COUNTERMEASURES AGAINST ENVIRONMENTAL LOAD AT HIGHWAY SERVICE AREAS IN JAPAN

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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 and a cost-benefit analysis concerning introducing low environmental load toilet such as waterless urinals and urine diversion toilets were performed. Moriya service area which is one of the large–scale service areas and Minori service area which is the middle–scale one were selected for the case study. As for the results, the environmental loads from the service area were reduced by introducing waterless urinals and urine-diverting toilets as urine was removed and water use was reduced. Concerning the cost, reduction of 210.9 and 16.5 thousand dollars, respectively, in Moriya and Minori service area was estimated by reducing the amount of water use. In order to consider the advantage of introducing the low environmental load toilets, a cost-benefit analysis was performed. Consequently, it was demonstrated that the payback period of the low environmental load toilets introduction was 4 and 19 years in case of Moriya and Minori service area respectively. These results of the estimation are valuable for considering the cost of treatment for removed urine in this system. Concerning the treatment for removed urine, so far, utilization as a fertilizer in the rape blossoms field in the vicinity is considered, as little cost and energy as possible, for recycling nutrients back into the environment.

1 INTRODUCTION

The effect of climate change appears mostly through "water" such as rainfall patterns and it has a strong influence on water resources. Therefore the efficient water use has been becoming indispensable even in Japan.

Japanese highway service areas that have the basic facilities, such as: car service 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 service 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 (Nakagawa *et. al.*, 2001):

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.

Therefore the newly low environmental load toilets have been developed toilets instead of the existed toilets. The aim of this paper is that 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 and a cost-benefit analysis concerning introducing low environmental load toilet such as waterless urinals and urine diversion toilets were performed. Moriya service area which is one of the large–scale service areas and Minori service area which is one of the middle–scale one in Ibaraki prefecture was selected for the 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.

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. Figure 2 shows water recycling type urine-diverting toilet newly developed. It is newly developed in 2010 by combining existed urine-diverting toilets and water recycling toilet. The exterior view is same as the existed water recycling toilet (Nakagawa *et. al.*, 2009) but it has newly additional function of the urine diversion. Figure 3 shows the schematic of it. Urine can be trapped under the toilet bowl by a weight and time sensitive switch. The disposed flushing water was reduced up to 0.6 L per use by the sensitive switch made of electromagnet which controls the flushing water for the black water or it for washing the toilet bowl. The 2.2 L of the flushing water for the toilet bowl isn't mixed with the black water and recycled many times. The captured urine is sent 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. Water recycling urine-diverting toilet (Reinforce,2010)

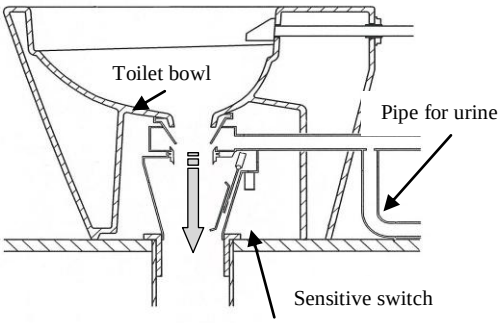

Figure 3. Schematic of water recycling urine-diverting toilet (Reinforce,2010).

Figure 4. Minori Service Area in Ibaraki prefecture

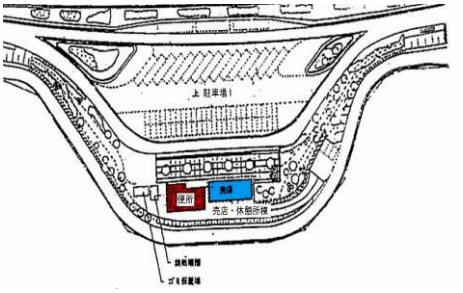

Figure 5. Schematic of Minori Service Area

Figure 6. Domestic wastewater treatment facility in Minori Service Area

Figure 7. Restroom for women at Minori Service Area.

Figure 8. Moriya Service Area in Ibaraki prefecture.

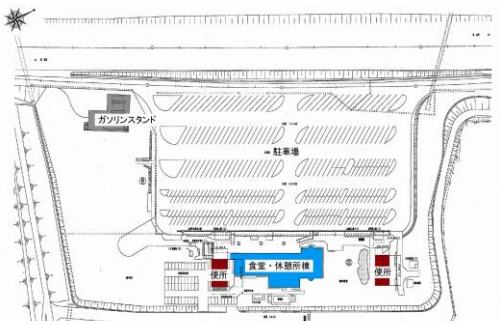

Figure 9. Schematic of Moriya Service Area.

Figure 10. Restroom for woman at Minori Service Area.

2.2 The Minori and Moriya Service Area in Ibaraki prefecture

Table 1. Feature of Minori and Moriya Service Area

Case Study			Moriya SA	Minori SA
Size of service area			Large	Medium
Wastewater treatment			Sewage	*DWTF
Number of Users		/ Year	8,080,000	560,000
	Men	/ Year	4,202,000	351,000
	Women	/ Year	3,878,000	214,000
Number of Toilets	For Men		*U 64/ R 28	U 30/ R 10
	For Women		For kids 5/ R 80	For kids 0/ R 30
	For Handicapped		2	2
Amount of Water Use	Total Amount	m^3/Year	132,670	16,138
	Total Cost	Dollar/Year	320,200	37,200
	For toilets	m^3/Year	70,794	7,063
	Cost for toilets	Dollar/Year	170,862	16,281
	Ratio of toilet water use for entire facility	%	**53.4%**	**43.8%**
Amount of Effluent		m^3/Year	134,249	16,548
Cost for sewage system		Dollar/Year	219,800	--
Electricity	Total	kWh/Year	3,250,368	233,681
	Total Cost	Dollar/Year	426,900	35,200
	For water treatment	kWh/Year	39,192	93,641
	Cost for water treatment	Dollar/Year	5,200	14,100
	Ratio of water treatment for entire facility	%	**1.2%**	**40.1%**

* DWTF : Domestic Wastewater Treatment Facility

*U 64/ R 28 : Number of Urinals is 64,Number of Regular Toilets is 28.

The Minori service area (Figure 4, Figure 5) is located about 100 km northeast of Tokyo, Japan and one of the middle–scale service areas. The feature of the Minori service area and Moriya service area are shown in Table 1. The effluent from this service is treated by the domestic wastewater treatment system (Figure 6). Figure 7 shows the restroom for woman at the Minori Service Area. The toilets are 10 L-type flush toilets with a bidet and a fountain of warm water. The Moriya service area (Figure 8, Figure 9) is located about 30 km northeast of Tokyo, Japan and one of the large–scale service areas. The effluent from this service is treated by the sewage treatment system. Figure 10 shows the restroom at the Moriya Service Area. The toilets are 8 L-type flush toilets with a bidet and a fountain of warm water. The feature of the Moriya service area is also shown in Table 1.

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, and the cost that occurred when the old-type toilets were replaced with the low environmental load ones, were calculated. In this case, we assumed replacing all old-type toilets with the waterless urinals and the water recycling urine-diverting toilets newly developed as written in sections 2.1. The basic data required for the calculation were obtained from NEXCO LTD, INAX LTD, and Reinforce LTD as shown in Tables 1. The flush volumes of the toilets in the case of introducing waterless toilets and urine-diverting toilets are shown in Table 2.

Table 2. Flush volume of the toilets

	Existing toilets				Low environmental load toilets	
	Minori PA		Moriya SA			
L/flush	Men	Women	Men	Women	Men	Women
For feces	10	10	8	8	0.6	0.6
For Urine	6		4		0	

3 RESULTS AND DISCUSSION

In both Minori and Moriya cases, the black water removed by the low environmental load toilets was assumed to be used effectively as fertilizer. The results of the estimation concerning the environmental loads by assuming the installation of waterless urinals and water recycling urine-diverting toilets are shown in Table 3. The amount of water use was reduced 30-40 % by introducing low environmental load toilets with low flush. Especially the reduction of water consumption is significant in the Moriya service area which is large-scale service area. Besides the influent to the sewage pipe and domestic wastewater facility is reduced by reduction of flush water volume, and along with it, the sewage cost and the cost of electricity concerning the domestic water treatment facility are also reduced in Moriya and Minori service area respectively. Concerning the energy consumption, in Moriya service area, it was increased because of the electric power to make the flushing water circulate and introducing many water recycling urine-diversion toilets. Considering the reduction of sewage cost mentioned above, the reduction of 210.9 thousand dollar per year was estimated in Moriya service area. Regarding Minori service area, reduction of 16.5 thousand dollar was estimated by reducing the energy consumption at the domestic wastewater treatment in spite of increasing the electricity concerning the water recycling urine-diversion toilets.

In order to consider the advantage of introducing the low environmental load toilets, a cost-benefit analysis was performed. In this analysis, all conventional toilets in the Moriya and Minori service area were assumed to be replaced with the waterless urinals and urine diversion toilets and the payback period was calculated. In other words, the required period for the cost generated by the introduction of those of low environmental load toilets to be paid back, by reduction of water and energy consumption, was calculated in cost aspect. Table 4 shows the cost for introducing the low environmental load toilets and cartridges which is part of the waterless urinals. These data are got from INAX LTD, Reinforce LTD.

Consequently, it was demonstrated that the payback period of the low environmental load toilets introduction was 4 and 19 years in case of Moriya and Minori service area respectively, in the cost aspect. This result of the estimation is valuable for considering the cost of treatment for removed urine in this system. Concerning the treatment for removed urine, so far, using it as a fertilizer in the rape

blossoms field in the vicinity is considered, without neither the cost nor energy as possible, for recycling nutrients back into the environment.

Table 3. Results of estimation assuming the installation of waterless urinals and urine-diverting toilets

Case Study			Moriya SA	Minori SA
Amount of Water Use	Total amount (m^3/Year)	After introducing	81,186	11,482
		Amount of reduction	51,484	4,656
	Total cost (dollar/Year)	After introducing	201,300	26,444
		Amount of reduction	**118,900**	**10,756**
	For toilets (m^3/Year)	After introducing	19,310	2,407
	Reduction rate for toilet use (for total amount)		39% (27%)	34 % (29%)
Waste water treatment	Amount of removed urine (m^3/Year)		1,616	112
	Amount of wastewater (m3/Year)	After introducing	81,149	11,780
		Amount of reduction	53,100	4,768
	Cost for sewage system (Dollar/Year)	After introducing	131,900	--
		Amount of reduction	**87,900**	--
	Reduction rate of wastewater		40 %	29 %
Electricity	Total amount (kWh/Year)	After introducing	3,219,780	195,448
		Amount of reduction	30,588	38,233
	Total cost (dollar/Year)	After introducing	4,229	294
		Amount of reduction	**40**	**58**
	For water treatment (dollar/Year)	After introducing	8,606	88,027
		Amount of reduction	30,588	25,614
	Reduction rate for total amount		1 %	16 %

Table 4. Cost for introducing the low environmental toilets

Case Study		Moriya SA	Minori SA
Cost for introducing the low environmental toilets (dollar/Year)	Waterless Urinals	207,200 (64 units)	97,300 (30 units)
	Water recycling urine-diversion toilets	432,000 (108 units)	160,000 (40 units)
	Total	**639,200**	**257,300**
Cost of cartridge for waterless urinals (dollar/Year)		**31,200**	**2,600**
Amount of cost reduction by introducing the low environmental toilets (dollar/Year)		**210,900**	**16,500**

4 CONCLUSIONS

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 and a cost-benefit analysis concerning introducing low environmental load toilet such as waterless urinals and urine diversion toilets were performed. Moriya service area which is one of the large–scale service areas and Minori service area which is the middle–scale one were selected for the case study. As for the results, the environmental loads from the service area were reduced by introducing waterless urinals and urine-diverting toilets as urine was removed and water use was reduced. Concerning the cost, reduction of 210.9 and 16.5 thousand dollars, respectively, in Moriya and Minori service area was estimated by reducing the amount of water use. In addition, it was demonstrated that the payback period of the low environmental load toilets introduction was 4 and 19 years in case of Moriya and Minori service area respectively.

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