

COAL ASH LEACHABILITY : DETAILED FIELD STUDIES

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1 INTRODUCTION

The successful management of coal ash waste from the combustion of coal for power production is a major engineering and environmental challenge. Presently, the Latrobe Valley power station complexes mix ash from the power station with water and hydraulically pump the resultant slurry to a disposal pond. However, a review of ash production rates and extended plant life at the Loy Yang complex found that the existing ash pond did not contain enough storage space for the projected life (Mudd *et al.*, 1996). The wall of the ash pond was subsequently raised in 1994 and detailed investigations into disposal of the ash into the overburden dump commenced.

The management regime that is currently being adopted involves two principal stages. Firstly, the Loy Yang Ash Pond Delta is divided into two ponds. The ash slurry is directed into one pond until it is full, and the slurry is then directed into the second pond. The ash in the first pond, after remaining saturated in the ash pond for a period of 6 to 12 months, is considered as *leached ash*. Secondly, the leached ash is then excavated and placed in approved gullies and locations in the overburden dump, with the resultant sites covered in a clay cap to prevent infiltration.

Previous work has indicated that after transport in the slurry system and deposition in the ash pond there is generally lower levels of soluble mass available within the ash for leaching (Mudd *et al.*, 1996). However, the key challenges for the environmental management of the disposal sites in the overburden dump is the leachability under field conditions, such as the concentrations in unsaturated leachate flow, and whether there would be any flow of leachate occurring from a disposal site that is therefore likely to influence groundwater quality.

In order to assess the overall processes of field leachability, trial leaching cells were established at the Loy Yang Ash Pond in mid 1997 and monitored to enable the determination of a water and solute balance in order to address the above issues. A review of the performance of these cells is given up to the end of May 1998.

2 DESIGN OF FIELD LEACHING TRIAL CELLS

The ash produced at Loy Yang is predominantly silt size and has a very high porosity, ranging from 60 to 80% depending on the level of compaction (Mudd, 1997), and thus a large storage capacity for moisture. This leads to the property that water will only flow through an ash profile in times of very high infiltration. The majority of rainfall that enters the ash will therefore be kept in storage and slowly evaporated, leaving minimal water available for flow through the profile to generate leachate.

In order to achieve a significant quantity of water flowing through the ash profiles, it was decided to build two different leaching cells at the Ash Pond - one which is open only to rainfall; and a second which is open to rainfall plus an external controlled water source. The two cells are referred to as the Dry and Wet Cells respectively. Both were constructed in late June 1997.

The two cells are 5x5 metres in area and 3 metres in depth. They are HDPE lined, and have 75 mm of coarse aggregate at the bottom to allow rapid drainage of any leachate. A collection pipe was placed in this drainage layer and extends outside the cells where it discharges into a collection tank. The flow rates from the discharge pipe and the total volumes collected in the tank are monitored regularly, with the frequency depending on the addition of external water and rainfall. The external water tank on the Wet Cell holds approximately 5,000 litres (the equivalent of 200 mm of rainfall for a 25 m² area). This is allowed to flow onto the Wet Cell at regular intervals.

Leachate samples are collected fortnightly (on average) from the Wet Cell and analysed for major ions and select trace metals. A comprehensive set of trace metals is analysed every two to three months.

3 WATER BALANCE

3.1 Dry Cell Water Balance

The Dry Cell has demonstrated that the majority of water will indeed be held in soil moisture storage and be evaporated, with only minor quantities of leachate generated to date. Initially, there was some small quantity of leachate flow from the cell, although the actual flow rates quickly declined (related to self-weight consolidation of the ash). These can be related to rainfall events at that time. There has been no leachate emanating from the cell since November 1997 up until late May 1998, and between mid-September and early November 1997, there was also no leachate flow.

Overall, there has been 11,930 litres of rainfall on the Dry Cell, and by calculating the area under the leachate flow rate versus time curve below (Figure 1), the total outflow of leachate is estimated to be 3,720 litres. Thus approximately 69% of influent water has been evaporated.

3.2 Wet Cell Water Balance

The Wet Cell has provided a good baseline study of unsaturated flow of water through an ash profile. The peak flow rate observed for each irrigation event (where the source tank was allowed to flow onto the cell) and the proportion of water flowing out as leachate compared to the total influent water can be related to the moisture content of the ash. As a general rule, the higher the moisture content of the ash, the higher the peak flow rate observed, and the higher proportion of influent water exiting the cell as leachate, conforming to unsaturated flow laws.

During the first months of operation in the winter of 1997, generally low flow rates would be sustained, which tend to give an overestimate of the total outflow since small flows over large times (several days) are likely to give error since the actual flow rate will vary quite considerably. As the trial progressed into summer, the flow of leachate would generally cease within 5 to 7 days of the irrigation event. This would be due to the upper profile drying out

and creating suction within the cell, holding in the moisture at the bottom of the cell and preventing drainage. As the winter months of 1998 were approaching, the higher rainfall and lower overall evaporation rates would allow the ash profile to remain wet and thus low flow rates would remain between irrigation events.

The overall budget for the Wet Cell is 98,831 litres of influent water, and a total outflow of 58,919 litres of leachate (refer to Figure 2). The total quantity of leachate is approximately 1.5 pore volumes of the ash, suggesting that a significant amount of leaching potential has been reached. The ash within the cell has consolidated over time.

4 LEACHATE QUALITY

4.1 Dry Cell Leachate Quality

The quality of leachate from the Dry Cell is of a similar chemical signature to that of the Loy Yang Ash Pond. That is, the leachate is dominated by sodium, sulphate and chloride, although the overall concentrations are slightly higher in the leachate than in the Ash Pond (refer to Table 1 below). Most trace metals do not leach out, although arsenic, boron, barium, molybdenum and selenium are present in the leachate.

The samples collected from the first few months of operation (when there was active leachate flow) are similar in concentration and thus only the averages are presented. The sample collected from early-November 1997 was of the same type of water chemistry, although higher in overall concentration. The level of most trace metals were the same, except for selenium, which was over three times higher in concentration. Overall, no distinct pattern of leaching can be observed due to the low volume of water passing through the Dry Cell.

Table 1 : Dry Cell Leachate Quality (mg/l)

TDS	pH	Na	K	Ca	Mg	Fe
10,600	8.53	3,560	98	119	42	0.23
Al	SiO ₂	SO ₄	Cl	HCO ₃	CO ₃	NO ₃
0.3	9.3	6,220	773	67	0.3	0.28
	As	B	Ba	Mo	Se	
	0.008	2.39	0.12	0.29	0.70	

4.2 Wet Cell Leachate Quality

The quality of the leachate from the Wet Cell is identical to that of the early Dry Cell leachate, being dominated by sodium, sulphate and chloride, with the only trace metals present being arsenic, boron, barium, molybdenum and selenium.

As the volume of water flowing through the Wet Cell is significantly higher, a distinct pattern of leaching has emerged. Initially, the concentrations of major ions in the leachate is quite high, similar to that of the Dry Cell. This lasts for a leachate volume of approximately 29,000 litres (or just short of one pore volume of ash), at which point the concentrations begin to decrease. From this point the leachate quality progressively improves with the levels of sodium, sulphate and chloride decreasing steadily as further quantities of water flow through

the cell. The overall leaching pattern (in terms of relative concentrations) is presented in Figure 3.

It can be expected from the literature (eg. - Côté, 1986; Black, 1990; Lu, 1996) and previous modelling work undertaken (Mudd & Kodikara, 1997) that after approximately 3 to 4 pore volumes of water through an ash profile, the leachate quality will achieve steady state or stable concentrations. As the Wet Cell was still under operation at the time of writing, this point on the leaching curve had not yet been reached. It can be observed, however, that there is an overall decreasing trend in the leachate quality. It is not known what the steady state concentration will be. The initial leachate chemistry (average from July 1997 to November 1997) and that observed in May 1998 is presented in Table 2.

Table 2 : Wet Cell Leachate Quality (mg/l)

	TDS	pH	Na	K	Ca	Mg	Fe
Initial	11,000	9.24	3,467	119	130	26	0.06
May 1998	4,500	9.3	1,400	68	68	14	0.10
	Al	SiO ₂	SO ₄	Cl	HCO ₃	CO ₃	NO ₃
Initial	0.81	9.3	6,780	671	38	68	0.39
May 1998	0.33	4.9	2,700	120	42	14	0.45
	F	As	B	Ba	Mo	Se	
Initial	1.43	0.009	3.3	0.07	0.26	0.81	
May 1998	1.10	<0.001	5.5	0.02	-	0.32	

It is possible to calculate the total mass leached based on the leachate concentration over time and the volume of water through the ash profile. In the same way that the concentration can be expected to decrease towards an asymptote or steady state concentration, the total mass leached of a particular constituent will increase towards an asymptote or maximum leachable mass. This approach is based on the work of Farquhar (1988). The leachability graph for sulphate is included in Figure 4 as an example.

Overall, the total amounts of different leachable components of the ash are presented in Table 3. The initial leachable mass present within the ash is also given, based upon the average concentrations from samples collected during construction and a dry density of 700 kg/m³ (Mudd, 1997).

Table 3 : Leachable Ash Mass (kg)

	SO ₄	Cl	Na	K
Initial	450	38	722	67
May 1998	160	13	576	62

A bore hole was drilled through the ash profile in the cell in early February 1998, and it confirmed that many of the more soluble components are leaching out and their concentration in the ash is steadily decreasing.

5 CONCLUSIONS & FUTURE DIRECTIONS

The operation of the field leaching cells has enabled the study of the interaction of complex leaching processes under field conditions. The most important conclusions from the results obtained to date are that :

- the significantly lower water-to-ash (liquid-to-solid) ratio found in field ash disposal sites yields a high leachate concentration which could not be predicted from a batch-type leaching experiment;
- leachate flow due to rainfall alone is likely to be minimal, if at all;
- modelling needs to take account of evaporation and unsaturated flow;
- leaching can be attained by flushing the ash with water.

The available mass within the ash and the trends for the different graphs of leachable mass and concentration indicate that steady state leachate conditions are being approached. They suggest that the quality of steady state leachate is likely to be of low to moderate salinity and of generally low trace metal content. This would be similar to the variable groundwater quality around the Loy Yang site (as discussed in Mudd *et al.*, 1998).

Clearly there is a need to keep running the cells for further periods of time to ensure that about 3 to 4 pore volumes or more are reached in the Wet Cell and that there is again minor leachate flow from the Dry Cell. However, the research shows that management of ash disposal sites can be considered in one of two philosophy's (or a combination of both) :

- assume that the disposal sites will receive minimal influent water (ie - a clay cap prevents infiltration and any leaching), or
- actively leach the ash to remove the soluble mass before disposal (ie - the quality of water that may pass through a disposal site is well below the EPA's regulatory limits).

The final data collected from the operation of the two cells is crucial to allow cost effective environmental management decisions to be made in the short term.

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8 FIGURES

Figure 1 : Dry Cell Water Balance

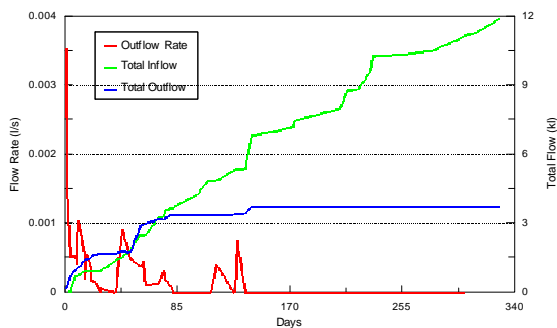


Figure 2 : Wet Cell Water Balance

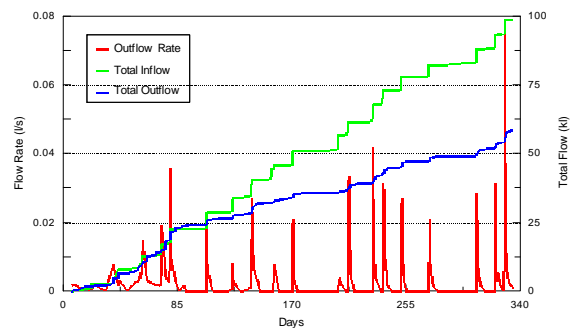


Figure 3 : Wet Cell Leachate Quality (Relative Concentrations Only)

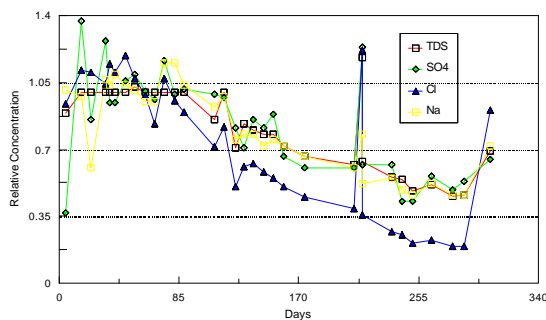


Figure 4 : Relative SO₄ Concentration and Leachable Mass

