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Consulting Engineers

CITY OF WARREN
WASTEWATER TREATMENT PLANT
BIOMASS TO ENERGY FEASIBILITY STUDY

HRC JOB NO. 20090322

General

The existing wastewater treatment process at the Warren WWTP uses primary settling tanks to remove solid organic materials from the wastewater and a biological activated sludge system to convert soluble organic materials to insoluble material which can be removed in secondary settling tanks. The settled solids (biomass) are partially dewatered and incinerated. The purpose of this study is to evaluate methods to utilize the energy contained in the biomass to produce electricity and thereby reduce the energy demand for the WWTP.

Primary Sludge

Primary sludge is pumped intermittently from eight primary settling tanks to four 78,000 gallon storage tanks. Each storage tank is equipped with decant valves and a bottom screw conveyor to convey stored sludge to the outlet pump. The primary sludge transfer system includes many automatic valves, two grinders, and three 140 gpm rotary lobe pumps, flow meters and sludge density meters.

Secondary Sludge

Waste activated sludge (WAS) is pumped directly from the east/west secondary clarifiers return sludge header to three 44,000 gallon sludge blending tanks. A single Gravity belt thickener and two activated sludge storage tanks are not routinely used but could be started and utilized to temporarily reduce the volume and concentrate the WAS solids during a solids processing failure. The WAS transfer system includes automatic valves, one constant speed 800 gpm pump, two variable speed 340 gpm pumps, flow meters and sludge density meters.

Sludge Blending System

Each primary sludge storage tank is decanted prior to processing. Sludge storage tank decant flows by gravity to the decant storage tank and is then pumped to the raw sewage wet well. Primary sludge is pumped from the four sludge storage tanks utilizing three 180 gpm variable speed sludge transfer pumps through the common WAS supply line to three blending tanks. The initial mixing of primary/was sludge occurs in the pipeline and further mixing is provided by a mechanical mixer in each blending tank. The sludge blending system also includes automatic valves, flow meters and density meters.

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Sludge Dewatering System

Blended primary/WAS sludge is pumped from the blending tanks to three belt filter presses equipped with inlet gravity belt thickeners. (Normally two presses are operating and one is in standby.) Sludge cake is transferred via belt conveyors to the incinerator or truck loading station. The sludge dewatering system also includes six rotary lobe feed pumps, automatic valves, flow meters with totalizers, four belt press wash water booster pumps, and a polymer feed system.

Estimated Sludge Volumes

The following annual average sludge volumes are based on recent (2009) WWTP monthly operating reports. The primary sludge volume is the approximate volume remaining after the storage tanks are decanted prior to transfer to the blending tanks. Polymer is added to the sludge in the dewatering process at an average rate of 6.0 lbs of polymer per ton of dry solids

Primary Sludge:	23.94 MG/year at 3.4% solids concentration 6,796,950 lbs/year dry solids
Waste Activated Sludge:	80.6 MG/year at 0.50% solids concentration 3,365,050 lbs/year dry solids
Blended Sludge:	121.7 MG/year at 1.0% solids concentration 10,162,000 lbs/year dry solids
Polymer Addition:	30,000 lbs/year dry solids
Dewatered Sludge Cake:	10,192,000 lbs/year dry solids

Biomass to Energy Alternatives

The following alternatives were considered and evaluated for this study:

1. Alternative A – Waste Heat Recovery System. Under this alternative, the existing solids handling/dewatering system would not be modified. A new heat exchanger and ancillary equipment would be installed to recover waste heat from the sludge incinerator exhaust air stream and utilize the available energy to produce electricity for use at the WWTP.

2. Alternative B – Two Phase Anaerobic Sludge Digestion with Combined Heat and Power System. Under this alternative, a new sludge digestion system would be constructed as a supplement to the existing solids handling system. Methane gas produced by the digestion system would be used as fuel for digestion system boilers and engine driven generators. The generators would produce electricity for use at the WWTP. The methane gas could also possibly be used as supplemental fuel for the sludge incinerator during periods of reduced demand for digester heating.

Alternative A Description

The waste heat recovery system, shown schematically in Figure A, includes a main heat exchanger, evaporator, power generation skids with turbine/generator, condenser and recirculation pumps. The main heat exchanger is an air-to-liquid type designed to transfer heat from the incinerator exhaust stream to a recirculating glycol solution loop. The glycol loop passes through an evaporator and transfers heat to an organic working fluid (R245FA refrigerant) confined in closed circuit pipe loop. This system is classified as an Organic Rankin Cycle (ORC). The refrigerant loop supplies the turbines driving the generators in each power generation skid. Expansion of the refrigerant vapor provides the motive force for the turbines and refrigerant discharge is conveyed to a downstream condenser for cooling. Condensate is returned to the evaporator to complete the thermodynamic cycle. The electricity produced by the system would be used at the WWTP and would supplement the existing DTE utility service.

Alternative B Description

The two phase anaerobic sludge digestion system and combined heat/power system would include a feed sequencing tank, two (2) thermophillic digesters, two (2) mesophillic digesters, one digester gas storage dome, heat exchangers, gas recirculation type digester mixers, gas compressors, hot water boiler, sludge transfer pumps, and electrical generators powered by methane fueled reciprocating engines. A new building would be required to house new system equipment such as pumps, heat exchangers, methane gas system equipment, control system, etc.

In addition, the existing solids handling system facilities and equipment would be incorporated in the system as indicated in Figure B.

Primary sludge and secondary waste activated sludge would continue to be combined and stored in the Blended Sludge Storage Tanks. Blended raw sludge would be pumped from the storage tanks to a heat recovery exchanger to supply pre-heated sludge to the digestion system Feed Sequencing Tank (FST). The digestion system would be operated as a batch system whereby a batch of pre-heated raw sludge is transferred from the feed sequencing tank through a heat exchanger (hot water/sludge) to the Thermophillic Digesters. At the same time, the equivalent volume of hot sludge would be pumped from the Thermophillic Digesters through the heat recovery exchanger (hot sludge/cold sludge) to the Mesophillic Digesters. (The thermophillic sludge temperature would be lowered to the Mesophillic range and raw sludge, which is entering the feed sequencing tank, would be pre-heated.)

Batches of completely digested sludge would be transferred from the Mesophillic Digesters to the new Digested Sludge Storage Tanks for interim storage prior to dewatering/disposal.

The combined heat and power system would offset the digestion system energy requirements and would also produce electrical power to reduce the WWTP demand on the electrical utility.

Methane gas produced by the digestion system would be used as boiler fuel, fuel for reciprocating type engines used to power generators, and possibly supplemental fuel for the existing sludge incinerator during periods of reduced demand for digester heating.

Hot water supplied by the boiler would supply sludge heat exchangers and mesophillic digester mixer heating jackets. Electrical power produced by the generators would supplement the WWTP electrical utility service. In addition, the heat produced by the generator engines would also be recovered and used in an air/water heat exchanger to pre-heat water in the boiler hot water recirculation system.

The stored digested sludge would be dewatered with the existing dewatering equipment and the sludge cake would be classified as Class A biosolids. Therefore, as an alternative to incineration, the sludge could be disposed of by land application, composting or landfilling. Dewatered sludge would typically be transferred to roll off type containers and then trucked to the disposal site. Interim storage of full/empty roll off containers at the WWTP site would also be required unless the disposal contractor can be scheduled to be on-site whenever a container is filled and replacement with an empty container is required. A roll off container truck stored at the WWTP site would also be required if the City was responsible for transferring/storing full and empty containers at the WWTP site. The additional offsite truck traffic associated with sludge cake disposal would not be acceptable since the only access to the WWTP is through a residential area. Incineration would continue to be the only viable means of biosolids disposal.

The biomass to energy system could possibly be operated whereby only a portion of the raw sludge is digested/dewatered and the remainder of the raw sludge is dewatered and incinerated per existing WWTP procedures. Full scale testing would be necessary to determine the optimum ratio of digestion/dewatering to provide the maximum overall energy efficiency of the solids handling system. Under this operating scenario, the digested/dewatered sludge could possibly be disposed of by land application, composting or landfilling since a lesser volume of Class A biosolids would be produced.

Incineration of the digested/dewatered sludge would most likely not be feasible since the BTU value of digested sludge is considerably less than raw sludge and, therefore, the supplemental fuel requirements for the incinerator would increase.

Conclusions

Alternative A (Waste Heat Recovery System) requires considerably fewer capital improvements compared to Alternative B (Two Phase Anaerobic Sludge Digestion with Combined Heat and Power System). Therefore, the Alternative A land space requirements, new building construction, site improvements, engineering costs, etc. will also be lower. The Waste Heat Recovery System will operate automatically to produce electricity for use at the WWTP and will not require any revisions to the existing solids handling system operations. The sludge incinerator would continue to be utilized and thereby minimize the volume of waste material which requires disposal offsite. Truck traffic associated with the disposal operations will not increase.

The Alternative B sludge digestion system with combined heat/power system would also operate automatically to produce electricity and Class A biosolids but would require major changes to the existing solids handling system operation. The operation of complex digestion, boiler and power generation systems would be required in addition to the continued operation of the existing dewatering system. Truck traffic associated with sludge disposal operations would increase drastically if the incinerator was no longer used and the dewatered Class a biosolids were disposed of by land application, composting or landfilling.

Both alternatives convert biomass energy to electrical power but Alternative A is considerably less complex, requires minimal capital improvements, and will not increase truck traffic in adjacent residential neighborhoods.