4-1 “Earth Plan 2010” Global Warming Prevention Plan of the Bureau of Sewerage, Tokyo Metropolitan Government

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Abstract

The Bureau of sewerage, prior to the Kyoto protocol, established the global warming prevention plan, "Earth Plan 2004" for the sewage works in September 2004 and have implemented greenhouse gas reduction measures. The result of this is that greenhouse gas emissions in fiscal 2009 were reduced by 16% from the fiscal 1990 level.

The bureau did not settle for this result and in order to further reduce greenhouse gas established “Earth Plan 2010” which took over “Earth Plan 2004” and showed a new path of global warming prevention for the sewage works. By implementing this plan surely, the greenhouse gas emitted by sewage works is to be reduced by 25% from the fiscal 2000 level by fiscal 2020.

Introduction

Japan obeyed the UN Framework convention on climate change (COP15) held in Copenhagen in December 2009 and submitted the goal of reducing greenhouse gas emissions by 25% from the fiscal 1990 by fiscal 2020 on the condition that “all major countries agree fair and effective goal” to the UNFCCC secretariat on the 26th of January in 2010.

Hereafter, looking towards this goal, government agencies, private companies and households inclusive must take measures to prevent global warming in unison.

However, the Tokyo sewerage system consumes a huge amount of energy through treating 5.6 million m³ of sewage a day at water reclamation centres (sewage treatment plants) and incinerating the 3300wet-t of sludge generated by the water treatment process at sludge plants. This electricity consumption was equivalent to around 1% (approx. 1 billion kWh) of the yearly electricity consumption of the Tokyo metropolis, and greenhouse gas emissions (around 856,000t-CO₂) by the bureau of sewerage (hereafter “this bureau”) accounted for about 1.5% of the total metropolis emissions (around 57.8 million t-CO₂) which meant that this bureau had a big responsibility to prevent global warming.

Under these conditions, this bureau established the “Earth Plan 2004” in September 2004, and advanced the reduction of greenhouse gas generated by the sewage works with the introduction and development of technology and other pioneering efforts.
Hereafter, by promoting the enhancement of sewerage functions such as improving treated sewage quality, reducing flood damage or improving the combined sewer overflow, increasing energy consumption has become unavoidable, so reducing greenhouse gas emissions further has become a pressing issue.

Therefore the “Earth Plan 2004” was succeeded by the “Earth Plan 2010” in February 2010 which shows a new path to prevent global warming for the sewage works and takes a leading role in greenhouse gas reduction measures in the metropolis.

**Past Efforts**

The Earth Plan 2004, in order to achieve the goals of the Kyoto protocol, aimed to reduce greenhouse gas emissions by more than 6% (reductions of 188,000 [t-CO$_2$]) from the fiscal 1990 level by fiscal 2009. (fig. 1)

![Figure 1. Earth Plan 2004 image for reductions](image)

As a main reduction measure, we focused on the sludge generated by sewage treatment, and worked aggressively to reduce the nitrous oxide (N$_2$O) generated by incinerating the sludge. N$_2$O, which is 310 times more powerful a greenhouse gas than carbon dioxide (CO$_2$), accounted for 40% of greenhouse gas emissions by this bureau and half of that in Tokyo metropolis. The fact made us the largest generator of N$_2$O in Tokyo metropolis. Regarding this N$_2$O, an original investigation by this bureau found that raising the sludge incineration temperature from 800 to
850°C could reduce N₂O by 70%. So making improvements to a high temperature incinerator and taking actual measures of introducing sludge carbonization furnace which heats sludge with shutting off the air in a high temperature contributed to great N₂O reductions.

Also, in the water treatment process, almost half of the electricity for water treatment was accounted for the reaction tank equipment. We focused on that equipment, and reduced greenhouse gas by introducing micro-bubble diffusers and energy efficient stirrers.

Other ways to reduce greenhouse gas was to utilize renewable energy sources such as small scale hydroelectric generators using the discharge height in water reclamation centres and biomass generators burning digestion gas.

Results and problems in Earth Plan 2004

From the above efforts, the 2009 greenhouse gas emissions were around 856,000 [t-CO₂] which exceeded the target reduction of 956,000 [t-CO₂] by a large margin. A comparison of greenhouse gas emissions in the fiscal 1990 (the base year) and fiscal 2009 is shown in fig. 2.

![Figure 2. Changes in the Bureau of Sewerage’s greenhouse gas emissions](image)

However, an analysis of the Earth Plan 2004 results and content brought to light the following problems in order to reduce greenhouse gas further hereafter.

First, electricity consumption from additional facilities increased due to introduction of
advanced treatment or strengthening countermeasures against flooding, the amount of auxiliary fuel burned in the incinerators increased with the improvement of high temperature sludge incineration, which meant the CO₂ emissions from the electricity and fuel consumption was greater in scale than the reduction measures. Therefore we needed alternate reduction measures necessary.

Second, over 90% of greenhouse gas reductions constituted of N₂O reduction by high temperature sludge incineration and sludge carbonization. Now the high temperature sludge incineration is largely complete, therefore a new reduction method for N₂O reduction is necessary.

Third, around 16% of greenhouse gas emissions (139,000 [t-CO₂]) in fiscal 2009 was accounted for N₂O emissions from water treatment. Now methods for suppressing it were not established, therefore development of technology is needed.

Formulation of Earth Plan 2010

Earth Plan 2010 takes its base year as fiscal 2000, and aims to make cuts of more than 25% (greenhouse gas emissions to under 743,000 [t-CO₂]) by fiscal 2020 and to make cuts of more than 18% (813,000 [t-CO₂]) by the mid-term of fiscal 2014 (fig. 3).

![Figure 3. Earth Plan 2010 greenhouse gas reduction image](image-url)
Through this process, we aim to achieve an advanced urban environment with the smallest environmental impact in the world and to contribute to the “carbon minus Tokyo 10 year project” (25% reductions from 2000 levels by 2020) promoted by Tokyo prefecture.

Also, the “Environmental regulations to secure the health and safety of citizens (Environmental security laws)” reformed to achieve the above project obliges large scale organizations which use the equivalent of more than 1500KL of crude oil annually to reduce carbon dioxide (CO₂). All of the water reclamation centres and part of the pumping stations, a total of 24 operation centres controlled by this bureau fall under these regulations, and are obliged to cut CO₂ by an average of 6% a year for the 5 year period of 2010-14.

**The current state of this bureau’s greenhouse gas emissions**

Sorting this bureau’s fiscal 2009 greenhouse gas emissions by source, as shown in fig. 4, can be classed into the following 3 groups.

![Figure 4. Breakdown of the Bureau of Sewerage’s greenhouse gas emissions (FY 2009)](image)

**Overall emissions: 856,000t-CO₂**

1. **CO₂ emissions by electricity consumption during water treatment and sludge treatment**

   Electricity used by equipment for water treatment such as pumps and blowers, and electricity used by equipment for sludge treatment such as dewatering machines, thickeners and incinerators accounts for around 44% of total emissions.
(2) N₂O emissions from water treatment and sludge incineration

Nitrous oxide (N₂O) is a powerful (310 times) greenhouse gas, and these emissions are generated through the action of microorganisms in the reactors of the sewage treatment process or from the incineration of sludge. N₂O emissions from water treatment and sludge incineration account for around 44% of total emissions.

(3) CO₂ emissions from fuel or chemical consumption

The greenhouse gases from auxiliary fuel for sludge incineration, the fuel used in back-up generators and from chemicals used for disinfection in water treatment or for concentrating or dewatering sludge. CO₂ emissions from fuel or chemical consumption account for around 12% of total emissions.

Furthermore, half of that, around 50,000t-CO₂, accounts for auxiliary fuel required for sludge incineration and the like.

Basic policies of Earth Plan 2010

The Earth Plan 2010, built on the success of Earth Plan 2004 and in consideration of future greenhouse gas emissions, has initiatives for cutting greenhouse gas with the following strategies as its pillars.

(1) We will take intensive measures during the plan period to accelerate implementation and realize reduction as soon as possible.

(2) We will pioneer the introduction of up-to-date technologies to further enhance the reduction effect.

(3) We will take various measures to reduce greenhouse gas emissions and enhance sewerage functions, including countermeasures against flooding, improvement of combined sewer overflow, and promotion of advanced treatment.

New measures in Earth Plan 2010

Based on these strategies, in solving the issues of greenhouse gas reduction, the measures are classified as follows to give specific reduction measures. Here several example measures are introduced.

(1) Promote exhaustive energy-saving efforts

In sewage treatment facilities, we will further reduce electricity consumption for blowers and stirrers by introducing micro-bubble diffusers and energy efficient stirrers, continuing from conventional measures.

Also, in sludge treatment facilities, greenhouse gas reduction is promoted through the new introduction of energy efficient thickener and dewatering equipment which can reduce electricity and chemical consumption, as well as conventional measures such as changing the incinerator auxiliary fuel from heavy oil to city gas.

(2) Overview of the treatment process/method

In addition to introduce individual equipment such as energy efficient equipment, by optimizing or changing the layout of equipment in consideration of the entire water/sludge
treatment processes, the system as a whole can become energy efficient and further reduce greenhouse gases.

Also, by changing the combustion method in sludge incinerators, the N₂O generated from the incinerator can be suppressed and the CO₂ generated from consumption of fuel or electricity can be reduced.

A. Optimization of the aeration system

When reconstructing the reaction tanks, the blowers and aeration equipment is simultaneously upgraded, and optimizing the airflow in the reaction tanks has the following greenhouse gas reduction effects. (fig 5)

By introducing micro-bubble diffusers, the bubbles are finer than the conventional method and increase the surface area in contact with mixed liquor in reaction tanks. Furthermore by installing the diffusers at depth in deep water, long contact periods with mixed liquor can be maintained. From the above, improvement of oxygen dissolving rate (percentage of oxygen dissolved in mixed liquor) reduces the airflow volume.

By installing small size blowers near the reaction tanks which provide the necessary airflow for each tank, blower pressure and airflow volume can be optimized and the loss of blowing air can be reduced compared with conventional measures.

Figure 5. Aeration system
B. Unitization of sludge treatment
As well as upgrading the sludge incinerators, by newly installing dewatering equipment near the incinerators, the following greenhouse gas reduction effects are attained (fig. 6).

**Figure 6. Unitization of sludge treatment**

By introducing energy efficient dewatering equipment, electricity and chemical consumption can be reduced.
By shortening the transportation distance of dewatered sludge, the electricity required to move the sludge with lower water content is decreased.
Incinerating sludge with lower water content makes the sludge itself easier to combust and reduces auxiliary fuel for the incinerator.

C. Introducing sludge incinerators with new combustion methods
When reforming incinerators which emitted large greenhouse gas or is dilapidated, the second generation incinerators (multilayered and turbo style) are being introduced. These incinerators can reduce not only N₂O by around 50%, but also CO₂ emissions by around 20% by reducing electricity and auxiliary fuel consumption compared to high-temperature sludge incineration (850°C).
Figure 7-1 shows one of these second generation incinerators, a multi-layer liquid incinerator. This multi-layer liquid incinerator can be introduced by improving existing incinerators.
By lowering the amount of combustion air blown into the low levels of the furnace, the
N₂O generation can be suppressed. In addition, by newly blowing combustion air into the mid-level, the high temperature state and gas holding time is maintained which improves the dissociation of N₂O and suppresses N₂O emissions. Furthermore, by improving combustion within the furnace, the amount of auxiliary fuel consumption can be reduced which means CO₂ is also reduced. Already, the Nanbu Sludge plant No. 3 incinerator (300t incinerator) had been converted to multi-layer liquid incinerator in June 2009, now the Shingashi water reclamation centre No. 4 incinerator (300t incinerator) is being converted too.

Figure 7-2 shows another second generation incinerator, a turbo liquid incinerator. A turbo liquid incinerator burns sludge at pressures of around 0.15MPa, and exhaust gas generated from the incinerator drives a turbo charger to get compressed air. Therefore some blowers become unnecessary and the electricity for driving blowers can be reduced. Furthermore, as combustion speed increases under pressure, the furnace itself is smaller. As a result, the incinerator becomes more compact because heat radiation from the furnace is less. In addition, the amount of auxiliary fuel consumption can be reduced compared to a high-temperature incinerator.

Also, as temperatures in the incinerator reach higher temperature ranges (about 870°C) than those of conventional incinerators, N₂O dissociation is promoted and N₂O emissions can be efficiently suppressed.
Currently, construction is under way at the Kasai water reclamation centre aiming for operation to begin in April 2014.

(3) Use of unused or renewable energy

In order to achieve the goal of Earth Plan 2010, it is necessary to take run further effective additional measures as well as making reductions through equipment upgrades by introducing energy efficient equipment. In order to achieve this, greenhouse gases must be reduced by utilizing unused or renewable energy held by this bureau.

A. Introducing solar power

In April 2010, new solar equipment, which was developed to improve electricity generation efficiency, was fully introduced to the Kasai water reclamation centre. This equipment is a “single-axis tracking” type (290kW) which combines ultra-thin solar cells on panels rotating to face the sun. Utilization on this scale is the first of its kind in Japan (fig.8). We can have the necessary workspace for facility inspections etc by making use of the vertically arranged panels (a feature of single-axis tracking) installed on the roof of the water treatment facility.

Also, “fixed” type panels are installed in the vicinity of the water treatment facility, effectively utilizing space in the whole facility. In 2010, around 630,000kWh was generated which exceeds the planned yearly electric-generating capacity (590,000kWh) and reduced
greenhouse gas emissions by around 240[t-CO₂].

B. Introduction of sludge carbonization furnaces

In November 2007, sludge carbonization furnace began operation at the Tobu sludge plant. That equipment produces carbon fuels by baking sludge at about 600°C under low oxygen or anaerobic conditions. By burning at high temperatures the pyrolysis gases which include nitrogen generated by the carbonizing process, it is possible to greatly reduce N₂O emissions. Greenhouse gas emissions of carbonization furnace are reduced by around 50% compared with high-temperature sludge incinerators (850°C furnaces).

Also, carbonized sludge which is a source of biomass, have 1/3rd the calorific value of general coal, and by using this as an alternative to coal in thermal power station, contributes to improving the sludge recycling rate.

In 2013, the Tobu sludge plant plans on opening its second sludge carbonization furnace in order to further reduce greenhouse gas emissions.
C. Introduction of sludge gas furnaces

The sludge gas furnace at the Kiyose water reclamation centre began operation in July 2010 which has higher baking temperature in the furnace than that in a sludge carbonization furnace and by making all heat included in the sewage sludge into gas, can greatly reduce N₂O (fig. 10).

![Figure 9. Sludge carbide furnace](image)

**Figure 9. Sludge carbide furnace**

![Figure 10. Sludge gas furnace](image)

**Figure 10. Sludge gas furnace**
The generated gas is not only used as the necessary heat source for drying sludge by burning it in a heat recycling furnace. By reforming and purifying the gas at around 1000°C it can be used as fuel for a gas engine to drive an electricity generator. The generated electricity is effectively used as part of the electricity needed to drive the gas furnace which goes towards reducing CO₂ emissions.

The gas furnace can cut greenhouse gas emissions by around 70% compared to a high temperature (850°C) sludge incinerator.

(4) Technological developments

To continuously reduce greenhouse gases from now on, in addition to the current measures, making technical developments in consideration for effective reduction of greenhouse gas in the treatment process in the light of mid- and long-term is important.

Especially, with regard to N₂O generated by the water treatment process, which is a large emission source of greenhouse gases from this bureau, there is still room for reducing greenhouse gas from the 139,000[t-CO₂]. To do this, this bureau developed a device to continuously measure N₂O generated from water treatment and applied it from 2010.

By using this device, currently, we understand the N₂O emissions generated from each treatment method and investigate/verify fluctuation etc in the N₂O emissions from operation methods. Then we continue to investigate in order to establish technology for suppressing N₂O generation, such as making some kinds of efforts in the water treatment process.

![Control of N₂O generated in the water treatment process with new technologies](image)

The cause of N₂O generation in the reaction tank is unknown

Measures to find the cause and a control method

Figure 11 N₂O emissions and control from the water treatment process
(5) Customer Communication

Earth Plan 2010 asks customers to install stormwater infiltration inlet within residential areas. It is new activities. With the spread of stormwater infiltration inlet, stormwater infiltrates underground and reduces the amount of rain water flowing into the sewer facilities. From this, 160m$^3$ of stormwater infiltrates the ground per household during one year. By this reduction, the electricity of pumping up stormwater etc is decreased. As a result, we can reduce greenhouse gas by around 70kg-CO$_2$ (calculation in case of 120m$^2$ residential area).

Conclusion

This bureau will promote and speed up measures in the Earth Plan 2010 in order to achieve the goal of reducing greenhouse gas emissions by 25% by fiscal 2020 from the fiscal 2000 level.

Hereafter, we will try to reduce greenhouse gas emissions further by introducing new ideas and new technology actively. At the same time, we will promote various measures comprehensively in order to satisfy both of improving sewer functionality (countermeasures against flooding, improvement of combined sewerage systems, and promotion of advanced treatment etc) and preventing global warming. And we will construct a sustainable society and inherit a comfortable world environment for the next generation.

Furthermore, the greenhouse gas reduction technology of the sewage works is leading age in the world. Therefore we will try to contribute worldwide by spreading “Tokyo’s greenhouse gas reduction technology.”