Atmospheric Hydroxyl Generating Technology as a Solution to Odour issues, Two Case Studies

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City of Sarnia, Devine Street Sewage Pumping Station

In 2011, with a population close to 73,000 people, the City of Sarnia commissioned a new sanitary sewage pumping station (SPS) in the City Works Yard located on Devine Street. Building this new pumping station was made possible through contributions from the City and the Canada Strategic Infrastructure Fund.

In the 1950s, the City's core area sewage collection system was built as a series of combined sewers, designed to convey both storm water and sanitary sewage directly to the St. Clair River, without treatment. Four main trunk sewers were constructed at that time along Exmouth, Devine, Wellington, and Cromwell Streets. Following 1951, the City grew east and the area was designed with separate storm and sanitary sewers, which discharged to the combined sewer system in the core area of the city.

An onset of sewer capacity problems began in the late 1950s and early 1960s, and storm relief sewers were built along newer streets in an effort to accommodate increased flows due to civil development. The Riverfront Interceptor Sewer was constructed in 1961, designed to intercept up to three times the average dry weather flow and convey it to the Sarnia Water Pollution Control Centre (WPCC), also newly constructed at that time, on St. Andrew Street. Flows exceeding the interceptor capacity continued to overflow to the St. Clair River. The four original trunk sewers and the Riverfront Interceptor still form the core of the combined sewer system.

Today, the new SPS receives wastewater from four other existing pumping stations via a new 1200 mm gravity interceptor sewer that was installed on Devine Street. A new 600 mm diameter (HDPE) sanitary forcemain conveys the pumped sanitary flow directly from the SPS to the Sarnia WPCC.

The SPS design incorporates two separate wet wells with a collective operating volume of 56,000 L. Each wet well influent channel is equipped with a channel grinder and a slide gate, installed upstream of each grinder to facilitate wet well isolation and maintenance. The wells are interconnected via a sluice-gated opening in the common wall to provide additional flexibility of use. As the wet well was not mechanically ventilated or heated, portable ventilation equipment and monitoring for hazardous gases and oxygen deficiency is required on entry. For this reason, the area is classified under the US National Electrical Code and all electrical equipment and appurtenances within the area are rated accordingly.

In lieu of mechanical ventilation, the wet well had short, stainless steel 'candy cane' venting pipes. Incorporated in the design were static, 203 mm OD intake and exhaust venting pipes that provided a minimal air exchange. However, as the SPS commenced operation, the City began to receive odour complaints from property owners across the street from the pumping station. In an effort to address a growing number of complaints, much taller vent pipes were installed to provide a solution by natural dispersion.

Before the search began for a viable odour abatement solution, the City hired an environmental air-testing firm to quantitatively establish the levels of fugitive hydrogen sulfide (H_2S). At that point in time, an average of 15 ppm to 30 ppm level was measured. Putting the effect of H_2S concentration into perspective, 2 ppm has been known to cause bronchial constriction in asthmatic individuals while 10 ppm to 50 ppm causes headaches, dizziness, nausea, coughing, vomiting, etc. The exposure limits for H_2S, as set out in the Ontario Health and Safety Act, is 10 ppm on a time-weighted average limit, with a 15-ppm short-term exposure limit.

Sarnia SPS before any odour control.

Sarnia SPS with Odorox® installed.

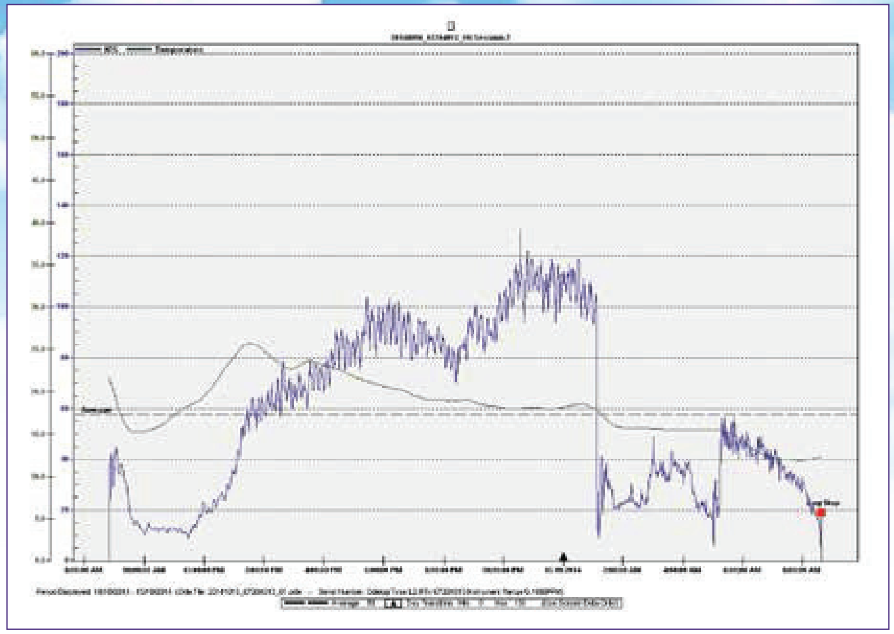
The City of Sarnia learned of atmospheric hydroxyl generation technology as provided by Hydroxyl Environmental under the Odorox® trade name while in attendance at the 2012 Canadian Waste and Recycling Expo in Toronto, Ontario. Sarnia was presented with a recent, successful WWTP case study from the USA. The City found the technology intriguing because it did not require the addition of chemicals, operated with low electrical requirements, and employed a very small footprint. In order to validate the technology for their application, Sarnia paid for a two-month trial of a system and based on a positive outcome, agreed to purchase that system outright upon trial completion.

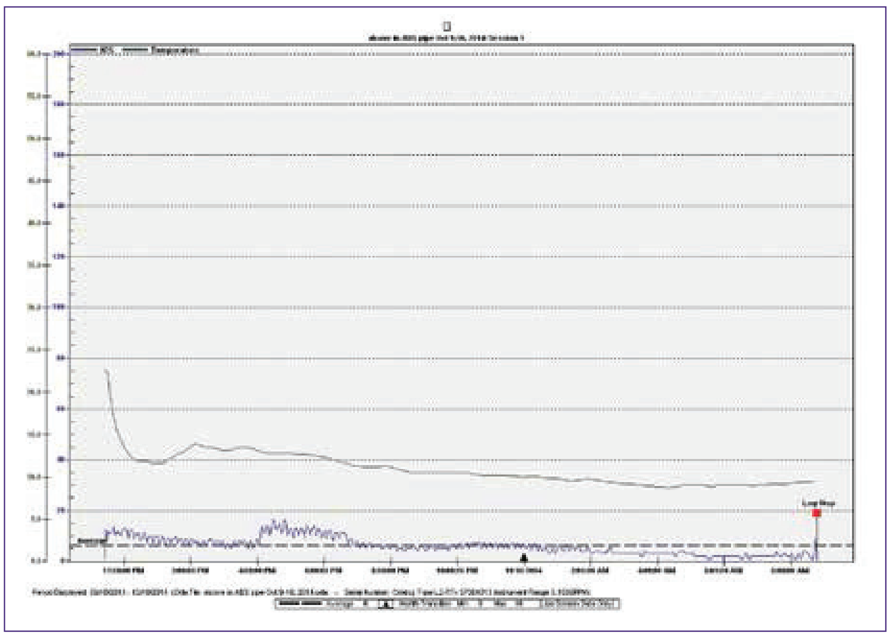
The Sarnia trial involved locating a single hydroxyl generator outdoors, placed on top of the 340 m^3 wet well while injecting hydroxyl-rich air at a rate of 595 m^3/hr into the original intake air vent, which discharges just above the odour source below. The low CFM of hydroxyl-rich airflow blanketing the odour source along with the passive air exchange provided enough retention time to sufficiently neutralize the H_2S such that the exhaust was no longer a nuisance to the neighbouring homes. Hydroxyl production demands are made through automation controls via direct feedback received by a Draeger Polytron 7000 oxidant sensor mounting beneath a shroud on the exhaust pipe, which acts to protect the unit from the outdoor environment. If the measured concentration is below a set-point, it is assumed that the generated hydroxyls are being consumed in reactions with odorous compounds and the device will receive a signal to maintain hydroxyl production. Once the measured oxidant level is above a set-point, hydroxyl production is stopped, which results in energy savings over an always-on configuration. Since the September 2013 installation, the City no longer receives odour complaints.

Courtice Water Pollution Control Plant (WPCP)

The Courtice WPCP team was experiencing hydrogen sulfide (H_2S) release that was coming from an upper vault located at the property line entry point. Hydrogen sulfide was finding its way down a hill and was being drawn into the headworks building via an air handler intake. The headworks building houses the plant's screens and grit classifier, as well as blowers and grit slurry pumps located in the building's basement.

The installation of hydroxyl generators to service the upper vault was able to reduce the quantity of H_2S that made its way down into the headworks. The following charts, prepared by the Region of Durham, show the effect the units had on the concentration of H_2S in the study area.


H_2S Levels [ppm] in the upper vault at the Courtice WPCP without odour abatement.


H_2S Levels [ppm] in the upper vault at the Courtice WPCP with the Odorox® units in operation.

Based on the success in addressing the H_2S in the headworks, further units were installed on site. Two Odorox® IDU™ units (induct) have been installed onto HVAC air handlers that supply fresh air into the sodium bisulfite and ferrous chloride chemical storage area and pump rooms. These in-duct units use the fresh air passing across the special multi-frequency, crystal quartz optics, while the HVAC infrastructure distributes the generated atmospheric hydroxyls into the targeted treatment spaces. The Courtice WPCP staff has noticed a drastic reduction in odour and corrosive contamination within these treatment spaces. Operators going into these rooms no longer suffer from the irritation they had previously experienced in these environments prior to the installation of the hydroxyl generators.

The Oxidation Process of Atmospheric Hydroxyl Generating Technology

The decomposition of volatile organic and inorganic compounds by hydroxyl radicals involves a complex series of free radical oxidation steps that gradually result in the loss of individual carbon atoms to eventually form carbon dioxide (CO_2).

Courtice WPCP Chemical Room being treated. Odorox® Induct units servicing chemical room through existing ductwork.

Courtice WPCP Upper Vault: 2 Odorox® units installed within off-the-shelf housing structure.

As efficient oxidants, hydroxyls are driven to regain one electron to restore their very stable valence configuration. The most facile way to accomplish this in an environment rich in Volatile Organic Compounds (VOCs) is to abstract a hydrogen atom with its single electron, leaving behind an organic free radical.

The newly formed organic free radical has an unpaired electron that is initially localized on the carbon atom.

$$\mathbf{R\text{-}CH_2\text{-}CH_2\cdot}$$

This moiety rapidly reacts with ambient oxygen to form a peroxy free radical in which the free electron is now localized on an oxygen atom.

$$\mathbf{R\text{-}CH_2\text{-}CH_2\text{-}O\text{-}O\cdot}$$

This species is a powerful oxidant in its own right, and will react with VOCs and inorganic gases. It is more stable than the hydroxyl radical and able to travel further away from the reaction chamber to react with VOCs and microorganisms in the treatment area. Peroxy radicals can also rapidly form oxy radicals in ambient air.

$$\mathbf{R\text{-}CH_2\text{-}CH_2\text{-}O\cdot}$$

Hydroxyl radicals are also generated throughout the treatment space by continued reactions of intermediate compounds. The free radical transfer reactions essentially 'unzip' carbon chains rapidly.

As long as hydroxyls are continuously formed, both thermodynamic and kinetic factors favour continued oxidation of VOCs. Hydroxyls have a very high oxidation potential and high reaction rates with most VOCs, characteristics that are well documented in the chemical literature.

In the cascade effect, successive generations of oxidants continue to decompose and dissociate VOC carbon chains. This is driven by the nature of the oxidation process, which introduces oxygen into the carbon chains. In oxygenated VOCs, the hydrogen atoms near the oxygen atoms are much more reactive because of polarization. Oxygen attracts electrons away from less electronegative atoms and makes them more reactive. As such, hydroxyls next to carbon-bearing oxygen(s) are more readily abstracted by another hydroxyl… and so on until that carbon atom is cleaved from the chain as stable CO_2.