4-1-2 Sludge Transportation Pipe Network utilized for Risk Management of Sludge Treatment

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Abstract
The Bureau of Sewerage have dewatered and incinerated sludge at 6 Sludge Treatment Plants to promote the reduction of sludge and the recycling of incineration ash by consolidating sludge from 13 Water Reclamation Center (hereinafter WRC) through the use of a “Sludge Transportation Pipe Network” in the 23wards of Tokyo. The consolidation of sludge enables efficient sludge treatment that takes advantage of scale, but fatal sludge transportation pipe failures or equipment failures due to disaster may make adversely affect sewerage treatment at related WRCs. To avoid it, we have strengthened risk management by establishing the backup system that transfer sludge to other facilities can treat sludge, utilizing the sludge transportation pipe network, and treat it.

Keywords
Risk Management, Sludge Treatment, Sludge Transportation

INTRODUCTION
Sewerage is treated 24 hours a day, every day in water reclamation center (hereinafter WRC) in the 23wards of Tokyo. It is a key how to stably treat the sludge while at the same time ensuring the water quality of both sewerage and public water bodies.

In the 23 wards of Tokyo, percentage of population served by sewerage collection has reached almost 100% in 1995. Our 13 WRCs treat 4.58 million m$^3$ of sewage per day and generate 2.5 thousand wet-t dewatered sludge. However, Bureau of Sewerage, Tokyo Metropolitan Government don’t have enough space to construct a new disposal site in Tokyo Bay. Therefore, we need to extend the life of the present site. To extend sludge disposal site life, our bureau have established a total incineration system for the whole amount in 2003, thereby active promoting the reduction of sludge and the recycling of incineration ash.

13 WRCs transfer sludge to 6 sludge plants (hereinafter SP) through the use of a sludge transportation pipe network in the 23wards of Tokyo. 6 SPs dewatered and incinerated sludge consolidated. (See Figure 1) The total network of pipes encompasses about 93 km.

**Figure 1. Systematic diagram of current sludge treatment**

13 WRCs transfer sludge to 6 sludge plants (hereinafter SP) through the use of a sludge transportation pipe network in the 23wards of Tokyo. 6 SPs dewatered and incinerated sludge consolidated. (See Figure 1) The total network of pipes encompasses about 93 km.
Consolidation of sludge enables efficient sludge treatment that takes advantage of scale. As a result, we can cut maintenance and operation cost (employment cost and energy bill). On the other hand, if WRCs can’t transfer sludge to SPs by fatal sludge transportation pipe failures or equipment failures due to disaster, they can’t treat primary sludge and waste sludge. WRCs are forced to store sludge in sedimentation tank. It affects final effluent quality. In the worst-case, effluent quality may exceed the reference standard.

In fact, in the Great East Japan Earthquake on March 11 2011, Tobu SP couldn’t use all incinerators because it couldn’t receive supply of treated sewage from Sunamachi WRC adjacent Tobu SP due to water treatment equipment failure in the 23wards of Tokyo. As a result, Tobu SP had to stop treating sludge consolidated from 6 WRCs. 6 WRCs lost sludge transportation route had to store sludge in themselves.

Thus, in order to avoid the declining whole sewerage treatment capacity linked with such unexpected decline sludge treatment capacity, it is necessary to establish the system to maintain constant treatment of sludge in unexpected emergencies. In particular, for sludge treatment, our bureau have strengthened risk management by establishing a backup system that enables sludge transfer to, and treat at other SPs, utilizing the sludge transportation pipe network.

METHODS OF STRENGTHENING RISK MANAGEMENT

In the 23wards of Tokyo, Bureau of Sewerage have made responses in tangible and intangible aspects as follows, based on the experiences of the Great East Japan Earthquake and of its responses to sludge transportation pipe emergencies.

Tangible measures

1. Promotion of earthquake-proof about transportation pipes and sludge facilities
   Part of transportation sludge pipes laid have exceeded useful life (50 years) and gotten older. Therefore, we are reconstructing the old sludge transportation pipes and working on improvement reliability. Sludge transportation pipes have laid under the ground directly up until now. In reconstruction, we lay them in pipe gallery constructed by shield tunnelling method. We improve pipe maintenance by setting up check and work spaces in pipe gallery. In particular, we prioritize reconstruction of pipeline that has already exceeded useful life. The area where daily check is difficult because of direct pipes laying under the ground was also prioritized.

   In addition, we work on earthquake-proof sludge facilities. Incinerators use flammable gas which have risk to bring on secondary disaster when it is damaged. To prevent gas leakage, incinerators are needed to take measures to prevent an equipment over-turning. Furthermore, we set seismometers in incinerators. If a big earthquake occurs, incinerators can be emergency stopped in conjunction with seismometers.

2. Duplication sludge transportation pipes
   We are duplicating all sludge transportation pipes basically. When sludge transportation pipes in use are damaged, we switch the pipeline to the other pipeline and continue transferring sludge.

3. Establishment of the sludge transportation pipe network
   We are establishing sludge transportation pumps and sludge storage tanks to be able to transfer sludge to each SP, sludge transportation pipes. If we can’t continue to transfer it due to sludge transportation pipe failures or equipment failures, we switch sludge transportation routes or sludge transportation direction. In addition, we are doing the following approaches as part of establishment of the sludge transportation pipe network.
a. Establishment of mutual sludge transportation between WRCs (See Figure 2)

![Flow diagram about transportation sludge equipment](image)

*Figure 2. Flow diagram about transportation sludge equipment*

We are constructing the equipment to be able to transfer sludge mutually between WRCs which usually transfer sludge to different SPs. We are progressing to set equipment between Miyagi WRC and Kosuge WRC and between Tobu SP and Kasai WRC now. By enabling mutual sludge transportation, the number of sludge transportation routes can increase. It makes us possible to respond flexibly when sludge transportation pipe failures or equipment failures are occurred. Up until now, one-way sludge transportation pipes have been laid. However, by being branched a new pipe from the existing head pipe and connecting new pipe to receiving pipe from another WRC, we can transfer sludge mutually by the existing transportation pump.

b. Construction the sludge treatment “key station”

We will rebuilt Miyagi WRC which stands inland area as sludge treatment key station for controlling sludge transportation volume between WRCs, efficient operation in normal time and backup in emergency. We decide to rebuild Miyagi WRC as the key station because it is at the center of the sludge transportation pipe network.

**Intangible measures**

1. **Making an implementation outline**

   We made an implementation outlines about sludge transportation between WRC and SP and between WRCs. In the outline, basic point about operation at the time of sludge transportation and how to respond in the case of emergency need to stop or begin transferring sludge urgently are set in.

2. **Improvement of the risk management and respond ability**

   We switch of sludge transportation pipes and drills for risk management routinely based on the implementation outlines. In addition, we test water transportation routinely. We confirm operation of sludge transportation pump and valve, flow in upstream WRC and downstream WRC whether there is any problem (e.g. leakage on a sludge transfer pipe) in the test. Their approaches make staff members improve their operation skill and the risk management. It enables us to respond rapidly in emergency.

3. **Establishment of the centralized management system of operating information about our sludge treatment**

   Currently, not only the sections transfer sludge or receive sludge but also the sections have jurisdiction over the area which sludge transportation pipeline pass through have mutual contact
system. At the time of switch of sludge transportation pipe or sludge transportation route, we spend a lot of time to contact and coordinate.
We have already controlled the information about sludge transportation volume and pressure by existing information system in the whole our bureau. By fulfilling the system and establishing centralized management system, we will be able to switch pipeline and detect the troubles about the sludge transportation facilities rapidly, and strengthen risk management.

METHODS AND APPROACHES FOR RISK MANAGEMENT

Our response procedure in cases sludge can’t be transferred due to sludge transportation equipment failures, and the drill for risk management are as follows.

Response procedure in WRC in the case of sludge transportation pipe failures
When we can’t transfer sludge due to sludge transportation pipe failures or decline treatment capacity in SP, we respond as follows;

1. If the damaged sludge transportation pipeline has already duplicated;
We switch from the damaged pipeline to the backup pipeline at upstream WRC.

2. If sludge transportation route can’t be used because of damaged pipes;
(Sludge transportation pipeline has not been duplicated or already duplicated but main sludge transportation pipeline can’t be used because of under construction)
   a. Decrease of transportation sludge volume in upstream WRC
      Because we can’t transfer sludge from the upstream WRC to the downstream WRC or SP, we store sludge temporarily at the upstream WRC to decrease sludge transportation volume. We store sludge as follows; (a) sludge storage tank, (b) primary sedimentation tank and final sedimentation tank by stopping removing sludge from the tanks, (c) storm water storage tank. Our bureau have already grasped about the number of storable days and storable place, and prioritize storage place. If WRC have to stop transferring sludge, we store sludge based on the priority.

   b. Switch sludge transportation routes
      If the sludge store time lengthened and it may affect final effluent quality, we check treatment condition of other SPs. After checking, we switch the sludge transportation routes and begin to transfer sludge to other SP. Afterward, we check sludge transportation pipe whether there is any problem (e.g. leakage on a sludge transfer pipes).

   c. Increase treatment volume of the other SPs
      After switching the routes, the other SPs treat more sludge than usual. We start up incinerator additionally as needed.

   d. Carry out dewatered sludge to other SPs by a track
      We put sludge exceeding process capacity at the acceptable SPs on a box track, and carried to the other acceptable SPs after dewatered and spraying deodorants. After arrival at the other SPs, we throw into dewatered sludge receiving hopper and burn it.

   e. Landfill dewatered sludge urgently at disposal site
      Sludge exceeding process capacity in acceptable SPs is carried to the disposal site and landfilled after being dewatered. Although, we did odor control by spraying deodorant before we transport as with d.
3. If sludge transportation route can be used but the capacity of the SPs as destination is declined temporarily;
   a. Suppression transportation sludge volume from upstream WRC
   The sludge is stored temporarily to decrease transportation sludge volume for suppression a load to downstream WRC as with 2.

After we finished a., we carry out from b. to e. are done as with 2.

Drill for risk management
Bureau of sewerage conduct the drills for risk management once a year to improve the operation skill and an consciousness of the risk management. In the drill, WRCs and the section which manage the whole sludge treatment in the 23wards of Tokyo (hereinafter facilities management section) participate in. We confirm the methods to conduct sludge transportation volume, the methods to consider and decide about switching sludge transportation route or direction, and communication system. The sections which maintenance sludge transportation pipes (hereinafter pipeline maintenance section) participated in, too. They confirm the methods about emergency restoration at accident location, the methods to check pipe when the upstream WRC switch sludge transportation route and communication system. (See Figure 3) Actually, we can’t complete to respond about transfer sludge in a short time. Because of limit of time for drill, we extract scenes which need drill and conduct it.

Figure 3. The drill for risk management and response in 2015

Through the drill, our bureau prepare to respond rapidly in emergency by sharing the information between related sections and confirming following 1. to 4.
1. The procedure for stopping sludge transportation, switching route, restarting sludge transportation and communication system.
2. The possession situation of emergency repair material and equipment of pipeline maintenance sections and sewerage maintenance cooperation.
3. The methods of operation valves, checking procedure and division of the roles during emergency repair.
4. The procedure of response at upstream WRC when downstream WRC is in an emergency.

THE EXAMPLES OF RISK MANAGEMENT UTILIZING THE SLUDGE TRANSPORTATION PIPE NETWORK

CASE1. The case of response when the sludge treatment capacity declined due to earthquake
We could not treat sludge due to the Great East Japan Earthquake on March 11 2011 at a part of SPs. Under such situation, we responded against this problem as follows;
1. Damage overview

Tobu SP in Tokyo bay area consolidates sludge from 6 WRCs (Nakano, Ochiai, Mikawashima, Miyagi, Sunamachi, Ariake) and treats them. At Tobu SP, we use the treated sewage receiving from Sunamachi WRC which is adjacent the Tobu SP to clean flue gas from the incinerators. Although, at Sunamachi WRC, the collectors in sedimentation tanks ran off and were damaged due to the earthquake. It made Sunamachi WRC be impossible to treat sewage and transfer treated water to Tobu SP. As a result, Tobu SP couldn’t operate incinerators and treat sludge. In addition, expansion joint of waste gas duct was cracked due to earthquake in Tobu SP. (See Figure 4)

![Cracked expansion joint of waste gas duct](image)

2. Response details

(The aftermath of the earthquake)

We asked manufacturer to repair equipment urgently at Sunamachi WRC and Tobu SP. Secondly, Miyagi WRC started up the incinerator urgently and started to burn sludge in upstream WRCs because full repair for equipment in Tobu SP might be needed to take a long time. Mikawashima WRC couldn’t transfer sludge, so stored it in the center. Sunamachi WRC transferred sludge generated in the sewerage treatment line where we could treat sewage but could not transfer treated sewage to Tobu SP, and stored it in storage tank in Tobu SP.

(7 days later)

Part of water treatment capacity of Sunamachi WRC was recovered. Because Sunamachi WRC could supply treated sewage to Tobu SP, Tobu SP could treat sludge within small volume. Therefore, Mikawashima WRC restarted to transfer sludge to Tobu SP. However, sludge transportation volume was limited.

(13 days later)

Miyagi WRC had treated sludge beyond the conventional capability after starting to burn sludge consolidated from upstream WRCs. However, sludge volume increased due to the first rain after the earthquake. Then, the capacities of sludge storage in sludge storage tank, primary sedimentation tank and final sedimentation tank were close to its limit. Consequently, the facilities management section decided to switch sludge transportation route as follows;

Before: Miyagi WRC - Mikawashima WRC – Tobu SP
After: Miyagi WRC – Kosuge WRC – Kasai WRC

By switching sludge transportation routes, we could ensure sludge treatment capacity throughout sludge transportation pipe network.

(40 days later)

The sludge receiving system was recovered at Tobu SP. Miyagi WRC switched sludge transportation route to regular route, and restarted to transfer sludge from Miyagi WRC to Tobu SP.
Mikawashima WRC brought sludge transportation volume back to normal.

Thanks to equipment manufacturer’s support, we could recover sewage treatment capacity early in the Great East Japan Earthquake. However, the earthquake affected sewage treatment capacity seriously. It made us take a long time to recover to sludge transfer situation before the earthquake. In particular, Mikawashima WRC was forced to stop transferring sludge to SPs for a long time. By transferring sludge to storage tank temporary and returning overflowed sludge from storage tank to the sewer main, Mikawashima WRC could ensure sewage treatment capacity with continuing to suppress sludge transportation. In addition, Mikawashima WRC has some sewage treatment lines and transferred waste sludge from the line which water quality got worse to the line which water quality was not comparatively worse. The effort enabled Mikawashima WRC to clear final effluent quality standard. Even in the bad situation like this case, thanks to flexible and careful operation by all staff members in Mikawashima WRC, water quality was suppressed worse. With this trouble, our bureau realized again that we need to strengthen our risk management.

In addition, the cause of incinerator’s stoppage was that there was only one line to supply treated water to incinerators. To solve the problem, our bureau duplicated treated supply line immediately after the earthquake.

CASE2. The case of response when one sludge transportation pipe damaged and the other was under construction

We could not treat sludge due to sludge transportation pipe failures between WRCs in 2013. Under such situation, we responded against this problem as follows;

1. Damage overview
Two pipelines are laid between Mikawashima WRC and Tobu SP. In this case, one of sludge transportation pipeline was out of service due to construction works. Under such situation, the valve of the other pipeline was in service was broken, and the leakage accident occurred. (see Figure.5)

2. Response details
(The aftermath of the accident)
First, Mikawashima WRC stopped transferring sludge to Tobu SP immediately based on the implementation outline. Secondly, facilities management section decided to switch sludge transportation routes to backup route as follows;
Before: Miyagi WRC - Mikawashima WRC – Tobu SP
After: Miyagi WRC – Kosuge WRC – Kasai WRC
By switching routes, we could treat sludge consolidated from 3 upstream WRCs temporarily with controlling sludge transportation volume in Kasai WRC. In parallel with switching routes, we decided to repair of the pipeline was under construction.

Figure5 Sludge transfer in an emergency situation
(1 day later)  
We checked pipe damage condition and started emergency repair the pipe which was under construction in the morning. During repair work, we stopped sludge transportation between Miyagi WRC and Mikawashima WRC. After being stopped sludge transportation, we flashed inside pipeline to prevent sludge from decaying. Before starting sludge transportation, we tested water transportation between Miyagi WRC and Kosuge WRC with checking pipeline condition. After checking whether there is air and water leak, we started transferring sludge. In the evening, we finished repairing sludge transportation. However, sludge transportation volume from Nakano WRC and Ochiai WRC to Kosuge WRC, and from Nakagawa WRC to Kosuge WRC was about 80% of usual. On the other hand, we finished the pipe emergency restart was under construction.

(2 days later)  
We tested water transportation between Mikawashima WRC and Tobu SP with checking pipe condition by pipeline maintenance section. After checking whether there is no trouble, we restarted transferring sludge.

(1 week later)  
We repaired air leak valve damaged in the accident. After repairing the valve, we switched sludge transportation route to usual route. Pipeline maintenance section checked whether there is no trouble, we completed accident response. As in this case, by communication and coordination with related sections based on the implementation outline, and switching to the backup routes, we could restart to treat sludge at upstream WRCs next day after the accident.

If WRC becomes to be difficult to transfer sludge, the sludge is circulated and pooled in sedimentation tank. It may make the effluent quality deteriorate with the risk of exceeding the effluent standard. In particular, accidents related to pipe have occurred twice a year in the 23wards of Tokyo. By taking measures in a previous describe and drill for risk management routinely, we could respond quickly in cooperation and minimize influence to upstream WRCs.

CONCLUSIONS  
Bureau of Sewerage, Tokyo Metropolitan Government can deal with the unexpected situation rapidly and keep sewerage treatment stably by implementing tangible measures and intangible measures as previous describes.

However, tangible measures are underway in one of area to complete measures now. (Establishment of mutual sludge transportation equipment, reconstruction of old sludge transportation pipe etc.) Our bureau will continue to promote a comprehensive sludge transportation pipe network to secure backup functions, and strive to strengthen our risk management system. On the other hand, we continue to strive to further strengthen our risk management system by analysing the response in emergency and accumulating the knowhow as the intangible measures.

By enrichment both tangible measures and intangible measures, we improve reliability of sludge treatment and ensure stability of sludge treatment over the future.

REFERENCE  