Composting provides a sustainable solution to the biosolids issues in Shenyang, China

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Abstract

Shenyang Biosolids Composting Plant is a one-of-a-kind facility that is designed to handle and treat up to 1,000 tonnes of 80% moisture content wet biosolids per day from four municipal wastewater treatment plants (WWTPs) that have a combined capacity of 1,600 MLD in Shenyang City, Liaoning Province, China. The composting plant covers an area of approximately 130,000 m². The moisture content of biosolids will be reduced to 35% by biodrying. The main facilities in the plant include the materials handling and mixing system (for wet sludge, raw material and compost), the agitated composting bed system, the ventilation and odor control system, the truck scale unit, the storerooms (for raw material and product), and the other auxiliary facilities. The design has incorporated the necessary environmental considerations for the protection of workers’ health and safety as well as the potential impacts on the neighboring communities. The finished compost product will be sold as soil amendment and/or auxiliary fuel. In comparison with other technologies, this plant is favored for the low capital cost (0.279 million RMB per wet tonne of sludge), the low operating cost (173.13 RMB per wet tonne sludge) and the low energy consumption/carbon footprint. The plant is currently under construction. The installation works of No.3 composting train is scheduled to be carried out in June 2012. When the plant is commissioned in September 2012, it will become a sustainable solution to the sludge problem in Shenyang City.

Key words: biosolids, China, composting, Shenyang, sustainability, treatment

BACKGROUND

Shenyang City with a total population of 7.4 millions, is the capital of Liaoning province and the economic, cultural and trade center of the eastern and northern area of China. With the rapid development of wastewater treatment facilities in the past ten years encouraged by the national environmental protection policies, the generation of biosolids has been on the rise correspondingly. Nevertheless, the provision of biosolids treatment and disposal facilities has been given minimal attention and priority due to the lack of government policies, regulatory standards or mandatory requirements. The sludge from the existing and operating wastewater treatment plants (WWTPs) is typically mechanically dewatered to 80% water content, and then transported to municipal landfills for disposal. Not only are the emitted nuisance odors resented by residents in the communities neighboring the landfills, the landfills are also running out of capacities. In order to keep the WWTP in service, some poorly-constructed emergency sludge landfill facilities are being used for sludge storage and disposal on an interim or temporary basis. The release of contaminants and pollutants from these facilities is considered as the secondary pollution which results in water quality degradation and other significant environmental impacts, and largely reduces the beneficial effects provided by the WWTPs. Since
2007, the standards for classification and qualities of disposal from WWTPs and sludge treatment guidelines have been successively promulgated by the national industrial authorities (Ministry of Housing and Urban-Rural Development of RPC 2009a, b, c, 2010, 2011; Ministry of Environmental Protection of PRC 2010a, b; General Administration of Quality Supervision, Inspection and Quarantine of PRC 2009a, b, c, 2010). In response to the urgent needs for complying with these new standards and mitigating the sludge problems, construction of the biosolids treatment facility in Shenyang city is being implemented on a fast-track programme.

GENERAL DESCRIPTION

The biosolids composting plant will receive sludge with 80% moisture contents from four WWTPs with a total capacity of 1,600 MLD. The projected total sludge production from the WWTPs is 920 wet tonnes per day (wt/d), as detailed in Table 1. Accordingly, the design capacity of the biosolids plant is established at 1,000 wt/d. The plant is strategically sited at the open farmlands of Xin Mintun Town in the Shenyang Economic and Technological Development Zone. This location is near the western WWTP, far from the residential areas, and has enough spaces for further expansion and upgrading.

<table>
<thead>
<tr>
<th>WWTPs</th>
<th>Capacity (MLD)</th>
<th>Biosolids Output (wt/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern WWTP</td>
<td>400</td>
<td>160</td>
</tr>
<tr>
<td>Xianw River WWTP</td>
<td>400</td>
<td>357</td>
</tr>
<tr>
<td>Shenshui Bay WWTP</td>
<td>200</td>
<td>123</td>
</tr>
<tr>
<td>Southern WWTP</td>
<td>600</td>
<td>280</td>
</tr>
<tr>
<td>Total</td>
<td>1,600</td>
<td>920</td>
</tr>
</tbody>
</table>

Various sludge treatment technologies were developed, screened, and evaluated based on economic and technical criteria. The rectangular agitated composting bed process was selected because of the lowest capital cost, the lowest operation cost, the lowest energy consumption, the lowest carbon footprint, and the most valuable and stable composting product which was deemed the most advantageous and suitable for the application in Shenyang city (Wang et al. 2010). An important aspect driving the decision was the identification of outlets for the compost product which would include being sold and use as a building material, a compound fertilizer, an auxiliary fuel, a soil amendment, and a cover material for landfills. During the composting process, a bulking agent and amendment is added to the wet sludge for porosity, moisture, and carbon : nitrogen (C:N) ratio control (Turovskiy & Mathai 2006). For the present application, the finished composting product is recycled to reduce the need of the bulking agent. Raw materials, from the nearby suburban agricultural activities, such as grinded corn stalks and straws, are selected for use as amendments to adjust the C:N ratio of the composting infeed mixture. The design moisture content of finished compost product is 35%. The plant consists of preprocessing, composting and post processing units, has the footprint of 130,680 m², and the greening rate of 35.5%.

Process flow

The wet sludge with 80% moisture content and grinded raw material (for use as amendment) are trucked to the plant and discharged into the receiving hoppers with live-bottoms inside the raw material receiving rooms. The materials are then transported into the secondary feeding silos in
composting building by hydraulic piston pumping system and pneumatic conveying system individually. The amendment, wet sludge and recycle compost are metered, handled and mixed, forming the infeed mixture with the moisture content of 55%, then fed into composting bays for compost. The composting bays are agitated daily and aerated by blowers. After the 21-day composting period, the finished compost is discharged into recycle feeding silo by belt conveyors for recycle. The excess compost will be discharged onto the floor, transported into the curing room by front end loaders for further curing of 30 days, and transported out for reuse when finished.

**DESIGN OF SHENYANG BIOSOLIDS COMPOSTING PLANT**

**Truck scale unit**

The truck scale unit is located near the guard rooms at the entrance of the plant. The wet sludge, the amendments and the composting products are weighed, coded, and sampled. With the provision of remote communication, the operation of the truck scale is monitored at the central control room.

The moisture content and qualities of raw sludge should meet the requirements of discharge standard of pollutants for municipal wastewater treatment plant (Ministry of Environmental Protection of PRC 2002). The raw material for use as the amendment will be procured from local suppliers. The maximum length of raw material should be less than 5 cm. The amount of surface area and the rate of aerobic decomposition increases with smaller particle size, but smaller particles reduce the effective porosity. The particle sizes range from 1/8 to 2 inches (0.3 to 5 cm) average diameters should be kept in order to obtain good results (Rynk 1992) The solid content of the amendment should be more than 85% and the bulking density is about 0.2 t/m³.

**Materials handling system**

**Raw materials receiving rooms**

Two raw materials receiving rooms are housed inside a two-storey structure adjacent to the compost building. Each room has the dimensions of 21.7 m length, 15.7 m width, and 21 m height. The ground floor with 15 m height is designed for truck loading and unloading. The lower basement floor with 6 m depth is used to accommodate two raw sludge hoppers with 140 m³ total effective volume and one amendment hopper with 70 m³ effective volume. Each sludge hopper with live bottom is equipped with one hydraulic sliding frame and one manual gate valve, one sludge feed screw conveyor \(Q = 45 \text{ m}^3/\text{h}\), one hydraulic piston pump \(Q = 25 \text{ m}^3/\text{h}\) and hydraulic power units \(N = 90 \text{ kw}\). The two sludge hoppers serve two secondary sludge silos in the composting building. The sludge in one of the two hoppers can be conveyed to one of the two silos by piping and valves switching for flexible operation. The amendment hopper is affiliated with pneumatic conveying system, including two blowers \(Q = 28 \text{ Sm}^3/\text{min}, H = 58 \text{ kpa}, \text{ one duty and one standby}\), one rotary feeding valve \(Q = 2 \text{ t/h}, N = 1.5 \text{ kw}\), one pneumatic driven diverter valve, and bag filters installed on the top of secondary silos for dust control and ancillary pulsed jet cleaning units. The amendment hopper serves the two secondary amendment silos in the composting building by piping and the diverter valve. The operation of raw material receiving and conveying system is automatically controlled by the ultrasonic level sensors in the hoppers and silos. The odorous gases emitting from raw sludge receiving hoppers are collected by exhausters and conveyed to biofilters for treatment before discharge to atmosphere.
Mixing system

The mixing system located at the middle area of the compost building consists of four mixing trains. Each train serves the corresponding composting train, equipped with three secondary live-bottom feeding silos (amendment silo and sludge silo with 15 m³ effective volumes, and recycle compost silo with 30 m³ effective volumes), the pug miller/stationary mixer \( (Q = 50 \text{ m}^3/\text{h}) \) and the affiliated feeding screw and discharge belt conveyors, and compost infeed mixture horizontal distribution belt conveyor with belt ploughs, and finished compost discharge belt conveyor. The wet sludge, wet sludge and recycle compost are discharged and metered by the discharge screw conveyors with variable frequency drives, and then unloaded onto the mixer feeding horizontal and inclined screw conveyors, and into the mixer for mixing. The mixture discharged from the mixer is unloaded onto the inclined belt conveyor and horizontal belt conveyor with belt plows for unloading. The target moisture content of composting infeed mixture is 55%. The moisture content of the mixture is monitored by online moisture sensors on the horizontal feeding distribution belt conveyor. The feed rates of screw conveyors below the feeding silos are controlled and automatically adjusted based on measurements from the online moisture sensors. The finished product at the end of the composting bay is discharged by agitator into horizontal belt conveyors and inclined belt conveyors and finally into the recycle composing feed silo. The moisture content in the compost product is also monitored by online moisture sensors on the horizontal belt conveyor. The excess finished composting product is discharged by the screw conveyor below the recycle compost silo to a mobile inclined screw conveyor, and transported to the product storehouse by the front end loader and trucks for further curing.

Agitated composting bed system

A composting building with four trains is designed with the dimension of 209.68 m length, 210.78 m width, and 12.2 m height. Each train has 24 bays. They are served by two IPS® agitators \( (Q = 668 \text{ m}^3/\text{h}) \) and two dollies. The custom-design 75 kw IPS® agitators can increase the effective depth of bay up to 2.4 m, and the corresponding footprint is minimized. Each bay has the dimensions of 91.4 m length, 3.05 m width, and 2.9 m height. It is segmented into one loading section and 6 aeration sections. Each aeration section is installed with its own dedicated resistance thermal detector, blower \( (Q = 2,000 \text{ Sm}^3/\text{h}, P = 4,500 \text{ Pa}, N = 2.98 \text{ kw}) \), perforated aeration pipes and air distribution graded gravel levels at the bottom in order to cater for the different specific oxygen demands and realize the precise temperature control.

For blower control, three aeration modes are designed with temperature mode, cycle mode and temperature-cycle mode. In the temperature mode, the operation of the blower in each section is interlocked to the reading of corresponding process temperature from RTD and the configurable setpoint. In the cycle mode, all the blowers in the bay that the dolly is parked in front of will start in sequence and continue to run for a period of time as set. The temperature-cycle mode is a combination of the temperature and cycle modes. It is the preferred mode of operation under normal operation conditions.

Each bay is loaded daily with the volumes of 31 m³ and agitated once per day to move the material backward by 3.9 m. The retention period in each bay will be 21 days. The water in the composting bays will be gradually lost and biosolids biodrying is realized during the course.

In each composting bay, the material should be maintained at the temperature of 55 degrees Celsius for three consecutive twenty-four hour periods to achieve pathogen destruction temperature compliance (Ministry of Housing and Urban-Rural Development of RPC 2009a, b, c). The compliance algorithm will begin counting a compliance day when the system records a temperature at or above 55 degrees Celsius. The main process parameters of the biosolids composting plant is summarized in Table 2.
Ventilation design

During the composting course, the aerobic condition should be maintained, and the water steam and odor emitting from the composting bays should be collected by exhausters. The strip curtains and partition panels are provided above the composting aeration sections of every train to isolate the odor generated from the composting aeration sections from the maintenance area and thus reduce the size of the odor control system. Fresh air is supplied by 38 low noise centrifugal blowers \( (Q = 32,000 \, \text{m}^3/\text{h}, \, N = 5.5 \, \text{kw}) \) installed on the roof above the loading area and mixing area (in the middle of the composting building). In the operating areas, the waste gas collecting and exhausting ports are located above the last aeration section in the other end of the bay. A total of 144 jet fans \( (Q = 9,800 \, \text{m}^3/\text{h}, \, N = 1.5 \, \text{kw}) \) will be installed on the roof between the air supply blowers and exhausting ports to introduce the airstream.

Biofilter for odor control design

Four biofilters will be provided for odor control by biological oxidation process. The generated wastewater is discharged into the sewage system of the plant. Each biofilter has the capacity of 350,000 m\(^3\)/h. It will serve the corresponding composting train with a two-stage treatment process: the first biological reaction stage, and the second biological reaction stage. There are 4 sub-units in each biofilter. Each sub-unit is equipped with one VSD centrifugal blower \( (Q = 87,500 \, \text{m}^3/\text{h}) \), one circulation water tank, two heaters \( (N = 8 \, \text{kw}) \) specific for the low temperature application (less than 4 °C), and two vertical circulation centrifugal pumps. The exhausted waste gas is collected and conveyed to the biofilters with duct work. The treated off-gas should meet the Class 2 requirements of Emission Standards of Odor Pollutants in China (Ministry of Environmental Protection of PRC 1993). The system will be deemed the largest odor control system of this kind in the world when it is put in service.

Auxiliary facilities

Raw material room and product storeroom

The raw material room and compost curing room are located at the west - south of the plant. The raw material for use as amendment will be supplied in bulk. The size of raw material room is 60.0 m (L) × 48.0 m (W) × 6.0 m (H). It is designed to cater for the buffering time of 120 days and 4,800 m\(^3\) raw material volume, reducing the adverse seasonally and weather influences on the normal operation of the plant. The size of the compost curing room is 120.0 m (L) × 48.0 m (W) × 6.0 m (H). It is designed to cater for the buffering time of 30 days, and 13,000 m\(^3\) compost volumes. The finished
compost that has been properly composted and cured is expected to have a low but still ongoing rate of microbial activity. The height of the storage piles should not exceed 12 feet (3.7 m), as the pile size increases the risks of sour compost and spontaneous combustion increase (Rynk 1992). To ensure the plant will maintain continuous safe and reliable operation, the curing height in the curing room is limited to 2.3 m.

Ancillary facilities

An electrical room, a garage, a maintenance room, and firefighting water tanks are provided as support facilities for the biosolids composting plant.

Safety and health considerations

In the material handling system, the position switches in the mixer are provided to de-energize the mixer if a clean-out door is opened. Emergency pull switches and cables are provided along the side of each belt conveyor. A zero speed switch, motor high temperature switch, and emergency switch, and safety guard are provided for the equipment motors. Other control interlocking is also considered in the design of control system.

The high degree automation of the plant will significantly reduce the risk of operators coming in contact with the pathogens and bioaerosols in the composting hall. The properly designed and operated ventilation and odor control system and other safety equipment, such as dust masks, half-mask respirators and air filter installed in the cabs of front end loaders, will limit the operators exposure to the composting microbiological environment.

Capital and operating costs

The estimated unit capital and operating costs are 0.279 million RMB per wt sludge and 173.13 RMB per wt sludge respectively. These costs are lower than the costs of thermal drying and incineration processes.

BENEFITS TO BE PROVIDED BY THE BIOSOLIDS COMPOSTING PLANT

The plant is currently under construction. The No.3 composting train will be installed in June 2012. When finished, the plant will become a much-needed and sustainable solution to the sludge problems in Shenyang City. According the Environment Bulletin in 2010 (Ministry of Environmental Protection of PRC 2010a, b), there are 2,881 municipal WWTPs in operation in China, and 27.69 billion cubic meter wastewater are treated in the year of 2010. While enormous amount of sludge is generated continuously, most of the sludge is not provided with proper treatment before disposal. The shenyang large-scale centralized biosolids composting plant will serve as a good model for the biosolids treatment and resource utilization for other developing cities in China because of its low capital cost, low operating cost and low energy consumption/carbon footprint.

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