Novel source separating sanitation approach for remote tourist facilities at sensitive coastal areas

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Keywords and introduction

Wastewater treatment systems in tourist areas of Europe without sewage infrastructure are facing extremely challenging conditions:

- **technical and legal requirements,**
- **extreme climatic conditions,**
- **limited energy and water supplies,**
- **large seasonal fluctuations.**

Because of

- **technical problems**
- **poor performance**
- **high water consumption**
- **environmental problems**
- **poor comfort**

Development of a source separation protoytpe for remote located tourist facilities (*7OP SANBOX*)

4 European research institutions :

- UL – University of Ljubljana, Slovenia
- UMB-Norwegian University of Life Sciences
- TU-University of Tartu, Estonia
- TTZ -Technologie Transfer Zentrum
- Bremerhaven, Germany

5 European SME:

- JETS Norway, Norplast Latvia, Seecon, Gysi Switzerland, Bioazul Spain

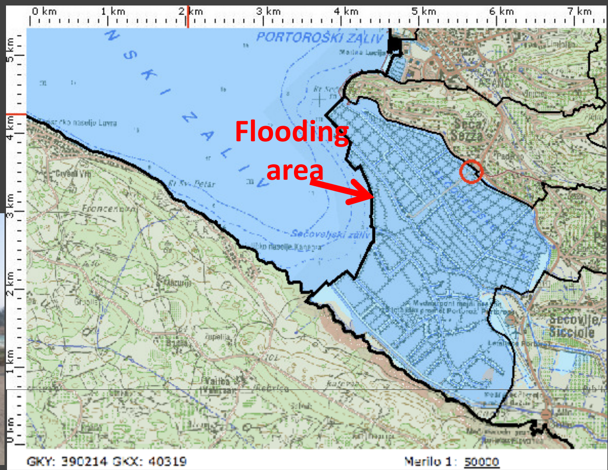
2 End-users:

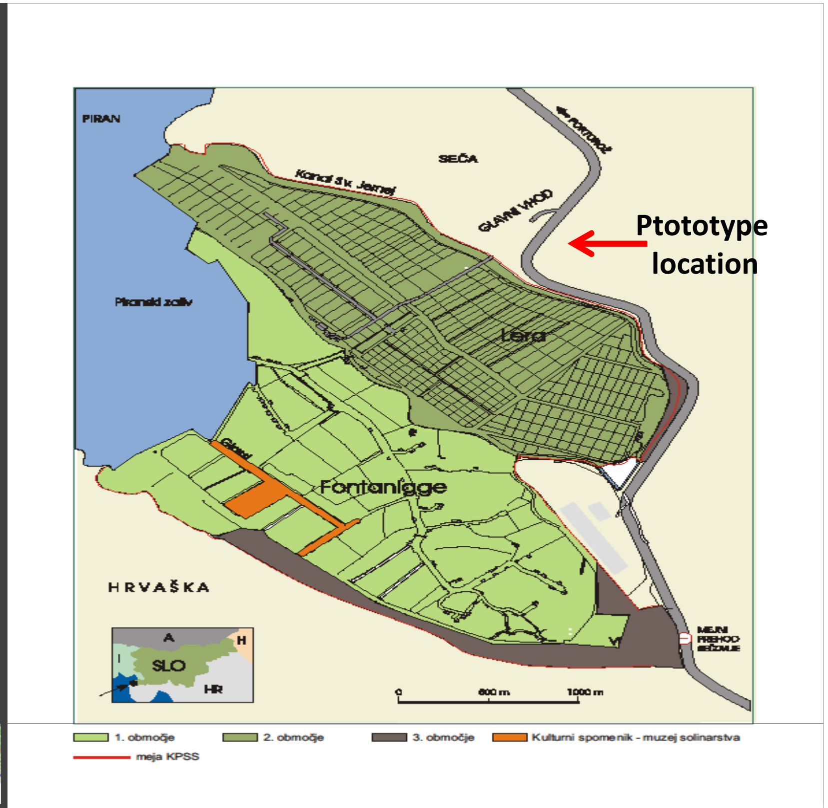
- SOLINE Natural park
- SAC- Swiss Alipne Club (Schweizerischer Alpenclub)

Protoype in Alps

Saas Fee
3000m

Mediterranean prototype





•sensitive area of Adriatic coast

•strong seasonal fluctuation in number of guests (summer peaks of approx. 15.000 visitors compared with annual average of 35.000)

•fluctuated wastewater load which is typical for tourist areas

Main goals

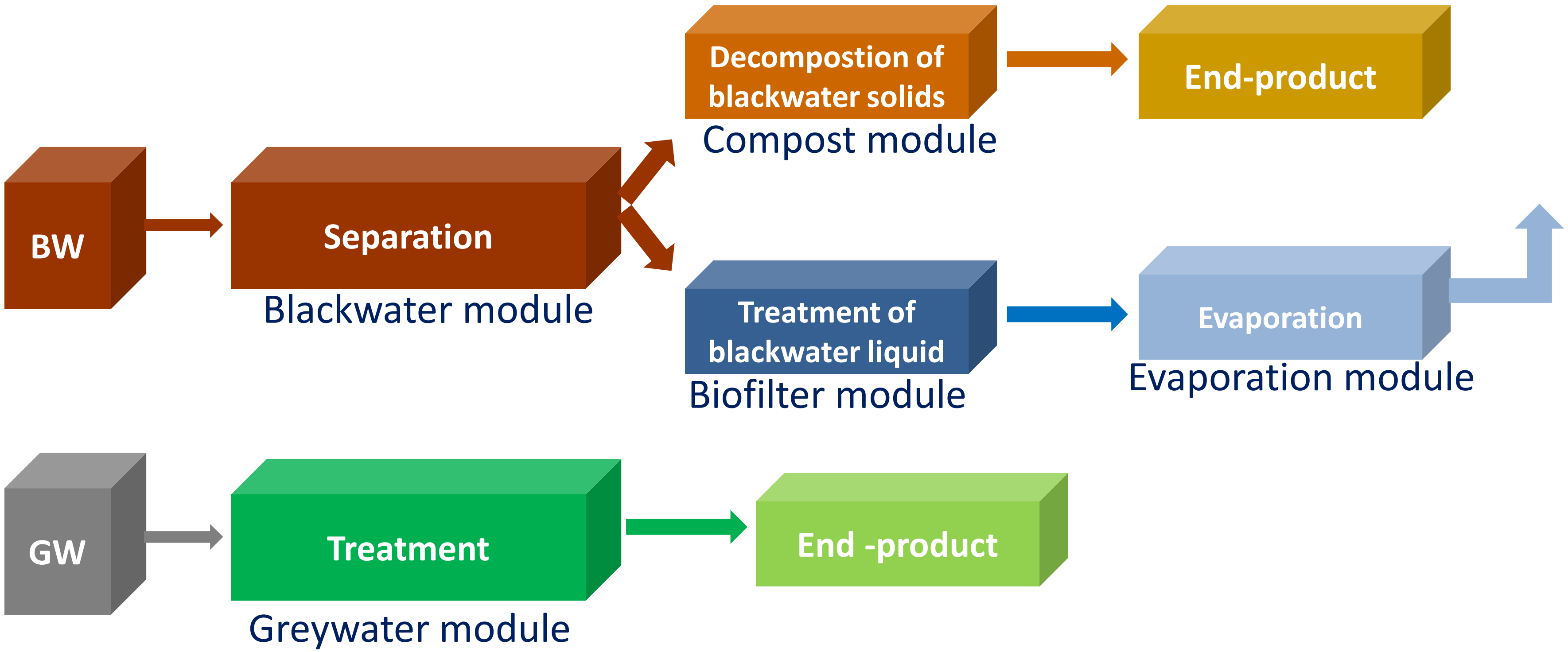
Source separation: **blackwater (BW)** = toilet waste
greywater (GW) = water from hand washing
yellow water = urine → added to BW

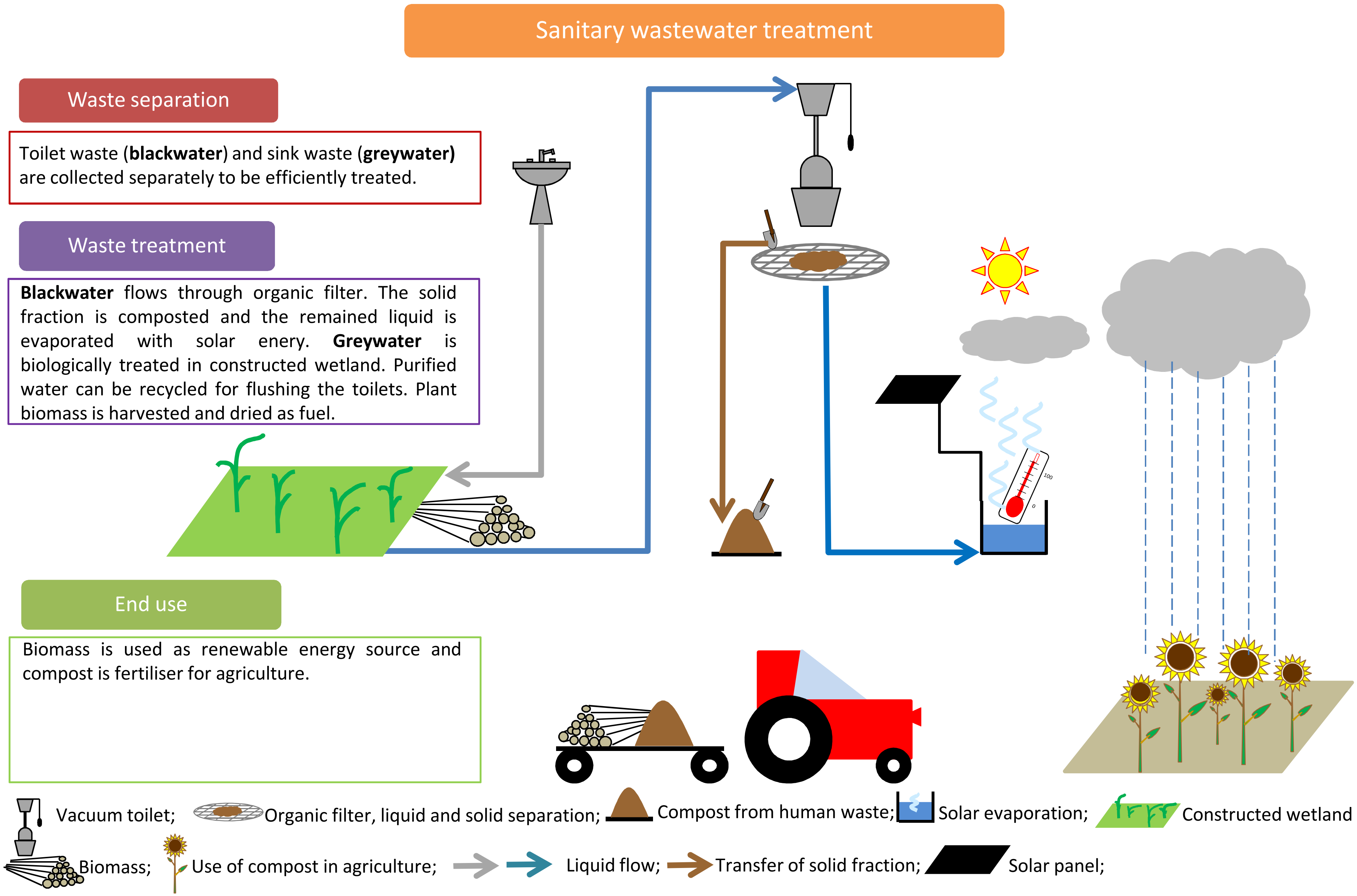
BWS; Solid fraction of BW with nutrients (N and P) will be retained in organic filters and further processed into safe compost for reuse in agriculture.

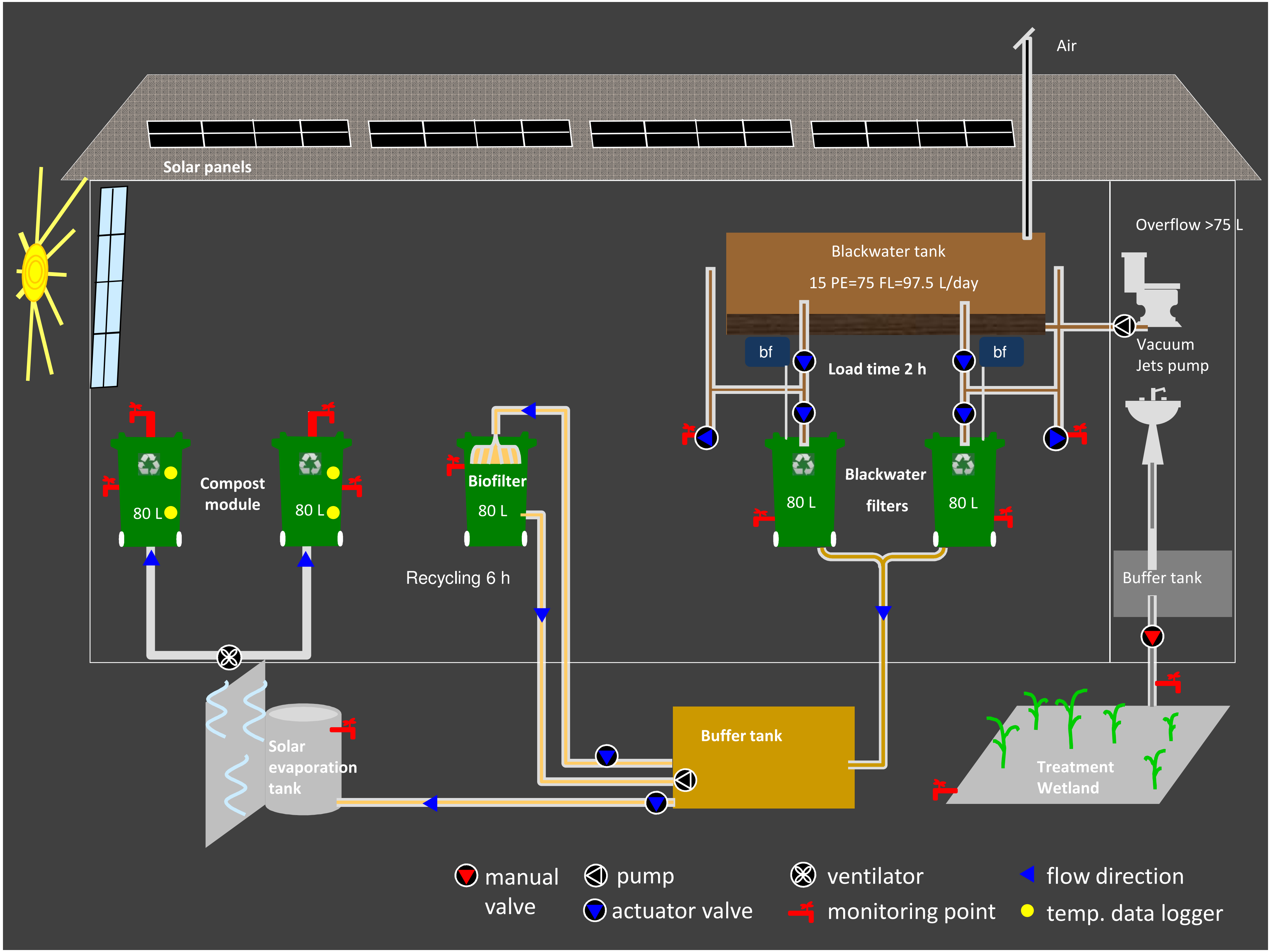
BWL; Liquid fraction. Reduction of TSS and N. The treated water will be evaporated by solar panel.

GW will be treated in a treatment wetland to produce water for flushing toilets.

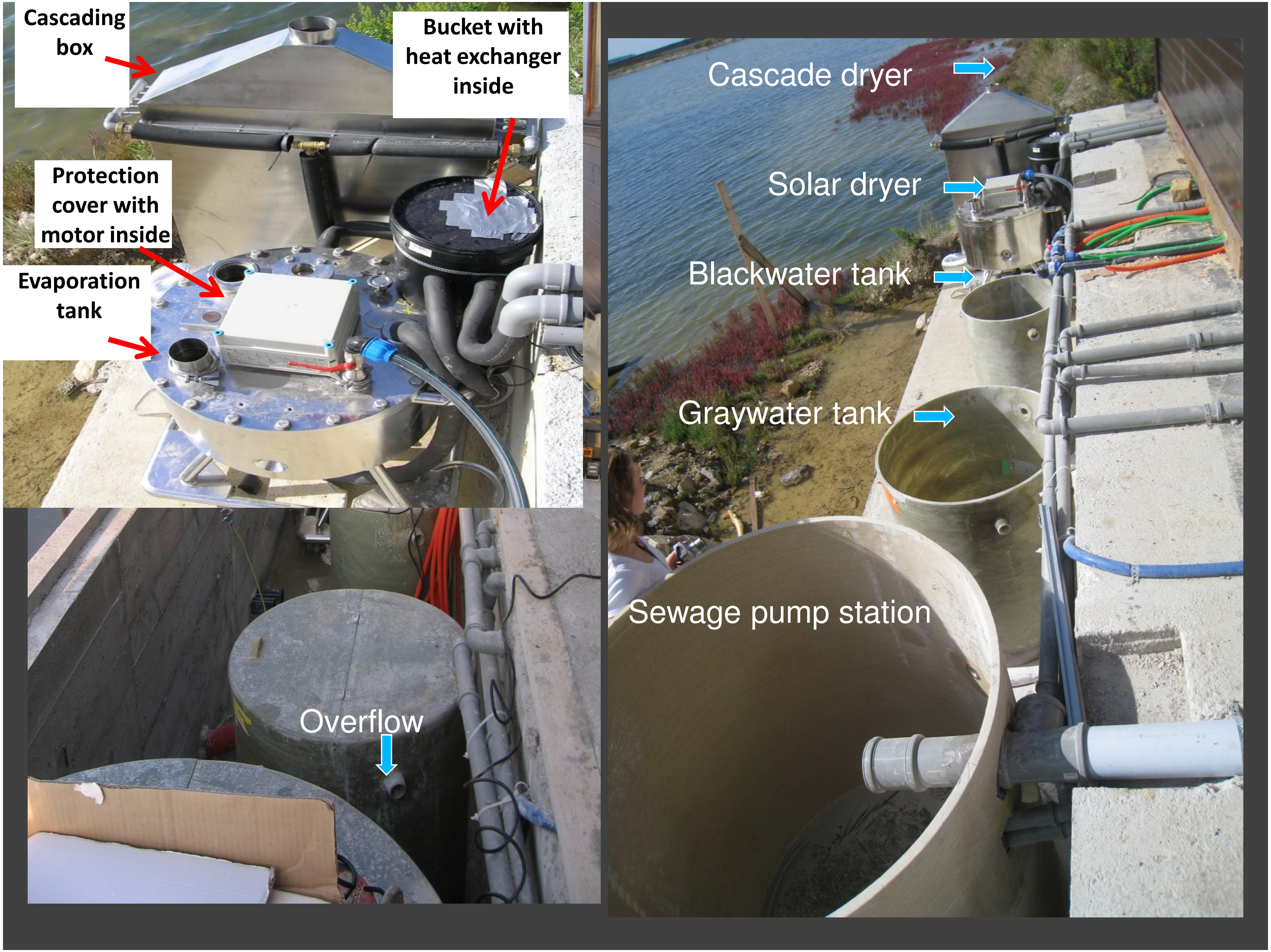
Protoype modules



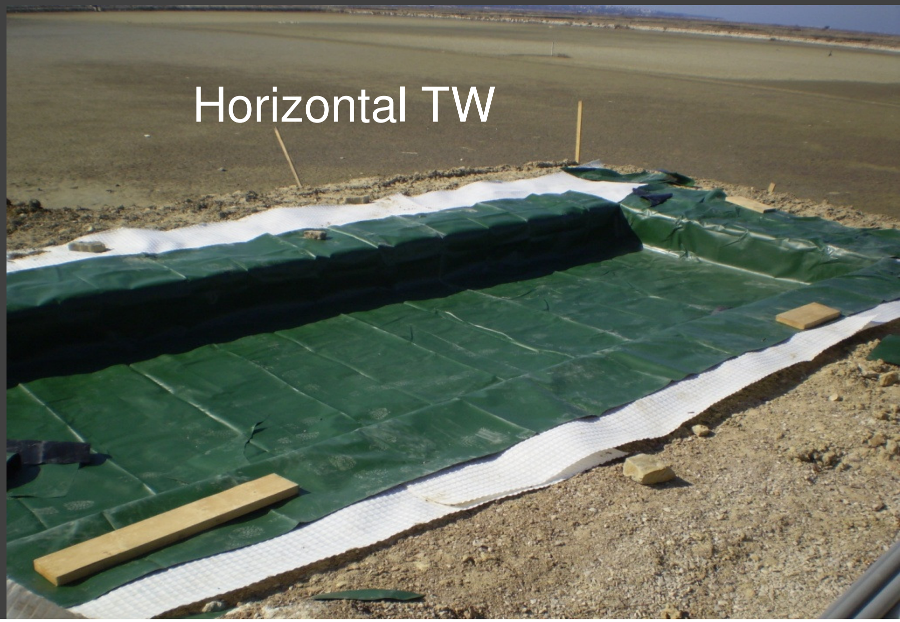

Sanitary wastewater treatment
Waste separation
Toilet waste (**blackwater**) and sink waste (**greywater)** are collected separately to be efficiently treated.
Waste treatment
Blackwater flows through organic filter. The solid fraction is composted and the remained liquid is evaporated with solar enery. **Greywater** is biologically treated in constructed wetland. Purified water can be recycled for flushing the toilets. Plant biomass is harvested and dried as fuel.
End use
Biomass is used as renewable energy source and compost is fertiliser for agriculture.
Vacuum toilet;
Organic filter, liquid and solid separation;
Compost from human waste;
Solar evaporation;
Constructed wetland
Biomass;
Use of compost in agriculture;
Liquid flow;
Transfer of solid fraction;
Solar panel;



Air
Solar panels
Overflow >75 L
Blackwater tank
15 PE=75 FL=97.5 L/day
bf
Load time 2 h
bf
Vacuum
Jets pump
Compost
module
80 L
80 L
Biofilter
80 L
Blackwater
filters
80 L
80 L
Recycling 6 h
Buffer tank
Solar
evaporation
tank
Buffer tank
Treatment
Wetland
manual
valve
pump
actuator valve
ventilator
monitoring point
flow direction
temp. data logger


Cascading box
Bucket with heat exchanger inside
Protection cover with motor inside
Evaporation tank
Overflow
Cascade dryer
Solar dryer
Blackwater tank
Graywater tank
Sewage pump station

Treatment wetland

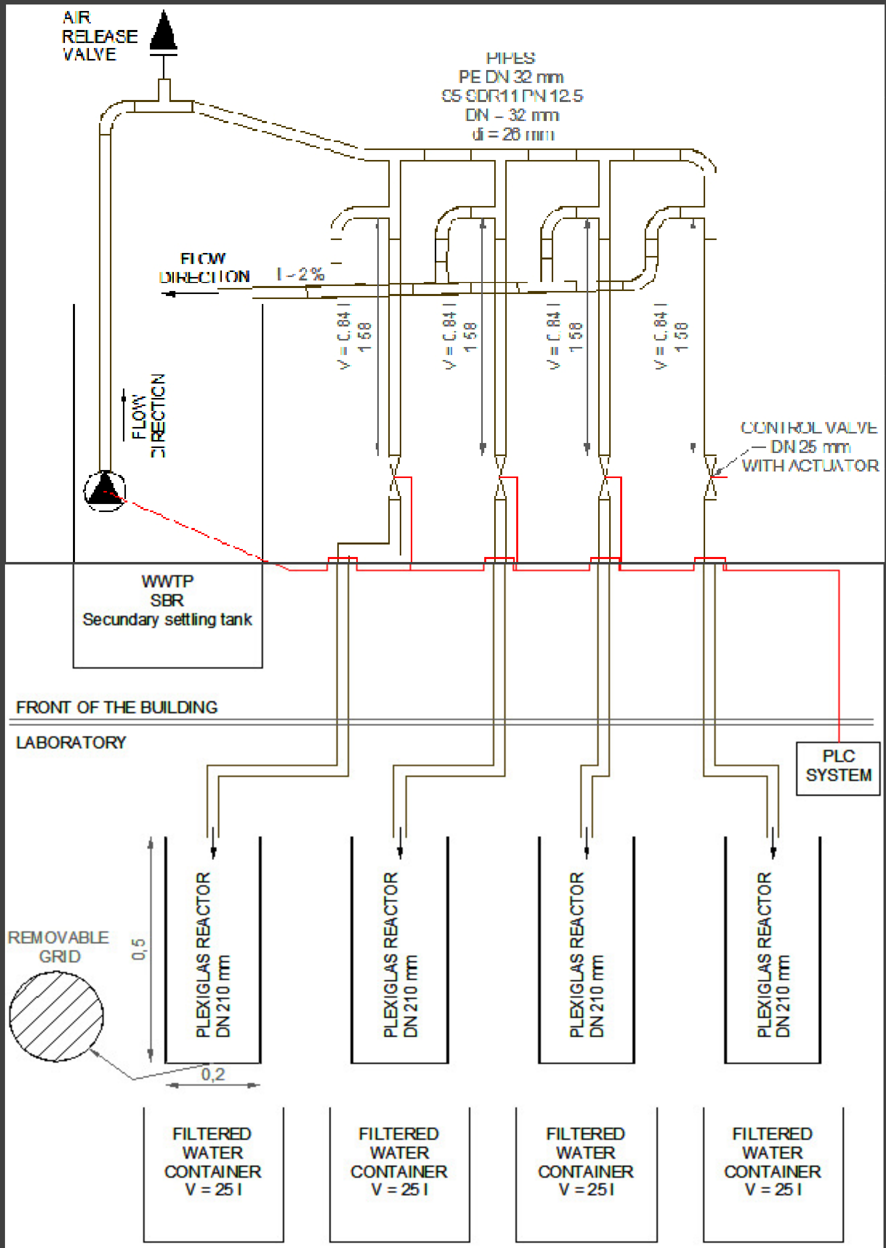


PARAMETRES	LAB EXPERIMENT			PILOT SCALE				
	BW module	Bioflter	Compost module	BW module	Biofilter	Compost module	Solar module	C W
T°	D	-	D	W	W	D	D	W
pH	D	-	W	W	W	W	-	W
TSS	D	-	W	W	W	W	-	W
Dry matter	D	-	W	W	W	W	-	W
Particles distribution	O	-	-	W	-	-	-	-
NH_4^+-N	D	-	W	W	W	W	-	W
NO_2^--N	D	-	W	W	W	W	-	W
NO_3^--N	D	-	W	W	W	W	-	W
PO_4^{3-}	D	-	W	W	W	W	-	W
P-tot	D	-	W	W	W	W	-	W
COD	D	-	-	W	W	-	-	W
BOD_5	D	-	-	W	W	-	-	W
CO_2, O_2, CH_4, N_2	-	-	D	-	-	D	-	-
Total bacterial count	-	-	-	W	W	W	W	W
Total coliforms	-	-	-	W	W	W	W	W
Faecal enteroccoci	-	-	-	W	W	W	W	W
Staphylococci	-	-	-	W	W	W	W	W
Escherichia coli	-	-	-	W	W	W	W	W

Legend: BW-blackwater module; HCW-hybrid constructed wetlands; D-daily; W-weekly

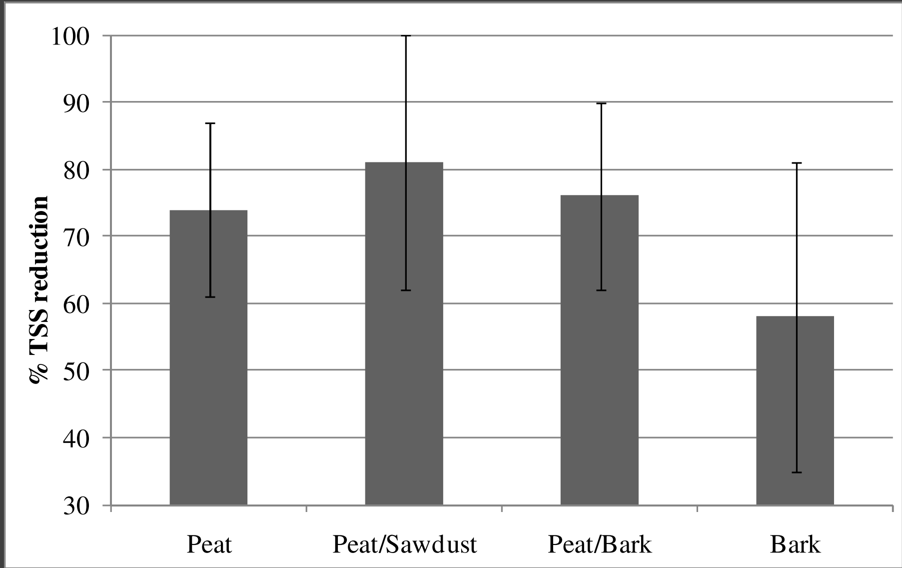
BW separation-Set-up

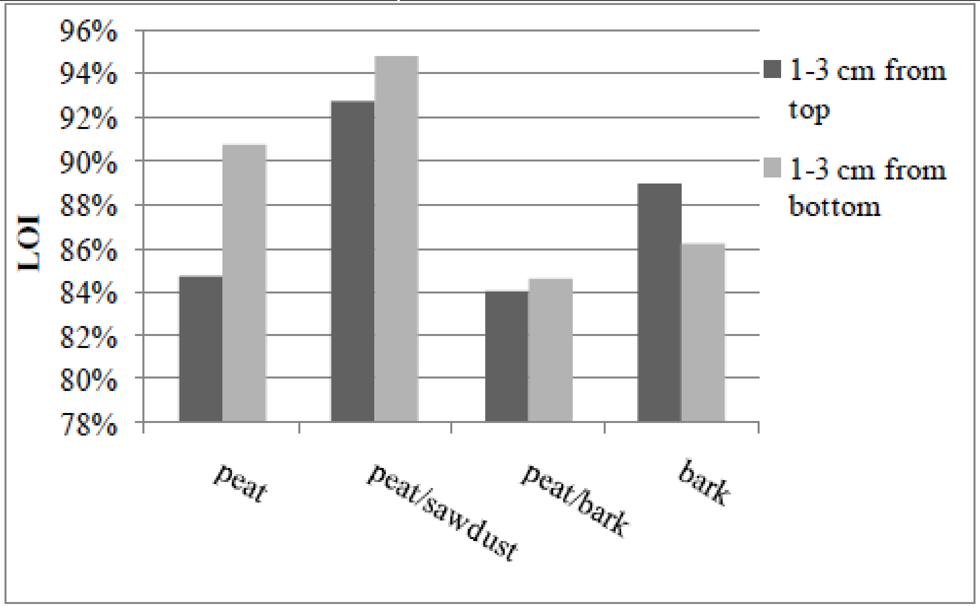
Lab experiment

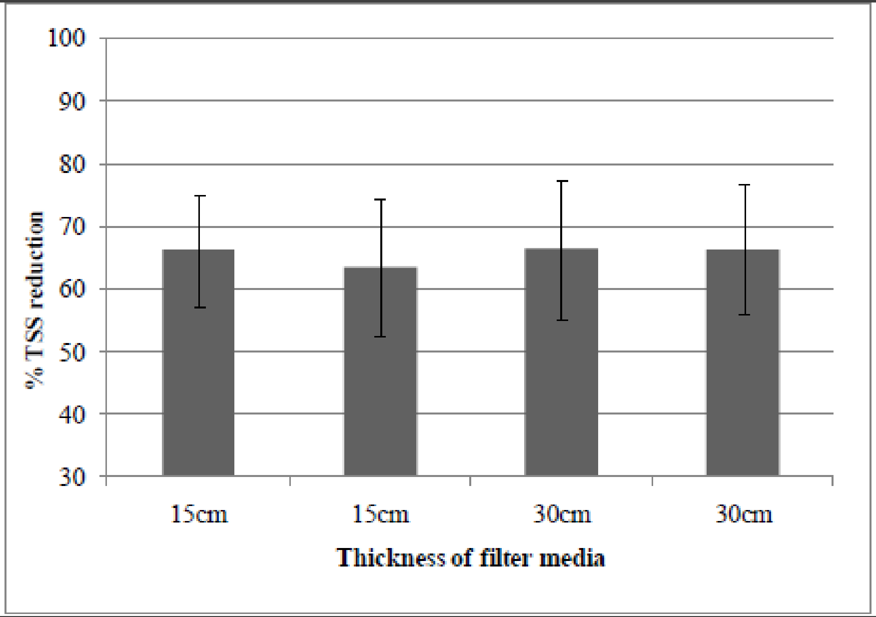


Results BW module

Lab experiment

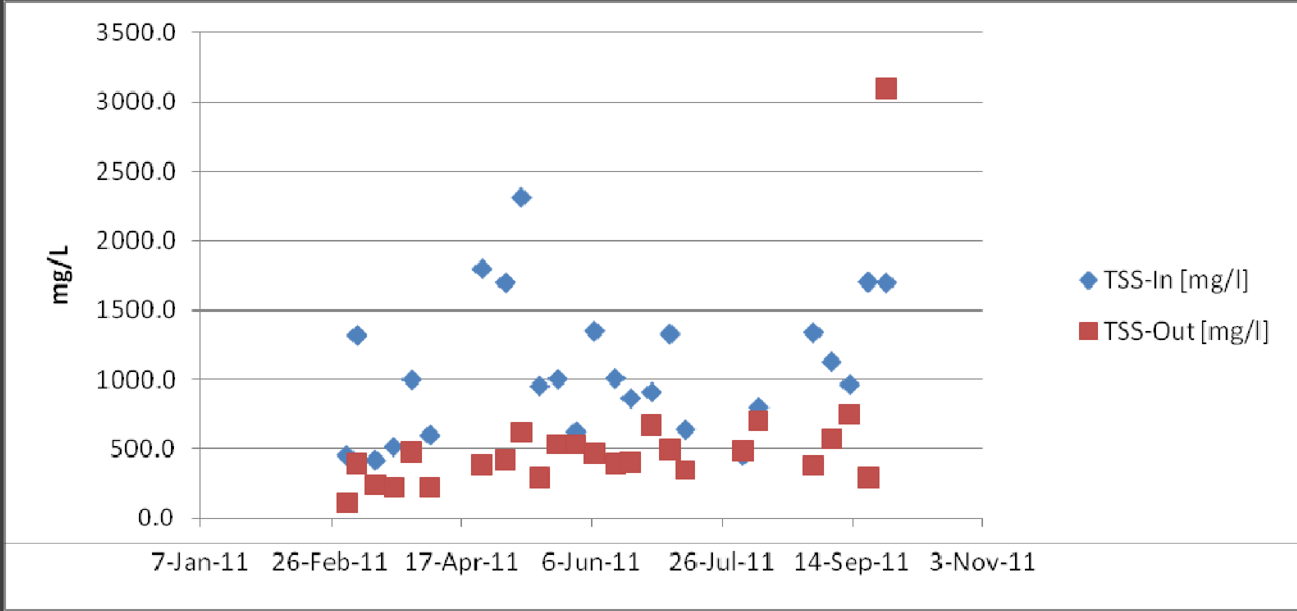


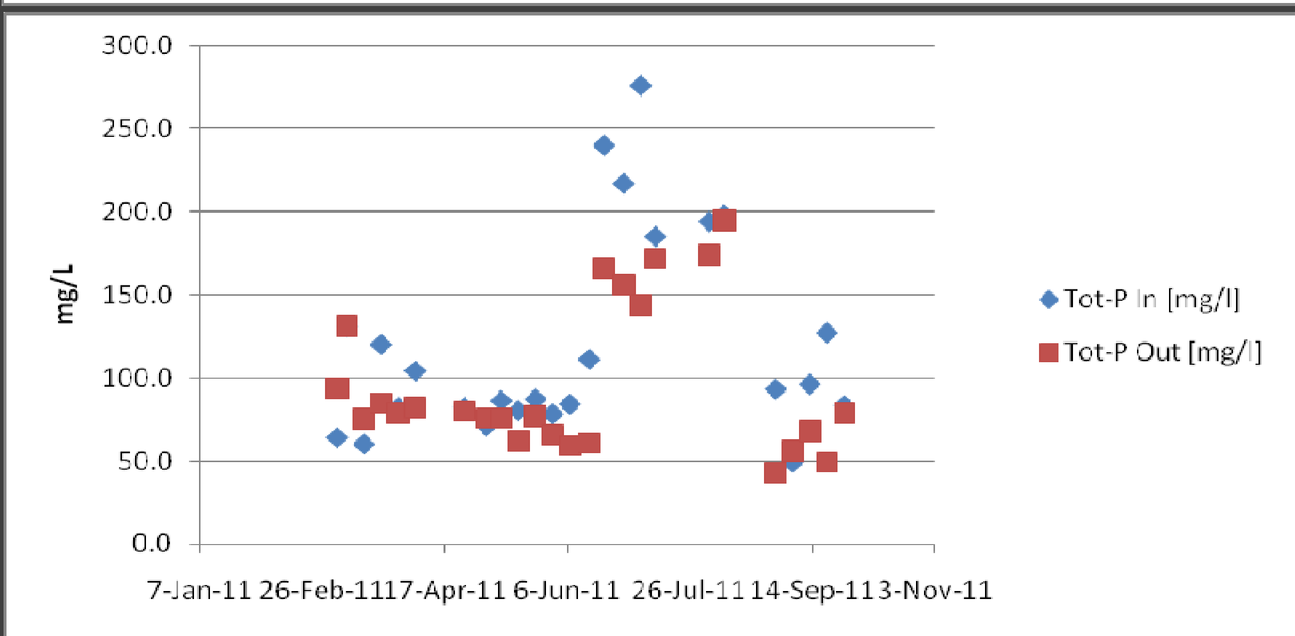




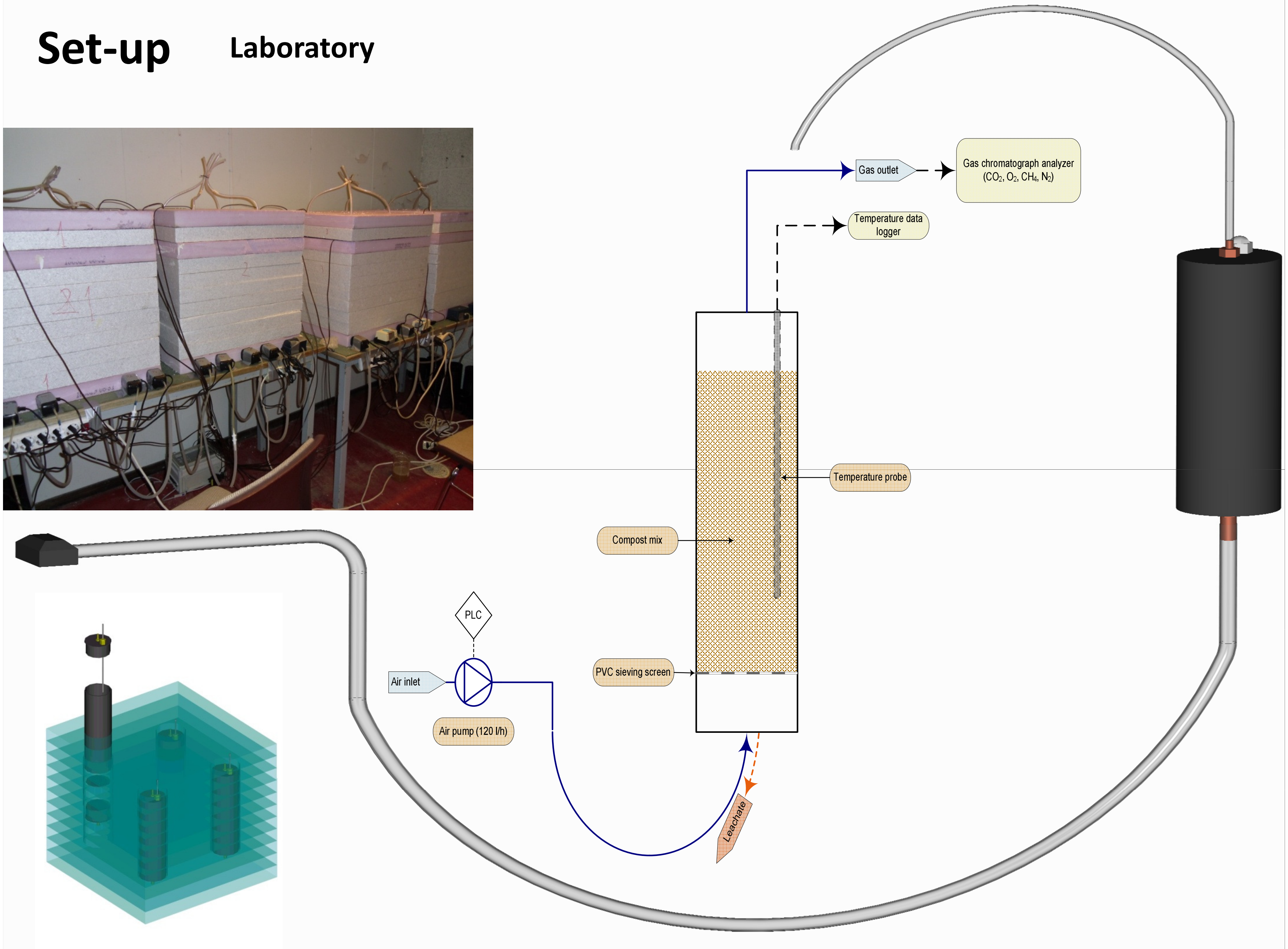
Results BW module

Pilot experiment



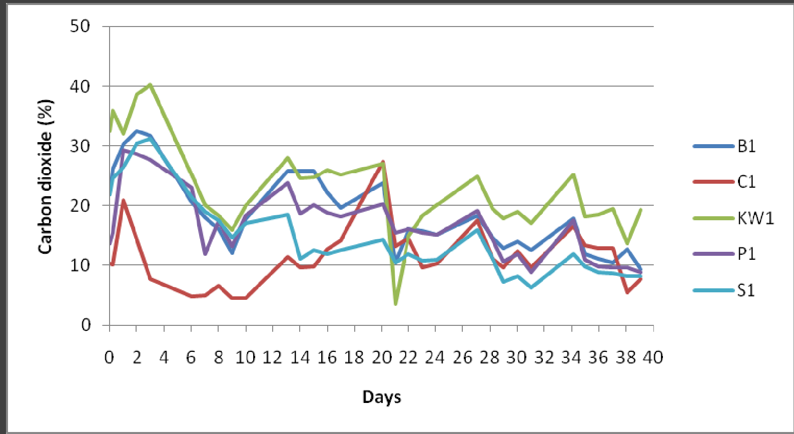


Set-up Laboratory

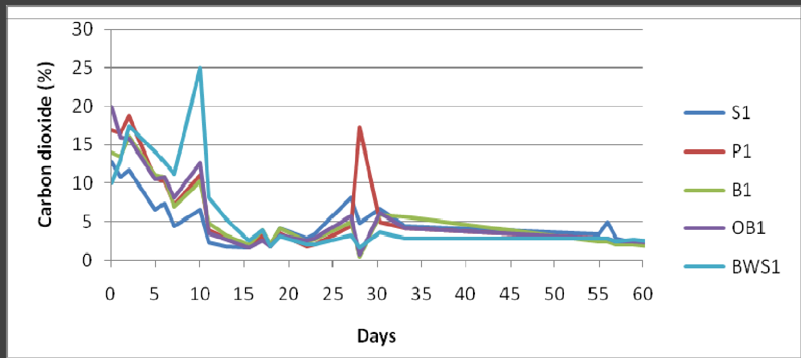


Results compost module

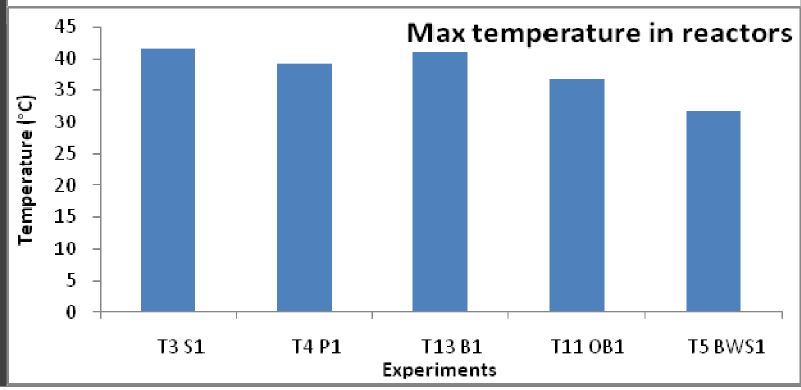
Lab experiment



CO_2 release in selected reactors with BWS compost under mesophilic and thermophilic conditions

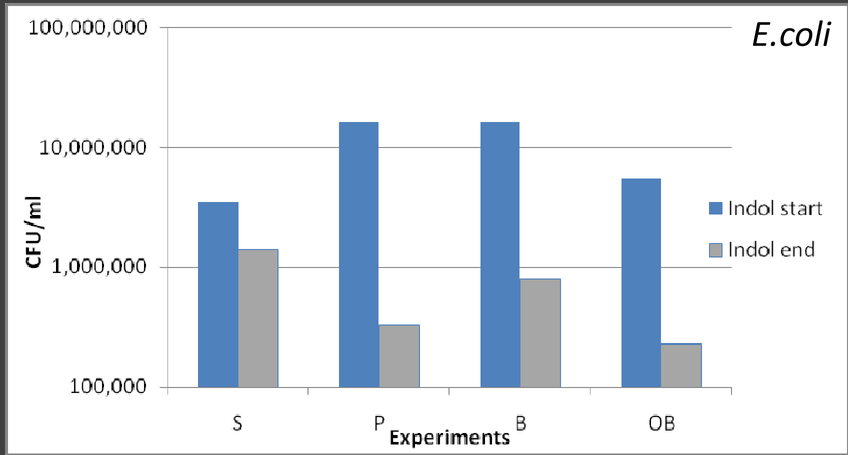


CO_2 release in BWS compost under mesophilic conditions in selected reactors



Results compost module

Lab experiment



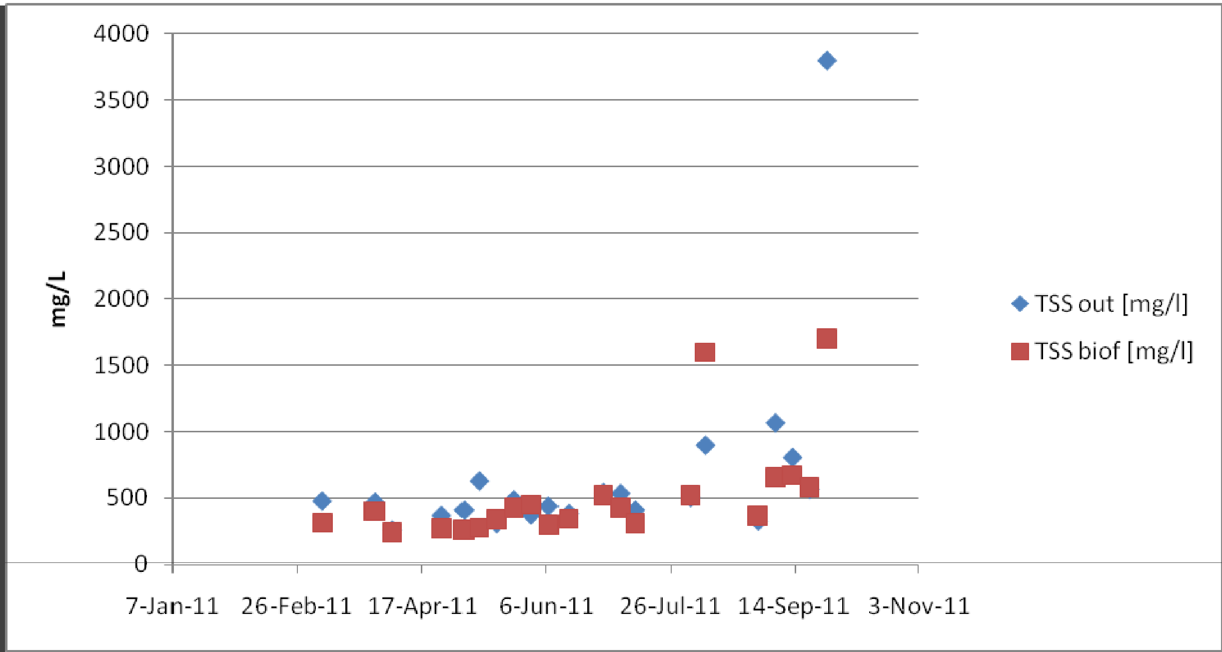
S mixture (BWS, sawdust, oat, bran) the reduction was up to 3 times, for P mixture (BWS, peat, oat, bran) 49 times, experiment B (BWS, bark, oat, bran) 20 times, OB (BWS, bark, oat, bran) 24 times

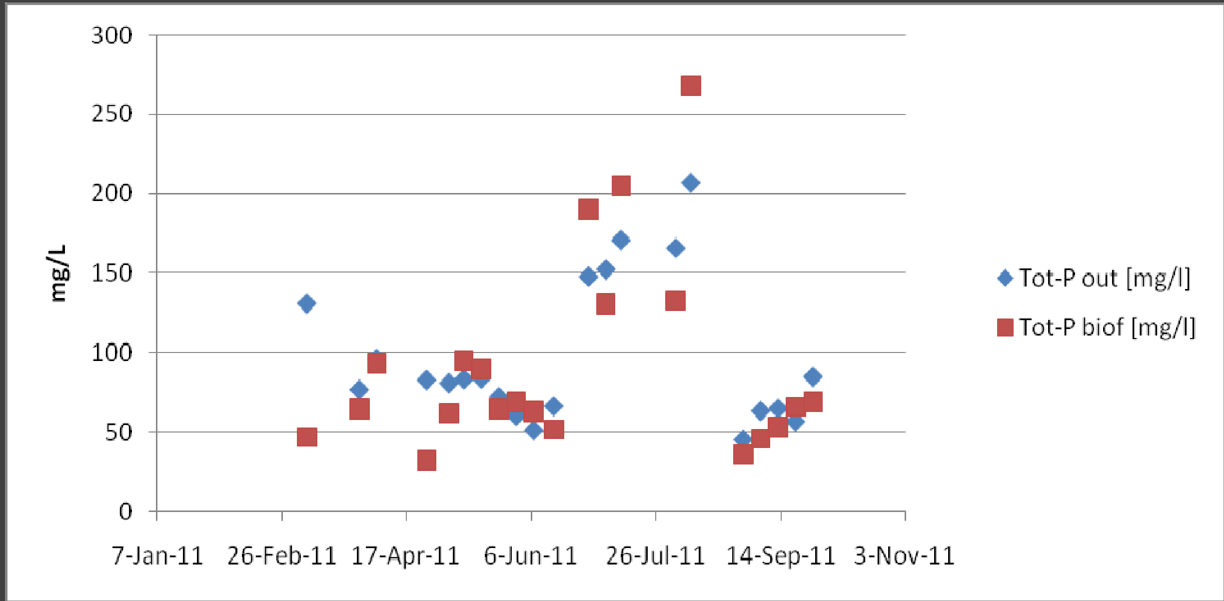
Pilot scale

Reactor		O_2 (%)	CO_2 (%)
A	min	10.5	0.5
A	max	19.6	5.9
A	avg	17.9	1.5
B	min	7.2	0.6
B	max	19.6	8.8
B	avg	17.1	2.2

Results biofilter

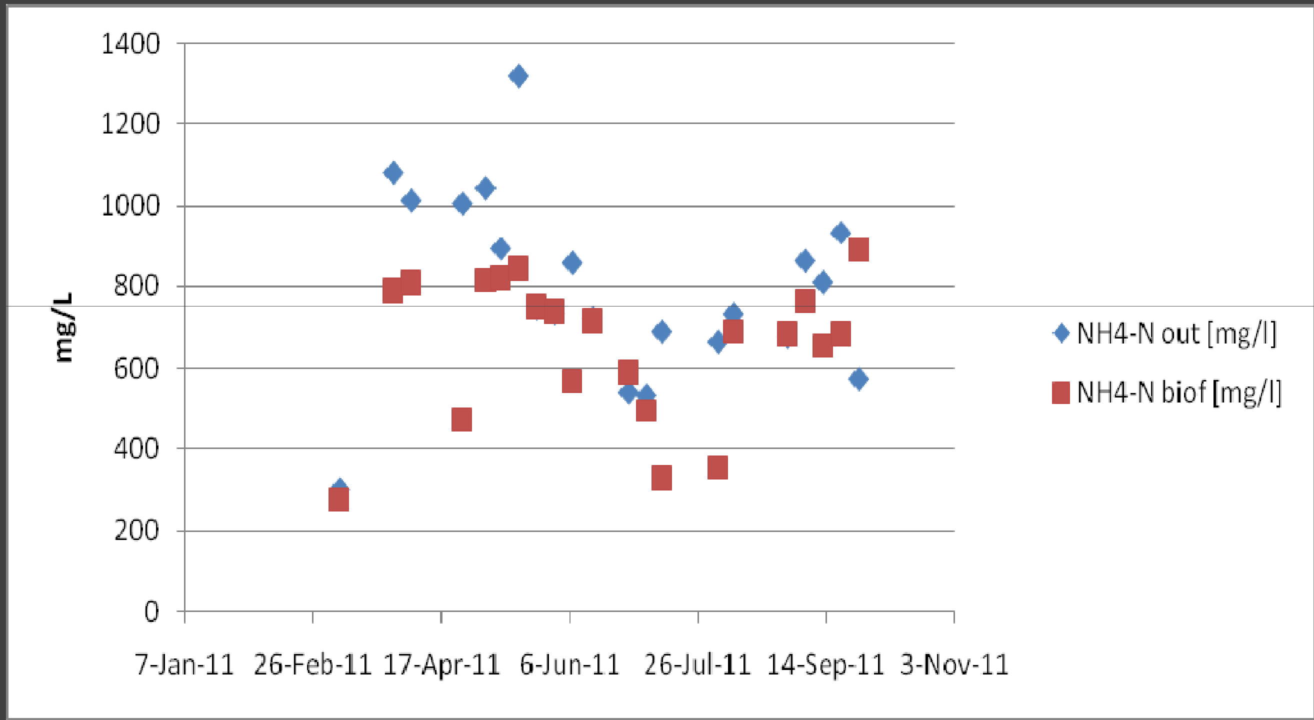
Pilot scale





Results biofilter

Pilot scale



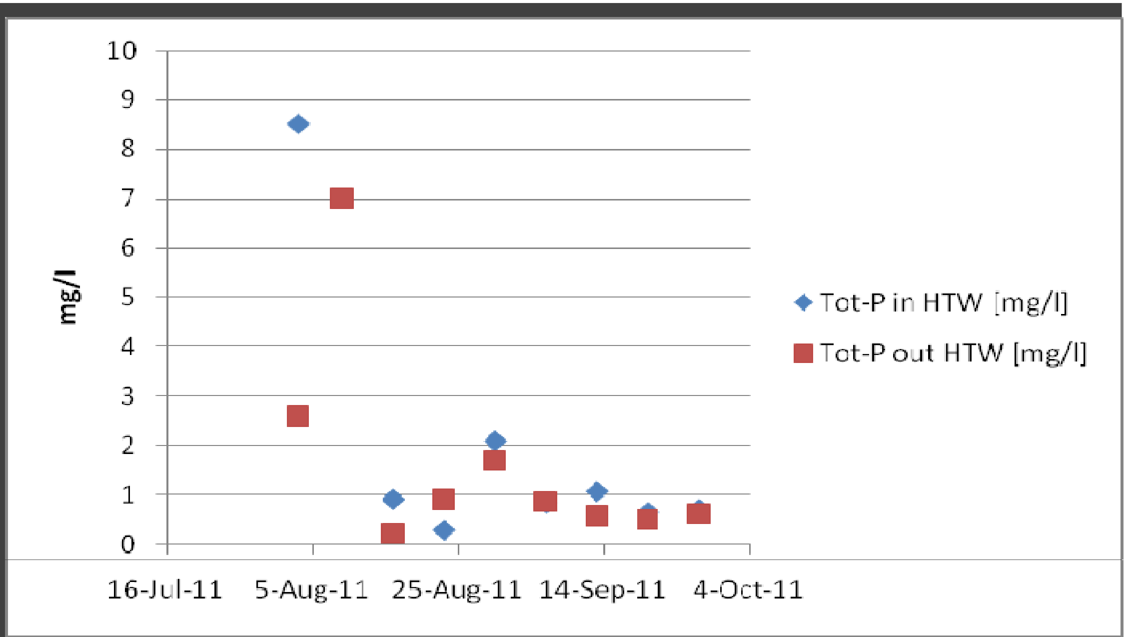
Results solar evaporating tank

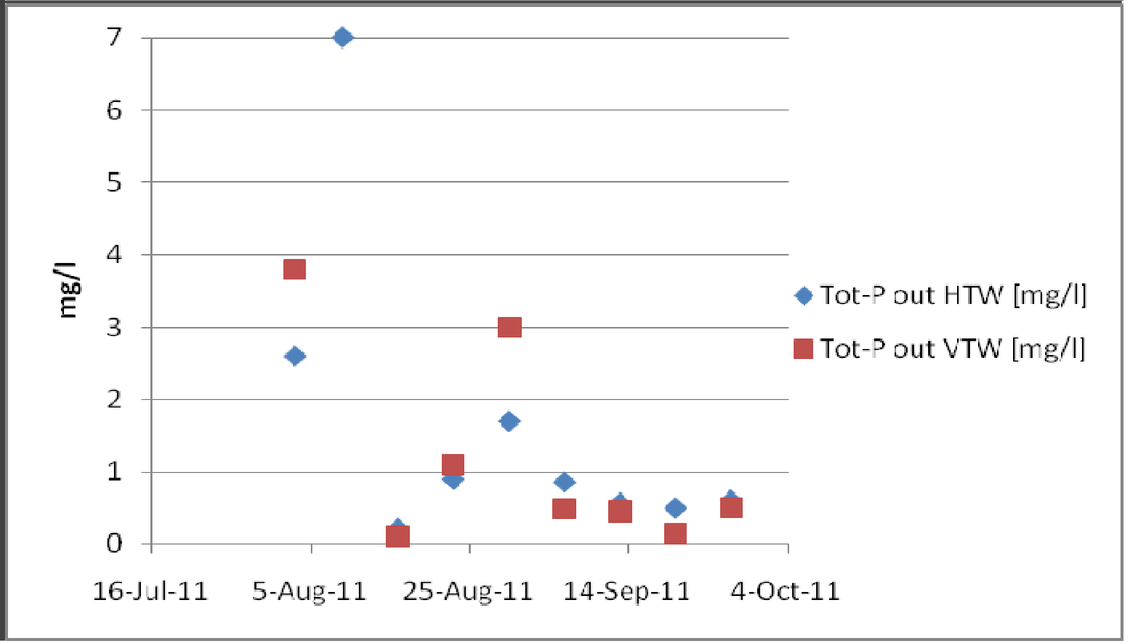
Pilot scale

Bacteriological parameters	**Unit**	**Solar evaporator**	**Removal (%)**
Total bacterial count	MPN/mL	$6x10^3$	98.0
Total coliforms	MPN/mL	<10	99.9
Faecal enteroccoci	MPN/mL	$1.1x10^3$	99.6
Staphylococci	MPN/mL	1	99.2
Escherichia coli	MPN/mL	no	-

Results treatment wetland

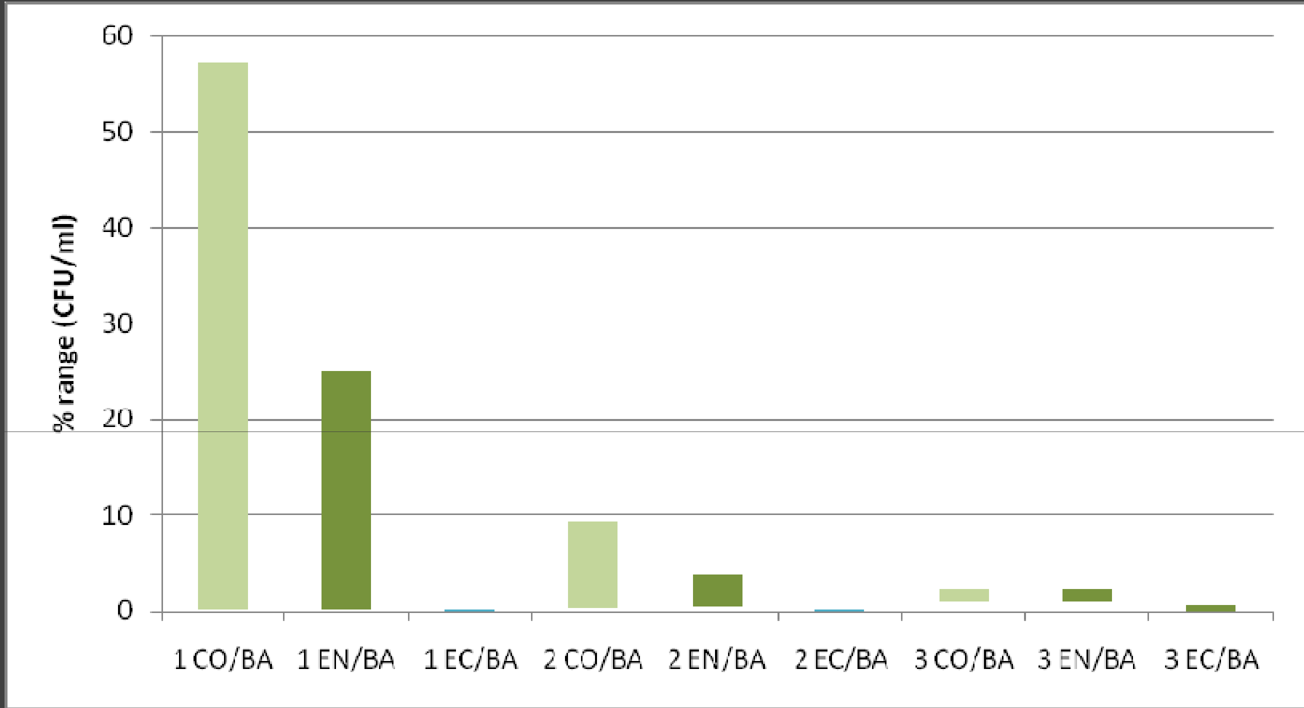
Pilot scale





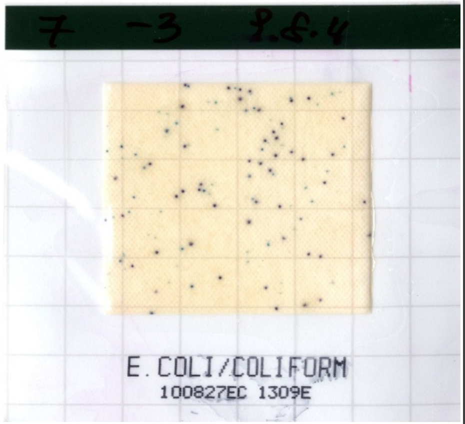
Results treatment wetland

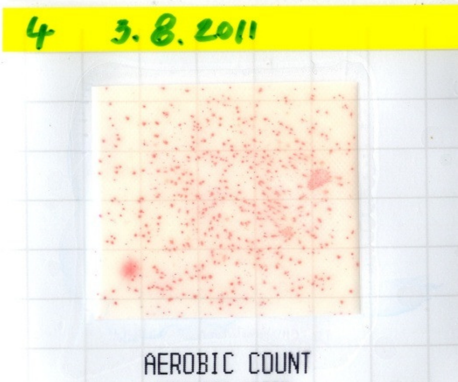
Pilot scale

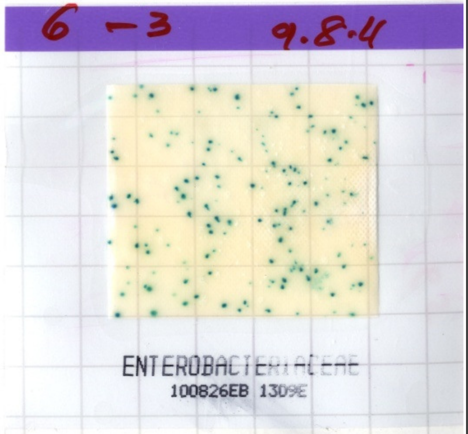


Legend: 1. Input Horizontal TW; 2. Output Horizontal TW; 3. Output Vertical TW; BA. Total bacterial count; CO. Total coliforms; EN. Enterobacteriace; EC. *E.coli*

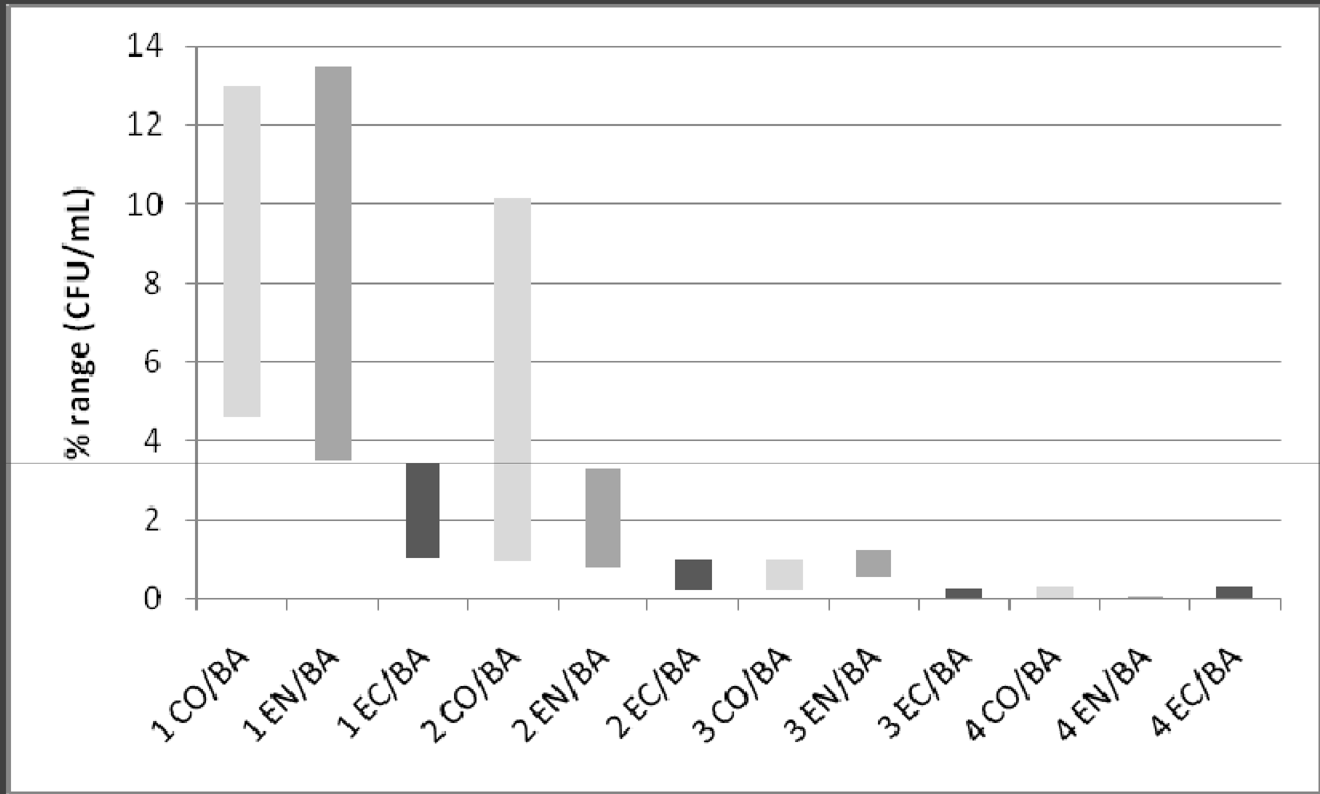
Microbiologicalr results







Pilot scale



Legend: 1. BW filters input; 2. BW filters output; 3. Biofilter; 4. Solar evaporation tank; BA. Total bacterial count; CO. Total coliforms; EN. Enterobacteriace; EC. *E.coli*

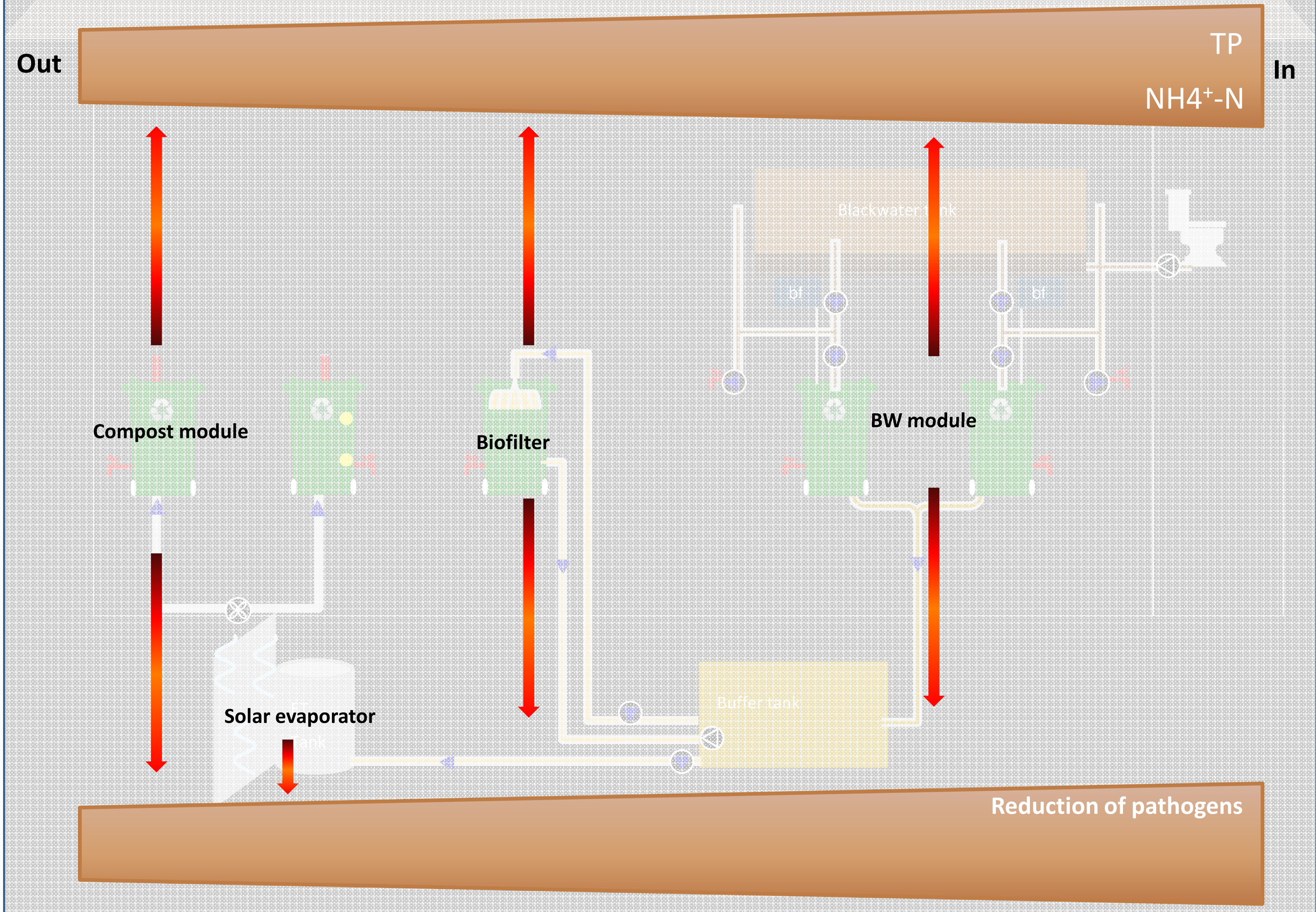
Genera of Enterobacteriaceae are: *Cedecea, Citrobacter, Enterobacter, Escherichia, Hafnia, Klebsiella, Kluyvera, Morganella, Proteus, Rahnella, Salmonella, Serratia, Shigella* and *Yersinia*.

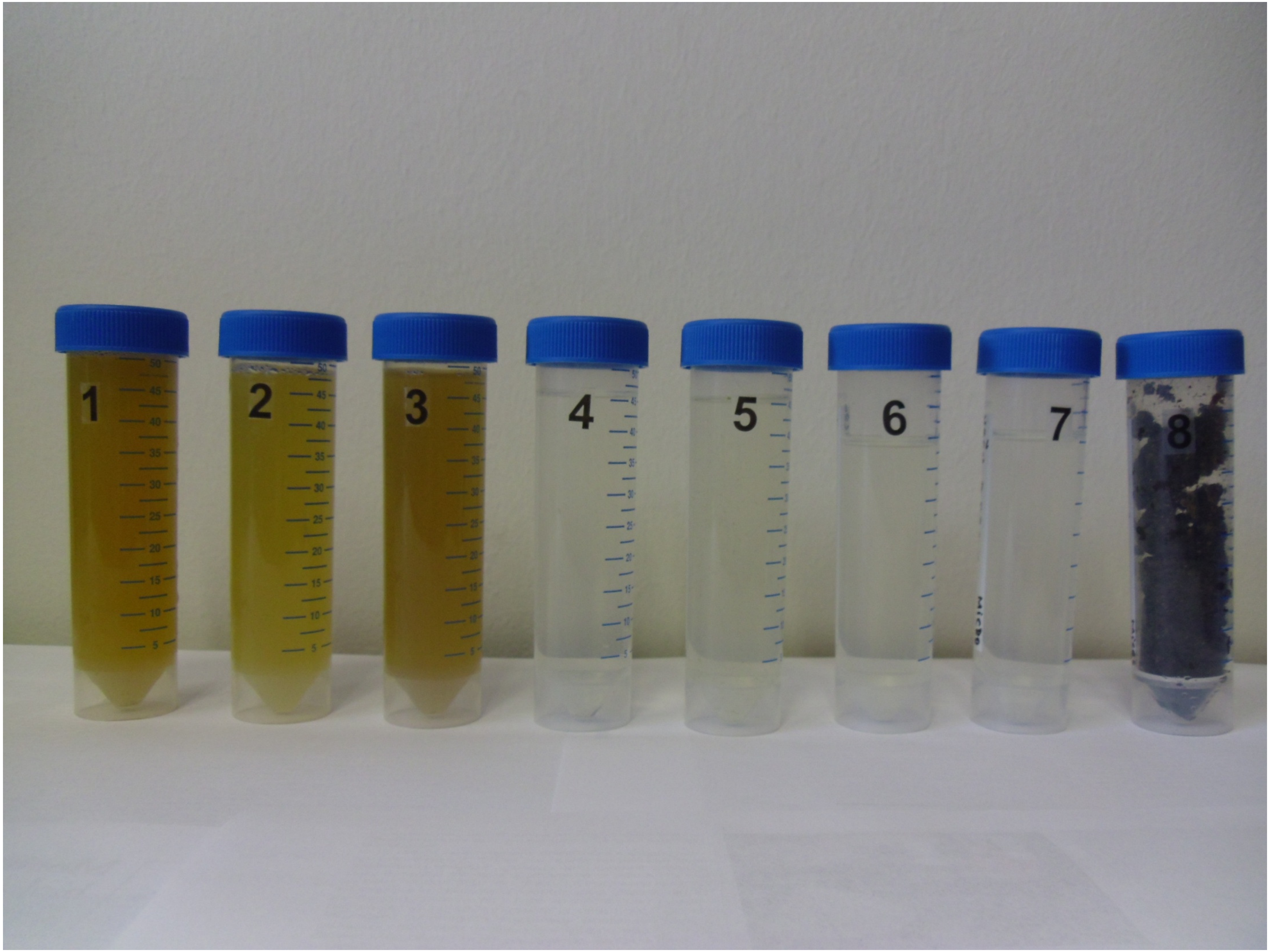
Results summary

	Inflow into peat filters (n=17)		Outflow from peat filters (n=17)		Expanded clay biofilter (n=12)		Legislation limit value (1)	Legislation limit value (2)
	average	range	average	range	average	range		
Physical and chemical parameters								
T (°C)	18.5±5.4	8.9-26.2	18.5±5.6	8.6-25.7	21.1±4.6	12-27.4	-	30
pH	8.9±0.6	7.3-9.4	8.7±0.5	7.7-9.2	8.7±0.3	8.3-9.2	-	6.5-9.0
DO (mg/L)	0.4±0.8	0.1-3.3	0.2±0.3	0.1-0.9	3.9±3.3	0.1-8.3	-	-
EC (mS/cm)	7.4±2	2.1-10.5	27.6±82.1	4.6-346	6.5±1.8	2.7-8.4	-	-
TSS (mg/L)	1044.1±434.4	431-1750	387.8±125.6	141.5-630	341.8±84.9	240-525	-	80
NH_4-N (mg/L)	799.3±277.3	127-1370	813.2±276.6	303-1315	647.7±208.7	225-845	-	10
NO_2-N (mg/L)	0.3±0.3	0-1	1.3±3.6	0-14.5	0.3±0.2	0-0.7	-	1
NO_3-N (mg/L)	50.2±60.5	10.9-252.3	46.2±52.6	14.5-215	41.5±54.2	7.8-208	-	25
PO_4-P (mg/L)	92.4±38	51.9-204.5	78±35.7	47-197	51.7±25.8	18-127	-	-
TP (mg/L)	109.9±44.4	65.2-217.5	93.9±39.5	51.5-211.5	74.2±39.8	32-190	-	2
COD (mg/L)	2080.3±1117.4	739-5267.5	1484.1±403.4	421.5-2125	738.1±347.1	110-1290	150	120
BOD_5 (mg/L)	1047.9±436.1	265-1825	962.5±429.4	325-1550	335.4±178.4	150-580	30	25
Bacteriological parameters								
Total bacterial count (MPN/mL)	$4x10^6$		$4x10^8$		$3x10^5$		-	-
Total coliforms (MPN/mL)	$6.5x10^5$		$1.6x10^7$		$3x10^4$		-	-
Faecal enteroccoci (MPN/mL)	$1.5x10^5$		$8x10^5$		$3x10^5$		-	-
Staphylococci (MPN/mL)	100		80		130		-	-
Escherichia coli (MPN/mL)	yes		no		no		-	-

(1) Slovenian regulations (Uradni list RS 98/2007) concerning the effluent discharges from small communal treatment plants.
(2) Slovenian regulations (Uradni list RS 47/2005) concerning the effluent discharges into the receiving waters.

Results summary

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Conclusions

- The testing results from the SANBOX prototype in Slovenia have proven that it is possible to reach substantial removal rates under the extreme challenging conditions that are related to a Mediterranean climate.
- BW from vacuum toilets differs considerably from conventional wastewater. It has not only a higher concentration on nutrients and organic matter, but has also a special characteristic regarding particle size and distribution (up to 10000 TSS mg/L, <10 µm size)
- Toilet paper layers were reducing hydraulic conductivity
- Solar panel was efficient because all BWL was evaporated
- In terms of high variability of input, the removal efficiency of the pollutants in the system regarding the BW treatment was satisfactory:
- -Bw filters, max values: TSS 83%, NH4-N 48%, TP 61%, COD 76%, BOD 52%
- -Biofilter, max values: TSS 56%, 52%, TP 64%, COD 79%, BOD 84%
- -Results of microbial analyses showed good reduction of different bacterial indicators in the system (BW : E.coli reduction 99.8%, Enterobacteriacea 99.9%, Yeats &Molds 98.8%; TW: E.coli 91.1%, Enterobacteriacea 99.8%, Yeats &Molds 87.6%)
- The prototype was an important step towards source separation and reuse of water and nutrients.

Thank you!