# 26. Global and Environmental Considerations Of Wastewater Control In Tokyo

**Presenter**

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# GLOBAL AND ENVIRONMENAL CONSIDERATIONS

# OF WASTEWATER CONTROL IN TOKYO

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## ABSTRACT

Since 1998, each municipality has tackled the global environmental problem in Japan. Tokyo, having an economic scale as large as Canada is also required to take a positive role in sustaining global environment. After sewage works were estimated to occupy 46% of $CO_2$ emission of all the public works done by Tokyo, Bureau of Sewerage established a long-range plan to cope with the reduction of $CO_2$ emission associated with sewage works. Above existing menus, an attempt to reduce Nitrous Oxide ($N_2O$) that has 310 times high potential as that of $CO_2$ is considered most effective. Monitoring work revealed the incineration temperature increase can reduce most of $N_2O$ from the exhaust gas.

Bureau of Sewerage however, does not limit its effort in technical fields. Certified Environmental Management System according to ISO14001 has produced systematic and effective energy saving activities in everyday works.


## INTRODUCTION

Since 1988, when Intergovernmental Panel on Climate Change (IPCC) was established, potential global climate change was widely recognized. The three Working Groups activities have continued to report scientific and socio-economic information relevant for the understanding of the risk of human-induced climate change.

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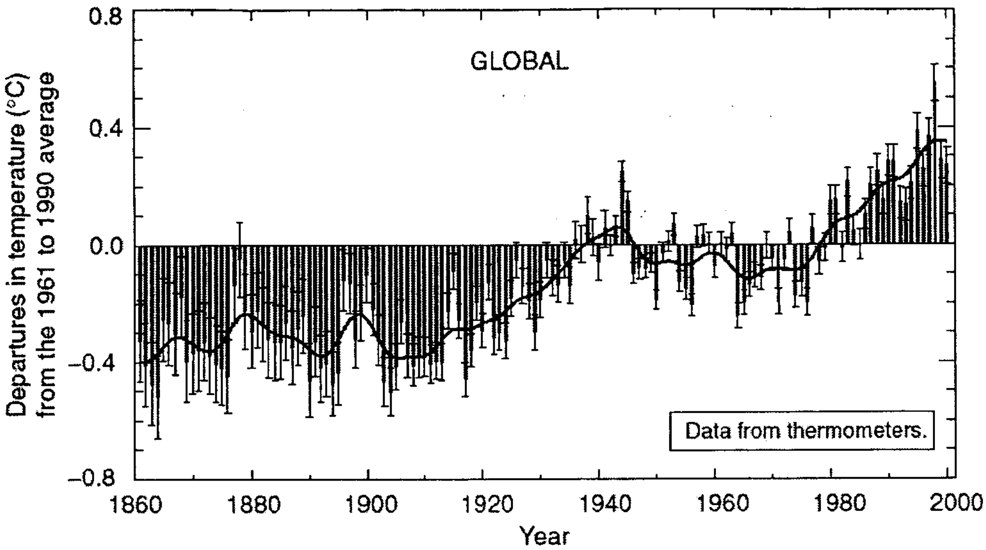
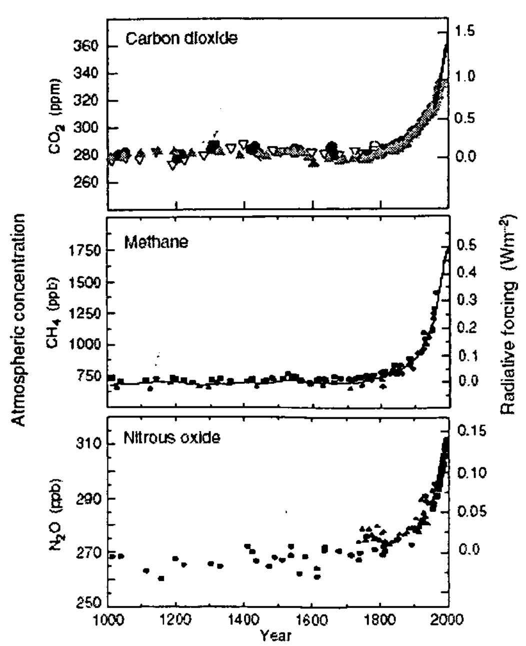



*From The Third Assessment Report of IPCC Working Group I*

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and provided a framework for action aimed at stabilizing atmospheric concentrations of greenhouse gases at a level that would prevent human-induced actions from leading to "dangerous interference" with the global climate system. Seven meetings of the Conference of Parties (COP) have taken place as well as numerous workshops thereafter.

After intense negotiations at COP3 held in Kyoto, Japan in December 1997, delegates agreed to a Protocol to the UNFCCC that commits developed countries and countries making the transition to a market economy to achieve quantified targets for decreasing their emissions of greenhouse gases. These countries, known under the UNFCCC as Annex I Parties, committed themselves to reducing their overall emissions of six greenhouse gases (by at least 5% (6% to Japan) below 1990 levels over the period between 2008 and 2012, with specific targets varying from country to country.

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The six greenhouse effect gases are

Carbon Dioxide($CO_2$), Methane($CH_4$), Nitrous Oxide($N_2O$), Hydrofluorocarbons (HFCs), Perfluorocarbons(PFCs) and Sulphur hexafluoride ($SF_6$).

In response to those international activities, a new legislation named "Promoting Prevention Measures Against Earth Temperature Increase" was established in 1998. In the article four, it prescribes local municipalities must promote measures controlling emission of those greenhouse effect gases in each region. Local municipalities also have to establish an action plan to reduce the emission from their public works.

In regard to wastewater control in Japan, it is said approximately 0.6% of total electric power is used for sewage works. Japan Sewage Works Association (JSWA) based on the request by the Ministry of Construction, now the Ministry of Land, Infrastructure and Transport (MLIT) published in 1999, a guiding [1)] to promote new technology and energy savings to control greenhouse effect gas emissions from sewage works.

## STATUS OF GLOBAL CONSIDERATIONS FOR PUBLIC WORKS IN JAPAN

Each municipality, based on the legislation of 1998, extended its global concept toward guiding private businesses to reduce greenhouse gas emission.

In Tokyo, "Ordinance on Environmental Preservation" was totally revised in 2001. It requires businesses that consume a large amount of energy to submit a "Counter Plan Against Global Warming" to the governor. In the plan, each business has to estimate how much greenhouse effect gas is emitted. The results of the plan should be opened to the public. As for HFCs used for such as refrigerators, it bans to emit them to atmosphere. As for controlling energy consumption by large buildings, it requires when building a large scale one with a total floor area over 10,000$m^2$, to submit a Building Environmental Plan that should state how much the environment-friendly measures are taken.

As Tokyo is one of the biggest cities that have economic scales larger than Canada, it requires positive role to promote reducing greenhouse gases. **Table.1** shows the consumed energy in Tokyo indicates a relatively low as around 6% of whole Japan, nevertheless its population covers 10% of the total. In other words, energy for Tokyo is consumed considerably in other places in the course of making products for it. For the time being, the targets to guide are business and transportation as well as domestic.

**Table.1 Energy consumption of Tokyo in 1998 (Unit PJ or $10^{15}$J)**

| | Tokyo | | Whole Japan | |
|---|---|---|---|---|
| Industry | 90 | 10% | 7,021 | 46% |
| Domestic | 166 | 19% | 2,100 | 14% |
| Business | 254 | 29% | 1,897 | 13% |
| Transportation | 357 | 41% | 3,818 | 25% |
| Others | - | - | 319 | 2% |
| Total | 867 | 100% | 15,155 | 100% |

**Table.2 $CO_2$ emission from public works of Tokyo in 1999 (Unit ton)**

| | $CO_2$ | $N_2O$ | $CH_4$ | Others | Total | Percentages |
|---|---|---|---|---|---|---|
| Bureau of Sewerage | 436,826 | 353,112 | 25,037 | 12,989 | 827,965 | 46.3 |
| Bureau of Waterworks | 311,087 | 145 | 637 | 1,615 | 313,486 | 17.5 |
| Bureau of Transportation | 217,308 | 544 | 47 | 1,938 | 219,838 | 12.3 |
| Metropolitan Police Department | 97,447 | 278 | 175 | 484 | 98,385 | 5.5 |
| Bureau of Public Health | 87,558 | 2,953 | 377 | 22 | 90,911 | 5.1 |
| Others | 236,390 | 682 | 808 | 1,284 | 239,159 | 13.3 |
| Total | 1,386,616 | 357,714 | 27,081 | 18,332 | 1,789,744 | 100 |

For the public works by the Tokyo Metropolitan Government (TMG) itself, it drew up a new plan called "Tokyo Metropolitan Plan to Preserve Earth". It requires greenhouse effect gas emission should be cut 2% of 1999 in year 2004.

**Table 2** shows the estimation of greenhouse effect gas emissions for whole public works of Tokyo in 1990. It is clear that emission from the sewage works occupies as much as 46.3%, the largest amount among the total public works.

## GLOBAL CONSIDERATIONS FOR WASTEWATER CONTROL IN TOKYO

Bureau of Sewerage recognizes its important role to reduce greenhouse effect gases and therefore newly established a long range plan "Sewerage Works Plan 2001"(Plan2001) which aims the amount of greenhouse effect gas emission in 2004 to be reduced by 30,000 $CO_2$ton or 3% of the year 1999.

In **Table 3** the total $CO_2$ emission by the sewage works in 1999 is listed in every item. Each $CO_2$ emission value was calculated mostly by the Guiding of JSWA 1999. The result shows the total $CO_2$ emission reached 823,000 tons, while 372,000 tons(45%) was occupied by wastewater treatment process, 428,000 tons(52%) by sludge treatment. It also indicates reuse of sewage resource such as heat recovery from sewage balances 11,000 tons(1.4%) of the total emission.

The concept of the Plan2001 focused for the time being however, on the amount of $CO_2$ reduction compared to the case no considerations have been taken. In other words, it does not promise to reduce the absolute amount of $CO_2$ emission. It is because the sewage works in Tokyo are still on the way to improve water environment. The future $CO_2$ increase is estimated in many fields such as incinerated sludge ratio from 93% in 1999 to 100% in 2004. It is because recycling of sludge is based on sludge ash and the landfill site is limited. Moreover, advanced wastewater treatment process needs much energy.

The plan established to attain reduction of 30,000 tons of $CO_2$ by the following four basic targets. In year 2000, the Bureau succeeded to attain 14,000 tons of $CO_2$ reduction compared to the previous year.

1. Increase incineration temperature to reduce Nitrous Oxide gas emission
2. Convert fuel source from heavy or light oil to city gas to lower $CO_2$ emission
3. Promote heat recovery from sewage
4. Improve energy saving by efficient operations

# Table 3 State of $CO_2$ emission in sewage works of Tokyo 1999

| | | Amount in 1999 | $CO_2$ (ton) | $CH_4$ (kg) | $N_2O$ (kg) | $CO_2$ Emission (ton) |
|---|---|---|---|---|---|---|
| Wastewater Treatment | ① Emission by Energy Use | | | | | |
| | Electric for Wastewater Treatment (kWh) | 484,472,871 | 186,038 | | | 186,038 |
| | Electric for Pumping Stations (kWh) | 77,819,569 | 29,883 | | | 29,883 |
| | Electric Pumping Reclaimed Water (kWh) | 5,312,204 | 2,040 | | | 2,040 |
| | Heavy Oil for Wastewater Treatment (kl) | 884 | 2,385 | | | 2,385 |
| | Kerosene for Wastewater Treatment (kl) | 1,312 | 3,317 | | | 3,317 |
| | Light Oil (kl) | 2 | 5 | | | 5 |
| | Propane (m3) | 16,630 | 98 | | | 98 |
| | Automobile gasoline (kl) | 141 | 333 | 292 | 26 | 347 |
| | Automobile light oil (kl) | 21 | 56 | 1 | 3 | 57 |
| | | | | | Subtotal | 224,170 |
| | ② Emission by Treatment Process | | | | | |
| | Amount of Biologically Treated wastewater (m3) | 1,762,217,820 | | 2,199,317 | 329,352 | 148,285 |
| | Subtotal | | | | | 372,455 |
| Sludge Treatment | ① Emission by Energy Use | | | | | |
| | Electric for Sludge Treatment (kWh) | 121,411,020 | 46,622 | | | 46,622 |
| | Electric for the two Sludge Treatment Plants (kWh) | 82,189,868 | 31,561 | | | 31,561 |
| | Electric for sludge cake mixing plant before landfill (kWh) | 966,570 | 371 | | | 371 |
| | Heavy Oil Incinerators (kl) | 9,262 | 24,986 | | | 24,986 |
| | Kerosene Incinerators (kl) | 2,966 | 7,499 | | | 7,499 |
| | City gas (1000m3) | 17,265 | 34,382 | | | 34,382 |
| | | | | | Subtotal | 145,421 |
| | ② Emission by Treatment Process | | | | | |
| | Incinerated Sludge Cake (ton) | 995,818 | | 35,800 | 911,173 | 283,215 |
| | Subtotal | | | | | 428,636 |
| Chemicals Etc. | ③ Emission by Chemical Use and Etc. | | | | | |
| | City Water (m3) | 544,337 | 1,095 | | | 1,095 |
| | Industrial Water (m3) | 49,100 | 5 | | | 5 |
| | SodiumHypochlorite (ton) | 14,333 | 4,601 | | | 4,601 |
| | Polymer (ton) | 926 | 6,050 | | | 6,050 |
| | Lime (ton) | 15,531 | 6,942 | | | 6,942 |
| | Ferric chloride (ton) | 11,064 | 3,518 | | | 3,518 |
| | Caustic soda (ton) | 6,601 | 6,192 | | | 6,192 |
| | Cement for sludge cake land filling (ton) | 5,939 | 4,496 | | | 4,496 |
| | Others (ton) | | 991 | | | 991 |
| | | | | | Subtotal | 33,890 |
| Recovery by Reuse | ④ Amount of Reduction by Utilization | | | | | |
| | Heat recovery from wastewater (kwh) | 18,851,792 | -7239 | | | -7239 |
| | Melted sludge slag (1,000 ton) | 1 | -7 | | | -7 |
| | Sludge Ash Bricks (¥10,000) | 4,515 | -1386 | | | -1386 |
| | Reclaimed Water (m3) | 26,653,502 | -2879 | | | -2879 |
| | | | | | Subtotal | -11511 |
| | | | | | Total | 823,470 |

## STATUS OF RECENT DEVELOPMENT FOR CONTROLLING GREEN HOUSE EFFECT GASES IN WASTEWATER TREATMENT PROCESSES

The first target to reduce $CO_2$ emission was thought to be the emission of Nitrous Oxide from sludge incinerators' exhaust gas as it has been estimated to cover 34% of the total emission according the guiding of JSWA 1999.

Followings are from the extract of research works using existing full-scale facilities.

### (1) Temperature effect on $N_2O$ emission from sludge incinerators

### Method

Infrared analyzer was used to monitor Nitrous Oxide from sludge incinerators' exhaust gas continuously. Monitored incinerators are multi-stage types and fluidized bed ones. Types of sludge cake for the former are lime and polymer and polymer for the latter. Length of monitoring ranged from 6 to 14 days depending to each case.

### Results

**Table 4** shows the variations of the $N_2O$ emission coefficients between two types of incinerators along with types of sludge. The two fluidized-bed types, new and existing one incinerates polymer sludge. The difference is the temperature adopted. The new one is afford to higher temperature incineration. The result shows different value from the guiding 1999 might be obtained depending on the conditions. The variations of the $N_2O$ in exhaust gas are also confirmed as shown in **Fig.1**.

**Table 4 $N_2O$ Emission coefficients of sludge incinerators**

| Type of Incinerator | Days | Average Temperature (℃) | Emission Coefficient (kg-$N_2O$/ton-DS) | Emission Coefficient (1999) |
|---|---|---|---|---|
| Multi-stage (Lime) | 11 | 754 | 3.53 | 1.32 |
| Multi-stage (Polymer) | 8 | 690 | 2.51 | 3.00 |
| Fluidized-bed (Existing) | 6 | 828 | 4.76 | 5.20 |
| Fluidized-bed (New type) | 14 | 838 | 2.74 | |

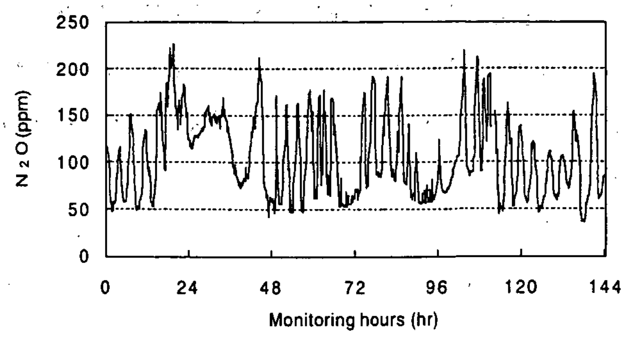


Fig. 1 Nitrous Oxide in exhaust gas from Sludge Incinerator

However, for the fluidized-bed that is adopted to most of the large-scale sludge incinerators today, it is clear from **Fig.2** that higher temperature can reduce $N_2O$ emission remarkably. The figure shows increase of temperature from 820 to 840 can reduce 50% of $N_2O$ emission from exhaust gas. The effectiveness of temperature increase covers the increase of $CO_2$ associated with the fuel to attain higher temperature.

The temperature increase however should not be adopted easily because of safety operation of incinerators. Bureau of Sewerage is going to adopt the higher temperature incineration to the construction of new ones.

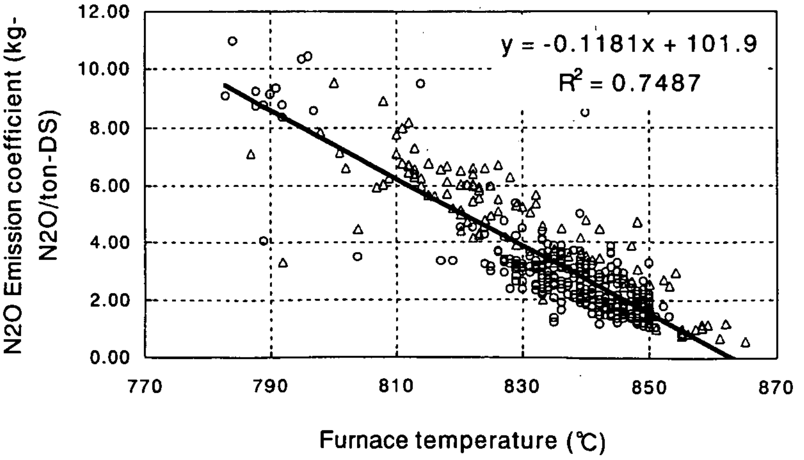


Fig. 2 Furnace temperature and N20 emission coefficient in fluidized bed incinerators

**(2) Installing a new type of battery system to utilize lower emission electricity**

As is well known in electricity, percent of consumed fossil fuel is lower at night-time (254 g-$CO_2$/kWh) than in day-time (354 g-$CO_2$/kWh) as well as in the costs. In 2001, Bureau of Sewerage adopted a full scale NaS battery system to utilize lower emission electricity to a wastewater treatment plant. The new battery, Sodium-Sulfur system has high potential of electric charge efficiency (79%) that 1,000 kW capacity is estimated to reduce $CO_2$ emission by 86 ton per year besides attaining electric cost saving as much as 25 million yen per year.

## SCOPE AND POLICY TO REACH THE GOAL

### Reevaluate emission coefficients for wastewater treatment process

There are however many problems left to reach the goal. One is the lack of actual greenhouse gas emission data that should be the key factor to estimate efficient strategy. The research work as mentioned confirmed incinerator development could reduce most of $N_2O$ emission from sludge treatment process. However, for gas emission from biological process, large-scale variation of $N_2O$ emission was monitored as in **Fig.3** for an example.

Further research showed those variations were caused by those of daily loadings and the influence of stormwater to the treatment plant. New classification as a result is proposed for estimating emission coefficient for wastewater treatment process.

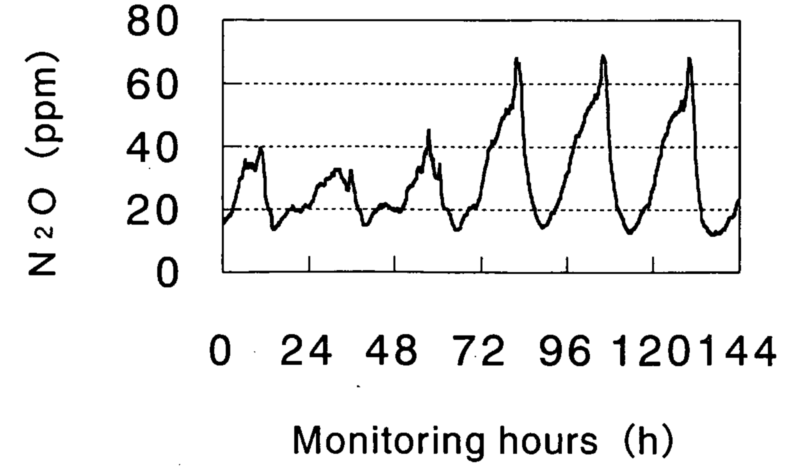


Fig.3 Nitrous Oxide in off-gas from bioreactor

**Table 5** proposes a modification of the guiding of JSWA 1999 to estimate more precise $N_2O$ emission for wastewater treatment process.

So, further planning should be recalculated on these new classification instead of that of the guiding of JSWA 1999.

In common sense, it is natural to assume promotion of better effluent quality and energy savings belong to a trade-off relation. Advanced wastewater treatment process that removes nitrogen by nitrification-denitrification consumes energy of 1.3 times as much as the conventional activated sludge process. However, it can also reduce nitrous oxide gas emission as listed in the **Table 5**.

**Table 5 A new classification of $N_2O$ emission by degree of nitrification**

| Classification | Effluent nitrogen (mg/l) | | | Number of data | Emission coefficient*) | JSWA 1999 |
|---|---|---|---|---|---|---|
| | $NH_4$-N | $NO_2$-N | $NO_3$-N | | | |
| Nitrate-type | Other than below | | | 177 | 0.061 | 0.011 |
| Nitrite-type 1 | — | > 1, ≦ 2 | — | 34 | 0.261 | 0.33 |
| Nitrite-type 2 | — | > 2 | — | 14 | 0.610 | |
| Nitrification-Denitrification | ≦ 1 | ≦ 1 | ≦ 5 | 14 | 0.014 | 0.012 |
| Un-nitrified | > 10 | ≦ 1 | — | 38 | 0.023 | 0.16 |

*Unit of emission co-efficient = g-$N_2O$/$m^3$-wastewater

An example of estimation based on the new emission co-efficient is shown in **Table 6** that indicates advancement of treatment level does not necessarily increase greenhouse effect gas emission. In 1999, the amount of advanced treatment in Tokyo stays around 7.6% of the total treated wastewater. However, the calculation shows the increase of advanced treatment would reduce process emission of greenhouse gas far more than the amount of the associated energy increase.

**Table 6 Effect of Advanced Treatment on Greenhouse Gas Emission**

| | | Ratio of Advanced Treatment | | | |
|---|---|---|---|---|---|
| | | (1999) 7.6% | 10% | 15% | 20% |
| Treatment Process | Wastewater Treatment | 100,527 | 98,661 | 94,772 | 90,882 |
| | Sludge Treatment | 283,215 | 283,215 | 283,215 | 283,215 |
| Energy Use | | 369,591 | 370,900 | 373,629 | 376,357 |
| Chemicals Etc. | | 33,890 | 33,890 | 33,890 | 33,890 |
| Recovery by Reuse | | -11,511 | -11,511 | -11,511 | -11,511 |
| Total $CO_2$ Emission | | 775,712<br>100% | 775,155<br>99.9% | 773,995<br>99.8% | 772,834<br>99.6% |

*Unit: ton-$CO_2$/year

**Environmental management approach**

Those mentioned approach that focuses mainly on the target (Nitrous Oxide) might not achieve the final goal. More systematic and overall management system is really needed to establish energy savings in sewage works.

One solution is the environmental management system (EMS) ISO14001. From 1999 Bureau Sewage started building EMS to each treatment plant and is going to obtain certification for all the organization under the total EMS.

The purpose of the EMS cannot be restricted to the upgrading energy performance of public works to attain the planned value. It also aims to establish public works of more communicative nature to the residents, more sensitive to the environmental change and technological development.

Being a relatively small activity as compared with the global scale, it may contribute a lot more than assumed if everyone understands the seriousness of global climate change. The Bureau of Sewerage will continue to improve both treatment level and greenhouse gas emission to serve people in better environment.

**Reference**

1):**"Guiding of making action plan for controlling greenhouse effect gas emission from sewage works (Japanese),"** Japan Sewage Works Association Aug. 1999