Glen Cairn Trunk Sewer
Pilot Biofilter

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Water Environment Association of Ontario
31st Annual Technical Symposium
April 21st to 23rd, 2002
Hamilton Convention Centre
Hamilton, Ontario

ABSTRACT

The Glen Cairn Trunk Sewer has been a source of odours since it was put into service in 1998. High concentrations of hydrogen sulphide gas have been historically observed at the manholes near its upstream end. The primary cause of the odours is hydrogen sulphide gas released by turbulence where three forcemains empty into the Glen Cairn Sewer. The odour associated with the gas has caused residents and motorists to complain. The manholes and vents have been sealed in the lined portion of the sewer to control the odours. Sealing the manholes and vents to inhibit odours has reduced natural sewer ventilation, which results in elevated hydrogen sulphide gas concentrations in the downstream, unlined sewer headspace.

At-grade, un-sheltered biofilters have been used effectively to control sewer odours in warm weather climates and in semi-cold climates in locations as far north as Cleveland, Ohio. However, their efficiency and effectiveness in cold weather climates such as Ottawa was not yet proven. A temporary biofilter was constructed and commissioned in June 2000 at an approximate cost of $160,000. The facility was constructed to provide immediate odour control for the Glen Cairn Trunk Sewer and has also provided the City with an opportunity to use the facility as an at-grade "pilot" biofilter.

Robinson Consultants in conjunction with the Ainley Group and Odor and Corrosion Technology Consultants Inc. were commissioned in May 2001 to continue to operate and monitor the pilot biofilter on behalf of the City of Ottawa. The additional monitoring will permit the optimal performance criteria to be used in the design of the permanent biofilter, which is to be constructed at the same location as the pilot biofilter. The optimized design parameters include the following:

- Biofilter size and construction configuration (above and/or below grade)
- Biofilter humidification requirements for optimal performance
- Biofilter heating requirements for cold weather operation (if required)

The data indicates that the pilot biofilter has controlled odours in the sewer and satisfied the performance requirements stipulated in the Certificate of Approval granted by the regulating government agency, including operation under winter conditions. The permanent facility can operate at grade and the cost of the permanent facility will be significantly reduced.

INTRODUCTION

The Glen Cairn trunk Sewer is a 3,500 metre pre-stressed concrete sewer located west of the center of the City of Ottawa. A biofilter was recommended as the longterm solution to control odours and reduce corrosion problems resulting from hydrogen sulphide gas in the sewer. An inexpensive pilot biofilter was constructed and commissioned in June 2000 to provide an immediate solution.

As previously mentioned, the use of biofilters in cold climates is not common. The average January temperature in Ottawa is –16ºC. Due limited information on the design, construction and operation of biofilters in such cold climates, it would have been necessary to make conservative assumptions which would have a direct impact on the overall project cost.

By using the temporary bio filter as a full scale pilot the project team was able to accurately determine the optimum requirements for the design of the permanent biofilter.

BACKGROUND

The location of the Glen Cairn Trunk Sewer is shown on **Figure 1** (following page). At its upstream end the Glen Cairn Trunk Sewer receives flow from three force mains and one gravity sewer. At its downstream end, the Glen Cairn Trunk Sewer discharges into the Tri-Township Collector sewer. The sewer is constructed of 1200-mm diameter AWWA 301 pre-stressed concrete cylinder pipe. Approximately 2680 meters of the upstream portion is lined with "T-Lock" as a protection against corrosion and the remaining downstream 820 meters is unlined. Robinson Consultants completed the "Glen Cairn Trunk Sewer Odour and Corrosion Control Preliminary Design Report" in October of 1999 which recommended construction of a biofilter near the end of the lined portion of the Glen Cairn Trunk Sewer. The recommended biofilter would draw approximately 6,900 m^3/hr (4,000 cfm) of odourous air from the sewer to control odours and mitigate corrosion. The time required for the approval and design process of the biofilter, resulted in the construction of a pilot biofilter facility that was placed in service on June 17, 2000. **Figure 2** (following page) shows the layout of the pilot biofilter.

METHODOLOGY - BIOFILTER MONITORING PROGRAM

In order to determine the optimal design parameters and design for the permanent Glen Cairn Biofilter the City of Ottawa authorized the monitoring and the operation of the pilot biofilter by Robinson Consultants in association with the Ainley Group and Odor and Corrosion Technology Consultants Inc. The purpose of the program was to monitor, operate and maintain the biofilter as well as monitor various conditions within the Glen Cairn Trunk Sewer in order that the permanent biofilter design may be optimized. The monitoring data will measure the pilot biofilter's performance under varied conditions (i.e. various design airflow rates, additional manhole sealing and/or sewer venting) and determine the permanent biofilter design.

The complete pilot biofilter and Glen Cairn Trunk Sewer monitoring program and data collection program was managed and completed by the Ainley Group, from Ottawa, Ontario.

Monitoring Instruments

Various parameters were monitored at the pilot biofilter. **Figure 3** shows the locations were the biofilter is being monitored. Some of the instrumentation used in the monitoring program are briefly described below:

1) **Jerome 631-X Hydrogen Sulfide Analyzer:** This unit was made by Arizona Instrument Corporation and measures the concentration of hydrogen sulfide from the bed. The manufacturer recommends operating environment conditions in a temperature range of 0 to 40ºC and in a non-condensing and non-explosive environment. The range of the unit is 0.003 to 50ppm H_2S, with the following accuracy:

   Range 0: ± 0.003ppm at 0.050ppm H_2S
   Range 1: ± 0.03ppm at 0.50ppm H_2S
   Range 2: ± 0.3ppm at 5.0ppm H_2S
   Range 3: ± 2ppm at 25ppm H_2S

   The unit can store 3.5 days of data when sampling every 5 minutes. The unit utilizes a rechargeable nickel cadmium battery, (which will last 6 hours between charges) and comes with an AC power plug. The unit is not designed for 'condensing' humid environments; the manufacturer recommends annual inspection of the analyzer for routine maintenance and calibration.

2) **Odalog Hydrogen Sulfide Meter:** This unit is fabricated by App-Tek International and collected the levels of H_2S in the GC 800 (intake of Biofilter). The manufacturer recommends operating environment conditions in a temperature range of 0 to 40ºC, and in a non-condensing environment. The range of the unit is 0 to 200ppm ±1ppm H_2S (some meters were in the 0 - 50 ppm range). The unit can store 3 months of data at 5 minute sample intervals. The unit uses three 1.5 V batteries which last approximately three months.

3) **Rotronic Humidity- Temperature Transmitter (Model FT2C-D):** This unit is fabricated by Rotronic Instrument Corp. and is used to measure the humidity and temperature of the air in the sewer. It operates effectively in a temperature range of -20 to 50ºC (±0.3ºC) and a humidity range of 10 to 100% RH (±2% RH). Use in temperatures outside this range can damage the unit. Since the Rotronic is a transmitter it does not hold any data nor have its own power source. For the purposes of this monitoring program an external power source and logger was used (ACR Smart Reader)

to log continuous data. Since these units are susceptive to damage in a corrosive environment, for this monitoring program a special protective cap was installed on the sensor to protect it.

4) **ACR Smart Reader Plus 7 Data Logger:** This unit is fabricated by ACR Systems Inc. and is available in a variety of memory sizes. The ACR logger has an internal temperature meter and requires an external power supply (110 VAC). This logger recorded data from the two Rotronics and two Setra units installed in the Biofilter. The model used has a 128KB memory and is able to store over 50 days of data (internal logger temperature, temperature and humidity of the sewer air inlet and from the Biofilter bed as well differential pressures of both fans in the Biofilter) at 5 minute sampling intervals. The temperature range is -40 to 70ºC with an accuracy of 0.2ºC (between 0 to 70ºC).

RESULTS

H_2S

Incoming hydrogen sulphide was continually monitored (sampling every 5 minutes) in the maintenance hole on the Glen Cairn Trunk Sewer just before entrance into the pilot biofilter with an "OdaLog" type data logger.

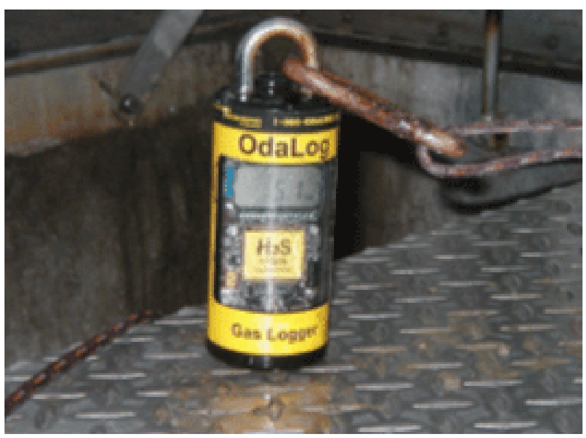

FIGURE 2 – ODALOG DATA LOGGER

H_2S measurements were made on the surface of the biofilter bed with a Jerome 631-X H_2S monitor complete with an automatic data logger.

FIGURE 3 – JEROME 631-X ANALYZER SET-UP

H_2S was collected alternatively in two separate fume hoods located on the surface of the biofilter bed. This permitted samples of air to be drawn back into the Jerome monitor with a vacuum pump located inside the biofilter fan building from the two different locations on the bed. The solenoid valve would close drawing in fresh air to a sampling cylinder until such time as an H_2S sample was required to be measured. The H_2S sampling frequency was typically set to once every 15 minutes.

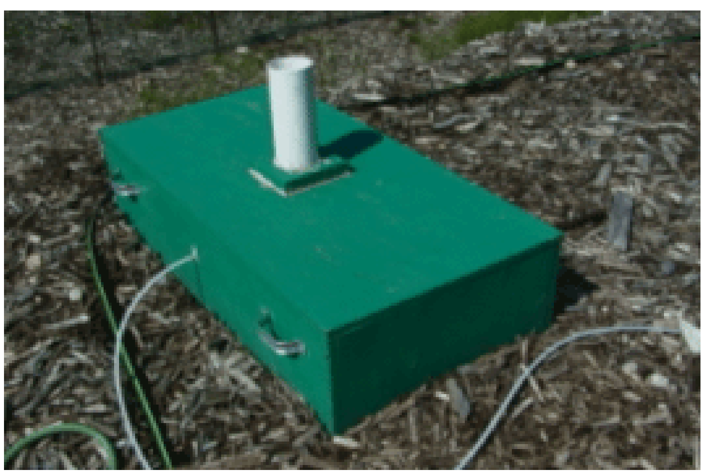

FIGURE 4 - BIOFILTER FUME COLLECTION HOOD

Results of the incoming H_2S data are presented below in Table 1.

TABLE 1
H_2S MONITORING IN PPM OF H_2S

Sample Location	Winter		Spring		Summer	
	Average	Peak	Average	Peak	Average	Peak
Incoming (GC 800)	0.37	44	4.9	26.5	7.5	184.3
Outgoing (on bed)	0.18	2.3	0.07	21[a]	0.046	20

[a] – peak value is unreliable

As can been seen from the incoming H_2S data the average levels noted during the winter months was 0.37 ppm, with a peak of 44 ppm. The spring data indicated an average of 4.9 ppm with a peak of 26.5 ppm. Similarly, the summer data was noted to be an average of 7.5 ppm with a peak of 184.5 ppm.

HUMIDITY DATA

Humidity measurements were made for the incoming sewer air to the biofilter using a Rotronic type temperature/humidity transmitter.

FIGURE 5 – ROTRONIC TEMPERATURE/HUMIDITY TRANSMITTER (INCOMING SEWER AIR)

TABLE 3
HUMIDITY MONITORING IN % RH

Sample Location	Winter		Spring		Summer	
	Average	Peak	Average	Peak	Average	Peak
Incoming (GC 800)	98.7	99.4	91.9	100	100	100
Outgoing (on bed)	93.3	100	n/a	n/a	99.4	100

Results of the humidity measurements indicate an average incoming relative humidity of 98.7% just ahead of the suction fans with a peak of 99.4% in the winter months. In the spring the average relative humidity was 91.4% with a peak of 100%. Similarly the summer months yielded an average and a peak of 100% relative humidity. The humidity data was noted to be suspect due to failure of several humidity probes due to the humid and corrosive environments experienced in the sewer gases. The probes failed several times and read 100% due to continuous condensation of moisture on the monitor probe.

Additional humidity monitoring was also completed using a similar arrangement to that described in the H_2S results section. A vacuum pump samples air from before the suction fans and/or off of the biofilter beds and then draws fresh outside air to maintain a drier atmosphere for the probe prior to data sampling. Samples are taken every 15 minutes with the solenoids then closing and drawing fresh air in, to dry the probes. This current sampling arrangement has proven to be more reliable for humidity monitoring and has been satisfactorily operating for the past month.

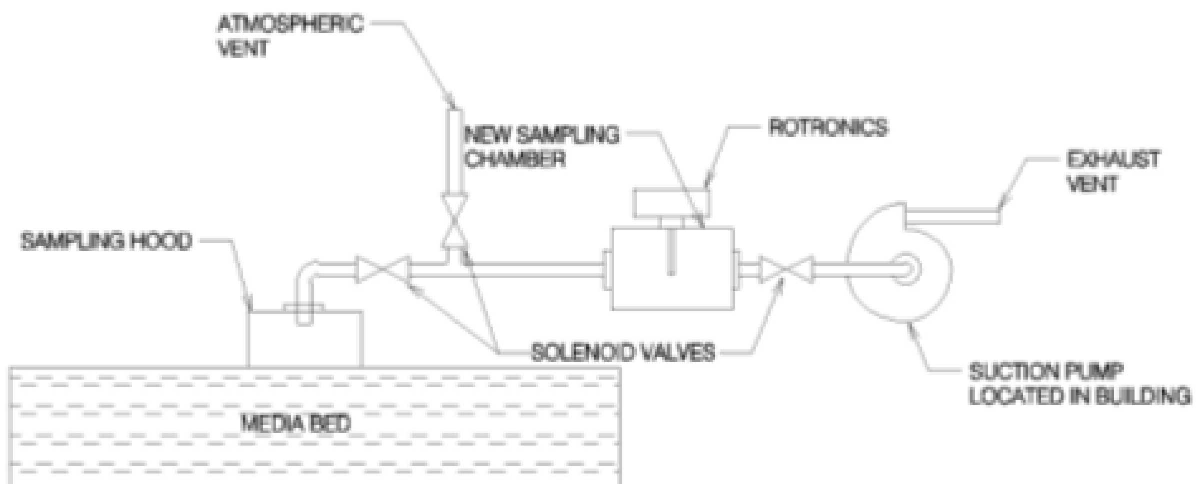

FIGURE 6 – GLEN CAIRN BIOFILTER HUMIDITY SAMPLING ARRANGEMENT

TEMPERATURE

Temperature was measured incoming into the biofilter fans (by an Odalog) and after the fans in the biofilter bed sampling collector hood (by a Dickson).

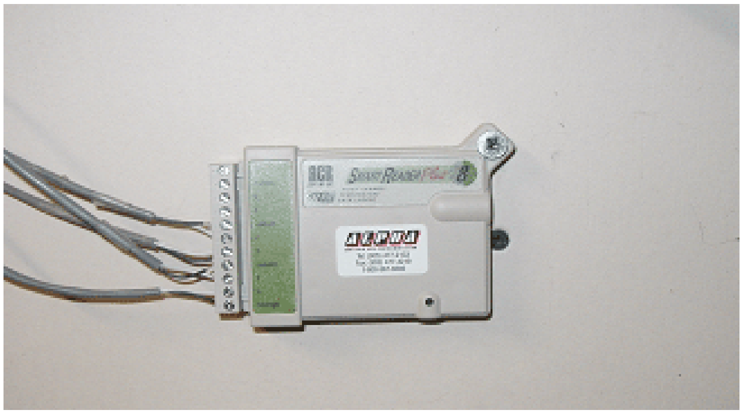

FIGURE 7 – INCOMING TEMPERATURE SENSOR

TABLE 4
TEMPERATURE MONITORING IN CELSIUS

Sample Location	Fall (°C)		Winter (°C)		Summer (°C)	
	Average	Peak	Average	Peak	Average	Peak
Ambient[1]	5.7	18.5	-5.5	11.5	20.2	37.5
Incoming (GC 800)	15.3	16.1	8.8	10.3	18.2	20.0
Outgoing (on bed)	10.9	15.5	5.3	11.0	18.3	22.0

1 – Ambient temperature sensor in direct sunlight, recorded values which may be higher than actual

During the fall season, the average temperature was noted to be 5.7°C with a peak of 18.5°C. Incoming sewer air had an average and peak temperature of 15.3°C and 16.1°C respectively, while the outgoing air on the bed had an average and peak temperature of 10.9°C and 15.5 °C respectively. During the winter season, the average temperature was noted to be -5.5°C with a peak of 11.5°C. Incoming sewer air had an average and peak temperature of 8.8°C and 10.3°C respectively, while the outgoing air on the bed had an average and peak temperature of 5.3°C and 11.0°C respectively. During the summer season, the average temperature was noted to be 20.2°C with a peak of 37.5°C. Incoming sewer air had an average and peak temperature of 18.2°C and 20.0°C respectively, while the outgoing air on the bed had an average and peak temperature of 18.3°C and 22.0°C respectively. Currently the biofilter bed is being monitored for temperature at various depths.

DISCUSSION

H_2S

H_2S discharge levels varied from an average removal efficiency of 64% in winter months to a maximum of 99.5% in summer months. These averages are based on the biofilter operating at an approximate airflow rate of 0.825 m^3/s (1700 cfm) @ 13 iwc (inches of water column), which is less than the design airflow rate. With a lower airflow the amount of H_2S gas entering the biofilter bed would be reduced thus reducing the loading rate for optimal biofilter performance. Design biofilter removal efficiency is typically in the order of 99.8% or greater.

The H_2S levels during the winter months are much lower than in other months as the cold conditions within the sewer do not lend themselves to the generation of hydrogen sulphide gases. The bacteria normally present in the sewer actively slow down during the winter months and less sulpher and sulphates are biologically reduced to sulphides, which cause the sewer odour and subsequent corrosion problems during the summer month.

During all seasons of the biofilter bed monitoring the discharge levels from the biofilter bed were in compliance with the facilities Certificate of Air Approval. This is an important finding as it was previously hypothesized that additional heating and/or insulation would be required to ensure the biofilters' optimal performance throughout the year. Reduced biofilter performance for the Glen Cairn pilot biofilter during colder months is not an operational problem as H_2S levels during winter months are also reduced. The lower removal efficiency is adequate to ensure the biofilter is operating within its' Certificate of Air Approval.

HUMIDITY

Results of the humidity measurements indicate an average incoming relative humidity of 96.7% just ahead of the suction fans with a peak of 99.4% in the winter months. In the spring the average relative humidity was 91.4% with a peak of 100%. Similarly the summer months yielded an average of and a peak of 100% relative humidity.

The importance of accurate humidity monitoring before and especially on the biofilter bed is a key to a successful and efficient biofilter operation. Too much or too little moisture can be harmful to the proper biofilter biological process. The provision of additional moisture, especially during the winter months would be very costly in the Ottawa area. This is due to the requirement to heat the water and the incoming odourous air to increase the relative humidity of the sewer air into the biofilter. As can be seen from the H_2S removal efficiency data additional humidity is not required during the winter months monitoring as biofilter performance was adequate to control incoming H_2S levels to meet the biofilters' Certificate of Air Approval.

During the summer months the relative humidity of the air entering the biofilter remains constant at near 100%. The odourous sewer air condenses within the biofilter media providing a moist environment for the development of Thiobacillus bacteria. Additional external humidification is only required during the hottest of summer months to ensure that that the biofilter bed does not dry out due to evaporation. Internal soaker hoses are also usually provided to wash out the media if excessive acidic conditions develop in the bottom of the media bed.

TEMPERATURE

Temperature in the biofilter bed was affected by:

1. Incoming sewer air temperature.
2. Local climatic conditions.

Biofilter operation was acceptable in winter months due to low of H_2S in sewage. This may be considered unique to northern climates as sewage temperature drop in the winter and the spring months. This seems to indicate that the biofilter performance is acceptable without supplemental heat as long as incoming odours are low in potency. Indirect supplemental heat (steam) is a very expensive addition to the operation of the biofilter.

SUMMARY OF FINDINGS AND RESULTS

- **Biofilter bed can be constructed above grade due to it's satisfactory operation during winter months, however it is recommended that the bed be constructed partially below grade to improve performance and improve aesthetics.**

- **Due to the ambient humidity, it is not necessary to humidify the airstream, however, supplemental irrigation for the biofilter bed is still required to prevent excessive drying during summer months.**

- **The data suggests that it is not necessary to add additional heat to the airstream if the bed is constructed partially below grade.**