Decentralized wastewater treatment - new concept and technologies for Vietnamese conditions

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Abstract
The decentralized approach is a new means of addressing wastewater management needs of sewered and unsewered areas in a comprehensive fashion. The basic idea of that is to treat the wastewater (possibly together with refuses) on-site by means of low-cost treatment systems, and make direct use the treatment products (water, compost, biogas). This alternative can meet a sustainable wastewater management requirement and has a promising future, especially for developing country of Vietnam, where the water and sanitation issues are becoming a more and more important issue and are under new period of infrastructure development. Further, the authors describe results from experiment on real wastewater treatment by baffled septic tank with anaerobic filter that could be most feasible option for on-site wastewater treatment in residential areas of Vietnam. The data show that baffled septic tank with or without anaerobic filter could effectively treat black wastewater from toilet in Vietnamese conditions, with removal efficiency by COD from 43.24 - 94.92 % (average 74.85%), by BOD from 47.13 - 90.87 % (average 71.47%), by SS from 37.40 - 97.18 % (average 71.14%). The decentralized schemes of wastewater management are also proposed for medium and small cities of Vietnam.

Keywords
Anaerobic filter, baffled septic tank, decentralized system, suspended solids, anaerobic digestion, wastewater treatment.

BACKGROUND

Nowadays there are 571 cities and towns in Vietnam. The country is under rapid urbanization and industrialization process, with positive indicators in socio-economic development. However, there is an increasing problem of water pollution. The water supply capacity has increased from 1.95 million m^3/day in 1990 to nearly 3 million m^3 /day in late 2001. In the same period, the urban population has raised from 12 million in late 1980 to nearly 18 million in late 1999, accounting for 23.5% of the population of the whole country. There is very low ratio of population served by adequate sanitation, especially in rural, peri-urban and poor urban areas. Urban sewerage and drainage systems are still poor and under degradation. In most of cities and towns, flood and inundation often occur in rainy season. Existing sewer networks (if any) in cities have been built for surface water drainage only. Mainly domestic wastewater from houses is directly discharged to the common sewerage network and then flows to the canals, lakes and ponds without any treatment. In consequence, self-purification capacity of receiving water bodies is overloaded and it causes surface and ground water pollution, impacting directly to the health of community, reducing the value of environment. More than ever, development of urban sewerage and drainage systems in Vietnam has become an urgent need.

In Vietnam, the septic tank is the most common on-site treatment facility in urban and peri-urban areas. In Hanoi, there are about 10,000 septic tanks in operation for treatment of the domestic wastewater. In urban centers the ratio of households equipped with septic tanks is nearly 50-80%. In the rest oarts of the city the ratio is 20-30% (Hanoi PC, 1998). Desludging of septic tanks is not often followed. There is still subsidizing form of management of public utilities including wastewater management, without or with very poor public involvement. Thus, looking for the appropriate solutions for wastewater management is becoming very hot issue and is to be paid adequate attention, especially in this period of increasing urbanization, industrialization, improvement and development of water supply and sanitation facilities.

CONVENTIONAL CONCEPTS FOR CENTRALIZED WASTEWATER MANAGEMENT SYSTEMS

In commonly called "centralized" water/wastewater management system all the water to be distributed in the urban area is purified at one discrete location, the water works, and the wastewater collected in the area is sent to one discrete plant for treatment and discharge. Centralized wastewater management has been the norm in municipal engineering circles for more than 100 years. Based on the "Pipe it away first, then think about what comes next" philosophy, centralized management is the structure of choice in most cities and countries.

Disadvantages of centralized wastewater management systems

- Only a minor fraction of the high quality water distributed in urban areas is used for drinking and cooking. The major fraction is used for cleaning, flushing and for watering plants and lawns. A significant amount of the drinking water is required just as a means to transport the pollutants to the wastewater treatment plant.
- Combining all kinds of wastewaters and occasionally storm water, in addition, leads to a highly complex mixture of a wide variety of pollutants fluctuation, heavily in composition and concentration. Thus, effective removal of the pollutants becomes very difficult.
- Wastewater and removed sludge contain components such as phosphorus, which could be used as fertilizer provided the product is not spoiled by problematic substances such as heavy metals.
- Eventhough the decentralized approach has a very long tradition in Vietnam; centralization is still being common solution for wastewater investment projects. Conventional sewerage systems often are a very costly part of the infrastructure (if rehabilitation is done). The costs for the installation of the sewer system are of almost an order of magnitude higher than the cost for building up the treatment facilities. In many cases, delay of water investment projects often occurs due to lack of money. Very high operation and maintenance cost is also big challenge for the municipal authorities, especially when cities are in the river delta plates and flat coastal areas, where pumping stations are required and sewers are installed with limited (minimum) slope. Inadequate operation and maintenance of sewers network may lead to sewer clogging, local flooding, pipe leak, and, as consequence, to pollution of soil and groundwater, or increase of the hydraulic loading of the treatment plant. Higher capacity of pipes and tanks are needed.

NEW APPROACH FOR URBAN WASTEWATER AND SANITATION MANAGEMENT

That approach may be changing. Most of small communities have found conventional systems to be hugely expensive and have begun to investigate decentralized concepts. The decentralized concept is base on a simple premise: Wastewater should be treated (and reused, if possible) as close to where it is generated as is practical.

That philosophy allows local governments to circumvent one of the major disadvantages of the conventional, centralized management system - huge investments in an extensive collection system that does nothing more than move pollution from place to place. (The phrase "decentralized management" is used here, but it is somewhat of a misnomer, because, while facilities are decentralized, management may be handled by a central entity).

In many places were faced with extending service. Its engineers determined that using decentralized treatment methods would be a far more cost-effective solution than extending the city's centralized system into the area. The elements that decentralized wastewater management systems comprise include: (1) wastewater pre-treatment, (2) wastewater collection, (3) wastewater treatment, (4) effluent reuse or disposal, and (5) biosolids and septage management. Although the components are the same as for large centralized systems, the difference is in the type of technology applied. It should also be noted that not every decentralized wastewater management system would incorporate all of above elements.

BAFFLED SEPTIC TANK WITH UP-FLOW ANAEROBIC FILTER FOR TREATMENT OF REAL DOMESTIC WASTEWATER AT CEETIA LABORATORY

Status of use of conventional septic tanks in cities of Vietnam

In Vietnam, most of septic tanks are often extremely outdated and damaged. They are not repaired and regularly overloaded, while sludge is not emptied regularly. Surveys and analyses carried out by CEETIA in the period 1998 - 2001 showed that most of septic tanks were under designed, and are operated with rather low treatment efficiency. The characteristics of effluent from surveyed septic tanks in 4 selected cities: Hanoi, Hai Duong, Vinh Yen and Thai Nguyen in northern part of Vietnam were: BOD_5 = 240-720 mg/l; COD = 320 - 1,200 mg/l; DO = 0.5-2.4 mg/l; TSS = 440 - 2,640 mg/l. Nitrogen ammonia and phosphorus content in most of effluents are high. All of investigated septic tanks are working without filtration chamber. In some cases suspended solids content in effluent eventually higher than in influent due to floating substances in un-emptyed septic tanks are washed out. In 1998, the Project of Water Supply, Sewerage and Environmental Sanitation for Hai Phong City, supported by FINIDA found similar values.

Experiment on treatment of real domestic (black) wastewater by baffled septic tank with up-flow anaerobic filter at CEETIA's Laboratory

Material and Method. From 2000, CEETIA has installed two models of baffled septic tank made by plexiglas. The scheme of septic tank models is shown in Figure 1. Dimensions of the models are shown in the Table 1. The first chamber in both models is separated in the middle through a wall (height 55 cm) with a hole (diameter 2 cm) in the middle to keep the scum back in the first chamber. It makes like a second settling-digestion chamber. Operation of those two septic tank models started since July 2001.

Real wastewater source comes from Toilet in Celia's building. This source was only enough for feeding of small septic tank. From August to October 2001, in order to ensure the quantity of WW for experiments, the feeding line, collecting WW from the toilet in H1 Building (classes) at the HUCE's campus to the CEETIA has been installed. This WW is pumped twice per day, storaged in 1,500-liters steeless steel tank before it is fed into Septic tank models by dosing pumps.

Table 1. Major parameters of septic tank models at CEETIA's Laboratory.

Parameters	Big Model	Small Model
Number of chambers	5	5
Material of tank walls	Plexiglas	Plexiglas
Material of filters		
First stage (6/2001 – 12/2001)	Charcoal	PVC pipe cuts
Second stage (1/2002 - 7/2002)	No	Charcoal
Height (m)	0.6	0.54
Length (m)	1.16	0.67
Total volume (m^3)	0.275	0.067
Used volume (m^3)	0.215	0.046

At the beginning no sludge is added to accelerate the growth of the sludge in the models. The septic tanks were fed continuously to simplify the experiment, the acclimatization and growth of the sludge. The more realistic batch feed will happen in a later phase. 2 dosing pumps feeding raw wastewater are shifted to operate daily to avoid the warming up of the pump.

Samples are collected daily each hour, mixed (composite sample) and kept in the fridge until they are analyzed. Parameters analyzed: COD (filtered and unfiltered), BOD (filtered and unfiltered), suspended solids (SS), nitrogenous compounds, pH, temperature, EC, TDS.

The critical parameter in a baffled reactor is the up-flow velocity. It must be guaranteed that the up-flow velocity has to be smaller than the settling velocity of the sludge, and, as consequence, sludge should not be transported to the next chamber. The experiment has been started with the up-flow velocity 0.3 m/h. The HRT in each chamber and total HRT are calculated: For the small ST: Velocity v = 0.3 m/h. Flow Q =5.3-6 l/h. HRT = 8.5 h. For the big ST: Velocity v = 0.3 m/h. Flow Q = 0.02 m3/h = 20 l/h. HRT = 12.4 h.

After 6 months of starting phase of the models (7/2001 - 12/2002), there are some remarks have been made. The sludge was grown naturally. The growth has been accelerated from second and third month. 15-cm depth layer of the sludge from 45 cm-total depth of the chambers has been reached after 4 months of operation. Due to selected 0.3 m/h up-flow was quite high for the small model so part of sludge from baffled chambers flown to the anaerobic filter and trapped by the media. The sludge layer formed on the PVC pipe media surface (in small tank) very slowly. The possible reason could be the surface of PVC material was too smooth. The better situation has been defined with filtration media of charcoal in big model.

Since January 2002, in order to compare the removal efficiency of septic tanks working with and without anaerobic filters we have removed the filtration media from last chamber of the big septic tank, and replaced filtration media of PVC pipe pieces in small model with that charcoal from the big model. Two models have been shifted to batch regime, similar to ''flush'' regime in practice. One other reason of shifting the operational regime was to avoid solids washing out from chambers of small model due to high wastewater flow-rate of selected dosing pump.

The models are fed with raw wastewater from the same source of toilets from H1 building of classes in HUCE and from CEETIA's toilet 4 times per day by dosing pump. Pumping period is 12 min. and 40 min. with flow rate 0.47 l/h and 14.3 l/h for small and big model respectively. Composed samples are collected during pumping period, kept in refrigerator and mixed at the end of every day before analyses.

RESULTS AND DISCUSSION
The results of experiments on septic tank models are shown in Figures 1 a, b, c, d, e, f.

- Implementation of baffled septic tank with or without up-flow anaerobic filter has positive results for real domestic (black) wastewater treatment in Vietnamese condition. It could be developed for practical use and included for design standard instead of under-designed and improperly operated existing septic tanks in residential areas in over the country.

- The treatment efficiency for the models reached 50% and more after 3 months of operation, after sludge layer has formed in bottom of up-flow chambers. The sludge was grown naturally. The growth has been accelerated from second and third month. 15-cm depth layer of the sludge from 45 cm-total depths of the chambers has been reached after 4 months of operation.

- The sludge layer formed on the PVC media surface very slowly. The possible reason could be the surface of PVC material of media was too smooth. The use of local material of charcoal that is available in any place in the country has positive evaluation for anaerobic filter media.

- pH values varies from 5.95 to 8.69 in inlet and from 5.89 to 8.73 in outlet. The value of pH has increasing value from the first chamber to the outlet, and it is more significant while the retention time of wastewater in the tank is increased. That could be explained by methano-fermentation stage of wastewater with long retention time.

- SS are removed mostly in the first chambers. Part of sludge from baffled chambers flown to the anaerobic filter and trapped by the media. Total SS removal efficiency is 41.53 - 91.17 % (average 67.90%) in big model and 37.40 - 97.18 % (average 71.14%) for small model.

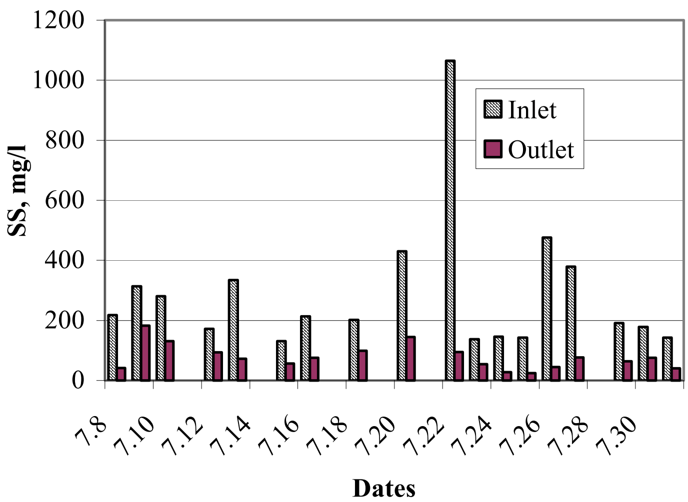
- COD removal efficiency is 38.49 - 83.83% (average 59.60%) in big model and 43.24 - 94.92 % (average 74.85%) for small model.

- BOD removal efficiency is 40.97 - 91.23% (average 59.31%) in big model and 47.13 - 90.87 % (average 71.47%) for small model.

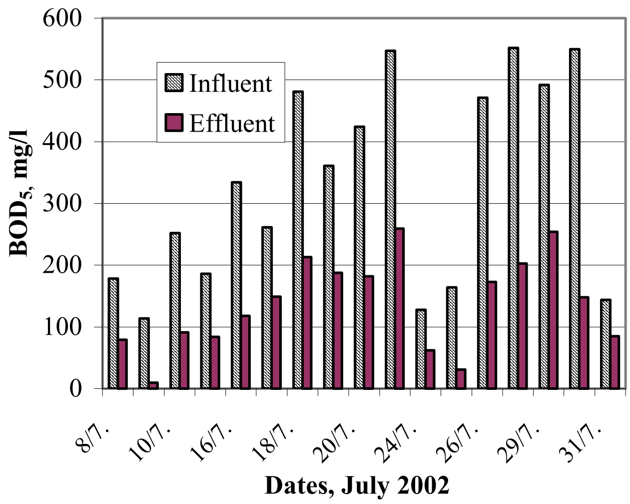
- With appropriate hydraulic regime (i.e. proper design) anaerobic filter placed at the end of baffled chamber could increase treatment efficiency of the model, especially for COD and BOD parameters (10 - 15%). Meanwhile, the improvement was not significant (less than 5%) for suspended solids. For the case of experiment, high flow rate during continuous operational regime led in washing out of suspended solids from chamber to the outlet. SS removal could be improved by reducing flow rate (i.e. increasing dimension of the septic tank for the same user). Batch regime (hence, with less flow rate and longer HRT) of both models gave much better SS removal.

- The up-flow chambers and the anaerobic filters have more significant removal efficiency with dissolved organic matters rather than the solids.

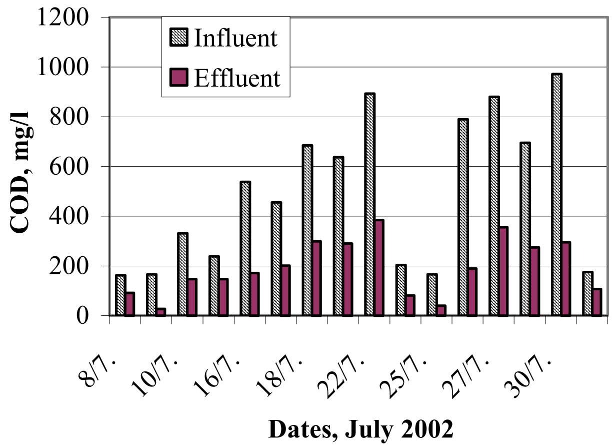
- In order to improve treatment efficiency of the models, there are possible options to be considered as follows: addition of baffled chambers; increase of retention time of wastewater in the tank. Increase of volume of primary settling chamber also mitigates risk of suspended flushing.



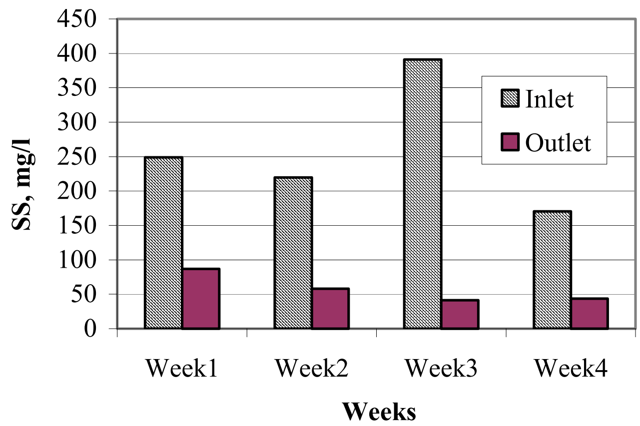
a) Big tank model, SS removal, July 2002



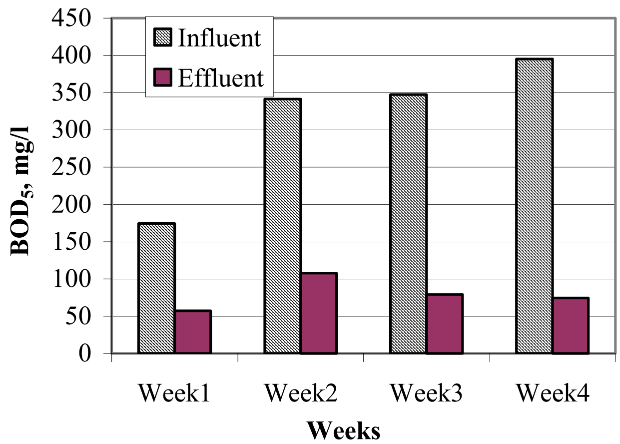
b) Big tank model, BOD_5 removal, July 2002



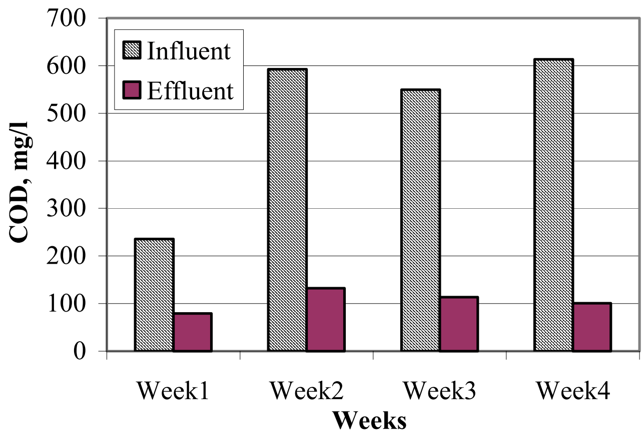
c) Big tank model, COD removal, July 2002



d) Small tank model, SS removal, July 2002



e) Small tank model, BOD_5 removal, July 2002



f) Small tank model, COD removal, July 2002

Figure 1. The results of experiments on septic tank models

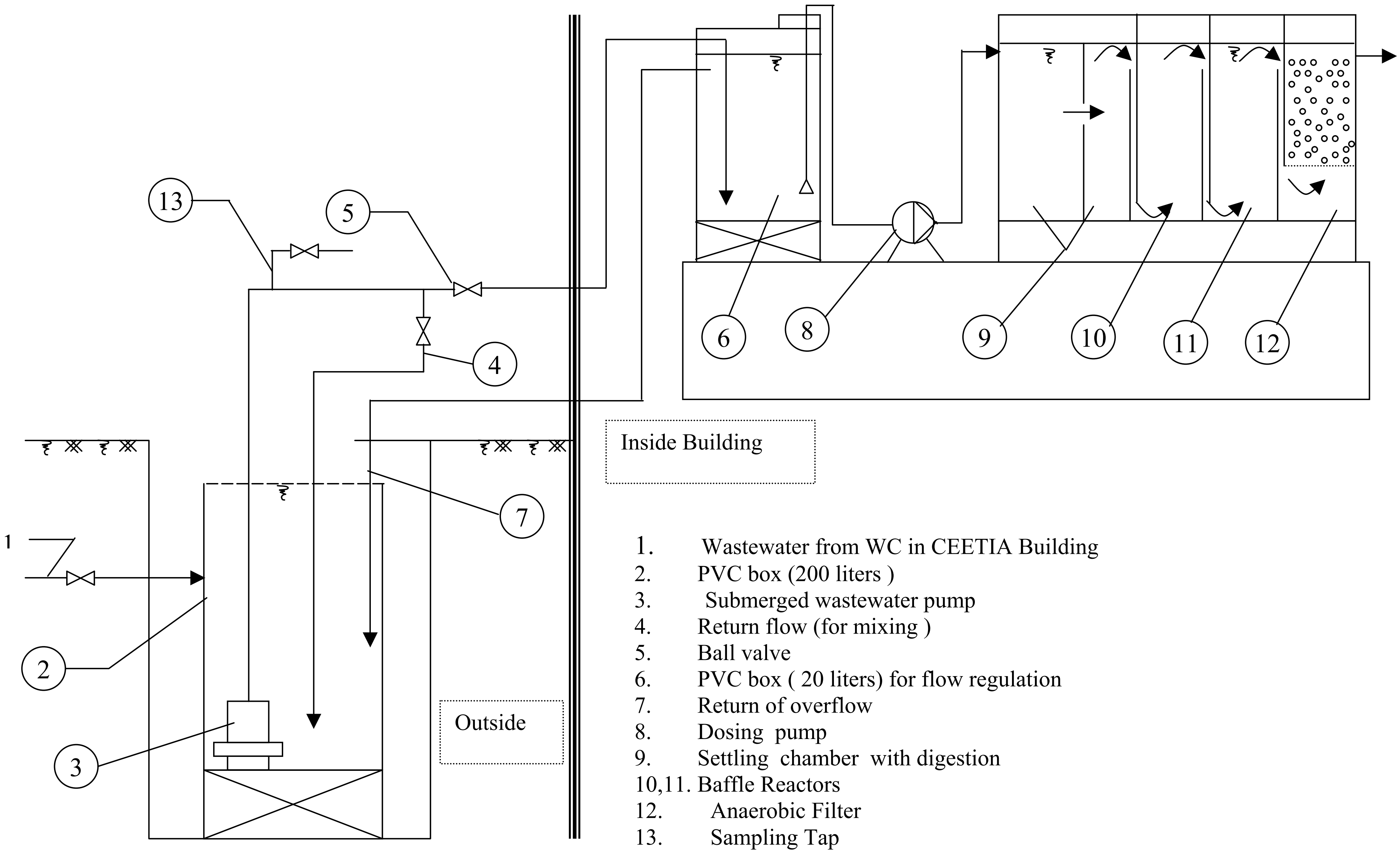


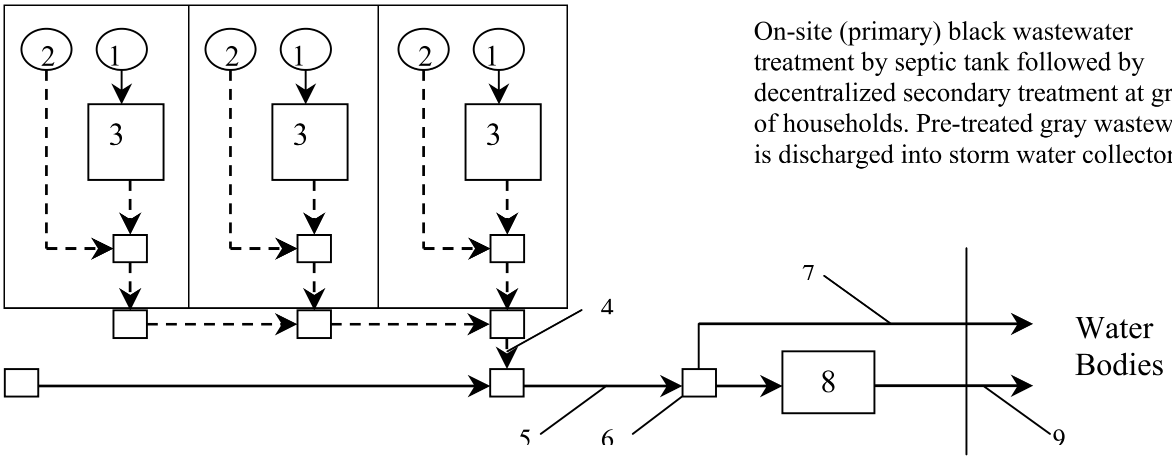
Figure 1. Septic tank model operational scheme

PROPOSAL OF DRAINAGE AND SEWERAGE SCHEMES FOR MEDIUM AND SMALL CITIES OF VIETNAM

Technological options

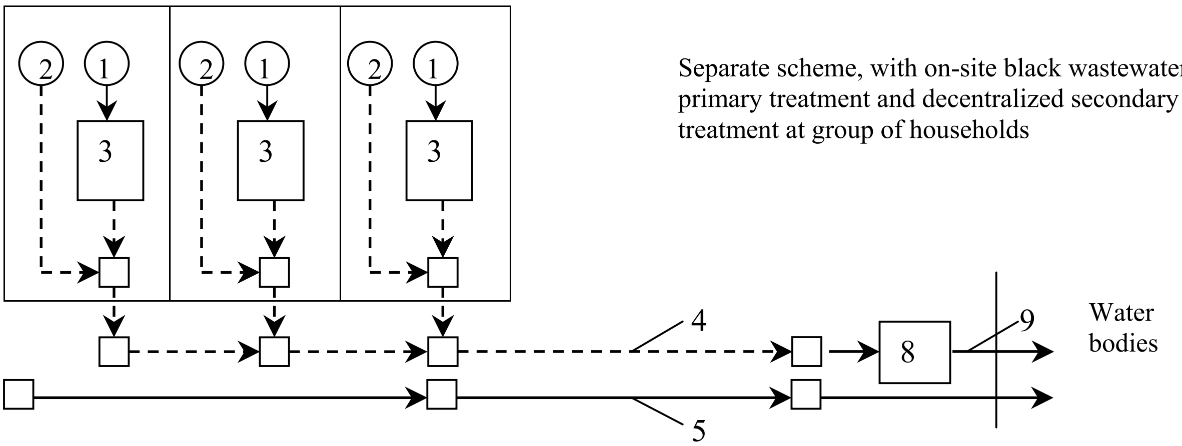
(1) Sedimentation and primary treatment in sedimentation ponds, septic tanks or imhoff tanks
(2) Secondary anaerobic treatment in fixed, bed filters or baffled septic tanks (baffled reactors).
(3) Secondary and tertiary aerobic, aerobic/anaerobic treatment in constructed wetlands (subsurface flow filters).
(4) Secondary and tertiary aerobic/anaerobic treatment in ponds.

Figure 2 proposes schemes of wastewater management that are proposed for medium and small cities of Vietnam.



On-site (primary) black wastewater treatment by septic tank followed by decentralized secondary treatment at group of households. Pre-treated gray wastewater is discharged into storm water collectors.

1- Black wastewater
2- Gray wastewater
3- Septic tank (Primary treatment)
4- Domestic wastewater collector
5- Combined sewer
6- Combined sewer overflow chamber
7- Overflow storm water
8- Wastewater treatment plant
9- Secondary treated wastewater



Separate scheme, with on-site black wastewater primary treatment and decentralized secondary treatment at group of households

1- Black wastewater
2- Gray wastewater
3- Septic tank (Primary treatment)
4- Domestic wastewater collector
5- Storm water collector
8- Wastewater treatment plant
9- Secondary treated wastewater

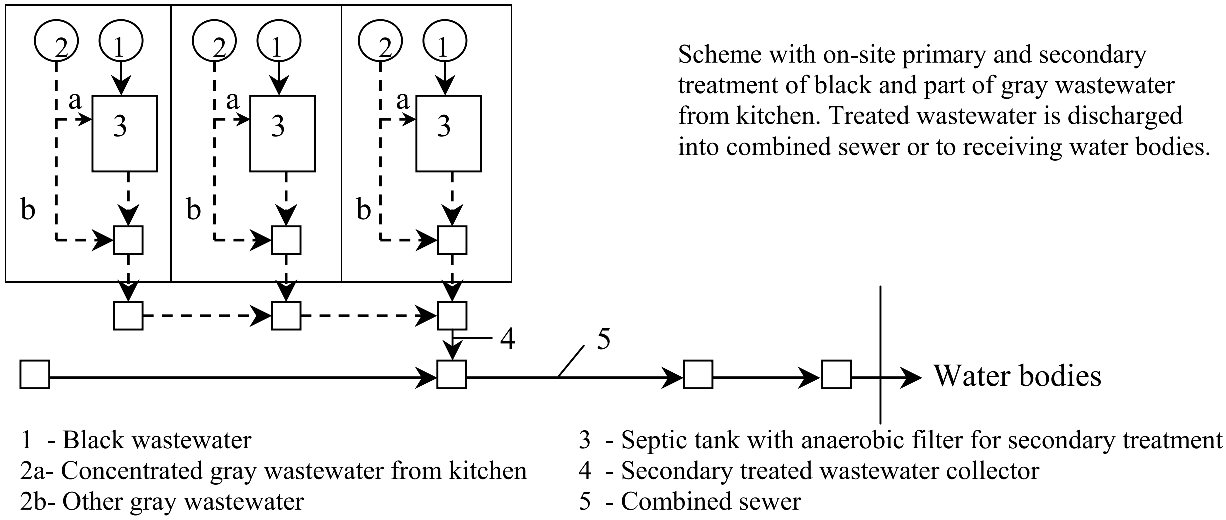


Figure 2 (a, b, c). Schemes of wastewater management proposed for medium and small cities of Vietnam.

Recommendations for existing residential areas

- Septic tank without filtration chamber is conventional primary wastewater treatment facility. It can remove only 40-50% suspended solids and 20-30% BOD. After septic tank wastewater is discharged to combined sewer and goes to secondary treatment. Conventional wastewater treatment plant includes grid removal, secondary biological treatment and disinfection. The biological treatment facilities could be oxidation ditch, trickling filter or activated sludge process, that allow to achieve concentration of BOD_5 = 30 mg/l, SS = 25-30 mg/l in effluent. In case of land availability, stabilization ponds in chain and constructed wetlands could be economically appropriate alternatives. For on-site wastewater effluent improvement, additional chambers could be constructed for individual household or group of households treating wastewater after existing septic tanks.

Recommendations for new residential areas of urban development

Implementation of decentralized wastewater systems with secondary treatment, i.e. BOD_5 = 25-30 mg/l, SS = 20 - 30 mg/l. Properly designed septic tank should be as required facility in approval of construction of the new house. On-site treatment of black wastewater by baffled septic tank with up-flow anaerobic filter (BASTAF) is one from feasible alternatives with promising high cost-benefit efficiency, according to the CEETIA's study. After treatment in BASTAF, treated black wastewater is discharged through combined sewers with gray wastewater into decentralized community's treatment plant, that consists of imhoff tank/waste stabilization ponds / constructed wetland and/or other low-cost options.

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