ENGINEERED REED BEDS - AN EFFECTIVE POLISHING METHOD FOR WASTEWATER

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ABSTRACT

With all Victorian Water Authorities seeking to reduce costs and improve services more innovative ways are being sought to treat wastewater. Portland Coast Water have constructed a new wastewater treatment plant to serve the City of Portland in Victoria's south west, designed to have very low operating costs. The plant, with a capacity of 4 ML/d, uses aerated facultative lagoons followed by engineered reed beds to provide a high quality effluent that is currently discharged to the ocean. The 6 ha of scoria filled reed beds are designed to polish the lagoon effluent by further reducing biochemical oxygen demand and suspended solids as well as reducing nutrient levels, particularly phosphorus. The plant has no daily production of bio-solids, is odourless, noiseless and creates no daily trauma for the operator.

1.0 BACKGROUND

The City of Portland in Victoria's south-west has a population of some 10,000 persons and is a major regional centre. It is the site of Alcoa's Portland Aluminium Smelter and is the third largest port in Victoria after Melbourne and Geelong.

Responsibility for water and wastewater services to the city rests with Portland Coast Water (PCW) who took over responsibilities previously held by the Portland Water Board. At this time Portland had one of the lowest water and sewage cost structures in Victoria, due largely to its use of groundwater, which had no treatment other than cooling and disinfection, and the lack of wastewater treatment costs.

In 1995 all of the town's wastewater was discharged to the ocean without treatment. The discharge point was Nelson Bay some 5 km from the city; a stretch of coastline bounded by high cliffs and no direct access from the land side.Average dry weather wastewater flows (ADWF) are 4 ML/d with a peak dry weather flow (PDWF) of 5.2 ML/d. Typical raw wastewater quality is shown in Table 1.

Table 1: ***Raw Wastewater Quality***

Parameter	Unit	Concentration
Five day biochemical oxygen demand (BOD_5)	mg/L	160
Suspended solids	mg/L	160
Ammonia nitrogen	mg/L	120
Organic nitrogen	mg/L	15
Total phosphorus	mg/L	10

The discharge was licenced by the Victorian Environment Protection Authority (EPA) which mandated the discharge conditions shown in Table 2.

Table 2: ***EPA Licence Conditions Prior to 1997***

Parameter	Unit	Concentration
Five day biochemical oxygen demand (BOD_5)	mg/L	< 300
Suspended solids	mg/L	< 300
E.coli bacteria	org/100 mL	< 1,200,000
Total residual chlorine	mg/L	< 1.0

2.0 REGULATORY INFLUENCES

In 1993 the EPA advised PCW that new discharge licence conditions would be applied to the discharge from 1997 as shown in Table 3.

Table 3: ***New EPA Licence Conditions***

Parameter	Unit	Concentration
Five day biochemical oxygen demand (BOD_5)	mg/L	90 percentile < 20
Suspended solids	mg/L	90 percentile <30
E.coli bacteria	org/100 mL	90 percentile < 400
Floating matter		None
PH	pH units	> 6.0 and < 9.0

These new conditions were a result of the EPA's determination to end the discharge of raw sewage to the ocean and many similar conditions were applied to other coastal towns along the Victorian coast. In addition to the revised licence conditions, the EPA stressed to PCW, its policy, as expressed in the State Environmental Pollution Policy (Waters of Victoria), of requiring discharge to land where practicable. While nutrients, particularly nitrogen and phosphorus are not licenced, the EPA require that regular testing include these parameters, along with a range of heavy metals.

3.0 PILOT WORK

Following the EPA's directive, PCW initiated a pilot study to examine several possible treatment alternatives. With a mind to keep the capital and operating costs of wastewater treatment low, the trialled technologies were land based with little or no mechanical equipment.

Primary treatment methods trialled were covered anaerobic lagoons and non-aerated facultative lagoons. Engineered reed beds were trialled for secondary treatment, or polishing, of the primary effluent. Table 4 shows details of the pilot facilities.

Table 4: ***Details of Pilot Plant***

Component	Description
Anaerobic lagoon	Area 196 m^2, Depth 2.5 m, Loading rate 40 kL/d/m^3
Facultative lagoon	Area 1125 m^2, Depth 2.0 m, Loading rate 160 kL/d/m^2
Reed bed	Area 0.2 ha, media bed depth 0.6 m, Loading rate 20 mm/d Medium of crushed graded bluestone, Planting with Phragmites Australis

The reed bed technology was developed by the CRC for Waste Management and Pollution Control.

The pilot plant was operated for one year. Table 5 presents typical results using the facultative lagoon followed by the reed beds.

Table 5: ***Typical Pilot Plant Results***

Parameter	Unit	Raw Wastewater	Lagoon Effluent	Reed Bed Effluent
Biochemical oxygen demand (BOD_5)	mg/L	84	39	8
Suspended solids	mg/L	110	65	6

The pilot plant's performance was encouraging and PCW made a decision to adopt facultative lagoons followed by engineered reed beds for their new treatment plant.

4.0 THE NEW PLANT

PCW commissioned WSL Consultants Pty Ltd (WSL) of Melbourne to design the new wastewater treatment plant to be located on a 25 ha site near the Portland Aluminium Smelter site and adjacent to the existing ocean outfall. The plant was to be designed for an ADWF of 4 ML/d with provision to increase to 6 ML/d in the future.

Site area constraints led WSL to adopt aerated facultative lagoons instead of the non-aerated lagoons trialled in the pilot work. This reduced the land requirement for primary treatment from 8 ha to 1 ha.

WSL examined the pilot plant results with a view of optimising the loading rate on the reed beds. While the low pilot loading rate of 20 mm/d produced excellent results it was considered too conservative for a full-scale plant and, after further consultation with the CRC, a loading rate of 70 mm/d was adopted. With this loading rate the effluent quality was expected to be slightly reduced, although within the EPA's 20/30 (BOD/SS) effluent limits.

The aerated lagoons were designed with a depth of 4 m and a surface area of 1 ha, giving a loading rate of 640 kg.BOD/ha/d. This capacity was provided in two lagoons to allow flexibility for maintenance and future desludging.

Based on the adopted loading rate of 70 mm/d, some 5.7 ha of reed beds were required. The final design incorporated 12 reed beds each 0.5 ha in area, providing an actual loading rate of 67 mm/d.

Table 6 shows details of the reed beds design criteria.

Table 6: ***Reed Bed Design Criteria***

Item	Description
Total area	6 ha
Number of reed beds	12
Hydraulic loading rate	667 kL/ha/d (67 mm/d)
Media depth	500 mm
Media size - main beds - inlet/outlet zones	10 mm one sized aggregate 40 mm one sized aggregate
Bed dimensions	65 m x 77 m
Inlet configuration	Centre of 65 mm end
Outlet configuration	Opposite end
Bed sealing	Compacted clay
Water depth	450 mm (50 mm below top of aggregate
Planting	Phragmites Australis

The design of the inlet and outlet piping for the reed beds allowed for operation either in parallel or in groups of three beds in series. While the parallel operating mode was designed as the normal mode of operation, provision for the series operation mode was suggested by the CRC as a means of further tertiary treatment. This requirement added considerable complexity to the design of the inlet and outlet pipework and particularly to the design of distribution and collection pits.

The uniform distribution of primary effluent to the reed beds was achieved solely through a system of weirs in the distribution pits. The variations in the levels of the beds, required to suit the topography of the site, further complicated the distribution hydraulics.

The reed bed design required some 6,000 m^3 of carefully graded single sized aggregate. The pilot plant had used granite (bluestone) similar to that commonly used for road making. When tenders were called for supply of granite aggregate the prices tendered exceeded budget allowance by a factor of 3. This was due in part to the haul distances involved and in part to the strict grading requirements. Aggregate types were reassessed by WSL, in conjunction with the CRC, and supply was re-tendered based on scoria aggregate which was much more common in the local region.

5.0 COSTS

The treatment plant was constructed using eight separate contracts. These were:

- Construction of primary lagoon and reed bed earthworks
- Supply and installation of aerators and associated electrics, instrumentation and control equipment.
- Supply of aggregate
- Placing of aggregate
- Supply of MDPE pipe and fittings
- Supply of uPVC pipe and fittings
- Construction of distribution pits and installation of pipework
- Supply and planting of reeds

Final construction costs are shown in Table 7.

Table 7: ***Final Construction Costs***

Contract	**$**
Primary lagoon and reed bed earthworks	1,020,000
Aerators and associated equipment.	141,000
Supply of aggregate	710,000
Placing of aggregate	138,000
Supply of MDPE pipe and fittings	67,000
Supply of uPVC pipe and fittings	80,000
Construction of distribution pits and installation of pipework	300,000
Supply and planting of reeds	20,000
Total	**$2,476,000**

Operating cost for such a plant are low due to the low labour requirements and the minimal electrical and mechanical equipment installed at the plant. The pre-construction estimate for operating cost was $67,000 per year, comprising $64,000 for power and $3,000 for maintenance. While it is too early to determine actual annual costs at this stage, they are expected to be of this order of magnitude.

On a cost per ML of capacity these costs are low by industry standards, representing a capital cost of $620/ML and operating cost of $17/ML/a.

6.0 PERFORMANCE

Due to some earthworks construction difficulties, the plant was not full operational until March, 2000. Planting of reeds commenced late December, 1999 and was completed in April, 2000, with seedling planted at 1.5 m spacing over the area of each bed.

During final construction of the reed beds they were brought on-line as soon as they were finished. During periods when not all reed beds had been finished, the primary effluent was directed to operational beds at the maximum achievable hydraulic loading rate of approximately 180 mm/d, with the remaining primary effluent bypassing the reed beds.

Early results to date are encouraging, particularly as the reeds are in the very early stages of establishment, and are not expected to fully cover the beds with dense growth until the summer of 2001-2002. To date only one set of data has been obtained with all reed beds operational. The results of this analysis is shown in Table 8:

Table 8: ***Plant Performance – All Reed Beds Operational***

Location	BOD5 mg/L	Reduction %	SS mg/L	Reduction %
Raw Wastewater	230	n/a	240	n/a
Aerated Lagoon Effluent	36	84	18	93
Reed beds Effluent	22	39	6	67

As indicated, the plant operated for a period of time with only a portion of the reed beds operation. During this period the beds were hydraulically and organically overloaded by a factor of 3 over the design load. Nevertheless a significant amount of treatment was attained over this period. Table 9 presents the average of the results obtained over this period.

Table 9: ***Average Plant Performance – During Hydraulic Overload of Reed Beds (6 tests)***

Location	BOD5 mg/L	Reduction %	SS mg/L	Reduction %
Raw Wastewater	220	n/a	158	n/a
Aerated Lagoon Effluent	59	73	38	76
Reed beds Effluent	27	54	6	84

7.0 POTENTIAL RE-USE

Portland Aluminium Smelters, in conjunction with PCW, have undertaken several trial reuse studies on Portland Aluminium property adjacent to the treatment plant site. These woodlots use treated effluent from the pilot facultative lagoons and reed beds. Currently 40 kL/d of effluent is reused on 7 ha of woodlots, planted with a variety of fast-growing eucalypts and some cypress.

This study is planned to continue for a further three years, by which time more conclusive evidence will be available with respect to the most appropriate tree species, the economic viability and environmental benefit.

In the short-term, effluent from the treatment plant will be disposed to Nelson Bay via the existing ocean outfall after primary, and secondary treatment.

To minimise the potential impact on the marine environment, Portland Coast Water have committed to implementing summer irrigation within the next five years, subject to favourable outcomes of existing and future investigations on the benefits and feasibility of irrigation.

8.0 LESSONS LEARNED

Lessons are learned from all projects and the construction of the Portland treatment plant was no exception.

The decision to use scoria as the reed bed medium instead of bluestone produced a number of unexpected consequences. Scoria, unlike crushed bluestone, settles during transport and handling and as a consequence initial quantities were under estimated and additional cost was incurred in this area. The specific single-size gradings required were not a standard size that most quarries stockpiled and this resulted in quarries crushing to order, which extended the supply time considerable. This longer supply time also meant that the aggregate had to be stockpiled prior to installation, which also increased aggregate placement costs.

With the effluent level in the reed beds only 50 mm below the top surface of the aggregate, tight placement and levelling tolerances were required. These proved difficult to achieve in practice over the

5,000 m^2 in each reed bed. Final level checks over the entire surface of each bed could only be made when effluent was introduced and some re-working proved necessary.

The choice of providing the 6 ha of reed bed area in 12 reed beds, while unavoidable due to the topography of the site, created complexity in the design, particularly with respect to the hydraulic design to permit the series and parallel modes of operation. Given suitable site topography a smaller number of larger beds would be simpler to design and would allow simpler distribution arrangements.

An operational problem that has emerged since the full-scale operation of the complete reed bed complex, is a minor carry over of finely dispersed solids from the aerated lagoon has collected in the inlet areas of the reed beds. Various methods are currently being considered to eliminate this problem, which is more aesthetic than functional.