

Present State of the Treated Wastewater Reuse in Japan

日本における下水処理水再利用の現状

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PRESENT STATE OF THE TREATED WASTEWATER REUSE IN JAPAN

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BACKGROUND

Japan's average annual rainfall is approximately 1,700mm that is twice the world average, but because its national land is small and its population is large, the total annual per capita rainfall is about 5,100m³ that is about 1/4 the world average and much smaller than in many foreign countries.

Japan reacted to the severe water shortage of 1978 by beginning to reuse treated wastewater to conserve valuable water resources in cities. Since the first reuse of treated wastewater as toilet flushing water in Fukuoka City in 1980, treated wastewater has been used as toilet flushing water, snow melting water, environmental water, industrial water, and spraying water. It is predicted that such uses will be more important in the future, and that this will increase the importance of appropriately reusing treated wastewater.

Some water quality criteria for reclaimed wastewater were proposed (Table 1). In order to renew and authorize them, we are now studying technological standards for the reuse of treated wastewater from the viewpoints that its use not harms hygienic safety, scenic environment, and functions of facilities.

Table 1. Proposed water quality criteria for reclaimed wastewater

	Japan Sewage Works Association (proposed in 1981)			Working group composed of Ministry of Construction and some big cities (proposed in 1990)	
	Toilet flushing use	Spraying use	Landscape use	Landscape use**	Recreational use***
Coliform group	10 or below (cfu/mL)	Not detective	Not detective	1,000 or below (cfu/100mL)	50 or below (cfu/100mL)
Chlorine Residual (mg/L)*	Trace amount	0.4 or over	-	-	-
Appearance	Not unpleasant	Not unpleasant	Not unpleasant	-	-
Color (color unit)	-	-	-	40 or below	10 or below
Turbidity (mg-kaolin equivalent/L)	-	-	10 or below	10 or below	5 or below
Odor	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
pH	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6
BOD (mg/L)	-	-	10 or below	10 or below	3 or below

Note : * combined residual chlorine, ** restricted human contact, *** limited human contact

This report outlines the present state of the reuse of treated wastewater in Japan from fiscal 2001 to fiscal 2002, and introduces the results of a questionnaire survey of treated wastewater users' awareness of the appearance of reused water that was necessary for a study of standards to maintain scenic environment.

PRESENT STATE OF THE REUSE OF TREATED WASTEWATER (fiscal 2001)

In fiscal 2001, a total of approximately 200 million m³ of treated wastewater were reused outside of sewerage treatment plants. This volume represented about 1.5% of the total treated wastewater that is approximately 13.0 billion m³/year. Treated wastewater from 216 treatment plants is reused at a total of 316 locations.

Figure 1 shows the numbers of locations outside of treatment plants where treated wastewater is used by purpose of use. The commonest purpose of use, at approximately 33% of all the locations, is spraying zones of trees and road surfaces. This is followed by environmental water (water for landscape use (water reused as amenity water not premised on direct contact by people with the water), water for recreational use (water reused as amenity water premised on direct contact by people with the water), and river maintenance water), that accounts for 30% of all locations reusing treated wastewater. Two thirds of all locations that reuse treated wastewater use it for one of these two purposes.

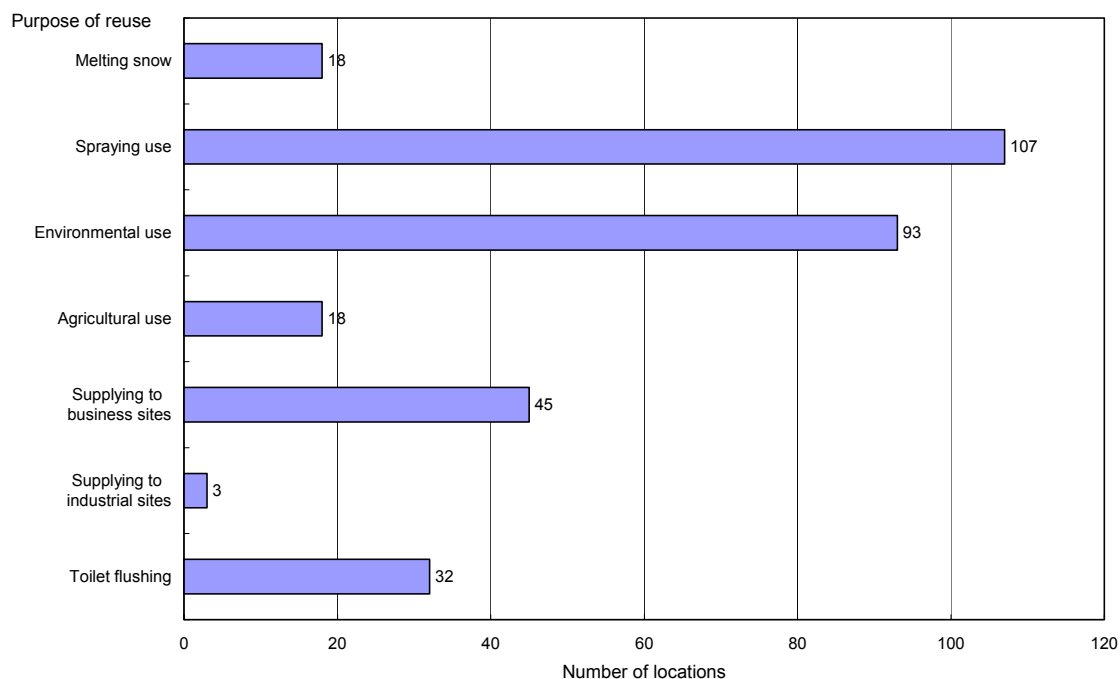


Figure 1. Number of locations using treated wastewater outside treatment plants
(fiscal 2001)

Figure 2 shows the annual volume reused by purpose of use, and Figure 3 shows the percentages of all reused treated water by purpose of use. Environmental water use is overwhelmingly high at 63% of all reused treated wastewater. And from Figure 1 and Figure 2, it appears the volume used to spray zones of trees and road surfaces per location is extremely low.

Figure 4 shows change over the years of the volume used by purpose of use until fiscal 2001, indicating that the volume used as environmental water has continued to be far higher than that used for other purposes. The volume used to melt snow has also continued to rise, making snow melting the second most important use. But the volumes supplied for industrial use and for agricultural use are both declining.

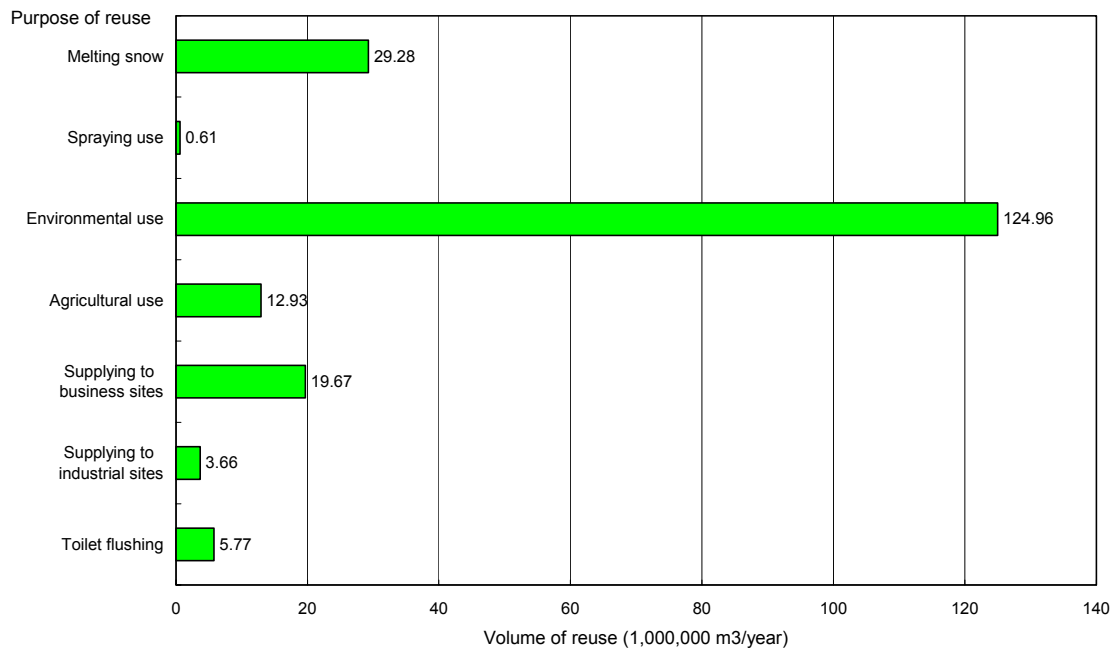


Figure 2. Volume of reused treated wastewater that were used outside treatment plants (fiscal 2001)

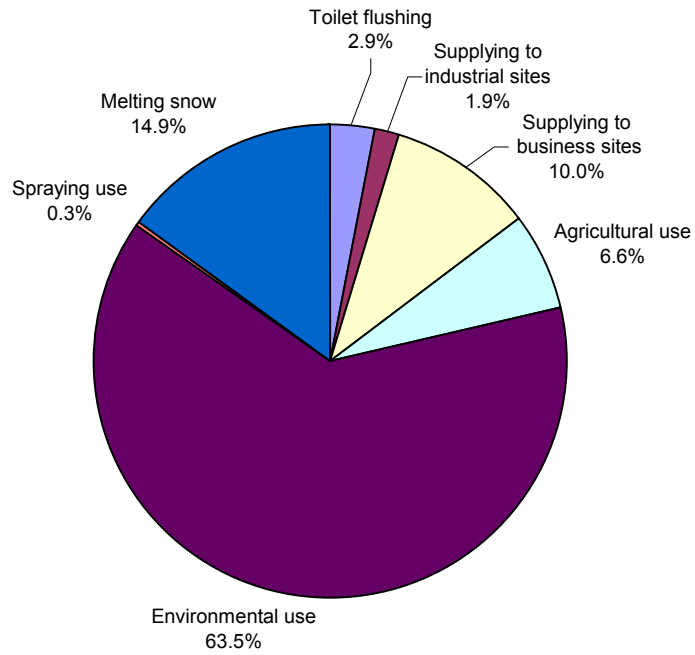


Figure 3. Percentage of volume of reused treated wastewater that were used outside treatment plants by purpose of use (fiscal 2001)

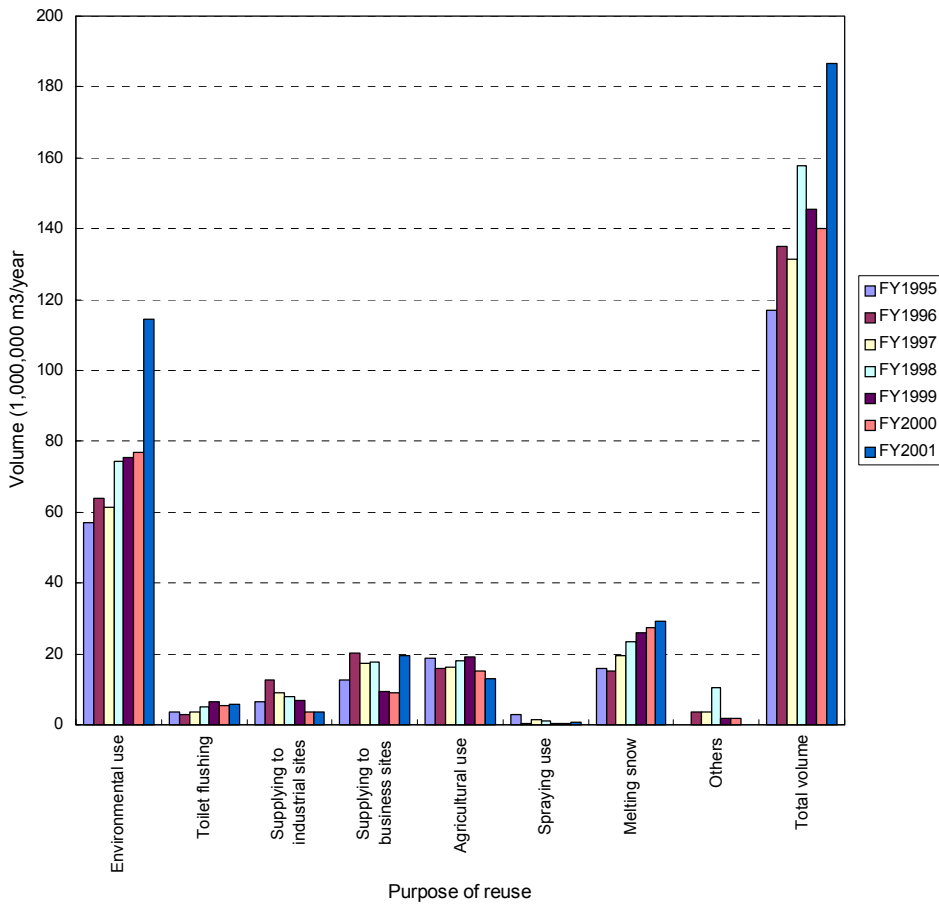


Figure 4. Volume of reused treated wastewater

PRESENT STATE OF TREATED WASTEWATER REUSE (fiscal 2002)

Objective of the survey

Of the various ways that treated wastewater is reused, those surveyed by the fact-finding survey of fiscal 2002 were limited to toilet flushing use, spraying use, and environmental use: uses that could cause people to directly contact the reclaimed wastewater. Among environmental water uses, landscape use and recreational use were surveyed.

Number of locations

Treated wastewater from a total of 141 treatment plants was reused as toilet flushing water, spraying water, water for landscape use, and water for recreational use at 206 locations. Figure 5 shows the number of locations reusing reclaimed wastewater by purpose of use, revealing that more locations use it as spraying water and water for landscape use than for other purposes.

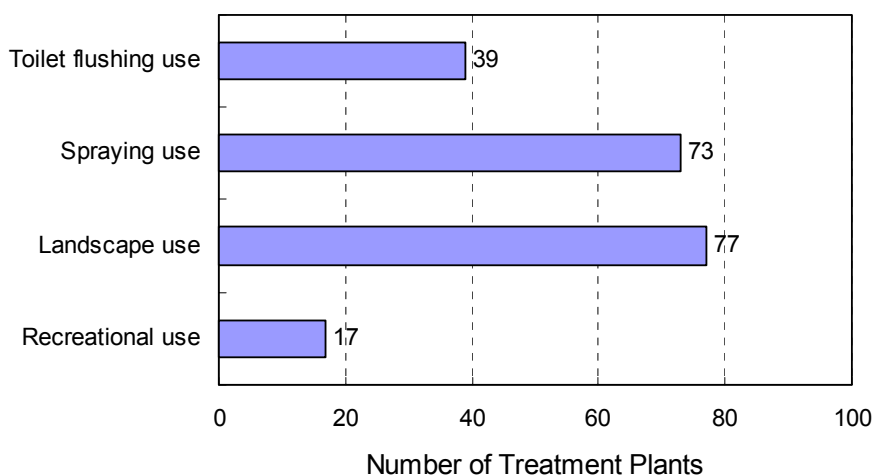


Figure 5. Number of locations of wastewater reuse by purpose of use (fiscal 2002)

Categories of users

Table 2 shows the users of toilet flushing water, revealing that most of it is used by public facilities. It appears that this difference is a result of the greater willingness of managers of public facilities to agree to the reuse of treated wastewater than managers of private facilities.

User type	Number of treatment plants
Home	4
Business building	10
Public facilities	35

As shown by Table 3, the most numerous users of spraying water spray it on trees, followed by those who spray it on road surfaces and lawns. The specific spraying methods they use are spraying trucks, sprinklers, nozzle equipped hydrants, and hoses etc. and include both manned spraying and unmanned spraying.

Table 3. Users of spraying use water (fiscal 2002)

User type	Number of treatment plants
Sports field	2
Tree zones	44
Lawns	17
Road surfaces	20

As shown by Table 4, the users of landscape use water and recreational use water use it to fill ponds and streams, create waterfalls, and supply fountains. There is a growing demand among the Japanese public for the creation of good quality waterside spaces in cities, and according to Figure 4, reuse for both landscape use and recreational use are expected to continue to grow.

Table 4. Users of landscape use water and recreational use water (fiscal 2002)

User type	Typological Characteristics	Number of treatment plants	
		Landscape use	Recreational use
Ponds	Storage	37	7
Streams	Flow	47	13
Waterfalls	Falling from above	36*	16**
Fountains	Spraying upwards	14*	5**

*: Total number within ponds and streams that reclaimed water for landscape use are supplied.

** : Total number within ponds and streams that reclaimed water for recreational use are supplied.

Treatment and disinfection methods

Figure 6 shows the rate of application of each unit process in the reuse treatment as a percentage of the total reuse treatment flow by purpose of use. Overall trends it reveals include the application of sand filtering as a reuse treatment method and the use of chlorination as a disinfection method at many locations.

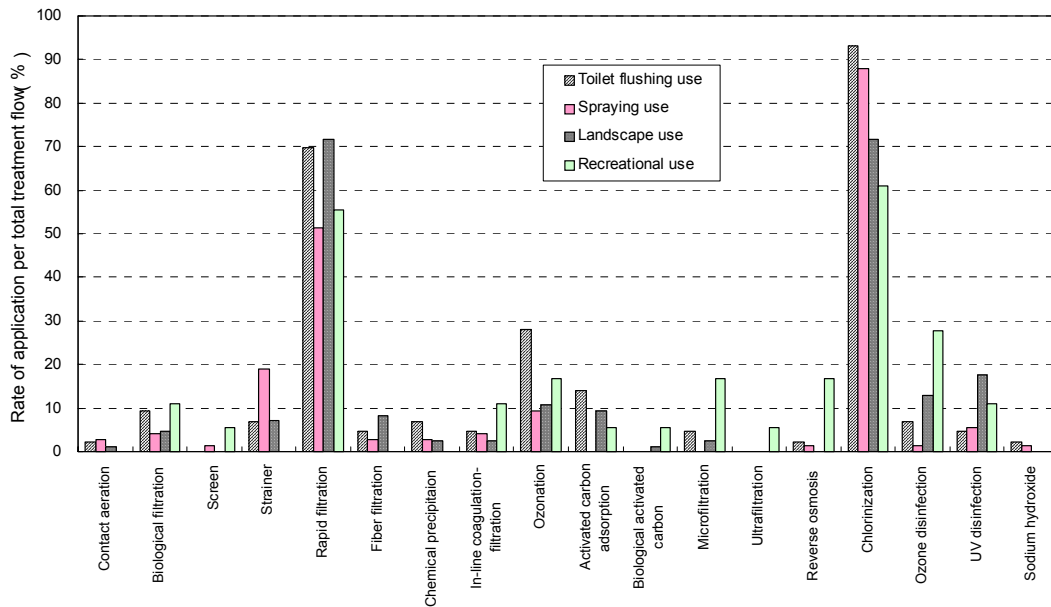


Figure 6. Categorization of treatment methods by purpose of use (fiscal 2002)

Characteristics by purpose of use show that water to be reused as spraying water is treated by simpler processes than that reused for other purposes, and that in many cases, only chlorination or a combination of chlorination and sand filtering is applied.

Water for landscape use is disinfected by ozone disinfection and ultraviolet disinfection more frequently than treated wastewater reused for other purposes. This indicates that at many locations, users replace chlorination with another disinfection method to prevent harm to the ecosystem.

Complaints and problems about reuse

Table 5 shows the state of complaints or environmental damage caused by the reuse of treated wastewater up to fiscal 2002 by numbers of treatment plants. It shows that a particularly large number of cases of environmental damage and complaints were caused by its use as toilet flushing water. But it may be that this high frequency of complaints and environmental damage is linked to the fact that more locations use treated waster as toilet flushing water than for other purposes, so that complaints and environmental damage are more conspicuous.

Characteristically, toilet flushing water results in more complaints about or environmental damage by chironomid or corrosion than other uses. It is assumed that chironomid are a problem also caused by other uses, but these rarely cause complaints or reports of environmental damage because the water is reused in open spaces where it does not bother the users. And corrosion is more likely to occur because both the distribution and supply channels that bring the water to its users are longer and include more supply devices than in the case of other uses. Frequent environmental damage also occurs because the many supply devices equipped with strainers increases the danger that corrosion will plug the devices.

Reuse as spraying water does not cause any particular serious complaints or environmental damage, mainly because there is little possibility of the users seeing the sprayed water. A characteristic of its use as scenic conservation water and human access water is that these uses cause many more complaints about the propagation of algae than other uses.

Table 5. State of complaints and environmental damage caused by use of treated wastewater (unit: treatment plants)

Type and Description	Toilet flushing	Spraying use	Landscape use	Recreational use	Total
Aesthetic elements					
Color	4			1	5
Turbidity	3			1	4
Odor	2		1		3
Dirt					
Adhering material	3				3
Algae			3	5	8
Chironomid	5		1		6
Harm to facility functions					
Corrosion	2	1	1		4
Plugging					
Corrosion	2		1		3
Living materials	2	1			3
Total occurrence	23	2	7	7	39

In cases where different kinds of environmental damage occurs or water is used for different purposes at one plant, totals are categorized accordingly.

State of measures to prevent accidental contact between reused treated wastewater pipes and water supply pipes

Figure 7 shows the rate of implementation of measures to prevent accidental contact between reclaimed wastewater pipes and water supply pipes (percentage of treatment plants that reuse treated wastewater whose operators responded that they had implemented countermeasures) by purpose of use. It reveals that as an overall trend, measures that are widely implemented include labeling water tanks, pipes, and other devices as parts of a treated wastewater system, and at locations where the treated wastewater is reused, clearly indicating that it is treated wastewater. The rate of implementation of all measures tended to be higher where it is used as toilet flushing water than where it is used for other purposes.

Notification of managers of underground structures when installing reclaimed wastewater pipes underneath public roads is done most frequently at locations where it is used as toilet flushing water. This is done because when used as spraying water, water supply methods not using pipes (spraying by a spraying truck for example) are often applied, and when it is reused as landscape and recreation water, the users are usually directly linked to the wastewater treatment plant supplying the water.

State of measures to prevent accidental drinking of treated wastewater

Figure 8 shows the rate of implementation of measures to prevent accidental drinking of reclaimed wastewater by purpose of use. As an overall trend, the most frequent measure

is indicating that it is reused water, and in particular, it is done at nearly 80% of locations where it is used as toilet flushing water. And at nearly 40% of locations where it is reused as toilet flushing water, low flush toilet tanks equipped with a hand washing function are prohibited.

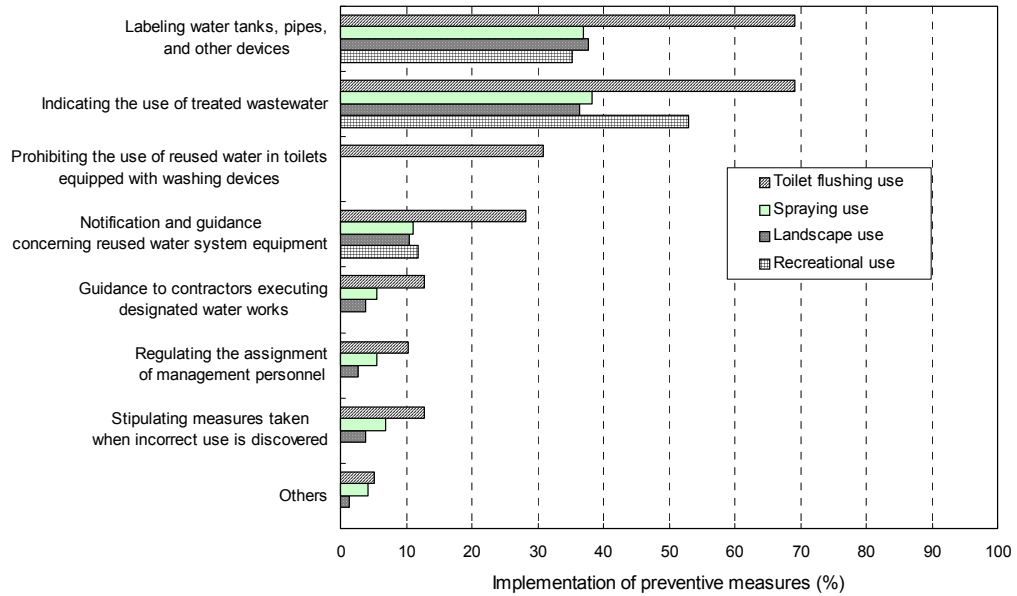


Figure 7. Rate of implementation of measures to prevent accidental contact between reclaimed wastewater pipes and water supply pipes by purpose of use (fiscal 2002)

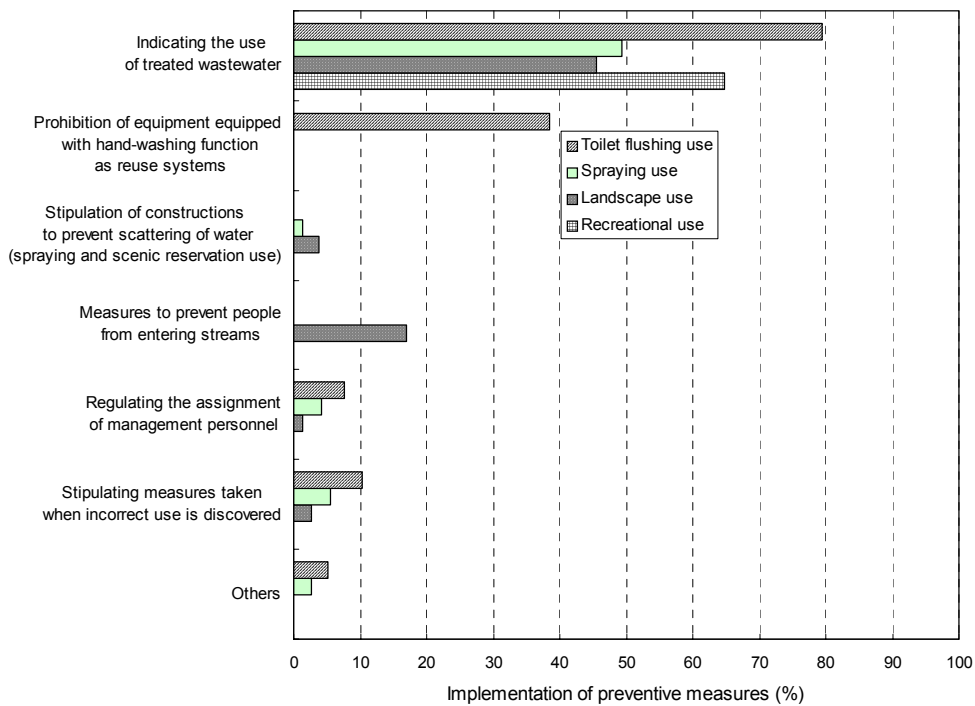


Figure 8. Rate of application of measures to prevent environmental damage such as the illness caused by accidentally drinking reclaimed wastewater

Landscape use is an amenity reuse of water premised on no direct contact with the water by people, but only about 17% of treatment facilities prohibit people from entering streams, and less than 50% of treatment facilities post signs indicating that it is reused water, suggesting that people may directly contact water for landscape use.

USER AWARENESS OF THE EXTERNAL APPEARANCE OF REUSED WATER

It is important to clarify users' preferences concerning external appearance when setting standards for the appearance of reused water. To assess how the color, turbidity, and strength of the odor of reused water will effect the tastes of users, a questionnaire survey of users' consciousness of the color, turbidity, and odor of reused water was performed in the survey range shown in Table 5 at facilities reusing treated wastewater in the prefectures of Saitama, Tokyo, and Osaka, and in the cities of Kobe, and Fukuoka.

Table 5. Background of this users' awareness survey

	Toilet flushing	Landscape use /Recreational use
Number of locations surveyed	5 locations	5 locations
Period of survey	Dec. 2003 to Feb. 2004	Dec. 2003 to Jan. 2004
Questionnaire method	Interviewing and by mail	Interviewing and by mail
Number of respondents	949 (41 to 341 per location)	954 (115 to 239 per location)

Figures 9 to 11 shows the relationships between color unit, turbidity, and odor of reused water obtained from the results of the questionnaire survey with the acceptance of users for color, turbidity, and odor (percentage of people who replied that it did not bother them).

Although at all surveyed locations, the color unit was less than 10 and was only slightly scattered, there was a little correlation between the color unit and acceptance in landscape and recreational uses. Because acceptance tends to be higher in toilet flushing water cases than in water for landscape and recreational uses cases, no differences between acceptances appeared within the range of color unit at surveyed locations.

At all surveyed locations, turbidity was 1 or less and displayed extremely small variance, failing to reveal any relationship of turbidity with acceptance.

The odor is scattered between survey locations, but no particular relationship with acceptance can be observed. Reasons for this result are presumed to be the fact that according to the location, there may be variations in the distance between the users and the reused water, and that the water temperature was low when the survey was performed, restricting the production of volatile substances that are the primary cause of odors, so a similar survey must be performed to confirm that there is no relationship when a survey is performed in the summer.

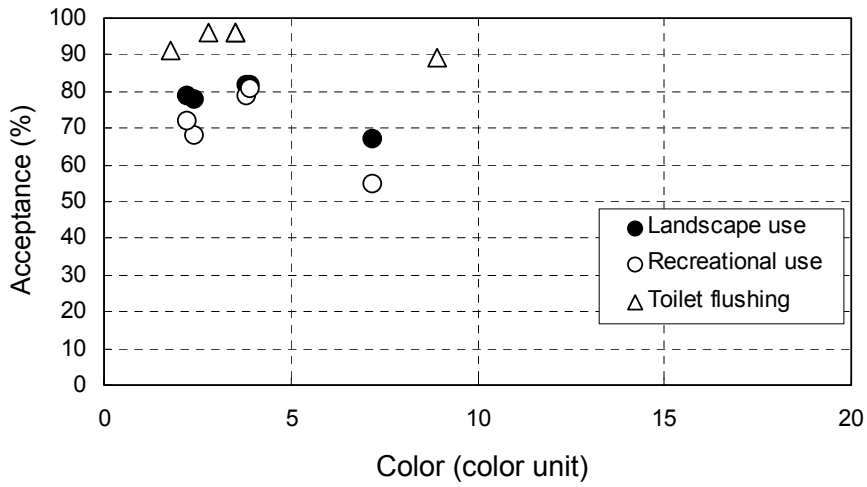


Figure 9. Relationship of color unit with users' acceptance

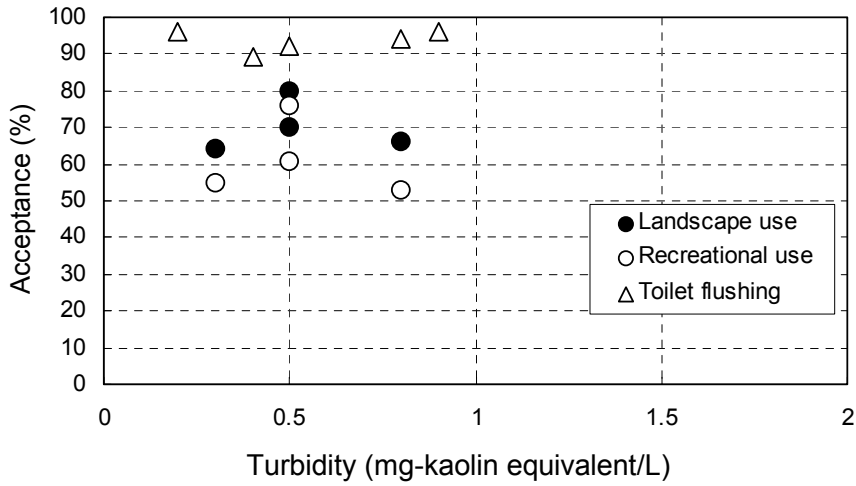


Figure 10. Relationship of turbidity with users' acceptance

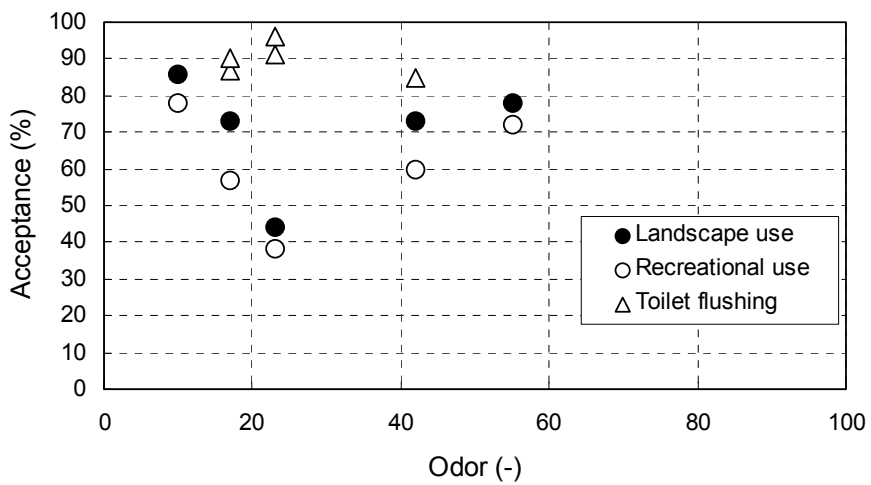


Figure 11. Relationship of odor with users' acceptance

CONCLUSION

A study of technological standards for reused treated wastewater will be conducted based on the present state of the reuse of treated wastewater and the results of the awareness of users of the external appearance of reused water that are described above.

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PRESENT STATE OF THE TREATED WASTEWATER REUSE IN JAPAN

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Background

Average annual rainfall in Japan
1,700 mm/y = 5,100 m³/y/person

↓

Twice the world average

↓

1 / 4 the world average

Toilet flushing use

Fukuoka city

Environmental use

Osaka prefecture

Proposed water quality criteria for reclaimed wastewater

	Japan Sewage Works Association (proposed in 1981)			Working group composed of Ministry of Construction and some big cities (proposed in 1990)	
	Toilet flushing use	Spraying use	Landscape use	Landscape use**	Recreational use***
Coliform group	10 or below (cfu/mL)	Not detective	Not detective	1,000 or below (cfu/100mL)	50 or below (cfu/100mL)
Chlorine Residual (mg/L)*	Trace amount	0.4 or over	-	-	-
Appearance	Not unpleasant	Not unpleasant	Not unpleasant	-	-
Color (color unit)	-	-	-	40 or below	10 or below
Turbidity (mg-kaolin equivalent/L)	-	-	10 or below	10 or below	5 or below
Odor	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
pH	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6
BOD (mg/L)	-	-	10 or below	10 or below	3 or below

Note : * combined residual chlorine, ** restricted human contact, *** limited human contact.

Outline

- Present state of the reuse of treated wastewater in Japan
- Users' awareness of the appearance of reclaimed wastewater

Outline

- Present state of the reuse of treated wastewater in Japan
- Users' awareness of the appearance of reclaimed wastewater

Present state of the reuse of treated wastewater in Japan

Reused outside of treatment plants:
200 million m³
= 1.5% of the total treated wastewater

216 treatment plants (316 locations)

How were they used ?

- Toilet flushing
- Spraying
- Industry
- Agriculture
- Environmental
(landscape, recreational, river maintenance)
-

9

Number of locations

Purpose of reuse	Number of locations
Melting snow	19
Spraying use	107
Environmental use	93
Agricultural use	73
Supplying to business sites	45
Supplying to industrial sites	3
Toilet flushing	32

10

Volume of reclaimed wastewater

Purpose of reuse	Volume of reuse (1,000,000 m ³ /year)
Melting snow	29.28
Spraying use	3.61
Environmental use	124.98
Agricultural use	12.92
Supplying to business sites	10.87
Supplying to industrial sites	3.66
Toilet flushing	5.77

11

Percentage of volume of reclaimed wastewater

Purpose of reuse	Percentage
Environmental use	63.5%
Melting snow	14.9%
Spraying use	0.3%
Toilet flushing	2.9%
Supplying to industrial sites	1.9%
Supplying to business sites	10.0%
Agricultural use	6.6%

12

Volume of reclaimed wastewater

13

How were they used ?

- Number of locations:
Spraying use, Environmental use
- Volume:
Environmental use
- Increasing:
Environmental use, Snow melting use

14

Further survey

- Toilet flushing use
- Spraying use
- Environmental use
(landscape, recreational)

141 treatment plants (206 locations)

15

Number of treatment plants by purpose of use

Purpose of use	Number of Treatment Plants
Toilet flushing use	39
Spraying use	73
Landscape use	77
Recreational use	17

16

Where were they used ?

- Toilet flushing use
- Spraying use
- Landscape use
- Recreational use

17

Users of toilet flushing use

User type	Number of treatment plants
Home	4
Business building	10
Public facilities	35

18

Users of spraying use water

User type	Number of treatment plants
Sports field	2
Tree zones	44
Lawns	17
Road surfaces	20

19

Users of landscape use water and recreational use water

User type	Typological Characteristics	Number of treatment plants	
		Landscape use	Recreational use
Ponds	Storage	37	7
Streams	Flow	47	13
Waterfalls	Falling from above	36*	16**
Fountains	Spraying upwards	14*	5**

*: Total number within ponds and streams that reclaimed water for landscape use are supplied.
 **: Total number within ponds and streams that reclaimed water for recreational use are supplied.

20

Where were they used ?

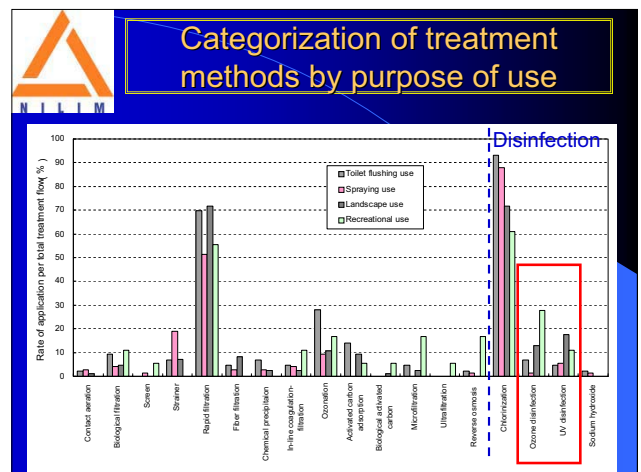
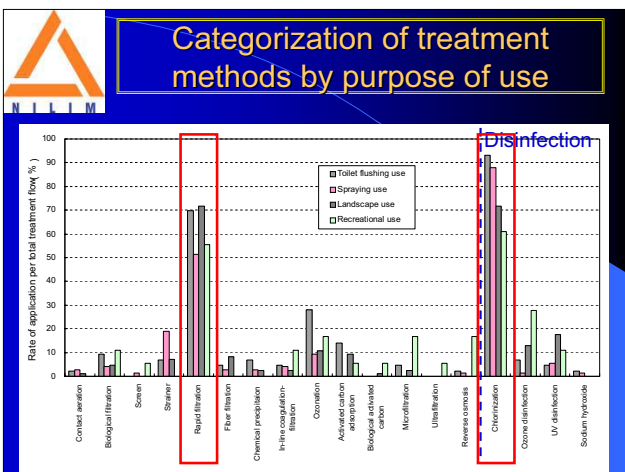
- Toilet flushing use: Public facilities
- Spraying use: Tree zones
- Landscape use: Streams and ponds
- Recreational use: Streams

21

How to make them ?

- Toilet flushing use
- Spraying use
- Landscape use
- Recreational use

22



How to make them ?

Basic: Sand filtration
Chlorination (Sodium hypochlorite)

- Landscape use: Ozonation, UV
- Recreational use: Ozonation

25

Were there any problems ?

- Toilet flushing use
- Spraying use
- Landscape use
- Recreational use

26

Complaints or troubles

Type and Description	Toilet flushing	Spraying use	Landscape use	Recreational use	Total
Aesthetic elements					
Color	4			1	5
Turbidity	3			1	4
Odor	2		1		3
Dirt					
Adhering material	3				3
Algae			3	5	8
Chironomid	5		1		6
Harm to facility functions					
Corrosion	2	1	1		4
Plugging					
Corrosion	2		1		3
Living materials	2	1			3
Total occurrence	23	2	7	7	39

In cases where different kinds of environmental damage occurs or water is used for different purposes at one plant, totals are categorized accordingly.

27

Complaints or troubles

Type and Description	Toilet flushing	Spraying use	Landscape use	Recreational use	Total
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Color	4			1	5
Turbidity	3			1	4
Odor	2		1		3
Dirt					
Adhering material	3				3
Algae			3	5	8
Chironomid	5		1		6
Harm to facility functions					
Corrosion	2	1	1		4
Plugging					
Corrosion	2		1		3
Living materials	2	1			3
Total occurrence	23	2	7	7	39

In cases where different kinds of environmental damage occurs or water is used for different purposes at one plant, totals are categorized accordingly.

28

Complaints or troubles

Type and Description	Toilet flushing	Spraying use	Landscape use	Recreational use	Total
Aesthetic elements					
Color	4			1	5
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Odor	2		1		3
Dirt					
Adhering material	3		3	5	3
Algae			3	5	8
Chironomid	5		1		6
Harm to facility functions					
Corrosion	2	1	1		4
Plugging					
Corrosion	2		1		3
Living materials	2	1			3
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In cases where different kinds of environmental damage occurs or water is used for different purposes at one plant, totals are categorized accordingly.

29

Measures to prevent accidental connection to tap water

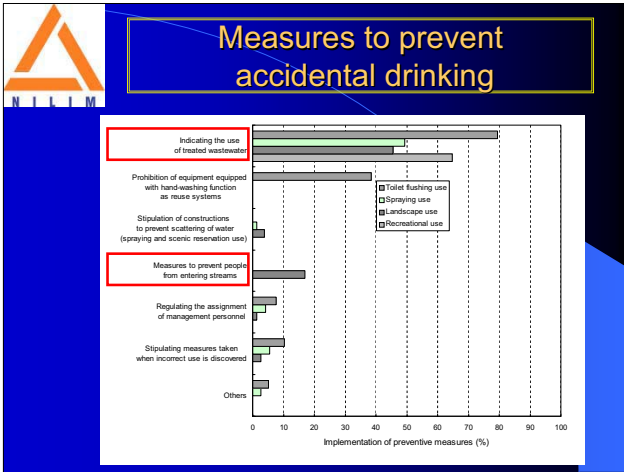
Measure	Toilet flushing use	Spraying use	Landscape use	Recreational use
Labeling water tanks, pipes, and other devices	~70	~35	~35	~35
Indicating the use of treated wastewater	~70	~35	~35	~35
Prohibiting the use of reused water in toilets equipped with washing devices	~70	~35	~35	~35
Notification and guidance concerning reused water system equipment	~15	~15	~15	~15
Guidance to contractors executing designated water works	~15	~15	~15	~15
Regulating the assignment of management personnel	~15	~15	~15	~15
Stipulating measures taken when incorrect use is discovered	~15	~15	~15	~15
Others	~5	~5	~5	~5

Measures to prevent accidental drinking

Measure	Toilet flushing use	Spraying use	Landscape use	Recreational use
Labeling water tanks, pipes, and other devices	~70	~35	~35	~35
Indicating the use of treated wastewater	~70	~35	~35	~35
Prohibiting the use of reused water in toilets equipped with washing devices	~70	~35	~35	~35
Notification and guidance concerning reused water system equipment	~15	~15	~15	~15
Guidance to contractors executing designated water works	~15	~15	~15	~15
Regulating the assignment of management personnel	~15	~15	~15	~15
Stipulating measures taken when incorrect use is discovered	~15	~15	~15	~15
Others	~5	~5	~5	~5

Measures to prevent accidental drinking

Measure	Toilet flushing use	Spraying use	Landscape use	Recreational use
Indicating the use of treated wastewater	~70	~35	~35	~35
Prohibition of equipment equipped with hand-washing function as reuse systems	~70	~35	~35	~35
Stipulation of constructions to prevent scattering of water (spraying and scenic restoration use)	~15	~15	~15	~15
Measures to prevent people from entering streams	~15	~15	~15	~15
Regulating the assignment of management personnel	~15	~15	~15	~15
Stipulating measures taken when incorrect use is discovered	~15	~15	~15	~15
Others	~5	~5	~5	~5



Were there any problems ?

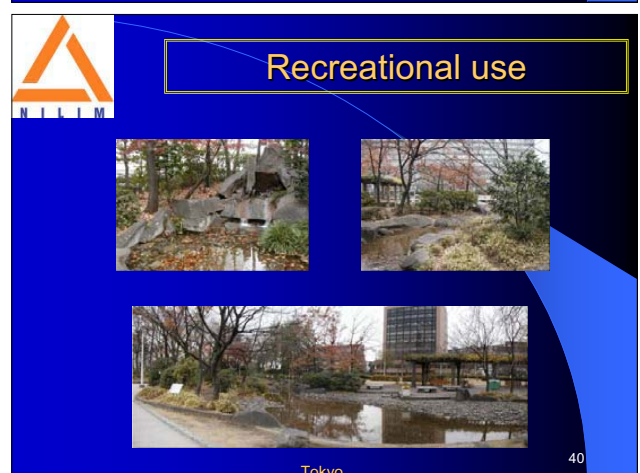
- Toilet flushing use: Chironomid
- Spraying use: A little
- Landscape use: Algae
- Recreational use: Algae

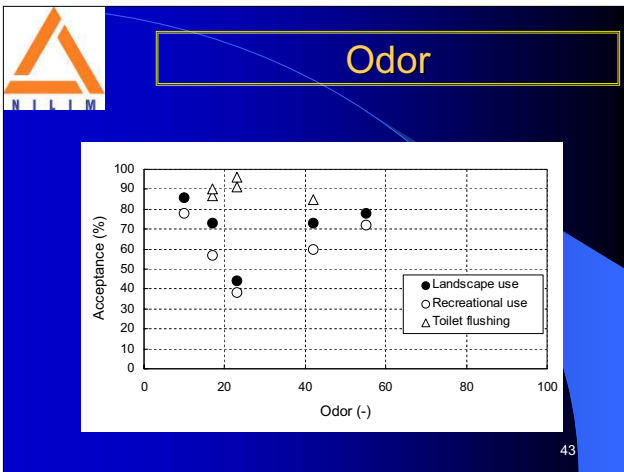
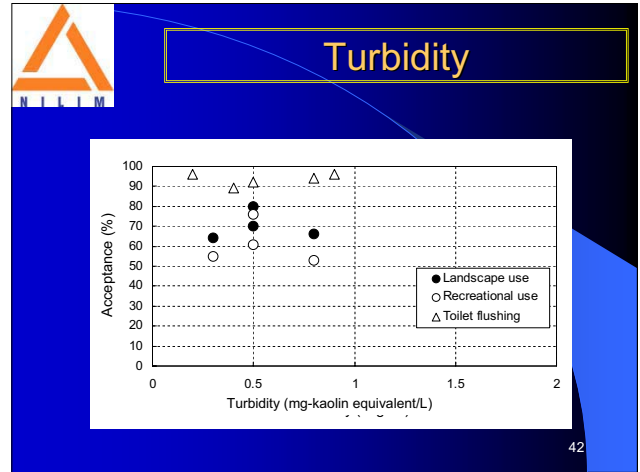
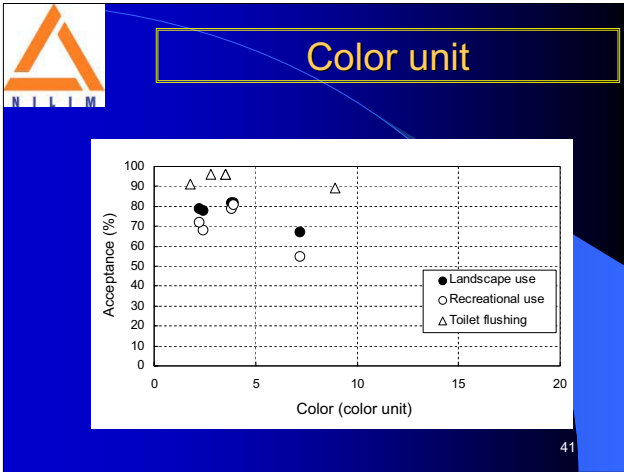
Outline

- Present state of the reuse of treated wastewater in Japan
- **Users' awareness of the appearance of reclaimed wastewater**

Users' awareness survey

	Toilet flushing	Landscape use /Recreational use
Number of locations surveyed	5 locations	5 locations
Period of survey	Dec. 2003 to Feb. 2004	Dec. 2003 to Jan. 2004
Questionnaire method	Interviewing and by mail	Interviewing and by mail
Number of respondents	949 (41 to 341 per location)	954 (115 to 239 per location)





Conclusion

Present state of the reuse of treated wastewater in Japan
(Environmental use 1)

- Increasing.
- Ozonation and/or UV are frequently used for disinfection.

Conclusion

Present state of the reuse of treated wastewater in Japan
(Environmental use 2)

- Troubles: Algae
- There were some locations that measures to prevent accidental contact with reclaimed wastewater for landscape use were not sufficient.

Conclusion

Users' awareness of the appearance of reclaimed wastewater

- In this survey, there were little relationship of color, turbidity, odor with acceptance of users.
- Further survey must be performed to decide standards for the appearance of reclaimed wastewater.

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PRESENT STATE OF THE TREATED WASTEWATER REUSE IN JAPAN

Thank you very much
for your attention !