Estimation of Environmental Load Reduction at Highway Service Areas in Japan by Introducing Low Environmental Load Toilets

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ABSTRACT: In this study, the reduction on the environmental load by the replacement of conventional toilets with low environmental load toilets at highway service areas in Japan was quantified from the perspective of water consumption, energy consumption, cost, and pollution load. Minori Parking in Ibaraki prefecture was selected for the case study. From the result of the estimation, the water use and energy consumption, cost, and pollution load, especially, total nitrogen and phosphorous were expected to be reduced as black water was removed by the waterless urinals and urine-diverting toilets.

1 INTRODUCTION

Japanese highway service areas that have the basic facilities, such as: car parking lots, toilets, and restaurants are required that those be comfortable, clean, safe, and environmental friendly. The Japanese highway management and maintenance company NEXCO owns about 300 of these parking areas, where, on average a total of 50-80 toilets are present. They are considering replacing some of these conventional toilets with low environmental load ones in the near future not only to contribute to ecological conservation but also to save on water usage costs.

Flush toilets have been widely accepted by the public including the highway service because of their comfort and good sanitation. That being said, they have the following drawbacks:

1. They consume a large share of water resources. Water consumed by flush toilets equals between 20 and 25% of domestic water use per person per day.
2. Substances discharged from flush toilets cause the eutrophication of rivers, seas, and lakes. It is said that the 80% of nitrogen and 60% of phosphorus contained in domestic sewage come from flush toilets.

In Japan, toilets of various kinds have been developed during the past 10 years. Most of them were developed after the Great Hanshin Earthquake (the earthquake that occurred in southern Hyogo prefecture in 1995. Its magnitude was 7.2 and 6,434 people died). After this earthquake, the water supply and sewage systems were disrupted and their restoration took a considerable amount of time. One result was that flush toilets were unusable. As a response to this, the newly developed toilets can be used even when the water supply system and sewage system are cut off. They have been used in mountainous areas and parks where the water supply is insufficient and in river basins where there have been rigorous demands placed on the discharge of waste water (Nakagawa, N. *et al.*, 2001).

The aim of this paper is to estimate environmental load reduction effects by introducing low environmental load toilets into Japanese highway service areas for the first time in Japan by selecting the Minori Parking Area for use in this case study

2 MATERIALS AND METHODS

2.1 Low environmental load toilets

Low environmental load toilets to be installed in the highway service area require the following conditions to be fulfilled:

① Having no unpleasant smells
② Comfortable
③ Easy to maintain

Therefore, we considered the following low environmental load toilets as candidates to be installed in the highway service area.

2.1.1 Waterless Urinal

Figure 1 shows a waterless urinal. This urinal requires no water at all. Urine is trapped in the storage area without the smell coming out by an oily liquid with a small relative density. The shape is easy to clean; however, regular maintenance is necessary.

2.1.2 Urine-diverting Toilet

Figure 2 shows a urine-diverting toilet. Urine-diverting toilets were developed and prevail throughout much of northern Europe. They have a special toilet bowl which captures the urine and sends it down a separate pipe into a container where it can be collected and stored for further use. As long as it is not contaminated with feces, it can serve as an excellent fertilizer after a simple dilution treatment.

Figure 1, *Waterless Urinal* (INAX,2009).

Figure 2, Urine-diverting toilet (Wost Man Ecology,2009).

2.1.3 Water Recycling Toilet

Figure 3 shows a water-recycling toilet. Water used to flush excrement from this toilet is treated *in situ* and reused many times. Various methods are used to purify the water, and in many cases, the technology used in septic tanks is employed for this purpose. These mitigate the bad odors and reduce the volume of sludge. In some toilets, the treated water is treated again by sand filtration. This makes the water clear as well as odorless. While evaporation reduces the quantity of water as it is recycled, it is sometimes increased, however, due to the urine. Water that is discharged from the system has a high density of nutrients.

Figure 3, Water-recycling Toilet (Reinforce, 2009).

2.2 Toilets installed in the Minori Parking Area in Ibaraki prefecture

The Minori Parking Area (Figure 4, Figure 5) is located about 100 km northeast of Tokyo, Japan. The toilets installed in the Minori Parking Area are shown in Table 1.The effluent from this parking is treated by the domestic wastewater treatment system (Figure 6). The toilets t are 12 L-type flush toilets with a bidet and a fountain of warm water.

Figure 4, Minori Parking Area in Ibaraki prefecture

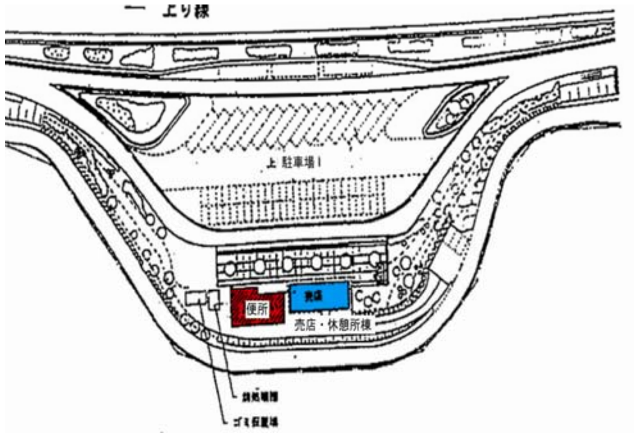

Figure 5, Schematic of Minori Parking Area

Figure 6, Domestic wastewater treatment facility in Minori Parking Area

Figure 7, Restroom for women at Minori Parking Area

2.3 Estimation of environmental load reduction

In order to consider the advantage of introducing the low environmental load toilets, the water consumption, the energy consumption, the cost, and the pollution loads, such as: BOD, COD, T-N, and T-P that occurred when the old-type toilets were replaced with the low environmental load ones, were calculated. In this case, we assumed introducing waterless urinals and the urine-diverting toilets among the low environmental load toilets as written in sections 2.1.1 and 2.1.2.

The basic data required for the calculation were obtained from NEXCO LTD. as shown in Tables 2 and 3. The pollution load rates including the urine and feces excreted by one person per day were calculated from the ratio of feces and urine in the excrement (Lens P. *et al.*, 2001). Also, as for the pollution loads included in the urine and excrements per person per day, (Japan Sewage Works Association Society, 1994) as shown in Table 4, assume intervals of urination of five times and feces excretion once per person per day. Furthermore, the flush volumes of the toilets in the case of introducing waterless toilets and urine-diverting toilets are shown in Table 5. Following this, how the amount of pollution loads would be reduced per year was estimated assuming the ratio of man and woman among users per year is equal and that 9 times out of 10 the toilets are used for the purpose of urination at the Minori Parking Area.

Table 1, Feature of Minori Parking Area

Parking	Large-sized	23		
	Medium-sized	52		
	Total	75		
Facility	Water Supply	Water supply system		
	Wastewater treatment	Domestic wastewater treatment facility		
Toilets	Toilets for men	Urinals		15
		Flush type toilets	Japanese style	3
			Western style	2
			Total	5
	Toilets for women	Small toilets for children		0
		Flush type toilets	Japanese style	11
			Western style	4
			Total	15
	Toilets for handicapped	Flush type toilets		1

Table 2, Data used for calculations.

Number of users (/year)	565,750
Domestic wastewater treatment facility	
Energy consumption (kwh/year)	88,496
Cost of energy consumption (dollar/year)	9,726
Amount of influent (Black water & Gray water)(m^3/year)	16,548
Influent from toilets (m^3/year)	8,316
Influent from toilets for men (m^3/year)	3,983
Influent from toilets for women (m^3/year)	4,333
Water rate (dollar/m^3)	2.4

Table 3, Water quality of influent and effluent.

	Influent	Effluent
BOD (mg/L)	155	0.6
COD (mg/L)	118	4.1
T-N (mg/L)	65	8.1
T-P (mg/L)	12	0.5

Table 4, Pollution load in black water.

	Feces	Urine
BOD (g/use)	14.4	0.7
COD (g/use)	8.0	0.4
T-N (g/use)	0.8	1.6
T-P (g/use)	0.3	0.1

Table 5, Flush volume of the toilets.

	Existing toilets		Low environmental load toilets	
	Feces(L/use)	Urine(L/use)	Feces(L/use)	Urine(L/use)
Men	8	2	2	0
Women	12	12	2	0.2

3 RESULTS AND DISCUSSION

The estimation was performed according to the following two cases.

Case 1. Just waterless urinals for the men's urinals are assumed to be introduced.
Case 2. Waterless urinals and urine-diverting toilets are assumed to be introduced.

In both cases 1 and 2, the black water removed by the low environmental load toilets was assumed to be used effectively as fertilizer. The results of the calculations concerning the domestic wastewater treatment facility are shown in Table 6. The value written in parentheses shows the reduction rate compared to the existing case. The energy consumption, energy consumption costs, and water usage costs were expected to be reduced by the reduction of the influent to the domestic wastewater treatment facility in both of cases 1 and 2. Besides, the pollution load, especially, total nitrogen and phosphorous were expected to be reduced 81.8 % and 69.2 %, respectively in case 2 as shown in Table 6 because the black water was removed by the waterless urinals and urine-diverting toilets.

Table 6, Results of estimation concerning the domestic wastewater facility by assuming the installation of waterless urinals and urine-diverting toilets.

Domestic wastewater treatment facility's	Existing case	Case 1	Case 2
Energy consumption (kwh/year)	88,496	73,363 (-17.1 %)	45,841 (-48.2 %)
Cost of energy consumption (dollar/year)	9,726	8,063 (-17.1 %)	5,038 (-48.2 %)
Amount of influent (Black water & Gray water) (m^3/year)	16,548	13,718 (-17.1 %)	8,572 (-48.2 %)
Water usage cost (dollar/year)	39,779	32,977 (-17.1 %)	20,606 (-48.2 %)
Pollution load to the water environment			
BOD (kg/year)	18.2	17.5 (-3.9 %)	12.6 (-31.0 %)
COD (kg/year)	54.1	52.6 (-2.8 %)	34.1 (-37.0 %)
T-N (kg/year)	84.9	61.6 (-27.4 %)	15.4 (-81.8 %)
T-P (kg/year)	5.6	4.5 (-19.5 %)	1.7 (-69.2 %)

4 CONCLUSIONS

This paper aims to quantify the reduction of environmental load by the replacement of a conventional toilet with the low environmental load toilet at highway service areas from the perspective of water consumption, energy consumption, cost, and pollution load. Minori Parking in Ibaraki prefecture was selected for the case study. From the results of the estimation, the water use and energy consumption, cost, and pollution load, especially, total nitrogen and phosphorous were expected to be reduced, because the black water was removed by the waterless urinals and urine-diverting toilets.

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