UPGRADING OF XIAOHONGMEN WWTP TO THE FIRST CAMBI ADVANCED ANAEROBIC DIGESTION PROJECT IN BEIJING—DESIGN, CONSTRUCTION AND COMMISSIONING

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Abstract

In this paper, we describe the strategy formulation of sludge treatment in Beijing Drainage Group with “1-5-1” symbol: 1-one main technological solution with Thermal Hydrolysis Advanced Digestion, 5-five large scale sludge projects, and 1-one disposal solution with biosolids for land application. As one of the first projects implemented for upgrading, Xiaohongmen WWTP has upgraded the existing traditional sludge digestion with five egg-shaped digesters into Thermal Hydrolysis Advanced Digestion based on pre-dewatering of both primary sludge and secondary sludge, CambiTHP® system, upgrading of existing egg-shaped digesters, installation of chamber filter presses, and reject water treatment with ReNoCar® deammonification process developed by Beijing Drainage Group. This paper is focusing on the main design issues for Xiaohongmen sludge treatment, the construction procedure, and the primary results of commissioning since 18 July 2016.

Keywords

Advanced Digestion, Biogas Utilization, Biosolids, Chamber Filter Press, Commissioning, Egg-shaped Digesters, Land Application, Sewage Sludge, Thermal Hydrolysis, Xiaohongmen WWTP.

Introduction

In 2014 Beijing Drainage Group took a great action to upgrade and expand existing WWTPs to “Water Reclamation Plants” to treat 4.13 million m³ wastewater per day in Beijing Downtown area. As part of this action plan, five sludge projects, Gaobeidian in the eastern area, Xiaohongmen in the southern area, Qinhge II in the northern area, Huaifang in the southwest area, and Gaoantun in the northeast area, will be constructed with Advanced Anaerobic Digestion with CambiTHP® as pre-treatment until 2017 to treat approximately 6100 t/d wet sludge at 20% dry solids (DS), corresponding to 1200 tDS/d. The five projects will treat sludge from 13 WWTPs in Beijing Downtown area, as shown in the Figure 1. The projects’ design includes sludge production increase when all existing plants will be upgraded to water reclamation level with tertiary treatment, so the current status of sludge production is somewhat lower than the numbers shown above.

In the “Three Years Action” for solving sludge treatment and disposal issue in Beijing, a profound feasibility study was carried out to analyse various combination of different treatment processes. In the end the study concluded to conduct sludge treatment and disposal as follows:
1. All sludge must be treated by anaerobic digestion with a well-documented pre-treatment Thermal Hydrolysis Process to largely enhance the efficiency in digestion process and the conversion of organic matter to biogas.

2. All final cake as biosolids must meet Class A type quality for potential land application with national requirement for DS content no less than 40%DS. Thermal hydrolysis as pre-treatment of all sludge before digestion was evaluated to meet these requirements.

3. Biogas to Combined Heat and Power to electricity with the waste heat to facilitate steam supply for Thermal Hydrolysis Process.

4. Extensive potential of biosolids to land application has been evaluated and supported by Beijing local government.

5. Reject water rich in ammonia shall be treated by the ReNoCar® deammonification process developed by and proven in full scale application by Beijing Drainage Group.

Figure 1: Dewatered sludge (@20%DS as a calculation basis from 13 existing (blue bars) and new WWTPs (red))

The five projects are located in various areas as shown in Figure 2.

Figure 2: Location of five sludge projects in Beijing

A strategic cooperation between Cambi and Beijing Drainage Group (with Beijing Drainage Construction as designated cooperation partner) was initiated in August 2014. After contracts were signed at the end of 2014 and early 2015, design and construction started up for the five sludge projects in Xiaohongmen, Gaobeidian, Huafang, Qinghe II, and Gaoantun. Xiaohongmen is in commissioning, Gaobeidian has finished construction and, the other three are under construction. As...
the first Cambi installation, Xiaohongmen WWTP has been upgraded with three lines of B12-5 CambiTHP® Thermal Hydrolysis System and a series of upgrades and new installation for the existing five egg-shaped Digesters.

To implement the first Cambi projects in China a strong cooperation team was set up including Beijing Drainage Construction Company as EPC contractor, Purac China as the main process integration, Beijing Municipal Engineering Design Institute as Consultant, and Cambi as THP supplier. The first project, Xiaohongmen, started ramping up on 18 July 2016 with the newly installed pre-dewatering, silos, THP, and upgrading of existing five egg-shaped digesters, together with final filter press dewatering. In addition, the ReNoCar® deammonification process developed by Beijing Drainage Group for reject water treatment is also under start-up.

**Xiaohongmen WWTP**

Xiaohongmen WWTP was first built up and put in operation in Nov 2005. The design capacity was then 600,000 m3/d mainly using the typical AAO (Anaerobic - Anoxic – Oxic) biological processes. The plant has just been upgraded to achieve wastewater reclamation effluent standard required by Beijing’s local government in order to recycle effluent partially to reuse and partially to refill local water bodies. Fig. 3 shows a Google map layout of Xiaohongmen after upgrading both in tertiary treatment and sludge treatment.

![A Google Map layout of Xiaohongmen WWTP after upgrading in 2016](image)

**Figure 3:** A Google Map layout of Xiaohongmen WWTP after upgrading in 2016

As shown in Figure 3, the whole plant is divided into four functional zones for biological wastewater treatment with primary settlers, AAOs, and clarifiers; for tertiary treatment; for sludge treatment; and for offices and labs.

The original flow sheet for sludge treatment prior to the upgrade is shown in Figure 4. Both primary sludge - PS (60 t DS/d) and biological / waste activated sludge - WAS (60 t DS/d) were thickened and fed into digestion, then dewatered by centrifuges to disposal. The flow diagram was later modified from the original, with no WAS to digesters, but only PS at 90 t DS/d was digested in the five egg-
shaped digesters. This indicated that the original design of 60 t DS/d for PS in real operation increased to 90 t DS/d.

The five egg-shaped digesters at a total of 60,000 m³ effective volume were operated at 36 °C. The digesters were fed with only 4% DS concentration.

The five egg-shaped digesters are among the biggest digesters in Asia, each with 12,300 m³ total volume. The total height is approx. 46 m, effective water depth 40 m and the widest diameter 27 m. Figure 5 shows a view of the egg-shaped digesters at Xiaohongmen.

![Diagram of sludge treatment process](image-url)

**Figure 4:** The original (top) and actual (down) flow diagrams of sludge treatment before upgrading.
Advanced Anaerobic Digestion for upgrading

After thorough evaluation, the client chose thermal hydrolysis advanced anaerobic digestion to upgrade the existing sludge treatment with the following main parts:

1. Existing and additional thickening and pre-dewatering required to achieve 16.5% DS before feeding into CambiTHP® system.
2. New CambiTHP® system with three lines of B12-5 type.
3. Upgrading of existing 5 digesters. After evaluation four of the five digesters will be required to still have a relatively conservative parameter for digestion. The mixing and pipelines were upgraded accordingly.
4. New filter press final dewatering in order to achieve approx. 40%DS for land application.
5. The reject water to be treated in ReNoCar® deammonification process.

The total sludge production is estimated as 180 t DS/d (or 900 t/d @ 20% DS) in which 90 t DS/d is primary sludge, 90 t DS/d is WAS, and there is some tertiary sludge in the future. The total design capacity of CambiTHP® is 180 t DS/d, although it is discussed whether or not the tertiary sludge should be put in digestion. Figure 6 shows the new flow diagram after upgrading the plant, now under commissioning.
The detailed flow diagram after upgrading is shown in Figure 6 below.

**Figure 6:** A detailed flow diagram of advanced anaerobic digestion in Xiaohongmen

A Google Map layout of sludge treatment after upgrading is viewed in Fig. 7 below.

**Figure 7:** A Google Map layout of sludge treatment facilities in Xiaohongmen after upgrading
Figure 8: A photo of CambiTHP® system on the right side and Silos on the left side
Design of advanced digestion

Mass and energy balance
A simplified mass and energy balance was evaluated as shown in Figure 9. Both primary sludge and bio-sludge (WAS) are thickened and pre-dewatered, then pumped to silos before feeding into THP system. After THP, around 2250 m$^3$/d thermal hydrolysed sludge is diluted to around 8%DS then fed to four out of five digesters. Around 42,000-55,000 m$^3$/d biogas will be produced depending on the incoming VS content in the sludge. The biogas is utilized for hot water boilers, biogas blowers, steam boilers, and the rest to burners. The digestate is pumped to filter presses to achieve high DS biosolids for final disposal.

Figure 9: Mass and energy balance of advanced digestion upgrade in Xiaohongmen

Upgrading of existing digesters
Main difference in digester design and related auxiliary system in advanced digestion is the cooling down of the thermal hydrolysed sludge instead of heating up of dilute sludge mixture. The viscosity of thermal hydrolysed sludge is much lower than for normal sludge, therefore the mixing capacity in existing digesters was also well evaluated. A series of modification of existing have been carried out, such as:

1. The heat exchangers in existing digesters were converted into cooling phase.
2. A main cooling system as pre-coolers is designed after CambiTHP® system
3. The existing gas mixing was reviewed and upgraded.
4. Other minor changes

Construction and commissioning with first results
The whole project was executed on a tight schedule. After contracting in early 2015, the design of the whole project was finished in the first half year in 2015. The first construction was the final dewatering filter presses before the whole upgrading started, in order to temporarily dewater the raw sludge (both
primary and secondary sludge) to disposal at the required 40% DS. The filter presses were able to achieve the DS concentration no less than 40% by addition of polymers and conditioning agents such as lime and iron chloride.

The digesters were then renovated and restored to restart from early 2016 for operation in a traditional way by adding primary sludge for initial start-up. Until May the digesters were operated under stable traditional operation mode.

In the meantime, the CambiTHP® system was manufactured with installation starting in early 2016, and finished at the end of June 2016. The pre-dewatering and sludge silos and other systems were also installed during the same time. All systems were ready for commissioning from mid of July 2016.

The commissioning of the CambiTHP® system started from June 2016 on water, then soon after with sludge and the formal commissioning of advanced digestion with CambiTHP® system and digestion started from 18 July 2016.

The Cambi®THP was first commissioned with only one THP line since the permanent power supply was only available until the end of September 2016. As of mid of October, one line of CambiTHP® is in stable operation on WAS together with bypassed primary sludge to digestion.

In order to demonstrate the effect of thermal hydrolysis, around 60 t DS/d of WAS is gradually fed into CambiTHP® system then to digestion while the rest of the sludge is still bypassed to digestion. The following part will discuss the effect of THP on biogas production in the first two months from 18 July until 10 Sept. More data may be available for presentation in conference.

**First results for one line of THP in operation**

The commissioning of the CambiTHP® system was smooth with water test first and then start up with sludge. From 18 July 2016, the first sludge feeding was started gradually, and it took around two months to reach the design capacity for one THP line. Figure 10 below shows the results of biogas production in the first two months after start-up.

![Graph showing biogas production and thermal hydrolysed sludge feeding](image)

**Figure 10:** The first results of biogas production after the first THP line was put into operation

It should be noted that the digesters were first commissioned in a traditional way with primary sludge fed into four digesters at around 4% DS. Until 18 July 2016, the four digesters were in stable
operation with around 3000 m$^3$/d biogas production. From 18 July 2016, addition of gradually thermally hydrolysed sludge resulted into steady increase in biogas production from around 3000 m$^3$/d up to around 18,000 m$^3$/d. So the difference between 18,000 and 3000 is the contribution of thermal hydrolysis of WAS to digestion efficiency. It is observed that the CambiTHP® is under stable operation since start-up, and the whole system is now accelerated with further thermal hydrolysis lines with permanent power supply and optimisation of digester operation. The specific biogas production is still improving during commissioning.

**Summary**

From the Xiaohongmen project planning, design, prefabrication of equipment including CambiTHP® system in China, until installation and first commissioning of the digesters and CambiTHP® system, all the processes have been well organised and have realised the objectives. It is therefore expected that the whole project will achieve the goals for upgrading of existing digestion to advanced anaerobic digestion.

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**References**

