Dairy wastewater treatment in vertical flow constructed wetlands using a mixture of perlite and sponge carriers as substrate material

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Introduction – Dairy industry/Dairy Wastewater

- **Dairy industry:**
  - Driving sector in the agricultural economy.
  - Large source of industrial wastewater.

- **Dairy wastewater:**
  - High concentrations of organic matter (COD : 80 – 95 g/L), TSS, TN and TP (Sultana et al., 2016).
  - Serious impacts on the environment, i.e. deterioration of water quality, reduction of dissolved oxygen and eutrophication (Carvalho et al., 2013).
  - High energy and economic requirements for its treatment.

Introduction – Constructed Wetlands (CWs)

- One possible management practice for the treatment of DW that has been used in recent years is CWs .

- "***innovative, low-cost and low-energy*** …" (Tunçsiper et al., 2015).

- They are designed and constructed to use the processes that take place in plants and substrates as well as microbial communities to treat wastewater (Gorra et al., 2014).

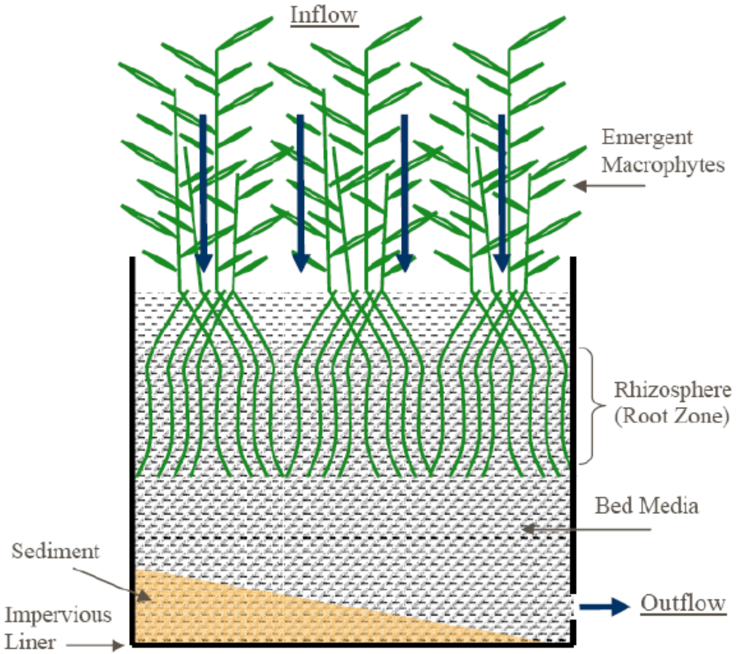
- ***Substrates help microbial processes*** to develop and act as catalysts ***for the removal of organic/ inorganic components*** in wastewater (Gorra et al., 2014).

Introduction – Scope and novelty

❖ Different types of CWs:

1. Free water surface wetlands
2. Constructed horizontal sub-surface flow wetlands (HSSF)
3. Constructed vertical flow wetlands (VFCW)

(typical substrates used in VFCW are sand and gravel)



Introduction – Scope and novelty

- **Perlite:** clay-silicate mineral of volcanic origin, chemically inert, with neutral pH and unlimited lifetime. It offers significant advantages to plants and soil; it improves the characteristics of the soil (better aeration for the development of the root system of plants and greater moisture retention).

- **Sponges cubic foam:** have high porosity, large surface area, ideal for supporting and protecting attached microbiological growth and leading to large bacterial populations (Dang et al., 2020).

Aim of the Project

01. To evaluate the effectiveness of contaminant removal.

02. To test for the first time the use mixtures of perlite and sponge foam in VFCWs for the treatment of real low-strength dairy wastewater effluents.

Materials and Methods - Experimental Design

Experimental Design

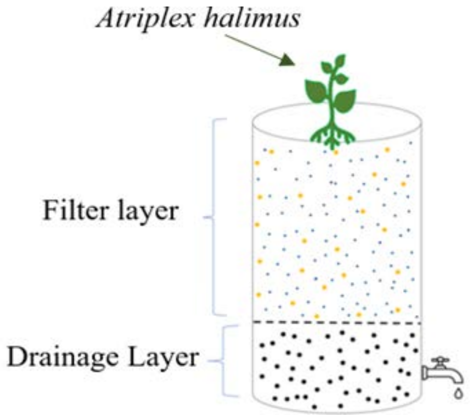
2 VFCWs

- ❖ Using modified cylindrical plastic containers (diameter:25cm, height:80cm)
- ❖ ***2 Layers***

  - ***Drainage layer*** (15cm) → ***coarse gravel*** (20-40 mm)

  - ***Filter layer*** (60cm) → a) ***gravel*** (named ***VFCW1***)

    → b)mixture of ***perlite*** and ***sponge cubid foam carriers*** (named ***VFCW2***)



- ❖ Halophytic plant: ***Atriplex halimus***

- ❖ HLR(Phase a) = ***40 mm/d***, HLR(Phase b) = ***20 mm***

Materials and Methods – Measurements/ Analysis

Chemical Analysis

pH
Conductivity (μS/cm)
Turbidity (NTU)
COD (mg/l)
BOD_5 (mg/l)
NH_4^+-N (mg/L)
Total-P (mg/L

Materials and Methods – Measurements/ Analysis

Chemical characteristics of dairy wastewater used in the experiment

Parameter	Dairy wastewater phase a mean ± SD (number of samples)	Dairy wastewater phase b mean ± SD (number of samples)
pH	8.4 ± 0.3 (27)	7.9 ± 0.4 (42)
EC (µS/cm)	3539 ± 252 (27)	1688 ± 235 (33)
Turbidity (NTU)	342 ± 191 (27)	113 ± 64 (33)
COD (mg/L)	894 ± 384 (22)	1033 ± 283 (42)
BOD_5 (mg/L)	247 ± 89 (5)	197 ± 49 (3)
NH_4^+-N (mg/L)	25 ± 9 (24)	34 ±11 (39)
Total-P (mg/L)	10 ± 4 (22)	23 ±13 (32)

Result Analysis

Results

Effluent quality of the VFCWs during the operation

Parameter	Dairy wastewater (mean ± SD) Phase A		Dairy wastewater (mean ± SD) Phase B	
	VFCW1	VFCW2	VFCW1	VFCW2
pH	8.6 ± 0.2 (n=27)	8.6 ± 0.3 (n=27)	8.0 ± 0.3 (n=42)	8.1 ± 0.2 (n=42)
COD (mg/L)	352 ± 111 (n=22)	174 ± 60 (n=22)	390 ± 176173 (n=42)	228± 125 (n=42)
BOD5 (mg/l)	113.5 ± 10.5 (n=5)	26 ± 10 (n=5)	116 ± 4 (n=3)	33 ± 2.5 (n=3)
Turbidity (NTU)	51 ± 12 (n=27)	11 ± 2 (n=27)	61.5 ± 16.5 (n=27)	23 ± 3 (n=27)
NH_4^-N (mg/L)	7 ± 4 (n=24)	4 ± 2 (n=24)	7 ± 4 (n=39)	4 ± 2 (n=39)
Total-P (mg/L)	7.7 ± 2.5 (n=22)	5.0 ± 1.4 (n=22)	21.1± 2.4 (n=32)	16.8± 1.7 (n=32)
EC (µS/cm)	3361 ± 375 (n=27)	3444 ± 370 (n=27)	1781 ± 382 (n=33)	1422 ± 288 (n=33)

pH

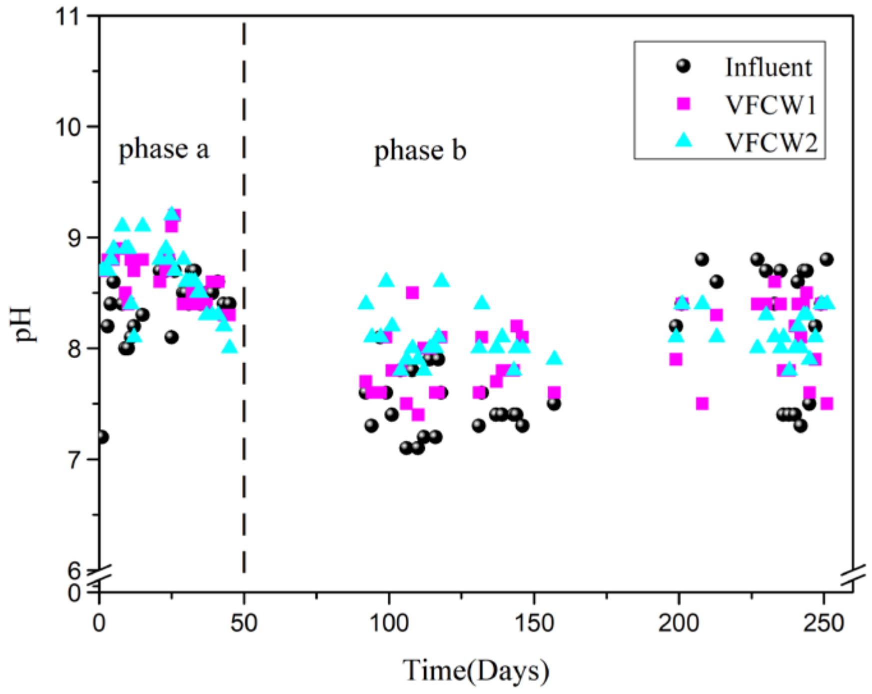


Figure 1. pH values of both VFCWs regarding the different materials and flows.

Phase a

- ❖ $pH_{influent}$= 8.4 ± 0.3
- ❖ pH_{VFCW1}= 8.6 ± 0.2
- ❖ pH_{VFCW2}= 8.6 ± 0.3

Phase b

- ❖ $pH_{influent}$= 7.9 ± 0.4
- ❖ pH_{VFCW1}= 8.0 ± 0.3
- ❖ pH_{VFCW2}= 8.1 ± 0.2

Turbidity

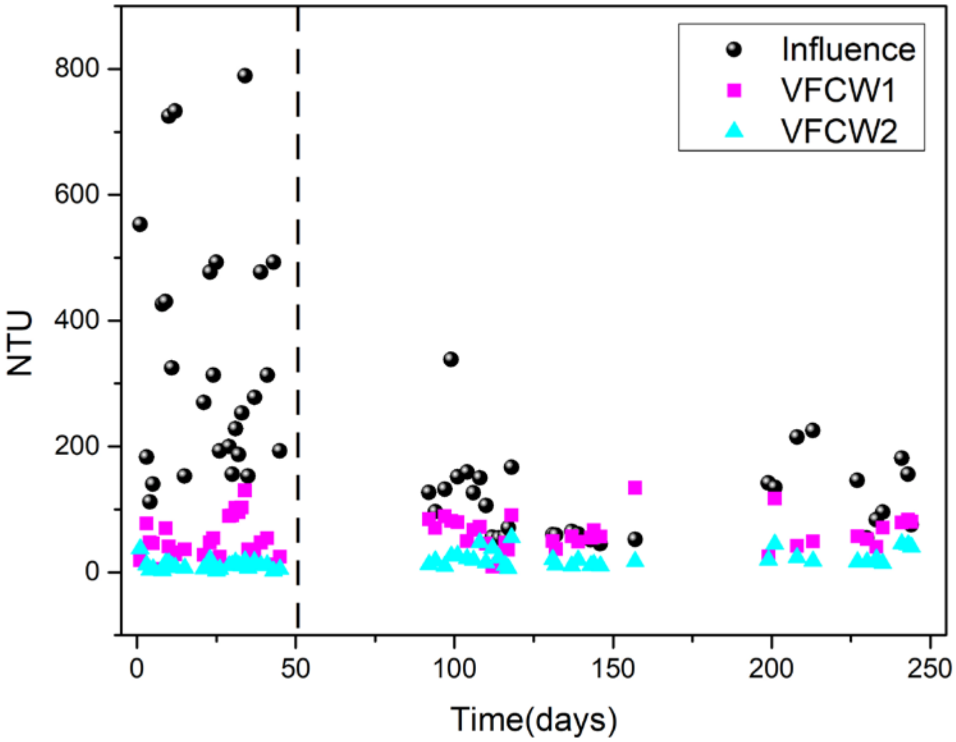


Figure 2. Turbidity values of both VFCWs regarding the different materials and flows.

Phase a

- Influent= 342 ± 191 NTU

VFCW1= 51 ± 32 NTU

VFCW2= 11 ± 7 NTU

Phase b

- Influent=1 13 ± 64 NTU
- VFCW1= 62 ± 26 NTU
- VFCW2= 23 ± 13 NTU

VFCW1→ **79% removal**
VFCW2→ **96% removal**

TSS

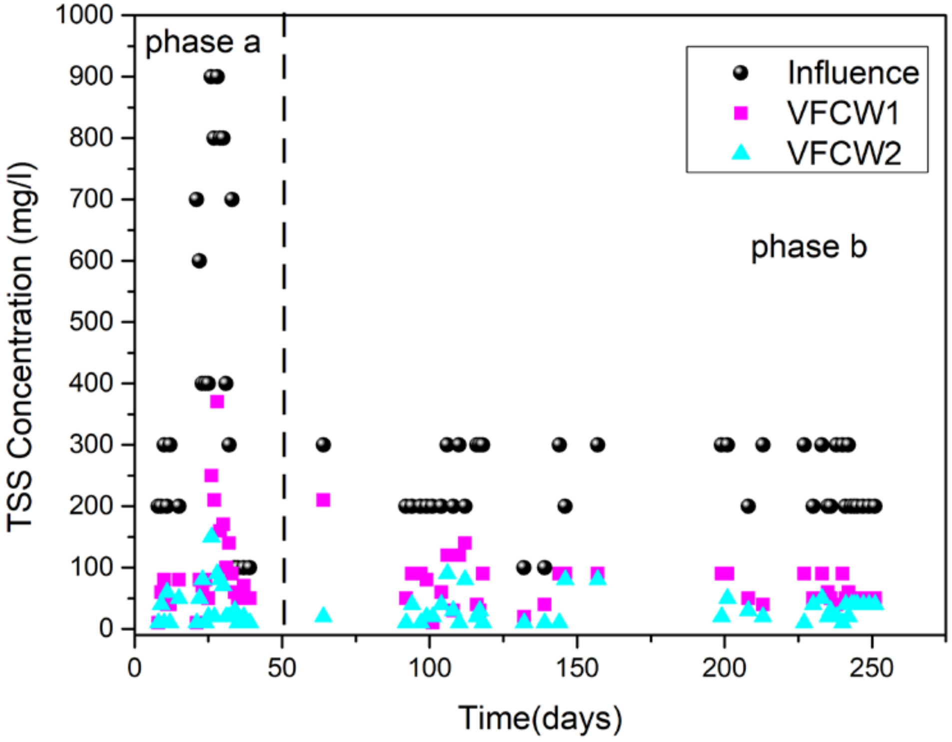


Figure 3. TSS (mg/l) values of both VFCWs regarding the different materials and flows.

Phase a

❖ Influent=430.4 ±270.1 mg/l

VFCW1 = 96.5 ± 46.5 mg/l → **78% removal**

VFCW2 = 43.0 ± 20.0 mg/l → **90% removal**

Phase b

❖ Influent=236,8 ±58,13 mg/l

VFCW1 = 69.5 ± 36.8 mg/l → **71% removal**

VFCW2 = 32.1 ± 11.3 mg/l→ **86% removal**

COD

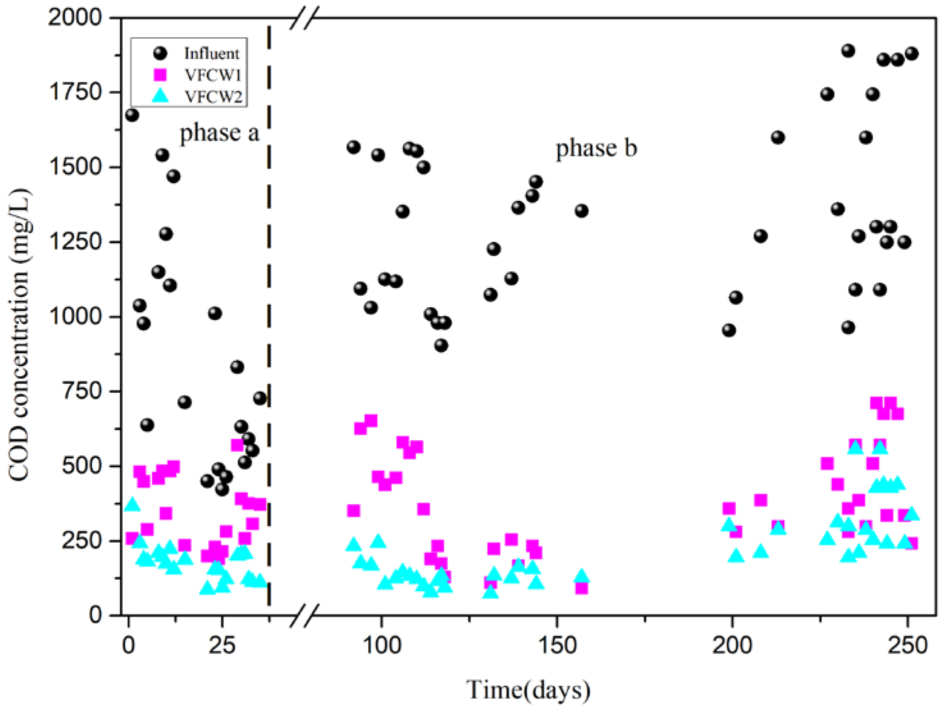


Figure 4. COD (mg/l) values of both VFCWs regarding the different materials and flows.

Phase a

❖ Influent=894 ±384 mg/l

VFCW1 = 352 ± 111 mg/l → **56% removal**

VFCW2 = 174 ± 60 mg/l → **70% removal**

Phase b

❖ Influent=1033 ±283 mg/l

VFCW1 = 390 ± 176 mg/l → **79% removal**

VFCW2 = 228 ± 125 mg/l → **83% removal**

$NH_{4-}{}^{+}N$

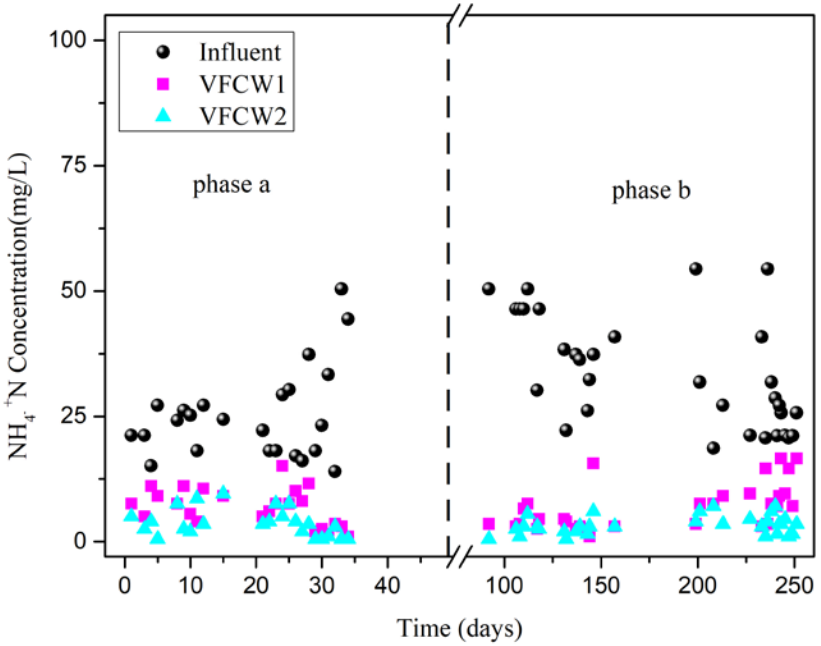


Figure 5. $NH_{4-}{}^{+}N$ (mg/l) values of both VFCWs regarding the different materials and flows.

Phase a

- Influent= 25± 9 mg/l

VFCW1 = 7 ± 4 mg/l → ***69% removal***

VFCW2 = 5 ± 1 mg/l → ***75% removal***

Phase b

- Influent= 34 ±11 mg/l

VFCW1 = 7 ± 4 mg/l → ***83% removal***

VFCW2 = 3 ± 2 mg/l → ***89% removal***

Average Removal

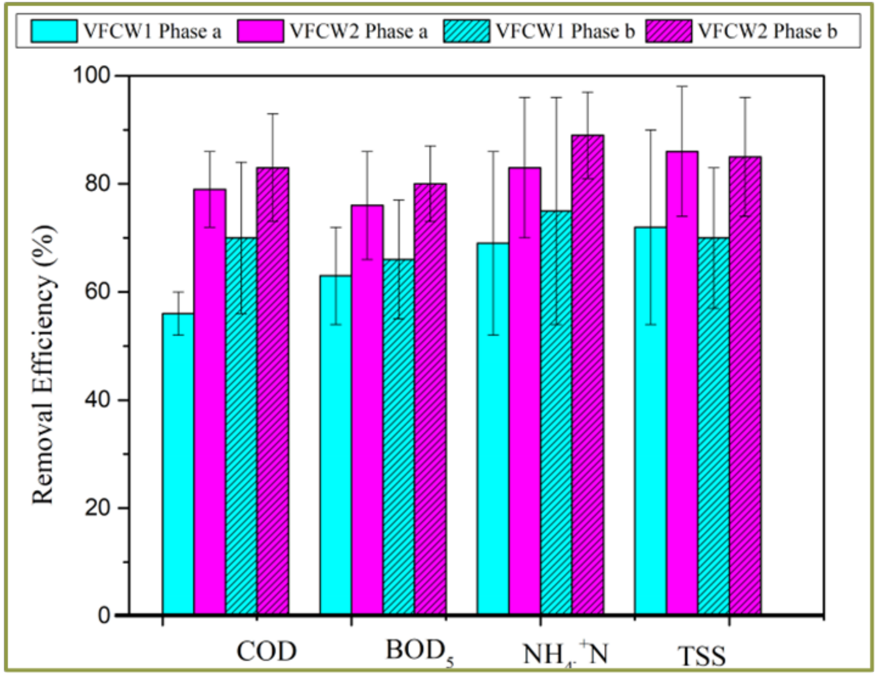


Figure 6. Average removal of COD, BOD, TSS, and N-NH4 in VFCWs during the experimental period. (Mean values and standard deviations were calculated from day 0 to day 251.

Two different cases of HLR were tasted

1. The concentration of all pollutants at the outlet of the two systems (except conductivity and pH) decreased with reduction of HLR.

2. The longer residence time of the waste in the system helped the systems to treat the wastewater.

VFCNW1

- ✓ $COD_{phase\ a}$ = ***56 %*** — $COD_{phase\ b}$ = ***70%***
- ✓ $BOD_{5\ phase\ a}$ = ***63%*** — $BOD_{5\ phase\ b}$ = ***66%***
- ✓ $NH_{4-}{}^{+}N_{phase\ a}$ = ***69%*** — $NH_{4-}{}^{+}N_{phase\ b}$ = ***75%***
- ✓ $TSS_{phase\ a}$ = ***78%*** — $TSS_{phase\ b}$ = ***90%***

VFCW2

- ✓ $COD_{phase\ a}$ = ***79%*** — $COD_{phase\ b}$ = ***83%***
- ✓ $BOD_{5\ phase\ a}$ = ***76%*** — $BOD_{5\ phase\ b}$ = ***80%***
- ✓ $NH_{4-}{}^{+}N_{phase\ a}$ = ***83%*** — $NH_{4-}{}^{+}N_{phase\ a}$ = ***89%***
- ✓ $TSS_{phase\ a}$ = ***71%*** — $TSS_{phase\ b}$ = ***86%***

Conclusions

1

CWs are innovative, low-cost and low-energy solution to treat dairy wastewater; a high-volume effluent do to intensive production.

2

The objective of this study was to evaluate the effectiveness of contaminant removal in VFCWs with perlite/sponge carrier mixtures.

3

VFCWs were effective for dairy wastewater treatment: lower effluent quality in terms of physical (turbidity, total suspended solids) and chemical characteristics(organic matter, nitrogen, phosphorus).

4

The application of lower HLR increased slightly the organic matter and nutrient removal in both examined systems.

Discussion of results – Future Work

Thank You

Do you have any questions?

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