ESTABLISHMENT OF GUIDELINES FOR THE REUSE OF TREATED WASTEWATER

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Abstract: The Committee on Reclaimed Wastewater Quality Criteria (Chairman: Dr. Mitsumi Kaneko, Visiting Professor of Ritsumeikan University) established new criteria and considerations for the reuse of treated wastewater such as for toilet flushing, sprinkling, landscape use and recreational use. Hygienic safety, appearance, user acceptance, and risk of facility malfunction were discussed. The new criteria and considerations were published as the Guidelines for the Reuse of Treated Wastewater from the Ministry of Land, Infrastructure and Transport of Japan. In the guidelines, new criteria were established for *Escherichia coli* (ND/100 mL) instead of for coliform groups as in the former guidelines with the exception of reuse as water for landscape use. Facility standards were also established, including required treatment methods and turbidity as the index used for ensuring effective treatment. Measures against loss of residual chlorine, cross connection, and accidental intake were also established as considerations for treated wastewater reuse.

Keywords: reclaimed wastewater quality standard, treated wastewater reuse.

Introduction

Japan's average annual rainfall is approximately 1,700 mm, which is twice the world average, but because of its small land area and large population, the annual per capita water resource is about 3,300 m^3, less than half the world average of 7,800 m^3. Only 905 m^3 (almost the same as in Egypt) is available in the Kanto district where Tokyo is located. Furthermore, the amount of precipitation has fluctuated greatly in recent years. For these reasons, more importance is now placed on managing water resources in Japan (MLIT, 2005a).

In response to the severe water shortage of 1978, Japan began reusing treated wastewater as an important water resource in urban areas, starting with reuse for toilet flushing in Fukuoka City in 1980. Since then, treated wastewater has also been used for snow melting, environmental and industrial use, sprinkling and so on. However, only 200 million m^3 per year of treated wastewater from 246 wastewater treatment plants (WTPs) is reused outside the plants, which is less than 2% of the 1.4 billion m^3 of effluent from 1,924 plants in FY 2003 (JSWA, 2005). It is expected that such applications will increase in the future from the viewpoint of saving water resources in

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urban areas, which will in turn increase the importance of appropriately reusing treated wastewater.

On the other hand, since several incidents of human health damage by pathogenic microbes have recently occurred in Japan, people have become more interested in the hygienic safety of water. Therefore, measures against these new problems must be taken if we are to promote the reuse of treated wastewater. In addition, it is necessary to maintain an appropriate color, clearness, and less odor to ensure that the public feels comfortable using the reclaimed wastewater, as well as protecting against facility malfunctions such as corrosion and blocking of pipes.

For the above reasons, the Sewerage and Wastewater Management Department, Ministry of Land, Infrastructure and Transport and the Water Quality Control Department, National Institute for Land and Infrastructure Management formed the Committee on Reclaimed Wastewater Quality Criteria (Chairman: Dr. Mitsumi Kaneko, Visiting Professor of Ritsumeikan University) with the objective of establishing new guidelines for the reuse of treated wastewater. The Ministry of Land, Infrastructure and Transport instituted the new criteria and considerations proposed by the committee as the Guidelines for the Reuse of Treated Wastewater (MLIT, 2005b) and announced it in April 2005. This report presents an outline of the guidelines.

Scope of application

Due to the numerous types of use applications for treated wastewater, we limited our study to those based on the actual conditions of treated wastewater reuse in Japan. Therefore, the guidelines take into consideration the reuse of wastewater for toilet flushing, sprinkling, landscape use (untouchable) and recreational use (touchable). These use applications pertain to a large number of unspecified persons and the reclaimed wastewater was distributed directly from WTPs. Sprinkling refers to watering for trees, plants and lawns or for road flushing. Landscape and recreational use refers to environmental water.

For the time being, we decided that reuse as large-scale waterfalls or fountains would be considered recreational use, because of the potential generation of mist.

Status of complaints and problems concerning treated wastewater reuse in Japan

The new guidelines were established from three points of view: hygienic safety, appearance and acceptance, and risk of facility malfunction. Details concerning appearance and acceptance, and facility malfunction are based on a study concerning

complaints and problems on actual treated wastewater reuse in Japan. The study is outlined below.

Methods

Questionnaires were sent out to WTPs that distributed reclaimed wastewater outside their plants in FY 2002 as water for toilet flushing, sprinkling, landscape use, and recreational use. The results of this research provided us with the details about complaints and problems regarding treated wastewater reuse in the past.

Results

We obtained the following information as a result of the study.

Appearance and acceptance

- Appearance of reclaimed wastewater

  Reclaimed wastewater is generally inferior to drinking water in color, clearness and odor, so these problems must be considered. There were complaints about the appearance of toilet flushing water but few complaints about other uses, most likely because people had more opportunity to observe the toilet flushing water.
- Growth of periphytic algae where treated wastewater is applied to landscape use and recreational use

  Reclaimed wastewater generally contains more nutrients, such as nitrogen and phosphorus, than drinking water. Nutrients accelerate the propagation of periphytic algae, which leads to complaints from facility users.
- Chironomid in toilet flushing water

  There were a number of complaints concerning the growth and propagation of Chironomid in the reservoir tank for toilet flushing water after being distributed from the WTP. On the other hand, there were few complaints about this problem in water for landscape use and recreational use because Chironomid scatters easily and is not as prominent in these applications.

Facility malfunction

Problems concerning corrosion and leaking of pipes and other equipment were reported. The corrosion may be caused by direct contact between the reclaimed wastewater and exposed iron or between different kinds of metals. Attention must be paid to corrosion in the case of highly corrosive reclaimed wastewater with significant amounts of chlorine ion, sulfate ion, or residual chlorine.

Problems with water supply due to the blockage of drains or pipe bends were also reported. Blockage of pipes may occur when the dissolved iron from corrosion is

oxidized by residual chlorine or dissolved oxygen and accumulates at the bend or at narrow areas of the pipes. Measures have already been taken against these problems and they have now been solved (Fukuoka City, 1999; 2000).

Guidelines for the reuse of treated wastewater

The guidelines are divided into criteria for wastewater reuse and considerations for wastewater reuse. They were established from three points of view: hygienic safety, appearance and acceptance, and risk of facility malfunction. The outline of the guidelines is as follows.

Three points of view in establishing the guidelines

Hygienic safety

In establishing the guidelines, consideration was given to measures against bacteria for which chlorine was comparatively effective, and measures against protozoa that had comparative chlorine tolerance. Measures against viruses could not be considered due to numerous problems concerning the virus detection methods.

Appearance and acceptance

The three points listed below were taken into consideration for establishing the guidelines. The second and third points were included only in the considerations for wastewater reuse, not in the criteria part, because different types of facilities cause different conditions for the second point, and the effects of measures have not yet been clarified for the third point.

- Appearance of reclaimed wastewater (color, clearness, odor)
- Growth of periphytic algae in facility water for landscape and recreational use
- Chironomid (imago/larva) in toilet flushing water

Facility malfunction

Measures against corrosion and blockage of pipes and other equipment were taken into consideration for establishing the guidelines.

New criteria for treated wastewater reuse

The new criteria established for the reuse of treated wastewater are shown in Table 1. The grounds for the new criteria are indicated as follows.

E. coli and coliform groups

The following criteria were selected from the viewpoint of measures against bacteria.

E. coli N.D./100 mL was set as a new criterion instead of the number of coliform groups. The number of coliform groups, which includes bacteria that propagates in soil, is not necessarily suitable as the index for indicating contamination by excrement. Furthermore, *E. coli* N.D./100 mL was set as the quality criteria for drinking water in Japan in 2003 based on establishing a quick and easy culture method.

The number of coliform groups set as effluent quality criteria was established as a provisional criterion for landscape use, where handling is not permitted, and the former criteria for treated wastewater reuse (coliform groups 1,000 CFU / 100 mL) was adopted on a provisional basis.

Facility standards (Required treatment methods and turbidity as control parameter)

The facility standards were established from the viewpoint of measures against facility malfunction and measures against protozoa for hygienic safety.

Designated treatment methods and turbidity conditions were set from the viewpoint of protecting against blockage for toilet flushing, sprinkling and landscape use, for which there is little possibility of accidental intake. Sand filtration or an equivalent treatment method was set as a required facility standard. Turbidity was also set as the control parameter to ensure effective treatment of the sand filtration. Turbidity of less than 2 mg-kaolin equivalent/L was set as the target value based on research results demonstrating that the turbidity of treated wastewater from a properly operated filtration system barely exceeded 2 mg-kaolin equivalent/L.

Chemical precipitation followed by sand filtration or an equivalent treatment method was set as a required facility standard to efficiently remove protozoa from recreational-use water for which there is a risk of accidental intake. Turbidity of less than 2 mg-kaolin equivalent/L was set as the value to be observed at all times.

Additional treatment, restricted use or halting the distribution of treated wastewater may be required in certain cases if hygienic safety is at risk due to a group infection outbreak caused by protozoa within the basin of the WTP.

pH

The pH level of 5.8–8.6 was set as an effluent quality criterion. It was established from the viewpoint of preventing corrosion in pipes and other equipment. In addition, it was recommended that corrosion-resistant structure and materials for pipes and other equipment be adopted.

Appearance, Color, and Odor

Appearance, color and odor were established from the viewpoint of appeal and acceptance. These criteria are the same as the former criteria. The target value of the color in the former criteria was set based on the results of user questionnaires in which almost all users accepted a color of 40 units under the premise of not handling the water, and a color of 10 units under the premise of handling (JSWA, 1981; MOC *et al.*, 1990). However, it is preferable that the values be set based on the wishes of regional users.

Residual chlorine

In terms of controlling bacterial growth in the distribution process, chlorine disinfection with long-term effects was regarded as the basic disinfection method and the concentration of residual chlorine was set as the target value. The concentration of residual chlorine set as the drinking water quality criteria in Japan (free: more than 0.1 mg/L or combined: more than 0.4 mg/L) was applied to the criteria for treated wastewater reuse. This was also based on research results indicating that bacteria hardly developed in the distribution process under conditions of values greater than 0.1 mg/L for free residual chlorine or 0.4 mg/L for combined residual chlorine.

Table 1 New criteria for the reuse of treated wastewater in Japan

<table>
<tr><th></th><th>Location relevant to standards</th><th>Toilet flushing water</th><th>Sprinkling water</th><th>Water for landscape use</th><th>Water for recreational use</th></tr>
<tr><td>E. coli</td><td rowspan="6">Outlet of reclaimed treatment facilities</td><td>N.D./100 mL</td><td>N.D./100 mL</td><td>≤1000 CFU /100 mL as coliform groups[1)]</td><td>N.D./100 mL</td></tr>
<tr><td>Appearance</td><td colspan="4">Not unpleasant</td></tr>
<tr><td>Turbidity</td><td colspan="3">≤ 2 [2)3)]</td><td>≤ 2[3)]</td></tr>
<tr><td>Color</td><td></td><td></td><td>≤ 40 units</td><td>≤ 10 units</td></tr>
<tr><td>Odor</td><td colspan="4">Not unpleasant</td></tr>
<tr><td>pH</td><td colspan="4">5.8 – 8.6</td></tr>
<tr><td>Residual chlorine</td><td>Admin. boundary</td><td>≥ free: 0.1 mg/L or combined: 0.4 mg/L [2)]</td><td>≥ free: 0.1 mg/L or combined: 0.4 mg/L[2)4)]</td><td></td><td>≥ free: 0.1 mg/L or combined: 0.4 mg/L[2)4)]</td></tr>
</table>

Treatment		Sand filtration or equivalent	Chemical precipitation + sand filtration or equivalent

1) Provisional value
2) Control target value
3) Unit: mg-kaolin equivalent/L
4) Not applicable for cases in which long-term effects of disinfection is unnecessary

For sprinkling and recreational use of treated wastewater, a value was not applied for cases in which long-term effects of disinfection are not required, for example, when the retention time from the WTP to the place of use is short.

A value was not set for landscape use because handling is not permitted in its use and treatment other than chlorine disinfection may be adopted from the viewpoint of ecosystem preservation.

Considerations for treated wastewater reuse

The main considerations for treated wastewater reuse are given below.

Measures against loss of residual chlorine

- Decrease, as much as possible, in ammonia nitrogen that easily consumes residual chlorine using secondary treatment and reclamation treatment.
- Construction of distribution networks so as to shorten the retention time. For example, the selection of pipes with suitable diameter and the avoidance of a dead end by looping of pipes. Also, pipes should be of a material not easily oxidized by residual chlorine.
- Consideration given to additional chlorine disinfection in places where residual chlorine is significantly decreased.
- Confirmation of suitable volume for the reservoir tank in facilities where reclaimed wastewater is used, and cleaning of the tank to control the consumption of residual chlorine.

Measures against cross connection

- Indication of treated wastewater by placing signs on pipes and other equipment or color-coding them in order to clearly distinguish the ones using reclaimed wastewater. An example of color-coding is given as Photo 1.
- Inspection for cross connections before starting the distribution of reclaimed wastewater. The sewerage administration departments must confirm that there is no cross connection. One example of inspection is opening and shutting the main

valves for the reclaimed wastewater and the drinking water after coloring the reclaimed wastewater.

Measures against accidental intake

- Posting of notices to users that reclaimed wastewater is used. Especially in the case of landscape use, accidental intake must be prevented by displaying explicit warnings against drinking.
- Regarding sprinkling, accidental intake of the mist can be prevented, for example, by sprinkling at a time when there are few people in the area.

Photo 1 Example of distinction by color-coding the pipes (Yellow is reclaimed wastewater, blue is drinking water)

Conclusion – Amendment of the Sewerage Law

The new criteria and considerations were published as the Guidelines for the Reuse of Treated Wastewater from the Ministry of Land, Infrastructure and Transport of Japan. The guidelines were used as a reference for the amendment of the Sewerage Law.

The objective of the Sewerage Law (enacted in 1958) is to develop sewerage systems, and thereby contribute to sound urban development and enhancement of public sanitation, and contribute to water quality control of public water bodies.

The last amendment of the Sewerage Law in October 2005 (enforced in April 2006) newly added the criteria for hygienic safety of recreational water in order to preserve the

living environment and protect human health. Specifically, under the structural standards for sewerage system facilities stipulated by the Sewerage Law, in principle, shielding and fences are installed and other measures taken to prevent entry to the facilities, but it is also stipulated that their installation is unnecessary under specified conditions. One such condition is that the recreational water that is used satisfies quality standards for final effluent, contains *E. coli* N.D./100 mL, and has turbidity of less than 2 mg-kaolin equivalent/L.

New structural standards not only encourage the suitable reuse of treated wastewater, but will also encourage the recovery of good quality waterside spaces in urban areas.

Acknowledgement

The new criteria and considerations for treated wastewater reuse described in this paper were proposed by the Committee on Reclaimed Wastewater Quality Criteria. We express our deep appreciation to the members of the committee who put extensive effort into developing and proposing the guidelines.

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1. Introduction

Importance of saving water resources in urban areas
- Annual per capita water resources - 3,300m³ (Japan) / 7,800m³ (world average)
- Decrease of the rainfall in drought years

Importance of hygienic safety of water
- Outbreak of Cryptosporidium disease (1996) etc.

→ Importance of appropriate use of treated wastewater

Review the guideline… ← Field survey (hygienic safety of reclaimed wastewater)

→ New Guidelines (2005)

Three points of view
- hygienic safety
- appearance and acceptance
- facility malfunction

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2. Framework of Establishment

- Local community/municipality
- Japanese Institute of wastewater engineering technology joint research project

Ministry of Land, Infrastructure and Transport (MLIT)
Sewerage and Wastewater Management Department
National Institute for Land and Infrastructure Management, Water Quality Control Department

Field survey ⇄ Committee on Reclaimed Wastewater Quality Criteria (Chairman: Dr. Mitsumi KANEKO, Ritsumeikan University)

Propose guideline

→ Announcement of guideline to sewage works administrator

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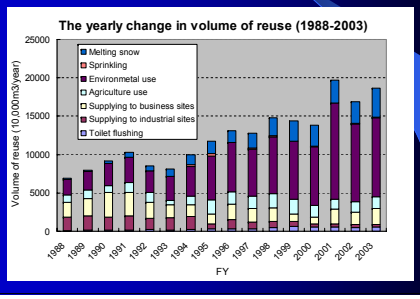
3. Present status of treated wastewater reuse in Japan (1)

186 million m³ (FY2003) = 1.4% of the total treated wastewater
246 WTPs (FY2003) = 13% of the total WTPs



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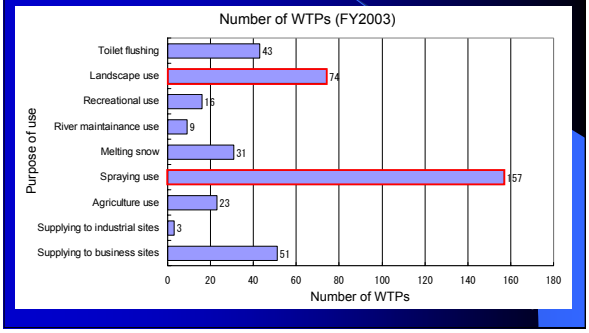
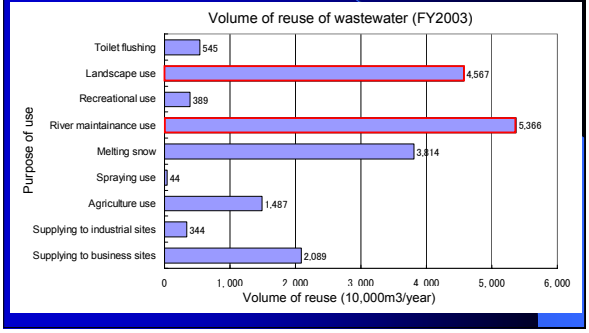
3. Present status of treated wastewater reuse in Japan (2)



3. Present status of treated wastewater reuse in Japan (3)



4. Scope of application (1)

- Applications pertain to a large number of unspecified persons
- Reclaimed wastewater that was distributed directly from WTPs

Toilet flushing

Sprinkling
(trees, plants, lawns, road flushing)

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4. Scope of application (2)

Landscape use
(Environmental use (untouchable))

Recreational use
(Environmental use)
* Including large-scale waterfalls or fountains that may produce aerosol

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5. Details of the examination

	Details	Standar-dization
Appearance and acceptance	Appearance (color, clearness, odor)	Yes
	Growth of periphytic algae (Landscape use, Recreational use)	No
	Outbreak of Chirnomid (imago/larva) (toilet flushing)	No
Facility malfunction	Corrosion and blockage of pipes and other equipment	Yes
Hygienic safety	Pathogenic microbes (bacteria, protozoa) *	Yes

* Not cover criteria for viruses for following reasons in this new guidelines

- Not establishment of identification and culture of virus
- PCR is not enough to evaluate infectiousness
- Fate of virus should be further investigated
- Dose/response model is to be developed for some species
- Resistance to disinfection is not sufficiently clarified/evaluated yet.

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6. Previous guidelines/standards for treated wastewater use (Reference)

	Japan Sewage Works Association (proposed in 1981)			Working group composed of Ministry of Construction and some big cities (proposed in 1990)	
	Toilet flushing	Sprinkling	Landscape use	Landscape use**	Recreational use***
Coliform group	≤10 (CFU/mL)	N.D.	N.D.	≤1000 (CFU/100mL)	≤50 (CFU/100mL)
Residual Chlorine (mg/L) *	Trace amount	≥ 0.4	-	-	-
Appearance	Not unpleasant	Not unpleasant	Not unpleasant	-	-
Color (color unit)	-	-	-	≤ 40	≤ 10
Turbidity (mg-kaolin equivalent/L)	-	-	≤ 10	≤ 10	≤ 5
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	≤ 10	≤ 3

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

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7. New criteria for the reuse of treated wastewater

	Toilet flushing	Sprinkling	Landscape use	Recreational use
E.coli	N.D./100mL	N.D./100mL	≤1000 CFU /100mL as Coliform groups [1]	N.D./100mL
Appearance	Not unpleasant			
Turbidity	≤ 2 (target value) [2]			≤ 2 [2]
Color			≤ 40 units	≤ 10 units
Odor	Not unpleasant			
pH	5.8 - 8.6			
Residual chlorine (target value)	≥ free: 0.1mg/L or combined: 0.4mg/L	≥ free: 0.1mg/L or combined: 0.4mg/L[3]		≥ free: 0.1mg/L or combined: 0.4mg/L[3]
Treatment	Sand filtration or equivalent			Chemical precipitation + sand filtration or equivalent
Notes	1) Provisional value 2) Unit: mg-kaolin equivalent/L 3) Not applicable for cases in which long-term effects of disinfection is unnecessary			

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8-1. Grounds for the new criteria (1)

E-coli / coliform groups)

Coliform groups not suitable as the index for contamination by excrement

E-coli N.D. / 100mL in drinking water by establishing a quick and easy culture method

No detection / 100mL, new criteria

However,

For landscape use, tentatively same as previous (Coliform groups 1000CFU /100mL) because handling not permitted and effluent criteria set as coliform group

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8-1. Grounds for the new criteria (2)

Residual chlorine

Control of regrowth of pathogenic bacteria in distribution

Field survey…

(Drinking water criteria)
Free: ≥ 0.1mg/L
Combined: ≥ 0.4mg/L

➡ Possible to control regrowth

new criteria
Free: ≥ 0.1mg/L
Combined: ≥ 0.4mg/L

However,

Not applicable for landscape use (handling not permitted, ecosystem preservation)

Not applicable for cases in which long-term effects of disinfection is unnecessary (sprinkling, recreational use)

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8-1. Grounds for the new criteria (3)

Treatments / Turbidity

Against facility malfunction

➡ No blockage, **sand filtration** should be added

➡ **Turbidity of 2 or less as target value** to ensure effective treatment

Against protozoa (recreational use)

➡ **Chemical precipitation and sand filtration** should be added

➡ **Turbidity of 2 or less as value to be observed at all times** to ensure effective treatment

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8-1. Grounds for the new criteria (4)

pH

Corrosion control / same as previous (**pH: 5.8 - 8.6**)

Appearance / Color / Odor

Appeal and acceptance / same as previous
(Appearance, Odor: Not unpleasant
Color: ≤ 40 units (Landscape use),
≤ 10 units (Recreational use))

However,

It is preferable to give criteria considering the wishes of regional users

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9-1. Consideration for treated wastewater reuse

Hygienic safety

1. Loss of residual chlorine in the distribution system
2. Cross-connection
3. Accidental intake
4. Deterioration of the quality of reclaimed wastewater

Appeal and acceptance

1. Red water, colorless, cloud
2. Growth of algae (Landscape use, Recreational use)
3. Outbreak of Chirnomid (imago/larva) (toilet flushing)

facility malfunction

1. Corrosion and blockage of pipes and other equipment

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9-2. Prevention of cross connection (1)

1) Place signs on or color-code pipes and other equipment

Example of distinction by color-coding the pipes
(Yellow is reclaimed wastewater, blue is drinking water)

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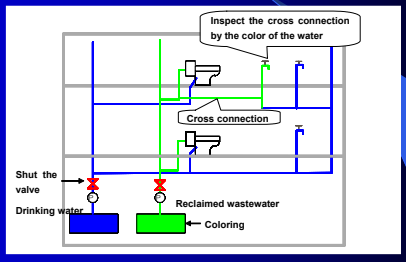
9-2. Prevention of cross connection (2)

2) Inspection for cross connection



Example of method for confirming cross connection

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9-3. Prevention of accidental intake (1)

1) Posting of notices to users that reclaimed wastewater is used

Example of posting of notices that reclaimed wastewater is used and not for drink

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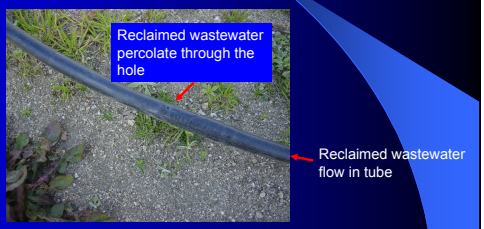
9-3. Prevention of accidental intake (2)

2) Prevention of accidental intake of aerosol (watering use)



Example of watering use that is hard to produce aerosol

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10. Amendment of sewerage law (1)

Objective

- Sound urban development
- Enhancement of public sanitation
- Water quality control of public water bodies

public sanitation

prevention of inundation

spread of flush toilet

water quality control in public water body

utilization of sewerage resources

creation of preferable water circulation and water environment

Growing interest in favorable water environment

Changes in roles of sewerage

10. Amendment of sewerage law (2)

Structural standards

~~Shielding, fences etc. must be installed to prevent entry to the facilities~~

- Culvert
- **Recreational use facilities** **NEW**

Quality standards for final effluent
***E.coli* N.D./100mL**
Turbidity of less than 2mg-kaolin equivalent/L
- …

Amendment in October 2005

Suitable reuse of treated wastewater

Recovery of good quality waterside spaces in urban areas

11. Future task

1. Study on the criteria for viruses
2. Study on the ingestion scenario
3. Improvement of analysis methods of pathogens
4. Development of cheap and advanced wastewater treatment
5. Study on the possibility of application to new purpose of use

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Acknowledgement

The new criteria and considerations were proposed by the Committee on Reclaimed Wastewater Quality Criteria. We express our deep appreciation to the members of the committee who extensive effort into developing and proposing the guidelines.

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4th Japan-U.S. Governmental Conference on
Drinking Water Quality Management and
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Thank you very much
for your attention !