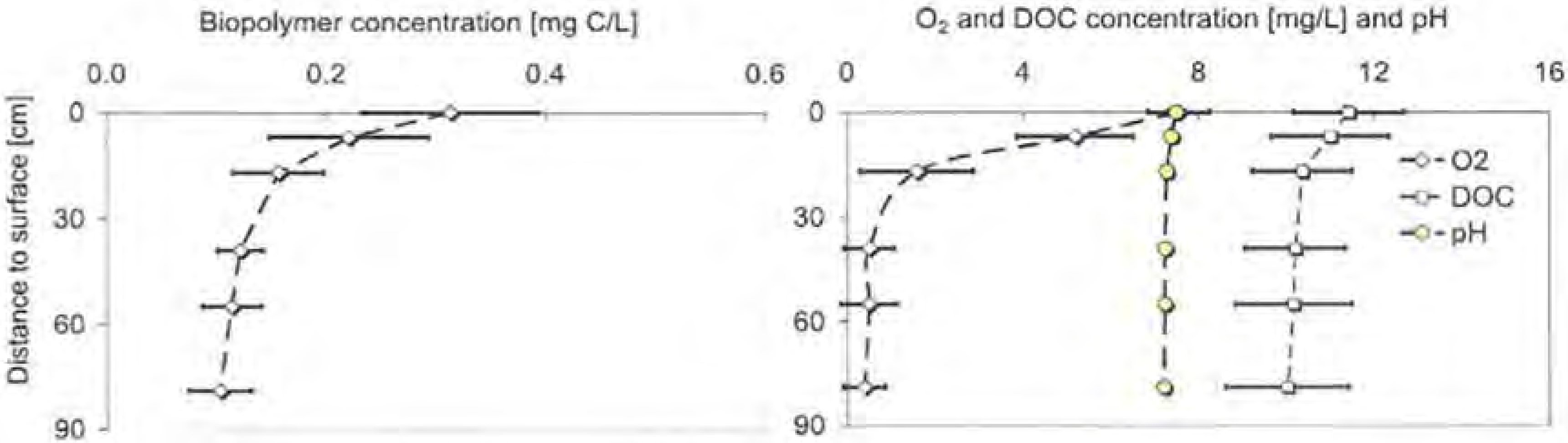
PROCESS/ PARAMETER	INFILTRATION INTERFACE	SOIL-PERCOLATION	GROUNDWATER TRANSPORT
Treatment Mechanisms	Filtration ✓, Biodegradation	Biodegradation ✓, Adsorption	Biodegradation, Adsorption, Dilution ✓
Transport	Saturated	Unsaturated	Saturated
Residence Time	Minutes	Hours to Days	Months to Years
Travel Distance	Centimeters / Inches	5 – 30 m / 15 – 100 ft	Variable
Mixing	No	No	Yes (regional G.W.)
Oxygen (O_2) Supply	Recharge Water	Unsaturated Zone	Regional G.W.
Biodegradable Org. Carbon Availability	Excess	Excess/Limiting	Limiting
Redox Conditions	Aerobic	Aerobic to Anoxic	Anoxic to Aerobic

SWITCH

4th Scientific Meeting
UNESCO-IHE
Delft, Netherlands
4 - 7 October 2009

Control of Organic Fouling in UF of Secondary Effluent by Bio-filtration

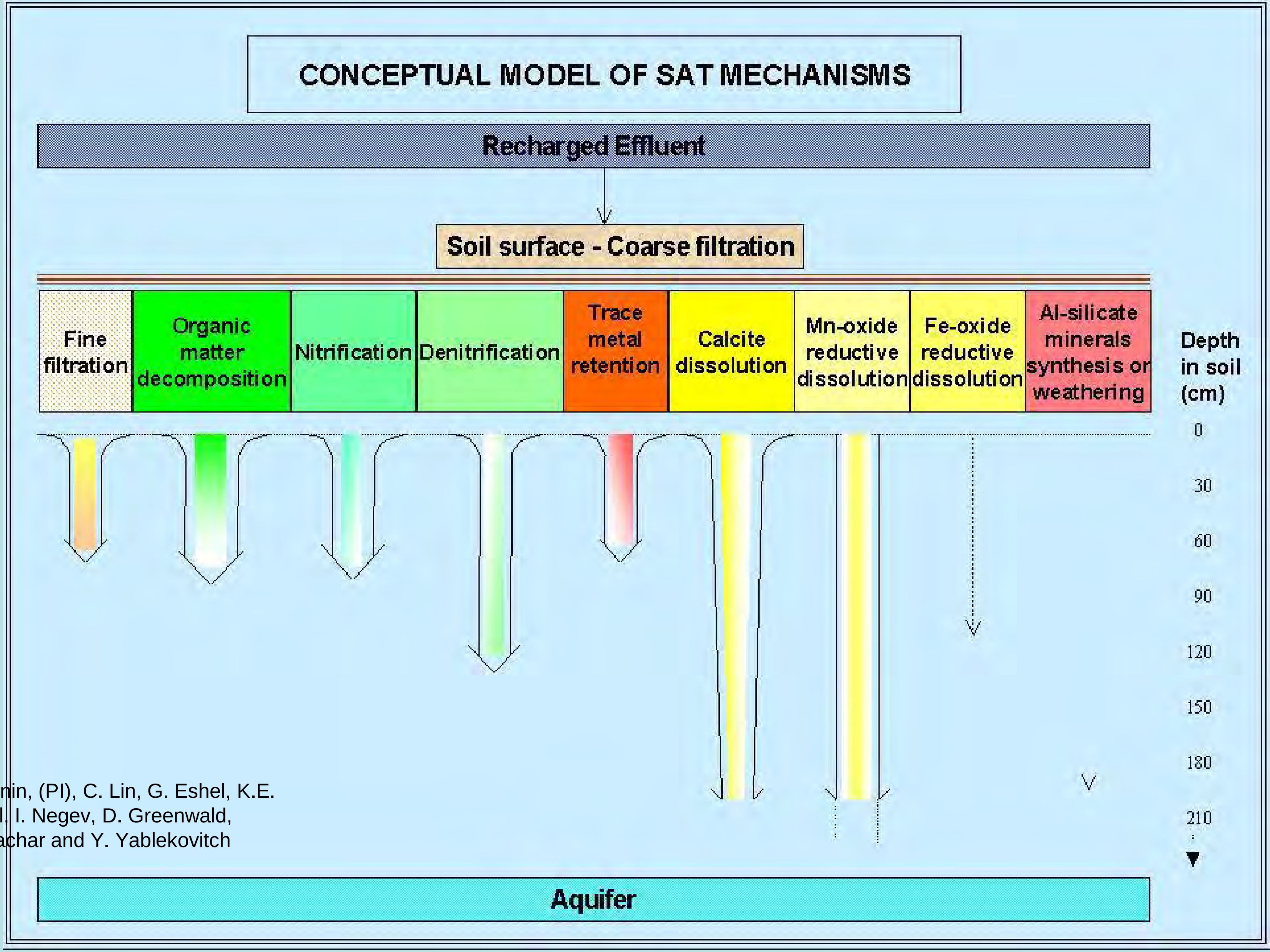
X. Zheng*, M. Ernst**, M. Jekel*



➡ The removal of biopolymers takes place mainly in the upper active sand layer

➡ The removal is related to biological processes

Ultrafiltration (UF) can be used as a promising process filtering secondary effluent to produce reuse water. However, membrane fouling caused by macromolecular organic compounds is a general drawback. In the present work, slow sand filtration is used to reduce fouling potential of secondary effluent prior to UF. The results show that it can remove particles, colloids and dissolved substances and improve the performance of a conjuncted UF significantly. Lab-scale membrane filtration tests show that biopolymers detected using LC-OCD are major organic foulants. Pilot-scale UF experiments verified this conclusion. Within slow sand filters the removal of biopolymers is observed to take place in the upper active sand layer. The sustainable elimination of biopolymers is mainly attributed to biological processes.



A. Banin, (PI), C. Lin, G. Eshel, K.E. Roehl, I. Negev, D. Greenwald, Y.Shachar and Y. Yablekovitch

Water quality in the SAT system (Mekorot, 2009)

Parameter	Unit	Influent conc'. (mg/l)	Effluent quality (mg/l)	Removal efficiency (%)
TSS*	mg/L	10-80	0	99-100
Turbidity*	NTU	<10	<0.5	>95
COD_f	mg/L	30-40	4-5	85-88
BOD	mg/L	5-40	<0.5	95-98
DOC	mg/L	4-20	1-3	85-90
NH_3-N	mg/L	1-20	0.02 -0.05	>99
N_{TOT}	mg/L	5-30	2-5**	85-93
P_{TOT}	mg/L	1-5	0.02	99
UV abs.	$cm^{-1}x10^3$	200-300	30-40	85-87
Total coliforms	MPN/100 ml	10^4-10^6	0-2	5 logs
Faecal coliforms	MPN/100 ml	10^3 -10^5	0-2	4 logs
Strept. Faecalis	MPN/100 ml	10^3 -10^5	0-2	4 logs
Enteroviruses	PFU/35l. inf. PFU/400 l. effl.	3-5	none	>99.99

***In order to prevent quick clogging of the fields in the recharged influent, Turbidity (should be <8 NTU and TSS < 15 mg/l (Dan Region experience)**

**** Mainly nitrates**

SAT treated water – Viruses, phages and spores analyses

Microbiological analysis*	Units	Method**	05/07 and 06/07 Secondary effluents	05/07 and 06/07 Mey-Dan well #9 (after SAT)
Total Bacteria count (35 °C)	cfu/mL	Heterotr. Plate Count (35 C. deg. / 48 hr.)	890,000	340
Faecal coliforms	cfu/100mL	MF	30,000	0
E.Coli	cfu/100mL		400	0
Enterococci	cfu/100mL	Fecal st. MF	4,000.00	0
clostridium spores	cfu/100mL		100,000.00	0
bacteriophages	pfu/mL	(amp F+)/10 L (Somatic CN13/10L. (f1MS2)/10L	724 1,249 7	0 0 0
Enterovirus	pfu/Vol.	/100 L	14	0

* In the context of the EU project RECLAIM (WP 2)

** All phages, spores and viruses analyses performed by the Health Ministry Lab. Dr. Yosi Manor

THE SHAFDAN SAT PROCESS

Dan Region WWTP and Reclamation

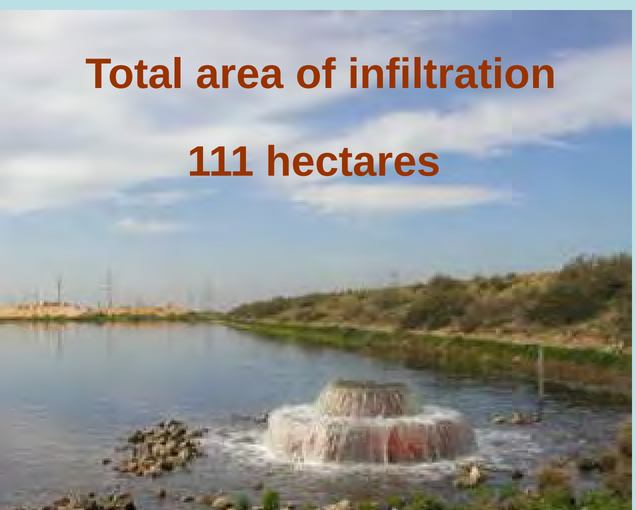
Treating 140 MCM/Y (0.12 MAF) of 2 .5 Million P.E

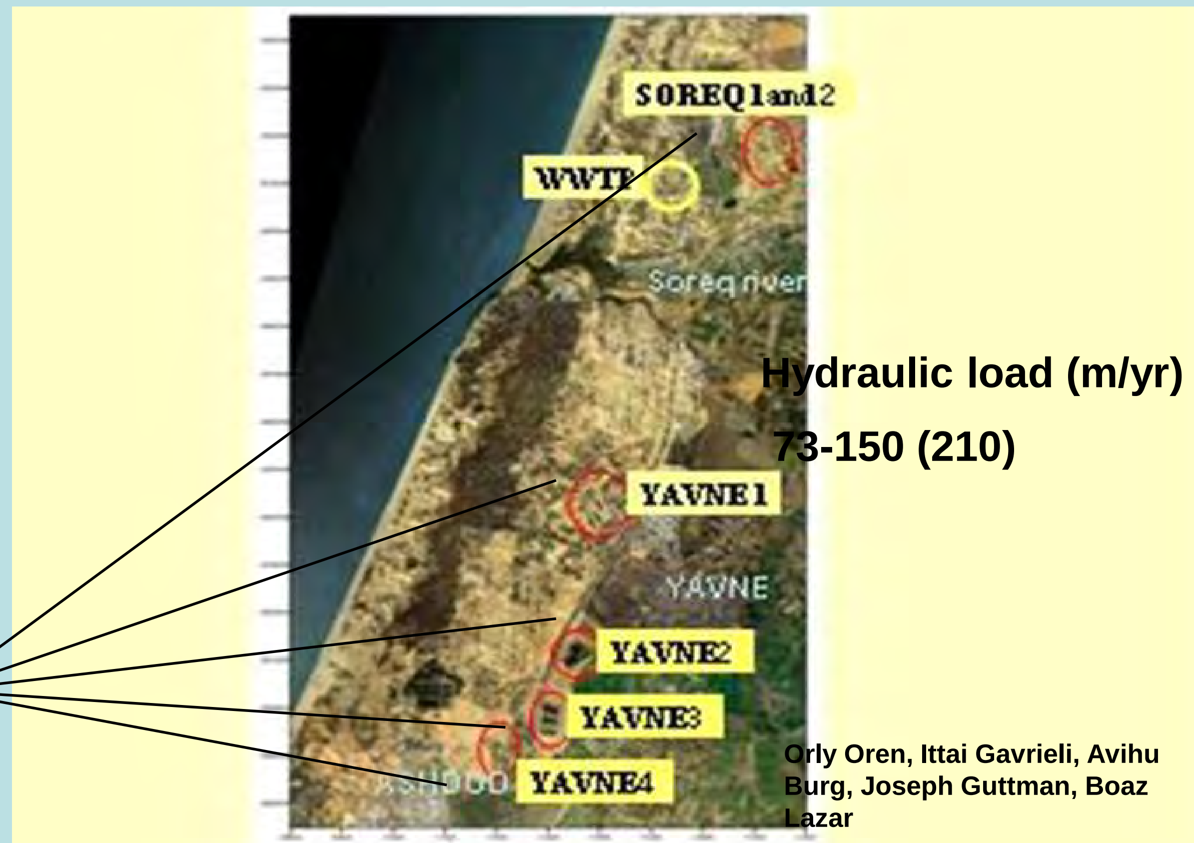
History of the SAT and the Third Line project in Israel

- Early days of the state: Septic tanks(groundwater contamination)
- In 50’s: Collection in main sewers, disposal to sea and rivers
- 1955: The authorities with Mekorot decided on the SAT concept
- 60’s: Start treating sewage in oxidation ponds
- 70’s: Start recharge effluents after oxidation ponds to groundwater
- 80’s : Start CAS (Conventional Activated Sludge), CAS eff recharge, Third Line operation to Negev (South of Israel)
- 90’s: Extending CAS and infiltration basins

Sewage collection system of the Dan Region

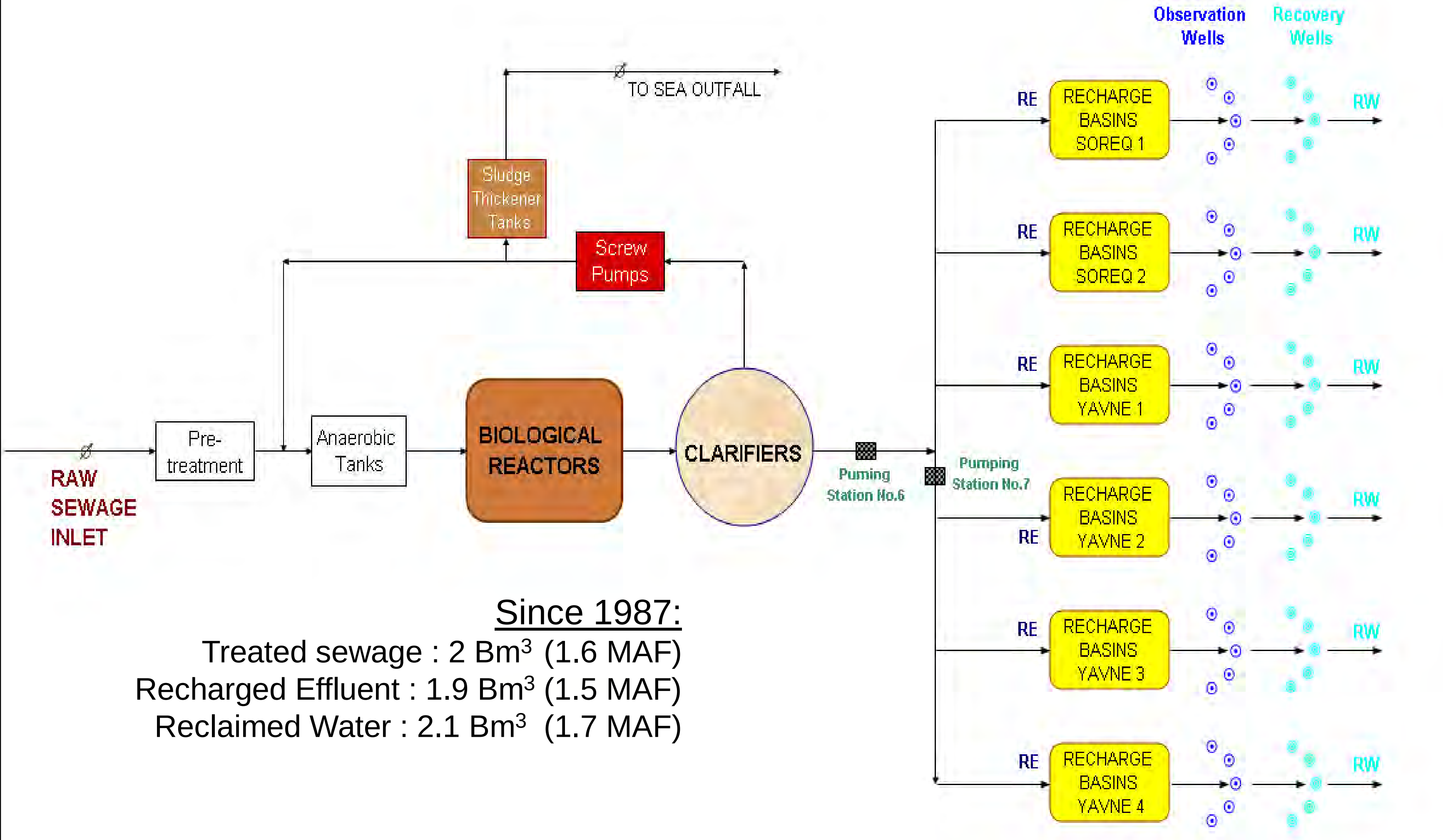
DAN REGION WWTP AND SAT FIELDS





Orly Oren, Ittai Gavrieli, Avihu Burg, Joseph Guttman, Boaz Lazar

Dan Region WWTP and the Soil Aquifer Treatment System



<u>Since 1987:</u>

Treated sewage : 2 Bm^3 (1.6 MAF)
Recharged Effluent : 1.9 Bm^3 (1.5 MAF)
Reclaimed Water : 2.1 Bm^3 (1.7 MAF)

Shafdan – Yavne 4 Infiltration Field

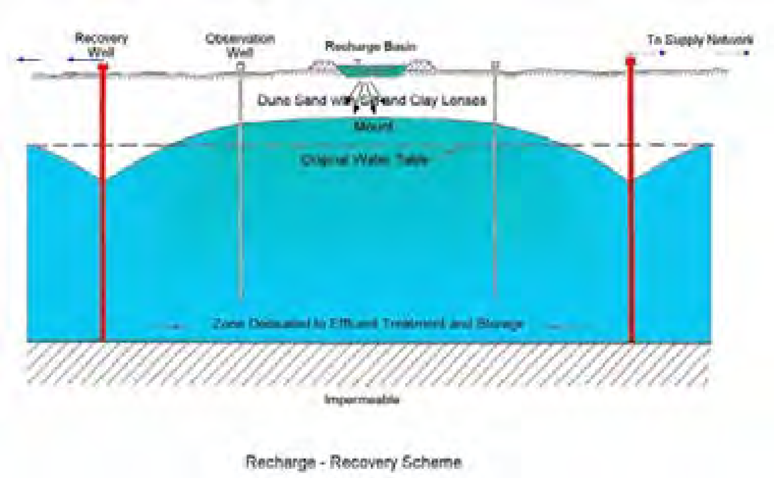
Automatic control of flooding basins

Operation of SAT in Shafdan

SAT basins – Each are divided to sub-basins

View from a sub-basin at the beginning of the filling cycle and a soil treatment machine

Cross Section of the
Soil and Aquifer
under the Recharge Area



Vadoze Zone
Aerobic/Anoxic

Ground Water
Level

Detention time: 6-12 months

The Third Line to the Negev

Distribution system of reclaimed water from Shafdan to Negev

Reclamation Aims

• Supply of 160 - 170 MCM/Year (130,000 – 140,000 AF/Y) for irrigation to replace fresh water with reclaimed water for agriculture

Granot pump station along the Third Line Project (25,000 Cm/h – 20 AF/h)

Seasonal reservoir in the Third Line Project North Bsor - 2.2 Mcm – 1780 AF

Operational reservoir in the Third Line Project
Granot B – 50’000 cm – 13.2 MG

Why SAT was chosen for effluent reuse in Israel

- Inexpensive
- Available open area and far from residential sites
- Warm climate
- Simple to operate
- Reliable process
- Seasonal storage in periods of low demand,
- Design options:
    1. Accidental drinking water quality
    2. Unrestricted irrigation quality

Operating Conditions for SAT

Hydraulic loading	m/d	0.2 - 0.6+
Wetting cycles	days	1 - 2
Drying cycles	days	2 - 4
Cleaning cycle	days	< 15 - > 30
Depth of Unsaturated Layer	m.	5 - 30
Depth to Saturated Layer	m.	20 - 50 (max. 100)
Retention time in ground	months	< 6 - > 12
Recovery	%	up to 100 %

Key Design/Operation Factors:

- Maintaining Infiltration (hydraulic loading)
- Soil mantel – Sandstone layer (Minimum Clay)
- (Residence) Time
- (Travel) Distance
- Managing Redox (oxidation-reduction)

Third Line elements for irrigation

- 150 recovery wells ,150 – 300 m^3/h – 5,000-10,000 F^3/h, 80-170 m’ depth, 300-1700 m’ from recharge basins.
- 70 observation wells, 35-190 m’ depth, 30-1,000 m’ from recharge basins
- 90 km of main pipeline, mostly 70”
- 8 pump stations up to 25,000 m^3/h (6,600 MG/h) with up to 80 meter Head
- 6 operational reservoirs ,510,000 m^3 - 18 MF^3
- 5 seasonal reservoirs, 17,500,000 m^3 – 620 MF^3
- Quantities supplied – 170 Mm^3/Y - 0.14 MAF/Y, 400 AF/day, 20 AF/h
- Quality – Accidental Drinking Water Standards
- Area irrigated – up to 125,000 Acres
- Crops irrigated – orchards, wheat, vegetables, flowers, spices

Design parameters for SAT system for 10 MCM/Year

- **Sandstone aquifer, minimum clay layers < 10%-20% , no karst layer**
- **Infiltration area : 10 hectare**
- **Divide to sub basins, apply cycles of flood and dry regime**
- **Total reclamation area : 100 hectare**
- **Vadose Zone depth : 10-30 m'**
- **Saturated layer :> 50 m'**
- **Reclamation Wells: 12 wells of 150-200 m3/h each (20 hours/day pumping with an excess capacity)**
- **Post - treatment devices against sand entrainment : Hydro - cyclone, Sand master, flow controlers**
- **Monitoring and prevention of contamination of adjacent drinking water wells**
- **Design of the supply system to consumers (pump stations with net wires against algae or floating covers and pipes)**
- **Seasonal storage reservoirs (months)**
- **Operational reservoirs (hours up to few days)**

CAPITAL AND OPERATIONAL COSTS FOR A TYPICAL INFILTRATION FIELD AND DISTRIBUTION LINE

Capital costs, O&M, labor, energy calculations

1. For area **A m^2** for only SAT infiltration the total area needed for including infrastructure, is **2A and the hydrological area under the SAT (Vadose Zone)** will be **10 A to a 60 - 100 m depth.**
2. **345 €/m. pipe for 36-44" SS pipe and 862 €/m. pipe for 70" cement coated SS pipes.**
3. **Useful Life: 40 years** for piping, for cement and infiltration ponds for the SAT system. **15 years** for pumping stations

a. **For a 20 Mm^3/yr infiltration field that was operated in 2003, including excavation equipment, sand** replacement, pipe - lines, electro-mechanical parts, valves, pumps. **0.2 €/m^3 effluent treated.**

b. **15 years return on investment on pumping stations and wells and 40 years for piping and infiltration** fields. The total cost of **0.23 -0.25 €/m^3 will be divided 30% investment 70% labor and operation maintenance costs.**

c. **Operation and maintenance for infiltration (including treatment for the clogging problem), recovery and** distribution would cost **0.1 - 0.15 €/m^3**

d. **Labor: For 140 Mm^3/yr for Dan Project In the distribution system 5 people in direct contact with the end** – users. For the SAT system one field person, 2-3 in the controlled room, 1-2 for field cleaning, for O & M, 2 -3 man for mechanical and 1-2 man for electrical , for distribution system another 10 persons for different O & M all this does not include the administrative staff and engineers that can put the whole project manpower to almost 70 .

e. **Energy consumption: 4 W - hr m^3/m head Total energy for secondary WWT, SAT, extraction and for** distribution **1.42 kWhr/m^3.**

f. **The SAT system does not generate any sludge. No chemicals are used.**

HYDRO-GEOLOGICAL ASPECTS AND DESIGN PARAMETERS SHAFDAN SAT WATER RECLAMATION SYSTEM

Geological cross section in the recharge basins

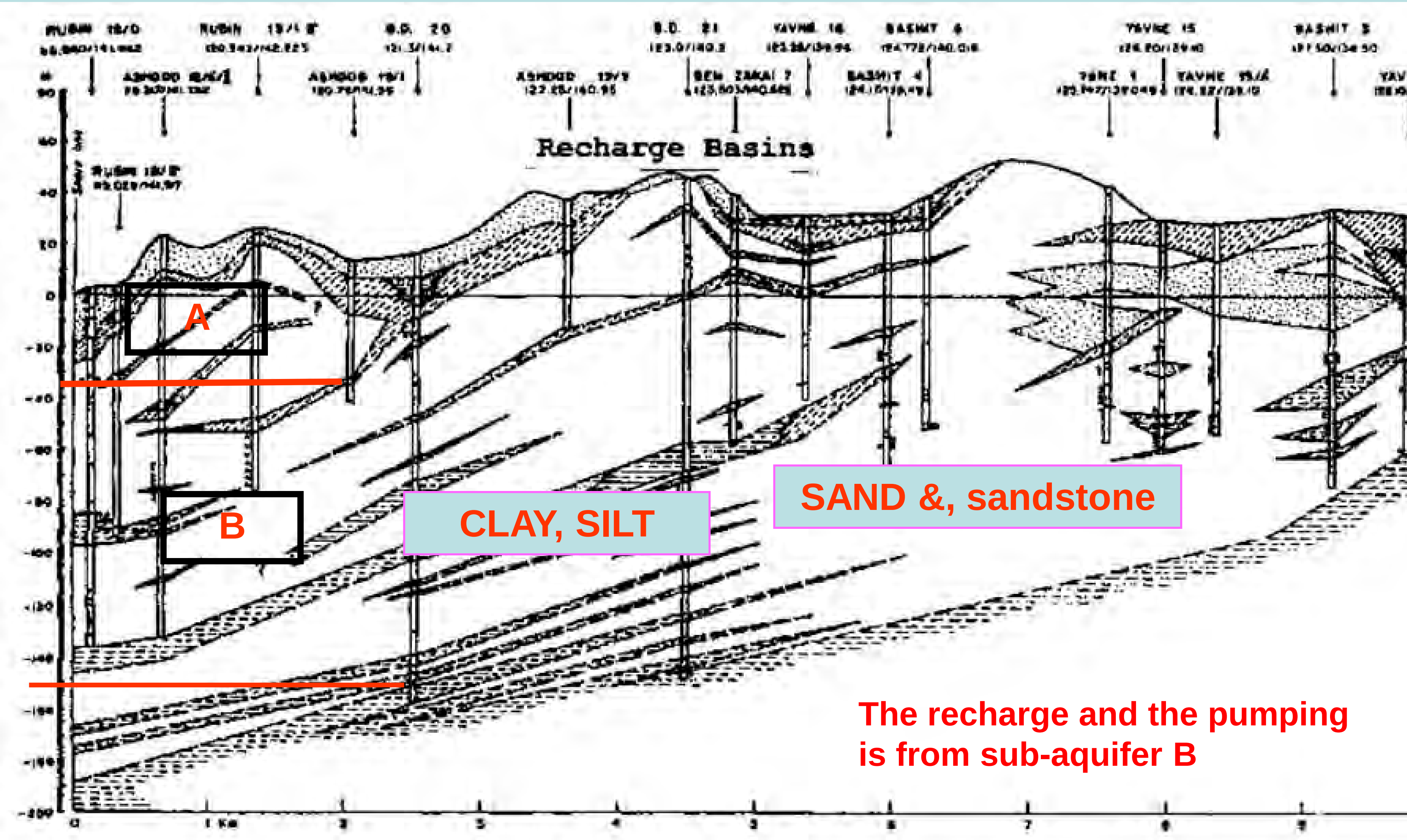


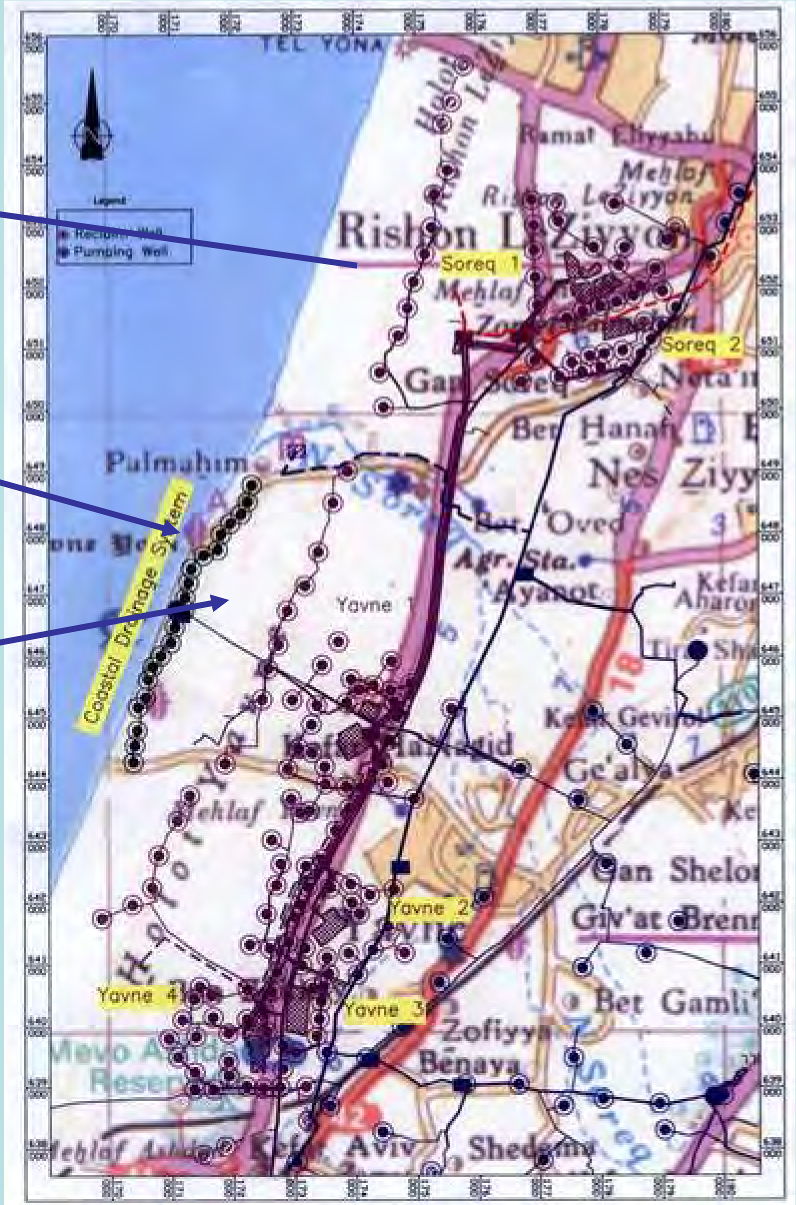
Fig. 3: Geological Cross-section through Yavne Recharge Basins

Location map

Rishon drainage system

Rivlin drainage system

Yavne drainage system



Near the sea, the coastal drainage system drain the effluent water from the aquifer help maintain a barrier between the sea and the secondary effluents aquifer. The wells draw water from the upper parts of the aquifer

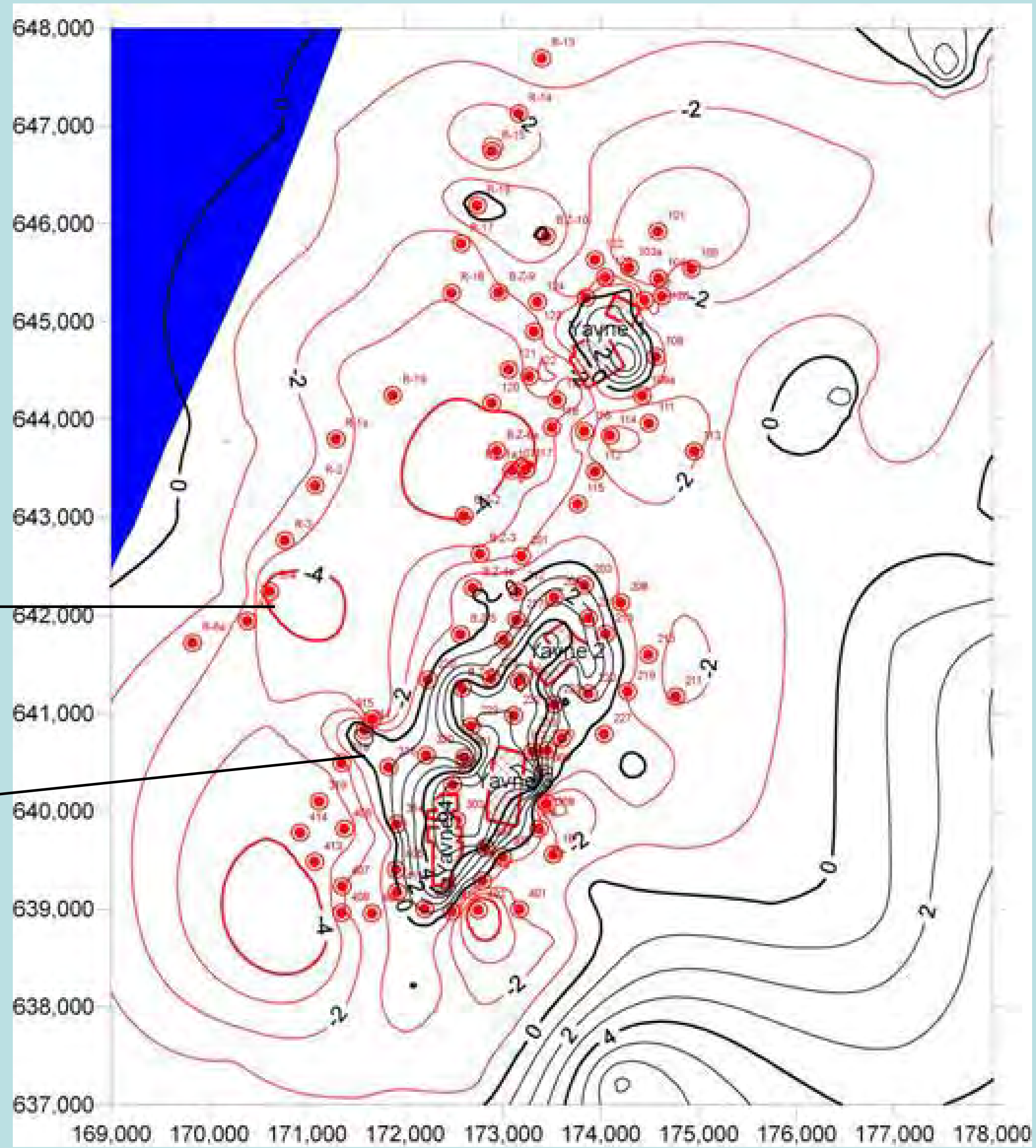
Water level autumn 2007

Temporary low water level between the ponds and the sea:

Not recommended situation

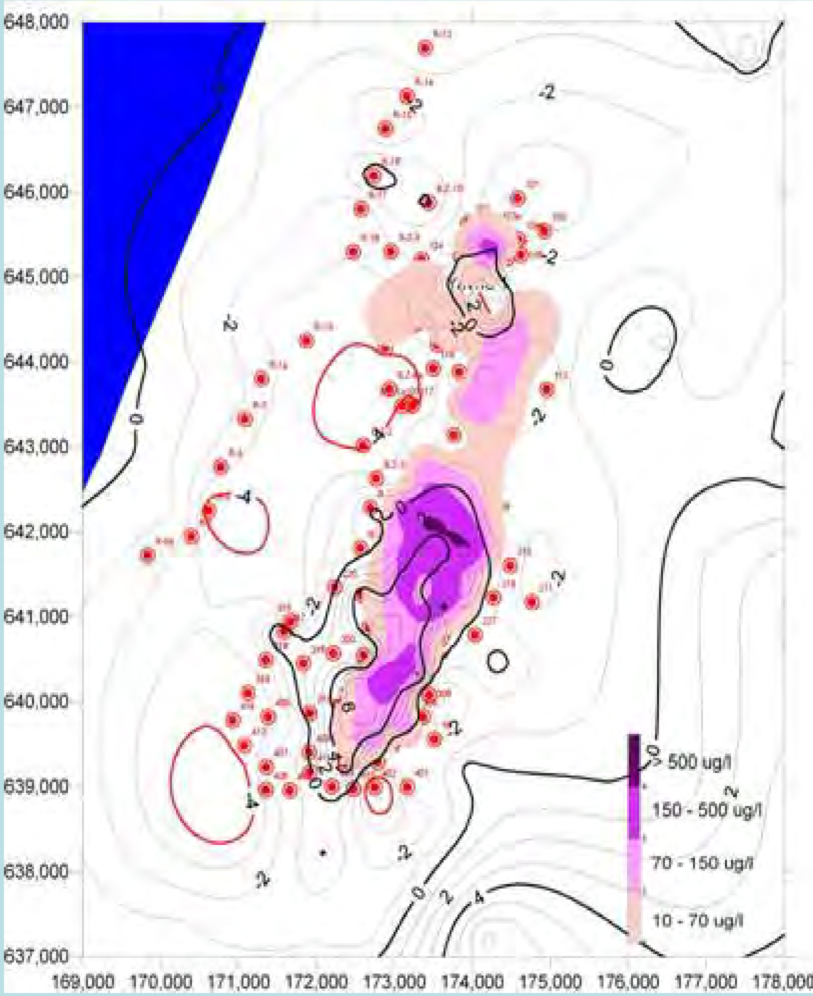
Lower than sea level

Higher than sea level

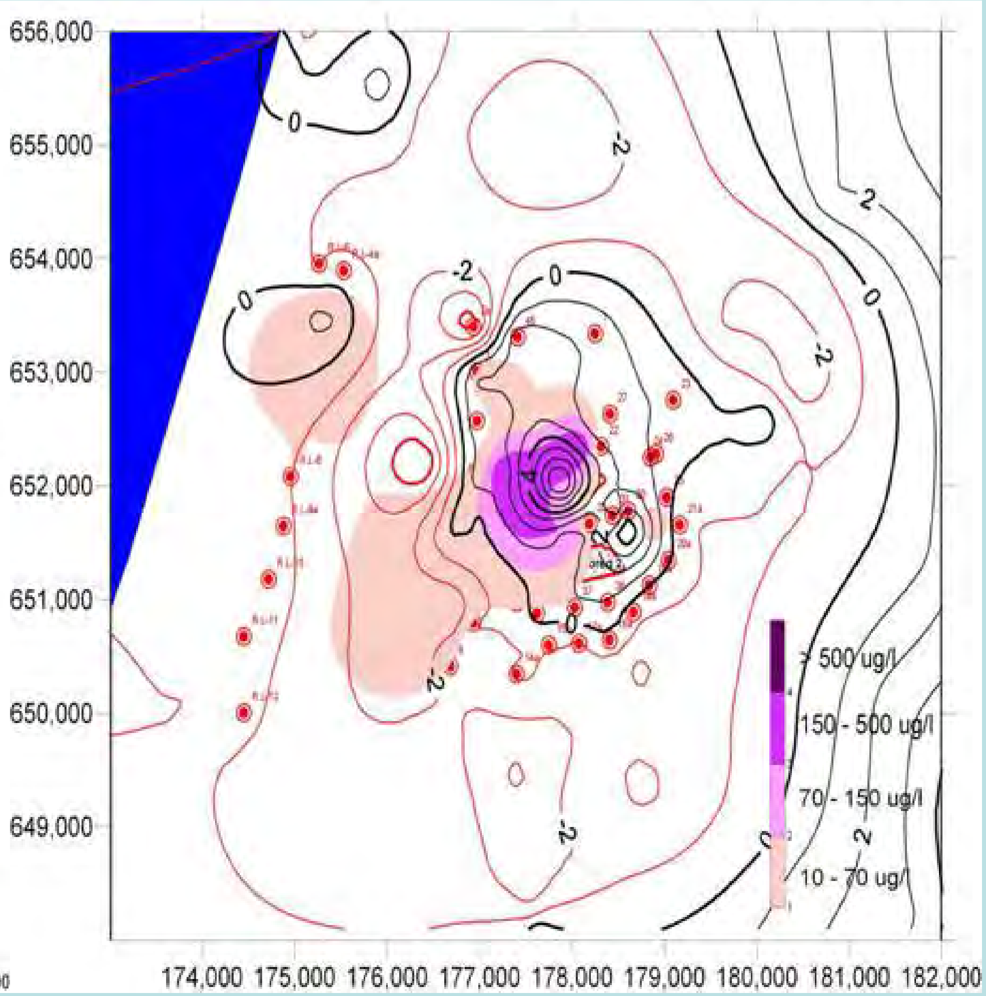


Mn concentration below the ponds

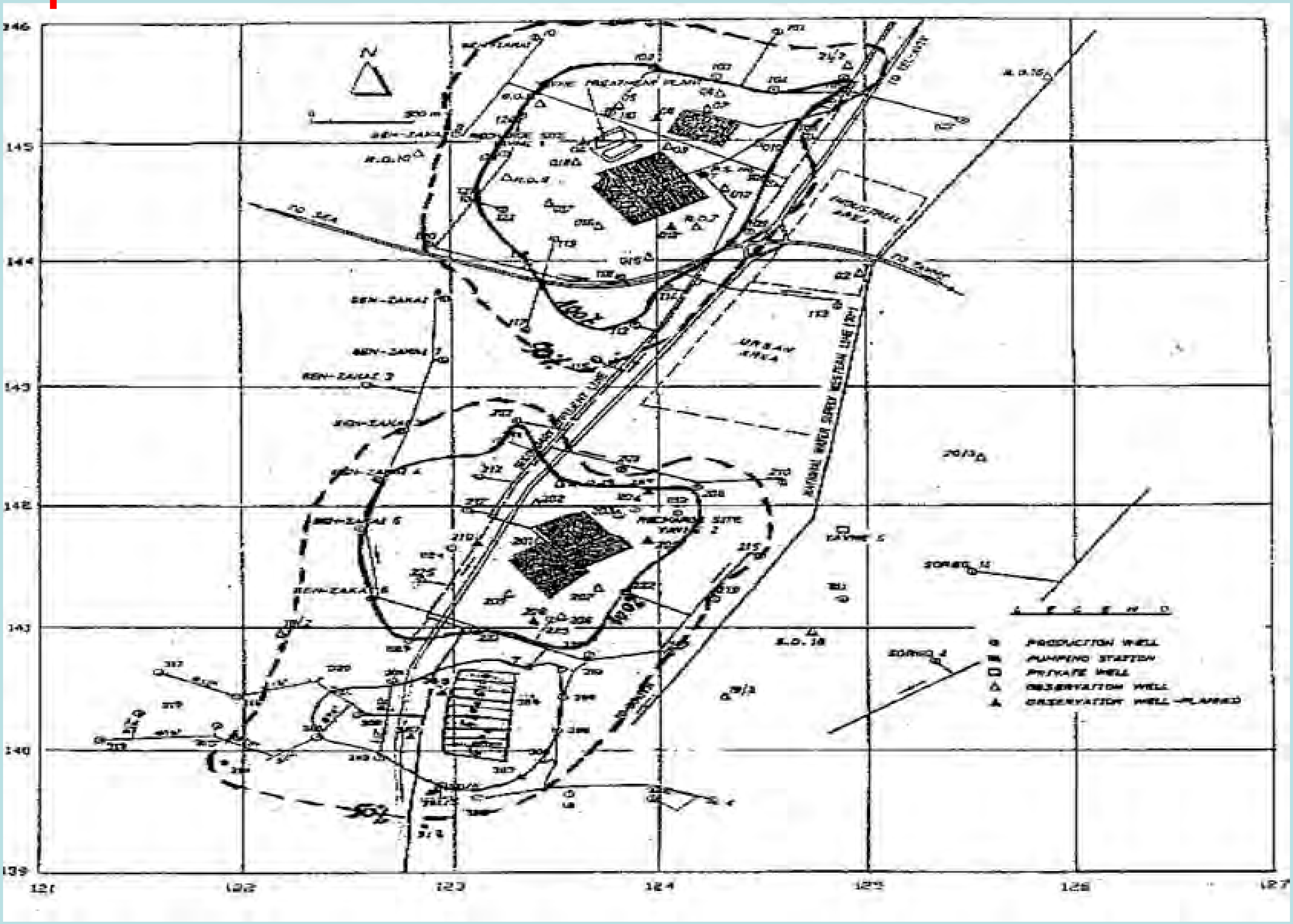
YAVNE



SOREQ

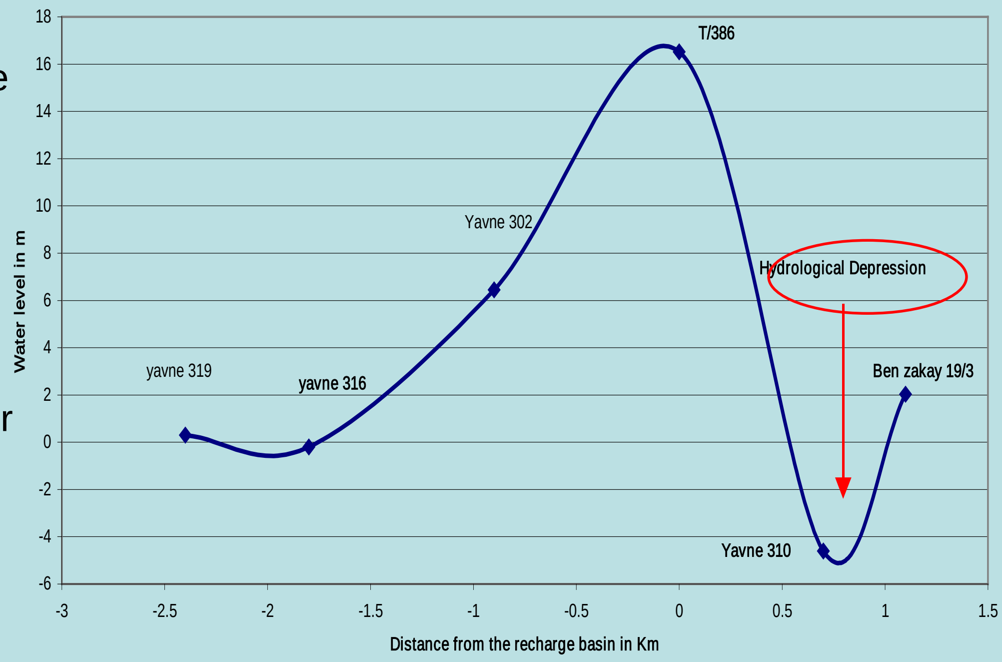


Approximate spread of recharge effluents in the aquifer November 2001 – YAVNE 1 and YAVNE 2



Simultaneous production of fresh and reclaimed water in adjacent areas.

- In proximity to the recharge basins there are well fields that pump water from the same layers as for drinking purposes and without any geological barrier between the two water bodies.
- The recharged water creates a mound of water beneath the basins. This water is flowing down streams in all directions and can contaminate the drinking water wells.
- To avoid any contamination and to allow simultaneous production of fresh water and reclaimed water in adjacent areas, a low water level zone has been created. This water level zone (hydrological depression) acts as a buffer zone.
- The water in this depression is a mixture of effluent and freshwater. This water is supplied for agricultural uses.
- The shape of the buffer zone is asymmetric with sharp gradient towards the recharge basins and low gradient towards the aquifer area- upstream. The asymmetric shape is a result of the high infiltration in the recharge basins (that raises the water levels) and the high pumping rate in wells close to the hydrological depression.
- The buffer zone enables us to operate simultaneously the drinking water aquifer and the effluent recharge to the same aquifer without any kind of geological barriers but only a hydrological barrier.

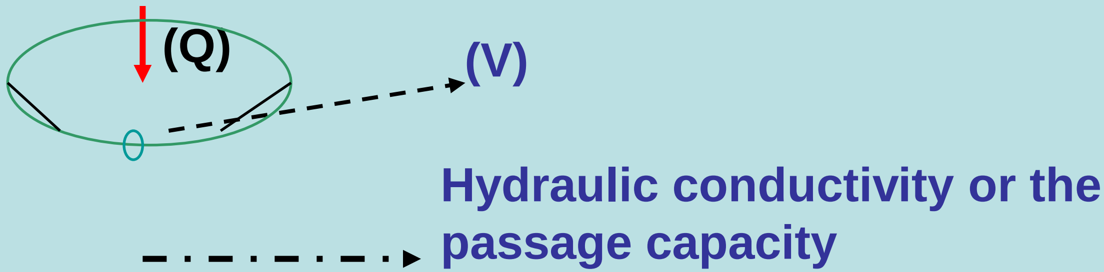


IMPROVED SAT SYSTEMS

The motivation for improved SAT processes

- Israel - A semi - arid country
- Population growth, expanding modern economy
- Agricultural irrigation could be mainly affected.
- A reliable, easy to operate and relatively cheap, effluent reuse process (Soil Aquifer Treatment – SAT) can be part of the solution.
- The actual SAT system saves 135 - 140 MCMY of fresh water by supplying an almost drinking water quality to agricultural irrigation.
- Due to lack of land for construction of new fields and some gradual clogging of the actual fields the SAT capacity is decreasing.

The "sink" effect



When the flow into the sink reaches the "passage capacity" overflow can occur.

Due to clogging, the "passage capacity" decreases and the incoming flow has to be reduced

<u>The same is true for the SAT system:</u>

1. Gradual decreases of the hydraulic conductivity also due to hydrophobicity
2. Due to lack of new infiltration areas while the effluent application rate increases, the hydraulic conductivity limits the drainage capacity and the over all infiltered volume decreases.

Research projects related to SAT in the Dan Region WWTP

In order to improve the hydraulic loading and to study the manganese dissolution phenomena, a series of research projects have been conducted in the Dan Region WWTP since the mid-90's.

These projects have been studying:

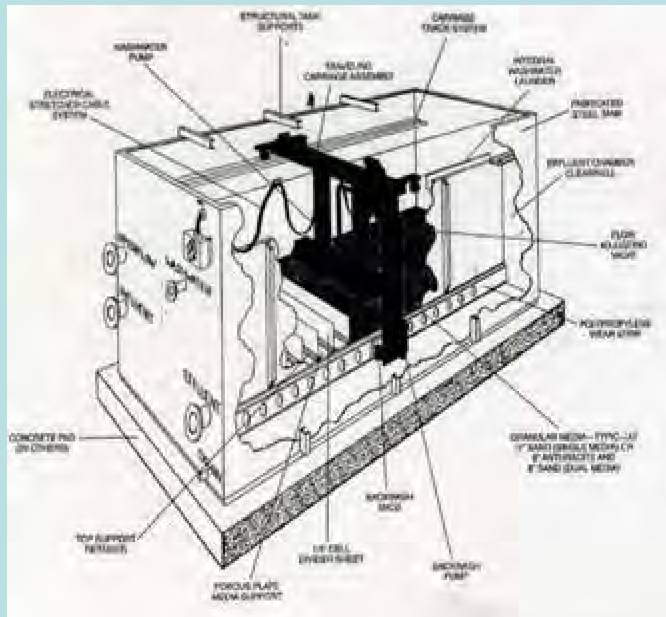
1. The geochemical processes
2. The pre-filtration methods before SAT
3. The Mn dissolution problem
4. The hydrophobicity of the soil
5. The ways to improve the operational conditions
6. New processes like UF-SAT and SAT-NF

Improvement of Infiltration Rates of Recharged Secondary Effluents at Shafdan by different pre-filtration systems

Mekorot Shafdan Engineers and Hebrew University, Jerusalem- A. Adin

(1997-1999)

Deep bed pressure filter



Cell (traveling-bridge) filter
(shallow –bed gravity filter)

Shallow bed pressure filter

700 micron wire and brush filter

Infiltration improvement experiments in pristine sand near the WWTP using 20 m^2 surface area SAT fields

Secondary effluents

In –line coagulated
(10-20 mg/l alum and 0.1 -0.2 mg/l P.E.)
and deep –bed pressure filtered effluents

A maximum of 11 m/d drainage rate was obtained by the coagulated-deep bed filtered effluents as compared to 2 m/d by the secondary effluents in the pristine sand and this as compared to 0.5-2 m/d in the actual SAT fields

Characteristics of different pre-filtration equipment

Jacobo Sack, Haim Cikurel, Itay Sirak, Nelly Tal, Remy Blank, Yehuda Reich

Period	*Total flooding days*		*Untreated effluents*	*Pre-filtered effluents*	*Deep bed pressure filter*	*Shallow bed pressure filter*	*Shallow bed gravity filter*	*7 μm fiber sieve filter*
7/11/97-12/1/98	14	Drainage rate m/day		3.6			10.6	6
1/2/98-31/3/98	12	Drainage rate m/day		2.6			9.8	6.5
6/4/98-15/6/98	15	Drainage rate m/day	2.4	3.1	10.9	10.7		
3/6/98-13/8/98	15	Drainage rate m/day	1.1	1.8		8.3		
		Average drainage rate m/day	**1.75**	**2.7**	**10.9**	**9.5**	**10.2**	**6.25**

- The flooding is 1 day and drying in 2-3 days.
- The drainage rate is the rate the effluents infilter through the 20 m^2 area.

Flocculants were used in all deep and shallow bed media filters

Conventional SAT:

Data

1. 140 MCM/year infiltration in 100 ha.
2. 1 day flooding, 2 days drying
3. Retention time – 6-12 months
4. After 30 years of infiltration
5. Infiltration velocity 1 m/d

Problems

1. Deterioration in Recharge Capacity (OM, Temp, Rain)
2. Bio-fouling of Effluent Pipelines (Before and after SAT)
3. Clogging of irrigation systems due to Mn , Fe release
4. No more new lands are available for infiltration !!

For this purpose, in recent years, new hybrid treatments have been proposed, including advanced pretreatment methods like:

1. Polishing of the secondary effluents before SAT by the use of UF, rapid infiltration of the UF effluents in a Dug-well and recovery of the water after a short SAT (15-20 m. travel distance and around 30 days residence time) to obtain very high quality water for unrestricted irrigation. EU RECLAIM

(Gaus et. al., 2007; Cikurel & Aharoni, 2011)

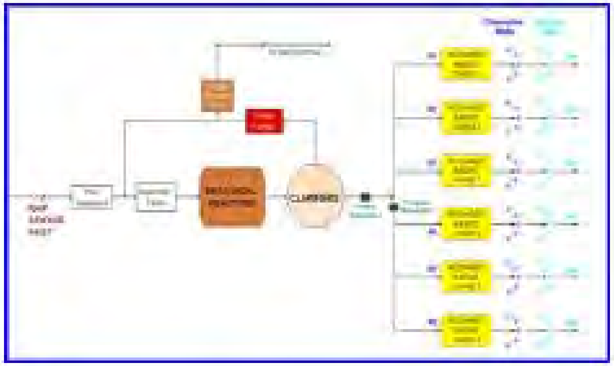
2. Surface spreading infiltration of tertiary treated effluents (sand filtered secondary effluents) in a short - SAT system (15 m.-20 m. travel distance and around 30 days residence time) as pretreatment for NF to polish the SAT effluents to indirect potable reuse quality water. EU SWITCH project

(**Cikurel et al., 2010**)

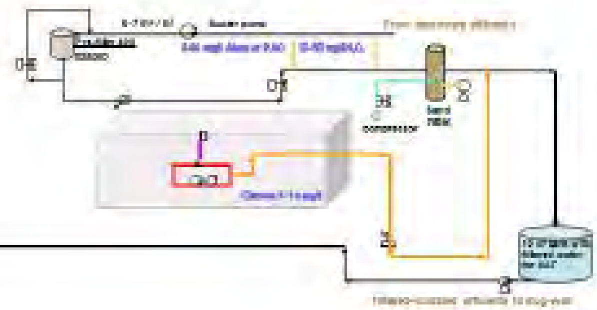
3. Flocculation-aeration-filtration and AOP (ozone-hydrogen peroxide) pretreatment prior to dug-well infiltration and short- SAT process for the degradation and removal of micropollutants and prevention of manganese solubilization. Pre ozonation –SAT project

(Maman et. al, 2010)

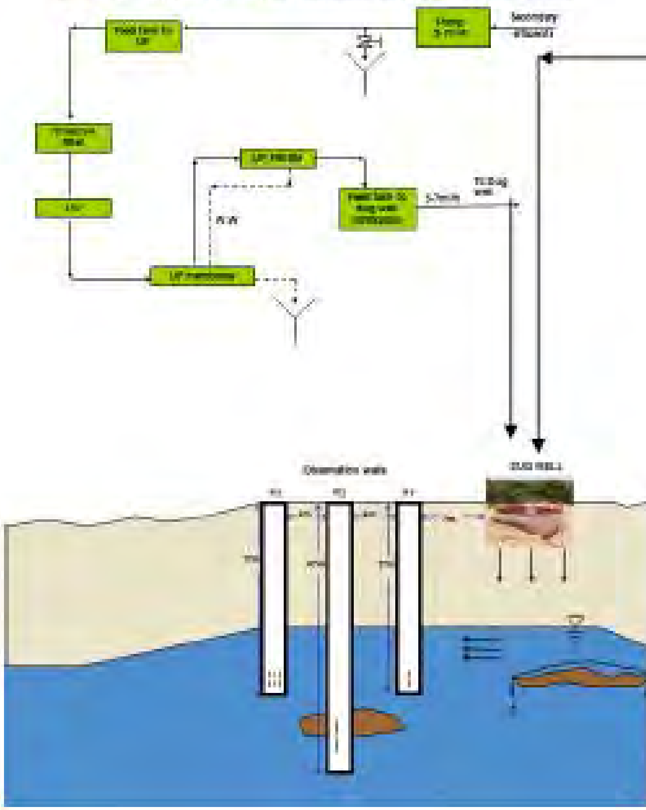
Conventional and Hybrid SAT systems



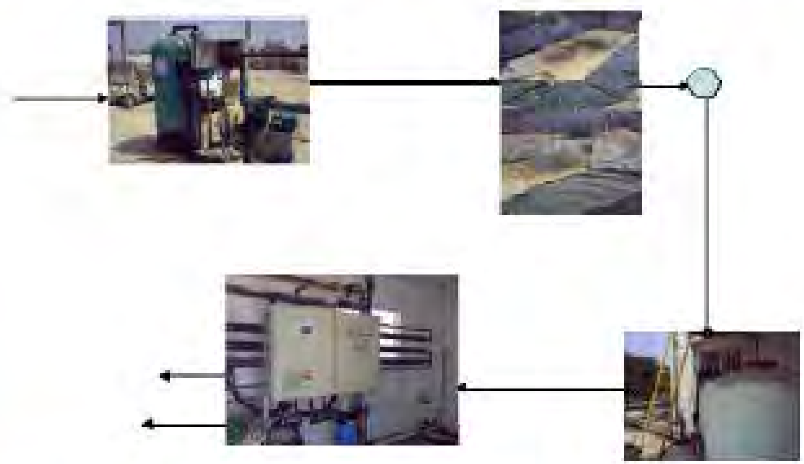
1. Dan Region WWTP and the Conventional Soil Aquifer Treatment (SAT)



2. RECLAIM pilot plant: UF filtration of secondary effluents



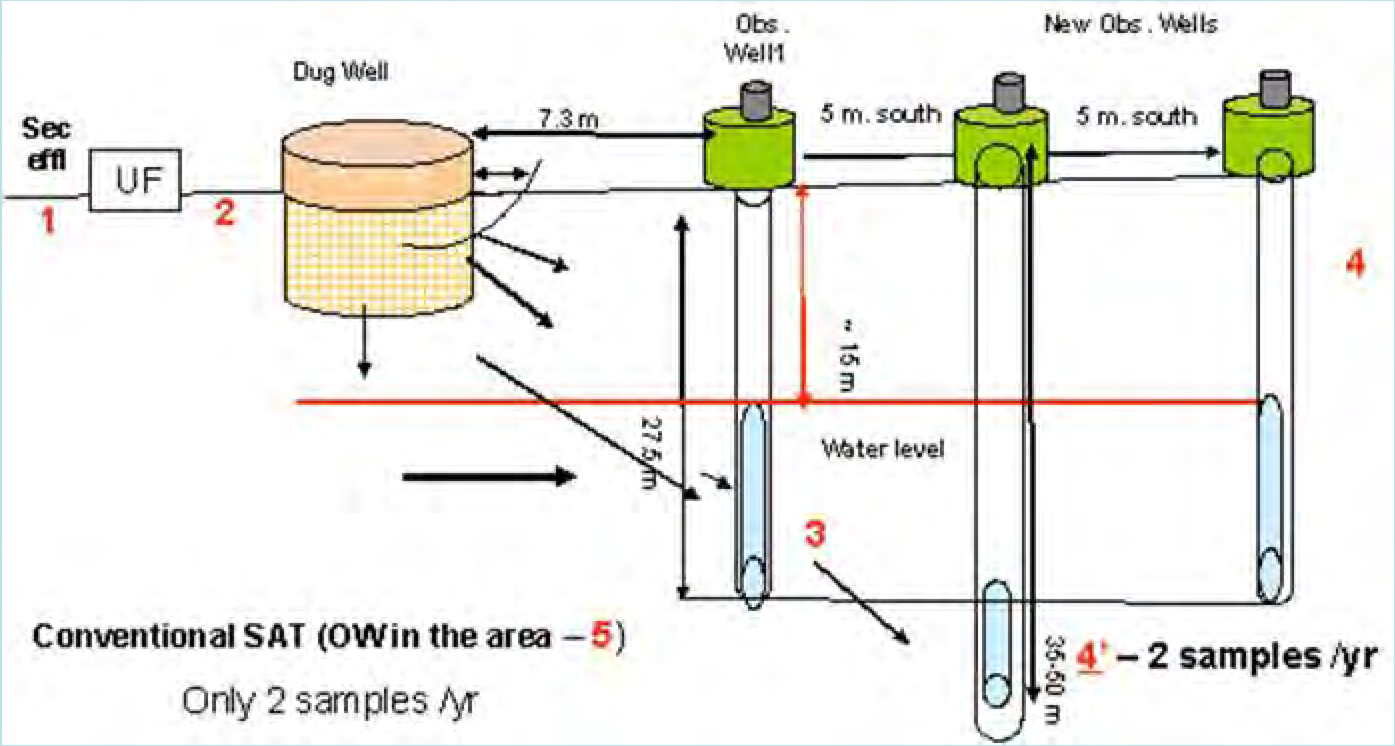
3. OZONATION pilot plant: improvement of the short SAT anoxic conditions and reduction of manganese dissolution by aeration-sand filtration - ozonation of the secondary effluents (German –Israeli cooperation project)



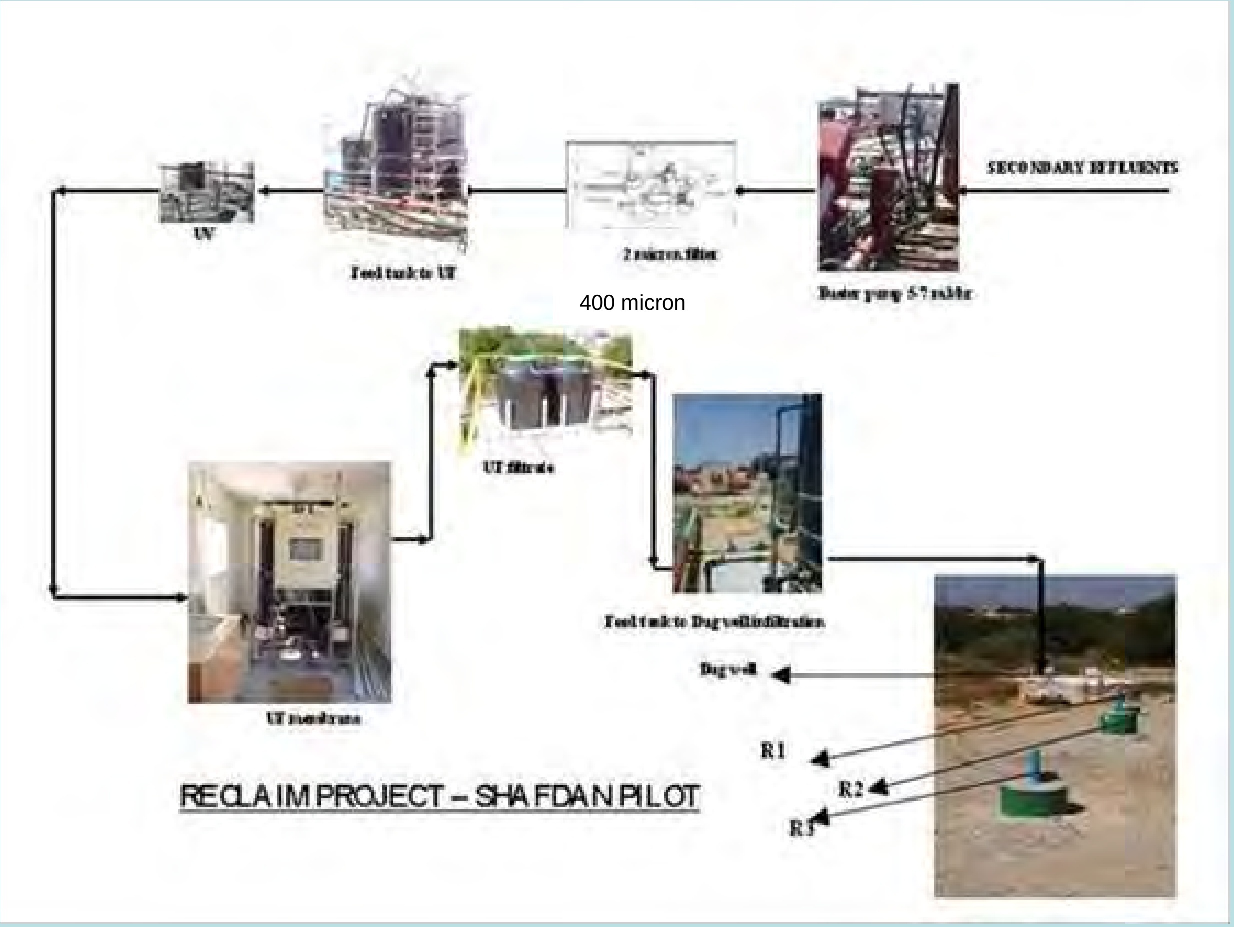
4. SWITCH pilot plant: Sand filter-Short SAT –NF to improve infiltration velocity, organics and micropollutants removal

Location of the Shafdan WWTP and the Reclaim pilot system

SAMPLING POINTS



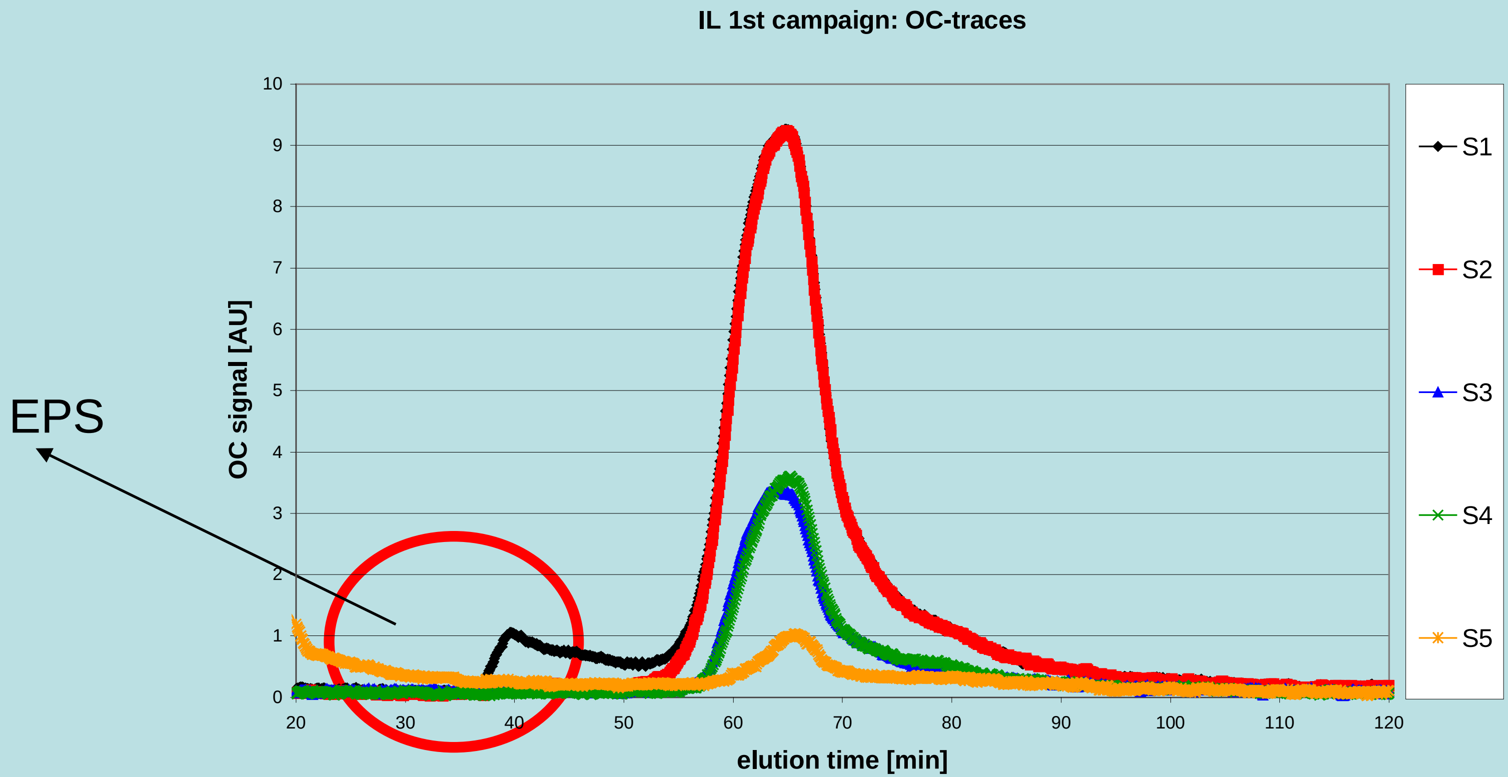
RECLAIM


SECONDARY EFFLUENTS
UV
Feed tank to UF
400 micron
UF filtrate
Dug well
R1
R2
R3
RECLAIM PROJECT – SHAFDAN PILOT

DOC distribution
(effluents after UF , after OW 1 and 3, after conv. SAT

Table 4.4: DOC concentrations – 1st campaign

Sample	S1	S2	S3	S4	S5
DOC, mg/l	8.45	7.88	3.24	1.97	1.21



- Exclusion effect of UF, no other differences on DOC distribution

From RECLAIM project Project no. 018309

RECLAIM

Chemical parameters:

Parameter	Unit	Sec. Effl.	R1	R3	CAS +LONG SAT***(max)
COD	mg/L	34-37	3-10	4-7	2-4
DOC	mg/L	10-12	2.1-3.2	1.6-2.5	0.5-0.6
Ammonia	mg/L	0.6-2.0	0.02-0.05	0.07-0.1	0.02-0.05
Phosphorous	mg/L	1.6-2.3	0.1-0.4	0.04-0.06	0.02-0.03
Nitrate	mg/L	0.2-0.3	2.5-3.2	0.2-0.7	6.3-6.8
Manganese	µg/l	11-15	109-218	260-410	12-17
Iron	µg/l	62-74	27-30	23-32	16-20

** After 1 year infiltration. The analyses results relate to 30 days retention time in the aquifer

*** After 30 years of infiltration. The analyses results relate to 300 days retention time in the aquifer

R1 – First OW 10, days retention time

R3 – Third OW, 35 days retention time

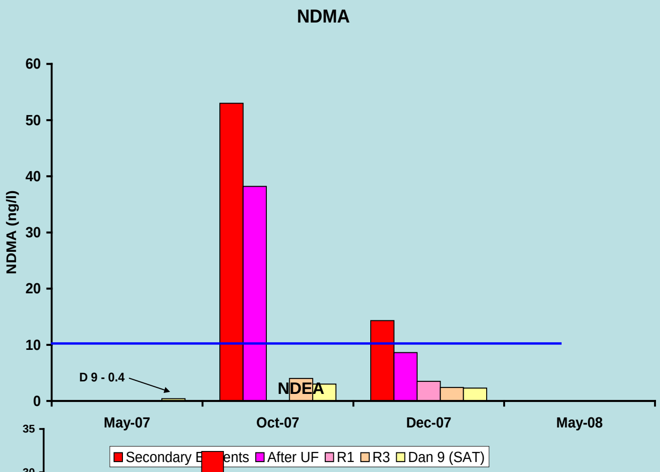
Microorganism removal:

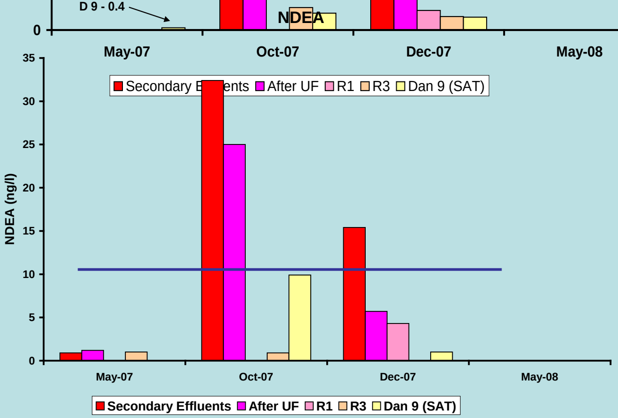
All microorganisms removed by the short SAT:

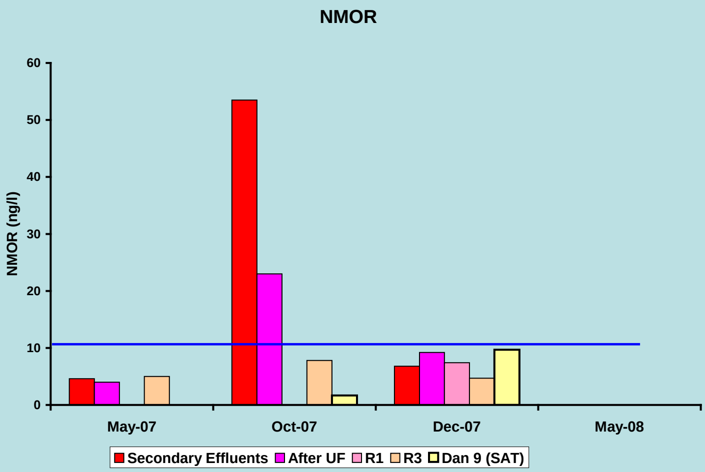
After UF filtration of the secondary effluents and SAT for 35 days retention time all pathogens were removed.

F. Coli (5-6 logs), Enterococci (5 logs), Clostridium (4-5 logs), MS 2 phage (4-5 logs) and complete removal of Enteroviruses

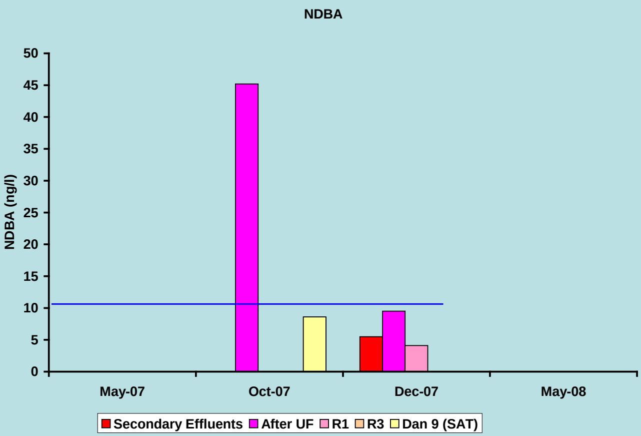
RESULTS
Chosen micro-pollutants







<u>NDMA compounds</u>

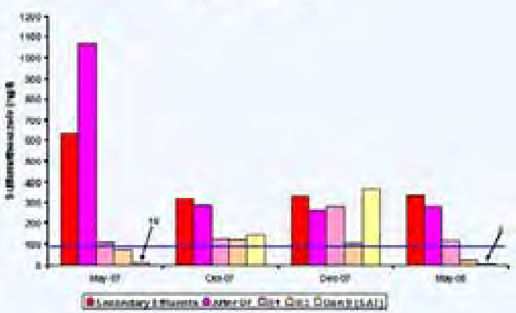


- In some cases when data is not mentioned the concentrations were very low out of the limit of detection.

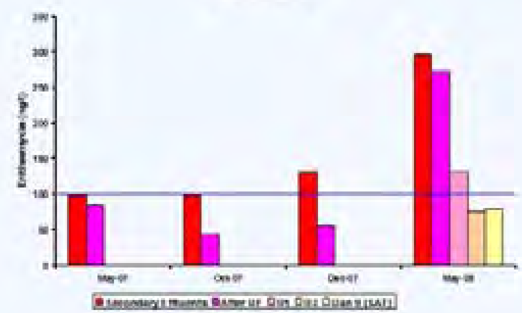
RESULTS

(Chosen micro-pollutants from protocol 2)

Sulfamethoxazole

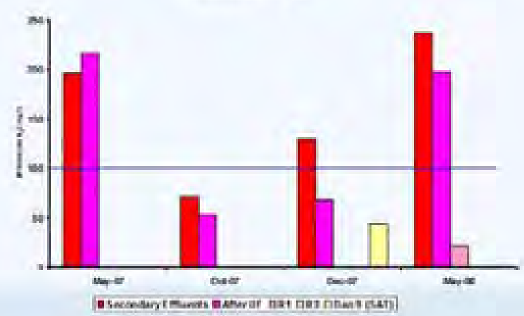


Erithromycin

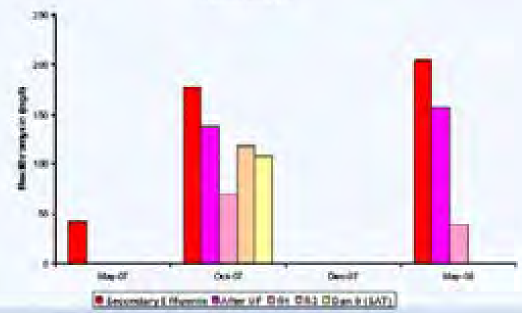


SULFANAMIDE AND MACROLIDE ANTIBIOTICS, CARBAMAZEPINE, BENZATRIAZOLES

Erithromycin. H_2O

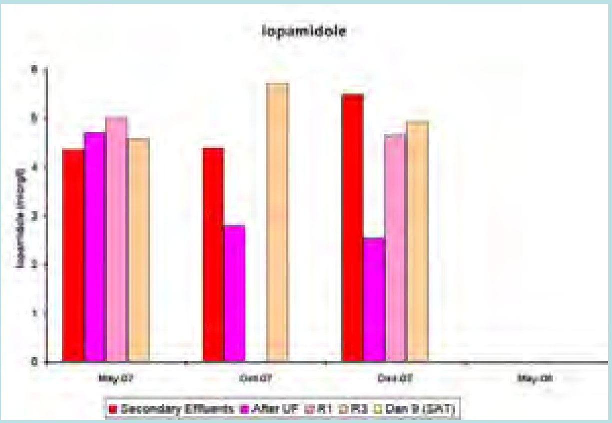


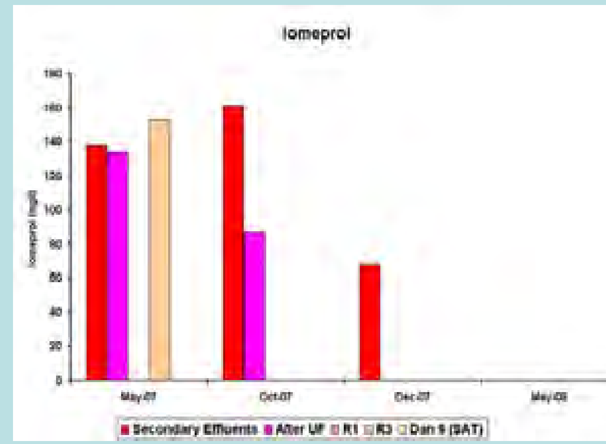
Roxithromycin



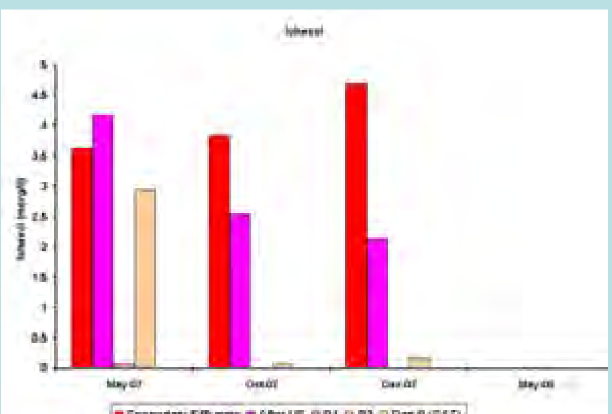
RESULTS
(Chosen micro-pollutants from protocol 2)

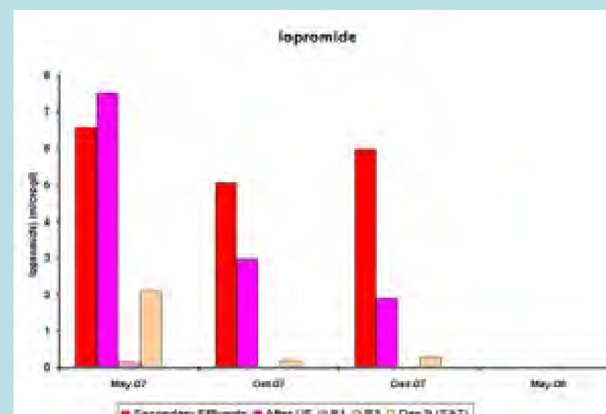
Iodine Contrast Media (ICM)





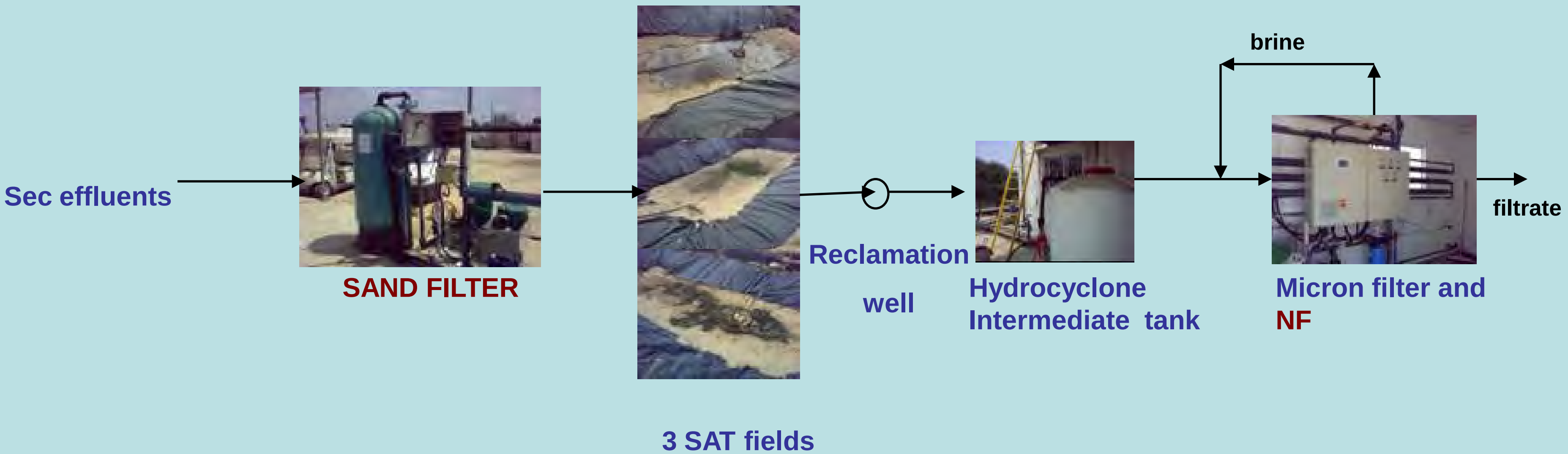
Complete ICM removal by long SAT





LOCATION OF THE SWITCH PILOT PLANT

SWITCH


Sec effluents
SAND FILTER
brine
Reclamation
well
Hydrocyclone
Intermediate tank
Micron filter and
NF
filtrate
3 SAT fields

OPERATING CONDITIONS

1. Sand filter

6 m3/hr, 6-8 m/hr, backwash every 8hrs, no flocculant and chlorine used

2. SAT system

120 m^3/d infiltration (5 m3/hr). 1 day flooding – 2 days drying, actually 3-4 times higher infiltration rate than conventional

3. Reclamation well

15 m3/d reclaimed, 30 days retention time from infiltration point (15 m)

4. Hydrocyclone + Micron filter

Removal of calcareous and loamy sand from SAT recovered water

5. Nanofilter

Dow NF-270: Polyamide-Thin Film Composite

Flow rate: 0.5 m3/hr TMP: 1.2-1.5 Bar Recovery ratio: 90%

Salt reduction ratio (as TDS): 15-20% CIP: Every 6 hrs. with acid

SWITCH

Chemical parameters:

Parameter	Unit	Sec. Effl.	A.Sh.SAT*	Rem. Eff. % (A.Sh. SAT-Sec. Effl.)	A. Nano Filter	Rem. Eff. % (A.NF-A. Sh.SAT)	CAS +LONG SAT**
COD	mg/L	29 - 40	5.0 - 9.0	78-83	2.0 - 3.0	60-67	2-4
DOC	mg/L	9.5 - 10.3	1.8 - 2.3	78-81	0.2 - 0.3	87-89	0.6-0.9
UVabs.	1/cm* 1000	209 - 224	46 - 68	70-78	6.0 - 7.0	87-90	9-13
Ammonia	mg/L	3.17-4.2	0.4-1.0	76-87	0.03-0.1	90-93	0.02-0.05
Phosphorous	mg/L	0.66-1.4	0.03-0.08	94-96	<0.03	>63	<0.03
TDS	mg/L	864 -900	786 - 897	-	687 - 718	13-20	796-852

* After 1 year infiltration. The analyses results relate to 30 days retention time in the aquifer

** After 30 years of infiltration. The analyses results relate to 300 days retention time in the aquifer

All secondary effluent data relate to an average of 2 years and take into account that there are no significant fluctuations in micropollutants concentrations in the Shafdan wastewater

Microorganism removal:

All microorganisms removed by the short SAT: F. Coli (5-6 logs), Enterococci (5 logs), Clostridium (4-5 logs) MS 2 phage (4-5 logs) and complete removal of Enteroviruses

Micropollutants (antibiotics, AOI) concentration in different tertiary treatments of the Shafdan secondary effluents

(Concentrations from all data from Reclaim and Switch)

Micropollutants / Process	Unit	CAS (Shafdan)	CAS+long SAT (conventional)**	CAS+ UF +RO (desalination)	CAS+ short SAT +NF (SWITCH)*	CAS+UF + short SAT (RECLAIM)*
Clarithromycin	ng/l	39-500	0-61	0	0	0
Erythromycin -H_2O	ng/l	93-594	0-43	0	0	0
Roxythromycin	ng/l	55-787	0-108	0	0	0-118
Sulfamethaxazole	ng/l	173-657	10-363	0	0-43	24-120
Sulfamethazine	ng/l	0	0	0	0	0
Trimethoprim	ng/l	62-349	0-18	0	0	0
AOI	µg/l	13-42	11-12.6	-	0.6-3.5	13-22.7
DOC	mg/l	9.8-13.8	0.5-0.6	0.2-0.3	0.2-0.3	1.6-2.3

CAS:Conventional activated sludge

CAS-UF-short SAT: UF polishing of the CAS effluent and infiltration in a 30 days SAT

CAS-short SAT-NF: CAS effluents infiltered through short (30 days SAT) and polished by NF

CAS-UF-RO: CAS effluents polished in two stage membranal treatment (ultrafiltration and reverse osmosis)

CAS-long SAT: CAS effluent infiltred in a 300 days SAT (D9 well)

Note: German recommendation for drinking water values for micropollutants (antibiotics) max. concentration - 100 ng/l.

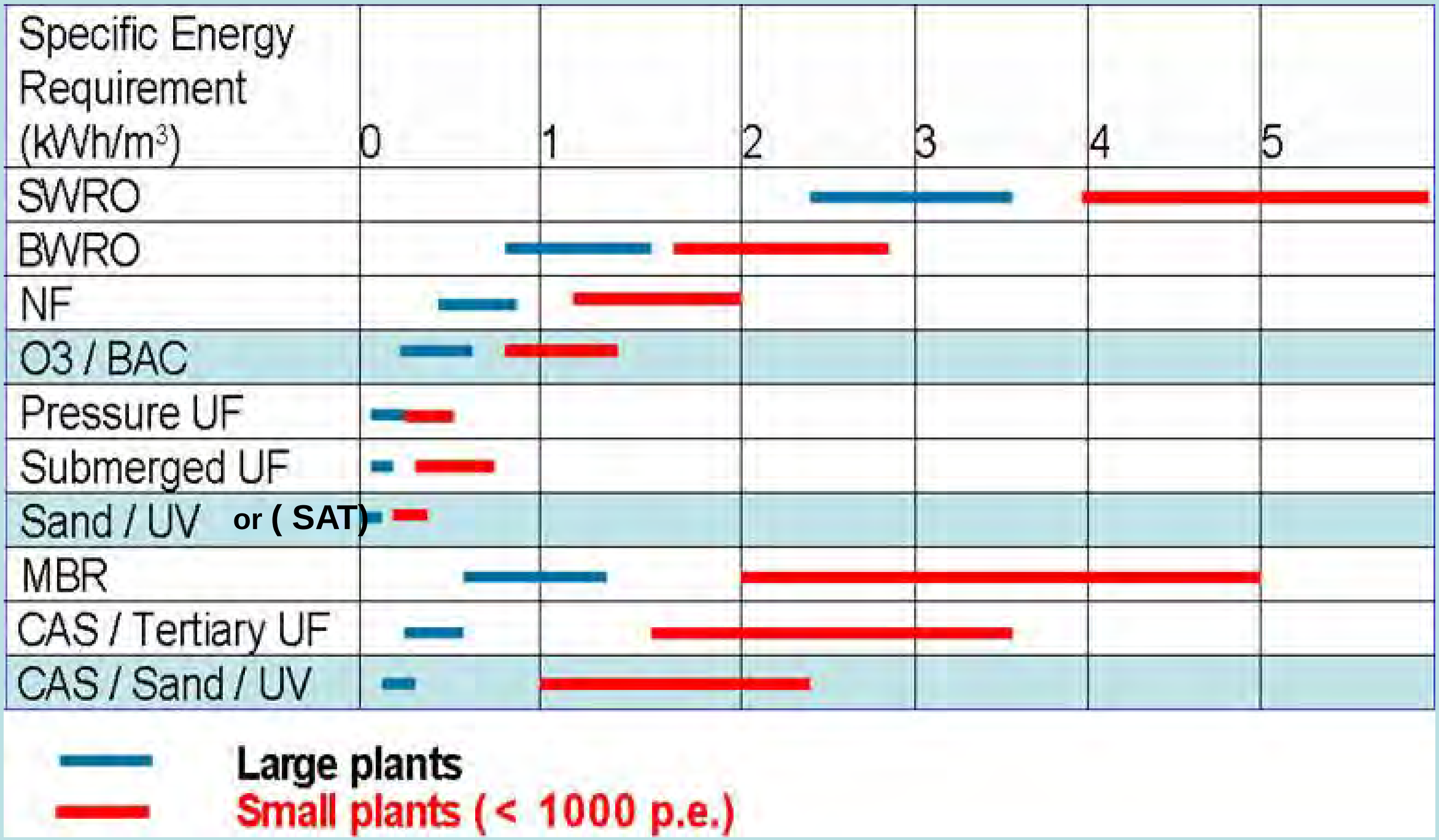
Interpretation of the micropollutants results

- The results obtained within the framework of RECLAIM WATER that
- included analysis at a specific well D9 in the conventional SAT showed in some samples higher than 100 ng concentrations for sulfamethaxazole.
- The UF as pretreatment to SAT and the subsequent short term SAT (RECLAIM WATER) did not effectively removed the sulfamethaxazole.
- In Switch demo experiment the NF polishing step was able to remove
- more effectively the sulfamethaxazole and also AOI obtaining a very low DOC comparable to UF-RO results.
- This was obtained with no significant clogging of the NF due to the short SAT pre bio-filtration.
- The interpretation of these results should take into account that the conventional SAT water is only used for unrestricted agricultural irrigation and not for drinking purposes and the results mentioned in the previous table are based on a specific well (D9).

Innovative features/science

- The importance of micropollutants in drinking water and reclaimed unrestricted irrigation water is more and more increasing as new detection methods decrease the limits of detection.
  Of major concern are the endocrine disruptors, antibiotics and pharmaceuticals.
  The Switch research and Demo is part of recently checked hybrid SAT treatments (membranes and SAT combination) to give an answer to these problems and at the same time reduce the GHG emissions (smaller carbon footprint) as compared to the UF-RO systems

Energy requirements for membranal processes



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- Our thanks to the EU research program FP6 RECLAIM and SWITCH projects that under their framework most of the development work was performed
- OUR THANKS TO DIFFERENT PARTNERS THAT PARTICIPATED IN BOTH RECLAIM AND SWITCH RESEARCH PROGRAM AND WERE RELATED TO OUR PILOT EXPERIMENTS

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