# Utilization of a single-stage vertical flow constructed wetland to treat raw domestic sewage in a developing country

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# 1. Problem description

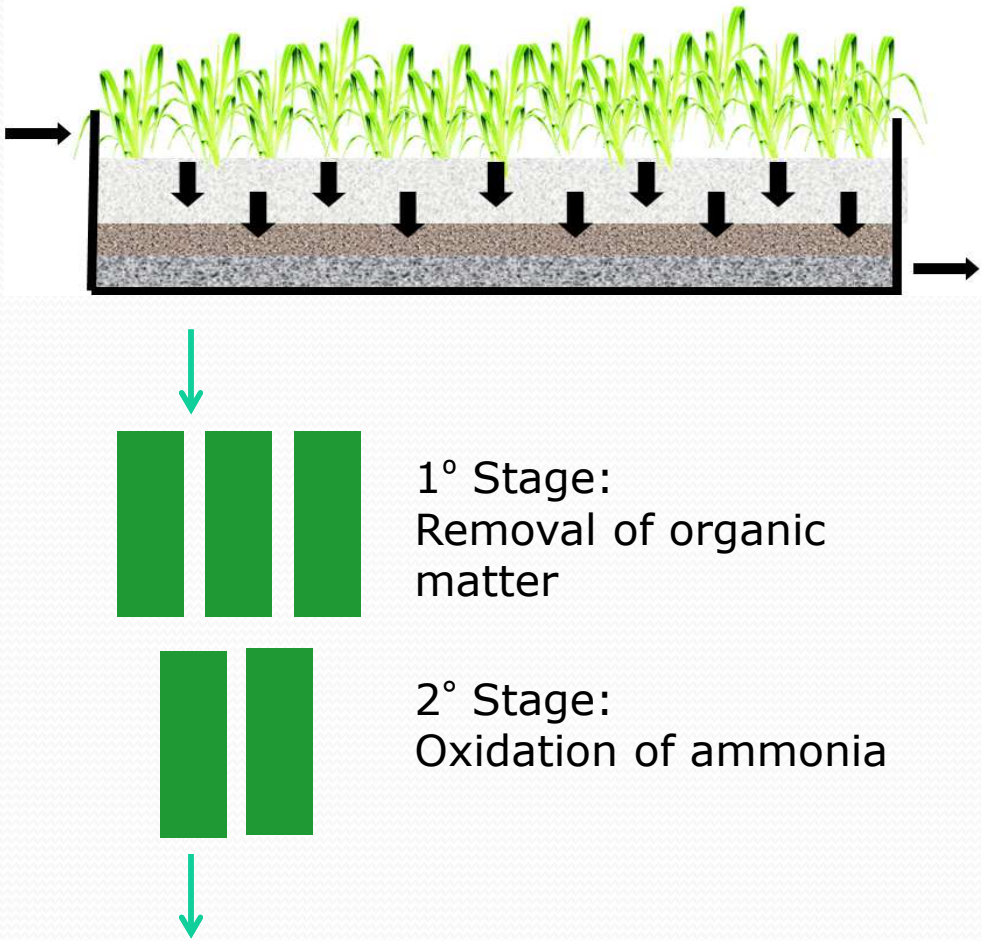
- ✓ Lack of infrastructure to cater for sanitation needs in developing countries
- ✓ Unsustainable sewerage systems
- ✓ Stabilization ponds


**Truck discharges content of septic tanks from household's to stabilization ponds in Maputo.**

# 2. Vertical Flow Constructed Wetlands- Franch System

- Operational simplicity
- Treatment of raw domestic sewage
- Potential for nitrification
- Low costs
  - construction
  - maintenance
  - Operation
- Warm and tropical regions
  - 1º Stage
- Good efficiency in the removal of contaminants.

**(Molle *et al.*, 2005)**



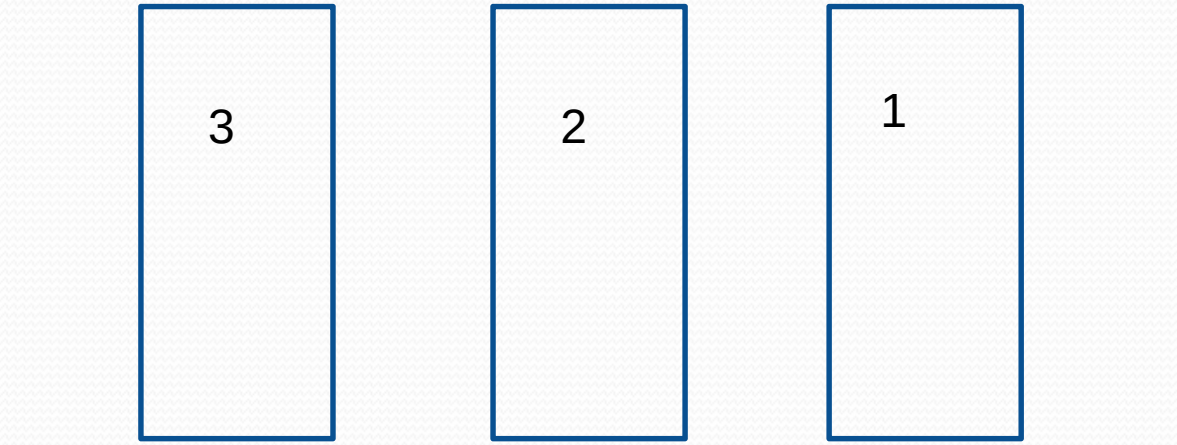
## 2. Vertical Flow Constructed Wetlands- Franch System

The study aimed at the reduction of 1/3 land requirements:

- Phase 1: 3 units (conventional 1st stage of the French system)
- Phase 2: only 2 units in the first stage

## Vertical flow constructed wetlands treating only sewage (French system)

**First Phase: From January-October, 2012**



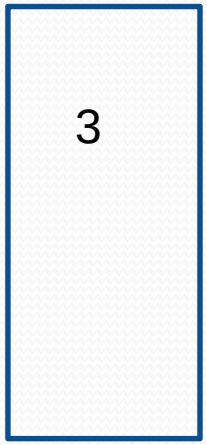

**Day 1**
1- Feed (batch)
2- Rest
3 -Rest

**Day 3**
1- Rest
2- Feed
3 - Rest

**Day 5**
1- Rest
2- Rest
3 -Feed

## Vertical flow constructed wetlands treating only sewage (French system)

**Second Phase: From February, 2013**

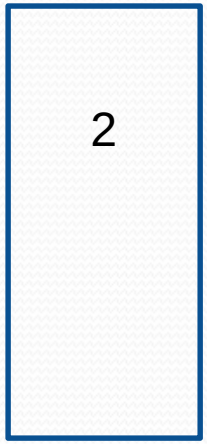



**3-Planted unit**

**2- Feed (batch)**

2- Seven days feeding.

3- Seven days resting




**2-Unplanted unit**

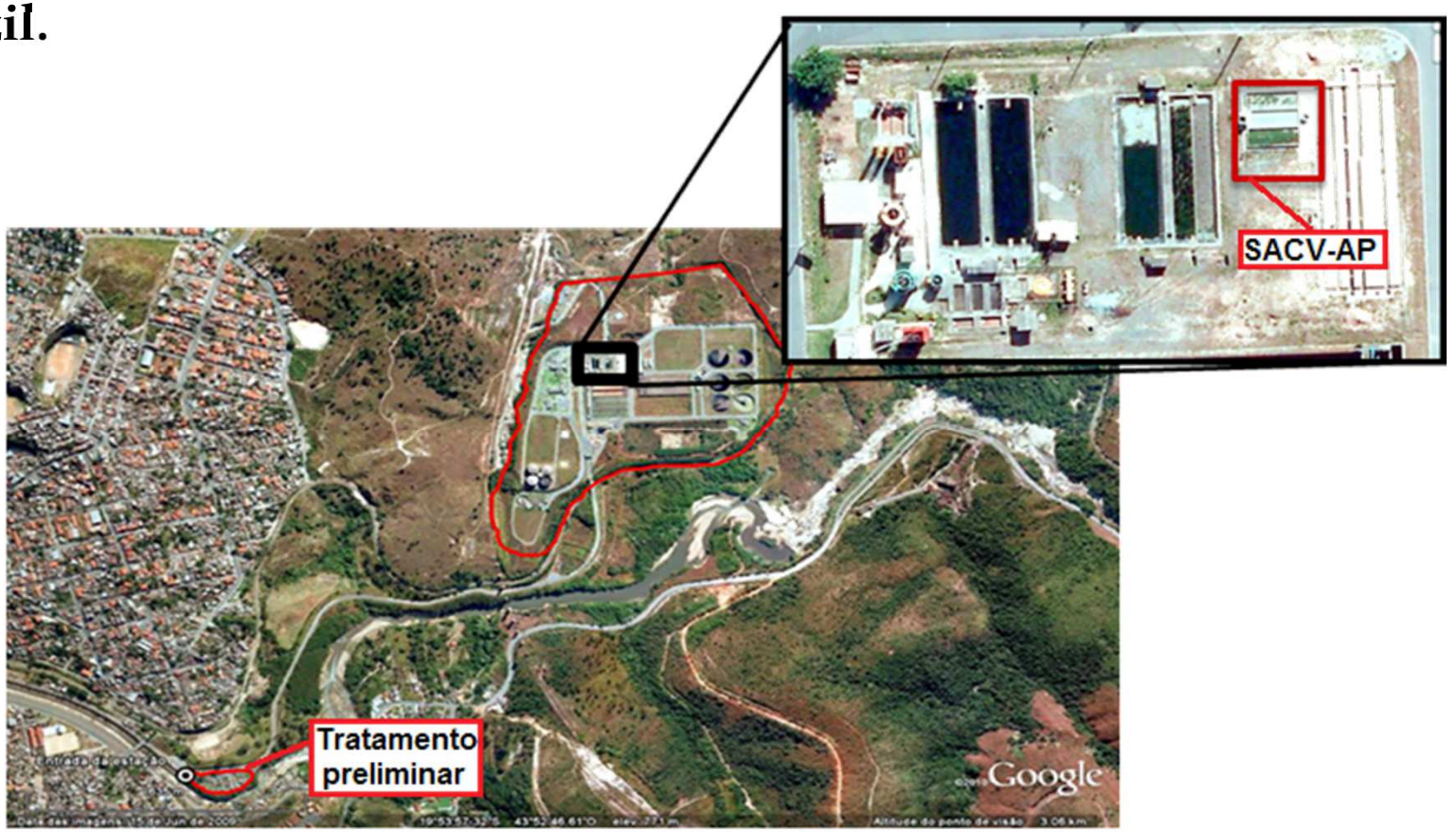
**3- Feed (batch)**

3- Seven days feeding

2- Seven days resting

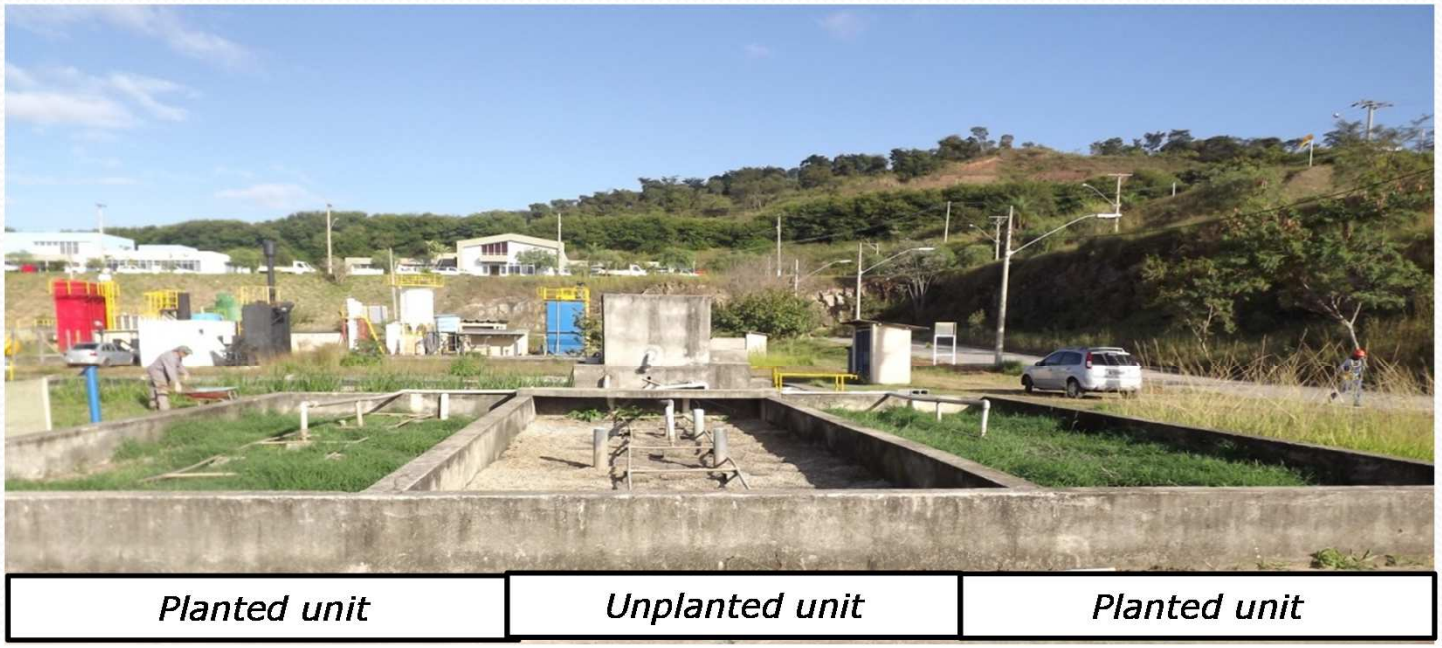
# 3. MATERIAL AND METHODS

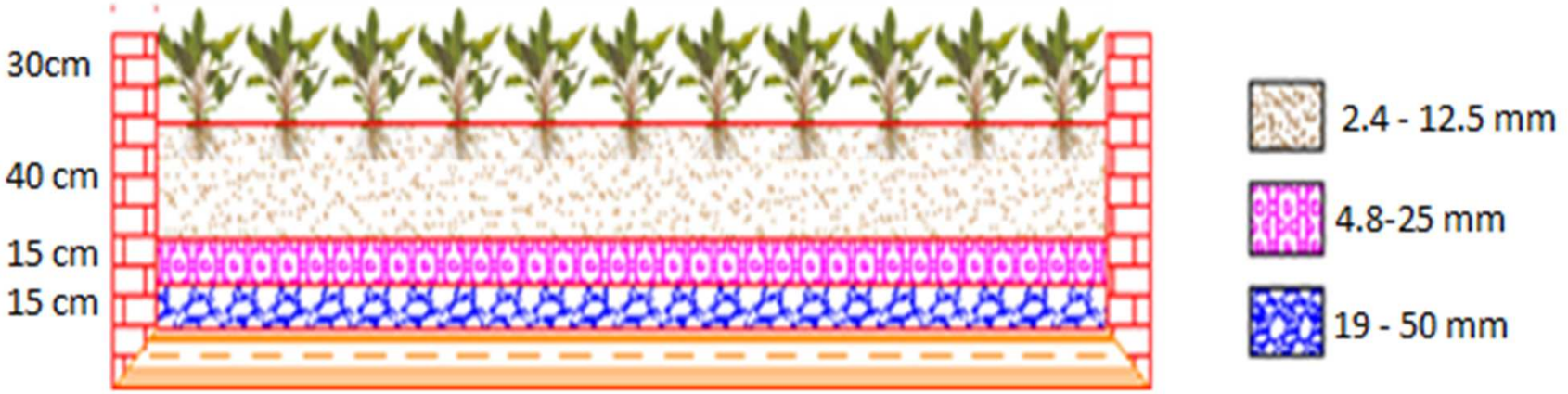
- **Investigations were conducted at the Centre for Research and Training in Sanitation (CePTS) UFMG/COPASA, in Belo Horizonte, Brazil.**




**WWTP UFMG/COPASA**

# 3. MATERIAL AND METHODS




**Vertical Flow constructed wetland units (CePTS UFMG/Copasa)**

# 3. MATERIAL AND METHODS

Raw sewage after preliminary treatment

Sieve for solids removal

Distribution box

Filling and emptying of box

Vertical Planted Bed

Effluent

# 3. MATERIAL AND METHODS

**Sample collection Inflow Monitoring**

**Laboratory Equipment for Physical Parameters**

**Parameters Determination in the laboratory at UFMG**

# 3. MATERIAL AND METHODS

## Operational parameters of vertical constructed wetland

| Parameters | Phase 1 | Phase 2 |
|---|---|---|
| Number of units | 3 | 2 |
| Area of each filter | 29.1 $m^2$ | 29.1 $m^2$ |
| Bed depth | 0.70 m | 0.70 m |
| Flow | 13 $m^3.d^{-1}$ | 13 $m^3.d^{-1}$ |
| Hydraulic loading rate (HLR) - total | 0.15 $m^3.m^{-2}.d^{-1}$ | 0.22 $m^3.m^{-2}.d^{-1}$ |
| Hydraulic loading rate (HLR) – working bed | 0.45 $m^3.m^{-2}.d^{-1}$ | 0.45 $m^3.m^{-2}.d^{-1}$ |
| Operational cycle | 2.4 d feed; 4.7 d rest | 7 d feed; 7 d rest |
| Number of batches per day | 24 | 24 |
| Surface area | 0.9 $m^2$/inhabitant | 0.6 $m^2$/inhabitant |

# 4. Results and discussion

## Average influent and effluent concentrations in both phases

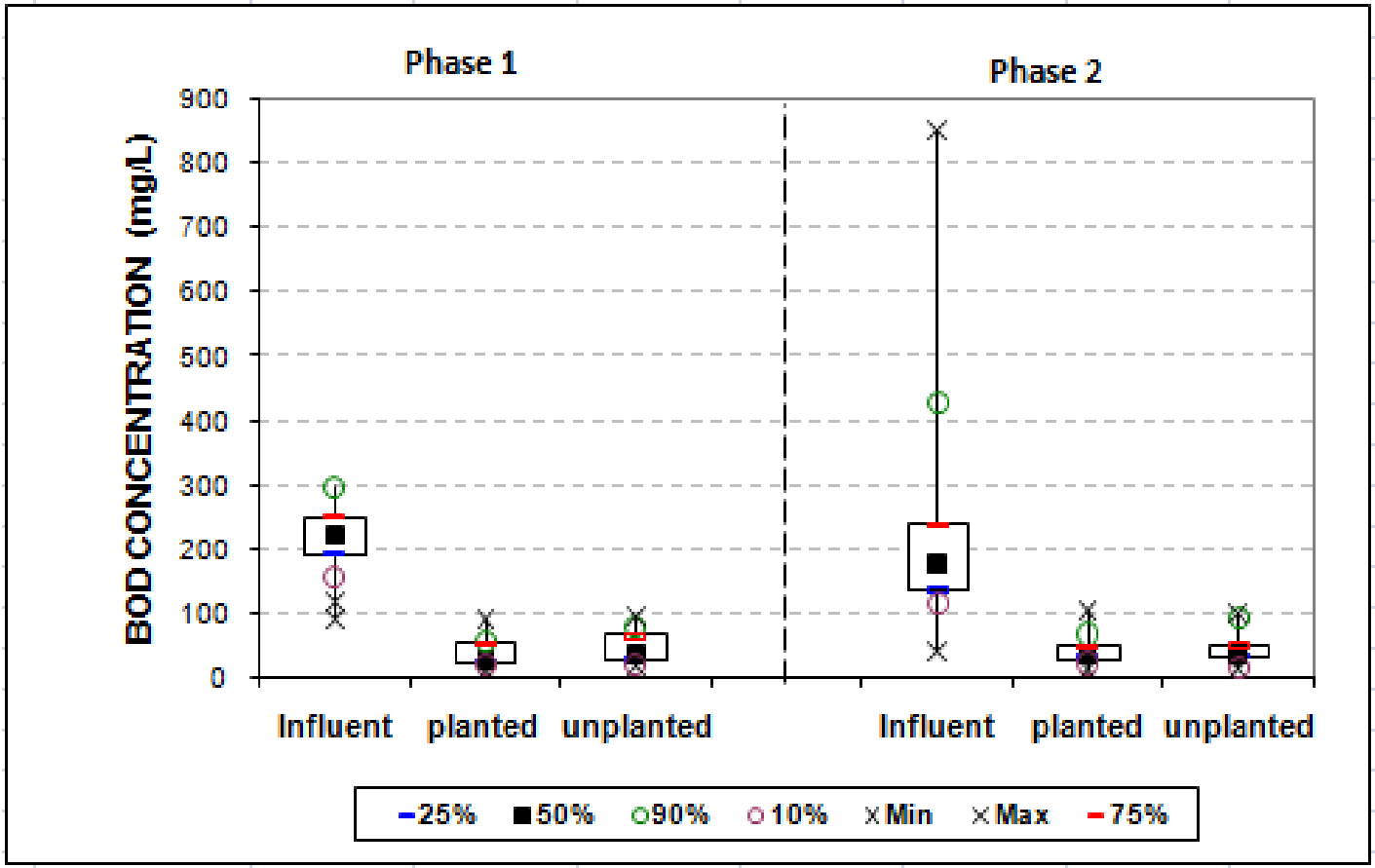
| Parameter | Influent | | Effluent | | | |
|---|---|---|---|---|---|---|
| | | | Phase 1 (3 beds)<br>HLR (total): 0.15m/d<br>HLR (bed): 0.45 m/d | | Phase 2 (2 beds)<br>HLR (total): 0.22m/d<br>HLR (bed): 0.45 m/d | |
| Concentration (mg/l) | Phase 1 | Phase 2 | Planted unit | Unplanted unit | Planted unit | Unplanted unit |
| BOD | 279 | 242 | 36 | 38 | 44 | 46 |
| COD | 465 | 558 | 71 | 70 | 267 | 198 |
| TSS | 293 | 215 | 34 | 39 | 65 | 79 |
| TKN | 31 | 39 | 14 | 15 | 19 | 23 |
| $NH_4^+$-N | 26 | 33 | 10 | 11 | 14 | 16 |

# 4. Results and discussion

## Average of removal efficiency in both phases

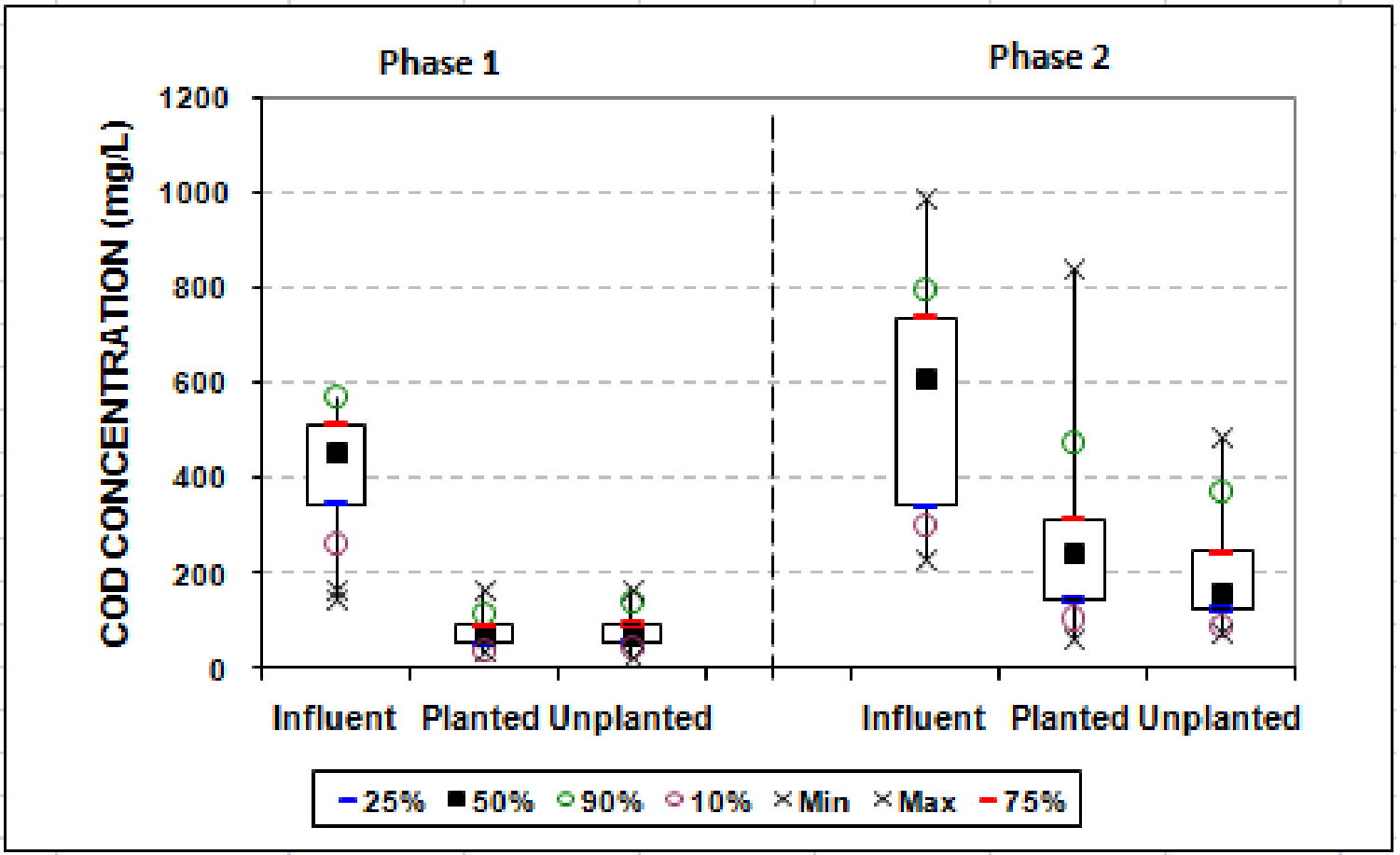
| | Phase 1 | Phase 2 | Phase 1 | Phase 2 |
|---|---|---|---|---|
| **Removal efficiency (%)** | **Planted** | | **Unplanted** | |
| BOD | 82 | 77 | 80 | 78 |
| COD | 81 | 56 | 81 | 61 |
| TSS | 85 | 64 | 74 | 57 |
| TKN | 56 | 50 | 54 | 38 |
| $NH_4^+$-N | 59 | 61 | 61 | 40 |

# 4. Results and discussion



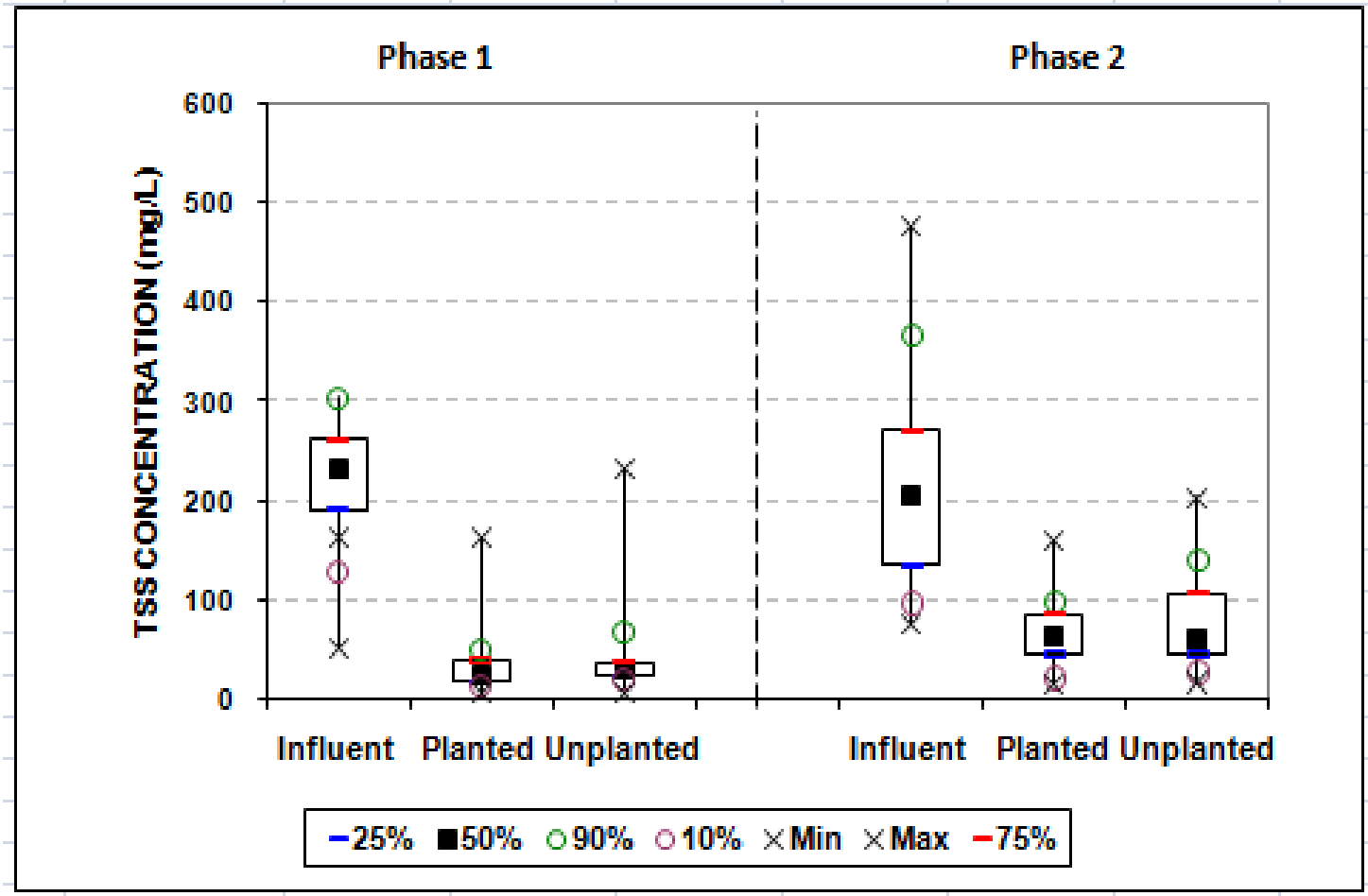

**Box-plot of BOD concentration during phases 1 and 2 in the planted and unplanted units**

# 4. Results and discussion



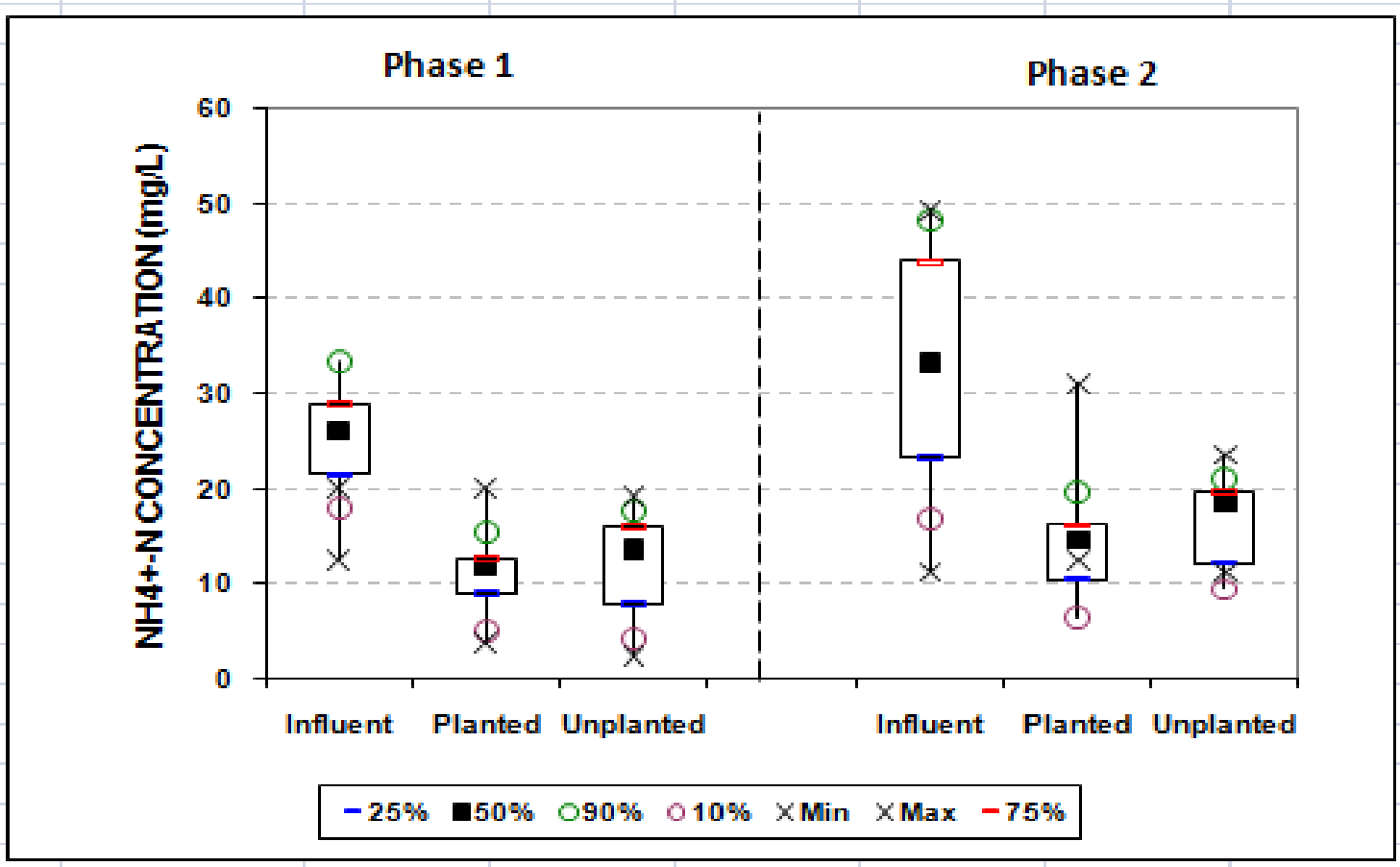

**Box-plot of COD concentration during phases 1 and 2 in the planted and unplanted units**

# 4. Results and discussion




**Box-plot of TSS concentration during phases 1 and 2 in the planted and unplanted units**

# 4. Results and discussion




**Box-plot of ammonia concentration during phases 1 and 2 in the planted and unplanted units**

# 4. Results and discussion

Table: Statistical comparison (Mann-Whitney U-test) of removal efficiencies in phases 1 and 2 in the planted bed

| Constituent | Mean removal efficiencies (%) | | Statistics | |
|---|---|---|---|---|
| | Phase 1 | Phase 2 | p-value | NS/S (*) |
| BOD | 82 | 77 | **0.34643558** | NS |
| COD | 81 | 56 | **4.8384E-06** | S |
| TSS | 85 | 64 | **0.00042168** | S |
| TKN | 56 | 50 | **0.26720049** | NS |
| $NH_4^+$-N | 59 | 61 | **0.77045632** | NS |

(*) S: Significant difference NS: Non-Significantdifference (at the 5% significance level)

## 4. Results and discussion

# Mass Loading Rates in the systems in both phases

| Parameter | Average Influent concentration (mg/l) | | Mass Loading Rate in the working unit ($g/m^2d$) | | Mass Loading Rate in the whole system ($g/m^2d$) | |
|---|---|---|---|---|---|---|
| | Phase1 | Phase 2 | Phase1 | Phase 2 | Phase 1 | Phase 2 |
| BOD | 223 | 242 | 100 | 107 | 33 | 53 |
| COD | 429 | 558 | 192 | 251 | 64 | 126 |
| TSS | 227 | 215 | 100 | 96 | 32 | 48 |
| TKN | 32 | 39 | 13,5 | 17,2 | 4,5 | 8.6 |

# 4. Results and discussion

**Partial clogging in the VFCW unplanted filter**

**Date: 24/06/2013**

## 5. Conclusion

- From the overall results, it can be concluded that the utilization of only the first stage of the French/Cemagref systems shows a large potential whenever simple systems are required for the treatment of raw domestic sewage in developing and warm-climate regions.

- Reduction of the first stage of the French system to only 2 units instead of 3 units (2/3 of the usual area) seems promising, although a reduction in removal efficiency was noted.

## 5. Conclusion

- The good performance and the associated simplicity, with no pre-treatment (apart from screens and grit removal), no post-treatment, no mechanization, no energy consumption and no sludge treatment make this system a very attractive alternative for developing countries when very stringent discharge standards are not applied.

# Thank you