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Field Testing of an Innovative Onsite Blackwater Treatment System for a Green School

Tatchai Pussayanavin[1], Thammarat Koottatep[2], Somporn Tanatvanit[1*] and Chongrak Polprasert[3]
[1]Environmental Science Program, Faculty of Science, Ramkhamheang University, Thailand
[2]Environmental Engineering and Management, Asian Institute of Technology, Pathum Thani, Thailand
[3]Department of Civil Engineering, Faculty of Engineering, Thammasat University, Bangkok, Thailand
[*]E-mail : pon2310@yahoo.com

Abstract

An innovative onsite blackwater treatment system by integrating conventional septic tank (CST) and up-flow anaerobic reactor (UF) has been proposed as a sustainable option for the green school concept. This study demonstrated the functionality and performance, under actual conditions, of the innovative onsite blackwater treatment system at the green school in Bangkok, Thailand**.** Four pilot-testing units of the integrated CST and UF (CST+UF 1-4) system were installed at the green school (IPC Green International Preschool and Nursery, Ramkhamhaeng 21)**.** During the 4-month operation, the integrated CST and UF system received blackwater from 4 public flush toilets (6-10 L water/flush), each with more than 60 users/day. The effluent COD and BOD_5 concentrations of the integrated CST and UF system could be maintained at approximately 100 and 50 mg/L, respectively, and meeting the local discharge standard of Thailand. The integrated CST and UF system is considered to be an innovative onsite wastewater treatment technology for alleviating the environmental concerns associated with septic tank effluent.

Keywords : Innovative blackwater treatment system; Modified septic tanks; Performance evaluation; Green school

Introduction

Currently, there are more than a billion people worldwide who live without access to basic sanitation facilities and safely managed sanitation services, resulting in about 1 million deaths every year, especially children [1]. Due to the lack of access to basic sanitation services in most developing countries, human wastes containing high organic pollutants and pathogens are discharged into nearby vicinities. This improper sanitation situation results in major economic losses through lost productive times, healthcare costs, and mortality. Septic tanks have proven to be a viable alternative technology with cost-effective and implementable onsite solutions to treat sewage or blackwater in households and communities [2-5].

Septic tank is usually watertight and has two main processes taking place: the settling of particles and decomposition of organic matters through biological decomposition. The septic

tank is classified as a primary treatment (or sedimentation basis) with respect to removing organic matters or solids from the household wastewater. Typical performance for the removal of those pollutants is mainly due to the separation of solid particles with a density higher than surrounding water by gravitational settling. The design of a septic tank has to ensure the removal of settleable solids as much as possible through biodegradation processes of soluble organics [6]. The treatment efficiencies of septic tanks depend mainly on retention time and temperature. Based on the low investment and installation costs, septic tanks are a popular onsite wastewater treatment system worldwide, including in Thailand.

However, due to flow short-circuiting and short hydraulic retention time, the treatment efficiency of a conventional septic tank is quite low, with a 5-days biochemical oxygen demand (BOD_5) reduction of about 50% [4, 7]. The septic tank effluent is still highly polluted and can leak to nearby soil, groundwater or surface water. The low treatment efficiency suggests that the septic tank requires a longer hydraulic retention time or the addition of post-treatment units [8]. Seabloom et al. (2014) [9] and Bodik et al. (2000) [10] found that the conventional septic tank (CST) system operated under actual conditions can remove only 25-50% of BOD_5. A spatial survey by Koottatep et al. (2014) [11] found that the treatment efficiencies of the CST to below (less than 60% removal of organic matters and solids) and contained with high concentrations of pollutants BOD_5 in the effluent (>200 mg/L).

The pollution problems caused by poor performance of the septic tanks require new techniques to improve the blackwater treatment efficiencies. To achieve the national regulatory standards for wastewater discharge, an "innovative onsite blackwater treatment system" which integrated a conventional septic tank (CST) and an up-flow anaerobic reactor (UF) was proposed. The modified UF inside the CST can help control wastewater entering from the septic tank chamber at the bottom and flows upward. The wastewater flows through it the suspended sludge inside the UF system. UF system could help to enhance the treatment performance of organic removal up to more than 80% by enhancing the contact between these microorganisms and blackwater [12-13].

The integrated CST and UF with upflow feeding mode was expected to have better treatment performance than a CST or UF alone. The integrated CST-UF system is a simple and inexpensive method for improving the quality of the septic tank effluents in urban areas. The enhanced contact between biomass and wastewater through the upflow mode should result in high organic matters removal efficiency and system stability during fluctuating flow conditions. The volume of blackwater flow from a residence fluctuates considerably depending on the flushing system and quantity.

Green School is a term for green education which focuses on both formal and informal environmental studies. One of the concepts of green schools is to adopt "Sustainable Solutions" for all environmental aspects. Due to the absence of effective onsite wastewater treatment technology (such as CST alone and etc.), the innovative CST-UF system for improving effluent qualities of septic tanks to meet the discharge standard could be an alternative and sustainable solution for the green schools. The objective of this study was to demonstrate and verify the functionality and performance of the innovative CST-UF system for

the treatment of blackwater under actual conditions at a green school.

Methodology

An IPC Green International Preschool and Nursery (benches at Ramkhamhaeng 21, Bangkok) was one of the leading green schools in Thailand newly constructed and chosen to install the full-scale system of this study. Four pilot-testing units of the integrated CST and UF (CST+UF 1-4) systems were installed at the school (Figures 1 and 2). The CST+UF units 1-3 were served for the toilets in each academic building and the CST+UF units 4 was used for the administrative budling. These units have been operated with the designed flow rates of 200-400 L/d with the estimated blackwater generation rate of about 15-20 L/cap.d [11, 14]. The units were made of polyethylene polymer, and the effective volume of each unit was 1000 L. The UF was installed in the middle of the CST whose dimensions were: 300 mm in diameter and 1200 mm high. The effluent passes as up-flow through the smaller inner-core chamber or the UF reactor (Figure 3).

Figure 1 IPC Green International Preschool and Nursery

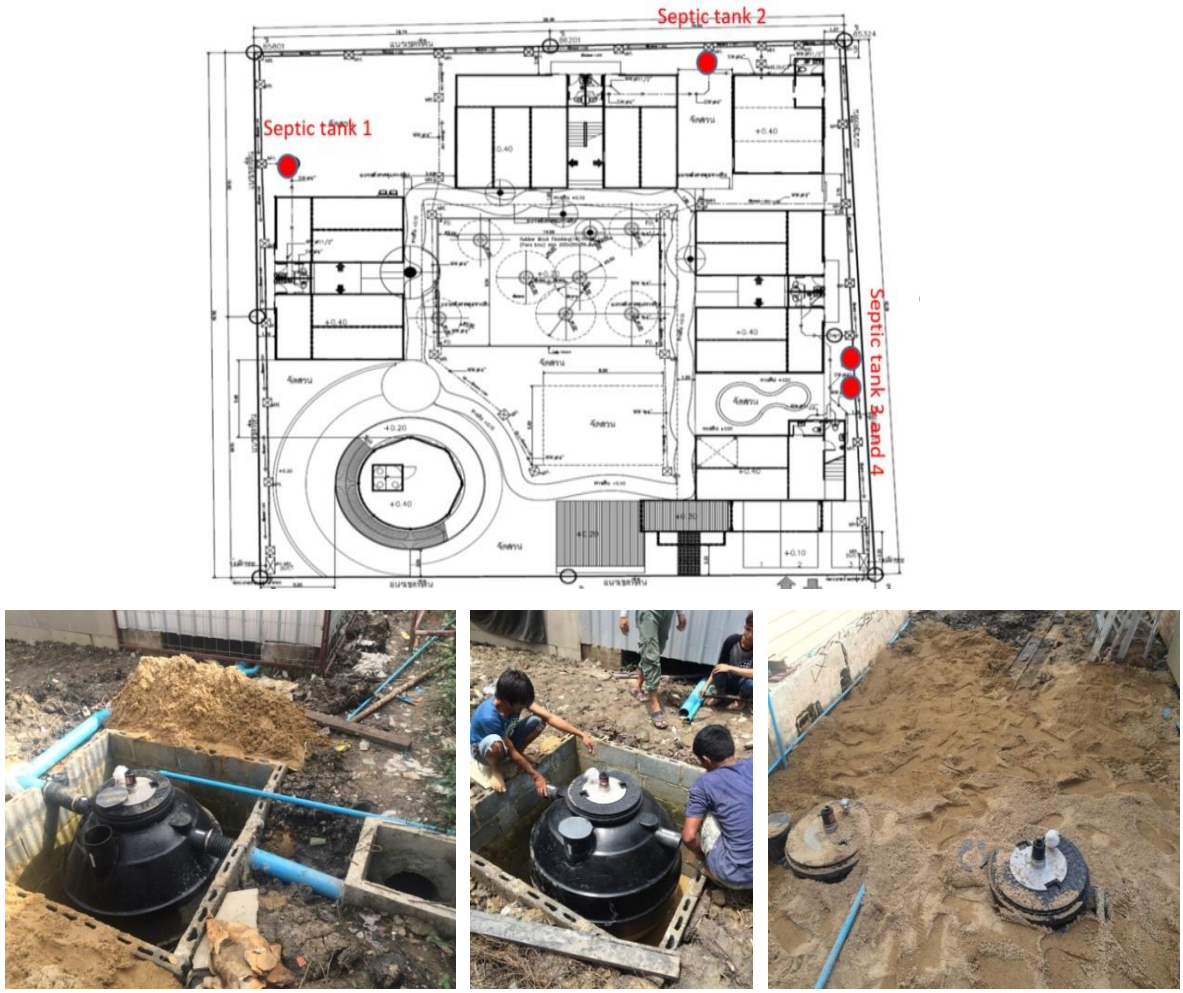

Figure 2 Four units of integrated CST and UF system (in the stage of the school construction)

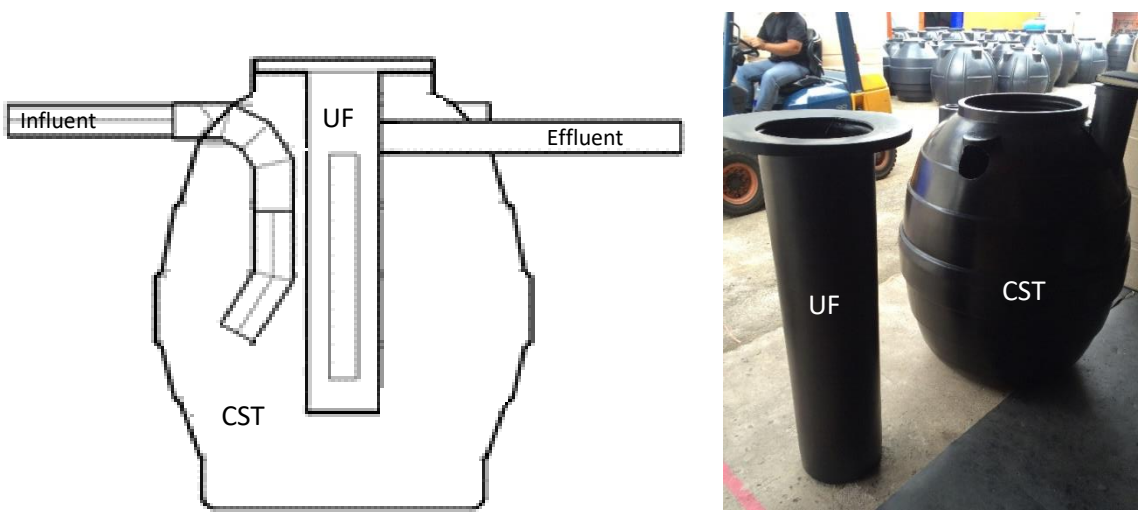

Figure 3 CST+UF system

During the 4-month operation, the integrated CST and UF system received the blackwater from 4 public flush toilets (6-10 L water/flush), each with more than 60 users/ day. The effluent samples were collected from the effluent pipe of each unit by using sealed buckets. The effluent samples (grab sampling) were collected once a week for analyses of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and total suspended solids (TSS) concentrations according to Standard Methods [15] (Figure 4). Analysis of variance (ANOVA) was an analysis tool used in statistics in this study.

Results and Discussion

As shown in Figures 5 and 6, the effluent COD and BOD_5 concentrations were found to fluctuate, caused by fluctuating number of users, but could be maintained at approximately 100 and 50 mg/L, respectively, and meeting the discharge standard of Thailand.

From interviews and observation data, the relatively high COD concentrations in the effluent during the January 2019 period were probably caused by the high number of toilet users, resulting in the high wastewater flow rates and correspondingly organic loading rates and the effluent concentrations of COD and were not significantly different between each units ($p>0.05$), Nevertheless, the effluent BOD_5 concentrations of the CST and UF units were lower than those reported in the literature for CST alone [11, 16], indicating the effective performance of the integrated CST and UF units in removing easily biodegradeble organic compounds.

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Figure 4 Field monitoring and effluent sampling

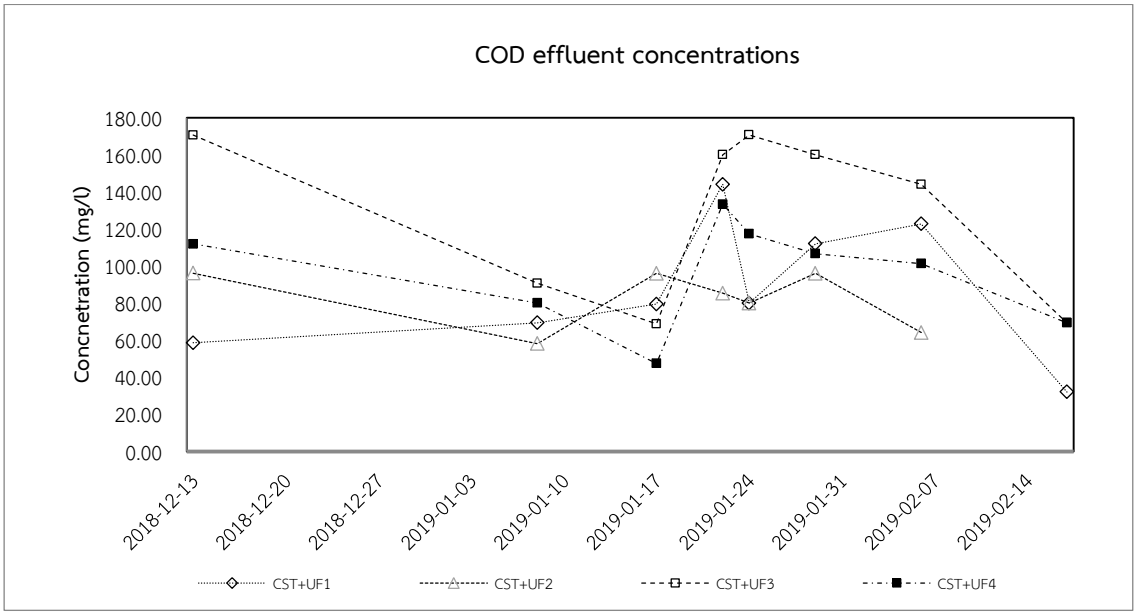

Figure 5 COD effluent concentrations

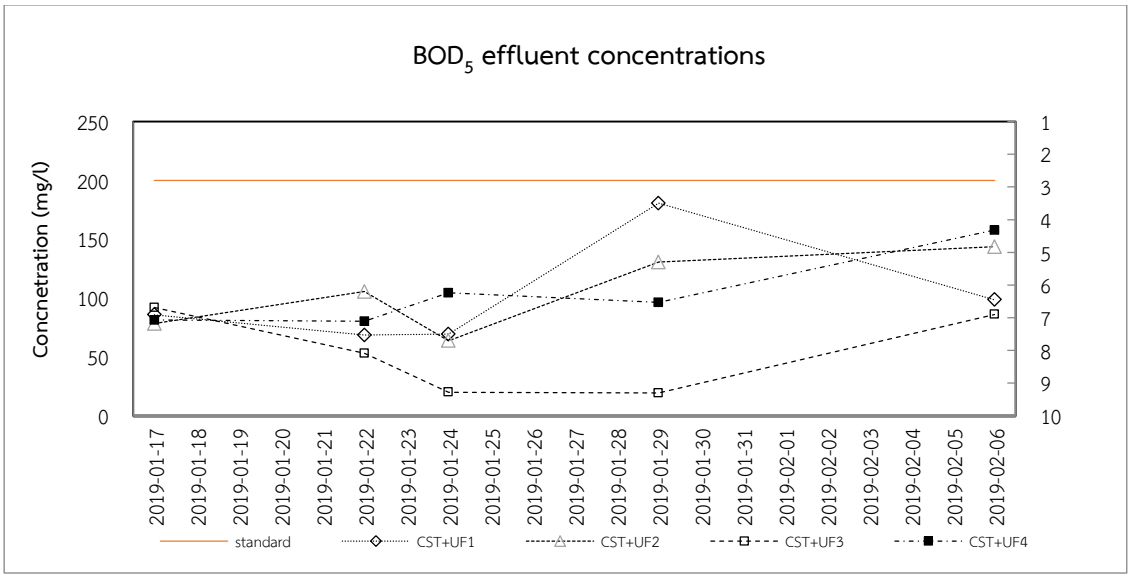

Figure 6 BOD_5 effluent concentrations

Because TSS contained in the blackwater are heavy materials such as feces or paper, they could easily settle in the integrated CST-UF units. Moreover, the installation of the UF in the CST could prevent the overflow of small particles, resulting in the effluent TSS concentrations being less than 100 mg/L (Figure 7). The average effluent COD, BOD_5 and TSS concentrations of the integrated CST-UF units are summarized in Figure 8 which are lower than the effluent COD, BOD_5 and TSS concentrations of a CST alone [16].

To comply with the World Health Organization [17] "Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture", it is recommended to improve the performance of the CST+UF system by increasing the liquid

temperature, similar to that of the solar septic tank (SST) [13, 16, 18]. By installing a solar water heater to raise the temperature inside the septic tank to be 40-50 °C, essential for inactivation of pathogens, about 3-4 log reductions of E.coli and total coliforms could be achieved.

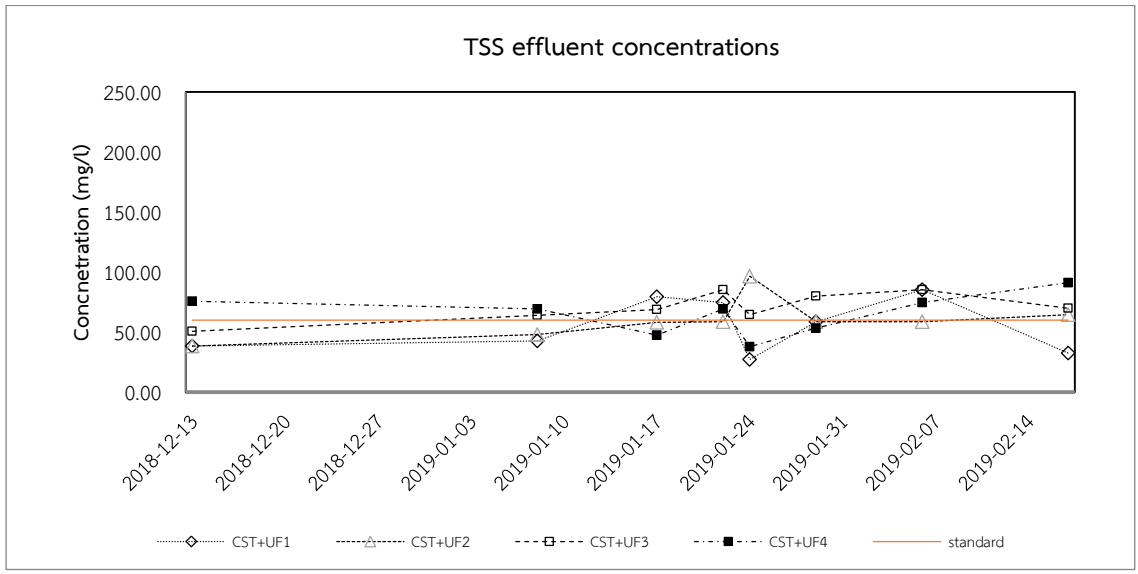

Figure 7 TSS effluent concentrations

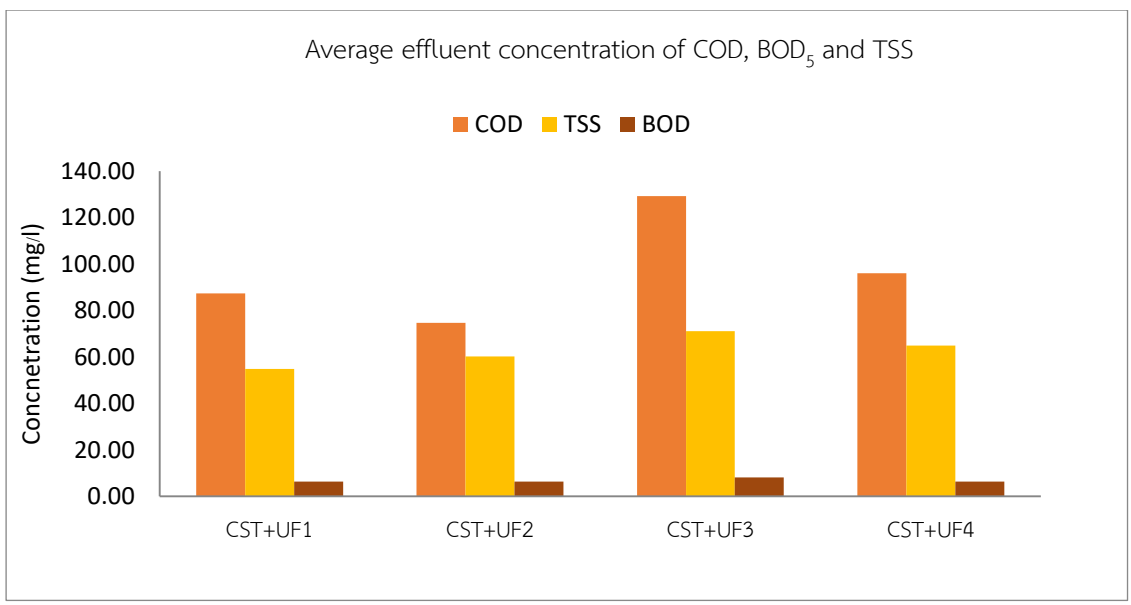

Figure 8 Average effluent concentrations of COD, BOD_5 and TSS

Conclusions

The integration of CST and UF is an innovative onsite wastewater treatment technology which could be considered as an effective sanitation technology for alleviating the environmental concerns associated with septic tank effluent. Depending on the situation, the unit can serve more than 60 users per day and is applicable for the green school concept.

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