AERATION SYSTEMS – DIFFUSED CHAOS OR CONTROLLED BOILING

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ABSTRACT

The paper describes the aeration system at the Black Rock Sewage Treatment Plant and discusses the methods adopted to effectively manage, maintain and replace the 42,000 fine bubble diffusers used to aerate the plant.

The objective of the work on the aeration system and diffusers at the plant is to maximise the life of the diffusers, minimise the energy used in the plant while providing optimum process performance.

The centrifugal compressors and diffused air distribution system are the heart and veins through which the lifeblood of the plant flows. The flow of air provides the oxygen which keeps aerobic micro-organisms alive and well in the Intermittently Decanted Extended Aeration (IDEA) plant.

KEYWORDS

Sewage treatment, IDEA, fine bubble diffusers, cleaning program, diffuser replacement program.

1.0 INTRODUCTION

Without an effective method of record keeping to track the history of maintenance and performance on each of the diffuser manifolds at the Black Rock Sewage Treatment Plant, decision making on when to replace the diffusers is at best just a stab in the dark. Decisions based on "those stabs in the dark" would have been very costly and contributed to a significant downturn in performance.

The Black Rock Sewage Treatment Plant south of Geelong in Victoria was upgraded in 1996 to Secondary Treatment utilising the IDEA process. The $46 Million upgrade established the plant as the largest of its type in the southern hemisphere at the time. The Black Rock plant receives wastewater from the Greater Geelong area extending from Lara in the north, east to Queenscliff and south to Torquay/Jan Juc with an equivalent population of approximately 200,000.

The plant has a design average dry weather flow capacity of 70 ML/day with a peak wet weather flow capacity of 210 ML/day. The plant has a minimum hydraulic retention time of 32 hours and operates with a sludge age of approximately 30 days. It treats effluent from domestic and industrial sources with an average biochemical oxygen demand (BOD) of 370 mg/L and suspended solids (SS) of 360 mg/L to produce an effluent consistently below 10 mg/L BOD and 10 mg/L SS.

The process uses two selector tanks that feed four aeration tanks with continuous inflow. The process is based around a four hour cycle that aerates for 2 hours settles for 1 hour and decants during the last hour. The aeration system consists of 3x750 kW Centrifugal Compressors that provide air to the 42,000 fine bubble diffusers mounted on 640 stainless steel manifolds. The manifolds are 12 metres long and 3.5 metres wide. Each manifold has 64 ethylene propylene diene monomer (EPDM) diffusers fitted. The aeration system in operation in Tank 4 is shown in Figure 1.

Figure 1: ***Aeration System in Operation***

2.0 DISCUSSION

The Operations and Maintenance manuals provided by Contractors following the construction of new works at any modern treatment facility contain much valuable information. However, there are many issues that are not included.

One basic piece of information not generally referred to is that of record keeping. It is fair to say that any reasonable operator would be expected to keep appropriate records. However, when you have a diffused air distribution system in four aeration tanks that has a total of 42,000 fine bubble diffusers it can be a major exercise to keep those records. So, how much detail is enough and what use can those records be?

Since the plant was constructed there have been a number of developments made possible in part because of the quality of the records kept. It was identified very early in the life of the IDEA plant that the operation and maintenance of the aeration system would be of major importance to not only the biological treatment process but to the efficiency and cost of running the plant.

Because it is possible to isolate and lift individual manifolds from each tank (while keeping the tank online), actions to clean or replace diffusers are usually carried out on all diffusers mounted on the manifold at the time of removal. Therefore it was considered unnecessary to keep records on the individual diffusers.

A record is kept of the maintenance history of each individual manifold. A coding system was developed to identify individual manifold locations and their history of maintenance. Microsoft Excel was chosen as a program suited to recording those details, which most plant staff could utilise without specialist training. The spreadsheet is formatted to reflect the actual manifold position in the tank. A typical maintenance record is shown in Figure 2.

Figure 2: ***Part of a typical maintenance record***

TANK 1														
Man.	1st Clean	2nd Clean	CELL 3	H No.	Man.	1st Clean	2nd Clean	CELL 2	H No.	Man.	1st Clean	2nd Clean	CELL 1	H No.
1	310102		R (A) 4.10.01	4	1		230103	N (B) 29.9.00	175	1	100102		R (A) 10.10.01	54
2	310102		R (A) 4.10.01	3	2	211201	220103	N (B) 29.9.00	6	2	090102		R (A) 10.10.01 C	193
3	310102		R (A) 4.10.01	2	3	211201	220103	N (B) 28.9.00	249	3	090102		R (A) 9.10.01 C	192
4	300102		R (A) 3.10.01	1	4	211201	210103	N (B) 28.9.00	252	4	080102		R (A) 9.10.01	191
5	300102		R (A) 3.10.01	161	5	201201	210103	N (B) 28.9.00	177	5	080102		R (A) 10.10.01	47
6	300102		R (A) 2.10.01	67	6	201201	230103	N (B) 27.9.00	254	6	080102		R (A) 30.8.01	4
7	290102		R (A) 12.9.01 BB	81	7	201201	230103	N (B) 26.9.00	136	7	070102		R (A) 30.8.01	86
8	290102		R (A)11.9.01	82	8	191201	240103	N (B) 26.9.00	135	8	070102		R (A) 30.8.01	46
9	280102		R (A)11.9.01	86	9	191201	200103	N (B) 26.9.00	244	9	070102		R (A) 23.7.01	130
10	280102		R (A)11.9.01	3	10	191201	210103	N (B) 22.9.00	142	10	060102		R (A) 23.7.01	414
11	280102		R (A) 7.9.01	6	11	181201	200103	N (B) 21.9.00	75	11	060102		R (A) 23.7.01	129
12	270102		R (A) 7.9.01 BB	250	12	171201	170103	N (B) 21.9.00	170	12	060102		R (A) 24.7.01	270

Legend

R – reconditioned diffuser
N – new diffuser
(A) – diffuser type A
(B) – diffuser type B
BB – s.s. band loose or missing
C – corrosion on manifold

The recording system allows operations staff to determine:

- The manifold position within the tank and cell;
- The manifold identification plate number;
- The type of diffuser installed;
- When the diffuser was installed;
- When the diffuser was cleaned;
- Whether diffusers have failed;
- If there has been any history of corrosion and repairs;
- Where testing and dosing connection points have been fitted.

Analysis of the records together with other performance data collected have become a valuable tool in assisting to:

- Establish an effective replacement program for the diffusers.
- Determine an efficient cleaning program to extend the effective life of the diffusers.
- Maintain effective and efficient process performance.
- Develop budgets for costs to clean and replace diffusers.

3.0 REPLACEMENT PROGRAM

As a result of issues that arose during construction of the plant, it was considered prudent to take a conservative approach in establishing a suitable diffuser replacement program.

3.1 Working Life

The working life of new EPDM diffusers was expected to be between 4 to 6 years largely depending on the characteristics of the wastewater entering the aeration tanks. The wastewater flow entering the plant is made up of 85% domestic flow with 15% from industrial sources. This type of reasonably aggressive influent had the potential to adversely effect the life of the diffusers. A number of splits in the diffuser membranes were apparent in the first 12 months following commissioning which added further to the uncertainty of the working life. This appears, however, to have been the result of the construction process.

3.2 Supply of Replacement Membranes

As the plant uses some 42,000 diffusers a further consideration in the replacement program is the ability to source, transport and physically replace that number of units. If it was proposed to wait until it was apparent that the diffusers had reached the end of their working life, then it must be recognised that it can take up to 6 months to have the membranes manufactured and delivered.

3.3 Diffuser Reconditioning

Several aspects have to be considered in the method of replacing diffusers. Initially, a decision has to be made as to whether to replace the membranes only or to replace the entire diffuser. As the membranes generally seemed to be the only component that had deteriorated in condition it was decided to replace only the membrane. This results in a net saving of about $5 per unit over replacing the entire diffuser. Where other components were found to be faulty they were replaced.

The reconditioning of 10,000 diffusers takes about 1 month to complete using specialist contractors. It is crucial to the process that the diffusers are very carefully checked for defects before leaving the factory and once again immediately prior to fitting. This level of checking is necessary to avoid fitting any diffusers with faults.

If faulty diffusers are installed it generally leads to the manifold and all of its diffusers filling with sludge. This results in having to remove the manifold from the tank, draining the manifold of sludge, removing and replacing each diffuser and then stripping, washing and rebuilding each of the flooded diffusers.

3.4 Method of Replacement

Originally it was felt that the best way to replace each diffuser was to isolate and drain each tank. The tank and diffused air equipment would be washed down and then each diffuser would be replaced. However it was difficult to quantify the time necessary to adequately clean down the tank. The tank has a flat floor with only one sump. Combined with a concrete inlet tunnel mounted on the floor dividing the tank, it was likely to be a time consuming task to clean out the tank thoroughly.

Any delays caused through either Occupational Health and Safety (OH&S) issues or industrial relations problems with the large labour force required would also have the effect of increasing costs considerably.

The alternative method of replacing the diffusers was to keep the tank online and remove each manifold one at a time. This has some clear operational and cost advantages over the first method considered. The cost of this method is approximately 40% of the alternative.
The Gantry Crane and rail system (see Figure 3) traverses the entire area of each of the four aeration tanks readily allowing isolation and removal of each of the manifolds individually.

Figure 3: *Gantry Crane and rail system*

This method also allows a more thorough inspection of the manifold condition and diffusers. The aeration tank stays online and does not have to be cleaned and desludged. Work is carried out by two persons who are also able to repair any areas of corrosion that are found. To date very few manifolds have required repair. As each diffuser was replaced the rubber "O" ring sealing the diffuser against the manifold was also replaced.

Due to the relatively long lead time required to carry out a diffuser replacement program and the significant number of membrane defects identified during commissioning and immediately after it was considered appropriate stagger or spread the replacement program over a number of years. It was also decided to adopt a fairly conservative working life of 4-5 years for the original diffusers. This allowed the program to be spread over a period of at least 4 years.

Figure 4: ***Schedule of Work***

Year	Tank 1	Tank 2	Tank 3	Tank 4
1995-1996	New	New	New	New
1996-1997				
1997-1998				
1998-1999				
1999-2000				
2000-2001	Half new	Part clean	Half new	Clean
2001-2002	Half new/clean	New	Half new/clean	
2002-2003	Part clean		Clean	New membranes
2003-2004	Clean	Clean		Fit
2004-2005			Clean	Clean
2005-2006	Membranes & fit	Clean		
2006-2007			Membranes & fit	Clean
2007-2008	Clean	Membranes & fit		
2008-2009			Clean	Membranes & fit
2009-2010	Clean	Clean		
2010-2011			Clean	Clean
2011-2012	Membranes & fit	Clean		
2012-2013			Membranes & fit	Clean
2013-2014	Clean	Membranes & fit		
2014-2015			Clean	Membranes & fit

4.0 CLEANING PROGRAM

Having adopted a fairly conservative program initially it was very important to establish the actual maximum working life of the diffusers as soon as possible. This also meant investigating methods to extend the working life of the diffusers. To make decisions toward this goal it was necessary to find ways to measure and record the performance of the diffusers.

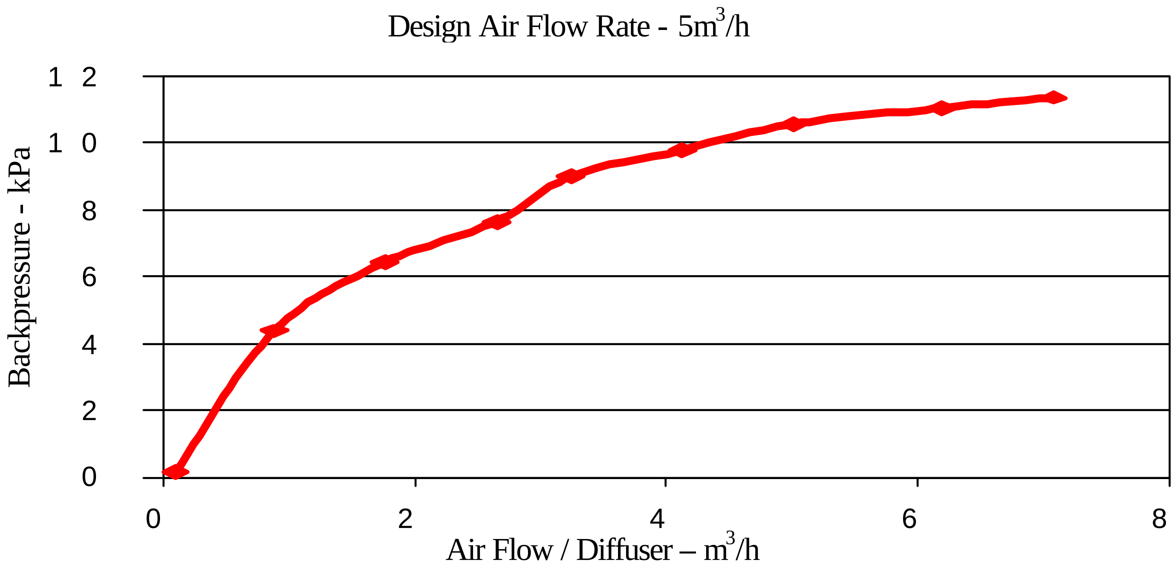
Originally it was thought that the main cause for the deterioration in diffuser performance was that of the EPDM material becoming brittle and thereby increasing diffuser backpressure. However, while examining the function of increasing backpressure it was identified that the growth of a biofilm over the membrane was also contributing to the increase in backpressure.

4.1 Measuring Performance

Aqua-Audit was contracted to assist with the measurement of diffuser performance. Tom Lawson from Aqua-Audits has had a long involvement in the development of diffusers in Australia and has developed a number of methods to measure diffuser performance. Barwon Water purchased monitoring equipment, which allows plant staff to carry out the performance testing inhouse.

A monitoring program was established to measure backpressure across the diffuser membranes. This allows the increase in backpressure to be monitored over time. It has also enabled the point where it is necessary to act to improve the diffuser membrane performance to be determined. This point is a backpressure around 13 kPa. A sample of the results of the testing is shown in Figure 5.

Figure 5: ***Typical Plot of Diffuser Backpressure against Flow***



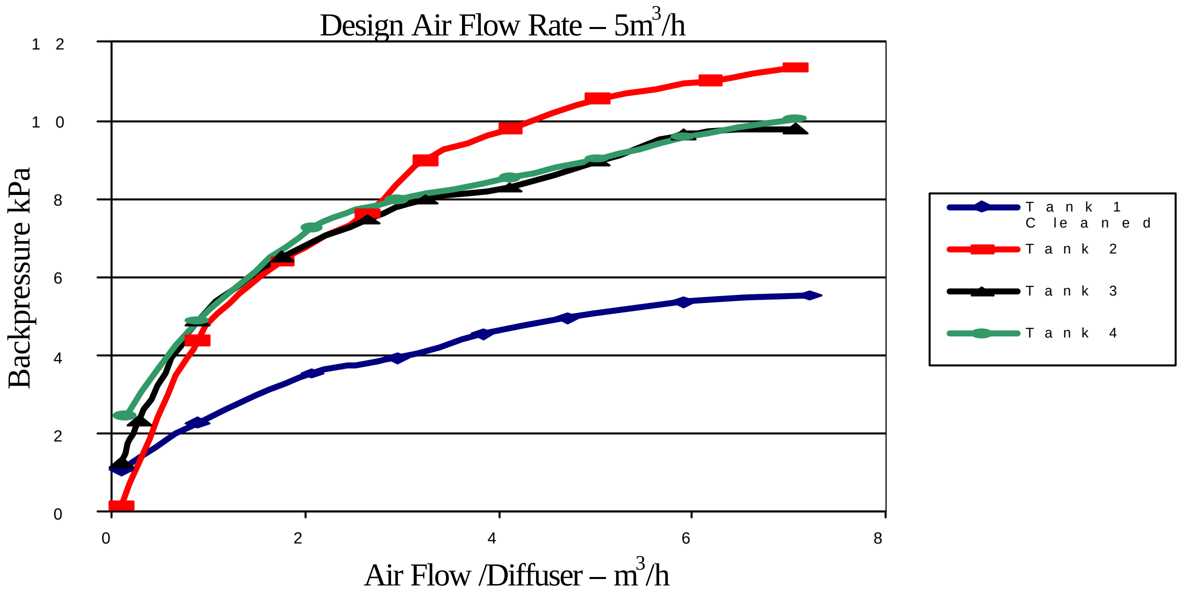
Several trials were carried out to determine the improvement in performance that could be gained by cleaning the membranes. A range of high-pressure cleaners was used with hot and cold water together with a number of different cleaning chemicals. Visual inspections showed that cleaning the diffusers produced a considerable improvement in aeration performance.

A cleaning program was commenced while further measurements were taken to quantify the improvement. Figure 6 shows the cleaning operation.

Figure 6: ***Diffuser cleaning***

Results show that following cleaning the diffusers return to a state similar to that when new (approximately 5-6 kPa.). A graph of the decrease in backpressure achieved through cleaning is shown in Figure 7.

Figure 7: ***Typical diffuser backpressure before and after cleaning***



It has been established that the diffusers should be cleaned every two years to ensure optimum efficiency. Better cleaning techniques are being developed to try to resist the growth of the biofilm and prevent damage to the membrane during cleaning. One version of the diffusers supplied has sustained minor damage as a result of using an aggressive approach to the cleaning.

A cleaning procedure has been developed to prevent damage during cleaning whilst retaining maximum benefit from the operation.

4.2 Further Challenges

The maintenance program is being continually developed to take advantage of improvements in diffuser technology and to prolong the life of the membranes through better cleaning techniques. Investigations are also underway in the use of chemicals to resist growth of biofilms on the diffuser membranes.

A number of tests on the use of formic acid dosing through the aeration system to clean the membranes have also been carried out. It remains to be seen whether the effect of this type of cleaning can match that of the current methods adopted. The performance of other diffusers in the market place also needs to be evaluated. A number of alternative types of diffusers are currently being trialed.

The effect of diffuser condition on energy efficiencies is also being monitored. The costs associated with the operation and maintenance of the aeration system at the plant make up a significant component of the plant budget. The aeration system directly affects the amount of power used at the plant, which is also a large part of the budget. The value of the developments mentioned should not be underestimated.

The program has been developed from the initial diffuser replacement frequency of 4 years to the point where diffuser replacement is now every 6 years. It is likely that the working life of the diffusers will be extended to 7 years in the near future. The annual costs of the diffuser maintenance and replacement to date have been reduced by $175,000.

5.0 CONCLUSIONS

A number of advances in the way the Operations Staff at the Black Rock Plant maintain and operate the Aeration Distribution System have been explained. However it must be acknowledged that few of the advances made to date would not have been possible without the establishment of an accurate and concise recording system.

The accuracy and completeness of the records relies on the cooperation and dedication of the contractors and plant staff. The Black Rock Plant has always had people prepared to commit to the system. As a result it can be demonstrated that plant efficiencies have increased and budgets decreased. It is clear that it is not a state of “diffused chaos” but one of “controlled boiling”.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

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