A measure for provisional-and-urgent sanitary improvement in developing countries: septic-tank performance improvement

H. Harada, N. T. Dong and S. Matsui

ABSTRACT

Although many cities have planed to develop sewerages in developing countries, sewerage establishment still requires huge investment and engineering efforts. Improvement of existing sanitation facilities may contribute the betterment of urban sanitation before sewerage establishment. The purpose of this study is to propose a measure to improve urban sanitation in areas where a sewerage development plan is proposed but has not been yet established, based on a case study in Hanoi, Vietnam. We found that 90.5% of human excreta flowed into septic tanks. However, 89.6% of septic tanks have never been desludged in the past and their performance was observed to be at a low level. The study also showed that if they introduce regular desludging with a frequency of once a year, they can eliminate 72.8% of COD loads from septic tanks. It was indicated that the performance can be dramatically recovered by regular desludging, which could contribute urban sanitation improvement in Hanoi. In conclusion, the performance recovery of septic tanks by regular desludging was proposed as a provisional-and-urgent measure for urban sanitation improvement, together with the septage treatment in sewage sludge treatment facilities, which should be established earlier than other facilities of sewage treatment systems.

Key words | developing country, Hanoi, performance, sanitation, septic tank, specific retention period of septage

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INTRODUCTION

Background

Improvement of sanitary conditions has been recognized as one of the crucial issues for developing countries. Although 80% of urban population had the access to improved toilets in 2004 (WHO and UNICEF 2006), most of urban areas of developing countries are still suffering from serious water pollution since water-flush toilets have been used in many urban households and most of wastewater from those toilets is discharged into water bodies without proper treatment.

Sewerage development has been recognized as a solution to treat wastewater and to improve urban environmental sanitation. Establishment of conventional sewerage, however, requires the decades-long construction and the huge investment, especially for sewer networks. Even though there are efforts to decrease the expense of sewerage development and shorten the period for construction such as technology of low-cost sewerage (Mara 1996), a provisional-and-urgent measure may be required to complement sewerage development for the improvement of urban sanitation.

It should not be disregarded that, differently from rural areas, many of urban dwellers have some sort of wastewater treatment facilities such as septic tanks and soak pit etc. Such facilities may play important roles for urban sanitation in developing countries. Even if a city already has a sewerage development plan, there may be no choice other

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than to keep using such existing facilities until the establishment of sewerage.

Septic tank seems to be one of major existing sanitation facilities in urban areas of many developing countries. The management of septic tanks, however, has been reported to be in serious conditions in many cases (ADB 2001; Straus *et al.* 2003), and performance and functionality of them are seemed to be at a very low level. To make matters worse, septic tank effluent is discharged into open channels, sewers, etc., of which most are connected to water bodies without treatment facilities. Improvement of existing sanitation facilities, namely recovery of septic-tank performance, might contribute the betterment of urban sanitation in developing countries, even though conventional septic tanks do not produce high quality effluent (Tchobanoglous & Burton 1991).

Hanoi city, Vietnam

Hanoi, which is the capital of Vietnam, is located in the Red River delta and within the bend of the Red River of northern Vietnam. Its population was increasing from 2.8 millions in 2000 to 3.2 millions in 2005 (HSO 2006). Ambient water in the urban areas is highly polluted with stream and ponds and lakes. Some drain streams release foul odor. It was reported that some lakes and ponds in the urban area had a COD of 40–120 mg/L (JICA and HPC 2000) and four drain streams in urban Hanoi such as Kim Nguu, Set, Lu, To Lich rivers had a BOD of 14–180 mg/L (World Bank 2003). Meanwhile, contamination by heavy metals is limited in Hanoi, but does occur extensively in some places near industrial areas (JICA and HPC 1995).

A sewer (drainage) system was firstly introduced into the city by the French colonial powers in 1897 in the inner portion of the city and at present consists of a network of underground combined sewers (UNDP 2000). Most of the sewers in Hanoi are, however, suffering from a lack of maintenance (UNEP-IETC 2002) and detailed data in regard to the sewers are not available. The city except some industrial areas has only small wastewater treatment plants for municipal wastewater and the areas covered by treatment amount to only 6.3 km^2 as of 2005, which is equivalent to 3.5% of the urban area (HSO 2006). The sewerage development is still at the beginning. Clearly, it will require some decades to establish the sewerage system and treatment plants in urban Hanoi.

Urban wastewater is typically discharged into the sewers without prior treatment in modern treatment facilities due to the lack of such facilities. Although details are not clear, it was mentioned that many people used water-flush toilets in urban Hanoi and in general that most of them were connected to septic tanks. Septic tanks seem to play a major role to treat household wastewater in Hanoi. However, the management conditions of septic tanks are briefly reported to be in quite serious conditions (JICA and HPC 2000; Fink 2001). Septic tanks in Hanoi are not likely to work properly.

There might be a possibility of improving the management of septic tanks and of increasing their performance to remove pollutants from wastewater as a provisional-and-urgent measure for the urban water environment in Hanoi. However, details are not clear for the present states of sanitation facilities in the city. In addition, there is no study to investigate how much the improvement of septic tank management can contribute to improve urban sanitation, even though such information is necessary for considering the strategic sanitation improvement.

Purpose

The purpose of this study is to propose a provisional-and-urgent measure to improve urban sanitation in areas where a sewerage development plan is proposed but it has not yet been established. As a case study, the present state of septic tanks together with other sanitation facilities were firstly investigated in Hanoi city of Vietnam. Secondly, effects of desludging on performance and functionality of septic tanks were examined. Then, we examined the possibility that the recovery of septic tank performance should be a measure for the provisional-and-urgent improvement of urban sanitation in developing countries.

METHODS

Investigation of present household sanitation facilities and desludging conditions of septic tanks in urban Hanoi

A statistical household-interview survey was carried out with a questioner for 750 households in urban Hanoi,

which were selected with a multi-stage sampling. Then, the sanitation coverage was investigated by the type of sanitation facilities, the discharging locations of effluent, and desludging conditions. Septic tanks in Hanoi are composed of two types: a box-type septic tank and a cylinder-type septic tank. The desludging condition of box-type septic tanks, which are used for most households in urban Hanoi, was questioned. The interview process was started at the beginning of December 2005 and finished at the middle of May 2006.

Analysis of the relationship between desludging conditions of septic tanks and pollution loads of the effluent

Sample and interview

In most cases in urban Hanoi, septic tanks effluent was taken as a sample at the outlet of ten of three-compartment box-type septic tanks in urban districts of Hanoi. All of them did not receive greywater. Samples were measured for COD_{Cr}, SS and Cl^- by Standard Methods (USEPA 1983).

Adjustment of sample concentrations with Cl^- concentrations

The volume of flush water into a septic tank varies by each toilet. To compare the performance of different septic tanks, the pollute concentration of each sample should be adjusted so that the effect of dilution by flushing water is eliminated. Here, we assume that, each person produces the excreta with the same concentration; the Cl^- concentration of all samples varies in accordance only with the dilution by flush water because of the high solubility and the low reactivity. We therefore adjusted the target sample concentrations using Cl^- concentration (*i.e.*, adjusted concentrations) as follows:

$$C_{Cl.i,j} = C_{i,j} \times \frac{Cl_{max}}{Cl_j} \quad (1)$$

where $C_{Cl,i,j}$ is the adjusted concentration of item i of the sample from septic tank j (mg/L), $C_{i,j}$ is the un-adjusted concentration of item i of the sample from septic tank j (mg/L), Cl_{max} is the highest concentration of Cl^- among all samples (mg/L), and Cl_j is the concentration of Cl^- of the sample from septic tank j (mg/L).

Analysis of the effect of retention periods of septage on effluent qualities

Considering the retention period of septage in septic tanks with a household size and a septic tank volume, we developed the following equation to indicate the desludging condition of a septic tank:

$$P_{SR} = \frac{P_R \times S}{V} \quad (2)$$

where P_{SR} is the specific retention period of septage (month·person/m^3), P_R is the retention period of septage (month), S is the household size that was using a septic tank (person), and V is the volume of a septic tank (m^3). The relationships between the specific retention period and the adjusted concentrations were examined by a simple regression analysis.

RESULTS AND DISCUSSION

Present household sanitation facilities in urban Hanoi

Sanitation coverage

The results of household interview of sanitation coverage in urban Hanoi are illustrated in Figure 1. The response rate of the survey was 92.5%. As shown in Figure 1, human excreta in urban Hanoi were mostly discharged into flush toilets (96.7%), and then most of flushed excreta flow into septic tanks (90.5%), which were mostly connected to old sewer pipes.

Considering most sewer pipes dose not lead to final treatment facilities, it can be said that the septic tank is almost the only facility to treat toilet wastewater from households in urban Hanoi at present and also will be so until modern sewerage will be established. It is implied that the performance of septic tanks greatly influences the quality of urban environmental sanitation in urban Hanoi.

Household septic tank management in urban Hanoi

Septic tanks in Hanoi consisted of box-type and cylinder-type septic tanks. The septic tank management was

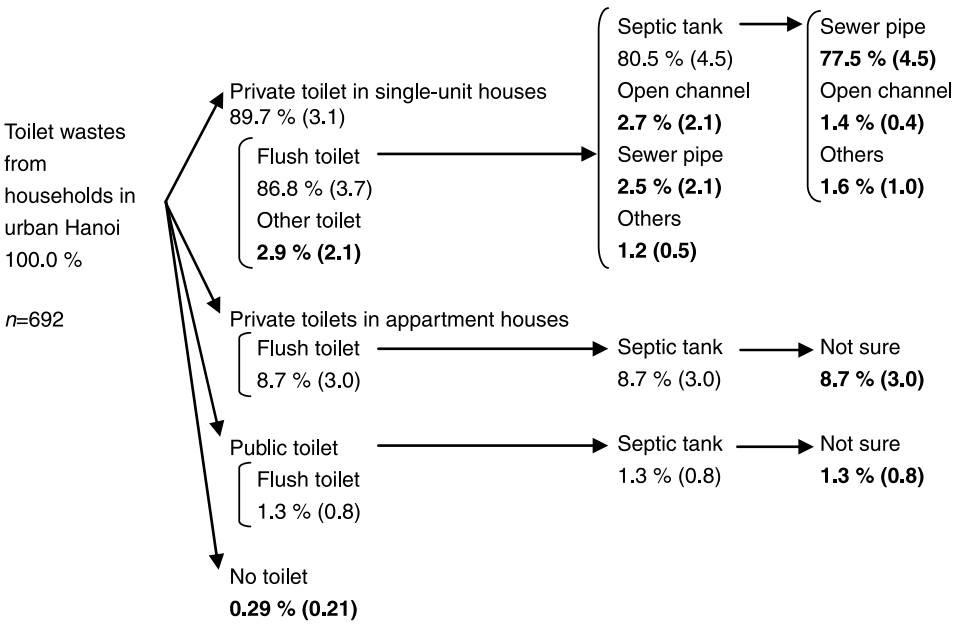

Figure 1 | The breakdown of sanitation coverage for toilet wastes discharged by households in urban Hanoi ($n = 692$). Figures in parenthesis indicate standard errors. Bold figures mean the ratios at the final destinations in this survey. Households having no toilet (0.29%) used neighbour's toilets or did not use any toilet but used a bag for excretion.

investigated for box-type ones, which accounted for most of septic tanks in urban Hanoi. The ratios of septic tanks with and without desludging experiences and with and without regular desludging are set out in Figure 2 (a) and (b) respectively.

Although the practice of regular desludging is recognized as one of the influential factors on septic tank performance (Butler & Payne 1995), it was found that 94.6% of box-type septic tanks in urban Hanoi was not desludged regularly (Figure 2a). Furthermore, nearly 90% of them were not at all desludged in the past (Figure 2b). According to interview results, most households desludge only when septic tanks have some serious problems such as clogging.

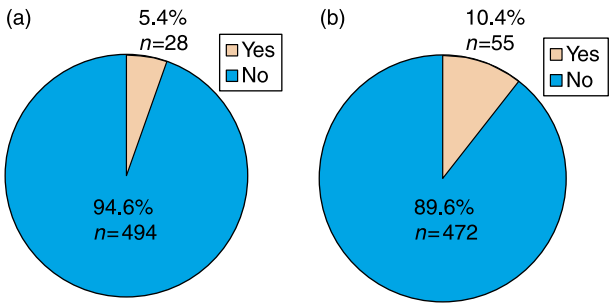

Figure 2 | The desludging conditions of box-type septic tanks: (a) households desludging regularly or not; (b) households having desludging experiences in the past or not.

The non-desludge period for septic tanks in urban Hanoi is shown in Figure 3. When a septic tank has no desludging experience in the past, the period was calculated after each household started using the tank. It was found that the desludging period has an average and a median of 8.1 years and 7.0 years respectively. Several reports mentioned that desludging should be executed at least every two to five years in general although the period vary depending upon conditions (USEPA 2000; UNEP-IETC 2002; IDI-J 2004). In the case of Hanoi, our results showed that septage were stored for more than two years and five years for 86.6% and 68.4% of box-type septic tanks respectively. It is concluded that most of septic tanks are not managed properly in urban Hanoi and the performance and functionality of the tanks are expected to be at a quite low level.

The effect of desludging conditions of septic tanks on pollution loads of the effluent

Effluents were sampled and analyzed for three-compartment septic tanks connected to cistern-flush toilets, which

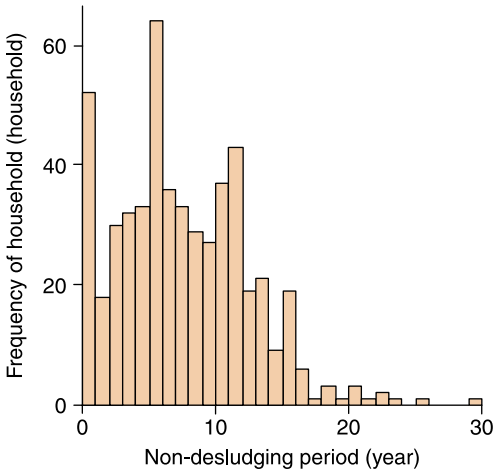

Figure 3 | Non-desludging period.

were the most dominant septic tank system in urban Hanoi. Adjusted concentrations of COD and SS of the effluent are illustrated against the specific retention period (Figure 4 (a) and (b)).

It was found that the adjusted concentrations of COD and SS increased with an increase in the specific retention period, and significant correlations were examined ($\alpha = 0.05$) between the period and each adjusted concentration of COD and SS. The values of coefficient determinations (R^2) were remarkably high, especially for COD (0.85). It was indicated that there are clear relationship between those concentrations and the specific retention period. The results could be interpreted that by decreasing the specific retention period, one can reduce the pollution loads of COD and SS discharged from the septic tanks.

The relationship between the adjusted pollutant concentrations and the specific retention period may be explained by settling and skimming functions of solid pollutants in the septic tanks. Settling performance could be depressed by an increase in the specific retention period as caused by accumulation of septage inside the tank. Another possible reason of the reduction, especially for COD, is that anaerobic digestion may decompose organic matter in the wastewater during retention of the fluid in the septic tank. The hydraulic retention time in a septic tank is one of the influential factors which affect the performance of anaerobic digestion but its effect may be decreased by over accumulation of septage in the septic tank.

The specific retention period could not explain 15% and 58% of variations for COD and SS respectively. The effluent quality of septic tanks depends on differences in tank configuration. In terms of configuration, only the compartment number and the tank volume were taken into consideration in this study. Differences of configurations not examined in this study may be one of possible reasons for the unexplained variations.

Regression equations between the specific retention period against adjusted concentrations of COD and SS were described in each as follows:

$$\mathrm{COD_{Cl}} = 13.9 \times P_{\mathrm{SR}} + 164.2 \quad (R^2 = 0.85,\ P < 0.001) \qquad (3)$$

$$\mathrm{SS_{Cl}} = 1.15 \times P_{\mathrm{SR}} + 177.8 \quad (R^2 = 0.42,\ P = 0.044) \qquad (4)$$

If the household size and the septic tank volume are fixed, a shorter septage retention period could provide a

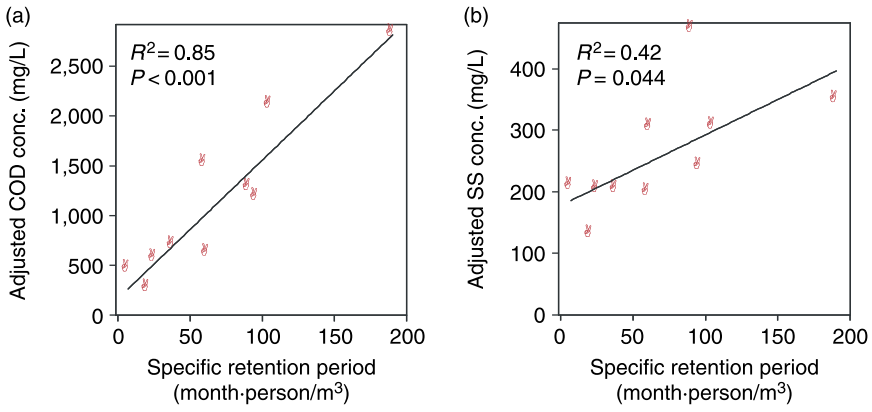

Figure 4 | Adjusted concentrations of pollutants of septic tank effluent samples depending on the specific retention period of septage in each septic tank: (a) for COD; (b) for SS.

superior effluent. It can be calculated from the Equation (3) and (4) that 72.8% of COD loads and 25.8% of SS loads from septic tanks could be eliminated by shortening the non-desludging period from seven years, the median value in urban Hanoi, to one year. Thus, quantitative effects of desludging conditions on effluent qualities can be calculated using this results and the reduction of septage retention period may dramatically reduce the pollution loads from septic tanks, especially in terms of COD.

A proposal for provisional-and-urgent improvement of urban sanitation

Due to the urgency of the sanitary improvement in developing countries, a provisional-and-urgent sanitation measure is required with the effort of sewerage development in the areas having sewerage development plans. The better performance of septic tanks is crucially important since 90.5% of human excreta flowed into septic tanks in the case of urban Hanoi and human excreta are the biggest source of pathogenic microorganisms found in wastewater. At the same time, excreta are main contributors for the pollution in urban water environment. Busser *et al.* (2006) estimated that nearly half of the COD loads of domestic wastewater come from toilet wastes in urban Hanoi; VACNE (2004) reported that domestic wastewater is a key contributor to water contamination and its discharge accounts for 80% of the total wastewater discharge from urban centers in Vietnam.

Even though present septic tank management was in serious conditions, regular and frequent desludging may recover septic tank performance dramatically. This study showed that regular desludging with a frequency of once a year can eliminate 72.8% of COD loads from septic tanks in urban Hanoi. Thus, execution of regular and frequent desludging shall greatly contribute to the betterment of sanitation in urban Hanoi as well as other cities in developing countries.

It should not be disregarded that regular and frequent desludging leads to an increase in the volume of collected septage, which should be treated in an appropriate way. Even if desludging is frequently executed, improper management of septage may deteriorate environmental and sanitary conditions. At present, the septage treatment facility in Hanoi has a limited capacity of 50 m^3/day (Chung & Duc 2005), and cannot handle all amount of collected septage if the regular desludging is executed. Here, we suggest that a sewage sludge treatment facility should be established prior to other facilities of sewerage, and then the facility could be used as the septage treatment facility with sewage sludge, of which the amount will be limited while the sewerage is still under development.

Although the septic tank is not a perfect solution of urban sanitation, improvement of its performance and functionality, which could be done by regular and frequent desludging, shall be a measure for provisional-and-urgent improvement of urban sanitation in developing countries. To implement this measure, public discussion on the appropriate septage management is necessary. In the case of Hanoi, institutional responsibility of septage management is not clear (Chung & Duc 2005). Also, the practice of desludging at a household level requires a proper understanding the residents and social acceptance in terms of cost bearing.

CONCLUSIONS

The septic tank played a major role for human excreta management in urban Hanoi but was in serious conditions. Its performance and functionality was observed to be at a very low level. Our study showed that the performance can be dramatically recovered by regular desludging which may greatly contribute the improvement of urban sanitation in Hanoi. Thus, we propose that performance recovery of septic tanks by regular desludging is a provisional-and-urgent measure for urban sanitation improvement, together with the septage treatment in sewage sludge treatment facilities, which should be established earlier than other facilities of sewage treatment systems.

A viable sanitation solution may consist of not only massive works for the decades-long sewerage development but also the operational improvement of simple existing sanitation facilities such as septic tanks. In order to improve urban sanitation in many developing countries that are using septic tanks but are not yet covered by sewerage networks with treatment facilities, they should focus on improvement of performance and functionality of septic

tanks. We believe that recovery of performance and functionality of septic tanks, namely practice of regular septage removal, could be a realistic solution for the provisional-and-urgent improvement of urban sanitation in developing countries.

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