6-3 Reclaimed Wastewater Supply Business in Tokyo and Introduction of New Technology

K. Yamada*, O. Matsushima* and K. Sone*

* Bureau of Sewerage, Tokyo Metropolitan Government, 2-8-1 Nishi-Shinjuku Shinjuku-ku, Tokyo 163-8001 Japan
(E-mail: *kinji_yamada@member.metro.tokyo.jp*)

Abstract Tokyo Metropolitan Government (TMG) has managed "wastewater reuse" business to utilize limited water resources effectively. In this business, municipal sewer wastewater is highly treated and reused for various urban non-potable purposes. The area-wide recycling systems which supplies reclaimed wastewater for toilet-flushing use was began in 1984. Now, average amount of 8400m^3 is daily supplied to 129 facilities in five areas and two more districts will be added to service area. Moreover, reclaimed sewer wastewater is discharged into many urban rivers whose flow amount has been decreased along with rapid urbanization. Additionally secondary effluent or highly treated wastewater is used for washing, fire-fighting, road-spraying, recreational use in park, and so on. On the other hand, to meet users' needs for quality of reclaimed water, we have developed a new wastewater reclamation system with "ozone-resistant membrane" which can produce reclaimed water of high quality in relatively low cost. We aim to expand "wastewater reuse" in the future by securing hygienic safety and reduction of the production cost.
Keywords area-wide recycling system; ozone resistant membrane; toilet flushing water; wastewater reuse

INTRODUCTION

Tokyo, the capital of Japan, is one of the largest cities in the world, with a population of approximately 12.5 million and a population density of 5700 persons/km^2. As for the geography, Tokyo is located in the middle of Japan and belongs to humid subtropical climate with four seasons. The rain falls long and often severely during rainy season and typhoon season, and the average annual rainfall is over 1500mm. However, because of the high population density, the available water resource per capita is only 900m^3/year. This value is one-third of the average in Japan.

Water Recycle Master Plan, Tokyo

This situation leads to more water resource development, the demand of rainwater harvesting, and wastewater reuse. To manage sustainable water recycle system in urban area, Tokyo Metropolitan government (TMG) drew up "Water Recycle Master Plan" in 1999. "Secure stable water supply" and "maintain healthy and comfortable water environment" are main targets of the plan, and sewerage treatment effluent is considered as a valuable water resource because of its stability in quality and quantity. In Tokyo, municipal sewerage service covers almost covers whole area. Coverage area is 2187km^2 and 5.5 million m^3 of wastewater is treated in a day.

WASTEWATER REUSE IN TOKYO

History of wastewater reuse in Tokyo is long and reclaimed wastewater is now used for various purposes (see Table1). Quality standard of reclaimed wastewater set by TMG is shown in Table2. The proportion of wastewater reuse has reached approximately 9% in 2006.

Table1. Major Events in Wastewater Reuse in Tokyo

Year	Description
1951	Reclaimed wastewater of Mikawashima Wastewater treatment plant (WTP) was experimentally delivered to a paper mill. (and operated in full-scale since 1955.)
1964	Reclaimed wastewater of Mikawashima WTP was supplied to industrial waterworks plant as raw water.
1984	Reclaimed wastewater of Tamagawa-Johryu WTP was discharged into a dried up channels, “Nobidome-Yohsui”. (to Tamagawa-Johsui in 1986, Senkawa-Johsui in 1989) Ochiai WTP also started to discharge into three urban rivers (Shibuyahawa and Furukawa River, Nomikawa River and Megurogawa River) in 1995.
	Model business of area-wide water recycling system was started in Shinjuku area. Reclaimed wastewater of Ochiai WTP was delivered to high-rise buildings for toilet-flushing use. (afterward, started at Ariake WTP in 1996, at Shibaura WTP in 1997)
1987	A park was opened next to Ochiai WTP. Reclaimed wastewater is supplied to an artificial stream in the park.
1989	Reclaimed wastewater of Morigasaki WTP was supplied to incineration plant for industrial uses.
2003	Road-spraying used reclaimed water was experimentally started at Shiodome. (and at Kasumigaseki since 2007)
2004	Operation of ozonation-MF system with “ozone-resistant membrane” was started at Shibaura WTP.

Table2. Quality Standard of Reclaimed Wastewater Reuse (Ministry of Land, Infrastructure and Transport, 2005)

	Toilet flushing	Spraying	Landscape irrigation	Recreational use
E.coli	Not detected	Not detected	-	Not detected
Total Coliform (CFU/100mL)	-	-	1,000 or below	-
Turbidity (mg-kaolin/L)	2 or below	2 or below	2 or below	2 or below
pH	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6	5.8 - 8.6
Appearance	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
Color (Color Unit)	-	-	40 or below	10 or below
Odor	Not unpleasant	Not unpleasant	Not unpleasant	Not unpleasant
Chlorine Residual (mg/L)	Free:0.1 or over or Total:0.4 or over	Free:0.1 or over or Total:0.4 or over	-	Free:0.1 or over or Total:0.4 or over

Uses in Wastewater Treatment Plants

In wastewater treatment plants, a part of secondary effluent is treated by rapid sand-filtration systems and used for various purposes such as scrubber water, washing of facilities, and cooling water. This type of wastewater reuse is introduced into all wastewater treatment plants in Tokyo and accounts for 80% of whole reclaimed wastewater use.

Industrial Uses

In 1951, a rapid filtration system was constructed in Mikawashima Wastewater Treatment Plant. This system daily treated 15000 m^3 of wastewater, and reclaimed water was supplied to a neighbor paper mill as industrial water. This is the first example of waste water reuse by TMG. Afterwards, secondary effluent of the plant was used as raw water of industrial waterworks, too.

Environmental Uses

Many urban rivers in Tokyo were reclaimed along with rapid urbanization since high-growth period. Additionally, increase of impervious ground surface using asphalt or concrete causes a decrease in the flow amount of remaining rivers. In this situation, reclaimed wastewater has become to be thought as attractive water resources in urban area for stream flow augmentation.

In 1984, tertiary treated wastewater of Tamagawa-Johryu Wastewater Treatment Plant treated by rapid sand-filtration system began to be discharged to a dried up channels. Ozonation process was added in 1991, to improve the water quality. Ochiai Wastewater Treatment Plant also discharged tertiary treated wastewater by rapid sand-filtration system to urban rivers. Daily average amount of reclaimed wastewater used for this purpose was approximately 110000m^3 in 2005.

Figure1. Change of Urban River Appearance: Megurogawa-River before (left) and after (right) the start of reclaimed water discharge

Toilet-Flushing Uses (Area-Wide Water Recycling System)

TMG, is now promoting the reuse of wastewater for toilet-flushing by area-wide water recycling system. In this system, the secondary effluent of municipal sewer system was treated by tertiary or advanced process and reclaimed water was supplied to buildings for toilet-flushing use.

In 1984, a model business of area-wide water recycling system was started, which supplied reclaimed wastewater to commercial buildings in Shinjuku for toilet-flushing use (Maeda *et al.*, 1996). This project is the first milestone of area-wide water recycling system in Japan. Now, 4000 m^3 of secondary effluent is treated by rapid sand-filtration system in Ochiai Wastewater Treatment Plant, and supplied to 28 high-rise buildings.

This type of area-wide recycling system is continuously introduced into bayside redeveloped area. In 2006, approximately 3 million m^3 of reclaimed water (daily average amount was 8400m^3) was produced at three wastewater treatment plant and supplied to 129 buildings in five areas. And, two

areas will be added into supply plan. To promote this type of water reuse further, TMG asks owners of buildings to install dual pipe systems when they construct large buildings having a certain scale.

Other Urban Uses

Some wastewater treatment plants supply reclaimed wastewater to artificial streams or ponds in parks adjacent to plants. To ensure hygienic safety in recreational use that occur human exposure, reclaimed wastewater is treated by reverse osmosis membrane (RO) system to remove pathogens.
Secondary effluent of wastewater treatment plants is also delivered to various facilities, for instance, incineration plants of domestic waste, a railway company, and tanks for fire-fighting use.
Recently, the reclaimed wastewater is used for road-spraying to alleviate heat island phenomenon in the urban area.

(a)

(b)

(c)

Figure2. Various Usage of Reclaimed Wastewater: (a) Discharge into artificial stream in park (b) Washing of railroad vehicles (c) Road-spraying to alleviate a heat island phenomenon

NEW WASTEWATER RECLAMATION SYSTEM IN TOKYO

As previously stated, TMG runs three area-wide water recycling systems. One of them is centered on Shibaura Wastewater Treatment Plant, which is one of the oldest wastewater treatment plants in Japan. Tertiary treated wastewater by rapid sand-filtration system was supplied at first, but opinions from users requested more pleasantness in use of reclaimed water, especially improvement of color and odor. To meet this need, we have developed a new wastewater reclamation system with “ozone-resistant membrane” (Ishida, 2004). A schematic description of the system is given in Figure3.

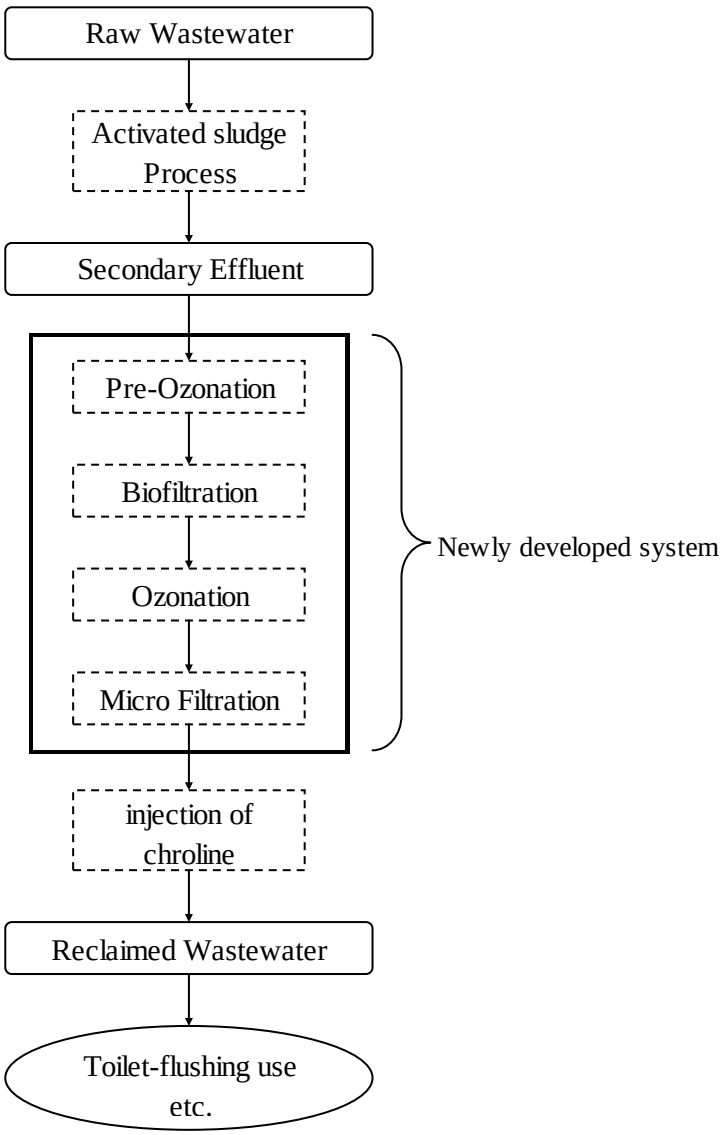

Figure3. Scheme of the newly developed system with ozone-resistant membrane

Principle of Treatment

This system is composed of 4 processes: (1) Pre-Ozonation (low rate injection of ozone), (2) Biofiltration, (3) Ozonation, and (4) Micro filtration (MF). To combine Ozonation and MF process, membrane made of PVDF (polyvinylidene difluoride), which has ozone-tolerance, is used.

Organic matters are degraded in Pre-Ozonation process and reduced with ammonia in Biofiltration process. This contributes to reduce total amount of ozone injected through the system. In Ozonation process, unpleasant odor and color are reduced. Microbes and bacteria are disinfected by ozonation and removed with other turbidity in MF process.

Existence of residual ozone prevents membrane fouling and enables high rate water flux ($5m^3/m^2/day$) in MF process, which are useful for reduction of maintenance cost. Estimated total cost of the new system is almost the same as "rapid sand filtration - ozonation" system.

Operation Result of Real Plant

A real plant of this system with treatment capacity of $4300m^3/day$ has been operated since April 2004. Till now, the plant has run well without major troubles for more than two years, and quality of reclaimed water keeps high. As a result, users' complaints about color and odor were disappeared.

Table3. Annual average of reclaimed water quality in 2005

	Secondary Effluent	after Biofiltration	After MF process	Criteria for toilet-flushing
E. coli (count/100mL)	-	-	ND	ND
Turbidity (mg-kaolin/L)	3.0	1.5	0.0	<2.0
pH	6.2~7.4	6.2~7.5	6.0~7.6	5.8~8.6
Appearance	Light yellow	-	Clear	Not unpleasant
Color (unit)	15	16	0.3	<10
Odor	Sewage odor	-	Not unpleasant	Not unpleasant
Residual Chlorine (mg/L)	-	-	-*	Free: >0.1, Total: >0.4

* NaClO (sodium hypochlorite) solution is injected to reclaimed water before supplied.

CONCLUSION

We believe that wastewater reuse contributes the achievement of "recycling society" which can reduce environmental burden. But, the reuse rate of wastewater has remained only 9% as previously stated. To manage the reclaimed wastewater supply business successfully, we have positively expanded the usage of reclaimed water to various urban uses. The other hand, we have developed new technologies, such as "ozone-resistant membrane", to reduce the production cost and improve the quality of service. Now, securing of hygienic safety is strongly needed. We try to examine the behavior of pathogens in the reclaimed wastewater such as virus.

References

K. Ishida (2004) *Seibutsumakuroka, Ozon,Ozontaiseimaku kara naru Saiseisui Seizou Shisutemu no Kaihatsu, Dohnyu (Development and Introduction of Wastewater Reclamation System Composed of Biofiltration, Ozonation and Micro Filtration by Ozone-Resistant Membrane), Journal of Japan Sewage Works Association*, **41**(499), 31-36.

M. Maeda, K. Nakada, K. Kawamoto and M. Ikeda (1996). Area-Wide Use of Reclaimed Water in Tokyo, Japan. *Water Science and Technology*, **33**(10-11), 51-57.

Ministry of Land, Infrastructure and Transport (2005) *Gesuisyorisui no Sairiyou Suishitu Kijun tou Manyuaru (Manual of Quality Standards for Sewage Treatment Effluent)* http://www.mlit.go.jp/kisha/kisha05/04/040422/05.pdf (accessed 22 June 2007)