Thai Environmental Engineering Journal Vol. 33 No. 3 (2019) : 65-75
www.eeat.or.th

Current State of Onsite Wastewater Treatment Systems of Rafts and Riverfront Buildings in Kanchanaburi, Uthai Thani and Phetchaburi Province, Thailand

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Abstract

Deterioration of water quality in rivers is quite a concern in Thailand especially in the provinces where there is high intensity of river-related tourism industry. In such provinces, rafts and riverfront buildings, serving as tourism services (i.e. restaurants, hotels and water activities), generate and directly discharge partially or even untreated wastewater into rivers causing damage to the waterbodies. Although most of the buildings have installed onsite wastewater treatment systems (OWWTs), they are not capable of providing effluent with good water quality. Where OWWTs are not applicable, especially on rafts, wastewater is directly discharged into the water bodies. Current state of OWWTs of the rafts and riverfront buildings is critical in order to cope with the deteriorated water quality of the rivers. In this study, we explored types and treatment efficiencies of OWWTs in three provinces in Thailand including Phetchaburi, Kanchanaburi and Uthai Thani Province. The investigation indicated that the types of OWWTs were traditional cesspools and commercial septic tanks whose effluent quality was not suitable for direct discharge. Wastewater management options were recommended for the rafts and riverfront buildings.

Keywords : onsite wastewater treatment; raft; riverfront building

Introduction

Rivers and canals have been involved in Thai culture ever since the old Siam Era. In the past, the Siamese people lived along rivers, canals and creeks owing to the benefit of the waterways including ability to access water resources for daily life activities, transportation and trading. Nowadays, rivers, canals and creeks have become important for Thai tourism industry which, in total, accommodated 2.3% of the total gross domestic product in 2018. These days, in addition to riverfront houses, there are rafts and riverfront hotels, restaurants and tourist attractions increasing in numbers to serve the increasing amounts of tourists. Kanchanaburi and Phetchaburi Province have high number of rafts and riverfront buildings open for tourist services (i.e. hotel, restaurant, water activities). The rafts and riverfront buildings unavoidably generate wastewater and, often, they do not have functional onsite wastewater treatment systems (OWWTs) resulting in deteriorated water quality of the waterbodies. Furthermore, it has potential to cause outbreaks of waterborne diseases such as diarrhea, typhoid, cholera and etc. which come with the fecal matters contaminated in the effluent [1].

In Thailand, it is required by law (Building Control Act, B.E. 2522) to have OWWTs for categorized buildings. Following the law, most of the buildings in Thailand usually install some forms of OWWTs. The effluent is usually either followed by centralized wastewater treatment wherein there are coverage of centralized wastewater treatment plants or discharged directly to the environment [2] as shown in **Figure 1**. The most frequently used OWWTs are one- and two-cesspools and commercial septic tanks. Treatment efficiencies of these treatment systems are quite low owing to the anaerobic mechanism [3]. Thus, subsequent treatment processes are needed in order to satisfy water quality standards for the effluents. In the case of rafts and riverfront buildings, a bill enacted by Thai Marine Department requires that appropriate toilets, storage tanks and further on-land treatments are required and direct discharge of the wastewater is strictly prohibited. However, in reality, those rafts and riverfront buildings do not have the appropriate ways to deal with the wastewater or OWWTs are not properly maintained resulting in poor effluent quality. OWWTs are often overlooked and are not taken care which cause the treatment system to underperform. Most of the raft and riverfront buildings release the effluents of onsite wastewater treatment, or even untreated wastewater, directly into waterbodies causing deteriorated water quality which indirectly damages tourism industry and other harmful results as aforementioned.

Data of types and current state of OWWTs (current condition, maintenance routine and treatment efficiencies) are crucial to prevent the deteriorated water quality of the rivers, canals and creeks wherein there are tremendous number of rafts and riverfront buildings. In this study, we explored the types and treatment efficiencies of onsite wastewater treatments of actual riverfront restaurants, hotels and houses in three provinces in Thailand including Phetchaburi, Kanchanaburi and Uthai Thani Province wherein there are tremendous number of rafts and riverfront buildings. In addition to wastewater samples, questionnaire survey was conducted to the landlords where the water samples were taken. Based on the data we collected, suitable wastewater treatment systems and management options of wastewater generated from rafts and riverfront buildings were recommended.

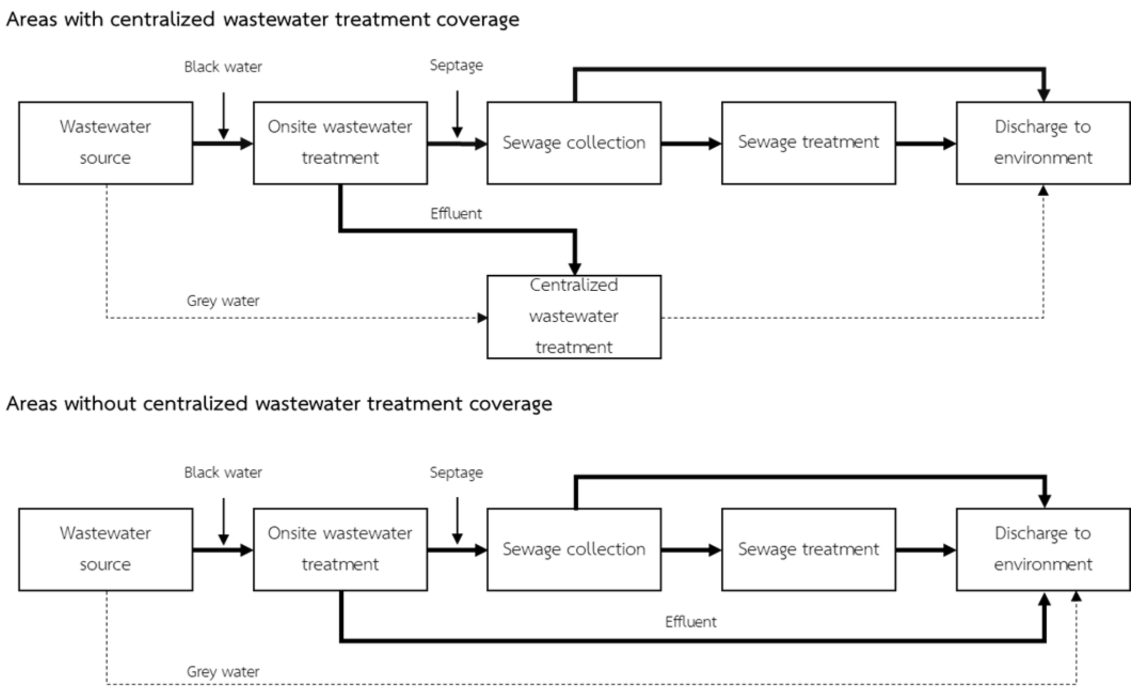

Figure 1 Domestic wastewater management in Thailand (modified from Boontanon and Buathong [4])

Materials and Methods

Sampling sites

One-time samplings were conducted and wastewater samples were collected from OWWTs of multiple rafts, riverfront houses, restaurants and hotels in Phetchaburi, Kanchanaburi and Uthai Thani province, Thailand on 21st, 23rd and 30th May 2019, respectively. The OWWTs in the sampling sites were one cesspools (OCPs), two cesspools in series (TCPs) and commercial septic tanks. To calculate the treatment efficiencies, wastewater quality parameters were compared between the samples collected in the first cesspool and second cesspool (in the case of TCPs) and in the septic tanks and effluent of septic tanks. As for OCPs, since the effluent seeped out below the cesspool, treatment efficiency of OCP was not considered.

Phetchaburi Province is an important tourism province of Thailand. It is located south-east of Bangkok. There are several waterfalls, mountains and famous beaches. Our sampling sites were located in the Bangtaboon Watershed (Bangtaboon Sub-district), Banlaem District in the province. Since it is located in between Amphawa and Cha-am, the sub-district had quite a potential to become popular tourism destination [5]. Consequently, on both sides of Bangtaboon River, there are resorts, hotels and restaurants open to accommodate the increasing tourists.

Kanchanaburi Province is famous for beautiful forests and rivers. Tourists can enjoy living and relaxing with nature. One of the most popular activity in Kanchanaburi is water activities especially rafting in rivers like Khwa Noi and Khwa Yai River. Nowadays, the province is quite popular for both Thai and foreign tourists and there are high number of hotels, restaurants and traveling rafts. Due to high intensity of tourism, water quality of the rivers is deteriorated as well as the tourism business.

In the past, people in Uthai Thani Province lived in riverfront houses and spent daily activities along rivers. This so called "The way of housing raft" has been done for almost a hundred years. Moreover, this has created occupations for the people (i.e. raft repair). Nowadays, installing new rafts in the rivers is strictly prohibited in the province due to the deteriorated water quality of rivers. This deterioration is due to the fact that domestic wastewater generated in the rafts is discharged directly into the waterbodies.

Water parameters

Wastewater samples were analyzed by 5-d biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total phosphorus (TP) and fecal coliform (FC). Analytical methods and significance of each parameters are shown in **Table 1**.

Calculations of treatment efficiencies of OWWTs were conducted for TCPs and CSTs comparing influent (wastewater in the first tanks of TCPs and in the CSTs) and effluent (the second tanks of TCPs). As for OCPs, calculation was impractical since effluent of OCPs could not be sampled.

Questionnaire survey

Questionnaire survey was conducted with the goal to collect the data of type of rafts/riverfront buildings, type of onsite wastewater treatment systems, knowledge of landlords regarding the wastewater treatment system, as well as operation and maintenance of wastewater treatment system. The questionnaire consisted of basic information of the sampling site including types (building or raft), types of establishment, number of persons or customers per day, types of OWWTs. In addition, a set of question designed to evaluate knowledge of landlords regarding OWWT (**Table 2**) was given to the landlords.

Table 1 Water parameters

Water parameters	Significance	Analytical methods
BOD_5	Organic pollution	5-day BOD test (5210-B)
COD	Organic and inorganic pollution	Closed reflux, titrimetric (5220-C)
TKN	Nutrient contamination	Macro-Kjeldahl (4500-Norg B
TP	Nutrient contamination	Digestion and colorimetry (4500-P)
FC	Fecal contamination	MPN technique

Table 2 Questions designed to evaluate knowledge of landlords regarding OWWTs

Question	Answer		
	Yes	No	Comment
1) Do you have OWWTs installed in your raft/building?			
2) Do you litter other waste (i.e. tissue paper, sanitary napkin) to the toilet?			
3) Do you momentarily remove septage from OWWTs?			
4) Do you know the effect of using high conc. detergent on OWWTs?			
5) Have you ever noticed abnormality of OWWTs?			

Results and Discussion

Type and treatment efficiency of onsite wastewater treatment systems in the study areas

There were 19 sampling sites from three provinces. The sampling sites consisted of residences, restaurants, hotels and general stores (**Table 3**). In Phetchaburi Province, since restaurants and hotels were newly built to accommodate the increasing number of tourists, most of the OWWTs were commercial septic tanks. In Kanchanaburi, most of the OWWTs were TCP and commercial septic tanks. In Uthai Thani provinces, the sampling sites were located in the old town and OWWTs consisted of mostly OCPs. In total, the percentages of OWWTs in this study were 37%, 26% and 37% for OCPs, TCPs and commercial septic tanks, respectively.

Calculations of treatment efficiency were done in terms of BOD_5, COD, TKN, TP and FC for TCPs and commercial septic tanks. As for OCPs, the calculation was not feasible as described above. Wastewater quality parameters are presented in **Table 4**. Wastewater samples in OWWTs had high concentrations of organic and nutrient (mean BOD_5, COD, TKN and TP were 347.6 mg/L, 1226.8 mg/L, 37.5 mg/L and 218.8 mg/L, respectively) as well as fecal indicator (mean FC was 1.79 10^7 MPN/100 mL). The parameters were similar to the design criteria of OWWT recommended by Meier [6] with an exception of TP. Meier [6] recommended the design criteria for TP as 38 mg/L. In this study, the concentrations of TP were much higher than the criteria (about 6-fold higher). This high concentration of TP should have been a result of use of dish washing, laundry and cleaning detergents which were also discharged into OWWTs.

Treatment efficiencies of TCPs calculated for the 7th sample of Kanchanaburi and 1st sample of Uthai Thani (**Table 4**) in terms of BOD_5, COD, TKN, TP and FC were 51.0%–86.2%, 4.7%–61.2%, 71.3%–88.4%, 0.0%–88.6% and 0.0–2.8 log removal, respectively. Although the removal rates were expected, the effluents were still higher than the provided effluent standards (Building Effluent Standards B.E. 2537). This indicates that effluents of TCPs could be a potential harm to the waterbodies if there were not enough soil attenuation.

Treatment efficiencies of commercial septic tanks calculated for the 3rd, 5th and 7th sample of Phetchaburi (**Table 4**) in terms of BOD_5, COD, TKN, TP and FC were 72.9%-73.7%, 78.8%-87.9%, 0.0%-51.3%, 8.7%-70.7% and 0.3-2.4 log removal. BOD_5 removal rates of commercial septic tanks were higher than that of TCPs while other parameters had comparable removal rates. Although BOD_5 removal rate was higher, the effluent still had quite high BOD_5 concentration (82.5-202.5 mg/L) and still higher than effluent standards. Moreover, since commercial septic tanks discharged the effluent directly into waterbodies without any attenuation, they may cause significant water quality problems to the receiving rivers.

Table 3 Number of types of rafts and riverfront buildings

Types	Phetchaburi	Kanchanaburi	Uthai Thani	Total
Residence	1	0	1	2
Restaurant	2	4	1	7
Hotel	3	3	0	6
Store	1	0	3	4

Table 4 Wastewater quality and treatment efficiency of onsite wastewater treatment system in Phetchaburi, Kanchanaburi and Uthai Thani Province

Province	No.	Type of onsite wastewater treatment system	BOD (mg/L, %)			COD (mg/L, %)			TKN (mg/L, %)			TP (mg/L, %)			Fecal coliform (MPN/100 mL, log removal)		
			Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal efficiency (%)	Influent (MPN/100 mL)	Effluent (MPN/100 mL)	Removal efficiency (log removal)
Phetchaburi	1	CST	110.0	-	-	1160.0	-	-	87.4	-	-	207.1	-	-	1.40E+07	-	-
	2	OCP	203.8	-	-	1060.0	-	-	68.6	-	-	386.9	-	-	5.40E+05	-	-
	3	CST	770.0	202.5	73.7	2080.0	440.0	78.8	31.5	89.6	-	401.9	307.0	23.6	1.10E+08	4.00E+05	2.4
	4	CST	187.0	190.0	-	800.0	460.0	42.5	33.6	54.6	-	294.5	296.8	-	4.00E+05	4.80E+04	0.9
	5	CST	383.8	82.5	78.5	840.0	120.0	85.7	79.1	38.5	51.3	148.3	43.4	70.7	3.50E+05	1.70E+05	0.3
	6	OCP	110.0	-	-	480.0	-	-	28.7	-	-	235.2	-	-	1.60E+05	-	-
	7	CST	710.0	192.5	72.9	5600.0	680.0	87.9	25.9	29.4	-	124.7	113.9	8.7	4.70E+05	1.60E+05	0.5
Kanchanaburi	1	OCP	280.0	-	-	360.0	-	-	24.5	-	-	293.8	-	-	7.00E+04	-	-
	2	OCP	230.0	-	-	320.0	-	-	11.2	-	-	105.0	-	-	2.20E+06	-	-
	3	OCP	630.0	-	-	1460.0	-	-	18.2	-	-	365.0	-	-	3.50E+05	-	-
	4	CST	500.0	750.0	-	1600.0	880.0	45.0	17.4	17.5	-	256.2	282.2	-	6.10E+05	4.60E+05	0.1
	5	OCP	650.0	-	-	750.0	-	-	16.8	-	-	53.7	-	-	5.40E+06	-	-
	6	CST	220.0	340.0	-	140.0	200.0	-	16.2	4.5	72.2	27.4	19.5	28.8			-
	7	TCP	490.0	240.0	51.0	1980.0	230.0	88.4	80.9	11.2	86.2	413.0	118.7	71.3	2.10E+07	3.40E+08	-
Uthai Thani	1	TCP	485.0	188.3	61.2	3320.0	380.0	88.6	63.0	65.1	-	224.5	213.9	4.7	1.60E+08	2.70E+05	2.8
	2	OCP	158.3	-	-	520.0	-	-	67.9	-	-	290.8	-	-	3.50E+05	-	-
	3	OCP	50.0	-	-	180.0	-	-	16.8	-	-	32.8	-	-	6.80E+04	-	-
	4	OCP	311.7	-	-	500.0	-	-	11.9	-	-	122.0	-	-	1.70E+06	-	-
	5	OCP	125.0	-	-	160.0	-	-	12.6	-	-	173.8	-	-	4.60E+06	-	-

Remark* OCP – One cesspool
TCP – Two cesspools in series
CST – Commercial septic tank

From the previous survey [4, 7], BOD_5 removal rate of OCPs, TCPs and septic tanks were in the range of 43%–59% with the effluent BOD_5 concentrations of 849-1,436 mg/L which were quite similar to this study reported. This indicates that although OWWTs in the rafts and riverfront buildings could operate as intended, removal rate was not enough and effluent should not be discharged directly into the waterbodies.

Questionnaire survey

Results of questionnaire survey aimed to evaluate knowledge of landlords regarding OWWTs in the sampling areas are presented in **Table 5**. The results indicated the followings;

- 26% of the sites littered into toilet

  Unwanted debris that go into OWWTs through littering in toilets can clog and result in short circuiting and ultimately poor effluent quality. In our survey, littering in toilet was quite difficult to control since the sampling sites were mostly restaurants and hotels. Prohibition might not be effective to customers. However, the landlords of the sites usually put signs and bins for littering in the toilets.

- 63% of the sites momentarily removed septage from OWWTs

  Periodic removal of septage is also important in maintaining good effluent quality from OWWTs. Since settleable solid and suspended solid are retained in the tanks, overtime, accumulated solids reduce the effective volume of the tanks and result in short wastewater retention time which ultimately deteriorate effluent quality. Most of the OWWTs at sampling sites momentarily removed septage from OWWTs. The removal frequency ranged from once in two months to two years. Such a high variation in period of septage removal comes from the fact that some sampling sites were commercial and some were residential wherein commercial sites had more frequent septage removal period.

- 16% of the sites realized the effect of concentrated detergents on operation of OWWTs

  Using concentrated cleaning detergents which are either highly acidic or basic can cause significant problems to OWWTs since they are harmful to microorganisms inside OWWTs. From the survey, there were only three sites where were aware of this issue.

- 42% of the sites had noticed abnormality of OWWTs

  Only 42% of the sampling sites had noticed the abnormality of OWWTs. This is quite a concern because if the abnormality occurred, the problems would be unnoticeable and resulted in poor removal rate of the OWWTs. Since most of the OWWTs rely on microorganisms which are sensitive to environmental stresses (i.e. organic overloading, off-pH, high acid or base), it is crucial to do regular check irregular circumstances occurred around the OWWTs (i.e. overflowing wastewater, irregular smell, toilets not flushed properly).

Table 5 Results of questionnaire survey

Questions	Yes*	No*
1) Do you have OWWTs installed in your raft/building?	19	0
2) Do you litter other waste (i.e. tissue paper, sanitary napkin) to the toilet?	5	14
3) Do you momentarily remove septage from OWWTs?	12	7
4) Do you know the effect of using high conc. detergent on OWWTs?	3	16
5) Have you ever noticed abnormality of OWWTs?	8	11

Remark * – Numbers represent the number of sampling sites.

Recommendations for wastewater management in rafts and riverfront buildings

In riverfront areas, OWWTs which rely on natural attenuation by soil should not be allowed. This is due to the fact that, in such areas, groundwater level is usually quite shallow. As such, there is insufficient depth/distance of natural attenuation. Furthermore, as seen in our results, effluent water quality of such systems is quite poor and not complied with water quality standards. For commercial septic tanks, the effluent should be followed by either on-land additional attenuation process or released to centralized wastewater treatment system. Small-scale constructed wetlands or drain field and effluent distribution box with appropriate setback-distance would be examples of alternative attenuation processes.

Type of OWWTs plays a vital role to prevent surface water contamination since most of OWWTs of riverfront buildings directly discharge the effluent into the waterbodies. The existing OWWTs in our survey (OCPs, TCPs and commercial septic tanks) had quite low removal rate in terms of BOD_5. Although it is to be expected from anaerobic process, the effluent quality is not complied building effluent standards. The appropriate OWWTs should have high removal rate and have the ability to stabilize pathogens. Thus, the OWWTs should be the combination of treatment processes and disinfection in series. An example is septic tank-anaerobic filter-aeration tank and disinfection. This OWWTs may not be practical in the area where the density of riverfront buildings is low, i.e. Uthai Thani, because capital and operation and maintenance cost are quite high. However, in denser areas, i.e. Kanchanaburi Province, this OWWT might be practical considering that it can cover the wastewater generated in the area and can serve as a semi-centralized wastewater treatment system.

Nutrients, nitrogen and phosphorus, are essential for aquatic plants including weeds, algae and phytoplankton. Since the concentrations of nutrients, especially phosphorus, were unexpectedly high, the discharge of the effluent can cause eutrophication [8]. The phenomenon does not only cause nuisance but also potential anaerobic condition in the waterbodies in the night when there is no photosynthesis. Additionally, the plants increase the organic loading to the waterbodies when they die out. Potential source of the nutrients in the OWWTs could be the fact that grey water, resulted from washing, bathing and laundry, was also discharged into the OWWTs in the sampling sites. This situation is worsened because the existing OWWTs were not designed to receive high concentration of nutrients. As a consequence, the nutrients were left untreated in the effluent and potentially stimulate eutrophication in the receiving waterbodies.

Management options for old areas

In the old area where OWWTs had been installed for a long time (i.e. Uthai Thani Province: “The way of housing rafts”), installing new and appropriate OWWTs or change/ modification of existing OWWTs are quite difficult or even impractical. However, the effects of the existing OWWTs on surround water resources are lacking and conclusive evidence on this issue is not clear. Thus, wastewater management option in this area could be done by monitoring the effect of existing OWWTs on the receiving waterbodies in order to point out the environmental burden of OWWTs. Further monitoring work should be done in terms of both organic pollution and fecal indicators. Previous study [9] recommended fingerprint compounds indicating the fecal contamination as the followings: Cl-to-Br ratio, sterol and stanol, and fecal coliform. In addition to fingerprint compounds, dyes can be used to track movement of effluent of the existing OWWTs. Once the effects of OWWTs are apparent, legal action can be placed.

Management options for newly developed areas

In newly developed areas, OWWT of choice is usually commercial onsite treatment system. The reliability of the commercial onsite treatment is widely accepted since they are available in sizes, desired treatment efficiencies and easy to install. However, for black water, the expected treatment efficiency of 90% achieved by aerobic commercial septic tank is insufficient to provide high quality effluent to meet the water quality standards. Since the effluent of traditional OWWTs (i.e. OCPs, TCPs and septic tank) still contained significant concentrations of such parameters, alternatives with higher efficiency OWWTs are recommended. Although aerobic septic tanks which are capable of higher effluent quality are commercially available, it is not suitable to treat black water owing to high organic loading of the wastewater. To treat black water, OWWTs should consist of anaerobic process (withstand high loading), aerobic process (good effluent quality) and disinfection process (stabilization of pathogens). Moreover, treating combination of grey and black water might be reasonable to obtain lowered loading rate. Successful implementation of such system can be seen in Japan, small-scale wastewater treatment system which treats combined grey and black water are installed at houses in rural areas. The system is called Johkasou which is essentially the combination of anaerobic and aerobic system and is capable of BOD_5, nutrients and pathogen removal [10]. To implement such a sophisticated system, subsidy and periodic maintenance are provided by Japanese Government (Japanese Building Standard Act).

Where it is impractical to implement sophisticated OWWTs whether it is due to space limitation or capital and maintenance cost are too high, conventional OWWTs must be installed on-land and have a sufficient setback-distance to allow appropriate soil attenuation. In New York, USA, prior to installation of septic tank and drain field, it is required to analyze soil samples and groundwater level whether the location is suitable for septic tank and drain field or not. In addition, the setback-distance of at least 50 feet from wells and rivers should be provided [11]. Soil condition, in which OWWTs are installed, should have hydraulic conductivity in an appropriate range in order to adsorb contaminants and unpleasant odor which can prevent ground- and surface water contamination [12, 13]. Mallin [14] also concluded that locations and density of septic system were also factors for environmental contamination of septic tanks.

Management options for onsite wastewater treatment systems for rafts

Onsite wastewater treatment system options for rafts are quite limited considering the fact that rafts can bear limited amount of weight and have limited space. In addition, most OWWT have quite low treatment efficiencies rendering the effluent not suitable for direct discharge. Therefore, an appropriate wastewater management for rafts should be holding tanks and regular transportation of the wastewater to central sewage treatment plants. As such, toilets on the rafts should be water efficient in order to minimize the generated wastewater which can prolong the wastewater holding period prior to transportation to centralized sewage treatment plants.

Conclusions

Investigation of types, efficiencies and suitability of OWWTs of rafts and riverfront buildings in Phetchaburi, Kanchanaburi and Uthai Thani Province indicated that most of the OWWTs in the areas were OCPs, TCPs and commercial septic tanks. The effluents of the systems were not suitable for direct discharge into the rivers. Management options of the wastewater can be done in several ways including proper installation of OWWTs, especially those rely on soil attenuation, restriction of direct discharge to the waterbodies. Alternatives such as Japanese Johkasou for combined grey and black water or combination of treatment processes have the potential to provide good effluent quality. Where OWWTs are not applicable, i.e. floating rafts, storage tanks can be installed incorporation with low-water-use toilets prior to collection and transportation to centralized sewage treatment plants. Intensive monitoring of the effects of OWWTs on waterbodies should be further investigated using tracing methods, chemical ratios and fingerprint compounds to draw a conclusive evidence and point out the problem of existing OWWTs. Finally, maintenance of OWWTs is crucial for OWWTs operation. Although OWWTs are designed in such a way that can provide good enough effluent quality for direct discharge, the OWWTs cannot operate as intended without proper maintenance owing to the fact that most of OWWTs rely on biological degradation which is quite sensitive to stresses including overloading, short circuiting, toxic chemicals and etc.

Acknowledgement

This study was funded by Environmental Health Division, Department of Public Health, Ministry of Public Health, Thailand.

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