EFFICIENCY OF VETIVER GRASS CULTIVATED WITH FLOATING PLATFORM TECHNIQUE IN DOMESTIC WASTEWATER TREATMENT

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Domestic wastewater

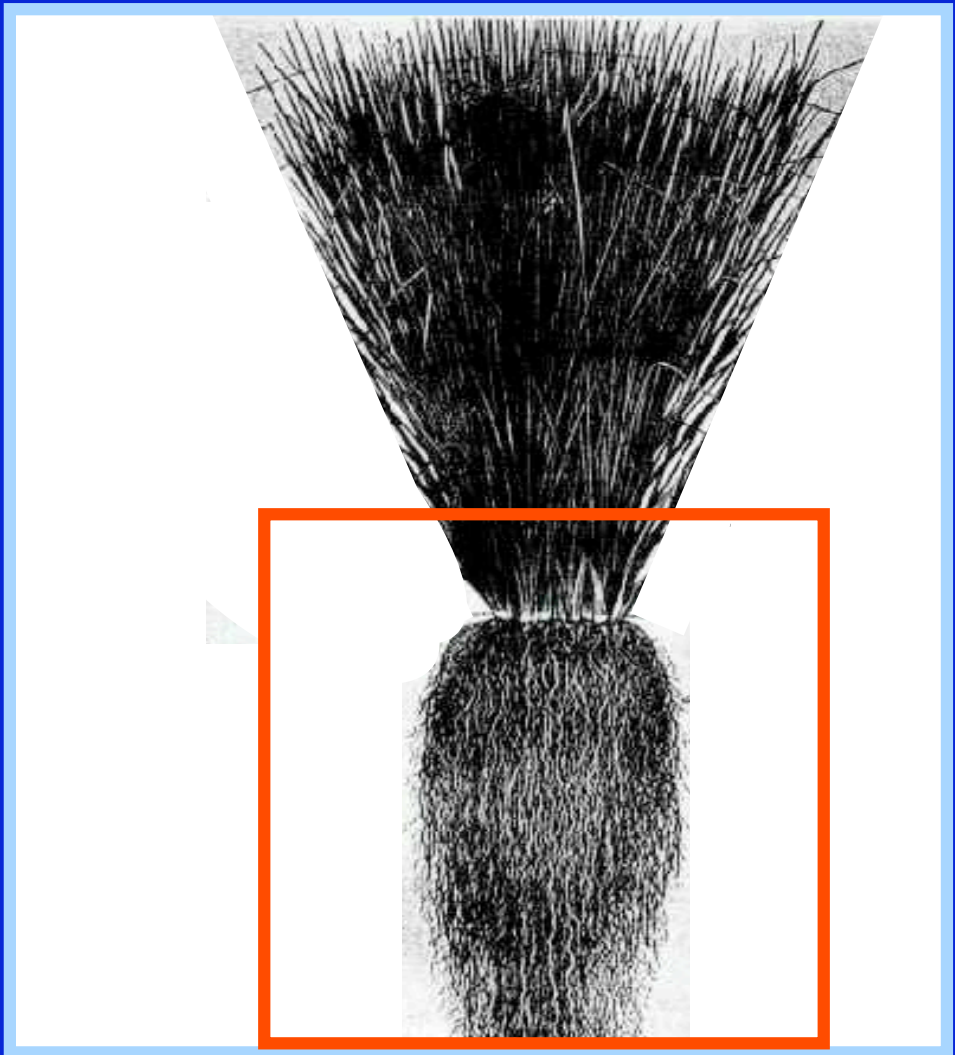
Domestic wastewater mainly contained organic waste and nutrients (nitrogen and phosphorus).

Phytoremediation

- **Phytoremediation is a clean up technology to exploit plant potential to remediate soil and water contaminate with pollutants.**
- **It is environmental friendly, inexpensive and can be carried out in polluted place.**
- **Utilization of vetiver system for wastewater treatment is a new and innovative technology.**

Vetiver Grass

(*Vetiveria zizaniodes* (L.) Nash



- No invasive
- Fast growing
- Deep root system
- High biomass production
- Tolerant to adverse envi' l condition
- Prefer wet and waterlogged habitat
- Powerful to remove N and P from water

Objectives

(1) to compare the efficiencies of two vetiver ecotypes in treating domestic wastewater of different strengths using hydroponic technique

(2) to determine the growth and the degree of nutrient accumulation in those two vetiver ecotypes received different strength wastewater


METHODOLOGY

Experimental Design

- 3 x 3 x 2 factorial
- 2 replicates
- total of 36 units

Experimental Design

HRT (days)	Vetiver ecotypes (B)	Wastewater strengths (C)	
		C1	C2
7 d (A1)	B1	A1B1C1	A1B1C2
	B2	A1B2C1	A1B2C2
	B3 (control)	A1B3C1	A1B3C2
5 d (A2)	B1	A2B1C1	A2B1C2
	B2	A2B2C1	A2B2C2
	B3 (control)	A2B3C1	A2B3C2
3 d (A3)	B1	A3B1C1	A3B1C2
	B2	A3B2C1	A3B2C2
	B3 (control)	A3B3C1	A3B3C2

Songkhla3

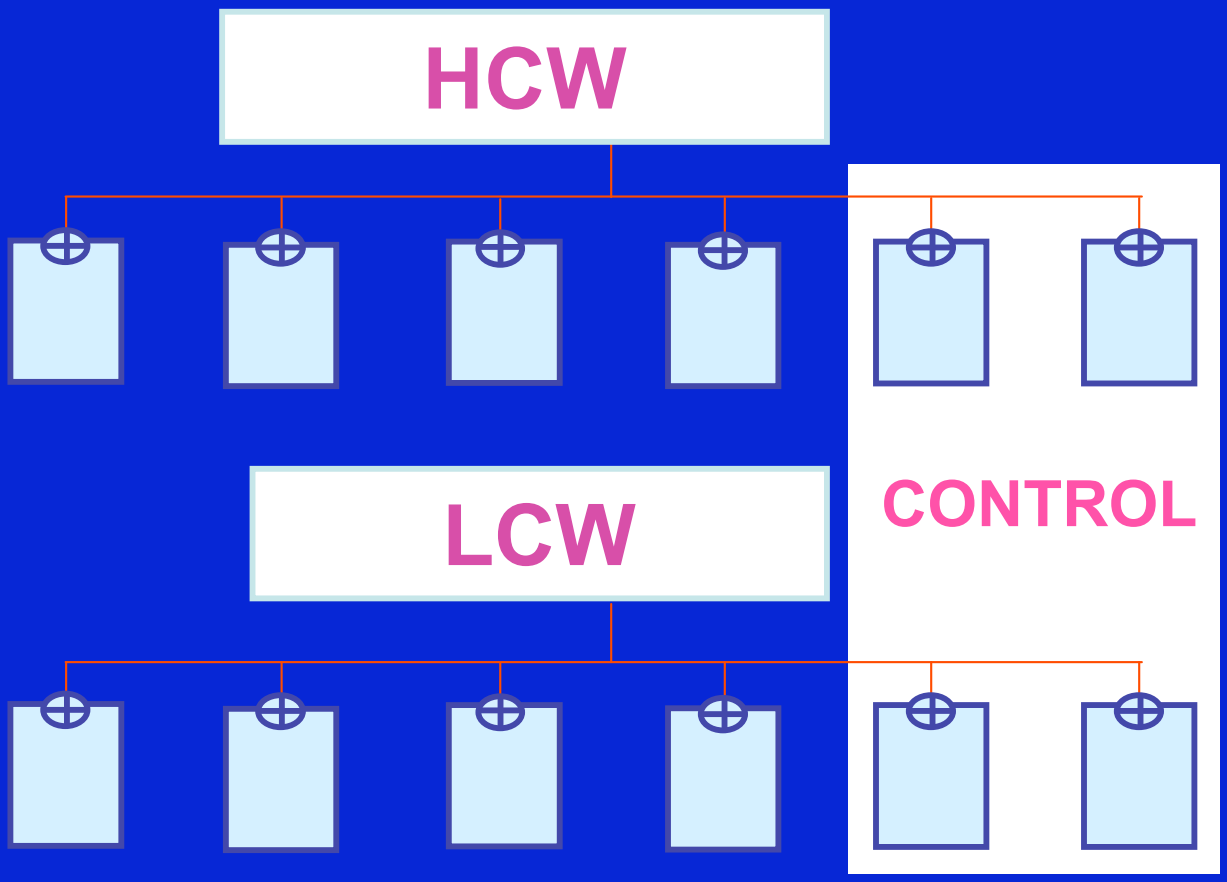
Surat thani

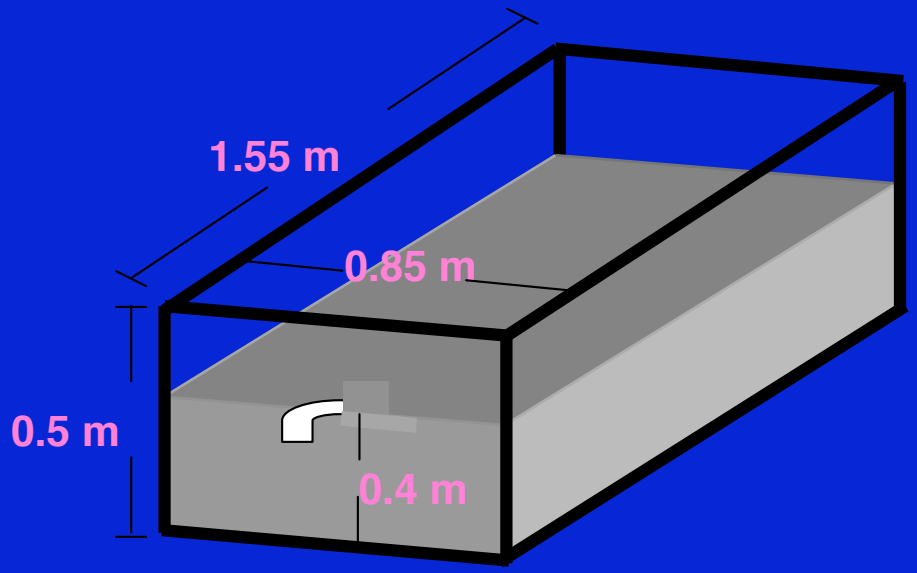
HCW

LCW

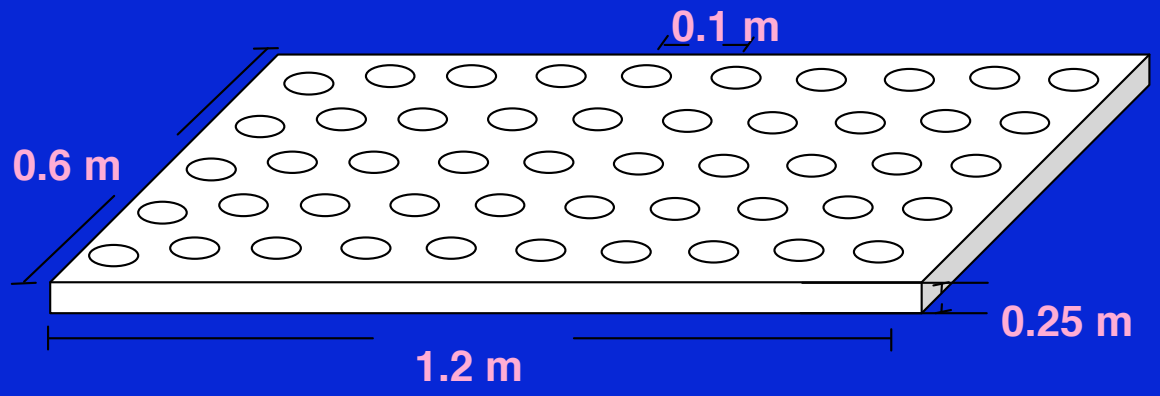
Methodology

- total of 36 units
- divided into 3 phases
  - Phase 1 — HRT 7 day
  - Phase 2 — HRT 5 day
  - Phase 3 — HRT 3 day
- each phase 12 units


HCW
LCW
CONTROL



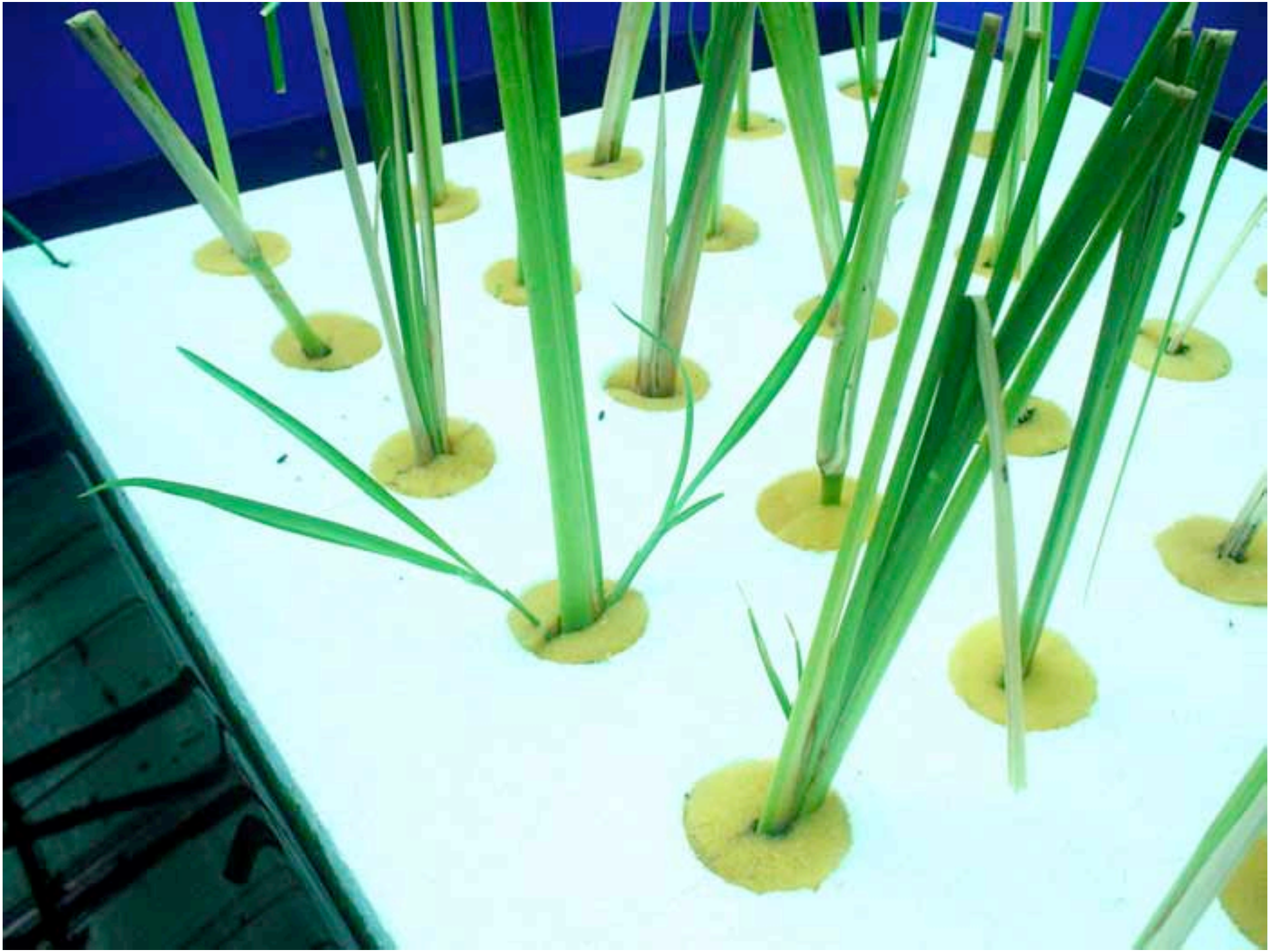
PVC container



60 holes

- Each vetivers were pruned to
    - 20 cm. for the shoots (stems and leaves)
    - 13.5 cm for the roots.

- Each vetiver was planted onto a hole in platform.



Water Analysis

Parameters	Methods
pH	pH meter
Dissolved oxygen	Modified wrinkler method (AWWA, 1998)
Conductivity	Electromethric method
BOD	5-day BOD test (AWWA, 1998)
TKN	Semi-micro-Kjedahl method (AWWA, 1998)
NH_4-N	Distillation-titration (AWWA, 1998)
NO_3-N	Cadmium reduction method (AWWA, 1998)
Total Phosphorus	Acid digestion-ascorbic acid method
Ortho-PO_4	Molybdenum blue method (AWWA, 1998)

Statistical Analysis

- tested for the significant difference between wastewater strengths, vetiver ecotypes and detention times using ANOVA.

- calculated for Duncan ’s new multiple range test at 5% probability level

RESULTS AND DISCUSSION

Treatment Efficiency

Wastewater Quality

Parameters	HCW	LCW
pH	7.1 - 7.4	6.9 - 7.2
DO (mg/l)	0.0	0.0
BOD (mg/l)	90 - 95	44 - 59
TKN (mg/l)	41.0 - 52.8	34.7 - 42.1
NH_4-N (mg/l)	28.0 - 32.3	30.4 - 35.0
NO_3-N (mg/l)	0.02 - 0.07	0.02 - 0.05
TP (mg/l)	5.9 - 6.7	4.8 - 5.5
Ortho-PO_4 (mg/l)	3.9 - 4.6	3.5 - 4.1

pH

HRT (days)	Conc.	Influent	Effluent		
			Song3	Surat	Control
7 d	HCW	7.36	7.14	7.11	7.20
	LCW	7.24	7.09	7.09	7.16
5 d	HCW	7.05	7.15	7.17	7.28
	LCW	6.93	7.14	7.18	7.26
3 d	HCW	7.09	7.11	7.13	7.14
	LCW	7.01	7.13	7.15	7.16

pH

- Influent pH was 6.9-7.4 and effluent pH was 7.0-7.3.
- Generally, effluent pH was higher than influent and the values became nearly neutral.
- Effluent pH of vetiver sets were slightly lower than the control set

  => higher organic decomposition rate (could be observed by the higher BOD removal efficiencies) resulted in CO_2 and acid production which finally lower the effluent pH.

Dissolved oxygen (mg/l)

HRT (days)	Conc.	Influent	Effluent		
			Song3	Surat	Control
7 d	HCW	0.00	°3.88	b°3.57	°4.08
	LCW	0.00	°4.12	a°4.76	°4.68
5 d	HCW	0.00	¢2.88	¢2.29	¢2.34
	LCW	0.00	¢2.47	¢2.22	¢2.28
3 d	HCW	0.00	§1.30	§1.34	§0.96
	LCW	0.00	§1.68	¢1.60	¢1.45

Superscript letters (left downward) denote the significant difference among wastewater concentrations at p=0.05.

Thai superscript letters (left downward) ⇨ detention times

Dissolved Oxygen

- **Effluent DO increased significantly from 0 to 1-5 mg/l.**

- **The rising of DO was the result of**
  - **-> aeration by wind**
  - **-> algal photosynthesis**
  - **-> translocation of O_2 through leaves and stems to roots**

Dissolved Oxygen

- Effluent DO of 7-d HRT was significantly higher than 5- and 3- day.
- During the 3-d HRT phase, effluent DO of vetiver sets were higher than control sets.
- Whereas during the 7-d HRT phase, the control sets showed higher effluent DO.
- The main factor influenced the rising of DO during

  -> short HRT phase - vetivers

  -> long HRT phase - aeration by wind, algal photosynthesis

Dissolved Oxygen

- The effluent DO in HCW system was lower than LCW

  => the available DO in HCW system may be consumed in aerobic decomposition of organic matter

BOD

HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)			Eff. (%)
			Song3	Surat	Control	
7 d	HCW	^{a}90.12	§7.91	$^{¢}$7.06	$^{¢}$7.20	79.9-91.4%
	LCW	^{b}44.28	§7.98	$^{¢}$7.18	§8.72	
5 d	HCW	^{a}94.88	$^{¢}$15.38	$^{a°}$20.66	$^{°}$21.23	69.0-78.0%
	LCW	^{b}58.97	$^{¢}$15.65	$^{b°}$15.28	$^{¢}$18.38	
3 d	HCW	^{a}94.97	$^{°}$21.62	$^{°}$21.34	$^{°}$27.15	48.4-77.4%
	LCW	^{b}51.28	$^{°}$22.53^{b}	$^{°}$16.76^{c}	$^{°}$25.75^{a}	

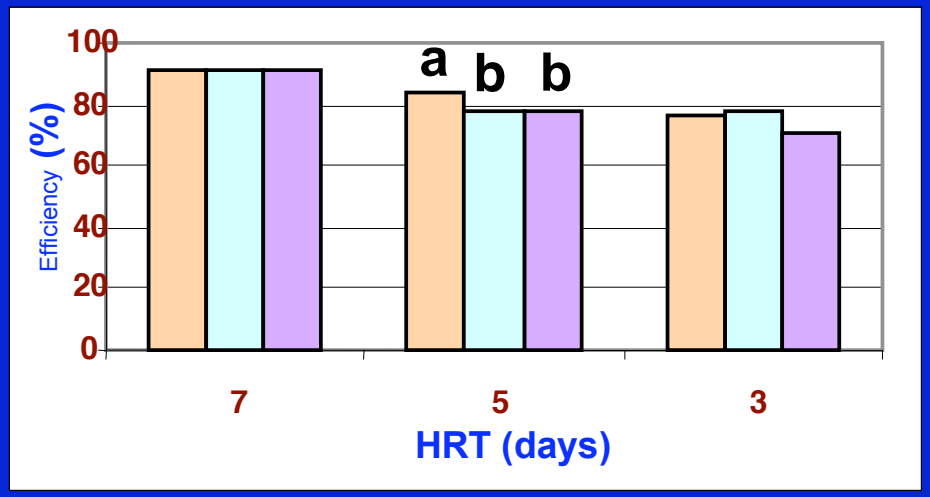
Superscript letters (right horizontal) ⇨ vetiver ecotypes
Superscript letters (left downward) ⇨ wastewater conc.
Thai superscript letters (left downward) ⇨ detention times

BOD

- The removal efficiencies of Surat Thani ecotype was significantly higher than Songkhla3.
- The removal efficiencies of vetiver sets was significantly higher than control sets especially during the 5- and 3-d HRT phases.

  => indicated the beneficial effect of vetiver
- The average BOD removal efficiencies of 7-d HRT was significantly higher than 5- and 3-d HRT respectively -> related to higher DO concentration
- The removal efficiencies of HCW system was significantly higher than LCW.

BOD

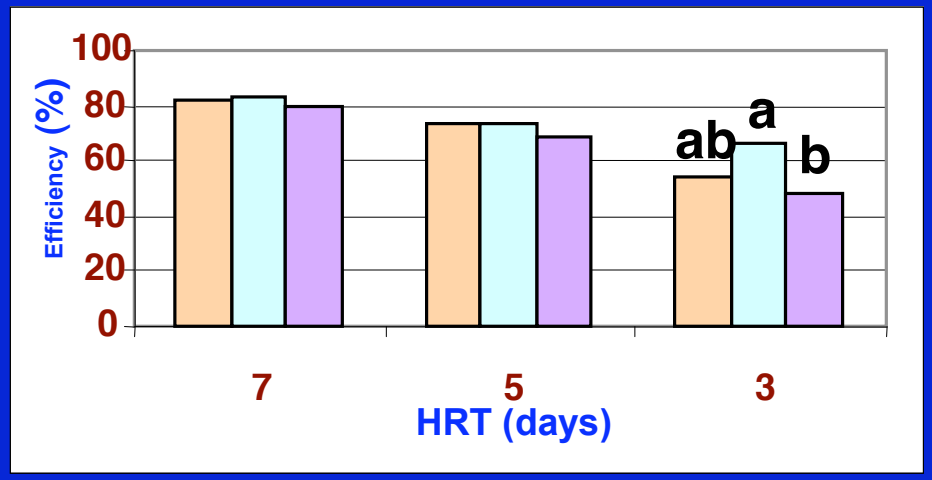


Songkhla3

Surat Thani

Control

HCW



Songkhla3

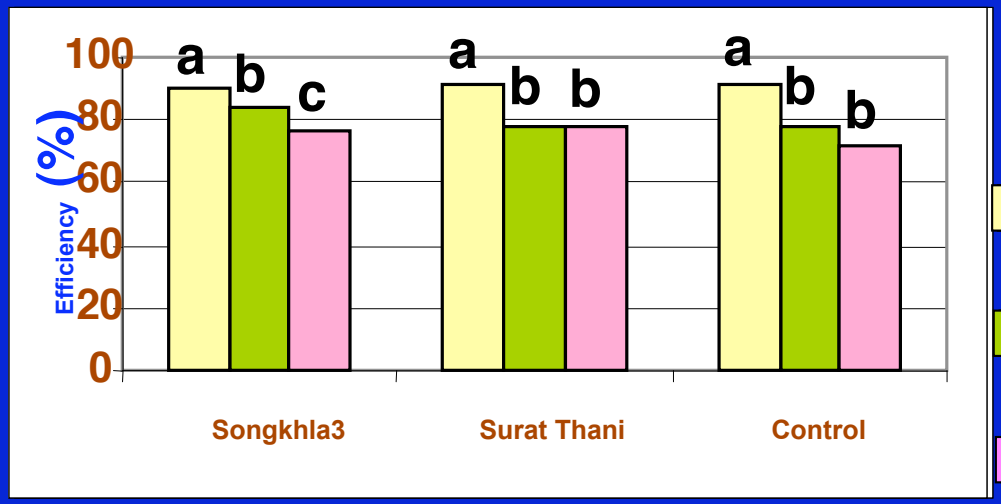
Surat Thani

Control

LCW

Different letters denote the significant difference among vetiver ecotypes at p=0.05.

BOD

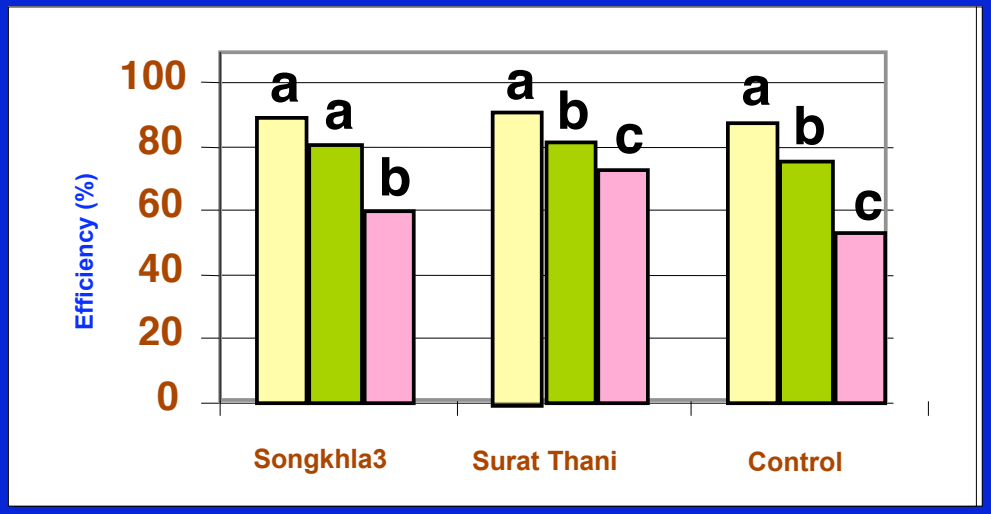


HRT 7 days

HRT 5 days

HRT 3 days

HCW



HRT 7 days

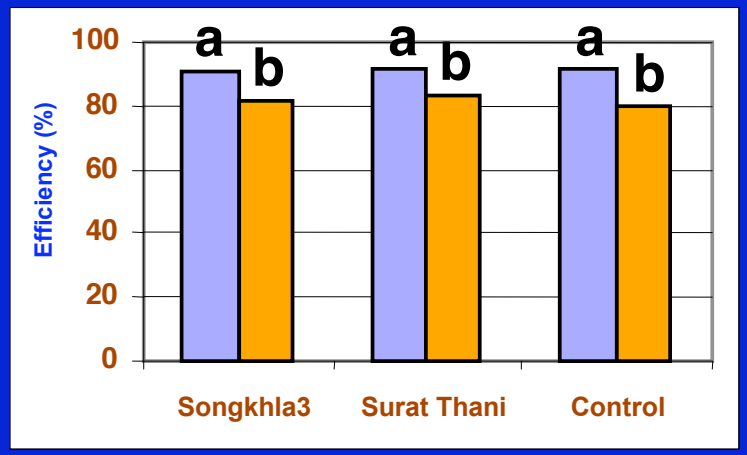
HRT 5 days

HRT 3 days

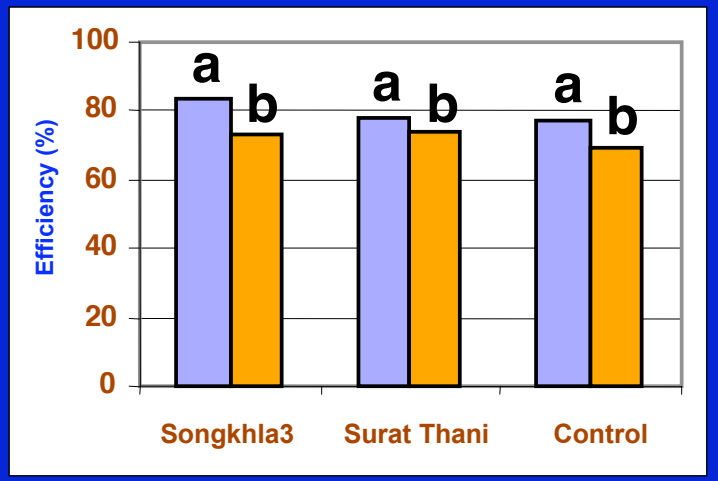
LCW

Different letters denote the significant difference among HRT at p=0.05.

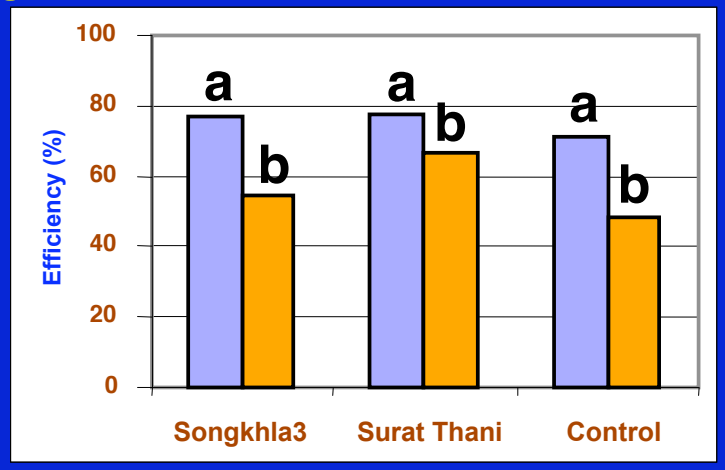
BOD



HRT 7 days



HRT 5 days



HRT 3 days

HCW

LCW

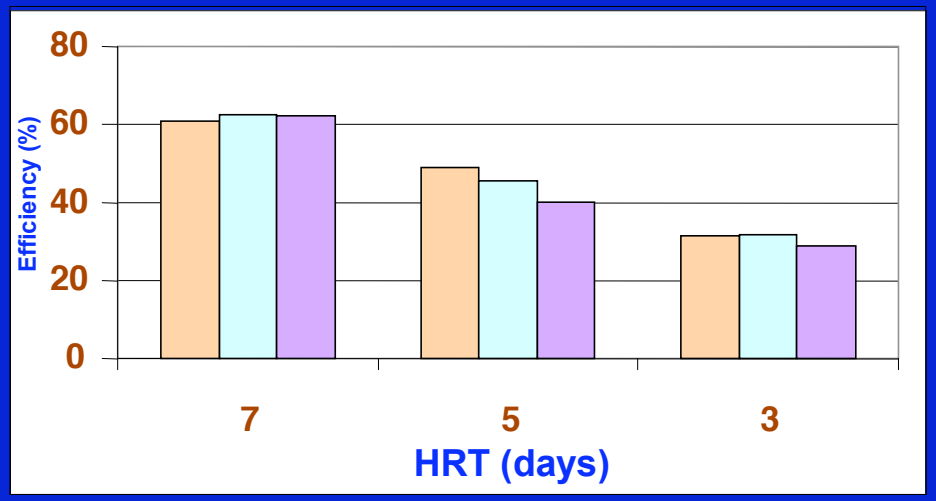
Different letters denote the significant difference among wastewater concentrations at p=0.05.

TKN

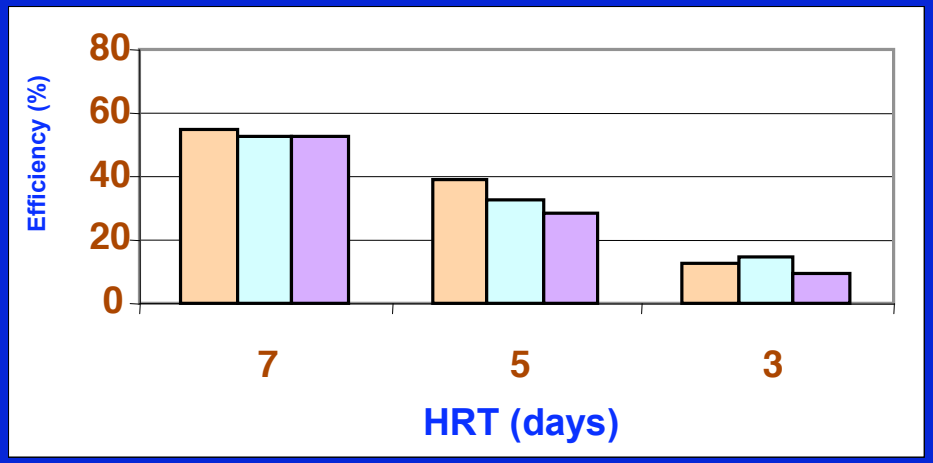
HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)			Eff. (%)
			Song3	Surat	Control	
7 d	HCW	^{a}52.81	$^{¢}$19.831	§19.094	§19.21	52.4-62.5%
	LCW	^{b}42.14	$^{¢}$18.675	§19.319	§19.51	
5 d	HCW	^{a}42.81	$^{¢}$21.78^{b}	$^{¢}$23.23^{ab}	$^{¢}$25.51^{a}	28.8-45.5%
	LCW	^{b}36.24	$^{¢}$22.02^{b}	$^{¢}$24.21^{ab}	$^{¢}$26.16^{a}	
3 d	HCW	^{a}41.03	$^{b°}$28.036	$^{b°}$27.99	$^{b°}$29.19	10.0-31.7%
	LCW	^{b}34.73	$^{a°}$30.32^{a}	$^{a°}$29.56^{b}	$^{a°}$31.22^{a}	

Superscript letters (right horizontal) ⇒ vetiver ecotypes
Superscript letters (left downward) ⇒ wastewater conc.
Thai superscript letters (left downward) ⇒ detention times

TKN



HCW

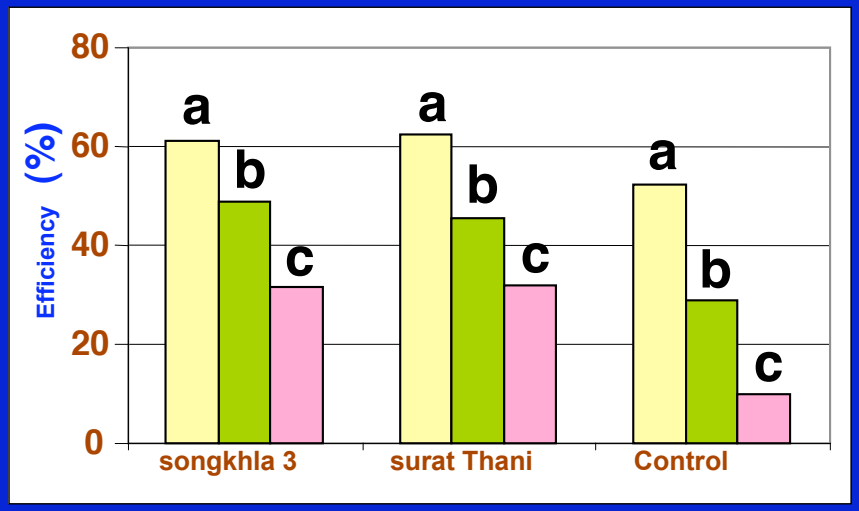


LCW

Songkhla3
Surat Thani
Control

Songkhla3
Surat Thani
Control

TKN

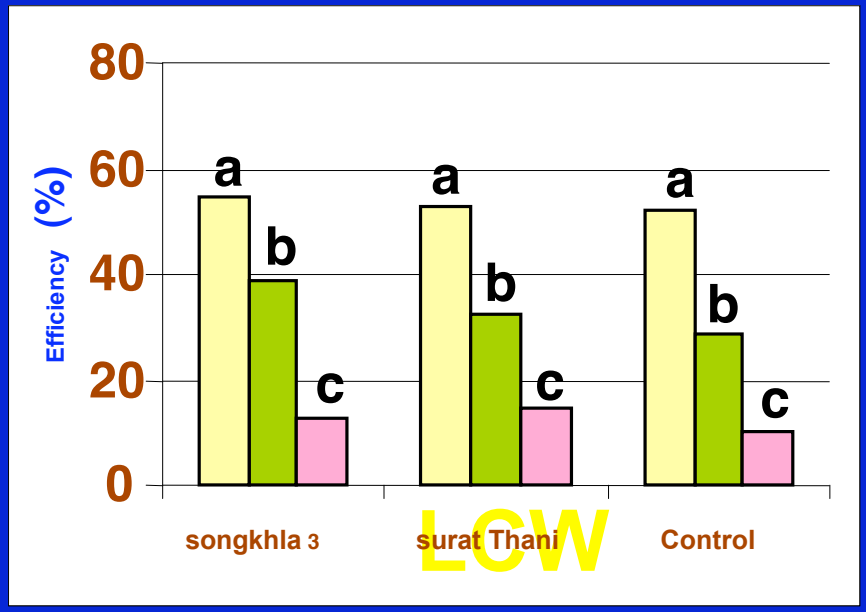


HRT 7 days

HRT 5 days

HRT 3 days

HCW



HRT 7 days

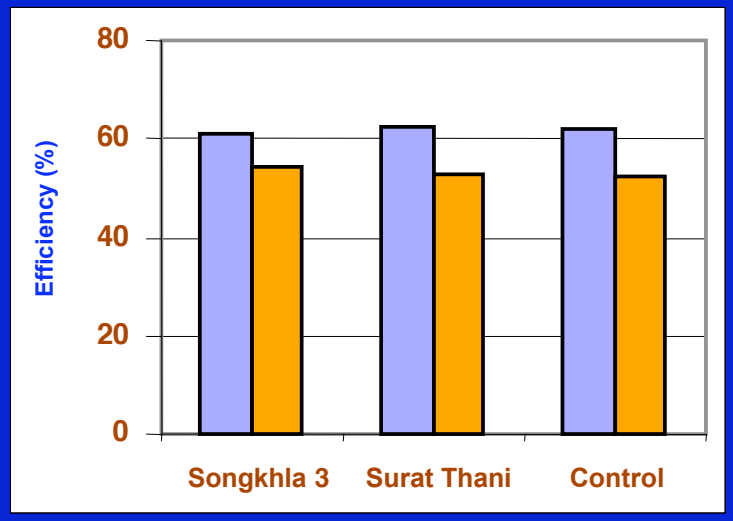
HRT 5 days

HRT 3 days

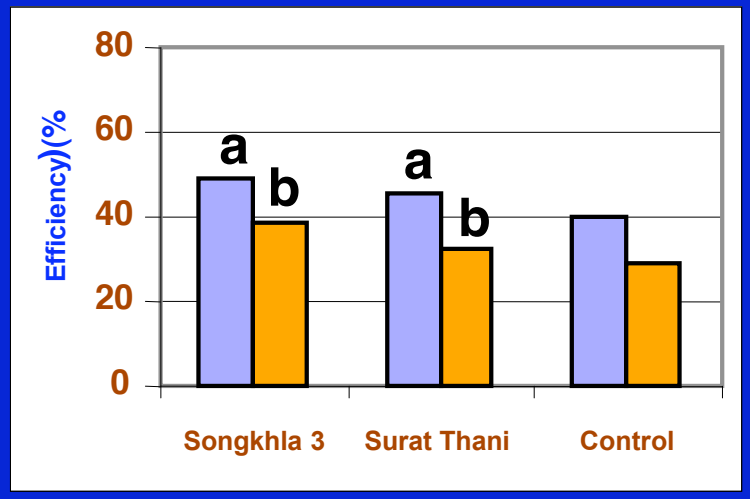
LCW

Different letters denote the significant difference among HRT at p=0.05.

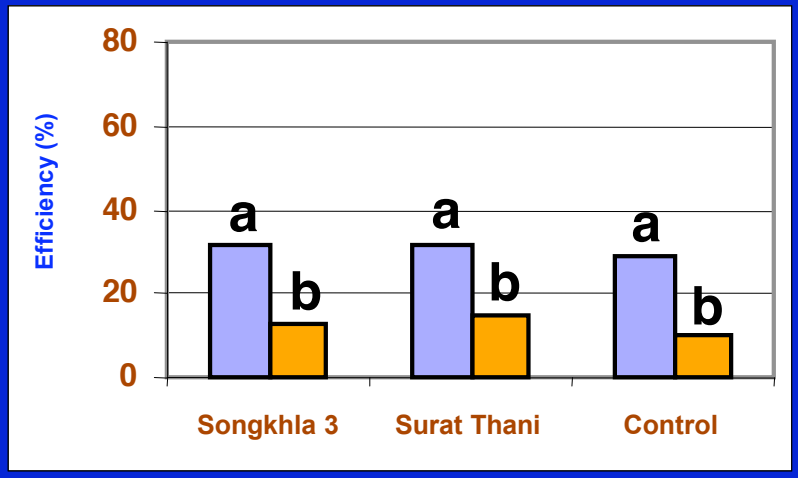
TKN



HRT 7 days



HRT 5 days



HRT 3 days

HCW

LCW

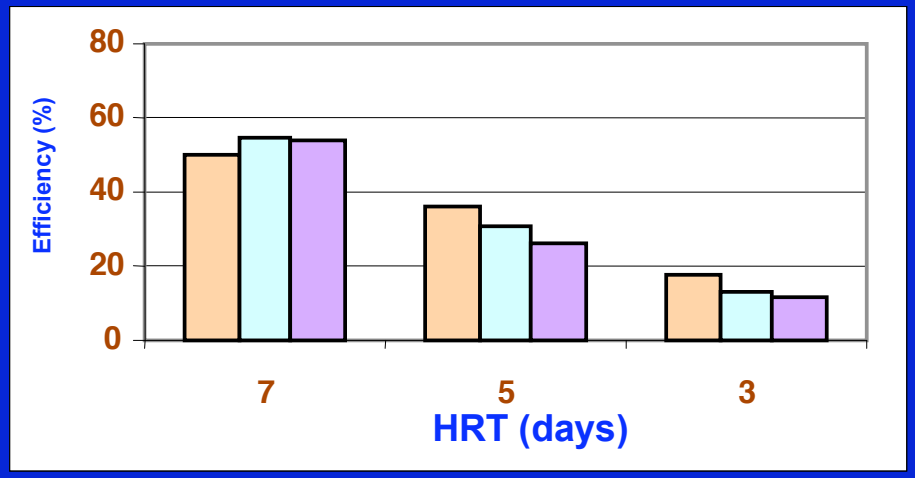
Different letters denote the significant difference among wastewater concentrations at p=0.05.

NH_4-N

HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)			Eff. (%)
			Song3	Surat	Control	
7 d	HCW	^{b}32.29	$^{¢}$15.65	§14.30	§14.37	50.2-58.6%
	LCW	^{a}35.02	$^{¢}$14.21	§15.21	§15.34	
5 d	HCW	^{b}28.34	$^{¢}$17.73	$^{¢}$19.30	$^{¢}$20.53	26.5-41.5%
	LCW	^{a}31.06	$^{¢}$18.10^{b}	$^{¢}$20.77^{ab}	$^{¢}$21.54^{a}	
3 d	HCW	^{b}28.00	$^{b°}$22.94^{b}	$^{b°}$24.21^{ab}	$^{b°}$24.67^{a}	11.6-16.0%
	LCW	^{a}30.35	$^{a°}$25.93	$^{a°}$25.40	$^{a°}$26.50	

Superscript letters (right horizontal) ⇨ vetiver ecotypes
Superscript letters (left downward) ⇨ wastewater conc.
Thai superscript letters (left downward) ⇨ detention times

NH_4-N

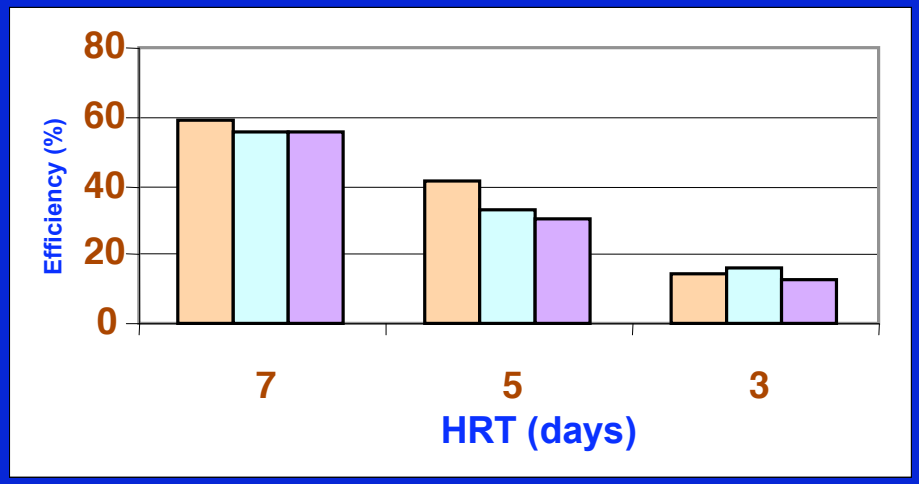


Songkhla3

Surat Thani

Control

HCW



Songkhla3

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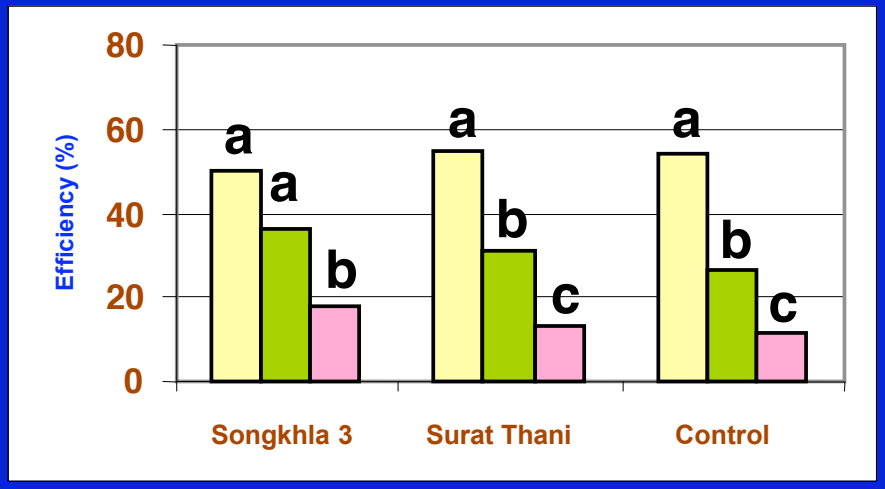
Control

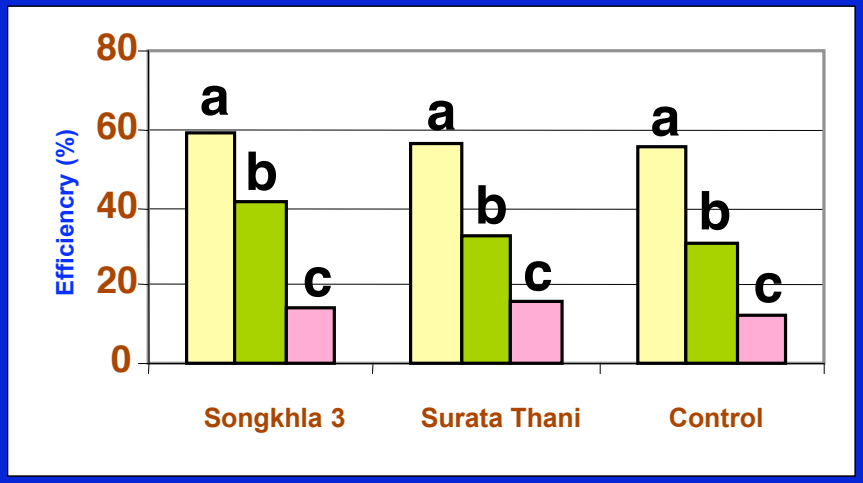
LCW

Different letters denote the significant difference among vetiver ecotypes at p=0.05.

NH_4-N



HCW



LCW

HRT 7 days

HRT 5 days

HRT 3 days

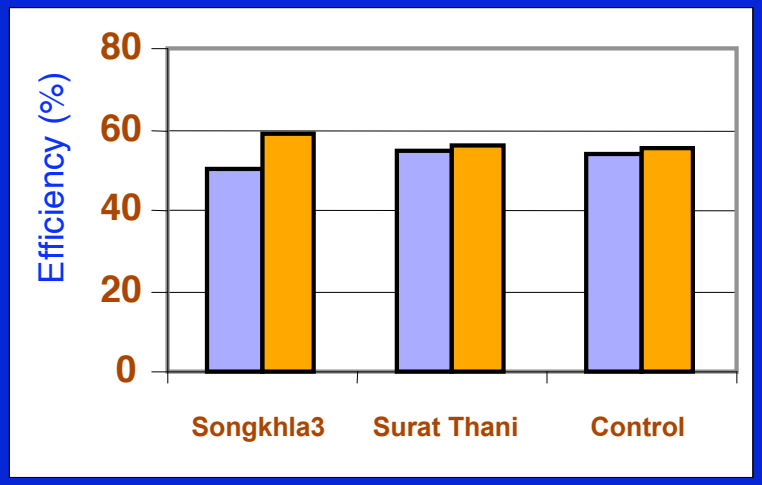
HRT 7 days

HRT 5 days

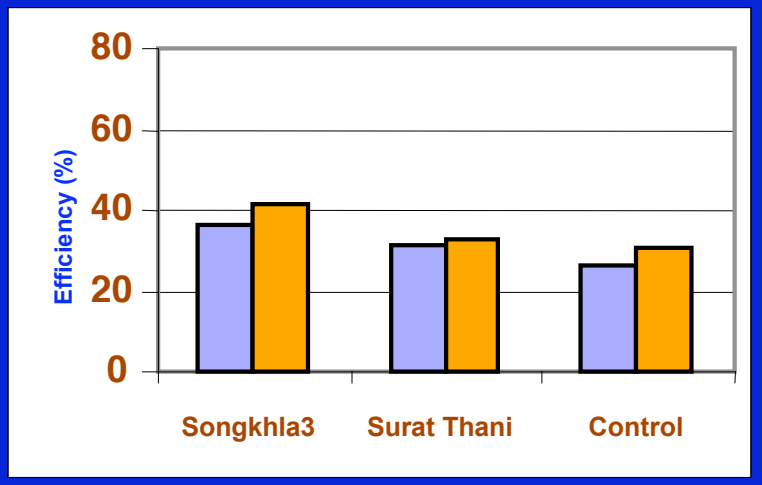
HRT 3 days

Different letters denote the significant difference among HRT at p=0.05.

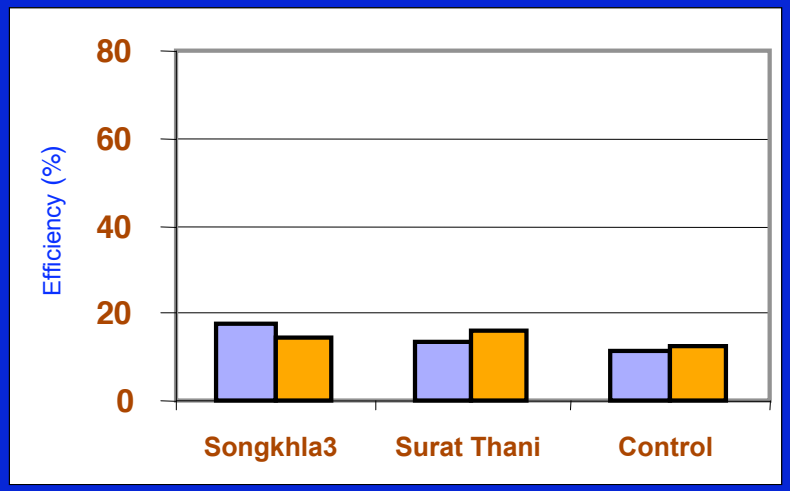
NH_4-N



HRT 7 days



HRT 5 days



HRT 3 days

LCW

HCW

Different letters denote the significant difference among wastewater concentrations at p=0.05.

NO_3-N (mg/l)

HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)		
			Song3	Surat	Control
7 d	HCW	[a]0.07	[¢]0.33	[˚]0.38	[¢]0.42
	LCW	[b]0.05	[˚]0.41	[˚]0.36	[¢]0.43
5 d	HCW	0.03	[˚]0.58[ab]	[˚]0.43[b]	[˚]0.70[a]
	LCW	0.03	[˚]0.48[b]	[˚]0.41[b]	[˚]0.71[a]
3 d	HCW	[b]0.02	[§]0.06	[¢]0.06	[§]0.07
	LCW	[a]0.02	[¢]0.07	[¢]0.07	[§]0.08

Superscript letters (left downward) denote the significant difference among wastewater concentrations at p=0.05.

Thai superscript letters (left downward) ⇨ detention times

Total Phosphorus

HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)			Eff. (%)
			Song3	Surat	Control	
7 d	HCW	a6.66	¢4.28b	¢4.24b	a5.46a	8.5-35.9%
	LCW	b4.84	¢4.06b	4.07b	b¢4.43a	
5 d	HCW	a6.55	°5.29	°5.15	5.90	7.2-21.2%
	LCW	b5.48	°4.62	4.47	°5.08	
3 d	HCW	a5.89	°4.83b	a°¢4.71b	a5.31a	6.3-20.3%
	LCW	b5.06	°4.54ab	b4.33b	b°¢4.74a	

Superscript letters (right horizontal) ⇨ vetiver ecotypes
Superscript letters (left downward) ⇨ wastewater conc.
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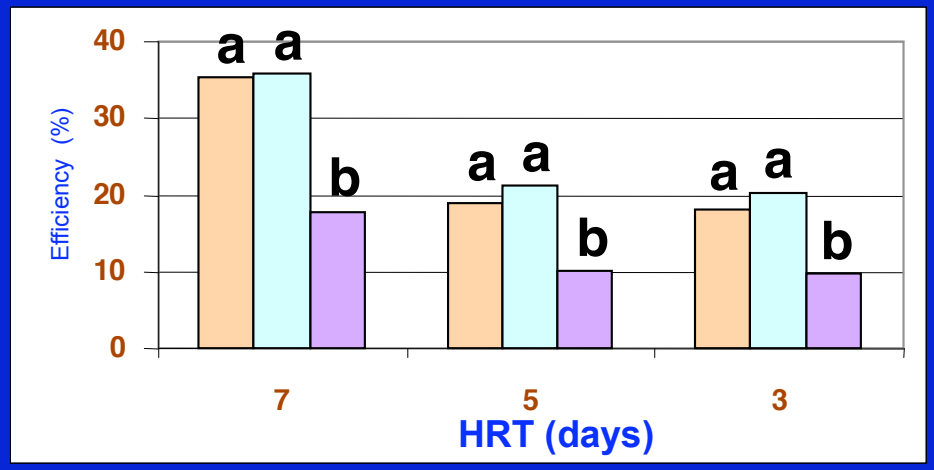
TP

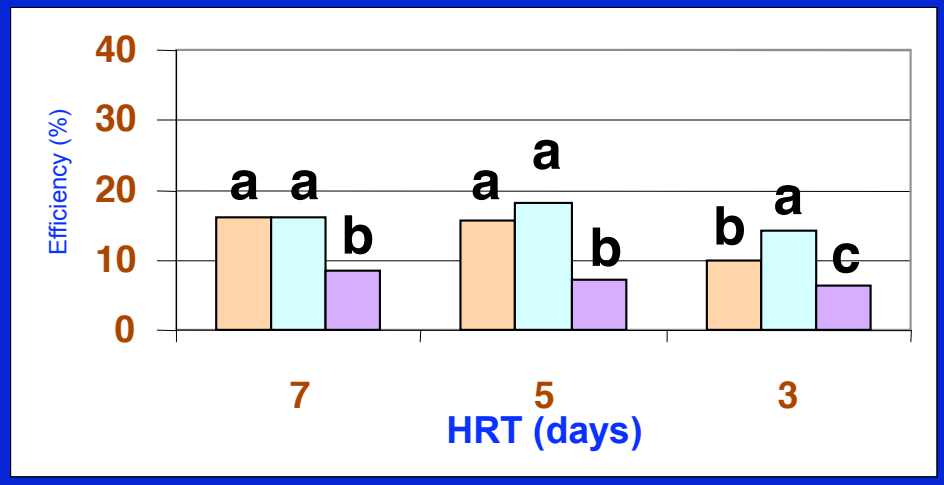


Songkhla3

Surat Thani

Control

HCW



Songkhla3

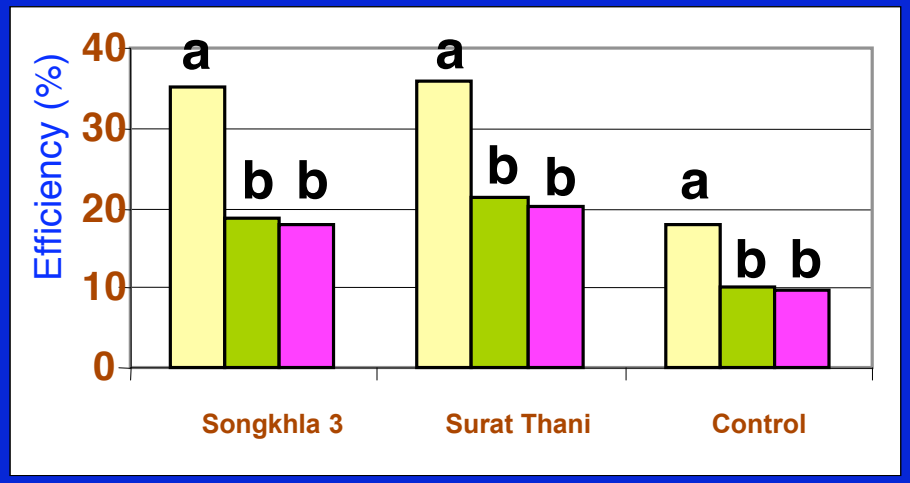
Surat Thani

Control

LCW

Different letters denote the significant difference among vetiver ecotypes at p=0.05.

TP

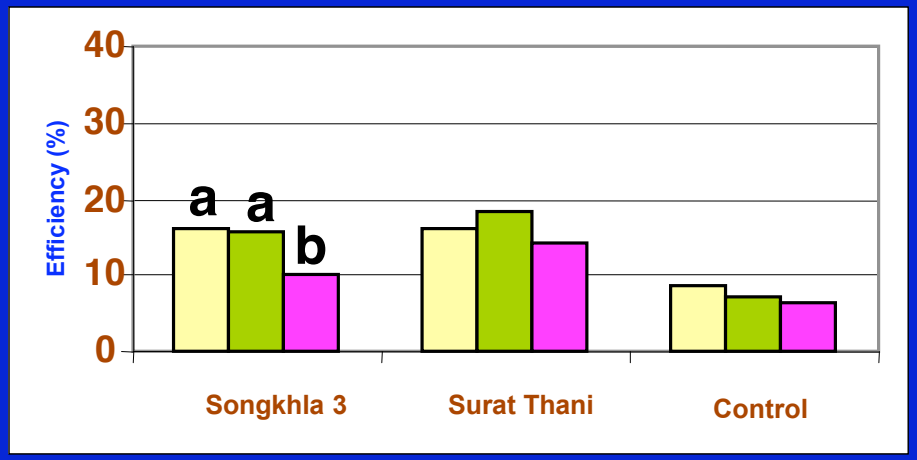


HRT 7 days

HRT 5 days

HRT 3 days

HCW



HRT 7 days

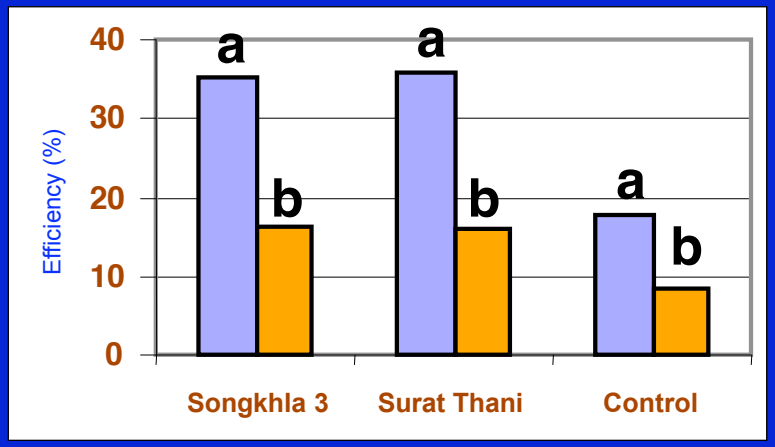
HRT 5 days

HRT 3 days

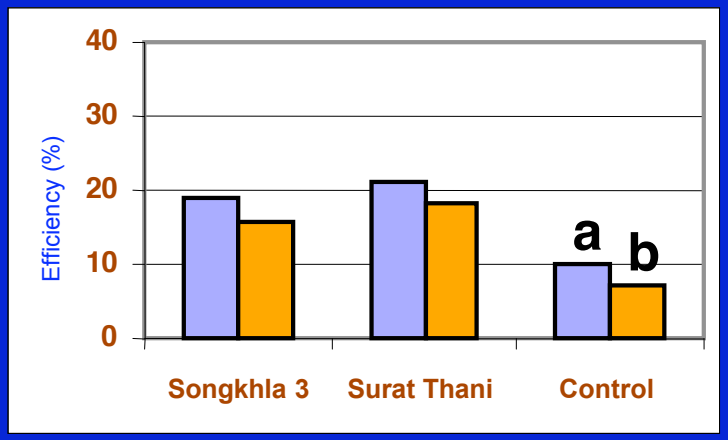
LCW

Different letters denote the significant difference among HRT at p=0.05.

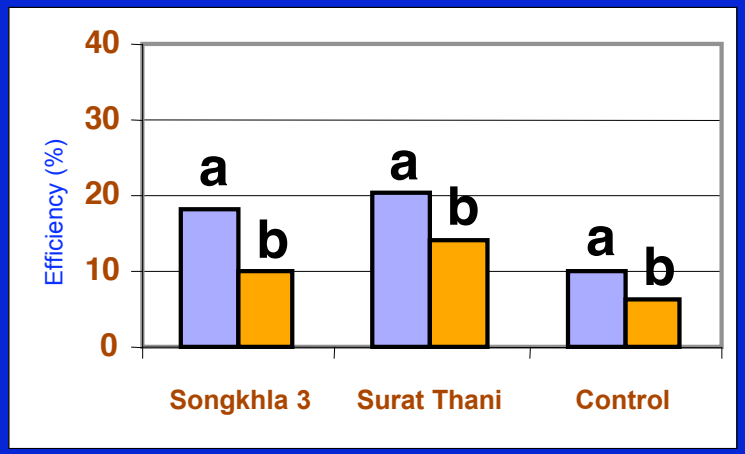
TP



HRT 7 days



HRT 5 days



HRT 3 days

HCW

LCW

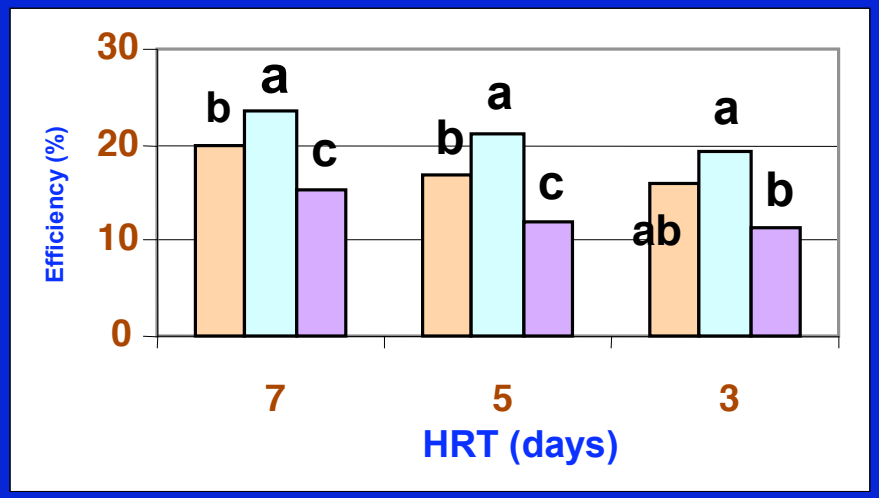
Different letters denote the significant difference among wastewater concentrations at p=0.05.

Ortho-PO_4

HRT (days)	Conc.	Influent (mg/l)	Effluent (mg/l)			Eff. (%)
			Song3	Surat	Control	
7 d	HCW	^{a}3.91	$^{a¢}$3.13^{b}	$^{¢}$2.99^{a}	$^{¢}$3.25^{a}	8.1-23.5%
	LCW	^{b}3.54	^{b§}2.99^{b}	$^{¢}$2.98^{b}	§3.31^{a}	
5 d	HCW	^{a}4.59	$^{a°}$3.82^{ab}	$^{°}$3.61^{b}	$^{a°}$4.04^{a}	10.6-21.2%
	LCW	^{b}4.10	$^{B¢}$3.50	$^{°}$3.46	$^{b¢}$3.65	
3 d	HCW	^{a}4.41	$^{°}$3.69^{ab}	$^{°}$3.47^{b}	$^{°}$3.89^{a}	7.4-19.3%
	LCW	^{b}4.08	$^{°}$3.70^{ab}	$^{°}$3.57^{b}	$^{°}$3.83^{a}	

Superscript letters (right horizontal) ⇒ vetiver ecotypes
Superscript letters (left downward) ⇒ wastewater conc.
Thai superscript letters (left downward) ⇒ detention times

PO_4-P

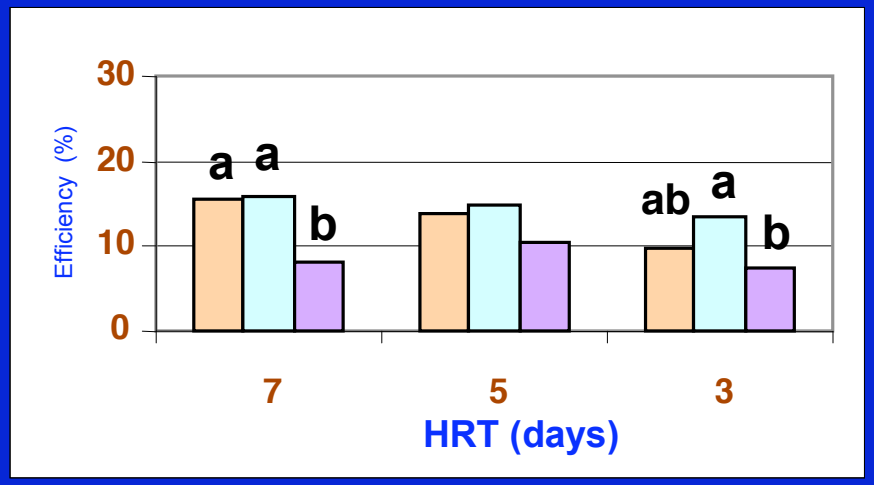


Songkhla3

Surat Thani

Control

HCW



Songkhla3

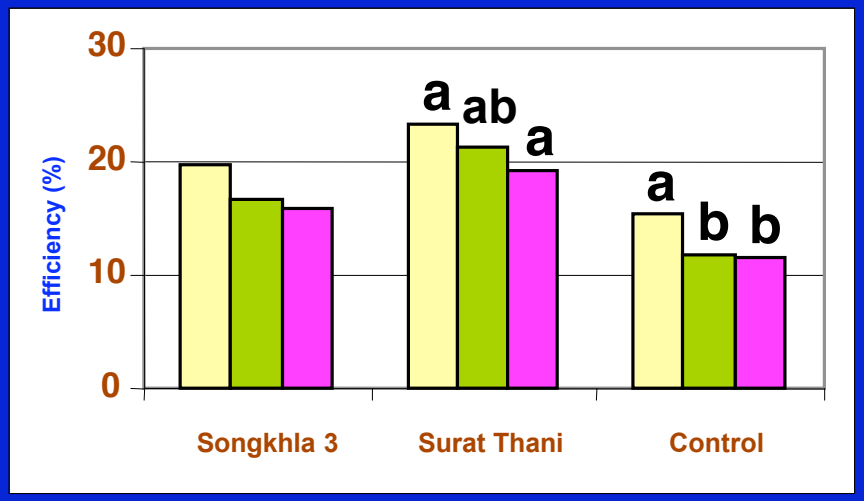
Surat Thani

Control

LCW

Different letters denote the significant difference among vetiver ecotypes at p=0.05.

PO_4-P

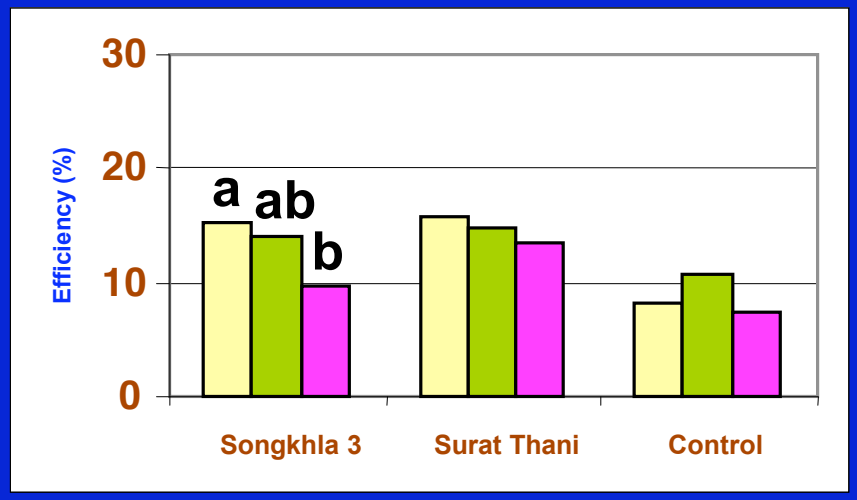


HRT 7 days

HRT 5 days

HRT 3 days

HCW



HRT 7 days

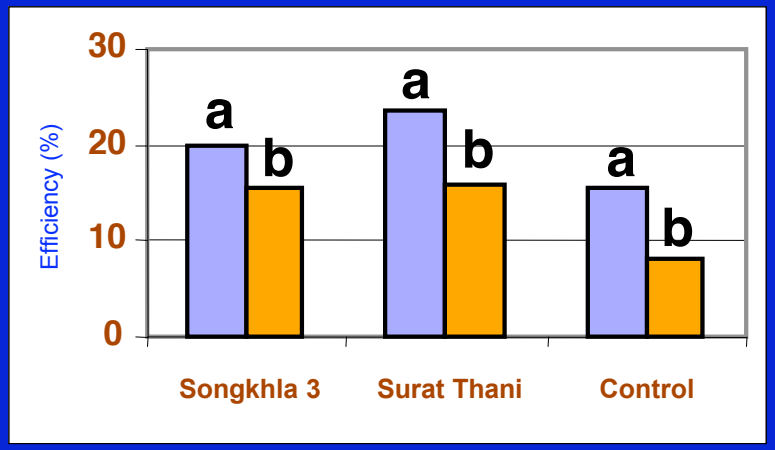
HRT 5 days

HRT 3 days

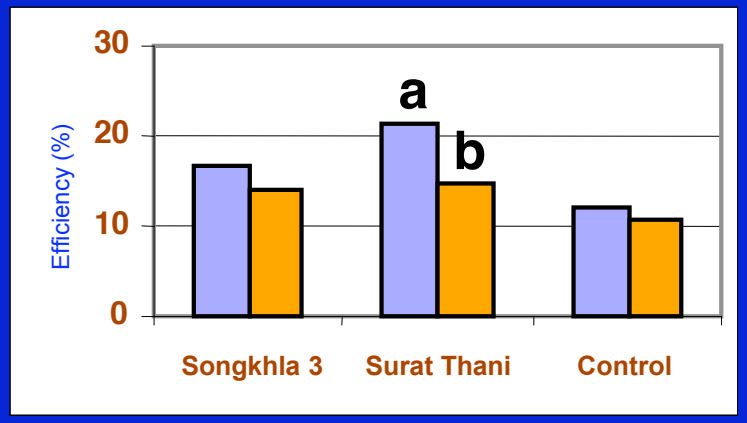
LCW

Different letters denote the significant difference among HRT at p=0.05.

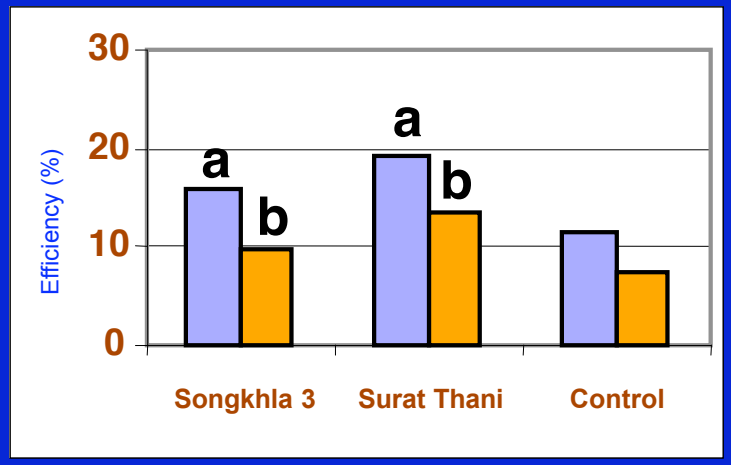
PO_4-P



HRT 7 days



HRT 5 days



HRT 3 days

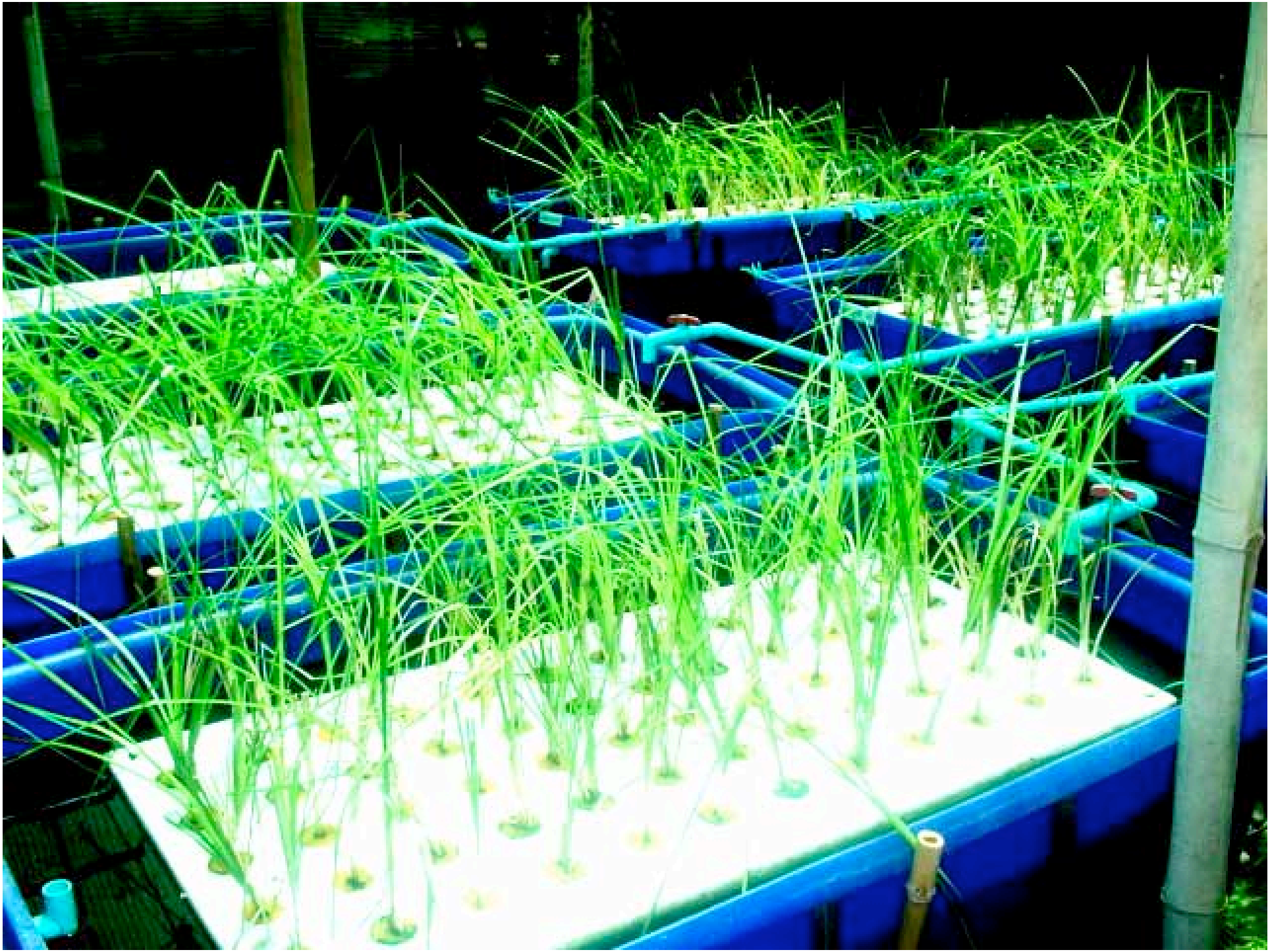
HCW

LCW

Different letters denote the significant difference among wastewater concentrations at p=0.05.

Growth and Biomass of Vetivers


สุราษฎร์ HW1



Growth of Vetivers

- The survival percentages of Surat Thani and Songkhla3 ecotypes were 75-100%.
- The survival percentage during 3-day HRT was lower than 7- and 5-day HRT.
  => low O_2 available
  => retarding respiration and ion absorption of vetivers.
- The survival percentage of vetivers planted in LCW was slightly higher than in HCW.

Biomass

- Surat Thani ecotype showed the tendency of higher increment of root biomass than Songkhla3.

=> Surat Thani ecotype could develop better root system

Biomass

- Songkhla3 planted in HCW tended to have higher shoot biomass than Surat Thani and than those planted in LCW.

- Surat Thani planted in LWC showed higher shoot and root biomass.

Nitrogen Accumulations

- Songkhla3 planted in HCW showed higher N accumulation in shoots and roots than Surat Thani.

- In contrast, Surat Thani planted in LCW showed higher N accumulation than Songkhla3.

Phosphorus Accumulations

- Generally, Surat Thani ecotype showed higher TP accumulation than Songkhla3.

=> This result correlated to higher TP and ortho-PO_4 treatment efficiencies of Surat Thani than Songkhla3.

CONCLUSION

Conclusions

- The results from this study using hydroponic technique indicated that even treatment efficiencies of N and P were low compare to other studies which had soils as media, vetivers showed a good potential to be used in situ to treat domestic wastewater.

Conclusions

- The 7-day HRT showed highest treatment efficiencies.
- The treatment efficiencies of BOD, TKN, TP, ortho-PO_4 and NH_4-N increased with concentrations which indicated high potential of vetiver to treat HCW.
- The treatment efficiencies of BOD, TP and ortho-PO_4 of Surat Thani ecotype were slightly higher than Songkhla3 ecotype.

Conclusions

- The results closely correlated with the study of growth which found that Surat Thani could develop better root system than Songkhla3 in both HCW and LCW.
  => As a results, it absorped higher amount of ortho-PO_4 for root development.

Conclusions

- The treatment efficiencies of NH_4-N of Songkhla3 was slightly higher than Surat Thani.

  => The results closely correlated with the study of growth which found that Songkhla3 planted in HCW tended to have higher shoot biomass and N accumulation.

Conclusions

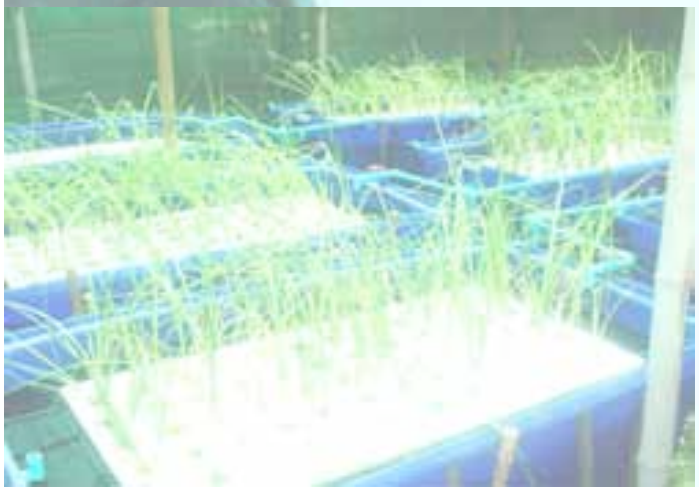
- The optimal condition of vetivers cultivated with floating platform technique in domestic wastewater treatment should be designed at 7-day HRT and planted with Surat Thani ecotype.
- But if wastewater contained high nutrients, Songkhla3 ecotype should be planted instead.

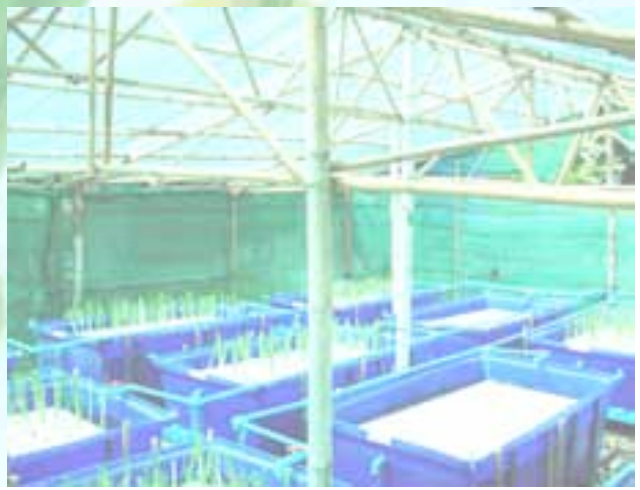
Conclusions

The method to increase oxygen in the system should be provided. Since available oxygen is one factor that limited the treatment efficiencies of nutrients, especially N; and growth of vetivers.

ACKNOWLEDGEMENT

RATCHADAPISEK SOMPHOT
CHULALONGKORN UNIVERSITY





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1.Õ“§“√™ÿ¥¬µ“¡°ÆÀ¡“¬«Ë“¥È«¬Õ“§“√™ÿ¥	µ—Èß·µË 500 ÀÈÕßπÕπ	100 - πâÕ¬°«Ë“ 500 ÀÈÕßπÕπ	πâÕ¬°«Ë“- 100 ÀÈÕßπÕπ	-	-
2.‚√ß·√¡µ“¡°ÆÀ¡“¬«Ë“¥È«¬‚√ß·√¡	µ—Èß·µË 200 ÀÈÕß	60 - πâÕ¬°«Ë“ 200 ÀÈÕß	πâÕ¬°«Ë“ 60 ÀÈÕß	-	-
3.ÀÕæ—°µ“¡°ÆÀ¡“¬«Ë“¥È«¬ÀÕæ—°	-	µ—Èß·µË 250 ÀÈÕß	50- πâÕ¬°«Ë“ 250 ÀÈÕß	10 - πâÕ¬°«Ë“ 50 ÀÈÕß	-
4. ∂“π∫√‘°“√	-	µ—Èß·µË 5,000 ¡^{2}	1,000 - πâÕ¬°«Ë“ 5,000 ¡^{2}	-	-
5.‚√ßæ¬“∫“≈¢ÕßΣ“ß√“™°“√À√◊ÕÕ ∂“πæ¬“∫“≈µ“¡°ÆÀ¡“¬	µ—Èß·µË 30 ‡µ’¬ß	10 - πâÕ¬°«Ë“ 30 ‡µ’¬ß	-	-	-

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6.Õ“§“√,√ß‡√’¬π√“…Æ√Ï ,√ß‡√’¬π¢ÕßΣ“ß√“™°“√ ,∂“∫—πÕÿ¥¡»÷°…“¢Õß‡Õ°™πÀ√◊Õ ∂“∫—πÕÿ¥¡»÷°…“¢ÕßΣ“ß√“™°“√	μ—Èß·μË 25,000 ¡.2	5,000-‰¡Ë‡°‘π°«Ë“ 25,000 ¡.2	-	-	-
7.Õ“§“√Σ’ËΣ”°“√¢ÕßΣ“ß√“™°“√ Õß§Ï°“√√–À«Ë“ßª√–‡Σ»À√◊Õ‡Õ°™π	μ—Èß·μË 55,000 ¡.2	10,000-‰¡Ë∂÷ß 55,000 ¡.2	5,000-‰¡Ë∂÷ß 10,000 ¡.2	-	-
8.Õ“§“√¢Õß»Ÿπ¬Ï°“√§È“ À√◊ÕÀÈ“ß √√æ‘π§È“	μ—Èß·μË2 5,000 ¡.2	5,000-‰¡Ë∂÷ß25 ,000 ¡.2	-	-	-
9. μ≈“¥	‡°‘π°«Ë“À√◊Õ ‡ΣË“°—∫2, 500 ¡.2	1,500-‰¡Ë∂÷ß 2,500 ¡.2	1,000-‰¡Ë∂÷ß 1,500 ¡.2	500-‰¡Ë∂÷ß 1,000 ¡.2	-
10.¿—μμ“§“√·≈–√È“πÕ“À“√	‡°‘π°«Ë“À√◊Õ ‡ΣË“°—∫2, 500 ¡.2	500-‰¡Ë∂÷ß 2,500 ¡.2	250-‰¡Ë∂÷ß 500 ¡.2	100-‰¡Ë∂÷ß 250 ¡.2	‰¡Ë∂÷ß100 ¡.2

Biomass

- Biomass increment of shoot and roots were lowest during the 3-day HRT and highest during 7-day HRT.

Nutrient Accumulations

- The nutrient (TN and TP) accumulations in roots during 7-day HRT was higher than 5- and 3-day HRT, respectively.

- But no obvious trend was observed in nutrient accumulations in shoots.

Nitrogen Accumulations

- The N accumulation in roots of both vetivers ecotypes were higher than shoots.

=> the size of vetivers was small. As a result, small amount of N was needed for the growth of stems and leaves.