Design, Commissioning and Operation of the Odor Control Systems for the Pine Creek Wastewater Treatment Plant

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ABSTRACT

An award winning, state-of-the-art Biological Nutrient Removal (BNR) Wastewater Treatment Plant (WWTP) was built in the south of the City of Calgary, surrounded by new residential developments. Odor control was a major commitment and a complete odor emission characterization study was carried out. Odor dispersion was modeled and four different systems were designed, three biofilters and one caustic scrubber. A prequalification process took place to select the biofilter vendor (BioRem). The systems have been built and are currently operating. Several issues were encountered during commissioning and operation but after resolving issues, a series of Guaranteed Performance tests proved the effectiveness of the systems. No odor complaints have been received after a year of operation.

KEYWORDS

Wastewater odors, odor characterization, biofiltration, caustic scrubbers, commissioning, performance testing, cold weather operation.

BACKGROUND

The 100 ML/d first stage of the new Pine Creek WWTP serves the southern areas of the City of Calgary and is located in the Bow River Valley, near new residential developments and a golf course. The site has ultimate capacity to treat 700 ML/d.

The plant's major liquid process areas are: influent pump station, headworks (screening and grit removal), primary clarifiers, bioreactors, secondary clarifiers, effluent filtration and UV disinfection. The major solids processes are: primary sludge fermentation, waste activated sludge thickening (dissolved air flotation), sludge digestion, and digested sludge storage and pumping.

The City of Calgary made major commitments to the residents of surrounding areas to incorporate odor control within the plant and adopted stringent odor emission standards. These commitments were based on 15 minute exposure and odor measurement in accordance with European standards. The odor limits are 25 Odor Units (OU) per m^3 at the plant property line and 10 OU/m^3 at the nearest receptor, under worst case meteorological conditions (hot, humid days with little or no wind).

The Pine Creek WWTP construction was carried out utilizing multiple construction and equipment supply contracts, in order to reduce the overall cost and as a strategy to facilitate

tender participation. Most of the process components were tested and commissioned in 2008. However, the primary sludge fermenters, sludge digestion and biogas handling components were not completed until late 2009.

ODOR EMISSION CHARACTERIZATION

The odor emission characterization was defined with data obtained from a two-phase air sampling program conducted at the other two wastewater treatment plants in the City (Bonnybrook and Fish Creek Wastewater Treatment Plants). Air samples from several unit processes were analyzed for odor concentration (dilutions to threshold) and 26 reduced sulphur compounds (including hydrogen sulfide). Odor dispersion from the Pine Creek WWTP was modeled using the US EPA's Industrial Source Complex-Short Term model (ISCST3) and considered four scenarios that included one or two stage treatment, use of stacks and dilution fans, containment of odors to reduce volume, and number and location of treated air discharge points, among other considerations.

Table 1 summarizes the odor emission characterization.

Table 1 - Pine Creek WWTP Odor Emission Characterization

Area	Odor Concentration (OU/m^3)
Influent Wet Well	2,000
Headworks	
Low level	2,000
General Area	100
Primary Clarifiers	22,000
Bioreactor	
Anaerobic zones	297
Anoxic zones	191
Aerobic zones	297
Secondary Clarifier Launders	900
DAF	
Low level	400
General area	100
Primary Sludge Fermenters	200,000
Digester Gas Room	400

ODOR CONTROL SYSTEMS DESIGN

Based on the odor emission characterization and odor dispersion models, the design of the odor control systems for the Pine Creek WWTP included odor containment and collection and three odor treatment systems: single stage biofiltration for the influent pump station and headworks areas, single stage biofiltration for the waste activated sludge thickening process, and a two stage (caustic scrubbers followed by biofiltration) for the primary clarifiers, bioreactor influent channel, and primary sludge fermenters.

The odor control systems selection assumed that the City would maintain influent dissolved sulfide concentration at less than 0.5 mg/L through the use of iron salt addition or other liquid phase control.

In order to minimize the volume of air to be treated and reduce the operators exposure to odorous air, tanks and process units such as screens, grit dewatering and screenings handling units, primary clarifiers, primary sludge fermenters, waste activated sludge thickening tanks, etc were covered with aluminum covers. Channels were also covered with concrete and stainless steel access hatches.

Table 2 summarizes the capacities for all the Pine Creek WWTP odor control systems.

Table 2 - Pine Creek WWTP Odor Control Systems capacities

Area	Airflow (m^3/h)	Odor (OU per m^3)	Odor Flux Rate (OU per sec)
Influent Wet Well & Sewer	3,000	2,000	1,667
Headworks Low Level	4,500	2,000	2,500
Primary Clarifiers, including influent and effluent channels to the bioreactors	22,000	22,000	134,444
Primary Sludge Fermenters	6,000	200,000	333,333
DAF Low Level	1,135	400	126

ODOR CONTROL BIOFILTERS

A prequalification process took place to select the biofilter vendor before the design was completed. The evaluation of proposals included supply, delivery, operation, maintenance costs and a life cycle analysis. All references provided by the vendors were contacted; replacement parts availability, delivery periods, media life, etc were also considered in the evaluation.

The headworks biofilter was designed to treat the foul air from the influent junction chamber, wet wells, screens influent channel, influent screens, vortex grit tanks, grit dewatering, and screenings and grit solids container. The biofilter consists of a FRP vessel with synthetic media (BioRem Biosorbens™ - organic and inorganic materials) and duty/standby fans, with capacity for 7,500 m^3/h, and a maximum inlet concentration of 2,000 OU/ m^3. The biofilter has an empty bed retention time (EBRT) of 22 seconds.

The DAF biofilter treats the foul air from the waste activated sludge thickening tanks headspace, with capacity for 1,135 m^3/h and a maximum inlet air concentration of 400 OU/m^3. This system also consists of a FRP vessel with BioRem Biosorbens™ media and duty/standby fans. The biofilter has an empty bed retention time (EBRT) of 22 seconds.

The Primaries odor control system was designed to treat the foul air from the primary clarifiers influent channel, primary clarifiers, bioreactors influent channel, and primary sludge fermenters. The first stage consists of caustic scrubbers located indoors, with two (one duty/one stand by) FRP cylindrical vessels with polypropylene media, designed with capacity to treat 25,000 m^3/h, a maximum inlet air concentration of 50 ppmv H_2S and a minimum removal efficiency of 90 percent. The second stage consists of two biofilters located outdoors, with capacity to treat 12,500 m^3/h each to further polish the treated air. The biofilters have an empty bed retention time (EBRT) of 22 seconds and consist of concrete vessels with BioRem Biosorbens™ media. A high plume dilution fan exhausts the treated air, mixing it with clean air to reduce the odor concentration of the discharged air and increase the effective plume height.

The biological population that grows on the media surface of a biofilter produces an odor (known as background or baseline odor) and the measurement of this baseline was unknown at the time of the design; therefore, all biofilters were designed for a maximum outlet air concentration of the biofilter baseline odor plus 100 OU/m^3. The baseline odor concentration was determined after the systems were fully acclimated by measuring biofilter exhaust odor concentration when fresh air is passed through the biofilter.

Winterization systems were required for the headworks and primary clarifier biofilters to maintain the temperature of the media within the optimal operating conditions during cold periods when the inlet foul air temperature is below 10 °C, the minimum inlet temperature recommended by the biofilter manufacturer. An immersion heater in the humidification chamber was provided for the headworks biofilter and a glycol heater for the primaries biofilter. The DAF biofilter inlet air was assumed at a minimum temperature of 10 °C since the process tankage is installed inside a heated building and therefore, no winterization was included for this system.

Table 3 describes the three odor control biofilters.

Table 3 - Pine Creek WWTP Odor Control Biofilters Design Criteria

Design Criteria	Headworks Biofilter	DAF Thickener Biofilter	Primaries Biofilters
Number	1	1	2 in parallel
Packing / media material	Proprietary mixture of organic and inorganic materials	Proprietary mixture of organic and inorganic materials	Proprietary mixture of organic and inorganic materials
Foul Air Flow each, m^3/h	7,500	1,135	25,000
Peak inlet odor concentration	2,000 OU/m^3	400 OU/m^3	1,680 OU/m^3
Peak outlet odor concentration	Baseline + 100 OU/m^3	Baseline + 100 OU/m^3	Baseline + 100 OU/m^3
Foul Air Fans	2 (duty, standby)	2 (duty, standby)	1 high plume dilution fan
Winterization System	Immersion heater	Not required	Glycol heater

ODOR CONTROL CAUSTIC SCRUBBERS

During sampling stages, the highest odor concentrations were found at the primary clarifiers and primary sludge fermenters. The modeling indicated that providing only one-stage treatment (90 percent odor removal) for the primary clarifiers and the primary sludge fermenters would be inadequate to meet the City's odor objectives. In order to comply with the required odor removals the odor control for these systems, a two-stage system was designed: Caustic scrubbers followed by biofiltration.

The design of the caustic scrubbers was based on experience with previous systems and communication with the available vendors. A design standard was selected and the odor control building was designed based on that design standard.

In order to meet architectural aesthetic requirements, the scrubbers and related chemical storage tank are located in a below-grade structure. The exhaust fans are located inside an adjacent building at ground level.

Two wet chemical scrubber systems were designed in parallel (duty; standby) and receive foul air (FA) from the headspace of the bioreactors influent channel, primary clarifiers, primary influent and effluent channels, and the primary sludge fermenters. The foul air flow is drawn through the scrubber by a centrifugal fan that transfers it to the biofilters. Following treatment in the biofilters to remove amine and VOC compounds, the treated air is released to the atmosphere.

Table 4 describes the Caustic Scrubbers.

Table 4 - Pine Creek WWTP Odor Control Caustic Scrubbers

Caustic Scrubbers	
Number	2 (duty, standby)
Packing depth, m	3
Empty Bed Retention Time, s	2
Operating pH	11.3 ± 0.5
Blowdown rate, l/min	Same as make up water, initially 5 l/min
Packing / media material	FRP
Foul Air Flow each, m^3/h	25,000
Peak inlet odor concentration	50 ppmv[1] H_2S
Peak outlet odor concentration	5 ppmv[1] H_2S
Foul Air Fans	2 (duty, standby)
Diameter, m	1.83
Recirculation Pumps	
Number	2 (one per scrubber)
Type	Centrifugal (corrosive service)
Capacity, L/s	22
Caustic Storage tank	
Number	1
Material	Fibreglass Reinforced Plastic
Volume, L	22,400
Caustic Feed Pumps	
Number	2 (duty; standby)
Type	Diaphragm, metering (corrosive service)
Capacity, L/h	0 - 45

[1] Parts per million by volume

COMMISSIONING

The construction of the Pine Creek WWTP was carried out utilizing multiple construction and equipment supply contracts, in order to reduce the overall cost and as a strategy to facilitate tender participation. A need for liquid stream commissioning and nitrification by the end of 2008 compelled the start-up and commissioning of the completed areas while others were still under construction.

The solids treatment was included in the last construction contract to be implemented. The interim operation stage included trucking the thickened waste activated sludge (TWAS) to other facilities. Primary sludge was stored on site for up to one week and then pumped to another wastewater treatment plant. The headspace of the tank used for primary sludge storage was connected to the Primaries odor control system. This interim stage implied a different approach than the one used during design, and the flow rate and odor concentration variations from the sludge storage tank were reflected in the performance of the scrubbers and primary biofilters.

Commissioning of the interim stage started in October, 2008 and the odor control systems started receiving foul air from the process areas (except from the primary sludge fermenters) at that time.

The commissioning of the biological odor control systems during the fall and winter was challenging due to several issues, mainly the local weather. Shortly after starting the systems, extreme temperatures with extreme wind chill were experienced and with all biofilters located outdoors, the risk of freezing the media was high when the winterization systems were not functional and several instruments froze. Also, the high humidity content of the treated air caused ice formation in the exhaust stacks and fans. To address those issues, a mist eliminator was installed in the exhaust stack of the headworks and DAF biofilters, a heat traced and insulated exhaust stack drain was installed for the DAF biofilter, and a heat traced and insulated drain was installed for the high plume dilution fan at the exhaust of the primaries biofilters.

Operational adjustments were also required, such as irrigation and humidification flows, winterization systems set points and controls, etc.

The caustic scrubbers did not present temperature issues because these systems were installed indoors, but several operational parameters were tested and optimized during commissioning.

OPERATION

Once the biofilter systems received foul air from the wastewater treatment processes, an acclimation period was required for the microorganisms to develop on the surface of the biofilter media. A Guaranteed Performance Test (GPAT) was required for all systems and the Biofilters underwent performance tests in the summer (August 10 to 14, 2009).

The GPAT for each Biofilter was conducted over an 8-hour period with sampling and data measurements evenly distributed over that time period.

The biofilter baseline odor was determined by sampling (air sampling in Tedlar® bags in accordance with EPA Method 18 for odor analysis by an external lab, in accordance with EN13725) at the primaries biofilter exhaust while clean air was flowing through the biofilter. It

was assumed that this baseline odor concentration is also applicable to the headworks and DAF biofilters. Once the samples were analyzed, it was determined that the baseline odor of these systems was 242 OU/m^3.

The GPAT results for the Biofilters are summarized in Table 4.

Table 4 - Pine Creek WWTP Odor Control Biofilter results

Parameter	Headworks Biofilter	DAF Biofilter	Primaries Biofilter	
			Cell 1	Cell 2
Airflow, m^3/h	9000 to 9250	1820 to 1850	7,000 to 7,250	4,000 to 10,320
Inlet temperature, °C	11.9 to 13.2	21.9 to 22.1	18.6 to 18.8	18.6 to 18.8
Average inlet H_2S Concentration	3.12 ppmv[1]	2.29 ppmv[1]	0.81	0.81
Average outlet H_2S Concentration	Below detection limit	0.002 ppmv[1]	Below detection limit	Not measured
Inlet odor concentration, OU/m^3	530 to 690	630 to 695	266	489
Outlet odor concentration	260 to 320 OU/m^3	244 to 266 OU/m^3	172	411

[1] Parts per million by volume

Before the GPAT tests took place, it was noticed that the Primaries biofilter cell #2 produced a more odorous air than cell #1 and that was confirmed with the outlet odor concentration analysis. Internal inspection at the time of GPAT indicated that several irrigation nozzles were broken (they probably froze in the winter) and media analysis indicated that the media moisture was below than the manufacturer's recommended range (15 to 30%). The nozzles were replaced during GPAT tests and the system was retested four weeks later. The results obtained during the second test were compliant with the specified odor removal; 850 OU/m^3 was measured in the inlet of Cell #2 and 130 OU/m^3 in the outlet.

The GPAT test for the Caustic Scrubbers was conducted on September 15 and 16, 2009, over one 8-hour period per caustic tower with sampling and data measurements evenly distributed over that time period. The specification also requested a second 8-hour period at peak sustained conditions using H_2S gas to simulate those peak sustained conditions, but the City considered that because the scrubbers are located underground the test would imply high health and safety

risks (if an accident had occurred and the bottled H_2S gas leaked, H_2S would have invaded the Plant's tunnel system, exposing operators and contractors working on the tunnel) and therefore the peak sustained conditions were not tested and both caustic scrubbers were tested at actual plant odor conditions.

A 25% solution sodium hydroxide (caustic) was used. A pH analyzer controlled the caustic pumps in order to maintain a pH of 11.0 ± 0.5 during both days of testing. Several parameters were recorded, such as make up water rate, differential pressure across media, pH levels, etc. The scrubbers were operated in automatic mode in order to automatically control caustic dosage. Table 5 summarizes the results from the Scrubbers GPAT tests.

Table 5 - Pine Creek WWTP Odor Control Scrubbers GPAT results

Parameter	Scrubber 1	Scrubber 2
Average Inlet H_2S Concentration, ppm	6.4	2.44
Average outlet H_2S Concentration	0.8	0.26
Average percent removal, %	87	89
Scrubbing solution pH	11.2 to 12.6	10.7 to 10.9
Makeup water flow rate, LPM	5	5

The outlet odor concentrations measured during the tests did not surpass the peak outlet concentration specified, due to the low inlet concentrations at the time of the tests. H_2S removal efficiencies of almost 90% were achieved.

At the time of the preparation of this manuscript, the primary sludge fermenters are still being commissioned and the scrubber's inlet concentration has not increased from what was measured before, still below 4 ppm. Higher concentrations are expected as the sludge fermenters are optimized and as the ambient temperature increases.

No odor issues have been reported to date, and no complaints from neighbors or the public have been received. The systems are expected to perform according to specified requirements with relatively low maintenance requirements and chemical consumption.

REFERENCES

European Committee for Standardization (CEN). Standard EN13725, Air Quality-Determination of Odor Concentration by Dynamic Olfactometry.