A Floating Cover Over Large Anaerobic Pond to Eliminate Odour and Produce Electricity

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ABSTRACT: This paper will discuss installation and design considerations of constructing a 200m x 150m floating cover over an active anaerobic lagoon which has a 150m long floating wall/gas cut off between anaerobic and aerobic portions of the lagoon. A $1.5 million (Aust.) project, the cover was installed over a period of 12 weeks. Complaints about odours from the lagoon had increased due to the population growth in the local area. Pressure from this community created the urgency for a solution.

The gas extraction and flaring equipment was a large component of the contract and considerable time and effort was spent on creating a facility that had the ability to accurately control the degree of inflation of the floating cover. The successful commissioning of one of the largest floating covers of its type paves the way for further floating covers and associated electricity generation plants.

1 INTRODUCTION

Melbourne Water is responsible for the collection and treatment of waste water from the homes and industries of over 3.5 million people. Waste water from the western and northern suburbs is treated at a 14,000 hectare farm near Werribee only 30km to the south west of the central business district of Melbourne, Victoria, Australia.

At Werribee the sewage is treated/used by a variety of methods, such as root filtration and direct irrigation. This paper is concerned with the use of anaerobic/aerobic bacteria in lagoon treatment systems. The 155 East Lagoon at Werribee is approximately 150m wide and 2000m long. The initial 200m is the anaerobic section where anaerobic bacteria consume organic material and in the process produce methane gas and hydrogen sulphide gas.

A floating cover and associated gas handling plant enables it to:

i) eliminate odorous hydrogen sulphide gas
ii) eliminate the passing of "greenhouse" methane gas into the atmosphere
iii) generate electricity
iv) enhance the anaerobic activity of the lagoon via insulation and the creation of a heat sink. Additionally, a heat exchanger can be used to turn heat from burnt gas into an increased temperature of the anaerobic pot further enhancing anaerobic activity.

2. DESIGN CONSIDERATIONS

2.1 Floating Cover

The overall plan dimensions of the cover are 150m wide by 200m long. It is restrained on three sides by anchor trenches. On the fourth side a cable stayed floating wall is in place. The cover is divided into 34 bays via weight pipes. A central longitudinal 300mm OD slurry filled HDPE pipe acts as the water collection trench. Smaller transverse 180mm OD water filled HDPE pipes then divide the cover into smaller bays approximately 75m x 12m.

Gas produced is then confined by these weight pipes limiting the size of bubbles that can be formed. The effect of wind passing over these bubbles is such that up lift pressures and drag loads are created. The cover material must be able to withstand these forces.

The design surface wind velocity was 130km per hour with the drag load initially calculated as being modelled by a 300mm high plate and later by a 4m deep wing.

The maximum fluctuation in the floating cover level was stipulated as 100mm and the sewage characteristics are as follows:

BOD	525mg/L
SS	525mg/L
pH	6.9
Temp. Range	12°C to 25°C
Total N	55mg/L
NH (as N)	32.0mg/L
Total P	9.0mg/L
Volatile SS	425mg/L

Raw sewage composite:

Compound	Concentration (ppB)
Dichloromethane	116
Ethane, 1,1, Dichloro	1
1,1,1, Trichloroethane	33
Chloroform	15
Benzene	262
1,2 - Dichloromethane	1
Trichloroethane	270
Toluene	238
Tetrachloroethene	61
Ethyle Benzene	188
1,4 - Dichlorobenzene	142
1,2 - Dichlorobenzene	62

The chemical resistance, tensile strength and lack of variation in water level allowed 2.5mm HDPE to be specified for the project.

2.2 Anchor Trenches

The anchor trenches also take into account the potential forces due to wind, however, as the lagoon does not have a bottom liner the depth of trench was increased to 1.5 metres.

This prevents the possible suction of air through the batter preventing an explosive condition as the oxygen content increases.

2.3 Floating Wall

As mentioned earlier, three sides of the cover are anchored in anchor trenches. The fourth wall is a cable stayed floating wall. This acts as the separator between the anaerobic section and aerobic section. It consists of a float and a 1.5m deep skirt of HDPE with a concrete filled pipe welded onto the end.

To determine the forces on the cables and hence on the cast in situ piles it was assumed that the float was a 300mm high wall with a 130 kilometre per hour wind acting on it.

2.4 Gas Collection Pipes

Gas collection pipes are located under the cover around the perimeter of the lagoon. The suction fans are located at one corner of the lagoon. As we require the suction pressure at all locations around the perimeter to be the same, the gas collection pipes have been "balanced". This was done by increasing the number of holes per metre of pipe as the distance from the suction point increases.

Expansion joints had to be incorporated into the collection system due to the expansion/ contraction of HDPE pipe.

2.5 Storm Water

A sump is created by the central longitudinal weight pipe. The pump was sized to cope with 1 in 100 year storms and is controlled via mercury float switches which are easily adjustable. This feature allows the quantity of water in the central trench to be varied.

3.0 CONSTRUCTION

As the anaerobic lagoon was

existing and in use before construction began, it was necessary to install the cover from a barge. The barge was 150m long so as to span the entire width of the lagoon.

As the lagoon continued to produce gas as the liner was installed, a temporary venting system utilising a suction fan running 24 hours a day powered via a diesel generator. The perimeter collect pipes were installed at the same time such that the temporary suction fan could be connected to these and the gas simply vented from a 6m stack.

As the construction progressed, the bubbles of gas made it necessary to trim the sheets square. The extra material required due to the bubbles meant that a straight edge could not be maintained. This, in effect, caused more material to be cut into the belly of the cover.

This created areas of the cover that has excessive slackness which allowed larger bubbles to be formed in certain areas. Corrective action included the installation of a float under the cover in one particular bay, the tightening of the floating wall such that it takes most of the slackness out of the middle and setting the stormwater pump such that the central weight trench was full with water.

4.0 COVER OPERATION

On the surface the cover works very simply. The gas builds up under the cover. Eventually the pressure is high enough to cause the bubble to "burp" up the batter and into the perimeter gas collection pipes.

4.1 Pressure Settings

The pressure in the collection pipes is critical. Settings of >-10mm H_2O cause the cover to be sucked onto the batter. Settings <+1.0mm H_2O does not cause a large enough pressure gradient to cause gas flow.

4.2 Sludge Concerns

Before the trialing of different pressure settings, a large build up of very firm sludge occurred in the first few bays. Eventually this sludge covered over half the lagoon. Samples taken of this sludge show it as green and fibrous and up to 1m thick. The growth of this sludge caused the central weight pipe to move over 15m sideways. This occurred twice, with the second time resulting in the damaging of a sample port allowing sewage to flow into the central water filled weight trench.

Severe stress was placed on the cover material as the sludge, forced by the current in the lagoon streched the cover causing large folds further exacerbating the size of bubbles due to slackness in the cover.

4.3 Hot Spots

In conjunction with the growth of the sludge the anaerobic activity of the lagoon moved further down stream. Some bays had higher than average gas production and large localised bubbles resulted. The sheet was a blown geomembrane with crease lines causing the cover to dip below water level sealing the bubble off from the gas collection pipes. Pressure from the trapped gas eventually caused the kinks to unfold, allowing the gas to escape. At one stage a bubble approximately 4m high was produced.

Many concerns were raised with regard to the uplift pressures and drag loads of such a large bubble, however, as the bubble is flexible and not a rigid wing, as assumed in the calculations, at higher speeds the bubble ripples causing turbulent flow and hence shedding energy.

4.4 Gas Handling Facility

The gas handling facility was designed to be capable of 200m^3 to 800m^3 per hour. It consists a manifold off take, suction fans, fan bypass valve, filters, gas sampling equipment and a flare. The cover was constructed during winter which is a low gas production period. During summer gas production exceeded 1200m^3 per hour due to the extra heat in the anaerobic pot. This caused problems with the flare as the additional heat melted much of the insulated cabling and distorted the upper wind cowl. Both of these were later replaced.

4.5 Residual Flame

An ongoing problem was the residual flame. This is the flame caused by the weight of the cover on the gas forcing the gas through the flare stack when the blowers are turned off. This slight flow allows a residual flame to continue to burn. This can occur for over 24 hours before it eventually ceases. This problem causes the ignition sequence on the flare to halt as the sensors designed to measure UV light see a flame during a flame out condition. As this problem was not foreseen, the initial electronics on the flare ignition system had to be replaced with a more advanced system.

4.6 Wet Gas

Gas extracted from underneath a floating cover contains a significant amount of moisture. This, coupled with the H_2S gas, turns any condensation build up into sulphuric acid. As such, all pipework on the plant are HDPE or stainless steel. The gas was so wet that the moisture and sediment traps were not collecting sufficient moisture. This allowed water to condensate into the oxygen and methane analysers despite having a dehumidifier to protect both these pieces of equipment. Improvements to moisture traps proved successful, however, the dehumidifier is an essential piece of equipment and its operation must be closely monitored.

5.0 ELECTRICITY PRODUCTION

An experimental electricity generator has been trialed successfully. The initial trial used a sacrificial generator which was run without scrubbing the H_2S gas. A full scale electricity generation plant is planned for future development.

6.0 CONCLUSION

The successful collection and flaring of gas generated from an anaerobic sewage lagoon and subsequent electricity generation at Werribee for Melbourne Water proves that what was previously a naturally occurring pollutant can be turned into a heat and electricity source. The potential for other such projects is now much more likely.

Even without the benefit of electricity generation the simple flaring of up to 20,000m^3 per day of gas is worthwhile from an environmental view point. This gas would have otherwise entered the atmosphere, reduced peoples standard of living due to odour and contributed to the greenhouse gas problem.

The generation of electricity allows such projects to be revenue positive over time. This allows the possibility of design construct and own schemes whereby private industry can construct public infrastructure without Government cash outlays.

Improved efficiency of the anaerobic lagoon allows more waste to be treated by the same lagoon delaying, possibly forever further construction of additional lagoon systems.