A Comprehensive Data Collection Framework for Hybrid CDS-NbS Stormwater Treatment Systems In Tropical Urban Environments

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Introduction

This study presents the methodology for evaluating a pilot-scale Hybrid Stormwater Treatment System (HSTS) under tropical urban conditions characterised by high rainfall, rapid runoff, and elevated pollutant loads. The research integrates experimental system design, controlled pilot-scale operation, and analytical assessment of hydraulic and water quality performance. The system adopts a multi-stage treatment train combining grey infrastructure with nature-based solutions, aligned with sustainable urban water management practices (Fletcher et al., 2015; Roy et al., 2008). Stormwater influent sourced from an existing drainage network ensures realistic conditions. Treatment stages include flow equalisation, Continuous Deflective Separation (CDS) for gross pollutant removal, a Chrysopogon zizanioides (vetiver) floating wetland for biological uptake, and final polishing using biochar and natural zeolite. Detailed monitoring and instrumentation are reported separately (Wong et al., 2025).

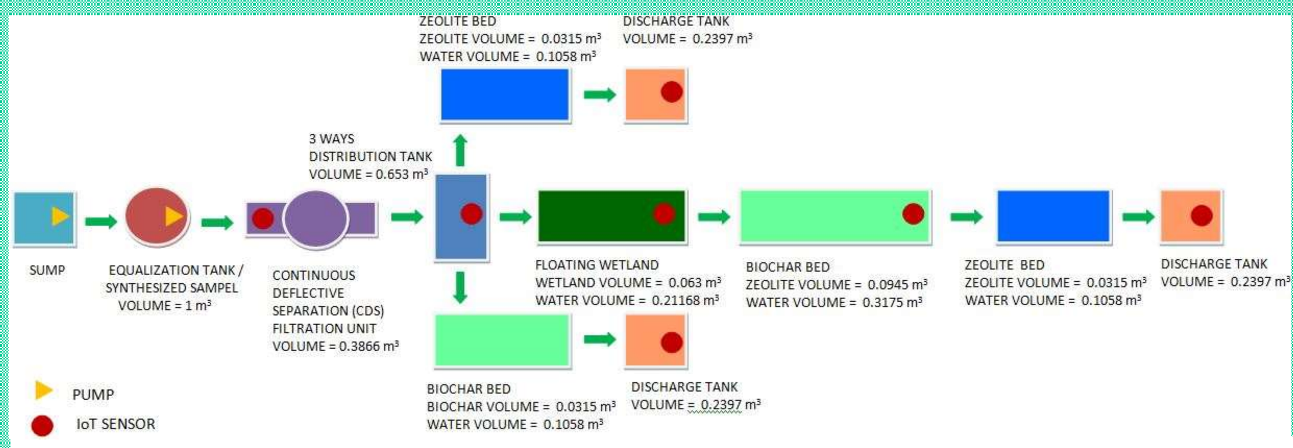
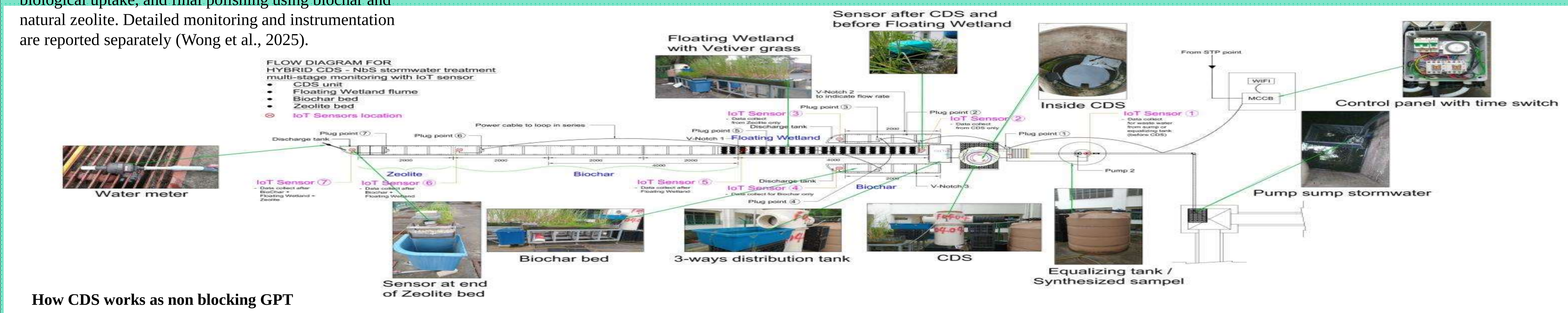


Fig. 1. Flow diagram for hybrid continuous deflection separation-nature-based solutions (CDS-NbS) stormwater treatment train. Source: EcoClean Technology & University of Nottingham Malaysia

Methodology

The methodology adopts a pilot-scale experimental approach to evaluate a Hybrid Stormwater Treatment System (HSTS) under realistic tropical urban conditions. Stormwater influent sourced from an existing drainage system was introduced via an equalisation tank and conveyed through a multi-stage treatment train comprising Continuous Deflective Separation (CDS), a Chrysopogon zizanioides (vetiver) floating wetland, and a final polishing stage using biochar and natural zeolite. The system was operated continuously under controlled hydraulic conditions to simulate real-world storm events, with sampling conducted at multiple points along the treatment train to assess progressive pollutant removal. A multi-point sampling strategy captured variations across treatment stages and flow conditions, ensuring robust performance evaluation. Water quality analyses, including physical (TSS, turbidity), chemical (BOD, COD, nutrients), microbiological (E. coli), and selected heavy metals (Pb, Cu), were conducted in accordance with standard methods (APHA, 2012) to ensure data reliability and comparability.



How CDS works as non blocking GPT

Fig. 2. The pilot system setup. Source: EcoClean Technology & University of Nottingham Malaysia

Results & Discussion

The pilot-scale Hybrid Stormwater Treatment System (HSTS) demonstrated strong and consistent pollutant removal performance under tropical urban conditions, supported by both laboratory validation (NAHRIM) and real-time IoT monitoring. The integrated system achieved significant reductions in key parameters, including TSS (90%), BOD (80%), NO_3^- (78%), TDS (57%), COD (57%), and oil and grease (50%), indicating effective synergy between physical, biological, and adsorption processes. The deployed IoT system, utilising Raspberry Pi and Python-based cloud dashboards, enabled near real-time tracking of water quality across treatment stages, with adaptive monitoring frequencies during storm events and automated alerts for operational control. Results confirm that the multi-stage treatment train can reliably improve stormwater quality towards WQI Class 2B standards with minimal human intervention. While extreme rainfall affected sensor durability, the system overall demonstrates strong resilience, operational feasibility, and potential for scalable, data-driven stormwater management in tropical environments

Table . Results achieved and complied to water quality index (WQI) Class 2B

Parameter	Unit	WQI Class 2B	Influent	Effluent	Remark
pH	–	6–9	7.05	6.58	more acidic
Temperature	° C	normal +2° C	22	22.7	tropical and constant
Turbidity	NTU	50	17.3	8.7	improve clarity by 58%
EC	µS·cm⁻¹	1,000	244	142	improve by 42%
TDS	mg·dm⁻³	1000	84	36	decrease by 57%
TSS	mg·dm⁻³	≤50	200	18	decrease by 90%
NO_3^-	mg·dm⁻³	–	1.9	0.4	remove by 78%
PO_4^{3-}	mg·dm⁻³	7	2.3	3.6	increase by 58%
NH_3-N	mg·dm⁻³	0.3	0.4	0.56	increase by 40%
Faecal coliform	cfu·(100 cm³)⁻¹	100	4,400	3300	variable due to sewer overflow
DO	mg·dm⁻³	5–7	8.2	8.6	almost constant
BOD	mg·dm⁻³	3	5	1	remove by 80%
COD	mg·dm⁻³	25	17.8	7.6	remove by 57%
Oil and grease	mg·dm⁻³	7,000	2.1	<1.0	remove by 50%

Table 3. Results achieved at every stage of processes

Parameter	Unit	WQI Class II 2B	Influent	After CDS	After wetland	After biochar	Effluent after zeolite
pH	–	6–9	7.05	7.00	6.98	6.3	6.58
Temperature	° C	normal +2 ºC	22	22.0	22.5	22.5	22.7
Turbidity	NTU	50	17.3	21.7	17.1	8.0	8.7
EC	µS·cm⁻¹	1,000	244	240	227	161	142
TDS	mg·dm⁻³	1,000	84	75	44	42	36
TSS	mg·dm⁻³	50	200	100	80	50	18
NO_3^-	mg·dm⁻³	–	1.9	2.8	1.6	0.7	0.4
PO_4^{3-}	mg·dm⁻³	7	2.3	2.2	3.1	4.5	3.6
NH_3-N	mg·dm⁻³	0.3	0.4	0.50	1.0	0.43	0.56
Faecal coliform	cfu·(100 cm³)⁻¹	100	4,400	>7,600	4,500	4,600	3,300
DO	mg·dm⁻³	5–7	8.2	8.4	8.6	8.7	8.6
BOD	mg·dm⁻³	3	5	5.0	2.0	2.0	1
COD	mg·dm⁻³	25	17.8	14.3	11.7	6.8	7.6
Oil and grease	mg·dm⁻³	7,000	2.1	1.9	–	<1.0	<1.0

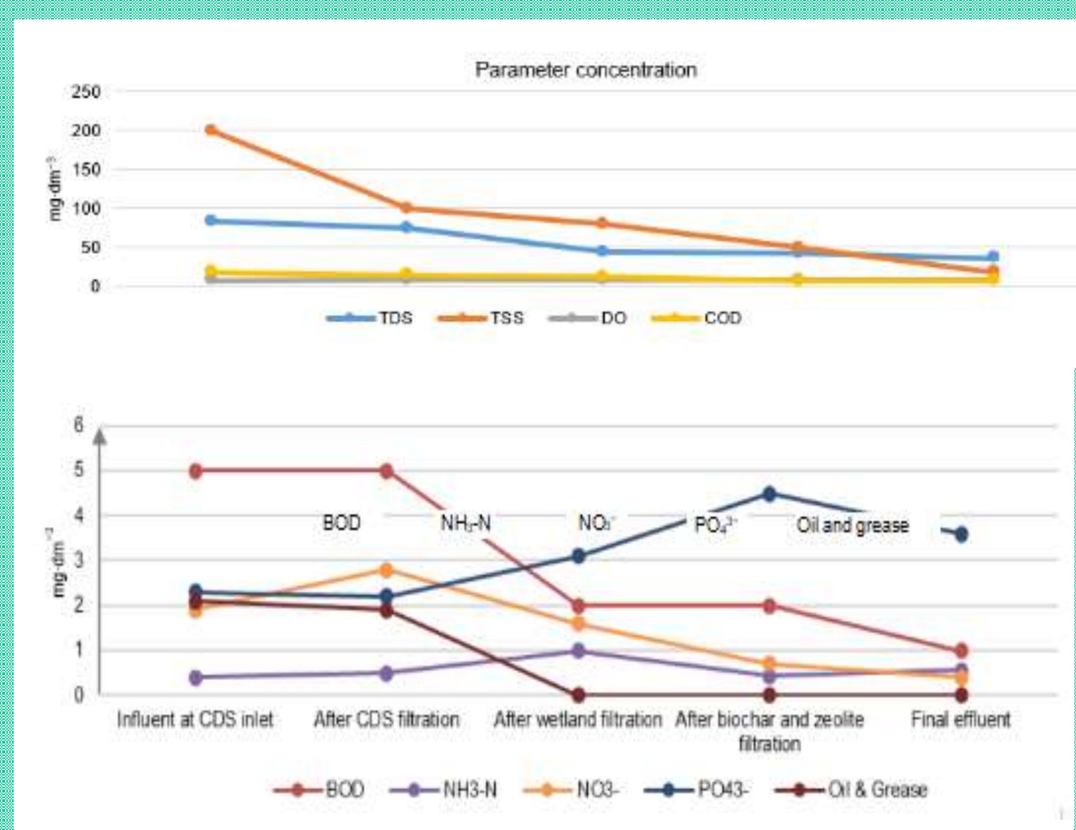


Fig 4. Pollutant concentration at each treatment stage as shown in Tables 2 & 3
Source: EcoClean Technology & University of Nottingham Malaysia

Conclusion

The study confirms that integrating CDS with nature-based solutions can transform urban stormwater into a valuable resource. Coupled with real-time IoT monitoring, the system offers a resilient, scalable pathway toward sustainable and circular water management.

Key References:Wong, Y.L. et al. (2025a) Hydrodynamic separation for stormwater pollution control: A review. Water, 17(4), 498.
Wong, Y.L. et al. (2025b) Integrated CDS and nature-based solutions for urban catchment management. Journal of Water and Land Development.